LIFE CYCLE, RELIABILITY-BASED, RIVER RESTORATION

by

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ABSTRACT

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Aquatic ecosystems worldwide are being severely altered or destroyed at a rate greater than they are being restored (*NRC, 1992*). According to the 1994 National Water Quality Inventory of 617,806 miles of rivers and streams, only 56 percent fully supported multiple uses, including drinking water supply, fish and wildlife habitat, recreation, and agriculture, as well as flood protection and erosion control (*FISRWG, 2001*). In 2005, the National River Restoration Science Synthesis (NRRSS) working group released the results of a multi-year study of the motivations and subsequent performance of completed river restoration projects within the United States. Through the development of a comprehensive database, the study found that although over $1 billion is spent on restoration projects each year, it was found that more than half the projects failed to meet the intended goals and design criteria (*Kondolf and Downs, 2004*).

River restoration is not a mature science (*Brookes and Shields, 1996*) and there exists significant gaps in scientific knowledge of river restoration, as well as undetermined biases and errors in the current empirical design formulations and numerical models, resulting in 'uncertainties' that dramatically impact the outcomes of these projects.

River restoration projects fail through the omission of essential parameters in the development and configuration of the project. In order to achieve reliable river restoration projects it is essential that the problem to be remedied is completely and comprehensively defined; that project-related uncertainties (i.e. physical, temporal, financial) be acknowledged, estimated, and accounted for; and interactive management approaches (such as adaptive management) be configured and employed to manage those parameters identified as having significant influence on the project and high magnitudes of uncertainty.

River restoration is evaluated from a life-cycle perspective. Additionally, reliability is a central theme of the research. By including reliability into river restoration, it becomes possible to directly incorporate project performance as well as the plethora of uncertainties that plague many river restoration efforts from achieving their intended outcomes.

Through literature reviews, this research synthesizes the current interdisciplinary river restoration body of knowledge (classified by NRRSS goal categories) and created a river restoration 'checklist' with associated resources (planning guides, design manuals, computer software programs, and GIS data) for planning and design to correlate minimum project requirements with intended restoration goals. Case studies are presented for validation and the case studies also present management strategies for restoration uncertainties and adaptive management.

Professor Robert G. Bea

Dissertation Committee Chair

Do not follow where the path may lead.

Go, instead, where there is no path and leave a trail.

Only those who will risk going too far can possibly find out how far one can go.

- *TS Eliot* -

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Acknowledgements

I would like to begin by thanking my advisor, Professor Robert G. Bea for providing me with an opportunity to engage in this intellectually challenging research endeavor. His tireless devotion and dedication to the field of Civil Engineering has been truly inspirational and taught me that an engineer's primary duty is to relentlessly ensure the proper performance of the engineered systems they work on, which at times may require advancing the state of the practice. I would also like to thank my committee members, Professors John Dracup, G. Mathias Kondolf, Karlene Roberts, Raymond Seed, and Raja Sengupta for their invaluable coaching during my doctorate program as well as their very helpful comments in the development of this document.

I would like to thank my friends and fellow graduate students who provided much friendship and support. A special thanks to Kofi Inkabi who tolerated my crazy ideas and was patient enough to dedicate many hours talking about risk, likelihoods, probability distributions, and human & organizational performance shaping factors.

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Chapter One

1 INTRODUCTION

1.1 Foreword

This dissertation provides river restoration practitioners with guidance on developing comprehensive solutions to river restoration projects by synthesizing our current state of the practice knowledge and resources. It is not the goal of this dissertation to establish river restoration project merits or goals, rather, existing common goal categories are used in this research. In order to provide a framework in which to develop the comprehensive solutions, the goal categories developed by the National River Restoration Science Synthesis (NRRSS) (*Bernhardt et al, 2005*) was selected. The author does not claim that this goal classification scheme is complete or comprehensive; rather, this pre-existing classification scheme was selected as a starting point for the development of a more comprehensive solution process. It is acknowledged that each river restoration stakeholder may identify unique goals relative to their project. For these situations, it is recommended that the guidance presented in this dissertation by adapted to the specific situation at hand.

This dissertation focuses on the development of quantitative reliability-based river restoration projects, rather than the "trial and error" projects of the past. During the initiation of my research, I found that the practice of river restoration was in a disparate state, with no standardized approaches or protocols. This lack of standardization made it difficult to relate experiences and results from one river restoration project to another project. As a result, I found it necessary to focus my research work on problem definition and alignment of terminology in order to synthesize cross-disciplinary knowledge.

My research was developed in three phases: Phase I (qualitative) consisted of a definition of river restoration as a system and synthesis of important elements; Phase II (qualitative and quantitative) identified requirements (as reported by the literature) associated with river restoration; and finally Phase III (quantitative) evaluated, through two case studies, river restoration performance from a reliability-based approach, with the direct inclusion of uncertainty.

It is the hope of the author that the results of this research will serve as a foundation for future river restoration projects so that more comprehensive river restoration 'learning' can occur thereby improving the State of the Practice.

1.2 Background

Aquatic ecosystems worldwide are being severely altered or destroyed at a rate greater than they are being restored (*NRC, 1992*). The United States has more than 3.5 million miles of rivers and streams (*FISRWG, 2001*) and approximately one-third of these rivers and streams are classified as impaired or polluted waters (*Bernhardt et al, 2005*). It is estimated that 92 to 98 percent of the total river and stream miles are so altered, that they do not fit the legislative criteria for national rivers or wild and scenic rivers (*NRC,* *1992*). According to the 1994 National Water Quality Inventory of 617,806 miles of rivers and streams, only 56 percent fully supported multiple uses, including drinking water supply, fish and wildlife habitat, recreation, and agriculture, as well as flood protection and erosion control (*FISRWG, 2001*).

In 2005, the National River Restoration Science Synthesis (NRRSS) working group released the results of a multi-year study of the motivations and subsequent performance of completed river restoration projects within the United States. Through the development of a comprehensive database (with over 37,000 entries), the study found that although over $1 billion (and this was judged to be a very conservative figure) is spent on restoration projects each year, the overwhelming majority of these projects do not have explicit success criteria and even fewer projects have post-construction validation to ensure that the intended project goals are being achieved (*Bernhardt et al, 2005*). In the few cases where systematic project assessment and monitoring was performed, it was found that more than half the projects failed to meet the intended goals and design criteria (*Kondolf and Downs, 2004*).

Environmental and ecological restoration has been practiced in some form for centuries (*Falk et al, 2006*), but science-based restoration has only emerged and taken hold since the years following World War II (*Brookes and Shields, 1996*). Science-based restoration has been defined (*Falk et al, 2006*) to consist of (1) explicitly stated goals, (2) a restoration design informed by knowledge, (3) quantitative assessment of system responses employing pre- and post restoration data collection, and (4) analysis and application of results from prior projects to inform subsequent efforts. “Science-based” projects should be documented with a sufficient description of procedures and assumptions so that other scientists can verify all calculations and, if necessary, have enough information to undertake a replication of the results (*Morgan et al, 1990*).

1.3 Problem Statement

Unfortunately, river restoration is not a mature science and there exists significant gaps in scientific knowledge of river restoration, incomplete project development that directly results in failure, as well as undetermined biases and errors in the current empirical design formulations and numerical models, resulting in 'uncertainties' that dramatically impact the outcomes of these projects. Prager and McPhillips (*2006*) acknowledged this uncertainty and stated:

> *In their zeal to enable restoration, some promoters have over simplified and over promised. Consequently, project owners, regulators, and the public sometimes have a strong misimpression that stream restoration is simple, certain and achievable by virtually anyone…. Given the significant gaps in scientific knowledge, our efforts will be functional approximations of truly natural streams at best and we should acknowledge this from the outset.*

Thus, river restoration requires complete and comprehensive project configurations as well as continued knowledge gathering to reduce the magnitude of uncertainties, thereby improving our ability to configure restoration projects that actually achieve their intended goals (*Darby and Sear, 2008; Kimmerer et al, 2005; Kondolf and Downs, 2004; Loucks, 2002; Morgan et al, 1990; Muste and Stern, 2000; Niezgoda et al,* *2007; Perry and Gracie, 2004; Prager and McPhillips, 2006; Schwar and Bernard, 1998; Thom et al., 2004; Wissmar and Bisson, 2003*).

River restoration projects fail through the omission of essential parameters in the development and configuration of the project. In order to achieve reliable river restoration projects it is essential that the problem to be remedied is completely and comprehensively defined; that project-related uncertainties (i.e. physical, temporal, financial) be acknowledged, estimated, and accounted for; and interactive management approaches (such as adaptive management) be configured and employed to manage those parameters identified as having significant influence on the project and high magnitudes of uncertainty.

Directly assessing and managing uncertainty in river restoration allows for the identification and segregation of high-uncertainty items from low-uncertainty items, then additional scientific studies can be completed to gain the additional knowledge required to decrease the magnitude of these uncertainties (*Wissmar and Bisson, 2003*). The spirit of this approach is captured by 'adaptive management,' which is "a way of establishing hypotheses early in the planning, then treating the restoration process as an experiment to test the hypotheses" (*FISRWG, 2001*). However, adaptive management does not systematically qualitatively or quantitatively characterize river restoration uncertainties.

In addition to inherent uncertainties due to a lack of adequate knowledge, river restoration systems are complex (*Madhur and Desrochers, 2004; Parrott, 2002; Prager and McPhillips, 2006; Thom et al., 2004; Wissmar and Bisson, 2003*). This adds another layer of uncertainty pertaining to the description of reactions and interfaces between different components of the system. Ecological systems are complex in that they are non-linear, display unpredictability, and may have multiple attractors (*Anand and Desrochers, 2004*). Behavior of these complex systems cannot be directly inferred from the behavior of the individual components (*Ackoff, 1999; Bea, 2002; Calvano and John, 2004; Churchman, 1979; Krone, 1980; Mitroff & Linstone, 1993; Senge, 2006*). The majority of the current design approaches focus on individual restoration components as opposed to the holistic response of the system. Thus the complex nature of restoration projects necessitates active monitoring, assessment, and analysis to study successful recoveries from restoration efforts (*Anand and Desrochers, 2004*).

In addition to 'science' aspects of restoration, organizational mechanics are equally important. The NRC (*1992*) highlighted that organizational fragmentation of ecosystem management is common and successful restoration depends directly on effective coordination among involved groups. Management responsibilities for various components of aquatic ecosystems are not only fragmented among multiple federal agencies, but also between state agencies, non-governmental agencies, the public, and the private sector (*NRC, 1992*). NRC (*1992*) recommended the creation of a unified national program for aquatic ecosystem restoration that 'synthesizes' organizational stakeholders as well as improving interagency communication and development of guidelines for the identification, evaluation, and financing of restoration projects.

The inherent complexity of river restoration requires systems thinking. Systems thinking is a shift of mind from seeing parts to seeing wholes (*Ackoff, 1999; Bea, 2002; Brooks and Shields, 1996; Calvano and John, 2004; Churchman, 1979; Everard and Powell, 2002; Krone, 1980; Mitroff & Linstone, 1993; NRC, 1992; and Senge, 2006*) and without which, there would be no incentive or means by which to integrate individual components once they have come into practice.

Systems theory addresses complexity (detail complexity and dynamic complexity) as well as feedback loops (*Senge, 2006*). Detail complexity relates to many variables whereas dynamic complexity addresses issues of cause and effect, especially where effects over time are not obvious (*Senge, 2006*). Feedback mechanisms are captured through system archetypes and interaction diagrams (Figure 1). Thus, the application of systems theory to river restoration provides a theoretical basis for merging the many physical and organizational components of river restoration.

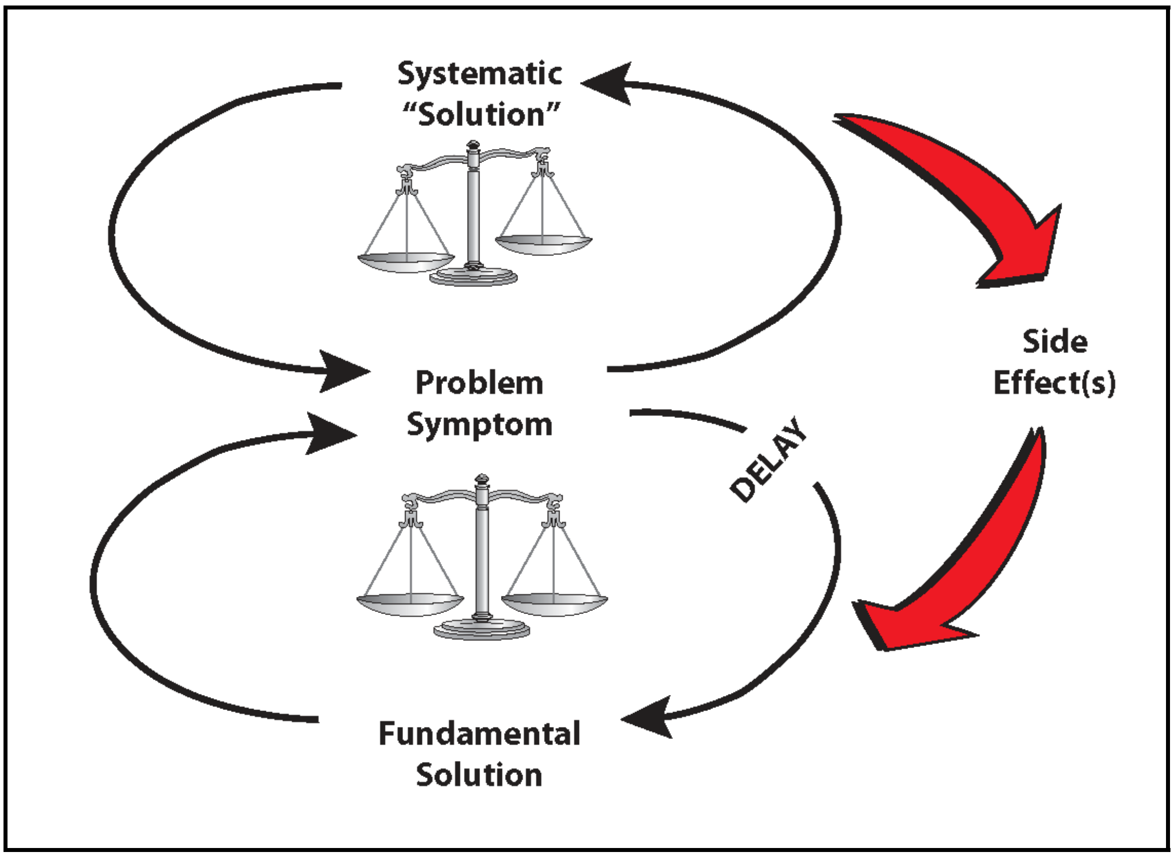

Figure 1: Feedback loops between system 'symptoms' and fundamental 'solutions' are not immediate and take time to occur (*Senge, 2006*)

River system complexity dictates that river restoration (as a system) has components that are highly inter-related, interactive, and inter-dependent, making it difficult to establish crisp, clear system boundaries and structure. In other words, river restoration is complicated and in order to adequately deal with it, effective systems thinking and theory must be employed.

Paramount in the river restoration systems approach is that all important multi-disciplinary evaluation factors be accounted for (politics, funding, physical, chemical, biological, etc.) and explicitly considered. River restoration projects that proceed without an adequate evaluation of these factors generally result in failure, although some projects "get lucky" at least for a short time.

1.4 Terminology

River restoration is a diverse field with many different disciplines and corresponding terminology. For my research and development of this dissertation, I adopted terminology established by the FISHWR (*2001*). A comprehensive glossary of terms associated with river restoration (derived from my literature review) is presented in its entirety in Appendix A.

I present definitions from FISHWR (*2001*) of some commonly used terms for river restoration in order to orient the reader with their meanings, which are critical to establish a normative context for subsequent chapters.

1.4.1 River system manipulation strategy terms

Non-intervention/Undisturbed Recovery – A passive management approach that does not involve active stream corridor manipulation. The river system is allowed to rehabilitate itself without direct anthropogenic influence.

Partial Intervention/Management – Actions to facilitate natural processes to aid in the recovery of a stream corridor that has a slow or uncertain recovery trajectory.

Substantial Intervention/Manipulation – An interactive environmental management approach used in situations where active repair options are required because the recovery of the desired functionality is beyond the natural repair capacity of the ecosystem. The river system is rehabilitated with direct anthropogenic influence.

1.4.2 River system improvement approaches

Reclamation – A series of activities intended to change the biophysical capacity of an ecosystem. The resulting ecosystem is different from the ecosystem existing prior to recovery. The term has implied the process of adapting wild or natural resources to serve a utilitarian human purpose such as the conversion of riparian or wetland ecosystems to agricultural, industrial, or urban uses.

Rehabilitation – Makes the land useful again after a disturbance through the recovery of ecosystem functions and processes in a degraded habitat. Rehabilitation does not necessarily reestablish the predisturbance condition, but does involve establishing geological and hydrologically stable landscapes that support the natural ecosystem mosaic.

Restoration – Reestablishment of the structure and function of ecosystems. Ecological restoration is the process of returning an ecosystem as closely as possible to pre-disturbance conditions and functions. Implicit in this definition is that ecosystems are naturally dynamic. It is therefore not possible to recreate a system exactly. The restoration process reestablishes the general structure, function, and dynamic but self-sustaining behavior of the ecosystem. Restoration differs from rehabilitation and reclamation in that restoration is a holistic process not achieved through the isolated manipulation of individual elements.

1.5 Problem Statement and Research Objective

This research synthesizes the current interdisciplinary river restoration body of knowledge and classifies by goal/intent categories to create a planning and design tool that will aid in configuring successful river restoration projects (with success being defined as projects that meet its intended goals over the lifetime of the project). My evaluation of river restoration incorporates the entire life-cycle of the project. The life-cycles of a project are planning, design, construction, and operations/maintenance (*Bea, 2002*). The requalification and decommissioning life-cycle phases will not be addressed as these phases are rarely (if ever) encountered in river restoration.

Reliability is a central theme of my research. Reliability is defined as the likelihood that an engineered system will perform as intended over a specified period of time (*Ang and Tang, 1975; Bea, 2002; Haimes and Stakhiv, 1987; Singh et al, 2007*). By incorporating reliability into river restoration, it becomes possible to directly characterize anticipated project performance as well as manage the plethora of uncertainties that plague many river restoration efforts from achieving their intended outcomes.

The first phase of a reliability-based approach is a (qualitative) definition and description of the system of concern, which occurs during the Planning and Design Life-Cycle phases. This phase requires synthesis in order to characterize the different elements of the system. The second phase is to identify (qualitatively and quantitatively) all applicable hazards, requirements, and constraints. The next phase is a quantitative evaluation of all identified hazards, requirements, constraints, and uncertainties and their impact on performance. This evaluation provides the context by which to configure monitoring efforts needed to be implemented after construction.

This dissertation is based within the systems context (*Ackoff, 1999; Bea, 2002; Brooks and Shields, 1996; Calvano and John, 2004; Churchman, 1979; Everard and Powell, 2002; Krone, 1980; Mitroff & Linstone, 1993; NRC, 1992; and Senge, 2006*) and the project goals used in my study are as established by the National River Restoration Science Synthesis or NRRSS (*Bernhardt et al, 2005*).

Systems analysis is a set of techniques – qualitative, quantitative, and mixed – with methods recruited from the scientific method, systems philosophy, and branches of various scientific disciplines dealing with the phenomenon of choice (*Krone, 1980*). Techniques and tools employed in my research to address the complex systems aspects of the research topic include: Modes of Inquiry, classification; synthesis; interaction mapping via diagrams and figures; Geographic Information Systems (merging of multidisciplinary databases and data layers); and reliability-based analyses. These techniques and tools are discussed in more detail in Chapter 2.

The primary contributions this dissertation adds to the river restoration community are:

- A validated Restoration Evaluation Checklist for planning and design that correlates minimum project requirements with intended restoration goals. Requirements include regulations/laws, physical, chemical, biological, and ecological factors. Restoration requires a combination of these requirements, thus the matrix format allows for management of complexity associated with specific goals. The matrix covers the entire life cycle of restoration projects; and

- A validated matrix synthesizing available resources (technical manuals, computer programs, data, etc.) by intended project goals to optimize implementation of 'State of the Practice' resources throughout all aspects of the restoration process (regulations/laws, physical, chemical, biological, and ecological).

Additional contributions this dissertation adds to the river restoration community include:

- Complex systems based perspective that synthesizes the disparate disciplines associated with river restoration into one comprehensive framework that encapsulates all life cycle phases of river restoration projects (planning, design, construction, operations/monitoring, requalification, and decommissioning) to enable practice-based adaptive management and organizational learning;
- Identification of complex systems characterization and modeling approaches and methods (i.e. Synthesis, Classification, Modes of Inquiry, Diamond Model, Geographical Information Systems, etc.) for application to river restoration projects to facilitate both qualitative and quantitative reliability and risk-based planning and design;
- Development of case study examples that demonstrate application of reliability-based design that explicitly accounts for uncertainty in project data and anticipated project performance. It was demonstrated how identified uncertainty during the planning and design phases can be used to configure a monitoring and adaptive management program. These case study examples also highlight the

critical nature of evaluating a project over its full projected life, instead of just after construction.

- Presentation of river restoration as a Technology Delivery System requiring cooperation between the Public, Industry, and Government in order to achieve restoration success;
- Development of a comprehensive river restoration glossary merging terminology from major Federal (EPA, USACE, USBR, USGS, USFWS, etc.) organizations;
- Development of a detailed overview of Federal and State of California organizations associated with river restoration, their general history and current activities related to river restoration;
- Compilation of 41 Post Project Appraisals and associated planning, design, construction, and monitoring data; and
- Facilitation of an online database of NRRSS Post Project Appraisals completed in California that allows users the ability to access the available original project related data generated during the planning, design, construction, and monitoring phases.

The majority of case studies and data generated as part of my research is a result of the NRRSS California Node Post Project Appraisal study under the direction of Professor G. M. Kondolf. Two detailed case studies are presented for validation of the developed 'requirements' matrix. These case studies are the Lower Santa Ynez bank stabilization project in Santa Barbara County (California) and the Tennessee Hollow creek daylighting and restoration project at the Presidio in San Francisco, California.

It is the conclusion of the author that the two primary reasons for failure of river restoration projects has been the (1) omission of key restoration evaluations (such as estimated river discharges, vegetation survival and growth rates, and construction and maintenance costs) and (2) lack of incorporation of 'uncertainties' in the planning and design of river restoration projects. Simple techniques (such as utilizing high, expected, and low bounds) exist to identify and manage uncertainty, however, these techniques are rarely (if ever) used. Through the development of the requirements matrices and case studies, guidance will be presented to aid river restoration practitioners in avoiding these two very common (and 'deadly') failure characteristics.

1.6 Organization of Paper

I present this paper in four sections. The first section consists of Chapters 1 and 2, providing an introduction to the subject addressed (Chapter 1) and the methods employed to achieve the research objective (Chapter 2). The second section consists of the direct contributions of my research (Chapters 3 and 4). These chapters present a summary of the comprehensive river restoration literature review (Chapter 3) and the 'requirements' matrix and associated restoration resources derived from the literature review (Chapter 4).

The third section (Chapters 5 and 6) validates the developed matrices through application to river restoration case studies and summarizes the archiving of river restoration documentation collected during this research effort.

The final section (Chapters 7 and 8) outlines future work and summarizes general research conclusions. The field of river restoration is far too complex to be fully characterized in one research project, but rather is a field with limitless opportunities for learning and sharing knowledge. This research endeavor signifies a launching point for my engineering career, not a terminus.

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Chapter Two

2 RESEARCH APPROACHES AND METHODS

Approaches are general themes applied to my river restoration research and methods are specific procedures implemented in my research. First, a discussion on general approaches on which the research is based is presented, then specific field, desktop studies, and analytic methods are explicated.

Although not specific methods, the approaches used in my research shaped the configuration of my research program. Approach themes include: Systems and System Theory; Restoration Technology Delivery System; Tiger Teams; Restoration Project Life-Cycle Phases; and Risk and Uncertainty.

Systems and System Theory provided a means by which to integrate the many aspects of river restoration into one holistic entity. This approach allows for ecology to be directly linked to physical form and river hydraulics. It allows for watershed management strategies to be included in river restoration project selection and configuration. It allows for the inclusion of political factors in policy choices and budget allocations to river restoration projects.

Restoration Technology Delivery System is a collaborative effort between the public, government, and industry to construct a system that produces 'desirable' outputs (*Bea, 2007a; Bea, 2007b; Wenk, 1996; Wenk, 2006*). In the case of river restoration, the output that is attempting to be achieved is rehabilitation of damaged ecosystems. The context of the TDS is valuable in that it provides a conceptual model by which to relate interactions and relationships between different stakeholders and technology developers.

Restoration Project Life-Cycle Phases provide a means by which to track river restoration project from the concept stage (inception) through planning, design, construction, and 'operations.' The operations phase accounts for the functioning of the project and includes activities such as effectiveness and validation monitoring. Accounting for the entire life-cycle of a project allows for the evaluation of transitions (and their impact on the integrity of the river restoration project) between development stages (i.e. planning, design, construction), as well as transitions between different organizations and groups involved with the development of the river restoration project (such as designers potentially misinterpreting conceptual plans developed by project planners).

Tiger Teams (*Clark and Wheelwright, 1992*) are an organizational approach whereby projects are developed by an integrated and unified team of applicable specialties. This integrated team works together on all aspects of the project development (life-cycle phases). The traditional approach to river restoration project development has followed the Functional Model (*Clark and Wheelwright, 1992*) whereby separate teams are responsible for different life-cycle stages of the restoration development. The benefit of "Tiger Teams" is that project development times can be significantly compressed (because all 'aspects' of project development are represented on the team) and potential project conflicts can be identified early on due to the requisite variety represented on the "Tiger Team" for the river restoration project, resulting in fewer transition errors and more reliable river restoration projects.

Risk and Uncertainty address performance of the river restoration project. Unfortunately, no project has a 100% anticipated success rate due to uncertainties in elements the project is exposed to (i.e. the magnitude of the 100-year flood, future land use changes, or the future effects of global climate change) and uncertainties associated with individual project components (such as survival rates of planted vegetation in the first five years within project completion or changes in channel geometry and roughness as a result of vegetation growth over time).

A more in-depth discussion of these approaches (Systems and System Theory; Restoration Technology Delivery System; Tiger Teams; Restoration Project Life-Cycle Phases; and Risk and Uncertainty) is presented below:

2.1 Systems and System Theory

The inherent complexity of river restoration requires systems thinking. Systems thinking is a shift of mind from seeing parts to seeing wholes (*Brookes and Shields, 1996; Everard and Powell, 2002; NRC, 1992; and Senge, 2006*) and without which, there would be no incentive or means by which to integrate individual components once they have come into practice.

Systems theory addresses complexity (detail complexity and dynamic complexity) as well as feedback loops (*Ackoff, 1999; Churchman, 1981; Krone, 1980, Senge, 2006*). Detail complexity relates to many variables whereas dynamic complexity addresses issues of cause and effect, especially where effect over time are not obvious (*Senge, 2006*). Feedback mechanisms are captured through system archetypes and interaction diagrams.

Thus, the application of systems theory to river restoration provides a theoretical basis for merging the many physical and organizational components of river restoration. This complexity means that river restoration (as a system) has components that are highly inter-related, interactive, and inter-dependent, making it virtually impossible to quickly establish crisp, clear system boundaries and structure.

Krone (*1980*) states that systems are characterized by wholeness; interdependence; dynamics (systems grow, alter, decay, die over time and through intervention); components of inputs, people, structure, process, outputs, and boundaries; interchanges with their environments; equifinality (a final state may be reached from many different beginning states, and from one beginning many end states may be reached); organized by complexity; experiences reciprocal dependence (an action within a system causes other actions); and reflects the Gestalt phenomenon (the whole is greater than the sum of the parts).

Systems are frequently thought of as a set of two or more elements that satisfies three conditions (*Ackoff, 1999*): the behavior or each element has an effect on the behavior of the whole; the behavior of the elements and their effects on the whole are interdependent; and however subgroups of the elements are formed, each has an effect on the behavior of the whole system and non has an independent effect on it. A system is a whole that can not be divided into independent parts: every part of a system has properties that it loses when separated from the system and every system has some (essential) properties that none of the parts do (*Ackoff, 1999*). Ackoff (*1999*) states the system principle as "if each part of a system, considered separately, is made to operate as efficiently as possible, the system as a whole will not operate as effectively as possible."

Synthesis (see *Section 2.8 - Synthesis*) is the key to systems thinking. Synthetic thinking (*Ackoff, 1999*) relates to understanding of a system. Analytic thinking (*Ackoff, 1999*) relates to knowledge of a system. Data are symbols that represent the properties of objects and events. Information consists of processed data. The nature of the difference between data and information is functional, not structural. Information is contained in descriptions, answers to questions that begin with who, what, when, where, and how many. Knowledge is conveyed by instructions, answers to how-to questions. Understanding is conveyed by explanations, answers to why questions. Synthetic thinking allows for an understanding of the system to be developed, not just a knowledge, or characterization of the system by select descriptive information.

An ounce of information is worth a pound of data

An ounce of knowledge is worth a pound of information

An ounce of understanding is worth a pound of knowledge (Ackoff, 1999)

In order to reliably manage systems, it is imperative that a fundamental <u>understanding of the system</u> be attained, as opposed to a pre-occupation of collecting of disparate data and hap-hazard knowledge on select components of the system.

Churchman (*1981*) proposes five basic considerations that must be kept in mind when thinking about the meaning of a system:

1. *The total system objectives and, more specifically, the performance measures of the whole system;*

2. *The system's environment: the fixed constraints;*
3. *The resources of the system;*
4. *The components of the system, their activities, goals, and measures of performance; and*
5. *The management of the system.*

Churchman (*1981*) emphasizes that although this 'system list' is commonly accepted, "it omits any mention of people (e.g. the people who should be served by the system or the people who should be making the decisions, or the people who should plan for change)." People have a dramatic influence on the practice of river restoration: which projects are completed and which are not, the allocation of resources to restoration projects, the technical rigor by which the river restoration projects are developed and implemented, and how the watersheds within which the river restoration projects are situated are managed. Although not addressed specifically in this Section, the impact of people on river restoration practices is discussed in *Section 2.2 Restoration Technology Delivery System*.

Systems analysis is a set of techniques – qualitative, quantitative, and mixed – with methods recruited from the scientific method, systems philosophy, and branches of various scientific disciplines dealing with the phenomenon of choice (*Krone, 1980*). Churchman (*1981*) suggests that there are four different (and independent) ideas as to what constitutes the premise for and drives "the systems approach." These ideas are efficiency, science, humanism, and anti-planning.

1. *Advocates of <u>efficiency</u> claim that the best approach to a system is to identify the trouble spots (especially places where there is waste), unnecessarily high costs, and then proceed to remove the inefficiency;*
2. *Advocates of <u>science</u> claim that there is an objective way to view the system and to build a 'model' of the system that describes how it works. The science that is used may consist of mathematics, economics, and/or behavioral (i.e. psychology, sociology, etc.);*
3. *Advocates of the use of human feelings (<u>humanists</u>) claim that systems are people and the fundamental approach to systems consists of first looking at human values: freedom, dignity, privacy. Above all, the 'systems approach' should avoid imposing plans or interventions of any kind; and*
4. *<u>Anti-planners</u> believe that any attempt to lay out specific and 'rational' plans is either foolish, dangerous, or outright evil. The correct 'approach' to systems is to live in them, to react in terms of one's experience, and not to try to change them by means of some grandiose scheme or mathematical model.*

These four ideas highlight (efficiency, science, humanism, and anti-planning) that there is not one correct way to view or analyze systems. As is discussed later in this paper (*Section 2.6 - Modes of Inquiry*), the Unbounded Systems Thinking (UST) and Multiple Realities modes of inquiry allows for multiple perspectives to be incorporated into the systems analysis process. It is not required that one viewpoint be embraced to perform systems analyses.

There are many levels of systems analysis. Meta-analyses (*Krone, 1980*) focus on (1) conceptualizing the underlying theory by which the analysis will be conducted, (2) an initial study to identify resources, knowledge, and time required to complete the system analysis, and (3) the configuration of a systems analysis approach or model (quantitative, qualitative, or mixed) appropriate for analysis of a category or problems. The development of the analysis model provides the technical framework by which to conduct the actual systems analysis.

The formal systems analysis should include (*Krone, 1980*) behavioral research that defines the current state and operation of the system, values research to identify preferences for the system, and normative research that identifies what should be created but with the inclusion of feasible alternatives and preparation of written reports and briefings for decision makers. Frequently, it is very challenging to analyze the entire system, so a manageable subsystem is selected as a pilot study or experiment (*Krone, 1980*). Krone (*1980*) emphasizes that the system model (developed during the meta-analyses) should be chronically updated and improved as additional information/knowledge is gained about the system. Krone (*1980*) states:

Create a new systems analysis model to evaluate or replace a model previously adopted with marginal or poor results and to identify improvements considering lessons learned from the earlier failure.

Do nothing under the assumption that: the present quality of the system is good enough; or, future events will resolve the problem without formal analysis; or, the *constraints on your analysis capability preclude systems improvements or redesign.*

Learning from failed analysis efforts provides crucial insights into important components of systems analysis that must be included to minimize the likelihood of undesirable results. Common pitfalls associated with systems analysis include (*Krone, 1980*):

- *Overlooking the importance of conceptualizing the systems analysis effort prior to selection of analysis techniques and methods;*
- *Overestimating and overselling the analytical performance capability and/or underestimating the time and effort available versus realistic and available resources;*
- *Adapting the problem to fit the available analytic models, tools, and methods (the "Procrustian" solution to complexity);*
- *Failing to reality test through model fixation;*
- *Assuming that no quantification is necessary or the corollary, assuming that quantification is all that is necessary;*
- *Confusing values (preferences) with value (utility);*
- *Assuming the analysis process is values neutral, thus failing to explicate values (either the analysts' or the system's);*
- *Failing to identify non-compromisable absolute values;*
- *Using the wrong techniques, models, criteria, or standards;*

- *Neglecting applicable feedback or crossed inputs;*
- *Assuming that analysis must always be costly;*
- *Depending too much on technology;*
- *Neglecting past and future time impacts;*
- *Group-thinking analysis team or institution;*
- *Overlooking unique system features;*
- *Making good incremental decisions that lead to bad end results;*
- *Neglecting the fact that systems analysis is an art (extra-rational expertise) as well as science (rational expertise);*
- *Forgetting risk analysis, limiting alternative search too much;*
- *Ignoring one of three feasibility categories (economic, technological, and political);*
- *Forming a poor image of the adversary (how might the system analysis be attacked or recommended actions counteracted);*
- *Forgetting that there are problems outside your domain of systems analysis dealing with faith, politics, communications, and culture; and*
- *Failure to communicate analysis understandability to decision-maker(s).*

Krone (*1980*) recommends that the systems analysis demonstrate to the decision-maker that the findings of the analysis flow from a structured, rational, scientific analysis that has also addressed extra-rational considerations and that the recommendations will, within acceptable risk and values parameters, result in net benefits. The analysis documentation should include a statement of the problems addressed, scope, methodology, findings, a clear summary of alternatives with associated impacts, conclusions, and recommendations for actions or further study. Concepts and relationships between variables should be clearly presented. The problem, as applicable, should be broken down into sub-issues susceptible to decisions; conclusions should be tested for sensitivity to assumptions, values, and uncertainties relating to alternative recommendations and alternative clients. The main interconnectedness with other issues and systems should be clearly identified. Finally, the presentation of the analysis should be designed for the audience receiving the message, should be concise and creative, and should withstand and counter criticism of the strongest antagonist.

The level of systems analysis that is conducted for this dissertation is limited to the meta-level. Specifically, I address the underlying theory by which the analysis was conducted and identify general river restoration resources and knowledge available to complete the system analysis (see Chapter 4 for a more detailed discussion). Detailed river restoration system analysis has been included as a future work item (Chapter 7), however, a systems-approach (as addressed in this dissertation) is required for reliability-based river restoration.

2.2 Restoration Technology Delivery System

River restoration can be conceptualized as a t*echnology*. Technology is defined as "the application of scientific knowledge, especially in industry or business" (*Webster, 1988*) and the development and application of this technology arises within the context of human society. A Technology Delivery System (TDS) is a collaborative effort between the public, government, and industry to construct a system that produces 'desirable' outputs (*Bea, 2007a; Bea, 2007b; Wenk, 1996; Wenk, 2006*).

The public, government, and industry must work collaboratively to develop a technology that yields the desired output. Inputs into the technology consist of things such as laws and regulations, financial resources, and human capital. The output of the technology must be compatible with, and be in dynamic equilibrium with, the natural environment (sustainability) and must also yield the desired results. Figure 2 shows a conceptual overview of a TDS.

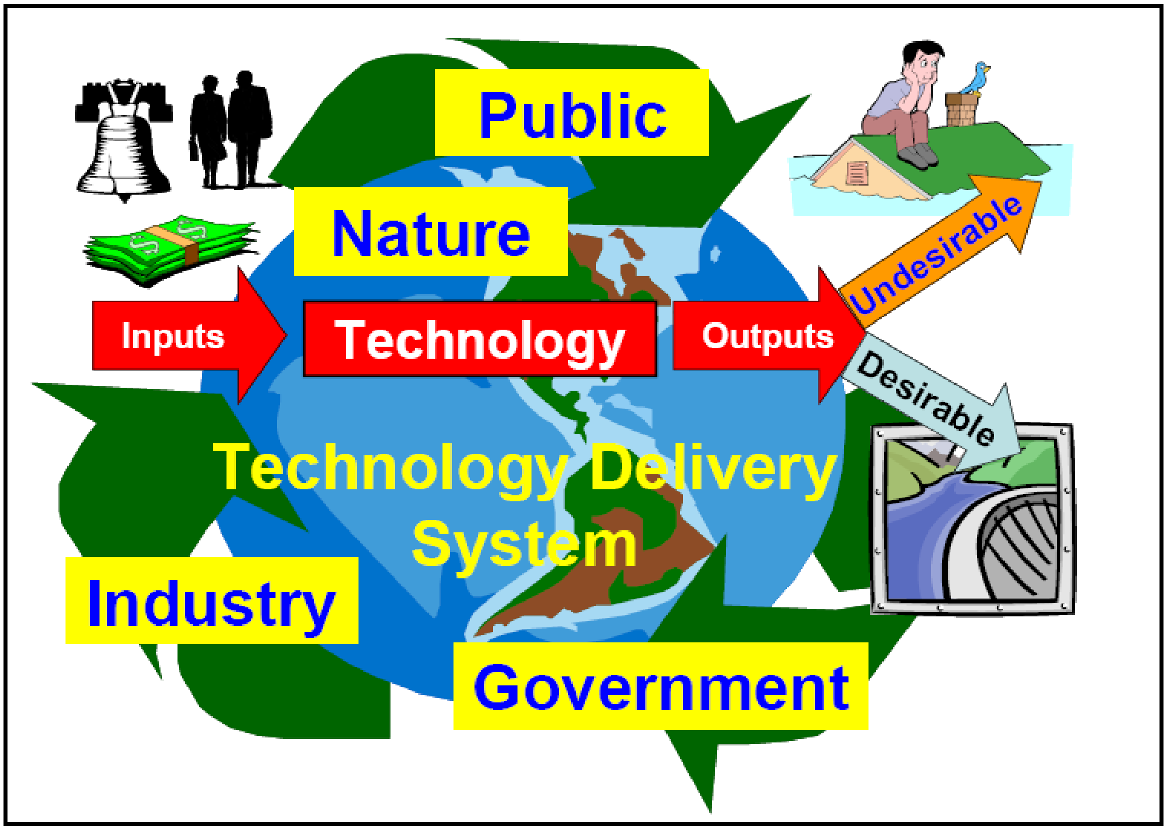

Figure 2: Conceptual overview of a Technology Delivery System (*Bea, 2007a*).

All three groups (public, government, and industry) impact the configuration of the technology and have major impact on the inputs to the technology, and as a result, have a major impact on the outputs of the technology. Technology development is iterative and when the desired outcome is not achieved based on the developed Technology, updates and revisions to the Technology process are generally implemented.

This Technology revision is most frequently encountered following a major natural disaster and is reflected in updates of building codes, allocation of research funding, and development and implementation of new technology tools.

In the case of river restoration, the output that is attempting to be achieved is rehabilitation of damaged ecosystems. The context of the TDS is valuable in that it provides a conceptual model by which to relate interactions and relationships between different stakeholders and technology developers. The river restoration TDS was the framework by which the 'state of the practice' scholarly literature review (Chapter 3) was conducted. The TDS highlights that 'we are all in this together.' The public, government, and industry must all work in unison in order for effective solutions to be developed and implemented.

2.3 Restoration Project Life-Cycle Phases

Life-cycles provide a means by which to track river restoration project from the concept stage (inception) through planning, design, construction, and 'operations.' The operations phase accounts for the functioning of the project and includes activities such as effectiveness and validation monitoring. Accounting for the entire life-cycle of a project allows for the evaluation of transitions (and their impact on the integrity of the river restoration project) between development stages (i.e. planning, design, construction), as well as transitions between different organizations and groups involved with the development of the river restoration project (such as designers potentially mis-interpreting conceptual plans developed by project planners).

Distinct river restoration project development activities occur during the progressive life-cycle stages. However, there is also significant overlap between the stages. For example, the collection of baseline data to be used during the design phase should be collected during the planning phase of the river restoration project. Common activities that occur during the river restoration life-cycles are:

- Planning – Watershed plans, problem definition, conceptual model development, constraints and requirements definition, conceptual alternatives development;
- Design – Cost/benefit/criteria 'solution' selection; engineering analyses; development of plans and specifications, construction schedules, cost estimates;
- Construction – Installation of prescribed project elements; construction oversight and as-built surveys are crucial;
- Operations (including Monitoring) – frequently ignored in restoration considerations; burn in failures; adaptive management; monitoring (implementation, performance/effectiveness, validation); establishment period.

The quality of projects produced is a function of the expertise and requisite variety of the project participants, and available resources. Identification of life-cycle phase activities and their impact on overall project success is part of the scope of my research and will be discussed in more detail in Chapter 4.

Because proper planning is critical to system success and little or no information on the subject matter has been presented within the context of river restoration systems, an in-depth discussion of planning concepts and principles of this life-cycle stage is presented.

2.3.1 Planning

Planning is the design of a desired future and of effective ways of bringing it about (*Ackoff, 1999*). It is a decision-making process (but we need to keep in mind that not all decision-making is planning). Planning is special in three ways (*Ackoff, 1999*):

1. *Planning is something we do in advance of taking action; that is, it is anticipatory decision-making. It is a process of deciding what to do and how to do it before action is required. If we desire a certain state of affairs at some future time and it takes time to decide what to do and how to do it, we must make the necessary decisions before taking action. If these decisions could be taken quickly without loss of efficiency, planning would not be required;*
2. *Planning is required when the future state that we desire involve a set of interdependent decisions; that is, a system of decisions. A set of decisions forms a system if the effect of each decision in the set on the relevant outcome depends on at least one other decision in the set. Some of the decisions in the set may be complex, others simple. But the principal complexity in planning derives from the interrelatedness of the decisions rather than from the decisions themselves. Sets of decisions that require planning have the following important characteristics:*
    a. *They are too large to handle all at once. Therefore, planning must be divided into stages or phases that are performed either sequentially by one decision-making body, or simultaneously by different bodies, or by some combination of sequential and*

simultaneous efforts. Planning must be staged or, put another way, it must be itself planned.

b. *The set of necessary decisions can not be subdivided into independent subsets. Hence a planning problem cannot be broken down into independent subplanning problems. The subplanning problems must be interrelated. This means that decisions made early in the planning process must be taken into account when making decisions later on in the process and the earlier decisions must be received in light of the decisions made subsequent to them. This is why planning must be carried out before action is required.*

3. *Planning is a process that is directed toward producing one or more future states which are desired and which are not expected to occur unless something is done. Planning is thus concerned both with avoiding incorrect actions and with reducing the frequency of failure to exploit opportunities. Obviously, if one believes that the natural course of events will bring about all that is desired, there is no need to plan. Thus planning always has both a pessimistic and an optimistic component. The pessimism lies in the belief that unless something is done a desired future state is not likely to occur. The optimism lies in the belief that something can be done to increase the chance that the desired state will occur.*

Ackoff (*1999*) proposes three planning principles:

- *<u>Participative Principle</u> – The most important part of planning is the process of developing the plan. Effective planning is not done 'to' or 'for' an effort, rather, it is done 'by' it. The planning efforts should involve all aspects (internal and external) affected and all stakeholders should be provided the information, knowledge, understanding, and motivation to enable effective planning;*
- *<u>The Principle of Continuity</u> – All plans are based on a large number of assumptions. An assumption is a proposition that we treat as though it were true; we act on it. It differs from a forecast. Because organizations and environments change continually, planners should explicitly document their assumptions and identify what will, will not, and can change. These assumptions should be monitored continually; and*
- *<u>The Holistic Principle</u> – The Holistic Principle has two parts: the principle of coordination and the principle of integration. Coordination has to do with the interaction of units at the same level and integration with units at different levels. The principle of coordination asserts that all parts of an organization at the same level should be planned for simultaneously and interdependently. No part or aspect of a particular system can be planned for effectively if planned for independently. Breadth is more important than depth, and interactions are more important than actions. The principle of integration asserts that planning done independently at any level of a system can not be effective; all levels*

should be planned for simultaneously and interdependently. It is common for a practice or policy established at one level of a system to create problems at another level. Therefore, the solution of a problem that appears at one level may best be obtained by changing a policy or practice established at another level.

There are three general temporal types of planning: proactive, interactive, and reactive (*Ackoff, 1999; Bea 2006*). Proactive planning is conducted at the very beginning stage of the system development. It is prospective in nature and relies on the previous experience and knowledge base of the planning team. It consists of preparation, predictions, and extrapolations and can extend a short time or long time into the future. The effectiveness of proactive planning is highly dependent upon the accuracy of the forecasts upon which it is based. Unfortunately the forecasts are frequently in errors and uncertainties due to extended factors such as economic, social, and political conditions (*Ackoff, 1999*). To address the errors and uncertainties, interactive planning and adaptive management (adaptive management is discussed in more detail in *Section 2.5.3 - Adaptive Management (interactive measures)*).

Proactive planning consists of five phases (*Ackoff, 1999*):

1. Formulation of the Mess – Determination of what problems and opportunities face the system planned for, how they interact, and what obstructs or constrains the system's response;
2. Ends Planning – Determination of what is wanted by means of an idealized design of the system. Goals, objectives, and ideals are extracted

from a four-step process: selecting a mission, specifying the desired properties of the system, developing an idealized design (or redesign for existing malfunctioning systems) and selecting the gaps between the new design and reference scenario. Comparison of the reference scenario and the idealized redesign identifies the gaps to be closed or narrowed by the planning process;

3. Means Planning – Determination of what should be done to close or narrow the gaps, which requires selecting or inventing appropriate courses of action, practices, projects, programs and policies;
4. Resource Planning – Determination of the types of resources and how much of each will be required by the means chosen, when they will be required, and how they are to be acquired or generated; and
5. Implementation and Control – Determination of who is to do what, when it is to be done, and how to assure that these assignments and schedules are carried out as expected and produce the desired effects on performance.

Similar to proactive planning, interactive planning acknowledges change, errors, and uncertainties. The most important benefit of planning is not derived from use of its product (a plan), but from engaging in its production (*Ackoff, 1999*). Interactive measures occur during the design, construction, and operations/maintenance system life cycles. These measures are used to mitigate undesirable system (or system component) performance before system (or system component) failure.

Reactive planning places emphasis on addressing changes after system (or system component) failure. It is retrospective in nature and generally results in the reformulation of planning strategies for future projects based on the 'lessons learned' from previous/past projects (*Ackoff, 1999; Bea, 2006*).

Planning is perhaps the single most important factor within a reliability-based approach. Figure 3 shows that the Planning phase offers the highest level of influence on a project, with the lowest cost implication for changes. As the project develops, it becomes more and more difficult to implement changes (or reconfigurations) of a project and the associated cost of change to implement those changes increases greatly. As a result, it is important (from a financial perspective) to 'get it right' at the beginning and/or to configure projects so that future changes are possible and the cost of implementation is minimized.

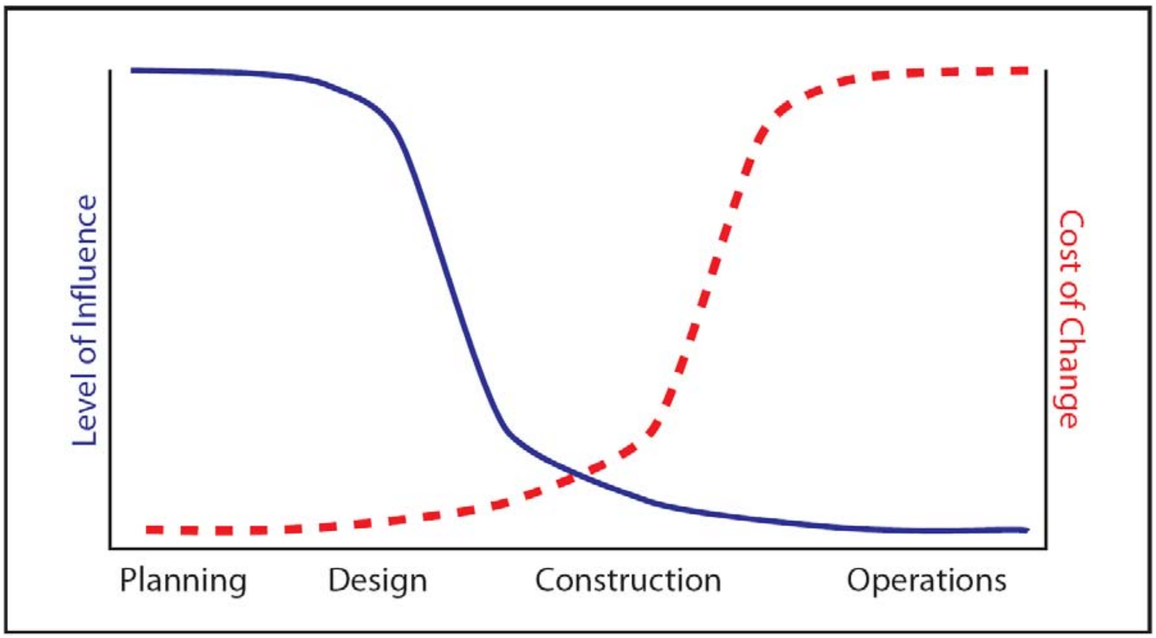

Figure 3: This conceptual graph shows that the level of influence is greatest during the planning phase, with the lowest cost of change (adapted from Burke, 1999).

2.4 Tiger Teams

Clark and Wheelwright (*1992*) propose four distinct team organizational structures:

- Functional;
- Lightweight;
- Heavyweight; and
- Tiger Teams (Autonomous teams).

The structure (Figure 4) and organizational composition of river restoration development teams have an impact on the configuration, design, and implementation of the projects. As a result, matching the structure of the river restoration development team to meet the characteristics of the problem being tackled is an important element of successful project development. In my research, I have found that Tiger Teams are an excellent means by which to configure teams to develop realistic solutions to the complexities of river restoration projects.

Tiger Teams are an organizational approach whereby projects are developed by an integrated and unified team of applicable specialties. Tiger Teams represent the concept of requisite variety. The law of requisite variety states that when the variety or complexity of the environment exceeds the capacity of a system (natural or artificial), the environment will dominate and ultimately destroy that system (*Ashby, 1956; Love and Cooper, 2007*). In another words, the diversity associated with the nature of the problem being addressed must be mirrored by the problem solving team in order to successfully resolve the problem. For example, a river restoration team that has no expertise in project funding will be very likely to fail during the construction phase of the project due to the lack of cost estimating and fund generation skills.

The majority of organizations today are structured around a classic Functional team structure (*Clark and Wheelwright, 1992*). Functional teams are primarily grouped by discipline (or specialty), working under the direction of a specialized subfunction manager. This approach of specialized sub-groups is also known as 'silos.' The different subfunctions must coordinate ideas through groups, with each group only having a limited understanding of the whole corresponding to their specialty. Over time, primary responsibility for the project passes sequentially from one functional group to the next, a transfer frequently termed "throwing it over the wall" (*Clark and Wheelwright, 1992*). This approach requires that tasks be known and pre-established at the outset of the project (which can be very difficult for non-conventional projects that have not been historically completed). The entire project development process is decomposed into separable, independent activities (*Clark and Wheelwright, 1992*). Because most tasks are not known for river restoration projects, coordination and integration can suffer. The Functional team structure works well for 'commodity' type projects that have a proven historical track record without much site-specific interpretation and adjustments required.

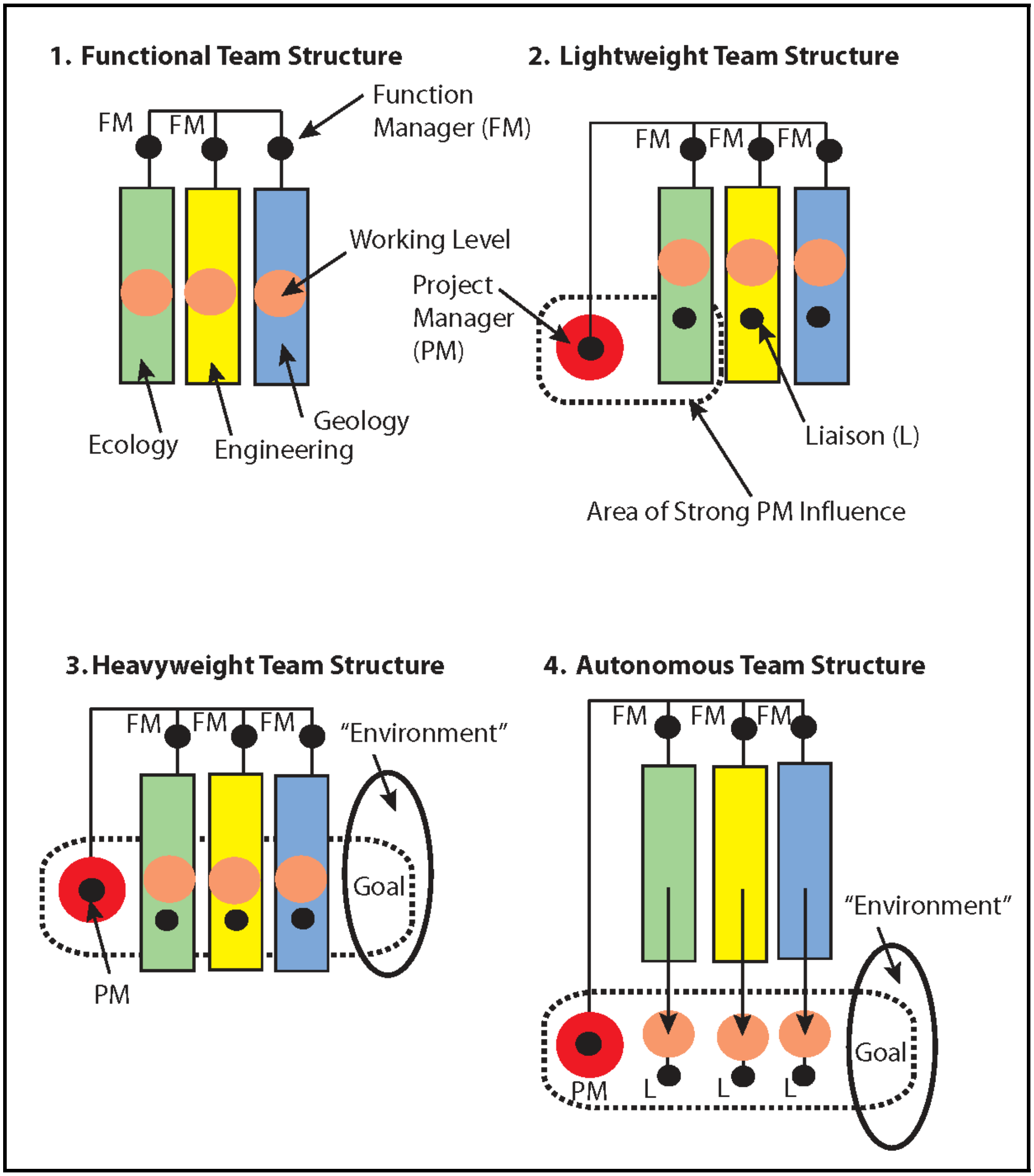

Figure 4: **Schematic team structures from *Clark and Wheelwright, 1992***

Similar to the Functional team structure, the Lightweight team structure have distinct functional specialties, but each subfunction designates a liaison to coordinate with an overall project manager (*Clark and Wheelwright, 1992*). This allows the many different subfunctions to interact and decrease coordination errors between the specialties.

The project managers are generally middle or junior level with little status or influence within the larger organization. These project managers are responsible for informing and coordinating the activities of the functional organizations, the key resources remain under the control of subfunction managers (*Clark and Wheelwright, 1992*). The lightweight manager does not have the power to reassign people or reallocate resources, instead, confirms schedules, updates time lines and facilitates cross-group communication. The Lightweight team structure is perhaps the most common river restoration organizational structure where engineers, landscape architects, geomorphologists, and biologist firms work cooperatively on a project and one of the disciplines takes the role of overall project manager (but that project manager is not an employee of all the individual collaborative organizations).

In contrast to the Lightweight teams, Heavyweight project managers have direct access to and responsibility for the work of all those involved on the project. These managers are 'heavyweights' in that they are generally senior managers within the organization and in addition to having expertise and experience, they also have significant organizational clout (*Clark and Wheelwright, 1992*). They have primary influence over the people working on the project and supervise their work directly through key functional people on the core teams. The core group of people are dedicated and physically co-located with the heavyweight project leader (*Clark and Wheelwright, 1992*). Although the Heavyweight manager has immediate impact on team members' status, longer term career development of individual team members remains with their original organization. The Heavyweight manager only has control with respect to the immediate project, not subsequent projects.

Finally, Tiger Teams (Autonomous Teams) have individuals from the different functional areas formally assigned, dedicated, and co-located to the project team (*Clark and Wheelwright, 1992*). The project leader is given full control over the resources contributed by the different functional groups. The project leader becomes the sole evaluator of the contribution made by individual team members. The team establishes its own incentives and rewards as well as norms for behavior. However, the team is fully accountable for the final results of the project: success or failure is its responsibility and on one else's (*Clark and Wheelwright, 1992*).

The fundamental strength of the Tiger Team structure is focus. Everything the individual team members and project manager do is concentrated on making the project successful, thereby allowing Tiger Teams to excel at rapid, efficient new process developments. They handle cross-functional integration extremely well (*Clark and Wheelwright, 1992*).

This integrated Tiger Team works together on all aspects of the project development (life-cycle phases). The traditional approach to river restoration project development has followed the Functional Model (*Clark and Wheelwright, 1992*) whereby separate teams are responsible for different life-cycle stages of the restoration development. The benefit of Tiger Teams is that project development times can be significantly compressed (because all 'aspects' of project development are represented on the team) and potential project conflicts can be identified early on due to the requisite variety represented on the Tiger Team for the river restoration project, resulting in fewer transition errors and more reliable river restoration projects.

Additionally, Tiger Teams have the added benefit of ensuring that all team participants have a clear understanding of the project concept. By having a clear understanding of the project concept, conceptual integrity of the project is maintained, reducing the likelihood of project misconfigurations or deviations. Requisite variety is an important component of a reliability-based approach to river restoration.

2.5 Risk and Uncertainty

Risk provides a measure (either qualitative or quantitative) of the likelihood and consequence associated with an event (such as the occurrence of a flood and the consequences of flooding from the flood event). Unfortunately, no project has a 100% anticipated success rate due to uncertainties in elements the project is exposed to (i.e. the magnitude of the 100-year flood, future land use changes, or the future effects of global climate change) and uncertainties associated with individual project components (such as survival rates of planted vegetation in the first five years within project completion or changes in channel geometry and roughness as a result of vegetation growth over time) as well as incompleteness in analyses and/or evaluations.

Rowe (*1998*) argues that there are five general approaches to managing uncertainty:

1. *Ignore it – although the simplest way to deal with uncertainty, ignoring is generally considered a poor decision that leads to missed goals and opportunities as well as significantly higher costs. In addition, the increased likelihood of unanticipated negative surprises can often lead to civil or even criminal liability due to negligence.*

2. *<u>Use margins of safety to provide contingencies</u> – this common approach (also referred to as Safety Factors) to address uncertainty provides for contingencies and "conservative" designs, where conservative implies erring on the "safe side." When used in more than one parameter, the margins of safety pyramid, resulting in extreme conservatism, resulting in increased costs. When margins of safety are applied at low levels by each designer in the organization (or more frequently organizations) the pyramiding effect leads to extreme conservatism in decision options. This can force the decision makers at the top into constrained choices that are neither optimal nor cost-effective. The masking of uncertainties (and resulting over-conservatism) suppresses other, perhaps more desirable, alternatives, leading to missed opportunities.*
3. *<u>Use contractual means to limit uncertainty and risk</u> – legal contracts can be used to limit one's responsibility for both competent and negligent error. This shifts the risk to others, usually at higher costs or inequitable distribution of risks. Greater uncertainty leads to higher negotiated costs. Contracts have loopholes. These can be established explicitly by document wording or may be implicit when not specifically addressed. Contracts can be voided in the courts by judicial means, as well as through bankruptcy and criminal negligence and behavior. As a result, in many cases, the negotiated legal requirements of the contracts may have no relation to reality.*

4. *<u>Buy insurance to spread the risks</u> – insurance and underwriting provide means to spread financial risks to an individual or organization over a much larger population. Premium charges are a function of the degree of uncertainty involved, the size and frequency of consequences, and last year's underwriting performance. However, limits are usually set for the extent and amount of coverage placed, with premiums reflecting these limits. Moreover, restrictions may be placed and underwriters may balk at payout time necessitating legal proceedings to obtain redress.*
5. *<u>Directly understand and manage the uncertainties</u> – Managing uncertainty (which is realized on river restoration projects through the implementation of Adaptive Management) requires acknowledging its existence in every decision, analyzing the impact of these uncertainties, having the means to help resolve the decisions involved, and taking remaining uncertainties into account. There is uncertainty in all parameters of a decision: performance, costs, benefits, risks, etc. Performance and benefit are often difficult to measure directly, particularly intrinsic benefits. Risks, the downside of a gamble involving probabilities, cannot be measured, only modeled (after the event occurs, the outcome is certain). The uncertainty in cost-estimation is often masked by accounting procedures which are designed for bookkeepers as opposed to estimation. The uncertainties in all these parameters must be addressed collectively.*

Reliability relies on the application of probability to system attributes. As a result, measures of reliability are only as good as the depth of analyses completed. The major benefit associated with reliability based approaches is to chronicle project elements and the associated uncertainty with those project elements. This list of project uncertainties and magnitudes becomes a basis to directly understand and manage uncertainties and for the application of adaptive management practices, allowing project participants to quickly identify the high-uncertainty, high-impact project aspects that should be monitored during the construction and operation phases of the project.

A systematic procedure has been developed for risk studies that are also directly applicable to reliability studies. This procedure consists of the following steps (*USACE IWR, 1996; USACE IWR, 1997; Yoe, 1998*):

1. **Select the analytic framework for analyses**
    a. Review and select models/techniques for evaluating the project components
    b. Understand the models selected for analysis
    c. Make an informed choice of tools
2. **Identify the types and sources of uncertainties**
    a. Know the types of uncertainty
    b. Know the sources of uncertainty
3. **Identify potential key variables**
    a. Determine the potential importance
4. **Design the Analysis**
    a. Assess importance of analysis

b. Review available tools

c. Select the tools

5. Collect data

a. Consider data needs of the analysis

b. Define your terminology

c. Design a data collection method

d. Use interval estimates

e. Use distributions

6. Identify major uncertainties

a. Review the potential key variables and identify actual key variables

b. Describe key uncertainties

c. Pay attention to key sources of uncertainty

7. Perform analyses

a. Do the analyses

b. Verify the analyses

c. Meet or exceed the minimum expectation of the analysis

d. Document your analysis

8. Communicate the results of the analysis

a. Tell the analysis story

b. Meet or exceed the minimum reporting requirements

c. Serve the risk (and reliability) management function

Traditional deterministic approaches assume that sufficiently conservative values for the demands and capacities on a system have been selected so that overall system performance success is achieved and management of uncertainty is unnecessary. For example, when evaluating the stability of a river bank slope, low strength values might be selected for the bank soils (capacity) and high water levels (demand) might be selected for the river level. The stability of the river bank slope (and resulting 'reliability' of the slope configuration) is the capacity divided by the demand. Conventional ratios (Factors of Safety) for river bank slopes range from about 1.3 to 1.5. Note that there is no basis for the Factor of Safety aside from historic use. A well-characterized site is frequently treated the same as a poorly-characterized site (with little to no site investigations and resulting basis for assigning demand and capacity values.

Unlike the deterministic approach, the reliability approach directly accounts for uncertainties in the demands and capacities. It is not required that 'conservative' values be selected and used in analyses. Not only does the reliability based approach account for demand and capacity uncertainties, but it also provides a rational basis by which to ascribe Factors of Safety in design and contingency in project budgeting. The more uncertainty there is, the greater the required Factor of Safety.

As mentioned earlier, river restoration is a relatively new endeavor and is fraught with uncertainties. Adaptive management is a very popular approach to interactively manage project uncertainties. By characterizing the magnitudes of project uncertainties, it becomes possible to rank and prioritize project aspects to monitor and refine. To illustrate this concept in the form of an example, two scenarios (A and B) for the design and determination of a crest elevation of a flood protection levee on a river are depicted in Figure 5.

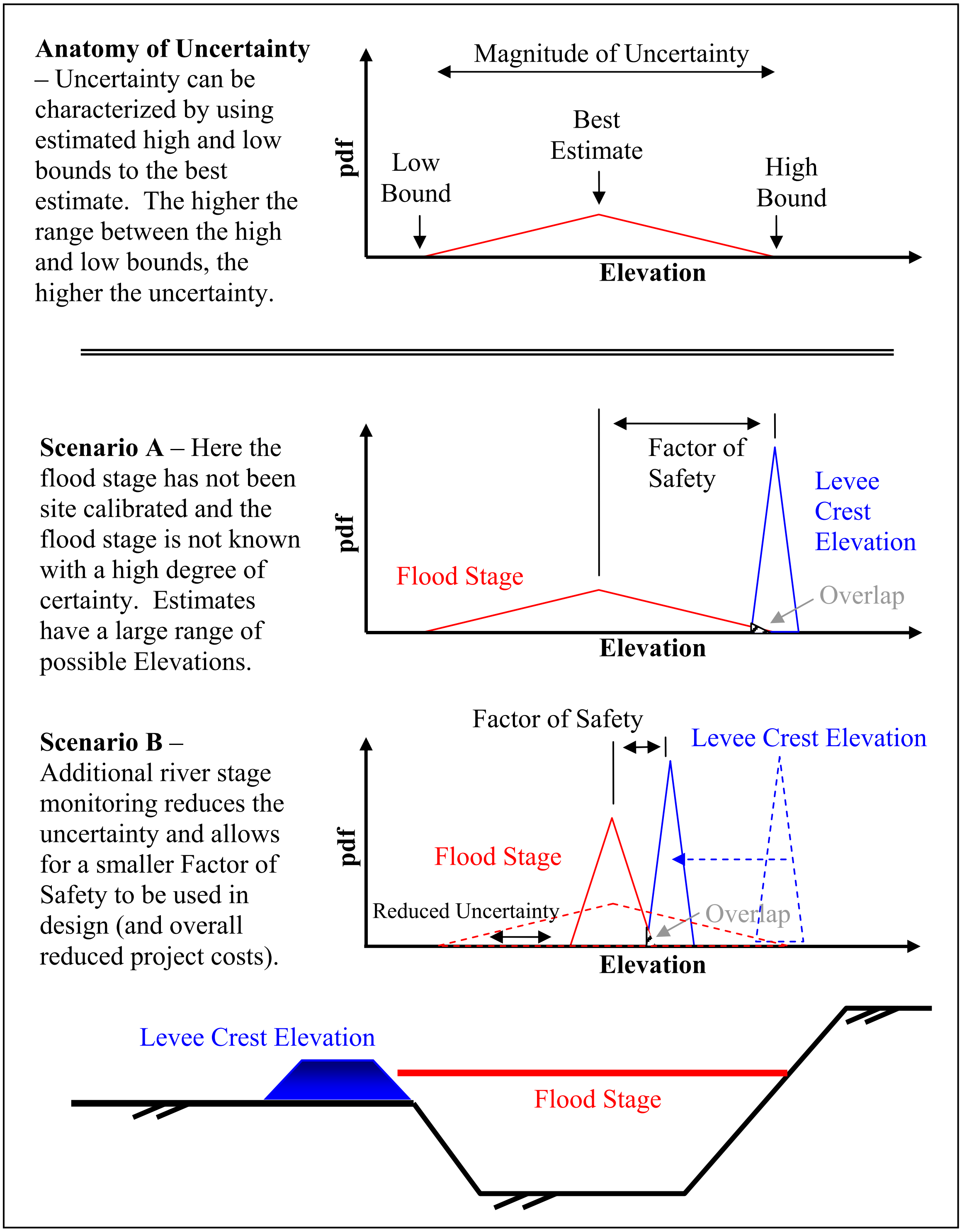

Figure 5: Reducing the uncertainty in the flood stage allows for a significant reduction in the design Factor of Safety for this example levee crest elevation.

Scenarios A and B each have different magnitudes of uncertainty for the demands (but note they have the same 'expected' elevation). Scenario A has a much larger uncertainty in the demand (corresponding to the river level stage for the design flood) than Scenario B. A reason for the difference in uncertainty might be because for Scenario B, river stage is monitored during the planning and design phases (perhaps on the order of 3-5 years) so discharge estimates can be calibrated with actual field data. As can be seen in the figure, in order for the likelihood of failure (proportional to the shaded area of overlap between the demand and capacity) of Scenario A and Scenario B to be the same, a much higher Factor of Safety must be used for Scenario A to account for the higher uncertainty in flood stage. Although a simple example, this clearly demonstrates the value of tracking uncertainties to show and quantify the benefit of additional studies (such as through adaptive management) to reduce uncertainty.

The above example highlighted one of many aspects of a system that can be characterized via a reliability evaluation. However, in order to comprehensively evaluate the reliability of the river restoration project, the system quality (see *Section 2.5.1 Quality Attributes*) attributes must be defined as well as the acceptable range (acceptable vs. unacceptable quality). A discussion of system quality is presented below. It should also be noted that a detailed discussion of Reliability will not be presented in this paper, rather basic reliability fundamentals used in my research will be highlighted and the reader is encouraged to review traditional reliability texts (*Ang and Tang, 1975; Ayyub and McCuen, 2002; Bea, 2006; Singh et al, 2007; USACE IWR, 1992; Vick, 2002*) for a more in-depth discussion of reliability theory.

Perhaps the most important aspect of reliability is the degree to which the analysis is complete and comprehensive. The combination of life-cycle phases into the reliability evaluation aids in ensuring that a more comprehensive system analysis is performed, compared with traditional reliability analyses that may focus primarily on one or two of the life cycle phases (design and operations). The primary means by which the adequacy of reliability analyses is confirmed is via validation (see Section for validation techniques used in this research).

However, due to the nature of river restoration projects, it can take 10-, 20-, or even 50-years to obtain a test of the completed project (for example a 100-year design flow event passing through the site). As a result, direct project validation is not necessarily feasible for all projects and the culmination of 'lessons learned' from previously completed projects (to calibrate reliability analyses) through the form of detailed case studies are critical. In order to develop case studies a rigorous documentation and monitoring program (consisting of implementation, effectiveness, and validation monitoring) is essential.

Key aspects of the case study documentation is to adequately describe the specific goals or project intents, the desired quality of the system, the anticipated performance characteristics of the project, and any adaptive management techniques (including motivations, implementation, and results) applied to the river restoration project. A more in-depth discussion of these attributes is presented below.

2.5.1 Quality Attributes

Quality is defined as fitness for purpose and freedom from unanticipated defects (*Bea, 2006*). Quality is <u>different</u> from restoration goals or intents. The quality of a project is a quantitative and/or qualitative characterization of a project goal. Quality consists of serviceability, safety, compatibility, and durability. Bea (*2006*) describes these quality aspects:

Serviceability – *functionality of the system and suitability for the proposed purposes. Serviceability is intended to guarantee the use of the system for the agreed purpose and under the agreed conditions of use.* An example of serviceability is the degree to which an in-stream habitat restoration project provides (continued) habitat for fish in the years following construction of the project.

Safety – *is the freedom from excessive danger to human life, the environment, and property damage. The capacity of a system to withstand its demands (loadings) and other hazards is directly related to and most often associated with safety.* An example of safety in river restoration is flood protection elements installed adjacent to rivers to protect residents within the protected area from high flood waters. If the flood protection elements fail during a major storm, the residents may be inundated and, if the flood waters are sufficiently deep, some residents may drown if caught unaware.

Compatibility – *assures that the system does not have unnecessary or excessive negative impacts on the environment and society during its life-cycle. It is also the ability of the system to meet economic, time, and aesthetic requirements.* An example of compatibility is the ability of a river restoration project to adhere to a project budget developed during the planning life-cycle phase (with significant uncertainty in cost estimates) during the construction life-cycle phase after months or years have passed and significant changes in the original cost estimate have occurred, but may not have been reflected through updated funding sources.

Durability – *is the freedom from unanticipated degradation, maintenance problems, and costs and assures that serviceability, safety, and compatibility are maintained during the intended life of the system.* Durability also incorporates the concepts of robustness, redundancy (defined below in the discussion of robustness), and resilience.

Robustness is derived from four strategies (*Bea, 2006*): *(1) configuration – the topology of the system elements, components, and system provides back-ups in the primary load carrying paths (frequently identified as redundancy); (2) ductility – the strain or deformation characteristics of the system elements, components and system are such that large inelastic deformations can be sustained without substantial losses in demand, load, or stress carrying capacities; (3) excess capacity – the demand, load, or stress characteristics of the system elements, components, and system are such that when excessive demands are experienced due to unanticipated overloadings or redistribution of demands from other elements and components in the system, the system is able to sustain these loadings and demands without undue distress. Capacity is related to appropriate capabilities to satisfy anticipated and unanticipated demands; and (4) correlation – in systems comprised of both series and parallel elements, if the correlation of the individual element capacities is high (correlation coefficients greater than about 80 %), then the likelihood of failure of the systems is determined by the probability of failure of the most likely to fail element in the system. Appropriate management of correlation is important in creation of robust systems.*

There has been some discussion of sustainability as a measure of quality (*Downs, 2008; Gregory and Downs, 2008; Hillman and Brierley, 2008*), but the actual context of sustainability in these discussions is more consistent with durability (robustness and resilience) as opposed to classical definitions of sustainability that relate to activity resource consumption over time. Classic sustainability is defined as the ability to "meet the needs of the present without compromising the ability of future generations to meet their own needs" (*Bruntland, 1987; EPA, 2008*).

2.5.2 Likelihood of success

The most important aspect of reliability based approaches is the establishment of acceptable thresholds of risk, where risk is the product of likelihood and consequences. The selection of appropriate risk levels is very challenging and should directly involve the project stakeholders. Numerous writings have addressed the issue of acceptable risk levels (*Bea, 2006; Bruins and Heberling, 2004; Fischoff et al, 1981; Glickman and Gough, 1991; Haimes et al, 1992; Mockett and Simm, 2002; Sing et al, 2007; USACE, 1999; Vick, 2003; Wenk, 2006*), but none of these writings have explicitly addressed river restoration projects.

The United States Army Corps of Engineers (*1999*) has guidelines for recommended target reliabilities for expected performance levels. These target reliabilities are presented in Table 1.

Table 1: Target Reliability Indices

Expected Performance Level	Beta (β)	Probability of Unsatisfactory Performance
High	5.0	0.0000003
Good	4.0	0.00003
Above average	3.0	0.001
Below average	2.5	0.006
Poor	2.0	0.023
Unsatisfactory	1.5	0.07
Hazardous	1.0	0.16

It is possible to correlate the target reliability indices (β) with Factors of Safety according to the following formula:

$$F.S._{50} = e^{\wedge}(\beta\sigma_{\ln RS}) \qquad \text{Equation 1}$$

In this formulation, β is the safety index, R is the capacity, S is the loading/demand, and σ is the coefficient of variation in the demands and capacities (assuming a lognormal distribution).

Alternative approaches to establishing design levels exist, but are oriented to those projects where life safety is a primary concern, such as development of a town, hospital, or jail in a flood plain area that could receive a large flood with significant inundation and possible loss of life due to drowning. A paper was presented in the ASCE *Journal of Geotechnical and Geoenvironmental Engineering* by John T. Christian (*2004*) that highlighted select approaches to risk management. Christian summarized studies performed by Baecher that back-calculated the annual probability of failure based on failures of actual engineered systems.

The lives lost or financial loss associated with the failure was plotted against the back-calculated annual probability of failure. This plot (Figure 6) provides a mechanism by which to ascertain the desired level of performance of a given engineered structure, based on historic performance. It is important to note that the two x-axes are used separately, not conjunctively (human life is not equated to a dollar value in this chart).

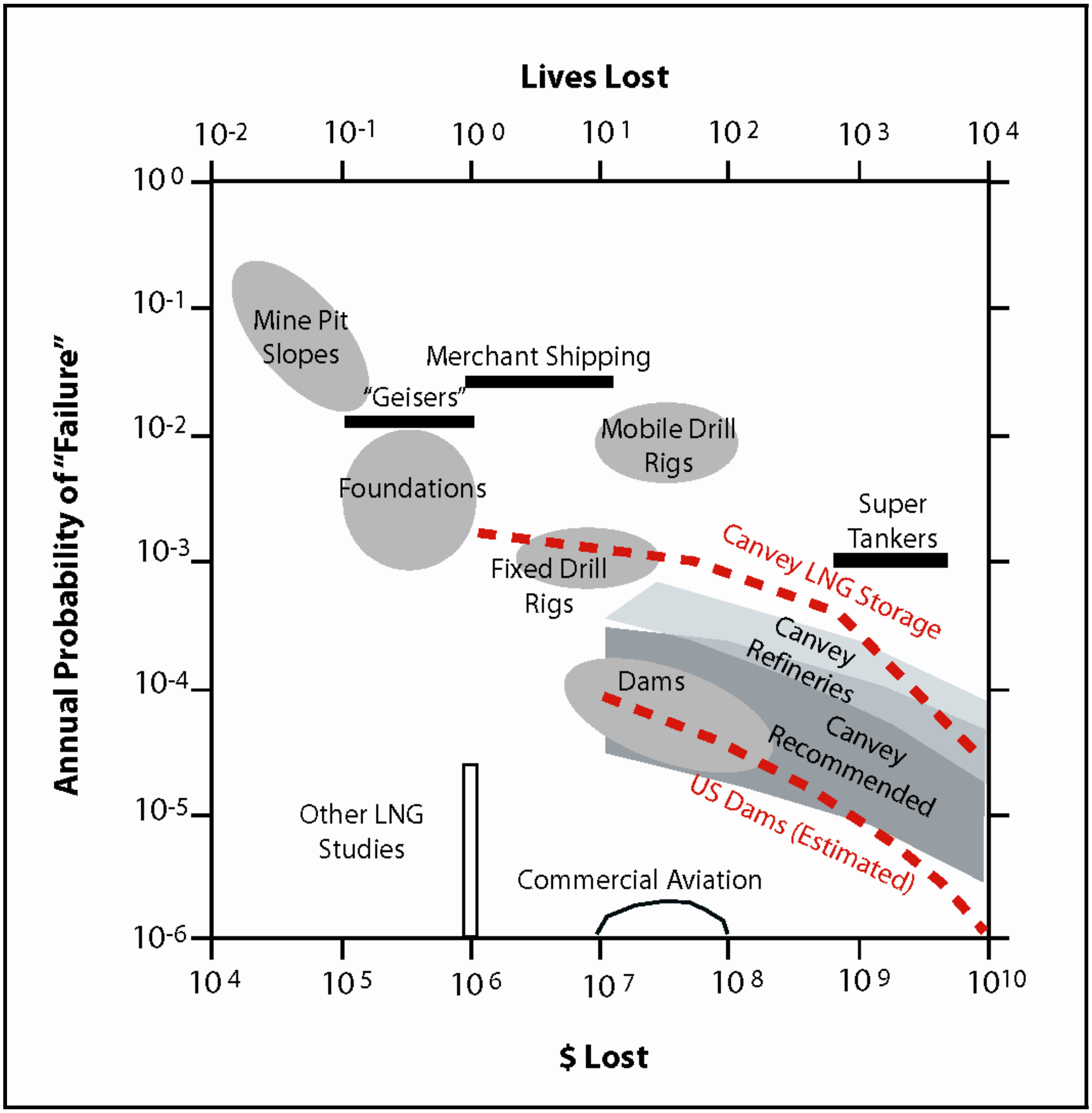

Figure 6: A plot of back-calculated annual probability of failure vs. lives lost and $ lost (note that either the "lives lost" or "$ lost" axes are used, they are not intended to be used in conjunction) (from *Christian, 2004*).

In addition to the studies by Baecher, Hong Kong and the Netherlands have risk-based decision making tools (Figure 7) as part of their planning process to establish acceptable levels of safety, from a life-safety standpoint, for engineered systems based on the expected number of fatalities (*Christian, 2004*). Failures that impact large populations and may result in fatalities greater than 1,000 are required to have very low annual probabilities of failure.

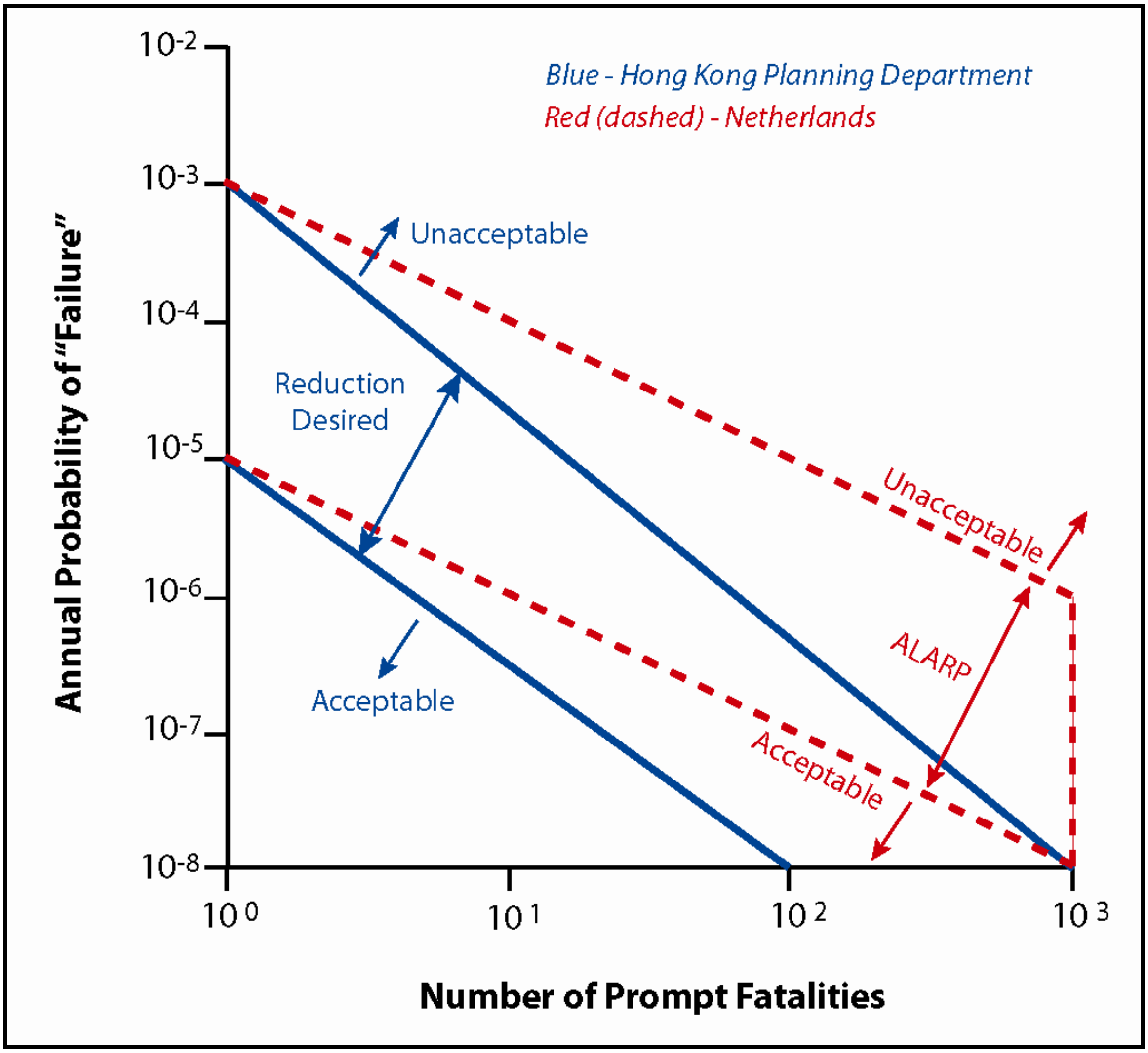

Figure 7: F-N diagrams adopted by the Hong Kong Planning Department and F-N diagram as proposed for planning and design use in the Netherlands. (*Christian, 2004*)

To convert the annual probability of failure (Pf_{pa}) to an "average return period, (ARP)" such as the 100-year or 1,000-year event, the following correlation can be used:

$$Pf_{pa} \approx (ARP)^{-1} \qquad \text{Equation 2}$$

Using the risk management planning tool (Figure 7) developed by the Hong Kong Government Planning Department as an example, a proposed engineered system that has the potential to result in 1,000 fatalities would have an acceptable risk (based on an annual frequency of occurrence) of 10^{-8}, the range over which the principle As Low As Reasonably Prudent is recommended varies from Pf_{pa} of 10^{-8} to 10^{-6}, and a risk with a Pf_{pa} of less than 10^{-6} is considered unacceptable.

Table 2: Risk Levels for a System with the Potential for 1,000 Fatalities

Risk Level	Pf_{pa}	Annual Return Period (yrs)
Acceptable	$<10^{-8}$	>100,000,000
ALARP	10^{-6} to 10^{-8}	1,000,000 to 100,000,000
Unacceptable	$>10^{-6}$	< 1,000,000

Table 2 presents a summary of calculated Annual Return Periods (in years), based on the probability of occurrence limits recommended by the Hong Kong Government Planning Department. This example highlights the sociological decision made in Hong Kong that high consequence events should occur very infrequently, with an annual return period of 1 million years! Although this may not be realistic due to natural and anthropogenic uncertainties, the premise of varying acceptable risk as a function of consequences is feasible.

The Eurocode 1, Part 1 provides recommendations on the total probability of failure over the design life of the project as well as the associated consequences of failure

(*Mockett and Simm, 2002*). The Eurocode performance requirements include (*Mockett and Simm, 2002*):

- *A structure shall perform its required function during an agreed percentage of time and remain fit to do so during its planned lifetime;*
- *A structure shall sustain all actions and influences likely to occur during execution and use; and*
- *A structure shall not be damaged to an extent that is disproportionate to the original cause.*

The Eurocode classifies consequences of failure as minor, moderate, and major (*Mockett and Simm, 2002*):

- *<u>Minor</u> – risk to life, given a failure, is low and also economic and social consequences are small or negligible;*
- *<u>Moderate</u> – risk to life, given a failure, is medium or economic and social consequences are considerable; and*
- *<u>Major</u> – risk to life, given a failure, is high, or economic and social consequences are very great.*

Mockett and Simm (*2002*) propose the concept of a "risk bubble" by which to manage multiple risks. This risk bubble (Figure 8) allows for both the visualization of tolerability and the interaction of stakeholders during the planning and design process.

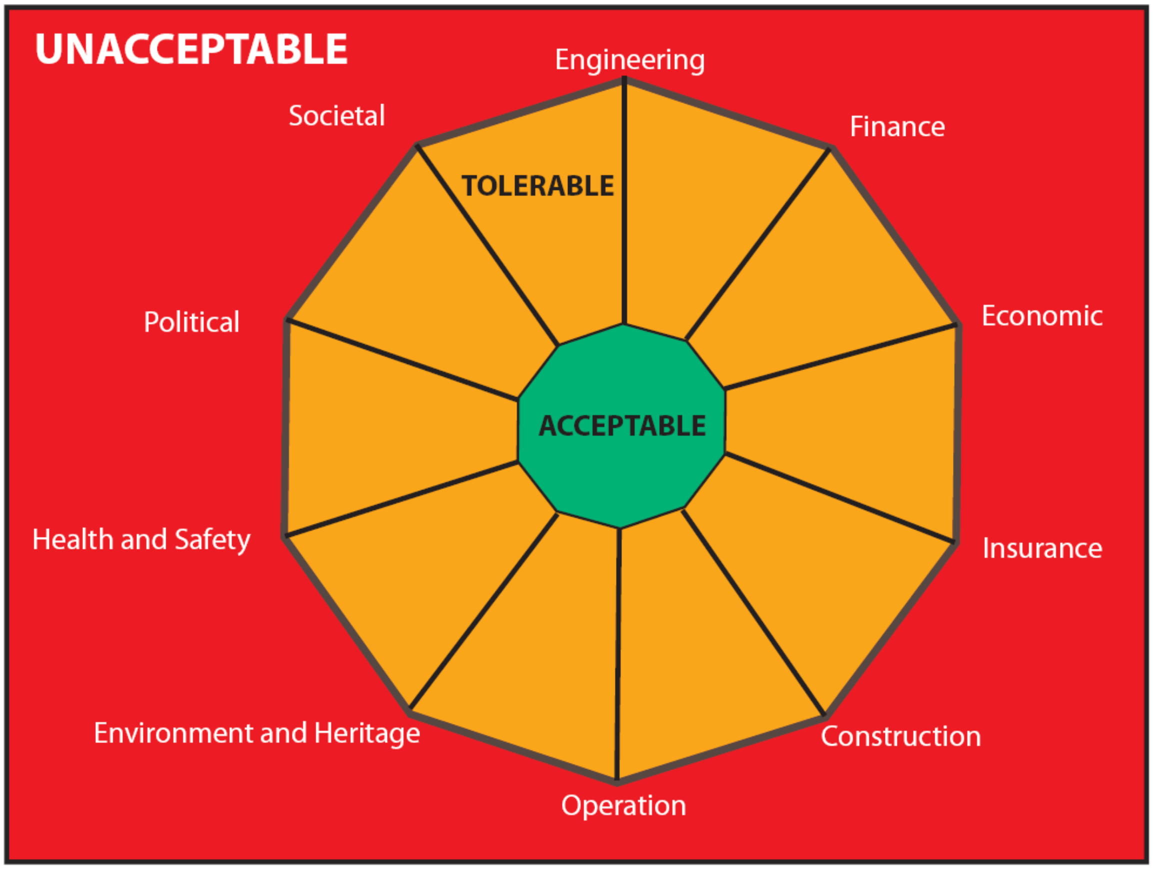

Figure 8: The risk bubble with multiple hazard areas (Mockett and Simm, 2002).

The risk bubble is a conceptual model of all the hazard categories involved in the project, with the center of the bubble being completely acceptable and the outer margins of the bubble being intolerable. The dimensions and units of each axis are constrained by the 'risk owner" using either qualitative or quantitative terms. The benefit of plotting all hazards areas together is that each stakeholder can understand the tolerance levels of the other stakeholders and aid in inter-stakeholder communication. This concept also facilitates conceptual integrity of the project and allows project designers to look at key issues that need to be considered and begin to get a feel for the bigger picture in terms of setting appropriate risk levels.

2.5.3 Adaptive Management (interactive measures)

Adaptive management is the practice of selecting management actions that will help answer questions about the system being managed while coping with unexpected outcomes and uncertainties that can not be quickly resolved (*Anderson et al, 2003; Downs and Gregory, 2004; Downs and Kondolf, 2002; Gordon et al, 2005; Halbert and Lee, 1991; NAS, 2004; Walters, 1986*). Deviations from anticipated system behavior can occur from a number of reasons, including (*Ackoff, 1999*):

- *The information used in making the decision was in error;*
- *The decision-making process may have been faulty;*
- *The decision may not have been implemented as intended; and/or*
- *The environment may change in a way that was not anticipated.*

Management is the control of a purposeful system by a part of that system and involves three functions and a continual supply of information to carry them out (*Ackoff, 1999*):

1. *Identification of actual and potential problems (threats and opportunities);*
2. *Decision-making (deciding what to do and doing it or having it done); and*
3. *Maintenance and improvement of performance under changing and unchanging conditions.*

Directly assessing and managing uncertainty in river restoration allows for the identification and segregation of high-uncertainty items from low-uncertainty items, then additional scientific studies can be completed to gain the additional knowledge required to decrease the magnitude of these uncertainties (*Wissmar and Bisson, 2003*). The spirit of this approach is captured by the 'adaptive management,' which is "a way of establishing hypotheses early in the planning, then treating the restoration process as an experiment to test the hypotheses" (*FISRWG, 2001*). Adaptive management does not systematically qualitatively or quantitatively characterize river restoration uncertainties.

Adaptive management does not encourage the postponement of actions until "enough" is known about the managed system, but rather designed to support action in the face of the limitations of scientific knowledge and the complexities and stochastic behavior or large systems (*NAS, 2004*). It enhances scientific knowledge and reduces uncertainties stemming from natural variability, stochastic behavior of ecosystems, and the interpretation of incomplete data.

A hierarchy of data sources was developed by Rowe (*1998*) to categorize the degree to which the data can be validated, ranging from empirical validation at the top and unvalidated data at the bottom. The hierarchy (*Rowe, 1998*) is:

1. Standard Distribution – Empirical data validated by many different investigations and generally agreed upon as a standard. This type of data is generated from validation monitoring.
2. Empirical Distribution – Empirical data validated for specific instances. This type of data is analogous to region-specific planning and design rules of thumb, such as Rantz's "Suggested Criteria for Hydrologic Design of Storm-Drainage Facilities in the San Francisco Bay Region, California" (*1971*).

3. Validated Model – A model that has been validated empirically validated. For example, a river flood stage record based on a gauging station with a 200-year period of record.
4. Unvalidated Model – A model which has not been empirically validated. For example, the utilization of the rational runoff method (*Dunne and Leopold, 1978*) without any site-specific calibration data.
5. Alternate Models – Alternate unvalidated models that seem to be less reasonable, but possible, can be used in a decision process.
6. Expert Value Judgment – In the absence of empirical data, the judgment of experts may be used. Since the information is unvalidated, the selection, framing, and bias of experts become dominant. Sometimes consensus may be important, otherwise, diversity may be important and retained.
7. Best-Guess Estimate – A form of presumably expert judgment based upon reasonable expectation and the framework in which the decisions are requested, but acknowledging the lack of integrity in the estimates at the outset.
8. Test Case – Artificial values used to test models for their sensitivity, critical variables, and the value of additional information.

The lower the data sources for river restoration projects fall on the data hierarchy list, the greater the need for project-specific validation and adaptive management strategies. Anderson et al (*2003*) propose four decision making strategies associated with adaptive management:

1. *Static decision making – takes the 'best available' information at the time and determines the best restoration plan in a single decision at the onset of the project. This strategy can be considered as an adaptive decision making strategy if it is structured to improve clarity and to take explicit account of uncertainties.*
2. *Passive adaptive management – uses the information available to choose good management or restorations at the start, but also specify future decision points where feedback and new information are analyzed so that the choice of subsequent restoration actions is based on the total information available at each decision point.*
3. *Active (or experimental) adaptive management – implements formal experiments with management options in different places or different times to test hypotheses about the system and management options as quickly as possible. An actively adaptive restoration plan might define a 5- or 10-year "learning period" in which various management or restoration options would be implemented in different places, preferably in well thought out experimental design. After the learning period is completed, the management options that appear best at that time would be implemented more widely. The learning period is not a delaying call for more research. The experimental program begins during the learning period on the same spatial and temporal scale as the main restoration activities.*

4. *<u>"Evolutionary" problem solving</u> – This strategy relies on temporal improvements in the restoration practice through innovation (a number of small, independent or prototype projects, intended to address a practical problem), diffusion (agreement on important variables to monitor and efficient, regular communication among the people involved with the project), and adaptation (selecting and adapting the most promising examples to new circumstances). Explicit structuring to encourage innovation, diffusion, and adaptation differentiates evolutionary problem solving from mere "trial and error." Evolutionary problem solving is especially appropriate when multiple goals are incommensurable (i.e. lacking a common measure or basis of comparison). The evolutionary approach takes advantage of people's ability to make decisions and solve problems by gathering cases and stories from experience.*

For the adaptive management strategies, NAS (*2004*) identifies six steps to be implemented:

1. Project objectives are regularly revisited and accordingly revised. As the project develops, the understanding of project participants on the system increases and social and political preferences are likely to evolve in addition to the occurrence of environmental and social "surprises."
2. A model of they system being managed is developed. This model provides an explicit baseline understanding of and assumptions about the system being managed. The system model helps explain responses to

management actions and helps identify gaps in the limits of scientific and other knowledge. The models contain clearly-defined variables that characterize the state of the system and its rates and direction of change. It is important that adaptive management participants understand the model assumptions and limits so that model results are not equated with reality.

3. A range of management choices are considered at the outset of the project in light of the stated objectives and the model(s) of system dynamics. When possible, simultaneously implementing two or more carefully monitored actions can allow for rapid discrimination among competing models.
4. Monitoring and evaluation of outcomes. Adaptive management requires some mechanism for comparing outcomes of management decisions. The gathering and evaluation of data allow for the testing of alternative hypotheses, and are central to improving knowledge of ecological, economic, and other systems. Monitoring should focus on significant and detectable indicators of progress toward management objectives. Monitoring should help distinguish between natural perturbations and perturbations caused by management actions. Monitoring, in and of itself, however, does not ensure progress, and monitoring should not be equated with adaptive management. Monitoring programs and results should be designed to improve understanding of environmental and economic systems and models, to evaluate the outcomes of management decisions,

and to provide a basis for better decision making. Monitoring systems should be an integral part of program design at the outset and not simply added post hoc after implementation.

5. A mechanism for incorporating learning into future decisions. Objectives, models, consideration of alternatives, and formal evaluation of outcomes all facilitate learning. There should be one or more mechanisms for feeding information gained back into the management process. The political will to act upon that information must also exist. Without a mechanism to integrate knowledge gained in monitoring into management actions, monitoring and learning will not result in better management decisions and policies.
6. A collaborative structure for stakeholder participation and learning must exist. Achieving meaningful stakeholder involvement that includes give and take, active learning (through cooperation with scientists), and some level of agreement among participants, represents a challenge, but is essential to adaptive management. This implies that some of the onus for adaptive management goes beyond mangers, decision makers, and scientists, and rests upon interest groups and even the general public (i.e. the river restoration Technology Delivery System).

Objective setting, performance measures, and accountability are important components of an adaptive management approach to river restoration programs, but few projects have been sufficiently documented and disseminated relative to the number of projects completed (*O'Donnell and Galat, 2008*). This implies that river restoration very rarely engages in actual adaptive management practices and to date, this approach is more an ideal rather than a state of the practice activity (*Gordon et al, 2004; Lee, 1993; NAS, 2004*).

As outlined in the above sections, the identified approaches in this research (Systems and Systems Theory; Restoration Technology Delivery System; Tiger Teams; Restoration Life-Cycle Phases; and Risk and Uncertainty) are integral to a reliability-based approach for river restoration.

In addition to the previously outlined approaches embraced by my research, I employed specific research, desktop, and field methods. A discussion of these methods I presented below:

2.6 Modes of Inquiry

An inquiry system is "a system of interrelated components for producing knowledge on a problem or issue of importance: (*Churchman, 1971; Mitroff and Lindstone, 1993*). Modes of inquiry are knowledge developing methods and consist of :

- Agreement;
- Analysis;
- Multiple realities;
- Conflict; and
- Unbounded Systems Thinking (UST).

The last three (multiple realities, conflict, and UST) are considered most appropriate for complex problems in that they do not require discrete system boundaries and structure. They are capable of dealing with unbounded and unstructured problems or ‘messes’.

Agreement (*Mitroff and Lindstone, 1993*) relies on tight correlations with observations and data that point toward a central tendency. This is an Inductive Consensual Inquiry System because a general conclusion is inferred from a limited set of observations, where the ‘correct’ answer is established through consensus. This method is appropriate for those problems that are bounded and well structured.

Analysis (*Mitroff and Lindstone, 1993*) is the mode of inquiry that engineers and scientists are very familiar with. This method is an Analytic-Deductive approach whereby a complex phenomenon is broken down into components and analyzed. The analysis typically consists of mathematical operations requiring numerical inputs and generating numerical outputs. Cause and effect relationships are defined with either dependent or independent variables. This approach requires a system to be well defined, with a clear structure and distinct boundaries.

The third mode of inquiry system is Multiple Realities (*Mitroff and Lindstone, 1993*) which is appropriate for those problems where there is at least an initial sense of what the ‘problem’ is. This approach acknowledges that each discipline has its own models, theories, variables, terminology and factors that are considered important. Analyses are performed using three or four or even ten different approaches. This mode can also be thought of as “triangulation” and reflects the concept of “requisite variety.” By looking at the problem from as many different perspectives as possible, your likelihood of capturing the essence of the system is far greater than only utilizing one discipline’s approach.

Unlike the Multiple Realities approach, the Conflict (*Mitroff and Lindstone, 1993*) mode of inquiry, would ideally not have any overlap between involved parties. The idea here is to get the two very extreme or polar views on the subject and have them 'battle it out.' In this context, 'information' is measured within the 'audience' by the degree of clarification or deepening entrenchment into the audience member's own position. Did the debate help reformulate your view on a subject matter by hearing the polar opposite argument, or did it confirm your original position? Clearly, this mode of inquiry is dependent upon the quality of the polar views expressed and range of topics debated.

The last mode of inquiry is Unbounded Systems Thinking (*Mitroff and Lindstone, 1993*), which assumes that everything interacts with everything and all of the sciences and professions are considered fundamental, none is superior to or better than any other. The basis for choosing a particular way of modeling or representing a problem is not characterized solely by conventional logic and rationality, rather also incorporates very general concepts such as aspects of social beliefs, ethics and morality, justice, and fairness. Unbounded Systems Thinking is TRANSdisciplinary and does not 'solve' problems within rigid pre-established frameworks. Rather, it's an interactive process by which to manage and synthesize messy systems that are not well-defined or structured so to as to establish some definition and structure, based on the system as a whole.

2.7 Scholarly Literature Review

Scholarly literature review will be used to synthesize the current 'state of the practice' aspects of river restoration. A scholarly literature review is a systematic, explicit, and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners (*Blaxter et al, 2006; Creswell, 2006; Turabian, 2007*).

2.8 Synthesis

Synthesis (or putting things together) is a method that is very useful to initially make ‘sense’ of messes and is a key element of systems thinking (*Ackoff, 1999*). Synthesis consists of:

1. Identifying a containing whole (system) of which the things to be explained is a part;
2. Explaining the behavior or properties of the containing whole; and
3. Then explaining the behavior or properties of the thing to be explained in terms of its role(s) or function(s) within its containing whole (*Ackoff, 1999; Bea, 2002*).

The synthesis approach is different from classical decomposition analysis approaches whereby problems are decomposed into separate elements; explanation of the behavior or properties of the separated individual element; aggregating the individual explanations into an explanation of the whole (*Ackoff, 1999*). Decomposition, thus, does not maintain conceptual integrity of the system, rather focuses conceptual integrity of the system elements.

Synthesis and analysis are complementary. Analysis focuses on structure and reveals how things work, whereas synthesis focuses on function and provides insights on why things operate the way they do (*Ackoff, 1999*).

Sensemaking (*Weick, 1995*) addresses key cognitive issues critical to the synthesis process. These issues include: placement of items into frameworks, comprehension, construction of meaning based on composition of disparate elements, interaction in pursuit of mutual understanding between multiple parties, patterns (creation and recognition), and redressing surprise.

2.9 Classification

Classification is the systematic arrangement in groups or categories according to established criteria (*Kondolf, 1995; Webster, 2008*). Classification refers to both the process of ordering objects in groups and the resulting system of groups (*Kondolf, 1995*). Utilization of classification schemes allows for the organization and grouping of information by interest areas. For this research, classification served as a primary tool by which to identify and to match restoration criteria with restoration goals.

A goal/intent classification scheme was developed by the NRRSS study (*Bernhardt et al, 2005*) as part of their nationwide river restoration project database (containing over 37,000 entries) and telephone survey interviews with restoration practitioners. This goal/intent classification scheme was adopted as part of this research. A short description of these goals/intents as defined by NRRSS (*Restoring Rivers, 2008*) is presented below:

- ***Aesthetics/Recreation/Education:*** *Activities that increase community value: use, appearance, access, safety, knowledge;*
- ***Bank Stabilization:*** *Practices designed to reduce/eliminate erosion or slumping of bank material into the river channel;*

- ***Channel Reconfiguration:*** *Alteration of channel plan form or longitudinal profile and/or day-lighting (converting culverts and pipes to open channels). Includes stream meander restoration and in-channel structures that alter the thalweg of the stream. Note that many in stream structures also claim to improve habitat;*
- ***Dam Removal/Retrofit:*** *Removal of dams and weirs or modifications/retrofits to existing dams to reduce negative ecological impacts. Excludes dam modifications that are simply for improving Fish Passage;*
- ***Fish Passage:*** *Removal of barriers to upstream/downstream migration of fishes. Includes the physical removal of barriers and also construction of alternative pathways. Includes migration barriers placed at strategic locations along streams to prevent undesirable species from accessing upstream areas;*
- ***Floodplain Reconnection:*** *Practices that increase the flood frequency of floodplain areas and/or promote flux of organisms and material between riverine and floodplain areas;*
- ***Flow Modification:*** *Practices that alter the timing and delivery of water quantity. Typically, but not necessarily associated with releases from impoundments and constructed flow regulators;*
- ***In-stream Habitat Improvement:*** *Altering structural complexity to increase habitat availability and diversity for target organisms and provision of breeding habitat and refugia from disturbance and predation;*
- ***In-stream Species Management:*** *Practices that directly alter aquatic native species distribution and abundance through the addition (stocking) or translocation of*

animal and plant species and/or removal of exotics. Excludes physical manipulations of habitat/breeding territory (see In-stream Habitat Improvement);

- ***Land Acquisition:*** *Practices that obtain lease/title/easements for stream-side land for the explicit purpose of preservation or removal of impacting agents and/or to facilitate future restoration projects. Note: Simple purchase and preservation to prevent potential future land conversion is insufficient for inclusion in the NRRSS database. Projects should demonstrate intended or actual cessation of detrimental activities in acquired land or active restoration components;*
- ***Riparian Management:*** *Revegetation of riparian zone and/or removal of exotic species (e.g. weeds, cattle). Excludes localized planting only to stabilize bank areas (see Bank Stabilization);*
- ***Stormwater Management:*** *Special case of Flow Modification that includes the construction and management of structures (ponds, wetlands and flow regulators) in urban areas to modify the release of storm runoff into waterways from watersheds with elevated imperviousness into waterways. These practices/structures generally aim to reduce peak flow magnitudes and extend flow duration. For the purposes of NRRSS Stormwater Management refers to water quantity not quality. Urban sediment, litter and temperature control should be categorized as Water Quality Management;*
- ***Livestock Exclusion:*** *Installation of physical barriers and/or land use changes that prevents direct access to the river by livestock.*
- ***Water Quality Management:*** *Practices that protect existing water quality or change the chemical composition and/or suspended particulate load. Remediation of acid*

mine drainage falls into this category as does CSO separation. Excludes urban runoff quantity management (see Stormwater Management); and

In addition to the NRRSS goal categories, restoration project life cycles (discussed in *Section 2.3 - Restoration Project Life-Cycle Phases*) will also be used as classification categories in the development of the restoration goal/intent 'Restoration Evaluation Checklist.'

2.10 Field Work

A number of field methods were employed during the execution of field work for this research. A description of the methods is presented below:

2.10.1 Total Station Survey

A Topcon GTS-211D Total Station was used for all Total Station surveys. The Total Station has an accuracy of +/- 0.25 cm. For each Total Station setup, two survey control points were established; an 'occupy' point over which the Total Station was centered and a 'backsight' point that enable the orientation of the Total Station to be locked into the site specified coordinate system. All coordinate systems are project specific and identified in the individual case studies.

2.10.2 Static GPS Surveys and Post Processing

Survey control was established using a survey grade Leica GPS receiver to collect GPS satellite data over established points. The GPS data was post-processed using the Online Positioning User Service (OPUS), provided by the National Oceanic and

Atmospheric Administration (*NOAA, 2008*). The horizontal and vertical datums are reported with each case study.

2.10.3 Terrestrial LiDAR Surveys

The LiDAR Field Surveys consist of mounting and leveling the ISITE 4400CR on a tripod with a standard tribrach mount at the selected scan location and then initiating a scan using a tablet PC interface. A primary advantage with the ISITE 4400CR is the ability to geolocate each scan in the field. This geolocation process consists of surveying the location of the LiDAR unit (to identify the 0,0,0 point of the scan) as well as backsighting the unit using the built in optical telescope onto a known point so that the orientation (azimuth) of the scan can be determined. Each scan is named and the reference location and backsight are identified. Upon completion of the scan, the data file is downloaded from the LiDAR scanner to the Tablet PC.

The ISITE 4400CR is a laser scanner that uses a time of flight pulsed range finder with a 905 nm laser and a beam divergence of 1.4mrad. The unit has a built in tilt compensator that ensures each scan is level prior to initiation of the scan. It has a measurement rate of 4400 points per second with a minimum angular separation of points of 0.108 degrees. The unit is outfitted with a 37 megapixel line scanning digital panoramic camera. The ISITE 4400CR has a scan range of approximately 3 m to 400 m (for high-reflectivity surfaces). The time required to scan at a medium density of points (1 million targeted points) is about 5 minutes. Point spacing at the high resolution scan mode at a distance of 5 m is approximately 1 cm and the point spacing at a distance of 200 m is approximately 40 cm.

2.10.4 Longitudinal Surveys

A longitudinal profile is a plot of channel elevation against distance down the channel, usually following the thalweg, the deepest part in the cross section. A measurement of the water surface elevation should also be performed at the same location at which the thalweg is measured to document water depth (this can later be used to validate the field survey points). Longitudinal profiles can be surveyed using a number of techniques, however a Total Station was used in this research.

Monitoring the longitudinal profile provides information on overall stream channel form and change over time. The long profile survey can identify steps in the profile, caused by bedrock outcrops or other grade control features, from a change in underlying geology or from regressive erosion or bed aggradation. Change in the longitudinal profile often occurs during high flows, so the timing of such surveys should be determined as a function of the sequence of flows.

2.10.5 Cross-Sectional Surveys

Cross-sections are profiles of elevations surveyed along a line transverse to the direction of creek flow. Cross-sections are commonly used in hydrologic modeling to determine bankfull dimensions, discharge values, and as input to calculations of soil-water shear stress (which impacts erodibility of the stream channel banks and bed mobility). Cross-sections can be surveyed using a number of techniques, however a Total Station was used in this research.

2.10.6 Features Mapping

Quantification of physical riparian and aquatic habitat through features mapping is a valuable tool to document physical habitat in and near the stream channel (*Storesund* *et al, 2007*). Features maps graphically summarize ecosystem habitat present in and near the stream channel by documenting the channel bed and substrate texture, physical and biological structures (i.e. willow walls), as well as habitat components (i.e. pool/riffle sequences). The channel bed and substrate is generally characterized via pebble counts (*Gordon et al., 2004; Kondolf, 1997*).

2.10.7 Photo-Documentation

Photo documentation consists of taking photographs from an established location with a pre-determined orientation at discrete time intervals (not necessarily regular time intervals) and with consistent lens, aperture, and lighting conditions (*Storesund et al, 2007*). Changes over time can then be observed, based on the collection of photographs.

2.11 Desktop Studies and Analyses

Desktop studies and analyses were conducted to aid with the validation of the developed 'requirements' matrix. A discussion of these methods is presented below.

2.11.1 Geographical Information System (GIS)

The computer program ArcGIS 9.2 (*ESRI, 2008*) was used to aggregate spatial case study data and to perform spatial analyses. ArcMap was the primary application used. ArcMap represents geographic information as a collection of layers and other elements in a map view. Common map elements include the data frame containing map layers for a given extent plus a scale bar, north arrow, title, descriptive text, and a symbol legend. Analysis extensions to ArcMap used in the analyses include 3D Analyst, and Spatial Analyst.

The ArcGIS 3D Analyst extension provides tools for three-dimensional (3D) visualization, analysis, and surface generation. 3D Analyst allows for the viewing of a surface from multiple viewpoints, querying a surface, creating realistic perspective imaging and provides tools for three-dimensional modeling and analysis, such as viewshed and line-of-sight analysis; spot height interpolation; profiling; steepest path determination; and contouring.

ArcGIS Spatial Analyst provides a broad range of powerful spatial modeling and analysis features. It allows for one to create, query, map, and analyze cell-based raster data; perform integrated raster/vector analysis; derive new information from existing data; query information across multiple data layers; and fully integrate cell-based raster data with traditional vector data sources. Spatial Analyst tools can be used to derive distance from points, polylines, or polygons; reclassify existing data into suitability classes; or create slope, aspect, or hillshade outputs from elevation data.

2.11.2 @Risk Computer Program

@RISK (*Palisades, 2005*) is an add-in and "links" directly to Excel to add Risk Analysis capabilities. The @RISK system provides all the necessary tools for setting up, executing and viewing the results of Risk Analyses. @RISK allows for the definition of uncertain cell values in Excel as probability distributions using functions. Distribution functions can be added to any number of cells and formulas throughout your worksheets and can include arguments which are cell references and expressions — allowing extremely sophisticated specification of uncertainty.

@RISK has sophisticated capabilities for specifying and executing simulations of Excel models. Both Monte Carlo and Latin Hypercube sampling techniques are supported, and distributions of possible results may be generated for any cell or range of cells in the spreadsheet model. Both simulation options and the selection of model outputs are entered with Windows style menus, dialog boxes and use of the mouse.

High resolution graphics are used to present the output distributions from the @RISK simulations. Histograms, cumulative curves and summary graphs for cell ranges all lead to a powerful presentation of results. And all graphs may be displayed in Excel for further enhancement and hard copy. An essentially unlimited number of output distributions may be generated from a single simulation — allowing for the analysis of even the largest and most complex spreadsheets.

2.11.3 ISITE Studio Terrestrial LiDAR Software

The I-SITE Studio (version 3.0 Beta) software program was used to assemble the collected Terrestrial LiDAR data (*ISITE, 2008*). The collected survey data was downloaded from the field unit, registered. Registration of the LiDAR scans consists of merging individual scans into the project coordinate system using the field surveyed locations of the LiDAR unit. The position of the scanner (which was surveyed in the field) and the location of the LiDAR backsight point (which is used to calculate the azimuth) are imported into the ISITE Software and are used to appropriately align all scans.

A number of data filters are available in the ISITE Software to manipulate the collected field data. Post processing consisted of implementing a topographic filter to eliminate data not representative of the ground surface. A filter grid was used to eliminate all points with the exception of the lowest elevation point in a specified cell dimension (such as a 1-m by 1-m cell). From the filtered data set, a topographic surfaces were generated.

The final accuracy associated with the completed Terrestrial LiDAR TINs (or surfaces) is dependent upon a number of factors. Errors accumulate during the field and post-processing stages of data collection and synthesizing. Applicable field errors include hardware (LiDAR instrument error of approximately 0 to 2 cm), survey error associated with the geolocation of the Terrestrial LiDAR unit (on the order of 1 cm for conventional survey methods such as Total Station or RTK GPS), and other factors such as instrument height, vegetation, and post-processing filtering approximations may also impact overall survey accuracy. Based on these factors, a tolerance of 2 to 10 cm should be considered applicable to the final results of the generated TIN surfaces.

2.11.4 HEC-SSP (from USACE, 2008a)

The U.S. Army Corps of Engineers Statistical Software Package (HEC-SSP) was developed by the Hydrologic Engineering Center (HEC). This software allows for the statistical analyses of hydrologic data. The current version of HEC-SSP performs flood flow frequency analysis based on Bulletin 17B, a generalized frequency analysis on not only flow data but other hydrologic data as well, and a volume-duration frequency analysis on high and low flows.

Data storage is accomplished through the use of "text" files (ASCII and XML), as well as the HEC Data Storage System (HEC-DSS). User input data are stored in flat files under separate categories of study, analyses, and a data storage list. Gage data are stored in a project HEC-DSS file as time series data. Output data is predominantly stored in HEC-DSS, while a summary of the results is written to an XML file. Additionally, an analysis report file is generated whenever a computation is made. This report file is written to a standard ASCII text file.

Data management is accomplished through the user interface and the modeler enters a Name and Description for each study being developed. Once the study name is entered, a directory with that name is created, as well as a study file. Additionally a set of subdirectories is created with the following names: Bulletin17bResults, GeneralFrequencyResults, VolumeFrequencyAnalysisResults, Layouts, and Maps. As the user creates new analyses, an analysis file is created in the main project directory. The interface provides for renaming and deletion of files on a study-by-study basis.

Graphics include a map window, plots of the raw data, and frequency curve plots. The map window can be used to display background map layers. Locations of the data being analyzed can be displayed on top of the map layers. Once data are brought into HEC-SSP, they can be plotted for visual inspection. The frequency curve plots shows the results of the analyses, which include the analytically computed curve, the expected probability curve, confidence limits, and the raw data points plotted based on the selected plotting position method. Tabular output consists of tables showing the computed frequency curves, confidence limits, and summary statistics. All graphical and tabular output can be displayed on the screen, sent directly to a printer (or plotter), or passed through the Windows Clipboard to other software, such as a word-processor or spreadsheet.

A report file is available for each analysis. This report file includes the input data, preliminary results, all of the statistical tests (Low and High Outliers, Broken Record, Zero Flows Years, Incomplete Record, Regional Skews, and Historic Information), and final results.

2.11.5 USACE GEO-RAS (from USACE, 2005)

HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI). The interface allows the preparation of geometric data for import into HEC-RAS and processes simulation results exported from HEC-RAS. To create the import file, the user must have an existing digital terrain model (DTM) of the river system in the ArcInfo TIN format. The user creates a series of line themes pertinent to developing geometric data for HEC-RAS. The themes created are the Stream Centerline, Flow Path Centerlines (*optional*), Main Channel Banks (*optional*), and Cross Section Cut Lines referred to as the *RAS Themes*.

Additional RAS Themes may be created/used to extract additional geometric data for import in HEC-RAS. These themes include Land Use, Levee Alignment, Ineffective Flow Areas, and Storage Areas. Water surface profile data and velocity data exported from HEC-RAS simulations may be processed by HEC-GeoRAS for GIS analysis for floodplain mapping, flood damage computations, ecosystem restoration, and flood warning response and preparedness.

2.11.6 HEC-RAS Software (from USACE, 2008b)

HEC-RAS is a computer program designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The user interacts with HEC-RAS through a graphical user interface (GUI). The main focus in the design of the interface was to make it easy to use the software, while still maintaining a high level of efficiency for the user. The interface provides for the following functions:

- File management;
- Data entry and editing;
- Hydraulic analyses;
- Tabulation and graphical displays of input and output data;
- Reporting facilities; and
- Context sensitive help

The HEC-RAS system contains four one-dimensional river analysis components for: (1) steady flow water surface profile computations; (2) unsteady flow simulation; (3) movable boundary sediment transport computations; and (4) water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four river analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed.

Graphics include X-Y plots of the river system schematic, cross-sections, profiles, rating curves, hydrographs, and many other hydraulic variables. A three-dimensional plot of multiple cross-sections is also provided. Tabular output is available. Users can select from pre-defined tables or develop their own customized tables. All graphical and tabular output can be displayed on the screen, sent directly to a printer (or plotter), or passed through the Windows Clipboard to other software, such as a word-processor or spreadsheet.

2.12 Post-Project Appraisals

Post-Project Appraisals (PPAs) are systematic assessments of built restoration projects designed to utilize existing data, and where necessary, collect additional data, to document changes in the river system resulting from restoration projects (*Downs and Gregory, 2004; Downs and Kondolf, 2002; Kondolf et al, 2007*). PPAs can provide data on the performance of various restoration approaches and techniques in light of specific geomorphic setting and site history, thereby providing feedback on project performance essential to the learning process in adaptive management (*Downs and Gregory, 2004; Downs and Kondolf, 2002*).

PPAs can range from detailed, comprehensive analyses of monitoring data collected on well-documented projects (e.g., including as-built drawings), conducted over a long term such as a decade (termed 'full PPA'), or a period of a few years ('short-term PPA'), all the way down to brief field mapping and assessment of poorly documented projects ('remains PPA') (*Downs and Kondolf, 2002*). Table 3 presents PPA components and categories from Downs and Kondolf (*2002*).

Table 3: Post Project Appraisal Categories (from *Downs and Kondolf, 2002*)

		Category of Post-Project Appraisal				
	PPA Component	**Full**	**Medium-Term**	**Short-Term**	**One-Shot**	**Remains**
				Level of Commitment		
Pre-Project	Success Criteria	Explicit	Explicit	Explicit	Implicit or Explicit	Implicit or Non-Existent
Pre-Project	Baseline Surveys	Thorough	Thorough	Thorough	Partial or Thorough	None
Pre-Project	Documented Design Rationale	Explicit	Explicit	Explicit	Implicit or Explicit	Implicit or Non-Existent
Pre-Project	Design Drawings	Thorough	Thorough	Thorough	Thorough or Conceptual	Conceptual or None
	As-Built (Record) Drawings	Exist	Exist	Beneficial	Beneficial	None
				Level of Commitment		
Post-Project Follow-Up	Periodic or Event-Driven Monitoring	> 10 yrs	5 - 10 yrs	< 5 yrs	Single Survey	Single Survey
Post-Project Follow-Up	Supplementary Historical Data	Beneficial	Beneficial	Beneficial	Necessary	Necessary
Post-Project Follow-Up	Secondary Analytical Procedures	Probably Unnecessary	Possibly Unnecessary	Beneficial	Highly Beneficial	Necessary
Learning Opportunities	Understanding Compliance With Design Intentions	Yes	Yes	Yes	Possible	Speculation
Learning Opportunities	Indication of Short-Term Geo-Hydraulic Performance	Yes	Probable	Possible	Possible	Speculation or None
Learning Opportunities	Longer-Term Evaluation of Geomorphological Sustainability	Probable	Possible	Speculation	Speculation	Speculation or None

PPAs consist of an eight-step approach (*Kondolf et al, 2007*):

1. *Search for and assemble relevant project documents and data*, such as technical background reports, catchment-scale assessment and management plans, stakeholder outreach documents, funding proposals, permitting documents, restoration plans and designs, as-built plans, baseline data (physical and ecological), monitoring data, and any prior assessments. Create a timeline on which to record dates of documents, key event such as grants/permits for the project, baseline data collection, available aerial photography, significant floods, project implementation and repairs, post-project monitoring, etc.

2. *Reconnaissance visit to the project site* and surrounding area to examine current field conditions and to get a sense of the project site, to match up actual features on the ground with those described in the documents, to qualitatively assess post-project changes in channel form and riparian vegetation, and to search for survey monuments and assess the feasibility of resurveys.

3. *Review project documents to extract goals, objectives, and design rationale*.

4. *Identify/compile existing data* (pre-project baseline, as-built, and post-project monitoring).

5. *Interview project designers/implementers* to understand project history, constraints, changes in the project as it was implemented and their causes. Ideally, project designers will come on-site to identify features that not obvious from printed documents, to point out post-project changes, and to help locate survey monuments.

6. *Resurvey* channel cross sections, long profiles, repeat pebble counts, repeat photo stations, perhaps re-sampling of vegetation, aquatic invertebrates, or fish, and re-mapping of sedimentary facies, large wood, and other channel features. Which resurveys are selected depend on the project objectives, constraints, what data are available, what surveys have been completed previously, resources available, and other factors.

7. *Data analysis and project evaluation* can range from sophisticated statistical analysis of a large data set down to qualitative assessment based on field observations of current conditions compared with an inferred pre-project condition.

8. *Dissemination of results* to the wider community that might stand to benefit from the lessons learned. Results are commonly disseminated in technical journals, conference proceedings, and case studies.

2.13 Validation

The final aspect of my research will be validation. The purpose of the validation is to ensure that the developed matrices are fit for purpose and positively benefit the practice of River Restoration. Four methods will be used, consisting of a guarantor, diamond model, heuristics, and case studies. These methods are described in more detail below.

2.13.1 Inquiry System Guarantor

The Inquiry System method has a 'built in' validation element, called the guarantor (Figure 9). The guarantor is a mechanism that evaluates the validity of the operator's transfer process. In my research, I am the operator and my transfer process is to synthesize river restoration information into the parameter and resources matrices.

The guarantor can be, for example, a critical review of the developed matrices by a group of multidisciplinary experts and agreement that the proposed matrices are correct.

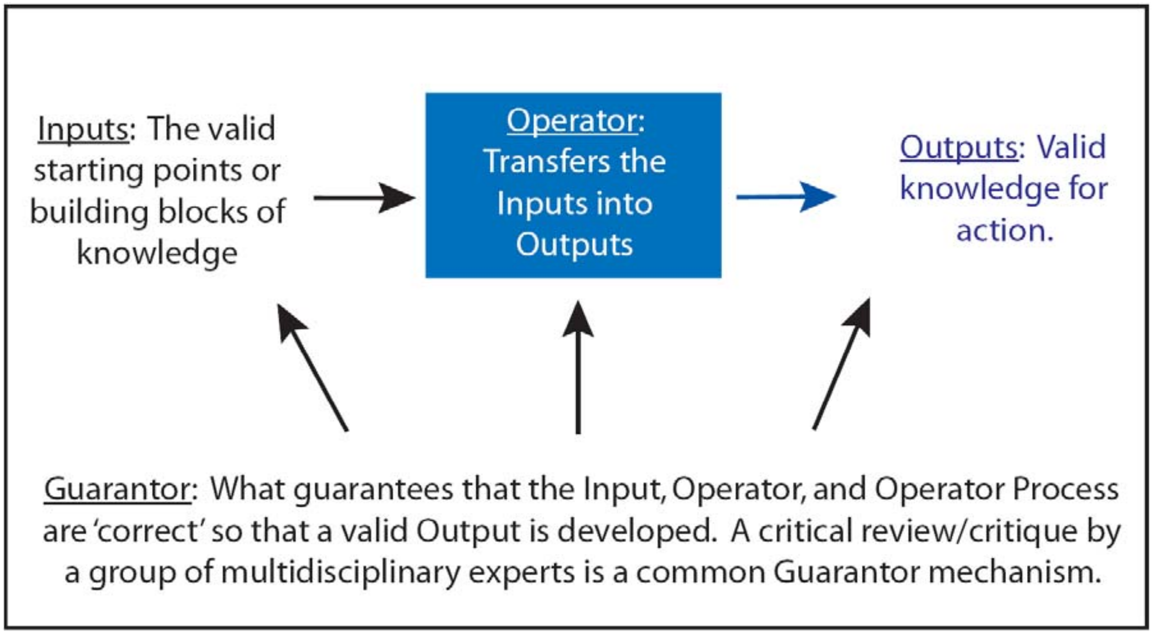

Figure 9: Guarantor validation model where the Operator's transfer process is evaluated to ensure valid Outputs.

2.13.2 Diamond Model

The second validation approach I propose to use is that of the Diamond Model (*Mitroff & Linstone, 1993*). This method is arguably the most rigorous way to validate proposed complex systems solutions. The Diamond Model (Figure 10) is an iterative interactive loop that generally starts with a problem being experienced. A conceptual model is then constructed that results in a broad outline of the problem. The development of a broad outline of the problem allows for the generation of a very structured and clearly bounded technical or 'scientific' model from which solutions can be generated.

The analyses performed using the scientific model result in development of proposed solutions to the problem, but we need to keep in mind, that these solutions are artifacts of the scientific model, not necessarily the original sensed problem, so only when the proposed solution is implemented and we're able to confirm that the devised solution remedies the initial sensed problem are we done with the iteration.

If the developed solution does not remedy the problem, we need to cycle through the interactive loop, updating and modifying the conceptual model, scientific model, and solution until our understanding of the system is refined enough enabling us to implement a solution that actually remedies the original sensed problem.

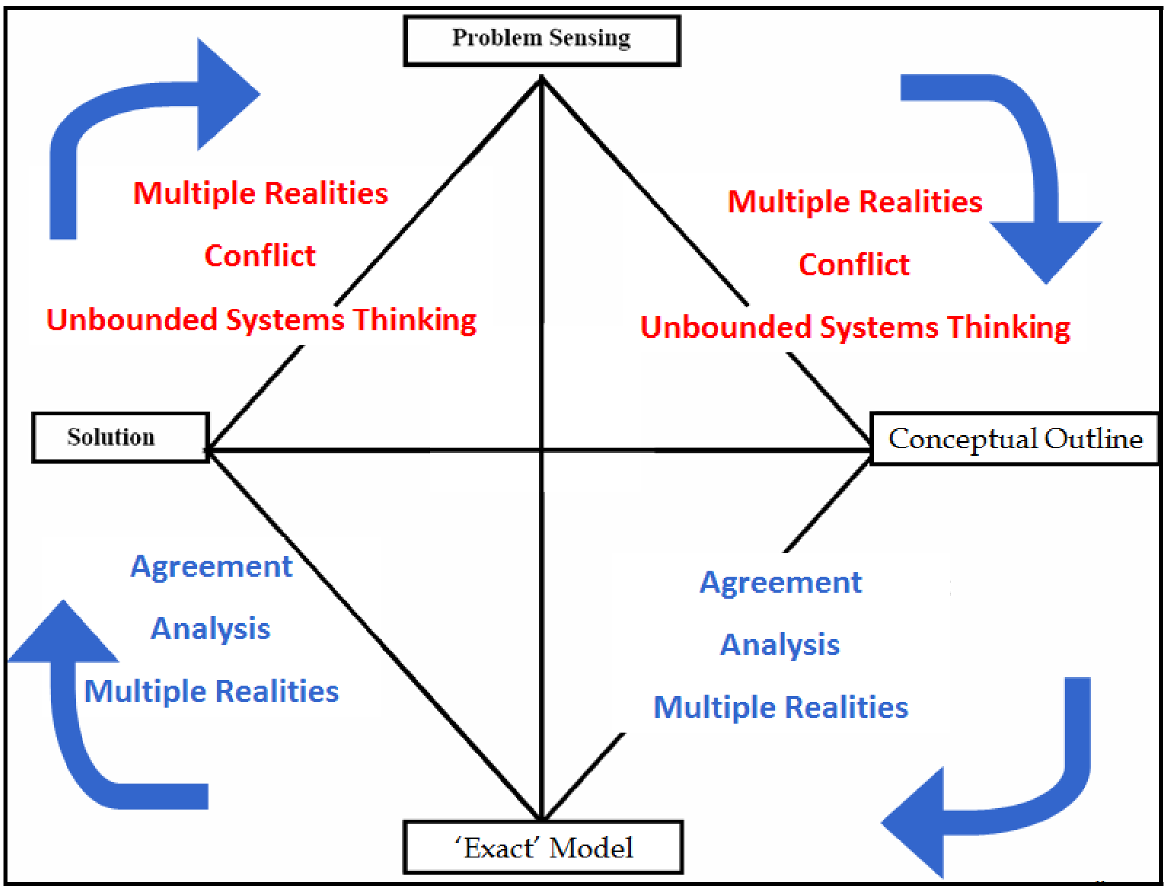

Figure 10: The "Diamond Model" validation method.

For my research, a number of California River Restoration Post Project Appraisal case studies, developed as part of the National River Restoration Science Synthesis were used for validation by evaluating correlation between the project's performance and the identified case study problem.

2.13.3 Heuristics

The developed Restoration Evaluation Checklist was validated via heuristics. Heuristic evaluation is a systematic inspection of a user interface design for usability and involves having a small set of evaluators examine the interface and judge its compliance with recognized usability principles (*Nielsen, 1993*). Heuristic evaluation is performed by having each individual evaluator inspect the interface alone. The individual evaluations are compiled and aggregated. This procedure ensures independent and unbiased evaluations from each evaluator.

2.13.4 Case Studies

The final aspect of my research validation is the use of case studies. Case studies are situations where a researcher explores in depth a program, event, activity, process, or one or more individuals (*Blaxter et al, 2006; Creswell, 2003*). The cases are bound by time and activity and detailed information is collected (using a variety of data collection procedures) over a period of time. A number of California River Restoration Post Project Appraisal case studies, developed as part of the National River Restoration Science Synthesis project will be used as case studies to validate the Restoration Evaluation Checklist.

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Chapter Three

3 RIVER RESTORATION ORGANIZATIONS

There are many hundreds of organizations that comprise the river restoration Technology Delivery System and impact the practice of river restoration in the United States. It was not possible in the timeframe for this doctoral program to catalog all the organizations and their impacts on river restoration, rather major organizations at the federal and State of California levels were summarized as well as notable non-governmental agencies (NGOs) that further the practice of river restoration. For this research, river restoration within the State of California was the primary focus. However, many of the same state organizations exist in other states, so the blueprint developed in this research can be applied to other states.

A summary of the organizations reviewed is presented in Table 4. Each organization reviewed was classified by the life-cycle phase as well as NRRSS goal in which they impact river restoration. These organizations contribute knowledge to the practice of river restoration on many levels and specific contributions are highlighted in Chapter 4.

Table 4: Summary of River Restoration Organizations and Interactions with Life-Cycles and NRRSS Goals

Agency Type	Organization name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	In stream Habitat Improvement	In stream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Federal Agencies	USDA - Forest Service	X	X		X					X	X		X	X		X			X	X	X
	USDA - Natural Resources Conservation Service	X	X	X	X	X			X	X	X	X	X	X	X	X			X	X	X
	USDA - Agricultural Research Service	X	X							X	X	X	X	X	X	X			X	X	X
	USDA - Cooperative State Research, Education, and Extension Service	X.	X		X																
	USDoC - National Environmental Satellite, Data, and Information Service	X	X		X																
	USDoC - National Weather Service	X	X		X																
	USDoC - National Oceanographic and Atmospheric Administration	X	X		X																
	US Congress	X																			
	USDoD - U.S. Army Corps of Engineers	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
	USEPA	X	X		X	X			X	X	X	X	X	X	X	X	X		X	X	X
	USDoHS - Federal Emergency Management Agency	X	X		X	X	X			X	X		X	X						X	X
	US Department of Housing and Urban Development																				
	USDOI - Bureau of Land Management	X	X	X	X	X	X	X		X	X	X	X	X	X	X			X	X	X
	USDoI - Bureau of Reclamation	X	X	X	X	X			X	X	X		X	X		X			X		X
	USDoI - National Park Service	X	X	X	X	X				X	X						X				X
	USDoI - U.S. Fish and Wildlife Service	X	X	X	X											X	X				
	USDoI - U.S. Geological Survey	X	X		X					X	X	X	X	X		X	X		X		X
	USDoT - Federal Highway Administration	X	X	X	X	X			X	X	X	X	X	X	X	X			X	X	X
	US - Federal Interagency Stream Restoration Working Group (FISRWG)	X	X		X	X				X	X			X		X	X		X		X

Agency Type	Organization name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	In stream Habitat Improvement	In stream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
California Agencies	CA - Bay Conservation and Development Commission (BCDC)	X			X				X										X	X	X
	CA - Coastal Commission	X																		X	
	CA - Coastal Conservancy	X																			
	CA - Environmental Protection Agency	X	X		X	X			X	X	X	X	X	X	X	X	X		X	X	X
	CA-RA - CALFED Bay-Delta Program	X	X											X		X	X				X
	CA-RA - California Conservation Corps	X	X	X						X	X		X			X			X		
	CA-RA - California Department of Conservation	X	X							X	X		X	X		X		X	X	X	X
	CA-RA - Department of Fish and Game	X	X	X	X	X				X	X	X	X	X		X			X	X	X
	CA-RA - Department of Water Resources	X	X	X																	
	CA-RA - California State Parks and Recreation	X																			
	CA - Central Valley Flood Protection Board (Reclamation Board)	X																			
	CA - Department of Transportation	X	X	X	X	X				X	X		X	X					X	X	X
Non-Governmental Agencies	Association of Bay Area Governments (ABAG)	X	X	X																X	
	American Rivers	X	X									X	X							X	
	Center for Ecosystem Management and Restoration	X	X										X			X					
	Environmental Defense Fund	X																			
	Friends of Creeks	X	X	X	X	X			X	X									X		X
	The National Academies	X	X		X														X		X
	The Natural Heritage Institute	X							X												
	The Nature Conservancy	X	X																X		
	The San Francisco Bay Joint Venture	X																	X		
	The San Francisco Estuary Institute	X																			X
	The Sierra Club	X															X		X		
	The Urban Creeks Council	X								X	X								X		
	The Watershed Project	X							X												X

A summary of key organizations for each of the life-cycle phases and NRRSS goals is discussed in this chapter. These organizations include: The Federal Interagency Stream Restoration Working Group (FISRWG), the United States Department of Agriculture (USDA), the United States Department of Commerce (USDoC), the United States Army Corps of Engineers (USACE), the United States Environmental Protection Agency (EPA), the United States Fish and Wildlife Service (USFWS), the United States Geological Survey (USGS), the California Department of Fish and Game (CDFG), the California Department of Transportation (Caltrans), the California Department of Water Resources (DWR), and the California Environmental Protection Agency (CalEPA).

A brief overview of each organization is presented as well as a snapshot of major contributions to the practice of river restoration. A more detailed background of each organization is presented in Appendix C – Organizational Literature Review.

3.1 Federal Interagency Stream Restoration Working Group

The Federal Interagency Stream Restoration Working Group (FISRWG) was a collaboration of fifteen federal agencies and other partners to produce a common reference on stream corridor restoration. The document, "Stream Corridor Restoration, Principles, Processes, and Practices," (*2001*) encapsulated the rapidly expanding body of knowledge related to stream corridors and their restoration (*FISRWG, 2002*). The original draft was first published in 1998 with a revision in 2001 and a new updated version is anticipated for publication in late 2008 or 2009.

This guidance document provides best practices on river restoration for both urban and rural settings and generally addresses all life-cycle phases of river restoration, (except requalification and decommissioning). Comprehensive processes and methods are presented for restoration practitioners to configure restoration projects that incorporate best practices.

The document also addresses a majority of restoration goals identified by the National River Restoration Science Synthesis group (*Bernhardt et al., 2005*). The primary NRRSS goals addressed in the guidance document include: bank stabilization, channel reconfiguration, floodplain reconnection, in-stream habitat management, in-stream species management, riparian management, and water quality management.

3.2 United States Department of Agriculture

The United States Department of Agriculture (USDA) is a diverse and complex organization with more than 100,000 employees that deliver more than $75 billion in public services through the USDA's more than 300 programs each year (*USDA, 2007*).

The seven USDA mission areas are: Natural Resources and Environment; Farm and Agricultural Services; Rural Development; Food, Nutrition, and Consumer Services; Food Safety; Research, Education, and Economics; and Marketing and Regulatory programs (*USDA, 2007*). Two missions directly impact river restoration and these are Natural Resources and Environment (NRE) as well as Research, Education, and Economics.

The NRE mission area consists of the Forest Service and the Natural Resources Conservation Service (NRCS). These agencies work to ensure the health of the land through sustainable management practices (*USDA, 2007*). The Forest Service manages 193 million acres of national forests and grasslands. NRCS assists farmers, ranchers and other private land owners in managing their acreage for environmental and economic sustainability (*USDA, 2007*). Both agencies work in partnership with Tribal, State and local Governments, communities, related groups and other Federal agencies to protect the Nation's soils, watersheds and ecosystems (*USDA, 2007*).

The REE is comprised of the Agricultural Research Service (ARS), the Cooperative State Research, Education and Extension Service (CSREES), the Economic Research Service (ERS), the National Agricultural Statistics Service (NASS), and the National Agricultural Library (NAL). The ARS and CSREES are the two efforts within the REE that directly impact river restoration.

The NRCS has a number of publications that are useful to the practice of river restoration. These documents and guides cover the areas of erosion, biology, conservation practices, ecology, engineering, environmental compliance, soils, and water resources. However, NRCS's primary contribution to river restoration are the soil survey maps for the United States, which provides an excellent resource for the planning and design life-cycle phases of river restoration and aid with the attainment of the bank stabilization, channel reconfiguration, and riparian management NRRSS goals.

The ARS has a number of research units that investigate topics related to river restoration. Results from the research efforts are mainly disseminated via technical journal publications as opposed to agency manuals and guidelines, thus it is difficult to comprehensively summarize 'best practices' in this document, however, select significant publications (with respect to river restoration practices). Major contributions ARS has made toward river restoration include numerous technical journal papers and software programs. Most notable are the Bank Stability and Toe Erosion Model, CONCEPTS and RUSLE, that are excellent tools for use during the planning and design life-cycle phases and also aid with the attainment of the bank stabilization and channel reconfiguration NRRSS goals.

Table 5 presents web links to prominent electronic resources available from the USDA. The Natural Resources Data provides access to experimental watersheds, water databases from small agricultural watersheds in the U.S., data collection from "Soil Climate Analysis Network" locations, and data from soil, plant, atmosphere, and water field and pond hydrology study sites. The Maps, Imagery, Data & Analysis site provides access to general USDA maps and imagery data. The Web Soil Survey allows access to GIS-based soils information for 95% of U.S. counties, summarizing key characteristics of soils and their spatial distribution.

Table 5: USDA Electronic Resources

Natural Resources Data	http://www.ars.usda.gov/services/docs.htm?docid=1328#natural
Maps, Imagery, Data, & Analysis	http://www.nrcs.usda.gov/technical/maps.html
Web Soil Survey	http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm

3.3 United States Department of Commerce

The U.S. Department of Commerce (USDOC) was established by Congress in 1903 through the passage of the Organic Act (*USDOC, 2008*) and the mission of the USDOC is to foster, promote, and develop the foreign and domestic commerce of the United States (*USDOC, 2008*). There are ten commerce bureaus that comprise the USDOC, and of these ten bureaus, the National Oceanographic & Atmospheric Administration (NOAA) has the greatest influence and contributions to river restoration.

Within NOAA, there are seven offices consisting of: National Environmental Satellite, Data, and Information Service; National Marine Fisheries Service; National Ocean Service; National Weather Service; Office of Marine and Aviation Operations; Office of Oceanic and Atmospheric Research; and Program Planning and Integration

(*NOAA, 2008b*). Of these offices, the National Environmental Satellite, Data, and Information Service and the National Weather Service directly impact the field of river restoration.

The National Climatic Data Center offers a comprehensive archive of climate data including climate events (storms, tornadoes, hurricanes, etc.), satellite images, limited paleoclimatology data, and access to climate data (temperature, precipitation, etc.) at thousands of monitoring stations throughout the United States.

The emphasis of the National Weather Service (NWS) is to provide information on real time climate conditions. The NWS also has access to some river stage monitoring locations and precipitation data. Both of these data sets have options for output to GIS shapefiles (where appropriate). In addition to the data archives, the NWS also produces several publications related to flood safety that are useful as planning and risk communication for public education related to river restoration activities.

The resources provided by NOAA are applicable to the planning, design, operation, and requalification life-cycle stages of river restoration projects and aid with the attainment of the NRRSS goals that require precipitation or stream discharge, such as bank stabilization, channel reconfiguration, dam removal/retrofit, fish passage, flood plain reconnection, flow modification, in-stream habitat modification, stormwater management, and water quality management.

Table 6 presents web links to prominent electronic resources available from NOAA. The National Climate Data Center provides summaries of climates and climate patterns throughout the United States, including land-based data, upper-air data, marine data, satellite data, weather and climate events, and paleoclimatology data. The NWS

Precipitation and River Observations provide access to real time observations of precipitation and river stage at instrumentation locations maintained by the NWS. The Regional Ecosystem Data Management program provides GIS information related to coastal and ocean ecosystems. The Western Regional Climate Center provides an excellent collection and archive of weather observations from the western United States (there are similar climate center for different regions of the United States). Site specific climate information can be obtained from this site.

Table 6: NOAA Electronic Resources

National Climate Data Center	http://www.ncdc.noaa.gov/oa/ncdc.html
National Weather Service Precipitation Observations	http://water.weather.gov/
National Weather Service River Observations	http://www.weather.gov/ahps/index.php
Regional Ecosystems Data Management	http://ecowatch.ncddc.noaa.gov/maps
Western Regional Climate Center	http://www.wrcc.dri.edu/

3.4 United States Army Corps of Engineers

Within the Department of Defense, the Army hosts the United States Army Corps of Engineers, which has significant influence on river restoration activities. In the 20th century, the USACE became the lead federal flood control agency and significantly expanded its civil works activities, becoming a major provider of hydroelectric energy and the Nation's leading provider of recreation. In 1980 the USACE began providing environmental restoration support services to the US EPA as a result of the passage of the Superfund Act (*USACE, 2008a*). This work was primarily limited to removal of hazardous materials from former military sites and the removal of unsafe buildings, ordnance, and other debris from both active and former military sites (*USACE, 2008a*). By 1984, the USACE assumed full control and management of the environmental restoration program for all former military sites, regardless of service branch.

In the mid 1990s, the USACE was tasked with ecosystem restoration. The purpose of Civil Works ecosystem restoration activities is to restore significant ecosystem function, structure, and dynamic processes that have been degraded (*USACE, 1999b*). Protection may be included as part of Civil Works ecosystem restoration initiatives, when such measures involve efforts to prevent future degradation of elements of an ecosystem's structure and functions (*USACE, 1999b*). Ecosystem restoration in the Civil Works program uses a 'systems view' in assessing and addressing restoration needs and opportunities. Recognition of the interconnectedness and dynamics of natural systems, along with human activities in the landscape, is integral and this philosophy promotes consideration of the effects of decisions over the long term and incorporates the ecosystem approach (*USACE, 1999b*).

The goal of USACE's ecosystem approach is to restore and sustain the health, productivity, and biological diversity of ecosystems and the overall quality of life through a natural resources management approach that is fully integrated with social and economic goals (*USACE, 1999b*). USACE's ecosystem approach recognizes and seeks to address the problems of habitat fragmentation and the piecemeal restoration and mitigation previously applied in addressing the Nation's natural resources (*USACE, 1999b*). The USACE recognizes that some restoration projects may only be able to address the symptoms of the disturbance or degradation, and not the cause(s), however, in these instances, the USACE recommends that "caution should be exercised" and consideration given as to whether the recommended action is a wise investment (*USACE, 1999b*). Addressing the symptoms without understanding the causes of disturbance or degradation, may reduce the likelihood of achieving long-term success (resilience and persistence), and potentially increase the need for extensive operation and maintenance, rather than a functional, self-regulating system (*USACE, 1999b*). The USACE strongly recommends for restoration initiatives to be conceived in the context of broader watershed or regional water resources management programs and objectives, which may involve contributive actions by other Federal and non-Federal agencies and other stakeholders (*USACE, 1999b*).

Consideration of ecosystems within (or encompassing) a watershed provides a useful organizing tool to approach ecosystem-based restoration planning. Ecosystem restoration projects that are conceived as part of a watershed planning initiative or other regional resources management strategy are likely to more effectively meet ecosystem management goals than those projects and decisions developed independently (*USACE, 1999b*). Independently developed ecosystem restoration projects, especially those formulated without a system context, may only partially and temporarily address symptoms of a chronic systemic problem. Some restoration problems may only be addressed effectively through an integrated, collaborative, systematic, regional or ecosystem approach. The USACEs' watershed perspective takes into account (1) the interconnectedness of water and land resources, (2) the dynamic nature of the economic and environmental factors, and (3) the variability of social interests over time (*USACE, 1999b*). It recognizes that watershed activities are not static, and that the strategy for managing the resources of the watershed needs to be adaptive (*USACE, 1999b*). Healthy and well functioning ecosystems are vital to the protection of our nation's biodiversity, to the achievement of quality of life objectives, and to the support of economies and communities (*USACE, 1999b*). The ecosystem approach recognizes the interrelationship between healthy ecosystems and sustainable economies. It is a common sense way for federal agencies to carry out their mandates with greater efficiency and effectiveness. The approach emphasizes (*USACE, 1999b*):

- Striving to consider all relevant and identifiable ecological and economic consequences (long term as well as short term).
- Improving coordination among federal agencies.
- Forming partnerships between federal, state, and local governments, Indian tribes, landowners, foreign Governments international organizations, and other stakeholders.
- Improving communication with the general public.
- Carrying out federal responsibilities more efficiently and cost-effective.
- Basing decisions on the best science.
- Improving information and data management.
- Adjusting management direction as new information becomes available.

In order to accomplish its ecosystem restoration work, the USACE relies on individual efforts from the Institute of Water Resource (IWR) and the Engineering Research and Development Center (ERDC).

The U.S. Army Institute for Water Resources (IWR) was formed in 1969 to provide the USACE with long-range planning capabilities to assist in improving the civil works planning process (*USACE, 2008c*) and hosts three facilities, the Hydrologic Engineering Center (HEC), the Navigation Data Center (NDC), and the Waterborne Commerce Statistics Center (WCSC). Technical specialty areas addressed by HEC include: precipitation-runoff processes, reservoir regulation, reservoir systems analysis, hydrologic statistics and risk analysis, river hydraulics and sediment transport, groundwater hydrology, water quality and analytical aspects of water resources planning. Application areas include: flood damage reduction, real-time water control, water control management, hydroelectric power, navigation, erosion control, water supply, watershed studies and ecosystem restoration.

The Mission of the Engineer Research and Development Center (ERDC) is to provide science, technology, and expertise in engineering and environmental sciences in support of our Armed Forces and the Nation (*USACE, 2008e*). In 1999, the USACE consolidated its individual research laboratories into one organization, ERDC (*USACE, 2008e*). Seven laboratories are located in four geographic sites around the country: the Coastal and Hydraulics, Environmental, Geotechnical and Structures, and Information Technology Laboratories in Vicksburg, Miss.; the Construction Engineering Research Laboratory in Champaign, Ill.; the Cold Regions Research and Engineering Laboratory in Hanover, N.H.; and the Topographic Engineering Center in Alexandria, Va. (*USACE, 2008e*). Of these laboratories, the Environmental Laboratory has the greatest impact on river restoration.

The Environmental Laboratory conducts research in environmental science and engineering and development in support of environmental systems (*USACE, 2008i*). Environmental Laboratory research includes a network of expertise and facilities from other Engineer Research and Development Center (ERDC) and Corps Laboratories, other government agencies, academia, and the private sector. Environmental Lab employees comprise a diverse workforce of biologist, ecologists, physical scientists and engineers with expertise and experience in the full spectrum of environmental science and engineering (*USACE, 2008i*). There are a number of facilities that comprise the Environmental Laboratory (*USACE, 2008i*): Aquatic and Wetlands Ecosystem Research and Development Center; Columbia River Research Facility; Eau Galle Aquatic Ecosystem Research Facility; Environmental Chemistry; Environmental Chemistry Laboratory; Geospatial Data Analysis Facility; Hazardous Waste Research Center; Lewisville Aquatic Ecosystem Research Facility; and Trotter's Shoals Limnological Research Facility.

The USACE is very active in all life-cycle phases of river restoration (planning, design, construction, operations/maintenance, requalification, and decommissioning), as well as most NRRSS goal categories: bank stabilization, channel reconfiguration, dam removal/retrofit, fish passage, floodplain reconnection, in-stream habitat modification, land acquisition, riparian management, stormwater management, and water quality management.

3.5 United States Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) was created in 1970 by President Nixon by 'reorganizing' 15 existing executive branch units into one independent organization (*EPA, 2008a*). The primary means by which the EPA impacts river restoration is through regulation and water quality and ecosystem health technology, via the Clean Water Act (CWA). The primary divisions/offices/units that carry out the CWA mandate is the Office of Science and Technology (OST), the Environmental Monitoring and Assessment Program, and National Exposure Research Laboratory.

The Office of Science and Technology (OST) is one of five water offices at EPA and is tasked with setting the national environmental baselines for the quality of the

Nation's waters and ensures the latest water pollution science and best available control technologies to support the Office of Water program goals to keep water safe and clean (*EPA, 2008h*). Every year under the Clean Water Act and Safe Drinking Water Act, OST produces regulations, guidelines, methods, standards, science-based criteria, and studies that are critical components of national programs that protect people and the aquatic environment (*EPA, 2008h*).

The Environmental Monitoring and Assessment Program (EMAP) is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources (*EPA, 2008c*). EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources (*EPA, 2008c*). EMAP objectives are to advance the science of ecological monitoring and ecological risk assessment, guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics (*EPA, 2008d*). EMAP aims to develop and demonstrate indicators to monitor the condition of ecological resources, and investigate multi-tier designs that address the acquisition and analysis of multi-scale data including aggregation across tiers and natural resources (*EPA, 2008d*).

Table 7 presents web links to prominent electronic resources available from The EPA. The EnviroMapper resource maps various types of environmental information, including air releases, drinking water, toxic releases, hazardous wastes, water discharge permits, and Superfund sites. The STORET database contains raw biological, chemical, and physical data on surface and ground water collected by federal, state and local agencies, Indian Tribes, volunteer groups, academics, and others. The Surf Your Watershed synthesizes environmental information available by geographic units which includes state, watershed (Surf's primary focus), county, metro area, and tribes. The Watershed Assessment, Tracking & Environmental Results (WATERS) is an integrated information system that connects individual EPA water program databases into one larger framework (known as the National Hydrography Dataset).

Table 7: EPA Electronic Resources

EnviroMapper	http://www.epa.gov/enviro/html/em/index.html
STORET	http://www.epa.gov/storet/
Surf Your Watershed	http://cfpub.epa.gov/surf/locate/index.cfm
WATERS	http://www.epa.gov/waters/

The EPA is active in the planning, design, and operations life-cycle phases of river restoration and primarily the stormwater and water quality management goals.

3.6 United States Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) is the only agency of the U.S. Government whose primary responsibility is fish, wildlife, and plant conservation (*DOI, 2008b*). The Service helps protect a healthy environment for people, fish and wildlife, and helps Americans conserve and enjoy the outdoors (*DOI, 2008b*). The Service's major responsibilities are for migratory birds, endangered species, certain marine mammals, and freshwater and anadromous fish (*DOI, 2008b*). Specific programs relevant to river restoration include: the environmental contaminants program and fisheries and habitat conservation.

The environmental contaminants program tackles contaminants prevention, contaminants identification and assessment, and contaminant cleanup and resource restoration. For contaminant prevention, USFWS review environmental documents, legislation, regulations, and permits and licenses with pollution potential to ensure that harmful effects on fish, wildlife, and plants are avoided or minimized (*USFWS, 2008a*).

The Fisheries and Habitat Conservation Program works to conserves and restores habitat to ensure that fish and wildlife populations are sustained for the benefit of current and future generations of Americans (*USFWS, 2008b*). Expertise areas within the Program include (*USFWS, 2008b*): habitat restoration; contaminant assessment and remediation; genetics; population dynamics and management; fish culture and fish health; fish passage; invasive species management; wetlands inventory, monitoring and mapping; water quality, development and management; wildlife management; and permitting in energy, transportation, and other activities.

The USFWS is active in the planning and operations life-cycle phases of river restoration and provide resources towards the fish passage and in-stream habitat management goals. The USFWS has in-depth resources on in-stream habitat management via their Habitat Suitability Index and Habitat Evaluation Procedures handbook (see Chapter 4).

3.7 United States Geological Survey

The U.S. Geological Survey (USGS) serves the Nation as an independent fact-finding agency that collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems (*DOI, 2008b*). The USGS is an important organization for river restoration and provides a large majority of data used in the proper configuration of restoration projects. The main science areas where the USGS provides valuable contributions include: Biology; Geography; Geology; Geospatial; and Water.

The Biological Resource Division (BRD) works to provide the scientific understanding and technologies needed to support the sound management and conservation of biological resources. There are eight programs within the BRD: biological informatics; contaminant biology; cooperative research units; ecosystems; wildlife, terrestrial and endangered resources; status and trends of biological resources; invasive species; and fisheries, aquatic and endangered resources.

The USGS Geography program observes the Earth with remote sensing satellites, USGS geographers monitor and analyze changes on the land, study connections between people and the land, and provide society with relevant science information to inform public decisions.

USGS Geology efforts address major societal issues that involve geologic hazards and disasters, climate variability and change, energy and mineral resources, ecosystem and human health, and ground-water availability and characterizes the geological landscape and provides the US with fundamental geochemical and geophysical data.

The Water program provides reliable, impartial, timely information that is needed to understand the Nation's water resources. The program includes: cooperative water program, national streamflow information program, national water quality assessment program, toxic substances hydrology (toxics) program, ground water resources program, hydrologic networks and analysis, hydrologic research and development, state water resources research institute program, international water projects, and water information program.

Table 8 presents a summary of electronic resources available from the USGS. These resources include aerial photography, elevation datasets, digital maps, water quality data, geologic maps, hydrography, and much more. The USGS offers a diverse and comprehensive vault of data for use in river restoration projects.

Table 8: USGS Electronic Resources

Database of Acute Toxicity	http://137.227.231.90/data/acute/acute.html
Earth Explorer	http://earthexplorer.usgs.gov/
EOS Data Gateway	http://eosims.cr.usgs.gov/imswelcome
Geospatial One-Stop	http://gos2.geodata.gov/wps/portal/gos
National Aerial Photography Program (NAPP)	http://edc.usgs.gov/products/aerial/napp.html
National Contaminant Biomonitoring Program	http://137.227.231.90/data/ncbp/ncbp.html
National Geologic Map Database	http://ngmdb.usgs.gov/
National Hydrography Dataset	http://nhd.usgs.gov/
National Map	http://nationalmap.gov/
National Map Seamless Server	http://seamless.usgs.gov/index.php
National Water Quality Assessment Data Warehouse	http://infotrek.er.usgs.gov/nawqa
Orthoimagery at the USGS EROS	http://gisdata.usgs.net/website/orthoimagery/
Sediment Effects Concentrations Databases	http://137.227.231.90/pubs/sedtox/sec.htm
USGS Center for LIDAR Information	http://lidar.cr.usgs.gov/
USGS Global Visualization Viewer	http://glovis.usgs.gov/
USGS Photo Finder	http://edcsns17.cr.usgs.gov/EarthExplorer/
USGS Photographic Library	http://libraryphoto.cr.usgs.gov/

The USGS provides information primarily for use during planning, design, and operations. The knowledge developed by this organization helps to achieve the bank stabilization, channel reconfiguration, fish passage, in-stream habitat improvement, and water quality management. Key information that the USGS provides for river restoration includes: topography, stream discharge, water quality, geologic maps, and imagery.

3.8 California Department of Fish and Game

The Department of Fish and Game (CDFG) is charged with maintaining native fish, wildlife, plant species and natural communities for their intrinsic and ecological value and their benefits to people, which includes habitat protection and maintenance in a sufficient amount and quality to ensure the survival of all species and natural communities (*CDFG, 2008a*). The department is also responsible for the diversified use of fish and wildlife including recreational, commercial, scientific and educational uses (*CDFG, 2008a*). The Mission of the Department of Fish and Game is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public (*CDFG, 2008a*).

There are seven CDFG regions: Northern, North Central, Bay Delta, Central, South Coast, Inland Deserts, and Marine and the CDFG programs involve regulation of fish and wildlife related recreation, marine resource management, oil spill response, enforcement of fish and wildlife laws, as well as resource management. CDFG's Resource Management program include: aquatic bioassessment, conservation planning, environmental reviewing and permitting, lands program, resource assessment program, wildlife, fish and plant information program, and the fisheries restoration grant program. Of these, the environmental reviewing and permitting and the fisheries restoration grant program have major implications to river restoration and are discussed in more detail below.

The Environmental Review and Permitting Programs are responsible to fulfill the mission of the State to encourage the preservation, conservation and maintenance of wildlife resources under the jurisdiction and influence of the State, including the conservation, protection and management of fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those species. This program: oversees the California Endangered Species Act Permitting process; consults with lead and responsible agencies and provides the requisite biological expertise to review and comment upon environmental documents and impacts arising from project activities under the California Environmental Quality Act; administers the Lake and Streambed Alteration program, which requires notification of any work undertaken in or near a river, stream, or lake that flows at least intermittently through a bed or channel. This includes ephemeral streams, desert washes, and watercourses with a subsurface flow. It may also apply to work undertaken within the flood plain of a body of water. If CDFG determines that the activity may substantially adversely affect fish and wildlife resources, a Lake or Streambed Alteration Agreement is required; and issues permits for road construction across streams and incidental lake permits when endangered species are involved.

The Fisheries Restoration Grant Program (FRGP) was established in 1981 in response to rapidly declining populations of wild salmon and steelhead trout and deteriorating fish habitat in California (*CDFG, 2008h*). The grant program has invested over $180 million to support projects from sediment reduction to watershed education throughout coastal California (*CDFG, 2008h*). Contributing partners include CDFG, federal and local governments; tribes, water districts, fisheries organizations, watershed restoration groups, the California Conservation Corps, AmeriCorps, and private landowners (*CDFG, 2008h*). The emphasis of the program is to restore anadromous salmon and steelhead habitat and to increase fish passage through California streams and rivers.

Table 9 presents a summary of electronic resources available from the CDFG. The Biographical Information and Observation System (BIOS) manages and allows for the visualization and analysis of biogeographic data. The California Habitat Restoration Project Database captures, manages and disseminates data about habitat restoration projects in California benefiting anadromous fish. In addition to serving as a comprehensive repository for information about California habitat restoration projects, the georeferenced project locations in the database enable geographical analyses of projects, aiding analysis of past trends and planning of future restoration work. The IMAPS viewer provides information on activities associated with the Fisheries Restoration Grant Program in a web-based GIS format.

Table 9: California Department of Fish and Game Electronic Resources

Biogeographic Information and Observation System	http://bios.dfg.ca.gov/
California Habitat Restoration Project Database	http://www.calfish.org/
IMAPS Viewer	http://imaps.dfg.ca.gov/viewers/frgp/app.asp

The California Department of Fish and Game impacts river restoration in the planning, design, construction, operations/maintenance, requalification (for example, vegetation removal within stream channels for flood control), and decommissioning (dam removal, and culvert removal for fish passage). The NRRSS goals that CDFG influences includes bank stabilization, channel reconfiguration, dam removal/retrofit, fish passage, floodplain reconnection, flow modification, in-stream habitat improvement, in-stream species management, riparian management, and water quality management.

3.9 California Department of Transportation

The California Department of Transportation (Caltrans) manages more than 45,000 miles of California's highway and freeway lanes, provides inter-city rail services, permits more than 400 public-use airports and special-use hospital heliports, and works with local agencies (*Caltrans, 2008*).

As part of roadway construction projects, Caltrans frequently impacts rivers and streams and they actively manage stormwater that both runs onto their freeway systems as well as the stormwater running from their projects. The Caltrans Highway Design

Manual has excellent technical design information related to hydrologic characteristics of rivers and streams. They also have a construction-related stormwater Best Management Practices manual to minimize nonpoint source pollution runoff during earthwork related construction activities. Caltrans also has a technical manual on fish passage through culverts. Some cost information is also available through the Cost Data Information database, an annual publication of construction costs (by Caltrans Item Number) for the previous year.

Caltrans provides information useful in river restoration for the planning, design, and construction life-cycle phases. Caltrans provides resources useful to achieve the bank stabilization, channel reconfiguration, fish passage, floodplain reconnection, riparian management, stormwater management, and water quality management. Table 10 presents select electronic resources available from Caltrans.

Table 10: California Department Transportation Electronic Resources

Caltrans Highway Design Manual	http://www.dot.ca.gov/hq/oppd/hdm/hdmtoc.htm
Stormwater Best Management Practices	http://www.dot.ca.gov/hq/oppd/stormwtr/
Fish Passage Manual	http://www.dot.ca.gov/hq/oppd/fishPassage/index.htm
Caltrans Cost Data Information	http://www.dot.ca.gov/hq/esc/oe/awards/

3.10 California Department of Water Resources

The California Department of Water Resources (DWR) is a department within the California Resources Agency responsible for the State of California's management and regulation of water usage. The department was created in 1956 by Governor Goodwin Knight following severe flooding across Northern California in 1955, combining the Division of Water Resources of the Department of Public Works with the State Engineer's Office, the Water Project Authority, and the State Water Resources Board (*Wikipedia, 2008c*).

There are a number of programs that have implications to river restoration, including: Aquatic restoration planning and implementation; Fish passage improvement; Flood protection corridor program; Mitigation and Restoration; Restoration, Planning, Monitoring, and Implementation; Urban Streams Restoration Program, and Water Quality Monitoring.

The Aquatic Restoration Planning and Implementation Section was established to support the CALFED Ecosystem Restoration Program by developing habitat enhancement and fish passage improvement in the Yolo Bypass (*DWR, 2008a*). The section collaborates with the Yolo Basin Foundation and other local groups to identify, study, and work to implement such opportunities on public lands and the lands of willing participants (*DWR, 2008a*). The Aquatic Restoration Planning and Implementation Section supports efforts to create regionally significant improvements in riparian, tidal marsh, and seasonal floodplain habitats in the Yolo Bypass and this effort is compatible with maintaining or improving seasonal flood flow capacity of the bypass while improving habitat diversity and quality (*DWR, 2008a*).

The Fish Passage Improvement Program (FPIP) identifies and evaluates the potential to modify or remove structures in waterways that impede migration of anadromous fish, primarily Chinook salmon (Oncorhynchus tshawytscha) and steelhead (Oncorhynchus mykiss), within the Central Valley (*DWR, 2008b*). The program provides (*DWR, 2008b*): feasibility studies (fish passage with reliable water supply); prioritization, evaluation, and development of fish passage enhancement projects; environmental documentation; coordination and consultation with stakeholders and the public; interdisciplinary teams of fish biologists, hydrologists, engineers, and environmental scientists to conduct barrier inventories. FPIP plans and implements fish passage projects to modify or remove in-stream barriers which impede migration and spawning of anadromous fish. These barriers include: dams, road crossings, bridges, culverts, canal and pipeline crossings, flood control channels, and erosion control structures (*DWR, 2008b*).

The Flood Protection Corridor Program (FPCP) was established when California voters passed Proposition 13, the "Safe Drinking Water, Watershed Protection and Flood Protection Act" in March of 2000 (*DWR, 2008c*). This proposition provided funding for nonstructural flood management projects that include wildlife habitat enhancement and/or agricultural land preservation and was first made available for direct expenditure projects during the fiscal year of 2001-2002, followed by a competitive solicitation for grant-funded project proposals in fiscal year 2002 -2003 (*DWR, 2008c*). Proposition 84, The Safe Drinking Water, Water Quality & Supply, Flood Control, River & Coastal Bond Act of 2006, provides renewed funding for the Flood Protection Corridor Program. Proposition 84 provides the sum of $40,000,000 be made available to continue the Flood Protection Corridor Program (*DWR, 2008c*).

The Mitigation and Restoration Branch is responsible for analysis and evaluation of ecological, water resource, and restoration projects for the State Water Project and State of California (*DWR, 2008d*). Branch staff members support the planning and implementation of the Bay Delta Conservation Plan as well as CALFED Record of Decision projects such as the Environmental Water Account and Prospect Island (*DWR, 2008d*). Branch staff also manages mitigation projects for the State Water Project such as the Delta Fish Agreement, survey biological and geomorphic resources, and design and implement monitoring and restoration programs for Department of Water Resources and California Bay Delta Authority (*DWR, 2008d*). The Branch is organized into four sections (*DWR, 2008d*): Restoration Planning, Monitoring, & Implementation; Delta Fish Agreement (Four Pumps), Bay Delta Conservation Plan; and Special Investigations; where staff members participate in a wide variety of projects.

The River Parkways and Urban Streams Restoration stemmed from the passage of the California Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006. The legislation appropriated $62 million for the acquisition, restoration, protection and development of river parkways in accordance with the California River Parkways Act of 2004 and $18 million for the Urban Stream Restoration program (*DWR, 2008e*). The goals of the River Parkways Program are: to protect and restore riparian and riverine habitat; and to directly improve the quality of life in California by providing important recreational, open space, wildlife, flood management, water quality, and urban waterfront revitalization benefits to communities in the State (*DWR, 2008e*). The goals of the Urban Streams Restoration Program (USRP) are to (*DWR, 2008e*): reduce property damage caused by flooding or erosion; restore, enhance, or protect the natural ecological values of streams; promote community involvement, education, and stewardship.

The mission of the Office of Water Quality (OWQ) is to meet the overall water quality needs of DWR and to provide a central focal point for the collection and dissemination of water quality information for DWR and stakeholders (*DWR, 2008f*). This mission is accomplished through comprehensive water quality monitoring, analysis, and assessment; applied research; implementation of a rigorous quality assurance and control program; and, data management and dissemination (*DWR, 2008f*). While the geographic focus is the Sacramento-San Joaquin Delta and the State Water Project, the Office also provides support to other departmental organizations and stakeholders throughout the State to meet their water quality-related needs, including providing water quality data and information in support of such activities as long-range planning, regulatory compliance, project operations, scientific research and policy development (*DWR, 2008f*).

The DWR Watershed Program works with locally led stewardship efforts to integrate the needs of communities, urban and rural, with resource management that sustains watershed ecology (*DWR, 2008g*). The program seeks to cultivate and nurture collaborative management that expands the natural, financial, and social capital that supports watershed management throughout the state and strives to inform and educate people about their watersheds and the benefits and values that those watersheds provide (*DWR, 2008g*).

Table 11 presents a summary of electronic resources available through the California Department of Water Resources. The California Data Exchange Center (CDEC) provides climate information throughout California on precipitation, river flow, reservoirs, snow, and general weather. The Water Data Library provides access to hydrologic data collected by the Division of Planning and Local Assistance (and cooperating organizations) on water quality, groundwater levels, and surface water data.

Table 11: Department of Water Resources Electronic Resources

California Data Exchange Center (CDEC)	http://cdec.water.ca.gov/
Water Data Library	http://wdl.water.ca.gov/

DWR influences river restoration during the planning, design, and construction life-cycle phases and has an impact on dam removal/retrofits, fish passage, floodplain reconnection, flow modification, land acquisition, stormwater management, riparian management, and water quality management.

3.11 California Environmental Protection Agency

The Cal/EPA departments consist of: the Office of the Secretary; the Air Resources Board; the Department of Pesticide Regulation; the Department of Toxic Substances Control; the Integrated Waste Management Board; the Office of Environmental Health Hazard Assessment; and the State Water Resources Control Board. The State Water Resources Control Board has a direct impact on river restoration.

The State Water Resources Control Board (SWRCB) is a five-member board that was created by the California Legislature in 1967, charged with setting statewide policy, coordinating and supporting the Regional Water Boards efforts, and reviewing petitions that contest Regional Board actions (*SWRCB, 2008a*). The mission of SWRCB is to preserve, enhance, and restore the quality of California's water resources and ensure their proper allocation and efficient use for the benefit of present and future generations. SWRCB is solely responsible for allocating surface water rights (*SWRCB, 2008a*).

There are nine regional water quality control boards statewide (1-North Coast; 2-San Francisco Bay; 3-Central Coast; 4-Los Angeles; 5-Central Valley; 6-Lahontan; 7-Colorado River Basin; 8-Santa Ana; and 9-San Diego) and these regional boards are semi-autonomous and are comprised of nine part-time Board members appointed by the Governor and confirmed by the Senate (*SWRCB, 2008a*). Regional boundaries are based on watersheds and water quality requirements are based on the unique differences in climate, topography, geology, and hydrology for each watershed (*SWRCB, 2008a*). Each Regional Board makes water quality decisions for its region, including setting standards, issuing waste discharge requirements, determining compliance with those requirements, and taking appropriate enforcement actions (*SWRCB, 2008a*).

There are a number of important resources available through the SWRCB and the Regional Water Boards for the practice of river restoration. These resources include the California Integrated Water Quality System Project (CIWQS), the Watershed Management Initiative (WMI); the Total Maximum Daily Load Program; the Construction Storm Water Program; and Educational and Public Outreach.

SWRCB regulates earthwork construction projects that disturb one or more acres of soil (or whose projects disturb less than one acre but are part of a larger common plan of development that in total disturbs one or more acres) as part of their nonpoint source stormwater pollution control program, and a General Permit for Discharges of Storm Water Associated with Construction Activity (Construction General Permit, 99-08-DWQ) must be obtained (*SWRCB, 2008g)*. Activities subject to this permit include clearing, grading and disturbances to the ground such as stockpiling, or excavation, but does not include regular maintenance activities performed to restore the original line, grade, or capacity of the facility (*SWRCB, 2008f*).

Table 12 presents a summary of electronic resources available from the California State Water Regional Control Boards. The California Integrated Water Quality System Project is a computer system used by the State and Regional Water Quality Control Boards to track information about places of environmental interest, manage permits and other orders, track inspections, and manage violations and enforcement activities. The

California Watershed Portal is a gateway to access watershed related information such as the California Watershed browser, the California Watershed Funding Database, the California Spatial Information Library, CalWater (Watershed Boundaries), and much more.

Table 12: State Water Regional Control Board Electronic Resources

California Integrated Water Quality System Project	http://www.waterboards.ca.gov/water_issues/programs/ciwqs/
California Watershed Portal	http://cwp.resources.ca.gov/map_tools.html

The SWRCB impacts river restoration during the planning, design, construction, and operations life-cycle phases. NRRSS goals that SWRCB influences include bank stabilization, channel reconfiguration, floodplain reconnection, stormwater management, and water quality management.

3.12 References

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Chapter Four

4 RESTORATION PARAMETERS AND RESOURCES

This chapter presents the results of the literature review of criteria and resources available from a sampling of organizations (Appendix C) that contribute to the river restoration Technology Delivery System. Table 13 (Restoration Evaluation Checklist) presents the identified physical, chemical, biological, and social parameters required to be addressed by NRRSS goals. Table 14 presents a general overview of components that comprise the parameters.

The identified physical parameters include channel form, connectivity, erosion/scour, groundwater, sediment transport, soils/geology, stream discharge, structures, and topography. The primary chemical parameter is water quality. Biological parameters include aquatic species, food web support, and riparian vegetation. Social aspects include community value, documentation (pertaining specifically to documentation of the project development so it can be incorporated into the river restoration knowledge database for future learning), and permits/regulatory. As mentioned earlier, examples of individual components that comprise each parameter are shown in Table 14. It is recommended that specific methods (see Appendix D) be selected and the identified method parameter components be utilized in project execution.

Table 13: Selection of Appropriate Evaluation Parameters based on Project Goals and Objectives

Goal/Objective	Physical: Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Chemical: Water Quality	Biological: Aquatic Species	Food Web Support	Riparian Vegetation	Social: Community Value	Documentation	Land Use	Permits/Regulatory	References
Aesthetics, Recreation, Education		R												R	R	R	R	1,2,10,17
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R	1,2,4,7,8,11,17,18
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R	1,2,4,7,8,17,18
Dam Removal/Retrofit	R	R	R		R	R	R	R	R				R	R	R	R	R	1,17
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R	1,2,6,17,18
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R	1,2,7,9,17
Flow Modification							R						R		R		R	1,17
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R	1,8,12,13,15,17,18
In-Stream Species Management		R								R	R	R	R	R	R	R	R	1,8,16,17,18
Land Acquisition								R	R					R	R	R		1,17,19
Riparian Management	R	R	R	R		R		R	R				R		R	R		5,17,18
Stormwater Management			R		R		R			R					R		R	1,17,21,22
Livestock Exclusion		R						R	R					R	R	R	R	1,17,20
Water Quality Management			R		R	R	R		R	R					R	R	R	1,14,17,18,20,21
References	1,2,5,6,8,9,11,12,13,15,17	6,8,10,12,17,20	1,2,5,8,9,11,12,13,17,21	3,5,8,17	2,4,8,9,11,12,17,21	2,6,8,9,11,12,13,15,17,21	1,2,6,8,9,11,12,13,15,17,21	1,5,6,8,9,11,12,13,17,20	5,6,8,9,11,12,13,15,17,21	4,8,12,13,14,15,16,17,19,21	4,6,8,12,13,15, 16,17,19	8,12,13,15,16,17,19	4,5,7,8,9,11,12,13,15,17,19	10,17,19,20	1,8,11,12,13,15,17,19,21	4,8,9,10,12,13,15,17,19,21	1,8,10,17,19,21	

Notes:
R=Recommended

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22 CA-TRANS - Storm Water Quality Handbooks: SWPPP and WPCP Preparation Manual (2007)

Table 14: Example Attributes to be Considered for Identified Restoration Goal Parameters

Channel Form	Connectivity	Erosion/Scour	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Groundwater
Bankfull Depth	Entrenchment	Bank Undercutting	Bed Load	Bedrock Conditions	Base flow	Baffles	Horizontal Datum	Aquifers
Bankfull Discharge	Lateral	Bed Scour	Bed Slope	Cantilever Failure	Channel Depth	Beaver Dams	Hypsography	Aquitards
Bankfull Width	Longitudinal	Contraction Scour	Channel Depth	Faults	Channel Width	Boulders	Latitude/Longitude	Capillarity
Bedrock Sheet	Terraces	Critical Velocity	Channel Width	Geologic Maps	Critical Depth	Bridges	Reach Slope	Connectivity
Cascades	Vertical	Dominant Substrate	Dynamic Viscosity	Landslides	Critical Flow	Culverts	Terraces	Downwelling
Channel depth		Fluvial Erosion	Gravel Bar Migration	Permeability	Drainage Area	Deflectors	USGS 7.5' Topo	Effective Grain Size (D10)
Channel slope		Freeze/Thaw	Landslides	Piping Failure	Duration	Dikes	USGS HUC 8	Fluid Density
Channel width		Gullies	Mass Wasting	Pop-out Failure	Head Loss	Fishways	Vertical Datum	Fracturing
Dominant Substrate		Headcutting	Particle Fall Velocity	Rotational Slip	Hydraulic Jumps	Gabions	Watershed	Hydraulic Conductivity
Edgewater		Landslide Erosion	Particle Side Distribution	Shallow Slide	Hydraulic Radius	Grade Controls		Hydraulic Gradient
Entrenchment		Livestock Trampling	Sediment Concentration	Slab/Block Failure	Intermittent/Ephemeral	J-Hooks		Hyporheic Zones
Flatwater		Mass Wasting	Sediment Diffusivity	Soil Infiltration	Irregular Flow	Large Woody Debris (LWD)		Permeability
Glide		Pier Scour	Sediment Load	Soil Types	Laminar Flow	Levees		Piezometric Surface
Pocket Water		Rilling	Stream Discharge	Soil/Rock Fall	Perennial	Log Jams		Porosity
Pool/Riffles		Runoff Erosion	Suspended Load	Stratigraphy	Precipitation	Obstructions		Saturation
Roughness Characteristics		Seepage/Piping	Velocity Profile	Substrate	Q2,Q10,Q50,Q100,Q500	Outfalls		Stratigraphy
Run		Surface Erosion	Wash Load	Terraces	Regular Flow	Palisades		Upwelling
Sediment load		Toe Scour			Roughness Characteristics	Retaining Walls		Water Retention
Sinuosity		Vertical Banks			Snowmelt Runoff	Retards		
Stream order		Wind Waves			Stage	Rip Rap		
Substrate					Supercritical Flow	Roadways		
Width/Depth Ratio					Turbulent Flow	Sheet Piles		
					Velocity	Vanes		
					Wetted Perimeter	Waterfalls/Inclines/Chutes		
						Wiers		

Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Benthic Macro invertebrates	Endemic Stocks	Benthic Algae	Canopy Density	Aesthetics	Historic Conditions	Agriculture	Anadromous Fish Conservation Act (NOAA)
Dissolved Oxygen	Habitat Type	Benthic Macro invertebrates	Coniferous Component	Cleanup Days	Baseline Survey	Developed Recreation	CEQA
Dissolved/Suspended Solids	Management Concept	Collectors	Deciduous Component	Cultural Resources	Constraints Definition	Skiing	Coastal Zone Management Act (CA Coastal Commission)
Electrical Conductivity	Cold water	Grazers	Density	Fishing	Requirements Definition	Campgrounds	County/State Right of Way Permit
Hardness	Anadromous	Gut Content Analyses	Grass	Hunting	Project Plan	Off-Highway Vehicles	CWA - Section 401 (SRWCB)
Nutrients	Warm Water	Meiofauna	Groundwater	Interactive Education	Project Permits	Mining	CWA - Section 404 (USACE)
Organic (BOD, TOC, etc.)	Natural Production	Microbes	Intermittently Flooded	Recreation	Feasibility Evaluation	Navigation	Endangered Species Act (USFWS)
pH	Mixed Production	Predators	Permanently Flooded	Volunteering	Plans and Specifications	Timber Harvest	Harbors and Rivers Section 10 (USACE)
Total Phosphorous	Other	Shredders	Seasonally Flooded		Cost Estimate	Urban	Landowner Access Agreement
Toxics	Species		Semipermanently Flooded		Construction Schedule	Water Facilities	MacAteer-Petris Act (BCDC)
Turbidity			Shrubs		As-Built Survey	Hydroelectric	National Marine Fisheries Service Permit
Water Temperature			Species			Diversion	NEPA
			Temporarily Flooded			Reservoirs	NPDES
			Trees			Wilderness	Porter-Cologne Water Quality Control Act (SRWCB)
							State Lands Commission
							Streambed Alteration Agreement (CDFG)

4.1 Developing Reliable River Restoration Projects

In order to achieve reliable river restoration projects it is essential that the problem to be remedied is completely and comprehensively defined (which Table 13 facilitates); that all applicable requirements and constraints be identified (i.e. physical, chemical, biological, social, political, financial, temporal, etc.), that project-related uncertainties (i.e. physical, temporal, financial) be acknowledged, estimated, and accounted for; and interactive management approaches (such as adaptive management) be configured and employed to manage those parameters identified as having significant influence on the project and high magnitudes of uncertainty.

The most common failure mechanism for river restoration projects (see Chapter 5) is the omission of essential parameters in the development and configuration of the project. For example, many bank stabilization projects are developed without any consideration of stream discharge and as a result, are inadequately designed and 'washed away' during high flow events. The intent of the Restoration Evaluation Checklist is to aid river restoration practitioners in avoiding this common error and help them configure more reliable projects.

In addition to the Restoration Evaluation Checklist, the Diamond Model (*Mitroff & Linstone, 1993*) offers an excellent framework for developing and implementing reliable river restoration projects because it requires not only a definition of the problem, generation of a conceptual model/framework, engineered solution, and implementation, but it also requires that the implemented solution be related back to the original problem, to ensure that the problem has been adequately resolved. In practice, some of the Diamond Model components are employed, but not all. Problem Definition, Exact

Solution generation, and Implementation are frequently employed. The development of a Conceptual Model framework and subsequent monitoring to ensure resolution of the problem are regularly omitted in river restoration.

Employment of all Diamond Model (Figure 11) components greatly improves the reliability of the completed projects because a full evaluation of the effectiveness of the developed solution to the problem is evaluated instead of relying on the assumption that the perceived interpretation of the problem and resulting action fully remedy the situation. The Diamond Model components include:

- Problem Definition – Almost all river restoration projects have adequate problem definition. The spatial and temporal scales associated with the problems are frequently omitted, leading to partial definitions of problems. An example of partial definitions is a bank stabilization project where the limits of bank to be stabilized are precisely defined, but the contributing land use factors outside the 'project limits' are ignored. Not addressing the problem from a holistic standpoint frequently results in incomplete solutions.
- Conceptual Model – Conceptual models provide an excellent means to develop a framework that establishes relationships between the identified problem and influencing parameters (such as those listed in the Restoration Evaluation Checklist). Conceptual models are rarely developed (or documented) as part of river restoration projects, but are considered as essential for development of reliable projects (*USACE, 2004; USACE, 2008*).

- Exact Model – This node of the Diamond Model is frequently completed. In fact, there is so much reliance on this component, that frequently there is no validation of the generated solution required because of the belief that "if the engineer obtained the result from their model, the result must be correct." This line of thinking does not account for the many simplifications required to reduce complex problems into simple representations so the model can be configured and it also does not take into consideration the wide range of uncertainties associated with the parameters used in the engineering models, or uncertainties generated as a result of simplifying the problem down to a point where it can be analyzed. As a result, many models that are thought of as 'exact,' are infact inexact and can lead decision makers to make improper decisions.
- Solution – All river restoration projects have some sort of solution implemented. The degree to which the solution remedies the identified problem, is debatable, but all projects implement some sort of solution. The documentation of the implemented solution (such as 'As-Built' drawings) is infrequent, making it very difficult to revisit implemented solutions after the project has been in service for a number of years to see if the actual performance matches the anticipated performance and that any deviations from the design conditions during construction are documented. More effort and resources needs to be enacted on projects to ensure that the as-constructed conditions are documented and baseline conditions established for performance monitoring.

- Monitor – The final aspect of the Diamond Model is validation that the developed solution actually remedies the problem (as characterized in the problem definition stage). Three monitoring strategies are common in river restoration: (1) implementation monitoring, (2) effectiveness monitoring, and (3) validation monitoring. Implementation monitoring evaluates the degree to which the design configuration was actually constructed and establishes the baseline for future project performance. Effectiveness monitoring compares the actual performance against the anticipated performance. This type of monitoring can be difficult in that the temporal scales associated with these types of project can be very large. For example, if the project was configured for the 100-year flood, it may take many years before the restoration project is exposed to an actual 100-year flood. If the anticipated performance for the project was not well documented and archived, it becomes impossible to perform the effectiveness assessment. Validation monitoring pertains to assessments of methods, not individual project performance. A large number of project effectiveness surveys are required to conduct meaningful validation monitoring.

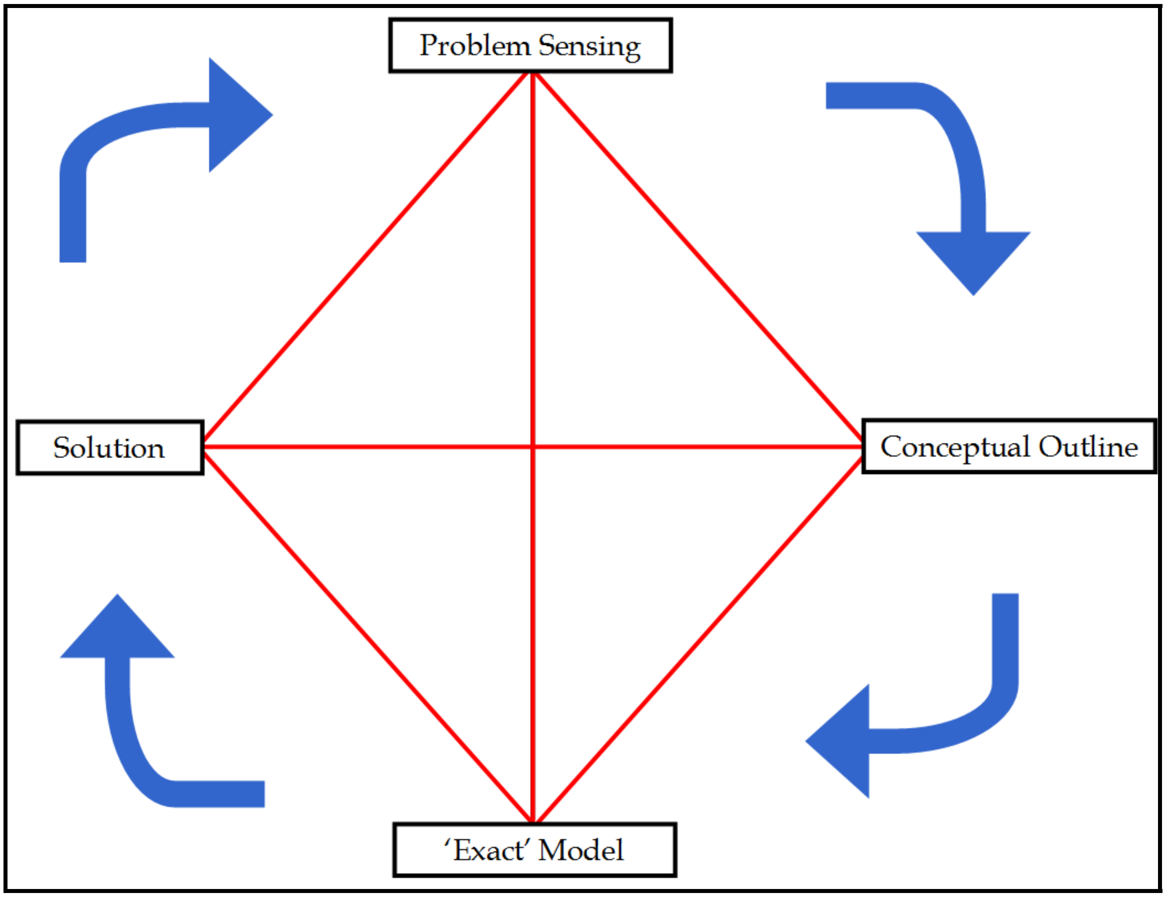

Figure 11: Diamond Model Nodes Consist of Problem Sensing, Conceptual Outline, Exact Model, and implementation of a Solution.

4.2 River Restoration Constraints

The parameters identified in the Restoration Evaluation Checklist are not the only factors to be considered during configuration of river restoration projects. There are other factors, specific to local conditions, which must be accounted for as well. Some of these factors include flood control, legal issues, resource availability, and politics. These factors are described in more detail below.

4.2.1 Flood Control

All river restoration projects should be evaluated for their impact on flood water conveyance as rivers have high longitudinal connectivity and projects in one area can have direct impacts on sites that are either upstream and/or downstream. The most common project components that impact the ability of a river channel to convey flood water is the riparian (and in-stream) vegetation configuration, reconfiguration of the stream channel and floodplain connection (construction of levees), and installation of structures (culverts, bridges, etc.) that may restrict water flow and/or encourage collection of rubbish that occludes flow. Streams in urban areas are the most critical to be evaluated for flood water conveyance. FEMA's Flood Insurance Rate Maps (http://msc.fema.gov/) are an excellent means by which to evaluate flood control conditions surrounding project sites in urban areas. Figure 12 shows an example of a reduction in flood conveyance in a stream restoration project as a result of establishment of riparian vegetation, used to stabilize the creek banks. The original design did not account for changes in channel roughness (and associated high water flows) following establishment of the riparian vegetation (see Chapter 5 – Tennessee Hollow for a more in-depth discussion of this project).

Figure 12: Establishment of riparian vegetation greatly impacts flood conveyance of rivers and must be accounted for in the configuration of the restoration project (Tennessee Hollow Restoration Project, San Francisco).

4.2.2 Legal Issues

In addition to the regulatory requirements associated with river restoration projects (Table 14), there are legal implications associated with the results of the completed projects. The intent of this section is not to provide a comprehensive overview of legal implications of river restoration, rather to highlight the issue and identify major factors to be cognizant of. An excellent overview of legal issues associated with river restoration has been prepared by Kusler (*2007*), from which these points have been obtained. It is strongly encouraged that the laws specific to individual restoration sites be evaluated during the planning phase of the project development, to ensure that all project constraints and requirements have been identified, prior to initiation of final project configuration (which saves a lot of heart-ache and possible re-design of the project).

- *<u>Rule of Reasonable Use</u> – Landowners and their design professionals may not, with their designs or other activities, "unreasonably" discharge surface waters onto other lands as well as block flood flows or increase flood heights and velocities in rivers, streams or other watercourses;*
- *<u>Adoption of Regulations</u> – More than 20,100 local governments and many states have adopted floodplain regulatory standards for elevation for flood-proofing of new structures and protection of floodway capacity. Failure to comply with these standards in design of a building, grading, fill or other activities will usually constitute a breach of a design contract (or at minimum) establish a prima facie case of neglect if damage results from such a failure;*

- *<u>Availability of Design Guidance</u> – Many flood-related design manuals have been published at the national and state levels by agencies such as the Corps of Engineers and the Federal Emergency Management Agency including manuals with recommended flood-proofing and construction practices. These materials are now also widely available on the Internet. The design professional can no longer claim ignorance or lack of information concerning flood-proofing and other flood loss reduction design techniques and, it may be argued, that a 'national' standard of care now applies to many flood-related design issues;*
- *<u>Enhanced Standard of Care</u> – Design professionals throughout the nation have applied increasingly sophisticated elevation and flood-proofing techniques to reduce flood damage to structures. They have also, increasingly, applied sophisticated flood routine techniques to determine flood heights and velocities and erosional potential. These efforts have established high standards of care and 'expertise' in the design profession 'community.' In addition, many state and community regulations now exceed the minimum Federal Emergency Management Agency standards for construction in flood hazard areas. These regulations and practices establish an enhanced standard of care for particular areas. Many communities that have adopted enhanced floodplain construction standards dealing with freeboard, use of flood resistant materials, and the design of critical facilities; and*

- *<u>Implied Warranty</u> – Courts have recognized an implied warranty of habitability or suitability for new residential structures in most states. Courts have also more broadly recognized fraud and misrepresentation as the basis for law suits when sellers conceal flood hazards or do not divulge known flood hazards. Developers and sellers are now, in many contexts, liable to buyers for flood damage…Design professionals are increasingly careful not to warrant total protection from flooding or other hazards in design contracts. Design professionals have increasingly added 'freeboard' and other safety factors in their designs. Design professionals have successfully urged state legislatures in most states to adopt statutes of 'repose' or 'limitation.' These limit the time period in which design professionals may be sued after the design is completed (e.g. statutes of 'repose') or the flood injury becomes known (e.g. statutes of limitations). States have also adopted 'tort claim' acts limiting the liability of governments for discretionary decision-making including permit approvals and the design of public roads and bridges.*

4.2.3 Resources

Consideration for each project should also include availability and abundance of resources specific to the geographic region where the project is to be initiated. For example, if a restoration project involves the removal of invasive tree species (eucalyptus frequently falls into this category), the remnants of the tree removal could be used to provide habitat features as part of the river restoration project configuration, design, and construction, instead of disposing of the removed trees and purchasing and installing trees from another source. Figure 13 shows an example where trees removed as part of the site clearing and preparation construction phase for the Redwood Creek restoration project (Marin County, California) have been incorporated into the channel reconfiguration design.

Figure 13: Use of demolition materials to construct grade stabilization and to increase in-stream habitat channel complexity (Redwood Creek, Marin County).

Although this is but one example, each project should be developed with an awareness of site-specific resources that can impact the development of the restoration project.

4.2.4 Politics

Politics is defined by Webster (*2008*) as "the total complex of relations between people living in society." Special interest groups and communities surrounding the restoration site can have both positive and negative influences on the project. Some geographic areas have more active special interest groups than other. Similarly, some areas may have a larger assemblage of special interest groups (such as the California Delta region) than other regions (such as Plumas County, in northeastern California). A common technique to account for the opinions and views held by these special interest groups is to form stakeholder advisory committees and to inform impacted special interest groups through public information campaigns. Common tools for receiving input from community members include (*FISWRG, 2001*):

- *Public hearings;*
- *Task forces;*
- *Training seminars;*
- *Surveys;*
- *Focus groups;*
- *Workshops;*
- *Interviews;*
- *Review groups;*
- *Referendums;*
- *Phone-in radio programs; and*
- *Internet websites.*

Common tools to inform community members about restoration activities include (*FISWRG, 2001*):

- *Public meetings;*
- *Internet websites;*
- *Fact sheets;*
- *News releases;*
- *Newsletters;*
- *Brochures;*
- *Radio or TV programs or announcements;*
- *Telephone hotlines;*
- *Report summaries;*
- *Federal register.*

Additional strategies are presented in FISRWG (*2001*). It should be noted that each restoration project is different and the project development team should evaluate the impact of politics on their project and react accordingly.

4.3 Uncertainty and Adaptive Management

Uncertainty plays an important role in the configuration of reliable river restoration projects. Identifying the components with uncertainty and the associated magnitude of uncertainty are essential during the planning and design phases of the projects. The magnitudes of uncertainties can be as simple as assuming a triangular or uniform distribution with a specified high bound, low bound, and mean (or expected value). In addition to quantifying the uncertainty range, it is often useful to characterize the type of uncertainty, the source of the uncertainty, provide an indication if the uncertainty can be reduced through more data collection or adaptive management, and a qualitative rating of the uncertainty (*Yoe, 1996*). This characterization allows for the development of an adaptive management program based on project prioritization that not only addresses the items of primary concern, but also allows for the documentation and communication of parameter uncertainty as the project is transferred from one life-cycle phase to another as well as providing a means by which to aggregate disparate uncertainties identified by different project disciplines into one comprehensive project listing of uncertainties.

The U.S. Department of the Interior has assembled a technical guide on Adaptive Management (*Williams et al, 2007*). Strategies for adaptive management are also presented in the Stream Corridor Restoration guide (*FISRWG, 2001*), and examples on the incorporation of uncertainty in ecological restoration projects are presented in Yoe et al (*1996*), Males (*2002*), and Thom and Difenderfer (*2004*).

Below is a discussion of example resources available to river restoration practitioners categorized by life-cycle phase.

4.4 Planning

There are two essential aspects of planning related to river restoration: watershed-based assessments and plans, and individual project development planning. Almost all organizations promoted and strongly encouraged the development of watershed assessments and plans PRIOR to initiation of individual restoration projects. Excellent guidance on the development of watershed assessments are presented by the U.S. EPA (*EPA, 2008a; EPA, 2008b*), the U.S. Forest Service (*1998*) the California

Department of Conservation (*DOC, 2008*), the USACE (*2000c*) and the Federal Interagency Stream Restoration Working Group (*FISRWG, 2001*). At a minimum, these watershed plans (*EPA, 2008a*):

1. Build partnerships;
2. Characterize the watershed to identify problems;
3. Set goals and identify solutions;
4. Design an implementation program;
5. Implement the watershed plan; and
6. Measure progress and make adjustments

Implementing watershed plans frequently fail due to the following factors (*EPA, 2008a*):

- The Planning activities were conducted at too great a scale;
- The plan was a one-time study rather than a long-term management process;
- Stakeholder involvement and local ownership were lacking;
- The plan skirted land use/management issues in the watershed;
- The document was too long or complex;
- The recommendations were too general;
- The plan failed to address conflicts.

Development of appropriate watershed plans provide a means by which to not only identify improvements to be made, but provides an excellent means by which to develop a standard suite of baseline conditions (with the identified goal evaluation parameters being minimum baseline condition criteria) and project requirements and constraints that all individual projects should be designed to adhere to, thus eliminating the need for these same parameters to be developed for each and every project.

Utilization of tiger teams in the development of watershed assessments and plans is an excellent way to ensure that a complete and comprehensive plan has been prepared. By having ecologists working with engineers, geologists, biologists, water quality experts, lawyers, land use specialist, etc., the breadth of problem representation more closely resembles the true nature of the watershed problem. By having these disparate groups working in close unison throughout the plan development process, each group gains insights into factors specific to the other interests and can offer counsel and perspectives based on their viewpoints.

In addition, the development of a watershed plan is complimentary to project-specific development plans. For example, the six-step planning process recommended by the USACE (*2000*) requires the following steps:

1. <u>Identifying problems and opportunities</u> – a watershed assessment can identify a number of possible projects that could be implemented to improve the 'health' of the watershed. Frequently, this aspect of planning is performed on a 'project by project' basis;
2. <u>Inventorying and forecasting conditions</u> – this step involves establishing a baseline evaluation of the watershed, noting historic conditions, existing conditions, and anticipated future conditions (i.e. such as a result of urban development). This aspect is frequently ignored for many river restoration projects. The Restoration Evaluation Checklist can be used as guidance

on the types of baseline information to be collected to be used in the development of alternative plans;

3. Formulating alternative plans – this step acknowledges that there are multiple potential solutions to every problem and encourages brainstorming of several possible solution configurations, with an emphasis on optimizing performance, cost, and implementation time. Very few river restoration projects evaluate multiple alternatives, rather one approach is selected at the outset of problem definition and implemented;
4. Evaluating alternative plans – this step serves to evaluate the positive and negative attributes of potential solutions so that the 'optimal' solution can be selected;
5. Comparing alternative plans – this step provides a means by which to confirm and apply selection criteria to proposed plans; and
6. Selecting a plan – this is the last phase before project implementation.

These six planning steps are not detailed enough for formal implementation of individual projects, but nicely demonstrate the value of conducting watershed assessments and then selecting restoration projects within this larger context. Much of the work for individual projects is completed during the generation of the watershed plan.

4.5 Design

The Design of river restoration projects should include a conceptual model that outlines the general problem solving approach employed for the project, a detailed accounting of all design rationales, input parameters, and calculations. Project plans, implementation schedule, and budget (with a line item breakdown and unit costs) should also be included.

There are a large number of available (and free) resources for the design of river restoration projects. Design resources are presented in the subsequent sections based on NRRSS goal category. In addition to those specific design resources, there are some general resources that are useful and apply to many NRRSS goals. These resources were discussed in Chapter 3 and select examples are presented in Table 15.

Table 15: Select Examples of General River Restoration Design Resources

Document	Reference
Caltrans Highway Design Manual	Caltrans, 2008
Stormwater Best Management Practices	Caltrans, 2007
Caltrans Cost Data Information	Caltrans, 2008b
California Salmonid Stream Habitat Restoration Manual	CDFG, 1998
Stream Corridor Restoration	FISRWG, 2002
NRCS Urban Hydrology for Small Watersheds	NRCS, 1986
USACE Stream Management Manual	USACE, 2000b
HEC-SSP - Determines stream discharge recurrence intervals and associated uncertainty	USACE, 2008c
HEC-RAS - Determines flow conveyance characteristics in channels	USACE, 2008d

The Caltrans Highway Design Manual (*2008*) provides a comprehensive hydrology and hydraulic design section that applies to general open channel flow design problems, with hydrology characteristics specific to California. The California Salmonid Stream Habitat Restoration Manual (*CDFG, 1998*), the NRCS Urban Hydrology for Small Watersheds (*NRCS, 1986*), and the USACE (*2000b*) Stream Management are also excellent general design references.

Design related to stormwater pollution control can be found in the Caltrans Stormwater Pollution Control design manuals (*Caltrans, 2007*).

Cost information for design purposes can be found from the Caltrans Cost Guide (*Caltrans, 2008b*), through general cost guides such as RS Means (*2008*). In addition, the

Evergreen Funding Consultants (*2003*) prepared a general restoration-oriented cost guide to aid planners and designers with approximate costs associated with different restoration activities.

4.6 Construction

Development of complete plans and specifications that clearly communicate the intent of the restoration design and installation requirements are crucial for the implementation of proper functioning projects. It is often the complaint by restoration practitioners that contractors are not familiar with river restoration practices and as a result, they make frequent errors during implementation. However, the large majority of river restoration projects are poorly documented and ineffectively communicated. The primary cause of implementation error is poor documentation, not lack of familiarity. Each restoration project is unique and implementation of a standard restoration template is rarely appropriate. Once the project is complete, 'as-built' drawings should be developed to document the as-installed condition of the project, noting any deviations from the original design drawings. Notes of deviations are an excellent means to provide feedback to the design (and planning) stages of project development, especially when there are assumptions that were not appropriate or valid.

Resources oriented towards construction practices are construction specifications available through Caltrans (*2006a, 2006b*) and the SPECSINTACT program, affiliated with the USACE (*NASA, 2008*). These standard specifications need to be modified to each individual project, but provide an excellent template for the types of information that must be included to reduce miscommunications (such as contractor payment measures, submittals, testing requirements, etc.).

4.7 Operations/Monitoring

There are numerous resources available to assist with the evaluation of the proper functioning of the completed restoration project. EPA's Field Operations Manual for Streams (*2001*) provides guidance on the evaluation of stream water quality and habitat quality. These resources were discussed in Chapter 3 and select examples are presented in Table 16.

Table 16: Select Examples of General River Restoration Design Resources

Document	Reference
California Salmonid Stream Habitat Restoration Manual	CDFG, 1998
Protocols for Monitoring the Response of Anadromous Salmon and Steelhead to Watershed Restoration in California	CDFG, 2005
Field Operations Manual for Streams	EPA, 2001
USACE Stream Management Manual	USACE, 2000b

4.8 Maintenance/Requalification

Very few resources were found pertaining to this life-cycle phase. It is recommended that any existing structures that have reached their intended life-span be evaluated based on the current design guidelines, based on NRRSS goal category.

4.9 Decommissioning

Very few resources were found pertaining to this life-cycle phase. A common decommissioning activity related to river restoration is dam removal and a discussion of resources associated with dam removal is presented in Section 4.13 - Dam Removal/Retrofit.

Below is a discussion of example resources available to river restoration practitioners categorized by NRRSS Goal Category.

4.10 Aesthetics/Recreation/Education

The Aesthetics/Recreation/Education goal consists of those activities that increase community value, use, appearance, access, safety and knowledge. This is a very subjective and qualitative goal. Evaluation parameters that were identified as applicable to this goal include: connectivity; community value; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 17.

Table 17: Example Resources for Aesthetics/Recreation/Education

Document	Reference
Shoreline Spaces Design Guidelines	BCDC, 2005
Shoreline Signs Design Guidelines	BCDC, 2005b
The California Storm Water Toolbox	SWRCB, 2008
Recreation Enhancements for Urban Streams	USACE, 2005
Landscaping Considerations for Urban Stream Restoration Projects	USACE, 2004b

4.11 Bank Stabilization

The bank stabilization goal consists of those practices designed to reduce/eliminate erosion or slumping of bank material into the river channel. Evaluation parameters that were identified as being applicable to this goal include: channel form; erosion/scour; groundwater; sediment transport; soil/geology; stream discharge; structures; topography; riparian vegetation; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 18.

Table 18: Example Resources for Bank Stabilization

Document	Reference
Bank Stability and Toe Erosion Model	ARS, 2008
Critical Tractive Forces on Channel Side Slopes	Bureau of Rec., 1950
California Bank and Shore Rock Slope Protection Design	Caltrans, 2000
California Salmonid Stream Habitat Restoration Manual	CDFG, 1998
Design of Roadside Channels with Flexible Linings	FHWA, 2005
Design of Riprap Revetment	FHWA, 1989
Stream Stability at Highway Structures	FHWA, 2001
Bioengineering for Streambank Erosion Control	USACE, 1997
The Stream Investigation and Streambank Stabilization Handbook	USACE, 1997b
Rootwad Composites for Streambank Erosion Control & Fish Habitat Enhancement	USACE, 2000e
Brush Mattresses for Streambank Erosion Control	USACE, 2001
Impacts of Stabilization Measures	USACE, 2001b
Live and Inert Fascine Streambank Erosion Control	USACE, 2001c
Gabions for Streambank Erosion Control	USACE, 2000d
Vegetated Reinforced Soil Slope Streambank Erosion Control	USACE, 2003
Live Stake and Joint Planting for Streambank Erosion Control	USACE, 2007
A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization	USFS, 2002

4.12 Channel Reconfiguration

The channel reconfiguration goal consists of the alteration of channel plan form or longitudinal profile and/or day-lighting (converting culverts and pipes to open channels). This includes stream meander restoration and in-channel structures that alter the thalweg of the stream. Evaluation parameters that were identified as being applicable to this goal include: channel form; connectivity; erosion/scour; groundwater; sediment transport; soil/geology; stream discharge; structures; topography; riparian vegetation; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 19.

Table 19: Example Resources for Channel Reconfiguration

Document	Reference
The Stable Channel Problem of Coarse Material	Bureau of Rec, 1949
Principles of Design of Stable Channels in Erodible Material	Bureau of Rec, 1950
Stable Channel Profiles	Bureau of Rec, 1951
California Salmonid Stream Habitat Restoration Manual	CDFG, 1998
The Bed-Load Function for Sediment Transport in Open Channel Flows	NRCS, 1950
n-Value Guide	NRCS, 1963
Design of Open Channels	NRCS, 1977
Stability Design of Grass Lined Open Channels	NRCS, 1987
The Flow of Water in Open Channels with High Gradients	Thomas, 1947
Roughness Characteristics of Natural Channels	USGS, 1967
Surface-Water Field Techniques. Verified Roughness Characteristics of Natural Channels	USGS, 2008
The Stream Investigation and Streambank Stabilization Handbook	USACE, 1997
Channel Rehabilitation: Processes, Design, and Implementation	USACE, 1999
Stability Thresholds for Stream Restoration Materials	USACE, 2001d
Reconnection of Floodplains with Incised Channels	USACE, 2000f
Resistance Due to Vegetation	USACE, 2000g
Coir Geotextile Roll and Wetland Plants for Streambank Erosion Control	USACE, 2000h
Determining Drag Coefficients and Area for Vegetation	USACE, 2000i
Design of Low-Flow Channels	USACE, 2002
Hydraulic Losses in River Meanders	USACE, 2007b
Vegetation Impacts Upon Stream Width	USACE, 2007c

4.13 Dam Removal/Retrofit

The dam removal/retrofit goal consists of the removal of dams and weirs or modifications/retrofits to existing dams to reduce negative ecological impacts. Excludes dam modifications that are simply for improving Fish Passage. Evaluation parameters that were identified as applicable to this goal include: channel form; erosion/scour; sediment transport; soil/geology; stream discharge; structures; topography; riparian vegetation; community value; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 20. An active database on dam removal is marinated at the Water Resources Library at the University of California at Berkeley (http://www.lib.berkeley.edu/WRCA/damremoval/).

Table 20: Example Resources for Dam Removal

Document	Reference
Paying for Dam Removal	American Rivers, 2000
Ecology of Dam Removal	American Rivers, 2002
Exploring Dam Removal: A Decision Making Guide	American Rivers, 2007

4.14 Fish Passage

The fish passage goal consists of the removal of barriers to upstream/downstream migration of fishes. Includes the physical removal of barriers and also construction of alternative pathways. Includes migration barriers placed at strategic locations along streams to prevent undesirable species from accessing upstream areas. Evaluation parameters that were identified as being applicable to this goal include: channel form; connectivity; erosion/scour; groundwater; sediment transport; soil/geology; stream discharge; structures; topography; water quality; aquatic species; food web support; riparian vegetation; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 21. In addition, updated resources specific to Fish Passage are posted on www.calfish.org.

Table 21: Example Resources for Fish Passage

Document	Reference
Fish Passage Design for Road Crossings	Caltrans, 2007b
California Salmonid Stream Habitat Restoration Manual	CDFG, 1998
Culvert Criteria for Fish Passage	CDFG, 2002
Design for Fish Passage at Roadway-Stream Crossings: Synthesis Report	FHWA, 2007
Pool and Riffle Fishways for Small Dams	MNRFB, 1995
Stream Analysis and Fish Habitat Design – A Field Manual	Newbury, 1993

4.15 Floodplain Reconnection

The floodplain reconnection goal consists of those practices that increase the flood frequency of floodplain areas and/or promote flux of organisms and material between riverine and floodplain areas. Evaluation parameters that were identified as applicable to this goal include: channel form; connectivity; erosion/scour; groundwater; sediment transport; soil/geology; stream discharge; structures; topography; riparian vegetation; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 22.

Table 22: Example Resources for Floodplain Reconnection

Document	Reference
Floodplain Connectivity and River Corridor Complexity: Implications for Restoration and Planning for Floodplain Management	Tompkins, 2006
Reconnection of Floodplains with Incised Channels	USACE, 2000f

4.16 Flow Modification

The flow modification goal consists of those practices that alter the timing and delivery of water quantity. Typically, but not necessarily associated with releases from impoundments and constructed flow regulators. Evaluation parameters that were identified as being applicable to this goal include: stream discharge; riparian vegetation; documentation; and permits/regulatory.

4.17 In-Stream Habitat Improvement

The in-stream habitat improvement goal consists of altering structural complexity to increase habitat availability and diversity for target organisms and provision of breeding habitat and refugia from disturbance and predation. Evaluation parameters that were identified as applicable to this goal include: channel form; connectivity; erosion/scour; groundwater; sediment transport; soil/geology; stream discharge;

structures; topography; water quality; aquatic species; food web support; riparian vegetation; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 23.

Table 23: Example Resources for In-Stream Habitat Improvement

Document	Reference
Protocols for Monitoring the Response of Anadromous Salmon and Steelhead to Watershed Restoration in California	Duffy, 2005
Field Operations Manual for Wadeable Streams	EPA, 2001
Restoration and enhancement of aquatic habitats	USACE, 1999b
Habitat Requirements for Freshwater Fishes	USACE, 2000k
Streambank Habitat Enhancement with Large Woody Debris	USACE, 2000j
Habitat Equivalency Analysis: A Potential Tool for Estimating Environmental Benefits	USACE, 2008b
Habitat Evaluation Procedures Handbook	USFWS, 1980

4.18 In-Stream Species Management

The in-stream species management goal consists of practices that directly alter aquatic native species distribution and abundance through the addition (stocking) or translocation of animal and plant species and/or removal of exotics. Excludes physical manipulations of habitat/breeding territory (see In-stream Habitat Improvement). Evaluation parameters that were identified as being applicable to this goal include: connectivity; water quality; aquatic species; food web support; riparian vegetation; community value; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 24.

Table 24: Example Resources for In-Stream Species Management

Document	Reference
Anadromous Fishes of California	CDFG, 1979

4.19 Land Acquisition

The land acquisition goal consists of practices that obtain lease/title/easements for stream-side land for the explicit purpose of preservation or removal of impacting agents and/or to facilitate future restoration projects. Simple purchase and preservation to prevent potential future land conversion are not considered sufficient for inclusion in the NRRSS database and all qualified projects should demonstrate intended or actual cessation of detrimental activities in acquired land or active restoration components. Evaluation parameters that were identified as applicable to this goal include: structures; topography; community value; documentation; land use; and permits/regulations.

4.20 Riparian Management

The riparian management goal consists of the revegetation of riparian zone and/or removal of exotic species (e.g. weeds, cattle) and excludes localized planting only to stabilize bank areas (see Bank Stabilization). Evaluation parameters that were identified as applicable to this goal include: channel form; connectivity; erosion/scour; groundwater; soil/geology; structures; topography; riparian vegetation; community value; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 25.

Table 25: Example Resources for Riparian Management

Document	Reference
Management techniques in riparian areas - Riparian area management	BLM, 1992
Process for assessing proper functioning condition Riparian area management	BLM, 1998
A Manual of California Vegetation	CNPS, 1995
Vegetation Rapid Assessment Protocol	CNPS, 2007
Environmental Value of Riparian Vegetation	USACE, 1996
Design Recommendations for Riparian Corridors and Vegetated Buffer Strips	USACE, 2000l
Determining Optimal Degree of Soil Compaction for Balancing Mechanical Stability and Plant Growth Capacity	USACE, 2000m
Irrigation Systems for Establishing Riparian Vegetation	USACE, 2000n
Plant Material Selection and Acquisition	USACE, 2001e
Riparian Restoration	USFS, 2004

4.21 Stormwater Management

The stormwater management goal is a special case of flow modification that includes the construction and management of structures (ponds, wetlands and flow regulators) in urban areas to modify the release of storm runoff into waterways from watersheds with elevated imperviousness into waterways. These practices/structures generally aim to reduce peak flow magnitudes and extend flow duration. For the purposes of NRRSS stormwater management refers to water quantity not quality. Urban sediment, litter and temperature control should be categorized as water quality management. Evaluation parameters that were identified as applicable to this goal include: connectivity; community value; documentation; land use; and permits/regulations. There is an active stormwater database project at www.bmpdatabase.org/. Some example resources available to help achieve this goal are listed in Table 26.

Table 26: Example Resources for Stormwater Management

Document	Reference
Manual of Standards for Erosion & Sediment Control Measures	ABAG, 1995
Hydrograph Modification Management Plan	ACCWP, 2005
Protecting Water Quality in Development Projects – A Guidebook of Post-Construction BMP Examples	ACCWP, 2005b
Start at the Source – Design Guidance Manual for Stormwater Quality	BASMAA, 1999
Storm Water Quality Handbook - Project Planning and Design Guide	Caltrans, 2007c
SWPPP/WPCP Preparation Manual March 2007	Caltrans, 2007d
Urban Stormwater BMP Performance Monitoring	Geosyntec, 2002
Construction Activities Storm Water General Permit Order No. 99-08-DWQ	SWRCB, 2008b

4.22 Livestock Exclusion

This goal was added as part of the California node Post-Project Appraisal phase of the NRRSS effort (Kondolf et al, 2007). This goal pertains to those physical/structural activities that exclude access for livestock to streams/rivers. Evaluation parameters that were identified as applicable to this goal include: connectivity; structures; topography; community value; documentation; land use; and permits/regulations.

4.23 Water Quality Management

The water quality management goal consists of those practices that protect existing water quality or change the chemical composition and/or suspended particulate load. Remediation of acid mine drainage falls into this category as does CSO separation. Excludes urban runoff quantity management (see Stormwater Management). Evaluation parameters that were identified as being applicable to this goal include: connectivity; community value; documentation; land use; and permits/regulations. Some example resources available to help achieve this goal are listed in Table 27.

Table 27: Example Resources for Water Quality Management

Document	Reference
Rapid Bioassessment Protocols for use in Streams and Wadeable Rivers	EPA, 1999
Field Operations Manual for Wadeable Streams	EPA, 2001
Recommendations for Core Water Quality Monitoring Parameters and Other Key Elements of the NPS Vital Signs Program	NPS, 2002
Draft – San Francisco Bay Area Network Freshwater Quality Monitoring Protocol	NPS, 2005
Site Specific Water Quality Objectives	SWRCB, 2003
Standard Operating Procedures for Collecting Benthic Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California	SWRCB, 2007
Review of Watershed Water Quality Models	USACE, 1999c
Spatial Interpolation Techniques for Water Quality Analysis	USACE, 2000o

4.24 Restoration Parameter and Resources Conclusions

In order to achieve reliable river restoration projects it is essential that the problem to be remedied is completely and comprehensively defined; that all applicable requirements and constraints be identified; that project-related uncertainties be acknowledged, estimated, and accounted for; and interactive management approaches (such as adaptive management) be configured and employed to manage those parameters identified as having significant influence on the project and high magnitudes of uncertainty. The most common failure mechanism for river restoration projects is the omission of essential parameters in the development and configuration of the project. It is the intent of the parameters and resources identified in this chapter to aid practitioners to minimize omissions by supplying an outline of parameters to be addressed and resources to successfully address the parameters.

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Chapter Five

5 CASE STUDIES AND VALIDATION

This chapter provides the primary basis by which the developed Restoration Evaluation Checklist (Table 13) will be validated. Validation consists of two methods (Chapter 2): case study evaluations (internal validation) and heuristic reviews by river restoration practitioners (external validation). Implementation of the developed Restoration Evaluation Checklist and incorporation into the Diamond Model was not feasible within the timeframe for this doctoral program, but aspects of the diamond model are highlighted in the Tennessee Hollow Lower Santa Ynez and case studies.

The purpose of the two case studies is to qualitatively confirm the correlation between goal attainment and completion of the identified evaluation parameters in the Restoration Evaluation Checklist as well as presenting a preliminary quantitative evaluation associated with the impacts of uncertainty in river restoration project development. It was not possible for this research effort (due to time constraints and the long development timeframe required to fully develop river restoration projects) to develop a fully documented quantitative evaluation example. As a result, the case studies quantitatively evaluate select goal components originally omitted by the project developers and show how uncertainty aspects can be incorporated into the analyses. A full quantitative evaluation of the estimated reliability of the project (likelihood to achieve successful goal completion) and comprehensive uncertainty analyses are items of future work and are discussed in more detail in Chapter 7.

First, a discussion of the general Restoration Evaluation Checklist validation through case studies (internal validation) and heuristic evaluations (external validation) is presented. Then, the two detailed case studies are presented that provide a more explicit qualitative evaluation of performance correlations with the elements presented in the Restoration Evaluation Checklist. Select goal components, originally omitted by the project developers, are highlighted and examples are developed that show how uncertainty aspects can be incorporated into the projects and the implications on project performance from a life-cycle standpoint.

5.1 Restoration Evaluation Checklist Validation – Case Studies

A total of 41 case studies have been collected by which to evaluate the validity of the Restoration Evaluation Checklist. A detailed discussion of these projects (except the Lower Santa Ynez Bank Stabilization project) is presented in Kondolf et al (*2007*). A brief project summary of these case studies is presented in Appendix E (NRRSS Case Study Backgrounds). It should be noted that the available documentation for these projects for this study may not be complete as only the documents that were made available by the project sponsors, planners, designers, contractors, and monitoring teams were incorporated into this study. As noted in Chapter 6, the river restoration community must make a more concerted effort to capture and archive project documentation in order for any meaningful advances in the state of the practice to be achieved.

For validation purposes, each case study was reviewed and the intended goals (either explicitly stated or implied based on project plans and specifications) were identified. Then, a comparison was made between the parameters completed as part of the project configuration vs. the evaluation parameters identified in the Restoration Evaluation Checklist. Each project was evaluated, based on available monitoring data, if it was achieving its intended goal(s). These evaluations are not suggested to be without bias from influences such as interpretation subjectivity, document availability, and operational time (i.e. exposure time) of the projects following construction. However, as reinforced by Darby and Sear (*2008*)*;* Kimmerer et al (*2005*); Kondolf and Downs (*2004*); Loucks (*2002*); Morgan et al (*1990*); Muste and Stern (*2000*); Niezgoda et al (*2007*); Perry and Gracie (*2004*); Prager and McPhillips (*2006*); Schwar and Bernard (*1998*); Thom et al (*2004*); Wissmar and Bisson, (*2003*) this approach is the standard of practice and the best available technique at this time.

A correlation was developed that compares goal attainment with actual evaluated parameters. This evaluation is presented in Appendix E – NRRSS PPA Case Study Backgrounds. The projects, their identified goals and the percent of goal attainment and percent of addressed Restoration Evaluation Checklist parameters are presented in Table 28. The average percent of identified Restoration Evaluation Checklist parameters addressed was 66% and the average percent goal attainment for all projects was 76%.

Through this validation analysis, I found that there was a strong correlation between goal attainment and projects that completed the identified evaluation parameters in the Restoration Evaluation Checklist. Those projects that did not evaluate the specified evaluation parameters rarely attained their intended goals. Figure 14 shows the scatter of projects plotted with the percent of the Restoration Evaluation Checklist parameters on the x-axis and the percent goal attainment is shown on the y-axis. A diagonal line represents a 1:1 ratio of percent goal attainment equal to percent Restoration Evaluation Checklist parameters addressed. The results indicate that the performance trend is not directly linear, which makes sense since not all parameters have equal influence on goal attainment.

Table 28: NRRSS Project Case Study Evaluation Summary Table

Project	Aesthetics, Recreation, Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofit	Fish Passage	Floodplain Reconnection	Flow Modification	In-Stream Habitat Improvement	In-Stream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Livestock Exclusion	Water Quality Management	**Percent Parameter Conducted**	**Percent Goal Attainment**
Ackerman Creek		X	X		X			X			X		X		22	30
Alameda Creek (Niles)				X	X										79	90
Alameda Creek (Sunol)				X	X										79	90
Alamo Creek (Main)		X	X			X					X				80	95
Alamo Creek East Branch		X	X								X				85	90
Arroyo de la Laguna		X	X												56	70
Arroyo Mocho			X		X			X			X				76	80
Arroyo Viejo Creek	X	X	X					X			X				41	65
Baxter Creek (Booker)	X		X								X			X	41	65
Baxter Creek (Gateway)	X		X								X			X	41	70
Baxter Creek (Pointsett)			X								X				40	80
Bear Creek			X		X	X		X							69	90
Blackberry Creek	X	X	X									X			23	75
Brandy Creek				X											77	95
Carmel (deDampierre)		X													50	50
Carmel (Schulte)		X									X				77	95
Castro Valley Creek	X	X	X								X				50	70
Cerrito Creek	X	X	X								X				50	65
Chorro Flats						X				X					89	95

Table 28: NRRSS Project Case Study Evaluation Summary Table (Cont'd)

Project	Aesthetics, Recreation, Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofit	Fish Passage	Floodplain Reconnection	Flow Modification	In-Stream Habitat Improvement	In-Stream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Livestock Exclusion	Water Quality Management	**Percent Parameter Conducted**	**Percent Goal Attainment**
Clarks Creek						X									62	80
Clear Creek	X			X	X		X	X							85	95
Cold Creek						X					X				62	50
Crocker Creek		X		X	X						X				75	85
Cuneo Creek		X	X												44	0
Green Valley Creek						X					X				83	90
Lower Guadalupe Reach B			X												77	95
Lower Ritchie Creek	X		X		X										53	80
Lower Silver Creek	X	X	X			X		X			X	X			73	80
Martin Canyon Creek		X	X												92	95
Miller Creek	X	X	X			X		X			X	X			95	95
Redwood Creek						X		X			X				100	95
Sausal Creek		X	X					X			X				65	80
Strawberry Creek	X		X												50	65
Tassajara Creek	X	X	X			X		X			X	X			86	95
Tennessee Hollow		X	X					X			X				86	95
Uvas Creek Restoration		X	X												44	0
Village Creek			X					X			X	X			52	60
Wildcat Creek (Alvarado)	X	X			X										42	65

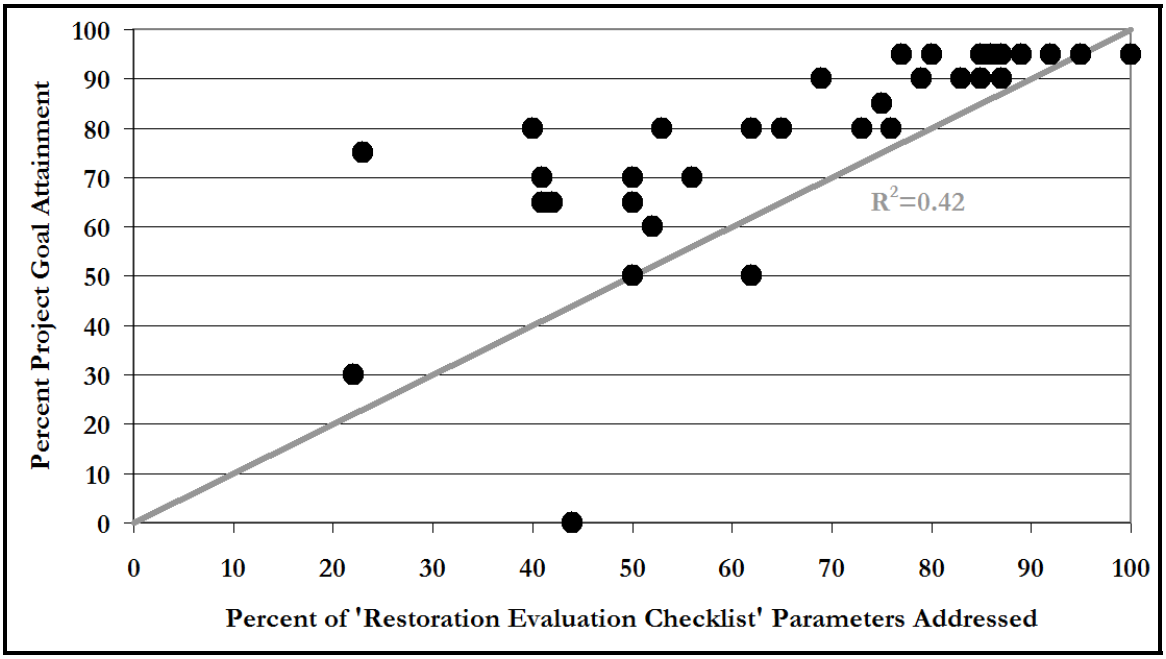


Figure 14: The case study validation evaluation found a strong correlation between goal attainment and percent of the Restoration Evaluation Checklist parameters addressed.

5.2 Heuristic Evaluations

Heuristic evaluation is a systematic inspection of a user interface design for usability and involves having a small set of evaluators examine the interface and judge its compliance with recognized usability principles (*Nielsen, 1993*). Evaluators were asked to review and judge the validity of the developed Restoration Evaluation Checklist. Evaluators were obtained from Federal, State of California, and City governments; from private industry; and from public citizen groups. The evaluators were ensured anonymity, but a summary of their comments and review is presented in Appendix F. All heuristic evaluators confirmed the validity of the developed Restoration Evaluation Checklist and strongly encouraged further refinement of the NRRSS Goal categories (Goal definition was not part of this dissertation effort).

5.3 Tennessee Hollow Daylighting Project

The Tennessee Hollow restoration project is one of many staged projects to achieve the long-term watershed restoration plan outlined by the Presidio Trust. The restoration project was developed as part of a larger watershed plan for the Presidio with specific restoration goals were bank stabilization, channel reconfiguration, in-stream habitat improvement, and riparian vegetation. This case study presents a background on the restoration project, presents a review of the Post Project Appraisal evaluation, and demonstrates the incorporation of reliability and life-cycle considerations into the restoration effort, specifically on in-stream habitat improvement definition, delineation of 'success' criteria, and identification of monitoring factors for an adaptive management approach.

5.3.1 Background

The Tennessee Hollow restoration site is located on the Presidio in the City and County of San Francisco, California (Figure 15). The site is situated northeast of Lincoln Boulevard, southeast of Halleck Street, and northwest of Girard Road. The site drains the hills within the Presidio and discharges to Crissy Field, before finally draining to San Francisco Bay (Figure 16). The drainage area associated with the site is approximately 1 km^2.

In fall 2005, the Presidio Trust restored an approximately 230 meter reach of Tennessee Hollow, a perennial stream draining into the restored Crissy Field wetland. This reach, informally known as Thompson Reach (also referred to as Fill Site 6A), was formerly contained in a culvert buried under a landfill.

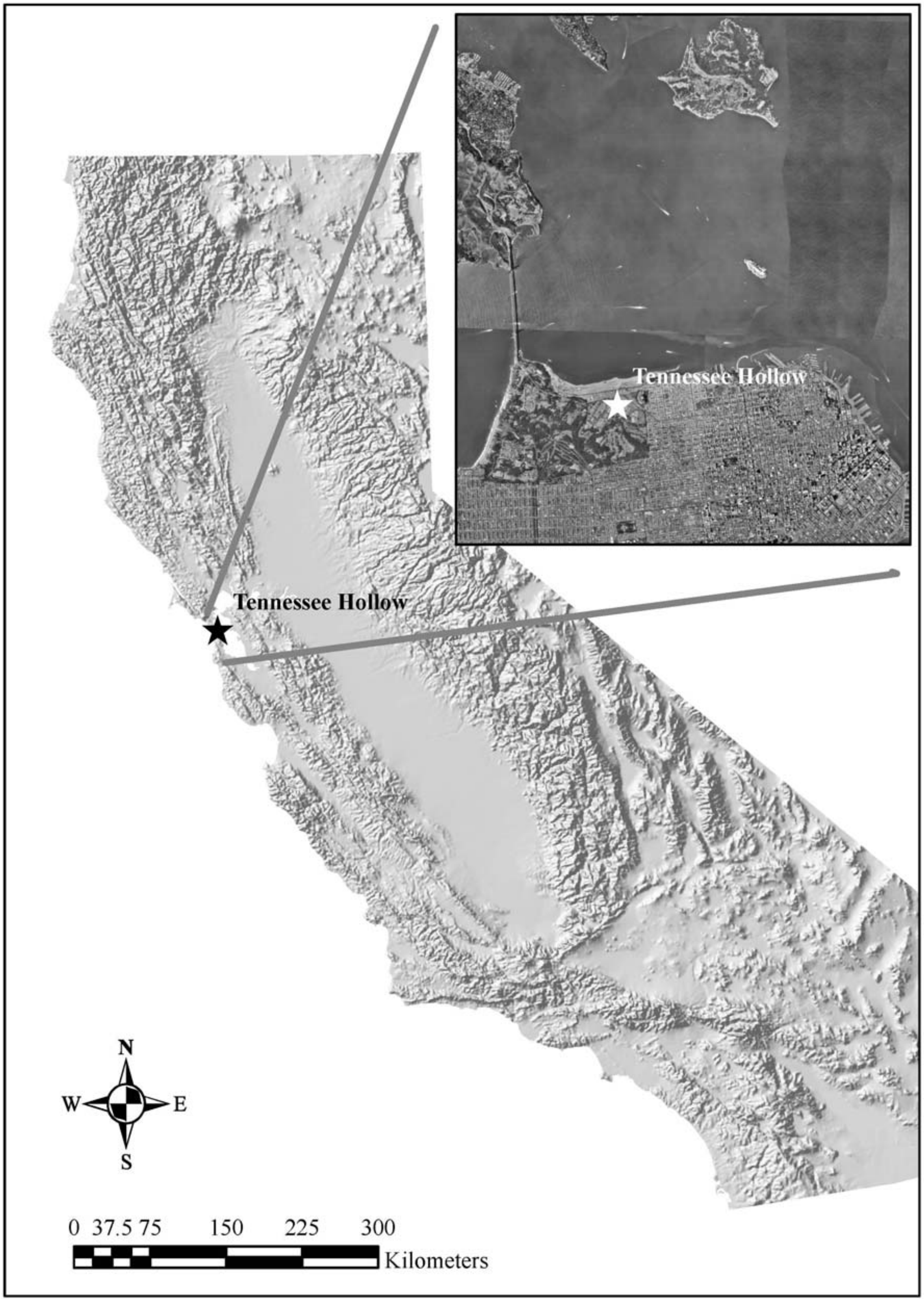


Figure 15: Vicinity map for the Tennessee Hollow restoration project.

Excavation and removal of the historic artificial fill placed in the old creek channel provided an opportunity to restore a surface stream and plan a riparian corridor. The completed creek daylighting effort resulted in excavation of approximately 1.2 hectares, removal of about 25,000 cubic meters of fill contaminated with mercury and PCBs, planting of approximately 0.5 hectares of native vegetation, and construction of a restored creek channel (*Frey, 2004*).

Figure 17 shows a comparison (aerial photograph) of the site from before (left photo) and after (right photo) of the restoration project. The creek was daylighted and the storm drain in which the creek passed was removed. The alignment of the storm drain is shown in Figure 17 (left photo) and runs in a roughly south to north orientation. Future restoration plans will continue the creek daylighting from the downstream terminus of this project all the way to the San Francisco Bay at Crissy Field.

Removal of the contaminated site soils and daylighting of the creek was an excellent opportunity to improve ecological habitat, while minimizing the need to purchase and import soils to fill the void resulting from removal of the contaminated soils. Photographs of contaminated fill removal are shown in Figures 18 through 21. The abandoned culvert that contained the creek prior to the daylighting project is indicated in Figure 17. Photographs of the meander construction and installation of erosion protection and erosion features are shown in Figures 22 through 27. All photographs were courtesy Mark Frey of the Presidio Trust.

Figure 16: Tennessee Hollow is located near Lincoln Blvd and Halleck St and discharges to Crissy Field (Google Earth)

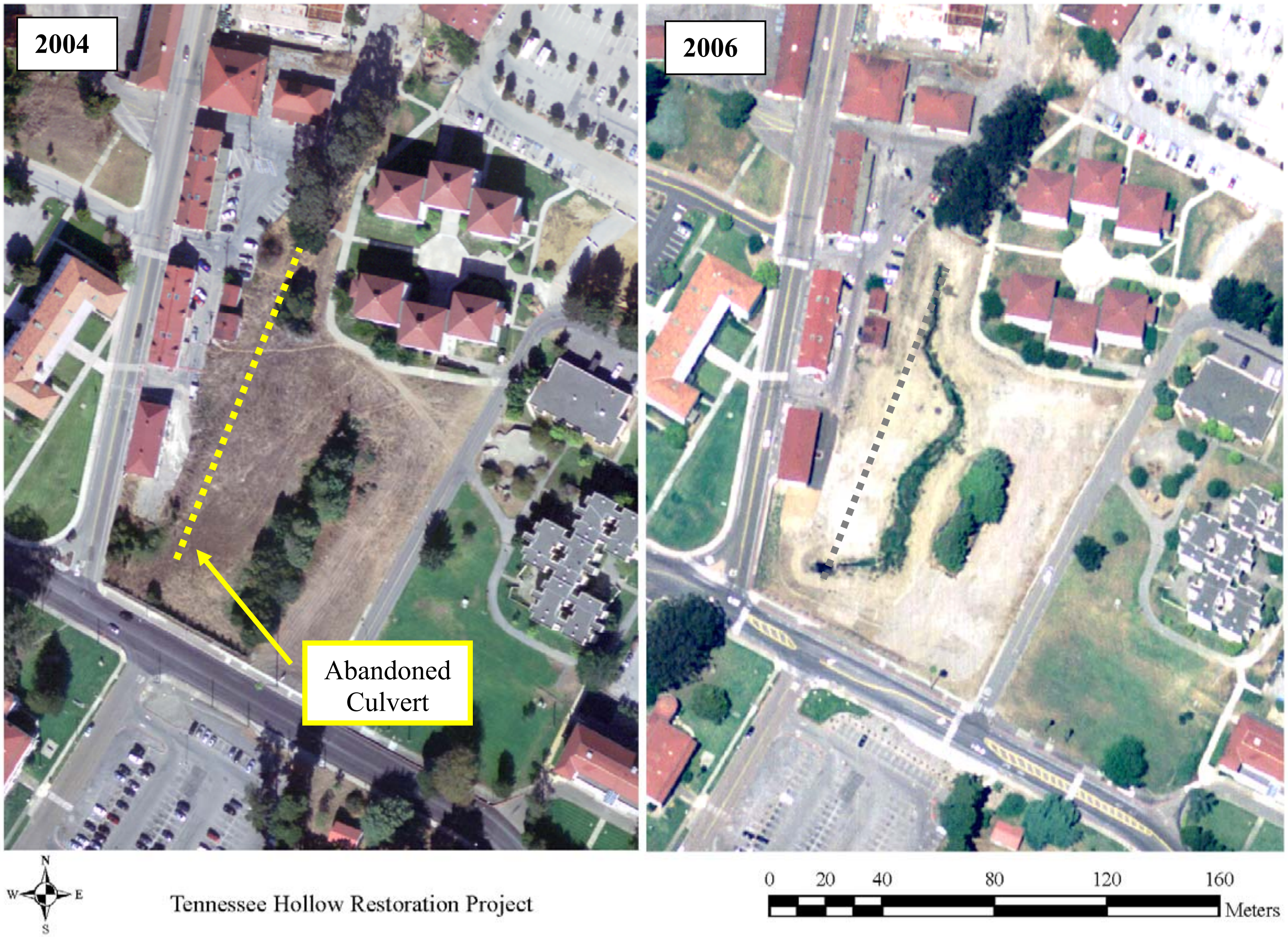


Figure 17: A comparison of pre-project (left) in 2004 and post-project (right) in 2006.

Figure 18: A view looking south, prior to initiation of contaminated soil removal.

Figure 19: Removal of contaminated soil with an excavator (looking south).

Figure 20: The culvert previously containing the Tennessee Hollow creek was removed during site grading. Temporary dewatering operations were required.

Figure 21: Groundwater encountered during excavation of onsite soils.

Figure 22: A northward view of the restoration near the end of earthwork operations shaping the new creek channel.

Figure 23: Installation of boulder and large woody debris features in the new channel.

Figure 24: Installation of woven willow walls for erosion protection at meander bends.

Figure 25: Large woody debris used to aid in bank stabilization.

Figure 26: Completion of earthwork and grading activities. Looking south.

Figure 27: Planting riparian vegetation was the final aspect of construction.

The restoration project was developed as part of a larger watershed plan for the Presidio (*Stone, 2002*). The Tennessee Hollow watershed is the single largest watershed at the Presidio and provided the Presidio Trust (the organization charged with running the Presidio after it's conversion to a National Park) with an opportunity to establish and implement a comprehensive watershed-based habitat restoration effort (*Stone, 2002*). The long-term vision was to restore the watershed and expand habitat so that a continuous wildlife corridor is established, connecting the upper watershed habitat (serpentine grassland and seeps) to the lower watershed (salt water marsh).

The Tennessee Hollow restoration project is one of many staged projects to achieve the long-term watershed restoration plan outlined by the Presidio Trust. For this project, the specific restoration goals were bank stabilization, channel reconfiguration, in-stream habitat improvement, and riparian vegetation (Table 29).

5.3.2 Post Project Appraisal Evaluation

This project had extensive planning and design documentation generated. As previously mentioned, the restoration was part of a larger watershed-based assessment and plan. Baseline surveys were performed relative to the restoration goals. Water quality information and stream discharge characteristics were obtained from within the storm drain culvert prior to restoration implementation. Since the creek was contained in a culvert, physical baseline surveys were not conducted.

Detailed construction documents and photographs exist for the project, detailing construction methods. Detailed as-built surveys were performed and a rigorous effectiveness monitoring program was established (*Storesund et al, 2007*) and a comprehensive baseline generated for all restoration goal elements. Documentation for the project was fairly complete and because one organization (the Presidio Trust) was responsible for all aspects of the restoration development, the documents were centralized and accessible.

Table 29: Restoration Goals for Tennessee Hollow

Goal	Explicit/ Inferred	Reference	Source
Bank Stabilization	Explicit	"Willow wall revetments installed along the outer meander radii that …. stabilize the constructed channel against excessive bank scour and lateral migration prior to establishment of the riparian corridor." (page 16)	Clearwater and MACTEC, 2004
Channel Reconfiguration	Explicit	"A moderately sinuous channel, with sinuosity of 1.4 percent, and a bed slope of 2.2 percent. The design includes a small scale sinuosity that proportionally emulates the channel plan from along the remnant natural reach in the eastern branch channel upstream of Presidio Drive." (page 15)	
In-Stream Habitat Improvement	Explicit	"Log and boulder weir and scour pool assemblages for habitat diversity at two selected locations along the sinuous channel reach and rapid-pool assemblages spaced at an average distance of 60 feet (4 bank full widths) along the lower constricted and less sinuous reach." (page 16)	
Riparian Management	Explicit	"Revegetation of the site using a combination of native and ornamental plants." (page 2)	

In reviewing the identified project goals and available documentation, it was found that 86% of the parameters identified in the Restoration Evaluation Checklist were evaluated, and, based on a PPA evaluation, it was estimated that the project achieved a 95% goal attainment. Table 30 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table 30: Summary of completed evaluation parameters for Tennessee Hollow

Goal/ Objective		Evaluation Parameters															
		Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization		R		R	R	R	R	R	R	R				R		R	R	R
		✓		✗	✓	✗	✓	✓	✓	✓				✓		✓	✓	✓
Channel Reconfiguration		R	R	R	R	R	R	R	R	R				R		R	R	R
		✓	✓	✗	✓	✗	✓	✓	✓	✓				✓		✓	✓	✓
In-Stream Habitat Improvement		R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
		✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Riparian Management		R	R	R	R		R		R	R				R		R	R	
		✓	✓	✗	✓		✓		✓	✓				✓		✓	✓	

Information was completed and available for all components of the Post Project Assessment (PPA), as shown in Table 31. Explicit success criteria were cited and baseline surveys established comparison values for success. The design rationale and input parameters were documented in a design report and available for future validation monitoring analyses and an active monitoring program was implemented to address performance of all restoration goals.

Due to the project having been recently completed (January 2006), not much data has been collected as part of the effectiveness monitoring effort, however, valuable 'lessons learned' are anticipated in the future once more information has been collected.

Table 31: Summary of PPA component evaluations

PPA Component	Available	Collection Method
Success Criteria	Yes	Permit documents.
Baseline Survey(s)	Yes	Some pre-project physical, biological, and water quality baseline data was available for this study.
Design Rationale	Yes	A detailed design rationale and design report was available.
Design Drawing(s)	Yes	Design drawings were available for this study.
As-Built Drawing(s)	Yes	An As-Built topographic map was performed by Chaudrhary & Associates, Inc. A Terrestrial LiDAR scan was also performed by the Menlo Park USGS and UC Berkeley.
Monitoring Program	Yes	Limited post-project monitoring of the completed restoration project has been completed by UC Berkeley and more extensive monitoring is being performed by The Presidio Trust.

The effectiveness monitoring program, detailed in Table 32, included physical (long profile and cross-section surveys, feature mapping (Figure 28), piezometers, water stage), chemical (BMI sampling, conductivity, turbidity, temperature), and biological (BMI sampling, vegetation sampling, bird surveys). Terrestrial LiDAR surveys (Figures 29 through 31) were also conducted. These surveys provide not only physical information, but biological as well. For example, the growth rates of vegetation were mapped using LiDAR. The baseline conditions were mapped with LiDAR immediately following construction (bare earth). Then, subsequent surveys measured the vegetation, allowing for the characterization of vegetation volume. This volume was then translated into survivability and growth rates. The growth rates could be applied to design configurations for other (future) restoration projects. A site plan (Figure 32) shows the specific location of monitoring activities, with surveyed locations clearly documented in the monitoring report (*Storesund et al, 2007*), facilitating repeatable future surveys.

Table 32: Summary of Effectiveness Monitoring Assessments

Project Goal	Evaluation Parameter	Assessment Method
Bank Stabilization	Erosion/Scour	Terrestrial LiDAR, Photo-documentation, Long Profile, Cross Sections
		Terrestrial LiDAR, Photo-documentation, Long Profile, Cross Sections
	Channel Form	Features Map
	Groundwater	Piezometers
	Structures	Features Map
	Sediment Transport	Not Evaluated
	Stream Discharge	Stream Stage
	Riparian Vegetation	Plot Samples
Channel Reconfiguration	Erosion/Scour	Terrestrial LiDAR, Photo-documentation, Long Profile, Cross Sections
		Terrestrial LiDAR, Photo-documentation, Long Profile, Cross Sections
	Channel Form	Features Map
	Groundwater	Piezometers
	Structures	Features Map
	Sediment Transport	Not Evaluated
	Stream Discharge	Stream Stage
	Riparian Vegetation	Plot Samples
In-Stream Habitat Improvement	Channel Form	Terrestrial LiDAR, Photo-documentation, Long Profile, Cross Sections
	Connectivity	Not Evaluated
	Groundwater	Piezometers
	Aquatic Species	BMI Sampling
	Sediment Transport	Not Evaluated
	Water Quality	WQ Instrumentation, BMI Sampling
	Stream Discharge	Stream Stage
	Riparian Vegetation	Plot Samples
Riparian Management	Connectivity	Not Evaluated
	Groundwater	Piezometers
	Riparian Vegetation	Plot Samples
	Terrestrial Species	Area Search Method (birds)

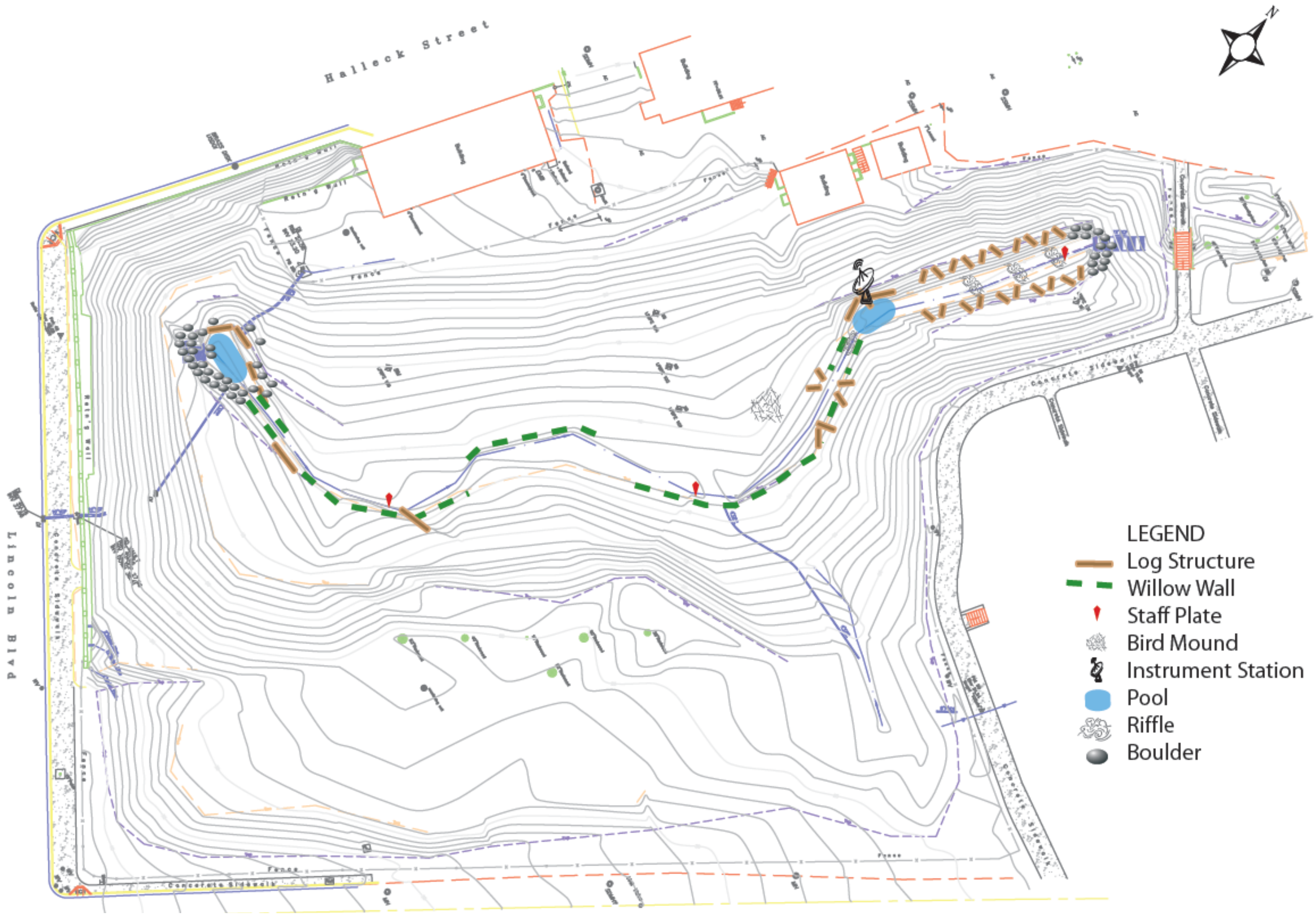


Figure 28: **A features map completed following construction, identifying restoration features (Storesund et al, 2007).**

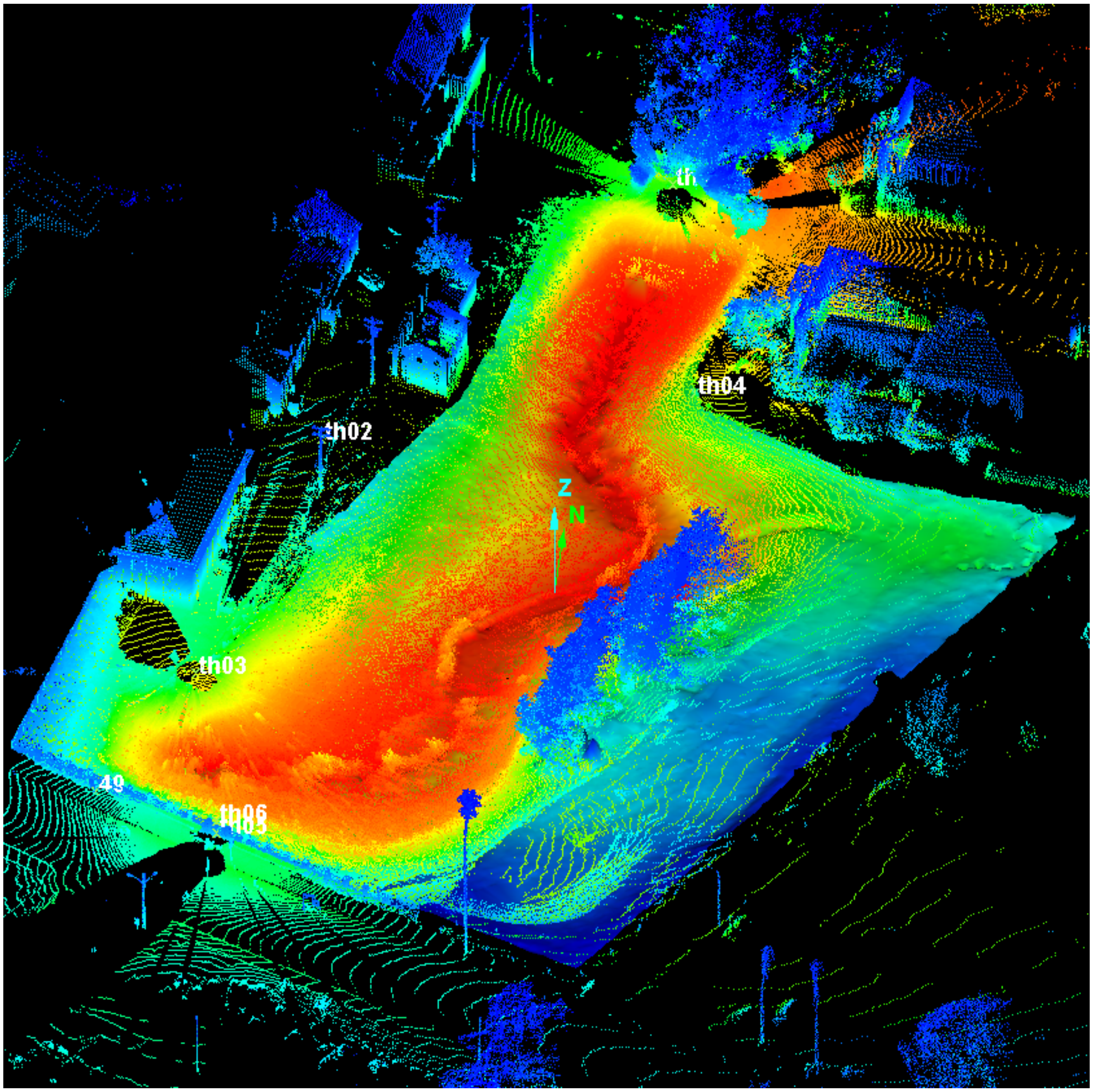


Figure 29: An aerial oblique view of the completed restoration site at Tennessee Hollow, based on a Terrestrial LiDAR survey (Storesund et al, 2007).

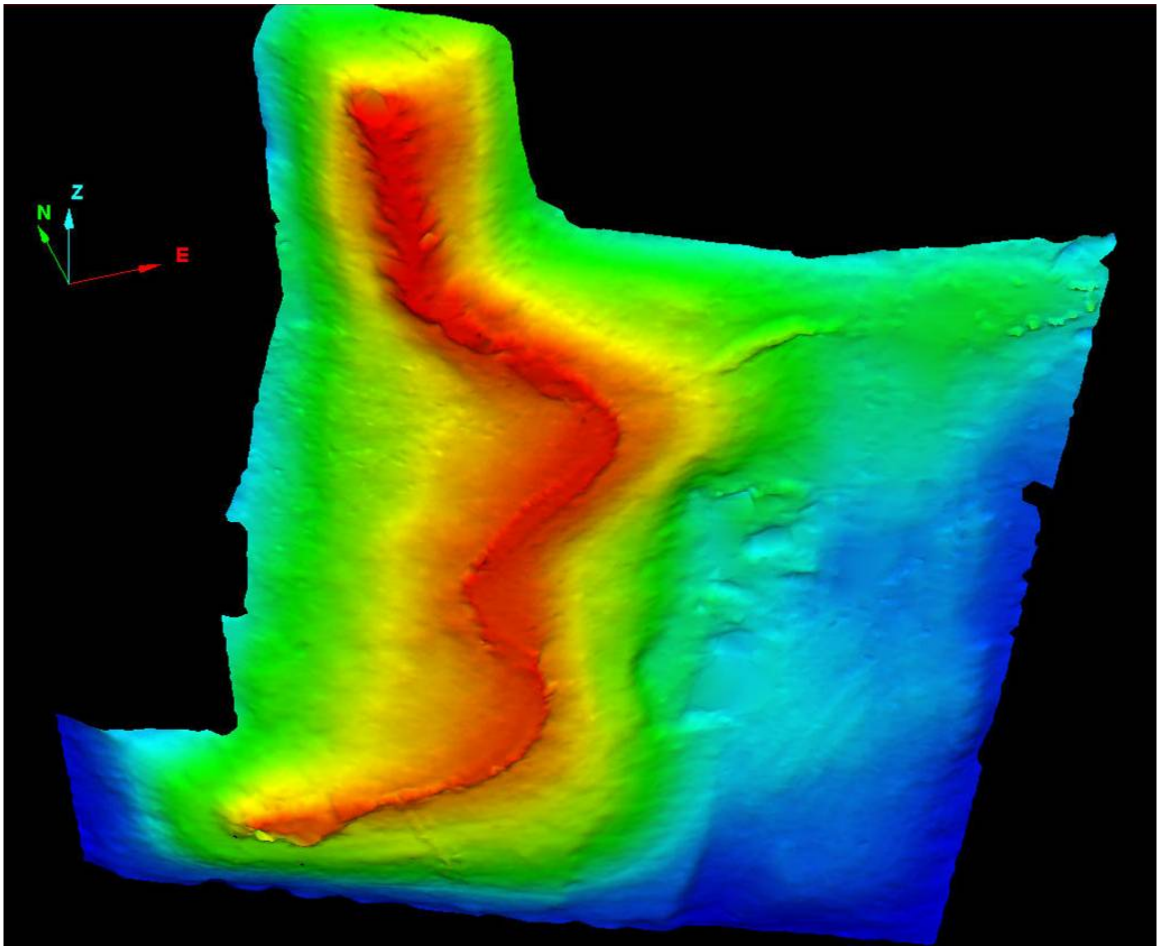


Figure 30: A bare-earth 3D surface generated based on the Terrestrial LiDAR survey (Storesund et al, 2007).

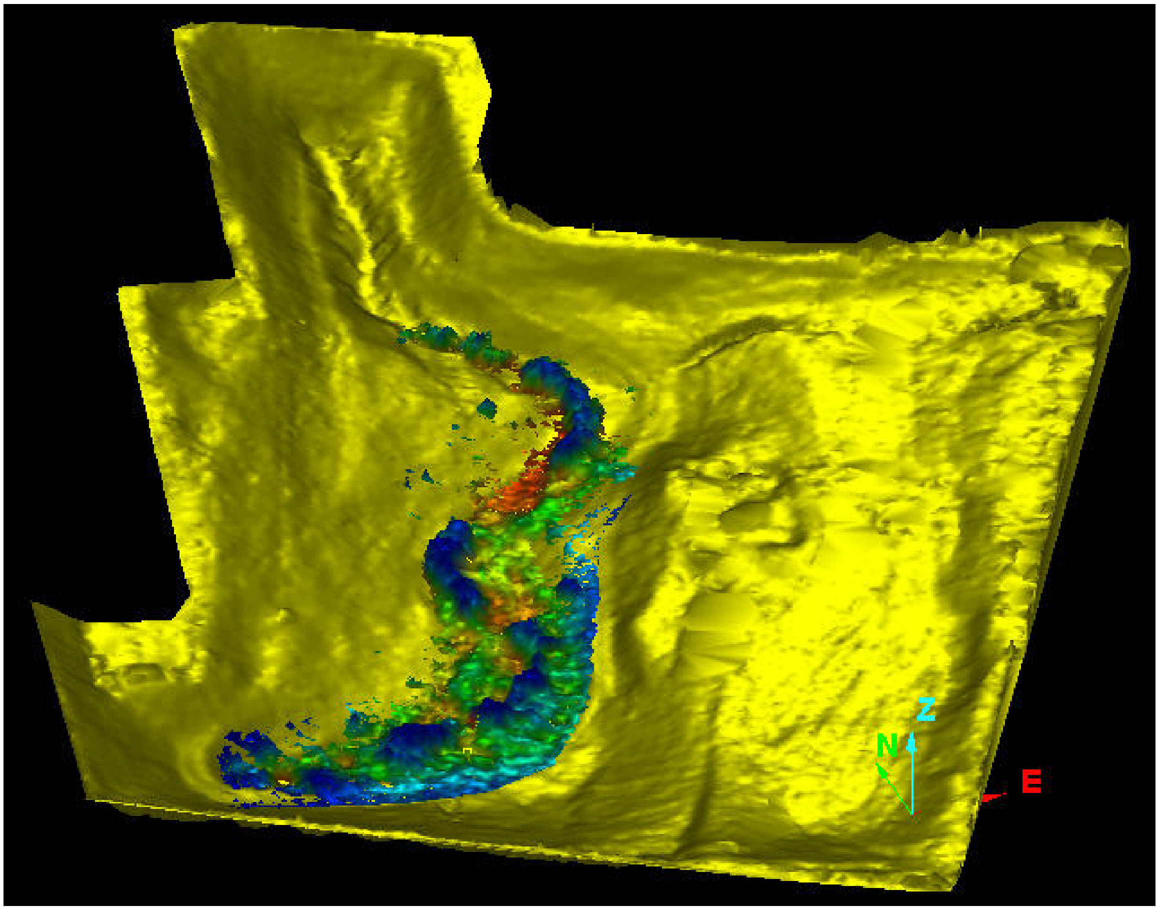


Figure 31: Monitoring of vegetation survivability and growth rates using Terrestrial LiDAR. The color coding relates to vegetation growth elevations (blue high and red low) (Storesund et al, 2007).

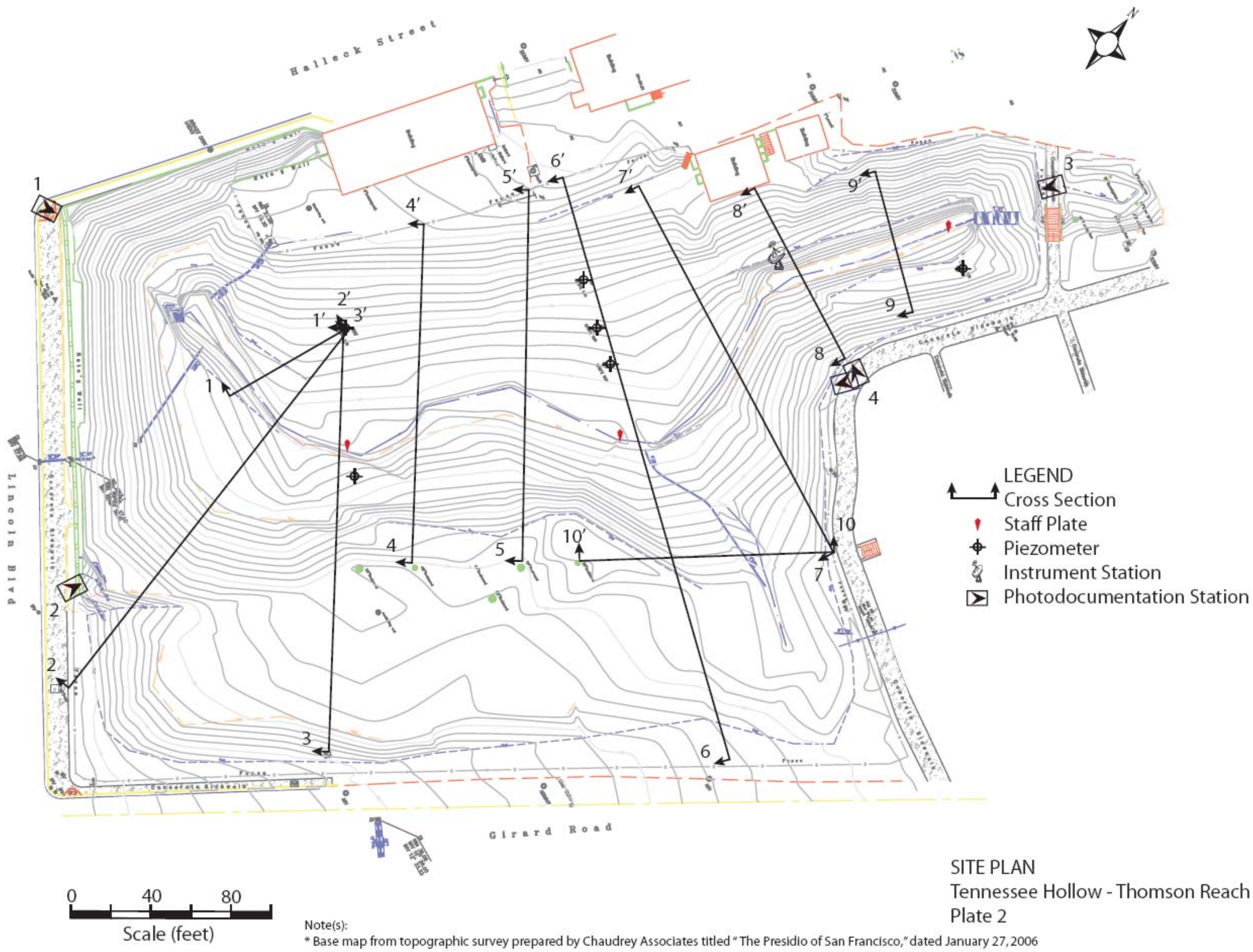


Figure 32: A site plan was generated specifying exact locations of monitoring activities (Storesund et al, 2007).

5.3.3 Incorporation of Reliability and Life-Cycle Considerations

This project addressed a majority of the parameters identified in the Restoration Evaluation Checklist (86%) and to date, goal attainment is high (95%), confirming that the parameters identified in the Restoration Evaluation Checklist yield more reliable restoration projects. Although this project was developed in the context of a watershed-based plan, with pre-project conditions characterized prior to project implementation, and the design rationale documented in design reports, the uncertainty associated with the design parameters was not characterized. Additionally, the ecological development of this project was not taken into consideration over the operational life-cycle phase of the project.

For example, a more rigorous design approach could have been implemented for the in-stream habitat management goal whereby explicit habitat quality parameters were defined for the pre-project conditions and specified post-project intervals, with an estimate for time required to achieve the specific habitat quality goals.

The California Stream Bioassessment Procedure (*CDFG, 1999*) lists specific habitat features and a corresponding mixed (qualitative and quantitative) rating scheme. These parameters are summarized in Table 33. This method does address erosion/scour and sediment transport (in a qualitative fashion), so the addition of this evaluation procedure addresses the omitted evaluation parameters (erosion/scour and sediment transport) for the Tennessee Hollow restoration project identified in Table 30.

The initial habitat parameter value before the daylighting project will be considered zero for all parameters in this example. This example will illustrate that development of suitable in-stream habitat occurs over time, so a life-cycle approach to the problem is critical in order to correctly capture the development of the restoration project over time. In this example, a target habitat score of 16 has been selected for each parameter. Projected habitat parameter values have been estimated for: year 1; year 2; year 3; year 4; year 5; year 10; and year 25. Annual descriptions were selected for the first five years to capture the establishment of habitat features immediately following construction of the restoration project and to provide metrics for utilization in adaptive management. A projection of the lowest, highest, and mean expected parameter scores are summarized along with a narrative providing the basis for the score range assigned in Tables 34 through 40.

Due to the very qualitative nature of this method, adaptive management as an interactive uncertainty management approach is critical. The habitat value projections are based on 'best-guess estimates' (see Chapter 2) and an active adaptive management approach (see Chapter 2) can be implemented that allows for an explicit learning exercise where annual performance projections can be compared with the actual experienced performance. In those cases where there is a large deviation from anticipated performance, the project designers receive an alert and can revisit their methods, information, etc. in order to identify the cause of the performance deviation.

A distribution of the anticipated habitat parameter quality score for each habitat parameter is presented in Table 41. A triangular distribution was used and configured based on the 'best-guess' of the lowest value anticipated, the highest value anticipated, and the expected value (note: it appears that the program @RISK modifies some distribution profiles, as seen in the "Riparian Vegetative Zone" graphical representation of the triangular distribution with a low of 0, an expected of 1, and a high of 2). Through

Monte Carlo simulations, an aggregate habitat quality parameter result for year one is calculated. Figure 33 shows the result of this simulation for year one. Based on the uncertainty associated with each individual habitat quality parameter, the aggregate resulting score is a low of 55, a high of 80, and a mean of 68. The mean score is not equivalent to the Expected value. The mean score is a function of the shape of the resulting statistical distribution. The expected score (as reported in this dissertation) is the anticipated/estimated.

Table 42 presents a summary of the Expected scores (E) and the coefficient of variation (C.O.V). The C.O.V. (defined as the standard deviation divided by the mean) provides a measure of the magnitude of uncertainty. The higher the C.O.V., the higher the amount of uncertainty. Similarly, the lower the C.O.V., the lower the amount of uncertainty. The top three C.O.V. habitat parameters for each year (following completion of construction) are highlighted in Table 42 and are denoted by red lettering. It should be noted that different habitat parameters are the 'high uncertainty' items during the development of the restoration project (i.e. between years 1 and 25).

Identification of these high-uncertainty items allows for proactive strategies to be employed to manage the potential range of habitat parameter performance (such as effectiveness monitoring). More information or testing could occur during the planning and/or design phase, prior to full implementation of the project, to gain a better understanding of the parameter. Alternatively, these high-uncertainty habitat parameters would be the primary candidates for monitoring activities and contingency plans would need to be developed to provide interactive mitigation measures should the actual performance fall below the target performance. In the case of vegetation, for example, it is very common that interactive measures (effectiveness monitoring) such as active irrigation and re-plantings occur during the first five years of the project (which also corresponds to the sensitive vegetation establishment period of vegetation) to ensure successful vegetation establishment.

Table 43 presents a hypothetical summary of pre-project ratings and design target habitat targets for the restoration effort. Since the riparian vegetation and channel form aspects of the restoration are not immediately completed following construction of the project, some time is required for the riparian canopy to become established and for the fluvial geomorphic attributes of the restoration project to stabilize. The projected ratings (by year), following completion of the restoration project area shown in Table 43. These reported ratings are a summation of the expected habitat quality parameters, not a summation of the mean habitat quality parameters. A plot of the habitat quality development is shown in Figure 34.

Table 33: Physical Habitat Quality Survey Form (CDFG, 1999)

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
Epifaunal Substrate/ Available Cover	Greater than70% (50% for low gradient streams) of substrate favorable for epifaunal colonization and fish cover; most favorable is a mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e. logs/snags that are not new fall and not transient).	40-70% (30-50% for low gradient streams) mix of stable habitat; well-suited for colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	40-40% (10-30% for low gradient streams) mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% (10% for low gradient streams) stable habitat; lack of habitat is obvious, substrate unstable or lacking.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Embedded-ness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Velocity/ Depth Regimes	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow).	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Table 33: Cont'd **Table Physical Habitat Quality Survey Form (CDFG, 1999)**

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% (<20% for low-gradient streams) of the bottom affected by sediment deposition.	Some new increases in bar formation, sand or fine sediment; 5-30% (20-50% for low-gradient) of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand, or fine sediment on old and new bars; 30-50% (50-80% for low gradient) of the bottom affected; sediment depositions at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% (80% for low-gradient) of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e. dredging (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Bank shored with gabion or cement; over 80% of the stream reach channelized and disrupted. In stream habitat greatly altered or removed entirely.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
Frequency of Riffles (or bends)	Occurrence of riffles relatively infrequent; ratio of distance between riffles divided by the width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Table 33: Table Physical Habitat Quality Survey Form (CDFG, 1999) Cont'd

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
Bank Stability	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. %-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
Lft Bank	10 9	8 7 6	5 4 3	2 1 0
Rt Bank	10 9	8 7 6	5 4 3	2 1 0
Vegetation Protection	More than 90% of the stream bank surfaces and immediate riparian zones covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the stream bank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the stream bank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the stream bank surfaces covered by vegetation; disruption of stream bank vegetation is very high; vegetation has been removed to 5 cm or less in average stubble height.
Lft Bank	10 9	8 7 6	5 4 3	2 1 0
Rt Bank	10 9	8 7 6	5 4 3	2 1 0
Riparian Vegetative Zone	Width of riparian zone >18 meters; human activities (parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone < 6 meters; little or no riparian vegetation due to human activities.
Lft Bank	10 9	8 7 6	5 4 3	2 1 0
Rt Bank	10 9	8 7 6	5 4 3	2 1 0

Table 34: Year one hypothetical habitat quality parameters

Habitat Parameter	Parameter Rating			Rationale
	Low	Expected	High	
Epifaunal Substrate/ Available Cover	0	2	5	Year one occurs immediately following construction, so minimal establishment of substrate is anticipated. A high degree of substrate movement is expected with the initial stream flows.
Embeddedness	0	2	5	Year one occurs immediately following construction, so a high degree of fines presence is expected. Several high flows are anticipated to flush the construction-related fines from the river channel.
Velocity/Depth Regimes	8	11	15	Since the bankfull channel is newly constructed, it is not anticipated that all four velocity regimes are fully established. It is anticipated that 2 to 4 velocity regimes are initially established.
Sediment Deposition	0	0	5	Heavy deposits of fine sediments are anticipated due to the recent construction activities. Riparian vegetation has not established to help minimize sediment deposition into the active channel.
Channel Flow Status	8	10	15	The highly urbanized condition of the watershed, presence of storm drains, and size of the watershed is anticipated to establish a condition whereby about 25% of the channel substrate is exposed on a daily basis.
Channel Alteration	13	16	18	The restored section of the creek may be considered to be absent of channelization, however, the inlet and outlet are channelized and there are stabilization features installed throughout the stream alignment that prevents 'natural' channel erosion and/or migration.
Frequency of Riffles/Bends	6	8	10	After the initial construction, it is anticipated that there will be occasional riffles and some bottom contour habitat may exist.
Bank Stability	12	14	16	Due to the recent planting of riparian vegetation, it is anticipated that small areas of erosion will occur. These areas are anticipated to be reduced in the future as the vegetation becomes established.
Vegetation Protection	0	0	2	Streambank surfaces are anticipated to be mostly bare during the first season as the vegetation has not had a chance to become established.
Riparian Vegetative Zone	0	0	2	The riparian vegetative zone has just been planted and no significant establishment is anticipated in the first year.

Table 35: Year two hypothetical habitat quality parameters

Habitat Parameter	Parameter Rating			Rationale
	Low	Expected	High	
Epifaunal Substrate/ Available Cover	2	6	12	A high degree of substrate movement is expected to have occurred and establishment of an 'equilibrium' sediment load is anticipated.
Embeddedness	2	6	12	High flows are anticipated to flush the construction-related fines from the river channel and establishment of the substrate gravels and cobble particles.
Velocity/Depth Regimes	8	11	15	Since the bankfull channel is newly constructed, it is not anticipated that all four velocity regimes are fully established. It is anticipated that 2 to 4 velocity regimes are initially established.
Sediment Deposition	6	8	10	Moderate deposits of fine sediments are anticipated due to the recent construction activities. Riparian vegetation has not established to help minimize sediment deposition into the active channel.
Channel Flow Status	8	10	15	The highly urbanized condition of the watershed, presence of storm drains, and size of the watershed is anticipated to establish a condition whereby about 25% of the channel substrate is exposed on a daily basis.
Channel Alteration	13	16	18	The restored section of the creek may be considered to be absent of channelization, however, the inlet and outlet are channelized and there are stabilization features installed throughout the stream alignment that prevents 'natural' channel erosion and/or migration.
Frequency of Riffles/Bends	11	14	16	Additional riffle establishment and increased bottom contour habitat is anticipated after the initial construction in year one.
Bank Stability	12	15	17	Due to the recent planting of riparian vegetation, it is anticipated that small areas of erosion will occur. These areas are anticipated to be reduced in the future as the vegetation becomes established.
Vegetation Protection	0	2	6	Streambank surfaces are anticipated to become more established following the first season.
Riparian Vegetative Zone	0	4	6	The riparian vegetative zone has just been planted and no significant establishment is anticipated in the first year.

Table 36: Year three hypothetical habitat quality parameters

Habitat Parameter	Parameter Rating			Rationale
	Low	Expected	High	
Epifaunal Substrate/ Available Cover	6	10	15	A high degree of substrate movement is expected to have occurred and establishment of an 'equilibrium' sediment load is anticipated. BMI testing should indicate suitable habitat.
Embeddedness	8	10	15	High flows are anticipated to flush the construction-related fines from the river channel and establishment of the substrate gravels and cobble particles.
Velocity/Depth Regimes	11	14	18	It is anticipated that all four velocity regimes start to become established.
Sediment Deposition	10	16	18	Minimal deposits of sediments are anticipated to occur within the restoration area. Riparian vegetation becomes more established to help minimize sediment deposition into the active channel.
Channel Flow Status	8	10	15	The highly urbanized condition of the watershed, presence of storm drains, and size of the watershed is anticipated to establish a condition whereby about 25% of the channel substrate is exposed on a daily basis.
Channel Alteration	13	16	18	The restored section of the creek may be considered to be absent of channelization, however, the inlet and outlet are channelized and there are stabilization features installed throughout the stream alignment that prevents 'natural' channel erosion and/or migration.
Frequency of Riffles/Bends	11	16	18	Additional riffle establishment and increased bottom contour habitat is anticipated to become mature.
Bank Stability	12	16	17	Vegetation becomes more established, minimizing active sediment runoff, bank instability, and deposition in the stream channel.
Vegetation Protection	4	8	12	Streambank surfaces are anticipated to become more established, with 50-70% of the stream bank surfaces covered with vegetation.
Riparian Vegetative Zone	4	10	12	The riparian vegetative zone becomes more established with an anticipated width of 6-12 meters.

Table 37: Year four hypothetical habitat quality parameters

Habitat Parameter	Parameter Rating			Rationale
	Low	Expected	High	
Epifaunal Substrate/ Available Cover	10	14	18	A high degree of substrate movement is expected to have occurred and establishment of an 'equilibrium' sediment load is anticipated. BMI testing should indicate suitable habitat. Habitat features more established.
Embeddedness	11	14	17	High flows are anticipated to flush the construction-related fines from the river channel and establishment of the substrate gravels and cobble particles. Substrate is anticipated to become established.
Velocity/Depth Regimes	11	15	18	It is anticipated that all four velocity regimes become established.
Sediment Deposition	10	16	18	Minimal deposits of sediments are anticipated to occur within the restoration area. Riparian vegetation becomes more established to help minimize sediment deposition into the active channel.
Channel Flow Status	8	10	15	The highly urbanized condition of the watershed, presence of storm drains, and size of the watershed is anticipated to establish a condition whereby about 25% of the channel substrate is exposed on a daily basis.
Channel Alteration	13	16	18	The restored section of the creek may be considered to be absent of channelization, however, the inlet and outlet are channelized and there are stabilization features installed throughout the stream alignment that prevents 'natural' channel erosion and/or migration.
Frequency of Riffles/Bends	11	16	18	Additional riffle establishment and increased bottom contour habitat is anticipated to become mature.
Bank Stability	12	18	19	Vegetation becomes more established, minimizing active sediment runoff, bank instability, and deposition in the stream channel.
Vegetation Protection	4	18	19	Streambank surfaces are anticipated to become more established, with >70% of the stream bank surfaces covered with vegetation.
Riparian Vegetative Zone	4	16	16	The riparian vegetative zone becomes more established with an anticipated width of 6-12 meters.

Table 38: Year five hypothetical habitat quality parameters

Habitat Parameter	Parameter Rating			Rationale
	Low	Expected	High	
Epifaunal Substrate/ Available Cover	10	16	18	A high degree of substrate movement is expected to have occurred and establishment of an 'equilibrium' sediment load is anticipated. BMI testing should indicate suitable habitat. Habitat features more established.
Embeddedness	11	16	17	High flows are anticipated to flush the construction-related fines from the river channel and establishment of the substrate gravels and cobble particles. Substrate is anticipated to become established.
Velocity/Depth Regimes	11	16	18	It is anticipated that all four velocity regimes become established.
Sediment Deposition	10	16	18	Minimal deposits of sediments are anticipated to occur within the restoration area. Riparian vegetation becomes more established to help minimize sediment deposition into the active channel.
Channel Flow Status	8	10	15	The highly urbanized condition of the watershed, presence of storm drains, and size of the watershed is anticipated to establish a condition whereby about 25% of the channel substrate is exposed on a daily basis.
Channel Alteration	13	16	18	The restored section of the creek may be considered to be absent of channelization, however, the inlet and outlet are channelized and there are stabilization features installed throughout the stream alignment that prevents 'natural' channel erosion and/or migration.
Frequency of Riffles/Bends	11	16	18	Additional riffle establishment and increased bottom contour habitat is anticipated to become mature.
Bank Stability	12	18	19	Vegetation becomes more established, minimizing active sediment runoff, bank instability, and deposition in the stream channel.
Vegetation Protection	4	18	19	Streambank surfaces are anticipated to become more established, with >70% of the stream bank surfaces covered with vegetation.
Riparian Vegetative Zone	4	16	16	The riparian vegetative zone becomes more established with an anticipated width of 6-12 meters.

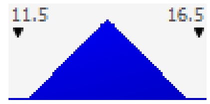
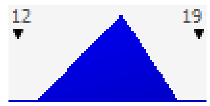
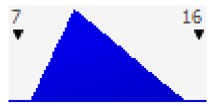
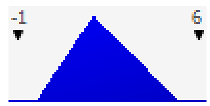
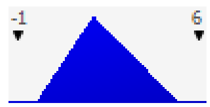
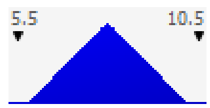
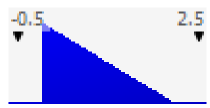
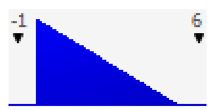
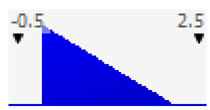
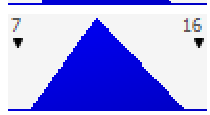
Table 39: Year ten hypothetical habitat quality parameters

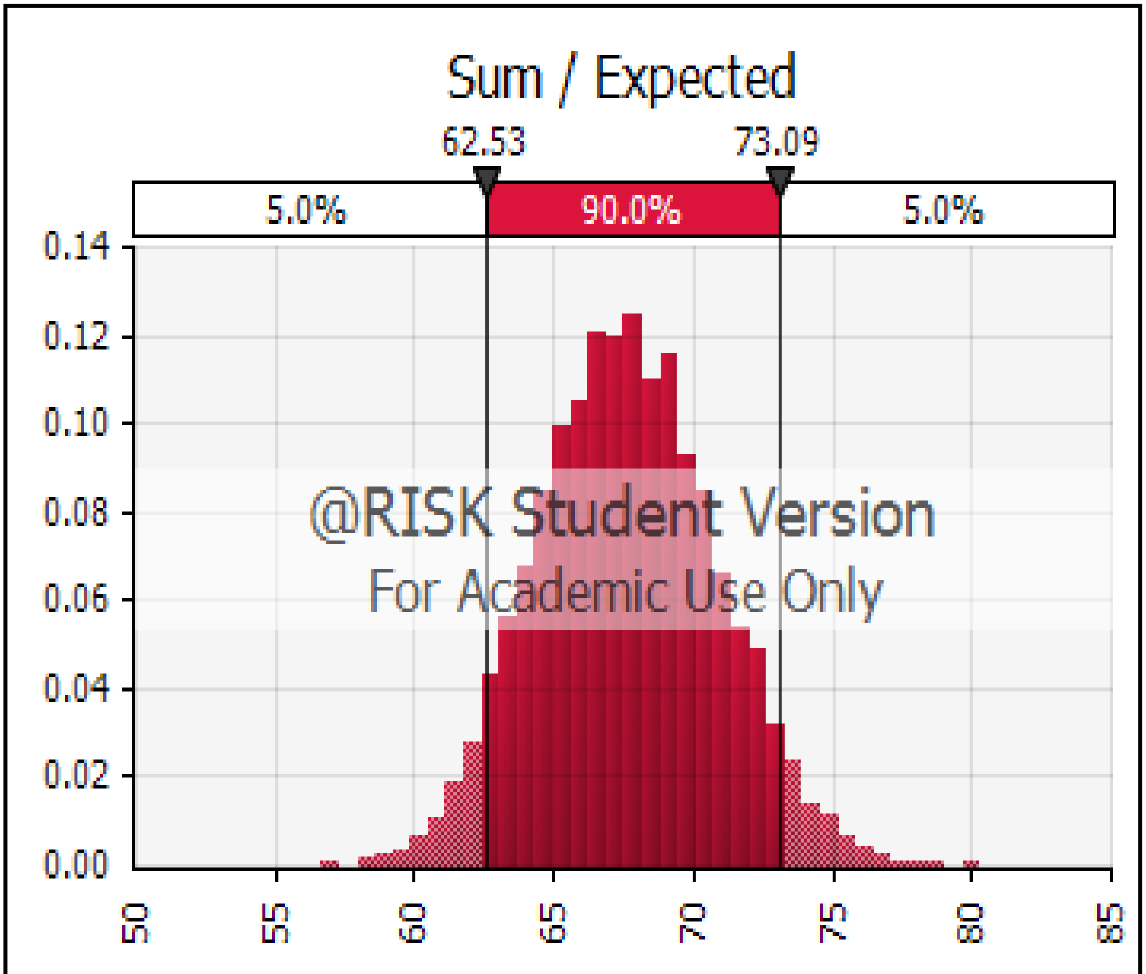
Habitat Parameter	Parameter Rating			Rationale
	Low	Expected	High	
Epifaunal Substrate/ Available Cover	10	16	18	A high degree of substrate movement is expected to have occurred and establishment of an 'equilibrium' sediment load is anticipated. BMI testing should indicate suitable habitat. Habitat features are established.
Embeddedness	11	16	17	Substrate is anticipated to be established.
Velocity/Depth Regimes	11	16	18	It is anticipated that all four velocity regimes are established.
Sediment Deposition	10	16	18	Minimal deposits of sediments are anticipated to occur within the restoration area. Riparian vegetation becomes established, minimizing sediment deposition into the active channel.
Channel Flow Status	8	10	15	The highly urbanized condition of the watershed, presence of storm drains, and size of the watershed is anticipated to establish a condition whereby about 25% of the channel substrate is exposed on a daily basis.
Channel Alteration	13	16	18	The restored section of the creek may be considered to be absent of channelization, however, the inlet and outlet are channelized and there are stabilization features installed throughout the stream alignment that prevents 'natural' channel erosion and/or
Frequency of Riffles/Bends	11	16	18	Additional riffle establishment and increased bottom contour habitat is anticipated to be mature.
Bank Stability	12	18	19	Vegetation is established, minimizing active sediment runoff, bank instability, and deposition in the stream channel.
Vegetation Protection	4	18	19	Streambank surfaces are established, with >70% of the stream bank surfaces covered with vegetation.
Riparian Vegetative Zone	4	16	16	The riparian vegetative zone becomes established with an anticipated width of 6-12 meters.

Table 40: Year 25 hypothetical habitat quality parameters

Habitat Parameter	Parameter Rating			Rationale
	Low	Expected	High	
Epifaunal Substrate/ Available Cover	10	16	18	A high degree of substrate movement is expected to have occurred and establishment of an 'equilibrium' sediment load is anticipated. BMI testing should indicate suitable habitat. Habitat features are established.
Embeddedness	11	16	17	Substrate is anticipated to be established.
Velocity/Depth Regimes	11	16	18	It is anticipated that all four velocity regimes are established.
Sediment Deposition	10	16	18	Minimal deposits of sediments are anticipated to occur within the restoration area. Riparian vegetation becomes established, minimizing sediment deposition into the active channel.
Channel Flow Status	8	10	15	The highly urbanized condition of the watershed, presence of storm drains, and size of the watershed is anticipated to establish a condition whereby about 25% of the channel substrate is exposed on a daily basis.
Channel Alteration	13	16	18	The restored section of the creek may be considered to be absent of channelization, however, the inlet and outlet are channelized and there are stabilization features installed throughout the stream alignment that prevents 'natural' channel erosion and/or
Frequency of Riffles/Bends	11	16	18	Additional riffle establishment and increased bottom contour habitat is anticipated to be mature.
Bank Stability	12	18	19	Vegetation is established, minimizing active sediment runoff, bank instability, and deposition in the stream channel.
Vegetation Protection	4	18	19	Streambank surfaces are established, with >70% of the stream bank surfaces covered with vegetation.
Riparian Vegetative Zone	4	16	16	The riparian vegetative zone becomes established with an anticipated width of 6-12 meters.

Table 41: Example habitat parameter uncertainty for year one

Name	Graph	Min	Mean	Max
Bank Stability		12	14	16
Channel Alteration		13	16	18
Channel Flow Status		8	11	15
Embeddedness		0	2	5
Epifaunal Substrate/ Available Cover		0	2	5
Frequency of Riffles/Bends		6	8	10
Riparian Vegetative Zone		0	1	2
Sediment Deposition		0	2	5
Vegetation Protection		0	1	2
Velocity/Depth Regimes		8	11	15



Summary Statistics for Sum / Expected			
Statistics		**Percentile**	
Minimum	54.8	**5%**	62.5
Maximum	80.3	**10%**	63.6
Mean	67.7	**15%**	64.3
Std Dev	3.2	**20%**	64.9

Figure 33: Example 'statistics' of the anticipated year 1 habitat quality.

Table 42: Uncertainty elements associated with in-stream habitat quality development

	Year 1		*Year 2*		*Year 3*		*Year 4*		*Year 5*		*Year 10*		*Year 25*	
Habitat Parameter	E	*C.O.V*	E	*C.O.V*	E	*C.O.V*	E	*C.O.V*	E	*C.O.V*	E	*C.O.V*	E	*C.O.V*
Epifaunal Substrate/Available Cover	2	*44%*	6	***31%***	10	***18%***	14	*12%*	16	*12%*	16	*12%*	16	*12%*
Embeddedness	2	*44%*	6	***31%***	10	*13%*	14	*9%*	16	*9%*	16	*9%*	16	*9%*
Velocity/Depth Regimes	11	*13%*	11	*13%*	14	*10%*	15	*10%*	16	*10%*	16	*10%*	16	*10%*
Sediment Deposition	0	***71%***	8	*10%*	16	*12%*	16	*12%*	16	*12%*	16	*12%*	16	*12%*
Channel Flow Status	10	*13%*	10	*13%*	10	*13%*	10	***13%***	10	***13%***	10	***13%***	10	***13%***
Channel Alteration	16	*7%*	16	*7%*	16	*7%*	16	*7%*	16	*7%*	16	*7%*	16	*7%*
Frequency of Riffles/Bends	8	*10%*	14	*8%*	16	*10%*	16	*10%*	16	*10%*	16	*10%*	16	*10%*
Bank Stability	14	*6%*	15	*7%*	16	*7%*	18	*9%*	18	*9%*	18	*9%*	18	*9%*
Vegetation Protection	0	***71%***	2	***47%***	8	***20%***	18	***25%***	18	***25%***	18	***25%***	18	***25%***
Riparian Vegetative Zone	0	***71%***	4	***37%***	10	***20%***	16	***24%***	16	***24%***	16	***24%***	16	***24%***

Table 43: Hypothetical development of habitat quality parameters

Habitat Parameter	Pre-Project	**Target**	*Projections* Year 1	*Year 2*	*Year 3*	*Year 4*	*Year 5*	*Year 10*	*Year 25*
Epifaunal Substrate/Available Cover	0	**16**	*2*	*6*	*10*	*14*	*16*	*16*	*16*
Embeddedness	0	**16**	*2*	*6*	*10*	*14*	*16*	*16*	*16*
Velocity/Depth Regimes	0	**16**	*11*	*11*	*14*	*15*	*16*	*16*	*16*
Sediment Deposition	0	**16**	*0*	*8*	*16*	*16*	*16*	*16*	*16*
Channel Flow Status	0	**16**	*10*	*10*	*10*	*10*	*10*	*10*	*10*
Channel Alteration	0	**16**	*16*	*16*	*16*	*16*	*16*	*16*	*16*
Frequency of Riffles/Bends	0	**16**	*8*	*14*	*16*	*16*	*16*	*16*	*16*
Bank Stability	0	**18**	*14*	*15*	*16*	*18*	*18*	*18*	*18*
Vegetation Protection	0	**18**	*0*	*2*	*8*	*18*	*18*	*18*	*18*
Riparian Vegetative Zone	0	**18**	*0*	*4*	*10*	*16*	*16*	*16*	*16*
TOTALS	0	166	*63*	*92*	*126*	*153*	*158*	*158*	*158*

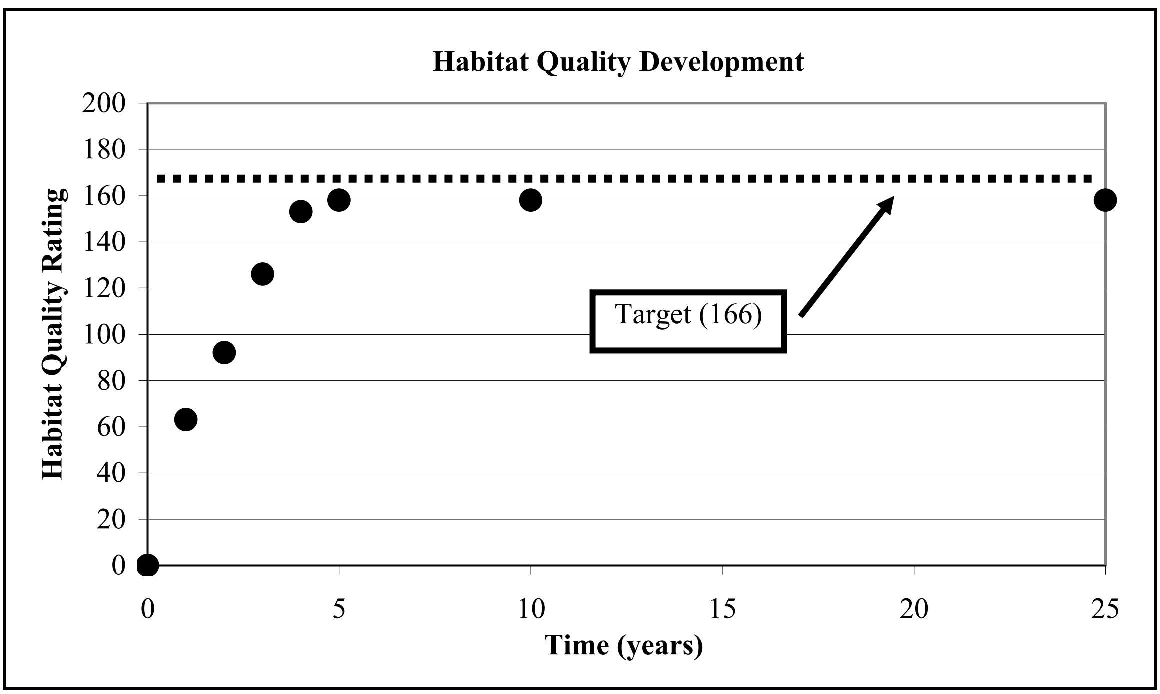


Figure 34: Progressive increase in habitat quality as restoration project establishes itself. Effectiveness monitoring confirms the estimated progression.

This example embraces both the reliability and life-cycle aspects of river restoration in that explicit targets have been defined for a comprehensive listing of influencing parameters and the development of these parameters occur over time (during the operational life-cycle phase) of the restoration project. The habitat goals are not achieved immediately upon completion of construction.

Effectiveness monitoring would ensure that the estimated development targets are achieved. If there were significant deviations from the anticipated habitat quality development, adaptive management techniques could be applied to mitigate the undesirable development trend and a validation evaluation of the assumptions and methods employed to configure the restoration project should be conducted to identify the reason for undesired performance. Lessons learned as part of this process should be included into the state of the practice so that future efforts can benefit from this river restoration Technology lesson.

5.4 Lower Santa Ynez Bank Stabilization Project

The lower Santa Ynez Bank Stabilization project at Rancho La Vina was an effort to stabilize approximately 500 meters of river bank to reduce sediment input to the river by a combination of grading, planting, and stabilization structures (*Land Trust, 2005*). The goal for the restoration project was bank stabilization. This case study presents a background on the restoration project, presents a review of the Post Project Appraisal evaluation, and demonstrates the incorporation of reliability and life-cycle considerations into the restoration effort, specifically on erosion and scour aspects associated with the bank stabilization goal.

5.4.1 Background

The Rancho La Vina Vineyard is located 16 km downstream of Buellton, CA (Figure 35) on the main stem of the Santa Ynez River. In the last 5-10 years the river has eroded 3 hectares of the 8 hectare agricultural field (Figure 36, 37) causing approximately 257,000 cubic meters of sediment to be washed into the river along with a 6-meter wide mature riparian buffer zone (*Land Trust, 2005*). The project construction grant application cites that "due to the Bradbury Dam releases, the river has periodic prolonged high flows that saturate banks causing the unconsolidated soils to fail" (*Land Trust, 2005*). The bank erosion resulted in near vertical banks along the southeast boundary of the restoration area (used as an agricultural field).

The restoration project consisted of grading the 9-meter tall vertical banks back to a 2:1 (horizontal:vertical) slope in the upper 6 meters of bank. A 3.7-meter wide planted relief terrace would be constructed at the base of the 2:1 slope, then a 3:1 slope would be constructed from the edge of the terrace to the active stream channel (Figure 38).

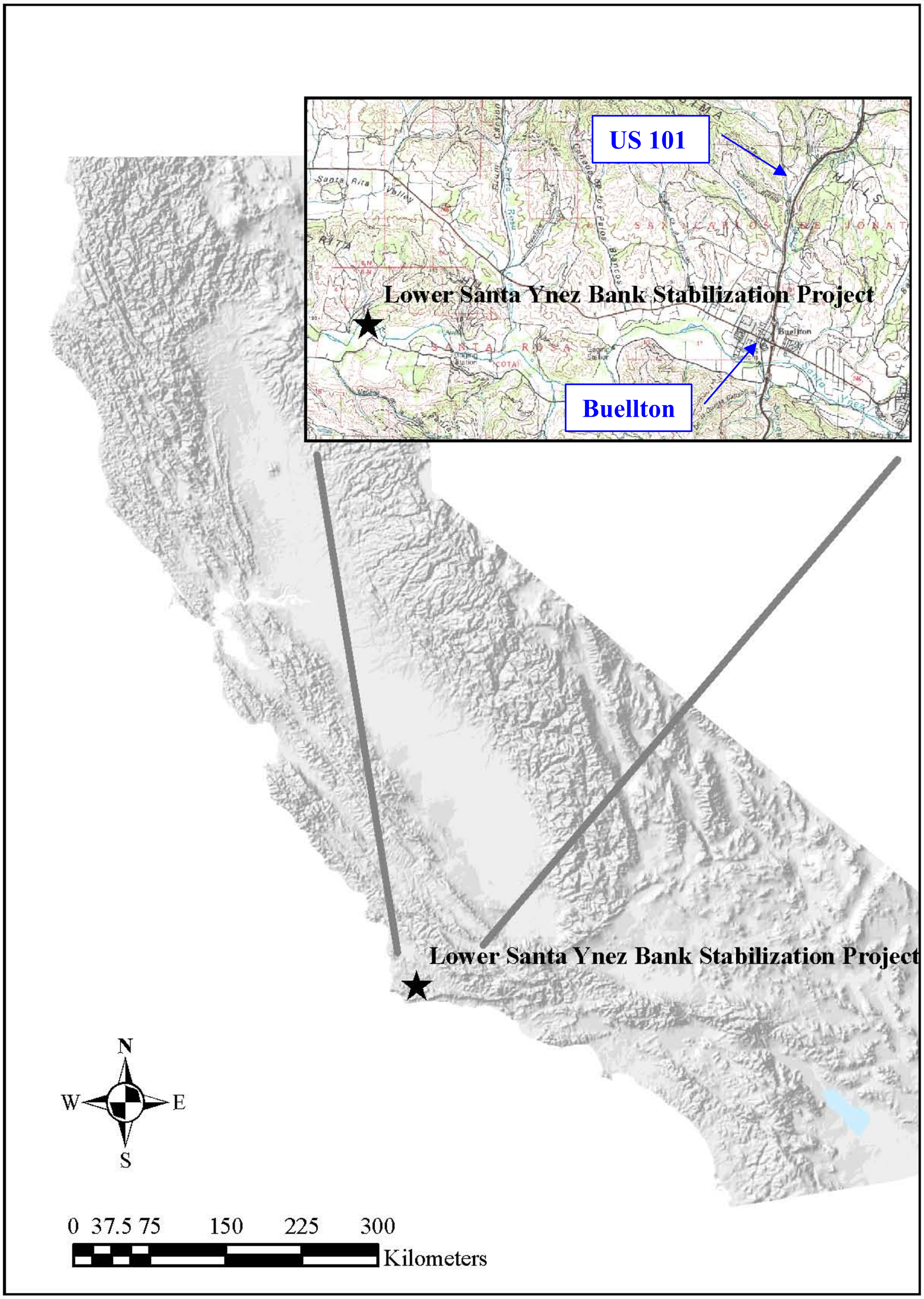


Figure 35: Vicinity map for the Lower Santa Ynez Bank Stabilization project.

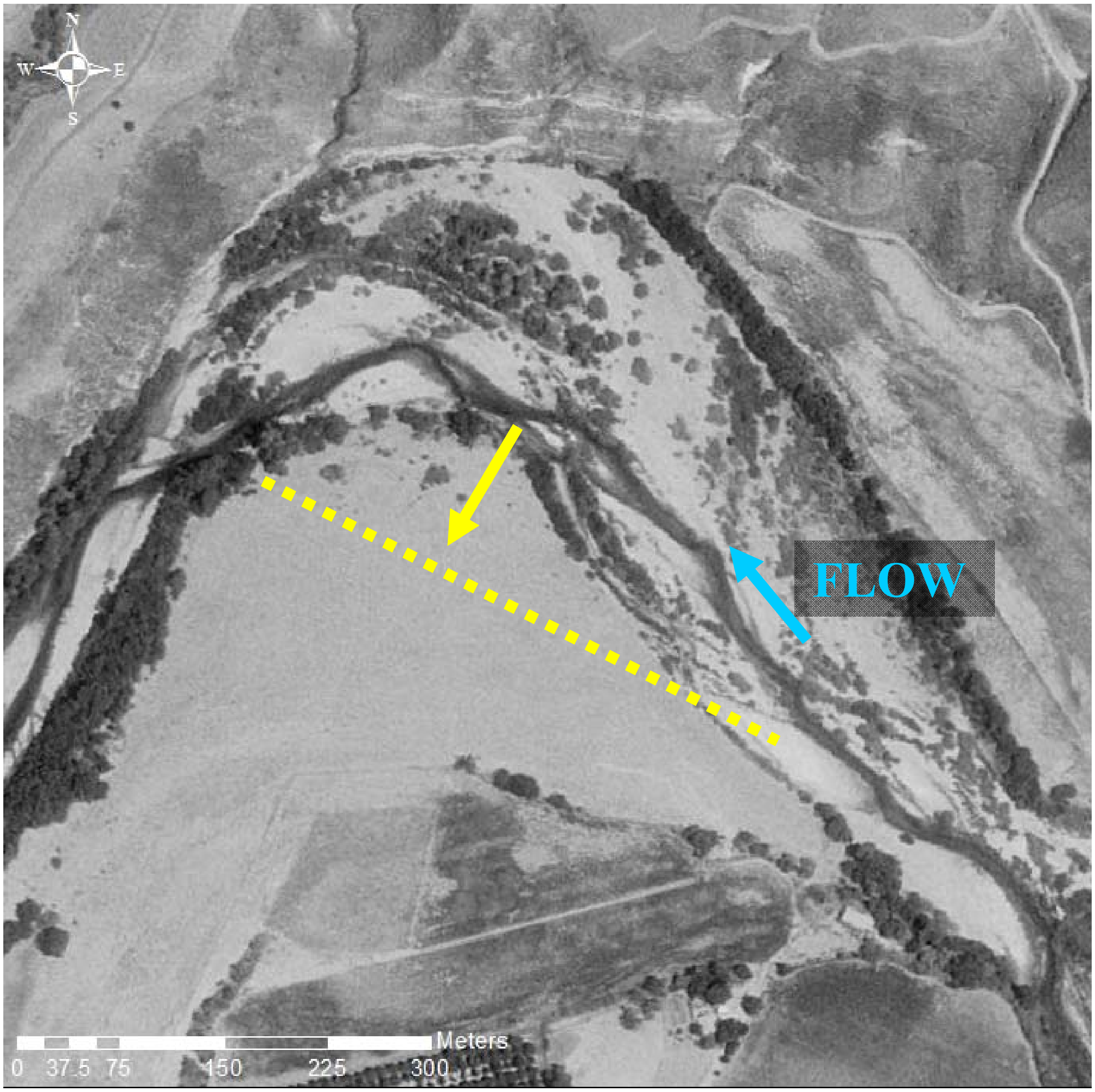


Figure 36: Since 1994 (date of photo) approximately 90 meters of agricultural land has been 'lost' to the river.

Figure 37: Location of right bank (looking upstream) prior to implementation of the restoration project in 2006 (Google Earth). Red line is at the same location as the yellow line in Figure 32.

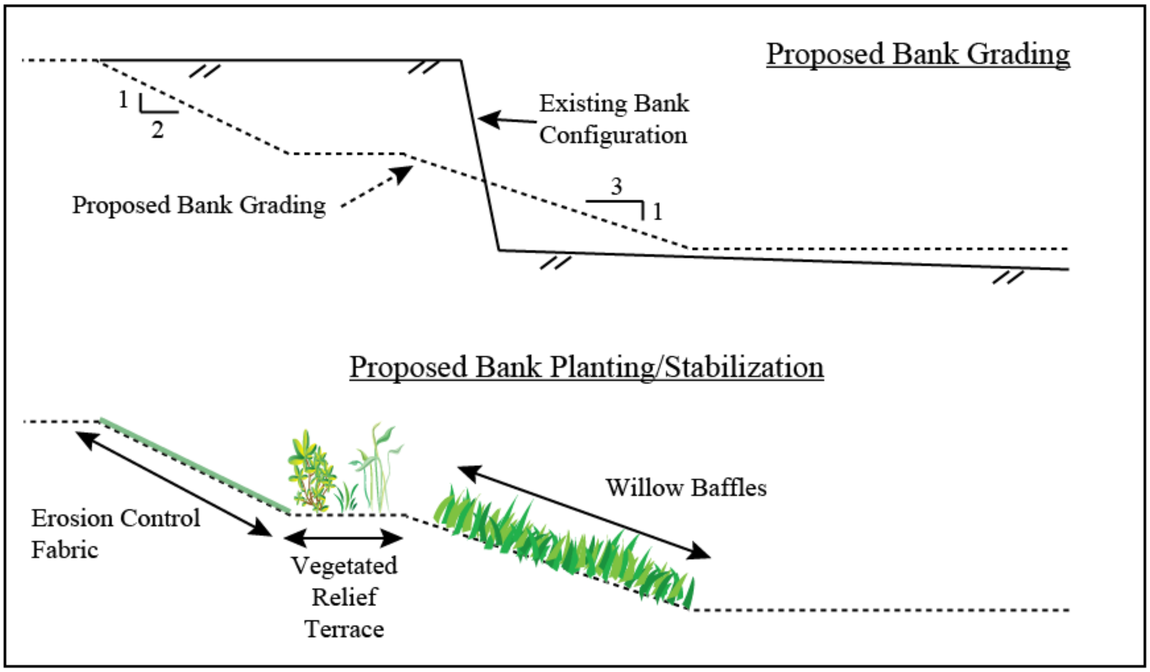


Figure 38: The proposed/planned bank re-grading plan and planting/ stabilization scheme, based on the Land Trust design plan.

The actual design plans developed for the project are shown in Figure 39. The plans were conceptual in nature, with the anticipation that the earthwork contractor would make decisions in the field with regards to cuts and fills so that a balance of earthen materials resulted in the final general desired configuration.

There were no explicit evaluations of stream discharge and/or evaluations of shear stresses and associated erosional forces on the completed restoration area. It was assumed that once established, the vegetation would provide the required stabilization to mitigate any erosion.

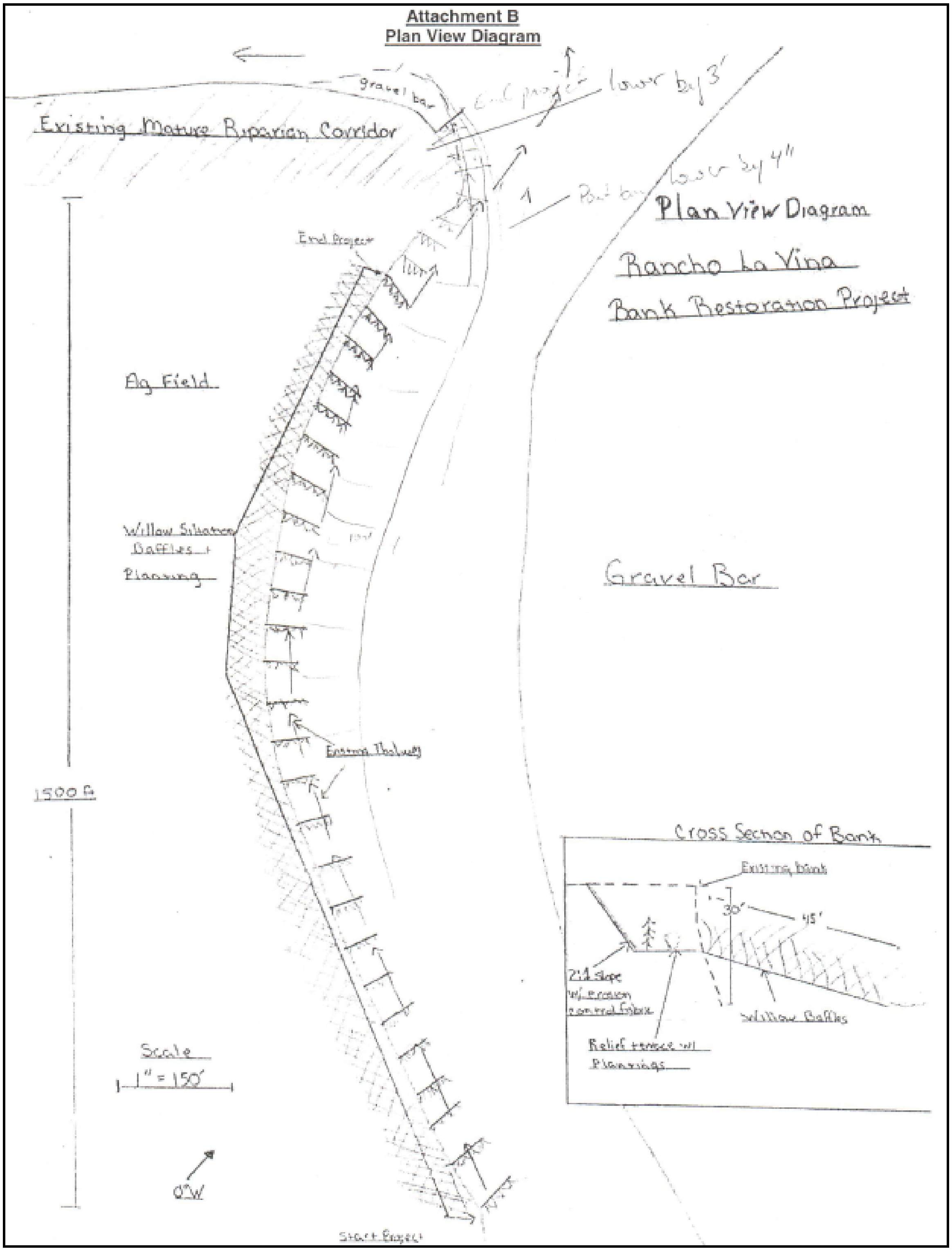


Figure 39: The design plans developed for construction of the project (*Land Trust, 2005*).

5.4.2 Post Project Appraisal Evaluation

The restoration goal of bank stabilization was explicitly determined (Table 44) from the project proposal application form (*Land Trust, 2005*). The design rationale was qualitative in nature and based on the California Department of Fish and Game's *California Salmonid stream Habitat Restoration Manual*.

Table 44: Restoration Goals for Lower Santa Ynez Bank Stabilization Project

Goal	Explicit/ Inferred	Reference	Source
Bank Stabilization	Explicit	"Approximately 1600 feet of vertical river bank will be stabilized to reduce sediment input to the river by a combination of grading, planting, and stabilizing structures." (page 4)	Land Trust, 2005

In reviewing the identified project goals and available documentation, it was found that 33% of the parameters identified in the Restoration Evaluation Checklist were evaluated, and, based on a PPA evaluation, it was estimated that the project achieved a 60% goal attainment. Table 45 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table 45: Summary of completed evaluation parameters for the Lower Santa Ynez Bank Stabilization Project.

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✗	✗	✗				✓		✓	✗	✓

A pre-project survey (Terrestrial LiDAR) was performed in March of 2006, prior to construction of the restoration project (Figures 40 and 41), however, the results of this survey was not incorporated into the restoration design. Survey control (Figure 42) was established at the site (GPS readings with an OPUS solution) so that all surveys could be georeferenced within the California State Plane (Zone 5, NAD 83) coordinate system. The Terrestrial LiDAR survey captured information on topography, active and inactive channel alignments, geometry of the eroding bank, and channel slope. A pre-project Digital Terrain Model (DTM) was created based on the Terrestrial LiDAR survey (Figure 43).

Figure 44 shows an oblique view of the bank stabilization construction activity. The excavations for the willow baffles can be seen at the toe of the newly graded slope. A temporary bypass channel was constructed to divert the water around the construction site. Figure 45 shows a view at the upstream end of the bypass channel (location “A”) and Figure 46 shows a view at the downstream end of the bypass channel (location “B”).

An ‘as-built’ Terrestrial LiDAR survey was performed in October 2007, following completion of the construction activities. Figure 47 shows a view of a completed willow baffle. Figure 48 shows a view of the 2:1 slope, terrace, and willow baffles. An oblique view of the Terrestrial LiDAR survey following construction is shown in Figure 49, with a close-up view of the willow baffle region in Figure 50. The as-built DTM is shown in Figure 51. This ‘as-built’ survey provides a baseline not just for physical aspects of the project (erosion/scour, bank instabilities, channel configurations, general topography, channel slope, etc.), but also for biological aspects, such as riparian development (growth rates, survivability, etc.) for the project.

Figure 40: **Pre-project view of project site looking downstream.**

Figure 41: **Pre-project Terrestrial LiDAR survey**

Figure 42: Survey control was established to allow for georeferenced surveys.

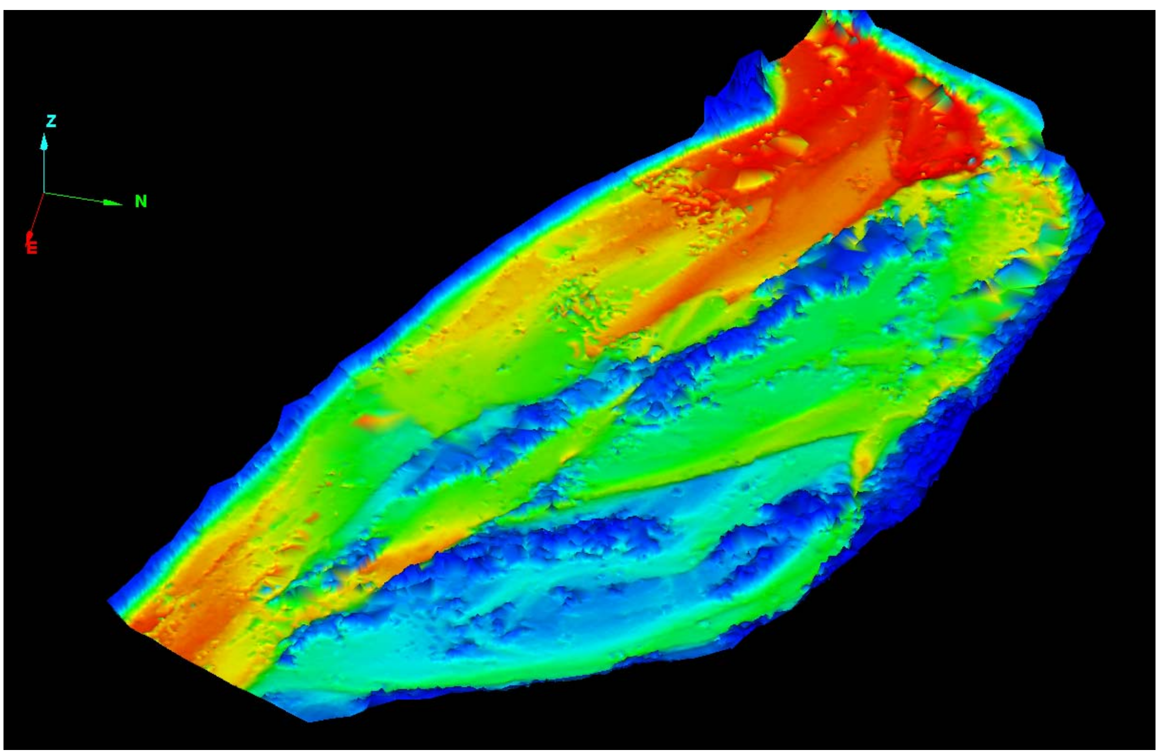


Figure 43: An aerial oblique view of the Digital Elevation Model generated based on the pre-project Terrestrial LiDAR survey.

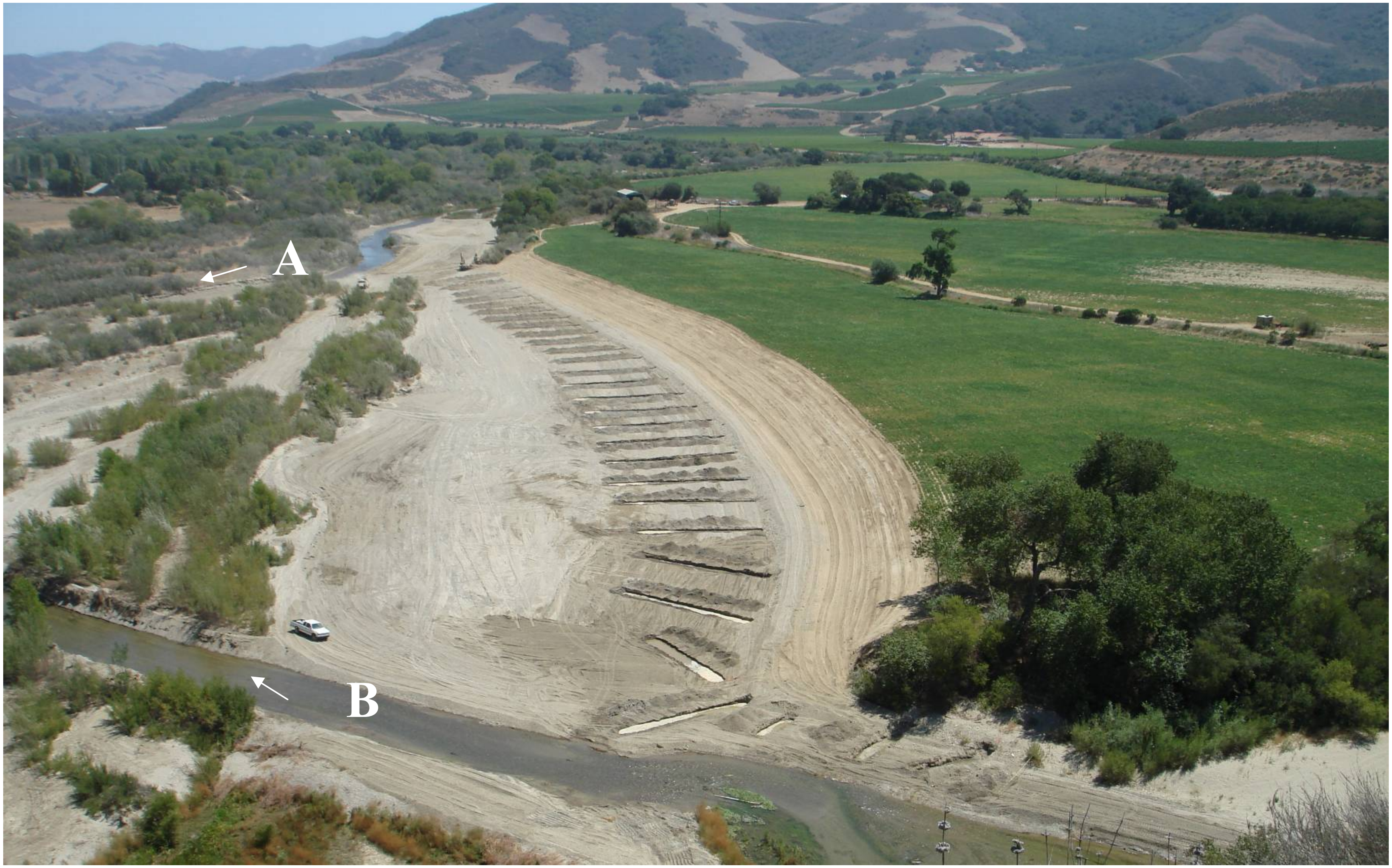


Figure 44: A view looking upstream with grading of the river bank in progress and excavations for the willow baffles is in progress. Photos from locations "A" and "B" are shown in Figures 45 and 46, respectively. *Photo by Meredith Hardy.*

Figure 45: The upstream start (location A) of the temporary bypass channel installed to divert flows during construction and for the first several years after construction to allow the bank stabilization vegetation time to establish.

Figure 46: The downstream end (location B) of the temporary construction bypass channel.

Figure 47: View of a completed willow baffle.

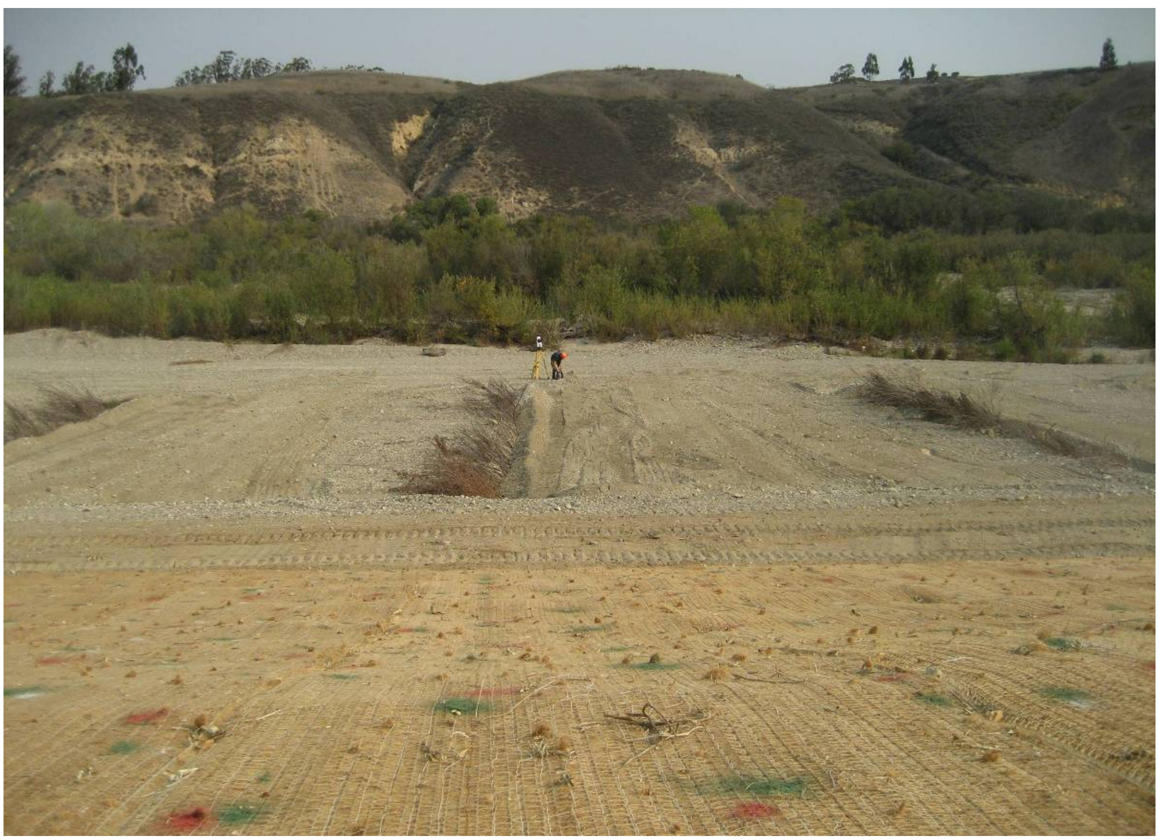


Figure 48: The as-constructed coir-fabric stabilized 2:1 slope, the (un-vegetated) relief terrace, and the willow baffle rows.

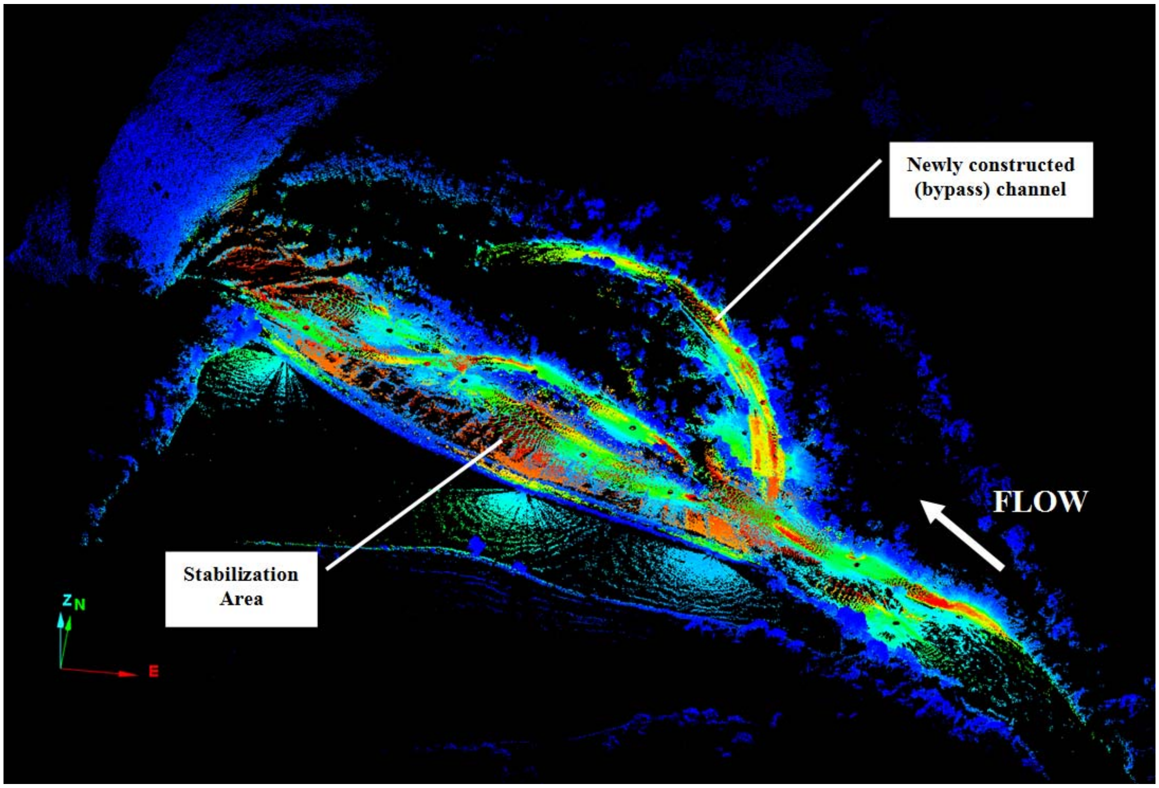


Figure 49: An oblique view of the Terrestrial LiDAR survey of the restoration area following construction. The bypass channel and stabilization areas are indicated.

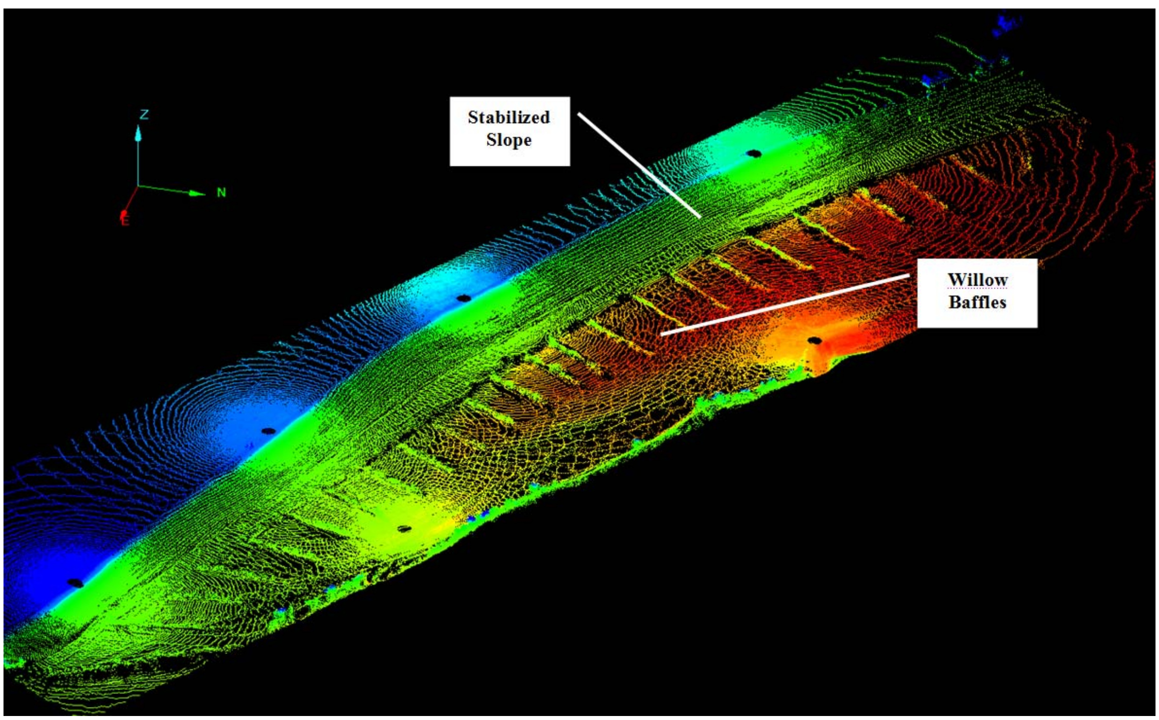


Figure 50: A close up view of the installed willow baffles from the Terrestrial LiDAR as-built survey.

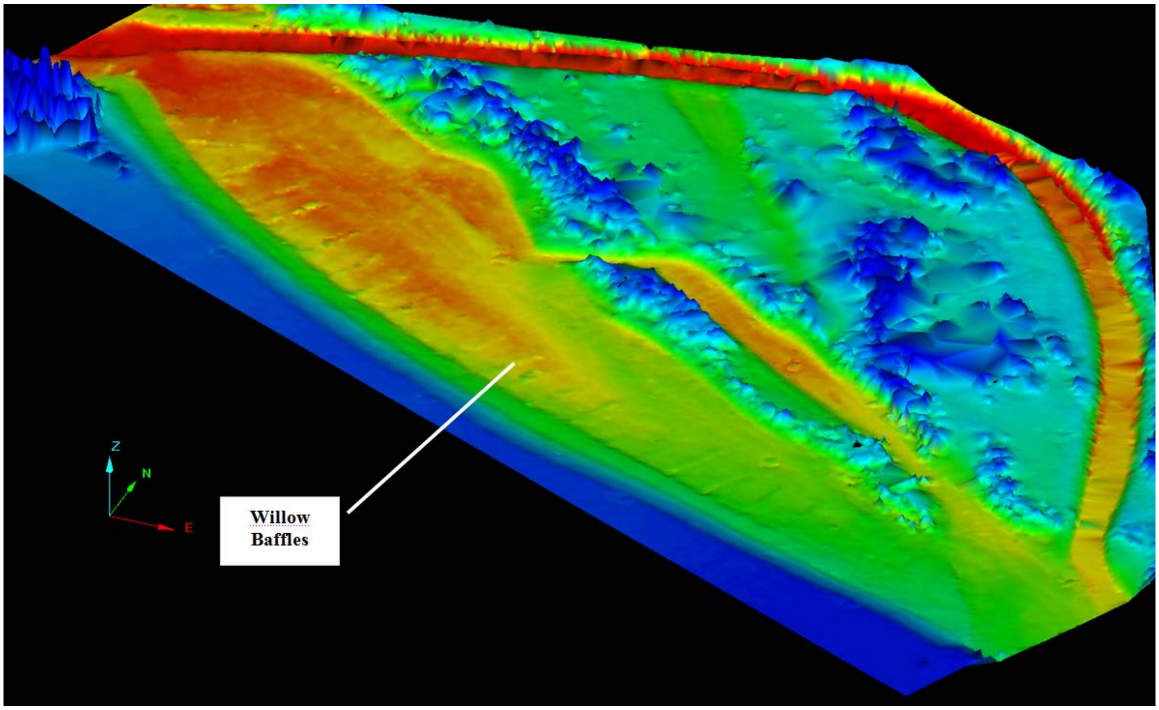


Figure 51: An oblique view of the as-built Digital Terrain Model created from the Terrestrial LiDAR surveys.

Information was completed and available for all components of the Post Project Assessment (PPA), as shown in Table 46. Explicit success criteria were not cited and baseline surveys were not established during the planning or design phases. A baseline Terrestrial LiDAR survey was performed by the author, but the results of this survey were not incorporated into the design for the restoration effort. The design rationale was reported as part of a grant application proposal (*Land Trust, 2005*).

Due to the project having been recently completed (Fall of 2006), not much data has been collected as part of the effectiveness monitoring effort, however, valuable 'lessons learned' are anticipated in the future once more information has been collected.

Table 46: Summary of PPA component evaluations

PPA Component	Available	Collection Method
Success Criteria	Yes	Permit documents.
Baseline Survey(s)	No*	No detailed baseline surveys were performed by the project designers, however, a Terrestrial LiDAR survey was performed before construction.
Design Rationale	Yes	A general design rationale was presented in the permit documents. No input parameters were specified.
Design Drawing(s)	Yes	Design drawings were available for this study.
As-Built Drawing(s)	Yes	An As-Built topographic map was performed using Terrestrial LiDAR.
Monitoring Program	Yes	Limited post-project Terrestrial LiDAR surveys have been performed (1-year, and a 2-year survey has been scheduled for June 2009).

The effectiveness monitoring program, detailed in Table 47, consists primarily of physical aspects with Terrestrial LiDAR surveys and photo-documentation. Stream flow data is based on a USGS gauging station near Lompoc, with a scaling factor applied accounting for the difference in drainage area with the gage site and actual project site. Figure 52 shows a pre-project (2006), after-construction (2007), and 1-year after completion (2008).

Table 47: Summary of Effectiveness Monitoring Assessments

Project Goal	Evaluation Parameter	Assessment Method
Bank Stabilization	Erosion/Scour	Terrestrial LiDAR Photo-documentation
	Channel Form	Terrestrial LiDAR
	Groundwater	Not Evaluated
	Structures	Terrestrial LiDAR Photo-documentation
	Sediment Transport	Not Evaluated
	Stream Discharge	Stream Stage (USGS Station 11133000)
	Riparian Vegetation	Terrestrial LiDAR Photo-documentation

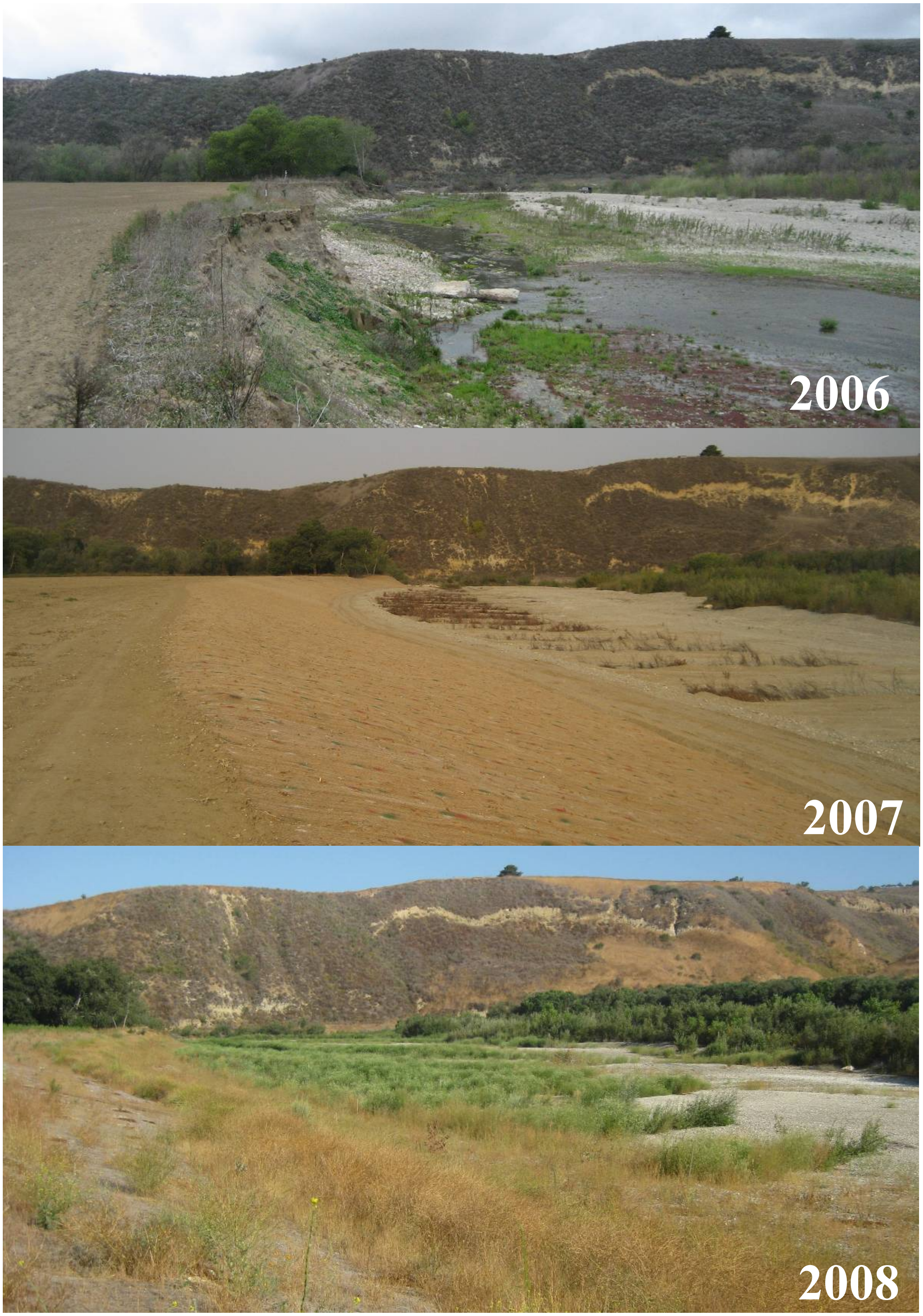


Figure 52: Photos showing pre- (2006), as-built (2007), and 1 year post-project (2008) views of the project.

An aerial oblique view of the restoration DTM (the survey did not fully capture the entire bypass channel, so the surface appears disconnected) after the first year of operation is shown in Figure 53. A temporary berm was to have been installed at location A in Figure 53 to divert the flows from the main channel to the bypass channel during the first several years to allow the planted riparian vegetation time to establish. It appears that the berm was never installed. Furthermore, there was no evaluation of dimensions for the berm to divert a 2- or 5-year flow into the bypass channel (and no evaluation if the bypass channel was of sufficient size either).

The winter storms of 2008 resulted in flows through the project area and the formation of a new active channel (as seen in Figures 54 and 55). Vegetation growth in the stabilization area is shown in Figure 56 and significant erosion and vegetation growth was observed in the bypass channel (Figure 56). Figures 57 and 58 show conditions at locations A and B from Figure 44 one year after construction. As can be seen in Figure 59, the lack of a diversion berm allowed flows to go through the stabilization area, with active erosion and scour.

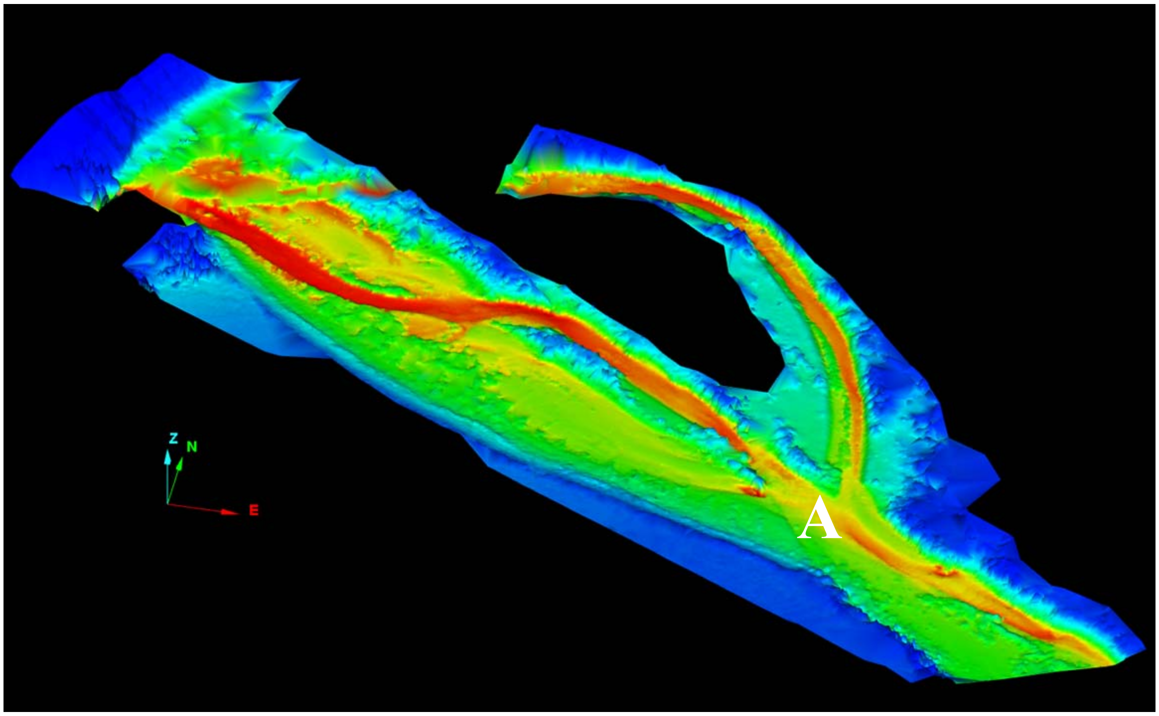


Figure 53: **An oblique view of the 1-year post-project Terrestrial LiDAR survey. A diversion berm was to have been constructed at location A, but appears to not have been installed, resulting in flows through the restoration area.**

Figure 54: **A view (downstream) of willow baffle segments damaged by the winter flows that 'jumped' the temporary bypass channel.**

Figure 55: The planted vegetation is becoming established. The willows in the willow baffles (green) are taking shape.

Figure 56: The bypass channel experienced significant bank erosion and vegetation growth.

Figure 57: A view of the upstream end (location "A") of the construction one year after construction.

Figure 58: A view of the downstream (location "B") end of the bypass channel one year after construction.

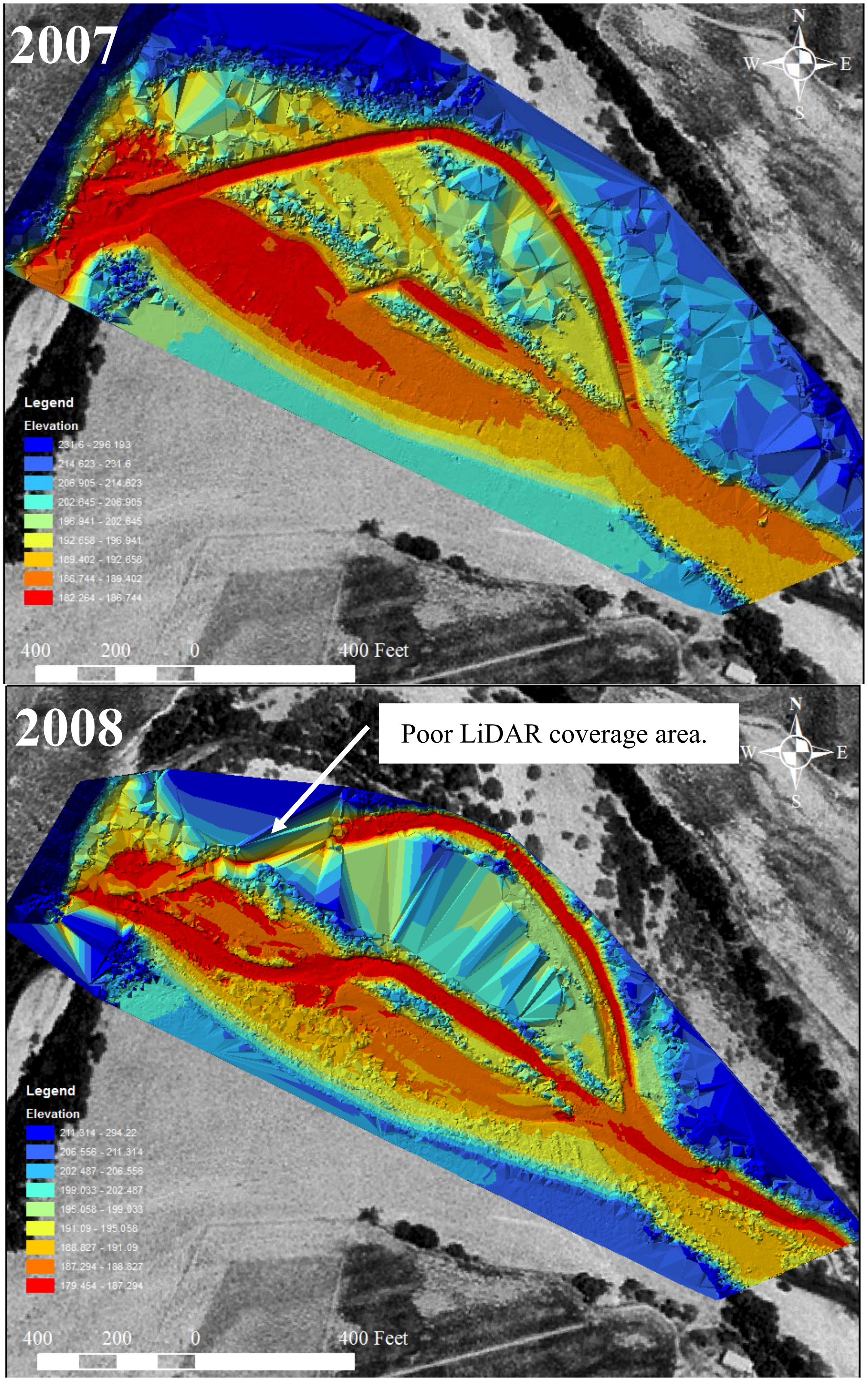


Figure 59: A comparison between the 'as-built' conditions in 2007 and in 2008, after 1-year of operation. Unanticipated erosion and scour occurred in the stabilization area.

5.4.3 Incorporation of Reliability and Life-Cycle Considerations

The first and immediate action item to improve the reliability of this restoration project is to evaluate the parameters identified in the Restoration Evaluation Checklist. Two very important parameters that influence the performance of the project are stream discharge and riparian vegetation. This example will detail how to evaluate erosion/scour potential within the bank stabilization through an evaluation of stream discharge and vegetation establishment over time (vegetation maturing over the life of the project). Four time 'snapshots' will be evaluated; t=0 years (immediately following construction of the project), t=5 years (projected vegetation establishment through a typical industry standard monitoring period), t=10 years (projected vegetation establishment), and t=25 years (projected vegetation establishment).

The establishment of riparian vegetation over time (life-cycle) was not explicitly considered for this project and it was assumed that the planting of vegetation would alleviate bank erosion. However, the configuration of the planting of the willow baffles, encourages higher flow velocities on the bank areas during significant storms (>5-10 year recurrence intervals), where the roughness of the vegetation is less than for the willow baffle areas. As conceptually shown in Figure 60, the sparse vegetation on the stabilized slope is susceptible to erosion and scour for larger flow events (on the order of 10-year and greater return flows). This example will evaluate the implications associated with vegetation establishment on bank erosion and scour and resulting projected performance of the bank stabilization project.

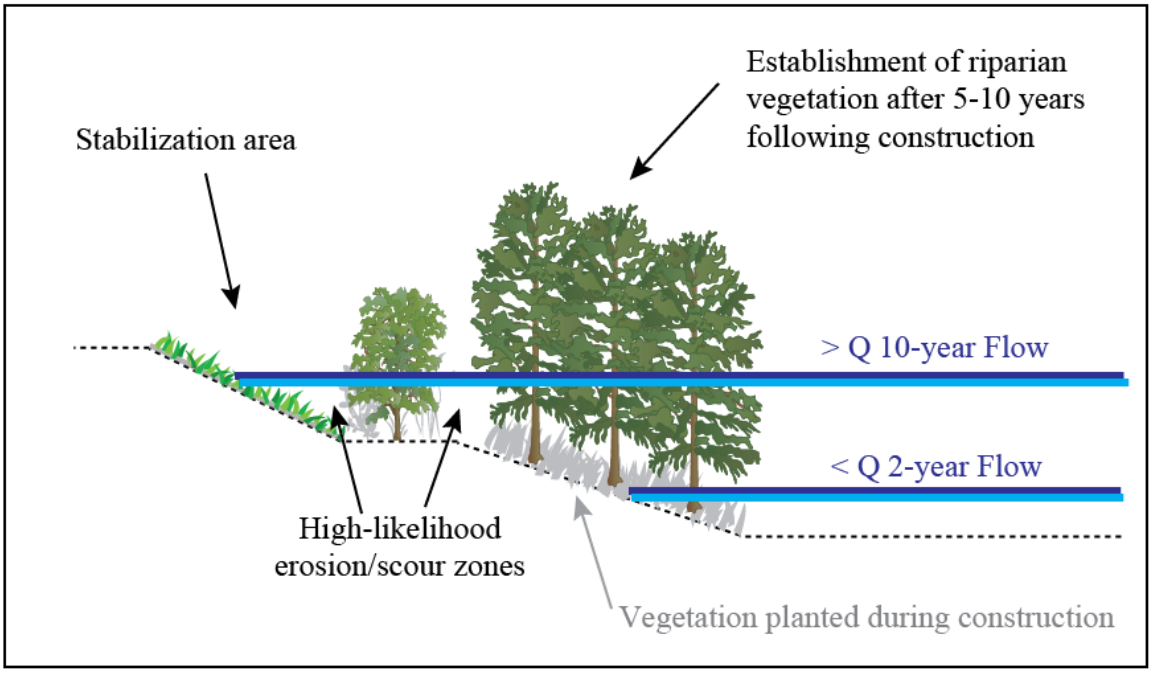


Figure 60: Consideration of riparian vegetation establishment (conceptual)

The example analysis will determine representative velocity profiles along the bank stabilization slope based on stream discharge, topography, and Manning's roughness coefficients. Stream discharge will be determined based on available USGS stream gauge records, scaled to the site based on drainage area ratios. Topography will be established based on available USGS NED elevation data and Terrestrial LiDAR data collected at the project site. Manning's roughness coefficients will be based on projected vegetation establishment over time and correlations between vegetation density/configuration and correlated Manning's coefficient.

5.4.3.1 Stream Discharge

Figure 61 shows delineated watershed for the Lower Santa Ynez Stabilization project in Santa Barbara County. The drainage area associated with the project site is approximately 1820 km2 and the USGS maintains a river stage gage near Lompoc (Gage Site No. 11133000), which was used as a basis to calculate the discharge/frequency curve for the site. The average precipitation within the watershed is 62 cm per year (Figure 62), with the majority of precipitation occurring in the period of November through April (Figure 63).

The USGS Gage No. 11133000 was used to estimate the discharge/frequency for the Lower Santa Ynez Bank Stabilization site. The discharge frequency for the USGS Gage was scale (based on the ratio (Figure 64) of the USGS Gage drainage area (2040 km^2) to the project drainage area (1820 km^2)). The program HEC-SSP was used to translate the historic peak annual flows into a characteristic discharge/frequency curve for the site. The HEC-SSP results, adjusted for the Lower Santa Ynez Bank Stabilization project drainage area, are presented in Table 48 and a plot of the discharges is presented in Figure 65.

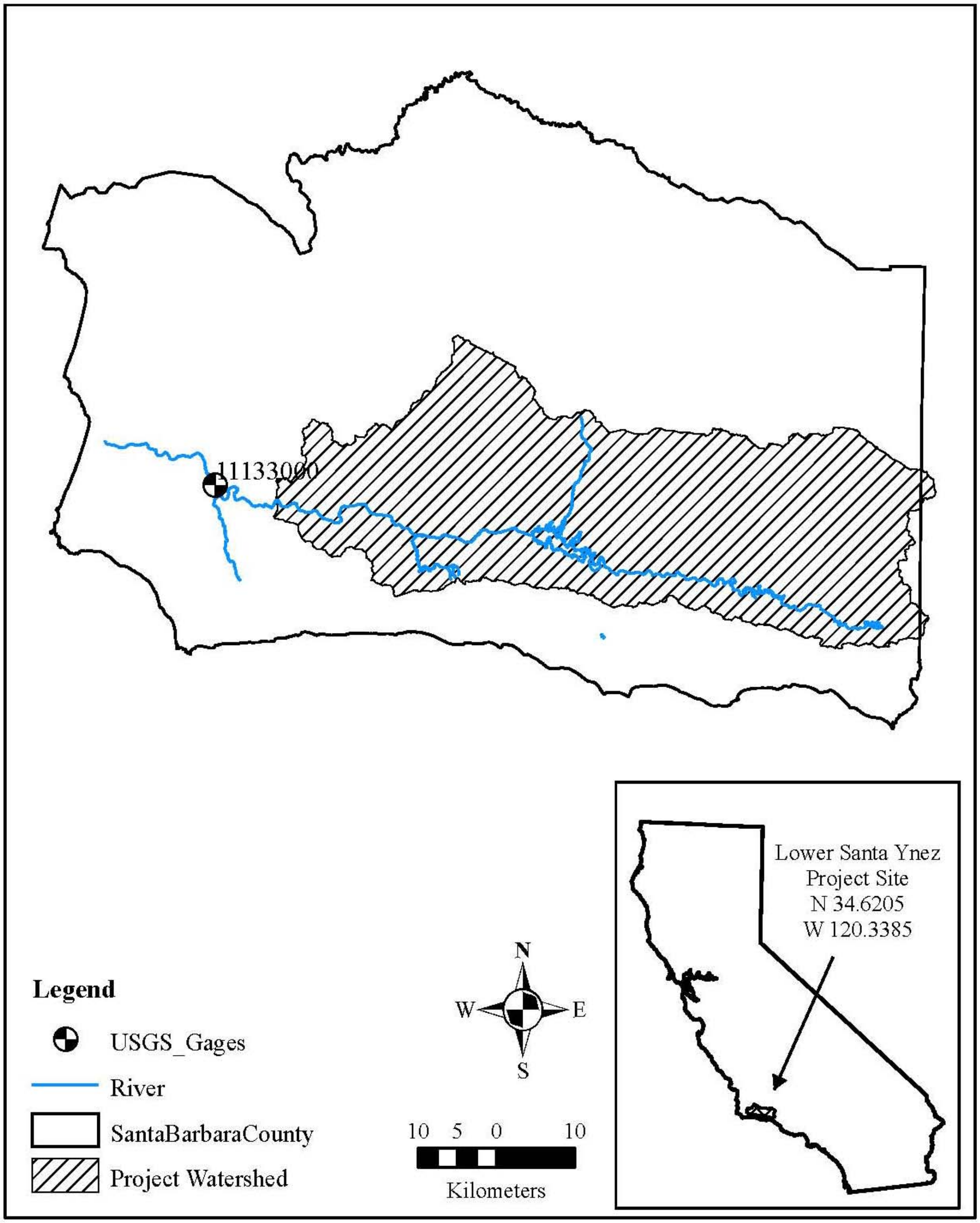


Figure 61: Delineation of the watershed for the project site.

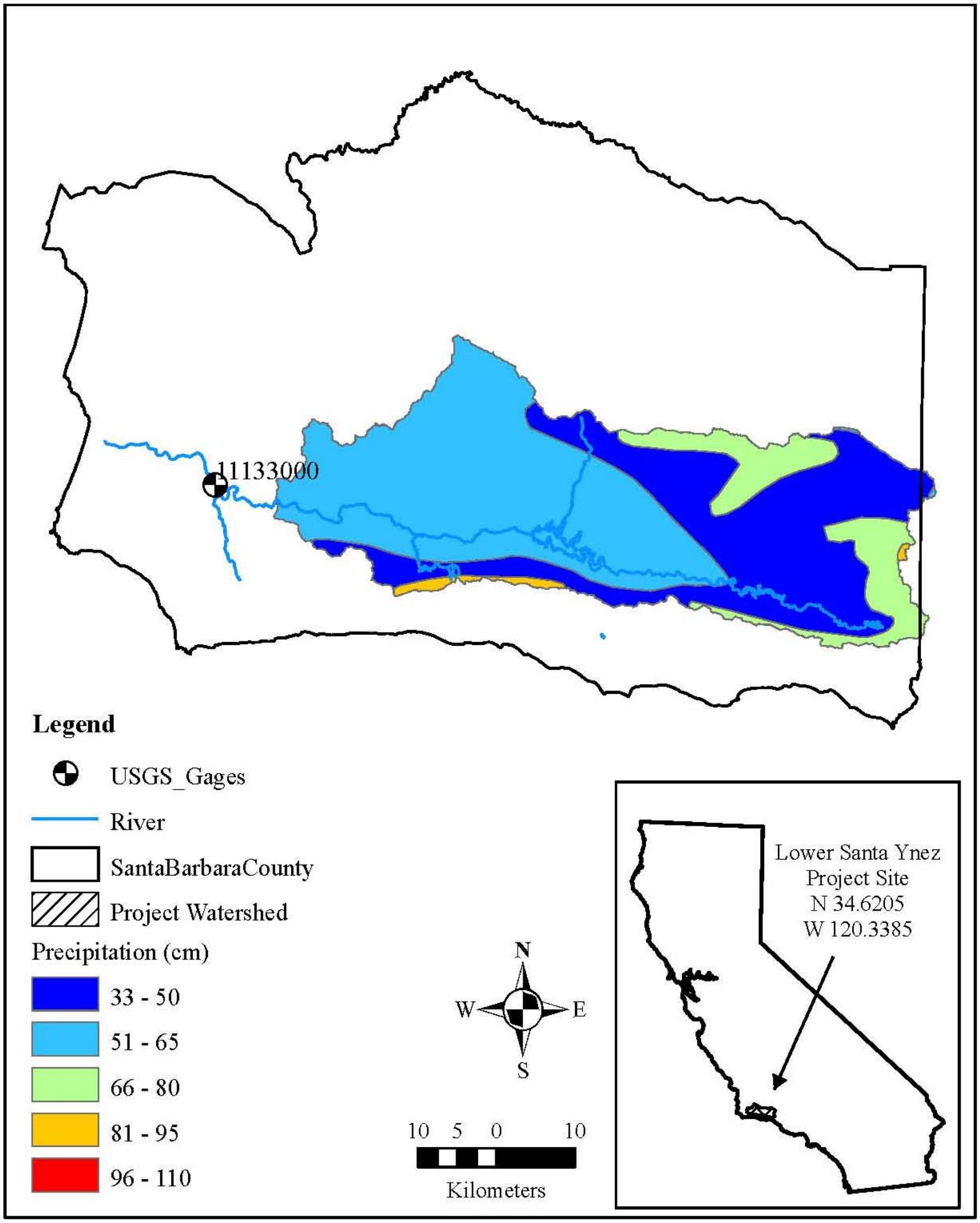


Figure 62: Average annual precipitation within the watershed is approximately 62 cm/yr.

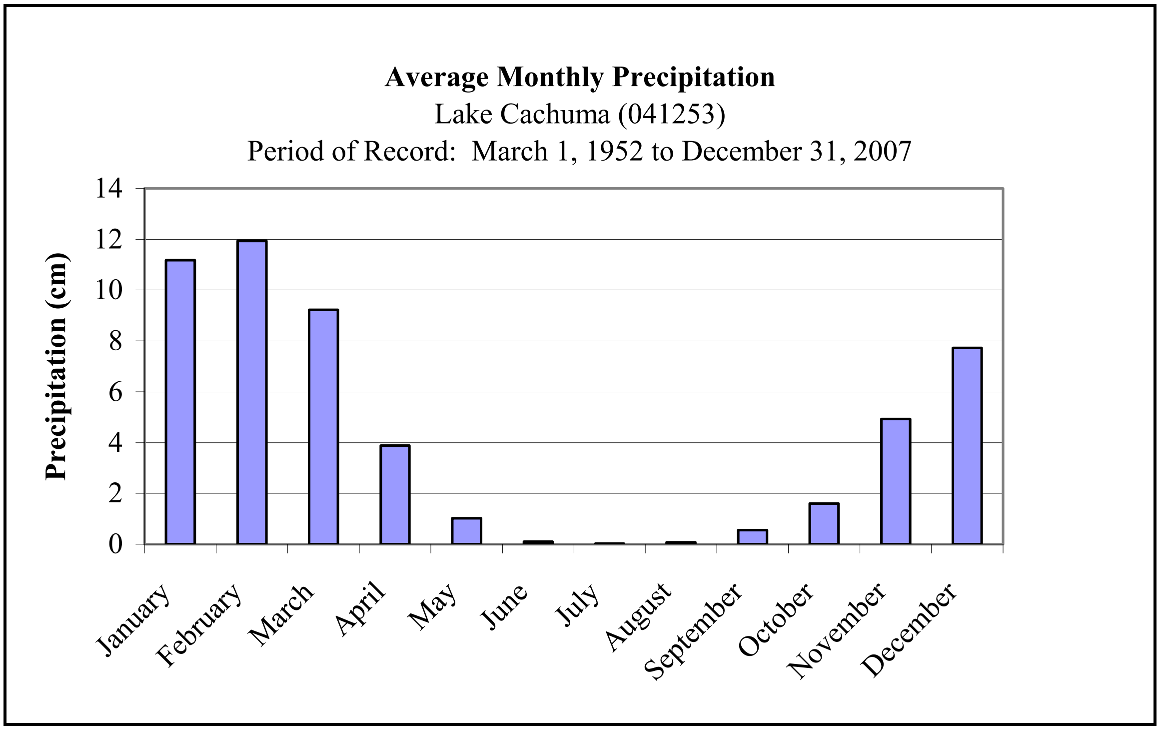


Figure 63: Average monthly precipitation at Lake Cachuma, within the watershed.

HEC-SSP calculated stream discharge estimates.

Percent Chance Exceedance	Flow - Peak (m^3/s)		Confidence Limits (m^3/s)	
	Computed Curve	Expected Curve	0.05	0.95
0.2	7251	8236	15992	3865
0.5	4952	5482	10383	2728
1	3562	3865	7149	2029
2	2443	2602	4699	1440
5	1347	1407	2405	836
10	768	791	1286	498
20	371	379	581	252
50	82	82	117	57
80	15	15	22	10
90	6	5	9	3
95	2	2	4	1
99	0	0	1	0

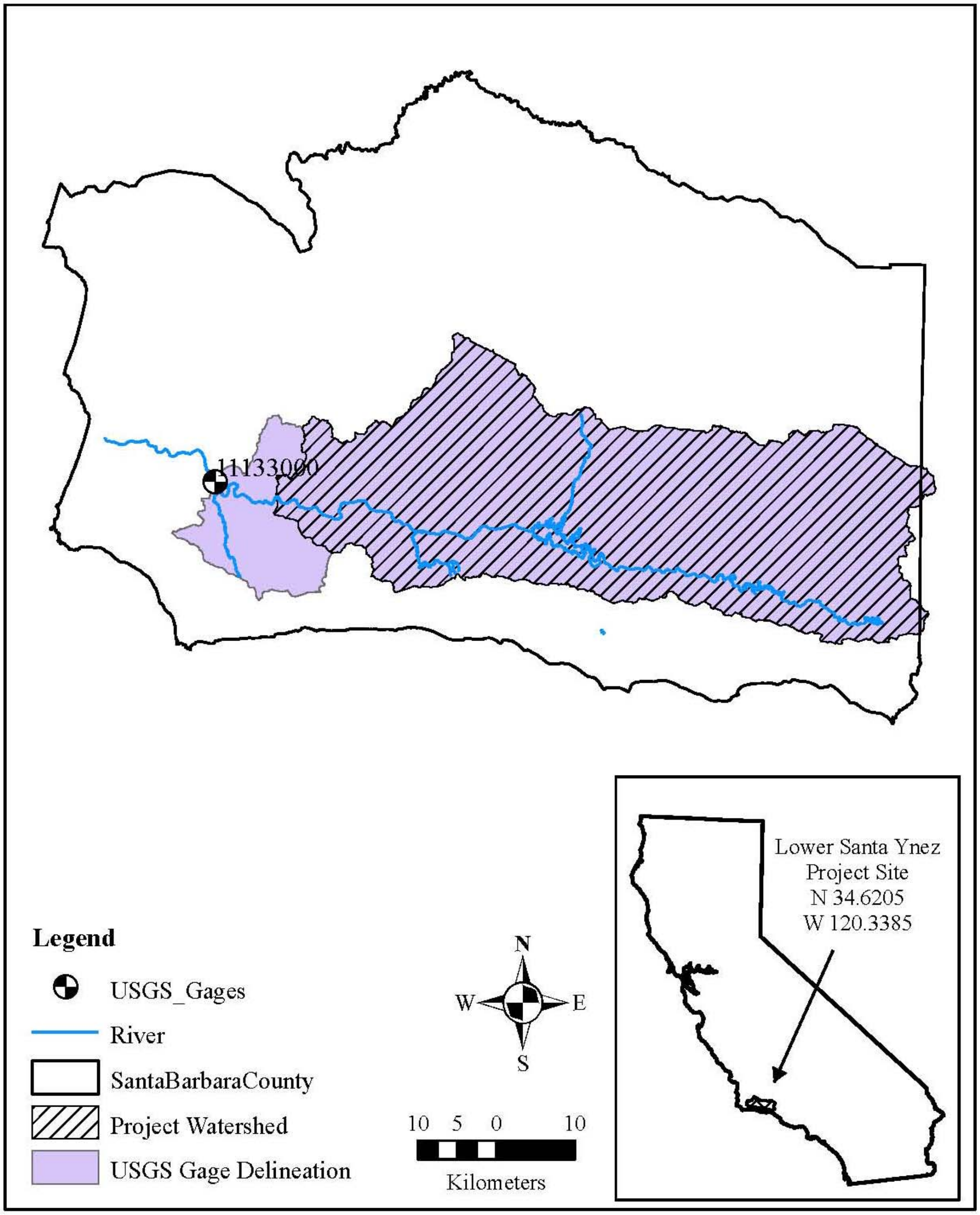


Figure 64: Delineation of the USGS gage drainage area as compared with the Lower Santa Ynez Bank Stabilization project drainage area.

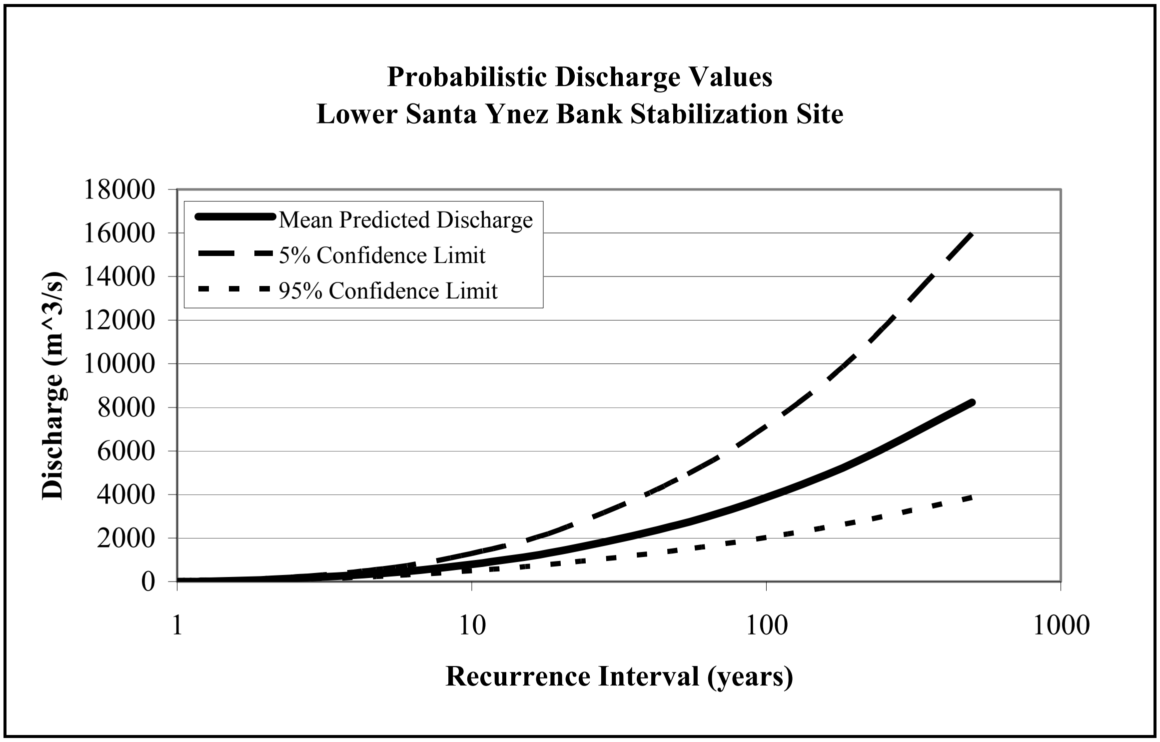


Figure 65: Estimated discharge rates for the Lower Santa Ynez bank stabilization site based on HEC-SSP analyses.

5.4.3.2 Topography

Topography for the site was established using available USGS NED elevation data (*USGS, 2009*) as well as elevation information collected as part of the as-built Terrestrial LiDAR survey, performed in October 2006. The elevation information was compiled using GIS and the HEC-RAS model configuration was accomplished using Geo-RAS (see Chapter 2 for a more detailed discussion of these methods). A slope of 0.0017 was used for the hydraulic calculations. A plan view of the 2007 as-built Terrestrial LiDAR image (USGS NED data used outside the Terrestrial LiDAR footprint is not shown), as well as the locations of the cross-sections used to configure the HEC-RAS model, is shown in Figure 66.

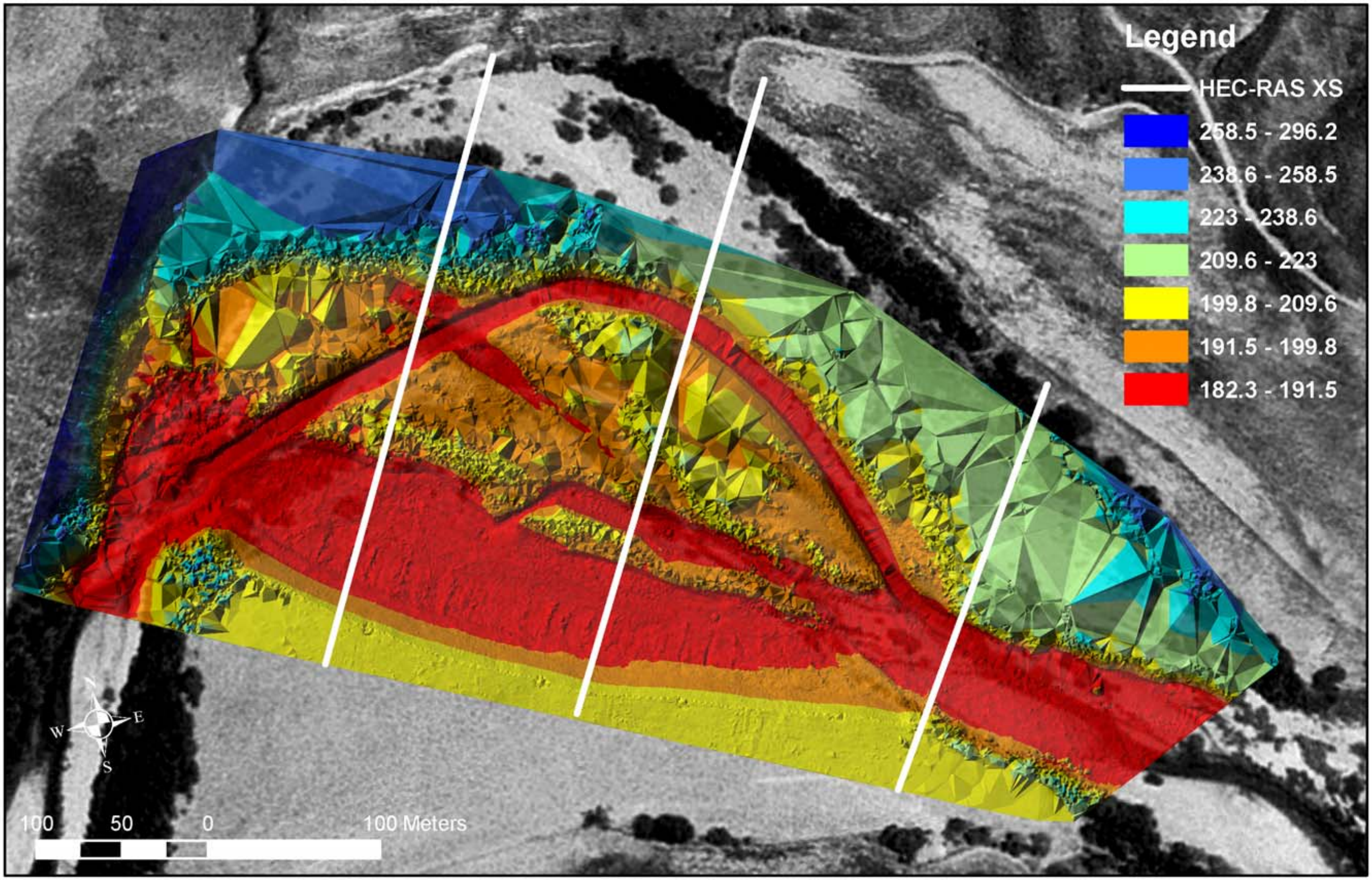


Figure 66: **Location of the HEC-RAS hydraulic evaluation cross sections and the as-built Terrestrial LiDAR data.**

5.4.3.3 Vegetation Establishment and Manning's Coefficient

Conceptual projects of vegetation growth in the bank stabilization area were made and associated Manning's roughness coefficients were estimated (*Caltrans, 2008; Hicks & Mason, 1998; King, 1939; USACE, 2008; USGS, 1967*) in order to allow hydraulic modeling and velocity forecasting within the limits of the project. Flow velocities were tracked at three vegetation regimes (Figure 67):

- Zone "A" – Vegetated bench at the toe of the stabilization slope and immediately south of the willow baffles. At full maturity, moderate roughness is anticipated.
- Zone "B" – Willow baffle stabilization feature. At full maturity, these baffles are anticipated to create significant roughness and will cause river flows to divert to the left and right of the willow baffles.
- Zone "C" – Active channel, no vegetation was installed in this are and is the desired flow path of the river.

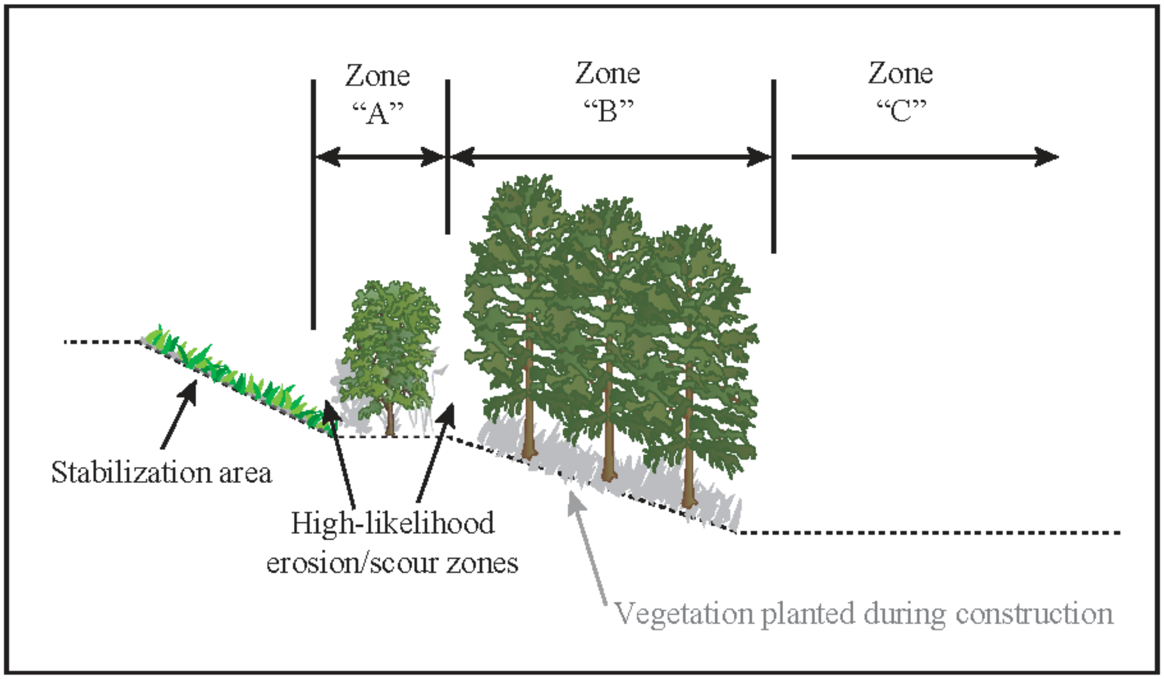


Figure 67: Location of the three monitoring zones to evaluate impact on flow velocity with vegetation establishment.

Figures 68 through 71 show the projected vegetation growth and associated Manning's coefficients used for the hydraulic modeling in years 0, 5, 10, and 25, respectively. The utilized Manning's coefficients for Zones "A," "B," and "C" are shown in Table 49.

Table 48: Summary of time-dependent Manning's roughness coefficients used.

Projected Year	Stabilized Slope	Zone "A"	Zone "B"	Zone "C"
Year = 0	0.03	0.03	0.03	0.048
Year = 5	0.05	0.05	0.07	0.048
Year = 10	0.05	0.07	0.15	0.048
Year = 25	0.05	0.07	0.2	0.048

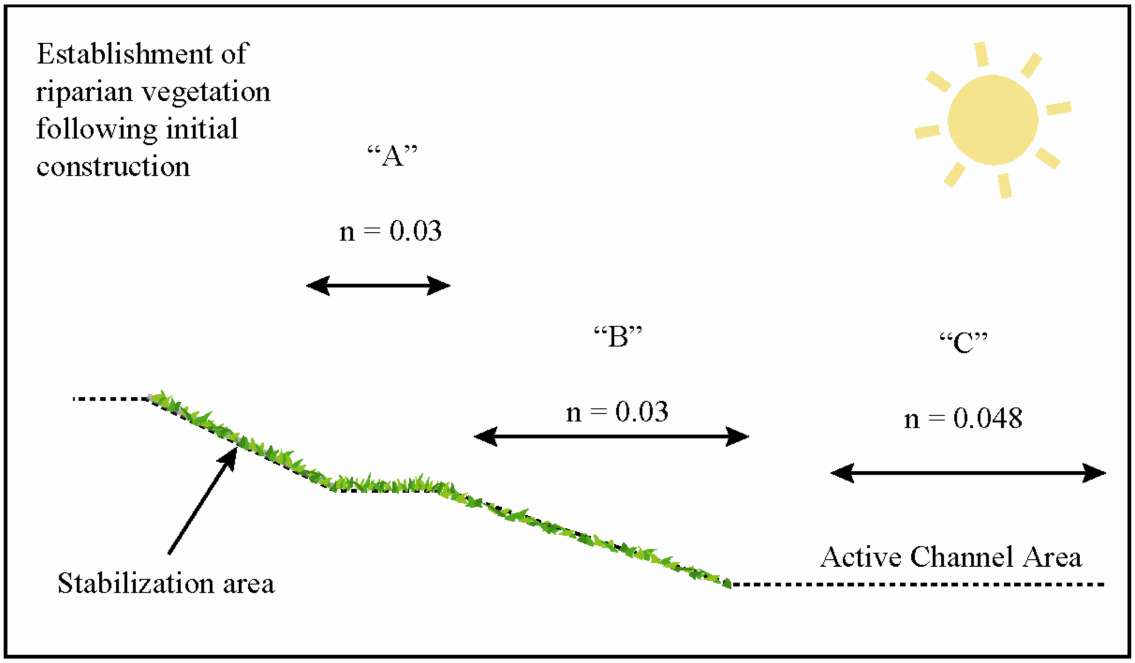


Figure 68: Manning’s roughness coefficients at Zone “A,” “B,” and “C” at Projection Year = 0.

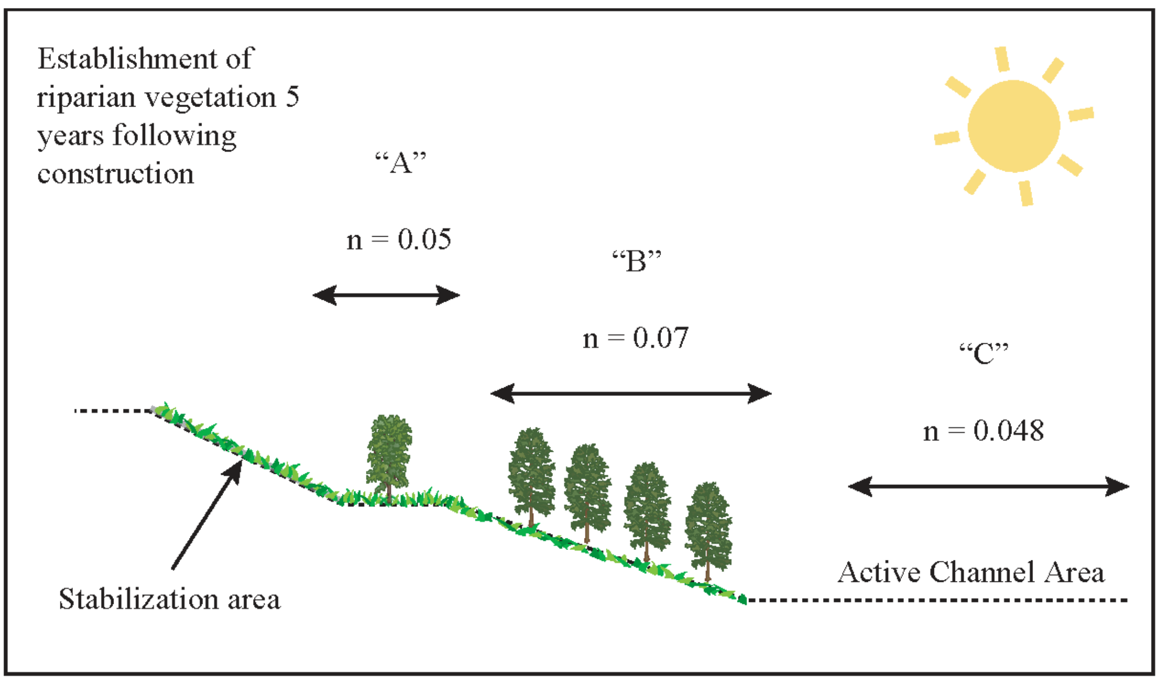


Figure 69: Manning’s roughness coefficients at Zone “A,” “B,” and “C” at Projection Year = 5.

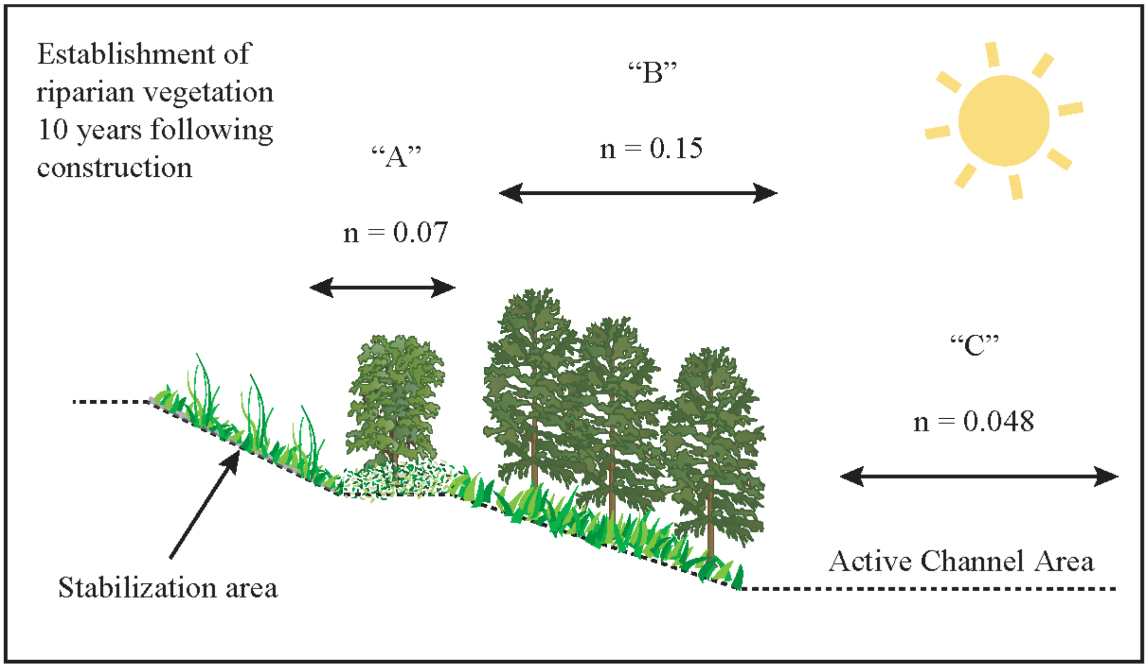


Figure 70: Manning's roughness coefficients at Zone "A," "B," and "C" at Projection Year = 10.

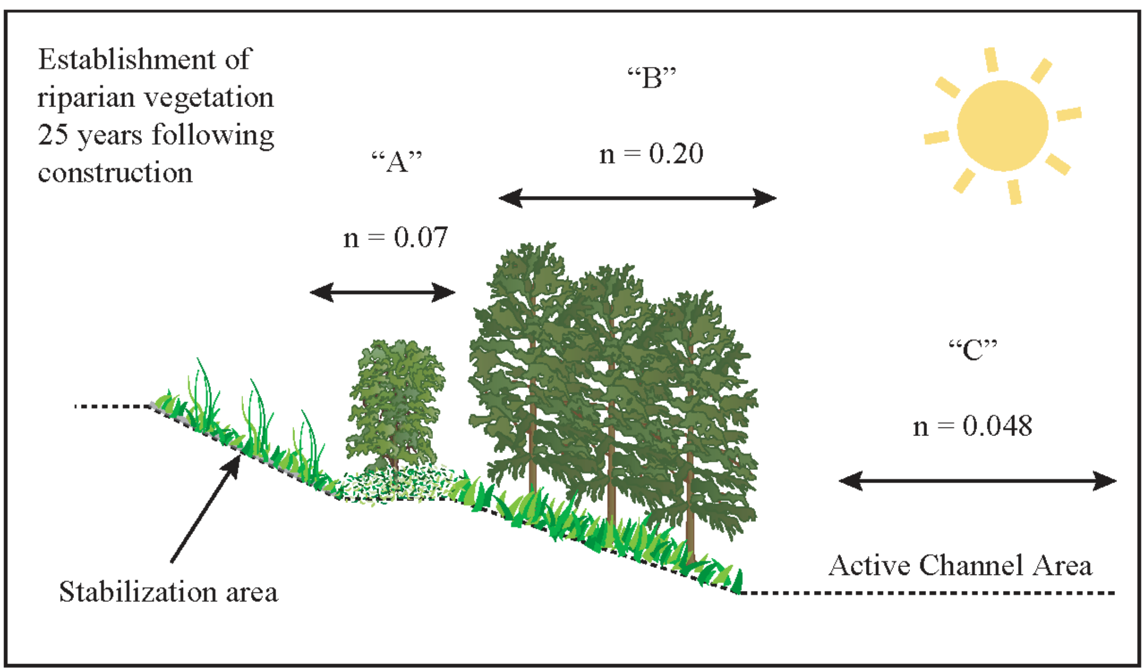


Figure 71: Manning's roughness coefficients at Zone "A," "B," and "C" at Projection Year = 10.

5.4.3.4 Analysis Results

The analyses found that the velocity profile of the river channel was directly impacted by the establishment of the vegetation and that the willow baffles encouraged river flow to either side. Figure 72 shows the results of the calculated velocity magnitudes (for simplicity in the diagram, only the expected 5-year return interval flows are shown in the comparison) at Zones "A," "B," and "C" in projection year 0, 5, 10, and 25. As the willow baffles become established, flow is diverted toward Zone "A" and the Active Channel Area. Due to the low resistance within the Active Channel Area, most of the flow (and corresponding velocities) occur in this region. However, the velocities in Zone "A" are greater than those in Zone "B" and the velocities are in a range susceptible to erosion and scour for sustained flows.

Table 50 presents a listing of permissible channel velocities before significant scour and/or erosion occurs. The soils at the Lower Santa Ynez bank stabilization sits are Sandy loams, implying that a permissible velocity of 0.5 (clear water) to 0.8 (turbid water) m/s.

Table 49: Permissible velocities (*USACE, 1999*)

Material	Clear water, no detritus (m/s)	Water transporting colloidal silts (m/s)
Fine sand (noncolloidal)	0.3	0.8
Sandy loam (noncolloidal)	0.5	0.8
Silt loam (noncolloidal)	0.6	0.9
Alluvial silt (noncolloidal)	0.6	1.1
Ordinary firm loam	0.8	1.1
Fine gravel	0.8	1.5
Stiff clay	1.1	1.5
Alluvial silt (colloidal)	1.1	1.5
Coarse gravel (noncolloidal)	1.2	1.8
Shales and hardpans	1.8	1.8

Calculated velocity magnitudes for Zones “A,” “B,” and “C” for the 2-, 10-, 50-, and 100-year return interval floods at the projected vegetative states at Year = 0, 5, 10, and 25, are presented in Tables 51, 52, 53, and 54, respectively. These velocity results include the 5%, expected (mean), and 95% confidence interval flow values to communicate the uncertainty associated with the flood discharge quantities and associated flow velocities. In comparing the calculated velocities at Zone “A” with the permissible velocities in Table 50, it can be seen that erosion and/or scour is expected for a flood event greater than the 5- to 10-year return period flood at all vegetation establishment time periods (Year = 0, 5, 10, and 25).

Plots of velocity magnitudes within the evaluation cross section, along with a conceptual diagram of the vegetation, for Year 0, 5, 10, and 25 are shown in Figures 73, 74, 75, and 76, respectively.

A comparison of the velocity profile just after completion of the bank stabilization construction activities (Year = 0) and the velocity profile after full establishment of the willow baffles (Year = 25) is shown in Figure 77. This comparison clearly shows the impact on the velocity profile distribution as a result of the configuration of the willow baffles.

Because the mature willow baffles provide such a high degree of ‘roughness,’ river flow is diverted toward the stabilized bank area, leaving the stabilized bank more vulnerable and prone to erosion and scour for sustained river floods (greater than the 5-year recurrence interval flood). No significant impact is anticipated in the stabilized bank area for flood events less than a 5-year return period flood because the range of flood stage elevations tend to fall below the elevation of this area.

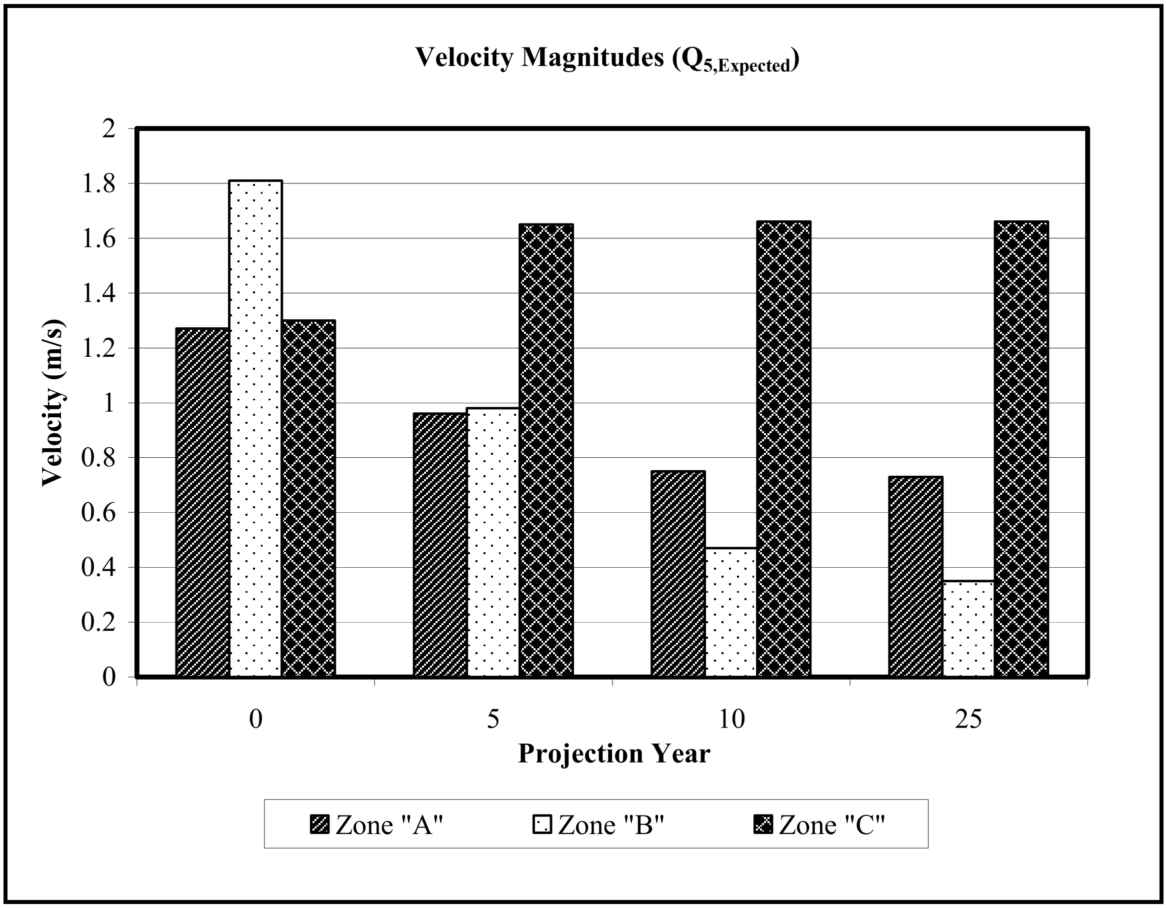


Figure 72: **Calculated expected velocities for Zones "A," "B," and "C" during a 5-year return period flood event.**

Table 50: Velocity (m/s) Magnitude Results for Year = 0

	Q_2			Q_{10}			Q_{50}			Q_{100}		
Location	0.95	Expected	0.05	0.95	Expected	0.05	0.95	Expected	0.05	0.95	Expected	0.05
A	N.A.	N.A.	0.4	1.5	1.9	2.4	2.6	3.4	4.5	3.0	4.1	5.4
B	0.8	1.0	1.1	2.0	2.4	2.9	3.0	3.8	4.8	3.5	4.5	5.7
C	0.8	1.0	0.8	1.4	1.7	2.0	2.0	2.5	3.2	2.3	2.9	3.7

Table 51: Velocity (m/s) Magnitude Results for Year = 5

	Q_2			Q_{10}			Q_{50}			Q_{100}		
Location	0.95	Expected	0.05	0.95	Expected	0.05	0.95	Expected	0.05	0.95	Expected	0.05
A	N.A.	N.A.	0.3	1.1	1.4	1.8	1.9	2.5	3.3	2.2	3.0	3.9
B	0.6	0.6	0.6	1.1	1.3	1.5	1.6	2.0	2.5	1.8	2.3	3.0
C	1.1	1.1	1.1	1.8	2.1	2.4	2.5	3.1	3.9	2.8	3.6	4.5

Table 52: Velocity (m/s) Magnitude Results for Year = 10

	Q_2			Q_{10}			Q_{50}			Q_{100}		
Location	0.95	Expected	0.05	0.95	Expected	0.05	0.95	Expected	0.05	0.95	Expected	0.05
A	N.A.	N.A.	0.3	0.8	1.0	1.3	1.4	1.8	2.3	1.6	2.1	2.8
B	0.2	0.3	0.3	0.5	0.6	0.7	0.7	0.9	1.2	0.9	1.1	1.4
C	1.0	1.1	1.2	1.8	2.1	2.4	2.5	3.1	3.8	2.8	3.6	4.5

Table 53: Velocity (m/s) Magnitude Results for Year = 25

	Q_2			Q_{10}			Q_{50}			Q_{100}		
Location	0.95	Expected	0.05	0.95	Expected	0.05	0.95	Expected	0.05	0.95	Expected	0.05
A	N.A.	N.A.	0.2	0.8	1.0	1.3	1.4	1.8	2.3	1.6	2.1	2.7
B	0.2	0.2	0.2	0.4	0.5	0.5	0.6	0.7	0.9	0.6	0.8	1.0
C	1.0	1.1	1.1	1.8	2.1	2.4	2.5	3.0	3.8	2.8	3.5	3.0

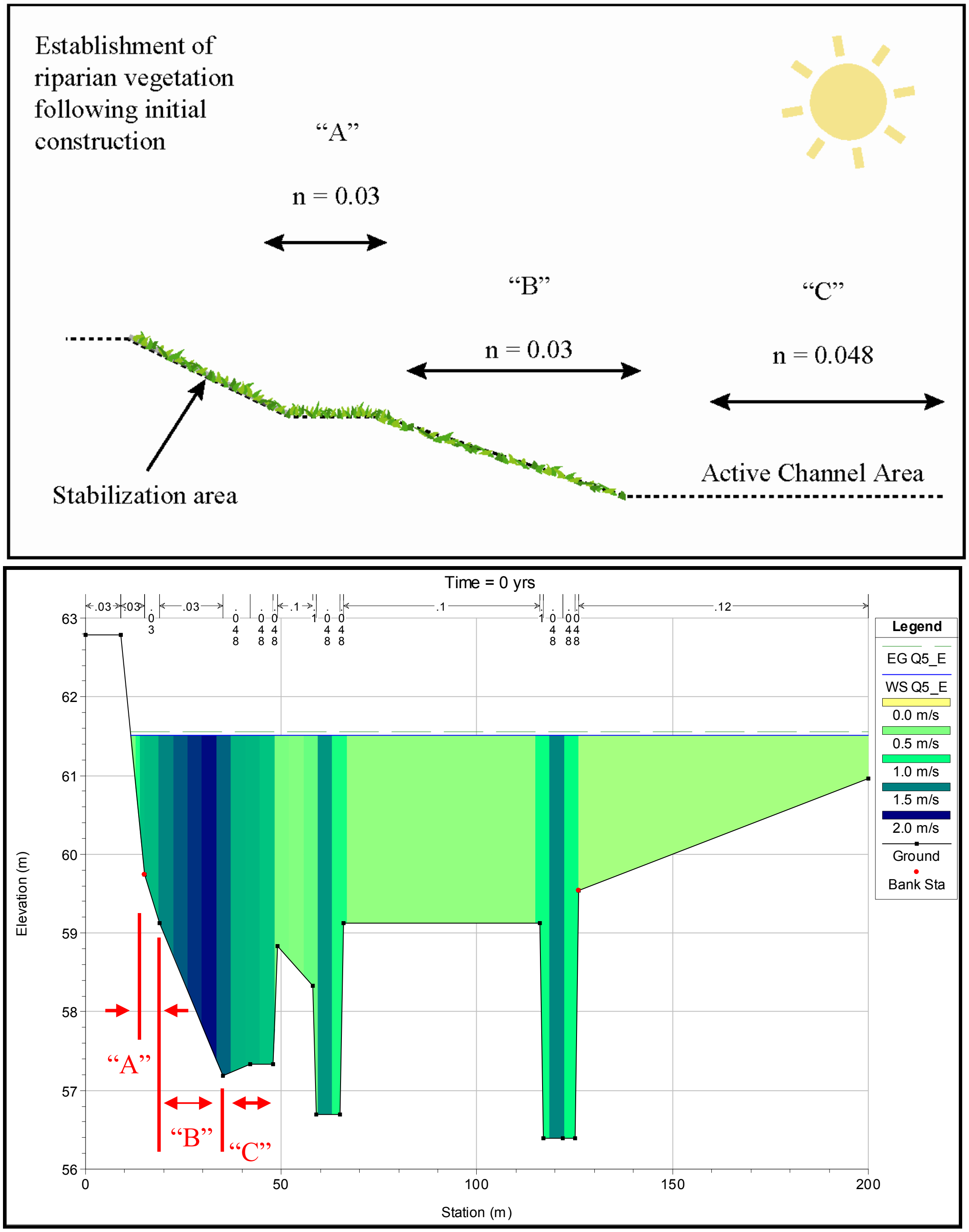


Figure 73: Calculated velocity profile (bottom) at Year = 0 before willow baffles have become established. Top shows a conceptual diagram of the vegetation establishment.

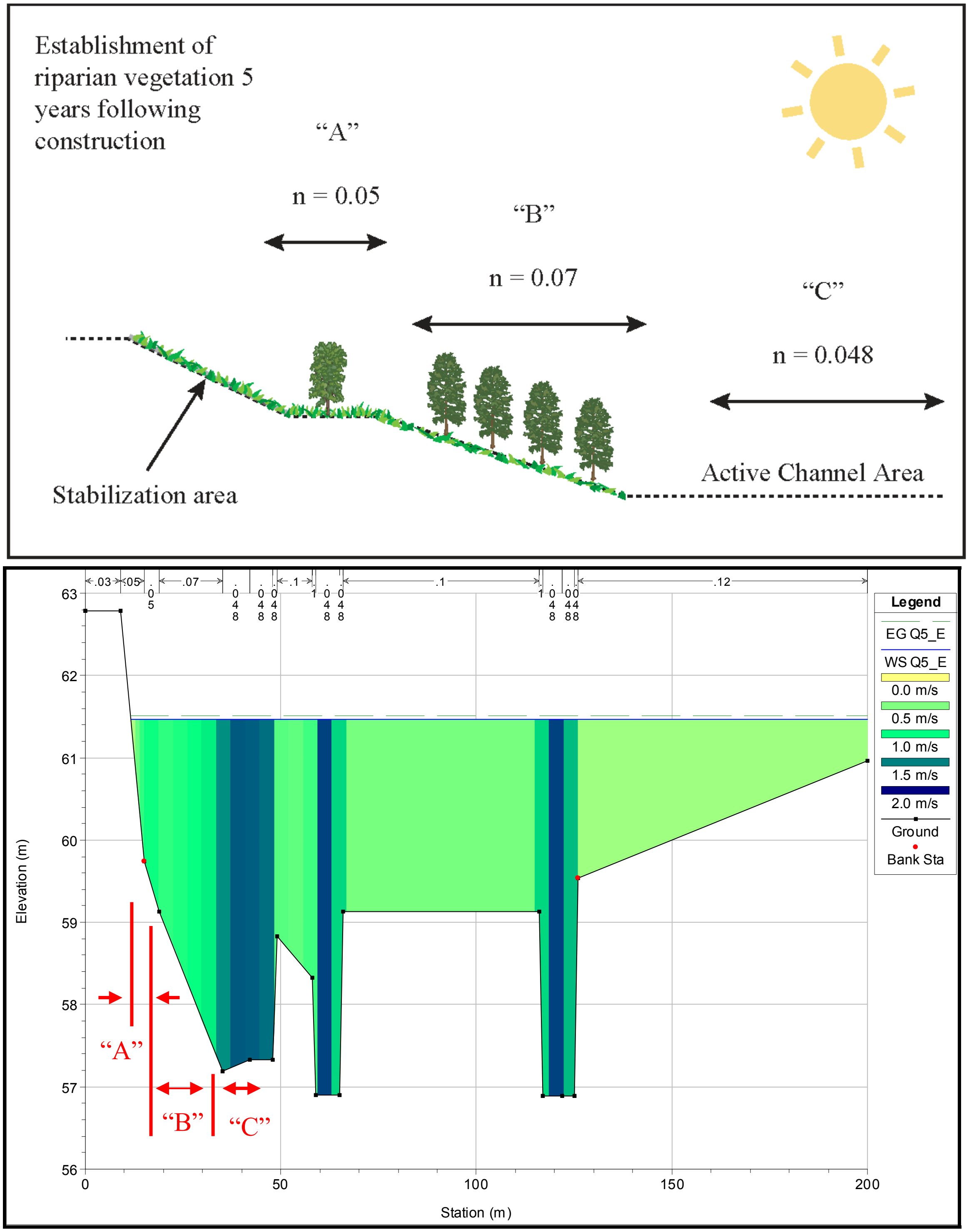


Figure 74: Calculated velocity profile (bottom) at Year = 5 as willow baffles start to become established. Top shows a conceptual diagram of the vegetation establishment.

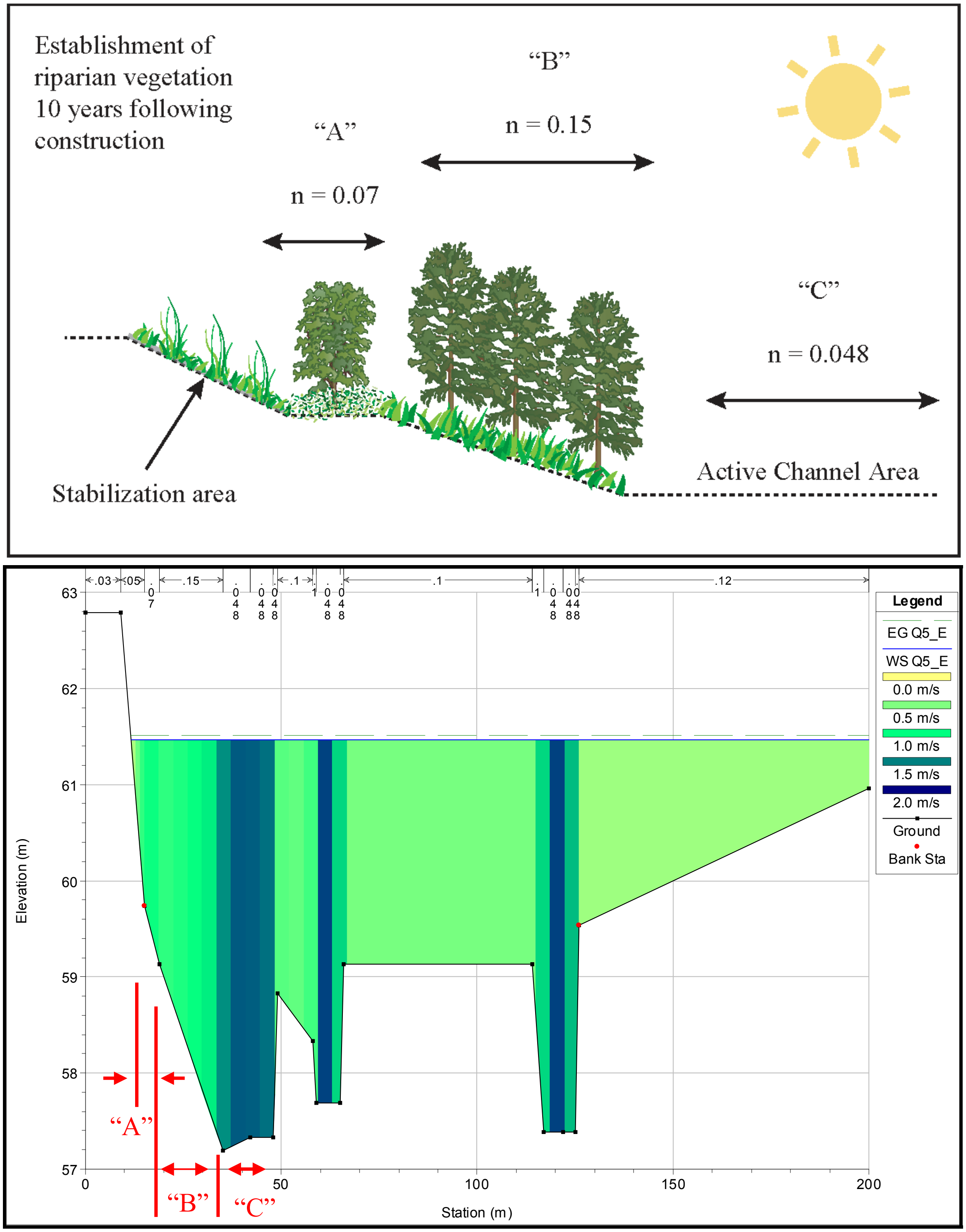


Figure 75: Calculated velocity profile (bottom) at Year = 10 after willow baffles have become established. Top shows a conceptual diagram of the vegetation establishment.

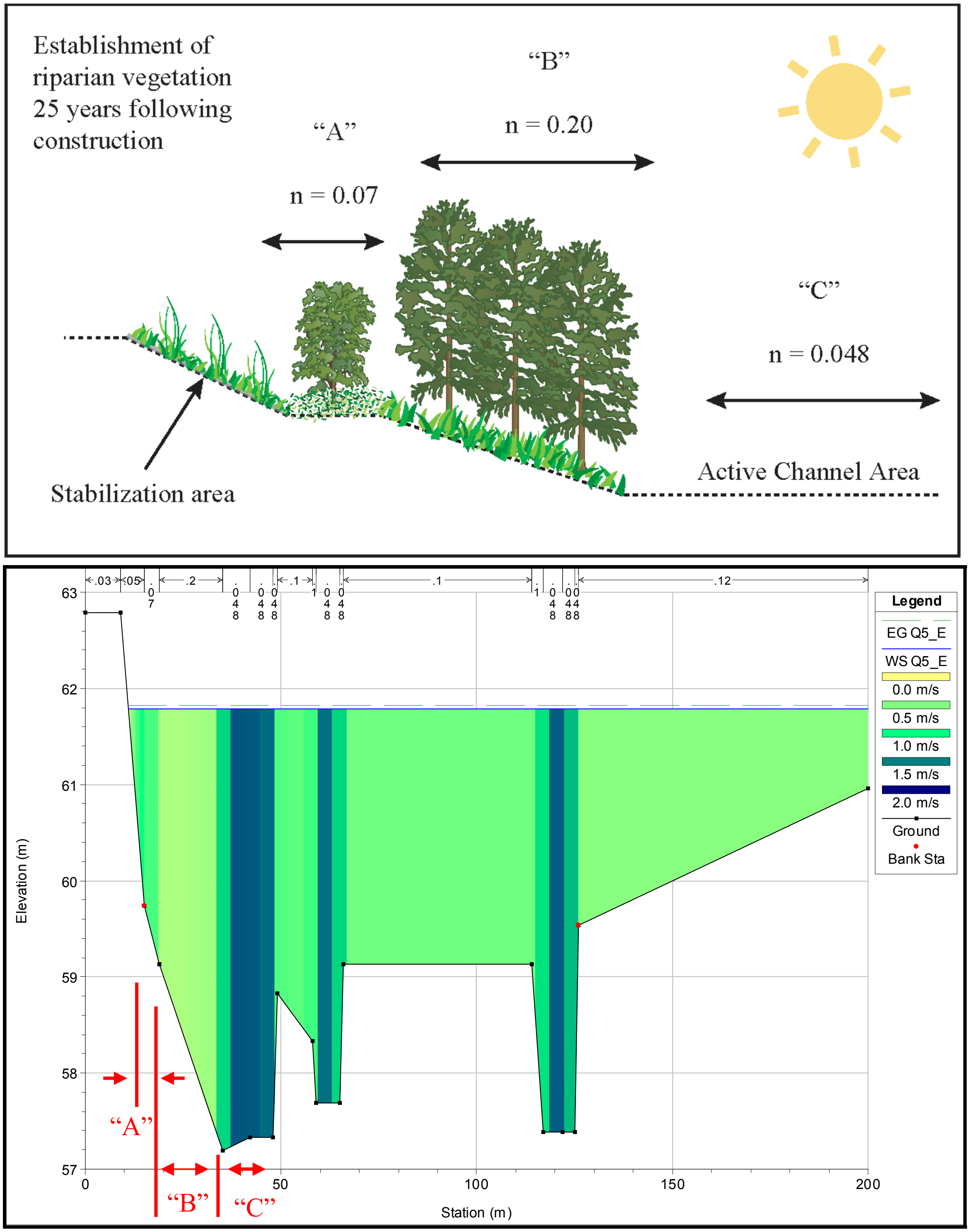


Figure 76: Calculated velocity profile (bottom) at Year = 25 after the willow baffles have matured and become firmly established. Top shows a conceptual diagram of the vegetation establishment.

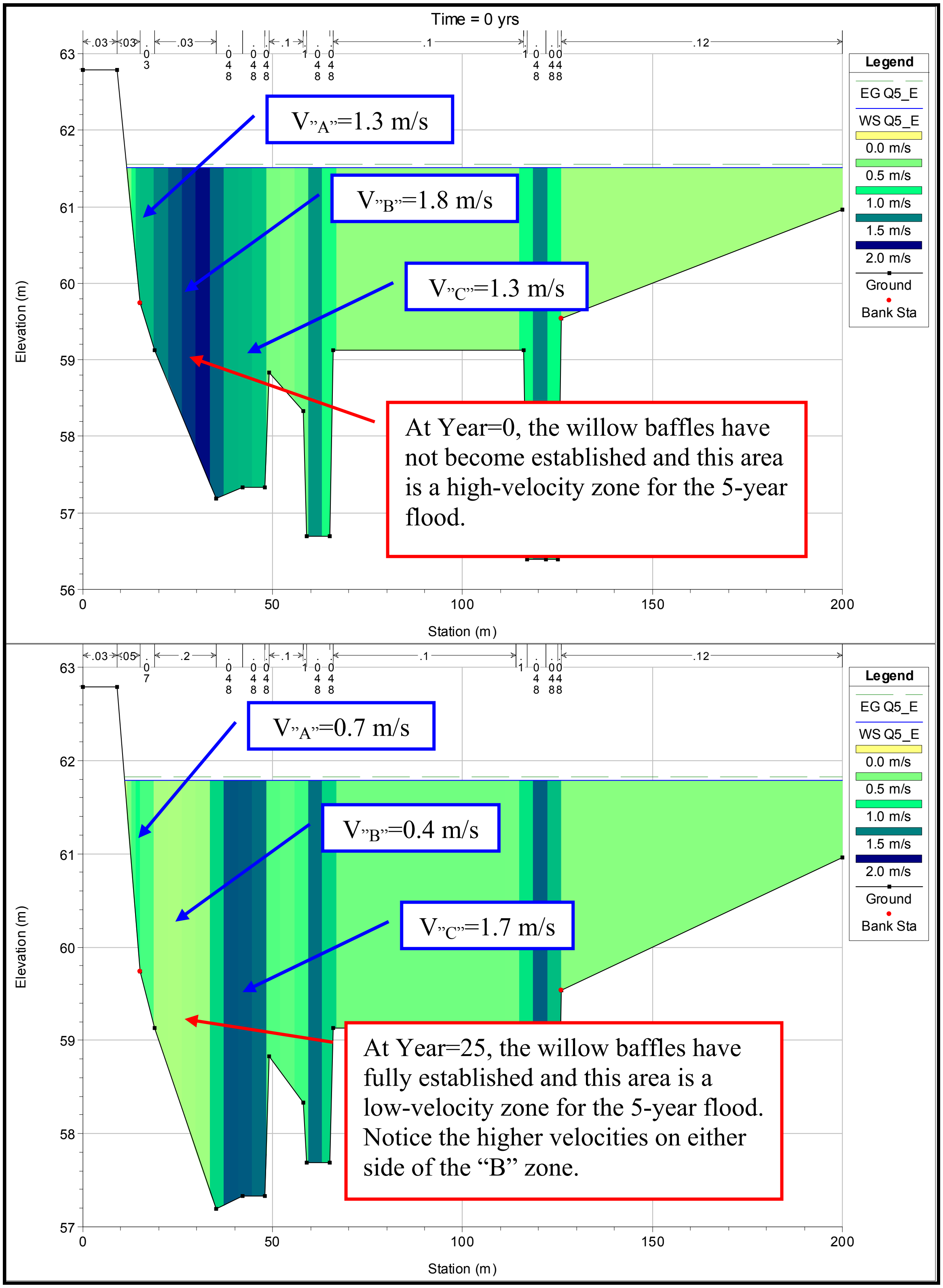


Figure 77: Comparison between calculated velocities immediately following construction (top) and after full establishment of the willow baffles in year 25 (bottom).

This example embraces both the reliability and life-cycle aspects of river restoration in that the stream discharge and riparian vegetation factors that were omitted during the original planning and design phases have direct implications on anticipated future performance of the project. By not explicitly accounting for these aspects of the restoration, the expected performance of the completed project is not as high (nor as durable) as had these factors been addressed.

Continued effectiveness monitoring would provide critical data on the projections presented in these analyses. If there were significant deviations from the anticipated performance (especially during 2- to 5-year return period flood events), adaptive management techniques could be applied to mitigate the undesirable development trend and a validation evaluation of the assumptions and methods employed to configure the restoration project should be conducted to identify the reason for undesired performance. Lessons learned as part of this process should be included into the state of the practice so that future efforts can benefit from this river restoration Technology lesson.

5.5 References

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Chapter Six

6 RIVER RESTORATION PROJECT DATABASE AND ARCHIVE

An example river restoration project database was developed as part of this research effort to demonstrate the feasibility, value, and operation of such a system. The database was also useful to propagate the information collected as part of this research effort for other river restoration researcher and practitioners. This chapter presents an overview of the database and archive system developed.

Due to the extended temporal nature of river restoration (Figure 78), it can be very challenging to capture and archive documents because there are many disparate firms that produce information for each project, and even within those individual organizations, there is frequently personnel turnover, resulting in a loss of conceptual integrity and institutional knowledge of the project. This database template applies to all life-cycle stages of the project development and alleviates the common problems of disparate firms by synthesizing all documentation into one location for each project. As documentation is completed during each life-cycle phase, it can be archived and made available through the river restoration database. For those projects with sensitive information, a timed-release can be established so that no information is made public until a specified period of time has passed.

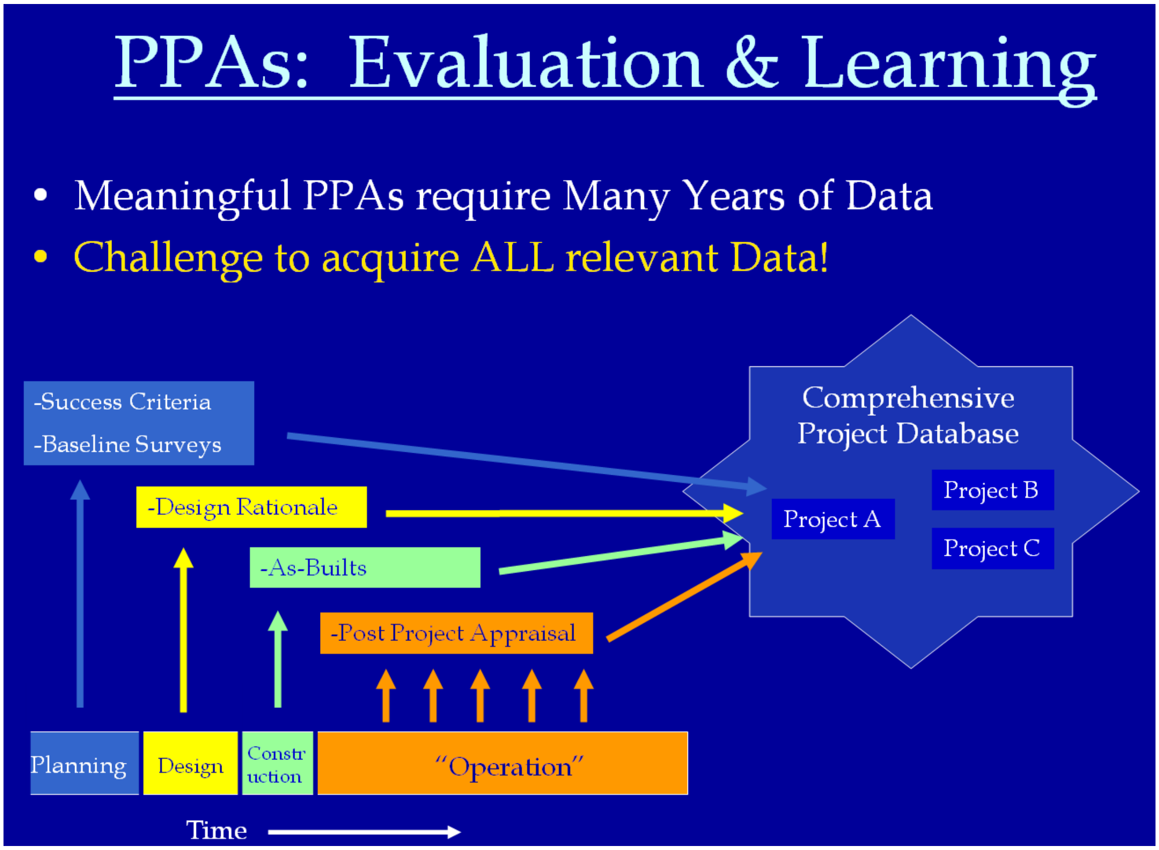

Figure 78: Capture of project documentation can take many years and covers multiple life-cycle phases.

All information would be contributed by individual river restoration project participants, as the documents are produced. This eliminates the need for one database administrator to input thousands of documents each year into the database, and frees them up to ensure the proper functioning and quality control of the posted documents.

6.1 Database Structure

The database was configured using Microsoft Access. An information table was created to store all the applicable information and forms were generated to facilitate the input of project-specific information (Figure 79).

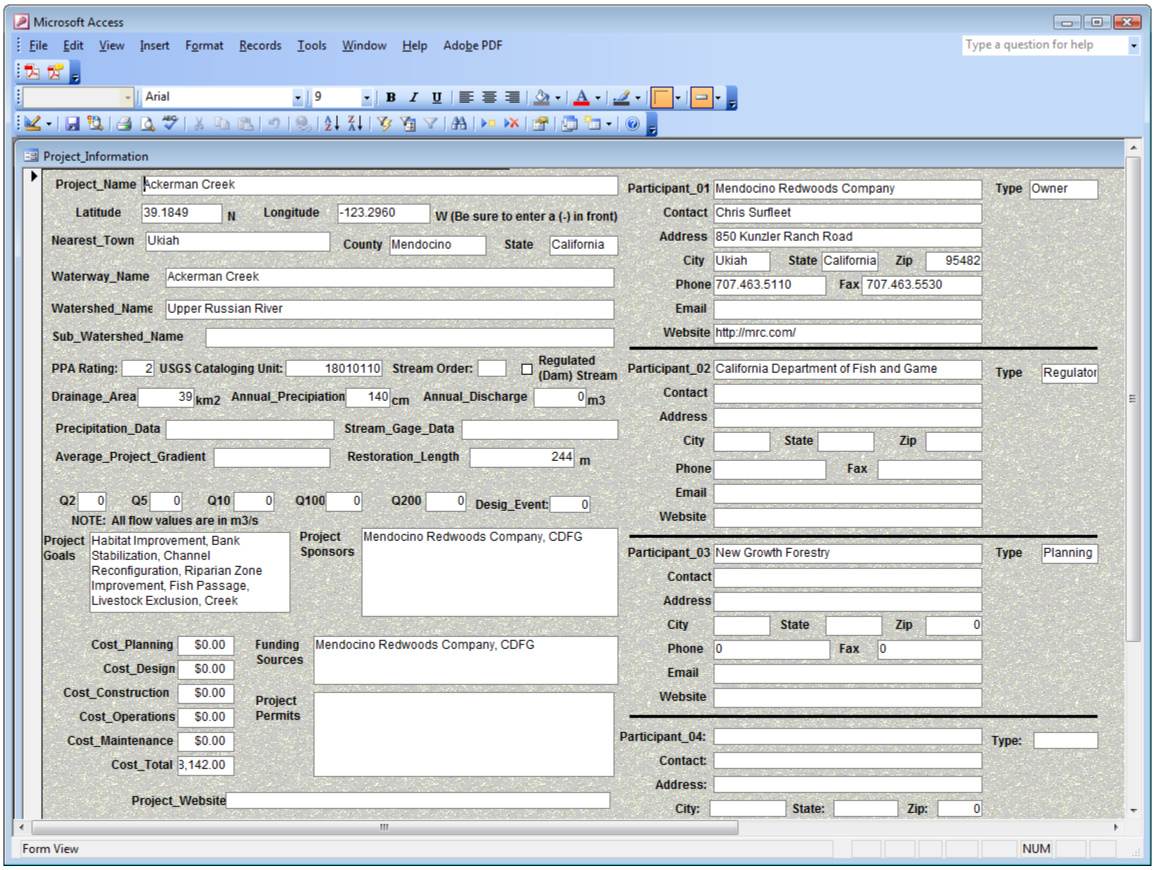

Figure 79: MS Access form used to input project information

A standard set of keywords were developed and assigned to each project. These keywords are presented in Table 55.

Table 54: Standard keywords used for project descriptions

Project Goals *(NRRSS, 2005)*

Aesthetics, Recreation, Education
Bank Stabilization
Channel Reconfiguration
Dam Removal/Retrofit
Fish Passage
Floodplain Reconnection
Flow Modification
In-Stream Habitat Improvement
In-Stream Species Management
Land Acquisition
Livestock Management
Riparian Management
Stormwater Management
Water Quality Management

Physical Structures

Barb
Barrier Fence
Boulder Clusters
Boulder Rip-Rap
Brush Layering
Check Dams
Coconut Fiber Rolls
Culverts
Daylighting
Fish Ladders/Screens
Fish Passage
Floodwalls
Gabions
Grade Control Structure
Gravel Augmentation
Jetty
Levees
Migration Barriers
Pool-Riffle Sequence
Riffle Starter
Rock Weirs/Sills
Root Wad
Sand Bars
Spur
Step Pools
Stone Toe Protection
Tree/Log Revetments
Wing Deflector

Public Interaction

Brochures
Fact Sheet
Federal Register
Focus Groups
Information Signs
Internet Website
Interviews
News Releases
Newsletters
Public Hearings
Public Meetings
Radio/TV Announcements
Referendums
Report Summaries
Review Groups
Surveys
Task Forces
Telephone Hotlines
Training Seminars
Workshops

Biological

Brush Mattress
Live Cribwalls
Live Fascine Bundles
Live Stakes
Log Barbs
Native Vegetation Planting
Tree Revetments
Vegetated Gabions
Vegetated Geogrids
Wattles
Willow Cuttings
Willow Mats
Willow Walls

PPA Methods/Monitoring

Adaptive Management
Aerial Photographs
BMI Survey
Cross Sections
Features Mapping
Fish Passage Monitoring
Long Profile
Monitoring Plan
Pebble Count
Photo Documentation
Sediment Transport
Standards of Success
Stream gauge
Terrestrial LiDAR
Vegetation Survey
Water Quality Testing

Waterbody Management

Dredging
Livestock Management
Maintenance of Hydraulic Connections
Riparian Buffer
Sediment Basins
Sediment Flushing
Stormwater Management
Stream Meander Construction
Water Level Control
Sediment Management
Vegetation Management

Once the projects were entered into the MS Access database, a master folder was created where all project-specific information was stored (Figure 80). Each project then has an index folder, which summarizes all the available information on the project (Figure 81). Documentation developed for each project is placed in the 'Documents' folder and organized by life-cycle stage (Figure 82).

An HTML template was developed by Jen Natali (graduate student in the Landscape, Architecture, and Environmental Planning Department) to convert the project information into a web-based interface where river restoration practitioners can access the information (Figure 83).

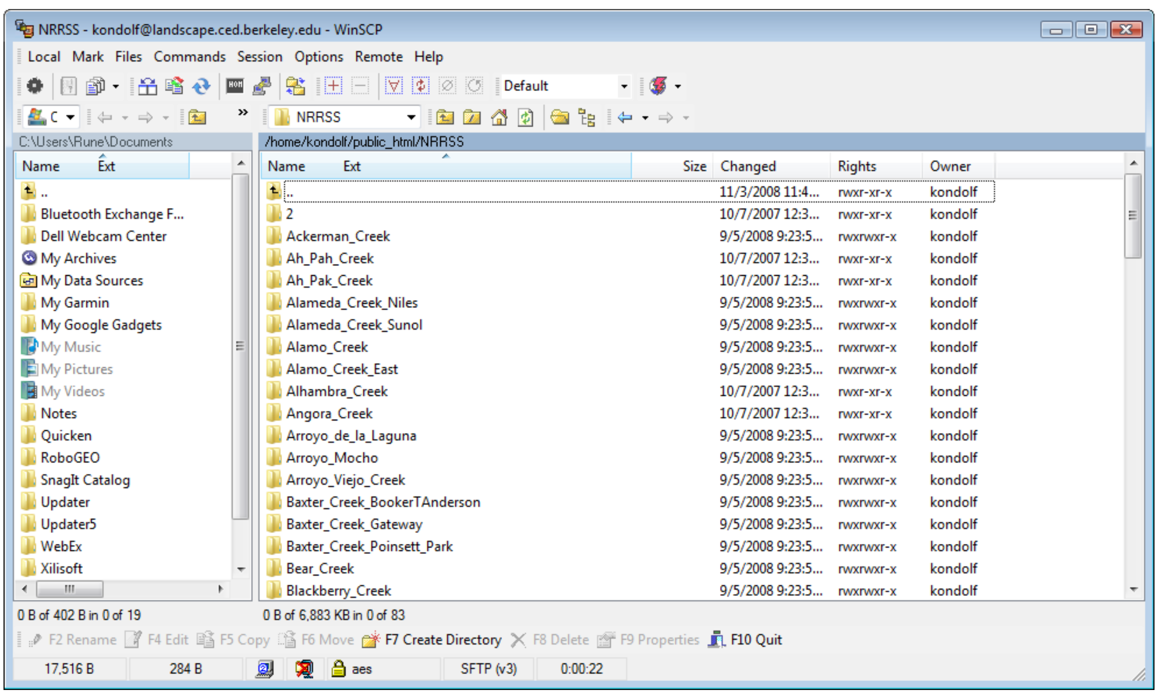

Figure 80: Individual information folders were created for each project.

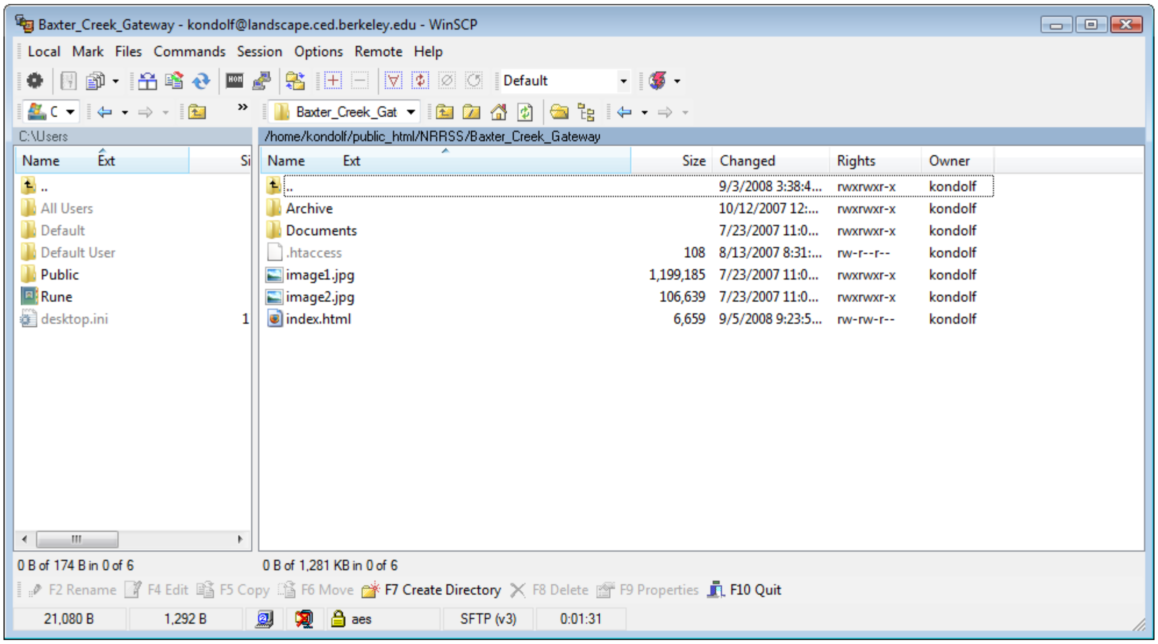

Figure 81: Each project has a folder to summarize information developed for each of the life-cycle stages ('Documents' folder).

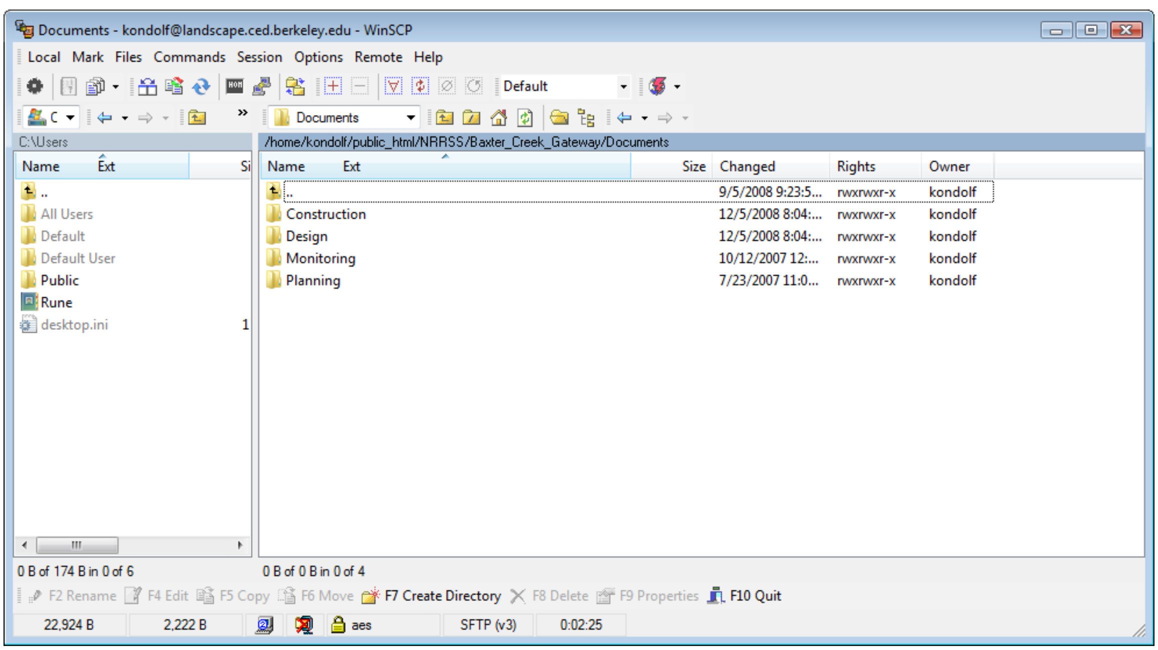

Figure 82: Within the 'Documents' folder, applicable life-cycle stage information is archived.

	%%image1%%	!!Project_Name!! Post Project Appraisal
	Year Completed	!!Construction_End!!
	Project Cost	!!Cost_Total!!
	Nearest Town	!!Nearest_Town!!
	County	!!County!!
	Waterway	!!Waterway_Name!!
	Watershed	!!Watershed_Name!!
	USGS Catalogue Number	!!USGS Cataloging Unit!!
	Long/Lat	!!Longitude!! N !!Latitude!! W
	Drainage Area	!!Drainage_Area!! km2
	Annual Precipitation	!!Annual_Percipitation!! cm
	Restored Length	!!Restoration_Length!! m
	Annual Discharge	Q1 !!Q1!! m3/s Q5 !!Q5!! m3/s Q10 !!Q10!! m3/s Q100 !!Q100!! m3/s Q200 !!Q200!! m3/s
	Project Goals	!!Project_Goals!!
	Funders	!!Funding_Sources!!
	Participants	!!Participant_01!! !!Participant_02!! !!Participant_03!! !!Participant_04!! !!Participant_05!! !!Participant_06!! !!Participant_07!! !!Participant_08!! !!Participant_09!! !!Participant_10!!
	%%image2%%	%%Documents%%

Figure 83: HTML template for the website project summary sheet.

6.2 Database Interface

The primary interface (Figure 84) to the database was constructed using Mapbuilder (www.mapbuilder.net) a free web-based program to create 'zoomable' maps (based on Google Earth) with hyperlinked markers (corresponding to each project location). This allows river restoration practitioners to visually search for projects located in a geographic area of interest. Future developments will include the ability to search for projects with keywords, allowing practitioners to see all projects that match their search criteria in a geographic region (such as all projects with large woody debris (LWD) structures).

The site is available at: http://landscape.ced.berkeley.edu/~kondolf/NRRSS/

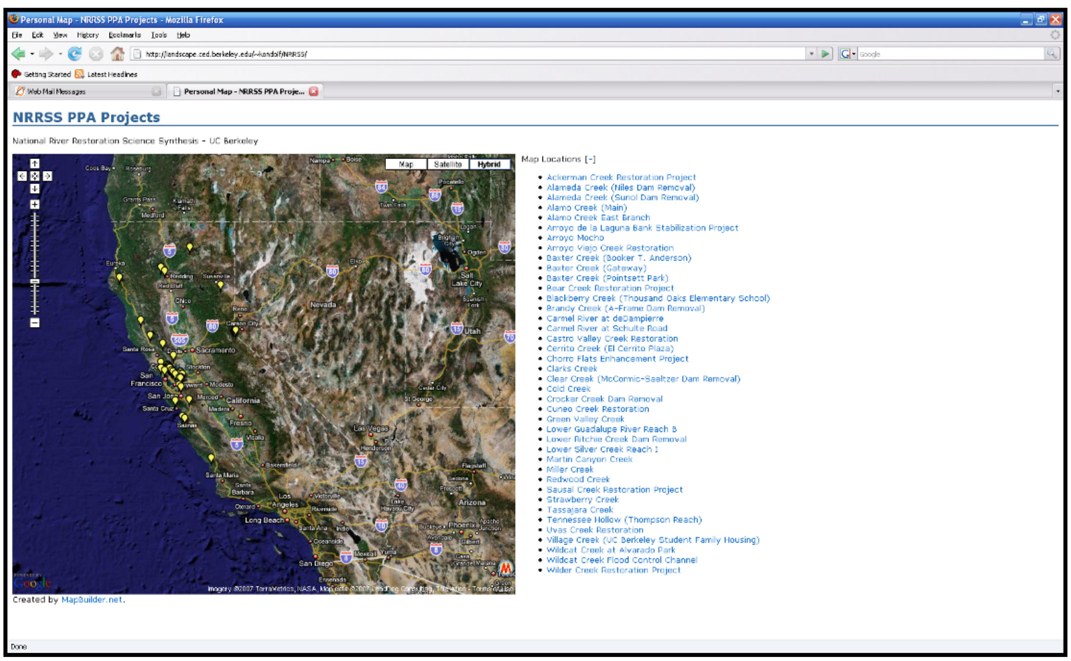

Figure 84: An overview map of all 40 NRRSS PPA projects in California.

Information associated for each project can be obtained by clicking on the project name in the “Map Locations” list, or by zooming in on the map and clicking on the appropriate project marker (Figure 85).

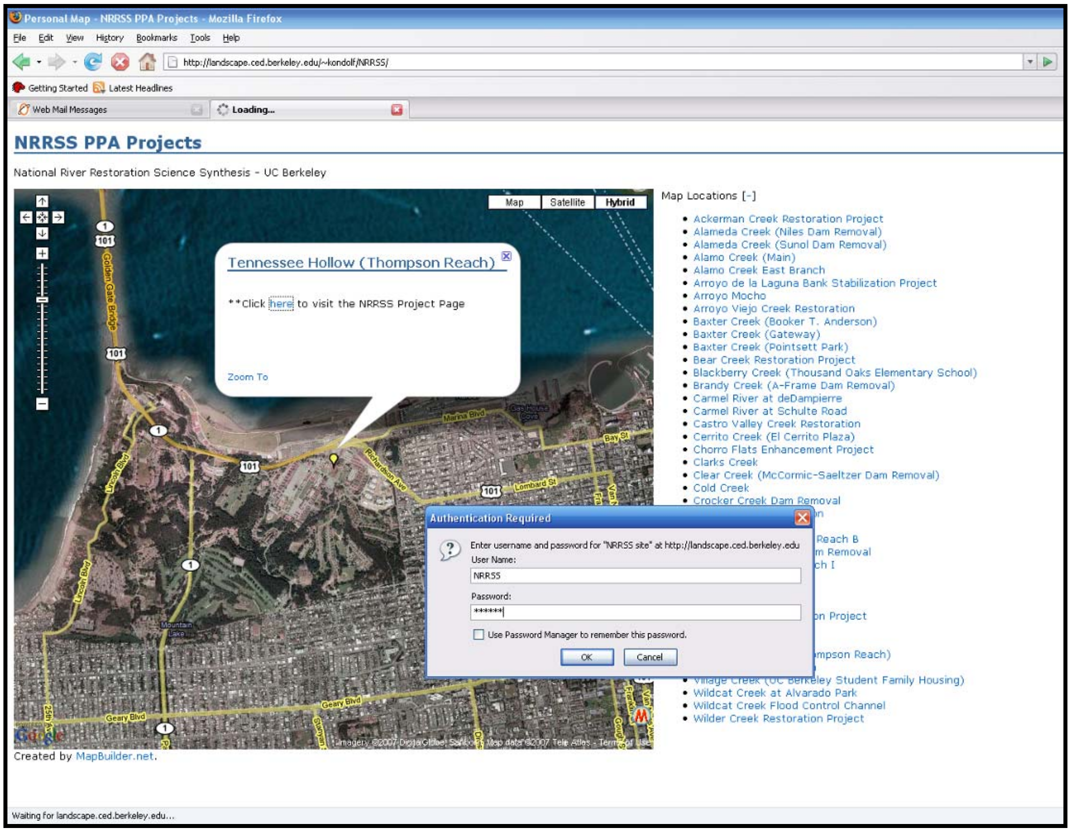

Figure 85: Project-specific information can be obtained by clicking on the project marker.

Once the project marker has been clicked, a dialog box opens up with a link to the project summary page (generated based on the HTML template developed by Ms. Natali). For those projects where permission from the project sponsors, planners, and designers has not yet been obtained (or there is sensitive project information), a password is required for access.

Once the project-specific page has been accessed, some basic overview information is presented (year completed, project cost, watershed, etc.), as well as a listing of all available information/documents, organized by life-cycle phase. Individual documents can be accessed by clicking on the hyperlink (Figure 86).

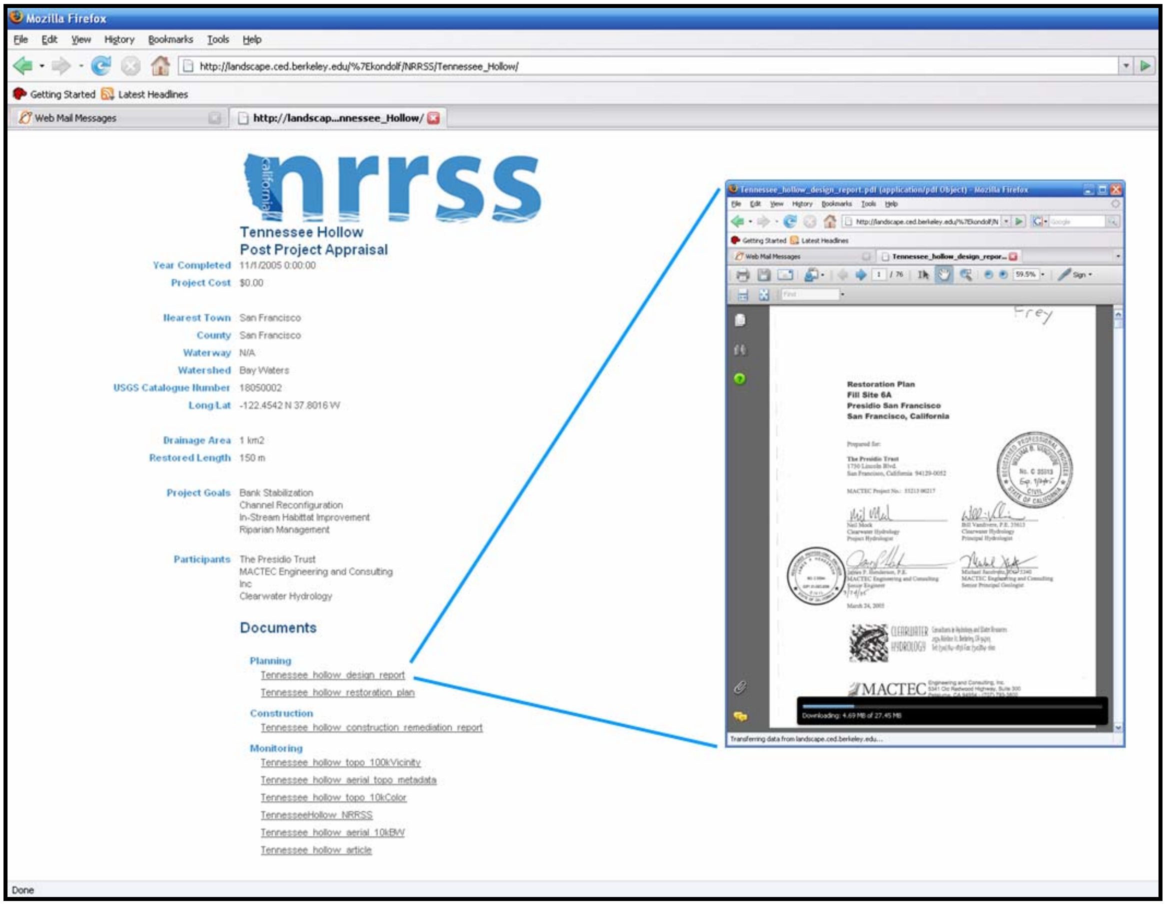

Figure 86: Documents can be accessed by clicking on the hyperlink.

6.3 Database Future Developments

Future developments for this database include incorporating this model with an existing database that is currently known in the industry and has a high rate of participation. Existing databases such as the Natural Resource Project Inventory (NRPI; http://www.ice.ucdavis.edu/nrpi/).

Significant more effort is required to capture all project related documentation, throughout all the life-cycle phases, synthesizing these documents into one location, and making this information base available to the river restoration community.

Further improvements such as enabling searches based on keywords, document type, etc will further improve the quality of the river restoration database.

Chapter Seven

7 FUTURE WORK

Due to the extremely broad-scale and far-reaching nature of the problem addressed in this research, it was not possible to comprehensively address all aspects in great detail. The primary focus was to identify, by restoration goal, which parameters need to be evaluated. A complete and comprehensive list of parameters then sets the stage for the types of information that is collected during the planning, design, construction, and operational phases of the project. If all the relevant problem parameters are not defined, then it becomes highly likely that key aspects will be omitted and the quality and value of the partial information greatly degrades the learning opportunity.

The following is a list of topics for future consideration. They are presented in no particular order.

7.1 National River Restoration TDS Development

This research effort outlined some of the organizations involved in river restoration. There are many more organizations, especially in the private sector. The impacts of the Executive and Judicial Branches were not accounted for in this research. Development of a river restoration Technology Delivery system allows for a blueprint to be created from which individual state TDS contributions can be input and inter-relationships mapped. Since many rivers traverse multiple states, it is crucial to link these different geographic regions into one TDS in order to evaluate the entire reach of the river being studied.

7.1.1 California River Restoration TDS Refinement

An initial beginning of the California river restoration TDS has been constructed in this research, but significantly more development is required (as discussed above). By developing a State of California river restoration TDS, a blueprint can be developed for use as a TDS development template in other states. Clearly, each state has specific and individual nuances, but the general approach can be used as a guide.

7.2 Monitoring

Complete and comprehensive monitoring of river restoration projects are an essential component required to advance the state of the practice. With the development of the Restoration Evaluation Checklist, key evaluation parameters have been identified. These parameters need to be addressed by all restoration projects and expected performance must be explicitly defined for all projects in all areas. This explicit definition becomes the basis by which results of monitoring will be compared and lessons learned used to update and improve the state of the practice. These monitoring efforts will include implementation, effectiveness, and validation.

7.2.1 Implementation Monitoring

Implementation monitoring occurs immediately following completion of the project. Based on Kondolf et al (*2007*), fewer than 40% of all projects reviewed conducted any sort of implementation monitoring. This type of monitoring should be conducted on all projects and serves as the baseline condition from which any and all future monitoring will be based.

7.2.2 Effectiveness Monitoring

Effectiveness monitoring evaluates the expected performance of the project compared with the actual performance of the project. Effectiveness monitoring tends to be project-specific. The durations of effectiveness monitoring vary from one year to as many as ten years, but these common durations may not always be fully appropriate. For example, if a project is designed for the 100-year flood, it may take more than 10 years for the design flood to occur. Until the 100-year flood occurs, it is debatable if the 'effectiveness' of the project has been fully evaluated. However, it is possible to evaluate the impacts of more frequent storms (10-, 25-, 50-year) and extrapolate the trend and estimate performance. This approach to effectiveness monitoring is rarely employed and needs significantly more activity in order to advance the state of the practice.

7.2.3 Validation Monitoring

Validation monitoring pertains to the methods, approaches, techniques, formulas, etc that constitute the practice of river restoration. Due to the temporal and spatial scales of these projects, it is very difficult to conduct laboratory, or small-scale tests, to evaluate the validity of these methods. By aggregating the effectiveness monitoring results from many different restoration projects completed in different geographic regions of the U.S. and with a range of operational time frames, a rigorous evaluation and validation of the river restoration methods and techniques is currently lacking.

7.3 Life-Cycle River Restoration Case Studies Archiving (web)

There are many online databases for river restoration information. Very few of these databases provide complete and comprehensive information related to the planning, design, construction, and operations (monitoring) of these projects. An example of a life-cycle river restoration case study archive was presented in Chapter 6, but the essential component of any database is population with content. As a community, river restoration practitioners need to establish and actively contribute to populating one central database from which everyone can share their experiences and learn from others.

7.4 River Restoration Component Performance Characteristics

To date there are no river restoration component performance characteristics for elements used in river restoration. For example, what is the success rate (or time to failure) of brush layering (a bank stabilization technique) as compared with willow staking. Cataloging these component performance characteristics can only occur as a result of effectiveness monitoring where the expected performance and associated design assumptions are explicitly stated and made available during the effectiveness validation monitoring.

7.5 Comprehensive River Restoration Best Practices Cost Index

Similar to the component performance characteristics, obtaining regional cost information related to river restoration best practices can help planners and designers configure projects with more reliable (and feasible) budgets. Projects can be configured to explicitly take into consideration component costs and associated anticipated performance, allowing the project developers to balance project costs with desired performance. To date, very little comprehensive cost information is available to the river restoration practitioner, mostly due to the fact that the anticipated (and more importantly, actual) project budgets have not been captured, archived, and made accessible to practitioners.

7.6 References

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Chapter Eight

8 SUMMARY AND CONCLUSIONS

8.1 Summary

In 2005, the National River Restoration Science Synthesis (NRRSS) working group released the results of a multi-year study of the motivations and subsequent performance of completed river restoration projects within the United States. Through the development of a comprehensive database (with over 37,000 entries), the study found that although over $1 billion (and this was judged to be a very conservative figure) is spent on restoration projects each year, the overwhelming majority of these projects do not have explicit success criteria and even fewer projects have post-construction validation to ensure that the intended project goals are being achieved (*Bernhardt et al, 2005*). In the few cases where systematic project assessment and monitoring was performed, it was found that more than half the projects failed to meet the intended goals and design criteria (*Kondolf and Downs, 2004*).

It has been the experience of the author that the two primary reasons for failure of river restoration projects has been the (1) omission of key restoration evaluations (such as estimated river discharges, vegetation survival and growth rates, and construction and maintenance costs) and (2) lack of incorporation of 'uncertainties' in the planning and design of river restoration projects. Simple techniques (such as utilizing high, expected, and low bounds) exist to identify and manage uncertainty, however, these techniques are rarely (if ever) used.

This dissertation synthesizes the current interdisciplinary river restoration body of knowledge and classifies by goal/intent categories to create a planning and design tool that will aid in configuring successful river restoration projects. My evaluation of river restoration includes the entire life-cycle of the projects.

Specific contributions this dissertation adds to the river restoration community include:

- A validated Restoration Evaluation Checklist for planning and design to correlate minimum project requirements with intended restoration goals. Requirements include regulations/laws, physical, chemical, biological, and ecological factors. Restoration requires combinations of these requirements, thus the checklist format allows for management of complexity associated with specific goals. The matrix covers the entire life cycle of restoration projects;
- A validated matrix that synthesizes available resources (technical manuals, computer programs, data, etc.) by intended project goals to optimize implementation of 'state of the practice' resources throughout all aspects of the restoration process (regulations/laws, physical, chemical, biological, and ecological);
- Complex systems based perspective that synthesizes the disparate disciplines associated with river restoration into one comprehensive

framework that encapsulates all life cycle phases of river restoration projects (planning, design, construction, operations/monitoring, requalification, and decommissioning) to enable practice-based adaptive management and organizational learning;

- Identification of complex systems characterization and modeling approaches and methods (i.e. Synthesis, Classification, Modes of Inquiry, Diamond Model, Geographical Information Systems, etc.) for application to river restoration projects to facilitate both qualitative and quantitative reliability and risk-based planning and design;
- Development of case study examples that demonstrate application of reliability-based design that explicitly accounts for uncertainty in project data and anticipated project performance. It was demonstrated how identified uncertainty during the planning and design phases can be used to configure a monitoring and adaptive management program. These case study examples also highlight the critical nature of evaluating a project over its full projected life, instead of just after construction.
- Presentation of river restoration as a Technology Delivery System requiring cooperation between the Public, Industry, and Government in order to achieve restoration success;
- Development of a comprehensive river restoration glossary merging terminology from major Federal (EPA, USACE, USBR, USGS, USFWS, etc.) organizations;

- Development of a detailed overview of Federal and State of California organizations associated with river restoration, their general history and current activities related to river restoration;
- Compilation of 41 Post Project Appraisals and associated planning, design, construction, and monitoring data; and
- Facilitation of an online database of NRRSS Post Project Appraisals completed in California that allows users the ability to access the available original project related data generated during the planning, design, construction, and monitoring phases.

The developed Restoration Evaluation Checklist and Resource Matrix were validated using case studies and a guarantor/heuristics (review and critique from river restoration technical experts).

8.2 Conclusions

There are many active river restoration projects in the United States, but a large majority of these projects are developed outside the watershed context, do not account for uncertainty, and are commonly inadequately configured. Furthermore, the quality of the documentation is poor and there are few efforts to capture, catalog, and archive these documents for later learning opportunities.

Most surprising is the uniform lack of project validation. Few funding agencies require contractors to submit 'as-built' documentation that confirms the specified work was constructed to expectations, and follow up validation (through monitoring) to ensure that the design methods and procedures accurately resolved the problem is even more infrequent. River restoration appears to be more a function of good intentions, as opposed to real improvement.

This dissertation synthesized that reliable river restoration projects require:

1) Complete and comprehensive problem characterization
    a. Restoration Evaluation Checklist
    b. Resources Matrix
2) Projects need to be examined from a Life-Cycle perspective
3) Track uncertainties
    a. Manage uncertainties through Adaptive Management
4) Validate that the implemented solution remedies the problem
    a. Implementation monitoring
    b. Effectiveness monitoring
    c. Validation monitoring
5) Contribute to the river restoration Body of Knowledge (TDS)

There is a lot of work to do, however it is possible to immediately start with the following:

- All projects must be situated within a watershed context
- Complete comprehensive characterization (Table 13)
- Acknowledge and incorporate uncertainties
- Validate project performance
- Complete documentation and archive for future access

8.3 References

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GLOSSARY

A

Abandoned Well	A well whose use has been permanently discontinued or which is in a state of such disrepair that it cannot be used for its intended purpose.	*EPA, 2008b*
Abatement	Reducing the degree or intensity of, or eliminating, pollution.	*EPA, 2008b*
Abatement	Reducing the degree or intensity of, or eliminating, pollution.	*USACE, 1999*
Abatement debris	Waste from remediation activities.	*EPA, 2008b*
Aberrant	Atypical, departing from the normal type or structure.	*USBR, 2008*
Abiotic	The absence of living organisms.	*USBR, 2008*
Ablation	The process by which ice and snow waste away as a result of melting and/or evaporation.	*USACE, 1999*
Abrasion	Wearing away of surfaces by friction.	*USBR, 2008*
Absolute pressure	Atmospheric pressure plus gauge pressure.	*USBR, 2008*
Absorbed dose	In exposure assessment, the amount of a substance that penetrates an exposed organism's absorption barriers (e.g. skin, lung tissue, gastrointestinal tract) through physical or biological processes. The term is synonymous with internal dose.	*EPA, 2008b*
Absorbed dose	The amount of a chemical that enters the body of an exposed organism.	*USBR, 2008*
Absorbed water	Water held mechanically in a soil or rock mass and having physical properties not substantially different from ordinary water at the same temperature and pressure. See adsorbed water.	*USBR, 2008*
Absorption	The uptake of water , other fluids, or dissolved chemicals by a cell or an organism (as tree roots absorb dissolved nutrients in soil).	*EPA, 2008b*
Absorption	Taking in of fluids or other substances through, or as if through, cells or tissues. The uptake of water or dissolved chemicals by a cell or an organism (as tree roots absorb dissolved nutrients in the soil). Should not be confused with adsorption.	*USBR, 2008*
Absorption barrier	Any of the exchange sites of the body that permit uptake of various substances at different rates (e.g. skin, lung tissue, and gastrointestinal-tract wall).	*EPA, 2008b*
Absorption factor	The fraction of a chemical making contact with an organism that is absorbed by the organism.	*USBR, 2008*
Abutment	That part of the valley wall against which the dam is constructed. The part of a dam that contacts the riverbank. A structure that supports the ends of a dam or bridge. An artificial abutment is sometimes constructed, as a concrete gravity section, to take the thrust of an arch dam where there is no suitable natural abutment. Action or place of abutting; the part of a structure that is the terminal point or receives thrust or pressure. Defined in terms of left and right as looking away from the reservoir, looking downstream (i.e., left abutment, right abutment).	*USBR, 2008*

Acceleration	In terms of flow, acceleration is the time rate of change of the velocity vector, either of magnitude or direction or both.	*USBR, 2008*
Accelerogram	The record from an accelerometer showing acceleration as a function of time.	*USBR, 2008*
Acceptable daily intake (ADI)	Estimate of the largest amount of a chemical to which a person can be exposed on a daily basis that is not anticipated to result in adverse effects (usually expressed in mg/kg/day). The daily exposure level which, during an entire lifetime of a human, appears to be without appreciable risk on the basis of all facts known at the time. See RFD.	*USBR, 2008*
Access charge	A charge levied on a power supplied, or its customer, for access to a utility's transmission or distribution system. It is a charge for the right to send electricity over another's wires.	*USBR, 2008*
Access control point	A location staffed to restrict entry of unauthorized personnel into a risk area during emergency and/or disaster events. Access control is normally performed just outside of the risk area and involves use of vehicles, barricades, or other measures to deny access to a particular area.	*USBR, 2008*
Access shaft	Concrete portion of an outlet works between the shaft house and the gate chamber. The access shaft provides vertical access to the gates.	*USBR, 2008*
Accident assessment	The evaluation of the nature, severity, and impact of an accident. Dam operating personnel are primarily responsible for accident assessment for incidents at Reclamation dams.	*USBR, 2008*
Accident site	The location of an unexpected occurrence, failure or loss, either at a plant or along a transportation route, resulting in a release of hazardous materials.	*EPA, 2008b*
Acclimation	Adjustment of an organism to a new habitat or environment.	*USBR, 2008*
Acclimatization	The physiological and behavioral adjustments of an organism to changes in its environment.	*EPA, 2008b*
Accrete	To add new material gradually to pre-existing material; opposite of erode.	*CCC, 2008*
Accretion	Process of growth whereby material is added to the outside of nonliving matter. The gradual increase in flow of a stream attributable to seepage, ground water discharge, or tributary inflow.	*USBR, 2008*
Accretion	Enlargement of a beach area caused by either natural or artificial means. Natural accretion on a beach is the build-up or deposition of sand or sediments by water or wind. Artificial accretion is a similar build-up due to human activity, such as the accretion due to the construction of a groin or breakwater, or beach fill deposited by mechanical means.	*CCC, 2008*
Accuracy	How closely an instrument measures the true or actual value of the process variable being measured or sensed.	*USBR, 2008*
Acid	A corrosive solution with a pH less than 7.	*EPA, 2008b*
Acid	A substance that has a pH value between 0 and 7. ACID - Anderson-Cottonwood Irrigation District.	*USBR, 2008*

Acid deposition	A complex chemical and atmospheric phenomenon that occurs when emissions of sulfur and nitrogen compounds and other substances are transformed by chemical processes in the atmosphere, often far from the original sources, and then deposited on earth in either wet or dry form. The wet forms, popularly called "acid rain," can fall to earth as rain, snow, or fog. The dry forms are acidic gases or particulates.	*EPA, 2008b*
Acid mine drainage	Drainage of water from areas that have been mined for coal or other mineral ores. The water has a low pH because of its contact with sulfur-bearing material and is harmful to aquatic organisms.	*EPA, 2008b*
Acid mine drainage (AMD	Water draining out of operating or abandoned mines that has very low pH and may contain high concentrations of various metals and/or sulfur.	*DOC, 2005*
Acid rain	Rainfall with a pH of less than 7.0. Long-term deposition of these acids is linked to adverse effects on aquatic organisms and plant life in areas with poor neutralization (buffering) capacity.	*USACE, 1999*
Acid rain	Precipitation which has been rendered acidic by airborne pollutants.	*USBR, 2008*
Acidic	The condition of water or soil that contains a sufficient amount of acid substances to lower the pH below 7.0.	*EPA, 2008b*
Acidic	The condition of water or soil in which the amount of acid substances are sufficient to lower the pH below 7.0.	*USACE, 1999*
Acidic	The condition of water or soil which contains a sufficient amount of acid substances to lower the pH below 7.0.	*USBR, 2008*
Acidified	The addition of an acid (usually nitric or sulfuric) to a sample to lower the pH below 2.0.	*USBR, 2008*
ACR	Alkali carbonate reaction.	*USBR, 2008*
Acre	A measure of an area equivalent to 43,560 ft2 (4,046.87 m2). One square mile equals 640 acres.	*USACE, 1999*
Acre (ac)	Unit for measuring land, equal to 43,560 sq. ft., 4840 sq. yds., or 160 sq. rds.	*USBR, 2008*
Acre-foot	A volume of water equal to 1 foot in depth and covering 1 acre; equivalent to 43,560 cubic feet or 325,851 gallons.	*USGS, 2008*
Acre-foot (ac-ft)	A term used in measuring the volume or amount of water needed to cover 1 acre (43,560 square feet) 1 foot deep (325,851 gallons or 1,233.5 cubic meters).	*USBR, 2008*
Acre-foot (af)	A quantity or volume of water covering 1 acre to a depth of 1 ft; equal to 43,560 ft3 or 325,581 gal.	*USACE, 1999*
ACRM	Assistant Commissioner-Resources Management.	*USBR, 2008*
Action	An activity or program of any kind authorized, funded, or carried out, in whole or in part, by a Federal agency in the United States or upon the high seas, such as: (a) an action intended to conserve listed species or their habitat; (b) the promulgation of a regulation; (c) the granting of a license, contract, lease, easement, right-of-way, permit, or grant-in-aid; or (d) an action directly or indirectly causing modification to the land, water, or air.	*USFWS, 2008*
Action area	All areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action.	*USFWS, 2008*

Action levels	1. Regulatory levels recommended by EPA for enforcement by FDA and USDA when pesticide residues occur in food or feed commodities for reasons other than the direct application of the pesticide. As opposed to "tolerances" which are established for residues occurring as a direct result of proper usage, action levels are set for inadvertent residues resulting from previous legal use or accidental contamination. 2. In the Superfund program, the existence of a contaminant concentration in the environment high enough to warrant action or trigger a response under SARA and the National Oil and Hazardous Substances Contingency Plan. The term is also used in other regulatory programs.	*EPA, 2008b*
Activated carbon	Adsorptive particles or granules of carbon usually obtained by heating carbon (such as wood). These particles or granules have a high capacity to selectively remove certain trace and soluble materials from water.	*USBR, 2008*
Active capacity	The reservoir capacity normally usable for storage and regulation of reservoir inflows to meet established reservoir operating requirements. It extends from the highest of either the top of exclusive flood control capacity, the top of joint use capacity, or the top of active conservation capacity, to the top of inactive capacity. It is also the total capacity less the sum of the inactive and dead capacities. The reservoir capacity that can be used for irrigation, power, municipal and industrial use, fish and wildlife, recreation, water quality, and other purposes.	*USBR, 2008*
Active conservation capacity (active storage)	The reservoir capacity assigned to regulate reservoir inflow for irrigation, power, municipal and industrial use, fish and wildlife, navigation, recreation, water quality, and other purposes. It does not include exclusive flood control or joint use capacity. It extends from the top of the active conservation capacity to the top of the inactive capacity (or dead capacity where there is no inactive capacity).	*USBR, 2008*
Active earth pressure	The minimum value of earth pressure. This condition exists when a soil mass is permitted to yield sufficiently to cause its internal shearing resistance along a potential failure surface to be completely mobilized.	*USBR, 2008*
Active fault	A fault which, because of its present tectonic setting, can undergo movement from time to time in the immediate geologic future. A fault, which has moved during the recent geologic past (Quarternary) and, thus, may move again. It may or may not generate earthquakes. See capable fault.	*USBR, 2008*
Active storage capacity	The total usable reservoir capacity available for seasonal or cyclic water storage. It is gross reservoir capacity minus inactive storage capacity.	*USACE, 1999*
Active transport	An energy-expending mechanism by which a cell moves a chemical across the cell membrane from a point of lower concentration to a point of higher concentration, against the diffusion gradient.	*USBR, 2008*
Activity	The ratio of the plasticity index to the percent by dry mass of soil particles finer than 0.002 mm (2 microns) in size.	*USBR, 2008*
ACTS	Action Correspondence Tracking System.	*USBR, 2008*

Acute	Occurring over a short period of time; used to describe brief exposures and effects which appear promptly after exposure.	*USBR, 2008*
Acute effect	An adverse effect on any living organism which results in severe symptoms that develop rapidly; symptoms often subside after the exposure stops.	*EPA, 2008b*
Acute exposure	A single exposure to a toxic substance which may result in severe biological harm or death. Acute exposures are usually characterized as lasting no longer than a day, as compared to longer, continuing exposure over a period of time.	*EPA, 2008b*
Acute exposure	A single exposure to a toxic substance which results in severe biological harm or death. Acute exposures are usually characterized as lasting no longer than a day.	*USBR, 2008*
Acute toxicity	The ability of a substance to cause poisonous effects resulting in severe biological harm or death soon after a single exposure or dose. Also, any severe poisonous effect resulting from a single short-term exposure to a toxic substance.	*USBR, 2008*
ACWA	Association of California Water Agencies.	*USBR, 2008*
Adaptation	Changes in an organism's physiological structure or function or habits that allow it to survive in new surroundings.	*EPA, 2008b*
Adaptation	Adjustment to environmental conditions.	*USBR, 2008*
Adaptive management	The process of establishing checkpoints to determine whether proper actions have been taken and are effective in providing the desired results. Provides the opportunity for 'course correction' through evaluation and action. The implementation, effectiveness, and validation components of performance monitoring provide a vehicle to determine the need for adaptive management.	*FISHWR, 2001*
Adaptive management	Approach where source controls are initiated while additional monitoring data are collected to provide a basis for future review and revision of the TMDL (as well as management activities).	*EPA, 2008c*
Adaptive management	Monitoring or assessing the progress toward meeting management objectives and incorporating what is learned into future conceptual models, management plans and actions, and monitoring.	*DOC, 2005*
Additive effect	Combined effect of two or more chemicals equal to the sum of their individual effects.	*USBR, 2008*
Adhesion	Shearing resistance between soil and another material under zero externally applied pressure.	*USBR, 2008*
ADI	acceptable daily intake.	*USBR, 2008*
Adit	A nearly horizontal underground excavation in an abutment having an opening in only one end. An opening in the face of a dam for access to galleries or operating chambers.	*USBR, 2008*
Administrative order	A legal document signed by EPA directing an individual, business, or other entity to take corrective action or refrain from an activity. It describes the violations and actions to be taken, and can be enforced in court. Such orders may be issued, for example, as a result of an administrative complaint whereby the respondent is ordered to pay a penalty for violations of a statute.	*EPA, 2008b*

Administrative order on consent	A legal agreement signed by EPA and an individual, business, or other entity through which the violator agrees to pay for correction of violations, take the required corrective or cleanup actions, or refrain from an activity. It describes the actions to be taken, may be subject to a comment period, applies to civil actions, and can be enforced in court.	*EPA, 2008b*
Administrative procedures act	A law that spells out procedures and requirements related to the promulgation of regulations.	*EPA, 2008b*
Administrative record	All documents which EPA considered or relied on in selecting the response action at a Superfund site, culminating in the record of decision for remedial action or, an action memorandum for removal actions.	*EPA, 2008b*
Adsorbate	The material being removed by the adsorption process.	*USBR, 2008*
Adsorbed water	Water in a soil or rock mass, held by physico-chemical forces, having physical properties substantially different from absorbed water or chemically combined water, at the same temperature and pressure.	*USBR, 2008*
Adsorbent	The material (for example activated carbon) that is responsible for removing the undesirable substance in the adsorption process.	*USBR, 2008*
Adsorption	Removal of a pollutant from air or water by collecting the pollutant on the surface of a solid material; e.g., an advanced method of treating waste in which activated carbon removes organic matter from waste-water.	*EPA, 2008b*
Adsorption	The process by which chemicals are held on the surface of a mineral or soil particle. The adherence of a gas, liquid, or dissolved material on the surface of a solid. An increase in concentration of gas or solute at the interface of a two-phase system. Should not be confused with absorption.	*USBR, 2008*
Advanced Decision Support System (ADSS)	Computer software designed to provide easy access to and allow efficient use of methods of analysis and information management.	*USBR, 2008*
Advisory	A non-regulatory document that communicates risk information to those who may have to make risk management decisions.	*EPA, 2008b*
Advisory Council on Historic Preservation (ACHP)	Executive agency responsible for ensuring requirements of National Historic Preservation Act and 36 CFR Part 800 are met. Visit the Advisory Council on Historic Preservation web site.	*USBR, 2008*
AEB	Elephant Butte Power and Storage Division (Truth or Consequences, NM).	*USBR, 2008*
Aeolian (eolian)	Materials carried, deposited, produced, or eroded by the wind.	*USBR, 2008*
Aeolian deposits	Wind-deposited material such as dune sands and loess deposits.	*USBR, 2008*
Aeolian transport	Movement of sediment by the wind. Aeolian sediments have a greater angularity of the grains, compared with waterborne particle.	*CCC, 2008*
Aerate	To impregnate with gas, usually air.	*USBR, 2008*
Aeration	A process which promotes biological degradation of organic matter in water. The process may be passive (as when waste is exposed to air), or active (as when a mixing or bubbling device introduces the air).	*EPA, 2008b*

Aeration	Any active or passive process by which intimate contact between air and liquid is assured, generally by spraying liquid in the air, bubbling air through water, or mechanical agitation of the liquid to promote surface absorption of air.	*USACE, 1999*
Aeration	The process of adding air to water by either passing air through water or passing water through air.	*USBR, 2008*
Aerial cover	Ground area circumscribed by the perimeter of the branches and leaves of a given plant or group of plants (generally used as a measure of relative density).	*USBR, 2008*
Aerobic	Life or processes that require, or are not destroyed by, the presence of oxygen.	*EPA, 2008b*
Aerobic	Characterizing organisms able to live only in the presence of air or free oxygen, and conditions that exist only in the presence of air or free oxygen. Contrast with anaerobic.	*USACE, 1999*
Aerobic	A condition in which free (atmospheric) or dissolved oxygen is present in water. The opposite of anaerobic.	*USBR, 2008*
Aesthetics/recreation /education	Activities that increase community value: use, appearance, access, safety, knowledge.	*NRRSS, 2005*
Affected environment	Existing biological, physical, social, and economic conditions of an area subject to change, both directly and indirectly, as the result of a proposed human action. Also, the chapter in an environmental impact statement describing current environmental conditions.	*USBR, 2008*
Affluent (stream)	A stream or river that flows into a larger one; a tributary.	*USACE, 1999*
AFO	Auburn-Folsom Office (Auburn, CA).	*USBR, 2008*
AFRP	Anadromous Fish Restoration Program.	*USBR, 2008*
Afterbay	A reservoir that regulates fluctuating discharges from a hydroelectric power plant or a pumping plant.	*USACE, 1999*
Afterbay (tailrace)	The body of water immediately downstream from a powerplant or pumping plant. A reservoir or pool that regulates fluctuating discharges from a hydroelectric power plant or a pumping plant.	*USBR, 2008*
Afterbay dam (reregulating dam)	A dam located downstream from a large hydroelectric powerplant used to regulate discharges downstream. See regulating dam.	*USBR, 2008*
Age tank (day tank)	A tank used to store a chemical solution of known concentration for feed to a chemical feeder.	*USBR, 2008*
Agent	Any physical, chemical, or biological entity that can be harmful to an organism (synonymous with stressors.)	*EPA, 2008b*
Aggradation	A progressive buildup or raising of the channel bed and floodplain due to sediment deposition. The geologic process by which streambeds are raised in elevation and floodplains are formed. Aggradation indicates that stream discharge and/or bed-load characteristics are changing. Opposite degradation.	*USACE, 1999*
Aggradation	To fill and raise the level of the bed of a stream by deposition of sediment.	*USFS, 2002*
Aggradation	The raising of the bed of a watercourse by the deposition of sediment.	*EPA, 2008c*
Aggradation	Geologic process wherein streambeds, floodplains, sandbars, and the bottom of water bodies are raised in elevation by the deposition of sediment; the opposite of degradation.	*USBR, 2008*

Aggregate	Crushed rock or gravel screened to sizes for use in road surfaces, concrete, or bituminous mixes. A mass or cluster of soil particles, often having a characteristic shape.	*USBR, 2008*
Agricultural drainage	The process of directing excess water away from root zones by natural or artificial means, such as by using a system of pipes and drains placed below ground surface level (also called subsurface drainage). The water drained away from irrigated farmland.	*USBR, 2008*
Agricultural pollution	Farming wastes, including runoff and leaching of pesticides and fertilizers; erosion and dust from plowing; improper disposal of animal manure and carcasses; crop residues, and debris.	*EPA, 2008b*
Agricultural waste	Poultry and livestock manure, and residual materials in liquid or solid form generated from the production and marketing of poultry, livestock or fur-bearing animals; also includes grain, vegetable, and fruit harvest residue.	*EPA, 2008b*
Agrochemical	Synthetic chemicals (pesticides and fertilizers) used in agricultural production.	*USBR, 2008*
Agroecosystem	Land used for crops, pasture, and livestock; the adjacent uncultivated land that supports other vegetation and wildlife; and the associated atmosphere, the underlying soils, groundwater, and drainage networks.	*EPA, 2008b*
Air quality	Measure of the health-related and visual characteristics of the air, often derived from quantitative measurements of the concentrations of specific injurious or contaminating substances.	*USBR, 2008*
Air slaking	The process of breaking up or sloughing when an indurated soil is exposed to air.	*USBR, 2008*
Air waves	Air borne vibrations caused by explosions.	*USBR, 2008*
Air-space ratio	Ratio of volume of water that can be drained from a saturated soil or rock under the action of force of gravity to total volume of voids.	*USBR, 2008*
Air-void ratio	The ratio of the volume of airspace to the total volume of voids in a soil mass.	*USBR, 2008*
Alert (Automated Local Evaluation in Real Time)	A flood warning system consisting of remote sensors, data transmission by radio, and a computer software package developed by the National Weather Service (NWS). Also, a generic term used for a decision making software package.	*USBR, 2008*
Alevin	A young fish which has not yet absorbed its yolk sac.	*USBR, 2008*
Algae	Simple rootless plants that grow in sunlit waters in proportion to the amount of available nutrients. They can affect water quality adversely by lowering the dissolved oxygen in the water. They are food for fish and small aquatic animals.	*EPA, 2008b*
Algae	Microscopic plants that grow in sunlit water containing phosphates, nitrates, and other nutrients. Algae, like all aquatic plants, add oxygen to the water and are important in the fish food chain.	*USACE, 1999*

Algae	Simple plants containing chlorophyll; most live submerged in water. Microscopic plants which contain chlorophyll and live floating or suspended in water. They also may be attached to structures, rocks or other submerged surfaces. They are food for fish and small aquatic animals. Excess algal growths can impart tastes and odors to potable water. Algae produce oxygen during sunlight hours and use oxygen during the night hours. Their biological activities appreciably affect the pH and dissolved oxygen of the water.	*USBR, 2008*
Algae	Chlorophyll-bearing nonvascular, primarily aquatic species that have no true roots, stems, or leaves; most algae are microscopic, but some species can be as large as vascular plants.	*USGS, 2008*
Algae bloom	A heavy growth of algae in and on a body of water as a result of high phosphate concentration from farm fertilizers and detergents.	*USBR, 2008*
Algal bloom	Rapid and flourishing growth of algae. Sudden, massive growths of microscopic and macroscopic plant life, such as green or bluegreen algae, which develop in lakes and reservoirs.	*USBR, 2008*
Algal blooms	Sudden spurts of algal growth, which can affect water quality adversely and indicate potentially hazardous changes in local water chemistry.	*EPA, 2008b*
Algicide	Substance or chemical used specifically to kill or control algae.	*EPA, 2008b*
Algicide	Any substance or chemical specifically formulated to kill or control algae.	*USBR, 2008*
Aliquot	A measured portion of a sample taken for analysis. One or more aliquots make up a sample.	*EPA, 2008b*
Aliquot	Portion of a sample.	*USBR, 2008*
Alkali	A soluble salt obtained from the ashes of plants. A substance having marked basic properties. Various soluble salts, principally of sodium, potassium, magnesium, and calcium, that have the property of combining with acids to form neutral salts and may be used in chemical water treatment processes.	*USBR, 2008*
Alkali-aggregate reaction (AAR)	A deterioration of concrete by which the alkali in the cement paste in the concrete reacts chemically with the silica or carbonate present in some aggregates. In the presence of free moisture, the gel (product of the reaction) will expand and manifest into cracking and differential movement in structures as well as other deleterious effects such as reduction in freeze-thaw durability and compressive and tensile strength. Three forms of alkali-aggregate reaction have been identified, see alkali-silica reaction, the slow/late-expanding type of reaction referred to as alkali-silicate reaction, and the alkali-carbonate reaction. Visit the Alkali-Aggregate Reactions database.	*USBR, 2008*
Alkali-carbonate reaction (ACR)	Reaction of alkalis which occurs between certain argillaceous dolomitic limestones and the alkaline pore solution in the concrete and causes expansion and extensive cracking. Expansive dolomite limestones are characterized by a matrix of fine calcite and clay minerals with scattered dolomite rhobohedra. This reaction usually occurs early and structures may show cracking within 5 years after construction. See alkali-aggregate reaction.	*USBR, 2008*

Alkaline	The condition of water or soil which contains a sufficient amount of alkali substance to raise the pH above 7.0.	*EPA, 2008b*
Alkaline	Having a pH of 7.0 or above. The condition of water or soil which contains a sufficient amount of alkali substances to raise the pH above 7.0. The quality of being bitter due to alkaline content.	*USBR, 2008*
Alkalinity	The capacity of bases to neutralize acids. An example is lime added to lakes to decrease acidity.	*EPA, 2008b*
Alkali-silica reaction (ASR)	Reaction of alkalis with aggregate with various forms of poorly crystalline reactive silica: opal, chert, flint and chalcedony and also tridymite, crystoblite and volcanic glasses. Aggregate containing such materials (e.g., some cherty gravels) may cause deterioration of concrete when present in amounts of 1% to 5%. Concrete made of these aggregates is characterized by the early onset of a relatively rapid expansion. Cracking of structures is often observed within 10 years of construction. See alkali-aggregate reaction.	*USBR, 2008*
Alkali-silicate/silica reaction (ASSR)	Reaction of alkalis with strained quartz is thought to be one reactive component of aggregates causing this reaction. A wide variety of quartz-bearing rocks have been found to be reactive including graywackes, argillites, quartzwackes, quartzarenites, quartzites, hornfels, quartz biotite, gneiss, granite, phyllite, arkose and sandstone. This type of reaction is characterized by a delayed onset of expansion and cracking may not become evident for up to 20 years after construction. See alkali-aggregate reaction.	*USBR, 2008*
Allelopathy	Influence of plants upon each other caused by products of metabolism, e.g., creosote bushes produce a toxic substance which inhibits the growth of other plants in the immediate vicinity.	*USBR, 2008*
Allocations	That portion of a receiving water's loading capacity that is attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background source. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading).	*EPA, 2008c*
Allochthonous	Exotic species of a given area. Also refers to deposits of material that originated elsewhere, e.g., drifted plant material on the bottom of a lake.	*USBR, 2008*
Allopatric	Having separate and mutually exclusive areas of geographical distribution.	*USBR, 2008*
Allowable bearing capacity	The maximum pressure that can be permitted on foundation soil, giving consideration to all pertinent factors, with adequate safety against rupture of the soil mass or movement of the foundation of such magnitude that the structure is impaired.	*USBR, 2008*
Allowable pile bearing load	The maximum load that can be permitted on a pile with adequate safety against movement of such magnitude that the structure is endangered.	*USBR, 2008*

Alluvial	Relating to and/or sand deposited by flowing water.	*EPA, 2008b*
Alluvial	Deposited by running water.	*USACE, 1999*
Alluvial	Soil deposited by running water	*USFS, 2002*
Alluvial	Related to, composed of, or found in alluvium. Sedimentary material transported and deposited by the action of flowing water, such as in a riverbed, flood plain, or delta.	*USBR, 2008*
Alluvial aquifer	A water-bearing deposit of unconsolidated material (sand and gravel) left behind by a river or other flowing water.	*USGS, 2008*
Alluvial fan	A large fan-shaped accumulation of sediment deposited by streams where they emerge at the front of a mountain range.	*USBR, 2008*
Alluvium	A general term for detrital deposits made by streams on riverbeds, floodplains, and alluvial fans, especially a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include sub aqueous sediments of seas or lakes.	*USACE, 1999*
Alluvium	Sediment deposited by flowing water, such as in a riverbed, floodplain, or delta. Ambient water quality. Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact to human health.	*EPA, 2008c*
Alluvium	Material transported and deposited by flowing water, such as clay, silt, sand, and gravel. Soil, the constituents of which have been transported in suspension by flowing water and subsequently deposited by sedimentation. A stratified bed of sand, gravel, silt, and clay deposited by flowing water.	*USBR, 2008*
Alluvium	Soil (sand, mud, or similar eroded material) deposited by streams. This deposit may be a stratigraphic (layered) deposit beneath the surface.	*CCC, 2008*
Alluvium	Deposits of clay, silt, sand, gravel or other particulate rock material left by a river in a streambed, on a flood plain, delta, or at the base of a mountain.	*USGS, 2008*
Alternate method	Any method of sampling and analyzing for an air or water pollutant that is not a reference or equivalent method but that has been demonstrated in specific cases-to EPA's satisfaction-to produce results adequate for compliance monitoring.	*EPA, 2008b*
Alternatives	Courses of action that may meet the objectives of a proposal at varying levels of accomplishment, including the most likely future conditions without the project or action.	*USBR, 2008*
Amalgamation	The dissolving or blending of a metal (commonly gold and silver) in mercury to separate it from its parent material.	*USGS, 2008*
Ambient	Surrounding natural conditions or environment at a given place and time. Environmental or surrounding conditions.	*USBR, 2008*
Ambient temperature	Temperature of the surrounding air (or other medium).	*USBR, 2008*
Ambient water quality	Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact to human health.	*EPA, 2008c*

Ambursen dam	A buttress dam in which the upstream part is a relatively thin flat slab usually made of reinforced concrete.	*USBR, 2008*
Ammonia	A compound of nitrogen and hydrogen (NH3) that is a common by product of animal waste. Ammonia readily converts to nitrate in soils and streams.	*USGS, 2008*
Ammonium	One form of nitrogen that is usable by plants.	*USBR, 2008*
Amphibian	Vertebrate animals that have life stages both in water and on land (e.g., salamanders, frogs, and toads). Animals capable of living either in water or land.	*USBR, 2008*
Amplification	Modification of the input bedrock ground motion by the overlying unconsolidation materials. Amplification causes the amplitude of the surface ground motion to be increased in some range of frequencies and decreased in others. Amplification is a function of the shear wave velocity and damping of the unconsolidated materials, its thickness and geometry, and the strain level of the input rock motion.	*USBR, 2008*
Anabranch	A diverging branch of a river that re-enters the main stream.	*USACE, 1999*
Anadromous	Pertaining to fish that spend a part of their life-cycle in the sea and return to freshwater streams to spawn.	*USACE, 1999*
Anadromous	Fish that leave freshwater and migrate to the ocean to grow and mature. They return to freshwater to spawn.	*USFS, 2002*
Anadromous	Fish that migrate from salt water to freshwater to breed. Going up rivers to spawn.	*USBR, 2008*
Anadromous	A type of life cycle where fish return from the ocean to freshwater to spawn.	*DOC, 2005*
Anaerobic	A life or process that occurs in, or is not destroyed by, the absence of oxygen.	*EPA, 2008b*
Anaerobic	A condition in which free (atmospheric) or dissolved oxygen is not present in water. The opposite of aerobic.	*USBR, 2008*
Anaerobic decomposition	Reduction of the net energy level and change in chemical composition of organic matter caused by microorganisms in an oxygen-free environment.	*EPA, 2008b*
Anastomosed streams	These stream types occur on flat gradients and have channels that are narrow and deep (as opposed to the wide, shallow channels found in braided streams). Their banks are typically made up of fine, cohesive sediments, making them relatively erosion-resistant. Streams formed when the downstream base level rises, causing a rapid buildup of sediment. Since the bank materials are not easily erodible, the original single-thread stream breaks up into multiple channels. Streams entering deltas in a lake or bay are often anastomosed. Streams on alluvial fans, in contrast, can be braided or anastomosed.	*FISHWR, 2001*
Anchor block	See thrust block.	*USBR, 2008*
Andesite	Fine-grained, medium gray volcanic rock of intermediate composition between rhyolite and basalt.	*USBR, 2008*
Angle of external friction (angle of wall friction)	Angle between the abscissa and the tangent of the curve representing the relationship of shearing resistance to normal stress acting between soil and surface of another material.	*USBR, 2008*
Angle of internal friction (angle of shear resistance)	The angle between the axis of normal stress and the tangent to the Mohr envelope at a point representing a given failure-stress condition for solid material.	*USBR, 2008*

Angle of obliquity	The angle between the direction of the resultant stress or force acting on a given plane and the normal to that plane.	*USBR, 2008*
Angle of repose	Angle between the horizontal and the maximum slope that a particular soil or geologic material assumes through natural processes. For dry granular soils, the effect of the height of slope is negligible; for cohesive soils, the effect of height of slope is so great that the angle of repose is meaningless.	*USBR, 2008*
Angle of wall friction	Angle between the abscissa and the tangent of the curve representing the relationship of shearing resistance to normal stress acting between soil and surface of another material.	*USBR, 2008*
Angler-day	The time spent fishing for any part of a day by one person.	*USACE, 1999*
Angler-day	The time spent fishing by one person for any part of a day.	*USBR, 2008*
Anisotropy	In hydrology, the conditions under which one or more hydraulic properties of an aquifer vary from a reference point.	*EPA, 2008b*
Anisotropy	Flow conditions vary with direction. Most aquifers are anisotropic.	*USBR, 2008*
Annex (functional)	An emergency operations plan element that describes the jurisdiction's plan for functioning in that component area of activity during emergencies.	*USBR, 2008*
Annual failure probability	The probability of the load multiplied by the probability of failure.	*USBR, 2008*
Annual flood	The maximum momentary peak discharge in each year of record (sometimes the maximum mean daily discharge is used).	*USGS, 1982*
Annual flood series	A list of annual floods.	*USGS, 1982*
Annual inspection (AI)	Annual inspections of a dam and appurtenant facilities are conducted by the local operating office. These examinations address both O&M and dam safety issues and use an "Annual Inspection Checklist" to aid in the examination and formal documentation of the inspection.	*USBR, 2008*
Annual operating cost	This is a general term which is sometimes called annual operating expense and includes all annual operation and maintenance expense, wheeling, purchased power, etc.	*USBR, 2008*
Annual series	A general term for a set of any kind of data in which each item is the maximum or minimum in a year.	*USGS, 1982*
Annual work plan	Annual budget document that describes proposed work to be performed at a specific Bureau of Reclamation project, and details the amount of funds required.	*USBR, 2008*
Annualized loss of life	The sum of the probability of dam failure multiplied by the annual probability of the loading and the estimated number of lives that would be lost (consequences) for each dam failure scenario under a particular loading category (i.e. (probability of failure)(probability of load)(potential loss of life)).	*USBR, 2008*
Annular	Ring-shaped.	*USBR, 2008*
Annular space	A ring-shaped space located between two circular objects, such as two pipes.	*USBR, 2008*
Anomalies	As related to fish, externally visible skin or subcutaneous disorders, including deformities, eroded fins, lesions, and tumors.	*USGS, 2008*
Anoxic	Without oxygen.	*USBR, 2008*
Antecedent flood	A flood or series of floods assumed to occur prior to the occurrence of an inflow design flood (IDF).	*USBR, 2008*

Anthropogenic	Pertains to the [environmental] influence of human activities.	*EPA, 2008c*
Anthropogenic	Human-created.	*USBR, 2008*
Anthropogenic	Occurring because of, or influenced by, human activity.	*USGS, 2008*
Anthropogenic cover	Land cover associated with human activities, such as agricultural fields, rock quarries, and urban areas. Literally, "land cover created by humans."	*EPA, 1997*
Anticline	A fold in rocks that curves upward in a convex way. Upward fold in rock layers that creates an arched or domelike uplift of sedimentary layers. See syncline.	*USBR, 2008*
Anti-degradation policies	Policies that are part of each state's water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that may impact the integrity of waterbodies.	*EPA, 2008c*
APN	Assessor's Parcel Number; identifies each parcel or lot for tax assessment purposes.	*CCC, 2008*
Application efficiency	The ratio of the average depth of irrigation water infiltrated and stored in the root zone to the average depth of irrigation water applied, expressed as a percent.	*USBR, 2008*
Applied water (delivered water)	Water delivered to a user. Applied water may be used for either inside uses or outside watering. It does not include precipitation or distribution losses. It may apply to metered or unmetered deliveries.	*USBR, 2008*
Appraisal estimate	An estimate used in an appraisal study as an aid in selecting the most economical plan by comparing alternative features or for determinimg whether more detailed investigations of a potential project are economically justified. Used to obtain approximate costs in a short period of time with inadequate data. Not to be used for project authorization.	*USBR, 2008*
Appraisal level of detail	The level of detail necessary to facilitate making decisions on whether or not to proceed with a detailed study and evaluation of any alternative.	*USBR, 2008*
Appraisal study (appraisal report)	A study incorporating an appraisal level of detail.	*USBR, 2008*
Approach channel	The channel upstream from that portion of the spillway having a concrete lining or concrete structure. Channel upstream from intake structure of an outlet works. Channel is generally unlined, excavated in rock or soil, with or without riprap, soil cement or other types of erosion protection.	*USBR, 2008*
Appropriation	Amount of water legally set apart or assigned to a particular purpose or use.	*USBR, 2008*
Appropriative	Water rights to or ownership of a water supply which is acquired for the beneficial use of water by following a specific legal procedure.	*USBR, 2008*
Appurtentant structures	Outlet works, spillways, bridges, drain systems, tunnels, towers, etc.	*USBR, 2008*

Apron (fore apron)	A section of concrete or riprap constructed upstream or downstream from a control structure to prevent undercutting of the structure. A short ramp with a slight pitch. A floor or lining of concrete, timber, or other suitable material at the toe of a dam, discharge side of a spillway, a chute, or other discharge structure, to protect the waterway from erosion from falling water or turbulent flow.	*USBR, 2008*
Aquaculture	A form of agriculture as defined in Section 17 of the Fish and Game Code. Aquaculture products are agricultural products, and aquaculture facilities and land uses shall be treated as agricultural facilities and land uses in all planning and permit-issuing decisions governed by this division.	*CCC, 2008*
Aquatic	Living, growing, or occurring in or on the water.	*USBR, 2008*
Aquatic algae	Microscopic plants that grow in sunlit water containing phosphates, nitrates, and other nutrients.	*USBR, 2008*
Aquatic buffers	Streamside vegetation that filters stormwater and protects stream banks.	*EPA, 2008c*
Aquatic classification system	Assigns a classification to a waterbody reflecting the water quality and the biological health (integrity). Classification is determined through use of biological indices (see IBI). Examples of classifications include oligosaprobic (cleanest water quality) and polysaprobic (highly polluted water).	*EPA, 2008c*
Aquatic corridor	The area where land and water meet. This can include floodplains, stream channels, springs and seeps, small estuarine coves, littoral areas, stream crossings, shorelines, riparian forest, caves, and sinkholes.	*EPA, 2008c*
Aquatic ecosystem	Any body of water, such as a stream, lake, or estuary, and all organisms and nonliving components within it, functioning as a natural system.	*USACE, 1999*
Aquatic ecosystem	The stream channel, lake, or estuary bed, water biotic communities, and the physical, chemical, and biological features that occur therein forming a system that interacts with associated terrestrial ecosystems.	*USFS, 2002*
Aquatic ecosystem	Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.	*EPA, 2008c*
Aquatic guidelines	Specific levels of water quality which, if reached, may adversely affect aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.	*USGS, 2008*
Aquatic habitat	Habitat that occurs in free water.	*USACE, 1999*
Aquatic life criteria	Water-quality guidelines for protection of aquatic life. Often refers to U.S. Environmental Protection Agency water-quality criteria for protection of aquatic organisms. See also Water-quality guidelines, Water-quality criteria, and Freshwater chronic criteria.	*USGS, 2008*

Aquatic life use	A use designation in State/Tribal water quality standards that generally provides for survival and reproduction of desirable fish, shellfish, and other aquatic organisms; classifications specified in state water quality standards relating to the level of protection afforded to the resident biological community.	*EPA, 2008c*
Aqueduct	Man-made canal or pipeline used to transport water.	*USBR, 2008*
Aqueduct	A pipe, conduit, or channel designed to transport water from a remote source, usually by gravity.	*DOC, 2005*
Aqueous	Something made up of water.	*EPA, 2008b*
Aqueous	Something made up of, similar to, or containing water; watery.	*USBR, 2008*
Aqueous solubility	The maximum concentration of a chemical that will dissolve in pure water at a reference temperature.	*EPA, 2008b*
Aquiclude	A layer of clay which limits the movement of ground water.	*USBR, 2008*
Aquifer	An underground geological formation, or group of formations, containing water. Are sources of groundwater for wells and springs.	*EPA, 2008b*
Aquifer	A body of rock that is sufficiently permeable to conduct groundwater and to yield economically significant quantities of water to wells and springs.	*USACE, 1999*
Aquifer	A water-bearing rock or rock formation.	*USFS, 2002*
Aquifer	A water-bearing stratum of permeable rock, sand, or gravel. A water-bearing formation that provides a ground water reservoir. Underground water-bearing geologic formation or structure. A geologic formation, group of formations, or part of a formation that stores and transmits water and yields significant quantities of water to wells and springs. A natural underground layer of porous, water-bearing materials (sand, gravel) usually capable of yielding a large amount or supply of water.	*USBR, 2008*
Aquifer	An underground layer of porous rock, sand, or other earth material containing water, into which wells may be sunk.	*CCC, 2008*
Aquifer	A geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.	*DOC, 2005*
Aquifer	A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.	*USGS, 2008*
Aquifer (confined)	Soil or rock below the land surface that is saturated with water. There are layers of impermeable material both above and below it and it is under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer.	*DOC, 2005*
Aquifer (unconfined)	An aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall.	*DOC, 2005*
Aquifer test	A test to determine hydraulic properties of an aquifer.	*EPA, 2008b*
Aquitard	Geological formation that may contain groundwater but is not capable of transmitting significant quantities of it under normal hydraulic gradients. May function as confining bed.	*EPA, 2008b*
Arable	Suitable for farming. Having soil or topographic features suitable for cultivation.	*USBR, 2008*

Arable land	Land which when farmed in adequate size units for the prevailing climatic and economic setting, and provided with the essential on-farm improvements of removing vegetation, leveling, soil reclamation, drainage, and irrigation related facilities, will generate sufficient income under irrigation to pay all farm production expenses; provide a reasonable return to the farm family's labor, management, and capital; and at least pay the operation, maintenance, and replacement costs of associated irrigation and drainage facilities.	*USBR, 2008*
Arch dam	A concrete or masonry dam which is curved upstream in plan so as to transmit the major part of the water load to the abutments and to keep the dam in compression. A solid concrete dam curved upstream in plan. An arch dam is most likely used in a narrow site with steep walls of sound rock. See thin arch dam, medium-thick arch dam, thick arch dam, arch-buttress dam, arch-gravity dam, constant angle arch dam, constant radius arch dam, double curvature arch dam, and multiple arch dam.	*USBR, 2008*
Archaic	In American archeology, a cultural stage following the earliest known human occupation in the New World (about 5,500 B.C. to A.D. 100). This stage was characterized by a generalized hunting and gathering lifestyle and seasonal movement to take advantage of a variety of resources.	*USBR, 2008*
Arch-buttress dam (or curved buttress dam)	A buttress dam which is curved in plan.	*USBR, 2008*
Archeology	Study of human cultures through the recovery and analysis of their material relics.	*USBR, 2008*
Arch-gravity dam	An arch dam which is only slightly thinner than a gravity dam.	*USBR, 2008*
Archimedean screw	An ancient water-raising device attributed to Archimedes, made up of a spiral tube coiled about a shaft or of a large screw in a cylinder, revolved by hand. A pump consisting of an inclined, revolving, corkscrew-shaped shaft tightly enclosed in a pipe.	*USBR, 2008*
Arching	The transfer of stress from a yielding part of a soil or rock mass to adjoining less-yielding or restrained parts of the mass.	*USBR, 2008*
Arcuate	A curved somewhat semi-circular feature; used to describe a rounded, concave shoreline.	*CCC, 2008*
Area of influence of a well	Area surrounding a well within which the piezometric surface has been lowered when pumping has produced a maximum steady rate of flow.	*USBR, 2008*
Area-capacity table	A table giving reservoir storage capacity, and sometimes surface areas, in terms of elevation increments.	*USBR, 2008*
Arid	A term describing a climate or region in which precipitation is so deficient in quantity or occurs so infrequently that intensive agricultural production is not possible without irrigation.	*USBR, 2008*
Arid	A term describing a climate or region in which precipitation is so deficient in quantity or occurs so infrequently that intensive agricultural production is not possible without irrigation.	*USACE, 1999*
Armor	To fortify a topographical feature to protect it from erosion (e.g., constructing a wall to armor the base of a sea cliff).	*CCC, 2008*

Armor rock (armor stone)	Natural or man-made rock or rock-like structures that are used for shoreline protection. Commonly, armor rock is used as the outermost layer of a groin or revetment. Many forms of these rocks are utilized; their overall stability depends largely on the type of mechanical interlock between the units, and in-place fitting.	*CCC, 2008*
Armoring	A natural process where an erosion-resistant layer or relatively large particles is established on the surface of the streambed through removal of finer particles by stream flow. A properly armored streambed generally resists movement of bed material at discharges up to approximately 3/4 bank-full depth.	*USACE, 1999*
Armoring	(a) The natural process of forming an erosion-resistant layer of relatively large particles on the surface of the streambed. (b) The artificial application of various materials to strengthen stream banks against erosion (see also Revetment).	*USFS, 2002*
Armoring	See riprap.	*USBR, 2008*
Array	A list of data in order of magnitude; in flood frequency analysis it is customary to list the largest value first, in a low-flow frequency analysis the smallest first.	*USGS, 1982*
Arroyo	A gully or channel cut by an intermittent stream. A water-carved channel or gulley in an arid area, usually rather small in cross section with steep banks, dry much of the time due to infrequent rainfall and the depth of the cut which does not penetrate below the level of permanent ground water.	*USBR, 2008*
Artesian (aquifer or well)	Water held under pressure in porous rock or soil confined by impermeable geological formations.	*EPA, 2008b*
Artesian well	Water held under pressure in porous rock or soil confined by impermeable geologic formations. An artesian well is free flowing. See confined aquifer.	*USBR, 2008*
Artifact	Any human-made or used object, intact or in pieces, 50 years or older. Artifacts are protected by the Archaeological Resources Protection Act of 1979.	*USBR, 2008*
Artificial drains	Man-made or constructed drains.	*USBR, 2008*
Artificial headland	A hard structure extending from the shore and turning parallel to it; built to stabilize the shoreline locally as a natural headland would.	*CCC, 2008*
Artificial nourishment	The process of enlarging a beach with material (usually sand) obtained from another location.	*CCC, 2008*
Artificial recharge	Addition of surface water to a groundwater reservoir by human activity, such as putting surface water into spreading basins. See also groundwater recharge, recharge basin.	*USACE, 1999*
Artificial recharge	Addition of surface water to a ground water reservoir by human activity, such as putting surface water into spreading basins. See ground water recharge, and recharge basin.	*USBR, 2008*
Artificial recharge	A process where water is put back into ground-water storage from surface-water supplies such as irrigation, or induced infiltration from streams or wells.	*DOC, 2005*
Artificial recharge	Augmentation of natural replenishment of groundwater storage by some method of construction, spreading of water, or by pumping water directly into an aquifer.	*USGS, 2008*
Assay	A test for a specific chemical, microbe, or effect.	*EPA, 2008b*

Assessment endpoint	In ecological risk assessment, an explicit expression of the environmental value to be protected; includes both an ecological entity and specific attributed thereof. entity (e.g. salmon are a valued ecological entity; reproduction and population maintenance--the attribute--form an assessment endpoint.)	*EPA, 2008b*
Assimilation	The ability of a body of water to purify itself of pollutants.	*EPA, 2008b*
Assimilative capacity	The capacity of a natural body of water to receive wastewaters or toxic materials without deleterious effects and without damage to aquatic life or humans who consume the water.	*EPA, 2008b*
Assimilative capacity	The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.	*EPA, 2008c*
Associated facility	A term used by Reclamation to describe those facilities examined by the respective regional or area office. These facilities include most carriage, distribution, and drainage systems, small diversion works, small pumping plants and powerplants, open and closed conduits, tunnels, siphons, small regulating reservoirs, waterways, and class B bridges.	*USBR, 2008*
Asymmetric	Not similar in size, shape, form or arrangement of parts on opposite sides of a line, point or plane.	*USBR, 2008*
ATF	An after the fact permit application is a coastal development permit application filed by the applicant after a development has occurred in order to seek authorization for the development.	*CCC, 2008*
Atmospheric deposition	The transfer of substances from the air to the surface of the Earth, either in wet form (rain, fog, snow, dew, frost, hail) or in dry form (gases, aerosols, particles).	*USGS, 2008*
Atmospheric pressure	Pressure of air enveloping the earth, averaged as 14.7 psi at sea level, or 29.92 inches of mercury as measured by a standard barometer.	*USBR, 2008*
At-rest earth pressure	The value of the earth pressure when the soil mass is in its natural state without having been permitted to yield or without having been compressed.	*USBR, 2008*
Attenuation	The process by which a compound is reduced in concentration over time, through absorption, adsorption, degradation, dilution, and/or transformation. an also be the decrease with distance of sight caused by attenuation of light by particulate pollution.	*EPA, 2008b*
Attenuation	Decrease in amplitude of the seismic waves with distance due to geometric spreading, energy absorption and scattering.	*USBR, 2008*
Atterberg limits (consistency limits)	The boundaries (determined by laboratory tests) of moisture content in a soil between the liquid state and plastic state (known as liquid limit), between the plastic state and the semisolid state (known as the plastic limit), and between the semisolid state and the solid state (known as the shrinkage limit).	*USBR, 2008*
Attribute survey	Survey to determine the important components of the recreational experience.	*USBR, 2008*
Auger	A rotating drill having a screw thread that carries cuttings away from the face.	*USBR, 2008*

Augmentation (of stream flow)	Increasing stream flow under normal conditions, by releasing storage water from reservoirs.	*USACE, 1999*
Authorization	An act by the Congress of the United States which authorizes use of public funds to carry out a prescribed action.	*USBR, 2008*
Authorized Reclamation project	A congressionally approved Bureau of Reclamation project that has been authorized for specific purposes.	*USBR, 2008*
Auxiliary equipment	Accessory equipment necessary for the operation of a generating station.	*USBR, 2008*
Auxiliary spillway	A spillway, usually located in a saddle or depression in the reservoir rim which leads to a natural or excavated waterway, located away from the dam which permits the planned release of excess flood flow beyond the capacity of the service spillway. A control structure is seldom furnished. The crest is set at the maximum water surface elevation for a 100-year flood or some other specific frequency flood. The auxiliary spillway thus has only infrequent use. Any secondary spillway which is designed to be operated very infrequently and possibly in anticipation of some degree of structural damage or erosion to the spillway during operation.	*USBR, 2008*
Availability session	Informal meeting at a public location where interested citizens can talk with EPA and state officials on a one-to-one basis.	*EPA, 2008b*
Available capacity	The amount of water held in the soil that is available to the plants. See water holding capacity.	*USBR, 2008*
Average	The arithmetic mean. The sum of the values divided by the number of values.	*USBR, 2008*
Average annual runoff	For a specified area, it is the average annual runoff amounts calculated for a whole hydrologic cycle of record that represents average hydrologic conditions.	*USACE, 1999*
Average annual runoff	For a specified area, the average value of annual runoff amounts calculated for a selected period of record that represents average hydrologic conditions.	*USBR, 2008*
Average degree of consolidation	The ratio of the total volume change in a soil mass at a given time to the total volume change anticipated in the soil mass due to primary consolidation.	*USBR, 2008*
Average energy	The total power generation produced by a powerplant during all of the years of its actual or simulated operation divided by the number of years of actual or simulated operation.	*USBR, 2008*
Average year supply	The average annual supply of a water development system over a whole hydrologic cycle.	*USACE, 1999*
Average year supply	The average annual supply of a water development system over a long period.	*USBR, 2008*
Average year water demand	Demand for water under average hydrologic conditions for a defined level of development.	*USACE, 1999*
Average year water demand	Demand for water under average hydrologic conditions for a defined level of development.	*USBR, 2008*
Avian	Having to do with birds.	*USBR, 2008*
Avoirdupois weight	An English and American system of weights based on a pound of 16 ounces.	*USBR, 2008*
Avulsion	A change in channel course that occurs when a stream suddenly breaks through its banks, typically bisecting an overextended meander arc.	*USACE, 1999*

Axis	A straight line around which a shaft or body revolves.	*USBR, 2008*
Axis of dam	A vertical plane or curved surface, appearing as a line in plan or cross section, to which horizontal dimensions can be referred.	*USBR, 2008*
Axis of dam (concrete)	A vertical reference surface coincident with the upstream face at the top of the dam.	*USBR, 2008*

B

Back pressure	A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the public water system.	*USBR, 2008*
Back swamps	Floodplain wetlands formed by natural levees.	*FISHWR, 2001*
Backbeach (dry beach)	The sand area inundated only by storm tides or extreme high tides. These areas supply sands to the dune system.	*CCC, 2008*
Backfill	Material used in refilling excavation, or the process of such refilling. Material used to fill an excavated trench.	*USBR, 2008*
Backfill concrete	Concrete used in refilling excavation in lieu of earth material.	*USBR, 2008*
Backflow	A reverse flow condition, created by a difference in water pressures, which causes water to flow back into the distribution system.	*USBR, 2008*
Backfurrow	The first cut of a plow, from which the slice is laid on undisturbed soil.	*USBR, 2008*
Background concentration	A concentration of a substance in a particular environment that is indicative of minimal influence by human (anthropogenic) sources.	*USGS, 2008*
Background level	1. The concentration of a substance in an environmental media (air, water, or soil) that occurs naturally or is not the result of human activities. 2. In exposure assessment the concentration of a substance in a defined control area, during a fixed period of time before, during, or after a data-gathering operation.	*EPA, 2008b*
Background levels	Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.	*EPA, 2008c*
Backshore	The region of the shore or beach lying between the foreshore and the coastline and acted upon by waves only during severe storms.	*CCC, 2008*
Backsiphonage	A form of backflow caused by a negative or below atmospheric pressure within a water system.	*USBR, 2008*
Backwater	A small, generally shallow body of water attached to the main channel, with little or no current of its own OR a condition in sub critical flow where the water surface elevation is raised by downstream flow impediments.	*USACE, 1999*
Backwater	A small, generally shallow body of water with little or no current of its own. Stagnant water in a small stream or inlet. Water moved backward or held back by a dam, tide, etc.	*USBR, 2008*
Backwater pool	A pool that formed as a result of an obstruction like a large tree, weir, dam, or boulder.	*USACE, 1999*
Bacteria	(Singular: bacterium) Microscopic living organisms that can aid in pollution control by metabolizing organic matter in sewage, oil spills or other pollutants. However, bacteria in soil, water or air can also cause human, animal and plant health problems.	*EPA, 2008b*

Baffle	A flat board or plate, deflector, guide, or similar device constructed or placed in flowing water or slurry systems to cause more uniform flow velocities to absorb energy and to divert, guide, or agitate liquids.	*EPA, 2008b*
Baffle	A flat board or plate, deflector, guide or similar device constructed or placed in flowing water to cause more uniform flow velocities, to absorb energy, and to divert, guide, or agitate the flow.	*USBR, 2008*
Baffle block (dentate)	One of a series of upright obstructions designed to dissipate energy as in the case of a stilling basin or drop structure. A block, usually of concrete, constructed in a channel or stilling basin to dissipate the energy of water flowing at high velocity.	*USBR, 2008*
Bailer	A 10- to 20-foot-long pipe equipped with a valve at the lower end. A bailer is used to remove slurry from the bottom or the side of a well as it is being drilled.	*USBR, 2008*
Balanced head condition	The condition in which the water pressure on the upstream and downstream sides of an object are equal (such as an emergency or regulating gate).	*USBR, 2008*
Ball-milling	The repeated churning action of cobbles, gravel, and sand caused by the force of water in a stilling basin or other structure by which severe concrete abrasion can occur.	*USBR, 2008*
Bank	The sloping ground that borders a stream and confines the water in the natural channel when the water level, or flow, is normal.	*USGS, 2008*
Bank Failure	Collapse of a mass of bank material.	*USFS, 2002*
Bank full	An established river stage at a given location along a river which is intended to represent the maximum safe water level that will not overflow the river banks or cause any significant damage within the river reach.	*USBR, 2008*
Bank full	Natural streams - The discharge that fills the channel without overflowing onto the floodplain.	*USFS, 2002*
Bank full discharge	The discharge at which water just begins to leave the channel and spread onto the floodplain. Bank full discharge is equivalent to channel-forming (conceptual) and effective (calculated) discharge.	*FISHWR, 2001*
Bank stability	The ability of a stream bank to counteract erosion or gravity forces.	*USACE, 1999*
Bank Stabilization	Practices designed to reduce/eliminate erosion or slumping of bank material into the river channel. This category DOES NOT include Stormwater Management	*NRRSS, 2005*
Bank storage	Water that has infiltrated from a reservoir into the surrounding land where it remains in storage until water level in the reservoir is lowered.	*USBR, 2008*
Bank-full channel depth	The maximum depth of a channel within a riffle segment when flowing at bank-full discharge.	*USACE, 1999*
Bank-full channel width	The top surface width of a stream channel when flowing at a bank-full discharge.	*USACE, 1999*
Bank-full width	The width of a river or stream channel between the highest banks on either side of a stream.	*USACE, 1999*
Bar	An accumulation of alluvium (usually gravel or sand) caused by a decrease in sediment transport capacity on the inside of meander bends or in the center of an overwide channel.	*USACE, 1999*

Bar	A streambed deposit of sand or gravel, often exposed during low-water periods. An alluvial deposit composed of sand, gravel, or other material that obstructs flow and induces deposition or transport.	*USFS, 2002*
Bar	An elongated sand ridge found offshore, composed of sand or gravel eroded from the beach.	*CCC, 2008*
Bar chart	A graphic representation of the frequency of different data values using rectangles with heights proportional to the frequencies.	*EPA, 1997*
Barchans	The crescent shaped sand mounds that form when there is one dominant wind direction but a limited supply of sand.	*CCC, 2008*
Barrage (gate-structure dam)	A barrier built across a river, comprising a series of gates which when fully open allow the flood to pass without appreciably increasing the flood level upstream of the barrage.	*USBR, 2008*
Barrel	A volumetric unit of measure for crude oil and petroleum products equivalent to 42 U.S. gallons.	*USBR, 2008*
Barrier	A physical block or impediment to the movement of migrating fish, such as a waterfall (natural barrier) or a dam (man-made barrier).	*USACE, 1999*
Basal or butt end	The bottom end or end nearest the trunk of a cutting taken from a riparian plant that will root if planted face down in the soil (opposite the budding tip's end of the cutting).	*USFS, 2002*
Basalt	Fine-grained, dark-colored volcanic rock rich in iron-bearing minerals.	*USBR, 2008*
Base	A substance that has a pH value between 7 and 14.	*USBR, 2008*
Base course	A layer of specified or selected material of planned thickness constructed on the subgrade or subbase for the purpose of serving one or more functions such as distributing load, providing drainage, minimizing frost action, etc.	*USBR, 2008*
Base exchange	The physicochemical process whereby one species of ions adsorbed on soil particles is replaced by another species.	*USBR, 2008*
Base flood	The flood having a one percent chance of being equalled or exceeded in any given year. This term is used in the National Flood Insurance Program (NFIP) to indicate the minimum level of flooding to be used by a community in its flood plain management regulations.	*USBR, 2008*
Base flood plain	The flood plain innundated by the 100-year flood.	*USBR, 2008*
Base flow	Precipitation that percolates to the ground water and moves slowly through substrate before reaching the channel. It sustains stream flow during periods of little or no precipitation.	*FISHWR, 2001*
Base flow	The sustained portion of stream discharge that is drawn from natural storage sources, and not affected by human activity or regulation.	*USACE, 1999*
Base flow	Ground water inflow to the river. Portion of stream discharge that is derived from natural storage.	*USBR, 2008*
Base flow	Streamflow coming from ground-water seepage into a stream.	*DOC, 2005*
Base flow	Sustained, low flow in a stream; groundwater discharge is the source of base flow in most places.	*USGS, 2008*
Base level	Lowest point to which a stream may erode its channel; the ultimate base level is sea level; temporary or local base levels are defined by rock, hardpan, or other strata that resist downcutting and force erosional processes laterally.	*EPA, 2008c*

Base safety condition (BSC)	The level of loading above which a dam failure does not contribute an incremental loss of life.	*USBR, 2008*
Base width or thickness	The maximum thickness or width of a dam measured horizontally between upstream and downstream faces and normal to the axis or centerline crest of the dam, but excluding projections for outlets or other appurtenant structures. The base thickness of the crown cantilever of an arch dam. In general, the term thickness is used for gravity or arch dams, and width is used for other dams.	*USBR, 2008*
Baseline (condition or alternative)	Conditions that would prevail if no actions were taken. See future without.	*USBR, 2008*
Baseline profile	Used for a survey of the environmental conditions and organisms existing in a region prior to unnatural disturbances.	*USBR, 2008*
Baseload	Minimum load in a power system over a given period of time. The minimum constant amount of load connected to the power system over a given time period, usually on a monthly, seasonal, or yearly basis.	*USBR, 2008*
Baseload plant	Powerplant normally operated to carry baseload; consequently, it operates essentially at a constant load. A plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.	*USBR, 2008*
Baseloading	Running water through a powerplant at a roughly steady rate, thereby producing power at a steady rate.	*USBR, 2008*
Basic Fixed Sites	Sites on streams at which streamflow is measured and samples are collected for temperature, salinity, suspended sediment, major ions and metals, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of streamwater in relation to hydrologic conditions and environmental settings.	*USGS, 2008*
Basin	See Drainage basin.	*USGS, 2008*
Basin and Range physiography	A region characterized by a series of generally north trending mountain ranges separated by alluvial valleys.	*USGS, 2008*
Basin runoff model	Any one of the computer programs that mathematically models basin characteristics to forecast reservoir inflow from rainfall and/or streamflow data.	*USBR, 2008*
BASINS (Better Assessment Science Integrating Point and Nonpoint Sources)	A computer-run tool that contains an assessment and planning component that allows users to organize and display geographic information for selected watersheds. It also contains a modeling component to examine impacts of pollutant loadings from point and nonpoint sources and to characterize the overall condition of specific watersheds.	*EPA, 2008c*
Bathymetry	Related to submarine contours or topography; also refers to depth measurements.	*CCC, 2008*
Batter	Inclination from the vertical. A pile driven at an angle to widen the area of support and to resist thrust.	*USBR, 2008*
Bay-Delta	Sacramento/San Joaquin River Delta and San Francisco Bay.	*USBR, 2008*
BButt joint (open joint)	In pipe, flat ends that meet but do not overlap.	*USBR, 2008*

Beach	The expanse of sand, gravel, cobble or other loose material that extends landward from the low water line to the place where there is distinguishable change in physiographic form, or to the line of permanent vegetation. The seaward limit of a beach (unless specified otherwise) is the mean low water line.	*CCC, 2008*
Beach nourishment program	Plan for conducting a series of beach nourishment projects at a specific location, typically over a period of 50 years. The program would be based on establishing the technical and financial feasibility of beach nourishment for the site and would include plans for obtaining funding and sources of sand for its duration.	*CCC, 2008*
Beach nourishment project	Placement of sand on a beach to form a designed structure in which an appropriate level of protection from storms is provided and an additional amount of sand (advanced fill) is installed to provide for erosion of the shore prior to the anticipated initiation of a subsequent project. The project may include dunes and/or hard structures as part of the design.	*CCC, 2008*
Beachfill	Sand or other material used to artificially replenish a beach. Dedicated beachfill is that which has been obtained specifically for beach replenishment. Opportunistic beachfill is that which has been excavated for other purposes then made available for beach replenishment.	*CCC, 2008*
Beachgrass	Any of the genus Ammophila of deeply rooted, tough, perennial grasses that grow on sandy beaches and are often planted to combat beach erosion.	*CCC, 2008*
Beaching	The action of water waves by which beach materials settle into the water because of removal of finer materials.	*USBR, 2008*
Bed elevation	Height of streambed above a specified level.	*USBR, 2008*
Bed layer	The flow layer, several grain diameters thick (usually taken as two grain diameters thick), immediately above the bed.	*USBR, 2008*
Bed load	Sediment particles resting on or near the channel bottom that are pushed or rolled along by the flow of water.	*EPA, 2008b*
Bed load	Sediment moving on or near the streambed and transported by jumping, rolling, or sliding on the bed layer of a stream. See also suspended load.	*USACE, 1999*
Bed load	The part of the total stream load that is moved on or immediately above the stream bed, such as the larger or heavier particles (boulders, pebbles, gravel) transported by traction or saltation (discontinuous movement) along the bottom: the part of the load that is not continuously in suspension or solution.	*USFS, 2002*
Bed load	Sediment that moves by rolling or sliding along the bed and is essentially in contact with the streambed in the bed layer.	*USBR, 2008*
Bed material	The sediment mixture that a streambed is composed of.	*USACE, 1999*
Bed material	Unconsolidated material, or sediment mixture, of which a streambed is composed.	*USBR, 2008*
Bed material load	The portion of the total sediment load with sediments of a size found in the streambed.	*USACE, 1999*
Bed roughness	A measure of the irregularity of the streambed as it contributes to flow resistance. Commonly expressed as a Manning 'n' value.	*USACE, 1999*
Bed sediment	The material that temporarily is stationary in the bottom of a stream or other watercourse.	*USGS, 2008*

Bed sediment and tissue studies	Assessment of concentrations and distributions of trace elements and hydrophobic organic contaminants in streambed sediment and tissues of aquatic organisms to identify potential sources and to assess spatial distribution.	*USGS, 2008*
Bed slope	The inclination of the channel bottom, measured as the elevation drop per unit length of channel.	*USACE, 1999*
Bedding	Ground, or layer of such, for support purposes on which pipe is laid. Soil placed beneath and beside a pipe to support the load on the pipe.	*USBR, 2008*
Bedding plane	A separation or weakness between two layers of rock, caused by changes during the building up of the rock-forming material.	*USBR, 2008*
Bedload	Coarse sediments carried along near the bottom of a river.	*USBR, 2008*
Bedload	Sediment that moves on or near the streambed and is in almost continuous contact with the bed.	*USGS, 2008*
Bed-load discharge	The quantity of bed load passing a cross section of a stream in a unit of time.	*USBR, 2008*
Bedload sediment	Portion of sediment load transported downstream by sliding, rolling, &/or bouncing along the channel bottom. Generally consists of particles >1 mm.	*EPA, 2008c*
Bed-material discharge	That part of the total sediment discharge which is composed of grain sizes found in the bed. The bed-material discharge is assumed equal to the transport capability of the flow.	*USBR, 2008*
Bedrock	The solid rock at the surface or underlying other surface materials. Rock of relatively great thickness and extent in its native location. A general term for any solid rock, not exhibiting soil-like properties, that underlies soil or other unconsolidated surficial materials. As distinguished from boulders. The consolidated body of natural solid mineral matter which underlies the overburden soils. The solid rock that underlies all soil, sand, clay, gravel, and other loose materials on the earth's surface. Any sedimentary, igneous, or metamorphic material represented as a unit in geology; being a sound and solid mass, layer, or ledge of mineral matter; and with shear wave velocities greater than 2500 feet per second.	*USBR, 2008*
Bedrock	Solid rock underlying soil and younger rock layers; generally the oldest exposed geological unit.	*CCC, 2008*
Bedrock	General term for consolidated (solid) rock that underlies soils or other unconsolidated material.	*USGS, 2008*
Behavior	Reaction of an animal to its environment.	*USBR, 2008*
Bell	An expanded, or enlarged, end of a pipe section, into which the next pipe fits. See spigot.	*USBR, 2008*
Bench	A working level or step in a cut.	*USBR, 2008*
Bench mark (BM)	A permanent or temporary monument of known elevation above sea level, used for vertical control at a construction site. A point of known or assumed elevation used as a reference in determining other elevations. A permanent reference point (elevation) used in a survey.	*USBR, 2008*
Bend	A change in the direction of a stream channel in plan view.	*USFS, 2002*
Bend	A change of direction in piping.	*USBR, 2008*
Beneficial use	Water loss through use for the betterment of society, e.g. irrigation or municipal use. See consumptive use.	*USBR, 2008*

Beneficiary	Any individual, entity, or governmental agency (local, State, or Federal) that benefits from a Reclamation project.	*USBR, 2008*
Benefit cost ratio (BCR)	The ratio of the monetary benefit of undertaking the project (including the deduction of any residual losses) over the whole-life cost of undertaking the project divided by the capital expenditure to undertake the project.	*Mockett & Simm, 2002*
Benefit-cost analysis	An economic method for assessing the benefits and costs of achieving alternative health-based standards at given levels of health protection.	*EPA, 2008b*
Benefit-cost ratio (B/C)	The ratio of the present value of project benefits to the present value of the project costs, used in economic analysis.	*USBR, 2008*
Benthic	Of or pertaining to animals and plants living on or within the substrate of a water body.	*USFS, 2002*
Benthic	Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.	*EPA, 2008c*
Benthic	Bottom of rivers, lakes, or oceans; organisms that live on the bottom of water bodies. Bottom- or depth-inhabiting.	*USBR, 2008*
Benthic	Referring to the bottom of a waterway.	*DOC, 2005*
Benthic	Refers to plants or animals that live on the bottom of lakes, streams, or oceans.	*USGS, 2008*
Benthic invertebrates	Aquatic animals without backbones that dwell on or in the bottom sediments of fresh or salt water (clams, crayfish, worms, etc.)	*USACE, 1999*
Benthic invertebrates	Insects, mollusks, crustaceans, worms, and other organisms without a backbone that live in, on, or near the bottom of lakes, streams, or oceans.	*USGS, 2008*
Benthic macroinvertebrates	Aquatic larval stages of insects such as dragonflies; aquatic insects such as aquatic beetles; crustaceans such as crayfish; worms; and mollusks. These small creatures live throughout the stream bed attached to rocks, vegetation, and logs and sticks or burrows into stream bottoms.	*EPA, 2006*
Benthic macroinvertebrates	Invertebrates (e.g., snails, worms, aquatic larvae of insects) living in or on the benthos (bottom) of waterways.	*DOC, 2005*
Benthic organisms	Organisms living in, or on, bottom substrates in aquatic ecosystems.	*EPA, 2008c*
Benthic/benthos	An organism that feeds on the sediment at the bottom of a water body such as an ocean, lake, or river.	*EPA, 2008b*
Benthos	All plants and animals living on or closely associated with the bottom of a body of water.	*USACE, 1999*
Benthos	Organisms living in or on the bottom of a lake, pond, ocean, stream, etc.	*USBR, 2008*
Bentonitic clay (bentonite)	A clay with a high content of the mineral montmorillonite, usually characterized by high swelling on wetting and shrinkage on drying.	*USBR, 2008*

Berm	A horizontal strip or shelf built into an embankment or cut to break the continuity of the slope, usually for the purpose of reducing erosion or to increase the thickness of the embankment at a point of change in a slope or defined water surface elevation. A horizontal step in the sloping profile of an embankment dam. A shelf that breaks the continuity of a slope, or artificial ridge of earth. A ledge or shoulder, as along the edge of a road or canal. An artificial ridge of earth.	*USBR, 2008*
Berm	A nearly horizontal portion of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms and others may have one or several.	*CCC, 2008*
Berms	Horizontal strips or shelves of material built contiguous to the base of either side of levee embankments for the purpose of providing protection from underseepage and erosion, thereby increasing the stability of the embankment or reducing seepage. Berms can be located on either side of levees, depending upon their purpose.	*FEMA, 2003*
Best management practice (BMP)	Methods that have been determined to be the most effective, practical means of preventing or reducing pollution from non-point sources.	*EPA, 2008b*
Best management practice (BMP)	Conservation measures intended to minimize or mitigate impacts from a variety of land-use activities.	*USACE, 1999*
Best management practice (BMP)	An agricultural practice that has been determined to be an effective, practical means of preventing or reducing nonpoint source pollution.	*USGS, 2008*
Best management practices (BMPs)	Methods, measures, or practices that are determined to be reasonable and cost-effective means for a land owner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.	*EPA, 2008c*
Bight	A bay caused by a bend in the coastline.	*CCC, 2008*
Binder (soil binder)	Portion of soil passing a No. 40 (0.425 mm) United States Standard sieve.	*USBR, 2008*
Binomial	Scientific name of plants or animals which has two parts: a genus and a species name.	*USBR, 2008*
Bioaccumulation	The intake and retention of nonfood substances by a living organism from its environment, resulting in a build-up of the substances in the organism.	*USBR, 2008*
Bioaccumulation	The biological sequestering of a substance at a higher concentration than that at which it occurs in the surrounding environment or medium. Also, the process whereby a substance enters organisms through the gills, epithelial tissues, dietary, or other sources.	*USGS, 2008*
Bioassay	Test which determines the effect of a chemical on a living organism.	*USBR, 2008*

Bioassessment	Biological assessment; the evaluation of an ecosystem using integrated assessments of habitat and biological communities in comparison to empirically defined reference conditions. Biochemical oxygen demand (BOD)The amount of oxygen per unit volume of water required to bacterially or chemically oxidize (stabilize) the oxidizable matter in water. Biochemical oxygen demand measurements are usually conducted over specific time intervals (5, 10, 20, 30 days). The term BOD generally refers to a standard 5-day BOD test.	*EPA, 2008c*
Bioassimilation	The accumulation of a substance within a habitat.	*USBR, 2008*
Bioavailability	The capacity of a chemical constituent to be taken up by living organisms either through physical contact or by ingestion.	*USGS, 2008*
Biochemical	Refers to chemical processes that occur inside or are mediated by living organisms.	*USGS, 2008*
Biochemical oxygen demand (BOD)	The amount of oxygen per unit volume of water required to bacterially or chemically oxidize (stabilize) the oxidizable matter in water. Biochemical oxygen demand measurements are usually conducted over specific time intervals (5, 10, 20, 30 days). The term BOD generally refers to a standard 5-day BOD test.	*EPA, 2008c*
Biochemical oxygen demand (BOD)	The amount of oxygen, measured in milligrams per liter, that is removed from aquatic environments by the life processes of microorganisms.	*USGS, 2008*
Biodegradation	Transformation of a substance into new compounds through biochemical reactions or the actions of microorganisms such as bacteria.	*USGS, 2008*
Biodiversity	Refers to the variety and variability among living organisms and the ecological complexes in which they occur. Diversity can be defined as the number of different items and their relative frequencies. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the biochemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, and genes.	*EPA, 2008b*
Biodiversity	The variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.	*USFWS, 2008*
Bioengineering	See Soil Bioengineering.	*USFS, 2002*
Bioengineering	Usually plant-based structural approaches to controlling geomorphological responses to land-uses and disturbance.	*DOC, 2005*
Biological assemblages	Key groups of animals and plants, such as benthic macroinvertebrates, fish, or aglae, that are studied to learn more about the condition of water resources.	*EPA, 2006*
Biological assessment	A document prepared for the section 7 process to determine whether a proposed major construction activity under the authority of a Federal action agency is likely to adversely affect listed species, proposed species, or designated critical habitat.	*USFWS, 2008*
Biological contaminants	Living organisms or derivates (e.g. viruses, bacteria, fungi, and mammal and bird antigens) that can cause harmful health effects when inhaled, swallowed, or otherwise taken into the body.	*EPA, 2008b*

Biological criteria	Also known as biocriteria, biological criteria are narrative expressions or numeric values of the biological characteristics of aquatic communities based on appropriate reference conditions. Biological criteria serve as an index of aquatic community health.	*EPA, 2008c*
Biological diversity	Number and kinds of organisms per unit area or volume; the composition of species in a given area at a given time.	*USBR, 2008*
Biological growth	The activity and growth of any and all living organisms.	*USBR, 2008*
Biological integrity	State of being capable of supporting and maintaining a balanced community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region.	*EPA, 2006*
Biological integrity	The ability to support and maintain balanced, integrated, functionality in the natural habitat of a given region. Concept is applied primarily in drinking water management.	*EPA, 2008b*
Biological magnification (biomagnification)	Step by step concentration of substances in successive levels of food chains. The enhancement of a substance (usually a contaminant) in a food web such that the organisms eventually contain higher concentrations of the substance than their food sources.	*USBR, 2008*
Biological opinion	A document stating the opinion of FWS or NOAA Fisheries on whether or not a Federal action is likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat.	*USFWS, 2008*
Biological Opinion (BO)	Document stating the U.S. Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) opinion as to whether a Federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat.	*USBR, 2008*
Biological oxygen demand (BOD)	An indirect measure of the concentration of biologically degradable material present in organic wastes. It usually reflects the amount of oxygen consumed in five days by biological processes breaking down organic waste.	*EPA, 2008b*
Biological processes	Processes characteristic of, or resulting from, the activities of living organisms.	*USBR, 2008*
Biological stressors	Organisms accidentally or intentionally dropped into habitats in which they do not evolve naturally; e.g. gypsy moths, Dutch elm disease, certain types of algae, and bacteria.	*EPA, 2008b*
Biology	The scientific study of life.	*USBR, 2008*
Biomass	All of the living material in a given area; often refers to vegetation.	*EPA, 2008b*
Biomass	The total mass or amount of living organism is in a particular area or volume.	*USFS, 2002*
Biomass	The amount, or weight, of a species, or group of biological organisms, within a specific volume or area of an ecosystem.	*EPA, 2008c*
Biomass	Total mass or amount of living organisms in a particular area or environment.	*USBR, 2008*
Biomass	The amount of living matter, in the form of organisms, present in a particular habitat, usually expressed as weight per unit area.	*USGS, 2008*
Biome	Entire community of living organisms in a single major ecological area. (See: biotic community.)	*EPA, 2008b*

Biomonitoring	1. The use of living organisms to test the suitability of effluents for discharge into receiving waters and to test the quality of such waters downstream from the discharge. 2. Analysis of blood, urine, tissues, etc. to measure chemical exposure in humans.	*EPA, 2008b*
Biosphere	The portion of Earth and its atmosphere that can support life.	*EPA, 2008b*
Biosphere	Portion of the solid and liquid earth where organisms live.	*USBR, 2008*
Biota	The animal and plant life of a given region.	*EPA, 2008b*
Biota	All living organisms of a region, as in a stream or other body of water.	*USACE, 1999*
Biota	Plant and animal life of a region.	*USBR, 2008*
Biota	Living things, such as plants, animals, and microorganisms.	*DOC, 2005*
Biota	Living organisms.	*USGS, 2008*
Biotechnology	Techniques that use living organisms or parts of organisms to produce a variety of products (from medicines to industrial enzymes) to improve plants or animals or to develop microorganisms to remove toxics from bodies of water, or act as pesticides.	*EPA, 2008b*
Biotic community	A naturally occurring assemblage of plants and animals that live in the same environment and are mutually sustaining and interdependent. (See: biome.)	*EPA, 2008b*
Biotic potential	Inherent capacity of an organism to reproduce and survive, which is pitted against limiting influences of the environment.	*USBR, 2008*
Biotic pyramid	Set of all food chains or hierarchic arrangements of organisms as eaters and eaten in a prescribed area when tabulated by numbers or by biomasses, usually takes the form of an inverted pyramid.	*USBR, 2008*
Biotope	Smallest geographical unit of a habitat, characterized by a high degree of uniformity in the environment and its plant and animal life, e.g., a decaying stump.	*USBR, 2008*
Biotype	Genetically homogeneous population composed only of closely similar individuals; a genotypic race or group of organisms.	*USBR, 2008*
Bituminous	Containing asphalt or tar.	*USBR, 2008*
Black water	Liquid and solid human body waste and the carriage water generated through toilet usage.	*USBR, 2008*
Blackout	The disconnection of the source of electricity from all the electrical loads in a certain geographical area brought about by an emergency forced outage or other fault in the generation, transmission, or distribution system serving the area. See brownout.	*USBR, 2008*
Blade	Usually a part of an excavator which digs and pushes dirt but does not carry it.	*USBR, 2008*
Blast	To loosen or move rock or soil by means of explosives or an explosion.	*USBR, 2008*
Blasting mats	A blanket usually composed of woven cable or interlocked rings placed over a blast to reduce flyrock.	*USBR, 2008*
Block fall	A type of landslide; specifically used to describe failure of a vertical cliff.	*CCC, 2008*
Blow down	Trees felled by high winds.	*USACE, 1999*
Blowouts	Circular rims or depressions formed where sand has been removed by wind; often caused by removal of vegetation.	*CCC, 2008*
Blue tops	Grade stakes whose tops indicate finish grade level.	*USBR, 2008*

Blue-baby syndrome	A condition that can be caused by ingestion of high amounts of nitrate resulting in the blood losing its ability to effectively carry oxygen. It is most common in young infants and certain elderly people.	*USGS, 2008*
Bluff (or cliff)	A scarp or steep face of rock, weathered rock, sediment or soil resulting from erosion, faulting, folding or excavation of the land mass. The cliff or bluff may be simple planar or curved surface or it may be steplike in section. For purposes of (the Statewide Interpretive Guidelines), cliff or bluff is limited to those features having vertical relief of ten feet or more and seacliff is a cliff whose toe is or may be subject to marine erosion.	*CCC, 2008*
Bluff edge (or cliff edge)	The upper termination of a bluff, cliff or seacliff. When the top edge of the cliff is rounded away from the face of the cliff as a result of erosional processes related to the presence of the steep cliff face, the edge shall be defined as that point nearest the cliff beyond which the downward gradient of the land surface increases more or less continuously until it reaches the general gradient of the cliff. In a case where there is a steplike feature at the top of the cliff face, the landward edge of the topmost riser shall be taken to be the cliff edge. The termini of the bluff line, or edge along the seaward face of the bluff, shall be defined as a point reached by bisecting the angle formed by a line coinciding with the general trend of the bluff line along the seaward face of the bluff, and a line coinciding with the general trend of the bluff line along the inland facing portion of the bluff. Five hundred feet shall be the minimum length of bluff line or edge to be used in mak	*CCC, 2008*
Bluff top retreat	The landward migration of the bluff or cliff edge, caused by marine erosion of the bluff or cliff toe and subaerial erosion of the bluff or cliff face.	*CCC, 2008*
BMP	Best Management Practices.	*USBR, 2008*
BOD5	The amount of dissolved oxygen consumed in five days by biological processes breaking down organic matter.	*EPA, 2008b*
Bog	A type of wetland that accumulates appreciable peat deposits. Bogs depend primarily on precipitation for their water source, and are usually acidic and rich in plant residue with a conspicuous mat of living green moss.	*EPA, 2008b*
Bog	Freshwater wetlands that are poorly drained and characterized by a buildup of peat.	*USACE, 1999*
Bog	Waterlogged ground or marshland (also known as a wetland).	*USFS, 2002*
Bole	Trunk of a tree.	*USFS, 2002*
Boom	1. A floating device used to contain oil on a body of water. 2. A piece of equipment used to apply pesticides from a tractor or truck.	*EPA, 2008b*
Borderline soils	Soils that have the characteristics of two of the classification groups in the Unified Soil Classification System.	*USBR, 2008*
Bore	To make a hole in or through with a drill or other device. Used commonly for determining stratigraphic (sedimentary) history, to reveal information on past site conditions and provide some guidance on future site stability or erosive potential.	*CCC, 2008*
Borehole	Hole made with drilling equipment.	*EPA, 2008b*
Boring	Rotary drilling.	*USBR, 2008*

Borrow	Material excavated from one area to be used as fill material in another area.	*USBR, 2008*
Borrow area	An area from which construction or beach replenishment material is mined for use in a different area.	*CCC, 2008*
Borrow areas	Generally, surface areas, that contain borrow pits. The area from which material for an embankment is excavated.	*USBR, 2008*
Borrow pits	Specific site(s) within a borrow area from which material is excavated for use.	*USBR, 2008*
Bottom land hardwoods	Forested freshwater wetlands adjacent to rivers in the southeastern United States, especially valuable for wildlife breeding, nesting and habitat.	*EPA, 2008b*
Boulder	A large substrate particle that is larger than a cobble (256 mm in diameter).	*USACE, 1999*
Boulder	A streambed substrate particle greater than 10 inches in its greatest dimension.	*USFS, 2002*
Boulder	A rock fragment, usually rounded by weathering or abrasion, with an average dimension of 12 inches or more: will not pass a 12-inch screen. A particle of rock that will not pass a 12-inch (300-mm) square opening. A rock which is too heavy to be lifted readily by hand.	*USBR, 2008*
Boulder clay	A geological term used to designate glacial drift that has not been subjected to the sorting action of water and therefore contains particles from boulders to clay sizes.	*USBR, 2008*
Boundary conditions	Values or functions representing the state of a system at its boundary limits.	*EPA, 2008c*
Bounding estimate	An estimate of exposure, dose, or risk that is higher than that incurred by the person in the population with the currently highest exposure, dose, or risk. Bounding estimates are useful in developing statements that exposures, doses, or risks are not greater than an estimated value.	*EPA, 2008b*
Box girder	A hollow steel beam with a square or rectangular cross section.	*USBR, 2008*
Brackish	Mixed fresh and salt water.	*EPA, 2008b*
Brackish	Mixed fresh and salt waters. Water containing too much salt to be useful to people but less salt than ocean water.	*USBR, 2008*
Brackish water	Generally, water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than seawater. Also, marine and estuarine waters with mixohaline salinity (0.5 to 17 ppt due to ocean salts). Water containing between 500-17,000 parts per million (PPM) total dissolved solids. The term brackish water is frequently interchangeable with saline water. The term should not be applied to inland waters.	*USACE, 1999*
Braided channel	A stream characterized by flow within several channels, which successively meet and divide. Braiding often occurs when the sediment loading is too large to be carried by a single channel.	*USACE, 1999*

Braided streams	Three conditions that promote formation of braided streams include: erodible banks, an abundance of coarse sediment, and rapid and frequent variations in discharge. Braided streams are created when a central sediment bar begins to form in a channel due to reduced stream flow or an increase in sediment load. The central bar causes water to flow into the smaller cross sections on either side. The smaller cross section results in higher velocity flow. Given erodible banks, this causes the channels to widen. As they do this, flow velocity decreases, which allows another central bar to form. This process is then repeated and more channels are created.	*FISHWR, 2001*
Braiding (of river channels)	Successive division and rejoining of river flow with accompanying islands.	*USACE, 1999*
Branch packing	Live woody branch cuttings and compacted soil used to repair slumped areas of stream bank.	*USFS, 2002*
Breach	A gap, rift, hole, or rupture in a dam; providing a break; allowing water stored behind a dam to flow through in an uncontrolled and unplanned manner. An eroded opening through a dam which drains the reservoir. A controlled breach is a constructed opening. An uncontrolled breach is an unintentional opening which allows uncontrolled discharge from the reservoir.	*USBR, 2008*
Breach	A breakthrough of part, or all, of a protective wall, beach sand barrier, beach berm, or the like by ocean waves, river or stream flow, mechanical equipment, or a combination of these forces. Breaching is sometimes purposefully done to protect a region from river overflow.	*CCC, 2008*
Breach hydrograph	A flood hydrograph resulting from a dam breach.	*USBR, 2008*
Breakdown product	A compound derived by chemical, biological, or physical action upon a pesticide. The breakdown is a natural process which may result in a more toxic or a less toxic compound and a more persistent or less persistent compound.	*USGS, 2008*
Breaker	A wave breaking on a shore, over a reef, etc. Breakers may be classified into four types; spilling, plunging, collapsing, and surging.	*CCC, 2008*
Breakwater	A structure or barrier protecting a shore area, harbor, anchorage, or basin from waves, usually constructed as a concrete or riprap (rock wall) structure.	*CCC, 2008*
Breccia	A type of sedimentary rock containing course, angular fragments.	*CCC, 2008*
Breccia (volcanic breccia)	Conglomerate-like rock made up of angular pieces of volcanic rock usually bound in volcanic ash.	*USBR, 2008*
Brecciated	A rock made up of highly angular, coarse fragments.	*USBR, 2008*
Breeding density	Density of sexually mature organisms in a given area during the breeding period.	*USBR, 2008*
Breeding potential	Maximum rate of increase in numbers of individuals of a species or population under optimum conditions.	*USBR, 2008*
Breeding rate	Actual rate of increase of new individuals in a given population; the breeding potential minus limiting factors.	*USBR, 2008*
Broad-crested weir	An overflow structure on which the nappe is supported for an appreciable length in the direction of flow. See weir.	*USBR, 2008*

Broken record	A systematic record which is divided into separate continuous segments because of deliberate discontinuation of recording for significant periods of time.	*USGS, 1982*
Brownout	The partial reduction of electrical voltages. A brownout results in lights dimming and motor-driven devices slowing down. See blackout.	*USBR, 2008*
Brush layer	Live branch cuttings laid in criss-crossed fashion on benches between successive lifts of soil.	*USFS, 2002*
Brush mattress	A combination of live stakes, fascines, and live branch cuttings installed to cover and protect stream banks and shorelines.	*USFS, 2002*
Bucket	A part of an excavator which digs, lifts, and carries dirt.	*USBR, 2008*
Budget Review Committee (BRC)	An ad hoc committee of representatives from each Region, the Reclamation Service Center, and the Washington Office, coordinates Reclamation budget activities through the formulation phase.	*USBR, 2008*
Buffer	A solution or liquid whose chemical makeup is such that it minimizes changes in pH when acids or bases are added to it.	*EPA, 2008b*
Buffer	A vegetated area of grass, shrubs, or trees designed to capture and filter runoff from surrounding land uses.	*USFS, 2002*
Buffer strip	A barrier of permanent vegetation, either forest or other vegetation, between waterways and land uses such as agriculture or urban development, designed to intercept and filter out pollution before it reaches the surface water resource.	*USACE, 1999*
Buffer strips	Strips of grass or other erosion-resisting vegetation between or below cultivated strips or fields.	*EPA, 2008b*
Buffer strips (filter strips, vegetated filter strips, grassed buffers)	Strips of grass or other close-growing vegetation that separates a waterway (ditch, stream, creek) from an intensive land use area (subdivision, farm).	*USBR, 2008*
Built environment	Human- modified environment, e.g. buildings, roads, and cities. See cultural resource.	*USBR, 2008*
Bulk sample	A small portion (usually thumbnail size) of a suspect asbestos-containing building material collected by an asbestos inspector for laboratory analysis to determine asbestos content.	*EPA, 2008b*
Bulkhead	A one-piece fabricated steel unit which is lowered into guides and seals against a frame to close a water passage in a dam, conduit, spillway, etc. An object used to isolate a portion of a waterway for examination, maintenance, or repair. A wall or partition erected to resist ground or water pressure.	*USBR, 2008*
Bulkhead	A structure or partition used to retain or prevent landslides and mass land movement. A secondary purpose is to protect the upland against damage from wave action.	*CCC, 2008*
Bulkhead gate	A gate used either for temporary closure of a channel or conduit before dewatering it for inspection or maintenance or for closure against flowing water when the head difference is small (e.g., for diversion tunnel closure).	*USBR, 2008*
Bulking	The increase in volume of a material due to manipulation. Rock bulks upon being excavated; damp sand bulks if loosely deposited, as by dumping, because the apparent cohesion prevents movement of the soil particles to form a reduced volume.	*USBR, 2008*

Burden	In blasting, the distance between the free face and the first row of holes or the distance between rows of holes parallel to the face. Apparent burden is the burden as outlined by the delay pattern.	*USBR, 2008*
Buttress dam	A dam consisting of a watertight upstream part (such as a concrete sloping slab) supported at intervals on the downstream side by a series of buttresses (walls normal to the axis of the dam). Buttress dams can take many forms. See arch-buttress dam, flat slab or slab and buttress dam, massive head buttress dam, multiple arch dam, and solid head buttress dam.	*USBR, 2008*

C

Cairn	A pile of stones used as a marker.	*USBR, 2008*
Caisson	A box or chamber used in construction work under water. A structure or chamber which is usually sunk or lowered by digging from the inside. Used to gain access to the bottom of a stream or other body of water.	*USBR, 2008*
Caisson	A supporting piling constructed by drilling a casing hole into a geologic formation and filling it with reinforcing bar and concrete; using for foundations.	*CCC, 2008*
Calcareous	Pertaining to or containing calcium carbonate.	*EPA, 2008c*
Calcite	Light-colored mineral composed of calcium carbonate that often fills veins in igneous rocks and forms the sedimentary rock limestone.	*USBR, 2008*
Caldera (crater)	Large circular depression formed by explosion or collapse of a volcano.	*USBR, 2008*
Calibration	The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.	*EPA, 2008c*
California Least Tern	An endangered bird species that nests on beaches and in salt marshes along California; smallest of the terns.	*CCC, 2008*
Camber	The extra height added to the crest of embankment dams to ensure that the freeboard will not be diminished by foundation settlement or embankment consolidation. The amount of camber is different for each dam and is dependent on the amount of foundation settlement and embankment expected to occur.	*USBR, 2008*
Canal	A constructed open channel for transporting water.	*USACE, 1999*
Canal	A channel, usually open, that conveys water by gravity to farms, municipalities, etc.	*USBR, 2008*
Canal headworks	The beginning of a canal.	*USBR, 2008*
Canal prism	The shape of the canal as seen in cross section.	*USBR, 2008*
Candidate Conservation Agreement (CCA)	A voluntary agreement between FWS or NOAA Fisheries and other Federal or non-Federal landowners that identifies specific conservation measures that the participants of the agreement will undertake to conserve species covered by the agreement, none of which are listed under the Endangered Species Act, with the intention of preventing any need to list the species.	*USFWS, 2008*

Candidate Conservation Agreement with Assurances (CCAA)	A voluntary agreement between FWS and a non-Federal property owner who agrees to manage lands or waters to remove threats to candidate or proposed species, with assurances that the property owner's conservation efforts will not result in future regulatory obligations that exceed those agreed to at the time the agreement is signed; it authorizes take through a section 10 permit if the species is later listed.	*USFWS, 2008*
Candidate species	Plant or animal species that are candidates for designation as endangered (in danger of becoming extinct) or threatened (likely to become endangered), but is undergoing status review by the U.S. Fish and Wildlife Service (FWS).	*USBR, 2008*
Candidate species (candidate)	A plant or animal species for which FWS or NOAA Fisheries has on file sufficient information on biological vulnerability and threats to support a proposal to list as endangered or threatened.	*USFWS, 2008*
Canopy	A layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand. Leaves, branches, and vegetation that are above ground and/or water that provide shade and cover for fish and wildlife.	*USACE, 1999*
Canopy	The overhead branches and leaves of riparian vegetation (see Cover).	*USFS, 2002*
Canopy angle	Generally, a measure of the openness of a stream to sunlight. Specifically, the angle formed by an imaginary line from the highest structure (for example, tree, shrub, or bluff) on one bank to eye level at midchannel to the highest structure on the other bank.	*USGS, 2008*
Canopy cover	Vegetation projecting over a stream, including crown cover (generally more than 3 feet above the water surface) and overhang cover (less than 3 feet above the water surface).	*USFS, 2002*
Cantilever walls	Vertical walls that use a deep foundation to resist horizontal wave forces. Walls are often constructed of pre-fabricated panels that are jetted or driven into the sand. Typically for every foot of exposed wall there should be at least half a foot of buried foundation wall to prevent overturning. (Engineered designs may vary, based on site-specific conditions.)	*CCC, 2008*
Capability	The maximum load that a generating unit, generating station, or other electrical apparatus can carry under specified conditions for a given period of time without exceeding approved limits of temperature and stress.	*USBR, 2008*
Capable fault	An active fault that is judged capable of producing macro-earthquakes and exhibits one or more of the following characteristics:(1) Movement at or near the ground surface at least once within the past 35,000 years.(2) Macroseismicity (3.5 magnitude Richter or greater) instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault.(3) A structural relationship to a capable fault such that movement on one fault could be reasonably expected to cause movement on the other.(4) Established patterns of microseismicity that define a fault, with historic macroseismicity that can reasonably be associated with that fault.	*USBR, 2008*

Capillary action	Movement of water through very small spaces due to molecular forces called capillary forces.	*EPA, 2008b*
Capillary action	The means by which liquid moves through the porous spaces in a solid, such as soil, plant roots, and the capillary blood vessels in our bodies due to the forces of adhesion, cohesion, and surface tension. Capillary action is essential in carrying substances and nutrients from one place to another in plants and animals.	*DOC, 2005*
Capillary action (capillarity)	The rise or movement of water in the interstices of a soil or rock due to capillary forces. The process by which water rises through rock, sediment or soil caused by the cohesion between water molecules and an adhesion between water and other materials that pulls the water upward. A property of surface tension that draws water upwards. See capillary movement.	*USBR, 2008*
Capillary attraction (capillary force)	The tendency of water to move into fine spaces, as between soil particles, regardless of gravity.	*USBR, 2008*
Capillary forces	The molecular forces which cause the movement of water through very small spaces.	*USBR, 2008*
Capillary fringe	The porous material just above the water table which may hold water by capillarity (a property of surface tension that draws water upwards) in the smaller void spaces.	*EPA, 2008b*
Capillary fringe	The zone above he water table within which the porous medium is saturated by water under less than atmospheric pressure.	*EPA, 2008b*
Capillary fringe zone	The zone above the free water elevation in which water is held by capillary action. The porous material just above the water table which may hold water by capillarity in the smaller void spaces.	*USBR, 2008*
Capillary head	The potential, expressed in head of water, that causes the water to flow by capillary action.	*USBR, 2008*
Capillary migration (capillary flow)	The movement of water by capillary action.	*USBR, 2008*
Capillary movement	Movement of underground water in response to capillary attraction. See capillary action.	*USBR, 2008*
Capillary rise	The height above a free water elevation to which water will rise by capillary action.	*USBR, 2008*
Capillary water	Underground water held above the water table by capillary attraction. Water subject to the influence of capillary action.	*USBR, 2008*
Capital costs	Costs (usually long-term debt) of financing construction and equipment. Capital costs are usually fixed, one-time expenses which are independent of the amount of water produced. All the implements, equipment, machinery and inventory used in the production of goods and services.	*USBR, 2008*
Capital investment	A general term used to identify any money amount which is to be considered as an investment as opposed to an annual expense. Can be either interest bearing or non interest bearing.	*USBR, 2008*
Carbonaceous	Pertaining to or containing carbon derived from plant and animal residues.	*EPA, 2008c*
Carbonate rocks	Rocks (such as limestone or dolostone) that are composed primarily of minerals (such as calcite and dolomite) containing the carbonate ion (CO32).	*USGS, 2008*
Carnivore	Any flesh-eating or predatory organism.	*USBR, 2008*
Carry over	The quantity of water which continues past an inlet.	*USBR, 2008*

Cartography	Art and science of graphically representing the features of the Earth's surface; synonymous with map making.	*USBR, 2008*
Cascade	A short, steep drop in streambed elevation often marked by boulders and agitated white water.	*USACE, 1999*
Case study	A brief fact sheet providing risk, cost, and performance information on alternative methods and other pollution prevention ideas, compliance initiatives, voluntary efforts, etc.	*EPA, 2008b*
Casing	A pipe lining for a drilled hole. The material that is installed in wells to prevent the collapse of the walls of the bore hole, to prevent pollutants from entering the well, and to house the pump and pipes.	*USBR, 2008*
Catastrophe	A sudden and great disaster causing misfortune, destruction, or irreplaceable loss extensive enough to cripple activities in an area.	*USBR, 2008*
Catch	At a recreational fishery, refers to the number of fish captured, whether they are kept or released.	*USBR, 2008*
Catchment	(1) The catching or collecting of water, especially rainfall. (2) A reservoir or other basin for catching water. (3) The water thus caught. (4) A watershed.	*USACE, 1999*
Catchment basin	Unit watershed; an area from which all the drainage water passes into one stream or other body of water.	*USBR, 2008*
Cathode	The negative pole or electrode of an electrolytic cell or system. The cathode attracts positively charged particles or ions (cations). See anode.	*USBR, 2008*
Cathodic protection	An electrical system for prevention of rust, corrosion, and pitting of metal surfaces which are in contact with water or soil. A low-voltage current is made to flow through a liquid (water) or a soil in contact with the metal in such a manner that the external electromotive force renders the metal structure cathodic. This concentrates corrosion on auxiliary anodic parts which are deliberately allowed to corrode instead of letting the structure corrode.	*USBR, 2008*
Cation	A positively charged ion in an electrolyte solution, attracted to the cathode under the influence of a difference in electrical potential. See anion.	*USBR, 2008*
Cation exchange capacity	The sum total of exchangeable cations that a soil can adsorb. Expressed in centimoles per kilogram of soil (or of other adsorbing material such as clay.)	*EPA, 2008c*
Caving	The collapse of a stream bank by undercutting due to wearing away of the toe or an erodible soil layer above the toe.	*USFS, 2002*
Cavitation	The formation and collapse of gas pockets or bubbles on the blade of an impeller or the gate of a valve; collapse of these pockets or bubbles drives water with such force that it can cause pitting of the gate or valve surface.	*EPA, 2008b*

Cavitation	The formation of partial vacuums in fast-flowing water caused by subatmospheric pressures immediately downstream from an obstruction or offset. Usually accompanied by noise and vibration. The formation of voids or cavities caused in a liquid due to turbulence or temperature which causes the pressure in local zones of the liquid to fall below the vapor pressure. This happens on the backside of ship propellers, water turbines, blades in pumps, in high-velocity flow lines, and similar locations, depending on the design of equipment and degree of turbulence. The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of this gas pocket or bubble drives water into the impeller or gate with a terrific force that can cause pitting on the impeller or gate surface. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or gate with a hammer. The attack on surfaces caused by subatmospheric pressures immediately downstream from an obstruction or offset. Usually accompanied by noise and vibration.	*USBR, 2008*
Cavitation damage	Damage caused when partial vacuums formed in a liquid by a swiftly moving solid body (e.g. a propeller) pit and wear away solid surfaces (e.g. metal or concrete). The attack on surfaces caused by the implosion of bubbles of water vapor.	*USBR, 2008*
CCMP	California Coastal Management Program.	*CCC, 2008*
Cellular gravity dam	See hollow gravity dam.	*USBR, 2008*
Celsius (C)	Unit of temperature. Degrees Celsius equals (5/9)x(degrees Fahrenheit-32).	*USBR, 2008*
Cementation	The process by which loose sediment is bound together into rock.	*CCC, 2008*
Center pivot irrigation	An automated sprinkler system involving a rotating pipe or boom that supplies water to a circular area of an agricultural field through sprinkler heads or nozzles.	*USGS, 2008*
Central flyway	An important international migration route for many birds.	*USBR, 2008*
Central Valley Project (CVP)	Federally operated water management and conveyance system that provides water to agricultural, urban, and industrial users in California.	*DOC, 2005*
Central Valley Project Improvement Act (CVPIA)	This federal legislation, signed into law on October 30, 1992, mandates major changes in the management of the federal Central Valley Project. The CVPIA puts fish and wildlife on an equal footing with agricultural, municipal, industrial, and hydropower users.	*DOC, 2005*
Certificate of Compliance	A certificate of compliance is a document issued and recorded by a local agency certifying that the subject parcel is a lot that complies with the requirements of the Subdivision Map Act and related local ordinances or certifying that the lot will comply with such requirements upon satisfaction of certain conditions.	*CCC, 2008*

Certification signature	Certification signatures are those of the persons who co-facilitated the risk analysis. These signatures signify that Reclamation methodology, processes, and requirements were followed. In addition, these signatures verify that qualifications of the persons making various probability estimates were appropriate. The purpose of endorsing qualifications is to reduce the potential for inappropriate estimates, or conflicts, arising from limited qualifications that might result in total rejection of risk analysis findings. Certification signatures also signify that the spirit of the risk analysis and team dynamics are represented by the document. In other words, any divergent views, critical issues or significant influencing factors have been captured. This is a check of the author's responsibility to fully capture and represent the team's thinking.	*USBR, 2008*
Certified water right	A State-issued document that serves as legal evidence that an approved application has been physically developed and the water put to beneficial use. The certificate establishes: priority date, type of beneficial use, and the maximum amount of water that can be used. Verification must be provided to the State through a survey conducted by an approved water-rights examiner. Even certified rights are subject to occasional review to ensure continued beneficial use.	*USBR, 2008*
Chamfer	To bevel or slope an edge or corner.	*USBR, 2008*
Channel	An area that contains continuously or periodically flowing water that is confined by banks and a streambed.	*USACE, 1999*
Channel	A stream, river, or artificial waterway that periodically or continuously contains moving water. It has a definite bed and banks that confine water.	*USFS, 2002*
Channel	A natural stream that conveys water; a ditch or channel excavated for the flow of water.	*EPA, 2008c*
Channel	Natural or artificial watercourse of perceptible extent, with a definite bed and banks to confine and conduct continuously or periodically flowing water. Rivers and streams. A general term for any natural or artificial facility for conveying water.	*USBR, 2008*
Channel forming (dominant) discharge	A constant stream discharge that results in channel morphology close to the existing channel. There is no method for directly calculating channel-forming discharge. An estimate of channel-forming discharge for a particular stream reach can, with some qualifications, be related to depth, width, and shape of the channel. Although channel-forming discharges are strictly applicable only to channels in equilibrium, the concept can be used to select appropriate channel geometry for restoring a disturbed reach.	*FISHWR, 2001*
Channel improvement	The improvement of the flow characteristics of a channel by clearing, excavation, realignment, lining, or other means in order to increase its capacity. Sometimes used to connote channel stabilization.	*EPA, 2008c*
Channel margin deposits	Narrow sand deposits which line channel banks.	*USBR, 2008*

Channel morphology	The change in a stream channel's width or the shape of the stream banks. Increased erosion often causes a stream channel to widen and to deepen. Additional aspects of channel morphology include height, angle, and extent of bank erosion, substrate embeddedness, sediment deposition, and substrate.	*EPA, 2008c*
Channel reconfiguration	Alteration of channel plan form or longitudinal profile and/or day-lighting (converting culverts and pipes to open channels). Includes stream meander restoration and in-channel structures that alter the thalweg of the stream. Note that many in stream structures also claim to improve habitat.	*NRRSS, 2005*
Channel stabilization	Erosion prevention and stabilization of velocity distribution in a channel using jetties, drops, revetments, vegetation, and other measures.	*EPA, 2008c*
Channelization	Straightening and deepening streams so water will move faster, a marsh-drainage tactic that can interfere with waste assimilation capacity, disturb fish and wildlife habitats, and aggravate flooding.	*EPA, 2008b*
Channelization	The process of changing (usually straightening) the natural path of a waterway.	*USACE, 1999*
Channelization	Modification of a stream, typically by straightening the channel, to provide more uniform flow; often done for flood control or for improved agricultural drainage or irrigation.	*USGS, 2008*
Characterization of ecological effects	Part of ecological risk assessment that evaluates ability of a stressor to cause adverse effects under given circumstances.	*EPA, 2008b*
Characterization of exposure	Portion of an ecological risk assessment that evaluates interaction of a stressor with one or more ecological entities.	*EPA, 2008b*
Check dam	A small dam designed to retard the flow of water and sediment in a channel, used especially to control soil erosion. Small barrier constructed in a gully or other small watercourse to decrease flow velocity, minimize channel scour, and promote deposition of sediment.	*USBR, 2008*
Check structure	A structure used to regulate the upstream water surface and control the downstream flow in a canal.	*USBR, 2008*
Checked signature	Checked signatures verify that all probability estimates, inputs and outputs and their distributions, were entered correctly into event trees, and that any other calculations, figures, or tables have been checked. This includes "back-of-the-envelope" calculations performed during the risk analysis but not documented in any place but the report. In addition, the accuracy of computer spreadsheets have been checked.	*USBR, 2008*
Chemical oxygen demand (COD)	A measure of the oxygen required to oxidize all compounds, both organic and inorganic, in water.	*EPA, 2008b*
Chemical stressors	Chemicals released to the environment through industrial waste, auto emissions, pesticides, and other human activity that can cause illnesses and even death in plants and animals.	*EPA, 2008b*
Chimney drain	A vertical or inclined layer of pervious material in an embankment to facilitate and control drainage of the embankment fill.	*USBR, 2008*
Chipping	Loosening of shallow rock by light blasting or air hammers.	*USBR, 2008*
Chironomid	Group of two-winged flying insects who live their larval stage underwater and emerge to fly about as adults.	*USBR, 2008*

Chisel plowing	Cropland preparation by a special implement (chisel) that avoids complete inversion of the soil (as occurs with conventional moldboard plowing). Chisel plowing can leave a protective cover of crop residues on the soil surface that helps prevent erosion and improve infiltration.	*USBR, 2008*
Chlordane Octachloro 4,7 methanotetrahy-droindane	An organochlorine insecticide no longer registered for use in the U.S. Technical chlordane is a mixture in which the primary components are cis - and trans - chlordane, cis - and trans - nonachlor, and heptachlor.	*USGS, 2008*
Chloride	An atom of chlorine in solution; an ion bearing a single negative charge.	*EPA, 2008c*
Chlorinated solvent	A volatile organic compound containing chlorine. Some common solvents are trichloroethylene, tetrachloroethylene, and carbon tetrachloride.	*USGS, 2008*
Chlorination	The application of chlorine to water, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results (aiding coagulation and controlling tastes and odors).	*USBR, 2008*
Chlorofluoro-carbons	A class of volatile compounds consisting of carbon, chlorine, and fluorine. Commonly called freons, which have been used in refrigeration mechanisms, as blowing agents in the fabrication of flexible and rigid foams, and, until several years ago, as propellants in spray cans.	*USGS, 2008*
Chronic effect	An adverse effect on a human or animal in which symptoms recur frequently or develop slowly over a long period of time.	*EPA, 2008b*
Chronic exposure	Multiple exposures occurring over an extended period of time or over a significant fraction of an animal's or human's lifetime (Usually seven years to a lifetime.)	*EPA, 2008b*
Chronic toxicity	The capacity of a substance to cause long-term poisonous health effects in humans, animals, fish, and other organisms. (See: acute toxicity.)	*EPA, 2008b*
Chrysene	See Polycyclic aromatic hydrocarbon (PAH).	*USGS, 2008*
Chute	A new channel formed across the base of a meander. As it grows in size, it carries more of the flow.	*FISHWR, 2001*
Chute	Portion of spillway between the gate or crest structure and the terminal structure, where open- channel flow conditions will exist. A conduit for conveying free-flowing materials at high velocity to lower elevations.	*USBR, 2008*
Cipolletti weir (trapezoidal weir)	A contracted weir of trapezoidal shape in which the sides of the notch are given a slope of 1 horizontal to 4 vertical.	*USBR, 2008*
Circle of influence	The circular outer edge of a depression produced in the water table by the pumping of water from a well.	*EPA, 2008b*
Circle of influence	The circular outer edge of a depression produced in the water table by the pumping of water from a well. See cone of influence.	*USBR, 2008*
Cirque	Bowl-like depression carved into a mountaintop by ice at the head of a glacier.	*USBR, 2008*
Cistern	Small tank or storage facility used to store water for a home or farm; often used to store rain water.	*EPA, 2008b*
Cistern	A small tank (usually covered) or a storage facility used to store water for a home or farm. Often used to store rain water.	*USBR, 2008*

CITES	The 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora, regulating or prohibiting international commerce of plant and animal species believed to be harmed by or that may be harmed by international trade. The authority to implement this is under section 8 of the ESA.	*USFWS, 2008*
Cladophora	Filamentous green alga.	*USBR, 2008*
Clast	Rock composed of fragments.	*CCC, 2008*
Clastic	Rock or sediment composed principally of broken fragments that are derived from preexisting rocks which have been transported from their place of origin, as in sandstone.	*USGS, 2008*
Clay	Substrate particles that are smaller than silt and generally less than 0.003 mm in diameter.	*USACE, 1999*
Clay	Fine-grained soil or the fine-grained portion of soil that can be made to exhibit plasticity (putty-like properties) within a range of moisture contents, and that exhibits considerable strength when air-dry. Plastic soil which passes a No. 200 (0.075 mm) United States Standard sieve.	*USBR, 2008*
Clay plug	A soil deposit developed at the intersection of the oxbow and the new main channel.	*FISHWR, 2001*
Clay size	That portion of the soil finer than 0.002 mm (0.005 mm in some cases).	*USBR, 2008*
Clay soil	Soil material containing more than 40 percent clay, less than 45 percent sand, and less than 40 percent silt.	*EPA, 2008b*
Clean sediment	Sediment that is not contaminated by chemical substances. Pollution caused by clean sediment refers to the quantity of sediment, as opposed to the presence of pollutant-contaminated sediment.	*EPA, 2008c*
Clean Water Act	See Federal Water Pollution Control Act of 1948.	*USBR, 2008*
Clean Water Act (CWA)	The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is section 303(d), which establishes the TMDL program.	*EPA, 2008c*
Clear cut	Harvesting all the trees in one area at one time, a practice that can encourage fast rainfall or snowmelt runoff, erosion, sedimentation of streams and lakes, and flooding, and destroys vital habitat.	*EPA, 2008b*
Clearance	A procedure used to establish, under tightly controlled discipline, a safe environment for maintenance, repair, or inspection. It includes systematically isolating pertinent equipment from all sources of hazardous energy (hydraulic, electrical, mechanical, pneumatic, chemical, etc.) and attaching safety tags or locks to the appropriate controls. Also, it includes a written statement that documents isolation of the equipment (also referred to as lockout or tagout).	*USBR, 2008*

Clearing	The removal of all vegetation such as trees, shrubs, brush, stumps, exposed roots, down timber, branches, grass, and weeds. The removal of all rubbish and all other objectionable material. See grubbing.	*USBR, 2008*
Climate	Average conditions of the weather over a number of years. See macroclimate and microclimate.	*USBR, 2008*
Climate	The sum total of the meteorological elements that characterize the average and extreme conditions of the atmosphere over a long period of time at any one place or region of the Earth's surface.	*USGS, 2008*
Climate change	(also referred to as 'global climate change'): The term 'climate change' is sometimes used to refer to all forms of climatic inconsistency, but because the Earth's climate is never static, the term is more properly used to imply a significant change from one climatic condition to another. In some cases, 'climate change' has been used synonymously with the term, 'global warming'; scientists however, tend to use the term in the wider sense to also include natural changes in climate.	*EPA, 2008b*
Climatic year	Continuous 12-month period during which a complete climactic cycle occurs.	*USBR, 2008*
Closed basin	A basin whose topography prevents surface outflow of water. It is considered to be hydrologically closed if neither surface nor underground outflow of water can occur.	*USACE, 1999*
Closure devices	Any movable and essentially watertight barrier, used in flood periods to close an opening in a levee, securing but not increasing the levee design level of protection.	*FEMA, 2003*
Cluster analysis	A statistical procedure which groups members of a population into similar categories (clusters) on the basis of more than one ecological indicator.	*EPA, 1997*
Coarse gravel protection	Gravel generally placed in a layer upon a finished surface to protect the finished surface from deterioration or erosion.	*USBR, 2008*
Coarse woody debris (CWD)	Portion of a tree that has fallen or been cut and left in the woods. Usually refers to pieces at least 20 inches in diameter.	*USACE, 1999*
Coastal access	The ability of the public to reach, use or view the shoreline of coastal waters or inland coastal recreation areas and trails.	*CCC, 2008*
Coastal county	A county or city and county which lies, in whole or in part, within the coastal zone.	*CCC, 2008*
Coastal development permit (CDP)	A permit for any development within the coastal zone that is required pursuant to subdivision (a) of Section 30600.	*CCC, 2008*
Coastal plan	The California Coastal Zone Conservation Plan prepared and adopted by the California Coastal Zone Conservation Commission and submitted to the Governor and the Legislature on December 1, 1975, pursuant to the California Coastal Zone Conservation Act of 1972 (commencing with Section 27000).	*CCC, 2008*
Coastal zone	Lands and waters adjacent to the coast that exert an influence on the uses of the sea and its ecology, or whose uses and ecology are affected by the sea.	*EPA, 2008b*
Coastal zone	Lands and waters adjacent to the coast that exert an influence on the uses of the sea and its ecology, or whose uses and ecology are affected by the sea.	*EPA, 2008c*

Coastal zone	That land and water area of the State of California from the Oregon border to the border of the Republic of Mexico, specified on the maps identified and set forth in Section 17 of that chapter of the Statutes of the 1975-76 Regular Session enacting this division, extending seaward to the state's outer limit of jurisdiction, including all offshore islands, and extending inland generally 1,000 yards from the mean high tide line of the sea. In significant coastal estuarine, habitat, and recreational areas it extends inland to the first major ridgeline paralleling the sea or five miles from the mean high tide line of the sea, whichever is less, and in developed urban areas the zone generally extends inland less than 1,000 yards. The coastal zone does not include the area of jurisdiction of the San Francisco Bay Conservation and Development Commission, established pursuant to Title 7.2 (commencing with Section 66600) of the Government Code, nor any area contiguous thereto, including any river, stream, tributary, creek, or flood control or drainage channel flowing into such area.	*CCC, 2008*
Coastal-dependent development or use	Any development or use which requires a site on, or adjacent to, the sea to be able to function at all.	*CCC, 2008*
Coastal-related development	Any use that is dependent on a coastal-dependent development or use.	*CCC, 2008*
Cobble	Substrate particles that are smaller than boulders and larger than gravels, and are generally 64-256 mm in diameter. Can be further classified as small and large.	*USACE, 1999*
Cobble	Well-rounded rocks along the shore and in river channels. Cobble size particles are between pebbles and boulders, generally larger than coarse gravel (76 mm). California has numerous cobble beaches, with cobble exposed year-round or covered by sand during mild wave periods and exposed during and after storm conditions.	*CCC, 2008*
Cobble (cobblestone)	A rock fragment, usually rounded or semirounded, with an average dimension between 3 to 12 inches; will pass a 12-inch screen, but not a 3-inch screen. A particle of rock that will pass a 12-inch (300-mm) square opening and be retained on a 3-inch (75-mm) U.S.A. Standard sieve.	*USBR, 2008*
Code of Federal Regulations (CFR)	Document that codifies all rules of the executive departments and agencies of the federal government. It is divided into fifty volumes, known as titles. Title 40 of the CFR (referenced as 40 CFR) lists all environmental regulations.	*EPA, 2008b*
Coefficient of compressibility	The slope of a one-dimensional compression curve relating void ratio to effective stress.	*USBR, 2008*
Coefficient of consolidation	A coefficient that relates the change in excess pore pressure with time to the excess pore pressure diffusion in the soil mass in terms of soil mass and pore fluid characteristics.	*USBR, 2008*
Coefficient of skewness	A numerical measure of index of the lack of symmetry in a frequency distribution. Function of the third moment of magnitudes about their mean, a measure of asymmetry. Also called 'coefficient of skew' or ' skew coefficient.'	*USGS, 1982*

Cofferdam	A temporary structure enclosing all or part of the construction area so that construction can proceed in the dry. A diversion cofferdam diverts a river into a pipe, channel or tunnel. A temporary barrier, usually an earthen dike, constructed around a worksite in a reservoir or on a stream, so the worksite can be dewatered or the water level controlled. See dam.	*USBR, 2008*
Cogenerator	A generating facility that produces electricity and another form of useful thermal energy (such as heat or steam), used for industrial, commercial, heating, or cooling purposes. To receive status as a qualifying facility (QF) under the Public Utility Regulatory Policies Act (PURPA), the facility must produce electric energy and "another form of useful thermal energy through the sequential use of energy," and meet certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC). (See the Code of Federal Regulations, Title 18, Part 292.)	*USBR, 2008*
Cohesion	The mutual attraction of soil particles due to molecular and capillary forces in the presence of water. Cohesion is high in clay (especially dry) but of little significance in silt or sand. The ability of a substance to stick to itself and pull itself together. Molecular attraction which holds two particles together.	*USBR, 2008*
Cohesionless materials (cohesionless soil)	Soil materials that when unconfined have little or no strength when air-dried and that have little or no cohesion when submerged. Soil that has little tendency to stick together whether wet or dry, such as sands and gravels.	*USBR, 2008*
Cohesive soil	Predominantly clay and silt soil, fine-grained particles, that sticks together whether wet or dry. A soil that, when unconfined, has considerable strength when air-dried, and that has significant cohesion when submerged.	*USBR, 2008*
Cold-water fishery	Water or water system which has an environment suitable for salmonoid fishes.	*USBR, 2008*
Coliform	Organisms common to the intestinal tract of humans and animals; the organisms' presence in waste water is an indicator of pollution.	*USBR, 2008*
Coliform index	A rating of the purity of water based on a count of fecal bacteria.	*EPA, 2008b*
Coliform organism	Microorganisms found in the intestinal tract of humans and animals. Their presence in water indicates fecal pollution and potentially adverse contamination by pathogens.	*EPA, 2008b*
Collar	The open end of a drill hole.	*USBR, 2008*
Collaring	Starting a drill hole. When the hole is deep enough to hold the bit from slipping out of it, it is said to be collared.	*USBR, 2008*
Colloidal particles	Soil particles that are so small that the surface activity has an appreciable influence on the properties of the aggregate. Particles smaller than 0.001 mm.	*USBR, 2008*
Colloidal suspension	A method of sediment transport in which water turbulence (movement) supports the weight of the sediment particles, thereby keeping them from settling out or being deposited.	*USBR, 2008*
Colloids	Very small, finely divided solids (that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.	*EPA, 2008b*

Colluvium	Soil and rock debris on a hillslope that has been transported from its original location.	*EPA, 2008c*
Colluvium	A general term applied to loose and incoherent deposits, usually at the foot of a slope and brought there chiefly by gravity.	*USBR, 2008*
Combined sewer overflow	A discharge of untreated sewage and stormwater to a stream when the capacity of a combined storm/sanitary sewer system is exceeded by storm runoff.	*USGS, 2008*
Comment period	Time provided for the public to review and comment on a proposed EPA action or rulemaking after publication in the Federal Register.	*EPA, 2008b*
Commercial river trip	Trips organized by boating companies that conduct tours for paying passengers or customers.	*USBR, 2008*
Commercial user day	Amount of commercial use within a 24-hour period or any portion thereof.	*USBR, 2008*
Commercial water use	Water for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions.	*USBR, 2008*
Commercial water use	Water used for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Water for commercial uses comes both from public-supplied sources, such as a county water department, and self-supplied sources, such as local wells.	*DOC, 2005*
Common excavation	All materials excavated not considered as rock. Boulders or detached pieces of solid rock less than 1 cubic yard in volume are classified as common excavation. See excavation.	*USBR, 2008*
Common material	All earth materials which do not fall under the definition of rock.	*USBR, 2008*
Common sense initiative	Voluntary program to simplify environmental regulation to achieve cleaner, cheaper, smarter results, starting with six major industry sectors.	*EPA, 2008b*
Community	In ecology, an assemblage of populations of different species within a specified location in space and time. Sometimes, a particular subgrouping may be specified, such as the fish community in a lake or the soil arthropod community in a forest.	*EPA, 2008b*
Community	Any assemblage of populations of plants and/or animals in a common special arrangement.	*USFS, 2002*
Community	All members of a specified group of species present in a specific area at a specific time; a group of people that see themselves as a unit.	*USBR, 2008*
Community	In ecology, the species that interact in a common area.	*USGS, 2008*
Community cohesion	Ability of a community to have a unified response when facing a problem; e.g., an external threat to their sustainability.	*USBR, 2008*
Community relations	The EPA effort to establish two-way communication with the public to create understanding of EPA programs and related actions, to ensure public input into decision-making processes related to affected communities, and to make certain that the Agency is aware of and responsive to public concerns. Specific community relations activities are required in relation to Superfund remedial actions.	*EPA, 2008b*
Community type	An aggregation of all plant communities distinguished by floristic and structural similarities in both overstory and undergrowth layers. A unit of vegetation within a classification.	*USFS, 2002*

Compacted backfill	Backfill which has been reduced to bulk by rolling, tamping, or soaking.	*USBR, 2008*
Compacted embankment	Embankment which has been reduced in bulk by rolling, tapping, or soaking.	*USBR, 2008*
Compaction	To make soil dense by mechanical manipulation. Mechanical action which increases the density by reducing the voids in a material. See dumped, dynamic compaction, jetting, ponding, puddling, rolling, saturation, sluicing, surface vibration, and tamping.	*USBR, 2008*
Compaction curve (Proctor curve, moisture-density curve)	The curve showing the relationship between the dry density (dry unit weight) and the moisture content of a soil for a given compactive effort.	*USBR, 2008*
Compaction test	A laboratory compacting procedure whereby a soil at a known moisture content is placed in a specified manner into a mold of given dimensions, subjected to a compactive effort of controlled magnitude, and the resulting dry unit weight determined. The procedure is repeated for various moisture contents sufficient to establish a relation between moisture content and dry unit weight.	*USBR, 2008*
Comparative assessment	An analysis of environmental characteristics which proceeds by evaluating members of a population relative to other members (as opposed to an analysis of charactersitics relative to a standard or preferred condition).	*EPA, 1997*
Comparative risk assessment	Process that generally uses the judgement of experts to predict effects and set priorities among a wide range of environmental problems.	*EPA, 2008b*
Compressibility	Property of a soil describing its susceptibility to decrease in volume when subjected to load.	*USBR, 2008*
Compression	The reduction in volume of a soil mass resulting from an increase in effective stress.	*USBR, 2008*
Compression curve	Any function relating volume change to effective stress.	*USBR, 2008*
Concentrated flow path	An existing hypothetical avenue of concentrated seepage. The descriptor "concentrated" implies sufficient energy to carry/move material and erode. Energy varies with material type, construction methods, geology, etc., since an anomaly may result in higher velocities adjacent to materials than more uniform flow through a given material.	*USBR, 2008*
Concentration	Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).	*EPA, 2008c*
Concentration	The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as microgram per liter (water sample) or micrograms per kilogram (sediment or tissue sample).	*USGS, 2008*
Concentration-based limit	A limit based on the relative strength of a pollutant in a wastestream, usually expressed in milligrams per liter (mg/L).	*EPA, 2008c*

Conceptual model	An abstract framework used to organize ideas and information into a form that is more easily examined. These models are often helpful when searching for commonalities between apparently unrelated phenomena, or when defining the scope of inquiry when organizing and interpreting measurements of biological conditions.	*EPA, 1997*
Conceptual model	A descriptive picture or diagram of the relationships among key factors within the watershed. Explicit statements of the hypothesized functional relationships underlying management decisions regarding environmental resources.	*DOC, 2005*
Concrete dam	See arch dam, buttress dam, or gravity dam. See also masonry dam. A concrete dam generally requires a sound rock foundation.	*USBR, 2008*
Concrete lift	In concrete work, the vertical distance between successive horizontal construction joints.	*USBR, 2008*
Concussion	Shock or sharp air waves caused by an explosion or heavy blow.	*USBR, 2008*
Condensation	Water vapor changing back into liquid.	*USBR, 2008*
Cone of depression	A depression in the water table that develops around a pumped well.	*EPA, 2008b*
Cone of influence	The depression, roughly conical in shape, produced in a water table by the pumping of water from a well.	*EPA, 2008b*
Cone of influence (cone of depression)	The depression, roughly conical in shape, produced in the water table by the pumping of water from a well. See circle of influence.	*USBR, 2008*
Cone penterometer testing (CPT)	A direct push system used to measure lithology based on soil penetration resistance. Sensors in the tip of the cone of the DP rod measure tip resistance and side-wall friction, transmitting electrical signals to digital processing equipment on the ground surface.	*EPA, 2008b*
Conference	The interagency cooperation process required for a Federal action that is likely to jeopardize the continued existence of a species proposed for listing or result in the destruction or adverse modification of proposed critical habitat.	*USFWS, 2008*
Confidence limits	Computed values on both sides of an estimate of a parameter that show for a specified probability range in which the true value of the parameter lies.	*USGS, 1982*
Confined aquifer	An aquifer in which ground water is confined under pressure which is significantly greater than atmospheric pressure.	*EPA, 2008b*
Confined aquifer	A water bearing subsurface stratum that is bounded above and below by formations of impermeable or relatively impermeable, soil or rock.	*USACE, 1999*
Confined aquifer	An aquifer in which ground water is confined under pressure which is significantly greater than atmospheric pressure. An aquifer that is bound above and below by dense layers of rock and contains water under pressure. See artesian well.	*USBR, 2008*
Confined aquifer (artesian aquifer)	An aquifer that is completely filled with water under pressure and that is overlain by material that restricts the movement of water.	*USGS, 2008*

Confined space	A space that is large enough to and so configured that a person can bodily enter and perform assigned work. A space that has limited or restricted means for entry and exit. A space not designed for continuous occupancy.	*USBR, 2008*
Confining layer	A layer of sediment or lithologic unit of low permeability that bounds an aquifer,	*USGS, 2008*
Confluence	(1) The act of flowing together, the meeting or junction of two or more streams, also the place where these two streams meet. (2) The stream or body of water formed by the junction of two or more streams, a combined flood.	*USACE, 1999*
Confluence	The place where two streams meet, or the stream formed from two joining streams.	*USBR, 2008*
Confluence	The flowing together of two or more streams; the place where a tributary joins the main stream.	*USGS, 2008*
Conglomerate	Sedimentary rock composed of rounded gravel (pebbles, cobbles, and boulders) cemented together, usually found with sandstone.	*USBR, 2008*
Conifer	A tree belonging to the order Gymnospermae, comprising a wide range of tree that are mostly evergreens. Conifers bear cones (hence, coniferous) and have needle-shaped or scale like leaves.	*USACE, 1999*
Conifers	Cone-bearing trees or shrubs, mostly evergreens such as pine, cedar, and spruce.	*USBR, 2008*
Conjunctive use	The operation of a groundwater basin in combination with a surface water storage and conveyance system. Water is stored in the groundwater basin for later use by intentionally recharging the basin during years of above-average water supply.	*USACE, 1999*
Conjunctive use	The coordinated use of surface water and ground water resources.	*USBR, 2008*
Conjunctive use	Integrated management of surface water and groundwater supplies to meet overall water supply and resource management objectives.	*DOC, 2005*
Connection	The physical connection (e.g. transmission lines, transformers, switch gear, etc.) between two electric systems permitting the transfer of electric energy in one or both directions.	*USBR, 2008*
Consequence	The outcome or result of an event, for example economic, social, or environmental impact. May be expressed by quantitatively (i.e. monetary value), by category (i.e. high, medium, low) or descriptively.	*Mockett & Simm, 2002*
Consequences	Potential loss of life or property damage downstream of a dam caused by flood waters released at the dam or by waters released by partial or complete failure of the dam. Includes effects of landslides upstream of the dam on property located around the reservoir. Potential number of lives that would be lost from a dam failure and an uncontrolled reservoir release (considers load, failure modes, and estimated population distribution warning times).	*USBR, 2008*
Conservation	Preserving and renewing, when possible, human and natural resources. The use, protection, and improvement of natural resources according to principles that will ensure their highest economic or social benefits.	*EPA, 2008b*

Conservation	The process or means of achieving recovery of viable populations.	*USACE, 1999*
Conservation	Increasing the efficiency of energy use, water use, production, or distribution.	*USBR, 2008*
Conservation area	Designated land where conservation strategies are applied for the purpose of attaining a viable plant or animal population.	*USACE, 1999*
Conservation banking	A method used to offset impacts occurring elsewhere to the same listed species. A "bank" consists of non-Federal land containing natural resource values conserved and managed in perpetuity.	*USFWS, 2008*
Conservation easement	Easement restricting a landowner to land uses that that are compatible with long-term conservation and environmental values.	*EPA, 2008b*
Conservation recommendation	A suggestion that FWS or NOAA Fisheries may provide with a biological opinion describing discretionary conservation actions; it is advisory and does not carry any binding legal force.	*USFWS, 2008*
Conservation recommendations	Suggestions by conservation agencies regarding discretionary measures to minimize or avoid adverse effects on a proposed action of federally listed threatened or endangered species or designated critical habitat.	*USACE, 1999*
Conservation strategy	A management plan for a species, group of species, or ecosystem that prescribes standards and guidelines that, if implemented, provide a high likelihood that species, groups of species, or ecosystem, with its full complement of species and processes, will continue to exist well-distributed throughout a planning area (i.e. a viable population).	*USACE, 1999*
Conserve, conserving, and conservation	The use of methods and procedures necessary to bring any endangered or threatened species to the point at which the measures provided under the Endangered Species Act are no longer necessary; includes research, census, law enforcement, habitat acquisition and maintenance, propagation, live trapping, and transportation, and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking.	*USFWS, 2008*
Consistency	The relative ease with which a soil can be deformed.	*USBR, 2008*
Consolidation	Reduction in particle spacing in a soil, and decrease in water content, resulting from an increase in external pressure.	*USBR, 2008*
Consolidation curve	Any function relating volume change to time.	*USBR, 2008*
Consolidation grouting	Strengthening an area of ground by injecting grout.	*USBR, 2008*
Consolidometer	Apparatus used for one-dimensional consolidation/compression testing.	*USBR, 2008*
Constant angle arch dam	An arch dam in which the angle subtended by any horizontal section is constant throughout the whole height of the dam.	*USBR, 2008*
Constant radius arch dam	An arch dam in which every horizontal segment or slice of the dam has approximately the same radius of curvature.	*USBR, 2008*
Constituent	A chemical or biological substance in water, sediment, or biota that can be measured by an analytical method.	*USGS, 2008*

Constituent(s) of concern	Specific chemicals that are identified for evaluation in the site assessment process.	*EPA, 2008b*
Construction joint	Construction joints are purposely placed in concrete to facilitate construction; to reduce initial shrinkage stresses and cracks; to allow time for the installation of embedded metalwork; or to allow for the subsequent placing of other concrete. Bond is required at construction joints regardless of whether or not reinforcement is continuous across the joint. A construction joint allows a reasonable size concrete placement or a point to terminate a placement. The interface between two successive placings of concrete where bond, and not permanent separation, is intended.	*USBR, 2008*
Consultation	The process required of a Federal agency under section 7 of the ESA when any activity authorized, carried out, or conducted by that agency may affect a listed species or designated critical habitat; consultation is with FWS or NOAA Fisheries and may be either informal or formal.	*USFWS, 2008*
Consumer surplus	The value of a commodity, good, or opportunity above the cost to the consumer; measured using willingness to pay, as specified in Federal guidelines for water resources planning.	*USBR, 2008*
Consumptive use	A use which lessens the amount of water available for another use. Water uses normally associated with man's activities, primarily municipal, industrial, and irrigation uses that deplete water supplies. Water removed from available supplies without direct return to a water resource system, for uses such as manufacturing, agriculture, and food preparation. A nonconsumptive use would be one such as boating or swimming. See beneficial use. Combined amounts of water needed for transpiration by vegetation and for evaporation from adjacent soil, snow, or intercepted precipitation. Also called: crop requirement, crop irrigation requirement, consumptive use requirement. See evapotranspiration.	*USBR, 2008*
Consumptive use	That part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.	*DOC, 2005*
Consumptive use	The quantity of water that is not available for immediate reuse because it has been evaporated, transpired, or incorporated into products, plant tissue, or animal tissue. Also referred to as "water consumption".	*USGS, 2008*
Consumptive water use	Total amount of water used by vegetation, man's activities, and evaporation of surface water.	*USBR, 2008*
Contact load	Sediment particles that roll or slide along in almost continuous contact with the streambed.	*USBR, 2008*
Containment levee	A dike or embankment to contain stream flow.	*USBR, 2008*
Contaminant	Any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil.	*EPA, 2008b*
Contaminant	A potentially harmful physical, biological, chemical or radiological substance in water. Any physical chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil.	*USBR, 2008*

Contaminate	To make impure or unclean by contact or mixture.	*USACE, 1999*
Contaminated sediments	Deposited or accumulated sediments, typically on the bottom of a waterbody, that contain contaminants. These may or may not be toxic as revealed by a whole sediment toxicity test, or as predicted by equilibrium partitioning.	*EPA, 2008c*
Contamination	Introduction into water, air, and soil of microorganisms, chemicals, toxic substances, wastes, or wastewater in a concentration that makes the medium unfit for its next intended use. Also applies to surfaces of objects, buildings, and various household and agricultural use products.	*EPA, 2008b*
Contamination	The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.	*EPA, 2008c*
Contamination	Degradation of water quality compared to original or natural conditions due to human activity.	*USGS, 2008*
Contiguous	Actual contact with; also, near or adjacent to.	*USBR, 2008*
Contiguous habitat	Habitat suitable to support the life needs of a species that is distributed continuously or nearly continuously across the landscape.	*USACE, 1999*
Continental shelf	The zone bordering a continent and extending from the low water line to depth (usually about 180 meters) where there is a marked or rather steep descent toward a greater depth.	*CCC, 2008*
Contingencies	Used in appraisal and feasibility estimates to estimate overruns on quantities, changed site conditions, change orders, etc. Contingencies are considered as funds to be used after construction starts and not for design changes or changes in project planning. Appraisal estimates should have 25 percent added and feasibility estimates should have 20 percent added for contingencies.	*USBR, 2008*
Contingent valuation	Survey method asking for the maximum values that users would pay for access to a particular activity.	*USBR, 2008*
Continuous discharge	A routine release to the environment that occurs without interruption, except for infrequent shutdowns for maintenance, process changes, etc.	*EPA, 2008b*
Continuous discharge	A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.	*EPA, 2008c*
Continuous sample	A flow of water, waste or other material from a particular place in a plant to the location where samples are collected for testing. May be used to obtain grab or composite samples.	*EPA, 2008b*
Continuous-flow irrigation	System of irrigation water delivery where each irrigator receives their allotted quantity of water at a continuous rate.	*USBR, 2008*
Contour	A line of constant elevation.	*USBR, 2008*
Contour	A line on a topographic map or bathymetric (depth) chart representing points of equal elevation with relation to a datum (point or set of points). Contour lines are usually spaced into intervals for easier comprehension and utilization.	*CCC, 2008*
Contour ditch	Irrigation ditch laid out approximately on the contour.	*USBR, 2008*

Contour farming	System of farming used for erosion control and moisture conservation whereby field operations are performed approximately on the contour. A conservation-based method of farming in which all farming operations (for example, tillage and planting) are performed across (rather than up and down) the slope. Ideally, each crop row is planted at right angles to the ground slope.	*USBR, 2008*
Contour flooding	Method of irrigation by flooding from contour ditches.	*USBR, 2008*
Contour map	Topographic map that portrays relief or elevation differences by the use of lines (contours) indiciating equal elevation.	*USBR, 2008*
Contour plowing	Plowing done in accordance with the natural outline or shape of the land by keeping the furrows or ditches at the same elevation as much as possible to reduce runoff and erosion.	*USBR, 2008*
Contour strip farming	A kind of contour farming in which row crops are planted in strips, between alternating strips of close-growing, erosion resistant forage (grass, grain, hay) crops.	*USBR, 2008*
Contract rate	The repayment or water service rate set forth in a contract to be paid by a district to the United States.	*USBR, 2008*
Contracted weir	The crest and sides of a retangular weir are far enough from the bottom and sides of the channel so that their effect on flow is negligible.	*USBR, 2008*
Contraction joint	Contraction joints are joints placed in concrete to provide for volumetric shrinkage of a monolithic unit or movement between monolithic units. Contraction joints have no bond between the concrete surfaces forming the joint. Except as otherwise provided for dowels, reinforcement is never continuous across a contraction joint. Contraction joints will not transfer moment and will not transfer shear unless keyed.	*USBR, 2008*
Contributing area	The area in a drainage basin that contributes water to streamflow or recharge to an aquifer.	*USGS, 2008*
Control area	Part of a power system, or a combination of systems, to which a common electrical generation allocation scheme is applied.	*USBR, 2008*
Control structure (control house)	Concrete portion of an outlet works, located at the downstream end of the tunnel or conduit, housing the control (regulation) gates. Water regulating structure. A structure on a stream or canal that is used to regulate the flow or stage of the stream.	*USBR, 2008*
Controlled low strength material (CLSM)	Also known as flowable fill or cement-slurry backfill, a mixture of pozzolan, Portland cement, water, coarse aggregate, and occasionally soil, typically used for pipe bedding and backfill with a strength of 50-100 psi at 28 days.	*USBR, 2008*
Conventional pollutants	As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.	*EPA, 2008c*
Conventional tillage	The traditional method of farming in which soil is prepared for planting by completely inverting it with a moldboard plow. Subsequent working of the soil with other implements is usually performed to smooth the soil surface. Bare soil is exposed to the weather for some varying length of time depending on soil and climatic conditions. See tillage.	*USBR, 2008*

Conveyance	Losswater that is lost in transit from a pipe, canal, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground-water source and be available for further use.	*DOC, 2005*
Conveyance loss (distribution loss)	Loss of water from a channel or pipe during conveyance, including losses due to seepage, leakage, evaporation and transpiration by plants growing in or near the channel. Water not available for further use.	*USBR, 2008*
Conveyance system efficiency	The ratio of the volume of water delivered to users in proportion to the volume of water introduced into the conveyance system.	*USBR, 2008*
Conveyor	A device that transports material by belts, cables, or chains.	*USBR, 2008*
Cooperative Agreement	Formal document that states the obligations of Reclamation to one or more other parties. A cooperative agreement provides the authority for the Bureau of Reclamation to issue funding to the other party(ies) listed in the agreement.	*USBR, 2008*
Coordinated operation	Generally, the operation of two or more interconnected electrical systems to achieve greater reliability and economy. As applied to hydropower resources, the operation of a group of hydropower plants to obtain optimal power benefits with due consideration to all other uses.	*USBR, 2008*
Coordination	The practice by which two or more interconnected electric power systems augment the reliability of bulk electric power supply by establishing planning and operating standards; by exchanging pertinent information regarding additions, retirements, and modifications, to the bulk electric power supply system; and by joint review of these changes to assure that they meet the predetermined standards.	*USBR, 2008*
Corduroy	A road made of logs laid crosswise on the ground or on other logs.	*USBR, 2008*
Core (impervious core or impervious zone)	A zone of low permeability material in an embankment dam. Sometimes referred to as "central core," "inclined core," "puddle clay core," and "rolled clay core." A cylindrical piece of an underground formation cut and raised by a rotary drill with a hollow bit.	*USBR, 2008*
Core area	The area of habitat essential in the breeding, nesting, and rearing of young up to the point of dispersal of the young.	*USACE, 1999*
Core drill	A rotary drill, usually a diamond drill, equipped with a hollow bit and a core lifter.	*USBR, 2008*
Core wall	A wall of substantial thickness built of impervious material, usually of concrete or asphaltic concrete, in the body of an embankment dam to prevent leakage. See membrane.	*USBR, 2008*
Correlation	The relation between two or more variables. A statistical test that sets a numerical value to the amount of interdependence.	*USBR, 2008*
Corridor	A special type of patch that links other patches in the matrix. Typically, a corridor is linear or elongated in shape, such as a stream corridor.	*FISHWR, 2001*
Corridor	Narrow strip of land reserved for location of transmission lines, pipelines, and service roads.	*USBR, 2008*

Corrosion	Wear or dissolving away through chemical action as by rusting, or acids. The gradual decomposition or destruction of a material by chemical action, often due to an electrochemical reaction. Corrosion may be caused by stray current electrolysis, galvanic corrosion caused by dissimilar metals, or differential concentration cells. Corrosion starts at the surface of a material and moves inward.	*USBR, 2008*
Cost effectiveness	Economic efficiency, obtaining the best method for the least amount of money.	*USBR, 2008*
Cost/benefit analysis	A quantitative evaluation of the costs which would have incurred by implementing an environmental regulation versus the overall benefits to society of the proposed action.	*EPA, 2008b*
Cost-benefit analysis	A quantitative evaluation of the costs which would be incurred versus the overall benefits to society of a proposed action.	*USBR, 2008*
Cost-share program	A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs are paid by the producer.	*EPA, 2008c*
Coulees	Small streams or dry streambeds. A deep gulch or ravine, usually dry in the summer.	*USBR, 2008*
Cover	Anything that provides protection for fish and/or wildlife from predators or ameliorates adverse conditions of stream flow and/or seasonal changes in metabolic costs. May be in stream structures such as rocks or logs, turbulence, and/or overhead vegetation. Anything that provides areas for escape, feeding, hiding, or resting.	*USFS, 2002*
Coyote holes	Horizontal tunnels in which explosives are packed for blasting a high rock face.	*USBR, 2008*
Crazing	A network pattern of fine cracks in concrete that do not penetrate much below the surface. Crazing cracks are very fine and are barely visible, except when the concrete is drying after it has become wet.	*USBR, 2008*
Creel census area	The collection of data concerning the number of fish caught by sport fishers on a particular stream or in a particular area.	*USACE, 1999*
Creep	Slow movement of rock debris or soil usually imperceptible except to observations of long duration. Time-dependent strain or deformation, for example, continuing strain with sustained stress.	*USBR, 2008*
Crest	The top surface of the dam. A roadway may be constructed across the crest to permit vehicular traffic or facilitate operation, maintenance, and examination of the dam. Also, the high point of the spillway control section.	*USBR, 2008*
Crest elevation (crest of dam, top of dam, dam crest)	The elevation of the uppermost surface of a dam, usually a road or walkway, excluding any parapet wall, railing, curb. etc. The crown of the roadway or the level of the walkway which crosses the dam. On embankment dams, the crest of the dam is the top of the embankment, not including camber, crown, or roadway surfacing.	*USBR, 2008*

Crest length (length of dam)	The distance, measured along the axis or centerline crest of the dam at the top level of the main body of the dam or of the roadway surface on the crest, from abutment contact to abutment contact exclusive of an abutment spillway; provided that, if the spillway lies wholly within the dam and not in any area especially excavated for the spillway, the length includes the spillway. The length along the top of a dam. This also includes the spillway, powerplant, navigation lock, fish pass, etc., where these form part of the length of the dam. If detached from the dam, these structures should not be included.	*USBR, 2008*
Crest structure	Portion of spillway between the inlet channel and the chute, tunnel or conduit, which does not contain gates.	*USBR, 2008*
Crest width (top thickness)	The thickness or width of a dam at the level of the top of dam (excluding corbels or parapets). In general, the term thickness is used for gravity and arch dams, and width is used for other dams.	*USBR, 2008*
Cretaceous	A period of geologic time spanning 136-64 million years ago.	*CCC, 2008*
Crib dam	A gravity dam built up of boxes, cribs, crossed timbers or gabions, filled with earth or rock.	*USBR, 2008*
Criteria	Descriptive factors taken into account by EPA in setting standards for various pollutants. These factors are used to determine limits on allowable concentration levels, and to limit the number of violations per year. When issued by EPA, the criteria provide guidance to the states on how to establish their standards.	*EPA, 2008b*
Criteria	(1) Under section 304(a) of the Clean Water Act, EPA publishes scientific information regarding concentrations of specific chemicals or levels of parameters in water that protect aquatic life and human health. (2)Levels of individual pollutants, or water quality characteristics, or descriptions of conditions of a water body, adopted into State water quality standards that, if met, will generally protect the designated use of the water. In many cases, States make use of the criteria developed by EPA under definition #1 above.	*EPA, 2008c*
Criterion	A standard rule or test on which a judgment or decision can be based.	*USGS, 2008*
Critical condition	The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.	*EPA, 2008c*
Critical depth	The depth of flow when the Froude number equals one. The depth of flow at which the discharge is maximum for a given specific energy, or the depth at which a given discharge occurs with minimum specific energy.	*USBR, 2008*
Critical discharge	The maximum discharge for a given specific energy, or the discharge which will occur with minimum specific energy.	*USBR, 2008*

Term	Definition	Source
Critical flow	When the Froude number is equal to one, the flow is critical and surface waves remain stationary in the flow. Flow at critical depth. Used to describe open channel flow when certain relationships exist between specific energy and discharge, and between specific energy and depth.	*USBR, 2008*
Critical habitat	Under the Endangered Species Act, critical habitat is defined as (1) the specific areas within the geographic area occupied by a federally listed species on which are found physical and biological features essential to the conservation of the species, and that may require special management considerations or protections; and (2) specific areas outside the geographic area occupied by a listed species, when it is determined that such areas are essential for the conservation of the species.	*USACE, 1999*
Critical habitat	Specific geographic areas, whether occupied by a listed species or not, that are essential for its conservation and that have been formally designated by rule published in the Federal Register.	*USFWS, 2008*
Critical habitat	Defined in Section 3(5)(A) of the Endangered Species Act (ESA) as: (1) The specific areas within the geographical area occupied by the species at the time it is listed, on which are found those physical and biological features essential to the conservation of the listed species and which may require special management considerations for protection; and (2) Specific areas outside the geographical area occupied by a species at the time it is listed upon a determination by the Secretary of the Department of Interior that such areas are essential for the conservation of the species. These areas have been legally designated via Federal Register notices.	*USBR, 2008*
Critical height	The maximum height at which a vertical or sloped bank of soil will stand unsupported under a given set of conditions.	*USBR, 2008*
Critical shear stress	The minimum amount of shear stress exerted by stream currents required to initiate soil particle motion. Because gravity also contributes to stream bank particle movement but not on streambeds, critical shear stress along stream banks is less than for streambeds.	*USACE, 1999*
Critical slope	The maximum angle with the horizontal at which a sloped bank of soil or rock of given height will stand unsupported. That slope which will sustain a given discharge at uniform critical depth in a given channel.	*USBR, 2008*
Critical velocity	The mean velocity when the discharge is critical.	*USBR, 2008*
Crop irrigation requirement	Quantity of water, exclusive of effective precipitation, that is needed for crop production. See irrigation requirement.	*USBR, 2008*
Crop root zone	The soil depth from which a mature crop extracts most of the water needed for evapotranspiration. The crop root zone is equal to effective rooting depth and is expressed as a depth in inches or feet. This soil depth may be considered as the rooting depth of a subsequent crop, when accounting for soil moisture storage in efficiency calculations.	*USBR, 2008*

Crop rotation	A pattern of changing the crops grown in a specific field from year to year in order to control pests and maintain soil fertility. A system of farming in which a regular succession of different crops are planted on the same land area, as opposed to growing the same crop time after time (monoculture).	*USBR, 2008*
Crop subsidy	Price support paid by the government to farmers.	*USBR, 2008*
Crop water requirement	Crop consumptive use plus the water required to provide the leaching requirements.	*USBR, 2008*
Cropping pattern	The acreage distribution of different crops in any one year in a given farm area such as a county, water agency, or farm. Thus, a change in a cropping pattern from one year to the next can occur by changing the relative acreage of existing crops, and/or by introducing new crops, and/or by cropping existing crops.	*USBR, 2008*
Cross-section	Slice of the channel and adjacent valley made perpendicular to the assumed flow. The ground surface and streambed elevations of this slice are used in hydraulic computations. An elevation view of a dam formed by passing a plane through the dam perpendicular to the axis.	*USBR, 2008*
Cross-sectional area	Wet area of a waterbody normal to the longitudinal component of the flow.	*EPA, 2008c*
Cross-sectional area	Area of a stream, channel or waterway, usually measured perpendicular to the flow.	*USBR, 2008*
Crown	The upper part of a tree or other woody plant that carries the main system of branches and the foliage.	*USACE, 1999*
Crown	The highest point of the interior of a circular conduit, pipe, or tunnel (also referred to as the soffit). The point in an arch dam which generally corresponds with where the height of the dam is a maximum. The elevation of a road center above its sides.	*USBR, 2008*
Crown cover	The degree to which the crowns of trees are nearing general contact with one another.	*USACE, 1999*
Crushed gravel	Gravel which has been produced by a machine.	*USBR, 2008*
Crushed rock	Rock which has been reduced in size by a machine.	*USBR, 2008*
Crusher	A machine which reduces rocks to smaller and more uniform sizes.	*USBR, 2008*
Cryptosporidium	See protozoa.	*EPA, 2008c*
Crystalline rocks	Rocks (igneous or metamorphic) consisting wholly of crystals or fragments of crystals.	*USGS, 2008*
Cubic feet per second (cfs or ft3/s)	A unit of discharge for measurement of a flowing liguid equal to a flow of 1 cubic foot per second (448.8 gallons per minute (gpm), 7.48 gallons per second, or 1.98 acre-feet per day). A rate of streamflow; the volume, in cubic feet, of water passing a reference point in 1 second.	*USBR, 2008*
Cubic feet per second (cfs)	A unit used to measure water flow. One cubic foot per second is equal to 449 gallons per minute.	*USACE, 1999*
Cubic feet per second (cfs)	A rate of the flow, in streams and rivers, for example. It is equal to a volume of water one foot high and one foot wide flowing a distance of one foot in one second. One cfs is equal to 7.48 gallons of water flowing each second. As an example, if your car's gas tank is 2 feet by 1 foot by 1 foot (2 cubic feet), then gas flowing at a rate of 1 cubic foot/second would fill the tank in two seconds.	*DOC, 2005*

Cubic foot per second (cfs or ft3/s)	As a rate of streamflow, a cubic foot of water passing a reference section in one second of time. A measure of a moving volume of water (1 cfs = 0.02832 m3/s).	*USBR, 2008*
Cubic foot per second (ft3/s, or cfs)	Rate of water discharge representing a volume of 1 cubic foot passing a given point during 1 second, equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute or 0.02832 cubic meter per second.	*USGS, 2008*
Cultural patrimony	Ancestral heritage and entitlement.	*USBR, 2008*
Cultural resource(s)	Any building, site, district, structure, or object significant in history, architecture, archeology, culture, or science. Can include a community's heritage and way of life.	*USBR, 2008*
Culvert	A buried pipe that allows flow to pass under a road.	*USACE, 1999*
Culvert	A pipe or small bridge for drainage under a road or structure. A conduit for the free passage of surface drainage water under a highway, railroad, canal, or other embankment.	*USBR, 2008*
Cumulative ecological risk assessment	Consideration of the total ecological risk from multiple stressors to a given eco-zone.	*EPA, 2008b*
Cumulative effect (cumulative impacts)	The incremental effects of an individual project shall be reviewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects.	*CCC, 2008*
Cumulative effects	For purposes of consultation under the ESA, the effects of future State or private activities not involving Federal activities that are reasonably certain to occur within the action area of an action subject to consultation. Cumulative effects are defined differently for purposes of the National Environmental Policy Act (NEPA).	*USFWS, 2008*
Cumulative environmental impact	The net result of more than one stress applied to a given unit of the landscape.	*EPA, 1997*
Cumulative impacts	Describes situations when the effects of an action are added to or interact with other effects in a particular place and within a particular time. A multi-purpose practice used for the removal of sediment that accumulates at the bottom of water bodies.	*EPA, 2008c*
Cumulative watershed effects (CWE)	The combined impact on watershed processes from multiple sources of natural and human disturbance in a watershed.	*DOC, 2005*
Curb stop (curb cock)	A water service shutoff valve located in a water service pipe near the curb and between the water main and the building. This valve is usually operated by a wrench or valve key and is used to start or stop flows in the water service line to a building.	*USBR, 2008*
Current	A flow of water in a particular direction. Such flows can be driven by wind, temperature or density differences, tidal forces, and wave energy. Currents are often classified by location, such as longshore current, surface current, or deep ocean currents. Different currents can occur in the same general area, resulting in different water flows, for example, a rip current can flow perpendicular to the shore through the surf zone, a long shore current may flow southerly, parallel to the coast and a seasonal deep water current may flow to the north.	*CCC, 2008*

Curtain grouting	The process of pressure grouting deep holes under a dam or in an abutment to form a watertight barrier and effectively seal seams, fissures, fault zones, or fill cavities in the foundation or abutment.	*USBR, 2008*
Curved gravity dam	A gravity dam which is curved in plan.	*USBR, 2008*
Cut	To lower an existing grade or surface level, or an area where this has been done. Gross cut is the total amount of excavation in a road or a road section, without regard to fill requirements. Net cut is the amount of excavated material to be removed from a road section, after completing fills in that section.	*USBR, 2008*
Cut off	A channel cut across the neck of a bend, eliminating the bend.	*USFS, 2002*
Cutoff	An impervious construction by means of which water is prevented from passing through foundation material.	*USBR, 2008*
Cutoff trench (keyway)	An excavation in the foundation of an embankment dam, usually located upstream of the dam axis or centerline crest which extends to bedrock or to an impervious stratum. The excavation is backfilled with impervious material to form a cutoff and reduce percolation under the dam. See foundation trench.	*USBR, 2008*
Cutoff wall	A wall of impervious material (e.g., concrete, asphaltic concrete, timber, steel sheet piling, or impervious grout curtain) located in the foundation beneath a dam and which forms a water barrier and reduces seepage under a dam or spillway.	*USBR, 2008*
Cutting	Excavating, lowering a grade.	*USBR, 2008*
Cycle	A completed round of regularly recurring events or phenomena.	*USBR, 2008*
Cyclopean dam	A gravity dam in which the mass masonry consists primarily of large one-man or derrick stone embedded in concrete.	*USBR, 2008*

D

Dam	A barrier built across a watercourse to impound or divert water. A barrier that obstructs, directs, retards, or stores the flow of water. Usually built across a stream. A structure built to hold back a flow of water. See afterbay dam, ambursen dam, arch dam, buttress dam, check dam, coffer dam, concrete dam, crib dam, detention dam, diversion dam, double curvature arch dam, earth dam, embankment dam, gabion dam, gravity arch dam, gravity dam, hollow gravity dam, hydraulic fill dam, industrial waste dam, masonry dam, mine tailings dam, multiple arch dam, multipurpose dam, overflow dam, precast dam, prestressed dam, regulating dam, rockfill dam, roller-compacted concrete dam, rubble dam, or saddle dam.	*USBR, 2008*
Dam failure	Catastrophic type of failure characterized by the sudden, rapid, and uncontrolled release of impounded water. It is recognized that there are lesser degrees of failure and that any malfunction or abnormality outside the design assumptions and parameters which adversely affect a dam's primary function of impounding water could be considered a failure. Such lesser degrees of failure can progressively lead to or heighten the risk of a catastrophic failure. They are, however, normally amenable to corrective action.	*USBR, 2008*

Dam failure hydrograph	A flood hydrograph resulting from a dam breach prepared for a specific location downstream from the dam.	*USBR, 2008*
Dam foundation	The excavated surface or undisturbed material upon which a dam is placed.	*USBR, 2008*
Dam removal/retrofit	Removal of dams and weirs or modifications/retrofits to existing dams to reduce negative ecological impacts. Excludes dam modifications that are simply for improving Fish Passage.	*NRRSS, 2005*
Dam safety deficiency	A physical condition capable of causing the sudden uncontrollable release of reservoir water by partial or complete failure of a dam, appurtenant structure, or facility.	*USBR, 2008*
Dam safety issue	Dam safety related issues and concerns are those which, if not adequately addressed could/would: 1 - Lead to a failure or malfunction reulting in an uncontrolled release of stored water that would place the downstream population potentially at risk or; 2 - Compromise the agency's ability to detect developing adverse dam performance and prudently respond to that performance.	*USBR, 2008*
Dam tender	The person responsible for the daily or routine operation and maintenance activities of a dam and its appurtenant structures. The dam tender commonly resides at or near the dam.	*USBR, 2008*
Data quality objectives (DQOs)	Qualitative and quantitative statements of the overall level of uncertainty that a decision-maker will accept in results or decisions based on environmental data. They provide the statistical framework for planning and managing environmental data operations consistent with user's needs.	*EPA, 2008b*
DataWeb	DataWeb is an electronic presentation of the Bureau of Reclamation's Project Data book and contains historical, statistical, and technical information on the projects of the Bureau of Reclamation.	*USBR, 2008*
Datum	Any level surface taken as a plane of reference from which to measure elevations.	*USBR, 2008*
DDT	Dichloro-diphenyl-trichloroethane. An organochlorine insecticide no longer registered for use in the United States.	*USGS, 2008*
Dead blow hammer	A hammer filled with lead shot or sand.	*USFS, 2002*
Dead capacity (dead storage)	The reservoir capacity from which stored water cannot be evacuated by gravity.	*USBR, 2008*
Dead man	A log, timber, block of concrete, or pipe buried in a stream bank that is used to anchor a revetment with cable or chain.	*USFS, 2002*
Dead stout stakes	Stakes, made from 2x4 lumber, used to hold erosion control fabric, fascines, and brush mattresses, and so on, in place.	*USFS, 2002*
Debris	Any material, organic or inorganic, floating or submerged, moved by a flowing stream.	*USFS, 2002*
Debris fan	Sloping mass of boulders, cobbles, gravel, sand, silt and clay formed by debris flows at the mouth of a tributary.	*USBR, 2008*
Debris flow	A rapidly moving mass of rock fragments, soil, and mud, with more than half of the particles being larger than sand size.	*USACE, 1999*
Debris flow	Flash flood consisting of a mixture of rocks and sediment containing less than 40 percent water, by volume; forms a debris fan.	*USBR, 2008*

Debris torrent	Rapid movement of a large quantity of materials (wood and sediment) down a stream channel during storms or floods. This generally occurs in smaller streams and results in scouring of the streambed.	*USACE, 1999*
Decay	The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.	*EPA, 2008c*
Deciduous	Trees and plants that shed their leaves at the end of the growing season.	*USACE, 1999*
Decision criteria	Set of formal criteria that is used to determine if an event is threatening and what action to implement.	*USBR, 2008*
Decision makers	Designated personnel responsible for interpreting data that has been collected and determining if an event is threatening enough to issue an alert or warning.	*USBR, 2008*
Decision making	The second of five Early Warning System components consisting of the processes and facilities necessary to translate incoming data about the threatening event into decisions to alert or warn the population at risk.	*USBR, 2008*
Decision/event/ fault tree	Ways of describing a system and the linkages between different parts of the system. Useful for identifying causes, tracing possible sequences of events and investigating the effects of decisions.	*Mockett & Simm, 2002*
Decompose	To rot or decay.	*DOC, 2005*
Decomposer	Any of various organisms (as many bacteria and fungi) that feed on and break down organic substances (such as dead plants and animals).	*USACE, 1999*
Decomposition	The breakdown of matter by bacteria and fungi, changing the chemical makeup and physical appearance of materials.	*EPA, 2008b*
Decomposition	The breakdown of matter by bacteria and fungi, changing the chemical makeup and physical appearance of materials.	*USACE, 1999*
Decomposition	The separation of organic or chemical matter.	*USFS, 2002*
Decomposition	Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. (See also Respiration.)	*EPA, 2008c*
Decomposition	Refers to subdividing a failure mode into discrete elements or sequential events so that the failure mode could be better understood, and probabilities can be more reasonably estimated for each step in an event tree.	*USBR, 2008*
Deed covenant	A term used in association with the sale of excess lands. In order for an eligible buyer of excess land to receive Reclamation irrigation water on such land, a covenant controlling the sale price of the land must be placed in the deed transferring the land to the buyer.	*USBR, 2008*
Deep percolation	The percolation of water through the ground and beyond the lower limit of the root zone of plants into a groundwater aquifer.	*USACE, 1999*
Deep percolation	The movement of water by gravity downward through the soil profile beyond the root zone; this water is not used by plants. Percolation of irrigation water past the plant root zone to regions of deeper ground-water aquifers.	*USBR, 2008*

Deficiency Verification Analysis (DVA)	This analysis verifies the existence or non-existence of Safety of Dams (SOD) deficiencies at the dam. Technical memorandums (TM) are prepared which document the analyses used in the investigation of the potential SOD deficiencies. A decision memorandum (DM) is also prepared which recommends if corrective actions should be taken to mitigate the SOD deficiencies. The DVA also includes the establishment of the Design Loading Criteria which include the design earthquake and the inflow design flood (IDF).	*USBR, 2008*
Deflagration	To burn with sudden and startling combustion. Describes explosion of black powder, as opposed to the more rapid detonation of dynamite.	*USBR, 2008*
Deflation	The force of wind erosion, e.g., blowouts.	*USBR, 2008*
Deflect	A decrease in the vertical diameter of a flexible pipe.	*USBR, 2008*
Deflection	Upstream or downstream movement of a dam or dike.	*USBR, 2008*
Deformation	Change in shape or size.	*USBR, 2008*
Degradation	(1) A progressive lowering of the channel bed due to scour. Degradation is an indicator that the stream's discharge and/or sediment load is changing. The opposite of aggradation. (2) A decrease in value for a designated use.	*USACE, 1999*
Degradation	The long-term hydraulic process by which stream and riverbeds lower in elevation. It is the opposite of aggradation.	*USFS, 2002*
Degradation	Process wherein the elevation of streambeds, sandbars, and flood plains is lowered by erosion. The opposite of aggradation.	*USBR, 2008*
Degradation products	Compounds resulting from transformation of an organic substance through chemical, photochemical, and/or biochemical reactions.	*USGS, 2008*
Delay	A device used to obtain detonation of charges at separate times. An electric blasting cap which explodes at a set interval after current is passed through it.	*USBR, 2008*
Delay pattern	Order of firing charges obtained by arranging delays to fire separate holes or series of holes at different times.	*USBR, 2008*
Delist	To remove an animal or plant species from the list of endangered and threatened wildlife and plants.	*USFWS, 2008*
Delivery	The amount of water delivered to the point of use. The difference between delivery and release is usually the same as consumptive use.	*USBR, 2008*
Delta	An alluvial sediment deposit normally formed where a river or stream enters a lake or estuary. Flat land mass of sediment deposit formed at the mouths of streams where they enter larger bodies of water. Sediment deltas are usually triangular in plan view, narrow at the upstream end and relatively wide at the downstream end. The sediment particles deposit because the river velocity and gradient are too low to keep the particles in motion. Active deltas contain diverging multiple channels that continually deposit sediment and migrate back and forth across the delta surface. The sediment particles of the delta deposit are usually well sorted such that the coarser particles (gravel and sand) deposit first at the upstream end, while finer particles (silt and clay) deposit farther downstream. A fan-shaped area at the mouth of a river.	*USBR, 2008*

Delta	An area of loose deposit of silt, sand, and gravel, roughly triangular in shape, formed at the mouth of a river or rivers.	*CCC, 2008*
Demand	Rate at which electric energy is used, expressed in kilowatts, whether at a given instant, or averaged over any designated period of time. Maximum water use under a specified condition.	*USBR, 2008*
Demand scheduling	Method of irrigation scheduling whereby water is delivered to users as needed and which may vary in flow rate, frequency and duration. Considered a flexible form of scheduling.	*USBR, 2008*
Demersal	Fish eggs or organisms that hatch on the bottom of a lake or stream.	*USBR, 2008*
Demographics	Relating to the statistical study of human populations.	*USBR, 2008*
Dendritic	Channel pattern of streams with tributaries that branch to form a tree-like pattern.	*USBR, 2008*
Denitrification	A process by which oxidized forms of nitrogen such as nitrate (NO3) are reduced to form nitrites, nitrogen oxides, ammonia, or free nitrogen: commonly brought about by the action of denitrifying bacteria and usually resulting in the escape of nitrogen to the air.	*USGS, 2008*
Density	A measure of how heavy a specific volume of a solid, liquid, or gas is in comparison to water. depending on the chemical.	*EPA, 2008b*
Density	Mass per unit volume. The total mass (solids plus water) per total volume. The weight of soil per unit volume, usually the weight of soil in one cubic foot (unit weight). The weight of a substance per unit of volume of the substance; for example, water has a density of 62.4 pounds per 1 cubic foot. Number per unit area of individuals of any given species at any given time (see population density).	*USBR, 2008*
Dependable supply	The annual average quantity of water that can be delivered during a drought period.	*USACE, 1999*
Depletion	A water use term. The water consumed within a service area and no longer available as a source of supply. For agriculture and wetlands, it is evapotranspiration of applied water (ETAW) and evapotranspiration (ET) of flooded wetlands, plus irrecoverable losses. For urban water use, it is ETAW (water applied to landscaping or home gardens), sewage effluent that flows to a salt sink, and incidental ET losses. For in stream use, it is the amount of dedicated flow that becomes groundwater and is not available for reuse.	*USACE, 1999*
Depletion	To permanently remove water from a system for a specific use. Loss of water from a stream, river, or basin resulting from consumptive use.	*USBR, 2008*
Depletion curve	In hydraulics, a graphical representation of water depletion from storage-stream channels, surface soil, and groundwater. A depletion curve can be drawn for base flow, direct runoff, or total flow.	*EPA, 2008b*
Deposition	The settlement of materials out of moving water and onto the channel beds, banks, and floodplains that occurs when the flowing water is unable to transport the sediment load.	*USFS, 2002*

Deposition	Material settling out of the water onto the streambed. Occurs when the energy of the flowing water is unable to support the load of suspended sediment. The process of dropping or getting rid of sediments by an erosional agent such as a river or glacier. See sedimentation.	*USBR, 2008*
Depth of cutoff	The vertical distance that the cutoff penetrates into the dam foundation.	*USBR, 2008*
Derrick	Usually a non-mobile tower equipped with a hoist, but may be used as a synonym for a crane.	*USBR, 2008*
Desalinization	The removal of dissolved salts from water by natural means (leaching) or by specific water treatment processes. The process of removing salt from seawater or brackish water.	*USBR, 2008*
Desertification	When soil erosion is so severe that plants and animals can no longer exist.	*USBR, 2008*
Desiccant	A drying agent which is capable of removing or absorbing moisture from the atmosphere in a small enclosure.	*USBR, 2008*
Desiccate	To dry up; remove moisture from a substance.	*USBR, 2008*
Desiccation	The process of drying out. A process used to thoroughly dry air; to remove virtually all moisture from air.	*USBR, 2008*
Design basis earthquake (DBE)	The earthquake which the structure is required to safely withstand with repairable damage. Those systems and components important to safety must remain functional and/or operable. For design purposes, the intended use of this earthquake loading is for economic design of structures or components whose damage or failure would not lead to catastrophic loss. For most usage in Reclamation, the DBE is defined to have a 90% probability of nonoccurrence in a 50-year-exposure period, which is equivalent to a recurrence interval of 474 years. Economic considerations for specific projects may lead to consideration of other values.	*USBR, 2008*
Design capacity	The average daily flow that a treatment plant or other facility is designed to accommodate.	*EPA, 2008b*
Design response spectra	Smooth, broad-banded spectra appropriate for specifying the level of seismic design force, or displacement, for earthquake-resistant design purposes.	*USBR, 2008*
Design stream flow	The stream flow used to conduct steady-state wasteload allocation modeling.	*EPA, 2008c*
Design summary	A document that summarizes the designers' development of the design that results in the specifications. It may include a section on the Designers' Operating Criteria.	*USBR, 2008*
Design water level	The maximum water elevation, including the flood surcharge, that a dam is designed to be able to withstand.	*USBR, 2008*
Design wind	The most severe wind that is reasonbly possible at a particular reservoir for generating wind setup and runup. The determination will generally include the results of meteorologic studies which combine wind velocity, duration, direction, and seasonal distribution characteristics in a realistic manner.	*USBR, 2008*
Designated floodway	The channel of a water course and those portions of the adjoining flood plain required to provide for the passage of a selected flood with a small increase in flood stage above that of natural conditions.	*USBR, 2008*

Designated frequency flood	Refers to the probability that a flood will occur in a given year. A 100-year flood is often considered in the design of diversion dams and for diversion-during-construction requirements. Service spillways, stilling basins, and some outlet works components may also be designed to pass certain level of floods designated by a return period. The return period should be thought as the chance that such a flood will be equaled or exceeded in any one year. For example, the 100-year flood is the flow level with a 0.01 annual exceedance probability, or there is 1 chance in 100 that this flood flow level will be equaled or exceeded in any given year.	*USBR, 2008*
Designated uses	Those water uses identified in state water quality standards that must be achieved and maintained as required under the Clean Water Act. Uses can include cold water fisheries, public water supply, and irrigation.	*EPA, 2008b*
Designated uses	Those uses specified in State/Tribal water quality standards for each water body or segment whether or not they are being attained. Sometimes referred to as Beneficial Uses, i.e., desirable uses that water quality should support. Examples are drinking water supply, primary contact recreation (such as swimming), and aquatic life support.	*EPA, 2008c*
Designers' Operating Criteria (DOC)	Detailed operating criteria which stress the designer's intended use and operation of equipment and structures in the interest of safe, proper, and efficient use of the facilities.	*USBR, 2008*
Desorption	The release or removal of an adsorbed material from the surface of a solid adsorbent.	*USBR, 2008*
Destratification	The development of vertical mixing within a lake or reservoir to eliminate (either totally or partially) separate layers of temperature, plant, or animal life. This vertical mixing can be caused by mechanical means (pumps) or through the use of forced air diffusers which release air into the lower layers of the reservoir.	*USBR, 2008*
Destruction or adverse modification of critical habitat	A direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species.	*USFWS, 2008*
Detect	To determine the presence of a compound.	*USGS, 2008*
Detection	The first of five Early Warning System components consisting of the processes and equipment necessary to collect information about the threatening event and the response of the dam and reservoir, and relay that information to the decision makers.	*USBR, 2008*
Detection limit	The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.	*EPA, 2008b*
Detection limit	The concentration below which a particular analytical method cannot determine, with a high degree of certainty, a concentration.	*USGS, 2008*
Detention dam	A dam built to store streamflow or surface runoff, and to control the release of such stored water.	*USBR, 2008*

Detention time	1. The theoretical calculated time required for a small amount of water to pass through a tank at a given rate of flow. 2. The actual time that a small amount of water is in a settling basin, flocculating basin, or rapid-mix chamber. 3. In storage reservoirs, the length of time water will be held before being used.	*EPA, 2008b*
Deterministic method	Method in which precise, single values are used for all variables and input values, giving a single value as the output.	*Mockett & Simm, 2002*
Deterministic model	A model that does not include built-in variability: same input will always equal the same output.	*EPA, 2008c*
Detritus	Any loose material produced directly from disintegration processes. Organic detritus consists of material resulting from the decomposition of dead organic remains.	*EPA, 2008c*
Detritus	Loose material that results directly from disintegration.	*USBR, 2008*
Development	On land, in or under water, the placement or erection of any solid material or structure; discharge or disposal of any dredged material or of any gaseous, liquid, solid, or thermal waste; grading, removing, dredging, mining, or extraction of any materials; change in the density or intensity of use of land, including, but not limited to, subdivision pursuant to the Subdivision Map Act (commencing with Section 66410 of the Government Code), and any other division of land, including lot splits, except where the land division is brought about in connection with the purchase of such land by a public agency for public recreational use; change in the intensity of use of water, or of access thereto; construction, reconstruction, demolition, or alteration of the size of any structure, including any facility of any private, public, or municipal utility; and the removal or harvesting of major vegetation other than for agricultural purposes, kelp harvesting, and timber operations which are in accordance with a timber harvesting plan submitted pursuant to the provisions of the Z'berg-Nejedly Forest	*CCC, 2008*
Development effects	Adverse effects such as altered growth, structural abnormality, functional deficiency, or death observed in a developing organism.	*EPA, 2008b*
Deviator stress	The difference between the major and minor principal stresses in a triaxial test.	*USBR, 2008*
Dew	Moisture in the air that condenses on solid surfaces when the air is saturated with water vapor.	*USBR, 2008*
Dew point	The temperature to which air with a given quantity of water vapor must be cooled to cause condensation of the vapor in the air.	*USBR, 2008*
Dewatering	As opposed to unwatering, dewatering is the removal and control of ground water from pores or other open spaces in soil or rock formations to the extent that allows construction activities to proceed as intended, including the relief of ground water pressure. Removing water by pumping, drainage, or evaporation. The removal of ground water and seepage from below the surface of the ground or other surfaces through the use of deep wells and wellpoints.	*USBR, 2008*
DFG	California State Department of Fish and Game.	*CCC, 2008*

Diagenesis	Production of sediment fluxes as a result of the flux of particulate organic carbon in the sediment and its decomposition. The diagenesis reaction can be thought of as producing oxygen equivalents released by various reduced species.	*EPA, 2008c*
Diaphragm wall	A sheet, thin zone, or facing made of a relatively impervious material such as concrete, steel, wood, plastic, etc. Also see core wall.	*USBR, 2008*
Diaphragm-type earthfill	An embankment dam which is constructed mostly of pervious material and having a diaphragm of impermeable material which forms a water barrier. The diaphragm which forms the water barrier may consist of earth, Portland cement concrete, bituminous concrete, or other material, and may occupy a position within the embankment or on the upstream face.	*USBR, 2008*
Diatom	Single-celled or colonial algae whose cell walls are made of silica.	*USBR, 2008*
Diatoms	Single-celled, colonial, or filamentous algae with siliceous cell walls constructed of two overlapping parts.	*USGS, 2008*
Diel	Involving a 24-hour period.	*EPA, 2008c*
Dieldrin	An organochlorine insecticide no longer registered for use in the United States. Also a degradation product of the insecticide aldrin.	*USGS, 2008*
Differential head (unbalanced head)	The condition in which the water pressure on the upstream and downstream sides of an object differ.	*USBR, 2008*
Diffraction (of water waves)	The phenomenon by which energy is transmitted laterally along a wave crest. When a barrier, such as a breakwater interrupts part of a train of waves, the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.	*CCC, 2008*
Digital map	An electronic representation of a portion of the earth's surface that stores both the geographic location of an object and descriptive data about the object.	*EPA, 1997*
Dike	A low wall that can act as a barrier to prevent a spill from spreading.	*EPA, 2008b*
Dike	(1) (Engineering) An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; a levee. (2) A low wall that can act as a barrier to prevent a spillfrom spreading. (3) (Geology) A tabular body of igneous (formed by volcanic action) rock that cuts across the structure of adjacent rocks or cuts massive rocks.	*USACE, 1999*
Dike	A low embankment, usually constructed to close up low areas of the reservoir rim and thus limit the extent of the reservoir. Embankment for restraining a river or a stream. Embankments which contain water within a given course. Usually applied to dams built to protect land from flooding. See saddle dam.	*USBR, 2008*
Dikes	Embankments constructed of earth or other suitable materials to protect land from overflows or to regulate water.	*FEMA, 2003*
Dilatancy	The expansion of cohesionless soils when subject to shear deformation.	*USBR, 2008*
Diluent	Any liquid or solid material used to dilute or carry an active ingredient.	*EPA, 2008b*

Dilution	The addition of some quantity of less concentrated liquid (water) that results in a decrease in the original concentration.	*EPA, 2008c*
Dilution	Reduction of the concentration of a substance in air or water.	*USBR, 2008*
Dilution ratio	The relationship between the volume of water in a stream and the volume of incoming water. It affects the ability of the stream to assimilate waste.	*EPA, 2008b*
Dimictic	Lakes and reservoirs that freeze over and normally go through two stratifications and two mixing cycles a year.	*EPA, 2008b*
Dip	The angle that a stratum or any planar feature makes with the horizontal, measured perpendicular to the strike and in the vertical plane. The slope of layers of soil or rock.	*USBR, 2008*
Direct runoff	Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.	*EPA, 2008b*
Direct runoff	Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.	*EPA, 2008c*
Direct runoff	Water that flows over the ground surface or through the ground directly into streams, rivers, or lakes.	*USBR, 2008*
Direct shear test	A shear test in which soil or rock under an applied normal load is stressed to failure by moving one section of the specimen container (shear box) relative to the other section.	*USBR, 2008*
Disaster	An event that demands a crisis response beyond the scope of any single line agency or service (e.g., beyond the scope of just the police department, fire department, etc.) and that presents a threat to a community or larger area. A disaster requires resources beyond what are available locally.	*USBR, 2008*
Discharge	Flow of surface water in a stream or canal or the outflow of ground water from a flowing artesian well, ditch, or spring. Can also apply tp discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.	*EPA, 2008b*
Discharge	A description of the volume of water moving down the channel per unit time.	*FISHWR, 2001*
Discharge	Flow of surface water in a stream or canal or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.	*EPA, 2008c*
Discharge	Volume of water that passes a given point within a given period of time. See flow. Any spilling, leaking, pumping, pouring, emitting, emptying, or dumping not including permitted activities in compliance with section 402 of the Clean Water Act.	*USBR, 2008*
Discharge	The volume of water that passes a given location within a given period of time. Usually expressed in cubic feet per second.	*DOC, 2005*
Discharge	Rate of fluid flow passing a given point at a given moment in time, expressed as volume per unit of time.	*USGS, 2008*
Discharge capacity	The maximum amount of water that can safely released from a given waterway.	*USBR, 2008*
Discharge monitoring report (DMR)	Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.	*EPA, 2008c*

Discharge permits (NPDES)	A permit issued by the U.S. EPA or a State regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. It is called the NPDES because the permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.	*EPA, 2008c*
Discount rate	The interest rate used in evaluating water (and other) projects to calculate the present value of future benefits and future costs or to convert benefits and costs to a common time basis.	*USACE, 1999*
Dispersing agent	An agent used to assist in separating individual fine soil particles and to prevent them from flocculating when in suspension.	*USBR, 2008*
Dispersion	The spreading of chemical or biological constituents, including pollutants, in various directions from a point source, at varying velocities depending on the differential in-stream flow characteristics.	*EPA, 2008c*
Dispersion	Distortion of the shape of a seismic-wave train because of variation of velocity with frequency.	*USBR, 2008*
Dissipate	To break up, scatter, dispel, or dispense energy. The many forms of breakwaters and revetments act as dissipaters of wave energy.	*CCC, 2008*
Dissolve	To enter into a solution.	*USBR, 2008*
Dissolved constituent	Operationally defined as a constituent that passes through a 0.45 micrometer filter.	*USGS, 2008*
Dissolved gas concentrations	The amount of chemicals normally occurring as gases, such as nitrogen and oxygen, that are held in solution in water, expressed in units such as milligrams of the gas per liter of liquid. Supersaturation occurs when these solutions exceed the saturation level of the water (beyond 100 percent).	*USACE, 1999*
Dissolved organic compounds	Carbon substances dissolved in water.	*USACE, 1999*
Dissolved oxygen	The amount of free (not chemically combined) oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent saturation.	*USACE, 1999*
Dissolved oxygen (DO)	The oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors. DO levels are considered a most important indicator of a water body's ability to support desirable aquatic life. Secondary and advanced waste treatment are generally designed to ensure adequate DO in waste-receiving waters.	*EPA, 2008b*
Dissolved oxygen (DO)	The amount of oxygen that is dissolved in water. This term also refers to a measure of the amount of oxygen available for biochemical activity in a waterbody, and is an indicator of the quality of that water.	*EPA, 2008c*

Dissolved oxygen (DO)	Amount of free oxygen found in water; perhaps the most commonly employed measurement of water quality. Low DO levels adversely affect fish and other aquatic life. The ideal dissolved oxygen for fish life is between 7 and 9 mg/L; most fish cannot survive when the DO level falls below 3 mg/L.	*USBR, 2008*
Dissolved solids	Disintegrated organic and inorganic material in water. Excessive amounts make water unfit to drink or use in industrial processes.	*EPA, 2008b*
Dissolved solids	Amount of minerals, such as salt, that are dissolved in water; amount of dissolved solids is an indicator of salinity or hardness.	*USGS, 2008*
Distillation	The act of purifying liquids through boiling, so that the steam or gaseous vapors condense to a pure liquid. Pollutants and contaminants may remain in a concentrated residue.	*EPA, 2008b*
Distinct population segment (DPS)	A subdivision of a vertebrate species that is treated as a species for purposes of listing under the Endangered Species Act. To be so recognized, a potential distinct population segment must satisfy standards specified in a FWS or NOAA Fisheries policy statement (See the February 7, 1996, Federal Register, pages 4722-4725). The standards require it to be separable from the remainder of and significant to the species to which it belongs.	*USFWS, 2008*
Distributary	The branching channels of marine deltas generated as a result of the reduction of the channel gradient and consequent deposition within the channel.	*CCC, 2008*
Distribution	Function describing the relative frequency with which events of various magnitudes occur.	*USGS, 1982*
Distribution-free	Requiring no assumptions about the kind of probability distribution a set of data may have.	*USGS, 1982*
Disturbance	Any event or series of events that disrupt ecosystem, community, or population structure and alters the physical environment.	*EPA, 2008b*
Disturbance	A change or cause of change in an ecosystem originating from natural or human sources. A natural disturbance could be fire or flood, a human-caused disturbance could be land development or logging.	*DOC, 2005*
Ditch	A long narrow trench or furrow dug in the ground, as for irrigation, drainage, or a boundary line.	*USACE, 1999*
Ditch	Generally, a long narrow excavation. Constructed open channel for conducting water.	*USBR, 2008*
Diversion	1. Use of part of a stream flow as water supply. 2. A channel with a supporting ridge on the lower side constructed across a slope to divert water at a non-erosive velocity to sites where it can be used and disposed of.	*EPA, 2008b*
Diversion	The transfer of water from a stream, lake, aquifer, or other source of water by a canal, pipe, well, or other conduit to another watercourse or to the land, as in the case of an irrigation system.	*USACE, 1999*

Diversion	A process which, having return flow and consumptive use elements, turns water from a given path. Removal of water from its natural channel for human use. Use of part of a stream flow as a water supply. Channel constructed across the slope for the purpose of intercepting surface runoff, changing the accustomed course of all or part of a stream. A structural conveyance (or ditch) constructed across a slope to intercept runoff flowing down a hillside, and divert it to some convenient discharge point.	*USBR, 2008*
Diversion	The action of taking water out of a river system or changing the flow of water in a system for use in another location.	*DOC, 2005*
Diversion	A turning aside or alteration of the natural course of a flow of water, normally considered physically to leave the natural channel. In some States, this can be a consumptive use direct from another stream, such as by livestock watering. In other States, a diversion must consist of such actions as taking water through a canal, pipe, or conduit.	*USGS, 2008*
Diversion capacity	The flow which can be passed through the canal headworks at a dam under normal head.	*USBR, 2008*
Diversion channel	(1) An artificial channel constructed around a town or other point of high potential flood damages to divert floodwater from the main channel to minimize flood damages. (2) A channel carrying water from a diversion dam.	*USACE, 1999*
Diversion channel (canal or tunnel)	A waterway used to divert water from its natural course. The term generally applies to a temporary arrangement (e.g., to bypass water around a damsite during construction). Channel is normally used instead of canal when the waterway is short. Occasionally the term is applied to a permanent arrangement (diversion canal, diversion tunnel, diversion aqueducts).	*USBR, 2008*
Diversion dam	A dam built to divert water from a waterway or stream into a different watercourse.	*USBR, 2008*
Diversion inlet	A conduit or tunnel upstream from an intake structure. Diversion inlet may be integral with the outlet works or be part of a separate conveyance structure that will only be used during construction.	*USBR, 2008*
Diversity	The distribution and abundance of difference plant and animal communities.	*USFS, 2002*
Divert	To direct a flow away from its natural course.	*USBR, 2008*
Divide	A ridge or high area of land that separates one drainage basin from another.	*USBR, 2008*
Domestic wastewater	Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.	*EPA, 2008c*
Domestic water use	Water used for household purposes, such as drinking, food preparation, bathing, washing clothes, dishes, and dogs, flushing toilets, and watering lawns and gardens. About 85% of domestic water is delivered to homes by a public-supply facility, such as a county water department. About 15% of the Nation's population supply their own water, mainly from wells.	*DOC, 2005*

Domestic water use (residential water use)	Water for household purposes, such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and water lawns and gardens.	*USBR, 2008*
Double curvature arch dam	An arch dam which is curved in plan and elevation, with undercutting of the heel and in most instances, a downstream overhang near the crest. An arch dam which is curved vertically as well as horizontally.	*USBR, 2008*
Downcoast	In the United States usage, it is the coastal direction generally trending toward the south; also the way in which current flows.	*CCC, 2008*
Downdrift	The direction of predominant movement of littoral (shore) materials.	*CCC, 2008*
Downgradient	The direction that groundwater flows; similar to "downstream" for surface water.	*EPA, 2008b*
Downstream face	The inclined surface of a dam away from the reservoir. See face.	*USBR, 2008*
Draft	The act of drawing or removing water from a reservoir.	*USBR, 2008*
Drainage	Improving the productivity of agricultural land by removing excess water from the soil by such means as ditches or subsurface drainage tiles.	*EPA, 2008b*
Drainage	Process of removing surface or subsurface water from a soil or area. A technique to improve the productivity of some agricultural land by removing excess water from the soil; surface drainage is accomplished with open ditches; subsurface drainage uses porous conduits (drain tile) buried beneath the soil surface.	*USBR, 2008*
Drainage area	The total surface area upstream of a point on a stream that drains toward that point. Not to be confused with watershed. The drainage area may include one or more watersheds.	*USACE, 1999*
Drainage area	The area which drains to a particular point on a river or stream. The drainage area of a stream at a specified location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the stream above the specified point.	*USBR, 2008*
Drainage area	The drainage area of a stream at a specified location is that area, measured in a horizontal plane, which is enclosed by a drainage divide.	*USGS, 2008*
Drainage basin	The area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel.	*EPA, 2008b*
Drainage basin	The total area of land from which water drains into a specific river.	*USACE, 1999*
Drainage basin	A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.	*EPA, 2008c*
Drainage basin	All of the area drained by a river system. The drainage basin is a part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water. The area of land that drains its water into a river.	*USBR, 2008*

Drainage basin	Land area where precipitation runs off into streams, rivers, lakes, and reservoirs. Large drainage basins, like the area that drains into the Mississippi River contain thousands of smaller drainage basins. Usually considered larger than a watershed.	*DOC, 2005*
Drainage basin	The portion of the surface of the Earth that contributes water to a stream through overland run off, including tributaries and impoundments.	*USGS, 2008*
Drainage blanket	A layer of pervious material placed directly over the foundation material to facilitate drainage of the foundation and/or embankment.	*USBR, 2008*
Drainage curtain	A line of vertical wells or boreholes to facilitate drainage of the foundation and abutments and to reduce water pressure (also called drainage wells or relief wells).	*USBR, 2008*
Drainage layer	A layer of pervious material in an earthfill dam to relieve pore pressures or to facilitate drainage of the fill.	*USBR, 2008*
Drainage system	Collection of surface and/or subsurface drains, together with structures and pumps, used to remove surface or ground water.	*USBR, 2008*
Drainage well (relief well)	Vertical wells or boreholes downstream of, or in downstream shoulder of, an embankment dam to collect and control seepage through or under the dam and so reduce water pressure. A line of such wells forms a drainage curtain.	*USBR, 2008*
Draw	A small valley or gully.	*USBR, 2008*
Drawdown	1. The drop in the water table or level of water in the ground when water is being pumped from a well. 2. The amount of water used from a tank or reservoir. 3. The drop in the water level of a tank or reservoir.	*EPA, 2008b*
Drawdown	Lowering of a reservoir's water level; process of depleting a reservoir or ground water storage. The drop in the water table or level of water in the ground when water is being pumped from a well. Vertical distance the free water surface elevation is lowered or the reduction of the pressure head due to the removal of free water. The difference between a water level and a lower water level in a reservoir within a particular time. The amount of water used from a reservoir.	*USBR, 2008*
Drawdown	A lowering of the ground-water surface caused by pumping.	*DOC, 2005*
Drawdown	The difference between the water level in a well before pumping and the water level in the well during pumping. Also, for flowing wells, the reduction of the pressure head as a result of the discharge of water.	*USGS, 2008*
Dredge	To dig under water. A machine that digs under water.	*USBR, 2008*
Dredging	Removal of mud from the bottom of water bodies. This can disturb the ecosystem and causes silting that kills aquatic life. Dredging of contaminated muds can expose biota to heavy metals and other toxics. Dredging activities may be subject to regulation under Section 404 of the Clean Water Act.	*EPA, 2008b*
Dredging	Removing material (usually sediments) from wetlands or waterways, usually to make them deeper or wider.	*USACE, 1999*
Drift	Food organisms, including algae, plankton, and even larval fish, dislodged and moved by river current. A small, nearly horizontal tunnel.	*USBR, 2008*

Drill	An activity designed to evaluate a single emergency response function. This involves an actual field response such as making contacts to check the information included in the communication directory. A drill's effectiveness lies in the focus on a single or relatively limited portion of the overall response system in order to evaluate and improve that function.	*USBR, 2008*
Drinking water standard or guideline	A threshold concentration in a public drinking water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.	*USGS, 2008*
Drip irrigation	An irrigation system in which water is applied directly to the root zone of plants by means of applicators (orifices, emitters, porous tubing, perforated pipe, and so forth) operated under low pressure. The applicators can be placed on or below the surface of the ground or can be suspended from supports.	*USGS, 2008*
Drip irrigation (trickle)	An irrigation method in which water is delivered to or near each plant in small-diameter plastic tubing. The water is then discharged at a rate less than the soil infiltration capacity through pores, perforations, or small emitters on the tubing. The tubing may be laid on the soil surface, be shallowly buried, or be supported above the surface (as on grape trellises).	*USBR, 2008*
Drop structure	A structure that conveys water to a lower elevation and dissipates the excess energy resulting from the drop.	*USBR, 2008*
Drought	Generally, the term is applied to periods of less than average or normal precipitation over a certain period of time sufficiently prolonged to cause a serious hydrological imbalance resulting in biological losses (impact flora and fauna ecosystems) and/or economic losses (affecting man). In a less precise sense, it can also signify nature's failure to fulfill the water wants and needs of man.	*USACE, 1999*
Drought	Climatic condition in which there is insufficient soil moisture available for normal vegetative growth. A prolonged period of below-average precipitation.	*USBR, 2008*
Drought	Commonly defined as being a time of less-than-normal or less-than-expected precipitation.	*USGS, 2008*
Dry ravel	Sloughing of sediment due to loss of cohesion in surface materials.	*EPA, 2008c*
Dry unit weight	The weight of solid particles per unit of total volume. See unit weight.	*USBR, 2008*
Dry wash	A streambed that carries water only during and immediately following rainstorms.	*USACE, 1999*
Dry well	A deep hole, covered, and usually lined or filled with rocks, that holds drainage water until it soaks into the ground.	*USBR, 2008*
Duckbill anchor	A short piece of steel tube, pointed at one end. A steel cable is attached to the tube halfway down its length. The duckbill is driven into the soil to the desired depth. Pulling up on the attached cable rotates the bill, making it somewhat parallel to the surface and setting the anchor.	*USFS, 2002*

Ductility	The property of a material that allows it to be formed into thin sections without breaking.	*USBR, 2008*
Duff	A spongy layer of decaying leaves, branches, and other organic materials covering the forest floor.	*USFS, 2002*
Dumped	A method of compacting soil by dumping the soil into place with no compactive effort.	*USBR, 2008*
Dune	Ridges or mounds of loose, wind-blown material usually sand. A dune structure often has a back and foredune area. Stable dunes are often colonized by vegetation.	*CCC, 2008*
Dynamic compaction	A method of compacting soil by dropping a heavy weight onto loose soil.	*USBR, 2008*
Dynamic equilibrium	Condition achieved when the average sand load transported by flowing water is in balance with the sand load being supplied by tributaries.	*USBR, 2008*
Dynamic equilibrium	A beach or coastline condition where neither erosion nor accretion is occurring, but where the beach is continuously being reshaped by wave action.	*CCC, 2008*
Dynamic model	A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.	*EPA, 2008c*
Dynamic pressure	When a pump is operating, the vertical distance from a reference point (such as a pump centerline) to the hydraulic grade line.	*USBR, 2008*
Dynamic simulation	Modeling of the behavior of physical, chemical, and/or biological phenomena and their variation over time.	*EPA, 2008c*

E

Early warning system (EWS)	A designed system that will ensure timely recognition of a threatening event and provide a reliable and timely warning and evacuation of the population at risk from dangerous flooding associated with large operational releases or dam failure. The designed system must address the five components of detection, decision making, notification, warning, and evacuation.	*USBR, 2008*
Early warning system feasibility	Study of the feasibility of installing some level of Early Warning System to meet the target times for alerts and warnings.	*USBR, 2008*
Earth dam (earthfill dam)	An embankment dam in which more than 50 percent of the total volume is formed of compacted earth material generally smaller than 3-inch size. Seepage through the dam is controlled by the designed use of upstream blankets and/or internal cores constructed using compacted soil of very low permeability.	*USBR, 2008*
Earth lining	Compacted layer of earth on surface of canal or other excavation.	*USBR, 2008*
Earth pressure	The pressure or force exerted by soil on any boundary. See active earth pressure, at-rest earth pressure, and passive earth pressure.	*USBR, 2008*

Earthquake	A sudden motion or trembling in the earth caused by the abrupt release of accumulated stress along a fault. See design basis earthquake (DBE), maximum credible earthquake (MCE), maximum design earthquake (MDE), operating basis earthquake (OBE), random earthquake, and safety evaluation earthquake.	*USBR, 2008*
Earthwork	Any one or combination of the operations involved in altering or movement of earth.	*USBR, 2008*
Easement	The right to use land owned by another for some specific purpose.	*USBR, 2008*
Easement	A limited right to make use of a land owned by another, for example, a right of way across the property.	*CCC, 2008*
Ebb tide	The period of tide between high water and the succeeding low water; a falling tide (opposite = flood tide).	*CCC, 2008*
Ecological entity	In ecological risk assessment, a general term referring to a species, a group of species, an ecosystem function or characteristic, or a specific habitat or biome.	*EPA, 2008b*
Ecological exposure	Exposure of a non-human organism to a stressor.	*EPA, 2008b*
Ecological function	Potentially impacted by changes in channel morphology, stream hydrology, water quality, and habitat structure. Ecological function can be measured by fish diversity, macroinvertebrate diversity, biological integrity, EPA Rapid Bioassessment Protocol, fish barriers, and the leaf pack processing rate.	*EPA, 2008c*
Ecological impact	The effect that a man-caused or natural activity has on living organisms and their non-living (abiotic) environment.	*EPA, 2008b*
Ecological indicator	A characteristic of the environment that is measured to provide evidence of the biological condition of a resource. Ecological indicators can be measured at different levels including organism, population, community, or ecosystem.	*EPA, 1997*
Ecological indicator	A characteristic of an ecosystem that is related to, or derived from, a measure of biotic or abiotic variable, that can provide quantitative information on ecological structure and function. An indicator can contribute to a measure of integrity and sustainability.	*EPA, 2008b*
Ecological integrity	A living system exhibits integrity if, when subjected to disturbance, it sustains and organizes self-correcting ability to recover toward a biomass end-state that is normal for that system. End-states other than the pristine or naturally whole may be accepted as normal and good.	*EPA, 2008b*
Ecological processes	Processes that act directly, indirectly, or in combination, to shape and form the ecosystem. These include streamflow, watershed (closely linked to streamflow; includes fire and erosion), stream channel (includes stream meander, gravel recruitment and transport, water temperature, and hydraulic conditions), and floodplain processes (include overbank flooding and sediment retention and deposition).	*DOC, 2005*

Ecological risk assessment	he application of a formal framework, analytical process, or model to estimate the effects of human actions(s) on a natural resource and to interpret the significance of those effects in light of the uncertainties identified in each component of the assessment process. Such analysis includes initial hazard identification, exposure and dose-response assessments, and risk characterization.	*EPA, 2008b*
Ecological studies	Studies of biological communities and habitat characteristics to evaluate the effects of physical and chemical characteristics of water and hydrologic conditions on aquatic biota and to determine how biological and habitat characteristics differ among environmental settings in NAWQA Study Units.	*USGS, 2008*
Ecological/ environmental sustainability	Maintenance of ecosystem components and functions for future generations.	*EPA, 2008b*
Ecology	The relationship of living things to one another and their environment, or the study of such relationships.	*EPA, 2008b*
Ecology	The study of the interrelationships of living organisms to one another and to their surroundings.	*USACE, 1999*
Ecology	Branch of biological science which deals with relationships between living organisms and their environments.	*USBR, 2008*
Economic analysis	A procedure that includes both tangible and intangible factors to evaluate various alternatives.	*USBR, 2008*
Economic demand	The consumer's willingness and ability to purchase some quantity of a commodity based on the price of that commodity.	*USACE, 1999*
Ecoregion	A physical region that is defined by its ecology, which includes meteorological factors, elevation, plant and animal speciation, landscape position, and soils.	*EPA, 2008c*
Ecoregion	An area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.	*USGS, 2008*
Ecoregions	Ecological regions that are similar in climate, vegetation, soil type, and geology; water resources within a particular ecoregion have similar natural characteristics and similar responses to stressors.	*EPA, 2006*
Ecosphere	The "bio-bubble" that contains life on earth, in surface waters, and in the air.	*EPA, 2008b*
Ecosystem	The interacting system of a biological community and its non-living environmental surroundings.	*EPA, 2008b*
Ecosystem	Recognizable, relatively homogeneous units, including the organisms they contain, their environment, and all the interactions among them.	*USACE, 1999*
Ecosystem	An ecological community considered together with nonliving factors of its environment as an environmental unit.	*USFS, 2002*
Ecosystem	An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.	*EPA, 2008c*
Ecosystem	A dynamic and interrelating complex of plant and animal communities and their associated nonliving (such as physical and chemical) environment.	*USFWS, 2008*

Ecosystem	Complex system composed of a community of people, animals, and plants as well as the chemical and physical environments.	*USBR, 2008*
Ecosystem	A biological community together with the physical and chemical environment with which it interacts.	*DOC, 2005*
Ecosystem	The interacting populations of plants, animals, and microorganisms occupying an area, plus their physical environment.	*USGS, 2008*
Ecosystem approach	A philosophy of resource management that focuses on protecting or restoring the function, structure, and species composition of an ecosystem, recognizing that all components are interrelated.	*USFWS, 2008*
Ecosystem element	An identifiable component, process, or condition of an ecosystem.	*USFS, 2002*
Ecosystem function	(a) The process through which the constituent living and nonliving elements of ecosystems change and interact, including biogeochemical processes and succession. (b) A role of the ecosystem that is of value to society.	*USFS, 2002*
Ecosystem function	1) any performance attribute or rate function at some level of biological organization (e.g., energy flow, detritus processing, nutrient spiraling; 2) Ecosystem productivity and functions of hydrology, feeding, and transport.	*DOC, 2005*
Ecosystem management	A strategy or plan to manage ecosystems to provide for all associated organisms, as opposed to a strategy or plan for managing individual species.	*USACE, 1999*
Ecosystem management	Management that integrates ecological relationships with sociopolitical values toward the general goal of protecting or returning ecosystem integrity over the long term.	*DOC, 2005*
Ecosystem structure	Attributes related to the instantaneous physical state of an ecosystem; examples include species population density, species richness or evenness, and standing crop biomass.	*EPA, 2008b*
Ecotone	A habitat created by the juxtaposition of distinctly different habitats; an edge habitat; or an ecological zone or boundary where two or more ecosystems meet.	*EPA, 2008b*
Ecotone	A relatively narrow overlap zone between two ecological communities.	*USFS, 2002*
Eddy	A circular current of water, usually resulting from an obstruction.	*USACE, 1999*
Eddy	Circular current of water moving against the main current. See recirculation zone.	*USBR, 2008*
Effective diameter	Particle diameter corresponding to 10 percent finer on the accumulative gradation curve.	*USBR, 2008*
Effective discharge	A calculated measure of channel-forming discharge. Computation of effective discharge requires long-term water and sediment measurements, either for the stream in question or for one very similar. Since this type of data is not often available for stream restoration sites, modeled or computed data are sometimes substituted. Effective discharge can be computed for either stable or evolving channels.	*FISHWR, 2001*
Effective force	The force transmitted through a soil or rock mass by intergranular pressures.	*USBR, 2008*

Effective peak ground acceleration	That acceleration which is most closely related to structural response and to damage potential of an earthquake.	*USBR, 2008*
Effective porosity	The ratio of the volume of a soil or rock mass that can be drained by gravity to the total volume of the mass.	*USBR, 2008*
Effectiveness monitoring	Monitoring that answers the question: "Did restoration measures achieve the desired results?" or more simply "Did the restoration initiative work?" Effectiveness monitoring evaluates success by determining whether the restoration had the desired effect on the ecosystem. Monitoring variables focus on indicators that document achievement of desired conditions and are closely linked with project goals. It is important that indicators selected for effectiveness monitoring are sensitive enough to show change, are measurable, are detectable and have statistical validity. This level of monitoring is more time-consuming than implementation monitoring, making it more costly. To save time and money, monitoring at this level is usually performed on a sample population or portion of a project with results extrapolated to the whole population.	*FISHWR, 2001*
Efficiency	Ratio of useful energy output to total energy input, usually expressed as a percent. Effective operation as measured by a comparison of production with cost.	*USBR, 2008*
Effluent	(1) Something that flows out or forth, especially a stream flowing out of a body of water. (2) (Water Quality) Discharged wastewater such as the treated wastes from municipal sewage plants, brine wastewater from desalting operations, and coolant waters from a nuclear power plant.	*USACE, 1999*
Effluent	Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.	*EPA, 2008c*
Effluent	Partially or completely treated wastewater flowing out of a treatment facility, reservoir, or basin. See influent.	*USBR, 2008*
Effluent	Material flowing from a source, such as wastewater from a treatment plant.	*DOC, 2005*
Effluent	Outflow from a particular source, such as a stream that flows from a lake or liquid waste that flows from a factory or sewage-treatment plant.	*USGS, 2008*
Effluent (gaining) reaches	Streams that receive discharges from an aquifer.	*FISHWR, 2001*
Effluent guidelines	Technical EPA documents that set effluent limitations for given industries and pollutants.	*EPA, 2008c*
Effluent limitation	Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.	*EPA, 2008c*
Effluent limitation	The maximum amount of a specific substance or characteristic that can be present in effluent discharge without violating water quality standards in receiving waters.	*USBR, 2008*
Effluent plume	Delineates the extent of contamination in a given medium as a result of a distribution of effluent discharges (or spills). Usually shows the concentration gradient within the delineated areas or plume of flow of contaminants.	*EPA, 2008c*

EGL	Energy grade line.	*USBR, 2008*
Electrical conductivity	A measure of the salt content of water.	*USBR, 2008*
Elevation	The height of a point above a plane of reference. Generally refers to the height above sea level. See datum.	*USBR, 2008*
EMAP Data	Environmental monitoring data collected under the auspices of the Environmental Monitoring and Assessment Program. All EMAP data share the common attribute of being of known quality, having been collected in the context of explicit data quality objectives (DQOs) and a consistent quality assurance program.	*EPA, 2008b*
Embankment	An artificial deposit of material that is raised above the natural surface of the land and used to contain, divert, or store water, support roads or railways, or for other similar purposes.	*USACE, 1999*
Embankment	An earth structure the top of which is higher than the adjoining surface. A shaped earth or rockfill dam. Fill material, usually earth or rock, placed with sloping sides and with a length greater than its height. An embankment is generally higher than a dike.	*USBR, 2008*
Embankment dam or fill dam	Any dam constructed of excavated natural materials. See diaphragm-type earthfill, earth dam or earthfill dam, homogeneous earthfill dam, hydraulic fill dam, rockfill dam, rolled fill dam, or zoned earthfill. See also berm and fill.	*USBR, 2008*
Embeddedness	The degree to which fine sediments (e.g., clays, silts) fill the spaces (interstices) between rocks, cobbles, and gravel on the bottom of a stream or river.	*EPA, 2008c*
Emergency	A condition of a serious nature which develops unexpectedly and endangers the structural integrity of a dam or endangers downstream property and human life and requires immediate action. An event that demands a crisis response beyond the scope of any single line agency or service (e.g., beyond the scope of just the police department, fire department, etc.) and that presents a threat to a community or larger area. An emergency is an event that can be controlled within the scope of local capabilities.	*USBR, 2008*
Emergency action plan (EAP)	Reclamation procedures for dam operating personnel to follow during emergency situations or unusual occurrences at a given dam to reduce potential for property damage and loss of life and to provide proper notification to downstream authorities. A formal plan of procedures designed to minimize an emergency situation or unusual occurrence at a given dam or reservoir. A set of Reclamation instructions and maps within the Standing Operating Procedures (SOP) that contain procedures to follow for an emergency situation or unusual occurrence at a given dam or reservoir. A formal plan of procedures to alleviate risk during construction of or after completion of a dam, or to reduce the consequences if conditions develop in which dam failure is likely or unpreventable. Also, a plan of action to be taken to reduce the potential for property damage and loss of life in an area affected by a dam failure or large flood.	*USBR, 2008*

Emergency broadcast system	A federally established network of commercial radio stations that voluntarily provide official emergency instructions or directions to the public during an emergency. Priorities for Emergency Broadcast System activation and use are first, Federal Government; second, local government; and third, State government.	*USBR, 2008*
Emergency classification levels	A phased system in which dam operating organizations classify dam safety emergency incidents into response levels according to how severe they are at the time of observation and as to time of occurrence. Declaring a response level is followed by providing appropriate notifications to downstream local authorities. This type of system is intended to provide early and prompt notification of minor events that could lead to more serious consequences given the potential for operator error or equipment failure or that might indicate more seroius conditions not yet realized.	*USBR, 2008*
Emergency Evacuation Zone I	The emergency evacuation zone immediately below a dam and located on both sides of the river or stream. Generally, it is recommended that this zone extend to a distance equivalent to a combination of floodwave travel time of 0-15 minutes and/or a warning time of 0-4 hours, whichever is most conservative. May be labeled as immediate response zone, evacuation zone I, evacuation zone A, or other appropriate name.	*USBR, 2008*
Emergency Evacuation Zone II	The second emergency evacuation zone, beyond emergency evacuation zone I and also located on both sides of the river or stream. Generally, it is recommended that this zone extend to a distance using a combination of floodwave travel times of between 15-90 minutes and/or warning times of between 4-6 hours, whichever is most conservative. May be labeled as protective action zone, evacuation zone II, evacuation zone B, or other appropriate name.	*USBR, 2008*
Emergency Evacuation Zone III	The outermost emergency evacuation zone, extending beyond emergency evacuation zone II and also located on both sides of the river or stream. Its furthest point is that beyond which emergency planning and evacuation for a dam failure inundation would not be required under most conditions; where the floodwave would be attenuated; and beyond which the potential negative impacts on humans would be virtually eliminated. May be labeled as precautionary zone, evacuation zone III, evacuation zone C, or other appropriate name.	*USBR, 2008*
Emergency evacuation zones	Geographical areas delineated in inundation areas downstream from a dam (hazard generator) that define the potential area of impact and allow prioritizing evacuation activities based on proximity of the populations at risk to the hazard in terms of distance and floodwave travel times.	*USBR, 2008*

Emergency Exercise	An activity designed to promote emergency preparedness; evaluate emergency operations, policies, plans, procedures, and facilities; train personnel in emergency management and response duties; and demonstrate operational capability. Exercises consist of performing duties, tasks, or operations very similar to the way they would be performed in a real emergency. However, the exercise performance is in response to a simulated event. Therefore, exercises require input to emergency personnel that motivates a realistic action. Reclamation "mock emergencies" have been replaced with the five components of an emergency exercise program as defined by the Federal Emergency Management Agency. These five components are: orientation seminar, tabletop exercise, drill, functional exercise, and full-scale exercise.	*USBR, 2008*
Emergency gate	A standby or auxiliary gate used when the normal means of water control is not available. The first gate in a series of flow controls, remaining open while downstream gates or valves are operating. See guard gate.	*USBR, 2008*
Emergency management	The system by which mitigation, preparedness, response, and recovery activities are undertaken to save lives and protect property from all hazards.	*USBR, 2008*
Emergency management agency	Any State or local agency responsible for emergency operations, planning, mitigation, preparedness, response, and recovery for all hazards. Names of emergency management agencies may vary, but could include: Division of Emergency Management, Comprehensive Emergency Management, Disaster Emergency Services, Civil Defense Agency, Emergency and Disaster Services, etc.	*USBR, 2008*
Emergency on-scene coordinator (Reclamation OSC)	At all times, there must be at least one employee either on the premises or on call (i.e., available to respond to an emergency by reaching the facility within a short period of time) with the responsibility for coordinating all emergency response measures. This emergency coordinator must be thoroughly familiar with all aspects of the facility's contingency plan, all operations and activities at the facility, the location and characteristics of hazardous substances handled, the location of all records within the facility, and the facility layout. In addition, this person must have the authority to commit the resources needed to carry out the contingency plan. See on-scene coordinator.	*USBR, 2008*
Emergency operations center	The location of facility where responsible officials gather during an emergency to direct and coordinate emergency operations, to communicate with other jurisdictions and with field emergency forces, and to formulate protective action decisions and recommendations during an emergency.	*USBR, 2008*

Emergency operations plan (State and local)	A plan, usually developed in accord with guidance contained in the Guide for the Development of State and Local Emergency Operations Plans, Civil Preparedness Guide 1-8, September 1990, and other similar guides. The emergency operations plan clearly and concisely describes a jurisdiction's emergency organization, its means of coordination with other jurisdictions, and its approach to protecting people and property from disasters and emergencies caused by any of the hazards to which the community is particularly vulnerable. It assigns functional responsibilities to the elements of the emergency organization, and details tasks to be carried out at times and places projected as accurately as permitted by the nature of each situation addressed. Emergency operations plans are multi-hazard, functional plans that treat emergency management activities generically. They have a basic section that provides generally applicable information without reference to any particular hazard. They also address the unique aspects of individual disasters in hazard-specific appendixes.	*USBR, 2008*
Emergency Preparedness Plan (EPP)	Predecessor to the term Emergency Action Plan (EAP).	*USBR, 2008*
Emergency program manager	The individual responsible on a day-to-day basis for a jurisdiction's effort to develop a capability for coordinated response to and recovery from the effects of emergencies and large-scale disasters. This official may be called the local emergency manager, civil defense director, disaster preparedness coordinator, or other similar title; the duties may vary from jurisdiction to jurisdiction.	*USBR, 2008*
Emergency reserve fund	Money reserved or required by contract to be reserved by an operating entity for use in emergency situations involving facilities under the entity's jurisdiction.	*USBR, 2008*
Emergency spillway	A spillway which provides for additional safety should emergencies not contemplated by normal design assumptions be encountered, i.e., inoperable outlet works, spillway gates, or spillway structure problems. The crest is usually set at maximum water surface. A spillway that is designed to provide additional protection against overtopping of a dam and is intended for use under extreme conditions such as misoperation or malfunction of the service spillway or other emergency conditions.	*USBR, 2008*
Empirical model	Use of statistical techniques to discern patterns or relationships underlying observed or measured data for large sample sets. Does not account for physical dynamics of waterbodies.	*EPA, 2008c*
End moraine (terminal moraine)	Ridge of sediment piled at the front edge of a glacier.	*USBR, 2008*
Endangered species	Animals, birds, fish, plants, or other living organisms threatened with extinction by anthropogenic (man-caused) or other natural changes in their environment. Requirements for declaring a species endangered are contained in the Endangered Species Act.	*EPA, 2008b*
Endangered species	An animal or plant species in danger of extinction throughout all or a significant portion of its range.	*USFWS, 2008*

Endangered species	A species or subspecies whose survival is in danger of extinction throughout all or a significant portion of its range.	*USBR, 2008*
Endangered species act (ESA)	This act provides a framework for the protection of endangered and threatened species. See Endangered Species Act of 1973. Also, see Endangered Species Act.	*USBR, 2008*
Endemic species	A species native and confined to a certain region; generally used for species with comparatively restricted distribution.	*USFWS, 2008*
Endocrine system	The collection of ductless glands in animals that secrete hormones, which influence growth, gender and sexual maturity.	*USGS, 2008*
Endpoint	An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).	*EPA, 2008c*
Energy	Force or action of doing work. Measured in terms of the work it is capable of doing; electric energy, the electric capacity generated and/or delivered over time, is usually measured in kilowatt hours (kWh).	*USBR, 2008*
Energy dissipation	The loss of kinetic energy of moving water due to internal turbulence, bottom friction, large rocks, debris, or other obstacles that impede flow.	*USACE, 1999*
Energy dissipator	A device constructed in a waterway to reduce the kinetic energy of fast flowing water. See stilling basin.	*USBR, 2008*
Energy facility	Any public or private processing, producing, generating, storing, transmitting, or recovering facility for electricity, natural gas, petroleum, coal, or other source of energy.	*CCC, 2008*
Energy grade line (EGL) (energy line, energy gradient)	The line showing the total energy at any point in a pipe. The total energy in the flow of the section with reference to a datum line is the sum of the elevation of the pipe centerline, the piezometric height (or pressure head), and the velocity head. The energy grade line will slope (drop) in the direction of flow except where energy is added by mechanical devices. The line representing the elevation of the total head of flow is the energy line. The slope of the line is known as the energy gradient. See hydraulic grade line.	*USBR, 2008*
Enhancement	Emphasis on improving the value of particular aspects of water and related land resources.	*USACE, 1999*
Enhancement	In the context of restoration ecology, any improvement of a structural or functional attribute.	*EPA, 2008c*
Enhancement	Improvement of a facility beyond its originally designed purpose or condition.	*USBR, 2008*
Enhancement	In the context of restoration ecology, any improvement of a structural or functional attribute.	*DOC, 2005*

Enhancement flow	Improved flows that result in better stream conditions for aquatic, terrestrial, and other resources.	*USBR, 2008*
Enhancement of survival permit	A type of permit issued by the Service under the authority of section 10(a)(1)(A) of the Endangered Species Act. It allows an otherwise prohibited action that benefits the conservation of a listed species. These permits are issued as part of a Safe Harbor Agreement or Candidate Conservation Agreement with Assurances.	*USFWS, 2008*
Entrain	To trap bubbles in water either mechanically through turbulence or chemically through a reaction.	*USBR, 2008*
Entrainment	Process by which aquatic organisms, suspended in water, are pulled through a pump or other device.	*USBR, 2008*
Environment	The sum of all external conditions affecting the life, development and survival of an organism.	*EPA, 2008b*
Environment	The sum of all external influences and conditions affecting the life and development of an organism or ecological community; the total social and cultural conditions.	*USACE, 1999*
Environment	All biological, chemical, social, and physical factors to which organisms are exposed. The surroundings that affect the growth and development of an organism.	*USBR, 2008*
Environmental analysis	An analysis of alternative actions and their predictable short-term and long-term environmental effects, incorporating physical, biological, economic, and social considerations.	*USACE, 1999*
Environmental analysis	Systematic process for consideration of environment factors in land management actions.	*USBR, 2008*
Environmental assessment	An environmental analysis prepared pursuant to the National Environmental Policy Act to determine whether a federal action would significantly affect the environment and thus require a more detailed environmental impact statement.	*EPA, 2008b*
Environmental assessment (EA)	A systematic analysis of site-specific activities used to determine whether such activities have a significant effect on the quality of the human environment and whether a formal environmental impact statement is required; and to aid an agency's compliance with the National Environmental Policy Act when no environmental impact statement is necessary.	*USACE, 1999*
Environmental assessment (EA)	A NEPA compliance document used to determine if an action would have a significant effect on the human environment. If not, a finding of no significant impact (FONSI) is written. If so, an environmental impact statement (EIS) is written.	*USBR, 2008*
Environmental audit	An independent assessment of the current status of a party's compliance with applicable environmental requirements or of a party's environmental compliance policies, practices, and controls.	*EPA, 2008b*

Environmental equity/justice	Equal protection from environmental hazards for individuals, groups, or communities regardless of race, ethnicity, or economic status. This applies to the development, implementation, and enforcement of environmental laws, regulations, and policies, and implies that no population of people should be forced to shoulder a disproportionate share of negative environmental impacts of pollution or environmental hazard due to a lack of political or economic strength levels.	*EPA, 2008b*
Environmental framework	Natural and human related features of the land and hydrologic system, such as geology, land use, and habitat, that provide a unifying framework for making comparative assessments of the factors that govern water quality conditions within and among Study Units.	*USGS, 2008*
Environmental impact	The positive or negative effect of any action upon a given area or resource.	*USACE, 1999*
Environmental impact statement	A document required of federal agencies by the National Environmental Policy Act for major projects or legislative proposals significantly affecting the environment. A tool for decision making, it describes the positive and negative effects of the undertaking and cites alternative actions.	*EPA, 2008b*
Environmental impact statement (EIS)	A formal document to be filed with the Environmental Protection Agency that considers significant environmental impacts expected from implementation of a major federal action.	*USACE, 1999*
Environmental impact statement (EIS)	A NEPA compliance document used to evaluate a range of alternatives when solving the problem would have a significant effect on the human environment. The EIS is more than a document, it is a formal analysis process which mandates public comment periods. An EIS covers purpose and need, alternatives, existing conditions, environmental consequences, and consultation and coordination.	*USBR, 2008*
Environmental indicator	A measurement, statistic or value that provides a proximate gauge or evidence of the effects of environmental management programs or of the state or condition of the environment.	*EPA, 2008b*
Environmental justice	The fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development and enforcement of environmental laws, regulations, and policies.	*EPA, 2008b*
Environmental medium	A major environmental category that surrounds or contacts humans, animals, plants, and other organisms (e.g. surface water, ground water, soil or air) and through which chemicals or pollutants move.	*EPA, 2008b*
Environmental monitoring and assessment program (EMAP)	A USEPA program to monitor and assess the ecological health of major ecosystems, including surface waters, forests, near-coastal waters, wetlands, agricultural lands, arid lands, and the Great Lakes, in an integrated, systematic manner. Although EMAP has been curtailed somewhat during recent years, the program is designed to operate at regional and national scales, for decades, and to evaluate the extent and condition of entire ecological resources by using a common sampling framework to sample approximately 12,500 locations in the conterminous United States.	*EPA, 2008c*

Environmental Protection Agency (EPA)	The Environmental Protection Agency's mission is to protect human health and to safeguard the natural environment.	*USBR, 2008*
Environmental sample	A water sample collected from an aquifer or stream for the purpose of chemical, physical, or biological characterization of the sampled resource.	*USGS, 2008*
Environmental setting	Land area characterized by a unique combination of natural and human related factors, such as row crop cultivation or glacial till soils.	*USGS, 2008*
Environmental site assessment	The process of determining whether contamination is present on a parcel of real property.	*EPA, 2008b*
Environmental sustainability	Long-term maintenance of ecosystem components and functions for future generations.	*EPA, 2008b*
Environmental/ ecological risk	The potential for adverse effects on living organisms associated with pollution of the environment by effluents, emissions, wastes, or accidental chemical releases; energy use; or the depletion of natural resources.	*EPA, 2008b*
Eocene	A period of geologic time spanning 54-38 million years ago.	*CCC, 2008*
Eolian	Windblown. See aeolian.	*USBR, 2008*
Ephemeral creek	A creek or stream that flows briefly only in direct response to precipitation and whose channel is above the water table. See intermittent stream.	*USBR, 2008*
Ephemeral stream	A stream or part of a stream that flows only in direct response to precipitation or snowmelt. Its channel is above the water table at all times.	*USGS, 2008*
Ephemeral streams	Streams with flow only during or immediately after periods of precipitation. These streams generally flow less than 30 days per year.	*FISHWR, 2001*
Ephemeral streams	Streams that flow only in direct response to precipitation and whose channel is at all times above the water table.	*USACE, 1999*
Epicenter	Focal point on the earth's surface directly above the origin of a seismic disturbance. Point on the Earth's surface vertically above the earthquake focus or hypocenter.	*USBR, 2008*
Epifauna	Animals which live on the benthos.	*USBR, 2008*
Epilimnion	The upper, or top, layer of a lake or reservoir with essentially uniform warmer temperatures. The upper layer of water in a thermally stratified lake or reservoir. This layer consists of the warmest water and has a fairly constant temperature. The layer is readily mixed by wind action. See stratification.	*USBR, 2008*
EPT index	The relative abundance of three pollution-sensitive orders of benthic macroinvertebrates to the abundance of a tolerant species of benthic macroinvertebrate. (the sum of the number of Ephemeroptera, Plecoptera, and Trichoptera divided by the total number of midges, Diptera: Chironomid).	*DOC, 2005*
EPT richness index	An index based on the sum of the number of taxa in three insect orders, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), that are composed primarily of species considered to be relatively intolerant to environmental alterations.	*USGS, 2008*

Equal width increment (EWI) sample	A composite sample across a section of stream with equal spacing between verticals and equal transit rates within each vertical that yields a representative sample of stream conditions.	*USGS, 2008*
Equilibrium beach width	The mean distance between the shoreline and backbeach line at which sand contributions and losses are balanced.	*CCC, 2008*
Equivalent diameter (equivalent size)	The diameter of a hypothetical sphere composed of material having the same specific gravity as that of the actual soil particle and of such size that it will settle in a given liquid at the same terminal veolcity as the actual soil particle.	*USBR, 2008*
Equivalent fluid	A hypothetical fluid having a unit weight such that it will produce a pressure against a lateral support presumed to be equivalent to that produced by the actual soil. This simplified approach is valid only when deformation conditions are such that the pressure increases linearly with depth and the wall friction is neglected.	*USBR, 2008*
Erode	To wear away or remove the land surface by wind, water, or other agents.	*USBR, 2008*
Erode	The gradual wearing away and removal of land surface by various agents such as waves; opposite of accrete.	*CCC, 2008*
Erosion	The wearing away of land surface by wind or water, intensified by land-clearing practices related to farming, residential or industrial development, road building, or logging.	*EPA, 2008b*
Erosion	Wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical, chemical, or biological forces.	*USACE, 1999*
Erosion	In the general sense, the wearing away of the land by wind and water. Also, the removal of soil particles from a bank primarily by water action.	*USFS, 2002*
Erosion	A gradual wearing away of soil or rock by running water, waves, or wind. Concrete surface disturbance caused by cavitation, abrasion from moving particles in water, impact of pedestrian or vehicular traffic, or impact of ice floes. Surface displacement of soil caused by weathering, dissolution, abrasion, or other transporting. The gradual wearing away of material as a result of abrasive action.	*USBR, 2008*
Erosion	The wearing away of land by natural forces. On a beach, the carrying away of beach material by wave action, currents or the wind.	*CCC, 2008*
Erosion	The process in which a material is worn away by a stream of liquid (water) or air, often due to the presence of abrasive particles in the stream.	*DOC, 2005*
Erosion	The process whereby materials of the Earth's crust are loosened, dissolved, or worn away and simultaneously moved from one place to another.	*USGS, 2008*
Erosion Control Fabric	Woven or spun material made from natural or synthetic fibers and placed to prevent surface erosion.	*USFS, 2002*
Erratic	Boulder transported by a glacier and left behind when the ice melted.	*USBR, 2008*
Escapement	Unharvested spawning stocks that return to the streams.	*USBR, 2008*
Escarpment	A cliff or steep slope that separates two level or gently sloping areas. Cliff or steep slope edging higher land.	*USBR, 2008*

Escarpment	A more or less continuous line of cliffs or steep slopes facing in one general direction, caused by erosion or faulting.	*CCC, 2008*
Essential element	A structural or geologic feature or an equipment item whose failure under the particular loading condition or set of circumstances being considered would create a dam safety deficiency. An equipment item or procedure required for safe operation of the dam or reservoir.	*USBR, 2008*
Essential experimental population	An experimental population whose loss would appreciably reduce the prospect of survival of the species in the wild. All other experimental populations are "Anon-essential."	*USFWS, 2008*
Esthetics	An emotional judgment about what is beautiful or pleasing.	*USBR, 2008*
Estuarine number	A nondimensional parameter accounting for decay, tidal dispersion, and advection velocity; used for classification of tidal rivers and estuarine systems.	*EPA, 2008c*
Estuary	Region of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix fresh and salt water. Such areas include bays, mouths of rivers, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife.	*EPA, 2008b*
Estuary	A coastal body of water that is semi enclosed, openly connected with the ocean, and mixes with freshwater drainage from land.	*USACE, 1999*
Estuary	Brackish-water areas influenced by the tides where the mouth of a river meets the sea.	*EPA, 2008c*
Estuary	The area of mixing of fresh water and salt water where a river flows into an ocean.	*USBR, 2008*
Estuary	The region near a river mouth in which the fresh water of the river mixes with the salt water of the sea.	*CCC, 2008*
Eustatic	Refers to worldwide changes in sea level.	*CCC, 2008*
Eutrophic	Usually refers to a nutrient enriched, highly productive body of water.	*USACE, 1999*
Eutrophic	Nutrient enrichment of a body of water that contains more organic matter than existing biological oxidization processes can consume. A body of water which has become, either naturally or by pollution, rich in nutrients and often seasonally deficient in dissolved oxygen. Reservoirs and lakes which are rich in nutrients and very productive in terms of aquatic animal and plant life.	*USBR, 2008*
Eutrophication	The slow aging process during which a lake, estuary, or bay evolves into a bog or marsh and eventually disappears. During the later stages of eutrophication the water body is choked by abundant plant life due to higher levels of nutritive compounds such as nitrogen and phosphorus. Human activities can accelerate the process.	*EPA, 2008b*
Eutrophication	The process of enrichment of water bodies by nutrients.	*USACE, 1999*
Eutrophication	A process where more organic matter is produced than existing biological oxidization processes can consume. The increase in the nutrient levels of a lake or other body of water; this usually causes an increase in the growth of aquatic animal and plant life.	*USBR, 2008*

Eutrophication	The gradual increase in nutrient concentrations of nutrients in a water-body from cycles of plant growth and decomposition, where the plant growth exceeds the consumption by grazing animals. This can result in low oxygen concentrations in the water due to microbial activity in the decomposing plant material.	*DOC, 2005*
Eutrophication	The process by which water becomes enriched with plant nutrients, most commonly phosphorus and nitrogen.	*USGS, 2008*
Evacuation	The fifth of five Early Warning System components consisting of the plans, personnel, equipment, and facilities needed to move the population at risk to safety. It involves taking protective actions to leave an area of risk until the hazard has passed and the area is safe for return.	*USBR, 2008*
Evacuation warning	A public warning message that local officials would issue following declaration of Response Level III by personnel of the dam operating organization. The evacuation warning is intended to notify the population at risk to evacuate flood inundation areas.	*USBR, 2008*
Evaluation	Process by which a project's performance is determined relative to criteria developed for this purpose.	*CCC, 2008*
Evaporation	The physical process by which a liquid (or a solid) is transformed to the gaseous state. In hydrology, evaporation is vaporization that takes place at a temperature below the boiling point.	*USACE, 1999*
Evaporation	Water vapor losses from water surfaces, sprinkler irrigation, and other related factors. Loss of water to the atmosphere. The process by which water is changed from a liquid into a vapor. Water from land areas, bodies of water, and all other moist surfaces is absorbed into the atmosphere as a vapor.	*USBR, 2008*
Evaporation	The process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces.	*DOC, 2005*
Evaporite minerals (deposits)	Minerals or deposits of minerals formed by evaporation of water containing salts. These deposits are common in arid climates.	*USGS, 2008*
Evapotranspiration	The sum of evaporation and transpiration.	*DOC, 2005*
Evapo-transpiration	The loss of water from the soil both by evaporation and by transpiration from the plants growing in the soil.	*EPA, 2008b*
Evapo-transpiration	The process by which plants take in water through their roots and then give it off through their leaves as a byproduct of respiration.	*USFS, 2002*
Evapo-transpiration	The quantity of water transpired by plants or evaporated from adjacent soil surfaces in a specific time period. Usually expressed in depth of water per unit area. The combined processes of evaporation and transpiration. It can be defined as the sum of water used by vegetation and water lost by evaporation. A collective term that includes water discharged to the atmosphere as a result of evaporation from the soil and surface water and as a result of plant transpiration.	*USBR, 2008*
Evapo-transpiration	A collective term that includes water lost through evaporation from the soil and surface water bodies and by plant transpiration.	*USGS, 2008*

Evapo-transpiration (ET)	The quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces. Quantitatively, it is usually expressed in terms of depth of water per unit area during a specified period of time.	*USACE, 1999*
Evapotranspira-tion of applied water (ETAW)	The portion of the total evapotranspiration provided by irrigation.	*USACE, 1999*
Evolutionarily significant unit (ESU)	A Pacific salmonid stock that is substantially reproductively isolated from other stocks of the same species and which represents an important part of the evolutionary legacy of the species. Life history, ecological, genetic, and other information can be used to determine whether a stock meets these two criteria. NOAA Fisheries uses this designation.	*USFWS, 2008*
Excavation	The action or process of excavating (to dig or remove earth). See common excavation, rock excavation, and unclassified excavation.	*USBR, 2008*
Exceedance	Violation of the pollutant levels permitted by environmental protection standards.	*EPA, 2008b*
Exceedance frequency	The percentage of values that exceed a specified magnitude, 100 times exceedance probability.	*USGS, 1982*
Exceedance probability	Probability that a random event will exceed a specified magnitude in a given time period, usually one year unless otherwise indicated.	*USGS, 1982*
Excess land	Irrigable land, other than exempt land, owned by any landowner in excess of the maximum ownership entitlement under applicable provision of Reclamation law.	*USBR, 2008*
Exchange capacity	The capacity to exchange ions as measured by the quantity of exchangeable ions in a soil or rock.	*USBR, 2008*
Exclusive flood control capacity	The reservoir capacity assigned to the sole purpose of regulating flood inflows to reduce flood damage downstream. In some instances, the top of exclusive flood control capacity is above the maximum controllable water surface elevation. See flood control capacity.	*USBR, 2008*
Exempt land	Irrigation land in a district to which the acreage limitation and pricing provisions of Reclamation law do not apply.	*USBR, 2008*
Existence value	Value people place on simply knowing an area or feature continues to exist in a particular condition.	*USBR, 2008*
Existing ground	The earth's surface as it is prior to any work. See original ground surface.	*USBR, 2008*
Existing use	Use actually attained in the waterbody on or after November 28, 1975, whether or not it is included in the water quality standards (40 CFR 131.3).	*EPA, 2008c*
Exit channel	See outlet channel.	*USBR, 2008*
Exit conference	A discussion following a facility review examination involving examination team members and interested representatives of the water uses, project, and region. The topics of discussion include the overall condition of the facility, any recommendations made as a result of the examination, and any other pertinent topics.	*USBR, 2008*
Exotic species	A species that is not indigenous to a region.	*EPA, 2008b*
Exotic species	A non-native species that is introduced into an area.	*USBR, 2008*
Expansion	The increase in volume of a soil mass.	*USBR, 2008*

Expansion joint	A separation between adjoining parts of a concrete structure which is provided to allow small relative movements, such as those caused by temperature changes, to occur independently. A flexible filler is provided in the joint, reinforcement does not pass through the joint. A joint that permits pipe to move as a result of expansion.	*USBR, 2008*
Expected probability	The average of the true probabilities of all magnitude estimates for any specified flood frequency that might be made from successive samples of a specified size.	*USGS, 1982*
Experimental population	A population (including its offspring) of a listed species designated by rule published in the Federal Register that is wholly separate geographically from other populations of the same species. An experimental population may be subject to less stringent prohibitions than are applied to the remainder of the species to which it belongs.	*USFWS, 2008*
Exploit	Excavate in such a manner as to utilize material in a particular vein or layer, and waste or avoid surrounding material.	*USBR, 2008*
Extinct species	A species that no longer exists. For ESA, a species currently believed to be extinct.	*USFWS, 2008*
Extirpated species	A species that no longer survives in regions that were once part of its range, but that still exists elsewhere in the wild or in captivity.	*USFWS, 2008*
Extirpated species	A species which has become extinct in a given area.	*USBR, 2008*
Extrados	The curved upstream surface of horizontal arch elements in an arch dam. See intrados.	*USBR, 2008*
Extrapolation	Estimation of unknown values by extending or projecting from known values.	*USBR, 2008*

F

Face	Exposed surface of dam materials (earth, rockfill, or concrete), upstream and downstream. The external surface which limits the structure, see neatlines. The more or less vertical surface of rock exposed by blasting or excavating. The cutting end of a drill hole.	*USBR, 2008*
Facilities	Structures associated with Reclamation irrigation projects, municipal and industrial water systems, power generation facilities, including all storage, conveyance, distribution, and drainage systems.	*USBR, 2008*
Facing	With reference to a wall or concrete dam, a coating of a different material, masonry or brick, for architectural or protection purposes, e.g., stonework facing, brickwork facing. With reference to an embankment dam, an impervious coating or face on the upstream slope of the dam.	*USBR, 2008*
Factor of safety	The ratio of the ultimate strength of the material to the allowable or working stress.	*USBR, 2008*
Fahrenheit (F)	Unit of temperature. Degrees Fahrenheit equals (9/5)x(degrees Celsius)+(32).	*USBR, 2008*
Failure	Collapse or slippage of a large mass of bank material into a stream	*USFS, 2002*

Failure	An incident resulting in the uncontrolled release of water from a dam. Destroyed and made useless, ceases to function as a dam. More severe and hazardous than a breach. See dam failure.	*USBR, 2008*
Failure potential assessment	A judgment of the potential for failure of an essential element within the expected life of the project. Five terms are used to describe the assessment: negligible, low, moderate, high, and urgent. A rating of negligible reflects the judgment that failure of the essential element is regarded as very unlikely; low reflects the judgment that failure is unlikely; moderate reflects the judgment that failure is possible and further data collection and/or analyses may be required; high reflects the judgment that failure is very probable; urgent reflects the judgment that failure is imminent.	*USBR, 2008*
Fall	The amount of slope given to horizontal runs of pipe.	*USBR, 2008*
Fallow	Land plowed and tilled and left unplanted.	*USBR, 2008*
Farm loss (water)	Water delivered to a farm which is not made available to the crop to be irrigated.	*USBR, 2008*
Fascine	see Live Fascine	*USFS, 2002*
Fatal flaw	Any problem, lack, or conflict (real or perceived) that will destroy a solution or process. A negative effect that cannot be offset by any degree of benefits from other factors.	*USBR, 2008*
Fatality rate	A multiplication factor based on the estimated severity of the flood, potential warning times, and the judgement related to the understanding of the flood severity.	*USBR, 2008*
Fate of pollutants	Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.	*EPA, 2008c*
Fault	A fracture or fracture zone in the earth's crust along which there has been displacement of the two sides relative to one another or in rock along which the adjacent rock surfaces are differentially displaced. Break in rocks along which movement has occurred. A shear with significant continuity that can be correlated between observation points. See active fault.	*USBR, 2008*
Fault	A rock fracture accompanied by displacement.	*CCC, 2008*
Fault-block (horst)	Uplifted section of rock bounded on both sides by faults. See graben.	*USBR, 2008*
Faulting	The movement which produces relative displacement along a fracture in rock.	*USBR, 2008*
Fauna	All animals associated with a given habitat, country, area, or period.	*USBR, 2008*
FDA action level	A regulatory level recommended by the U.S. Environmental Protection Agency for enforcement by the FDA when pesticide residues occur in food commodities for reasons other than the direct application of the pesticide. Action levels are set for inadvertent pesticide residues resulting from previous legal use or accidental contamination. Applies to edible portions of fish and shellfish in interstate commerce.	*USGS, 2008*

Feasibility	A determination that something can be done. A feasibility report is required in some planning processes to examine the situation and determine if a workable solution can be developed and implemented.	*USBR, 2008*
Feasibility estimate	An estimate used for determining the economic feasibility of a project, the probable sequence and cost for construction of a project, and as a guide in the choice between alternative locations or plans.	*USBR, 2008*
Feasibility study	1. Analysis of the practicability of a proposal; e.g., a description and analysis of potential cleanup alternatives for a site such as one on the National Priorities List. The feasibility study usually recommends selection of a cost-effective alternative. It usually starts as soon as the remedial investigation is underway; together, they are commonly referred to as the "RI/FS". 2. A small-scale investigation of a problem to ascertain whether a proposed research approach is likely to provide useful data.	*EPA, 2008b*
Feasible	Capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors.	*CCC, 2008*
Feather	To blend the edge of new material smoothly into the old surface.	*USBR, 2008*
Fecal bacteria	Microscopic single-celled organisms (primarily fecal coliforms and fecal streptococci) found in the wastes of warm-blooded animals. Their presence in water is used to assess the sanitary quality of water for body-contact recreation or for consumption. Their presence indicates contamination by the wastes of warm-blooded animals and the possible presence of pathogenic (disease producing) organisms.	*USGS, 2008*
Fecal coliform	See Fecal bacteria.	*USGS, 2008*
Fecal coliform bacteria	Bacteria found in the intestinal tracts of mammals. Their presence in water or sludge is an indicator of pollution and possible contamination by pathogens.	*EPA, 2008b*
Federal action agency	Any department or agency of the United States proposing to authorize, fund, or carry out an action under existing authorities.	*USFWS, 2008*
Federal coastal act	The Federal Coastal Zone Management Act of 1972 (16 U.S.C. 1451, et seq.), as amended.	*CCC, 2008*
Federal Consistency Review	As described in the 1972 Federal Coastal Zone Management Act, states with approved coastal management programs are responsible for reviewing proposed federal and federally-authorized activities to assess their consistency with the state program. These activities, within the coastal zone or outside the coastal zone, that affect any land or water use or natural resource of the coastal zone shall be carried out in a manner which is consistent the enforceable policies of the coastal management program.	*CCC, 2008*
Federal Emergency Management Agency (FEMA)	Federal agency responsible for enforcing the legislation for disaster and emergency planning and response. See FEMA.	*USBR, 2008*

Federal Energy Regulatory Commission (FERC)	Established in 1977 (replacing the Federal Power Commission) the the primary responsibility of ensuring the Nation's consumers adequate energy supplies at just and reasonable rates and providing regulatory incentives for increased productivity, efficiency, and competition. Its primary functions are to establish and enforce rates and regulations regarding interstate aspects of the electric, natural gas, and oil industries. It also issues licenses for non-Federal hydroelectric plants and certifies small power production and cogeneration facilities. See FERC.	*USBR, 2008*
Federal organizations	Agencies, departments, or their components of the Federal Government that have a role in dam safety emergency planning and preparedness (i.e., Reclamation, U.S. Army Corps of Engineers, National Weather Service, etc.).	*USBR, 2008*
Federal Register	The official daily publication for actions taken by the Federal government, such as Rules, Proposed Rules, and Notices of Federal agencies and organizations, as well as Executive Orders and other Presidential Documents.	*USFWS, 2008*
Feeder beach	An artificially widened beach serving to nourish downdrift beaches by natural littoral currents or forces.	*CCC, 2008*
Feedlot	A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.	*EPA, 2008c*
Feldspar	Group of light-colored minerals often found as crystals in intrusive igneous rocks. The most common rock-forming mineral.	*USBR, 2008*
Fen	A type of wetland that accumulates peat deposits. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium.	*EPA, 2008b*
Fertilizer	Any of a large number of natural or synthetic materials, including manure and nitrogen, phosphorus, and potassium compounds, spread on or worked into soil to increase its fertility.	*USGS, 2008*
Fetch	The open area and distance across a body of water in which wind can exert energy on waves to increase their strength of impact on the shoreline.	*USFS, 2002*
Fetch	The straight line distance across a body of water subject to wind forces. The distance which wind passes over water. The fetch is one of the factors used in calculating wave heights in a reservoir. The area in which waves are generated by a wind having a fairly constant direction and speed.	*USBR, 2008*
Fetch	The area in which sea waves are generated by a wind having a fairly constant speed and direction. Commonly associated with waves over the deep portion of the ocean that exhibit fairly stable speed and direction.	*CCC, 2008*
Field capacity (field moisture capacity)	Depth of water retained in the soil after ample irrigation or heavy rain when the rate of downward movement has substantially decreased, usually one to three days after irrigation or rain, expressed as a depth of water in inches or feet.	*USBR, 2008*

Field tile	Short lengths of clay pipe that are installed as subsurface drains.	*USBR, 2008*
Fill	Man-made deposits of natural soils or rock products and waste materials.	*EPA, 2008b*
Fill	(1) (Geology) Any sediment deposited by any agent such as water so as to fill or partly fill a channel, valley, sink, or other depression. (2) (Engineering) Soil or other material placed as part of a construction activity.	*USACE, 1999*
Fill	Manmade deposits of natural soils or the process of the depositing. Manmade deposits of natural soils or rock products and waste materials designed and installed in such a manner as to provide drainage, yet prevent the movement of soil particles due to flowing water. An earth or broken rock structure or embankment. Soil or loose rock used to raise a grade. Soil that has no value except as bulk.	*USBR, 2008*
Fill	Earth or any other substance or material, including pilings placed for the purposes of erecting structures thereon, placed in a submerged area.	*CCC, 2008*
Fill material	Soil that is placed at a specific location to bring the ground surface up to a desired elevation or angle of slope.	*USFS, 2002*
Fillet	The concave accumulation of sand upcoast of a natural or artificial structure.	*CCC, 2008*
Filling	Depositing dirt, mud or other materials into aquatic areas to create more dry land, usually for agricultural or commercial development purposes, often with ruinous ecological consequences.	*EPA, 2008b*
Filter (filter zone)	One or more layers of granular material which is incorporated in an embankment dam and is graded (either naturally or by selection) to allow seepage through or within the layers while preventing the migration of material from adjacent zones. A layer or combination of layers of pervious materials designed and installed in such a manner as to provide drainage, yet prevent the movement of soil particles due to flowing water.	*USBR, 2008*
Filter cake (mud cake)	A deposit of mud on the walls of a drill hole.	*USBR, 2008*
Filter cloth	A type of strong permeable plastic cloth that is used landward of seawalls or revetments to reduce or minimize scour behind the wall.	*CCC, 2008*
Filter Strip	Strip or area of vegetation used for removing sediment, organic matter, and other pollutants from runoff and wastewater.	*EPA, 2008b*
Final environmental impact statement (FEIS)	The final report of environmental effects of proposed action on an area of land. This is required for major federal actions under Section 102 of the National Environmental Policy Act. It is a revision of the draft environmental impact statement to include public and agency responses to the draft.	*USACE, 1999*
Financial analysis	Procedure that considers only tangible factors when evaluating various alternatives.	*USBR, 2008*

Finding of no significant impact	A document prepared by a federal agency showing why a proposed action would not have a significant impact on the environment and thus would not require preparation of an Environmental Impact Statement. An FNSI is based on the results of an environmental assessment.	*EPA, 2008b*
Finding of no significant impact (FONSI)	A NEPA compliance document which affirms that an environmental assessment found that alternatives were evaluated and a proposed action would have no significant impact on the human environment.	*USBR, 2008*
Fines	Silt and clay particles.	*USFS, 2002*
Fines	Fine particulate material such as silt and clay particles typically of less than .85 mm diameter.	*EPA, 2008c*
Fines	Portion of a soil finer that a No. 200 U.S. Standard sieve. Clay or silt particles in soil.	*USBR, 2008*
Finger drains	A series of parallel drains of narrow width (instead of a continuous drainage blanket) draining to the downstream toe of the embankment dam.	*USBR, 2008*
Finished grade	The elevation or surface of the earth after all earthwork has been completed (also finish grade). The final grade required by specifications.	*USBR, 2008*
Firm energy (power)	Non-interruptible energy and power guaranteed by the supplier to be available at all times, except for uncontrollable circumstances.	*USBR, 2008*
Firm yield	The maximum quantity of water that can be guaranteed with some specified degree of confidence during a specific critical period. The critical period is that period in a sequential record that requires the largest volume from storage to provide a specified yield.	*USBR, 2008*
Fish community	See Community.	*USGS, 2008*
Fish habitat	The aquatic environment and the immediately surrounding terrestrial environment that meet the necessary biological and physical requirements of fish species during various life stages.	*USFS, 2002*
Fish ladder (fishway)	An inclined trough which carries water from above to below a dam so that fish can easily swim upstream. There are various types, some with baffles to reduce the velocity of the water and some consisting of a series of boxes with water spilling down from one to the next.	*USBR, 2008*
Fish passage	Removal of barriers to upstream/downstream migration of fishes. Includes the physical removal of barriers and also construction of alternative pathways. Includes migration barriers placed at strategic locations along streams to prevent undesirable species from accessing upstream areas.	*NRRSS, 2005*
Fish weir	A type of fish ladder.	*USBR, 2008*
Fishery	The aquatic region in which a certain species of fish lives.	*USBR, 2008*
Fishing	The operation of recovering an object left or dropped in a drill hole.	*USBR, 2008*
Fixed amount-frequency scheduling	Method of irrigation scheduling that involves water delivery at a fixed rate or a fixed volume and at constant intervals. Examples include rotation and continuous flow methods. Considered a rigid form of scheduling.	*USBR, 2008*

Fixed Sites	NAWQA's most comprehensive monitoring sites. See also Basic Fixed Sites and Intensive Fixed Sites.	*USGS, 2008*
Flap gate	A gate hinged along one edge, usually either the top or bottom edge. Examples of bottom-hinged flap gates are tilting gates and fish belly gates - so called from their shape in cross section.	*USBR, 2008*
Flash flood	A sudden flood of great volume, usually caused by a heavy rain. Also, a flood that crests in a short length of time and is often characterized by high velocity flows.	*USACE, 1999*
Flash flood	A flood which follows within a few hours of heavy or excessive rainfall. A flood of short duration with a relatively high peak rate of flow, usually resulting from a high intensity rainfall over a small area.	*USBR, 2008*
Flash flood warning	Flash flooding has been reported or is imminent.	*USBR, 2008*
Flash flood watch	Flash flooding is possible within the designated watch area.	*USBR, 2008*
Flashboards	Temporary barriers, consisting of either timber, concrete or steel, anchored to the crest of a spillway as a means of increasing the reservoir storage. Flashboards can be removed, lowered, or carried away at the time of flooding either by a tripping device or by deliberate failure of the flashboards or their supports. Structural members of timber, concrete, or steel placed in channels or on the crest of a spillway to raise the reservoir water level but that may be quickly removed in the event of a flood.	*USBR, 2008*
Flat slab or slab and buttress dam	A buttress dam with buttresses which support the flat slab of reinforced concrete which forms the upstream face.	*USBR, 2008*
Flatirons	Triangular-shaped landforms along mountain ranges formed by erosion of steeply inclined rock layers or hogbacks.	*USBR, 2008*
Fleet angle	The angle between the position of a rope or cable at the extreme end wrap on a drum and a line drawn perpendicular to the axis of the drum. The fleet angle is used to indicate how effective or efficient the rope or cable is for raising a load.	*USBR, 2008*
Fling	Refers to a near field long period pulse from a strong ground motion resulting in a unidirectional ground heave after rupture. Great kinetic energy may be associated with a fling and is important in near field records.	*USBR, 2008*
Floatable days	The number of days during the recreation season on which it is safe to allow floating activities on recreation facilities.	*USBR, 2008*
Floatable flows	River flows which make rafting and other floating recreation possible.	*USBR, 2008*
Floc	Loose, open-structured mass formed in a suspension by the aggregation of minute particles. Clumps of bacteria and particulate impurities that have come together and formed a cluster. Found in flocculation tanks and settling or sedimentation basins. Clumps of impurities removed from water during the purification process; formed when alum is added to impure water.	*USBR, 2008*
Flocculation	The process by which suspended colloidal or very fine particles are assembled into larger masses or floccules that eventually settle out of suspension.	*EPA, 2008c*
Flocculation	The process of forming flocs. A step in water filtration in which alum is added to cause particles to clump together.	*USBR, 2008*

Flood	A temporary rise in water levels resulting in inundation of areas not normally covered by water. May be expressed in terms of probability of exceedance per year such as 1-percent chance flood or expressed as a fraction of the probable maximum flood or other reference flood.	*USBR, 2008*
Flood	Flow that exceeds the capacity of the channel. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.	*DOC, 2005*
Flood	Any relatively high streamflow that overtops the natural or artificial banks of a stream.	*USGS, 2008*
Flood boundary	Line drawn or outer edge of colored (inundation) area on an inundation map to show the limit of flooding.	*USBR, 2008*
Flood control capacity	Reservoir capacity assigned to the sole purpose of regulating flood inflows to reduce flood damage downstream. See exclusive flood control capacity.	*USBR, 2008*
Flood control pool (flood pool)	Reservoir volume above active conservation capacity and joint use capacity that is reserved for flood runoff and then evacuated as soon as possible to keep that volume in readiness for the next flood.	*USBR, 2008*
Flood frequency	Refers to the probability (in percent) that a flood will occur in a given year.	*USBR, 2008*
Flood gate	A gate to control flood releases from a reservoir.	*USBR, 2008*
Flood hydrograph	A graph showing, for a given point on a stream, the discharge, height, or other characteristic of a flood with respect to time.	*USBR, 2008*
Flood irrigation	Method of irrigating where water is applied from field ditches onto land which has no guide preparation such as furrows, borders or corrugations.	*USBR, 2008*
Flood irrigation	The application of irrigation water where the entire surface of the soil is covered by ponded water.	*USGS, 2008*
Flood plain	Nearly level land, susceptible to floods, that forms the bottom of a valley. An area, adjoining a body of water or natural stream, that has been or may be covered by floodwater.	*USBR, 2008*
Flood plain	A strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood.	*DOC, 2005*
Flood plain	The relatively level area of land bordering a stream channel and inundated during moderate to severe floods.	*USGS, 2008*
Flood pool index	Computed as the ratio of the flood control pool depth to the depth below the pool, multiplied by the percent of time the reservoir water surface will be within the flood control pool.	*USBR, 2008*
Flood routing	A process of determining progressively over time the amplitude of a flood wave as it moves past a dam or downstream to successive points along a river or stream.	*USBR, 2008*
Flood severity	Qualitative description of how severe a possible flood could be (High, Medium, Low) depending on failure modes (including rate of failure), flood velocity, channel width, magnitude of damage potential, rate of rise for flood waters, etc. High severity would be associated with structures being swept clean from their foundations. Low severity would indicate that a slow, gradual rise of flood waters is anticipated.	*USBR, 2008*

Flood severity understanding	Understanding as to what degree flooding might affect the downstream population. The judgement on flood severity understanding is based on type of loading and is described as either vague or precise.	*USBR, 2008*
Flood stage	An established gage height within a given river reach above which a rise in water surface level is defined as a flood.	*USBR, 2008*
Flood tide	The period of tide between low water and the succeeding high water; a rising tide. (opposite = ebb tide)	*CCC, 2008*
Flood, 100-year	A 100-year flood does not refer to a flood that occurs once every 100 years, but to a flood level with a 1 percent chance of being equaled or exceeded in any given year.	*DOC, 2005*
Floodplain	The flat or nearly flat land along a river or stream or in a tidal area that is covered by water during a flood.	*EPA, 2008b*
Floodplain	A highly variable area on one or both sides of the stream channel that is inundated by floodwaters at some interval, from frequent to rare.	*FISHWR, 2001*
Floodplain	Land built of sediment that is regularly covered with water as a result of the flooding of a nearby stream.	*USACE, 1999*
Floodplain (100-year)	The area adjacent to a stream that is on average inundated once a century.	*USACE, 1999*
Floodplain reconnection	Practices that increase the flood frequency of floodplain areas and/or promote flux of organisms and material between riverine and floodplain areas.	*NRRSS, 2005*
Floodwalls	Concrete walls constructed adjacent to streams for the purpose of preventing flooding of property on the landside of the wall; normally constructed in lieu of or to supplement levees where the land required for levee construction is more expensive or not available.	*FEMA, 2003*
Flora	All plant life associated with a given habitat, country, or period. Bacteria are considered flora.	*USBR, 2008*
Flow	The amount of water passing a particular point in a stream or river, usually expressed in cubic feet per second (cfs).	*USACE, 1999*
Flow	Volume of water that passes a given point within a given period of time. See base flow, discharge, enhancement flow, instream flow requirements, interstitial flow, minimum flow, peak flow, and return flow.	*USBR, 2008*
Flow augmentation	Increased flow from release of water from storage dams.	*USACE, 1999*
Flow augmentation	The release of water stored in a reservoir or other impoundment to increase the natural flow of a stream.	*USBR, 2008*
Flow channel	The portion of a flow net bounded by two adjacent flow lines.	*USBR, 2008*
Flow curve	The locus of points obtained from a standard liquid limit test and plotted on a graph representing moisture content as ordinate on an arithmetic scale and the number of blows as abscissa on a logarithmic scale.	*USBR, 2008*
Flow failure	Failure in which a soil mass moves over relatively long distances in a fluidlike manner.	*USBR, 2008*
Flow line	The path that a particle of water follows in its course of seepage under laminar flow conditions.	*USBR, 2008*

Flow modification	Practices that alter the timing and delivery of water quantity (DOES NOT include Storm water Management). Typically, but not necessarily associated with releases from impoundments and constructed flow regulators.	*NRRSS, 2005*
Flow net	A graphical representation of flow lines and equipotential (piezometric) lines used in the study of seepage phenomena.	*USBR, 2008*
Flow rate	The rate, expressed in gallons -or liters-per-hour, at which a fluid escapes from a hole or fissure in a tank. Such measurements are also made of liquid waste, effluent, and surface water movement.	*EPA, 2008b*
Flow slide	The failure of a sloped bank of soil in which the movement of the soil mass does not take place along a well-defined surface of sliding.	*USBR, 2008*
Flowage	Water that floods onto adjacent land.	*USBR, 2008*
Flowage easement	The right or easement to overflow, submerge, or flood certain lands; a right to prohibit building on certain floodways.	*USBR, 2008*
Flowpath	An underground route for groundwater movement, extending from a recharge (intake) zone to a discharge (output) zone such as a shallow stream.	*USGS, 2008*
Flowpath study	Network of clustered wells located along a flowpath extending from a recharge zone to a discharge zone, preferably a shallow stream. The studies examine the relations of landwater flow, and contaminant occurrence and transport. These studies are located in the area of one of the land use practices, grounduse studies.	*USGS, 2008*
Fluctuating flows	Water released from a dam that varies in volume with time.	*USBR, 2008*
Fluctuating zone	Area of a sandbar or vegetation zone that is within the range of fluctuating flow.	*USBR, 2008*
Flume	A natural or man-made channel that diverts water.	*EPA, 2008b*
Flume	Shaped, open-channel flow sections that force flow to accelerate. Acceleration is produced by converging the sidewalls, raising the bottom, or a combination of both. An artificial channel, often elevated above ground, used to carry fast flowing water. See long- throated flume, Parshall flume, and short-throated flume.	*USBR, 2008*
Flushing	A method used to clean water distribution lines by passing a large amount of water through the system.	*USBR, 2008*
Fluvial	Migrating between main rivers and tributaries. Of or pertaining to streams or rivers.	*USACE, 1999*
Fluvial	Pertains to streams and stream processes.	*USBR, 2008*
Fluvial	Of or pertaining to rivers; growing or living in a stream or river; produced by the action of a stream or river.	*USBR, 2008*
Fluvial	To do with streams and rivers.	*DOC, 2005*
Fluvial deposit	A sedimentary deposit consisting of material transported by suspension or laid down by a river or stream.	*USGS, 2008*
Fluvial geomorphology	The effect of rainfall and runoff on the form and pattern of riverbeds and river channels.	*EPA, 2008c*
Flux	Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.	*EPA, 2008c*

Fly ash	A by-product of coal-fired powerplants which reacts with water and the free lime in cement while generating only half the heat of an equal amount of cement.	*USBR, 2008*
Food chain	A sequence of organisms, each of which uses the next, lower member of the sequence as a food source.	*EPA, 2008b*
Food chain	A succession of organisms in a community in which food energy is transferred from one organism to another as each consumes a lower member and, in turn, is consumed by a higher member.	*USBR, 2008*
Food web	The feeding relationships by which energy and nutrients are transferred from one species to another.	*EPA, 2008b*
Foot	Twelve inches. One of a number of projections on a cylindrical drum of a tamping roller.	*USBR, 2008*
Footer log	A log placed below the expected scour depth of stream. A foundation for a root wad or log revetment.	*USFS, 2002*
Footing	A sill under a foundation. Ground, in relation to its load bearing and friction qualities. Portion of the foundation of a structure that transmits loads directly to the soil.	*USBR, 2008*
Foot-Pound	Unit of work equal to the force in pounds multiplied by the distance in feet through which it acts. When a 1 pound force is exerted through a 1 foot distance, 1 foot pound of work is done.	*USBR, 2008*
Forage	Vegetation used for animal consumption.	*USBR, 2008*
Forage fish	Generally, small fish that produce prolifically and are consumed by predators.	*USBR, 2008*
Forb	A weed or a broad-leafed plant.	*USBR, 2008*
Forced outage	Unscheduled shut down of a generating unit or other facility for emergency or other unforeseen reasons.	*USBR, 2008*
Forcing functions	External empirical formulation used to provide input describing a number of processes. Typical forcing functions include parameters such as temperature, point and tributary sources, solar radiation, and waste loads and flow.	*EPA, 2008c*
Ford	A shallow place in a body of water, such as a river, where one can cross by walking or riding on an animal or in a vehicle.	*USACE, 1999*
Ford	A place where a road crosses a stream under water.	*USBR, 2008*
Forebay	A reservoir or pond situated at the intake of a pumping plant or power plant to stabilize water levels; also a storage basin for regulating water for percolation into groundwater basins.	*USACE, 1999*
Forebay (headrace)	Impoundment immediately upstream from a dam or hydroelectric plant intake structure. The term is applicable to all types of hydroelectric developments (storage, run-of-river, and pumped-storage).	*USBR, 2008*
Forebeach (wet beach)	The sand area affected regularly by tides and wave action.	*CCC, 2008*
Forepole	A plank driven ahead of a tunnel face to support the roof or wall during excavation. See horsehead.	*USBR, 2008*
Foreshore	That part of the shore between the ordinary high-and low-watermarks and generally crossed by the tide each day.	*USBR, 2008*
Foreshore (or beach face)	Region of the coast extending from the berm crest (or the highest point of wave wash at high tide) to the low-water mark which is measured at low tide.	*CCC, 2008*

Formal consultation	The required process under section 7 of the ESA between FWS or NOAA Fisheries and a Federal agency or applicant conducted when a Federal agency determines its action is likely to adversely affect a listed species or its critical habitat; used to determine whether the proposed action is likely to jeopardize the continued existence of listed species or adversely modify critical habitat. This determination is stated in a biological opinion.	*USFWS, 2008*
Formation	Any sedimentary, igneous, or metamorphic material represented as a unit in geology; generally called rock, but not necessarily meeting the definition of rock.	*USBR, 2008*
Formation	A unit of rock that is distinctive and persistent over a large area.	*CCC, 2008*
Formulation process	First phase performed by the Early Warning System design team, which includes an Early Warning System reliability, local capabilities assessment, and conceptual level designs for an Early Warning System.	*USBR, 2008*
Fossiliferous	Rock units containing fossils.	*CCC, 2008*
Fossorial insects	Insects that live in the soil.	*USBR, 2008*
Foundation	Lower part of a structure that transmits loads directly to the soil. The excavated surface upon which a dam is placed.	*USBR, 2008*
Foundation drains	Tile or pipe for collecting seepage within a foundation.	*USBR, 2008*
Foundation material (foundation soil)	The upper part of the earth mass carrying the load of the structure.	*USBR, 2008*
Foundation surface	The surface of the upper part of the earth mass carrying the load of the structure.	*USBR, 2008*
Foundation trench	A trench built at and into the foundation of a dam and filled with clay or other impermeable substances to prevent water from seeping beneath the dam. See cutoff trench.	*USBR, 2008*
Fracture	A break in a rock formation due to structural stresses; e.g. faults, shears, joints, and planes of fracture cleavage.	*EPA, 2008b*
Fracture (joint)	Crack or break in rocks along which no movement has occurred.	*USBR, 2008*
Freeboard	1. Vertical distance from the normal water surface to the top of a confining wall. 2. Vertical distance from the sand surface to the underside of a trough in a sand filter.	*EPA, 2008b*
Freeboard	The difference in elevation between the maximum water surface in the reservoir and the dam crest. The vertical distance between a stated water level and the top of a dam, without camber. Thus "net freeboard," "dry freeboard," or "flood freeboard" is the vertical distance between the maximum water surface and the top of the dam. "Gross freeboard" or "total freeboard" is the vertical distance between the normal water surface and the top of the dam. That part of the "gross freeboard" attributable to the depth of flood surcharge is sometimes referred to as the "wet freeboard," but this term is not recommended as it is preferable that freeboard be stated with reference to the top of dam.	*USBR, 2008*
Freezeout	Deeply frozen over for long periods of time.	*USBR, 2008*
Freeze-thaw damage	Damage to concrete caused by extreme temperature variations as noted by random pattern cracking. Damage is accelerated by the presence of water and commonly more severe on the south-facing side of structures.	*USBR, 2008*

French drain	A covered ditch containing a layer of fitted or loose stone or other pervious material.	*USBR, 2008*
Frequency demand scheduling	Method of irrigation scheduling similar to demand scheduling, but typically involves a fixed duration of the delivery, such as 24 hours. This method is considered flexible, although somewhat less so than demand scheduling from the water users' perspective.	*USBR, 2008*
Fresh water	Water that generally contains less than 1,000 milligrams-per-liter of dissolved solids.	*EPA, 2008b*
Freshwater	Water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.	*USBR, 2008*
Freshwater chronic criteria	The highest concentration of a contaminant that freshwater aquatic organisms can be exposed to for an extended period of time (4 days) without adverse effects. See also Water-quality criteria.	*USGS, 2008*
Friction	Resistance to motion when one body is sliding or tending to slide over another.	*USBR, 2008*
Front end loader	A tractor loader that both digs and dumps in front.	*USBR, 2008*
Frost action	Freezing and thawing of moisture in materials and the resultant effects on these materials and on structures of which they are a part of with which they are in contact.	*USBR, 2008*
Frost heave	The raising of a surface due to the accumulation of ice in the underlying soil or rock.	*USBR, 2008*
Frost line	The greatest depth to which ground may be expected to freeze.	*USBR, 2008*
Froude number	The ratio of inertial forces to gravitational forces in flow. It is also the ratio of the flow velocity to the velocity of a small gravity wave in the flow. When the Froude number is less than one, the flow is tranquil. When the Froude number is greater than one, the flow is rapid. When the Froude number is equal to one, the flow is critical.	*USBR, 2008*
Fry	A recently hatched fish.	*USACE, 1999*
Fry	Young, newly hatched fish.	*EPA, 2008c*
Fry	Life stage of fish between the egg and fingerling stages. Depending on the species of fish, fry can measure from a few millimeters to a few centimeters.	*USBR, 2008*
Full pool	Volume of water in a reservoir at normal water surface. The reservoir level that would be attained when the reservoir is fully utilized for all project purposes, including flood control.	*USBR, 2008*

Full-Scale Exercise	An activity in which emergency preparedness officials respond in a coordinated manner to a timed, simulated incident but includes the mobilization of field personnel and resources and the actual movement of emergency workers, equipment, and resources required to demonstrate coordination and response capability. This exercise is intended to evaluate the entire emergency organization or its major parts in an interactive manner over a substantial period of time. It mobilizes emergency officials in an emergency operations center plus the activation of one or more emergency functions outside of the center. Reclamation will not generally conduct this level of exercise, but will participate in exercises conducted by others when our facilities are involved.	*USBR, 2008*
Fumigant	A substance or mixture of substances that produces gas, vapor, fume, or smoke intended to destroy insects, bacteria, or rodents.	*USGS, 2008*
Functional equivalent	Term used to describe EPA's decision-making process and its relationship to the environmental review conducted under the National Environmental Policy Act (NEPA). A review is considered functionally equivalent when it addresses the substantive components of a NEPA review.	*EPA, 2008b*
Functional Exercise	An activity in which participants respond in a coordinated manner to a timed, simulated incident that parallels a real operational event as close as possible. This exercise is generally conducted in an emergency operations center or Incident Command Post, and messages are passed to the participants in written form by telephone, radio, FAX, computer, or other method of communication. The functional exercise uses information such as emergency plans, maps, charts, and other information available in a real event and creates stress by increasing the frequency of messages, intensity of activity, and complexity of decisions and/or requirements for coordination. It does not involve actual mobilization of emergency response forces in the field. Participants should include management, key agency staff, and personnel from outside organizations as appropriate.	*USBR, 2008*
Furrow	A natural or man-made narrow depression in the earth's surface. A narrow trenchlike plowed depression in the earth surface to keep surface water away from the slopes of cuts.	*USBR, 2008*
Furrow irrigation	A type of surface irrigation where water is applied at the upper end of a field and flows in furrows to the lower end.	*USGS, 2008*
Future without	What would occur if no action were taken. The future without taking any action to solve the problem. See baseline condition.	*USBR, 2008*

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Gabion	A wire basket or cage that is filled with gravel or cobble and generally used to stabilize stream banks.	*USACE, 1999*
Gabion	Wire basket, filled with stones, used to stabilize banks of a water course and to enhance habitat.	*USBR, 2008*
Gabion dam	Special name given to a crib dam when built with gabions. See dam.	*USBR, 2008*

Gabions	A mesh box or enclosure filled with rocks, cobbles, stones, etc. and used as building units for dams, dikes, or shoreline protection.	*CCC, 2008*
Gage height (G.H.)	The water surface elevation referred to some arbitrary gage datum. Gage height is often used interchangeably with the more general term "stage," although gage height is more appropriate when used with a reading on a gage. See gauge height.	*USBR, 2008*
Gaging station	A particular site in a stream, lake, reservoir, etc., where hydrologic data are obtained.	*USACE, 1999*
Gaging station	A particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.	*USBR, 2008*
Gaging station	A site on a stream, lake, reservoir or other body of water where observations and hydrologic data are obtained.	*DOC, 2005*
Gaging station	A particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.	*USGS, 2008*
Gaining stream	Stream or reach that receives water from the zone of saturation.	*USBR, 2008*
Gallery	A passageway within the body of a dam, its foundation, or abutments used for inspection, foundation grouting, and/or drainage.	*USBR, 2008*
Gallon	A unit of measure equal to four quarts or 128 fluid ounces.	*USBR, 2008*
Gallons per minute (gpm)	A unit used to measure water flow.	*USACE, 1999*
Galvanize	To coat a metal (especially iron or steel) with zinc. Galvanization is the process of coating a metal with zinc.	*USBR, 2008*
Game fish	Species like trout, salmon, or bass, caught for sport. Many of them show more sensitivity to environmental change than "rough" fish.	*EPA, 2008b*
Gametes	Eggs or sperm.	*USBR, 2008*
Gantry	An overhead structure that supports machines or operating parts, such as a gantry crane.	*USBR, 2008*
Gantry crane	A fixed or traveling, bent-supported crane for handling heavy equipment.	*USBR, 2008*
Gaseous supersaturation	Condition of higher levels of dissolved gases in water due to entrainment, pressure increases, or heating.	*USBR, 2008*
Gate	A device that controls the flow in a conduit, pipe, or tunnel without obstructing any portion of the waterway when in the fully open position. Structure or device for controlling the rate of flow into or from a canal or ditch. A movable, watertight barrier for the control of water in a waterway. See bear-trap gate, bulkhead gate, clam shell gate, coaster gate, crest gate, cylinder gate, drum gate, emergency gate, fixed-wheel gate, flap gate, flood gate, guard gate, high-pressure gate, jet-flow gate, outlet gate, paradox gate, radial gate, regulating gate, ring gate, ring- follower gate, ring seal gate, roller gate, skimmer gate, slide gate, sluice gate, stoney gate, tainter gate, tractor gate, vertical lift gate, or wicket gate.	*USBR, 2008*

Gate chamber (valve chamber)	A chamber in which a guard gate in a pressurized outlet works or both the guard and regulating gates in a free-flow outlet works are located. A room from which a gate or valve can be operated, or sometimes in which the gate is located. Concrete portion of an outlet works containing gates between upstream and downstream conduits and/or tunnels.	*USBR, 2008*
Gauge (gage)	Device for registering water level, discharge, velocity, pressure, etc. Thickness of wire or sheet metal. A number that defines the thickness of the sheet used to make steel pipe. The larger the number, the thinner the pipe wall.	*USBR, 2008*
Gauge pressure	Absolute pressure minus atmospheric pressure. The pressure within a closed container as measured with a gauge. Sometimes referred to as relative pressure.	*USBR, 2008*
Gauging station	Specific location on a stream where systematic observations of hydrologic data are obtained through mechanical or electrical means. See gauge.	*USBR, 2008*
Generalized skew coefficient	A skew coefficient derived by a procedure which integrates values obtained at many locations.	*USGS, 1982*
Geochemical	Referring to chemical reactions involving earth materials such as soil, rocks, and water.	*EPA, 2008c*
Geographic Information System (GIS)	A computer system designed for storing, manipulating, analyzing, and displaying data in a geographic context.	*EPA, 2008b*
Geographic information system (GIS)	A computer system capable of storing and manipulating spatial data.	*USACE, 1999*
Geographic information system (GIS)	A tool used to collect, store, combine, analyze and present geographic data (e.g., computer software such as ArcView, ESRI Inc.).	*DOC, 2005*
Geohazard	A risk associated with geologic processes or events.	*CCC, 2008*
Geohydrology	Geological study of the character, source, and mode of ground water.	*USBR, 2008*
Geological log	A detailed description of all underground features (depth, thickness, type of formation) discovered during the drilling of a well.	*EPA, 2008b*
Geology	The science that deals with the physical history of the earth, the rocks of which it is comprised, and the physical changes which the earth has undergone or is undergoing.	*USBR, 2008*
Geomorphic	Of or relating to the form or shape of the earth.	*USBR, 2008*
Geomorphology	A branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place due to erosion of the primary elements and the buildup of erosional debris.	*USACE, 1999*
Geomorphology	The geologic study of the characteristics, origin, and development of landforms.	*USFS, 2002*
Geomorphology	The study of the evolution and configuration of landforms.	*EPA, 2008c*
Geomorphology	Geological study of the configuration, characteristics, origin, and evolution of land forms and earth features.	*USBR, 2008*
Geomorphology	The study of earth surface processes and landforms, including landslides on hillslopes or erosion and sedimentation in rivers.	*DOC, 2005*

Geophysics	Refers to the physics of the earth, e.g., seismology, oceanography, volcanology, geomagnetism, etc.	*USBR, 2008*
Geotextiles	Any fabric or textile (natural or synthetic) used as an engineering material in conjunction with soil, foundations, or rock. Geotextiles provide the following uses: drainage, filtration, separation of materials, reinforcement, moisture barriers, and erosion protection.	*USBR, 2008*
Geothermal	Relating to the Earth's internal heat; commonly applied to springs or vents discharging hot water or steam.	*USGS, 2008*
Giant salvinia (Salvinia molesta)	An aquatic fern prohibited in the United States by Federal law. An invasive, rapidly growing plant that covers the surfaces of lakes and streams forming floating mats that shade and crowd out important native plants. Thick mats reduce oxygen content, degrading water quality for fish and other organisms, impeding boating, fishing and swimming, and clogging water intakes for irrigation and electrical generation. The plant spreads aggressively by fragmenting and has oblong floating leaves, 1/2 to 1 1/2 inches long. Young plants have smaller leaves that lie flat on the water surface. As the plant matures and aggregates into mats, leaves fold and compress into upright chains. For more information visit the Giant Salvinia website.	*USBR, 2008*
GIS (Geographic Information System)	A GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information. A GIS allows analysis of spatial relationships between many different types of features based on their location in the landscape.	*CCC, 2008*
Glacial moraine	A mass of loose rock, soil, and earth deposited by the edge of a glacier.	*USBR, 2008*
Glacial striations	Lines carved into rock by overriding ice, showing the direction of glacial movement.	*USBR, 2008*
Glacial till	Material deposited by glaciation, usually composed of a wide range of particle sizes, which has not been subjected to the sorting action of water.	*USBR, 2008*
Glacier (ice sheet)	A large thick mass of ice formed on land by the compacting and recrystallization of old snow and move under the influence of gravity. Glaciers survive from year to year, and creep downslope or outward due to the stress of their own weight.	*USBR, 2008*
Glide	A section of stream that has little or no turbulence.	*USACE, 1999*
Global positioning systems (GPS)	Space-based radio positioning systems that provide 24-hour, three-dimensional position, velocity, and time information to suitably equipped users anywhere on or near the surface of the Earth.	*USBR, 2008*

Global warming	An increase in the near surface temperature of the Earth. Global warming has occurred in the distant past as the result of natural influences, but the term is most often used to refer to the warming predicted to occur as a result of increased emissions of greenhouse gases. Scientists generally agree that the Earth's surface has warmed by about 1 degree Fahrenheit in the past 140 years. The Intergovernmental Panel on Climate Change (IPCC) recently concluded that increased concentrations of greenhouse gases are causing an increase in the Earth's surface temperature and that increased concentrations of sulfate aerosols have led to relative cooling in some regions, generally over and downwind of heavily industrialized areas.	*EPA, 2008b*
Global warming potential	he ratio of the warming caused by a substance to the warming caused by a similar mass of carbon dioxide. CFC-12, for example, has a GWP of 8,500, while water has a GWP of zero.	*EPA, 2008b*
Gneiss	Metamorphic rock that displays distinct banding of light and dark mineral layers.	*USBR, 2008*
Goal	The desired state or condition that a resource management policy or program is designed to achieve.	*USFS, 2002*
Grab sample	A single sample collected at a particular time and place that represents the composition of the water, air, or soil only at that time and place.	*EPA, 2008b*
Graben	Down-dropped block of rock bounded on both sides by faults. See fault-block.	*USBR, 2008*
Gradation	Proportion of material of each grain-size present in a given soil. The proportions by mass of a soil or fragmented rock distributed in specified particle-size ranges.	*USBR, 2008*
Grade	The individual profile and pattern that a river has developed to efficiently move the discharge and sediment delivered to it.	*USFS, 2002*
Grade (pitch)	The elevation of a surface or a surface slope. The elevation of the invert of the bottom of a pipeline, canal, culvert, or conduit. The fall (slope) of a line of pipe in reference to a horizontal plane. The inclination or slope of a pipeline, conduit, stream channel, or natural ground surface; usually expressed in terms of the ratio or percentage of number of units of vertical rise or fall per unit of horizontal distance (rise over run).	*USBR, 2008*
Grade stake	A stake indicating the amount of cut or fill required to bring the ground to a specified level.	*USBR, 2008*
Graded stream	Streams that receive and carry away equal amounts of sediment.	*USBR, 2008*
Gradient	Vertical drop per unit of horizontal distance.	*USACE, 1999*
Gradient	The rate of change of the value of one quantity with respect to another; for example, the rate of decrease of temperature with depth in a lake.	*EPA, 2008c*
Gradient	General slope or rate of change in vertical elevation per unit of horizontal distance of water surface of a flowing stream. Slope along a specific route, as of a road surface, channel or pipe.	*USBR, 2008*
Granite	Light-colored, coarse-grained intrusive igneous rock with quartz and feldspar as dominant minerals and typically peppered with mica and hornblende.	*USBR, 2008*
Granitic	General term for all light-colored, granite-like igneous rocks.	*USBR, 2008*
Granitic rock	A coarse-grained igneous rock.	*USGS, 2008*

Granodiorite	Coarse-grained intrusive igneous rock with less quartz and more feldspar than true granite and typically darker.	*USBR, 2008*
Grapple	A clamshell-type bucket having three or more jaws.	*USBR, 2008*
Grass/forb	Herbaceous vegetation.	*USACE, 1999*
Grassed waterway	Natural or constructed watercourse or outlet that is shaped or graded and established in suitable vegetation for the disposal of runoff water without erosion.	*EPA, 2008b*
Gravel	An unconsolidated natural accumulation of rounded rock fragments, mostly of particles larger than sand (diameter greater than 2 mm), such as boulders, cobbles, pebbles, granules, or any combination of these.	*USACE, 1999*
Gravel	Loose rounded fragments of rock that will pass a 3-inch sieve and be retained on a No. 4 U.S. Standard sieve (3/16 inch).	*USBR, 2008*
Gravel blanket	Thin layer of gravel spread over an area either of natural ground, excavated surface, or embankment.	*USBR, 2008*
Gravel fill	Gravel used to fill holes or spaces.	*USBR, 2008*
Gravel surfacing	Layer of gravel spread over an area intended for vehicular or personnel traffic, such as roads, parking lots and sidewalks.	*USBR, 2008*
Gravity arch dam	A dam designed to combine load resisting features of both a gravity and arch type dam.	*USBR, 2008*
Gravity dam	A dam constructed of concrete and/or masonry which relies on its weight and internal strength for stability. Gravity dams are generally used where the foundation is rock and earthfill in proper quality and quantity is not available. See arch-gravity dam, crib dam, curved gravity dam, cyclopean dam, and hollow gravity dam.	*USBR, 2008*
Gravity irrigation	Irrigation method that applies irrigation water to fields by letting it flow from a higher level supply canal through ditches or furrows to fields at a lower level.	*USBR, 2008*
Gravity outlets	Culverts, conduits, or other similar conveyance openings through the line-of-protection that permit discharge of interior floodwaters through the line-of-protection by gravity when the exterior stages are relatively low. Gravity outlets are equipped with gates to prevent riverflows from entering the protected area during time of high exterior stages.	*FEMA, 2003*
Gravity walls	Massive, self-supporting walls which resist horizontal wave forces through their sheer mass. (For example, the O'Shaughnessy Seawall in San Francisco weighs approximately 12 tons per linear foot.)	*CCC, 2008*
Gray water	Domestic wastewater composed of wash water from kitchen, bathroom, and laundry sinks, tubs, and washers.	*EPA, 2008b*
Gray water	Wastewater from a household or small commercial establishment that specifically excludes water from a toilet, kitchen sink, dishwasher, or water used for washing diapers.	*USACE, 1999*
Gray water	Wastewater other than sewage, such as sink and bath drainage or washing machine discharge.	*USBR, 2008*
Grizzly (grizzlie)	A coarse screen used to remove oversize pieces from earth or blasted rock. A gate or closure on a chute.	*USBR, 2008*
Groin	The contact between the upstream or downstream face of a dam and the abutments. The area along the contact (or intersection) of the face of a dam with the abutments.	*USBR, 2008*

Groin	A shoreline protection structure built (usually perpendicular to the shoreline) to trap nearshore sediment or retard erosion of the shore. A series of groins acting together to protect a section of beach is known as a groin system or groin field.	*CCC, 2008*
Gross crop value	This value is the sum of annual receipts from sale of crops produced. Production of crops, such as pasture and hay which normally are consumed on the farm by livestock, shall be converted to cash market values and included with crop sales. Total market value of all crop production from irrigated lands before deducting costs of production. Unit prices represent the weighted average prices received by farmers for the part of the crop that is sold. Production and price information are obtained from reports of farmers, project-operating personnel, local agricultural specialists, and State-Federal agricultural statisticians.	*USBR, 2008*
Gross generation	Total amount of electrical energy produced by a generating station or stations, measured at generator terminals.	*USBR, 2008*
Ground motion	A general term including all aspects of ground motion, namely particle acceleration, velocity, or displacement, from an earthquake or other energy source.	*USBR, 2008*
Ground motion parameters	Numerical values representing vibratory ground motion, such as particle acceleration, velocity, and displacement, frequency content, predominant period, spectral intensity, and duration.	*USBR, 2008*
Ground water	The supply of fresh water found beneath the Earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants or leaking underground storage tanks.	*EPA, 2008b*
Ground water	The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.	*EPA, 2008c*
Ground water	Water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper level of the saturated zone is called the water table. Water stored underground in rock crevices and in the pores of geologic materials that make up the earth's crust. That part of the subsurface water which is in the zone of saturation; phreatic water. Water found underground in porous rock strata and soils, as in a spring. Water under ground, such as in wells, springs and aquifers. Generally, all subsurface water as distinct from surface water; specifically, that part of the subsurface water in the saturated zone where the water is under pressure greater than atmospheric.	*USBR, 2008*
Ground water	(1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturate zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.	*DOC, 2005*

Ground water	In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.	*USGS, 2008*
Ground water mining (overdraft)	Pumping of ground water for irrigation or other uses, at rates faster than the rate at which the ground water is being recharged.	*USBR, 2008*
Ground water recharge	The flow to ground water storage from precipitation, inflitration from streams, and other sources of water.	*USBR, 2008*
Ground water table	The upper boundary of ground water where water pressure is equal to atmospheric pressure, i.e., water level in a bore hole after equilibrium when ground water can freely enter the hole from the sides and bottom.	*USBR, 2008*
Groundwater	Subsurface water and underground streams that can be collected with wells, or that flow naturally to the earth's surface through springs.	*USACE, 1999*
Groundwater	Water contained in the voids of the saturated zone of geologic strata (the open spaces between the individual soil particles are filled with water). Above the ground water table and below the ground surface, water in the soil does not fill all the pores.	*USFS, 2002*
Groundwater	Subsurface water occupying the zone of saturation usually found in porous rock strata and soils.	*CCC, 2008*
Groundwater basin	A groundwater reservoir, defined by an overlying land surface and the underlying aquifers that contain water stored in the reservoir. In some cases, the boundaries of successively deeper aquifers may differ and make it difficult to define the limits of the basin.	*USACE, 1999*
Ground-water discharge	Ground water entering near coastal waters which has been contaminated by landfill leachate, deep well injection of hazardous wastes, septic tanks, etc.	*EPA, 2008b*
Groundwater overdraft	The condition of a groundwater basin in which the amount of water withdrawn by pumping exceeds theamount of water that recharges the basin over a period of years during which water supply conditions approximate average.	*USACE, 1999*
Groundwater prime supply	Long-term average annual percolation into major groundwater basins from precipitation falling on the land and from flows in rivers and streams.	*USACE, 1999*
Groundwater recharge	Increases in groundwater storage by natural conditions or by human activity. See also artificial recharge.	*USACE, 1999*
Groundwater storage capacity	The space or voids contained in a given volume of soil and rock deposits.	*USACE, 1999*
Groundwater table	The upper surface of the zone of saturation, except where the surface is formed by an impermeable body.	*USACE, 1999*
Grout	A fluid mixture of cement and water or sand, cement, and water used to seal joints and cracks in a rock foundation. A fluid material that is injected into soil, rock, concrete, or other construction material to seal openings and to lower the permeability and/or provide additional structural strength. There are four major types of grouting materials: chemical, cement, clay, and bitumen.	*USBR, 2008*
Grout blanket	An area of the foundation systematically grouted to a uniform shallow depth.	*USBR, 2008*

Grout cap	A concrete pad or wall constructed to facilitate subsequent pressure grouting of the grout curtain beneath the grout cap.	*USBR, 2008*
Grout curtain (grout cutoff)	A vertical zone, usually thin, in the foundation into which grout is injected to reduce seepage beneath a dam.	*USBR, 2008*
Grouting	Filling cracks and crevices with a cement mixture.	*USBR, 2008*
Growing season	The period, often the frost-free period, during which the climate is such that crops can be produced.	*USBR, 2008*
Grubbing	Removal of stumps, roots, and vegetable matter from the ground surface after clearing and prior to excavation.	*USBR, 2008*
Gully erosion	Severe erosion in which trenches are cut to a depth greater than 30 centimeters (a foot). Generally, ditches deep enough to cross with farm equipment are considered gullies.	*EPA, 2008b*
Gully erosion	The erosion process whereby water accumulates in narrow channels and, over short periods, removes the soil form this narrow area to considerable depths, ranging from 1-2 feet to as much as 75-100 feet	*EPA, 2008c*
Gullying	Small-scale stream erosion.	*USBR, 2008*
Gunnite	Slurry concrete that is sprayed onto forms or structures; often used as a facing material for structural seawalls or retaining walls. Almost all strength comes from the supporting material or forms.	*CCC, 2008*

H

Habitat	The place where a population (e.g. human, animal, plant, microorganism) lives and its surroundings, both living and non-living.	*EPA, 2008b*
Habitat	The local environment in which organisms normally live and grow.	*USACE, 1999*
Habitat	A place where a biological organism lives. The organic and non-organic surroundings that provide life requirements such as food and shelter.	*USFS, 2002*
Habitat	The place where a plant or animal lives.	*EPA, 2008c*
Habitat	The place or environment where a plant or animal naturally lives and grows (a group of particular environmental conditions).	*USFWS, 2008*
Habitat	The area or type of environment in which a plant or animal normally lives or occurs.	*USBR, 2008*
Habitat	The part of the physical environment where plants and animals live.	*USGS, 2008*
Habitat conservation plan (HCP)	An agreement between the Secretary of the Interior and either a private entity or a state that specifies conservation measures that will be implemented in exchange for a permit that would allow taking of a threatened or endangered species.	*USACE, 1999*
Habitat Conservation Plan (HCP)	A plan that outlines ways of maintaining, enhancing, and protecting a given habitat type needed to protect species; usually includes measures to minimize impacts, and may include provisions for permanently protecting land, restoring habitat, and relocating plants or animals to another area. Required before an incidental take permit may be issued.	*USFWS, 2008*

Habitat corridor	An area of land, such as a linear drainage ditch, a hedgerow, or railway embankment, that connects islands of wildlife habitat. Habitat corridors may also be referred to as stream corridors, wildlife corridors, or riparian zones.	*EPA, 2008c*
Habitat diversity	The number of different types of habitat within a given area.	*USACE, 1999*
Habitat fragmentation	The breaking up of habitat into discrete islands through modification or conversion of habitat by management activities.	*USACE, 1999*
Habitat indicator	A physical attribute of the environment measured to characterize conditions necessary to support an organism, population, or community in the absence of pollutants; e.g. salinity of estuarine waters or substrate type in streams or lakes.	*EPA, 2008b*
Habitat structure	Defined by the pool-riffle ratio, pool frequency, depth and substrate, habitat complexity, instream cover, riffle substrate quality, riparian vegetative cover, riffle embeddedness.	*EPA, 2008c*
Habitats	Areas that provide specific conditions necessary to support plant, fish, and wildlife communities.	*DOC, 2005*
Halophytic	Salt-loving. Plants that thrive in soils that contain salt and/or sodium. A plant that grows in salty or alkaline soil.	*USBR, 2008*
Hanger	A support for pipe.	*USBR, 2008*
Harass	To intentionally or negligently, through act or omission, create the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns such as breeding, feeding, and sheltering (defined by FWS regulation; NOAA Fisheries has not defined "harass" by regulation).	*USFWS, 2008*
Hard water	Alkaline water containing dissolved salts that interfere with some industrial processes and prevent soap from sudsing.	*EPA, 2008b*
Hard water	Water high in multivalent cations, such as calcium and magnesium. This type of water does not lather easily when used with soap and forms a scale in containers when allowed to evaporate.	*USACE, 1999*
Hard water	Water may be considered hard if it has a hardness greater than the typical hardness of water from the region.	*USBR, 2008*
Hardness	A characteristic of water determined by the levels of calcium and magnesium. Water hardness is largely the result of geological formations of the water source. Public acceptance of hardness varies. Hardness of more than 300-500 mg/l as calcium carbonate is considered excessive for a public water supply and results in high soap consumption as well as objectional scale in heating vessels and pipes, and sometimes causes objectionable tastes in drinking water. Many consumers object to water harder than 150 mg/l, a moderate figure being 60-120 mg/l.	*USBR, 2008*
Hardpan	A layer of nearly impermeable soil beneath a more permeable soil, formed by natural chemical cementing of the soil particles.	*USACE, 1999*
Hardpan	A hard, impervious layer, composed chiefly of clay, that is cemented by relatively insoluble materials, that does not become plastic when mixed with water, and definitely limits the downward movement of water and roots. A cemented or compacted layer of soil near the surface that is essentially impermeable to water. A hard, tight soil. A hard layer that may form just below plow depth on cultivated land.	*USBR, 2008*

Harm	To perform an act that kills or injures wildlife; may include significant habitat modification or degradation when it kills or injures wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering.	*USFWS, 2008*
Harrow	An agricultural tool that loosens and works the ground surface.	*USBR, 2008*
Harvest	In a recreational fishery, refers to numbers of fish that are caught and kept. See catch.	*USBR, 2008*
Hatch box	A device used to incubate relatively small numbers of fish eggs. The hatch box is usually located adjacent to a stream, which supplies the box with water.	*USACE, 1999*
Hatchery	A place for hatching fish eggs.	*USBR, 2008*
Haul distance	The distance measured along the center line or most direct practical route between the center of the mass of excavation and the center of mass of the fill as finally placed. It is the distance material is moved. Average haul is the average distance a grading material is moved from cut to fill. See overhaul.	*USBR, 2008*
Haunches (haunch)	The outside areas between the springline and the bottom of a pipe. In pipe, the sides of the lower third of the circumference.	*USBR, 2008*
Hazard	1. Potential for radiation, a chemical or other pollutant to cause human illness or injury. 2. In the pesticide program, the inherent toxicity of a compound. Hazard identification of a given substances is an informed judgment based on verifiable toxicity data from animal models or human studies.	*EPA, 2008b*
Hazard	A situation with the potential to result in harm. A hazard does not necessarily lead to harm.	*Mockett & Simm, 2002*
Hazard	Something (e.g., a dam) that creates the potential for adverse consequences such as loss of life (LOL), property damage, and adverse social and environmental impacts. From a dam safety perspective, impacts may be from floodwaters released from dam structures or waters released by partial or complete failure of the dam. In this case, impacts would be to a defined area downstream. Impacts may also be to an area upstream of the dam from effects of backwater flooding or effects of landslides around the reservoir perimeter.	*USBR, 2008*
Hazard assessment	Evaluating the effects of a stressor or determining a margin of safety for an organism by comparing the concentration which causes toxic effects with an estimate of exposure to the organism.	*EPA, 2008b*

Hazard classification	The rating for a dam based on the potential consequences of failure. The rating is based on potential for loss of life and damage to property that failure of the dam could cause. Such classification is related to the amount of development downstream of a dam. Hazard classification is not associated with the existing condition of a dam and/or its appurtenant structures or the anticipated performance or operation of a dam. Rather, hazard classification is a statement of the most realistic adverse impact on human life and downstream developments should a designated dam fail. Hazard classification is used as a tool for prioritizing program activities, allocating resources for accomplishment of objectives, and scheduling safety of dams reassessments. See high hazard, low hazard, and significant hazard.	*USBR, 2008*
Hazard evaluation	A component of risk evaluation that involves gathering and evaluating data on the types of health injuries or diseases that may be produced by a chemical and on the conditions of exposure under which such health effects are produced.	*EPA, 2008b*
Hazard identification	Determining if a chemical or a microbe can cause adverse health effects in humans and what those effects might be.	*EPA, 2008b*
Hazardous materials	Anything that poses a substantive present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed.	*USACE, 1999*
Hazardous materials	Materials that pose the potential for grave, immediate, future, and genetic injury and illness when handled without proper equipment and precautions. Such materials may be toxic, flammable, explosive, corrosive, combinations of these, or otherwise injurious to life and health. Besides being potentially injurious to the discoverer of the materials, toxic materials may be transported to co-workers, children, or pets from shoes or clothing.	*USBR, 2008*
Hazardous substances	Element or compound other than oil which when discharged into the environment, in any quantity, presents an imminent or substantial threat to public health or welfare.	*USBR, 2008*
Hazardous Waste Indicators	Indicators that may signal the presence of hazardous materials include stressed vegetation or unusual lack of vegetation; dead or sick domestic stock, wildlife, or birds; fish kills or otherwise unexplained stream sterility or diminished species and numbers of flora and fauna; unusual coloration or discoloration of the land surface; and acrid or other chemical odors. However, some of the indicators may be ambiguous.	*USBR, 2008*
Hazardous waste sites	Any spill, authorized or unauthorized dumping, abandoned, or inactive waste disposal sites containing or suspected of containing hazardous materials. Materials may be in drums, cylinders, canisters, sacks, or may be uncontained in piles of solids, pools of liquids, abandoned tailings, ponds, or as clouds of gasses.	*USBR, 2008*

Hazards analysis	Procedures used to (1) identify potential sources of release of hazardous materials from fixed facilities or transportation accidents; (2) determine the vulnerability of a geographical area to a release of hazardous materials; and (3) compare hazards to determine which present greater or lesser risks to a community.	*EPA, 2008b*
Hazards identification	Providing information on which facilities have extremely hazardous substances, what those chemicals are, how much there is at each facility, how the chemicals are stored, and whether they are used at high temperatures.	*EPA, 2008b*
Head	Differential of pressure causing flow in a fluid system, usually expressed in terms of the height of a liquid column that pressure will support. The difference in number of feet between two water surface elevations. Height of water above a specified point. The back-pressure against a pump. The vertical distance between two points in a fluid. The vertical distance that would statically result from the velocity of a moving fluid.	*USBR, 2008*
Head loss	The energy lost from a flowing fluid due to friction, transitions, bends, etc.	*USBR, 2008*
Headcut	The development and upstream movement of a vertical or near vertical change in bed slope, generally evident as falls or rapids. Headcuts are often an indicator or major disturbances in a stream system or watershed (see also Nick Point).	*USFS, 2002*
Header	See manifold.	*USBR, 2008*
Heading	In a tunnel, a digging face and its work area.	*USBR, 2008*
Headland (Head)	A high, steep-faced projection extending into the sea, usually marking an area of fairly stable and rigid landform.	*CCC, 2008*
Headrace	See forebay.	*USBR, 2008*
Headwall	An upstream wall.	*USBR, 2008*
Headwater	Referring to the source of a stream or river.	*USACE, 1999*
Headwater	The source and upper part of a stream; water upstream of a dam or powerhouse.	*USBR, 2008*
Headwater streams	The small streams in the upper parts of the watershed that feed into larger streams below.	*DOC, 2005*
Headwaters	The uppermost reaches of a stream or river.	*USFS, 2002*
Headwaters	The source and upper part of a stream.	*USGS, 2008*
Health advisory	Nonregulatory levels of contaminants in drinking water that may be used as guidance in the absence of regulatory limits. Advisories consist of estimates of concentrations that would result in no known or anticipated health effects (for carcinogens, a specified cancer risk) determined for a child or for an adult for various exposure periods.	*USGS, 2008*
Heap	The soil carried above the sides of a body or bucket.	*USBR, 2008*
Heave	The upward movement of land surfaces or structures due to subsurface expansion of soil or rock, or vertical faulting of rock. Upward movement of soil caused by expansion or displacement resulting from phenomena such as moisture absorption, removal of overburden, driving of piles, frost action, and loading of an adjacent area.	*USBR, 2008*

Heavy metals	Metallic elements with high atomic weights; (e.g. mercury, chromium, cadmium, arsenic, and lead); can damage living things at low concentrations and tend to accumulate in the food chain.	*EPA, 2008b*
Heavy metals	Mettalic elements with high atomic weights (mercury, chromium, cadmium, arsenic, and lead). They can damage living things at low concentrations and tend to accumulate in the food chain.	*USACE, 1999*
Hectare	A measure of area in the metric system similar to an acre. One hectare is equal to 10,000 square meters and 2.4711 acres.	*USBR, 2008*
Heel of dam	The junction of the upstream face of a concrete gravity dam or arch dam with the ground surface. For an embankment dam, the junction is referred to as the upstream toe of the dam.	*USBR, 2008*
Height of dam	See hydraulic height or structural height.	*USBR, 2008*
Herbicide	A compound, usually a man-made organic chemical, used to kill or control plant growth.	*USBR, 2008*
Herbicide	A chemical or other agent applied for the purpose of killing undesirable plants. See also Pesticide.	*USGS, 2008*
Herbivore	Animal that feeds on plants.	*USBR, 2008*
Herpetofauna	Reptiles and amphibians.	*USBR, 2008*
High dam	A dam over 300 feet high. See low dam and medium-height dam.	*USBR, 2008*
High hazard	A downstream hazard classification for dams in which more than 6 lives would be in jeopardy and excessive economic loss (urban area including extensive community, industry, agriculture, or outstanding natural resources) would occur as a direct result of dam failure. This classification also applies to structures other than dams.	*USBR, 2008*
High-risk community	A community located within the vicinity of numerous sites of facilities or other potential sources of envienvironmental exposure/health hazards which may result in high levels of exposure to contaminants or pollutants.	*EPA, 2008b*
Hillslope targets	Quantitative measure that links the upslope sources of sediment and instream impacts of sediment discharge.	*EPA, 2008c*
Historic range	The geographic area where a species was known to or believed to occur within historic time.	*USFWS, 2008*
Hoe	A shovel that digs by pulling a broom-and-stick-mounted bucket toward itself.	*USBR, 2008*
Hogback	Ridge formed by erosion of resistant, steeply inclined sedimentary layers.	*USBR, 2008*
Hollow gravity dam (cellular gravity dam)	A dam which has the outward appearance of a gravity dam but is of hollow construction. A dam constructed of concrete and/or masonry on the outside but having a hollow interior and relying on its weight for stability.	*USBR, 2008*
Holocene	In geologic time, less than 11,000 years ago; also called Recent.	*CCC, 2008*
Homogeneity	Records from the same populations.	*USGS, 1982*
Homogeneous earthfill dam	An embankment dam construction throughout of more or less uniform earth materials, except for possible inclusion of internal drains or blanket drains. Used to differentiate it from a zoned earthfill dam. An embankment type dam constructed of only one type of material.	*USBR, 2008*
Hopper	A storage bin or a funnel that is loaded from the top, and discharges through a door or chute in the bottom.	*USBR, 2008*

Hornblende	Black blade-like mineral common in igneous and metamorphic rocks.	*USBR, 2008*
Hornfels	Fine-grained, gray-green metamorphic rock produced by "baking" of sedimentary rocks by an igneous intrusion in which sedimentary features may still be preserved.	*USBR, 2008*
Horton overland flow	A shallow, sheet like, and locally of very high velocity as it moves across the landscape…It is extremely effective at eroding loose soil and even bedrock.	*USFS, 2002*
Human environment	Natural and physical environment and the relationship of people with that environment, including all combinations of physical, biological, cultural, social, and economic factors in a given area.	*USBR, 2008*
Human health advisory	Guidance provided by U.S. Environmental Protection Agency, State agencies or scientific organizations, in the absence of regulatory limits, to describe acceptable contaminant levels in drinking water or edible fish.	*USGS, 2008*
Humus	Decayed organic matter. A dark fluffy swamp soil composed chiefly of decayed vegetation. A brown or black material formed by the partial decomposition of vegetable or animal matter. The organic portion of the soil remaining after prolonged microbial decomposition. See peat.	*USBR, 2008*
Hydraucone	A draft tube in which the emerging water impinges on a plate.	*USBR, 2008*
Hydraulic	Powered by water. Having to do with water in motion.	*USBR, 2008*
Hydraulic conductivity	The rate at which water can move through a permeable medium. (i.e. the coefficient of permeability.)	*EPA, 2008b*
Hydraulic efficiency	Efficiency of a pump or turbine to impart energy to or extract energy from water. The ability of hydraulic structure or element to conduct water with minimum energy loss.	*USBR, 2008*
Hydraulic fill	Fill material that is transported and deposited using water.	*USBR, 2008*
Hydraulic fill dam	An embankment dam constructed of materials, often dredged, which are conveyed and/or placed by suspension in flowing water.	*USBR, 2008*
Hydraulic fill structure	A dam or impoundment made of hydraulic fill.	*USBR, 2008*
Hydraulic grade line (HGL) (Hydraulic gradient)	The hydraulic grade line lies below the energy grade line by an amount equal to the velocity head at the section. The two lines are parallel for all sections of equal cross sectional area. The distance between the pipe centerline and the hydraulic grade line is the pressure head, or piezometric height, at the section. The line showing the pressure head, or piezometric height, at any point in a pipe. The slope of the hydraulic grade line is known as the hydraulic gradient. The hydraulic gradient is the slope of the water surface in an open channel.	*USBR, 2008*
Hydraulic gradient	In general, the direction of groundwater flow due to changes in the depth of the water table.	*EPA, 2008b*
Hydraulic gradient	The slope of the water surface. See also streambed gradient.	*USACE, 1999*
Hydraulic height	Height to which the water rises behind the dam, and is the difference between the lowest point in the original streambed at the axis or the centerline crest of the dam, or the invert of the lowest outlet works, whichever is lower, and the maximum controllable water surface. See structural height.	*USBR, 2008*

Hydraulic radius	The cross-sectional area of a stream divided by the wetted perimeter.	*USACE, 1999*
Hydraulics	Having to do with the mechanical properties of water in motion and the application of these properties in engineering.	*USBR, 2008*
Hydric	Wet.	*USACE, 1999*
Hydric	Characterized by, or thriving in, an abundance of moisture.	*USBR, 2008*
Hydrodynamic model	Mathematical formulation used in describing fluid flow circulation, transport, and deposition processes in receiving water.	*EPA, 2008c*
Hydro-geochemistry	Chemistry of ground water and surface water.	*USBR, 2008*
Hydrogeologic conditions	Conditions stemming from the interaction of ground water and the surrounding soil and rock.	*USBR, 2008*
Hydrogeologic cycle	The natural process of recycling water from the atmosphere down to (and through) the earth and back to the atmosphere again.	*USBR, 2008*
Hydrogeological cycle	The natural process recycling water from the atmosphere down to (and through) the earth and back to the atmosphere again.	*EPA, 2008b*
Hydrogeologist	A person who studies and works with ground water.	*USBR, 2008*
Hydrogeology	The geology of ground water, with particular emphasis on the chemistry and movement of water.	*EPA, 2008b*
Hydrogeology	The geology of ground water, with particular emphasis on the chemistry and movement of water.	*USBR, 2008*
Hydrograph	A curve showing stream discharge over time.	*USACE, 1999*
Hydrograph	A graphical representation of the stage or discharge as a function of time at a particular point on a watercourse; a time-discharge curve of the unsteady flow of water. A graph showing, for a given point on a stream, river, or conduit, the discharge, stage, velocity, available power, rate of runoff, or other property of water with respect to time. This can be measured or modeled.	*USBR, 2008*
Hydrograph	A graph showing variation of in stage (depth) or discharge of water in a stream over a period of time.	*EPA, 2008c*
Hydrograph	Graph showing variation of water elevation, velocity, streamflow, or other property of water with respect to time.	*USGS, 2008*
Hydrography	Scientific study of physical aspects of all waters on the Earth's surface. Water features in 7.5-minute quads include lakes, shorelines, and drainage routing.	*USBR, 2008*
Hydrologic balance	An accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time.	*USACE, 1999*
Hydrologic cycle	Movement or exchange of water between the atmosphere and earth.	*EPA, 2008b*
Hydrologic cycle	The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.	*EPA, 2008c*

Hydrologic cycle	Cycle of water movement from atmosphere to Earth by precipitation and its return to the atmosphere by interception, evaporation, runoff, infiltration, percolation, storage, and transpiration. The natural recycling process powered by the sun that causes water to evaporate into the atmosphere, condense and return to earth as precipitation.	*USBR, 2008*
Hydrologic cycle	The cyclic transfer of water vapor from the Earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, and lakes, and ultimately into the oceans.	*DOC, 2005*
Hydrologic cycle	The circulation of water from the sea, through the atmosphere, to the land, and thence back to the sea by overland and subterranean routes.	*USGS, 2008*
Hydrologic floodplain	The land adjacent to the base flow channel residing below bank full elevation. It is inundated about two years out of three. Not every stream corridor has a hydrologic floodplain.	*FISHWR, 2001*
Hydrologic region	A study area, consisting of one or more planning sub areas, that has a common hydrologic factor.	*USACE, 1999*
Hydrologic reserves	Undeveloped areas responsible for maintaining the predevelopment hydrologic response of a watershed. The three most common land uses are crops, forest, and pasture.	*EPA, 2008c*
Hydrologic unit	A distinct watershed or river basin defined by an 8-digit code.	*USACE, 1999*
Hydrologic unit code	An eight-digit number used to identify a geographic area representing part or all of a surface drainage basin or distinct hydrologic feature.	*USBR, 2008*
Hydrologic unit code (HUC)	A code used by the USGS to reference hydrologic accounting units throughout the United States.	*EPA, 1997*
Hydrology	The science dealing with the properties, distribution, and circulation of water.	*EPA, 2008b*
Hydrology	The scientific study of the water of the earth, its occurrence, circulation, and distribution, its chemical and physical properties, and its interaction with its environment, including its relationship to living things.	*USACE, 1999*
Hydrology	The study of the occurrence, circulation, properties, and distribution of water and its atmosphere.	*USFS, 2002*
Hydrology	The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.	*EPA, 2008c*
Hydrology	Scientific study of water in nature: its properties, distribution, and behavior. The science that treats the occurrence, circulation properties, and distribution of the waters of the earth and their reaction to the environment. Science dealing with the properties, distribution and flow of water on or in the earth.	*USBR, 2008*
Hydromet	A system of data collection platforms that gathers hydrometeorological data, and transmits that data via GOES Satelite to a computer downlink.	*USBR, 2008*
Hydrometeorological Report (HMR)	A series of hydrometeorological reports published by the National Weather Service (NWS) addressing meteorological issues related mainly to developing estimates of probable maximum precipitation used in the determination of the probable maximum flood for design of water control structures.	*USBR, 2008*

Hydrometer	A device for measuring the specific gravity of fluids.	*USBR, 2008*
Hydrophilic	Having a strong affinity (liking) for water. The opposite of hydrophobic.	*USBR, 2008*
Hydrophobic	Having a strong aversion (dislike) for water. The opposite of hydrophilic.	*USBR, 2008*
Hydrostatic	Relating to pressure or equilibrium of fluids. The pressures and forces resulting from the weight of a fluid at rest.	*USBR, 2008*
Hyetograph	Graph of rainfall rate during a storm event.	*EPA, 2008c*
Hyperconcentrated flow	Moving mixture of sediment and water between 40 and 80 percent water by volume.	*USBR, 2008*
Hypocenter	The point or focus within the earth which is the center of an earthquake and the origin of its elastic waves. The location within the Earth where the sudden release of energy is initiated. The focus of an earthquake.	*USBR, 2008*
Hypolimnetic	Pertaining to the lower, colder portion of a lake or reservoir which is separated from the upper, warmer portion (epilimnion) by the thermocline.	*USBR, 2008*
Hypolimnion	The lower, or bottom, layer of a lake or reservoir with essentially uniform colder temperatures. The lowest layer in a thermally stratified lake or reservoir. This layer consists of colder, more dense water, has a constant temperature and no mixing occurs. See stratification.	*USBR, 2008*
Hyporheic zone	The area under the stream channel and floodplain where groundwater and the surface waters of the stream are exchanged freely.	*USACE, 1999*
Hyporheic zone	Ground water habitats created by the movement of river water from the active channel to areas to the side and beneath the active channel. Uniquely adapted organisms that can provide food for fish live in the ground water habitat.	*USBR, 2008*
Hypsography	Elevation measurement system based on a sea level datum.	*USBR, 2008*

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Ichthyology	The scientific study of fish.	*USBR, 2008*
Igneous	Rock formed by molten magma. Rock that forms from the solidification of molten rock or magma.	*USBR, 2008*
Imminent hazard	One that would likely result in unreasonable adverse effects on humans or the environment or risk unreasonable hazard to an endangered species during the time required for a pesticide registration cancellation proceeding.	*EPA, 2008b*
Imminent threat	A high probability that exposure is occurring.	*EPA, 2008b*
Immiscibility	The inability of two or more substances or liquids to readily dissolve into one another, such as soil and water. Immiscibility The inability of two or more substances or liquids to readily dissolve into one another, such as soil and water.	*EPA, 2008b*

Impact	The estimated loss associated with the risk. While loss may be measured in time, quality, money, control, understanding, etc, the primary effect can be evaluated in one dimension: failure of the project. Terminal-If the event occurs, the project will fail. This is a show stopper event. Significant-If the event occurs, the project may fail, or it may succeed, but with substantially lower value. Moderate-If the event occurs, the project will probably succeed, but with substantially lower value. Minor-If the event occurs, the project will succeed, but with chronic issues that may lower its value.	*USBR, 2008*
Impermeable	Not easily penetrated. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water.	*EPA, 2008b*
Impermeable	Having a texture that does not permit water to move through quickly. Not easily penetrated. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water.	*USBR, 2008*
Impermeable layer	A layer of solid material, such as rock or clay, which does not allow water to pass through.	*DOC, 2005*
Impervious	Not permeable; not allowing liquid to pass through. Resistant to movement of water.	*USBR, 2008*
Impervious material	Relatively waterproof soils. Clay, for example, since water will percolate through clay at about one millionth of the rate at which it will pass through gravel.	*USBR, 2008*
Impervious surface	Usually a human-manufactured surface that water cannot penetrate (e.g., asphalt-covered street).	*DOC, 2005*
Impinge	To collide or strike.	*USBR, 2008*
Implementation monitoring	Monitoring that answers the question: "Were restoration measures done and done correctly?" Evaluating the effectiveness of restoration through physical, biological, and/or chemical monitoring can be time-consuming, expensive, and technically challenging. The process documents what was done and whether or not it was done properly and yields valuable information that promotes refinement of restoration practices.	*FISHWR, 2001*
Implementation process	Procurement, installation, and implementation of all the components of an Early Warning System; includes inspecting and exercising the system.	*USBR, 2008*
Implementation schedule	An outline of actions, with responsible parties, estimated costs and timeframes, for meeting the recovery objectives described in a species' recovery plan.	*USFWS, 2008*
Implementing actions	The ordinances, regulations, or programs which implement either the provisions of the certified local coastal program or the policies of Chapter 3 of the Coastal Act which are submitted pursuant to Section 30502.	*CCC, 2008*
Impoundment	A body of water or sludge confined by a dam, dike, floodgate, or other barrier.	*EPA, 2008b*
Impoundment	Body of water created by a dam.	*USBR, 2008*
Improvement	Structural measures for the betterment, modernization, or enhancement of an existing facility or system to improve the social, economic, and environmental benefits of the project.	*USBR, 2008*

In situ	In place; in situ measurements consist of measurements of components of processes in a full-scale system or a field, rather than in a laboratory.	*EPA, 2008c*
In situ	In place, the original location, in the natural environment.	*USBR, 2008*
Inactive capacity (inactive storage)	The reservoir capacity exclusive of and above the dead capacity from which the stored water is normally not available because of operating agreements or physical restrictions. Under abnormal conditions, such as a shortage of water or a requirement for structural repairs, water may be evacuated from this space. The inactive capacity extends from the top of inactive capacity to the top of dead capacity.	*USBR, 2008*
Incident command system	The combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure to effectively respond to an emergency or disaster.	*USBR, 2008*
Incidental take	Take that results from, but is not the purpose of, carrying out an otherwise lawful activity.	*USFWS, 2008*
Incidental take permit	A permit issued under section 10(a)(1)(B) of the ESA to a non-Federal party undertaking an otherwise lawful project that might result in the take of an endangered or threatened species. Application for an incidental take permit is subject to certain requirements, including preparation by the permit applicant of a conservation plan, generally known as a "Habitat Conservation Plan" or "HCP."	*USFWS, 2008*
Incidental take statement	The part of a non-jeopardy biological opinion that estimates the amount or extent of incidental take of listed species likely to result from the action subject to consultation and exempts that take from section 9 take prohibitions. Per section 7(o)(2) of the ESA, actions that are conducted in conformance with the terms and conditions of an incidental take permit are exempt from the section 9(a)(1) prohibitions on take.	*USFWS, 2008*
Incised channel	A stream that through degradation has cut its channel into the bed of the valley.	*USFS, 2002*
Incised river	A river that erodes its channel by the process of degradation to a lower base level that existed previously or is consistent with the current hydrology.	*USACE, 1999*
Incised stream	A stream that has cut its channel into the bed of the valley through degradation.	*USBR, 2008*
Incomplete record	A stream flow record in which some peak flows are missing because they were too low or high to record or the gage was out of operation for a short period because of flooding.	*USGS, 1982*
Incremental loss of life	A measurement for assessing damage after a dam fails. The difference between the projected loss of life had the dam not been built and the projected loss of life with the dam in place.	*USBR, 2008*
Index of biotic integrity (IBI)	The IBI uses measurements of the distribution and abundance or absence of several fish species types in each waterbody for comparison. A portion of a waterbody is compared to a similar, unimpacted waterbody in the same ecoregion.	*EPA, 2008c*
Index of Biotic Integrity (IBI)	An aggregated number, or index, based on several attributes or metrics of a fish community that provides an assessment of biological conditions.	*USGS, 2008*

Index value	The realized measurement of an indicator for a given landscape unit.	*EPA, 1997*
Indicator	In biology, any biological entity or processes, or community whose characteristics show the presence of specific environmental conditions. 2. In chemistry, a substance that shows a visible change, usually of color, at a desired point in a chemical reaction. 3.A device that indicates the result of a measurement; e.g. a pressure gauge or a moveable scale.	*EPA, 2008b*
Indicator	A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.	*EPA, 2008c*
Indicator	Organism, species, or community which indicates certain environmental conditions.	*USBR, 2008*
Indicator sites	Stream sampling sites located at outlets of drainage basins with relatively homogeneous land use and physiographic conditions; most indicator	*USGS, 2008*
Indicators	Measurable characteristics of the environment, both abiotic and biotic, that can provide quantitative information on ecological resources.	*EPA, 2008*
Indicators	Features or attributes of the system that are expected to change over time in response to implementation of management actions. Indicators are selected to provide measurable evaluations of important ecological processes, habitats, and species whose status individually and cumulatively provide an assessment of ecological health. Indicators of ecosystem health are the gauges we will use to measure progress toward the goal.	*DOC, 2005*
Indigenous	Native to a given area.	*USBR, 2008*
Indirect effect	An effect caused by a proposed action that takes place later in time than the action, but is still reasonably certain to occur.	*USFWS, 2008*
Industrial waste dam	An embankment dam, usually built in stages, to create storage for the disposal of waste products from an industrial process. The waste products are conveyed as fine material suspended in water to the reservoir impounded by the embankment. The embankment may be built of conventional materials but sometimes incorporates suitable waste products.	*USBR, 2008*
Infiltration	1. The penetration of water through the ground surface into sub-surface soil or the penetration of water from the soil into sewer or other pipes through defective joints, connections, or manhole walls. 2. The technique of applying large volumes of waste water to land to penetrate the surface and percolate through the underlying soil.	*EPA, 2008b*
Infiltration	That portion of rainfall or surface runoff that moves downward into the subsurface rock and soil.	*USFS, 2002*
Infiltration	Flow of a liquid into a substance through pores of small openings. The gradual flow or movement of water into and through the pores of a soil. See permeability, percolation.	*USBR, 2008*
Infiltration	Flow of water from the land surface into the subsurface.	*DOC, 2005*
Infiltration	Movement of water, typically downward, into soil or porous rock.	*USGS, 2008*
Infiltration (soil)	The movement of water through the soil surface into the soil.	*USACE, 1999*

Infiltration capacity	The capacity of a soil to allow water to infiltrate into or through it during a storm.	*EPA, 2008c*
Infiltration gallery	A horizontal conduit for intercepting and collecting ground water by gravity flow. A subsurface ground water collection system, typically shallow in depth, constructed with open-jointed or perforated pipes that discharge collected water into a water-tight chamber. From this chamber the water is pumped to treatment facilities and into a distribution system. Infiltration galleries are usually located close to streams or ponds and may be under the direct influence of surface water. A horizontal well or subsurface drain that intercepts underflow in permeable materials or infiltration of surface water.	*USBR, 2008*
Infiltration rate	The quantity of water that can enter the soil in a specified time interval.	*EPA, 2008b*
Infiltration rate	The rate of water entry into the soil expressed as a depth of water per unit of time in inches per hour or feet per day. The infiltration rate changes with time during irrigation.	*USBR, 2008*
Inflow	Entry of extraneous rain water into a sewer system from sources other than infiltration, such as basement drains, manholes, storm drains, and street washing.	*EPA, 2008b*
Inflow	Water that flows into a stream, lake, reservoir, or forebay during a specified period.	*USACE, 1999*
Inflow	Water that flows into a body of water. The amount of water entering a reservoir expressed in acre-feet per day or cubic feet per second.	*USBR, 2008*
Inflow design flood (IDF)	The flood used to design and/or modify a specific dam and its appurtenant works; particularly for sizing the spillway and outlet works, and for determining surcharge storage and height of dam requirements. The flood used for design of a safe structure. It may be the probable maximum flood (PMF), but in sparsely developed areas where judgment indicates minimal property damage and no probable loss of life, the IDF may be less than the PMF.	*USBR, 2008*
Influent	Untreated water flowing into a treatment facility, reservoir, or basin. See effluent.	*USBR, 2008*
Influent (losing) reaches	Streams that lose water to aquifers.	*FISHWR, 2001*
Informal consultation	An optional process that includes all discussions, correspondence, etc., between FWS or NOAA Fisheries and the Federal agency or the designated non-Federal representative prior to formal consultation, if required.	*USFWS, 2008*
Initial responders (first responders)	Individuals who are likely to witness or discover a hazardous substance release and who have been trained to initiate an emergency response sequence by notifying the proper authorities of the release.	*USBR, 2008*
Inlet channel (inlet structure)	Concrete lined portion of spillway between approach channel and gate or crest structure.	*USBR, 2008*
Innovative technologies	ew or inventive methods to treat effectively hazardous waste and reduce risks to human health and the environment.	*EPA, 2008b*
Inorganic	Substances that are of mineral origin. See organic.	*USBR, 2008*

Inquiry system	A system of interrelated components for producing knowledge on a problem or issue of importance.	*Mitroff and Linstone, 1993*
Insecticide	A substance or mixture of substances intended to destroy or repel insects.	*USGS, 2008*
In-situ	In its original place; unmoved unexcavated; remaining at the site or in the subsurface.	*EPA, 2008b*
Installed capacity	The total of the capacities shown on the nameplates of the generating units in a powerplant.	*USBR, 2008*
Instantaneous discharge	The volume of water that passes a point at a particular instant of time.	*USGS, 2008*
Instream cover	The layers of vegetation, like trees, shrubs, and overhanging vegetation, that are in the stream of immediately adjacent to the wetted channel.	*USACE, 1999*
In-stream fish habitat	Areas fish need for concealment and feeding. These areas include large wood within the stream banks, boulders, undercut banks, and tree roots.	*EPA, 2006*
Instream flow requirements	Amount of water flowing through a defined stream channel needed to sustain instream values, e.g. flows designated for fish and wildlife.	*USBR, 2008*
Instream flows	(1) Portion of a flood flow that is contained by the channel. (2) A minimum flow requirement to maintain ecological health in a stream.	*USACE, 1999*
In-stream habitat improvement	Altering structural complexity to increase habitat availability and diversity for target organisms and provision of breeding habitat and refugia from disturbance and predation. (In some cases habitat improvement may be an action with the intent of In-stream Species Management, in other cases Habitat Improvement may be the intent, and might be accomplished through Channel Reconfiguration, be very careful to separate action from intent when deciding whether to select this category.	*NRRSS, 2005*
In-stream species management	Practices that directly alter aquatic native species distribution and abundance through the addition (stocking) or translocation of animal and plant species and/or removal of exotics. Excludes physical manipulations of habitat/breeding territory (see In-stream Habitat Improvement).	*NRRSS, 2005*
Instream use	Use of water that does not require diversion from its natural watercourse. For example, the use of water for navigation, recreation, fish and wildlife, aesthetics, and scenic enjoyment.	*USACE, 1999*
Instream use	Water use taking place within the stream channel for such purposes as hydroelectric power generation, navigation, water-quality improvement, fish propagation, and recreation. Sometimes called nonwithdrawal use or in-channel use.	*USGS, 2008*
Instream uses	Water uses that can be carried out without removing the water from its source, as in navigation and recreation.	*USBR, 2008*
Instrumentation	Any device used to monitor the performance of the structure during its construction and throughout its useful life. An arrangement of devices installed into or near dams (i.e., piezometers, inclinometer, strain gages, measurement points, etc.) and used to evaluate the structural behavior and performance parameters of the structure.	*USBR, 2008*

Intake	Any structure through which water can be drawn into a waterway. Any structure in a reservoir, dam, or river through which water can be discharged.	*USBR, 2008*
Intake structure	Concrete portion of an outlet works, including trashracks and/or fish screens, upstream from the tunnel or conduit portions. The entrance to an outlet works.	*USBR, 2008*
Intangible factors	Factors that affect a decision, but that cannot be expressed in monetary terms. Examples include employee morale, safety, system reliability, environmental effects, and politics.	*USBR, 2008*
Integrated early warning system	A flood warning system tied into adjacent systems so that multiple users can access the basin data and monitor the event.	*USBR, 2008*
Integrated resource management	Resource management that seeks to restore the structure and function of whole ecosystems by striving to understand and respond holistically to cumulative ecological impacts.	*DOC, 2005*
Integrated resource planning (IRP)	A public planning process and framework within which the costs and benefits of both demand and supply side resources are evaluated to develop the least total cost mix of utility resource options. In many states, IRP includes a means for considering environmental damages caused by electricity supply/transmission and identifying cost-effective energy efficiency and renewable energy alternatives. IRP has become a formal process prescribed by law in some states and under some provisions of the Clean Air Act Amendments of 1992.	*USBR, 2008*
Integrated water management	A way to maximize water quality and quantity to meet water needs for consumptive use and aquatic ecosystems by integrating water and land-use decision-making by local and regional agencies.	*DOC, 2005*
Integrator or Mixed use site	Stream sampling site located at an outlet of a drainage basin that contains multiple environmental settings. Most integrator sites are on major streams with relatively large drainage areas.	*USGS, 2008*
Intensity scale	An arbitrary scale to describe the degree of shaking at a particular place. The scale is not based on measurement, but on assessment by an experienced observer. A numerical index describing the effects of an earthquake on mankind, on structures built by mankind, and on the earth's surface. The scale in common use in the U. S. today is the Modified Mercalli Scale of 1931 with grades indicated by Roman numerals from I to XII. For more information, visit the U.S. Geological Survey National Earthquake Information Center.	*USBR, 2008*
Intensive Fixed Sites	Basic Fixed Sites with increased sampling frequency during selected seasonal periods and analysis of dissolved pesticides for 1 year. Most NAWQA Study Units have one to two integrator Intensive Fixed Sites and one to four indicator Intensive Fixed Sites.	*USGS, 2008*
Interconnected system	System consisting of two or more individual power systems normally operating with connecting tie lines.	*USBR, 2008*
Interdependent action	An action that has no independent utility apart from the proposed action that is subject to consultation.	*USFWS, 2008*
Interflow	Lateral movement of water in the upper layer of soil.	*USBR, 2008*

Intermittent (ephemeral) streams	Streams that flow only during part of the year, such as in the spring and early summer after snowmelt.	*EPA, 2006*
Intermittent stream	Any nonpermanent flowing drainage feature having a definable channel and evidence of scour or deposition. This includes what are sometimes referred to as ephemeral streams if they meet these two criteria.	*USACE, 1999*
Intermittent stream	A stream that flows only when it receives water from rainfall runoff or springs, or from some surface source such as melting snow.	*USGS, 2008*
Intermittent stream (seasonal stream)	A stream which flows part of the time, usually after rainstorm, during wet weather, or for only part of the year. Also referred to as an ephemeral stream. Stream on or in contact with the ground water table that flows only at certain times of the year when the ground water table is high.	*USBR, 2008*
Intermittent streams	Streams that only flow during certain times of the year. Seasonal flow in an intermittent stream usually lasts longer than 30 days per year.	*FISHWR, 2001*
Internal drainage	Movement of water down through soil to porous aquifers or to surface outlets at lower elevations. Drainage within a basin that has no outlet.	*USBR, 2008*
Internal erosion	The formation of voids within soil or soft rock caused by the mechanical or chemical removal of material by seepage. See erosion.	*USBR, 2008*
Internal rate of return	The discount rate at which the net present value is equal to zero	*Mockett & Simm, 2002*
Internal vibration	A method of consolidating soil in which vibrators are used within a thoroughly wetted soil mass to consolidate the soil to the desired density.	*USBR, 2008*
Interrelated action	An action that is part of a larger action, and that depends on the larger action for its justification.	*USFWS, 2008*
Interstate commerce permit	A permit issued under section 10(a)(1)(A) of the ESA that allows the transport and sale of federally listed species across state lines for scientific research and other activities benefiting the recovery of the species.	*USFWS, 2008*
Interstice	An opening or space in a rock or soil. See void.	*USBR, 2008*
Interstitial flow	Portion of surface water that infiltrates the streambed and moves through pores in subsurface.	*USBR, 2008*
Intolerant organisms	Organisms that are not adaptable to human alterations to the environment and thus decline in numbers where human alterations occur. See also Tolerant species.	*USGS, 2008*
Intrados	The curved downstream surface of horizontal arch elements of an arch dam. See extrados.	*USBR, 2008*
Intrusion	A feature (landform, vegetation, or structure) that is generally considered out of context because of excessive contrast and disharmony with characteristic landscape.	*USBR, 2008*
Inundate	To cover with impounded waters or floodwaters.	*USBR, 2008*

Inundation map	A map delineating the area that would be flooded by a particular flood event. It includes the ground surfaces downstream of a dam showing the probable encroachment by water released because of failure of a dam or from abnormal flood flows released through a dam's spillway and/or other appurtenant works.	*USBR, 2008*
Invert	The lowest point of an underground excavation or the lowest point of the interior of a circular conduit, pipe, or tunnel. The lowest portion of the inside of any horizontal pipe. The lowest point of the channel inside a pipe, conduit, or canal.	*USBR, 2008*
Invertebrate	An animal having no backbone or spinal column. See also Benthic invertebrate.	*USGS, 2008*
Invertebrate drift	Stream and terrestrial invertebrates that float with the current.	*USACE, 1999*
Invertebrates	All animals without a vertebral column, e.g. spiders, crabs, or worms.	*USBR, 2008*
Iowa vane	A flow deflector that will divert water in a way calculated to attract fish.	*USBR, 2008*
IRIS	EPA's Integrated Risk Information System, an electronic data base containing the Agency's latest descriptive and quantitative regulatory information on chemical constituents.	*EPA, 2008b*
Irretrievable	Commitments that are lost for a period of time.	*USBR, 2008*
Irreversible	Commitments that cannot be reversed, except perhaps in the extreme long term.	*USBR, 2008*
Irrigable acreage for service (irrigable area for service)	The acreage classified as irrigable for which project works have been constructed and project water is available. This acreage may change from year to year, generally increasing, as project works are completed and service is made available to additional acreage. Upon completion of the project, the irrigable acreage for service will equal the irrigable land as presented in the repayment contract or most recent project authorization. See irrigated acreage. Lands that have not been classified but which are furnished water under Special or Warren Act contracts and lease or water rental agreements are shown as a part of the irrigable area for service.	*USBR, 2008*
Irrigable area not for service	Part of the total irrigable area for which service eventually will be available but for which project facilities have not yet been constructed.	*USBR, 2008*
Irrigable land	Arable land under a specific plan for which a water supply is or can be made available and which is provided with or planned to be provided with irrigation, drainage, flood protection, and other facilities as necessary for sustained irrigation.	*USBR, 2008*
Irrigated acreage	Irrigable acreage actually irrigated in any one year. It includes irrigated cropland harvested, irrigated pasture, cropland planted but not harvested, and acreage in irrigation rotation used for soil-building crops.	*USBR, 2008*
Irrigation	Applying water or wastewater to land areas to supply the water and nutrient needs of plants.	*EPA, 2008b*
Irrigation	Applying water or wastewater to land areas to supply the water and nutrient needs of plants.	*EPA, 2008c*

Irrigation	Act of supplying dry land with water in order to grow crops or other plants. Application of water to lands for agricultural purposes.	*USBR, 2008*
Irrigation	The controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall.	*DOC, 2005*
Irrigation check	Small dike or dam used in the furrow alongside an irrigation border to make the water spread evenly across the border.	*USBR, 2008*
Irrigation district	A cooperative, self-governing public corporation set up as a subdivision of the State government, with definite geographic boundaries, organized and having taxing power to obtain and distribute water for irrigation of lands within the district; created under the authority of a State legislature with the consent of a designated fraction of the landowners or citizens.	*USBR, 2008*
Irrigation diversion	Generally, a ditch or channel that deflects water from a stream channel for irrigation purposes.	*USACE, 1999*
Irrigation efficiency	The amount of water stored in the crop root zone compared to the amount of irrigation water applied.	*EPA, 2008b*
Irrigation efficiency	The efficiency of water application and use. Computed by dividing evapotranspiration of applied water by applied water and converting the result to a percentage. Efficiency can be computed at three levels: farm, district, or basin.	*USACE, 1999*
Irrigation efficiency	The ratio of the average depth of irrigation water that is beneficially used to the average depth of irrigation water applied, expressed as a percent. Beneficial uses include satisfying the soil water deficit and any leaching requirement to remove salts from the root zone.	*USBR, 2008*
Irrigation requirement	Quantity of water, exclusive of effective precipitation, that is required for crop production. See crop irrigation requirement.	*USBR, 2008*
Irrigation return flow	Surface and subsurface water which leaves the field following application of irrigation water.	*EPA, 2008b*
Irrigation return flow	Applied water that is not transpired, evaporated, or deep percolated into a groundwater basin but returns to a surface water supply.	*USACE, 1999*
Irrigation return flow	Surface and subsurface water that leaves a field after the application of irrigation water.	*EPA, 2008c*
Irrigation return flow	The part of irrigation applied to the surface that is not consumed by evapotranspiration or uptake by plants and that migrates to an aquifer or surface	*USGS, 2008*
Isochrome	A curve showing the distribution of the excess hydrostatic pressure at a given time during a process of consolidation.	*USBR, 2008*
Isothermal	Having a constant temperature.	*USBR, 2008*
Isotropic mass	A mass having the same property (or properties) in all directions.	*USBR, 2008*

J

Jackson turbidity units (JTU)	An alternative way (to NTU) to measure turbidity in water based on the length of a light path through a suspension that causes the image of a standard candle flame to disappear.	*EPA, 2008c*

Jeopardize the continued existence of	To engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.	*USFWS, 2008*
Jeopardy biological opinion	A FWS or NOAA Fisheries section 7 biological opinion determining that a Federal action is likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat.	*USFWS, 2008*
Jeopardy opinion	U.S. Fish and Wildlife Service (FWS) or National Marine Fisheries Service (NMFS) opinion that an action is likely to jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat. The opinion includes reasonable and prudent alternatives, if any. See no jeopardy opinion.	*USBR, 2008*
Jetting	A method of compacting soil using a hose or other device, with a high velocity stream of water, worked down through the depth of soil placed. Drilling with high pressure water or air jets.	*USBR, 2008*
Jetting pump	A water pump that develops very high discharge pressure.	*USBR, 2008*
Jetty	Pier or other structure built out into a body of water to influence the current or tide, or to protect a harbor or shoreline. A long fill or structure extending into water from the shore, that serves to change the direction or velocity of water flow.	*USBR, 2008*
Jetty	On open seacoasts, a structure extending away from the shore, which is designed to prevent shoaling of a channel and to direct and confine the stream or tidal flow. Jetties are built at the mouths of rivers, harbors, or tidal inlets to help deepen and stabilize the access channel.	*CCC, 2008*
Job hazard analysis (JHA)	A study of a job or activity to identify hazards or potential accidents associated with each step or task, and develop solutions that will eliminate, nullify, or prevent such hazards or accidents.	*USBR, 2008*
Joint planting	The insertion of live stakes in the spaces or joints, between previously placed rock riprap. When placed properly, the cuttings are capable of rooting and growing.	*USFS, 2002*
Jurisdiction	Boundary of authorization for a State, county, and/or city emergency management agency. A term used to describe the level of management responsibility an entity has for a specific area using its rules and regulations.	*USBR, 2008*
Juvenile	Young fish older than 1 year but not capable of reproduction.	*USBR, 2008*
Juvenile salmon	All early lifestages of downstream migrating salmon (fry through smolt).	*USBR, 2008*

K

Karst	A geologic formation of irregular limestone deposits with sinks, underground streams, and caverns.	*EPA, 2008b*
Karst	A type of topography that results from dissolution and collapse of carbonate rocks such as limestone and dolomite, and characterized by closed depressions or sinkholes, caves, and underground drainage.	*USGS, 2008*

Karst geology	Solution cavities and closely-spaced sinkholes formed as a result of dissolution of carbonate bedrock.	*EPA, 2008c*
Key watershed	As defined by National Forest and Bureau of Land Management District fish biologists, a watershed containing (1) habitat for potentially threatened species or stock of anadromous salmonids or other potentially threatened fish, or (2) greater than 6 square miles with high-quality water and fish habitat.	*USACE, 1999*
Keyed In	Refers to tying the ends of a structure into the bank to prevent water from going behind it.	*USFS, 2002*
Kill	Dutch term for stream or creek.	*USGS, 2008*
Kilo	A prefix meaning "thousand".	*USBR, 2008*
Kinetic energy	The energy of a body with respect to the motion of the body. See potential energy.	*USBR, 2008*
Kinetic processes	Description of the rates and modes of changes in the transformation or degradation of a substance in an ecosystem.	*EPA, 2008c*

L

Laccolith	Igneous intrusion that squeezes between sedimentary layers and domes the overlying layers.	*USBR, 2008*
Lacustrine habitat	Lake or reservoir wetland habitat.	*USBR, 2008*
Lag time	The time between the middle of the rainfall event and the runoff peak.	*FISHWR, 2001*
Lagging	In tunneling, planking placed against the dirt or rock walls and ceiling, outside the ribs.	*USBR, 2008*
Lagomorphs	The order of mammals including rabbits, hares, and pikas.	*USBR, 2008*
Lagoon	1. A shallow pond where sunlight, bacterial action, and oxygen work to purify wastewater; also used for storage of wastewater or spent nuclear fuel rods. 2. Shallow body of water, often separated from the sea by coral reefs or sandbars.	*EPA, 2008b*
Lagoon	A shallow body of water, such as a pond or lake, usually located near or connected to the sea.	*CCC, 2008*
Lake	An inland body of standing water deeper than a pond, an expanded part of a river, a reservoir behind a dam.	*USACE, 1999*
Laminar flow	Flow in which the head loss is proportional to the first power of the velocity. The flow field can be characterized by layers of fluid, one layer not mixing with adjacent ones. The flow is laminar or turbulent depending on the value of the Reynolds number, which is a dimensionless ratio of the inertial forces to the viscous forces. In laminar flow, viscous forces are dominant and the Reynolds number is relatively small. In turbulent flow, the inertial forces are very much greater than the viscous forces and the Reynolds number is large. Laminar flow occurs very infrequently in open channel flow.	*USBR, 2008*

Land acquisition	Practices that obtain lease/title/easements for stream-side land for the explicit purpose of preservation or removal of impacting agents and/or to facilitate future restoration projects. Note: Simple purchase and preservation to prevent potential future land conversion is insufficient for inclusion in the NRRSS database. NRRSS projects should demonstrate intended or actual cessation of detrimental activities in acquired land or active restoration components.	*NRRSS, 2005*
Land classification	Reclamation's systematic placing of lands into classes based on their suitability for sustained irrigated farming. Land classes are defined by productivity, with Class 1 being the most productive. For other classes, the equivalent acreage to Class 1 for the same productivity is defined (Class 1 equivalency). For example, (the productivity of) X acres of Class 2 land is equal to (the productivity of) 1 acre of Class 1 land.	*USBR, 2008*
Land ownership	Land held in title.	*USBR, 2008*
Land retirement	Permanent removal of land from agricultural production.	*USBR, 2008*
Land trusts	Legal entities which can operate locally, regionally, or nationally designed to own titles to or conservation easements on specific properties. Land trusts provide a focused venue for characterizing, prioritizing, and purchasing land or easements, and have an excellent track record of achieving the benefits sought.	*EPA, 2008c*
Land use plan	The relevant portions of a local government's general plan, or local coastal element which are sufficiently detailed to indicate the kinds, location, and intensity of land uses, the applicable resource protection and development policies and, where necessary, a listing of implementing actions.	*CCC, 2008*
Landfill	An open area where trash is buried. Facility in which solid waste from municipal and/or industrial sources is disposed; sanitary landfills are those that are operated in accordance with environmental protection standards.	*USBR, 2008*
Landholder	A landholder is an individual or legal entity owning or leasing land subject to the acreage limitation provisions.	*USBR, 2008*
Landscape	The traits, patterns, and structure of a specific geographic area, including its biological composition, its physical environment, and its anthropogenic or social patterns. An area where interacting ecosystems are grouped and repeated in similar form.	*EPA, 2008b*
Landscape	A heterogeneous land area with interacting ecosystems that are repeated in similar form throughout.	*USACE, 1999*
Landscape characterization	Documentation of the traits and patterns of the essential elements of the landscape.	*EPA, 2008b*
Landscape conditions	The apparent status or characteristics of a landscape unit as measured by one or more landscape indicators.	*EPA, 1997*
Landscape diversity	The size, shape, and connectivity of different ecosystems across a large area.	*USACE, 1999*
Landscape ecology	The study of the distribution patterns of communities and ecosystems, the processes that affect those patterns and changes in pattern and process over time.	*EPA, 1997*

Landscape ecology	The study of the distribution patterns of communities and ecosystems, the ecological processes that affect those patterns, and changes in pattern and process over time.	*EPA, 2008b*
Landscape features	The land, water, vegetation, and structures that compose the characteristic landscape.	*USACE, 1999*
Landscape indicator	A characteristic of the environment that is measured to provide evidence of the biological condition of one or more resources at the ecosystem level. See also 'ecological indicator' and 'landscape ecology.'	*EPA, 1997*
Landscape indicator	A measurement of the landscape, calculated from mapped or remotely sensed data, used to describe spatial patterns of land use and land cover across a geographic area. Landscape indicators may be useful as measures of certain kinds of environmental degradation such as forest fragmentation.	*EPA, 2008b*
Landscape unit	Designed to identify repeating patterns associated with dominant land uses in an area, and defined by the relative proportions of forest, agriculture, and developed (urban) land cover contained in that area.	*EPA, 1997*
Landslide	A movement of earth mass down a steep slope.	*USACE, 1999*
Landslide	The failure of a sloped bank of soil or rock in which the movement of the mass takes place along a surface of sliding.	*USBR, 2008*
Land-use study	A network of existing shallow wells in an area having a relatively uniform land use. These studies are a subset of the Study Unit Survey and have the goal of relating the quality of shallow ground water to land use. See also Study Unit Survey.	*USGS, 2008*
Large woody debris	Any large pieces of woody material that intrude or are embedded in the stream channel, several inches in diameter and equal to or greater in length than the average bank full width.	*USFS, 2002*
Large woody debris (LWD)	Pieces of wood larger than 10 feet long and 6 inches in diameter, in a stream channel.	*USACE, 1999*
Larval fish	An immature stage that develops from the fertilized egg before assuming the characteristics of the adult.	*USBR, 2008*
Latency	Time from the first exposure of a chemical until the appearance of a toxic effect.	*EPA, 2008b*
Lateral	A channel that conveys water from a canal to a farm, municipality, etc.	*USBR, 2008*
Lateral moraine	Ridge-like pile of sediment along the side of a glacier.	*USBR, 2008*
Laundering weir	Sedimention basin overflow weir.	*EPA, 2008b*
Lava	Fluid, molten igneous rock erupted on the earth's surface.	*USBR, 2008*
LCP (Local Coastal Program)	Local coastal program means a local government's (a) land use plans, (b) zoning ordinances, (c) zoning district maps, and (d) within sensitive coastal resources areas, other implementing actions, which, when taken together, meet the requirements of, and implement the provisions and policies of, this division at the local level.	*CCC, 2008*
Leach	To remove components from the soil by the action of water trickling through.	*USBR, 2008*
Leachate	Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills, and can result in hazardous substances entering surface water, groundwater, or soil.	*EPA, 2008c*

Leachate	A liquid that results from water collecting contaminants as it trickles through wastes, agricultural pesticides or fertilizers. Leachate may occur in farming areas, feedlots, and landfills, and may result in hazardous substances entering surface water, ground water, or soil.	*USBR, 2008*
Leaching	The flushing of minerals or pollutants from the soil or other material by the percolation of applied water.	*USACE, 1999*
Leaching	Removal of soluble material from soil or other permeable material by the passage of water through it. The removal of soluble soil material and colloids by percolating water. The process by which soluble substances are dissolved and transported down through the soil by recharge.	*USBR, 2008*
Leaching	The removal of materials in solution from soil or rock to ground water; refers to movement of pesticides or nutrients from land surface to ground water.	*USGS, 2008*
Leaching field (leaching cesspool)	A lined or partially lined underground pit into which raw household water (sewage) is discharged and from which the liquid seeps into the surrounding soil.	*USBR, 2008*
Leaching requirement	Quantity of irrigation water required for transporting salts through the soil profile to maintain a favorable salt balance in the root zone for plant development.	*USBR, 2008*
Lead (Pb)	A heavy metal that is hazardous to health if breathed or swallowed. Its use in gasoline, paints, and plumbing compounds has been sharply restricted or eliminated by federal laws and regulations.	*EPA, 2008b*
Lead agency	An agency from among two or more agencies involved in a proposed Federal action that is assigned lead responsibility for a consultation. When a federal action involves more than one Federal agency, the agencies may coordinate to designate a lead agency for purposes of consultation with the FWS or NOAA Fisheries.	*USFWS, 2008*
Lead office	FWS field office responsible for coordinating all or most actions taken to study, propose, list, conserve, and delist a species. The lead office is given the lead responsibility over the entire range of a species, including anywhere it occurs in other regions.	*USFWS, 2008*
Lead region	FWS region responsible for coordinating all actions taken to study, propose, list, conserve, and delist a species.	*USFWS, 2008*
Lead time	Time available for Decision Makers to determine if conditions at a dam and reservoir, or in the basin, warrant declaration of a specific emergency classification level.	*USBR, 2008*
Leaf area index	A measure of the total area of leaves, twigs, stems, etc. relative to the area of the canopy in a forest.	*USACE, 1999*
Leakage	Free flow loss of water through a hole or crack.	*USBR, 2008*

Least disturbed condition	The best available existing conditions with regard to physical, chemical, and biological characteristics or attributes of a water body within a class or region. These waters have the least amount of human disturbance in comparison to others within the water body class, region or basin. Least disturbed conditions can be readily found, but may depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition may change significantly over time as human disturbances change	*EPA, 2008c*
Leeward	The direction toward which the wind is blowing.	*CCC, 2008*
Left or right designation	In the context of dams and river channels, the designation of left or right is made with the observer looking in the downstream direction.	*USBR, 2008*
Leg	A side post in tunnel timbering.	*USBR, 2008*
Length of dam	See crest length.	*USBR, 2008*
Lentic	Standing waters, such as lakes, ponds, and marshes.	*USBR, 2008*
Letter of Agreement (LOA)	See Memorandum of Understanding (MOU).	*USBR, 2008*
Levee	An embankment constructed to prevent a river from overflowing (flooding).	*USACE, 1999*
Levee	A natural or man-made barrier that helps keep rivers from overflowing their banks. See dike.	*USBR, 2008*
Levee systems	Flood protection systems that consist of a levee, or levees, and associated structures, such as closure and drainage devices, which are constructed and operated in accordance with sound engineering practices.	*FEMA, 2003*
Levees	Manmade structures, usually earthen embankments, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water so as to provide protection from temporary flooding.	*FEMA, 2003*
Level	To make level or to cause to conform to a specified grade. Any instrument that can be used to indicate a horizontal line or plane.	*USBR, 2008*
Level of protection (LOP)	As used in the evaluation process, it is the level of loading selected to which corrective actions will be designed to prevent dam failure.	*USBR, 2008*
Level of significance	The probability of rejecting a hypothesis when it is in fact true. At a "10-percent" level of significance, the probability is 1/10.	*USGS, 1982*
Life cycle	Various stages an animal passes through from egg fertilization to death.	*USBR, 2008*
Lift	A step or bench in a multiple layer excavation or fill.	*USBR, 2008*
Lift line	Horizontal construction joint created when new concrete is placed on previously placed concrete.	*USBR, 2008*
Lifts	Layers of loose soil wrapped in an erosion fabric used to rebuild and recontour a bank.	*USFS, 2002*
Light saturation	The optimal light level for algae and macrophyte growth and photosynthesis.	*EPA, 2008c*
Limestone	Sedimentary rock composed mostly of the mineral calcite and often containing marine fossils.	*USBR, 2008*
Limited degradation	An environmental policy permitting some degradation of natural systems but terminating at a level well beneath an established health standard.	*EPA, 2008b*

Limiting factor	A condition whose absence or excessive concentration, is incompatible with the needs or tolerance of a species or population and which may have a negative influence on their ability to thrive.	*EPA, 2008b*
Limiting factor	A requirement such as food, cover, or another physical, chemical, or biological factor that is in shortest supply with respect to all resources necessary to sustain life and thus "limits" the size or retards production of a population.	*USACE, 1999*
Limnological conditions	Conditions on freshwater lakes.	*USBR, 2008*
Limnology	The study of the physical, chemical, hydrological, and biological aspects of fresh water bodies.	*EPA, 2008b*
Limnology	The study of life in lakes, ponds, and streams.	*USACE, 1999*
Limnology	Scientific study of the physical characteristics and biology of lakes, ponds, and streams.	*USBR, 2008*
Line item	A specified amount in a budget to spend on a particular activity.	*USBR, 2008*
Lineament	A rectilinear topographic feature.	*USBR, 2008*
Lines-of-protection	Locations of levees or walls that prevent floodwaters from entering an area.	*FEMA, 2003*
Lining	Any protective material used to line the interior surface of a conduit, pipe, or tunnel. With reference to a canal, tunnel or shaft, a coating of asphaltic concrete, concrete, reinforced concrete, or shotcrete to provide watertightness, to prevent erosion, or to reduce friction. Protective covering over the perimeter of a conduit, reservoir, or channel to prevent seepage losses, to withstand pressure, or to resist erosion.	*USBR, 2008*
Liquefaction	Changing a solid into a liquid.	*EPA, 2008b*
Liquefaction	When a solid form is turned into a liquid form. During an earthquake, low density materials act like water and lose their supporting strength. A condition whereby soil undergoes continued deformation at a constant low residual stress or with low residual resistance, due to the buildup and maintenance of high pore water pressures, which reduces the effective confining pressure to a very low value. Pore pressure buildup leading to liquefaction may be due either to static or cyclic stress applications, and the possibility of its occurrence will depend on the void ratio or relative density of a cohesionless soil and the confining pressure.	*USBR, 2008*
Liquefaction	The process of becoming liquid, especially applied to sand that loses its bearing strength due to strong shaking.	*CCC, 2008*
Liquid limit (LL)	The moisture content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil. The water content at which a pat of soil, cut by a groove of standard dimensions, will flow together for a distance of 1/2 inches under the impact of 25 blows in a standard liquid limit apparatus. Minimum moisture content which will cause soil to flow if jarred slightly.	*USBR, 2008*
Listed species	A species, subspecies, or distinct population segment that has been added to the Federal list of endangered and threatened wildlife and plants.	*USFWS, 2008*

Listing	The formal process through which FWS or NOAA Fisheries adds species to the Federal list of endangered and threatened wildlife and plants.	*USFWS, 2008*
Listing priority	A number from 1 to 12 indicating the relative urgency for listing a plant or animal species as threatened or endangered, using criteria that reflect the magnitude and immediacy of threat to the species, as well as its relative taxonomic distinctness or isolation.	*USFWS, 2008*
Lithology	Mineralogy, grain size, texture, and other physical properties of granular soil, sediment, or rock.	*EPA, 2008b*
Litter	1. The highly visible portion of solid waste carelessly discarded outside the regular garbage and trash collection and disposal system. 2. leaves and twigs fallen from forest trees.	*EPA, 2008b*
Littoral	Pertaining to the shore.	*USBR, 2008*
Littoral	Of or pertaining to a shore, especially of the sea.	*CCC, 2008*
Littoral cell	A region that encompasses most features affecting sediment transport. The boundaries of the cell are usually delineated by river drainage areas, promontory headlands, or submarine canyons on the periphery, the continental shelf-continental slope boundary on the seaward side and by inland ridges and river inlets on the landward side. Sediment within these cells generally travel seaward by river drainage, southward (downcoast) by longshore currents, and are eventually lost to the continental slope area or submarine canyon.	*CCC, 2008*
Littoral drift	The sedimentary material moved in the littoral zone under the influence of waves and currents; consisting of silt, sand, gravel, cobbles, and other beach material.	*CCC, 2008*
Littoral Shelf	The sedimentary material on shorelines formed by waves and currents.	*USFS, 2002*
Littoral Transport	The movement of sedimentary, either parallel (long-shore transport) or perpendicular (on-shore transport), to the shoreline.	*USFS, 2002*
Littoral transport	The movement of sediment in the littoral zone by waves, currents, and tides. This includes movement parallel (longshore transport) and perpendicular (on-offshore transport) to the shore.	*CCC, 2008*
Littoral zone	1. That portion of a body of fresh water extending from the shoreline lakeward to the limit of occupancy of rooted plants. 2. A strip of land along the shoreline between the high and low water levels.	*EPA, 2008b*
Littoral zone	The zone or strip of land along the shoreline between the high and low water marks. That portion of a body of fresh water extending from the shoreline lakeward to the limit of occupancy of rooted plants.	*USBR, 2008*
Littoral zone	The region where waves, currents, and winds interact with the land and its sediments. This region comprises a backshore, foreshore, inshore, and offshore and is broken down into littoral cells.	*CCC, 2008*
Live branch cuttings	Living, freshly cut branches from woody shrub and tree species that readily propagate when embedded in soil.	*USFS, 2002*

Live capacity (live storage)	That part of the total reservoir capacity which can be withdrawn by gravity. This capacity is equal to the total capacity less the dead capacity.	*USBR, 2008*
Live crib wall	A rectangular framework of logs or timbers constructed with layers of live plant cuttings that are capable of rooting.	*USFS, 2002*
Live fascine	Bound, elongated, cylindrical bundles (6 to 8 inches in diameter) of live branch cuttings used to stabilize stream banks that are placed in shallow trenches, partly covered with soil, and staked in place, also referred to as wattle.	*USFS, 2002*
Live siltation	Live branch cuttings that are placed in trenches at an angle from shoreline to trap sediment and protect the shore against wave action.	*USFS, 2002*
Live stake	Live branch cuttings that are tamped or inserted into the earth to take root and produce vegetative growth.	*USFS, 2002*
Load	General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.	*USGS, 2008*
Load allocation (LA)	The portion of a receiving water's loading capacity that is attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished. (40 CFR 130.2(g))	*EPA, 2008c*
Loading	The influx of pollutants to a selected water body.	*USACE, 1999*
Loading capacity (LC)	The greatest amount of loading that a water can receive without violating water quality standards.	*EPA, 2008c*
Loading, Load, Loading rate	The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.	*EPA, 2008c*
Loam	A soft, easily worked soil containing sand, silt, and clay.	*USBR, 2008*
Local capabilities assessment	Evaluation and report performed by members of the Early Warning System design team and/or community planners to assess the warning and evacuation capabilities of local jurisdictions located downstream from Reclamation dams.	*USBR, 2008*
Local coastal element	That portion of a general plan applicable to the coastal zone which may be prepared by local government pursuant to this division, or any additional elements of the local government's general plan prepared pursuant to Section 65303 of the Government Code, as the local government deems appropriate.	*CCC, 2008*
Local coastal program	A local government's (a) land use plans, (b) zoning ordinances, (c) zoning district maps, and (d) within sensitive coastal resources areas, other implementing actions, which, when taken together, meet the requirements of, and implement the provisions and policies of, this division at the local level.	*CCC, 2008*
Local emergency operations plan (LEOP)	A general planning document, required by law, that describes the responsibilities and actions to be performed in the event of an emergency and/or disaster (also refer to as emergency operations plans).	*USBR, 2008*

Local emergency planning committee (LEPC)	A committee made up of local officials, citizens, and industry representatives charged with development and maintenance of emergency response plans for the local emergency planning district as per SARA Title III requirements. Planning procedures include hazardous materials inventories, plans, hazardous material response training, and assessment of local response capabilities.	*USBR, 2008*
Local government	Any chartered or general law city, chartered or general law county, or any city and county.	*CCC, 2008*
Local officials/authorities	The personnel authorized by election or job title to carry out the operation, planning, mitigation, preparedness, response, and recovery functions of the emergency management programs at local levels.	*USBR, 2008*
Local organization	The local government agency or office having the principal or lead role in emergency planning and preparedness. Generally, this will be the county government. Other local government entities (e.g., towns, cities, municipalities, etc.) are considered to be sub-organizations with supportive roles to the principal or lead local government organization responsible for emergency planning and preparedness. In some cases, there will be more than one lead organization at the local level.	*USBR, 2008*
Local runoff	Water running off a local area, such as rainfall draining into a nearby creek.	*USBR, 2008*
Loess	Wind-deposited silt. A uniform aeolian deposit of silty material having an open structure and relatively high cohesion due to cementation of clay or calcareous material at grain contacts. A characteristic of loess deposits is that they can stand with nearly vertical slopes.	*USBR, 2008*
Loess	Homogeneous, fine-grained sediment made up primarily of silt and clay, and deposited over a wide area (probably by wind).	*USGS, 2008*
Loessial	Medium-textured materials (usually silt or very fine sand) transported and deposited by wind action. These materials may be deposited in depths ranging from less than 1 foot to well over 100 feet.	*USBR, 2008*
Log boom	A floating structure used to protect the face of a dam by deflecting floating material and waves away from the dam. A device used to prevent floating debris from obstructing spillways and intakes. A chain of logs, drums, or pontoons secured end to end and floating on the surface of a reservoir so as to divert floating debris, trash, and logs.	*USBR, 2008*
Longitudinal	Pertaining to or extending along the long axis, or length, of a structure. Lengthwise. See transverse.	*USBR, 2008*
Longitudinal dispersion	The spreading of chemical or biological constituents, including pollutants, downstream from a point source at varying velocities due to the differential in-stream flow characteristics.	*EPA, 2008c*
Longshore	Parallel to and near the shoreline.	*CCC, 2008*
Longshore current	A flow of water in the breaker zone, moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.	*CCC, 2008*
Long-term monitoring	Data collection over a period of years or decades to assess changes in selected hydrologic conditions.	*USGS, 2008*

Loose yards	Measurement of soil or rock after it has been loosened by digging or blasting.	*USBR, 2008*
Losing stream	A stream or reach that contributes water to a zone of saturation.	*USBR, 2008*
Lotic	Meaning or regarding things in running water.	*USACE, 1999*
Lotic	Flowing water, such as rivers and streams.	*USBR, 2008*
Low dam	A dam up to 100 feet high. See medium-height dam and high dam.	*USBR, 2008*
Low density material	A material having a low weight per unit volume either as it occurs in its natural state or after compacting it, such as loess with a density of 80 pounds per cubic foot or less.	*USBR, 2008*
Low hazard	A downstream hazard classification for dams in which no lives are in jeopardy and minimal economic loss (undeveloped agriculture, occasional uninhabited structures, or minimal outstanding natural resources) would occur as a result of failure of the dam. This classification also applies to structures other than dams.	*USBR, 2008*
Low-flow (7Q10)	Low-flow (7Q10) is the 7-day average low flow occurring once in 10 years; this probability-based statistic is used in determining stream design flow conditions and for evaluating the water quality impact of effluent discharge limits.	*EPA, 2008c*
LUP (Land Use Plan)	Land use plan means the relevant portion of a local government's general plan, or local coastal element which are sufficiently detailed to indicate the kinds, location, and intensity of land uses, the applicable resource protection and development policies and, where necessary, a listing of implementing actions.	*CCC, 2008*
Lysimeter	An isolated block of soil, usually undisturbed and in situ, for measuring the quantity, quality, or rate of water movement through or from the soil.	*USBR, 2008*

M

Macro invertebrate	Invertebrates visible to the naked eye, such as insect larvae and crayfish.	*USACE, 1999*
Macro invertebrates	An invertebrate animal (without backbone) large enough to see without magnification.	*USFS, 2002*
Macroclimate	The climate representative of relatively large area.	*USBR, 2008*
Macrohabitat	An extensive habitat presenting considerable variation of the environment, containing a variety of ecological niches and supporting a large number and variety of complex flora and fauna.	*USBR, 2008*
Macroinvertebrate index of biotic condition.	The sum of a number of individual measures of biological condition, such as the number of taxa in a sample, the number of taxa with different habits and feeding strategies, etc.	*EPA, 2006*
Macrophytes	Aquatic plants that are large enough to be seen with the naked eye.	*USACE, 1999*
Macrophytes	A plant large enough to be seen by the naked eye.	*USBR, 2008*
Magma	Molten or fluid rock material from which igneous rock is derived.	*USBR, 2008*

Magnitude	A rating of a given earthquake, independent of the place of observation. It is calculated from measurements on seismographs and it is expressed in ordinary numbers and decimals based on a logarithmic scale. A measure of the strength of an earthquake, or the strain energy released by it, as determined by seismographic observations. See Richter scale.	*USBR, 2008*
Main and tributary levees	Levees that lie along a main stream and its tributaries, respectively.	*FEMA, 2003*
Main channel	The deepest or central part of the bed of a stream, containing the main current.	*USBR, 2008*
Main channel pool	Reach of a stream or river with a low bed elevation, relative to rapids or riffles.	*USBR, 2008*
Main stem	The principal channel of a drainage system into which other smaller streams flow.	*USACE, 1999*
Main stem	The principal course of a river or a stream.	*USGS, 2008*
Mainstream (mainstem)	The main course of a stream where the current is the strongest.	*USBR, 2008*
Maintenance	All routine and extraordinary work necessary to keep the facilities in good repair and reliable working order to fulfill the intended designed project purposes. Maintaining structures and equipment in intended operating condition, equipment repair, and minor structure repair.	*USBR, 2008*
Maintenance management system	Any organized system used to ensure that all operations and maintenance activities (e.g., maintenance, inspection, operational testing) at a facility is accomplished and documented.	*USBR, 2008*
Major facility	A term used by Reclamation to describe those facilities for which an examination is conducted every third year, alternately conducted by the Denver and respective regional office. Major facilities include storage dams and reservoirs, diversion dams with significant storage or where major equipment and operation are complex, large pumping plants and powerplants, large canal systems, large complex closed conduit systems, and Group A bridges.	*USBR, 2008*
Major ions	Constituents commonly present in concentrations exceeding 1.0 milligram per liter. Dissolved cations generally are calcium, magnesium, sodium, and potassium; the major anions are sulfate, chloride, fluoride, nitrate, and those contributing to alkalinity, most generally assumed to be bicarbonate and carbonate.	*USGS, 2008*
Manning's roughness coefficient (n)	A coefficient used to describe the relative roughness of a channel and overbank areas; used in hydraulic computations.	*USBR, 2008*
Manometer	An instrument for measuring pressure.	*USBR, 2008*
Mantle	A thick layer of rock deep within the earth that separates the earth's crust above from the earth's core below.	*USBR, 2008*
Map	Usually a two-dimensional representation of all or part of the Earth's surface showing selected natural or manmade features or data, preferably constructed on a definite projection with a specified scale.	*USBR, 2008*

Marble	Metamorphic rock formed by the "baking" and recrystallization of limestone.	*USBR, 2008*
Margin of exposure (MOE)	The ratio of the no-observed adverse-effect-level to the estimated exposure dose.	*EPA, 2008b*
Margin of safety	Maximum amount of exposure producing no measurable effect in animals (or studied humans) divided by the actual amount of human exposure in a population.	*EPA, 2008b*
Margin of safety (MOS)	A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).	*EPA, 2008c*
Marginal land	Land which, in its natural state, is not well suited for a particular purpose, such as raising crops.	*USBR, 2008*
Marine terrace	A flat or gentle seaward sloping wave-cut bench, which is a remnant of an old coastline. Marine terraces are conspicuous along most of the California coast where uplift has occurred.	*CCC, 2008*
Marsh	A type of wetland that does not accumulate appreciable peat deposits and is dominated by herbaceous vegetation. Marshes may be either fresh or saltwater, tidal or non-tidal.	*EPA, 2008b*
Mass balance	An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.	*EPA, 2008c*
Mass loading	The quantity of a pollutant transported to a waterbody.	*EPA, 2008c*
Mass movement	The down slope movement of earth caused by gravity. Includes but is not limited to landslides, rock falls, debris avalanches, and creep. It does not however, include surface erosion by running water. It may be caused by natural erosional processes, or by natural disturbances (i.e. earthquakes, fires) or human disturbances (i.e. mining, road construction).	*USACE, 1999*
Mass wasting	Downslope transport of soil and rocks due to gravitational stress.	*EPA, 2008c*
Massive head buttress dam	A buttress dam in which the buttress is greatly enlarged on the upstream side to span the gap between buttresses. See solid head buttress dam.	*USBR, 2008*
Mastic	A soft sealing material.	*USBR, 2008*
Mathematical model	A system of mathematical expressions that describe the spatial and temporal distribution of water quality constituents resulting from fluid transport and the one, or more, individual processes and interactions within some prototype aquatic ecosystem. A mathematical water quality model is used as the basis for waste load allocation evaluations.	*EPA, 2008c*
Matrix	Land cover that is dominant and interconnected over the majority of the land surface. Often the matrix is forest or agriculture, but theoretically it can be any land cover type.	*FISHWR, 2001*

Maximum acceptable toxic concentration	For a given ecological effects test, the range (or geometric mean) between the No Observable Adverse Effect Level and the Lowest Observable Adverse Effects Level.	*EPA, 2008b*
Maximum contaminant level	The maximum permissible level of a contaminant in water delivered to any user of a public system. MCLs are enforceable standards.	*EPA, 2008b*
Maximum contaminant level (MCL)	The highest concentration of a constituent in drinking water permitted under federal and State Safe Drinking Water Act regulations.	*USACE, 1999*
Maximum Contaminant Level (MCL)	The highest level of a contaminant that is allowed in drinking water. MCL's are set as close to the Maximum Contaminant Level Goal as feasible using the best available treatment technology.	*USBR, 2008*
Maximum contaminant level (MCL)	Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable standards established by the U.S. Environmental Protection Agency.	*USGS, 2008*
Maximum contaminant level goal (MCLG)	Under the Safe Drinking Water Act, a non-enforceable concentration of a drinking water contaminant, set at the level at which no known or anticipated adverse effects on human health occur and which allows an adequate safety margin. The MCLG is usually the starting point for determining the regulated Maximum Contaminant Level.	*EPA, 2008b*
Maximum Contaminant Level Goal (MCLG)	The level of a contaminant in drinking water below which there is no known or expected risk to health.	*USBR, 2008*
Maximum controllable water surface	The highest reservoir water surface elevation at which gravity flows from the reservoir can be completely shut off.	*USBR, 2008*
Maximum credible earthquake (MCE)	The largest hypothetical earthquake that may be reasonably expected to occur along a given fault or other seismic source could produce under the current tectonic setting. It is a believable event which can be supported by all known geologic and seismologic data. A hypothetical earthquake is deterministic if its fault or source area is spatially definable and can be located a particular distance from the dam under consideration. A hypothetical earthquake is probabilistic if it is considered to be a random event, and its epicentral distance is determined mathematically by relationships of recurrence and magnitude for some given area. The MCE can be associated with specific surface geologic structures and can also be associated with random or floating earthquakes (movements that occur at depths that do not cause surface displacements). The seismic evaluation criteria determines which faults or seismic sources are assigned an MCE. The most severe earthquake that can be expected to occur at a given site on the basis of geologic and seismological evidence. The severest earthquake that is believed to be possible at the site on the basis of geol	*USBR, 2008*
Maximum demand	The greatest of all demands of the load that has occurred within a specified period of time.	*USBR, 2008*
Maximum depth	The greatest depth of a waterbody.	*EPA, 2008c*

Maximum design earthquake (MDE)	The earthquake selected for design or evaluation of the structure. This earthquake would generate the most critical ground motions for evaluation of the seismic performance of the structure among those loadings to which the structure might be exposed. For example, if a site were assigned MCE's from two separate sources, the MCE which would be expected to generate the most severe ground motions would be the maximum design earthquake. The response of the structure to specific ground motion parameters (frequency, duration, etc.) needs to be considered in specifying this event. In certain cases, more than one maximum design earthquake may be specified to reflect the differing response of various components of the structure to earthquake loading. A postulated seismic event, specified in terms of specific bedrock motion parameters at a given site, which is used to evaluate the seismic resistance of manmade structures or other features at the site.	*USBR, 2008*
Maximum exposure range	Estimate of exposure or dose level received by an individual in a defined population that is greater than the 98th percentile dose for all individuals in that population, but less than the exposure level received by the person receiving the highest exposure level.	*EPA, 2008b*
Maximum flood control level	The highest elevation of the flood control storage.	*USBR, 2008*
Maximum tolerated dose	The maximum dose that an animal species can tolerate for a major portion of its lifetime without significant impairment or toxic effect other than carcinogenicity.	*EPA, 2008b*
Maximum unit weight	The dry unit weight defined by the peak of a compaction curve. See unit weight.	*USBR, 2008*
Maximum water surface (maximum pool)	The highest acceptable water surface elevation with all factors affecting the safety of the structure considered. It is the highest water surface elevation resulting from a computed routing of the inflow design flood through the reservoir under established operating criteria. This surface elevation is also the top of the surcharge capacity.	*USBR, 2008*
Maximum wave	The highest wave in a wave group.	*USBR, 2008*
Mean	The average of a set of observations, unless otherwise specified.	*USGS, 2008*
Mean annual discharge	Daily mean discharge averaged over a period of years. Mean annual discharge generally fills a channel to about one-third of its bank-full depth.	*USACE, 1999*
Mean depth	Volume of a waterbody divided by its surface area.	*EPA, 2008c*
Mean discharge (MEAN)	The arithmetic mean of individual daily mean discharges during a specific period, usually daily, monthly, or annually.	*USGS, 2008*
Mean high water	The 19-year average of all high water heights (if the tide is either semidiurnal or mixed) or the higher high water heights if the tide is diurnal. For diurnal tides high water and higher high water are the same.	*CCC, 2008*
Mean higher high water	The 19-year average of only the higher high water heights.	*CCC, 2008*

Mean low water	The 19-year average of all low water heights (if the tide is either semidiurnal or mixed) or the lower low water heights if the tide is diurnal. For diurnal tides low water and lower low water are the same.	*CCC, 2008*
Mean lower low water	The 19-year average of only the lower low water heights.	*CCC, 2008*
Mean number	The average number.	*USBR, 2008*
Mean sea level	The 19-year average height of the surface of the sea for all stages of the tide, usually determined from hourly height readings (see NGVD of 1929).	*CCC, 2008*
Mean sea level (msl)	The elevation of the ocean halfway between high and low tide.	*USBR, 2008*
Mean velocity	The average cross-sectional velocity of water in a stream channel. Surface values typically are much higher than bottom velocities. May be approximated in the field by multiplying the surface velocity (as determined with a float) times 0.8.	*USACE, 1999*
Meander	The winding of a stream channel, usually in an erodible alluvial valley. A series of sine-generated curves characterized by curved flow and alternating banks and shoals.	*USACE, 1999*
Meander	A circuitous winding or bend in the river.	*USFS, 2002*
Meander	Big bend and loops in a river channel as the river snakes through a flat land area.	*USBR, 2008*
Meander amplitude	The distance between points of maximum curvature of successive meanders of opposite phase in a direction normal to the general course of the meander belt, measured between center lines of channels.	*USACE, 1999*
Meander belt width	The distance between lines drawn tangentially to the extreme limits of fully developed meanders. Not to be confused with meander amplitude.	*USACE, 1999*
Meander length	The lineal distance down valley between two corresponding points of successive meanders of the same phase.	*USACE, 1999*
Meander scroll	A sediment formation marking former channel locations.	*FISHWR, 2001*
Mean-square error	Sum of the squared differences between the true and estimated values of a quantity divided by the number of observations. IT can also be defined as the bias squared plus the variance of the quantity.	*USGS, 1982*
Measure of effect/ measurement endpoint	A measurable characteristic of ecological entity that can be related to an assessment endpoint; e.g. a laboratory test for eight species meeting certain requirements may serve as a measure of effect for an assessment endpoint, such as survival of fish, aquatic, invertebrate or algal species under acute exposure.	*EPA, 2008b*
Measure of exposure	A measurable characteristic of a stressor (such as the specific amount of mercury in a body of water) used to help quantify the exposure of an ecological entity or individual organism.	*EPA, 2008b*
Media	Specific environments--air, water, soil--which are the subject of regulatory concern and activities.	*EPA, 2008b*
Median	Middle value in a distribution, above and below which lie an equal number of values.	*USBR, 2008*

Median	The middle or central value in a distribution of data ranked in order of magnitude. The median is also known as the 50th percentile.	*USGS, 2008*
Medium-height dam	A dam between 100 and 300 feet high. See low dam and high dam.	*USBR, 2008*
Medium-size water system	A water system that serves greater than 3,300 and less than or equal to 50,000 persons.	*USBR, 2008*
Medium-thick arch dam	An arch dam with a base thickness to structural height ratio between 0.2 and 0.3 (previously defined as between 0.3 and 0.5).	*USBR, 2008*
Mega	A prefix meaning "million".	*USBR, 2008*
Memorandum of Understanding (MOU)	A formal document that states the intentions and/or responsibilities of the signatory parties. A memorandum of understanding does not provide the authority to transfer any funding from Reclamation to another party, but may cover Reclamation services reimbursed by others.	*USBR, 2008*
Meniscus	The curved top of a column of liquid in a small tube.	*EPA, 2008b*
Meniscus	The curved top of a column of liquid in a small tube caused by surface tension.	*USBR, 2008*
Mercury (Hg)	Heavy metal that can accumulate in the environment and is highly toxic if breathed or swallowed.	*EPA, 2008b*
Mesa	An isolated, relatively flat geographical feature, often demarcated by canyons (from Spanish mesa, table).	*CCC, 2008*
Mesh	In wire screen, the number of openings per lineal inch.	*USBR, 2008*
Mesic	Moderately wet.	*USACE, 1999*
Mesotrophic	Reservoirs and lakes which contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life.	*EPA, 2008b*
Mesotrophic	Reservoirs and lakes which contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life. See oligotrophic.	*USBR, 2008*
Metabolite	A substance produced in or by biological processes.	*USGS, 2008*
Metalimnion	Middle layer of a thermally stratified lake or reservoir with a rapid temperature decrease with depth. See stratification and thermocline.	*USBR, 2008*
Metamorphic	Rock compressed or changed by pressure, heat, or water. A rock formed from a preexisting rock that is altered ("baked") by high temperatures and pressures, causing minerals to recrystallize but not melt.	*USBR, 2008*
Metamorphic rock	Rock that has formed in the solid state in response to pronounced changes of temperature, pressure, and chemical environment.	*USGS, 2008*
Method detection limit	The minimum concentration of a substance that can be accurately identified and measured with present laboratory technologies.	*USGS, 2008*
Method of moments	A standard statistical computation for estimating the moment of a distribution from the data sample.	*USGS, 1982*
Mica	Group of minerals that form thin, platy flakes, typically with shiny surfaces, especially common in metamorphic rocks.	*USBR, 2008*
Micro	Small. A prefix meaning "one millionth".	*USBR, 2008*

Microclimate	1. Localized climate conditions within an urban area or neighborhood. 2. The climate around a tree or shrub or a stand of trees.	*EPA, 2008b*
Microclimate	The climate of a small area, particularly that of the living space of a certain species, group or community.	*USBR, 2008*
Microgram per liter	Equivalent to 1 part per billion.	*USBR, 2008*
Micrograms per liter (╡ g/L)	A unit expressing the concentration of constituents in solution as weight (micrograms) of solute per unit volume (liter) of water; equivalent to one part per billion in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.	*USGS, 2008*
Microhabitat	A small, specialized, and effectively isolated location. See macrohabitat.	*USBR, 2008*
Micron	A unit of length equal to one millionth of a meter, and one thousandth of a millimeter. One inch equals 25,400 microns.	*USBR, 2008*
Microsystem irrigation	Method of precisely applying irrigation water to the immediate root zone of the target plant at very low rates.	*USBR, 2008*
Midden	Refuse heap or other deposit left by ancient humans.	*CCC, 2008*
Midge	A small fly in the family Chironomidae. The larval (juvenile) life stages are aquatic.	*USGS, 2008*
Migmatite	Rock composed of a complex mixture of metamorphic rock and igneous granitic rock.	*USBR, 2008*
Migratory	Moving from one area to another on a seasonal basis.	*USBR, 2008*
Mil	A unit of length equal to 0.001 of an inch. Used in measuring the diameter of wires, and the thickness of fabric and plastic sheeting.	*USBR, 2008*
Milestone	A measurable action, state, or goal which marks a point of achievement on the way to solving the problem.	*USBR, 2008*
Military crest	A ridge that interrupts the view between a valley and a hilltop.	*USBR, 2008*
Mill	Monetary cost and billing unit used by utilities; equal to 1/1000 of U.S. dollar (or 1/10 of one cent).	*USBR, 2008*
Milli	A prefix meaning "one thousandth".	*USBR, 2008*
Milligram (mg)	A mass equal to 0.001 grams.	*USGS, 2008*
Milligram per liter (mg/l)	Equivalent to 1 part per million.	*USBR, 2008*
Milligrams per liter (mg/l)	The weight in milligrams of any substance dissolved in one liter of liquid; nearly the same as parts per million by weight.	*USACE, 1999*
Milligrams per liter (mg/L)	A unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water; equivalent to one part per million in most streamwater and ground water. One thousand micrograms per liter equals 1 mg/L.	*USGS, 2008*
Million acre-feet (maf)	The volume of water that would cover 1 million acres to a depth of 1 foot.	*USBR, 2008*
Millisecond delay (short period delay)	A type of delay cap with a definite but extremely short interval between initiation, or passing of current, and explosion.	*USBR, 2008*
Mine tailings dam	An industrial waste dam in which the waste materials come from mining operations or mineral processing.	*USBR, 2008*
Mineralization	The process whereby concentrations of minerals, such as salts, increase in water, often a natural process resulting from water dissolving minerals found in rocks and soils through which it flows.	*USACE, 1999*

Mineralization	The transformation of organic matter into a mineral or an inorganic compound.	*EPA, 2008c*
Minimally disturbed	The physical, chemical, and biological conditions of a water body with very limited, or minimal, human disturbance in comparison to others within the water body class or region. Minimally disturbed conditions can change over time in response to natural processes.	*EPA, 2008c*
Minimum flow	Negotiated lowest flow in a regulated stream that will sustain an aquatic population of agreed-upon levels. Flow may vary seasonally. Lowest flow in a specified period of time.	*USBR, 2008*
Minimum operating level	The lowest level to which the reservoir is drawn down under normal operating conditions.	*USBR, 2008*
Minimum reporting level (MRL)	The smallest measured concentration of a constituent that may be reliably reported using a given analytical method. In many cases, the MRL is used when documentation for the method detection limit is not available.	*USGS, 2008*
Mining	Usually removal of soil or rock having value because of its chemical composition.	*USBR, 2008*
Mining of an aquifer	Withdrawal over a period of time of ground water that exceeds the rate of recharge of the aquifer.	*EPA, 2008b*
Miocene	A period of geologic time spanning 27-26 million years ago.	*CCC, 2008*
Mitigation	Measures taken to reduce adverse impacts on the environment.	*EPA, 2008b*
Mitigation	Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.	*EPA, 2008c*
Mitigation (measures)	Methods or plans to reduce, offset, or eliminate adverse project impacts. Action taken to avoid, reduce the severity of, or eliminate an adverse impact. Mitigation can include one or more of the following:	*USBR, 2008*
MOA	Memorandum of Agreement.	*CCC, 2008*
Model	A representation of reality used to simulate a process, understand a situation, predict and outcome, or analyze a problem. A model is structured as a set of rules and procedures, including spatial modeling tools that relate to locations on the earth's surface.	*EPA, 1997*
Modeling	Use of mathematical equations to simulate and predict real events and processes.	*USBR, 2008*
Moderate frequency flood	A flood of lesser magnitude than the IDF, used for the service spillway design when supplemented by a separate auxiliary spillway.	*USBR, 2008*

Modification Decision Analysis (MDA)	The process of determining with confidence whether dam safety deficiencies exist for maximum loading conditions. The MDA process is a technical, state-of-the-art evaluation whose complexity can range from the simplified SEED Analysis Report evaluations using available data, to advanced engineering and geologic analyses conducted using material properties and other data obtained from detailed field and laboratory investigations. The MDA evaluates suspected safety of dam deficiencies, identifies the critical types of loading conditions that may cause dam failure, (e.g., earthquake, flood, and static reservoir loading), and eliminates or verifies suspected deficiencies which are capable of causing failure of the dam.	*USBR, 2008*
Modified homogeneous earthfill dam	A homogeneous earthfill dam that uses pervious material specially placed in the embankment to control seepage. See embankment dam.	*USBR, 2008*
Modified Mercalli scale	An earthquake intensity scale which has twelve divisions ranging from I (not felt by people) to XII (nearly total damage). For more information on the modified Mercalli scale, visit the U.S. Geological Survey National Earthquake Information Center.	*USBR, 2008*
Mohr circle	A graphical representation of the stresses acting on the various planes at a given point.	*USBR, 2008*
Moisture content	1.The amount of water lost from soil upon drying to a constant weight, expressed as the weight per unit of dry soil or as the volume of water per unit bulk volume of the soil. For a fully saturated medium, moisture content indicates the porosity. 2. Water equivalent of snow on the ground; an indicator of snowmelt flood potential.	*EPA, 2008b*
Moisture content (water content)	The ratio of the weight of water in a soil sample to the weight of the dry soil, expressed as a percentage. See optimum moisture content.	*USBR, 2008*
Moisture stress	A condition of physiological stress in a plant caused by lack of water.	*USACE, 1999*
Monitoring	Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.	*EPA, 2008b*
Monitoring	Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.	*EPA, 2008c*
Monitoring	Systematic collection of physical, biological, or economic data or a combination of these data on a beach nourishment project in order to make decisions regarding project operation or to evaluate project performance.	*CCC, 2008*
Monitoring	The periodic collection of information about a process (e.g., change in vegetation in response to disturbance) or attribute (e.g., water temperature) that may be an indicator of condition or management actions.	*DOC, 2005*
Monitoring	Repeated observation or sampling at a site, on a scheduled or event basis, for a particular purpose.	*USGS, 2008*

Monitoring well	1. A well used to obtain water quality samples or measure groundwater levels. 2. A well drilled at a hazardous waste management facility or Superfund site to collect ground-water samples for the purpose of physical, chemical, or biological analysis to determine the amounts, types, and distribution of contaminants in the groundwater beneath the site.	*EPA, 2008b*
Monitoring well	A well designed for measuring water levels and testing ground-water quality.	*USGS, 2008*
Monocline	Bend or steplike fold in rock layers where all strata are inclined in the same direction.	*USBR, 2008*
Monocoque gate	A thin-shell radial gate in which the usual skin plate and cross-beam framework are replaced by a hollow shell having an approximate elliptical cross section. This type of gate deviates considerably from the conventional beam and skin-plate design in that the shell itself is relied upon to withstand the beam action.	*USBR, 2008*
Monocyclic aromatic hydrocarbons	Single-ring aromatic compounds. Constituents of lead-free gasoline; also used in the manufacture of monomers and plasticizers in polymers.	*USGS, 2008*
Monomictic	Lakes and reservoirs which are relatively deep, do not freeze over, and undergo a single stratification and mixing cycle during the year. These lakes and reservoirs usually become destratified during the mixing cycle, usually in the fall. Warm-water lakes which turn over annually, usually in winter, and where the temperature never falls below 4 degrees C.	*USBR, 2008*
Monte Carlo modeling	A numerical technique for assessing the probability of different outcomes from two or more variables.	*Mockett & Simm, 2002*
Monte Carlo simulation	A stochastic modeling technique that involves the random selection of sets of input data for use in repetitive model runs. Probability distributions of receiving water quality concentrations are generated as the output of a Monte Carlo simulation.	*EPA, 2008c*
Morning glory spillway	A circular or glory hole form of a drop inlet spillway. Usually free standing in the reservoir and so called because of its resemblance to the morning glory flower. See shaft spillway.	*USBR, 2008*
Morphology	The form, shape, or structure of a stream or organism.	*USACE, 1999*
Morphology	Science of structure of organisms. River morphology deals with the science of analyzing the structural makeup of rivers and streams.	*USFS, 2002*
Mosaic	A collection of patches, none of which are dominant enough to be interconnected throughout the landscape.	*FISHWR, 2001*
MOU	Memorandum of Understanding.	*CCC, 2008*
Mouth	The place where a stream discharges to a larger stream, a lake, or the sea.	*USGS, 2008*
Muck	Mud rich in humus. Stone, dirt, debris, or useless material; or an organic soil of very soft consistency. Finely blasted rock, particularly from underground.	*USBR, 2008*
Muck soils	Earth made from decaying plant materials.	*EPA, 2008b*
Mud	Generally, any soil containing enough water to make it soft. A mixture of soil and water in a fluid or weakly solid state.	*USBR, 2008*

Mudflat	A mud-covered, gently sloping tract of land alternately covered and left bare by water. The muddy, nearly level bed of a dry lake.	*USBR, 2008*
Mudstone	Fine-grained sedimentary rock formed from hardened clay and silt that lacks the thin layers typical of shale.	*USBR, 2008*
Mulch	A layer of material (wood chips, straw, leaves, etc.) placed around plants to hold moisture, prevent weed growth, and enrich or sterilize the soil.	*EPA, 2008b*
Mulch	Material spread on the ground to reduce soil erosion and evaporation of water. Any substance spread or allowed to remain on the soil surface to conserve soil moisture and shield soil particles from the erosive forces of raindrops and runoff.	*USBR, 2008*
Multi-media approach	Joint approach to several environmental media, such as air, water, and land.	*EPA, 2008b*
Multiple arch dam	A buttress dam, the upstream part of which comprises a series of arches.	*USBR, 2008*
Multiple use	Use of land for more than one purpose; e.g., grazing of livestock, watershed and wildlife protection, recreation, and timber production. Also applies to use of bodies of water for recreational purposes, fishing, and water supply.	*EPA, 2008b*
Multiple use	Use of water or land for more than one purpose.	*USBR, 2008*
Multiple-purpose reservoir (multipurpose reservoir)	A reservoir planned to operate for more than one purpose.	*USBR, 2008*
Multiple-thread streams	Streams with multiple channels. These are also categorized as either braided or anastomosed streams.	*FISHWR, 2001*
Multipurpose dam	A dam constructed for two or more purposes (e.g. storage, flood control, navigation, power generation, recreation, or fish and wildlife enhancement.)	*USBR, 2008*
Multipurpose project	A project designed to serve more than one purpose. For example, one that provides water for irrigation, recreation, fish and wildlife, and at the same time, controls floods or generates electric power.	*USACE, 1999*
Multipurpose project	A project designed for irrigation, power, flood control, municipal and industrial, recreation, and fish and wildlife benefits, in any combinations of two or more (contrasted to single-purpose projects serving only one need).	*USBR, 2008*
Multistage remote sensing	A strategy for landscape characterization that involves gathering and analyzing information at several geographic scales, ranging from generalized levels of detail at the national level through high levels of detail at the local scale.	*EPA, 2008b*
Municipal water system	A water system that has at least five service connections or which regularly serves 25 individuals for 60 days; also called a public water system.	*DOC, 2005*
Municipalization	The process by which a municipal entity assumes responsibility for supplying utility service to its constituents. In supplying electricity, the municipality may generate and distribute the power or purchase wholesale power from other generators and distribute it.	*USBR, 2008*

N

Nanometer (millimicron)	One millionth of a millimeter.	*USBR, 2008*
Narrative criteria	Nonquantitative guidelines that describe the desired water quality goals.	*EPA, 2008c*
National Academy of Sciences/National Academy of Engineering (NAS/NAE) recommended maximum concentration in water	Numerical guidelines recmmended by two joint NAS/NAE committees for the protection of freshwater and marine aquatic life, respectively. These guidelines were based on available aquatic toxicity studies, and were considered preliminary even at the time (1972). The guidelines used in the summary reports are for freshwater.	*USGS, 2008*
National disaster medical system	A system designed to deal with extensive medical care needs in very large disasters or emergencies. The system is a cooperative effort of the Department of Health and Human Services, Federal Emergency Management Agency, Department of Defense, State and local governments, and the private sector.	*USBR, 2008*
National Environmental Policy Act (NEPA)	An act requiring analysis, public comment, and reporting for environmental impacts of Federal actions. See National Environmental Policy Act of 1969.	*USBR, 2008*
National Geodetic Vertical Datum of 1929 (NGVD)	A fixed reference for elevations, equivalent to the 1929 Mean Sea Level Datum. The geodetic datum is fixed and does not take into account the changing stands of sea level. NGVD should not be confused with mean sea level. (see Mean Sea Level)	*CCC, 2008*
National hydrography dataset	Comprehensive set of digital spatial data, based on USGS 1:100,000 scale topographic maps, that contains information on surface water features such as streams, rivers, lakes, and ponds.	*EPA, 2006*
National Institute for Occupational Safety and Health (NIOSH)	NIOSH is the Federal agency responsible for conducting research and making recommendations for the prevention of work-related disease and injury.	*USBR, 2008*
National Interagency Fire Center (NIFC)	The National Interagency Fire Center is the nation's support center for wildland firefighting.	*USBR, 2008*
National Oceanic and Atmospheric Administration (NOAA)	The National Oceanic and Atmospheric Administration's mission is to describe and predict changes in the Earth's environment, and conserve and wisely manage the Nation's coastal and marine resources.	*USBR, 2008*
National Park Service (NPS)	The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. NPS is an agency within the U.S. Department of the Interior.	*USBR, 2008*
National Pollutant Discharge Elimination System (NPDES)	A provision of the Clean Water Act which prohibits discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state, or, where delegated, a tribal government on an Indian reservation.	*EPA, 2008b*

National Pollutant Discharge Elimination System (NPDES)	A provision of Section 402 of the Federal Clean Water Act of 1972 that established a permitting system for discharges of waste materials to watercourses.	*USACE, 1999*
National Pollutant Discharge Elimination System (NPDES)	The national program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under Sections 307, 402, 318, and 405 of the Clean Water Act.	*EPA, 2008c*
National Pollutant Discharge Elimination System (NPDES)	A permitting program under section 402 of the Clean Water Act required for all point sources discharging pollutants into waters of the United States. The purpose of the NPDES program is to protect human health and the environment.	*USBR, 2008*
National Priorities List (NPL)	EPA's list of the most serious uncontrolled or abandoned hazardous waste sites identified for possible long-term remedial action under Superfund. The list is based primarily on the score a site receives from the Hazard Ranking System. EPA is required to update the NPL at least once a year. A site must be on the NPL to receive money from the Trust Fund for remedial action.	*EPA, 2008b*
National Register of Historic Places	A federally maintained register of districts, sites, buildings, structures, architecture, archeology, and culture. Visit the National Register of Historic Places website.	*USBR, 2008*
National Response Center (NRC)	Located at the U.S. Coast Guard Headquarters in Washington, D.C., the NRC is a 24-hour national communications center and the single point of contact for pollution - incident reporting. It is also the National Response Team's communications center. Immediate reporting is required for reportable quantities of petroleum or hazardous substances 40 CFR 300.125(c).	*USBR, 2008*
National Response Team (NRT)	NRT consists of representatives from several Federal agencies including the Department of the Interior (DOI) and the Bureau of Reclamation. NRT is primarily a policy board which provides program direction, planning and preparedness guidance, and review of regional response activites. NRT should be activated as an emergency response team when an oil or hazardous substance release exceeds the response capability of the region(s), transects regional boundaries; or involves a significant threat to public health or welfare or the environment, substantial amounts of property, or substantial threats to natural resources.	*USBR, 2008*
National Water Quality Assessment Program	Describes current water quality conditions for a large part of the United States freshwater stream, rivers, and aquifers. Describes how water quality is changing over time. Improves understanding of the primary natural and human factors that affect water quality conditions.	*USBR, 2008*
National Weather Service (NWS)	The National Weather Service provides weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy.	*USBR, 2008*

Nationwide Rivers Inventory (NRI	The Nationwide Rivers Inventory is a listing of more than 3,400 free-flowing river segments in the United States that are believed to possess one or more "outstandingly remarkable" natural or cultural values judged to be of more than local or regional significance.	*USBR, 2008*
Natural floodway	The channel of a water course and those portions of the adjoining flood plain which are reasonably required to carry a selected probability flood.	*USBR, 2008*
Natural flow	The flow past a specified point on a natural stream that is unaffected by stream diversion, storage, import, export, return flow, or change in use caused by modifications in land use.	*USACE, 1999*
Natural frequency (f)	The natural frequencies of a structure are the frequencies of free vibration. Free vibration is vibration that occurs in the absence of forced vibration. In a structure undergoing vibration, a mode of vibration is a characteristic pattern (shape) assumed by the structure in which the motion of every particle is simple harmonic motion with the same frequency. The fundamental mode of vibration of a structure is the mode having the lowest natural frequency.	*USBR, 2008*
Natural levees	Formations built up along the bank of some streams that flood. As sediment-laden water spills over the bank, the sudden loss of depth and velocity causes coarser-sized sediment to drop out of suspension and collect along the edge of the stream.	*FISHWR, 2001*
Natural period of vibration (T)	The period of vibration of a a structure is the time required for one cycle of the simple harmonic motion in one of these characteristic patterns (shapes). T = 1/f.	*USBR, 2008*
Natural waters	Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.	*EPA, 2008c*
Naturalness	Area which generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable.	*USBR, 2008*
Navigable waters	Traditionally, waters sufficiently deep and wide for navigation by all, or specified vessels; such waters in the United States come under federal jurisdiction and are protected by certain provisions of the Clean Water Act.	*EPA, 2008b*
Navigable waters	Waters of the United States including: (a) All waters that are currently used, were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters that are subject to the ebb and flow of the tide. (b) Interstate waters, including interstate wetlands. (c) All other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats and wetlands, the use, degradation, or destruction of which would affect or could affect interstate or foreign commerce, including waters used or which could be used for industries in interstate commerce. (d) All impoundments of waters otherwise defined as navigable waters. (e) Tributaries of waters identified in (a) through (d). (f) Wetlands adjacent to waters identified in (a) through (d).	*USBR, 2008*

Nearshore zone	An indefinite zone extending seaward from the shoreline well beyond the breaker zone; it defines the area of nearshore currents.	*CCC, 2008*
Neatlines (of structure)	A line which defines the limits of work, such as an excavation, cut stone, etc. Also, the true face line of a building regardless of the projections of the stones; a line back of, or inside of, incidental projections. Any material removed beyond the neat line is overbreak.	*USBR, 2008*
Negative pressure	Pressure within a pipe that is less than atmospheric pressure.	*USBR, 2008*
Neoprene	A synthetic rubber with superior resistance to oils; often used as gasket and washer material.	*USBR, 2008*
Neotropic migrant (neotropical)	A bird that migrates to tropical regions during the winter.	*USBR, 2008*
Nephelometric	Method of of measuring turbidity in a water sample by passing light through the sample and measuring the amount of the light that is deflected.	*EPA, 2008b*
Nephelometric	A means of measuring turbidity in a sample by using an instrument called a nephelometer. A nephelometer passes light through a sample and the amount of light deflected (usually at a 90-degree angle) is then measured. The unit of measure for turbidity is a nephelometric turbidity unit (NTU).	*USBR, 2008*
Nephelometric turbidity units (NTU)	The units of measurement for turbidity in water as determined by the degree light is scattered at right angles when compared to a standard reference solution.	*EPA, 2008c*
Net cut	The cut required, less the fill required, at a particular station or part of a road.	*USBR, 2008*
Net economic benefits	Economic benefits less economic costs.	*USBR, 2008*
Net fill	The fill required, less the cut required, at a particular station or part of a road.	*USBR, 2008*
Net present value	The difference between funds spent and revenue generated discounted over a period of time.	*Mockett & Simm, 2002*
Net primary productivity	A measure of carbon flux over a given landscape unit, roughly, the actual amount of organic matter created by green plants, whether it accumulates in plants, is eaten by animals, or becomes dead material over a fixed time interval.	*EPA, 1997*
Net water demand (net water use)	The amount of water needed in a water service area to meet all requirements. It is the sum of evapotranspiration of applied water (ETAW) in an area, the irrecoverable losses from the distribution system, and the outflow leaving the service area; does not include reuse of water within a service area (such as reuse of deep-percolated applied water or the use of tailwater).	*USACE, 1999*
Neutralization	Decreasing the acidity or alkalinity of a substance by adding alkaline or acidic materials, respectively.	*EPA, 2008b*
New York rod	A leveling rod marked with narrow lines, ruler-fashion.	*USBR, 2008*
Newton	A force which, when applied to a body having a mass of one kilogram, gives it an acceleration of one meter per second squared.	*USBR, 2008*
Nick point	The point where the stream is actively eroding the streambed to a new base level. Nick points migrate upstream (see also Headcut).	*USFS, 2002*

Nipple	A short piece of pipe with male threads on each end.	*USBR, 2008*
Nitrate	An ion consisting of nitrogen and oxygen (NO3). Nitrate is a plant nutrient and is very mobile in soils.	*USGS, 2008*
No action alternative	The projected baseline condition, or future without. The expected future condition if no action is taken (not necessarily the same as the present condition). The effects of action alternatives are measured against this baseline condition.	*USBR, 2008*
No jeopardy opinion	U.S. Fish and Wildlife Service (FWS) or National Marine Fisheries Service (NMFS) opinion that an action is not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat. See jeopardy opinion.	*USBR, 2008*
Nominal diameter	An approximate measurement of the diameter of a pipe. Although the nominal diameter is used to describe the size or diameter of a pipe, it is usually not the exact inside diameter of the pipe.	*USBR, 2008*
Nominal dollars	Dollar value in the indicated year, not adjusted for inflation.	*USBR, 2008*
Nominal size	The approximate dimension(s) of standard materials.	*USBR, 2008*
Non-Aqueous Phase Liquid (NAPL)	Contaminants that remain undiluted as the original bulk liquid in the subsurface, e.g. spilled oil.	*EPA, 2008b*
Nonconsumptive water uses	Water uses that do not substantially deplete water supplies, including swimming, boating, waterskiing, fishing, maintenance of stream related fish and wildlife habitat, and hydropower generation.	*USBR, 2008*
Noncontact water recreation	Recreational activities, such as fishing or boating, that do not include direct contact with the water.	*USGS, 2008*
Non-conventional pollutant	Any pollutant not statutorily listed or which is poorly understood by the scientific community.	*EPA, 2008b*
Non-intervention/undisturbed recovery	A passive management approach that does not involve active stream corridor manipulation. The river system is allowed to rehabilitate itself without direct anthropogenic influence.	*FISHWR, 2001*
Non-jeopardy biological opinion	A FWS or NOAA Fisheries section 7 biological opinion that determines that a Federal action is not likely to jeopardize the existence of a listed species or result in the destruction or adverse modification of critical habitat.	*USFWS, 2008*
Nonparametric	The same as 'distribution-free.'	*USGS, 1982*
Nonpoint source	Pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.	*EPA, 2008c*

Nonpoint source	A contributing factor to water pollution that cannot be traced to a specific spot. Man-made or man-induced alteration of the chemical, physical, biological, or radiological integrity of water, originating from any source other than a point source. Pollution which comes from diffuse sources such as urban and agricultural runoff. Major nonpoint sources of pollution include excess farm and lawn nutrients that move through the soil into the ground water or enter local water directly through runoff during heavy rains; uncontrolled storm water runoff from construction sites; forestry operations; animal wastes; and even pollutants released directly into the atmosphere. Pollution sources which are diffuse and do not have a single point of origin or are not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater runoff. The commonly used categories for nonpoint sources are: agriculture, forestry, urban, mining, construction, dams and channels, land disposal, and saltwater intrusion.	*USBR, 2008*
Nonpoint source	A pollution source that cannot be defined as originating from discrete points such as pipe discharge. Areas of fertilizer and pesticide applications, atmospheric deposition, manure, and natural inputs from plants and trees are types of nonpoint source pollution.	*USGS, 2008*
Non-point source (NPS) pollution	Pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land-use activities, which are carried to lakes and streams by surface runoff. Non-point source pollution is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants, such as nutrients and pesticides.	*DOC, 2005*
Nonpoint source contaminant	A substance that pollutes or degrades water that comes from lawn or cropland runoff, the atmosphere, roadways, and other diffuse sources.	*USGS, 2008*
Non-point source pollution (NPS)	Pollution that does not originate from a clear or discrete source.	*USACE, 1999*
Non-point sources	Diffuse pollution sources (i.e. without a single point of origin or not introduced into a receiving stream from a specific outlet). The pollutants are generally carried off the land by storm water. Common non-point sources are agriculture, forestry, urban, mining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.	*EPA, 2008b*
Nonpoint-source water pollution	Water contamination that originates from a broad area (such as leaching of agricultural chemicals from crop land) and enters the water resource diffusely over a large area.	*USGS, 2008*
Non-potable	Water that is unsafe or unpalatable to drink because it contains pollutants, contaminants, minerals, or infective agents.	*EPA, 2008b*
Non-potable	Water that may contain objectionable pollution, contamination, minerals, or infective agents and is considered unsafe and/or unpalatable for drinking.	*USBR, 2008*

Non-reimbursable	Cost of constructing, operating, or maintaining a Reclamation project that is borne by the Federal taxpayer and is not reimbursed by any other individual, entity, or organization.	*USBR, 2008*
Nonselective herbicide	Kills or significantly retards growth of most higher plant species.	*USGS, 2008*
Nonterritorial communities	Networks of associations around shared goals, values, and norms, such as the agricultural, environmental, or recreational community; also known as "special interest communities."	*USBR, 2008*
Non-uniform flow	The velocity varies with position.	*USBR, 2008*
Normal depth	The depth of flow that would exist for a steady-uniform flow condition.	*USBR, 2008*
Normal distribution	A probability distribution that is symmetrical about the mean, median, and mode (bell-shaped). It is the most studied distribution in statistics, even though most data are not exactly normally distributed, because of its value in theoretical work and because many other distributions can be transformed into normal. It is also known as Gaussian, The Laplacean, the Gauss-Laplace, or the Laplace-Gauss distribution, or the Second Law of Gauss.	*USGS, 1982*
Normal loading conditions	Loading conditions that occur or are anticipated to occur with some degree of regularity or frequency, as constrasted to unusual loading conditions such as an MCE or PMF.	*USBR, 2008*
Normal water surface	The highest elevation at which water is normally stored, or that elevation which the reservoir should be operated for conservation purposes. Usually the elevation at the top of the active conservation capacity. The maximum elevation to which the reservoir may rise under normal operating conditions exclusive of flood control capacity.	*USBR, 2008*
Normalization	The mathematical manipulation of a variable to allow comparisons with an otherwise different variable.	*USACE, 1999*
Normalized demand	The process of adjusting actual water use in a given year to account for unusual events such as dry weather conditions, government interventions for agriculture, rationing programs, or other irregularities.	*USACE, 1999*
Notification	The third of five Early Warning System components consisting of communicating alerts and warnings about an emergency condition at a dam to appropriate local officials so they can take proper action(s).	*USBR, 2008*
Nourishment	The process of replenishing or enlarging a beach. It may be brought about naturally by longshore transport or artificially by the deposition of dredged materials.	*CCC, 2008*
NPS	Nonpoint source pollution or polluted runoff.	*CCC, 2008*
Numeric target	A measurable value determined for the pollutant of concern which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.	*EPA, 2008c*
Numerical model	Model that approximates a solution of governing partial differential equations which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.	*EPA, 2008c*

Nutrient	Any substance assimilated by living things that promotes growth. The term is generally applied to nitrogen and phosphorus in wastewater, but is also applied to other essential and trace elements.	*EPA, 2008b*
Nutrient	An element or compound required by a living organism for growth.	*DOC, 2005*
Nutrient	Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.	*USGS, 2008*
Nutrient depletion	Detrimental changes at a site in the total amount of nutrients and/or their rates of input, uptake, release, movement, transformation, or export.	*USACE, 1999*
Nutrient pollution	Contamination of water resources by excessive inputs of nutrients. In surface waters, excess algal production is a major concern.	*EPA, 2008b*
Nutrients	Substances such as nitrogen and phosphorus that are essential to life but can overstimulate the growth of algae and other plants in water. Excess nutrients in streams and lakes can come from agricultural and urban runoff, leaking septic systems, sewage discharges, and similar sources.	*EPA, 2006*
Nutrients	Animal, vegetable, or mineral substance which sustains individual organisms and ecosystems. Any substance that is assimilated by organisms and promotes growth.	*USBR, 2008*

O

O/E (Observed/ Expected) ratio of taxa loss	A ratio comparing the number of taxa expected (E) to exist at a site to the number that are actually observed (O). The taxa expected at individual sites are based on models developed from data collected at reference sites.	*EPA, 2006*
Oakum	Loosely woven hemp rope that has been treated with oil or other waterproofing agent; it is used to caulk joints in a bell and spigot pipe and fittings.	*USBR, 2008*
Obligate riparian species	A species that depends completely upon habitat along a body of water.	*USBR, 2008*
Observation well	A hole used to observe the ground-water surface at atmospheric pressure within soil or rock.	*USBR, 2008*
Occurrence and distribution assessment	Characterization of the broad-scale spatial and temporal distributions of water-quality conditions in relation to major contaminant sources and background conditions for surface water and ground water.	*USGS, 2008*
Off-channel area	Any relatively calm portion of a stream outside of the main flow.	*USACE, 1999*
Offshore	Off or away from the shore. This area extends from beyond the breaker zone to the outer limit of the littoral zone and beyond.	*CCC, 2008*
Off-site enhancement	The improvement in conditions for fish and wildlife species away from the site or development activities that may have detrimental effects on fish and/or wildlife, as part or total compensation for those effects.	*USACE, 1999*
Offstream use	Water withdrawn from surface or groundwater sources for use at another place.	*EPA, 2008b*

Offstream uses	Water withdrawn from surface or ground water sources for use at another place.	*USBR, 2008*
Ogee crest	The shape of the concrete spillway crest that represents the lower profile of the undernappe of a jet of water flowing over a sharp-crested weir at a design depth.	*USBR, 2008*
Oil	Defined as oil of any kind or in any form including, but not limited to, petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes.	*USBR, 2008*
Oil spill contingency fund	A revolving fund for spill control efforts has been authorized in cases where the Federal government has taken over containment and cleanup operations. The fund is administered by the U.S. Coast Guard. Once the responsible party is determined, they are required to reimburse the fund for the oil removal costs.	*USBR, 2008*
Oligotrophic	Reservoirs and lakes which are nutrient poor and contain little aquatic plant or animal life. See mesotrophic.	*USBR, 2008*
Oligotrophic lakes	Deep clear lakes with few nutrients, little organic matter and a high dissolved-oxygen level.	*EPA, 2008b*
Omnivore	Animal that eats both vegetable and animal substances.	*USBR, 2008*
On-district storage	Small water storage facilities located within the boundaries of an irrigation entity, including reregulating reservoirs, holding ponds, or other new storage methods that allow for efficient water use.	*USBR, 2008*
One-dimensional model (1-D)	A mathematical model defined along one spatial coordinate of a natural water system. Typically 1-D models are used to describe the longitudinal variation of water quality constituents along the downstream direction of a stream or river. In writing the model, it is assumed that the cross-channel (lateral) and vertical variability is relatively homogenous and can, therefore, be averaged over those spatial coordinates.	*EPA, 2008c*
On-farm	Activities (especially growing crops and applying irrigation water) that occur within the legal boundaries of private property.	*USBR, 2008*
On-farm irrigation efficiency	The ratio of the volume of water used for consumptive use and leaching requirements in cropped areas to the volume of water delivered to a farm (applied water).	*USBR, 2008*
Ongoing Visual Inspection (OVI)	The Ongoing Visual Inspection Checklist identifies specific visual inspection items that should regularly receive special attention. At the time of all formal examinations, the OVI checklist should be reviewed with onsite personnel to answer questions concerning conducting the ongoing inspections, and improve the effectiveness of the ongoing visual inspections by altering/updating the OVI checklist form as appropriate.	*USBR, 2008*
Onshore (inshore)	The region between the seaward edge of the foreshore and the seaward edge of the breakers or waves.	*CCC, 2008*
Open-cut	A method of excavation in which the working area is kept open to the sky. Used to distinguish from cut-and-cover and underground work.	*USBR, 2008*

Open-work materials	Poorly-graded (uniform or gap-graded gradation) gravels, cobbles and boulders with few fines in the matrix, resulting in a deposit containing a large amount of interconnected void space through which seepage water (and soil particles) can easily move.	*USBR, 2008*
Operating basis earthquake (OBE)	The earthquake that the structure must safely withstand with no damage. All systems and components necessary to the uninterrupted functioning of the project are designed to remain operable during the ground motions associated with the OBE. This includes the dam, appurtenant structures, electrical and mechanical equipment, relays, spillway gates, and valves. For most usage in Reclamation, the OBE is specified to have a 90% probability of nonoccurrence in a 25-year-exposure period. This is equivalent to a recurrence interval of 237 years. Economic considerations for specific projects may lead to consideration of other values. The earthquake(s) for which the structure is designed to resist and remain operational. It reflects the level of earthquake protection desired for operational or economic reasons and may be determined on a probabilistic basis considering the regional and local geology and seismology.	*USBR, 2008*
Operational losses	Losses of water resulting from evaporation, seepage, and spills.	*USBR, 2008*
Operational waste	Water that is lost or otherwise discarded from an irrigation system after having been diverted into it as part of normal operations.	*USBR, 2008*
Operations and maintenance (O&M)	Operation, maintenance, repairs, replacements, testing, and exercising of any or all portions of an Early Warning System for the life of the system.	*USBR, 2008*
Operations and maintenance costs	The ongoing, repetitive costs of operating and maintaining a water system.	*USBR, 2008*
Optimum moisture content, or Optimum water content	The one water content (percent of dry weight of the total material) of a given soil and a given compactive effort that will result in a maximum dry density of the soil.	*USBR, 2008*
Option value	Value associated with people who know they can visit an area in the future if they so desire. Also a reversible decision or an option to develop at some time in the future have option value.	*USBR, 2008*
Ordinary high-water (OWH) mark	The mark along a stream bank where the waters are common and usual. This mark is generally recognized by the difference in the character of the vegetation above and below the mark or the absence of vegetation below the mark (see Bank full Discharge).	*USFS, 2002*
Ore	Rock or earth containing workable quantities of a mineral or minerals of commercial value.	*USBR, 2008*
Organic	1. Referring to or derived from living organisms. 2. In chemistry, any compound containing carbon.	*EPA, 2008b*
Organic	Any chemical containing the element carbon. Substances that come from animal or plant sources. See inorganic.	*USBR, 2008*
Organic chemicals/ compounds	Naturally occuring (animal or plant-produced or synthetic) substances containing mainly carbon, hydrogen, nitrogen, and oxygen.	*EPA, 2008b*

Organic detritus	Any loose organic material in streams such as leaves, bark, or twigs removed and transported by mechanical means, such as disintegration or abrasion.	*USGS, 2008*
Organic matter	Carbonaceous waste contained in plant or animal matter and originating from domestic or industrial sources.	*EPA, 2008b*
Organic matter	The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substance synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.	*EPA, 2008c*
Organism	Any form of animal or plant life.	*EPA, 2008b*
Organism	Any form of animal or plant life.	*USBR, 2008*
Organochlorine compound	Synthetic organic compounds containing chlorine. As generally used, term refers to compounds containing mostly or exclusively carbon, hydrogen, and chlorine. Examples include organochlorine insecticides, polychlorinated biphenyls, and some solvents containing chlorine.	*USGS, 2008*
Organochlorine insecticide	A class of organic insecticides containing a high percentage of chlorine. Includes dichlorodiphenylethanes (such as DDT), chlorinated cyclodienes (such as chlordane), and chlorinated benzenes (such as lindane). Most organochlorine insecticides were banned because of their carcinogenicity, tendency to bioaccumulate, and toxicity to wildlife.	*USGS, 2008*
Organochlorine pesticide	See Organochlorine insecticide.	*USGS, 2008*
Organonitrogen herbicides	A group of herbicides consisting of a nitrogen ring with associated functional groups and including such classes as triazines and acetanilides. Examples include atrazine, cyanazine, alachlor, and metolachlor.	*USGS, 2008*
Organophosphate insecticides	A class of insecticides derived from phosphoric acid. They tend to have high acute toxicity to vertebrates. Although readily metabolized by vertebrates, some metabolic products are more toxic than the parent compound.	*USGS, 2008*
Organo-phosphates	Pesticides that contain phosphorus; short-lived, but some can be toxic when first applied.	*EPA, 2008b*
Organophos-phorus insecticides	Insecticides derived from phosphoric acid and are generally the most toxic of all pesticides to vertebrate animals.	*USGS, 2008*
Orientation Exercise (Seminar)	An activity designed to introduce, discuss, and update emergency planning documents, organization structure, or early warning system (EWS) component to familarize key personnel with the emergency procedures and their responsibilities. This may be through a lecture, panel discussion, or general discussion and can include visual presentations. This should involve all personnel with a role in the plan, problem, or procedure. It should also include a review of past cases, if any, for lessons learned.	*USBR, 2008*
Orifice	An opening with a closed perimeter and a regular form through which water flows. If the perimeter is not closed or if the opening flows only partially full, the orifice becomes a weir.	*USBR, 2008*

Original ground (surface)	The surface of the earth as it exists in an unaltered state (i.e. prior to any earthwork). See existing ground.	*USBR, 2008*
O-ring	A rubber seal used around stems of some valves to prevent water from leaking past.	*USBR, 2008*
OTD (offer to dedicate)	An OTD is a document, recorded against the title to a property, which is an offer of dedication to the people of the State of California of an easement over the property or a portion of the property. Generally, an OTD allows for specific uses in of the area of the property involved (for example, allowing the public to walk across the area). The offer conveys an easement in perpetuity only upon its acceptance on behalf of the people by a public agency or by a nonprofit private entity approved by the executive director of the Coastal Commission.	*CCC, 2008*
Outfall	The place where effluent is discharged into receiving waters.	*EPA, 2008b*
Outfall	The mouth or outlet of a river, stream, lake, drain, or sewer.	*USACE, 1999*
Outfall	The point where water flows from a conduit, stream, or drain.	*EPA, 2008c*
Outflow	The amount of water passing a given point downstream of a structure, expressed in acre-feet per day or cubic feet per second. Water flowing out of a body of water.	*USBR, 2008*
Outlet	An opening through which water can be freely discharged from a reservoir to the river for a particular purpose.	*USBR, 2008*
Outlet capacity	The amount of water that can be safely released through the outlet works.	*USBR, 2008*
Outlet channel (exit channel)	Channel downstream from terminal structure that conveys releases back to the "natural" stream or river. Channel can be excavated in rock or soil, with or without riprap, soil cement or other types of erosion protection.	*USBR, 2008*
Outlet gate	A gate controlling the flow of water through a reservoir outlet.	*USBR, 2008*
Outlet Works	A combination of structures and equipment required for the safe operation and control of water released from a reservoir to serve various purposes, i.e., regulate stream flow and quality; release floodwater; and provide irrigation, municipal, and/or industrial water. Included in the outlet works are the intake structure, conduit, control house-gates, regulating gate or valve, gate chamber, and stilling basin. A series of components located in a dam through which normal releases from the reservoir are made. A device to provide controlled releases from a reservoir. A pipe that lets water out of a reservoir, mainly to supply downstream demands.	*USBR, 2008*
Outlet works tower	A tower within a reservoir that contains the mechanisms to open the entrance to the outlet works.	*USBR, 2008*
Outlier	Outliers (extreme events) are data points which depart from the trend of the rest of the data.	*USGS, 1982*
Outwash	Soil material washed down a hillside by rainwater and deposited upon more gently sloping land.	*USGS, 2008*

Overall safety of dams classification	One of the following classifications is assigned to a dam following an onsite examination and subsequent analyses using available data and state-of-the-art knowledge: Satisfactory. - No existing or potential dam safety deficiencies are recognized. Safe performance is expected under all anticipated loading conditions, including such events as the maximum credible earthquake (MCE) and the probable maximum flood (PMF). Fair. - No existing dam safety deficiencies are recognized for normal loading conditions. Infrequent hydrologic and/or seismic events would probably result in a dam safety deficiency. Conditionally Poor. - A potential dam safety deficiency is recognized for unusual loading conditions that may realistically occur during the expected life of the structure. Conditionally Poor may also be used when uncertainties exist as to critical analysis parameters that identify a potential dam safety deficiency; further investigations and studies are necessary. Poor. - A potential dam safety deficiency is clearly recognized for normal loading conditions. Immediate actions to resolve the deficiency are recommended; reservoir restrictions may b	*USBR, 2008*
Overbreak	Moving or loosening of rock as a result of a blast, beyond the intended line of cut.	*USBR, 2008*
Overburden	Rock and soil cleared away before mining.	*EPA, 2008b*
Overburden	Soil or rock lying on top of a pay formation.	*USBR, 2008*
Overdraft	The pumping of water from a groundwater basin or aquifer in excess of the supply flowing into the basin; results in a depletion or "mining" of the groundwater in the basin.	*EPA, 2008b*
Overdraft	The pumping of water from a ground water basin or aquifer in excess of the supply flowing into the basin. This pumping results in a depletion or "mining" of the ground water in the basin.	*USBR, 2008*
Overexcavation	Excavation beyond specified or directed excavation. Removing unsuitable foundation material.	*USBR, 2008*
Overflow dam	A dam designed to be overtopped.	*USBR, 2008*
Overflow spillway (ogee spillway)	A spillway that has a control weir that is ogee-shaped (S-shaped) in profile. A spillway on a dam that functions like a dam, but allows water to safely flow over it.	*USBR, 2008*
Overhang	Projecting parts of a face or bank.	*USBR, 2008*
Overhaul	Movement of (earth) material far enough so that payment, in addition to excavation pay, is made for haulage. The distance in excess of that given as the stated haul distance to haul excavated material.	*USBR, 2008*
Overland flow	A land application technique that cleanses waste water by allowing it to flow over a sloped surface. As the water flows over the surface, contaminants are absorbed and the water is collected at the bottom of the slope for reuse.	*EPA, 2008b*
Overland flow	The part of surface runoff flowing over land surfaces toward stream channels.	*USGS, 2008*
Overtopping	Flow of water over the top of a dam or embankment.	*USBR, 2008*

Overturn	The almost spontaneous mixing of all layers of water in a reservoir or lake when the water temperature becomes similar from top to bottom. This may occur in the fall/winter when the surface waters cool to the same temperature as the bottom waters and also in the spring when the surface waters warms after the ice melts.	*USBR, 2008*
Overwash	The process by which severe storm waves sweep over a dune, beach, or shore structures, often causing flooding.	*CCC, 2008*
Overwinding	A rope or cable wound and attached so that it stretches from the top of a drum to the load.	*USBR, 2008*
Oxbow	A term used to describe the severed meander after a chute is formed.	*FISHWR, 2001*
Oxbow	An abandoned meander in a river or stream, caused by a cutoff. Used to describe the U-shaped bend in the river or the land within a bend of a river.	*USACE, 1999*
Oxbow channel	A natural U-shaped channel in a river as viewed from above.	*USBR, 2008*
Oxbow lake	A body of water created after clay plugs the oxbow from the main channel.	*FISHWR, 2001*
Oxygen demand	Measure of the dissolved oxygen used by a system (microorganisms) in the oxidation of organic matter. (See also Biochemical oxygen demand.)	*EPA, 2008c*
Oxygen depletion	A deficit of dissolved oxygen in a water system due to oxidation of organic matter.	*EPA, 2008c*
Ozonation	The application of ozone to water for disinfection or for taste and odor control.	*USBR, 2008*
Ozone	A gas that is bubbled through water to kill germs.	*USBR, 2008*

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Pacific flyway	An established air route of migratory birds along the west coast of the United States.	*USBR, 2008*
Paleo	Refers to the studies of the geolgic past.	*USBR, 2008*
Paleoflood	Paleoflood peak discharges are estimated using geology, fluvial, geomorphology, and stratigraphic records. Geologic information is used to determine flood depths, carbon 14 dating techniques are typically used to determine the time frame when these depths were reached, and hydraulic models, such as step backwater techniques, are used to determine the associated flow given the depth. These floods are used to extend gage records. Floods that have happened approximately 200- to 10,000-years ago can be estimated.	*USBR, 2008*
Paleoflood data	Paleoflood data include two broad categories: fluvial geomorphic evidence and botanical evidence. Paleoflood data are distinguished from both historical and systematic (conventional) flood data by lack of human observation, regardless of the time of occurrence.	*USBR, 2008*

Paleoflood hydrology	The study of past or ancient floods which occurred prior to the time of human observation or direct measurement by modern hydrologic procedures. The study of the movements of water and sediment in channels before the time of continuous hydrologic records or direct measurements.	*USBR, 2008*
Palustrine habitat	Marsh habitat.	*USBR, 2008*
Pan evaporation	Evaporative water losses from a standardized pan. Pan evaporation is sometimes used to estimate crop evapotranspiration and assist in irrigation scheduling.	*USBR, 2008*
Paradox gate	Similar to a ring follower gate except the gate leaf is supported along either side by endless trains of rollers. The gate seals by the rollers disengaging from support of the leaf when the gate is completely closed, allowing hydrostatic forces to seal the gate.	*USBR, 2008*
Parallel path flow	As defined by the North American Electric Reliability Council, this refers to the flow of electric power on an electric system's transmission facilities resulting from scheduled electric power transfers between two other electric systems. Electric power flows on all interconnected parallel paths in amounts inversely proportional to each path's resistance.	*USBR, 2008*
Parameter	A variable, measurable property whose value is a determinant of the characteristics of a system; e.g. temperature, pressure, and density are parameters of the atmosphere.	*EPA, 2008b*
Parameter	A characteristic descriptor, such as a mean or standard deviation.	*USGS, 1982*
Parameter	Measured or observed property.	*DOC, 2005*
Parapet wall	A solid wall built along the top of a dam (upstream and/or downstream edge) used for ornamentation, for safety of vehicles and pedestrians, or to prevent overtopping caused by wave runup.	*USBR, 2008*
Parshall flume	Device used to measure the flow of water in an open channel.	*EPA, 2008b*
Parshall Flume (Improved Venturi Flume)	A flume with a specially shaped open-channel flow section that may be installed in a drainage lateral or ditch to measure the rate of flow of water. A calibrated device consisting of a broad and flat converging section, a narrow downward sloping throat, and a diverging upward sloping section developed to measure a wide range of flows in an open channel. A calibrated device, based on the principle of critical flow, used to measure the flow of water in open channels. See short-throated flume.	*USBR, 2008*
Part per million (ppm)	Unit of concentration equal to one milligram per kilogram or one milligram per liter.	*USGS, 2008*
Partial intervention/ management	Actions to facilitate natural processes to aid in the recovery of a stream corridor that has a slow or uncertain recovery trajectory.	*FISHWR, 2001*
Particle acceleration	The time rate of change of particle velocity.	*USBR, 2008*
Particle displacement	The difference between the initial position of a soil particle and any later temporary position during shaking.	*USBR, 2008*
Particle size	Diameter of the various particles comprising a particular soil.	*USBR, 2008*
Particle velocity	The time rate of change of particle displacement.	*USBR, 2008*
Partner	Any entity who voluntarily participates with another on a project.	*USFWS, 2008*

Partnership	An informal or formal effort by two or more partners to achieve a shared objective or complete a project.	*USFWS, 2008*
Parts per billion (ppb)	A measurement of concentration on a weight or volume basis. Equivalent to micrograms per liter. One ppb is equivalent to one drop of water in 55,000 gallons.	*USBR, 2008*
Parts per million (ppm)	A measurement of concentration on a weight or volume basis. Equivalent to milligrams per liter (mg/l). One ppm is comparable to one drop of water in 55 gallons.	*USBR, 2008*
Pascal (Pa)	The pressure or stress of one newton per square meter. 1 psi = 6895 Pa.	*USBR, 2008*
Pass	A working trip or passage of an excavating, grading, or compaction machine. See compaction.	*USBR, 2008*
Passive earth pressure	The maximum value of earth pressure. This condition exists when a soil mass is compressed sufficiently to cause its internal shearing resistance along a potential failure surface to be completely mobilized.	*USBR, 2008*
Patch	A non-linear area (polygon) that is less abundant than, and different from, the matrix.	*FISHWR, 2001*
Pathogen	Disease-causing agent, especially microorganisms such as bacteria, protozoa, and viruses.	*EPA, 2008c*
Pathogen	A disease-producing agent; usually applied to a living organism. Generally, any viruses, bacteria, or fungi that cause disease.	*DOC, 2005*
Pathogens	Microorganisms (e.g., bacteria, viruses, or parasites) that can cause disease in humans, animals and plants.	*EPA, 2008b*
Pathogens	Any viruses, bacteria, or fungi that cause disease.	*USACE, 1999*
Pattern cracking	Fine cracks in the form of a pattern on a concrete surface.	*USBR, 2008*
Pay formation	A layer or deposit of soil or rock whose value is sufficient to justify excavation.	*USBR, 2008*
Payline	Lines of excavation, backfill, compacted backfill or embankment which are described in the specifications or shown on the drawings which describe or show the limits to which earthwork is paid for.	*USBR, 2008*
Pea gravel	A uniformly graded gravel with a particle size of approximately 3/16".	*USBR, 2008*
Peak flow	Maximum instantaneous flow in a specified period of time.	*USBR, 2008*
Peak flow	The maximum instantaneous discharge of a stream or river at a given location.	*DOC, 2005*
Peak ground acceleration (PGA)	That acceleration representing the peak acceleration of ground motion.	*USBR, 2008*
Peak runoff	The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.	*EPA, 2008c*
Peat	Partially decomposed plants and other organic material that build up in poorly drained wetland habitats.	*USACE, 1999*
Peat	A fibrous mass of organic matter in various stages of decomposition, generally dark brown to black in color and of spongy consistency. A soft light swamp soil consisting mostly of decayed vegetation. See humus.	*USBR, 2008*
Pegmatite	Very coarse-grained intrusive igneous rock of granitic composition that typically fills fractures to form veins.	*USBR, 2008*

Penstock	A pipeline or conduit designed to withstand pressure surges leading from a forebay or reservoir to power-producing turbines, or pump units. Conduit used to convey water under pressure to the turbines of a hydroelectric plant. A pressurized pipeline or shaft between the reservoir and hydraulic machinery.	*USBR, 2008*
Per capita use	The average amount of water used per person during a standard time period, generally per day.	*USBR, 2008*
Per capita water use	The water produced by or introduced into the system of a water supplier divided by the total residential population; normally expressed in gallons per capita per day (gpcd).	*USACE, 1999*
Percent chance	A probability multiplied by 100.	*USGS, 1982*
Percent saturation	The amount of a substance that is dissolved in a solution compared to the amount that could be dissolved in it.	*EPA, 2008b*
Perched beach	A sill that retains sand (sediment) behind or landward of it. The sill can be placed offshore or above the high tide line to hold and protect a fill and eliminate the need for offshore sand to form a stable beach.	*CCC, 2008*
Perched groundwater	Groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater with which it is not hydrostatically connected.	*USACE, 1999*
Perched water	Zone of unpressurized water held above the water table by impermeable rock or sediment.	*EPA, 2008b*
Perched water table	Underground water lying over dry soil, and sealed from it by an impervious layer. A water table usually of limited area maintained above the normal free water elevation by the presence of an intervening relatively impervious confining stratum.	*USBR, 2008*
Percolating water	Water that passes through rocks or soil under the force of gravity.	*EPA, 2008b*
Percolation	1. The movement of water downward and radially through subsurface soil layers, usually continuing downward to ground water. Can also involve upward movement of water. 2. Slow seepage of water through a filter.	*EPA, 2008b*
Percolation	The downward movement of water through the soil or alluvium to a groundwater table.	*USACE, 1999*
Percolation	Downward movement of water through the soil profile or other porous media. Water soaking into the ground. Flow through a porous substance. See seepage.	*USBR, 2008*
Percolation	The movement of water through the openings in rock or soil.	*DOC, 2005*
Percolation rate	The rate at which water moves through porous media, such as soil. The intake rate used for designing wastewater absorption systems.	*USBR, 2008*
Perennial stream	A stream that flows continually throughout the year.	*USBR, 2008*
Perennial stream	A stream that normally has water in its channel at all times.	*USGS, 2008*
Perennial streams	Streams that flow continuously throughout the year.	*EPA, 2006*
Perennial streams	Streams that flow continuously during both wet and dry times. Base flow is dependably generated from the movement of groundwater into the channel.	*FISHWR, 2001*
Perennial streams	Streams that flow continuously.	*USACE, 1999*

Perennial yield	The maximum quantity of water that can be annually withdrawn from a groundwater basin over a long period of time (during which water supply conditions approximate average conditions) without developing an overdraft condition. Sometimes referred to as sustained yield.	*USACE, 1999*
Perennial yield	Maximum quantity of water that can be annually withdrawn from a ground water basin over a long period of time (during which water supply condditions approximate average conditions) without developing an overdraft condition.	*USBR, 2008*
Perforated pipe	Pipe designed to discharge water through small, multiple, closely spaced orifices or nozzles, placed in a segment of its circumference for irrigation purposes.	*USBR, 2008*
Perimeter foundation	A foundation type that supports a building on a low wall or footing extending around the outer edge of the building.	*CCC, 2008*
Periodic Facility Review (PFR)	A field review performed on a high- or significant-hazard dam every 6 years that entails a thorough examination from both operation and maintenance and dam safety perspectives. An examination on dams generally without the involvement of a senior dam engineer. The periodic facility review covers both O&M and dam safety issues. The regional office has primary lead responsibility for these reviews. Periodic facility reviews are generally followed every 3 years by a comprehensive facility review.	*USBR, 2008*
Periphyton	Microscopic underwater plants and animals that are firmly attached to solid surfaces such as rocks, logs, and pilings.	*EPA, 2008b*
Periphyton	Microscopic underwater plants and animals that are firmly attached to solid surfaces such as rocks, logs, pilings, and other structures.	*EPA, 2008c*
Periphyton	Microscopic plants and animals that are firmly attached to solid surfaces under water such as rocks, logs, pilings and other structures.	*USBR, 2008*
Periphyton	Organisms that grow on underwater surfaces, including algae, bacteria, fungi, protozoa, and other organisms.	*USGS, 2008*
Permafrost	Perennially frozen soil.	*USBR, 2008*
Permanent wilting point (permanent wilting percentage)	Soil water content below which plants cannot readily obtain water and permanently wilt. See wilting point.	*USBR, 2008*
Permeability	The rate at which liquids pass through soil or other materials in a specified direction.	*EPA, 2008b*
Permeability	The capability of soil or other geologic formations to transmit water.	*USACE, 1999*
Permeability	The measure of the flow of water through soil. The ease (or measurable rate) with which gasses, liquids, or plant roots penetrate or pass through a layer of soil or porous media. The capacity or ability of a porous rock, sediment, or soil to allow the movement of water through its pores.	*USBR, 2008*
Permeability	The ability of a material to allow the passage of a liquid, such as water through rocks. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas impermeable materials, such as clay, don't allow water to flow freely.	*DOC, 2005*

Permeable	Having pores or openings that permit liquids or gasses to pass through.	*USBR, 2008*
Permeameter	Device for containing the soil sample and subjecting it to fluid flow in order to measure permeability or hydraulic conductivity.	*USBR, 2008*
Permeate	To penetrate and pass through, as water penetrates and passes through soil and other porous materials.	*USBR, 2008*
Permissible dose	The dose of a chemical that may be received by an individual without the expectation of a significantly harmful result.	*EPA, 2008b*
Permit	An authorization, license, or equivalent control document issued by EPA or an approved Federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.	*EPA, 2008c*
Permit	Permits enable the public to engage in legitimate wildlife-related activities that would otherwise be prohibited by law. Under ESA, a document issued by FWS or NOAA Fisheries under authority of section 10 of the ESA allowing an action otherwise prohibited under section 9. The FWS has two different programs that issue ESA permits. The Endangered Species Program issues ESA permits for native species (except for permits to import/export native species). The Division of Management Authority issues ESA permits for non-native species and also for the import/export of both non-native and native species. NOAA Fisheries issues ESA permits for marine species, and FWS/NOAA have joint responsibilities for some species such as sea turtles.	*USFWS, 2008*
Permit	Any license, certificate, approval, or other entitlement for use granted or denied by any public agency.	*CCC, 2008*
Permit compliance system (PCS)	Computerized management information system which contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.	*EPA, 2008c*
Persistence	Refers to the length of time a compound stays in the environment, once introduced. A compound may persist for less than a second or indefinitely.	*EPA, 2008b*
Persistent pesticides	Pesticides that do not break down chemically or break down very slowly and remain in the environment after a growing season.	*EPA, 2008b*
Person	Any individual, organization, partnership, limited liability company, or other business association or corporation, including any utility, and any federal, state, local government, or special district or an agency thereof.	*CCC, 2008*
Pervious	Permeable, having openings that allow water to pass through.	*USBR, 2008*
Pervious zone	A part of the cross section of an embankment dam comprising material of high permeability.	*USBR, 2008*
Pest	An insect, rodent, nematode, fungus, weed or other form of terrestrial or aquatic plant or animal life that is injurious to health or the environment.	*EPA, 2008b*

Pesticide	Substances or mixture there of intended for preventing, destroying, repelling, or mitigating any pest. Also, any substance or mixture intended for use as a plant regulator, defoliant, or desiccant.	*EPA, 2008b*
Pesticide	A chemical applied to crops, rights of way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents or other "pests."	*USGS, 2008*
Pesticide tolerance	The amount of pesticide residue allowed by law to remain in or on a harvested crop. EPA sets these levels well below the point where the compounds might be harmful to consumers.	*EPA, 2008b*
Petcock	A small drain valve. A small ground key type valve used with soft copper tubing.	*USBR, 2008*
Petition	A formal request from an interested individual to list, reclassify, or delist a species, or to revise critical habitat for a listed species under ESA. Critical habitat can be petitioned for designation under the Administrative Procedures Act.	*USFWS, 2008*
pH	An expression of the intensity of the basic or acid condition of a liquid; may range from 0 to 14, where 0 is the most acid and 7 is neutral. Natural waters usually have a pH between 6.5 and 8.5.	*EPA, 2008b*
pH	The negative algorithm of the molar concentration of the hydrogen ion, or more simply, acidity.	*USACE, 1999*
pH	The symbol for the logarithm of the reciprocal of hydrogen ion concentration in gram atoms per liter. A measurement of soil acidity. A relative scale, from 0 to 14, of how acidic or basic (alkaline) a material is, where a pH of 7 is neutral, smaller readings increasingly acid. Indicator of acidity. An expression of the intensity of the basic or acid condition of a liquid. Natural waters usually have a pH between 6.5 and 8.5.	*USBR, 2008*
pH	A measure of the relative acidity or alkalinity of water. Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity (high concentration of hydrogen ions), while pH levels higher than 7 indicate increasingly basic solutions (low concentration of hydrogen ions).	*DOC, 2005*
pH	The logarithm of the reciprocal of the hydrogen ion concentration (activity) of a solution; a measure of the acidity (pH less than 7) or alkalinity (pH greater than 7) of a solution; a pH of 7 is neutral.	*USGS, 2008*
Phased approach	Under the phased approach to TMDL development, LAs and WLAs are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.	*EPA, 2008c*
Phenols	A class of organic compounds containing phenol (C6H5OH) and its derivatives. Used to make resins, weed killers, and as a solvent, disinfectant, and chemical intermediate. Some phenols occur naturally in the environment.	*USGS, 2008*
Philadelphia rod	A leveling rod in which the hundredths of feet, or eights of inches, are marked by alternate bars of color the width of the measurement.	*USBR, 2008*

Phosphates	Certain chemical compounds containing phosphorus.	*EPA, 2008b*
Phosphorus	An essential chemical food element that can contribute to the eutrophication of lakes and other water bodies. Increased phosphorus levels result from discharge of phosphorus-containing materials into surface waters.	*EPA, 2008b*
Phosphorus	A nutrient essential for growth that can play a key role in stimulating aquatic growth in lakes and streams.	*USGS, 2008*
Photogrammetry	Techniques of obtaining precise measurements from images. This process can derive elevation from specially created stereo pairs of aerial photos.	*USBR, 2008*
Photosynthesis	The manufacture by plants of carbohydrates and oxygen from carbon dioxide mediated by chlorophyll in the presence of sunlight.	*EPA, 2008b*
Photosynthesis	Process in which chlorophyll-containing cells convert light into chemical energy, forming organic compounds from inorganic compounds.	*USBR, 2008*
Photosynthesis	Synthesis of chemical compounds by organisms with the aid of light. Carbon dioxide is used as raw material for photosynthesis and oxygen is a product.	*USGS, 2008*
Phreatic surface	The free surface of water seeping at atmospheric pressure through soil or rock.	*USBR, 2008*
Phreatophyte	Water-loving plant. Vegetation that consumes much water.	*USBR, 2008*
Phthalates	A class of organic compounds containing phthalic acid esters [C6H4(COOR)2] and derivatives. Used as plasticizers in plastics. Also used in many other products (such as detergents, cosmetics) and industrial processes (such as defoaming agents during paper and paperboard manufacture, and dielectrics in capacitors).	*USGS, 2008*
Physical habitat	For streams and rivers, the area in and around the stream or river, including its bed, banks, in -stream and overhanging vegetation, and riparian zone.	*EPA, 2006*
Physiography	Description of nature or natural phenomenon in general.	*USBR, 2008*
Physiography	A description of the surface features of the Earth, with an emphasis on the origin of landforms.	*USGS, 2008*
Phytophagous	Plant eating.	*USBR, 2008*
Phytoplankton	Minute plants, usually algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.	*USACE, 1999*
Phytoplankton	Small, usually microscopic plants (such as algae), found in lakes, reservoirs, and other bodies of water.	*USBR, 2008*
Phytoplankton	See Plankton.	*USGS, 2008*
Pico	A prefix meaning "one trillionth".	*USBR, 2008*
Picocurie (pCi)	One trillionth (10-12) of the amount of radioactivity represented by a curie (Ci). A curie is the amount of radioactivity that yields 3.7 x 1010 radioactive disintegrations per second (dps). A picocurie yields 2.22 disintegrations per minute (dpm) or 0.037 dps.	*USGS, 2008*
Piezometer	A nonpumping well, generally of small diameter, for measuring the elevation of a water table.	*EPA, 2008b*

Piezometer	An instrument which measures pressure head or hydraulic pressures in a conduit or hydraulic pressures within the fill of an earth dam or the abutment; at the foundation because of seepage or soil compression; or on a flow surface of a spillway, gate, or valve.	*USBR, 2008*
Piezometric surface	The surface at which water will stand in a series of piezometers.	*USBR, 2008*
Pig	An air manifold having a number of pipes which distribute compressed air coming through a single large line.	*USBR, 2008*
Pile	Relatively slender structural element which is driven, or otherwise introduced, into the soil, usually for the purpose of providing vertical or lateral support.	*USBR, 2008*
Pile	A long, heavy timber or section of concrete or metal driven or drilled into the earth or seabed to serve as a support or protection.	*CCC, 2008*
Pioneering	The first working over of rough or overgrown areas.	*USBR, 2008*
Pipe	A circular conduit constructed of any one of a number of materials that conveys water by gravity or under pressure. A cylindrical conduit or conductor, the wall thickness of which is sufficient to receive a standard pipe thread. See crown, flexible pipe, haunches, invert, rigid pipe, and springline.	*USBR, 2008*
Pipe trench	A temporary excavation in which pipe is placed and eventually covered with soil material.	*USBR, 2008*
Piping	The erosion of embankment or foundation material (soil) due to leakage. The action of water passing through or under an embankment dam and carrying with it to the surface at the downstream face some of the finer material. The progressive removal of soil particles from a mass by percolating water leading to the development of channels. The progressive development of internal erosion by seepage, appearing downstream as a hole discharging water. The process of conveying erodible embankment or foundation materials through a continuous, open "pipe" which is able to maintain a self-supported roof. The pipe normally begins at an unprotected exit and works it's way upstream (up gradient) along an erodible flow path until the reservoir is reached.	*USBR, 2008*
Pit	Any mine, quarry, or excavation area worked by the open-cut method to obtain material of value.	*USBR, 2008*
Pit run gravel	Natural gravelly material taken from excavation. Gravelly material which is not processed.	*USBR, 2008*
Pitching	Squared masonry, precast blocks, or embedded stones laid in regular fashion with dry or filled joints on the upstream slope of an embankment dam or on a reservoir shore or on the sides of a channel as a protection against wave and ice action.	*USBR, 2008*
Pixel	A contraction of the phrase 'picture element.' The smalles unit of information in an image or raster map. Referred to as a cell in an image or grid.	*EPA, 1997*
Placed	To put in a particular place or in a particular state.	*USBR, 2008*
Planimeter	A device that measures area.	*USBR, 2008*

Plankton	Tiny, usually microscopic, plants (phytoplankton)and animals (zooplankton) with limited powers of locomotion, usually living free in the water away from substrates. Minute plants and animals floating in bodies of water; often a major source of nutrition for larger aquatic life forms.	*USBR, 2008*
Plankton	Floating or weakly swimming organisms at the mercy of the waves and currents. Animals of the group are called zooplankton and the plants are called phytoplankton.	*USGS, 2008*
Planning basis	Guidance concerning: (1) size of planning area (distance); (2) time dependence of releases; and (3) flood characteristics of releases.	*USBR, 2008*
Planning standard(s)	Standards which emergency plans of the dam operating organization and local authorities should conform to.	*USBR, 2008*
Plant	Station where mechanical, chemical, and/or nuclear energy is converted into electric energy.	*USBR, 2008*
Plastic limit	The water content corresponding to an arbitrary limit between the plastic and the semisolid state of consistency of a soil; water content at which a soil will just begin to crumble when rolled into a thread approximately 1/8 inches in diameter. The minimum amount of water in terms of percent of oven-dry weight of soil that will make the soil plastic.	*USBR, 2008*
Plastic soil	A soil that exhibits plasticity.	*USBR, 2008*
Plasticity	The property of a soil or rock which allows it to be deformed beyond the point of recovery without cracking or appreciable volume change.	*USBR, 2008*
Plasticity index	Numerical difference between the liquid limit and the plastic limit.	*USBR, 2008*
Playa	An intermittent shallow lake formed at the bottom of an undrained desert basin after heavy rains.	*USBR, 2008*
Pleistocene	A period of geologic time spanning 2 million - 11,000 years ago.	*CCC, 2008*
Pliocene	A period of geologic time spanning 7-2 million years ago.	*CCC, 2008*
Plot	Area of land that is studied or used for an experimental purpose, in which sample areas are often located.	*USBR, 2008*
Plumb	Exactly vertical; at right angles to the horizontal.	*USBR, 2008*
Plumb Bob	A pointed weight hung from a string. Used for vertical alignment.	*USBR, 2008*
Plume	1. A visible or measurable discharge of a contaminant from a given point of origin. Can be visible or thermal in water, or visible in the air as, for example, a plume of smoke. 2 The area of radiation leaking from a damaged reactor. 3. Area downwind within which a release could be dangerous for those exposed to leaking fumes.	*EPA, 2008b*
Plunge pool	A natural or artifically created pool that dissipates the energy of free-falling water.	*USBR, 2008*
Ply	One of several layers of fabric or of other strength-contributing material.	*USBR, 2008*
Pneumatic	Powered or inflated by compressed air.	*USBR, 2008*
Pocket beach	A small beach formed between two points or headlands, often at the mouth of a coastal stream. Pocket beaches are common throughout the California coastline.	*CCC, 2008*

Point bar	The convex side of a meander bend that is built up due to sediment deposition.	*USACE, 1999*
Point bar	A gravel or sand deposit on the inside of a river bend; an actively mobile river feature.	*USFS, 2002*
Point source	A stationary location or fixed facility from which pollutants are discharged; any single identifiable source of pollution; e.g. a pipe, ditch, ship, ore pit, factory smokestack.	*EPA, 2008b*
Point source	Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.	*EPA, 2008c*
Point source	Any discernible, confined, or discrete conveyance from which pollutants are or may be discharged, including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft. A stationery location or fixed facility from which pollutants are discharged or emitted. Any single identifiable source of pollution. Pollution that comes from a well-defined source.	*USBR, 2008*
Point source	A source at a discrete location such as a discharge pipe, drainage ditch, tunnel, well, concentrated livestock operation, or floating craft.	*USGS, 2008*
Point source (pollution) (PS)	(1) A stationary or clearly identifiable source of large individual water or air pollution emission, generally of an industrial nature. (2) Any discernible, confined, or discrete conveyance from which pollutants are or may be discharged, including (but not limited to) pipes, ditches, channels, tunnels, conduits, wells, containers, rolling stock, concentrated animal feeding operations, or vessels. Point source is also legally and more precisely defined in the federal regulations. Contrast with non-point source (NPS) pollution.	*USACE, 1999*
Point source contaminant	Any substance that degrades water quality and originates from discrete locations such as discharge pipes, drainage ditches, wells, concentrated livestock operations, or floating craft.	*USGS, 2008*
Point-source pollution	Water pollution coming from a single point, such as a sewage-outflow pipe.	*DOC, 2005*
Pollen	The fertilizing element of flowering plants; background air pollutant.	*EPA, 2008b*
Pollutant	Generally, any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.	*EPA, 2008b*
Pollutant	(1) Something that pollutes, especially a waste material that contaminates air, soil, or water. (2) Any solute or cause of change in physical, chemical, or biological properties that renders water unfit for a given use.	*USACE, 1999*
Pollutant	Something that is harmful, destructive, or deadly.	*USFS, 2002*

Pollutant	Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water. (CWA Section 502(6)).	*EPA, 2008c*
Pollutant	Any inorganic or organic substance that contaminates air, water or soil. Generally, any substance introduced into the environment that adversely affects the usefulness of a resource.	*USBR, 2008*
Pollutant	Any substance that, when present in a hydrologic system at sufficient concentration, degrades water quality in ways that are or could become harmful to human and/or ecological health or that impair the use of water for recreation, agriculture, industry, commerce, or domestic purposes.	*USGS, 2008*
Pollution	Generally, the presence of a substance in the environment that because of its chemical composition or quantity prevents the functioning of natural processes and produces undesirable environmental and health effects. Under the Clean Water Act, for example, the term has been defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water and other media.	*EPA, 2008b*
Pollution	Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or maninduced alteration of the physical, biological, chemical, and radiological integrity of water.	*EPA, 2008c*
Pollution	A resource that is out of place. Generally, the presence of matter or energy whose nature, location or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, and radiological integrity of water.	*USBR, 2008*
Pollution (of water)	The alteration of the physical, chemical, or biological properties of water by the introduction of any substance into water that adversely affects any beneficial use of water.	*USACE, 1999*
Polychlorinated biphenyls (PCBs)	A mixture of chlorinated derivatives of biphenyl, marketed under the trade name Aroclor with a number designating the chlorine content (such as Aroclor 1260). PCBs were used in transformers and capacitors for insulating purposes and in gas pipeline systems as a lubricant. Further sale for new use was banned by law in 1979.	*USGS, 2008*
Polycyclic aromatic hydrocarbon (PAH)	A class of organic compounds with a fused-ring aromatic structure. PAHs result from incomplete combustion of organic carbon (including wood), municipal solid waste, and fossil fuels, as well as from natural or anthropogenic introduction of uncombusted coal and oil. PAHs include benzo(a)pyrene, fluoranthene, and pyrene.	*USGS, 2008*
Polyvinyl Chloride (PVC)	A type of plastic used to make pipe and fittings for water distribution and irrigation.	*USBR, 2008*
Pond	A body of water smaller than a lake, often artificially formed.	*USACE, 1999*
Pond	A small lake. Water impounded by a diversion dam.	*USBR, 2008*

Ponding (or flooding)	A method for compacting soil using water added after the soil is in place until free water stands on the surface.	*USBR, 2008*
Pool	A reach of stream that is characterized by deep, low-velocity water and a smooth surface.	*USACE, 1999*
Pool	Portion of a stream with reduced current velocity, often with deeper water than surrounding areas and with a smooth surface.	*EPA, 2008c*
Pool	A deep area of a stream between rapids or where the current is slow.	*USBR, 2008*
Pool	A small part of the stream reach with little velocity, commonly with water deeper than surrounding areas.	*USGS, 2008*
Pool/riffle ratio	The ratio of surface area or length of pools to the surface area or length of riffles in a given stream reach, frequently expressed as the relative percentage of each category. Used to describe fish habitat rearing quality.	*USACE, 1999*
Pools	Deep areas within stream channels. Pools typically form in the thalweg near the outside bank of bends. The pool-to-pool spacing is normally about 5 to 7 times the channel width at bank full discharge.	*FISHWR, 2001*
Population	A group of interbreeding organisms occupying a particular space; the number of humans or other living creatures in a designated area.	*EPA, 2008b*
Population	The entire (usually infinite) number of data from which a sample is taken or collected. The total number of past, present, and future floods at a location on a river is the population of floods for that location even if the floods are not measured or recorded.	*USGS, 1982*
Population	Total of individuals occupying an area.	*USBR, 2008*
Population at risk	A population subgroup that is more likely to be exposed to a chemical, or is more sensitive to the chemical, than is the general population.	*EPA, 2008b*
Population at risk (PAR)	The population potentially affected by flood waters as a result of large operational releases or dam failure. The potential number of persons whose lives are at risk in the event of a dam failure.	*USBR, 2008*
Population density	Number per unit area of individuals of any given species at a given time.	*USBR, 2008*
Pore	A small to minute opening or interstice in a rock or soil.	*USBR, 2008*
Pore pressure	The interstitial pressure of fluid (air or water) within a mass of soil, rock, or concrete.	*USBR, 2008*
Pore spaces	The open areas, or spaces, in soil, sediments, and rocks that are filled by air or water.	*USBR, 2008*
Pore-water pressure	Internal hydrostatic pressure in an embankment caused by the level of water in the reservoir acting through pressure-transmitting paths between soil particles in the fill.	*USBR, 2008*
Porosity	Degree to which soil, gravel, sediment, or rock is permeated with pores or cavities through which water or air can move.	*EPA, 2008b*

Porosity	The ratio of the volume of void space to the total volume of an undisturbed sample. A measure of the ratio of open space within a rock or soil to its total volume. A nondimensional value that expresses the ratio of the volume of pores to the total volume of a porous material and is usually expressed as a percentage. Porosity ranges from less than 1 percent to as much as 80 percent in some recently deposited clays, but in most granular materials it falls between about 5 and 40 percent. In free aquifers the porosity is equal to the specific retention plus the specific yield. The capacity of soil or rock to hold water.	*USBR, 2008*
Porosity	A measure of the water-bearing capacity of subsurface rock. With respect to water movement, it is not just the total magnitude of porosity that is important, but the size of the voids and the extent to which they are interconnected, as the pores in a formation may be open, or interconnected, or closed and isolated. For example, clay may have a very high porosity with respect to potential water content, but it constitutes a poor medium as an aquifer because the pores are usually so small.	*DOC, 2005*
Port governing body	The Board of Harbor Commissioners or Board of Port Commissioners which has authority over the Ports of Hueneme, Long Beach, Los Angeles, and San Diego Unified Port District.	*CCC, 2008*
Portal	An opening into a tunnel.	*USBR, 2008*
Positive pressure	Pressure within a pipe that is greater than atmospheric pressure.	*USBR, 2008*
Postaudit	A subsequent examination and verification of model predictive performance following implementation of an environmental control program.	*EPA, 2008c*
Posted operating instructions	Operations and maintenance instructions taken from the Standing Operating Procedures (SOP) that pertain to the mechanical features in the immediate area of the dam and which are posted adjacent to those features.	*USBR, 2008*
Postemergence herbicide	Herbicide applied to foliage after the crop has sprouted to kill or significantly retard the growth of weeds.	*USGS, 2008*
Potable water	Water that is safe for drinking and cooking.	*EPA, 2008b*
Potable water	Water that is safe and satisfactory for drinking and cooking.	*USBR, 2008*
Potable water	Water of a quality suitable for drinking.	*DOC, 2005*
Potential dam safety deficiency	A condition that currently does not significantly affect the safety of the dam, but is capable of becoming a dam safety deficiency; for example, continuing erosion, tree growth, or a potential adverse response of the dam to an unusual loading condition such as a PMF or MCE. A potential dam safety deficiency is considered to exist when critical analysis parameters are unknown such that additional investigations and studies are needed to conclusively determine whether or not a dam safety deficiency actually exists.	*USBR, 2008*
Potential energy	The energy of a body with respect to the position of the body. See kinetic energy.	*USBR, 2008*
Potential evapo-transpiration	Rate at which water, if available, would be removed from soil and plant surfaces.	*USBR, 2008*
Potential spill	An accident or other circumstances which threatens to result in discharge of oil or other hazardous substances.	*USBR, 2008*

Pounds per square inch (psi or lb/in2)	A pressure designation for pounds per square inch. May be pounds per square inch gage (psig) or absolute (psia). Psig measures pressure above the local atmospheric pressure. Psia measures pressure with absolute vaccuum as a reference.	*USBR, 2008*
Precast dam	A dam constructed mainly of large precast concrete blocks or sections.	*USBR, 2008*
Precautionary principle	When information about potential risks is incomplete, basing decisions about the best ways to manage or reduce risks on a preference for avoiding unnecessary health risks instead of on unnecessary economic expenditures.	*EPA, 2008b*
Precipitate	A substance separated from a solution or suspension by chemical or physical change.	*EPA, 2008b*
Precipitation	Removal of hazardous solids from liquid waste to permit safe disposal; removal of particles from airborne emissions as in rain (e.g. acid precipitation).	*EPA, 2008b*
Precipitation	The total measurable amount of water received in the form of snow, rain, drizzle, hail, and sleet. The process by which atmospheric moisture falls onto a land or water surface as rain, snow, hail, or other forms of moisture.	*USBR, 2008*
Precipitation	Rain, snow, hail, sleet, dew, and frost.	*DOC, 2005*
Precipitation	Any or all forms of water particles that fall from the atmosphere, such as rain, snow, hail, and sleet.	*USGS, 2008*
Predominant period	The period(s) at which maximum spectral energy is concentrated.	*USBR, 2008*
Preemergence herbicide	Herbicide applied to bare ground after planting the crop but prior to the crop sprouting above ground to kill or significantly retard the growth of weed seedlings.	*USGS, 2008*
Preference	Priority access to Federal power by public bodies and cooperatives.	*USBR, 2008*
Preliminary assessment	The process of collecting and reviewing available information about a known or suspected waste site or release.	*EPA, 2008b*
Prescribed elevation	The elevation as called out or dictated in notes, drawings or specifications paragraphs.	*USBR, 2008*
Prescriptive	Water rights which are acquired by diverting water and putting it to use in accordance with specified procedures; e.g. filing a request with a state agency to use unused water in a stream, river, or lake.	*EPA, 2008b*
Pressure	The load divided by the area over which it acts.	*USBR, 2008*
Pressure conduits	Closed conduits designed to convey interior flows through the line-of-protection under internal pressure. The inlet to a pressure conduit that discharges interior flows by force of gravity must be at a higher elevation than the river stage against which it functions. Some pressure conduits may serve as discharge conduits from pumping stations.	*FEMA, 2003*
Pressure head	The amount of force or pressure created by a depth of one foot of water.	*USBR, 2008*
Pressure relief pipes	Pipes used to relieve uplift or pore-water pressure in a dam foundation or in the dam structure.	*USBR, 2008*
Prestressed dam	A dam, the stability of which depends in part on the tension in steel wires, cables, or rods that pass through the dam and are anchored into the foundation rock. See Stewart Mountain Dam.	*USBR, 2008*

Primacy	The responsibility for ensuring that a law is implemented, and the authority to enforce a law and related regulations. A primacy agency has the primary responsibility for administrating and enforcing regulations.	*USBR, 2008*
Primary constituent element	A physical or biological feature essential to the conservation of a species for which its designated or proposed critical habitat is based on, such as space for individual and population growth, and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and habitats that are protected from disturbance or are representative of the species' historic geographic and ecological distribution.	*USFWS, 2008*
Primary excavation	Digging in undisturbed soil, as distinguished from rehandling stockpiles.	*USBR, 2008*
Primary production	Creation of organic matter by photosynthesis.	*USBR, 2008*
Primary productivity	A measure of the rate at which new organic matter is formed and accumulated through photosynthesis and chemosynthesis activity of producer organisms (chiefly, green plants). The rate of primary production is estimated by measuring the amount of oxygen released (oxygen method) or the amount of carbon assimilated by the plant (carbon method).	*EPA, 2008c*
Prime	The action of filling a pump casing with water to remove the air. Most pumps must be primed before startup or they will not pump any water.	*USBR, 2008*
Prime agricultural land	Those lands defined in paragraph (1), (2), (3), or (4) of subdivision (c) of Section 51201 of the Government Code.	*CCC, 2008*
Prior appropriation	A doctrine of water law that allocates the right to use water on a first-come first-serve basis.	*USBR, 2008*
Private sector	Industry, volunteer, quasi-governmental, etc., having a role in emergency planning and preparedness.	*USBR, 2008*
Probabilistic method	Method in which the variability of input values and the sensitivity of the results are taken into account to give results in the form of a range of probabilities for different outcomes.	*Mockett & Simm, 2002*
Probability	The likelihood that the risk (event) will occur. The probability that the event will occur is measured based on the following guidelines: High - Greater than or equal to 90 percent. Mitigation efforts must be vigorous and imaginative in order to reduce the probability of occurrence, commensurate with the severity of impact. Substantial - Greater than or equal to 75 percent but less than 90 percent. Mitigation efforts must be developed and pursued vigorously commensurate with possible impact. Medium - Greater than or equal to 50 percent but less than 75 percent. Mitigation efforts should be developed and pursued commensurate with possible impact. Low - Less than 50 percent. Indicates the risk is one that should be monitored, but appears to have been turned around and no action is needed.	*USBR, 2008*
Probability	The relative proportion or frequency of events leading to that outcome, out of all possible events.	*Mockett & Simm, 2002*
Probability of exceedance	The probability that a random flood will exceed a specified magnitude in a given period of time.	*USACE, 1999*

Probability of failure	Likelihood that, given the loading event and failure mode, the structure responds with the necessary adverse occurrences to ultimately result in uncontrolled reservoir release.	*USBR, 2008*
Probability of load	Likelihood that a certain loading event (static, seismic, hydrologic, other) occurs at a structure site.	*USBR, 2008*
Probability-based design	A type of random sampling technique in which every element of the population has a known probability of being selected for sampling.	*EPA, 2006*
Probable maximum flood (PMF) (maximum probable flood, MPF)	The largest flood that may reasonably be expected to occur at a given point on a stream from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible on a particular watershed. This term identifies estimates of hypothetical flood characteristics (peak discharge, volume, and hydrograph shape) that are considered to be the most severe "reasonably possible" at a particular location, based on relatively comprehensive hydrometeorological analyses of critical runoff-producing precipitation (and snowmelt, if pertinent) and hydrologic factors favorable for maximum flood runoff. The maximum runoff condition resulting from the most severe combination of hydrologic and meteorologic conditions that are considered reasonably possible for the drainage basin under study.	*USBR, 2008*
Probable maximum precipitation (PMP)	Theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a certain time of the year.	*USBR, 2008*
Production	Act or process of producing electrical energy from other forms of energy; also, amount of electrical energy produced expressed in kilowatt-hours (kWh).	*USBR, 2008*
Profile	A sectional view showing grades and distances, usually taken along the centerline.	*USBR, 2008*
Profundal	Deepest part of the ocean or lake where light does not penetrate. This layer usually has fewer nutrients, more silt, and fewer organisms than the surface.	*USBR, 2008*
Programmatic consultation	Consultation addressing multiple actions of an agency on a program-wide, regional, or other basis.	*USFWS, 2008*
Programmatic environmental impact statement (PEIS)	An environmental impact statement that addresses a proposal to implement a specific policy, to adopt a plan for a group of related actions, or to implement a specific statutory program.	*USBR, 2008*
Project	A single financial entity which can be composed of several units or divisions, integrated projects, or participating projects.	*USBR, 2008*
Project Hazardous Waste Coordinator (PHWC)	Individual designated by the Area Manager to coordinate records and maintain proper management of hazardous wastes on each project; acts as primary contact with the Regional Hazardous Waste Management Coordinator (HWMC).	*USBR, 2008*

Proper functioning condition	The functioning condition of riparian-wetland areas is a result of interaction among geology, soil, water, and vegetation. Riparian-wetland areas are functioning properly when adequate vegetation is present to dissipate stream energy associated with high-water flows, thereby reducing erosion and improving water quality; filter sediment and aid floodplain development; improve floodwater retention and ground water recharge; develop root masses that stabilize stream banks against cutting action; develop diverse ponding and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl, breeding, and other uses; and support greater biodiversity.	*USFS, 2002*
Proposed species	A species of animal or plant that is proposed in the Federal Register to be listed under section 4 of the Endangered Species Act.	*USFWS, 2008*
Proratable water	That portion of the total water supply available under provisions of sections 18 and 19 of Civil Action No. 21 (Federal District Court Judgment of January 31, 1945) that is subject to proration in times of water shortage.	*USBR, 2008*
Protective Action	An action or measure taken to avoid or reduce exposure to a hazard.	*USBR, 2008*
Protective action decision making (recommendations)	The process whereby local authorities select one of more actions to protect threatened populations. Personnel of the dam operating organization will make recommendations as part of the accident assessment and emergency classification level system process.	*USBR, 2008*
Protocol	A series of formal steps for conducting a test.	*EPA, 2008b*
Protozoa	One-celled animals that are larger and more complex than bacteria. May cause disease.	*EPA, 2008b*
Public Alert and Notification System	The system for obtaining the attention of the public and providing appropriate emergency information. Sirens are the most commonly used public alert devices but frequently are suppplemented by tone alert radios, visual warning devices for the hearing impaired, and telephone-based alert/notification systems.	*USBR, 2008*
Public comment period	The time allowed for the public to express its views and concerns regarding an action by EPA (e.g. a Federal Register Notice of proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).	*EPA, 2008b*
Public hearing	A formal meeting wherein EPA officials hear the public's views and concerns about an EPA action or proposal. EPA is required to consider such comments when evaluating its actions. Public hearings must be held upon request during the public comment period.	*EPA, 2008b*
Public involvement	Process of obtaining citizen input into each stage of development of planning documents. Citizen input is required in all environmental impact statements.	*USBR, 2008*
Public involvement plan	Document that presents the procedural plans of the Bureau of Reclamation to inform and gather information from project beneficiaries and the general public.	*USBR, 2008*

Public land order	An action on Federal lands to withdraw it from public use for a specified purpose.	*USBR, 2008*
Public notice	1. Notification by EPA informing the public of Agency actions such as the issuance of a draft permit or scheduling of a hearing. EPA is required to ensure proper public notice, including publication in newspapers and broadcast over radio and television stations. 2. In the safe drinking water program, water suppliers are required to publish and broadcast notices when pollution problems are discovered.	*EPA, 2008b*
Public supply	Water withdrawn by public governments and agencies, such as a county water department, and by private companies that is then delivered to users. Public suppliers provide water for domestic, commercial, thermoelectric power, industrial, and public water users.	*DOC, 2005*
Public supply withdrawals	Water withdrawn by public and private water suppliers for use within a general community. Water is used for a variety of purposes such as domestic, commercial, industrial, and public water use.	*USGS, 2008*
Public Trust Lands	Public Trust lands shall be defined as all lands subject to the Common Law Public Trust for commerce, navigation, fisheries, recreation, and other public purposes. Public Trust Lands include tidelands, submerged lands, the beds of navigable lakes and rivers, and historic tidelands and submerged lands that are presently filled or reclaimed and which were subject to the Public Trust at any time. (From California Code of Regulations, section 13577; see tidelands and submerged lands.)	*CCC, 2008*
Public Utilities Commission (Public Service Commission)	The state regulatory agency that governs retail utility rates and practices and, in many cases, issues approvals for the construction of new generation and transmission facilities. On average, roughly 90 percent of a utility's operations are regulated by the state commission. There are regulatory commissions in all 50 states, as well as the District of Columbia, Puerto Rico, and the Virgin Islands. The state commissions vary in size from three to seven members, and most states provide that commissioners will be appointed by the state governors. In some states, commissioners are elected. The typical term of office is six years.	*USBR, 2008*
Public water use	Water supplied from a public-water supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pools.	*DOC, 2005*

Public works	(a) All production, storage, transmission, and recovery facilities for water, sewerage, telephone, and other similar utilities owned or operated by any public agency or by any utility subject to the jurisdiction of the Public Utilities Commission, except for energy facilities. (b) All public transportation facilities, including streets, roads, highways, public parking lots and structures, ports, harbors, airports, railroads, and mass transit facilities and stations, bridges, trolley wires, and other related facilities. For purposes of this division, neither the Ports of Hueneme, Long Beach, Los Angeles, nor San Diego Unified Port District nor any of the developments within these ports shall be considered public works. (c) All publicly financed recreational facilities, all projects of the State Coastal Conservancy, and any development by a special district. (d) All community college facilities.	*CCC, 2008*
Publics	Any interested group or individual, including Federal, State and local agencies, interest groups, ad hoc groups, and the general public.	*USBR, 2008*
Puddle	To compact loose soil by soaking it and allowing it to dry.	*USBR, 2008*
Puddling	A method of compacting soil with the soil deposited into a pool of water and then stirred or rodded.	*USBR, 2008*
Pull shovel (dragshovel or hoe)	A shovel with a hinge-and-stick mounted bucket that digs while being pulled inward.	*USBR, 2008*
Pump	See centrifugal pump, diaphragm pump, jetting pump.	*USBR, 2008*
Pumped storage project	A hydroelectric power plant and reservoir system in which water released for generating energy during peak load periods is stored and pumped back into the upper reservoir, usually during periods of reduced water demand.	*USACE, 1999*
Pumping	Mechanical transfer of fluids.	*USBR, 2008*
Pumping stations	Pumps located at or near the line-of-protection to discharge interior flows over or through the levees or floodwalls (or through pressure lines) when free outflow through gravity outlets is prevented by high exterior stages.	*FEMA, 2003*
Purveyor	An agency or person that supplies water.	*USBR, 2008*
Pyroclastic	Ash mixed with larger igneous rock fragments produced by explosive volcanic eruptions.	*USBR, 2008*

Q

Quadrat	Sampling area, most commonly one square meter, used for analyzing vegetation. A square or rectangular plot of land marked off for the study of plants and animals.	*USBR, 2008*
Qualitative	Having to do with quality or qualities. Descriptive of kind, type or direction, as opposed to size, magnitude or degree.	*USBR, 2008*
Qualitative methods	Approaches which use descriptive rather than numerical values for assessment and decision making.	*Mockett & Simm, 2002*
Quality assurance	Evaluation of quality-control data to allow quantitative determination of the quality of chemical data collected during a study. Techniques used to collect, process, and analyze water samples are evaluated.	*USGS, 2008*

Quality assurance/ quality control	A system of procedures, checks, audits, and corrective actions to ensure that all EPA research design and performance, environmental monitoring and sampling, and other technical and reporting activities are of the highest achievable quality.	*EPA, 2008b*
Quantitative	Having to do with quantity, capable of being measured. Descriptive of size, magnitude or degree.	*USBR, 2008*
Quantitative methods	Approaches which use numerical values (or ranges of values) for assessment and decision making.	*Mockett & Simm, 2002*
Quantitative precipitation forecasts	A projection that uses the interpretation of various observational, numerical, and objective aids to estimate the amount, location, and duration of precipitation. The precipitation forecasts are used as a decision making tool for flood warning systems in basins subject to flash floods.	*USBR, 2008*
Quarry	A rock pit. An open cut mine in rock chosen for physical rather than chemical characteristics.	*USBR, 2008*
Quartz	Very hard, clear or translucent mineral composed of silica.	*USBR, 2008*
Quartzite	Metamorphic rock composed of sand-sized quartz grains that have fused together by heat and pressure. Also, a hard, well-cemented quartz-rich sandstone.	*USBR, 2008*
Quaternary	Refers to the geologic period of the last 2,000,000 years and includes the Pleistocene and Holocene (last 10,000 years) epochs.	*USBR, 2008*
Quaternary	A period of geologic time comprising the past 2 million years; includes the Pleistocene and Holocene ages.	*CCC, 2008*
Quicksand	Fine sand or silt that is prevented from settling firmly together by upward movement of ground water. Any wet inorganic soil so unsubstantial that it will not support any load.	*USBR, 2008*
Quintile	Any of the four values that divide the items of a frequency distribution into five classes with each containing one fifth of the total population.	*EPA, 1997*

R

Radial	Lines converging at a single center.	*USBR, 2008*
Radius	Horizontal distance from the center of rotation.	*USBR, 2008*
Radius of influence	1. The radial distance from the center of a wellbore to the point where there is no lowering of the water table or potentiometric surface (the edge of the cone of depression); 2. the radial distance from an extraction well that has adequate air flow for effective removal of contaminants when a vacuum is applied to the extraction well.	*EPA, 2008b*
Radon	A naturally occurring, colorless, odorless, radioactive gas formed by the disintegration of the element radium; damaging to human lungs when inhaled.	*USGS, 2008*
Raffinate ponds	Liquid resulting from extractions with a solvent.	*USBR, 2008*
Ramp flume	A flume calibrated to measure the flow of liquid in an open channel.	*USBR, 2008*
Ramp rate	The rate of change in instantaneous output from a powerplant. The ramp rate is established to prevent undesirable effects due to rapid changes in loading or discharge.	*USBR, 2008*

Random earthquake	In addition to earthquakes that occur on mapped faults, hazards are also presented by earthquakes not associated with known geological structures. The occurrence of these events is best viewed as a random process, hence the term "random" earthquake. Based on earthquake recurrence relationships for an area, estimates of source-to-site distances can be calculated for various magnitudes and probabilities of occurrence.	*USBR, 2008*
Range	The geographic area a species is known to or believed to occupy.	*USFWS, 2008*
Range	Geographic region in which a given plant or animal normally lives or grows.	*USBR, 2008*
Rapid	A section of a river where the current is very fast moving, caused by a steep descent in the riverbed through a constriction of the main channel.	*USBR, 2008*
Rapid flow	Also refered to as supercritical flow, rapid flow is distinguished from tranquil flow by a dimensionless number called the Froude number. If the Froude number is less than one, the flow is tranquil. If the Froude number is greater than one, the flow is rapid. If the Froude number is equal to one, the flow is critical. Surface waves can propagate only in the downstream direction. Control of rapid flow depth is always at the upstream end of the rapid flow region.	*USBR, 2008*
Rapids	A reach of stream that is characterized by small falls and turbulent, high-velocity water.	*USACE, 1999*
Raptors	Birds of prey.	*USBR, 2008*
Rated capacity	That capacity which a hydrogenerator can deliver without exceeding mechanical safety factors or a nominal temperature rise. In general this is also the nameplate rating except where turbine power under maximum head is insufficient to deliver the nameplate rating of the generator.	*USBR, 2008*
Rated head	Water depth for which a hydroelectric generator and turbines were designed.	*USBR, 2008*
Rating curve	A drawn curve showing the relation between gage height and discharge of a stream at a given gaging station.	*DOC, 2005*
Ratio of reduction	The relationship between the maximum size of the stone which will enter a crusher, and the size of its product.	*USBR, 2008*
Reach	A discrete segment of a stream.	*EPA, 2006*
Reach	A section of stream between two defined points.	*USACE, 1999*
Reach	A length of stream that has generally similar physical and biological characteristics.	*USFS, 2002*
Reach	Any specified length of stream, channel, or other water conveyance. A portion of a stream or a river. The area of a canal or lateral between check structures. Sometimes also used to describe a contiguous stretch of river.	*USBR, 2008*
Reactive power	The portion of power that is produced by load inductances or capacitances. It is the time average of the instantaneous product of the voltage and current, with current phase shifted 90 degrees. It is expressed as volt-amperes reactive or VARS.	*USBR, 2008*
Ready reserve	Generation capacity that can be synchronized and ready to serve load in a short time period, usually 10 minutes or less.	*USBR, 2008*

Reaeration	The net flux of oxygen occurring from the atmosphere to a body of water with a free surface.	*EPA, 2008c*
Real-time monitoring	Monitoring and measuring environmental developments with technology and communications systems that provide time-relevant information to the public in an easily understood format people can use in day-to-day decision-making about their health and the environment.	*EPA, 2008b*
Rearing habitat	Areas in rivers or streams where juvenile fish find food and shelter to live and grow.	*USACE, 1999*
Rearing pond	An artificial impoundment in which juvenile fish are raised prior to release into the natural habitat.	*USACE, 1999*
Reasonable and prudent alternative (RPA)	A recommended alternative action identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that is economically and technologically feasible, and that FWS or NOAA Fisheries believes would not jeopardize the continued existence of listed species or the destruction or adverse modification of designated critical habitat.	*USFWS, 2008*
Reasonable and prudent measure (RPM)	An action that FWS or NOAA Fisheries believes necessary or appropriate to minimize the impacts (the amount or extent) of incidental take caused by an action that was subject to consultation.	*USFWS, 2008*
Reattachment deposit	Sand deposit located where downstream flow meets the channel bank at the downstream end of a recirculating zone.	*USBR, 2008*
Rebar	Steel reinforcement bar used primarily for reinforcing concrete. It has a variety of uses in restoration work.	*USFS, 2002*
Rebar	Reinforcing steel bar. Reinforcement.	*USBR, 2008*
Receiver beach	For beach nourishment, the area where beach material is placed.	*CCC, 2008*
Receiving waters	A river, lake, ocean, stream or other watercourse into which wastewater or treated effluent is discharged.	*EPA, 2008b*
Receiving waters	Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.	*EPA, 2008c*
Receptor	Ecological entity exposed to a stressor.	*EPA, 2008b*
Recession limb	The portion of the storm hydrograph that describes how long it takes a stream to return to base flow condition following a precipitation event.	*FISHWR, 2001*
Recharge	The process by which water is added to a zone of saturation, usually by percolation from the soil surface; e.g., the recharge of an aquifer.	*EPA, 2008b*
Recharge	Increases in ground water storage due to precipitation, infiltration from streams, or human activity.	*USBR, 2008*
Recharge	Water added to an aquifer. For instance, rainfall that seeps into the ground.	*DOC, 2005*
Recharge	Water that infiltrates the ground and reaches the saturated zone.	*USGS, 2008*
Recharge area	A land area in which water reaches the zone of saturation from surface infiltration, e.g., where rainwater soaks through the earth to reach an aquifer.	*EPA, 2008b*

Recharge basin	A surface facility, often a large pond, used to increase the percolation of surface water into a groundwater basin.	*USACE, 1999*
Recharge rate	The quantity of water per unit of time that replenishes or refills an aquifer.	*EPA, 2008b*
Recharge rate	The quantity of water per unit time that replenishes or refills an aquifer.	*USBR, 2008*
Recirculation zone	Area of flow composed of one or more eddies immediately downstream from a constriction in the channel, such as a debris fan or rock outcrop.	*USBR, 2008*
Reclamation	(In recycling) Restoration of materials found in the waste stream to a beneficial use which may be for purposes other than the original use.	*EPA, 2008b*
Reclamation	A series of activities intended to change the biophysical capacity of an ecosystem. The resulting ecosystem is different from the ecosystem existing prior to recovery. The term has implied the process of adapting wild or natural resources to serve a utilitarian human purpose such as the conversion of riparian or wetland ecosystems to agricultural, industrial, or urban uses.	*FISHWR, 2001*
Reclassify	To change a species' official status from threatened to endangered or vice-versa.	*USFWS, 2008*
Recommended maximum contaminant level (RMCL)	The maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on human health would occur, and that includes an adequate margin of safety. Recommended levels are nonenforceable health goals.	*EPA, 2008b*
Recovery	The process by which the decline of an endangered or threatened species is stopped or reversed, or threats to its survival neutralized so that its long-term survival in the wild can be ensured, and it can be removed from the list of threatened and endangered species.	*USFWS, 2008*
Recovery outline	The first FWS or NOAA Fisheries recovery document provided for a newly listed species. While brief, the document serves to direct recovery efforts pending the completion of the species' recovery plan.	*USFWS, 2008*
Recovery permit	A permit issued under section 10(a)(1)(A) of the Endangered Species Act for scientific research and other activities benefiting the recovery of federally listed species; allows for research pertaining to species recovery, such as taking blood samples from a peregrine falcon for genetic analysis, or conducting surveys of freshwater mussel beds to determine species status and distribution.	*USFWS, 2008*
Recovery plan	A document drafted by FWS, NOAA Fisheries, or other knowledgeable individual or group, that serves as a guide for activities to be undertaken by Federal, State, or private entities in helping to recover and conserve endangered or threatened species.	*USFWS, 2008*

Recovery priority	A rank, ranging from a high of 1C to a low of 18, whereby priorities are assigned to listed species and recovery tasks; assignment of rank is based on degree of threat, recovery potential, taxonomic distinctiveness, and presence of an actual or imminent conflict between the species and development activities.	*USFWS, 2008*
Recovery team	A group of people appointed by the lead FWS Regional Director/NOAA Assistant Administrator to guide the recovery of a listed species through such actions as developing a recovery plan or providing guidance on recovery implementation. Members of the recovery team generally include species experts from the FWS/NOAA, State governments, conservation organizations and the private sector, as well as stakeholders.	*USFWS, 2008*
Recovery unit	A management sub-unit of the listed entity, geographically or otherwise identifiable, that is essential to the recovery of the entire listed entity; conserves genetic or demographic robustness, important life history stages, or other feature for long-term sustainability of the entire listed entity. Recovery units are optional, but, where used, should collectively encompass the entire listed entity. Recovery criteria for the listed entity should address each identified recovery unit, and every recovery unit must be recovered before the species can be delisted.	*USFWS, 2008*
Recreation	Recreational opportunities at more than 1,900 federal recreation sites managed by the Bureau of Reclamation and other federal agencies can be found at the interagency Recreation.Gov website (www.recreation.gov).	*USBR, 2008*
Recreational benefit	Value of recreational activity to the recreationist, usually measured in dollars above the cost of participating in the recreational activity (travel, entrance fees, etc). Used for valuing recreational resources produced through Federal projects, synonymous with the consumer surplus associated with the recreational activity.	*USBR, 2008*
Recreational rivers	Rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shoreline, and that may have undergone some impoundment or diversion in the past.	*USACE, 1999*
Recreation-day	Participation in a recreational activity, such as skiing, biking, hiking, fishing, boating, and/or camping, for any part of a day by one person.	*USACE, 1999*
Recruitment	Survival of young plants and animals from birth to a life stage less vulnerable to environmental change.	*USBR, 2008*
Rectangular weir	A contracted or suppressed weir with a horizontal crest, rectangular in shape, having vertical sides. See weir.	*USBR, 2008*
Recurrence interval	The average period in years between storm events equal to or larger than a given amount. The reciprocal of the probability of that storm event being equaled or exceeded in any year.	*USBR, 2008*

Recurrence interval (return period, exceedance interval)	The average time interval between actual occurrences of a hydrologic event of a given or greater magnitude. In an annual flood series, the average interval in which a flood of a given size is exceeded as an annual maximum. In a partial duration series, the average interval between floods of a given size, regardless of their relationship to the year or any other period of time. The distinction holds even though for large floods recurrence intervals are nearly the same for both series.	*USGS, 1982*
Recurved or concave-faced walls	Vertical concrete walls with either a seaward facing curve at the top of the wall or along the entire height of the wall. The purpose of the curved face is to reflect the wave energy seaward and prevent overtopping or toe scour.	*CCC, 2008*
Recycled water	Urban wastewater that becomes suitable, as a result of treatment, for a specific direct beneficial use. See also water recycling.	*USACE, 1999*
Red border	An EPA document undergoing review before being submitted for final management decision-making.	*EPA, 2008b*
Redd	Nest made in gravel, consisting of a depression hydraulically dug by a fish for egg deposition (and then filled) and the associated gravel mounds.	*EPA, 2008c*
Redd	The nest that a spawning female salmon digs in gravel to deposit her eggs. Depression in riverbed or lakebed dug by fish to deposit eggs.	*USBR, 2008*
Reference condition	The least-disturbed condition available in an ecological region; determined based on specific criteria and used as a benchmark for comparison with other sample sites in the region.	*EPA, 2006*
Reference condition (biological integrity)	The condition that approximates natural, un-impacted conditions (biological, chemical, physical, etc.) for a water body. Reference condition (biological integrity) is best determined by collecting measurements at a number of sites in a similar waterbody class or region under undisturbed or minimally disturbed conditions (by human activity), if they exist. Since undisturbed or minimally disturbed conditions may be difficult or impossible to find, least disturbed conditions, combined with historical information, models or other methods may be used to approximate reference condition as long as the departure from natural or ideal is understood. Reference condition is used as a benchmark to determine how much other water bodies depart from this condition due to human disturbance.	*EPA, 2008c*
Reference condition (biological integrity)	1) Minimally disturbed condition. The physical, chemical, and biological conditions of a waterbody with very limited, or minimal, human disturbance in comparison to others within the waterbody class or region. Minimally disturbed conditions can change over time in response to natural processes.	*EPA, 2008c*

Reference condition (biological integrity)	(2) Least disturbed condition. The best available existing conditions with regard to physical, chemical, and biological characteristics or attributes of a waterbody within a class or region. These waters have the least amount of human disturbance in comparison to others within the waterbody class, region or basin. Least disturbed conditions can be readily found, but may depart significantly from natural, undisturbed conditions or minimally disturbed conditions. Least disturbed condition may change significantly over time as human disturbances change.	*EPA, 2008c*
Reference site	A NAWQA sampling site selected for its relatively undisturbed conditions.	*USGS, 2008*
Reference sites	Waterbodies that are representative of the characteristics of the region and subject to minimal human disturbance.	*EPA, 2008c*
Refill	Material which had previously been excavated as a result of construction activities and again placed to the lines as shown on the drawings.	*USBR, 2008*
Reflection	Redirection of a wave when it impinges on a steep beach, cliff or other barrier;	*CCC, 2008*
Reforestation	The natural or artificial restocking of an area with forest trees.	*USACE, 1999*
Refraction	(1) Process which changes the direction of a wave moving into shallow water at an angle to the contours -- the part of the wave advancing in shallower water moves more slowly than the part in deeper water, causing the wave crest to bend toward alignment with the underwater contours. (2) Bending of wave crests by currents.	*CCC, 2008*
Refuge compatibility requirements	Requirements under the Refuge Administration Act that all uses of a national wildlife refuge must be compatible with the purpose for which the refuge was established.	*USBR, 2008*
Regime	A natural pattern in at least two time scales: for example, the daily-to-seasonal variation in water and sediment loads, and the annual-to-decadal patterns of floods and droughts.	*DOC, 2005*
Regime theory	A theory of channel formation that applies to streams that make a part of their boundaries from their transported sediment load and a portion of their transported sediment load from their boundaries. Channels are considered in regime or equilibrium when bank erosion and bank formation are equal.	*USACE, 1999*
Regional reference condition	Description of the chemical, physical, or biological condition based on an aggregation of data from reference sites that are representative of a water body type in an ecoregion, subecoregion, watershed, or political unit.	*EPA, 2008c*
Regulating dam (reregulating dam)	A dam impounding a reservoir from which water is released to regulate the flow downstream. See afterbay dam.	*USBR, 2008*
Rehabilitation	Makes the land useful again after a disturbance through the recovery of ecosystem functions and processes in a degraded habitat. Rehabilitation does not necessarily reestablish the predisturbance condition, but does involve establishing geological and hydrologically stable landscapes that support the natural ecosystem mosaic.	*FISHWR, 2001*

Rehabilitation	The process of renovating a facility or system whose performance is failing to meet the original criteria and needs of the project.	*USBR, 2008*
Rehabilitation	Used primarily to indicate improvements of a visual nature to a natural resource; putting back into good condition or working order.	*DOC, 2005*
Reimbursable	Costs of constructing, operating, or maintaining a Reclamation project that are repaid to the Federal Government by some other individual, entity, or organization.	*USBR, 2008*
Relative abundance	The number of organisms of a particular kind present in a sample relative to the total number of organisms in the sample.	*USGS, 2008*
Relative density	Used in construction control for cohesionless soils where the in-place density is compared to the minimum and maximum density of the soil from laboratory tests. The ratio of the difference between the void ratio of a cohesionless soil in the loosest state and any given void ratio to the difference between its void ratios in the loosest and in the densest states.	*USBR, 2008*
Relative ecological sustainability	Ability of an ecosystem to maintain relative ecological integrity indefinitely.	*EPA, 2008b*
Relative humidity	The ratio of the amount of moisture in the air to the maximum amount of moisture the air could hold under the same conditions; usually expressed as a percentage.	*USBR, 2008*
Relative permeability	The permeability of a rock to gas, or water, when any two or more are present.	*EPA, 2008b*
Relative risk assessment	Estimating the risks associated with different stressors or management actions.	*EPA, 2008b*
Release	The amount of water released after use. The difference between delivery and release is usually the same as consumptive use.	*USBR, 2008*
Reliability	Probability that a device will function without failure over a specified time period or amount of usage. The ability to deliver uninterrupted electricity to customers on demand, and to withstand sudden disturbances such as short circuits or loss of major system components. This encompasses both the reliability of the generation system and of the transmission and distribution system. Reliability maybe evaluated by the frequency, duration, and magnitude of any adverse effects on consumer service.	*USBR, 2008*
Relict	A species, population, etc., which is a survivor of a nearly extinct group. Any species surviving in a small local area and widely separated from closely related species.	*USBR, 2008*
Relief	Term designating the path of least resistance through which energy from explosions can be released. This path is usually taken to a free face or surface where rock can displace and energy can be released.	*USBR, 2008*
Relief valve	A valve which will allow air or fluid to escape if its pressure becomes higher than the valve setting. A safety device that automatically provides protection against excessive temperatures, excessive pressures, or both.	*USBR, 2008*
Relief well	See drainage well.	*USBR, 2008*
Remediation	A process by which something is fixed or repaired.	*DOC, 2005*

Remote operation	Operation of mechanical features from an on-site location other than at the feature.	*USBR, 2008*
Remote sensing	The collection and interpretation of information about an object without physical contact with the object; e.g., satellite imaging, aerial photography, and open path measurements.	*EPA, 2008b*
Remote sensing	Method for determining characteristics of an object, organism or community from afar.	*USBR, 2008*
Remote sensing	The detection of conditions (e.g., types of plants) on the landscape through the use of satellite and aerial photography/imagery.	*DOC, 2005*
Renewable resources	Renewable energy resources are naturally replenishable, but flow limited. They are virtually inexhaustible in duration but limited in the amount of energy that is available per unit of time. Some (such as geothermal and biomass) may be stock limited in that stocks are depleted by use, but on a time scale of decades, or perhaps centuries, they can probably be replenished. Renewable energy resources include: biomass, hydro, geothermal, solar and wind. In the future they could also include the use of ocean thermal, wave, and tidal action technologies. Utility renewable resource applications include bulk electricity generation, on site electricity generation, distributed electricity generation, non grid connected generation, and demand reduction (energy efficiency) technologies.	*USBR, 2008*
Reportable quantities	Quantities of hazardous substances which require notification to the National Response Center and the appropriate state agency.	*USBR, 2008*
Representative sample	A portion of material or water that is as nearly identical in content and consistency as possible to that in the larger body of material or water being sampled.	*EPA, 2008b*
Reregulation dam	See afterbay dam.	*USBR, 2008*
Reserve capacity	Pollutant loading rate set aside in determining stream waste load allocation accounting for uncertainty and future growth.	*EPA, 2008c*
Reserve generating capacity	Extra generating capacity available to meet unanticipated capacity demand for power in the event of generation loss due to scheduled or unscheduled outages of regularly used generating capacity.	*USBR, 2008*
Reserved works	Facilities operated and maintained by Reclamation.	*USBR, 2008*
Reservoir	Any natural or artificial holding area used to store, regulate, or control water.	*EPA, 2008b*

Reservoir	A body of water impounded by a dam and in which water can be stored. Artificially impounded body of water. Any natural or artificial holding area used to store, regulate, or control water. Body of water, such as a natural or constructed lake, in which water is collected and stored for use. Dam design and reservoir operation utilize reservoir capacity and water surface elevation data. To ensure uniformity in the establishment, use, and publication of these data, the following standard definitions of water surface elevations shall be used. See maximum controllable water surface, maximum water surface, normal water surface, top of active conservation capacity, top of dead capacity, top of exclusive flood control capacity, top of inactive capacity, and top of joint use capacity.	*USBR, 2008*
Reservoir	A pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.	*DOC, 2005*
Reservoir capacity	The storage capacity available in a reservoir for all purposes, from the streambed to the normal maximum operating level. Includes dead (or inactive) storage, but usually excludes surcharge (water temporarily stored above the elevation of the top of the spillway).	*USACE, 1999*
Reservoir capacity	The capacity of the reservoir, usually in acre-feet. Dam design and reservoir operation utilize reservoir capacity and water surface elevation data. To ensure uniformity in the establishment, use, and publication of these data, the following standard definitions of reservoir capacities shall be used. Reservoir capacity as used here is exclusive of bank storage capacity. See active capacity, active conservation capacity, dead capacity, exclusive flood control capacity, flood control capacity, inactive capacity, joint use capacity, live capacity, and total capacity.	*USBR, 2008*
Reservoir inflow	The amount of water entering a reservoir expressed in acre-feet per day or cubic feet per second.	*USBR, 2008*
Reservoir surface area	The area covered by a reservoir when filled to a specified level.	*USBR, 2008*
Residence time	Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.	*EPA, 2008c*
Residual	Amount of a pollutant remaining in the environment after a natural or technological process has taken place; e.g., the sludge remaining after initial wastewater treatment, or particulates remaining in air after it passes through a scrubbing or other process.	*EPA, 2008b*
Residual risk	The extent of health risk from air pollutants remaining after application of the Maximum Achievable Control Technology (MACT).	*EPA, 2008b*
Residual risk	The risk that remains after risk management and mitigation. May include, for example, risk due to very severe (above the design event) storms or risks from unforeseen hazards.	*Mockett & Simm, 2002*
Residual saturation	Saturation level below which fluid drainage will not occur.	*EPA, 2008b*

Resilience	Ability of any system to resist or to recover from stress or hardship.	*USBR, 2008*
Resistance	For plants and animals, the ability to withstand poor environmental conditions or attacks by chemicals or disease. May be inborn or acquired.	*EPA, 2008b*
Resource Management Plan	A written plan that addresses the existing resources of an area and provides future objectives, goals, and management direction.	*USBR, 2008*
Response Level I	The first, and least serious, of three response levels that the dam operating organization will declare after analyzing a potentially threatening event. An event in this alert category may be perceived as an emergency or may be of general interest to the public, but does NOT pose a hazard, either at the dam or to downstream populations at risk when observed. Declaring Response Level I allows internal notifications to agency (Reclamation and/or operating agency) technical staff and decision makers that conditions at the dam and reservoir, or in the basin, represent a potentially threatening event; provides trigger points for technical staff to begin predicting future basin runoff, reservoir levels, and the likelihood of life-threatening releases and/or structural failure; and provides a "communications check" to downstream local authorities concerning conditions at the dam.	*USBR, 2008*
Response Level II	The second of three response levels the dam operating organization will declare after analyzing a threatening event. Declaring Response Level II means that emergency conditions are such that populations at risk should prepare to leave predetermined inundation areas for higher ground and safe shelter. Declaration of Response Level II means that an event has occurred or is likely to occur that will actually threaten the structure and/or areas downstream from the dam if the event continues and/or intensifies.	*USBR, 2008*
Response Level III	The third, and most serious, response level the dam operating organization will declare after analyzing threatening events. Declaring Response Level III indicates that life-threatening flood waters, as a result of high operational releases or dam failure, present imminent danger to the public located downstream from a dam. Declaration of Response Level III should prompt local officials to immediately evacuate populations at risk.	*USBR, 2008*
Response spectrum	A plot of the maximum response of a series of single-degree-of-freedom damped oscillators (elastic systems) as a function of their natural periods, or frequencies, when the oscillators are subjected to a vibratory ground motion. The maximum values of acceleration, velocity, and/or displacement of an infinite series of single-degree-of-freedom system subjected to an earthquake. The maximum response values are expressed as a function of natural period for a given damping. The response spectrum acceleration, velocity, and displacement values may be calculated from each other assuming a sinusoidal relationship between them.	*USBR, 2008*

Restoration	Measures taken to return a site to pre-violation conditions.	*EPA, 2008b*
Restoration	Reestablishment of the structure and function of ecosystems. Ecological restoration is the process of returning an ecosystem as closely as possible to predisturbance conditions and functions. Implicit in this definition is that ecosystems are naturally dynamic. It is therefore not possible to recreate a system exactly. The restoration process reestablishes the general structure, function, and dynamic but self-sustaining behavior of the ecosystem. Restoration differs from rehabilitation and reclamation in that restoration is a holistic process not achieved through the isolated manipulation of individual elements.	*FISHWR, 2001*
Restoration	The return of an ecosystem to a close approximation of its condition prior to disturbance.	*USACE, 1999*
Restoration	Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.	*EPA, 2008c*
Restoration	1) return of an ecosystem, or ecosystem process to a close approximation of its condition prior to human disturbance; 2) the renewal of a natural process (e.g., natural fire regimes) or feature (e.g., native fish species) through human actions.	*DOC, 2005*
Restoration, ecological	Involves replacing lost or damaged biological elements (populations, species) and reestablishing ecological processes (dispersal, succession) at historical rates.	*DOC, 2005*
Restoration, stream	Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream due to urbanization, farming, or other disturbance.	*DOC, 2005*
Retaining wall	A wall separating two levels.	*USBR, 2008*
Retaining wall - Low wall used to support or retain an earth embankment or area of fill.		*CCC, 2008*
Retrospective analysis	Review and analysis of existing data in order to address NAWQA objectives, to the extent possible, and to aid in the design of NAWQA studies.	*USGS, 2008*
Return flow	The portion of withdrawn water not consumed by evapotranspiration or system losses that returns to its source or to another body of water.	*USACE, 1999*
Return flow	Drainage water from irrigated farmlands that re-enters the water system to be used further downstream. May contain dissolved salts or other materials that have been leached out of the upper layers of the soil. That portion of the water previously diverted from a stream which finds its way back to that stream or to another body of ground or surface water. The water that reaches a ground or surface water source after release from the point of use and thus becomes available for further use.	*USBR, 2008*
Return flow	(1) that part of a diverted flow that is not consumptively used and returned to its original source or another body of water. (2) (Irrigation) Drainage water from irrigated farmlands that re-enters the water system to be used further downstream.	*DOC, 2005*

Return period	The average length of time separating extreme events (i.e. a flood) of similar magnitude.	*Mockett & Simm, 2002*
Return-flow system (reuse system)	A system of pipelines or ditches to collect and convey surface or subsurface runoff from an irrigated field for reuse.	*USBR, 2008*
Reuse	The additional use of previously used water.	*USACE, 1999*
Revetment	A facing of stone, wood, or other natural materials placed on a bank as protection against wave action and currents.	*USFS, 2002*
Revetment	An embankment or wall of sandbags, earth, etc., constructed to restrain material from being transported away. A facing of stone, cement, sandbags, etc., to protect a wall or embankment.	*USBR, 2008*
Revetment	A sloped retaining wall; a facing of stone, concrete, blocks, rip-rap, etc. built to protect an embankment, bluff, or development against erosion by wave action and currents.	*CCC, 2008*
Rhyolite	Light-colored volcanic igneous rock that is the extrusive equivalent of granite.	*USBR, 2008*
Richter scale	A scale of numerical values, proposed by C. F. Richter, to describe the magnitude of an earthquake, ranging from 1 to 9, by measurements made in well-defined conditions and with a given type of seismograph. The zero of the scale is fixed arbitrarily to fit the smallest recorded earthquake. The largest recorded earthquake magnitudes are near 8.7. This is the result of observations and not an arbitrary upper limit like that of the intensity scale. For more information about the Richter Scale visit the U.S. Geological Survey National Earthquake Information Center.	*USBR, 2008*
Riffle	A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.	*USACE, 1999*
Riffle	A rocky shoal or sand bar located just below the surface of the water.	*EPA, 2008c*
Riffle	A stretch of choppy water caused by an underlying rock shoal or sandbar. A run is a long riffle.	*USBR, 2008*
Riffle	The part of a stream with shallow, fast-moving water flowing over cobbles or rocks.	*DOC, 2005*
Riffle	A shallow part of the stream where water flows swiftly over completely or partially submerged obstructions to produce surface agitation.	*USGS, 2008*
Riffle and pool complex	A water habitat composed of riffles (characterized by water flowing rapidly over a coarse substrate) and pools (deeper areas of water associated with riffles).	*USBR, 2008*
Riffles	Shallow areas within stream channels. Riffle areas usually form between two bends at the point where the thalweg crosses from one side of the channel to the other. The riffle-to-riffle spacing is normally about 5 to 7 times the channel width at bank full discharge.	*FISHWR, 2001*
Rift	A shallow or rocky place in a stream, forming either a ford or a rapid.	*USACE, 1999*
Right-of-way	The land on and immediately surrounding a structure that is owned by the entity holding title to the structure.	*USBR, 2008*
Rill	A small channel eroded into the soil by surface runoff; can be easily smoothed out or obliterated by normal tillage.	*EPA, 2008b*

Rill	A small channel eroded into the soil surface by runoff, rills easily can be smoothed out (obliterated) by normal tillage. Small grooves, furrows, or channels in soil made by water flowing down over its surface. A small stream.	*USBR, 2008*
Rill	The channel of a small stream or gully.	*CCC, 2008*
Rill Erosion	Removal of soil particles from a bank slope by surface runoff moving through relatively small narrow channels.	*USFS, 2002*
Rill erosion	An erosion process in which numerous small channels of only several centimeters in depth are formed; occurs mainly on recently cultivated soils.	*EPA, 2008c*
Ring levees	Levees that completely encircle or "ring" an area subject to inundation from all directions.	*FEMA, 2003*
Rip current	A strong surface current flowing seaward from the shore. It usually appears as a visible band of agitated water and is the return movement of water piled up on the shore by incoming waves and wind. With the seaward movement concentrated in a limited band its velocity is accentuated. Rip currents can pull inexperienced swimmers and waders into deeper water away from the shore. Since a rip current is usually quite narrow, the most effective way to get out of it is to swim perpendicular to the direction of the flow (in most cases, parallel to the beach). Rip currents can often develop adjacent to a jetty or groin.	*CCC, 2008*
Riparian	Living on or adjacent to a water supply such as a riverbank, lake, or pond. Of, on, or pertaining to the bank of a river, pond, or lake.	*USBR, 2008*
Riparian	The region of the landscape immediately adjacent to and influenced by a waterway with moving water.	*DOC, 2005*
Riparian	Pertaining to a stream or river and its adjacent area.	*EPA, 2006*
Riparian	Areas adjacent to rivers and streams with a high density, diversity, and productivity of plant and animal species relative to nearby uplands.	*USGS, 2008*
Riparian area	An area of land and vegetation adjacent to a stream that has a direct effect on the stream. This includes woodlands, vegetation, and floodplains.	*USACE, 1999*
Riparian areas	Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.	*EPA, 2008c*
Riparian disturbance	A measure of the evidence of human activities in and alongside streams, such as dams, roadways, pastureland, and trash.	*EPA, 2006*
Riparian habitat	Areas adjacent to rivers and streams with a differing density, diversity, and productivity of plant and animal species relative to nearby uplands.	*EPA, 2008b*
Riparian habitat	The aquatic and terrestrial habitat adjacent to streams, lakes, estuaries, or other waterways.	*USACE, 1999*
Riparian management	Revegetation of riparian zone and/or removal of exotic species (e.g. weeds, cattle). Excludes localized planting only to stabilize bank areas (see Bank Stabilization).	*NRRSS, 2005*
Riparian rights	Entitlement of a land owner to certain uses of water on or bordering the property, including the right to prevent diversion or misuse of upstream waters. Generally a matter of state law.	*EPA, 2008b*

Riparian vegetation	Vegetation growing along banks of streams, rivers, and other water bodies tolerant to or more dependent on water than plants further upslope.	*USFS, 2002*
Riparian vegetation	Hydrophytic vegetation growing in the immediate vicinity of a lake or river closely enough so that its annual evapotranspiration constitutes a factor in the lake or river regime.	*EPA, 2008c*
Riparian vegetative cover	Vegetation corridor alongside streams and rivers. Intact riparian vegetative cover reduces pollution runoff, prevents streambank erosion, and provides shade, lower temperatures, food, and habitat for fish and other aquatic organisms.	*EPA, 2006*
Riparian zone	The area of vegetation located on the bank of a natural watercourse, such as a river, where the flows of energy, matter, and species are most closely related to water dynamics. Linear corridors associated with streams and stream-side vegetation.	*EPA, 1997*
Riparian zone	The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.	*EPA, 2008c*
Riparian zone	Pertaining to or located on the bank of a body of water, especially a stream.	*USGS, 2008*
Ripple	(1) A specific undulated bed form found in sand bed streams. (2) Undulations or waves on the surface of flowing water.	*USACE, 1999*
Ripple	In a streambed, a ripple is a small triangle-shaped elements having gentle upstream slopes and steep downstream slopes.	*USBR, 2008*
Riprap	Rock or other material with a specific mixture of sizes referred to as a 'gradation,' used to stabilize stream banks or riverbanks from erosion or to create habitat features in a stream.	*USACE, 1999*
Riprap	A layer, facing, or protective mound of rubble or stones randomly placed to prevent erosion, scour, or sloughing of a structure or embankment; also, the stone used for this purpose.	*USFS, 2002*
Riprap	A layer of large uncoursed stones, broken rock, boulder, precast blocks, bags of cement, or other suitable material generally placed in random fashion on the upstream and downstream faces of embankment dams, stream banks, on a reservoir shore, on the sides of a channel, or other land surfaces to protect them from erosion or scour caused by current, wind, wave, and/or ice action. A protective blanket of large loose stones, which are usually placed by machine to achieve a desired configuration. Riprap is usually placed by dumping or other mechanical methods but, in some cases, is hand placed. It consist of relatively large pieces as distinguished from a gravel blanket. Very large riprap is sometimes referred to as "armoring."	*USBR, 2008*
Riprap	A protective layer or facing of rock, concrete blocks or quarrystone, placed to prevent erosion, scour, or sloughing of an embankment or bluff.	*CCC, 2008*
Rising limb	The portion of the hydrograph that lies to the left of the peak showing how long it takes the stream to peak following a precipitation event.	*FISHWR, 2001*

Risk	A measure of the probability that damage to life, health, property, and/or the environment will occur as a result of a given hazard.	*EPA, 2008b*
Risk	The product of probability and consequence.	*Mockett & Simm, 2002*
Risk	The relationship between the consequences resulting from an adverse event and its probability of occurrence. The potential for losing credibility, failing to solve a problem, or getting hurt. The ability to describe potential outcomes using historic probability. The likelihood or chance of an unacceptable event occurring.	*USBR, 2008*
Risk (adverse) for endangered species	Risk to aquatic species if anticipated pesticide residue levels equal one-fifth of LD10 or one-tenth of LC50; risk to terrestrial species if anticipated pesticide residue levels equal one-fifth of LC10 or one-tenth of LC50.	*EPA, 2008b*
Risk assessment	Qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants.	*EPA, 2008b*
Risk assessment	Consideration of hazards inherent in a project and the risks associated with them.	*Mockett & Simm, 2002*
Risk assessment	As applied to dam safety, the process of identifying the likelihood and consequences of dam failure to provide the basis for informed decisions.	*USBR, 2008*
Risk assessmentanalysis	Characterization, and possible quantification of the risks to health or the environment from disturbing agents or stressors.	*DOC, 2005*
Risk averse	The decision maker adopts the option with a more certain return even if the potential benefit is less.	*Mockett & Simm, 2002*
Risk characterization	The last phase of the risk assessment process that estimates the potential for adverse health or ecological effects to occur from exposure to a stressor and evaluates the uncertainty involved.	*EPA, 2008b*
Risk communication	The exchange of information about health or environmental risks among risk assessors and managers, the general public, news media, interest groups, etc.	*EPA, 2008b*
Risk estimate	A description of the probability that organisms exposed to a specific dose of a chemical or other pollutant will develop an adverse response, e.g., cancer.	*EPA, 2008b*
Risk factor	Characteristics (e.g., race, sex, age, obesity) or variables (e.g., smoking, occupational exposure level) associated with increased probability of a toxic effect.	*EPA, 2008b*
Risk for non-endangered species	Risk to species if anticipated pesticide residue levels are equal to or greater than LC50.	*EPA, 2008b*
Risk management	The process of evaluating and selecting alternative regulatory and non-regulatory responses to risk. The selection process necessarily requires the consideration of legal, economic, and behavioral factors.	*EPA, 2008b*
Risk management	The activity of mitigating and monitoring risks, which occurs predominantly after the project appraisal stage.	*Mockett & Simm, 2002*
Risk neutral	The decision maker makes no distinction between probability and consequence when selecting an option.	*Mockett & Simm, 2002*

Risk owner	An individual or organization who is responsible for a specific risk.	*Mockett & Simm, 2002*
Risk prone	The decision maker adopts the option that has the largest benefit even though it is less likely to occur (i.e. takes more of a gamble).	*Mockett & Simm, 2002*
Risk register	An auditable record of the project risks, their consequences and significance, and proposed mitigation and management measures.	*Mockett & Simm, 2002*
Risk workshop	A workshop where all parties involved in the project come together and discuss collectively the risks or concerns involved.	*Mockett & Simm, 2002*
Risk-based targeting	The direction of resources to those areas that have been identified as having the highest potential or actual adverse effect on human health and/or the environment.	*EPA, 2008b*
Risk-specific dose	The dose associated with a specified risk level.	*EPA, 2008b*
River	A natural stream of water of considerable volume, larger than a brook or creek.	*DOC, 2005*
River basin	The land area drained by a river and its tributaries.	*EPA, 2008b*
River channels	Large natural or artificial open streams that continuously or periodically contain moving water, or which form a connection between two bodies of water.	*USACE, 1999*
River corridor	A river and the strips of land adjacent to it, including the talus slopes at the bases of cliffs, but not the cliffs themselves.	*USBR, 2008*
River mile (RM)	A unit of measurement (in miles) used on rivers.	*USBR, 2008*
River miles	Generally, miles from the mouth of a river to a specific destination or, for upstream tributaries, from the confluence with the main river to a specific destination.	*USACE, 1999*
River reach	Any defined length of a river.	*USACE, 1999*
River stage	The elevation of the water surface at a specific station above some arbitrary zero datum (level).	*USACE, 1999*
River trash wall	Walls constructed to deflect heavy floating debris away from the upper ends of a fishway.	*USBR, 2008*
Riverine	Relating to, formed by, or resembling a river including tributaries, streams, brooks, etc.	*USACE, 1999*
Riverine	Riparian; pertaining to a riverbank.	*USBR, 2008*
Riverine habitat	The aquatic habitat within streams and rivers.	*USACE, 1999*
Rock	A naturally formed mass of minerals.	*USACE, 1999*
Rock	The hard, firm and stable parts of the earth's crust. A sound and solid mass, layer, or ledge of mineral matter inplace, and of such hardness and texture that it cannot be effectively loosened or broken down by a 6-pound drifting pick or by ripping in a single pass. Natural solid mineral matter occurring in large masses or fragments. Naturally formed, consolidated material composed of grains of one or more minerals.	*USBR, 2008*
Rock anchor	A steel rod or cable placed in a hole drilled in rock, held in position by grout, mechanical means, or both. In principle, the same as a rock bolt, but usually the rock anchor is more than 4 meters long.	*USBR, 2008*
Rock bolt	A steel rod placed in a hole drilled in rock, held in position by grout, mechanical means, or both. A rock bolt can be pretensioned.	*USBR, 2008*

Rock excavation	Hard and firm parts of the earth's crust which is dug out and removed from a particular site or area, see rock. Boulders or detached pieces of solid rock more than 1 cubic yard in volume are classified as rock excavation. See excavation.	*USBR, 2008*
Rock fragment	Detached pieces of rock which generally are not rounded.	*USBR, 2008*
Rockfill dam	An embankment dam in which more than 50 percent of the total volume is comprised of compacted or dumped cobbles, boulders, rock fragments, or quarried rock generally larger than 3-inch size. The rock provides structural integrity for the dam around an impervious core.	*USBR, 2008*
Rolled fill dam	An embankment dam of earth or rock in which the material is placed in layers and compacted by the use of rollers or rolling equipment.	*USBR, 2008*
Roller compacted concrete (RCC)	A mixture of cement, water, and aggregate compacted by rolling.	*USBR, 2008*
Roller-compacted concrete dam	A concrete gravity dam constructed by the use of a dry mix concrete transported by conventional construction equipment and compacted by rolling, usually with vibratory rollers.	*USBR, 2008*
Rolling	A method of compacting soil using a sheepsfoot roller or a smooth drum roller.	*USBR, 2008*
Root wad	The mass of roots associated with a tree adjacent to or in a stream that provides refuge for fish and other aquatic life.	*USACE, 1999*
Root wad	A short length of tree trunk with a root mass.	*USFS, 2002*
Root zone	That depth of soil which plant roots readily penetrate and in which the predominant root activity occurs. The area where a low-angle thrust fault steepens and descends into the crust.	*USBR, 2008*
Rough fish	Fish not prized for sport or eating, such as gar and suckers. Most are more tolerant of changing environmental conditions than are game or food species.	*EPA, 2008b*
Rough fish	A nonsport fish.	*USBR, 2008*
Roughness coefficient	A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.	*EPA, 2008c*
Route alerting	A supplement to the public alert system; a method for alerting people in areas not covered by the primary system or if the primary system fails. Route alerting is accomplished by emergency personnel in vehicles traveling along assigned roads and delivering emergency instructions with public address systems or by door-to-door notification.	*USBR, 2008*
Route of exposure	The avenue by which a chemical comes into contact with an organism, e.g., inhalation, ingestion, dermal contact, injection.	*EPA, 2008b*
Rubble dam	A stone masonry dam in which the stones are unshaped or uncoursed. See dam.	*USBR, 2008*
Rulemaking	The formal process of publishing a draft and final Federal regulation in the Federal Register; establishes a comment period for public input into the decision-making process. For example, plants and animals must be proposed for listing as threatened or endangered, and the resulting public comments must be analyzed, before the FWS or NOAA Fisheries can make a final decision.	*USFWS, 2008*
Run	The straight fast-moving section of a stream between riffles.	*USFS, 2002*

Run	Seasonal upstream migration of anadromous fish. One or more lengths of pipe that continue in a straight line.	*USBR, 2008*
Run (in a stream or river)	A reach of stream characterized by fast-flowing, low-turbulence water.	*USACE, 1999*
Running and quick-start capability	The net capability of generating units that carry load or have quick-start capability. In general, quick-start capability refers to generating units that can be available for load within a 30-minute period.	*USBR, 2008*
Runoff	Water that flows over the ground and reaches a stream as a result of rainfall or snowmelt.	*USACE, 1999*
Runoff	That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface-water. It can carry pollutants from the air and land into receiving waters.	*EPA, 2008b*
Runoff	The portion of precipitation, snow melt, or irrigation that flows over the soil, eventually making its way to surface water supplies. Liquid water that travels over the surface of the Earth, moving downward due to the law of gravity; runoff is one way in which water that falls as precipitation returns to the ocean.	*USBR, 2008*
Runoff	That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or ground-water runoff.	*DOC, 2005*
Runoff	Excess rainwater or snowmelt that is transported to streams by overland flow, tile drains, or ground water.	*USGS, 2008*
Run-of-river plants	The regulated inflow of one powerplant is equal to the outflow from a powerplant upstream. A hydroelectric powerplant using the flow of a stream as it occurs and having little or no reservoir capacity for storage or regulation.	*USBR, 2008*
Runup	The vertical distance above the setup that the rush of water reaches when a wave breaks on the dam embankment.	*USBR, 2008*
Rural area	Predominantly agricultural, prairie, forest, range, or undeveloped land where the population is small.	*USBR, 2008*

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Sacred site	Any specific, discrete, narrowly delineated location on Federal land that is identified by an Indian Tribe, or Indian individual determined to be an appropriately authoritative representative of an Indian religion, as sacred.	*USBR, 2008*
Saddle dam	A subsidiary dam of any type constructed across a saddle or low point on the perimeter of a reservoir. See dike.	*USBR, 2008*
Safe	Condition of exposure under which there is a practical certainty that no harm will result to exposed individuals.	*EPA, 2008b*

Safe Harbor Agreement (SHA)	A voluntary agreement signed by FWS or NOAA Fisheries and a property owner and any other cooperator that (a) sets forth specific management activities that the non-Federal property owner will undertake or forgo to provide a net conservation benefit to species covered by the agreement, and (b) provides the property owner with the Safe Harbor assurances described within the agreement and authorized in an enhancement of survival permit.	*USFWS, 2008*
Safe water	Water that does not contain harmful bacteria, toxic materials, or chemicals, and is considered safe for drinking even if it may have taste, odor, color, and certain mineral problems.	*EPA, 2008b*
Safe yield	The annual amount of water that can be taken from a source of supply over a period of years without depleting that source beyond its ability to be replenished naturally in "wet years."	*EPA, 2008b*
Safe yield	The annual quantity of water that can be taken from a source of supply over a period of years without depleting the source beyond its ability to be replenished naturally in wet years.	*USBR, 2008*
Safety Evaluation Earthquake (SEE)	The earthquake expressed in terms of magnitude and closest distance from the damsite or in terms of the characteristics of the time history of free-field ground motions for which the safety of the dam and critical structures associated with the dam are to be evaluated. In many cases, this earthquake will be the maximum credible earthquake to which the dam will be exposed. However, in other cases where the possible sources of ground motion are not easily apparent, it may be a motion with prescribed characteristics selected on the basis of a probabilistic assessment of the ground motions that may occur in the vicinity of the dam. To be considered safe, it should be demonstrated that the dam can withstand this level of earthquake shaking without release of water from the reservoir.	*USBR, 2008*
Safety evaluation flood (SEF)	The largest flood for which the safety of a dam and appurtenant structure(s) are to be evaluated.	*USBR, 2008*
Safety Evaluation of Existing Dams (SEED) examination	The onsite examination performed initially and at predetermined intervals (approximately every 6 years). The design, construction, operation, performance, and existing condition of all features are evaluated in accordance with state-of-the-art criteria. See overall safety of dams classification.	*USBR, 2008*
Safety Evaluation of Existing Dams (SEED) report	A compilation of independent technical reports that evaluate the design, construction, and performance of a dam for its structural and hydraulic integrity using available data; identify existing or potential dam safety deficiencies; and recommend future actions appropriate for the safety of the dam. Evaluation includes review of hydrology, geology, seismicity, seepage, structural adequacy, design criteria, construction, operation, instrumentation records, existing field conditions, and past performance. See evaluation report. See overall safety of dams classification.	*USBR, 2008*

Saline	The condition of containing dissolved or soluble salts. Saline soils are those whose productivity is impaired by high soluble salt content. Saline water is that which would impair production if used to irrigate sensitive crops without adequate leaching to prevent soil salinization.	*USBR, 2008*
Saline sodic land	Soil that contains soluble salts in amounts that impair plant growth but not an excess of exchangeable sodium.	*USBR, 2008*
Saline water	Water that contains more than 1,000 milligrams per liter of dissolved solids.	*USBR, 2008*
Salinity	The percentage of salt in water.	*EPA, 2008b*
Salinity	The concentration of mineral salts dissolved in water. Salinity may be measured by weight (total dissolved solids), electrical conductivity, or osmotic pressure. Where seawater is known to be the major source of salt, salinity is often used to refer to the concentration of chlorides in the water.	*USACE, 1999*
Salinity	Saltiness. The relative concentration of dissolved salts, usually sodium chloride, in a given water supply. A measure of the concentration of dissolved mineral substances in water.	*USBR, 2008*
Salinity intrusion	The movement of salt water into a body of fresh water. It can occur in either surface water or groundwater bodies.	*USACE, 1999*
Salmonids	Fish of the family Salmonidae, including salmon, trout, char, whitefish, ciscoe, and grayling.	*USFS, 2002*
Salmonids	Family of fish that includes salmon and steelhead.	*USBR, 2008*
Salt marsh	Saltwater wetlands that occur along many coasts.	*USACE, 1999*
Salt water intrusion	The invasion of fresh surface or ground water by salt water. If it comes from the ocean it may be called sea water intrusion.	*EPA, 2008b*
Saltation	The movement of sand or fine sediment by short jumps above a streambed under the influence of a water current too weak to keep it permanently suspended in the moving water.	*USBR, 2008*
Salts	Minerals that water picks up as it passes through the air, over and under the ground, or from households and industry.	*EPA, 2008b*
Saltwater barrier	A physical facility or method of operation designed to prevent the intrusion of salt water into a body of fresh water.	*USACE, 1999*
Sample	An element, part, or fragment of a 'population.' Every hydrologic record is a sample of a much longer record.	*USGS, 1982*
Sample error	Random variation reflecting the inherent variability within a population being counted.	*USBR, 2008*
Sampling frequency	The interval between the collection of successive samples.	*EPA, 2008b*
Sand	Small substrate particles, generally from 0.06 to 2 mm in diameter. Sand is larger than silt and smaller than gravel.	*USACE, 1999*
Sand	Mineral grains whose particle size vary from a No. 4 sieve to a No. 200 sieve. A loose soil composed of particles between 1/16 mm and 2 mm in diameter.	*USBR, 2008*
Sand backfill	Material which has a particle size which varies from a No. 4 sieve to a No. 200 sieve and is used for refilling an excavation.	*USBR, 2008*

Sand boil	Seepage characterized by a boiling action at the surface surrounded by a cone of material from deposition of foundation and/or embankment material carried by the seepage. A swirling upheaval of sand or soil on the surface of or downstream from an embankment caused by water leaking through the embankment. The ejection of sand and water resulting from piping.	*USBR, 2008*
Sand by-pass	Deliberate transfer of sand along the shore around a barrier such as a jettied harbor entrance or inlet. In the case where sand accumulates preferentially on one side of an inlet, this action may result in nourishment of the beach on the eroding (receiving) side.	*CCC, 2008*
Sand source	Resource of sand that can be economically used for beach nourishment. The sand must meet the requirements for size distribution and cleanliness and its removal and transfer must not create unacceptable environmental effects. The source may be on land, offshore, in a nearby inlet, or in a navigational channel, a shoal, or other area in which sand accumulates.	*CCC, 2008*
Sandstone	Sedimentary rock composed of sand-sized grains (usually quartz) cemented together.	*USBR, 2008*
Sandstone	A rock composed predominantly of sand grains that have undergone cementation.	*CCC, 2008*
Sanitary sewer overflows	Properly designed, operated, and maintained sanitary sewer systems are meant to collect and transport all of the sewage that flows into them to a publicly owned treatment works (POTW). However, occasional unintentional discharges of raw sewage from municipal sanitary sewers occur in almost every system. These types of discharges are called sanitary sewer overflows.	*EPA, 2008c*
Saprolite	A soft, clay-rich, thoroughly decomposed rock formed in place by chemical weathering of igneous or metamorphic rock. Forms in humid, tropical, or subtropical climates.	*EPA, 2008b*
Saprophytes	Organisms living on dead or decaying organic matter that help natural decomposition of organic matter in water.	*EPA, 2008b*
Saturated unit weight	The wet unit weight of soil when saturated. See unit weight.	*USBR, 2008*
Saturated zone	The area below the water table where all open spaces are filled with water under pressure equal to or greater than that of the atmosphere.	*EPA, 2008b*
Saturated zone	A zone in which all voids are filled with water. The area below the water table where all open spaces are filled with water. See ground water.	*USBR, 2008*
Saturation	The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.	*EPA, 2008b*
Saturation (and internal vibration)	A method of compacting soil using water added to soil and internal vibrators (such as a concrete vibrator) are worked down through the depth of soil placed. The condition of being filled to capacity.	*USBR, 2008*

Scale	(1) The spatial or temporal dimension over which an object or process can be said to exist, as in, for example, "the scale of forest habitat." (2) The spatial, attribute, and temporal parameters associated with making an observation or measurement, usually including resolution, extent, window size, classification system (nomenclature), and lag. Important because measured values often change with the 'scale of measurement.' (3) The way in which objects, parts of objects, or processes are related as the scale of measurement changes. For example, fractal models are used to descrdibe some types of 'scaling behavior.' (4) The amount of information or detail about an area. For example, 'coarse-scale' maps have less detailed information than 'fine-scale' maps. Related terms include 'broad scale' (covering a large area). The cartographic terms 'large-scale' and 'small-scale' are (contrary to expectation) equivalent to 'fine-scale' and 'coarse-scale,' respectively.	*EPA, 1997*
Scale	Ratio of map distance to Earth distance. Thus, in a 1:24,000 scale map, one centimeter, inch, or foot equals 24,000 centimeters, inches, or feet on the ground. Graphic scales typically show equivalent map and ground distance in the form of a line or bar.	*USBR, 2008*
Scaling	Prying loose pieces of rock off a face or roof to avoid danger of their falling unexpectedly. An adjustment to an earthquake time history or response spectrum where the amplitude of acceleration, velocity, and/or displacement is increased or decreased, usually without change to the frequency content of the ground motion. The earthquake time history or response spectrum can be scaled based on ground motion parameters of peak acceleration, peak velocity, peak displacement, spectrum intensity, or other appropriate parameters.	*USBR, 2008*
Scarp	Sloped bank.	*FISHWR, 2001*
Scarp (beach scarp)	An almost vertical slope along the beach caused by wave erosion. It may vary in height from a few centimeters to a meter or more, depending on wave action and the nature and composition of the beach.	*CCC, 2008*
Scatter	A concentration of artifacts.	*USBR, 2008*
Scenic rivers	Rivers or sections of rivers that are free from impoundments, with shorelines or watersheds still largely primitive, and shorelines largely undeveloped, but accessible in places by roads.	*USACE, 1999*
Schist	Metamorphic rock composed of platy mica minerals aligned in the same direction.	*USBR, 2008*
Science Advisory Board (SAB)	A group of external scientists who advise EPA on science and policy.	*EPA, 2008b*

Scientific name	A formal Latin or latinized name applied to a taxonomic group of animals or plants. A species' scientific name is a two-part combination consisting of the genus followed by the species. The name is italicized or underlined. For example, the scientific name of the little brown bat is Myotis lucifugus. The genus name is Myotis, and the species name is lucifugus. If an animal species has been further divided into subspecies, or a plant species further divided into varieties, a third part is added to the scientific name. The Arizona bat is Myotis lucifugus occultus; "occultus" distinguishes the Arizona subspecies from other subspecies of the little brown bat.	*USFWS, 2008*
Scientific take permit	See Recovery permit.	*USFWS, 2008*
Scoping modeling	A method of approximation that involves simple, steady-state analytical solutions for a rough analysis of a problem.	*EPA, 2008c*
Scour	The erosive action of running water in streams, which excavates and carries away material from the bed and banks. Scour may occur in both earth and solid rock material and can be classed as general, contraction, or local scour.	*USACE, 1999*
Scour	Concentrated erosive action of flowing water in streams that removes and carries away material from the bed and banks.	*USFS, 2002*
Scour	To abrade and wear away. Used to describe the weathering away of a terrace or diversion channel or streambed. The clearing and digging action of flowing water, especially the downward erosion by stream water in sweeping away mud and silt on the outside of a meander or during flood events.	*EPA, 2008c*
Scour	Erosion in a stream bed, particularly if caused or increased by channel changes.	*USBR, 2008*
Scour	Removal of material by waves and currents, especially at the back, base, toe or edges of a shore structure.	*CCC, 2008*
Scrape	A nest made from scratching in the ground.	*USBR, 2008*
Screen	A mesh or bar surface used for separating pieces or particles of different sizes. A filter.	*USBR, 2008*
Screening risk assessment	A risk assessment performed with few data and many assumptions to identify exposures that should be evaluated more carefully for potential risk.	*EPA, 2008b*
Sea	The Pacific Ocean and all harbors, bays, channels, estuaries, salt marshes, sloughs, and other areas subject to tidal action through any connection with the Pacific Ocean, excluding nonestuarine rivers, streams, tributaries, creeks, and flood control and drainage channels. Sea does not include the area of jurisdiction of the San Francisco Bay Conservation and Development Commission, established pursuant to Title 7.2 (commencing with Section 66600) of the Government Code, including any river, stream, tributary, creek, or flood control or drainage channel flowing directly or indirectly into such area.	*CCC, 2008*
Sea level	The height of the ocean relative to land; tides, wind, atmospheric pressure changes, heating, cooling, and other factors cause sea-level changes.	*CCC, 2008*
Seam	A layer of rock, coal, or ore.	*USBR, 2008*

Seas (waves)	Waves caused by wind at the place and time of observation. (see swell).	*CCC, 2008*
Seasonal application efficiency (SAE)	The sum of evapotranspiration of applied water and leaching requirement divided by the total applied water, expressed as a percentage: SAE=(ETAW+LR)/AW.	*USACE, 1999*
Seasonal stream	See intermittent stream.	*USBR, 2008*
Seawall	A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. It is usually a vertical wood or concrete wall as opposed to a sloped revetment.	*CCC, 2008*
Secchi depth	A relatively crude measurement of the turbidity (cloudiness) of surface water. The depth at which a Secchi disc can no longer be seen.	*USACE, 1999*
Secchi depth	A measure of water clarity.	*USBR, 2008*
Secchi disc	A circular plate, generally about 10-12 inches (24.5-30.5 cm) in diameter, used to measure the transparency or clarity of water by noting the greatest depth at which it can be visually detected. Its primary use is in the study of lakes.	*USACE, 1999*
Second foot (sec-ft)	Shortened term for cubic foot per second (cfs or ft3/s).	*USBR, 2008*
Second units	Auxiliary residential units on a lot with an existing primary residential unit. Second units may lack full facilities, such as kitchens.	*CCC, 2008*
Secondary effect	Action of a stressor on supporting components of the ecosystem, which in turn impact the ecological component of concern.	*EPA, 2008b*
Secondary maximum contaminant level (SMCL)	The maximum contamination level in public water systems that, in the judgment of the U.S. Environmental Protection Agency (USEPA), are required to protect the public welfare. SMCLs are secondary (nonenforceable) drinking water regulations established by the USEPA for contaminants that may adversely affect the odor or appearance of such water.	*USGS, 2008*
Secondary treatment	In sewage, the biological process of reducing suspended colloidal, and dissolved organic matter in effluent from primary treatment systems. Secondary treatment usually involves the use of trickling filters for the activated sludge process.	*USACE, 1999*
Section	An area equal to 640 acres or 1 square mile.	*USBR, 2008*
Section 4(d) rule	A regulation developed by FWS or NOAA Fisheries establishing prohibitions that apply for a threatened species. Any prohibitions adopted must be those necessary and advisable to provide for the conservation of the species.	*USFWS, 2008*
Secure maximum contaminant level	Maximum permissible level of a contaminant in water delivered to the free flowing outlet of the ultimate user, or of contamination resulting from corrosion of piping and plumbing caused by water quality.	*EPA, 2008b*
Sediment	Topsoil, sand, and minerals washed from the land into water, usually after rain or snow melt.	*EPA, 2008b*
Sediment	Soil or mineral material transported by water or wind and deposited in streams or other bodies of water.	*USACE, 1999*
Sediment	Soil particles that have been transported and/or deposited by wind or wave action.	*USFS, 2002*

Sediment	Particulate organic and inorganic matter that accumulates in a loose, unconsolidated form on the bottom of natural waters.	*EPA, 2008c*
Sediment	Any finely divided organic and/or mineral matter deposited by air or water in nonturbulent areas. Unconsolidated solid material that comes from weathering of rock and is carried by, suspended in, or deposited by water or wind.	*USBR, 2008*
Sediment	Grains of soil, sand, or rock that have been transported from one location and deposited at another.	*CCC, 2008*
Sediment	Usually applied to material in suspension in water or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.	*DOC, 2005*
Sediment	Particles, derived from rocks or biological materials, that have been transported by a fluid or other natural process, suspended or settled in water.	*USGS, 2008*
Sediment budget	An account of the sand and sediment along a particular stretch of coast; the sources, sinks, rates of movement, or the supply and loss of sediment.	*CCC, 2008*
Sediment budget	A mass balance of sediment supply, storage, and yield over time.	*DOC, 2005*
Sediment concentration	The quantity of sediment relative to the quantity of transporting fluid, or fluid-sediment misture. The concentration may be by weight or by volume. When expressed in ppm, the concentration is always in ratio by weight.	*USBR, 2008*
Sediment delivery	Contribution of transported sediment to a particular location or part of a landscape.	*EPA, 2008c*
Sediment discharge	Rate at which sediment passes a stream cross-section in a given period of time, expressed in millions of tons per day (mtd).	*USBR, 2008*
Sediment guideline	Threshold concentration above which there is a high probability of adverse effects on aquatic life from sediment contamination, determined using modified USEPA (1996) procedures.	*USGS, 2008*
Sediment load	The sediment transported through a channel by a stream flow.	*USFS, 2002*
Sediment load	Mass of sediment passing through a stream cross section in a specified period of time, expressed in millions of tons (mt). Amount of sediment carried by running water. The sediment that is being moved by a stream.	*USBR, 2008*
Sediment loading	The solid material transported by a stream, expressed as the dry weight of all sediment that passes a give point in a given time.	*EPA, 1997*
Sediment oxygen demand (SOD)	The solids discharged to a receiving water are partly organics, and upon settling to the bottom, they decompose anaerobically as well as aerobically, depending on conditions. The oxygen consumed in aerobic decomposition represents another dissolved oxygen sink for the waterbody.	*EPA, 2008c*
Sediment production	Delivery of colluvium or bedrock from hillslope to stream channel. The production rate is evaluated as the sum of the rates of colluvial bank erosion and sediment transport across channel banks.	*EPA, 2008c*
Sediment quality guideline	Threshold concentration above which there is a high probability of adverse effects on aquatic life from sediment contamination, determined using modified USEPA (1996) procedures.	*USGS, 2008*
Sediment yield	The quantity of sediment arriving at a specific location.	*EPA, 2008b*

Sediment yield	Amount of sediment passing a particular point (e.g., discharge point of the basin) in a watershed per unit of time.	*EPA, 2008c*
Sediment yield	Amount of mineral or organic soil material that is in suspension, is being transported, or has been moved from its site of origin. The portion of eroded material that does travel through the drainage network to a downstream measuring or control point. The dry weight of sediment per unit volume of water-sediment mixture in place, or the ratio of the dry weight of sediment to the total weight of water-sediment mixture in a sample or a unit volume of the mixture.	*USBR, 2008*
Sediment yield rate	The sediment yield per unit of drainage area.	*USBR, 2008*
Sedimentary	Rock resulting from the consolidation of loose eroded sediment, remains of organisms, or crystals forming directly from water.	*USBR, 2008*
Sedimentation	Letting solids settle out of wastewater by gravity during treatment.	*EPA, 2008b*
Sedimentation	(1) The combined processes of soil erosion, entrainment, transport, deposition, and consolidation. (2) Deposition of sediment.	*USACE, 1999*
Sedimentation	Process of deposition of waterborne or windborne sediment or other material; also refers to the infilling of bottom substrate in a waterbody by sediment (siltation).	*EPA, 2008c*
Sedimentation	Deposition of waterborne sediments due to a decrease in velocity and corresponding reduction in the size and amount of sediment which can be carried.	*USBR, 2008*
Sediments	Soil, sand, and minerals washed from land into water, usually after rain. They pile up in reservoirs, rivers and harbors, destroying fish and wildlife habitat, and clouding the water so that sunlight cannot reach aquatic plants. Careless farming, mining, and building activities will expose sediment materials, allowing them to wash off the land after rainfall.	*EPA, 2008b*
Seed protectant	A chemical applied before planting to protect seeds and seedlings from disease or insects.	*EPA, 2008b*
Seep	A spot where ground water oozes slowly to the surface, usually forming a pool.	*USBR, 2008*
Seepage	Percolation of water through the soil from unlined canals, ditches, laterals, watercourses, or water storage facilities.	*EPA, 2008b*
Seepage	The gradual movement of a fluid into, through, or from a porous medium.	*USACE, 1999*
Seepage	The slow movement or percolation of water through soil or rock. Movement of water through soil without formation of definite channels. The movement of water into and through the soil from unlined canals, ditches, and water storage facilities. The slow movement or percolation of water through small cracks, pores, interstices, etc., from an embankment, abutment, or foundation.	*USBR, 2008*
Seepage	(1) The slow movement of water through small cracks, pores, Interstices, etc., of a material into or out of a body of surface or subsurface water. (2) The loss of water by infiltration into the soil from a canal, ditches, laterals, watercourse, reservoir, storage facilities, or other body of water, or from a field.	*DOC, 2005*

Seepage collar	A projecting collar of concrete built around the outside of a tunnel or conduit, within an embankment dam, to reduce seepage along the outer surface of the conduit.	*USBR, 2008*
Seepage force	The force transmitted to the soil or rock grains by seepage.	*USBR, 2008*
Seepage loss	Water loss by capillary action and slow percolation.	*USBR, 2008*
Seepage velocity	The rate of discharge of seepage water through a porous medium per unit area of void space perpendicular to the direction of the flow.	*USBR, 2008*
Seiche	A standing wave oscillation in an enclosed waterbody that continues (in a pendulum fashion) after the cessation of the originating force. Seiches can be caused by tidal action or an offshore seismic event.	*CCC, 2008*
Seiche wave	A wave generated by either a landslide into a reservoir or by a sudden displacement or deformation of a fault line in a reservoir floor during a major earthquake.	*USBR, 2008*
Seismic	Of or related to movement in the earth's crust caused by natural relief of rock stresses.	*USBR, 2008*
Seismic evaluation criteria	A guideline for determining which faults or seismic sources need to be assigned MCE's. For high hazard structures, faults with Holocene or latest Pleistocene displacement are included and probabilistic assessments are based on an annual probability of occurrence of 2 x 10-5. For significant hazard structures, faults with Holocene displacement are included and probabilistic assessments are based on an annual probability of occurrence of 1 x 10-4.	*USBR, 2008*
Seismic intensity	Subjective measurement of the degree of shaking at a specified place by an experienced observer using a descriptive scale. See intensity scale.	*USBR, 2008*
Seismic parameters	Descriptors of earthquake loading or earthquake size, such as magnitude, peak acceleration, location (distance and focal depth), spectrum intensity, or any of many other parameters useful in characterizing earthquake loadings.	*USBR, 2008*
Seismo	Pertains to earthquakes.	*USBR, 2008*
Seismotectonic	Of, relating to, or designating structural features of the earth which are associated with or revealed by earthquakes.	*USBR, 2008*
Seismotectonic Province	A geographic area characterized by a combination of geology and seismic history.	*USBR, 2008*
Seize	To bind wire rope with soft wire, to prevent it from ravelling when cut.	*USBR, 2008*
Select material	Backfill materials specially selected and segregated from excavated materials.	*USBR, 2008*
Selective herbicide	Kills or significantly retards growth of an unwanted plant species without significantly damaging desired plant species.	*USGS, 2008*
Selective pesticide	A chemical designed to affect only certain types of pests, leaving other plants and animals unharmed.	*EPA, 2008b*
Semi-confined aquifer	An aquifer partially confined by soil layers of low permeability through which recharge and discharge can still occur.	*EPA, 2008b*
Semipermeable membrane device (SPMD)	A long strip of low-density, polyethylene tubing filled with a thin film of purified lipid such as triolein that simulates the exposure to and passive uptake of highly lipid-soluble organic compounds by biological membranes.	*USGS, 2008*

Semipervious zone	See transition zone.	*USBR, 2008*
Semivolatile organic compound (SVOC)	Operationally defined as a group of synthetic organic compounds that are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and Polycyclic aromatic hydrocarbons (PAHs).	*USGS, 2008*
Senescence	The aging process. Sometimes used to describe lakes or other bodies of water in advanced stages of eutrophication. Also used to describe plants and animals.	*EPA, 2008b*
Sensitive coastal resource areas	Those identifiable and geographically bounded land and water areas within the coastal zone of vital interest and sensitivity. Sensitive coastal resource areas include the following: (a) Special marine and land habitat areas, wetlands, lagoons, and estuaries as mapped and designated in Part 4 of the coastal plan. (b) Areas possessing significant recreational value. (c) Highly scenic areas. (d) Archaeological sites referenced in the California Coastline and Recreation Plan or as designated by the State Historic Preservation Officer. (e) Special communities or neighborhoods which are significant visitor destination areas. (f) Areas that provide existing coastal housing or recreational opportunities for low- and moderate-income persons. (g) Areas where divisions of land could substantially impair or restrict coastal access.	*CCC, 2008*
Sensitive species	Species not yet officially listed but undergoing status review for listing on the U.S. Fish and Wildlife Service's (FWS) official threatened and endangered list; species whose populations are small and widely dispersed or restricted to a few localities; and species whose numbers are declining so rapidly that official listing may be necessary.	*USBR, 2008*
Sensitivity testing	Method in which the impact on the output of an analysis is assessed by systematically changing the input values.	*Mockett & Simm, 2002*
Separation deposit	Sand deposit located at the upstream end of a recirculation zone, where downstream flow becomes separated from the channel bank.	*USBR, 2008*
Seral	Successional sequence of plants in a specific plant community. Stage of plant development from pioneer to climax.	*USFS, 2002*
Service spillway (primary spillway)	A structure located on or adjacent to a storage or detention dam over or through which surplus or floodwaters which cannot be contained in the allotted storage space are passed, and at diversion dams to bypass flows exceeding those which are turned into the diversion system. Included as part of the spillway would be the intake and/or control structure, discharge channel, terminal structure, and entrance and outlet channels. A spillway that is designed to provide continuous or frequent regulated or unregulated releases from a reservoir without significant damage to either the dam or its appurtenant structures.	*USBR, 2008*
Setback levees	Levees that are built on the land side of existing levees, usually because the existing levees have suffered distress or are in some way being endangered, as by river migration.	*FEMA, 2003*

Settleable solids	Those solids that will settle to the bottom of a cone-shaped container, an Imhoff cone, in a 60-minute period.	*EPA, 2008c*
Settlement	The sinking of land surfaces because of subsurface compaction, usually occuring when moisture, added deliberately or by nature, causes a reduction in void volumes.	*USBR, 2008*
Setup	The vertical rise in the stillwater level at the upstream face of a dam caused by wind stresses on the water surface.	*USBR, 2008*
Sewage	The liquid waste from domestic, commercial, and industrial establishments.	*USACE, 1999*
Sewer	A channel or conduit that carries wastewater and stormwater runoff from the source to a treatment plant or receiving stream. "Sanitary" sewers carry household, industrial, and commercial waste. "Storm" sewers carry runoff from rain or snow. "Combined" sewers handle both.	*EPA, 2008c*
Shale	A rock formed of consolidated mud. Fine-grained sedimentary rock formed from hardened clay and silt that typically splits into thin layers.	*USBR, 2008*
Shale	A rock composed predominantly of clay minerals.	*CCC, 2008*
Shear	A structural break where differential movement has occurred along a surface or zone of failure.	*USBR, 2008*
Shear strength	The internal resistance of a body to shear stress. Typically includes frictional and cohesive components. Expresses the ability of soil to resist sliding.	*USFS, 2002*
Shear strength	The maximum resistance of a soil or rock to shearing stresses.	*USBR, 2008*
Shear stress	The force per unit area tending to deform a material in the direction of flow. The pull on a bank that may cause it to slide.	*USFS, 2002*
Shear wall	A vertical lateral-force-resisting element in a structure assigned to resist wind or earthquake generated lateral forces. Depending on detailing and transfer mechanisms, a shear wall can be load-bearing.	*USBR, 2008*
Shear zone	An area where the rock mass has moved along the plane of contact which often becomes a channel for ground water.	*USBR, 2008*
Sheepsfoot roller	A tamping roller having lugs with feet extending at their outer tips.	*USBR, 2008*
Sheet erosion	Also Sheetwash. Erosion of the ground surface by unconcentrated (i.e. not in rills) overland flow.	*EPA, 2008c*
Sheet piling	Steel strips shaped to interlock with each other when driven into the ground.	*USBR, 2008*
Sheet wash	A flow of rainwater that covers the entire ground surface with a thin film and is not concentrated into streams.	*USBR, 2008*
Sheetwash	Also sheet erosion. Erosion of the ground surface by unconcentrated (i.e. not in rills) overland flow.	*EPA, 2008c*
Shell	See shoulder.	*USBR, 2008*
Shelterbelt	A natural or planned barrier of trees or shrubs to reduce erosion and provide shelter from winds or storms.	*USBR, 2008*
Shelterbelt	A natural or planned barrier of trees or shrubs to reduce erosion and provide shelter from winds or storms.	*USBR, 2008*
Sheltering (in-place)	A protective action that involves taking cover in upper levels of a building that is able to withstand high flood levels.	*USBR, 2008*

Shoal	A shallowing of the depth of water, often a navigational channel. This shallowing may be caused by the deposition of river sediments or littoral materials and often becomes a hazard to navigation. Incoming ocean waves will heighten and may break as they approach the shallowing shoreline. Dredging and channel modification is often utilized to reduce deposition.	*CCC, 2008*
Shore	Narrow strip of land in immediate contact with the sea, including the zone between high and low water. A shore of unconsolidated material is usually called a beach.	*CCC, 2008*
Shore protection	Structures or sand placed at or on the shore to reduce or eliminate upland damage from wave action or flooding during storms.	*CCC, 2008*
Shoreline	Intersection of the ocean or sea with land; the line delineating the shoreline on National Ocean Service nautical charts and surveys approximates the mean low water line from the time the chart was prepared.	*CCC, 2008*
Shoreline armoring	Protective structures such as vertical seawalls, revetments, riprap, revetments, and bulkheads built parallel to the shoreline for the purposes of protecting a structure or other upland property.	*CCC, 2008*
Shoring	Temporary bracing to hold the sides of an excavation from caving.	*USBR, 2008*
Short-throated flumes	Short-throated flumes are considered short because they control flow in a region that produces curvilinear flow. While they may be termed shortthroated, the overall specified length of the finished structure, including transitions, may be relatively long. The Parshall flume is the main example of this kind of flume. These flumes would require detailed accuracy and accurate knowledge of the individual streamline curvatures for calculated ratings which is usually considered impractical. Thus short-throated flumes are determined empirically by comparison with other more precise and accurate water measuring systems.	*USBR, 2008*
Shoulder (shell)	The upstream and downstream parts of the cross section of an embankment dam on each side of the core or core wall. Hence the expression upstream shoulder or downstream shoulder. The graded part of a road on each side of the pavement. The side of a horizontal pipe, at the level of the center line.	*USBR, 2008*
Shrinkage	Loss of bulk of soil when compacted in a fill.	*USBR, 2008*
Shrinkage index (SI)	The numerical difference between the plastic and shrinkage limits.	*USBR, 2008*
Shrinkage limit (SL)	The maximum water content at which a reduction in water content will not cause a decrease in volume of the soil mass.	*USBR, 2008*
Shrinkage ratio (R)	The ratio of a given volume change, expressed as a percentage of the dry volume, to the corresponding change in moisture content above the shrinkage limit, expressed as a percentage of the weight of the oven-dried soil.	*USBR, 2008*
Sideslope gradient	The representative change in elevation in a given horizontal distance (usually about 300 yards) perpendicular to a stream; the valley slope along a line perpendicular to the stream (near the water	*USGS, 2008*

Significant hazard	A downstream hazard classification for dams in which 1-6 lives are in jeopardy and appreciable economic loss (rural area with notable agriculture, industry, or worksites, or outstanding natural resources) would occur as a result of failure of the dam. This classification also applies to structures other than dams.	*USBR, 2008*
Significant wave height	The average height of the one-third highest waves of a given wave group.	*USBR, 2008*
Siliciclastic rocks	Rocks such as shale and sandstone which are formed by the compaction and cementation of quartz-rich mineral grains.	*USGS, 2008*
Sill	A submerged structure across a river to control the water level upstream. The crest of a spillway. The horizontal gate seating, made of wood, stone, concrete, or metal at the invert of any opening or gap in a structure. Hence, the expressions: gate sill, stoplog sill.	*USBR, 2008*
Silt	Sedimentary materials composed of fine or intermediate-sized mineral particles.	*EPA, 2008b*
Silt	Substrate particles smaller than sand and larger than clay (3 to 60 mm).	*USACE, 1999*
Silt	Slightly cohesive to noncohesive soil composed of particles that are finer than sand but coarser than clay; commonly in the range of 0.004 to 0.0625 mm, silt will crumble when rolled into a ball.	*USFS, 2002*
Silt	Noncohesive soil whole individual particles are not visible to the unaided human eye (0.002 to 0.05 mm). Silt will crumble when rolled into a ball.	*EPA, 2008c*
Silt (rock flour)	The fine-grained portion of soil that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry. Nonplastic soil which passes a No. 200 United States Standard sieve. A soil composed of particles between 1/256 mm and 1/16 mm in diameter. A heavy soil intermediate between clay and sand.	*USBR, 2008*
Siltation	The deposition or accumulation of fine soil particles.	*USACE, 1999*
Siltation	The process by which a river, lake, or other water body becomes clogged with sediment.	*EPA, 2008c*
Silting	Filling with soil or mud deposited by water.	*USBR, 2008*
Siltstone	Fine-grained sedimentary rock composed mainly of silt-sized particles.	*USBR, 2008*
Silviculture	Management of forest land for timber.	*EPA, 2008b*
Similarity of appearance	A species may be treated as endangered or threatened if it resembles in appearance a species which has been listed under section 4 and enforcement personnel would have difficulty distinguishing between the listed and the unlisted species; if the effect of this difficulty is an additional threat to the listed species; and if such treatment of the unlisted species would improve protection for the listed species. A similarity of appearance listing must be formalized by rule.	*USFWS, 2008*

Simulation	The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.	*EPA, 2008c*
Simulid	Group of two-winged flying insects who live their larval stage underwater and emerge to fly about as adults.	*USBR, 2008*
Single-stage pump	A pump that has only one impeller.	*USBR, 2008*
Single-thread stream	Streams with only one channel.	*FISHWR, 2001*
Sink	Place in the environment where a compound or material collects.	*EPA, 2008b*
Sink	Depression in the land surface, especially one having a central playa or saline lake with no outlet.	*USBR, 2008*
Sinkhole	A steep-sided depression formed when removal of subsurface embankment or foundation material causes overlying material to collapse into the resulting void.	*USBR, 2008*
Sinkhole	A steep-sided depression formed when removal of subsurface embankment or foundation material causes overlying material to collapse into the resulting void.	*USBR, 2008*
Sinuosity	A measure of channel curvature computed by dividing the channel centerline length by the length of the valley centerline. If the channel length/valley length ratio is more than about 1.3, the stream can be considered meandering in form. Sinuosity is generally related to the product of discharge and gradient.	*FISHWR, 2001*
Sinuosity	The ration of channel length to direct down-valley distance. Also may be expressed as the ratio of down-valley slope to channel slope.	*USACE, 1999*
Sinuosity	The degree to which a river or stream bends.	*EPA, 2008c*
Sinuosity	The ratio of the length of a river's thalweg to the length of the valley proper. A measure of a river's meandering. Rivers with a sinuosity less than 1.5 are usually considered straight.	*USBR, 2008*
Sinuosity	The ratio of the channel length between two points on a channel to the straight line distance between the same two points; a measure of meandering.	*USGS, 2008*
Siphon	A pipe connecting two canals. A tube or pipe through which water flows over a high point by gravity.	*USBR, 2008*
Siphon tube	Relatively short, light-weight, curved tube used to convey water over ditch banks to irrigate furrows or borders.	*USBR, 2008*
Siphonage	A partial vacuum created by the flow of liquids in pipes.	*USBR, 2008*
Site	In archeology, any location of past human activity.	*USBR, 2008*
Skewed	On a horizontal angle, or in an oblique course or direction.	*USBR, 2008*
Skip	A non-digging bucket or tray that hoists material	*USBR, 2008*
Skiving	To dig in thin layers.	*USBR, 2008*
Slab	The deck or floor of a concrete bridge.	*USBR, 2008*
Slab foundation	A foundation type that supports a building in a thin layer of steel reinforces concrete.	*CCC, 2008*
Slaking	The process of breaking up or sloughing when an indurated soil is immersed in water.	*USBR, 2008*

Slate	Fine-grained metamorphic rock formed by "baking" and recrystallizing shale or mudstone and which splits easily along flat, parallel planes.	*USBR, 2008*
Sleet	Precipitation that consists of clear pellets of ice; sleet is formed when raindrops fall through a layer of cold air and freeze.	*USBR, 2008*
Slide	A small landslide.	*USBR, 2008*
Slope	The ratio of change in elevation over distance.	*USACE, 1999*
Slope	The amount of vertical rise divided by the horizontal run.	*USFS, 2002*
Slope	The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04); degrees (2 degrees 18 minutes), or percent (4 percent).	*EPA, 2008c*
Slope	An inclined surface usually defined by the ratio of the horizontal distance to the vertical distance, i.e. 2:1 (2 horizontal units to 1 vertical unit). Change in elevation per unit of horizontal distance. Side of a hill or a mountain. The inclined face of a cut, canal, or embankment. Inclination from the horizontal. Expressed in percent when the slope is gentle; in this case also termed gradient. Degree of deviation of a surface from the horizontal, usually expressed in percent or degrees. Sometimes referred to as batter when measured from vertical.	*USBR, 2008*
Slope protection	The protection of an embankment slope against wave action or erosion.	*USBR, 2008*
Slope stability	The resistance of a natural or artificial slope or other inclined surface to failure by mass movement.	*USACE, 1999*
Slough	A shallow backwater inlet that is commonly exposed at low flow or tide.	*USACE, 1999*
Slough	An inlet or backwater, sometimes an alternate branch of a river.	*USFS, 2002*
Slough	Movement of a soil mass downward along a slope because of a slope angle too great to support the soil, wetness reducing internal friction among particles, or seismic activity. It is also called a slope failure, usually a rather shallow failure. A wet place of deep mud or mire, or a temporary or permanent lake; ordinarily found on or at the edge of the flood plain or a river. Also refers to a creek or sluggish body of water in a bottomland.	*USBR, 2008*
Slough	To erode the uppermost layer of soil, or to crumble and fall away from the face of a cliff.	*CCC, 2008*
Sloughing	The downward slipping of a mass of soil, moving as a unit usually with backward rotation, down a bank. Also called sloughing off or slumping. Sloughing is similar to a landslide.	*USFS, 2002*
Slug	Large initial amount. A unit of mass which will undergo an acceleration of 1 foot per second squared when a force of 1 pound is applied to it.	*USBR, 2008*
Sluice	An opening for releasing water from below the static head elevation.	*USBR, 2008*
Sluice gate	A gate that can be opened or closed by sliding in supporting guides.	*USBR, 2008*
Sluiceway	An opening in a diversion dam used to discharge heavy floating debris safely past the dam.	*USBR, 2008*
Sluicing	A method of compacting soil where the soil is washed into placed with a high velocity stream of water.	*USBR, 2008*

Slurry	Watery mixture of insoluble matter which is pumped beneath a dam to form an impervious barrier. Cement grout.	*USBR, 2008*
Slurry trench	A narrow excavation whose sides are supported by a mud slurry filling the excavation. Sometimes used incorrectly to describe the cutoff itself.	*USBR, 2008*
Smolts	Adolescent salmon 3 to 7 inches long.	*USBR, 2008*
Snag	Any standing dead, partially dead, or defective (cull) tree at least 10 inches in diameter at breast height and at least 6 feet tall. Snags are important riparian habitat features.	*USACE, 1999*
Snow	Precipitation that consists of frozen flakes formed when water vapor accumulates on ice crystals, going directly to the ice phase.	*USBR, 2008*
Social value (psychological value)	Concept that the existence of wilderness provides a condition that could allow an individual to achieve control over stressful conditions, thus contributing to the psychological health of many off-site users.	*USBR, 2008*
Sodic soil	Contains sufficient exchangeable sodium to interfere with the growth of most crop plants. The sodium-adsorption ratio of the saturation extract is 15 or more.	*USBR, 2008*
Sodicity	The exchangeable-sodium content of the soil. High sodium content.	*USBR, 2008*
Soft water	Any water that does not contain a significant amount of dissolved minerals such as salts of calcium or magnesium.	*EPA, 2008b*
Soft water	Water that contains low concentrations of multivalent cations, such as calcium and magnesium. This type of water does not precipitate soaps and detergents.	*USACE, 1999*
Soil	Sediments or other unconsolidated accumulations of solid particles produced by the physical and chemical disintegration of rocks, and which may or may not contain organic matter. Soil components may consist of clay, silt, sand, or gravel. The loose surface material of the earth's crust.	*USBR, 2008*
Soil and water conservation practices	Control measures consisting of managerial, vegetative, and structural practices to reduce the loss of soil and water.	*EPA, 2008b*
Soil bioengineering	An applied science that combines structural, biological, and ecological concepts to construct living structures for erosion, sediment, and flood control. It is always based on sound engineering practices integrated with ecological principles.	*USFS, 2002*
Soil cement	A mixture of water, cement, and natural soil, usually processed in a tumble and mixed to a specific consistency, then placed in lifts and rolled to compact to provide slope protection. A mixture of Portland cement and pulverized soil placed in layers on the upstream face of a dam to provide slope protection. A tightly compacted mixture of pulverized soil, Portland cement, and water that, as the cement hydrates, forms a hard, durable, low-cost paving material.	*USBR, 2008*

Soil classification	Systematic arrangement of soils into classes of one or more categories or levels of classification for a specific objective. Broad groupings are made on the basis of general characteristics and subdivisions are made on the basis of more detailed differences in specific properties. See Unified Soil Classification System.	*USBR, 2008*
Soil conditioner	An organic material like humus or compost that helps soil absorb water, build a bacterial community, and take up mineral nutrients.	*EPA, 2008b*
Soil conservation	Protection of soil against physical loss by erosion and chemical deterioration by the application of management and land-use methods that safeguard the soil against all natural and human-induced factors.	*USBR, 2008*
Soil erodibility	An indicator of a soil's susceptibility to raindrop impact, runoff, and other erosive processes.	*EPA, 2008b*
Soil moisture	The water contained in the pore space of the unsaturated zone.	*EPA, 2008b*
Soil moisture	Water stored in soils.	*USBR, 2008*
Soil subsidence	The lowering of the normal level of the ground, usually due to overpumping of water from wells.	*USBR, 2008*
Soil-cement bedding	A mixture of soil, portland cement, and water placed for pipe bedding.	*USBR, 2008*
Soldier pile wall	Vertical pilings or steel H-beams deeply embedded into the sand or bedrock, with horizontal planks or beams landward of the vertical supports.	*CCC, 2008*
Sole-source aquifer	An aquifer that supplies 50-percent or more of the drinking water of an area.	*EPA, 2008b*
Sole-source aquifer	A groundwater system that supplies at least 50 percent of the drinking water to a particular human population; the term is used to denote special protection requirements under the Safe Drinking Water Act and may be used only by approval of the U.S. Environmental Protection Agency.	*USGS, 2008*
Solid head buttress dam	A buttress dam in which the upstream end of each buttress is enlarged to span the gap between buttresses. The terms "round head," "diamond head," "tee head" refer to the shape of the upstream enlargement. See massive head buttress dam.	*USBR, 2008*
Solid phase extraction	A procedure to isolate specific organic compounds onto a bonded silica extraction column.	*USGS, 2008*
Solubility	The amount of mass of a compound that will dissolve in a unit volume of solution. Aqueous Solubility is the maximum concentration of a chemical that will dissolve in pure water at a reference temperature.	*EPA, 2008b*
Soluble minerals	Naturally occurring substances capable of being dissolved.	*USACE, 1999*
Solute	A substance that is dissolved in another substance, thus forming a solution.	*DOC, 2005*
Solute	See Solution.	*USGS, 2008*
Solution	Formed when a solid, gas, or another liquid in contact with a liquid becomes dispersed homogeneously throughout the liquid. The substance, called a solute, is said to dissolve. The liquid is called the solvent.	*USGS, 2008*
Solvent	See Solution.	*USGS, 2008*

Sorption	he action of soaking up or attracting substances; process used in many pollution control systems.	*EPA, 2008b*
Sorption	General term for the interaction (binding or association) of a solute ion or molecule with a solid.	*USGS, 2008*
Source rocks	The rocks from which fragments and other detached pieces have been derived to form a different rock.	*USGS, 2008*
Source water	Untreated water from streams, rivers, lakes, or underground aquifers which is used to supply private wells and public drinking water.	*EPA, 2008c*
Spalling (spall)	The loss of surface concrete usually caused by impact, abrasion, or compression. To break off from a surface in sheets or pieces.	*USBR, 2008*
Spatial concentration	The dry weight of sediment per unit volume of water-sediment mixture in place, or the ratio of the dry weight of sediment to the total weight of water-sediment mixture in a sample or a unit volume of the mixture.	*USBR, 2008*
Spatial database	A collection of information that contains data on the phenomenon of interest, such as forest condition or stream pollution, and the location of the phenomenon on the earth's surface.	*EPA, 1997*
Spatial pattern	Generally, the way things are arranged on a map. For example, the pattern of forest patches can be described by their number, size, shape, distance between patches, etc. The spatial pattern exhibited by a map can also be described in terms of its overall texture, complexity, and other indicators.	*EPA, 1997*
Spatial segmentation	A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.	*EPA, 2008c*
Spawn	To lay eggs, refers mostly to fish.	*USBR, 2008*
Spawning	The depositing and fertilizing of eggs (or roe) by fish and other aquatic life.	*USACE, 1999*
Spawning beds	Places in which eggs of aquatic animals lodge or are placed during or after fertilization.	*USBR, 2008*
Special district	Any public agency, other than a local government, formed pursuant to general law or special act for the local performance of governmental or proprietary functions within limited boundaries. Special district includes, but is not limited to, a county service area, a maintenance district or area, an improvement district or improvement zone, or any other zone or area, formed for the purpose of designating an area within which a property tax rate will be levied to pay for a service or improvement benefiting that area.	*CCC, 2008*
Special examination	A field review performed on a high- or significant-hazard dam to address an identified visible dam safety deficiency or to investigate significant changes in operating or loading conditions. Participation in these reviews may be by either the Denver, regional, and/or area offices depending on the nature of the concern.	*USBR, 2008*
Special features	Area containing ecological, geological, or other features of scientific, educational, scenic, or historical value.	*USBR, 2008*

Special populations	Those individuals or groups that may be institutionalized and have needs that require special consideration in emergencies.	*USBR, 2008*
Special rule	See Section 4(d) rule.	*USFWS, 2008*
Special treatment area	An identifiable and geographically bounded forested area within the coastal zone that constitute a significant habitat area, area of special scenic significance, and any land where logging activities could adversely effect public recreation area or the biological productivity of any wetland, estuary, or stream especially valuable because of its role in a coastal ecosytem.	*CCC, 2008*
Species	1. A reproductively isolated aggregate of interbreeding organisms having common attributes and usually designated by a common name.2. An organism belonging to belonging to such a category.	*EPA, 2008b*
Species	For purposes of the Endangered Species Act, this term includes any species or subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.	*USFWS, 2008*
Species	Basic category of biological classification intended to designate a single kind of animal or plant. See candidate species, endangered species, exotic species, extirpated species, obligate riparian species, sensitive species, and threatened species.	*USBR, 2008*
Species	Populations of organisms that may interbreed and produce fertile offspring having similar structure, habits, and functions.	*USGS, 2008*
Species (taxa) richness	The number of species (taxa) present in a defined area or sampling unit.	*USGS, 2008*
Species diversity	The relative density of an individual or group of species compared to the density of all species.	*DOC, 2005*
Species diversity	An ecological concept that incorporates both the number of species in a particular sampling area and the evenness with which individuals are distributed among the various species.	*USGS, 2008*
Species of concern/risk	An informal term referring to a species that might be in need of conservation action. This may range from a need for periodic monitoring of populations and threats to the species and its habitat, to the necessity for listing as threatened or endangered. Such species receive no legal protection and use of the term does not necessarily imply that a species will eventually be proposed for listing. A similar term is "species at risk," which is a general term for listed species as well as unlisted ones that are declining in population. Canada uses the term in its new "Species at Risk Act." “Imperiled species” is another general term for listed as well as unlisted species that are declining.	*USFWS, 2008*
Specific conductance	Rapid method of estimating the dissolved solid content of a water supply by testing its capacity to carry an electrical current.	*EPA, 2008b*
Specific conductance	A measure of the ability of a liquid to conduct an electrical current.	*USGS, 2008*
Specific gravity	The ratio of the mass of a body to an equal volume of water.	*USBR, 2008*
Specific weight	The weight per unit volume.	*USBR, 2008*
Specific yield	The amount of water a unit volume of saturated permeable rock will yield when drained by gravity.	*EPA, 2008b*

Spectrum intensity	The integral of the pseudo-velocity response spectrum taken over the range of significant structural vibration periods of the structure being analyzed.	*USBR, 2008*
Spigot	The plain end of a cast-iron pipe. The spigot is inserted into the bell end of the next pipe to make a water tight joint.	*USBR, 2008*
Spile (forepole)	A plank driven ahead of a tunnel face for roof support.	*USBR, 2008*
Spills	Water releases that cannot be put to use for project purposes (includes floodflows).	*USBR, 2008*
Spillway	A channel for reservoir overflow.	*USACE, 1999*
Spillway	A structure that passes normal and/or flood flows in a manner that protects the structural integrity of the dam. Overflow channel of a dam or impoundment structure. A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway. Any passageway, channel, or structure designed to discharge surplus water from a reservoir. See auxiliary spillway, emergency spillway, service spillway, morning glory spillway, shaft spillway, and fuse plug spillway.	*USBR, 2008*
Spillway channel	An open channel or conduit conveying water from the spillway inlet downstream.	*USBR, 2008*
Spillway chute	A steeply sloping spillway channel that conveys discharges at super-critical velocities.	*USBR, 2008*
Spillway crest	The lowest level at which water can flow over or through a spillway.	*USBR, 2008*
Spinning reserves	Available capacity of generating facilities synchronized to the interconnected electric system where it can be called upon for immediate use in response to system problems or sudden load changes.	*USBR, 2008*
Spit	A small, naturally formed point of land or a narrow shoal projecting into a body of water from the shore.	*CCC, 2008*
Splays	Delta-shaped deposits of coarser sediments that occur when a natural levee is breached. Natural levees and splays can prevent floodwaters from returning to the channel when floodwaters recede.	*FISHWR, 2001*
Split sample	A sample prepared by dividing it into two or more equal volumes, where each volume is considered a separate sample but representative of the entire sample.	*USGS, 2008*
Splitter wall	A wall or pier parallel to the direction of flow in a channel that separates flows released from different sources as a means of energy dissipation.	*USBR, 2008*
Spoil	Dirt or rock removed from its original location--destroying the composition of the soil in the process--as in strip-mining, dredging, or construction.	*EPA, 2008b*
Spoil	Dirt or rock which has been removed from its original location. Excavated material.	*USBR, 2008*
Sprawl	Unplanned development of open land.	*EPA, 2008b*

Sprawl	Patterns of urban growth which includes large acreage of low-density residential development, rigid separation between residential and commercial uses, residential and commercial development in rural areas away from urban centers, minimal support for non-motorized transportation methods, and a lack of integrated transportation and land use planning.	*EPA, 2008c*
Spring	Ground water seeping out of the earth where the water table intersects the ground surface.	*EPA, 2008b*
Spring	Ground water seeping or flowing out of the earth where the water table intersects the ground surface.	*USBR, 2008*
Spring melt/thaw	The process whereby warm temperatures melt winter snow and ice. Because various forms of acid deposition may have been stored in the frozen water, the melt can result in abnormally large amounts of acidity entering streams and rivers, sometimes causing fish kills.	*EPA, 2008b*
Springline	An imaginary horizontal reference line located at midheight, or halfway point, of a circular conduit, pipe, tunnel, or the point at which the side walls are vertical on a horseshoe-shaped conduit. Also the maximum horizontal dimension or diameter of a circular conduit, pipe, or tunnel. The meeting of the roof arch and the sides of a tunnel. The guideline for laying a course of bricks.	*USBR, 2008*
Sprinkler irrigation	A method of irrigation in which the water is sprayed, or sprinkled, through the air to the ground surface.	*USBR, 2008*
Spur levees	Levees that project from the main levee and serve to protect the main levee from the erosive action of stream currents. Spur levees are not true levees; they are training dikes.	*FEMA, 2003*
Stability	Tendency of systems, especially ecosystems, to persist, relatively unchanged, through time; also, persistence of a component of a system.	*USBR, 2008*
Stabilization pond	Large earthen basin used for the treatment of wastewater by natural processes involving the use of both algae and bacteria.	*EPA, 2008c*
Stable channel	A stream channel with the right balance of slope, plan form, and cross section to transport both the water and sediment load without net long-term bed or bank sediment deposition or erosion throughout the stream segment.	*USACE, 1999*
Staff gauge	A graduated scale on a plank or metal plate used to indicate the height of the water in a canal.	*USBR, 2008*
Stage	Same as elevation or depth of water. The height of a water surface above an established datum. See water surface elevation and gage height.	*USBR, 2008*
Stage	The height of the water surface above an established datum plane, such as in a river above a predetermined point that may (or may not) be near the channel floor.	*USGS, 2008*
Stagnation	Lack of motion in a mass of air or water that holds pollutants in place.	*EPA, 2008b*
Stakeholder	Any organization, governmental entity, or individual that has a stake in or may be impacted by a given approach to environmental regulation, pollution prevention, energy conservation, etc.	*EPA, 2008b*
Stakeholder	An individual or organization who has an interest in a project.	*Mockett & Simm, 2002*

Stakeholder	Any person or organization who has an interest in the actions discussed or is affected by the resulting outcomes of a project or action.	*USFWS, 2008*
Stakeholder	Someone who will be impacted socially, culturally, financially, physically, or in some other manner by a decision or decision process.	*DOC, 2005*
Standard deviation	A measure of the dispersion or precision of a series of statistical values such as precipitation or stream flow. It is the square root of the sum of squares of the deviations from the arithmetic mean divided by the number of values or events in the series. It is now standard practice in statistics to divide by the number of values minus one in order to get an unbiased estimate of the variance from the sample data.	*USGS, 1982*
Standard error	An estimate of the standard deviation of a statistic. Often calculated from a single set of observations. Calculated like the standard deviation but differing from it in meaning.	*USGS, 1982*
Standard sample	The part of finished drinking water that is examined for the presence of coliform bacteria.	*EPA, 2008b*
Standby reserves	Unused capacity in an electric system in machines that are not in operation but that are available for immediate use if required.	*USBR, 2008*
Standing Operating Procedures (SOP)	A comprehensive single-source document covering all aspects of dam and reservoir operation and maintenance and emergency procedures. Its purpose is to ensure adherence to approved operating procedures.	*USBR, 2008*
Standpipe	Pipe or tank connected to a closed conduit and extending to or above the hydraulic grade line of the conduit to afford relief from surges of pressure in pipelines. A tank used for storage of water in distribution systems.	*USBR, 2008*
State Emergency Response Commission (SERC)	Commission appointed by each state governor according to the requirements of SARA Title III. The SERCs designate emergency planning districts, appoint local emergency planning committees, and supervise and coordinate their activities.	*EPA, 2008b*
State Environmental Goals and Indication Project	Program to assist state environmental agencies by providing technical and financial assistance in the development of environmental goals and indicators.	*EPA, 2008b*
State management plan	Under FIFRA, a state management plan required by EPA to allow states, tribes, and U.S. territories the flexibility to design and implement ways to protect ground water from the use of certain pesticides.	*EPA, 2008b*
State organization	The State government agency or office having the principal or lead role in emergency planning and preparedness.	*USBR, 2008*
State university	The University of California and the California State University.	*CCC, 2008*
State Water Project (SWP)	A state-operated water management and conveyance system that provides water to agricultural, urban, and industrial users in California.	*DOC, 2005*
Static head	The difference in elevation between the pumping source and the point of delivery. The vertical distance between two points in a fluid.	*USBR, 2008*

Static water depth	The vertical distance from the centerline of the pump discharge down to the surface level of the free pool while no water is being drawn from the pool or water table.	EPA, 2008b
Static water level	1. Elevation or level of the water table in a well when the pump is not operating. 2. The level or elevation to which water would rise in a tube connected to an artesian aquifer or basin in a conduit under pressure.	EPA, 2008b
Station	Any one of a series of stakes or points indicating distance from a point of beginning or reference.	USBR, 2008
Station use	Energy used in a generating plant as necessary in production of electricity. Includes energy consumed for plant light, power, and auxiliaries regardless of whether such energy is produced at plant or comes from another source.	USBR, 2008
Stationary white noise	Random energy with statistical characteristics that do not vary with time.	USBR, 2008
Statistics	A branch of mathematics dealing with the collection, analysis, interpretation, and presentation of masses of numerical data.	USGS, 2008
Steady flow	Flow in an open channel is said to be steady if the depth of flow does not change over a given time interval. No change occurs with repect to time.	USBR, 2008
Steady state condition	When model input values are nearly constant for a defined period of time.	USBR, 2008
Steady-state model	Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations.	EPA, 2008c
Steam	Water vapor that rises from boiling water.	USBR, 2008
Stemming	Crushed stone, soil, sand, or drill cuttings used to plug the unloaded portion of a drill hole.	USBR, 2008
Sticky limit	The lowest moisture content at which a soil will stick to a metal blade drawn across the surface of the soil mass.	USBR, 2008
Still water level	The elevation that the surface of the water would assume if all wave action were absent.	CCC, 2008
Stilling basin	Concrete portion downstream from conduit, tunnel, or control structure. A pool, usually lined with reinforced concrete, located below a spillway, gate, or valve into which the discharge dissipates energy to avoid downstream channel degradation. A basin constructed to dissipate the energy of rapidly flowing water (e.g., from a spillway or outlet) and to protect the riverbed from erosion. See terminal structure.	USBR, 2008
Stilling pool	A pool located below a spillway, gate, or valve into which the discharge dissipates energy to avoid downstream channel degradation. An unlined stilling basin usually constructed in natural ground or rock.	USBR, 2008
Stockpile	A storage pile of materials.	USBR, 2008
Stoichiometric ratio	Mass-balance-based ratio for nutrients, organic carbon and algae (e.g., nitrogen-to-carbon ratio).	EPA, 2008c
Stone	Rock of rock fragments used for construction.	USACE, 1999
Stone	A concretion of earthy or mineral matter; rock.	USBR, 2008

Stoney gate	The fundamental difference between Stoney and fixed-wheel gates is that a moving train of rollers is substituted for the fixed wheels. A gate for large openings that bears on a train of rollers in each gate guide.	*USBR, 2008*
Stop logs	Logs, planks, cut timber, steel, or concrete beams fitting into end guides between walls or piers to close openings in levees, floodwalls, dams, or other hydraulic structures. The stop logs are usually handled or placed one at a time.	*FEMA, 2003*
Stoping	An upward erosion/piping action into an embankment or foundation (possibly leading to a breach). Stoping occurs if the piping process is impeded or terminated prior to reaching the reservoir (by encountering non-erodible material, or the occurrence of a roof collapse). Either there will be no further detrimental consequence to the dam, or the horizontal seepage/piping component could translate upward by stoping, possibly intercepting the reservoir or resulting in sinkholes.	*USBR, 2008*
Stoplogs	Large logs, planks, cut timbers, steel or concrete beams placed on top of each other with their ends held in guides between walls or piers to close an opening in a dam, conduit, spillway, etc., to the passage of water; the logs are usually handled one at a time. Used to provide a cheaper or more easily handled means of temporary closure than a bulkhead gate.	*USBR, 2008*
Storage	The retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of overflow areas, as in the progression of a flood wave through a natural stream channel. See reservoir capacity.	*USBR, 2008*
STORET	U.S. Environmental Protection Agency (EPA) national water quality database for STORage and RETrieval (STORET). Mainframe water quality database that includes physical, chemical, and biological data measured in waterbodies throughout the United States.	*EPA, 2008c*
Storm flow	Precipitation that reaches the channel over a short time frame through overland or underground routes.	*FISHWR, 2001*
Storm hydrograph	A tool used to show how the discharge within a channel changes with time.	*FISHWR, 2001*
Storm runoff	Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or waterbodies or is routed into a drain or sewer system.	*EPA, 2008c*
Storm sewer	A sewer that carries only surface runoff, street wash, and snow melt from the land. In a separate sewer system, storm sewers are completely separate from those that carry domestic and commercial wastewater (sanitary sewers).	*DOC, 2005*
Storm surge	A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes the rise in level due to atmospheric pressure reduction as well as that due to wind stress.	*CCC, 2008*

Stormwater management	Special case of Flow Modification that includes the construction and management of structures (ponds, wetlands and flow regulators) in urban areas to modify the release of storm runoff into waterways from watersheds with elevated imperviousness into waterways. These practices/structures generally aim to reduce peak flow magnitudes and extend flow duration. For the purposes of NRRSS Stormwater Management refers to water quantity not quality. Urban sediment, litter and temperature control should be categorized as Water Quality Management.	*NRRSS, 2005*
Strain	The change in length per unit of length in a given direction.	*USBR, 2008*
Strata (stratum)	Distinct layers of stratified rock. A layer of sedimentary rock, visually separable from other layers above and below. Layers of rock.	*USBR, 2008*
Strategic plan	A written plan outlining a government agency's framework for management.	*USBR, 2008*
Stratification	Separating into layers.	*EPA, 2008b*
Stratification	Thermal layering of water in lakes and streams. Lakes usually have three zones of varying temperature, the epilimnion, the metalimnion, and the hypolimnion. The formation of separate layers (of temperature, plant, or animal life) in a lake or reservoir. See thermal stratification.	*USBR, 2008*
Stratification	Subdivision of the environmental framework. The Study Unit is divided into subareas that exhibit reasonable homogeneous environmental conditions, as determined by both natural and human influences.	*USGS, 2008*
Stratification (of waterbody)	Formation of water layers each with specific physical, chemical, and biological characteristics. As the density of water decreases due to surface heating, a stable situation develops with lighter water overlaying heavier and denser water.	*EPA, 2008c*
Stratified reservoir	A reservoir with several thermal layers of water.	*USBR, 2008*
Stratigraphy	Study of the formation, composition, and sequence of sediments, whether consolidated or not.	*EPA, 2008b*
Stratigraphy	Geology that deals with the origin, composition, distribution, and succession of strata. Study or description of layered or stratified rocks.	*USBR, 2008*
Stream	A general term for a body of water flowing by gravity; natural watercourse containing water at least part of the year. In hydrology, the term is generally applied to the water flowing in a natural narrow channel as distinct from a canal.	*USACE, 1999*
Stream	Natural water course containing water at least part of the year. The type of runoff where water flows in a channel. See ephemeral stream, gaining stream, incised stream, intermittent stream, losing stream, or perennial stream.	*USBR, 2008*
Stream	A general term for a body of flowing water; natural water course containing water at least part of the year. In hydrology, it is generally applied to the water flowing in a natural channel as distinct from a canal.	*DOC, 2005*
Stream bank	The side slopes of a channel between which the stream flow is normally confined.	*USFS, 2002*
Stream bank erosion	The removal of soil from stream banks by flowing water.	*USACE, 1999*

Stream bank Failure	Collapsing or slippage of a large mass of bank material into the channel caused by hydraulic or geotechnical modes, or a combination of both.	*USFS, 2002*
Stream bank stabilization	The lining of stream banks with riprap, matting, etc. or other measures intended to control erosion.	*USACE, 1999*
Stream capacity	Total volume of water that a stream can carry within the normal high water channel.	*USBR, 2008*
Stream channel	A channel with flowing water at least part of the year.	*FISHWR, 2001*
Stream channel	A long narrow depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.	*USACE, 1999*
Stream flow	The rate at which water passes a given point in a stream or river, usually expressed in cubic feet per second (cfs).	*USACE, 1999*
Stream flow	The movement of water through a channel.	*USFS, 2002*
Stream gradient	A general slope or rate of change in vertical elevation per unit of horizontal distance of the bed, water surface, or energy grade of a stream.	*USACE, 1999*
Stream hydrology	The flow regime of a stream. Several variables of hydrology can be altered by construction, development, or land conversion including summer dry weather flow, wetted perimeter, cross-sectional area of the stream, and peak storm flow. Increased runoff can increase flood peaks and the magnitude and frequency of bankfull storms, and decrease baseflow between storms.	*EPA, 2008c*
Stream line	An imaginary line within the flow which is everywhere tangent to the velocity vector.	*USBR, 2008*
Stream mile	A distance of 1 mile along a line connecting the midpoints of the channel of a stream.	*USGS, 2008*
Stream morphology	The form and structure of streams.	*USACE, 1999*
Stream order	Stream size, based on the confluence of one stream with another. First-order streams are the origin or headwaters. The confluence of joining two 1st-order streams forms a 2nd-order stream, the confluence of two 2nd-order streams forms a 3rd order strea, and so on.	*EPA, 2006*
Stream order	A method of classifying or ordering the hierarchy of natural channels within a watershed. The uppermost channels in a drainage network (i.e. headwater channels with no upstream tributaries) are designated as first-order streams down to their confluence. A second-order stream is formed below the confluence of two first-order channels. Third order streams are created when two second-order channels join, and so on. The intersection of a channel with another channel of lower order does not raise the order of the stream below the intersection (e.g. a fourth-order stream intersecting with a second-order stream is still a fourth-order stream below the intersection).	*FISHWR, 2001*
Stream order	A hydrologic system of stream classification. Each small unbranched tributary is a first-order stream. Two first order streams join to make a second-order stream. A third-order stream has only first and second-order tributaries, and so forth.	*USACE, 1999*

Stream order	The relative size of a stream compared to other streams in the watershed; first-order streams are the smallest and twelfth order the largest.	*DOC, 2005*
Stream order	A ranking of the relative sizes of streams within a watershed based on the nature of their tributaries. The smallest unbranched tributary is called first order, the stream receiving the tributary is called second order, and so on.	*USGS, 2008*
Stream power	Measure of energy available to move sediment, or any other particle in a stream channel. It is affected by discharge and slope.	*USFS, 2002*
Stream reach	An individual segment of stream that has beginning and ending points defined by identifiable features such as where a tributary confluence changes the channel character to order.	*USACE, 1999*
Stream reach	A portion of a stream that is relatively homogeneous based on geomorphology, stream form, geology, and sinuosity.	*USFS, 2002*
Stream reach	A continuous part of a stream between two specified points.	*USGS, 2008*
Stream restoration	Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream due to urbanization, farming, or other disturbance.	*EPA, 2008c*
Stream-aquifer interactions	Relations of water flow and chemistry between streams and aquifers that are hydraulically connected.	*USGS, 2008*
Streambed	(1) The unvegetated portion of a channel boundary below the base flow level. (2) The channel through which a natural stream of water runs or used to run, as a dry streambed.	*USACE, 1999*
Streambed	The bottom of a channel.	*USFS, 2002*
Streambed at the dam axis	The lowest-point elevation in the streambed at the axis or centerline crest of the dam prior to construction. This elevation defines the hydraulic height and normally defines the zero for the area-capacity tables.	*USBR, 2008*
Streambed sediments	Fine sediments and silt on the streambed. In excess quantities, they can fill in the habitat spaces between stream pebbles, cobbles, and boulders and suffocate macroinvertebrates and fish eggs.	*EPA, 2006*
Streamflow	Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term streamflow is more general than "runoff" as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.	*EPA, 2008c*
Streamflow	Discharge that occurs in a natural channel.	*USBR, 2008*
Streamflow	The water discharge that occurs in a natural channel. A more general term than runoff, streamflow may be applied to discharge whether or not it is affected by diversion or regulation.	*DOC, 2005*
Streamflow	A type of channel flow, applied to that part of surface runoff in a stream whether or not it is affected by diversion or regulation.	*USGS, 2008*
Street gates	Closure gates used during flood periods to close roadway openings through levees or floodwalls.	*FEMA, 2003*
Stress	The force per unit area.	*USBR, 2008*
Stressor	Any physical, chemical, or biological entity that can induce an adverse response.	*EPA, 2008c*

Stressor	Natural or unnatural sources of stress to a system or component of a system (usually called the ôreceptorö for the stressor).	*DOC, 2005*
Stressors	Factors that adversely effect, and therefore degrade, quatic ecosystems. Stressors may be chemical (i.e. excess nutrients), physical (i.e. excess sediments on the streambed), or biological (i.e. competing invasive species).	*EPA, 2006*
Striation	Scratch or groove in bedrock caused by rocks within a glacier grinding the earth's surface as the glacier moves.	*USBR, 2008*
Strike	The direction taken by a bedding or fault plane as it intersects the horizontal. To be aligned or to trend in a direction at right angles to the direction of the dip.	*USBR, 2008*
Strip cropping	A crop production system that involves planting alternating strips of row crops and close-growing forage crops; the forage strips intercept and slow runoff from the less protected row crop strips.	*USBR, 2008*
Strip-mining	A process that uses machines to scrape soil or rock away from mineral deposits just under the earth's surface.	*EPA, 2008b*
Stripping	Removal of a surface layer or deposit for the purpose of excavating other material beneath it.	*USBR, 2008*
Structural Height	Distance between the lowest point in the excavated foundation (excluding narrow fault zones) and the top of dam. The structural height of a concrete dam is the vertical distance between the top of the dam and lowest point of the excavated foundation area, excluding narrow fault zones. The structural height of an embankment dam is the vertical distance between the top of the embankment and the lowest point in the excavated foundation area, including the main cutoff trench, if any, but excluding small trenches or narrow backfilled areas. The top elevation does not include the camber, crown, or roadway surfacing. See hydraulic height.	*USBR, 2008*
Structure	The spatial arrangement of the living and nonliving elements of an ecosystem.	*USFS, 2002*
Structure	Includes, but is not limited to, any building, road, pipe, flume, conduit, siphon, aqueduct, telephone line, and electrical power transmission and distribution line.	*CCC, 2008*
Strut	An inside brace.	*USBR, 2008*
Stud	A bolt having one end firmly anchored.	*USBR, 2008*
Student's "t" Distribution	A distribution used in evaluation of variables which involve sample standard deviation rather than population standard deviation.	*USGS, 1982*
Study Unit	A major hydrologic system of the United States in which NAWQA studies are focused. Study Units are geographically defined by a combination of ground and surface water features and generally encompass more than 4,000 square miles of land area.	*USGS, 2008*
Study Unit Survey	Broad assessment of the water quality conditions of the major aquifer systems of each Study Unit. The Study Unit Survey relies primarily on sampling existing wells and, wherever possible, on existing data collected by other agencies and programs. Typically, 20 to 30 wells are sampled in each of three to five aquifer subunits.	*USGS, 2008*

Subaerial	Formed, existing, or taking place on the land surface; contrasted with subaqueous or underwater.	*CCC, 2008*
Subaerial erosion	Erosion that occurs on the land surface due to removal of surface material by wind, water, weathering, and gravity. (see erosion).	*CCC, 2008*
Subbase	A layer used in a pavement system between the subgrade and base course, or between the subgrade and portland cement concrete pavement.	*USBR, 2008*
Subcritical flow	Those conditions of flow for which the depths are greater than critical and the velocities are less than critical.	*USBR, 2008*
Subdrilling	Overdrilling or drilling below final grade. Sometimes necessary to assure that final grade is obtained when blasting.	*USBR, 2008*
Subgrade	Soil prepared and compacted to support a structure or pavement system.	*USBR, 2008*
Subgrade	The soil prepared amd compacted to support a structure or a pavement system.	*USBR, 2008*
Subgrade surface	The surface of the earth or rock prepared to support a structure or a pavement system.	*USBR, 2008*
Subirrigation	Applying irrigation water below the ground surface either by raising the water table within or near the root zone, or by use of a buried perforated or porous pipe system which discharge directly into the root zone.	*USBR, 2008*
Sublevees	Levees built for the purpose of underseepage control. Sublevees encircle areas behind main levees, which are subject, during high-water stages, to high uplift pressures and possibly the development of sand boils. Sublevees normally tie into the main levees, thus providing a basin that can be flooded during high-water stages, thereby counterbalancing excess head beneath the top stratum within the basin. Sublevees are rarely employed as the use of relief wells or seepage berms make them unnecessary except in emergencies.	*FEMA, 2003*
Submarine canyon	A steep-sided underwater valley commonly crossing the continental shelf and slope.	*CCC, 2008*
Submerged aquatic vegetation	Vegetation that lives at or below the water surface; an important habitat for young fish and other aquatic organisms.	*EPA, 2008b*
Submerged aquatic vegetation (SAV)	Aquatic vegetation, such as sea grasses, that cannot withstand excessive drying and therefore live with their leaves at or below the water surface. This type of vegetation provides an important habitat for young fish and other aquatic organisms.	*USBR, 2008*
Submerged lands	Submerged lands shall be defined as lands which lie below the line of mean low tide (from California Code of Regulations, section 13577; see Public Trust Lands).	*CCC, 2008*
Sub-organization	Any organization such as agencies, departments, offices, or local jurisdictions having a supportive role in emergency planning and preparedness.	*USBR, 2008*
Subsidence	Sinking of the land surface due to a number of factors, including ground water extraction.	*USBR, 2008*
Subsidence	Compression of soft aquifer materials in a confined aquifer due to pumping of water from the aquifer.	*USGS, 2008*

Subspecies	A taxonomic rank below that of species, usually recognizing individuals that have certain heritable characteristics distinct from other subspecies of a species.	*USFWS, 2008*
Substantial intervention/ manipulation	Active environmental management approach used in situations where passive repair options are required because the recovery of the desired functionality is beyond the repair capacity of the ecosystem. The river system is rehabilitated with direct anthropogenic influence.	*FISHWR, 2001*
Substation	Facility equipment that switches, changes, or regulates electric voltage.	*USBR, 2008*
Substation capacity	The substation capacities are given in kVA (kilovolt-amperes). To determine the load in kilowatts, which could be served from the transformers, the kilovolt-ampere rating should be multiplied by the load power factor.	*USBR, 2008*
Substrate	(1) The composition of a streambed, including either mineral or organic materials. (2) Material that forms an attachment medium for organisms.	*USACE, 1999*
Substrate	Refers to bottom sediment material in a natural water system.	*EPA, 2008c*
Substrate	Surface on which a plant or animal grows or is attached. The base on which an organism lives; a substance acted upon.	*USBR, 2008*
Substrate	The sediment material that makes up the benthos of a waterway.	*DOC, 2005*
Substrate size	The diameter of streambed particles such as clay, silt, sand, gravel, cobble and boulders.	*USGS, 2008*
Subsurface drain	A shallow drain installed in an irrigated field to intercept the rising groundwater level and maintain the water table at an acceptable depth below the land surface.	*USGS, 2008*
Subsurface drainage	Rainfall that is not evapotranspirated or does not become surface runoff.	*USACE, 1999*
Subsurface irrigation system	Irrigation by means of underground porous tile or its equivalent.	*USBR, 2008*
Subwatershed	Vegetation that lives at or below the water surface; an important habitat for young fish and other aquatic organisms.	*EPA, 2008b*
Succession	Directional, orderly process of community change in which the community modifies the physical environment to eventually establish an ecosystem which is as stable as possible at the site in question.	*USBR, 2008*
Sulfate attack	Damage to concrete caused by the effects of a chemical reaction between sulfates in soils or ground water and hydrated lime and hydrated calcium aluminate in cement paste. The attack results in considerable expansion and disruption of paste.	*USBR, 2008*
Sump	A pit or pool for draining, collecting, or storing water. A chamber located at the entrance to the pump which provides water to the pump.	*USBR, 2008*
Sump pump	A pump used for removing collected water from a sump.	*USBR, 2008*
Supercritical flow	Those conditions of flow for which the depths are less than critical and the velocities are greater than critical.	*USBR, 2008*
Superfund list	A list of the hazardous waste disposal sites most in need of cleanup. The list is updated annual by the U.S. Environmental Protection Agency (EPA) based primarily on how a site scores using the Hazard Ranking System. Also referred to as the National Priorities List (NPL).	*USACE, 1999*

Supplemental irrigation service land	Irrigable land now receiving, or to receive, an additional or reregulated supply of water through facilities constructed by or to be constructed by the Bureau of Reclamation. This water together with that obtained from nonproject sources, generally will constitute an adequate supply.	*USBR, 2008*
Supply augmentation	Alternative water management programs such as conjunctive use, water banking, or water project facility expansion, that increase supply.	*USACE, 1999*
Suppressed weir	A rectangular weir that has only the crest far removed from the channel bottom, the sides are coincident with the sides of the approach channel, so no lateral contraction of water passing through the weir is possible.	*USBR, 2008*
Surcharge	To fill or load to excess. Any storage above the full pool.	*USBR, 2008*
Surcharge capacity (surcharge storage)	The reservoir capacity provided for use in passing the inflow design flood through the reservoir. It is the reservoir capacity between the maximum water surface elevation and the highest of the following elevations: top of exclusive flood control capacity, top of joint use capacity, or top of active conservation capacity. Temporary storage.	*USBR, 2008*
Surf zone	Area between the outermost breaking waves and the limit of wave uprush.	*CCC, 2008*
Surface area	The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.	*EPA, 2008c*
Surface erosion	The detachment and transport of soil particles by wind, water, or gravity. Or a group of processes whereby soil materials are removed by running water, waves and currents, moving ice, or wind.	*USACE, 1999*
Surface pump	A mechanism for removing water or wastewater from a sump or wet well.	*USBR, 2008*
Surface runoff	Precipitation, snow melt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of non-point source pollutants in rivers, streams, and lakes.	*EPA, 2008b*
Surface runoff	That potion of precipitation that moves over the ground toward a lower elevation and does not infiltrate the soil.	*USFS, 2002*
Surface runoff	Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.	*EPA, 2008c*
Surface runoff	Precipitation, snow melt, or irrigation in excess of what can infiltrate the soil surface and be stored. Surface runoff is a major transporter of non-point source pollutants.	*USBR, 2008*
Surface soil	Upper part of the soil ordinarily moved in tillage, or its equivalent in uncultivated soils, about 10 to 20 cm in thickness.	*USBR, 2008*
Surface supply	Water supply from streams, lakes, and reservoirs.	*USACE, 1999*
Surface vibration	A method of compacting soil using a vibrating plate or vibrating smooth drum roller used on the surface of soil placed.	*USBR, 2008*
Surface water	All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.)	*EPA, 2008b*

Surface water	All waters whose surface is naturally exposed to the atmosphere, for example, rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc. and all springs, wells or other collectors directly influenced by surface water.	*USACE, 1999*
Surface water	All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.	*EPA, 2008c*
Surface water	Water on the surface of the earth. An open body of water, such as a river, stream or lake. All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors which are directly influenced by surface water.	*USBR, 2008*
Surface water	Water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.	*DOC, 2005*
Surface water	An open body of water, such as a lake, river, or stream.	*USGS, 2008*
Surficial	Relating to the earth's surface.	*CCC, 2008*
Surge	A rapid increase in the depth of flow.	*USBR, 2008*
Surge chamber	A chamber or tank connected to a pipe and located at or near a valve that may quickly open or close or a pump that may suddenly start or stop. When the flow of water in a pipe starts or stops quickly, the surge chamber allows water to flow into or out of the pipe and minimize any sudden positive or negative pressure waves or surges in the pipe.	*USBR, 2008*
Surge irrigation	A surface irrigation technique wherein flow is applied to furrows (or less commonly, borders) intermittently during a single irrigation set.	*USBR, 2008*
Surplus water	Developed water supplies in excess of contract entitlement or apportioned water.	*USACE, 1999*
Surrogate data	Vegetation that lives at or below the water surface; an important habitat for young fish and other aquatic organisms.	*EPA, 2008b*
Survey	Sampling of any number of sites during a given hydrologic condition.	*USGS, 2008*
Susceptibility analysis	An analysis to determine whether a Public Water Supply is subject to significant pollution from known potential sources.	*EPA, 2008b*
Suspended	The state of floating in water rather than being dissolved in it.	*USBR, 2008*
Suspended (as used in tables of chemical analyses)	The amount (concentration) of undissolved material in a water sediment mixture. It is associated with the material retained on a 0.45 micrometer filter.	*USGS, 2008*
Suspended and bedded sediments	Particulate organic and inorganic matter that suspend in or are carried by the water, and/or accumulate in a loose, unconsolidated form on the bottom of natural water bodies.	*EPA, 2008c*
Suspended load	The part of the total sediment load that is carried by the water for a considerable period of time at the velocity of the flow, free from contact with the streambed (see also Bed load).	*USFS, 2002*
Suspended load (suspended sediment)	Sediment that is supported by the upward components of turbulence in a stream and that stays in suspension for an appreciable length of time.	*USBR, 2008*
Suspended loads	Specific sediment particles maintained in the water column by turbulence and carried with the flow of water.	*EPA, 2008b*

Suspended sediment	Sediment suspended in a fluid by the upward components of turbulent currents, moving ice, or wind.	*USACE, 1999*
Suspended sediment	Very fine soil particles that remain in suspension in water for a considerable period of time without contact with the bottom. Such material remains in suspension due to the upward components of turbulence and currents and/or by suspension.	*DOC, 2005*
Suspended sediment	Particles of rock, sand, soil, and organic detritus carried in suspension in the water column, in contrast to sediment that moves on or near the streambed.	*USGS, 2008*
Suspended sediment concentration	The velocity weighted concentration of suspended sediment in the sampled zone (from the water surface to a point approximately 0.3 foot above the bed) expressed as milligrams of dry sediment per liter of water sediment mixture (mg/L).	*USGS, 2008*
Suspended sediment load	That portion of a stream's total sediment load that is transported within the body of water and has very little contact with the streambed.	*USACE, 1999*
Suspended solids	Different from suspended sediment only in the way that the sample is collected and analyzed.	*USGS, 2008*
Suspended solids concentration (SSC)	The amount of organic and inorganic particles suspended in water. SSC is determined by measuring the dry weight of all the sediment from a known volume of a water-sediment mixture.	*EPA, 2008c*
Suspended solids or load	Organic and inorganic particles (sediment) suspended in and carried by a fluid (water). The suspension is governed by the upward components of turbulence, currents, or colloidal suspension. Suspended sediment usually consists of particles <0.1 mm, although size may vary according to current hydrological conditions. Particles between 0.1 mm and 1 mm may move as suspended or be deposited (bedload).	*EPA, 2008c*
Suspension	A method of sediment transport in which air or water turbulence supports the weight of the sediment particles, thereby keeping them from settling out or being deposited.	*USBR, 2008*
Sustainability	The ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time.	*USFS, 2002*
Swale	A low place in a tract of land. A wide, shallow ditch, usually grassed or paved. A wide open drain with a low center line.	*USBR, 2008*
Swamp	A type of wetland dominated by woody vegetation but without appreciable peat deposits. Swamps may be fresh or salt water and tidal or non-tidal.	*EPA, 2008b*
Swell	Increase of bulk in soil or rock when excavated.	*USBR, 2008*
Swell pressure	The pressure required to maintain zero expansion.	*USBR, 2008*
Switching station	Facility equipment used to tie together two or more electric circuits through switches. The switches are selectively arranged to permit a circuit to be disconnected, or to change the electric connection between the circuits.	*USBR, 2008*
Synchronous condensers	A synchronous machine running without mechanical load and supplying or absorbing reactive power.	*USBR, 2008*
Syncline	A fold in rocks in which the strata dip inward from both sides toward the axis. Troughlike downward sag or fold in rock layers. Opposite of an anticline.	*USBR, 2008*
Synergism	An interaction of two or more chemicals that results in an effect greater than the sum of their separate effects.	*EPA, 2008b*

Synoptic sites	Sites sampled during a short term investigation of specific water quality conditions during selected seasonal or hydrologic conditions to provide improved spatial resolution for critical water quality conditions.	*USGS, 2008*
Synthetic earthquake	Earthquake time history records developed from mathematical models that use white noise, filtered white noise, and stationary and nonstationary filtered white noise, or theoretical seismic source models of failure in the fault zone.	*USBR, 2008*
System	Physically connected generation, transmission, and distribution facilities operated as an integrated unit under one central management, or operating supervision.	*USBR, 2008*

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Tabletop Exercise	An informal activity involving discussions of actions to be taken on described emergency situations. A tabletop exercise is done without time constraints, which allows the participants to practice emergency situation problem solving, evaluate plans and procedures, and to resolve questions of coordination and assignment of responsibilities. A series of messages are issued to participants in the exercise, and they respond verbally to the simulated incident in a nonstressful atmosphere. This exercise should involve management, key agency staff, and personnel from outside organizations as appropriate.	*USBR, 2008*
Tail water	The runoff of irrigation water from the lower end of an irrigated field.	*EPA, 2008b*
Tailings	Residue of raw material or waste separated out during the processing of crops or mineral ores.	*EPA, 2008b*
Tailings	Second grade or waste material separated from pay material during screening or processing.	*USBR, 2008*
Tailings	Rock that remains after processing ore to remove the valuable minerals.	*USGS, 2008*
Tailwater	The water in the natural stream immediately downstream from a dam. The elevation of water varies with discharge from the reservoir. Applied irrigation water that runs off the lower end of a field. Tailwater is measured as the average depth of runoff water, expressed in inches or feet.	*USBR, 2008*
Tailwater	(1) The area immediately downstream of a spillway. (2) Applied irrigation water that runs off the end of a field.	*USACE, 1999*
Take	To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct; may include significant habitat modification or degradation if it kills or injures wildlife by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering.	*USFWS, 2008*
Talus	Sloping accumulation of rock debris; also, rock fragments at the base of a cliff as the result of slides or falls. Rock fragments mixed with soil at the foot of a natural slope from which they have been separated. Accumulation of broken rocks or boulders at the base of a cliff.	*USBR, 2008*
Talus	A pile of rock debris at the base of a cliff.	*CCC, 2008*

Tamp	To pound or press soil to compact. To firmly compact earth during backfilling.	*USBR, 2008*
Tamper	A tool for compacting soil in spots not accessible to rollers.	*USBR, 2008*
Tamping	A method of compacting soil using the impact of a power or hand tamper on the surface of the soil placed.	*USBR, 2008*
Tamping roller	One or more steel drums, fitted with projection feet, used to densify soil. See sheepsfoot roller.	*USBR, 2008*
Tandem	A pair in which one part follows the other.	*USBR, 2008*
Tangent	A line that touches a circle and is perpendicular to its radius at the point of contact.	*USBR, 2008*
Taproot	A big root that grows downward from the base of a tree.	*USBR, 2008*
Taxa	Plural of taxon; groupings of living organisms, such as phylum, class, order, family, genus, or species. Scientists organize organisms into taxa in order to better identify and understand them.	*EPA, 2006*
Taxa richness	See Species richness.	*USGS, 2008*
Taxon (plural taxa)	Any identifiable group of taxonomically related organisms.	*USGS, 2008*
TDC (Transfer of Development Credit)	A transfer of development credit program is used to mitigate the cumulative impacts from new subdivisions in the coastal zone. For each new parcel created, the development potential of one or more existing parcels must be extinguished through a recorded document. This process helps ensure that the overall development potential in an area does not increase and directs development to those areas more suitable for development.	*CCC, 2008*
Technology	The application of scientific knowledge, especially in industry or business	*Webster, 1988*
Tectonic	Related to the earth's surface.	*CCC, 2008*
Tectonics	The science that deals with the structure of the earth's crust.	*USBR, 2008*
Telescope	To slide one piece inside another.	*USBR, 2008*
Temporary irrigation service land	Irrigable land for which a water supply is delivered under temporary arrangements. The acreage may vary from year to year. When repayment and water service contracts are finalized upon such lands, they will be placed in either the Full or the Supplement Service category.	*USBR, 2008*
Temporary structure	Any structure that can be readily and completely dismantled and removed from the site between periods of actual use. The structure may or may not be authorized at the same site from season to season or from year to year.	*USBR, 2008*
Tensiometer	Instrument, consisting of a porous cup filled with water and connected to a manometer or vacuum gauge, used for measuring the soilwater matrix potential.	*USBR, 2008*
Terminal structure	Portion of spillway downstream from chute, tunnel or conduit, which generally dissipates or stills releases. Concrete portion of an outlet works downstream from a conduit, tunnel, or control structure. The structure dissipates or stills releases. See stilling basin.	*USBR, 2008*
Terms and conditions	Required actions described in an Incidental Take Permit under section 10 or Incidental Take Statement intended to implement the Reasonable and Prudent Measures under section 7.	*USFWS, 2008*

Terrace	A ridge, a ridge and hollow, or a flat bench built along a ground contour. The surface form of a high sediment deposit having a relatively flat surface and steep slope facing the river. A broad channel, bench, or embankment constructed across the slope to intercept runoff and detain or channel it to protected outlets, thereby reducing erosion from agricultural areas.	*USBR, 2008*
Terrace	A gently sloping platform cut by wave action.	*CCC, 2008*
Terracing	Dikes built along the contour of sloping farm land that hold runoff and sediment to reduce erosion.	*EPA, 2008b*
Terrain	Ground surface.	*USBR, 2008*
Terrestrial	Living or growing on land. Land-based.	*USBR, 2008*
Territorial communities	Populations that function within a particular geographic area.	*USBR, 2008*
Tertiary treated sewage	The third phase of treating sewage that removes nitrogen and phosphorus before it is discharged.	*USGS, 2008*
Tertiary treatment	In sewage, the additional treatment of effluent beyond that of secondary treatment to obtain a very high quality of effluent for reuse.	*USACE, 1999*
Test of significance	A test made to learn the probability that a result is accidental or that a result differs from another result. For all the many types of test there are standard formulas and tables. In making a test it is necessary to choose a "level of significance," the choice being arbitrary but generally not less than the low level of 10 percent nor more than the high level of 1 percent.	*USGS, 1982*
Test pit	Pit dug for geologic investigation or inspection and testing of earthwork placement.	*USBR, 2008*
Thalweg	The deepest part of the water channel.	*FISHWR, 2001*
Thalweg	(1) The lowest thread along the axial part of a valley or stream channel. (2) A subsurface, groundwater stream percolating beneath and in the general direction of a surface stream course or valley. (3) The middle, chief, or deepest part of a navigable channel or waterway.	*USACE, 1999*
Thalweg	Deepest part of a stream channel.	*EPA, 2008c*
Thalweg	Deepest part of a river channel in a cross section of a river profile. The path of deepest flow. Line connecting the deepest points along a riverbed. The lowest thread along the axial part of a valley. The middle or chief navigable channel of a waterway.	*USBR, 2008*
Theory	Possible or plausible explanation of phenomena based on available evidence. A pound of crops is worth a ton of theory.	*USBR, 2008*
Thermal pollution	A reduction in water quality caused by increasing its temperature, often due to disposal of waste heat from industrial or power generation processes. Thermally polluted water can harm the environment because plants and animals can have a hard time adapting to it.	*DOC, 2005*
Thermal stratification	The formation of layers of different temperatures in a lake or reservoir.	*EPA, 2008b*
Thermal stratification	The formation of layers of different temperatures in bodies of water. See stratification.	*USBR, 2008*
Thermocline	The middle layer of a thermally stratified lake or reservoir. In this layer, there is a rapid decrease in temperatures in a lake or reservoir.	*EPA, 2008b*

Thermocline	The middle layer of a lake, separating the upper, warmer portion (epilimnion) from the lower, colder portion (hypolimnion). The middle layer in a thermally stratified lake or reservoir. In this layer there is a rapid decrease in temperature with depth. See metalimnion.	*USBR, 2008*
Thick arch dam	An arch dam with a base thickness to structural height ratio of 0.3 or greater (previously defined as 0.5 or greater).	*USBR, 2008*
Thickness or width of dam	The thickness or width of a dam as measured horizontally between the upstream and downstream faces and normal to the axis or centerline crest of the dam.	*USBR, 2008*
Thin arch dam	An arch dam with a base thickness to structural height ratio of 0.2 or less (previously defined as 0.3 or less).	*USBR, 2008*
Thixotrophy	The property of a material that enables it to stiffen in a relatively short time on standing but, upon agitation or manipulation, to change to a very soft consistency or to a fluid of high viscosity, the process being completely reversible.	*USBR, 2008*
Threatened	A legal classification for a species which is likely to become endangered within the foreseeable future.	*USBR, 2008*
Threatened species	An animal or plant species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.	*USFWS, 2008*
Threatened species	Any species which has potential of becoming endangered in the near future.	*USBR, 2008*
Three-dimensional model (3-D)	Mathematical model defined along three spatial coordinates where the water quality constituents are considered to vary over all three spatial coordinates of length, width, and depth.	*EPA, 2008c*
Threshold	The lowest dose of a chemical at which a specified measurable effect is observed and below which it is not observed.	*EPA, 2008b*
Threshold level	Time-weighted average pollutant concentration values, exposure beyond which is likely to adversely affect human health.	*EPA, 2008b*
Thropic levels	A functional classification of species that is based on feeding relationships (e.g. generally aquatic and terrestrial green plants comprise the first thropic level, and herbivores comprise the second).	*EPA, 2008b*
Through cut	An excavation between parallel banks that begins and ends at original grade.	*USBR, 2008*
Thrust block (anchor block)	A massive block of concrete built to withstand a thrust or pull. A mass of concrete or similar material appropriately placed around a pipe to prevent movement when the pipe is carrying water. Usually placed at bends and valve structures.	*USBR, 2008*
Tidal epoch (National Tidal Datum Epoch)	The specific 19 year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and averaged to form tidal datums. This period occurs when the new and full moon would recur on the same day of the year. The present tidal epoch used is 1960 through 1978.	*CCC, 2008*
Tidal flats	Saltwater wetlands that are characterized by mud or sand and daily tidal fluctuations.	*USACE, 1999*

Tidal prism	The total amount of water that flows into a harbor or estuary or out again with movement of the tide, excluding any freshwater flow.	*CCC, 2008*
Tidal range	Difference between consecutive high and low (of higher high and lower low) waters. (see tides).	*CCC, 2008*
Tidal wave	Wave movement of the tides. Often improperly used for tsunamis (see tsunami).	*CCC, 2008*
Tide	The periodic rising and falling of the water that results from gravitational attraction of the moon and sun, and other astronomical bodies, acting upon the rotating earth. The California coast has a mixed tidal occurrence, with two daily high tides of different elevations and two daily low tides, also of different elevations. Other tidal regimes are diurnal tides, with only one high and one low tide daily, and semidiurnal, with two high and two low tides daily, with comparatively little daily inequality between each high or each low tide level	*CCC, 2008*
Tidelands	Tidelands shall be defined as lands which are located between the lines of mean high tide and mean low tide (from California Code of Regulations, section 13577; see Public Trust Lands).	*CCC, 2008*
Tie back levees	Levees that extend from the main levees along rivers, lakes, or coasts to bluff lines (high ground) and are part of the line-of-protection.	*FEMA, 2003*
Tie-back walls	Vertical walls that are braced into the material behind them by tie rods or cables connecting to anchors or deaden.	*CCC, 2008*
Tied in	An expression used to indicate that a technique is constructed to prevent stream flow between the structure and the bank (see Keyed In).	*USFS, 2002*
Tier 1	Reclamation public protection guideline dealing with loss of life (LOL) considerations. See annualized loss of life.	*USBR, 2008*
Tier 1 sediment guideline	Threshold concentration above which there is a high probability of adverse effects on aquatic life from sediment contamination, determined using modified USEPA (1996) procedures.	*USGS, 2008*
Tier 2	Reclamation public protection guideline dealing with public trust responsibilities based on the annual failure probability of the structure.	*USBR, 2008*
Tiering	The coverage of general matters in a broad National Environmental Policy Act document with subsequent narrowly focused documents; helps to eliminate repetitive discussions and allows the site-specific documents to focus on specific issues.	*USBR, 2008*
Tight	Soil or rock formations lacking veins of weakness.	*USBR, 2008*
Tile	Pipe made of baked clay.	*USBR, 2008*
Tile drain	A buried perforated pipe designed to remove excess water from soils.	*USGS, 2008*
Till	A deposit of sediment formed under a glacier, consisting of an unlayered mixture of clay, silt, sand, and gravel ranging widely in size and shape.	*USBR, 2008*
Tillage	Plowing, seedbed preparation, and cultivation practices. See conventional tillage.	*USBR, 2008*
Tilth	Soil condition in relation to lump or particle size.	*USBR, 2008*
Timber	Wood beams larger than 4 x 6.	*USBR, 2008*

Timbering	Wood bracing in a tunnel or excavation.	*USBR, 2008*
Timbering set	A tunnel support consisting of a roof beam or arch, and two posts.	*USBR, 2008*
Time of concentration	The time required for storm runoff to flow from the most remote point of a catchment or drainage area to the outlet or point under consideration. It is not a constant, but varies with depth of flow, grades, and condition of conduit and/or channel.	*USBR, 2008*
Tissue study	The assessment of concentrations and distributions of trace elements and certain organic contaminants in tissues of aquatic organisms.	*USGS, 2008*
Toe	The break in slope at the foot of a stream bank where it meets the streambed.	*USFS, 2002*
Toe (toe of dam)	The point of intersection between the bottom of a slope or the upstream or downstream face of a dam and the natural ground, for example, the upstream or downstream toe of a dam or the downstream toe of a landslide or debris fan. The junction of the face of a dam with the ground surface. For a concrete dam, see heel.	*USBR, 2008*
Toe drain(s)	Open-jointed tile or perforated pipe located at the toe of the dam used in conjunction with horizontal drainage blankets to collect seepage from the embankment and foundation and conveys the seepage to a location downstream from the dam. A system of pipe and/or pervious material along the downstream toe of a dam used to collect seepage from the foundation and embankment and convey it to a free outlet. Tile or pipe used to collect external seepage along the downstream toe of an embankment.	*USBR, 2008*
Toe weight	Additional material placed at the toe of an embankment dam to increase its stability.	*USBR, 2008*
Tolerability	The measure that an individual or organization will endure or tolerate a specific risk.	*Mockett & Simm, 2002*
Tolerant species	Those species that are adaptable to (tolerant of) human alterations to the environment and often increase in number when human alterations occur.	*USGS, 2008*
Tombolo	Bar or spit that connects or ties an island to the mainland or to another island.	*CCC, 2008*
Top of active conservation capacity	The reservoir water surface elevation at the top of the capacity allocated to the storage of water for conservation purposes only. See reservoir.	*USBR, 2008*
Top of bank	The break in slope between the stream bank and the surrounding upland terrain.	*USFS, 2002*
Top of dam	See crest elevation.	*USBR, 2008*
Top of dead capacity	The lowest elevation in the reservoir from which water can be drawn by gravity.	*USBR, 2008*
Top of exclusive flood control capacity	The reservoir water surface elevation at the top of the reservoir capacity allocated to exclusive use for the regulation of flood inflows to reduce damage downstream. See reservoir.	*USBR, 2008*

Top of inactive capacity	The reservoir water surface elevation below which the reservoir will not be evacuated under normal conditions. The highest applicable water surface elevation described below usually determines the top of inactive capacity. (1) The lowest water surface elevation at which the planned minimum rate of release for water supply purposes can be made to canals, conduits, the river, or other downstream conveyance systems. Normally, this elevation is established during the planning and design phases and is the elevation at the end of extreme drawdown periods. (2) The established minimum water surface elevation for fish and wildlife purposes. (3) The established minimum water surface elevation for recreation purposes. (4) The minimum water surface elevation as set forth in compacts and/or agreements with political sudivision(s). (5) The minimum water surface elevation at which the powerplant is designed to operate. (6) The minimum water surface elevation to which the reservoir can be drawn down using established operating procedures without endangering the dam, appurtenant structures, or reservoir shoreline. (7) The minimum water s	*USBR, 2008*
Top of joint use capacity	The reservoir water surface elevation at the top of the reservoir capacity allocated to joint use, i.e., flood control and conservation purposes. See reservoir.	*USBR, 2008*
Top of surcharge capacity	The maximum water surface of a reservoir.	*USBR, 2008*
Top width or thickness	The thickness or width of a dam at the level of the top of dam (excluding corbels or parapets). In general, the term thickness is used for gravity and arch dams, and width is used for other dams.	*USBR, 2008*
Topographic floodplain	The land adjacent to the channel including the hydrologic floodplain and other lands up to an elevation based on the elevation reached by a flood peak of a give frequency (for example the 100-year floodplain).	*FISHWR, 2001*
Topographic map	A map indicating surface elevation and slope. U.S. Geological Survey quadrangle series maps showing the shape of the earth's surface by contours. They also show control data, boundaries, roads, buildings, watercourses, lakes and reservoirs, and other land features. The 7.5-minute series is appropriate for doing inundation mapping.	*USBR, 2008*
Topography	The physical features of a surface area including relative elevations and the position of natural and man-made (anthropogenic) features.	*EPA, 2008b*
Topography	The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.	*EPA, 2008c*
Topography	Physical shape of the ground surface. Collective features of the Earth's surface, especially the relief and contour of the land. The arrangement of hills and valleys in a geographic area.	*USBR, 2008*
Topsoil	The topmost layer of soil, usually containing organic matter. Usually refers to soil containing humus which is capable of supporting plant growth.	*USBR, 2008*
Torrent	(1) A turbulent, swift-flowing stream. (2) A heavy downpour, a deluge.	*USACE, 1999*

Total capacity	The reservoir capacity below the highest of the elevations representing either the top of exclusive flood control capacity, the top of joint use capacity, or the top of active conservation capacity. In the case of a natural lake which has been enlarged, the total capacity includes the dead capacity of the lake. Total capacity is used to express the total quantity of water which can be impounded and is exclusive of surcharge capacity.	*USBR, 2008*
Total concentration	Refers to the concentration of a constituent regardless of its form (dissolved or bound) in a sample.	*USGS, 2008*
Total DDT	The sum of DDT and its metabolites (breakdown products), including DDD and DDE.	*USGS, 2008*
Total Dissolved Solids (TDS)	All material that passes the standard glass river filter; now called total filtrable residue. Term is used to reflect salinity.	*EPA, 2008b*
Total dissolved solids (TDS)	A quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per liter, see also salinity.	*USACE, 1999*
Total dissolved solids (TDS)	A quantitative measure of the residual mineral dissolved in water that remains after the evaporation of a solution. Usually expressed in milligrams per liter or parts per million. Total amount of dissolved material, organic and inorganic, contained in water.	*USBR, 2008*
Total dynamic head (TDH)	When a pump is lifting or pumping water, the vertical distance from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.	*USBR, 2008*
Total Maximum Daily Load (TMDL)	A calculation of the highest amount of a pollutant that a water body can receive and safely meet water quality standards set by the state, territory, or authorized tribe.	*EPA, 2008b*
Total maximum daily load (TMDL)	The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.	*EPA, 2008c*
Total maximum daily loads (TMDL)	Estimates of the amount of specific pollutants that a body of water can safely take without threatening beneficial uses.	*USBR, 2008*
Total Maximum Daily Loads (TMDLs)	The maximum amounts of individual pollutants contributing to impairment of the ôbeneficial usesö of the waterbody allowed to enter a waterbody from watershed sources.	*DOC, 2005*
Total Suspended Solids (TSS)	A measure of the suspended solids in wastewater, effluent, or water bodies, determined by tests for "total suspended non-filterable solids."	*EPA, 2008b*
Total suspended solids (TSS)	The entire amount of organic and inorganic particles dispersed in water. TSS is measured by several methods, most of which entail measuring the dry weight of sediment from a known volume of a subsample of the original.	*EPA, 2008c*
Totalizer (integrator)	A device or meter that continuously measures and calculates (adds) total flow.	*USBR, 2008*

Toxic chemical	Any chemical listed in EPA rules as "Toxic Chemicals Subject to Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986."	*EPA, 2008b*
Toxic concentration	The concentration at which a substance produces a toxic effect.	*EPA, 2008b*
Toxic dose	The dose level at which a substance produces a toxic effect.	*EPA, 2008b*
Toxic pollutants	Materials that cause death, disease, or birth defects in organisms that ingest or absorb them. The quantities and exposures necessary to cause these effects can vary widely.	*EPA, 2008b*
Toxic Release Inventory	Database of toxic releases in the United States compiled from SARA Title III Section 313 reports.	*EPA, 2008b*
Toxic substance	A chemical or mixture that may present an unreasonable risk of injury to health or the environment.	*EPA, 2008b*
Toxicant	A harmful substance or agent that may injure an exposed organism.	*EPA, 2008b*
Toxicity	The degree to which a substance or mixture of substances can harm humans or animals. Acute toxicity involves harmful effects in an organism through a single or short-term exposure. Chronic toxicity is the ability of a substance or mixture of substances to cause harmful effects over an extended period, usually upon repeated or continuous exposure sometimes lasting for the entire life of the exposed organism. Subchronic toxicity is the ability of the substance to cause effects for more than one year but less than the lifetime of the exposed organism.	*EPA, 2008b*
Toxicity assessment	Characterization of the toxicological properties and effects of a chemical, with special emphasis on establishment of dose-response characteristics.	*EPA, 2008b*
Toxicity testing	Biological testing (usually with an invertebrate, fish, or small mammal) to determine the adverse effects of a compound or effluent.	*EPA, 2008b*
Toxicological profile	An examination, summary, and interpretation of a hazardous substance to determine levels of exposure and associated health effects.	*EPA, 2008b*
Toxin	Poisonous substance, generally from a plant or animal.	*USBR, 2008*
Trace element	An element found in only minor amounts (concentrations less than 1.0 milligram per liter) in water or sediment; includes arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.	*USGS, 2008*
Tracer	A stable, easily detected substance or a radioisotope added to a material to follow the location of the substance in the environment or to detect any physical or chemical changes it undergoes.	*USGS, 2008*
Tractive force	The drag on a streambed or bank caused by passing water, which tends to pull soil particles along with stream flow.	*USACE, 1999*
Traditional cultural property (TCP)	A site or resource that is eligible for inclusion in the National Register of Historic Places because of its association with cultural practices or beliefs of a living community.	*USBR, 2008*

Traffic control point	A location staffed to ensure the continued movement of traffic inside or outside an area of risk during an emergency or disaster. Traffic control is a temporary function for use where normal traffic controls are inadequate or where redirection of traffic becomes necessary due to emergency conditions.	*USBR, 2008*
Training wall	A wall built to confine or guide the flow of water.	*USBR, 2008*
Tranquil flow	Distinguished from rapid flow by a dimensionless number called the Froude number. If the Froude number is less than one, the flow is tranquil. If the Froude number is greater than one, the flow is rapid. If the Froude number is equal to one, the flow is critical. In tranquil flow, surface waves propagate upstream as well as downstream. Control of tranquil flow depth is always downstream.	*USBR, 2008*
Transducer	A device which senses some varying condition and converts it to an electrical signal for transmission to some other device (a receiver) for processing or decision making.	*USBR, 2008*
Transect	A path or line along which one counts and studies various aspects of a stream, river, or other study area.	*EPA, 2006*
Transformation	The change of numerical values of data to make later computations easier, to linearize a plot or to normalize a skewed distribution by making it more nearly a normal distribution by making it more nearly a normal distribution. The most common transformations are those changing ordinary numerical values into their logarithms, square roots, or cube roots; many others are possible.	*USGS, 1982*
Transformed flow net	A flow net whose boundaries have been properly modified (transformed) so that a net consisting of curvilinear squares can be constructed to represent flow conditions in an anisotropic porous medium.	*USBR, 2008*
Transit	A surveying instrument that can measure both vertical and horizontal angles.	*USBR, 2008*
Transit time	In nutrient cycles, the average time that a substance remains in a particular form; ratio of biomass to productivity.	*EPA, 2008c*
Transition zone (semipervious zone)	A substantial part of the cross section of an embankment dam comprising material whose grading is of intermediate size between that of an impervious zone and that of a permeable zone.	*USBR, 2008*
Transitional upland fringe	A portion of the upland on one or both sides of the floodplain that serves as a transitional zone or edge between the floodplain and the surrounding landscape.	*FISHWR, 2001*
Transmissivity	The ability of an aquifer to transmit water.	*EPA, 2008b*
Transmissivity	The ability of an aquifer to transmit water.	*USBR, 2008*
Transpiration	The process by which water vapor is lost to the atmosphere from living plants. The term can also be applied to the quantity of water thus dissipated.	*EPA, 2008b*
Transpiration	An essentially physiological process in which plant tissues give off water vapor to the atmosphere.	*USACE, 1999*
Transpiration	The process by which water in plants is transferred into water vapor in the atmosphere. Evaporation of water through the leaves of plants.	*USBR, 2008*

Transpiration	Process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores.	*DOC, 2005*
Transport capacity	The capacity of a river to carry sediment in suspension or to move sediment along the riverbed. Usually expressed as mass per unit of time.	*USBR, 2008*
Transport of pollutants (in water)	Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) diffusion, or transport due to turbulence in the water.	*EPA, 2008c*
Transverse	Pertaining to or extending along the short axis, or width, of a structure. Perpendicular to or across the long axis, or length, of a structure. See longitudinal.	*USBR, 2008*
Transverse dunes	The ridges and sand mounds that form essentially perpendicular to the prevailing wind direction. These form when there is one dominant wind direction and a large supply of sand.	*CCC, 2008*
Trash rake	A device that is used to remove debris which has collected on a trashrack to prevent blocking the associated intake.	*USBR, 2008*
Trashrack	A metal or reinforced concrete structure placed at the intake of a conduit, pipe, or tunnel that prevents entrance of debris over a certain size. A device or structure located at an intake to prevent floating or submerged debris from entering the intake.	*USBR, 2008*
Trashrake	A device that is used to remove debris which has collected on a trashrack to prevent blocking the associated intake.	*USBR, 2008*
Travel time	Time measured from the start of a dam breach to flooding at a particular location. The flood level corresponding to that travel time is usually either the arrival of the leading flood wave or the peak flow at that location.	*USBR, 2008*
Treatment works	Has the same meaning as set forth in the Federal Water Pollution Control Act (33 U.S.C. 1251, et seq.) and any other federal act which amends or supplements the Federal Water Pollution Control Act.	*CCC, 2008*
Tremie	A device used to place concrete or grout under water.	*USBR, 2008*
Trestle	A bridge, usually of timber or steel, that has a number of closely spaced supports between the abutments.	*USBR, 2008*
Triaxial shear test	A test in which a specimen of soil or rock encased by an impervious membrane is subjected to a confining pressure and then loaded axially to failure.	*USBR, 2008*
Triazine herbicide	A class of herbicides containing a symmetrical triazine ring (a nitrogen-heterocyclic ring composed of three nitrogens and three carbons in an alternating sequence). Examples include atrazine, propazine, and simazine.	*USGS, 2008*
Triazine pesticide	See Triazine herbicide.	*USGS, 2008*
Tributary	A stream that flows into another stream, river, or lake.	*USACE, 1999*
Tributary	A lower order stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.	*EPA, 2008c*
Tributary	River or stream flowing into a larger river or stream.	*USBR, 2008*
Tributary	A smaller river or stream that flows into a larger river or stream. Usually, a number of smaller tributaries merge to form a river.	*DOC, 2005*
Tributary	A river or stream flowing into a larger river, stream or lake.	*USGS, 2008*

Trickle irrigation	Method in which water drips to the soil from perforated tubes or emitters.	*EPA, 2008b*
Tripod	A three-legged support for a surveying instrument.	*USBR, 2008*
Tritium	A radioactive form of hydrogen with atoms of three times the mass of ordinary hydrogen; used to determine the age of water.	*USGS, 2008*
Trophic level	Place of an animal in the food chain.	*USBR, 2008*
Troposhpere	The layer of the atmosphere closest to the earth's surface.	*EPA, 2008b*
Tsunami	A long period wave, or seismic sea wave, caused by an underwater disturbance such as a volcanic eruption or earthquake. Commonly misnamed a Tidal Wave.	*CCC, 2008*
Tuff	Igneous rock formed from hardened volcanic ash.	*USBR, 2008*
Tundra	A type of treeless ecosystem dominated by lichens, mosses, grasses, and woody plants. Tundra is found at high latitudes (arctic tundra) and high altitudes (alpine tundra). Arctic tundra is underlain by permafrost and is usually water saturated.	*EPA, 2008b*
Tunnel	Covered portion of spillway between the gate or crest structure and the terminal structure, where open channel flow and/or pressure flow conditions may exist. Portion of an outlet works between upstream and downstream portals, excluding the gate chamber. Tunnels are generally located in the dam abutments, and are concrete lined or concrete/steel lined. An enclosed channel that is constructed by excavating through natural ground. A tunnel can convey water or house conduits or pipes. A long underground excavation with two or more openings to the surface, usually having a uniform cross section used for access, conveying flows, etc.	*USBR, 2008*
Turbid	Having a cloudy or muddy appearance.	*USBR, 2008*
Turbidimeter	A device that measures the cloudiness of suspended solids in a liquid; a measure of the quantity of suspended solids.	*EPA, 2008b*
Turbidimeter	A device that measures the amount of suspended solids in a liquid.	*USBR, 2008*
Turbidity	1. Haziness in air caused by the presence of particles and pollutants. 2. A cloudy condition in water due to suspended silt or organic matter.	*EPA, 2008b*
Turbidity	A measure of the content of suspended matter that interferes with the passage of light through the water or in which visual depth is restricted. Suspended sediments are only one component of turbidity.	*USACE, 1999*
Turbidity	(1) The scattering of light by fine, suspended particles which causes water to have a cloudy appearance. Turbidity is an optical property of water. More specifically, turbidity is the intensity of light scattered at one or more angles to an incident beam of light as measured by a turbidity meter or nephelometer. (2) A principal characteristic of water clarity,expressed as the optical property of water that causes light to be absorbed by particles and molecules rather than be transmitted in straight lines through a water sample. It is caused by suspended matter or impurities that interfere with the clarity of water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble colored organic compounds, and plankton and other microscopic organisms.	*EPA, 2008c*

Turbidity	Measure of extent to which light passing through water is reduced due to suspended materials (see nephelometric). The optical property of water based on the amount of light reflected by suspended particles. Cloudiness of water, measured by how deeply light can penetrate into the water from the surface. The cloudy appearance of water caused by the presence of suspended and colloidal matter. The scattering and absorption of light that makes the water look murky. Caused by the content and shape of matter suspended in the water. The state of having sediment or foreign particles suspended or stirred up in water.	*USBR, 2008*
Turbidity	The amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter. Thus, turbidity makes the water cloudy or even opaque in extreme cases.	*DOC, 2005*
Turbidity	Reduced clarity of surface water because of suspended particles, usually sediment.	*USGS, 2008*
Turbine	A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.	*USBR, 2008*
Turbulence	A type of flow in which any particle may move in any direction with respect to any other particle and not in a smooth or fixed path. Turbulent water is agitated by cross current and eddies. Turbulent velocity is that velocity above which turbulent flow will always exist and below which the flow may be either turbulent or laminar.	*EPA, 2008c*
Turbulent flow	A flow characterized by agitated and irregular, random-velocity fluctuations.	*EPA, 2008c*
Turbulent flow	That type of flow in which any water particle may move in any direction with respect to any other particle, and in which the head loss is approximately proportional to the second power of the velocity. Open channel flow characterized by random fluid motion. The flow is laminar or turbulent depending on the value of the Reynolds number, which is a dimensionless ratio of the inertial forces to the viscous forces. In laminar flow, viscous forces are dominant and the Reynolds number is relatively small. In turbulent flow, the inertial forces are very much greater than the viscous forces and the Reynolds number is large. Turbulent flows are predominant in nature.	*USBR, 2008*
Turn angles	To measure the angle between directions with a surveying instrument.	*USBR, 2008*
Turning point (transfer point)	A point whose elevation is taken from two or more instrument positions to determine their height in relation to each other.	*USBR, 2008*
Turnout	A structure used to divert water from a supply channel to a smaller channel.	*USBR, 2008*

Two-dimensional model (2-D)	A mathematical model defined along two spatial coordinates where the water quality constituents are considered averaged over the third remaining spatial coordinate. Examples of 2-D models include descriptions of the variability of water quality properties along: (a) the length and width of a river that incorporates vertical averaging of depth, or (b) length and depth of a river that incorporates lateral averaging across the width of the waterbody.	*EPA, 2008c*

U

Ultimate bearing capacity	The load per unit of area required to produce failure by rupture of a supporting soil or rock mass.	*USBR, 2008*
Unbalanced head	See differential head.	*USBR, 2008*
Uncertainty	Describes situations where potential outcomes cannot be estimated based on historical events.	*USBR, 2008*
Uncertainty factor	One of several factors used in calculating the reference dose from experimental data. UFs are intended to account for (1) the variation in sensitivity among humans; (2) the uncertainty in extrapolating animal data to humans; (3) the uncertainty in extrapolating data obtained in a study that covers less than the full life of the exposed animal or human; and (4) the uncertainty in using LOAEL data rather than NOAEL data.	*EPA, 2008b*
Uncertainty factors	Factors used in the adjustment of toxicity data to account for unknown variations. Where toxicity is measured on only one test species, other species may exhibit more sensitivity to that effluent. An uncertainty factor would adjust measured toxicity upward and downward to cover the sensitivity range of other, potentially more or less sensitive species.	*EPA, 2008c*
Unclassified excavation	Excavation paid for at a fixed price per yard, regardless of whether it is common or rock excavation.	*USBR, 2008*
Uncompacted backfill	Material used in refilling an excavation without the material being compacted. See backfill.	*USBR, 2008*
Unconfined aquifer	An aquifer containing water that is not under pressure; the water level in a well is the same as the water table outside the well.	*EPA, 2008b*
Unconfined aquifer	An aquifer containing water that is not under pressure; the water level in a well is the same as the water table outside the well. An aquifer that discharges and recharges with an upper surface that is the water table.	*USBR, 2008*
Unconfined aquifer	An aquifer whose upper surface is a water table; an aquifer containing unconfined ground water.	*USGS, 2008*
Unconformity	A break or gap in the geologic record where rock layers were eroded or never deposited.	*USBR, 2008*
Unconsolidated deposit	Deposit of loosely bound sediment that typically fills topographically low areas.	*USGS, 2008*
Undercut bank/cut bank	The steep or overhanging slope on the outside of a meander curve, typically produced by lateral erosion of the stream. For all undercut banks, a protrusion of the upper portion of the bank overhangs the water surface at a flow equal to or less than bank full.	*USFS, 2002*

Underground storage tank (UST)	A tank located at least partially underground and designed to hold gasoline or other petroleum products or chemicals.	*EPA, 2008b*
Understory	Vegetation underneath the trees.	*USBR, 2008*
Undertaking	Any project, activity, or program that could change the character or use of historic properties.	*USBR, 2008*
Undertow	A seaward current near the bottom on a sloping inshore zone, caused by the return, under the action of gravity, of the water carried up on the shore by waves. Commonly misnamed a Rip Current.	*CCC, 2008*
Undisturbed sample	A soil sample that has been obtained by methods in which every precaution has been taken to minimize disturbance to the sample.	*USBR, 2008*
Unified Soil Classification System	A method of grouping and describing soils according to their engineering properties.	*USBR, 2008*
Uniform flow	Open channel flow where the depth and discharge remain constant with respect to space. Also, the velocity at a given depth is the same everywhere.	*USBR, 2008*
Un-ionized	The neutral form of an ionizable compound (such as an acid or a base).	*USGS, 2008*
Un-ionized ammonia	The neutral form of ammonia-nitrogen in water, usually occurring as NH4OH. Un-ionized ammonia is the principal form of ammonia that is toxic to aquatic life. The relative proportion of un-ionized to ionized ammonia (NH4+) is controlled by water temperature and pH. At temperatures and pH values typical of most natural waters, the ionized form is dominant.	*USGS, 2008*
Unit hydrograph	The direct runoff hydrograph resulting from a unit depth of excess rainfall produced by a storm of uniform intensity and specified duration. A hydrograph with a volume of 1 inch of runoff resulting from a storm of a specified duration and areal distribution. Hydrographs from other storms of the same duration and distribution are assumed to have the same time base but with ordinates of flow in proportion to the runoff volumes.	*USBR, 2008*
Unit weight	Weight per unit volume. See density, dry unit weight, maximum unit weight, saturated unit weight, unit weight of water, wet unit weight.	*USBR, 2008*
Unit weight of water	The weight per unit volume of water. See unit weight.	*USBR, 2008*
Unlisted items	Line item used in an appraisal estimate for design changes and to estimate pay items that have little influence on the total cost. The allowance for unlisted items in appraisal estimates should be at least 10 percent of the listed items. Line item used in a feasibility estimate for quantity changes due to receiving more design data and to estimate pay items that have little influence on the total cost. The allowance for unlisted items in a feasibility estimate varies between 2 percent and 15 percent of the listed items, depending on the form of the specifications quantities.	*USBR, 2008*
Unload-reload cycle	A loading sequence resulting in rebound and recompression.	*USBR, 2008*

Unpaid Federal investment	A year-end amount owned to the Treasury which remains to be repaid and is synonymous to "balance to be repaid."	*USBR, 2008*
Unreasonable risk	Under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), "unreasonable adverse effects" means any unreasonable risk to man or the environment, taking into account the medical, economic, social, and environmental costs and benefits of any pesticide.	*EPA, 2008b*
Unsaturated zone	The area above the water table where soil pores are not fully saturated, although some water may be present.	*EPA, 2008b*
Unsaturated zone	The subsurface zone, usually starting at the land surface and ending at the water table, that includes both water and air in spaces between rocks. See zone of aeration.	*USBR, 2008*
Unsaturated zone	The zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. These zones differ from an aquifer, where the pores are saturated with water.	*DOC, 2005*
Unstable bank	The stream bank shows evidence of active erosion, shearing, tension cracking, breakdown, and/or sloughing. Undercut banks are considered unstable if tension cracks show on the ground surface at the back of the undercut.	*USFS, 2002*
Unsteady flow	The velocity at a point varies with time.	*USBR, 2008*
Unstratified	Indicates a vertically uniform or well-mixed condition in a waterbody. See also stratified.	*EPA, 2008c*
Unsuitable material	Those soils that cannot be compacted in embankment or backfill or where excavated to finished grade result in unstable material.	*USBR, 2008*
Unwatering	As opposed to dewatering, unwatering is the interception and removal of ground water outside of excavations and the removal of ponded or flowing surface water from within excavations. To remove or drain off water. The removal and control of ponded or flowing surface water, surface seepage, and precipitation from within and adjacent to excavations by the use of channels, ditches, and sumps.	*USBR, 2008*
Upcoast	In the United States usage, the coastal direction, generally trending toward the north, from which a current comes. Sediment will often deposit on the upcoast side of a jetty, groin, or headland, reducing the amount of sediment that is available for transport further downcoast.	*CCC, 2008*
Updrift	The direction opposite that of the predominant movement of littoral materials.	*CCC, 2008*
Upgradient	Of or pertaining to the place(s) from which ground water originated or traveled through before reaching a given point in an aquifer.	*USGS, 2008*
Upland	Elevated land above low areas along a stream or between hills; elevated region from which rivers gather drainage.	*USGS, 2008*
Uplift	(a) The upward pressure in the pores of a material (interstitial pressure) on the base of a structure. An upward force on a structure caused by frost heave or windforce. The upward water pressure on a structure.	*USBR, 2008*
Upper detection limit	The largest concentration that an instrument can reliably detect.	*EPA, 2008b*

Upstream blanket	An impervious blanket placed on the reservoir floor and abutments upstream of a dam. For an embankment dam, the blanket may be connected to the impermeable element or core.	*USBR, 2008*
Upstream face	The inclined surface of the dam that is in contact with the reservoir. See face.	*USBR, 2008*
Uranium	A heavy silvery white metallic element, highly radioactive and easily oxidized. Of the 14 known isotopes of uranium, U238 is the most abundant in nature.	*USGS, 2008*
Urban area	Predominantly cities, towns or developed areas where the population is significant.	*USBR, 2008*
Urban runoff	Storm water from city streets and adjacent domestic or commercial properties that carries pollutants of various kinds into the sewer systems and receiving waters.	*EPA, 2008b*
Urban runoff	Storm water from city streets and gutters that usually carries a great deal of litter and organic and bacterial wastes into the sewer systems and receiving waters.	*USACE, 1999*
Urban site	A site that has greater than 50 percent urbanized and less than 25 percent agricultural area.	*USGS, 2008*
Urbanization	To become urban in nature or character; residential, commercial, and industrial development.	*USBR, 2008*
Usable storage capacity	The quantity of ground water of acceptable quality that can be economically withdrawn from storage.	*USBR, 2008*
Use attainability analysis (UAA	A structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, and economic factors as described in section 131.10(g). (40 CFR 131.3)	*EPA, 2008c*
Use value	The economic benefit associated with the physical use of a resource, usually measured by the consumer surplus or net economic value associated with such use. The contingent value method is one technique used to estimate use value.	*USBR, 2008*
User day	The participation in a recreation activity at a given resource during a 24-hour period by one person.	*USBR, 2008*
User fee	A fee which is collected only from those persons who use a particular service, as opposed to one collected from the public in general. User fees generally vary in proportion to the degree of use of the service.	*USBR, 2008*
Utility	A regulated entity which exhibits the characteristics of a natural monopoly. For the purposes of electric industry restructuring, "utility" refers to the regulated, vertically integrated electric company. "Transmission utility" refers to the regulated owner/operator of the transmission system only. "Distribution utility" refers to the regulated owner/operator of the distribution system which serves retail customers.	*USBR, 2008*

V

Validation (of a model)	Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical process under investigation.	*EPA, 2008c*

Validation monitoring	Monitoring that answers the question: "Are the assumptions used in restoration design and cause-effect relationships correct?" Validation monitoring considers assumptions made during planning and execution of restoration measures. This level of monitoring considers assumptions made during planning and execution of restoration measures. This level of monitoring is performed in response to non-achievement of desired results once proper implementation is confirmed. A restoration initiative that fails to achieve the intended results could be the result of improper assumptions relative to ecological conditions or selection of invalid monitoring indicators. This level of monitoring is always costly and requires scientific expertise.	*FISHWR, 2001*
Vane shear test	An in-place shear test in which a rod with thin radial vanes at the end is forced into the soil and the resistance to rotation of the rod is determined.	*USBR, 2008*
Variable costs	Input costs that change as the nature of the production activity of its circumstances change; for example, as production levels vary.	*USBR, 2008*
Variance	A measure of the amount of spread or dispersion of a set of values around their mean, obtained by calculating the mean value of the squares of the deviations from the mean, and hence equal to the square of the standard deviation.	*USGS, 1982*
Varved	A sedimentary bed or lamination that is deposited within one year's time.	*USBR, 2008*
Vebe time	The time for concrete to fully consolidate in a Vebe cylinder.	*USBR, 2008*
Vegetated geogrid	Live branch cuttings placed in layers with soil lifts wrapped in erosion control fabric.	*USFS, 2002*
Vegetative controls	Nonpoint source pollution control practices that involve plants (vegetative cover) to reduce erosion and minimize the loss of pollutants.	*USBR, 2008*
Vein	A layer, seam, or narrow irregular body of material different from surrounding formations.	*USBR, 2008*
Velocity	In this concept, the speed of water flowing in a watercourse, such as a river.	*USACE, 1999*
Velocity	Rate of flow of water expressed in feet per second or miles per hour. The time rate of displacement of a fluid particle from one point to another. Velocity is a vector quantity that has magnitude and direction.	*USBR, 2008*
Velocity (of water in a stream)	The distance that water can travel in a specific direction during an interval of time. Usually expressed in feet per second (fps).	*USFS, 2002*
Venturi	A pressure jet that draws in and mixes air.	*USBR, 2008*
Verification (of a model)	Testing the accuracy and predictive capabilities of the calibrated model on a data set independent of the data set used for calibration.	*EPA, 2008c*
Vernal pool	A small depression, with hard-panned floor, whose depth fluctuates with the seasons and rain patterns. It is dry for a part of the year. Vegetation within and adjacent to the pool is unique.	*USFS, 2002*
Vernier	A device permitting finer measurement or control than standard markings or adjustments.	*USBR, 2008*

Vertical curve	The meeting of different gradients in a road or pipe.	*USBR, 2008*
Vesicular (vesicles)	Containing many small cavities formed by the expansion of a gas bubble or steam when the rock solidifies. Tiny holes in volcanic rock caused by gas bubbles trapped in lava when it cooled.	*USBR, 2008*
Vibrating screen	A screen which is vibrated to separate and move pieces resting on it.	*USBR, 2008*
Virgin compression	Compression corresponding to stresses greater than the preconsolidation stress.	*USBR, 2008*
Virgin compression curve	The portion of the compression curve corresponding to virgin compression.	*USBR, 2008*
Virgin compression line	Straight line approximating the virgin compression curve.	*USBR, 2008*
Viscosity	A measure of the resistance of a fluid to flow. For liquids, viscosity increases with decreasing temperature.	*USACE, 1999*
Viscosity	The resistance of a fluid to flow. A liquid with a high viscosity rating will resist flow more readily than will a liquid with a low viscosity.	*USBR, 2008*
Visitor day	Twelve visitor hours which may be aggregated by one or more persons in single or multiple visits.	*USBR, 2008*
Visitor use	Visitor use of recreation and wilderness resource for inspiration, stimulation, solitude, relaxation, education, pleasure, or satisfaction.	*USBR, 2008*
Visitor-day	See recreation-day	*USACE, 1999*
V-notch weir	A weir that is V-shaped, with its apex downward, used to accurately measure small rates of flow.	*USBR, 2008*
Void	Space in a soil or rock mass not occupied by solid mineral matter. This space may be occupied by air, water, or other gaseous or liquid material.	*USBR, 2008*
Void ratio	The ratio of the volume of void space to the volume of solid particles in a given soil mass.	*USBR, 2008*
Volatile organic compounds (VOCs)	Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by	*USGS, 2008*
Volcanic rock	Rock that forms from the solidification of molten rock or magma at the earth's surface (extrusive igneous rock).	*USBR, 2008*
Volume of Concrete	The total space occupied by concrete forming the dam structure computed between abutments and from the top to the bottom of the dam. No deduction is made for small openings such as galleries, adits, tunnels, and operating chambers within the dam structure. The volume includes all mass concrete appurtenances not separated from the dam by construction or contraction joints. Where a powerplant is located at the downstream toe of a concrete dam, the limit of concrete in the dam should be taken as the downstream face projected to the general excavated foundation surface.	*USBR, 2008*

Volume of dam	The total space occupied by the materials forming the dam structure computed between abutments and from the top to the bottom of the dam. No deduction is made for small openings such as galleries, adits, tunnels, and operating chambers within the dam structure. Portions of power plants, locks, spillway, etc., may be included only if they are necessary for the structural stability of the dam.	*USBR, 2008*
Volumetric shrinkage	The decrease in volume, expressed as a percentage of the soil mass when dried, of a soil mass when the moisture content is reduced from a given percentage to the shrinkage limit.	*USBR, 2008*
Vortex	A revolving mass of water (whirlpool) in which the streamlines are concentric circles and in which the total head is the same. Water rotating about an axis.	*USBR, 2008*

W

Wadeable streams	Streams that are small and shallow enough to adequately sample by wading, without a boat.	*EPA, 2006*
Wakefield bulkhead	Vertical boards imbedded in sand using a tongue and groove arrangement, with horizontal planks reinforcing the seaward face.	*CCC, 2008*
Wall friction	Frictional resistance mobilized between a wall and the soil or rock in contact with the wall.	*USBR, 2008*
Warm-water fishery	Generally, water or water system that has an environment suitable for species of fish other than salmonids.	*USBR, 2008*
Warning	The fourth of five Early Warning System components consisting of the processes (including the media) and equipment necessary to make the public aware of potential, probable, or imminent danger or risk. A warning should be designed to prompt the population at risk to take protective action.	*USBR, 2008*
Warning stage	The depth of water in a river at which the National Weather Service (NWS) reviews basin conditions for potential flooding.	*USBR, 2008*
Warning time (WT)	The amount of time between detection of failure or incipient failure and arrival of dam failure flood. It is a function of, and related to, detection, response, breach formation, travel time, evacuation capability, and breach formation time.	*USBR, 2008*
Warranted but precluded	A 12-month petition finding that a petitioned action should be undertaken, but cannot because the resources necessary to do so are being devoted to actions with higher priority.	*USFWS, 2008*

Wash	(1) To carry, erode, remove, or destroy by the action of moving water. To be carried away, removed, or drawn by the action of water. Removal or erosion of soil by the action of moving water. (2) A deposit of recently eroded debris. (3) Low or marshy ground washed by tidal waters. A stretch of shallow water. (4) Western United States: The dry bed of a stream, particularly a watercourse associated with an alluvial fan, stream, or river channel. Washes are often associated with arid environments and are characterized by large, high-energy discharges with high bed-material load transport. Washes are often intermittent and their beds sparsely vegetated. (5) Turbulence in air or water caused by the motion or action of an oar, propeller, or airfoil.	*USACE, 1999*
Wash	A dry streambed. Usually found in the West.	*USFS, 2002*
Wash load	That part of the total sediment discharge which is composed of particle sizes finer than those found in appreciable quantities in the bed material, and is determined by available bank and upslope supply rate.	*USBR, 2008*
Washload	Sediments smaller than 63 microns which are not from the bed but could be from bank erosion or upland sources.	*EPA, 2008c*
Washout	(1) Erosion of a relatively soft surface, such as a roadbed, by a sudden gush of water, as from a downpour or floods. (2) A channel produced by such erosion.	*USACE, 1999*
Waste	Digging, hauling and dumping of valueless material to get it out of the way; or the valueless material itself.	*USBR, 2008*
Wastebank	A bank made of excess or unstable material excavated from a construction site.	*USBR, 2008*
Wasteload allocation (WLA)	The portion of a receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).	*EPA, 2008c*
Wastewater	The water, liquid waste, or drainage from a community, industry, or institution.	*USACE, 1999*
Wastewater	Usually refers to effluent from a sewage treatment plant. See also domestic wastewater.	*EPA, 2008c*
Wastewater treatment	Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water in order to remove, reduce, or neutralize contaminants.	*EPA, 2008c*
Wasteway	A waterway used to drain excess irrigation water dumped from the irrigation delivery system.	*USGS, 2008*
Water budget	An accounting of the inflow, outflow, and storage changes of water in a hydrologic unit.	*USGS, 2008*
Water budget (water balance model)	An analytical tool whereby the sum of the system inflows equals the sum of the system outflows. A summation of inputs, outputs, and net changes to a particular water resource system over a fixed period.	*USBR, 2008*
Water column studies	Investigations of physical and chemical characteristics of surface water, which include suspended sediment, dissolved solids, major ions, and metals, nutrients, organic carbon, and dissolved pesticides, in relation to hydrologic conditions, sources, and transport.	*USGS, 2008*

Water conservation	Reduction in applied water due to more efficient water use such as implementation of Urban Best Management Practices or Agricultural Efficient Water Management Practices. The extent to which these actions actually create a savings in water supply depends on how they affect net water use and depletion.	*USACE, 1999*
Water conveyance efficiency	Ratio of the volume of irrigation water delivered by a distribution system to the water introduced into the system.	*USBR, 2008*
Water conveyance structure	Any structure that conveys water from one location to another.	*USBR, 2008*
Water cycle	The movement of water from the air to and below the Earth's surface and back into the air. See hydrologic cycle.	*USBR, 2008*
Water cycle	The circuit of water movement from the oceans to the atmosphere and to the Earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation.	*DOC, 2005*
Water delivery system	Reservoirs, canals, ditches, pumps, and other facilities to move water.	*USBR, 2008*
Water demand	Water requirements for a particular purpose, as for irrigation, power, municipal supply, plant transpiration or storage.	*USBR, 2008*
Water demand schedule	A time distribution of the demand for prescribed quantities of water for specified purposes. It is usually a monthly tabulation of the total quantity of water that a particular water user intends to use during a specified year.	*USACE, 1999*
Water hammer (hydraulic transient)	Refers to pressure fluctuations caused by a sudden increase or decrease in flow velocity, usually associated with a rapid closure or opening of a valve in a pipeline.	*USBR, 2008*
Water holding capacity	Amount of soil water available to plants. See available capacity. The smallest value to which the moisture content of a soil can be reduced by gravity drainage.	*USBR, 2008*
Water management plan	A plan developed during construction to help assure water quality compliance for both point and nonpoint pollution sources.	*USBR, 2008*
Water pollution	Generally, the presence in water of enough harmful or objectionable material to damage the water's quality.	*USACE, 1999*
Water purveyor	An agency or person that supplies water.	*USBR, 2008*
Water quality	A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.	*USACE, 1999*
Water quality	The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.	*EPA, 2008c*
Water quality	The condition of water as it relates to impurities.	*USBR, 2008*
Water quality	A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.	*DOC, 2005*

Water quality criteria	Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.	*EPA, 2008c*
Water quality criteria	Specific levels of water quality which, if reached, are expected to render a body of water unsuitable for its designated use. Commonly refers to water quality criteria established by the U.S. Environmental Protection Agency. Water quality criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.	*USGS, 2008*
Water quality guidelines	Specific levels of water quality which, if reached, may adversely affect human health or aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.	*USGS, 2008*
Water quality management	Practices that protect existing water quality or change the chemical composition and/or suspended particulate load. Remediation of acid mine drainage falls into this category as does CSO separation. Excludes urban runoff quantity management (see Storm water Management).	*NRRSS, 2005*
Water quality management plans	Prescribe the regulatory, construction, and management activities necessary to meet the water body goals.	*EPA, 2008c*
Water quality standard	Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an anti-degradation statement.	*EPA, 2008c*
Water quality standards	Provisions in State or Tribal law or regulations that define the water quality goals of a water body, or segment thereof, by designating the use or uses to be made of the water; setting criteria necessary to protect the uses; and protecting existing water quality through anti-degradation policies and implementation procedures.	*EPA, 2008c*
Water quality standards	State-adopted and U.S. Environmental Protection Agency-approved ambient standards for water bodies. Standards include the use of the water body and the water quality criteria that must be met to protect the designated use or uses.	*USGS, 2008*
Water quality-based effluent limitations	Effluent limitations applied to dischargers when mere technology-based limitations would cause violations of water quality standards. Usually WQBELs are applied to discharges into small streams.	*EPA, 2008c*
Water quality-based permit	A permit with an effluent limit more stringent than one based on technology performance. Such limits may be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry or water supply).	*EPA, 2008c*

Water quality-limited segments	Those water segments which do not or are not expected to meet applicable water quality standards even after the application of technology-based effluent limitations required by sections 301(b) and 306 of the Clean Water Act (40 CFR 130.29(j)). Technology-based controls include, but are not limited to, best practicable control technology currently available (BPT) and secondary treatment.	*EPA, 2008c*
Water quality-limited segments	Those water segments which do not or are not expected to meet applicable water quality standards even after the application of technology-based effluent limitations required by sections 301(b) and 306 of the Clean Water Act (40 CFR 130.29(j)). Technology-based controls include, but are not limited to, best practicable control technology currently available (BPT) and secondary treatment.	*EPA, 2008c*
Water reclamation	Includes water recycling, seawater desalting, groundwater reclamation, and desalting agricultural brackish water.	*USACE, 1999*
Water recycling	The treatment of urban wastewater to a level rendering it suitable for a specific, direct, beneficial use.	*USACE, 1999*
Water right	A legally protected right to take possession of water occurring in a natural waterway and to divert that water for beneficial use.	*USACE, 1999*
Water saturation	That point at which a material will no longer absorb water.	*USBR, 2008*
Water supplier	A person who owns or operates a public water system.	*USBR, 2008*
Water surface elevation (stage)	The elevation of a water surface above or below an established reference level, such as sea level. See datum.	*USBR, 2008*
Water table	See groundwater table.	*USACE, 1999*
Water table	The surface of underground, gravity-controlled water. The level of ground water. The boundary in the ground between where the ground is saturated with water (zone of saturation) and where the ground is filled with water and air (zone of aeration). The upper surface of the zone of saturation of ground water above an impermeable layer of soil or rock (through which water cannot move) as in an unconfined aquifer. This level can be very near the surface of the ground or far below it.	*USBR, 2008*
Water table	The top of the water surface in the saturated part of an aquifer.	*DOC, 2005*
Water table	The point below the land surface where ground water is first encountered and below which the earth is saturated. Depth to the water table varies widely across the country.	*USGS, 2008*
Water transfers	Selling or exchanging water or water rights among individuals or agencies. Artificial conveyance of water from one area to another.	*USBR, 2008*
Water use	Water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human's interaction with and influence on the hydrologic cycle, and includes elements, such as water withdrawal from surface- and ground-water sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and instream uses, such as using water to produce hydroelectric power.	*DOC, 2005*
Water user	Any individual, district, association, government agency, or other entity that uses water supplied from a Reclamation project.	*USBR, 2008*

Water year	A continuous 12-month period for which hydrologic records are compiled and summarized. In California, it begins on October 1 and ends September 30 of the following year.	*USACE, 1999*
Water year	The continuous 12-month period, October 1 through September 30, in U.S. Geological Survey reports dealing with the surface water supply. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1980, is referred to as the "1980" water year.	*USGS, 2008*
Water year (WY)	Period of time beginning October 1 of one year and ending September 30 of the following year and designated by the calendar year in which it ends. A calendar year used for water calculations.	*USBR, 2008*
Water yield	The quantity of water derived from a unit area of watershed.	*USACE, 1999*
Waterfall	A sudden, nearly vertical drop in a stream, as it flows over rock.	*USACE, 1999*
Watershed	A region or area bounded by ridge lines or other physical divides and draining ultimately to a particular watercourse or body of water.	*EPA, 1997*
Watershed	An area of land that drains water, sediment, and dissolved materials to a common outlet at some point along a stream channel.	*FISHWR, 2001*
Watershed	An area of land whose total surface drainage flows to a single point in a stream.	*USACE, 1999*
Watershed	A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.	*EPA, 2008c*
Watershed	The geographical area drained by a river and its connecting tributaries into a common source. A watershed may, and often does, cover a very large geographical region.	*CCC, 2008*
Watershed	The region draining into a river, river system, or other body of water above a particular point.	*DOC, 2005*
Watershed	See Drainage basin.	*USGS, 2008*
Watershed (drainage area)	Surface drainage area above a specified point on a stream. Area which drains into or past a point. A geographical portion of the Earth's surface from which water drains or runs off to a single place like a river. The area of land that drains its water into a stream or river. All the land and water within the confines of a certain drainage area. Vertically, it extends from the top of the vegetation to the underlying rock layers that confine water movement. An area of land that contributes runoff to one specific delivery point.	*USBR, 2008*
Watershed assessment	A process for analyzing a watershed's current condition and the likely causes of these conditions, usually resulting in a report documenting findings of the process.	*DOC, 2005*
Watershed divide	The divide or boundary between catchment areas (or drainage areas).	*USBR, 2008*
Watershed health	1) an index or estimate of the degree to which the generation and transport of water and its constituents within a watershed function in a relatively natural manner; 2) an index or estimate of the natural functioning of the watershed relative to a reference or historic condition.	*DOC, 2005*

Watershed management	The analysis, protection, development, operation, or maintenance of the land, vegetation, and water resources of a drainage basin for the conservation of all its resources for the benefit of its residents.	*USACE, 1999*
Watershed management	1) a multiple-step, iterative process consisting of watershed monitoring, assessment, planning, implementation, and evaluation; 2) a process for making decisions about activities that will affect the health of a watershed.	*DOC, 2005*
Watershed plan	The product of a planning process a the watershed scale considering natural and human processes relevant at the scale (e.g., natural and artificial flows). Sometimes used synonymously with ôwatershed management planö. A watershed plan consists of an overall vision or set of goals for the watershed, a series of steps needed to achieve those goals, and detailed consideration of how to implement those steps.	*DOC, 2005*
Watershed project	A comprehensive program of structural and nonstructural measures to preserve or restore a watershed to good hydrologic condition. These measures may include detention reservoirs, dikes, channels, contour trenches, terraces, furrows, gully plugs, revegetation, and possibly other practices to reduce flood peaks and sediment production.	*USACE, 1999*
Watershed protection approach (WPA)	The USEPA's comprehensive approach to managing water resource areas, such as river basins, watersheds, and aquifers. WPA has four major features—targeting priority problems, stakeholder involvement, integrated solutions, and measuring success.	*EPA, 2008c*
Watershed restoration	Improving current conditions of watersheds to restore degraded habitat and provide long-term protection to aquatic and riparian resources.	*USACE, 1999*
Watershed restoration	Reestablishing the structure and function of an ecosystem, including its natural diversity; a comprehensive, long-term program to return watershed health, riparian ecosystems, and fish habitats to a close approximation of their condition prior to human disturbance.	*DOC, 2005*
Watershed-based trading	Watershed-based trading is an efficient, market-driven approach that encourages innovation in meeting water quality goals, but remains committed to enforcement and compliance responsibilities under the Clean Water Act. It involves trading arrangements among point source dischargers, nonpoint sources, and indirect dischargers in which the "buyers" purchase pollutant reductions at a lower cost than what they would spend to achieve the reductions themselves. Sellers provide pollutant reductions and may receive compensation. The total pollution reduction, however, must be the same or greater than what would be achieved if no trade occurred.	*EPA, 2008c*
Watershed-scale approach	A consideration of the entire watershed, including the land mass that drains into the aquatic ecosystem.	*EPA, 2008c*
Waterstage recorder	A motor-driven (spring wound or electric) instrument for monitoring water surface elevation.	*USBR, 2008*

Waterstop (water bar)	A continuous strip of waterproof material placed at concrete joints designed to control cracking and limit moisture penetration.	*USBR, 2008*
Wattle	see Live Fascine	*USFS, 2002*
Wave	A ridge, deformation, or undulation of the surface of a liquid. On the ocean, most waves are generated by wind and are often referred to as wind waves.	*CCC, 2008*
Wave climate	The range if wave parameters (Height, period and direction) characteristic of a coastal location.	*CCC, 2008*
Wave height	The vertical distance from a wave trough to crest.	*CCC, 2008*
Wave length (wavelength)	The horizontal distance between successive crests or between successive troughs of waves.	*CCC, 2008*
Wave period	The time for a wave crest to traverse a distance equal to one wavelength, which is the time for two successive wave crests to pass a fixed point.	*CCC, 2008*
Wave runup	Vertical height above the sill water level to which water from a specific wave will run up the face of a structure or embankment.	*USBR, 2008*
Wave run-up	The distance or extent that water from a breaking wave will extend up a beach or structure.	*CCC, 2008*
Wave-cut platform	The near-horizontal plane cut by wave action into a bedrock formation at the shoreline.	*CCC, 2008*
Weather	The state of the atmosphere at any particular time and place.	*USGS, 2008*
Wedge	A piece that tapers from a thick end to a chisel point.	*USBR, 2008*
Weep hole	A drain embedded in a concrete or masonry structure intended to relieve pressure caused by seepage behind the structure.	*USBR, 2008*
Weighted Means	A value obtained by multiplying each of a series of values by its assigned weight and dividing the sum of those products by the sum of the weights.	*USGS, 1982*
Weighting of a slope	Additional material placed on the slope of an embankment.	*USBR, 2008*
Weir	A structure to control water levels in a stream. Depending upon the configuration, weirs can provide a specific 'rating' for discharge as a function of the upstream water level.	*USACE, 1999*
Weir	An overflow structure built across an open channel to raise the upstream water level and/or to measure the flow of water. A measuring or gaging weir is calibrated for depth of flow over the crest. A weir generally consists of a rectangular, trapezoidal, triangular, or other shaped notch, located in a vertical, thin plate over which water flows. The height of water above the weir crest is used to determine the rate of flow. See Cipolletti weir, rectangular weir, and v-notch weir. Other types of weirs include broad-crested weir, sharp-crested weir, drowned weir or submerged weir. See contracted weir and suppressed weir.	*USBR, 2008*
Weir (fish trap)	Usually a barrier constructed to catch upstream migrating adult fish.	*USACE, 1999*
Weld	To build up or fasten together metals by bonding on molten metal.	*USBR, 2008*

Well	A hole or shaft drilled into the earth to get water or other underground substances. A bored, drilled, or driven shaft, or a dug hole, whose depth is greater than the largest surface dimension and whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.	*USBR, 2008*
Well (water)	An artificial excavation put down by any method for the purposes of withdrawing water from the underground aquifers. A bored, drilled, or driven shaft, or a dug hole whose purpose is to reach underground water supplies or oil, or to store or bury fluids below ground.	*DOC, 2005*
Well field	Area containing one or more wells that produces usable amounts of water.	*USBR, 2008*
Well graded	A good representation in the material of all particle sizes present from the largest to smallest.	*USBR, 2008*
Wellpoint	A pipe fitted with a driving point and a fine mesh screen used to remove underground water. A complete set of equipment for drying up ground including wellpoints, connecting pipe and pump.	*USBR, 2008*
Wet unit weight	The unit weight of solids plus water per unit volume, irrespective of the degree of saturation.	*USBR, 2008*
Wetland	An area of land that is saturated at least part of the year by water. Usually found in depressions, low-lying areas, or along floodplain or coastal areas.	*USFS, 2002*
Wetland	An area that is saturated by surface water or ground water with vegetation adapted for life under those soil conditions, as in swamps, bogs, fens, marshes, and estuaries.	*EPA, 2008c*
Wetland	Lands within the coastal zone which may be covered periodically or permanently with shallow water and include saltwater marshes, freshwater marshes, open or closed brackish water marshes, swamps, mudflats, and fens.	*CCC, 2008*
Wetland	An area of the landscape that is periodically or frequently inundated and containing vegetation and animals adapted to that condition.	*DOC, 2005*
Wetlands	Lands including swamps, marshes, bogs, and similar areas such as wet meadows, river overflows, mudflats, and natural ponds. An area characterized by periodic inundation or saturation, hydric soils, and vegetation adapted for life in saturated soil conditions. Any number of tidal and nontidal areas characterized by saturated or nearly saturated soils most of the year that form an interface between terrestrial and aquatic environments; including freshwater marshes around ponds and channels, and brackish and salt marshes. A jurisdictional wetland is subject to regulation under the Clean Water Act. A nonjurisdictional is subject to consideration under the Fish and Wildlife Coordination Act.	*USBR, 2008*
Wetlands	Ecosystems whose soil is saturated for long periods seasonally or continuously, including marshes, swamps, and ephemeral ponds.	*USGS, 2008*

Wetted perimeter	The distance along the bottom and sides of a stream, creek, or channel in contact with the water. Length of the wetted contact between a conveyed liguid and the open channel or closed conduit conveying it, measured in a plane at right angles to the direction of flow.	*USBR, 2008*
Whaler	A horizontal beam in a bracing structure.	*USBR, 2008*
Wheeling	The transmission of electricity by an entity that does not own or directly use the power it is transmitting. Wholesale wheeling is used to indicate bulk transactions in the wholesale market, whereas retail wheeling allows power producers direct access to retail customers. This term is often used colloquially as meaning transmission.	*USBR, 2008*
White noise	Random energy containing all frequency components in equal proportions.	*USBR, 2008*
Wild rivers	Rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted.	*USACE, 1999*
Wilderness	Tract or region of land uncultivated and uninhabited by human beings, or unoccupied by human settlements.	*USBR, 2008*
Wilderness resource	Resources identified in officially designated wilderness areas on Forest Service or Bureau of Land Management administered land.	*USBR, 2008*
Wildlife tree	A live tree retained to become future snag habitat.	*USACE, 1999*
Willingness to pay	Method of estimating the value of activities, services, or other goods, where value is defined as the maximum amount a consumer would be willing to pay for the opportunity rather than do without. The total willingness to pay, minus the user's costs of participating in the opportunity, defines the consumer surplus and benefits.	*USBR, 2008*
Wilting point	The soil water content below which plants growing in that soil will remain wilted even when transpiration is nearly eliminated. See permanent wilting point.	*USBR, 2008*
Winch	A drum that can be rotated so as to exert a strong pull while winding in a line.	*USBR, 2008*
Wind setup	The vertical rise in the still water level at the face of a structure or embankment caused by wind stresses on the surface of the water.	*USBR, 2008*
Windfall	Trees or parts of trees felled by high winds.	*USACE, 1999*
Windrow	A ridge of loose material.	*USBR, 2008*
Windthrow	A tree or trees uprooted or felled by the wind.	*USACE, 1999*
Windward	The direction from which the wind is blowing.	*CCC, 2008*
Wing wall	A wall that guides a water into a conveyance structure.	*USBR, 2008*
Wire-to-water efficiency (overall efficiency)	The efficiency of a pump and motor together.	*USBR, 2008*
Withdrawal	Water removed from the ground or diverted from a surface-water source for use. The process of taking water from a source and conveying it to a place for a particular type of use.	*USBR, 2008*
Withdrawal	Water removed from a ground- or surface-water source for use.	*DOC, 2005*
Withdrawal	The act or process of removing; such as removing water from a stream for irrigation or public water supply.	*USGS, 2008*

Woody debris	Referring to wood in the streams.	*USACE, 1999*
Woody debris	Coarse wood material such as twigs, branches, logs, trees, and roots that fall into streams.	*USFS, 2002*
Work plan	Plans that are prepared which detail the scope, direction, and purpose of a proposed Resource Management Plan.	*USBR, 2008*

X

Xenobiota	Any biotum displaced from its normal habitat; a chemical foreign to a biological system.	*EPA, 2008b*
Xeriscape	Landscaping that does not require a lot of water.	*USBR, 2008*

Y

Yield	The quantity of water (expressed as a rate of flow or total quantity per year) that can be collected for a given use from surface or groundwater sources.	*EPA, 2008b*
Yield	The quantity of water that can be collected for a given use from surface or ground water sources. See safe yield.	*USBR, 2008*
Yield	The mass of material or constituent transported by a river in a specified period of time divided by the drainage area of the river basin.	*USGS, 2008*
Young-of-year	Refers to young (usually fish) produced in one reproductive year. Small fish, hatched from eggs spawned in the current year, are considered young-of-year (age 0).	*USBR, 2008*

Z

Zero air voids curve	The curve showing the relationship between dry unit weights and corresponding moisture contents, assuming that all of the voids are completely filled with water.	*USBR, 2008*
Zone of aeration	The comparatively dry soil or rock located between the ground surface and the top of the water table. The zone of aeration is not saturated with water because its pores are filled partly by air and partly by water.	*USBR, 2008*
Zone of Saturation	The layer beneath the surface of the land containing openings that may fill with water.	*EPA, 2008b*
Zone of saturation	The soil or rock located below the top of the ground water table that is saturated with water. See water table.	*USBR, 2008*
Zoned earthfill (or zoned embankment)	An embankment dam composed of zones of selected materials where the permeability of the material increases to the upstream or downstream face from the relatively impermeable core material.	*USBR, 2008*
Zoning	Identification of areas of specified uses or restrictions.	*USBR, 2008*
Zoning ordinance	An ordinance authorized by Section 65850 of the Government Code or, in the case of a charter city, a similar ordinance enacted pursuant to the authority of its charter.	*CCC, 2008*
Zooplankton	Small (often microscopic) free-floating aquatic plants or animals.	*EPA, 2008b*
Zooplankton	Small, usually microscopic animals (such as protozoans), found in lakes and reservoirs.	*USBR, 2008*
Zooplankton	See Plankton.	*USGS, 2008*

Appendix B

B-1 TECHNOLOGY DELIVERY SYSTEM (TDS)

River Restoration can be conceptualized as a t*echnology*. Technology is defined as “the application of scientific knowledge, especially in industry or business” (*Webster, 1988*) and the development and application of this technology arises within the context of human society. A Technology Delivery System (TDS) is a collaborative effort between the public, government, and industry to construct a system that produces ‘desirable’ outputs (*Bea, 2007a; Bea, 2007b; Wenk, 1996; Wenk, 2006*). In the case of River Restoration, the output that is attempting to be achieved is rehabilitation of damaged ecosystems. The context of the TDS is valuable in that it provides a conceptual model by which to relate interactions and relationships between different stakeholders and technology developers.

The public, government, and industry must work collaboratively to develop a technology that yields the desired output. Inputs into the technology consist of things such as laws and regulations, financial resources, and human capital. The output of the technology must be compatible with the natural environment (sustainability) and must also yield the desired results. Figure B1 (*Bea, 2007a*) shows a conceptual overview of a TDS. All three organizations impact the configuration of the technology and have major impact on the inputs to the technology, and as a result, have a major impact on the outputs of the technology. Technology development is iterative and when the desired outcome is not achieved based on the developed Technology, updates and revisions to the Technology process are generally implemented. This Technology revision is most frequently encountered following a major natural disaster and is reflected in updates of building codes, allocation of research funding, and development and implementation of new technology tools.

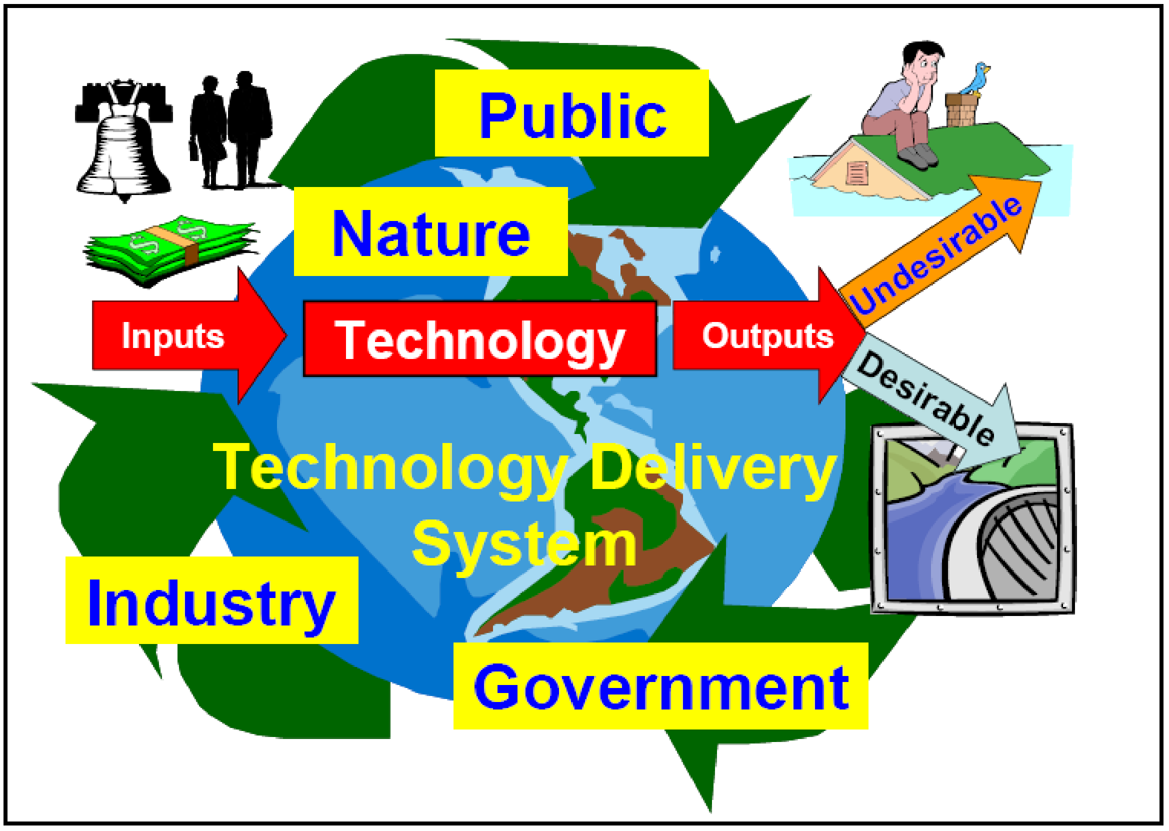

Figure B1: Conceptual overview of a Technology Delivery System (*Bea, 2007a*).

B-1.1 Application of TDS to the Columbia River Basin

To provide an overview example to demonstrate the collaboration between the public, government, and industry the Columbia River Basin Salmon and Steelhead recovery project serves as an excellent case study. The Columbia River Basin salmon and steelhead populations were once the world's largest. Before 1850, an estimated 16 million salmon and steelhead returned to the basin annually to spawn, but since the 1970s, the number of returning salmon and steelhead returning to the Columbia Basin has averaged around 660,000 per year (*GAO, 2002*). The dramatic population decline has resulted in the listing of 12 salmon and steelhead populations within the basin being listed as threatened or endangered species under the Endangered Species Act (*GAO, 2002*).

The Columbia Basin is North America's fourth largest, draining about 258,000 square miles, extending through the states of Idaho, Montana, Oregon, Washington, and Canada (Figure B2). The basin contains over 250 reservoirs and about 150 hydroelectric projects, including 18 dams on the Columbia River and its primary tributary, the Snake River. The Columbia River Basin provides habitat for many species including steelhead and four species of salmon: Chinook, Chum, Coho, and Sockeye (*GAO, 2002*).

The Columbia River has been labeled a "great organic machine" (*Williams et al, 2006*) that dominates the economy of the Pacific Northwest. The Columbia and Snake River mainstems are dominated by technological operations supporting the region's economy (e.g., hydropower production, irrigation systems, flood control, commercial barging) and these operations directly constrain the conservation and restoration efforts due to the immediate and direct impact on the associated economies and water use for the residents and communities within the Columbia River Basin (*Williams et al, 2006*).

Figure B2: The geographic coverage of the Columbia River Basin spans significant portions of Idaho, Montana, Oregon, Washington, as well as portions of southwest Canada (*GAO, 2002*).

Efforts to increase salmon and steelhead stocks in the Columbia River Basin began as early as 1877 with the construction of the first fish hatchery. As dams were built in the 1900s, attempts were made to minimize their impacts by installing fish ladders and bypass systems to help salmon and steelhead migrate up and down the rivers. In the 1980s, several other actions were taken to increase salmon and steelhead populations including: (1) a treaty between the United States and Canada limiting the ocean harvesting of salmon; (2) the passage of the Pacific Northwest Electric Power Planning and Conservation Act (P.L. 96-501), which called for the creation of an interstate compact to develop a program to protect, enhance, and mitigate fish and wildlife affected by hydropower development; (3) the beginning of major state, local and tribal efforts to address habitat restoration (*GAO, 2002*). The Columbia River Basin region attempted to provide technological solutions for losses of salmon habitat and reductions in salmon survival, first through construction and operation of salmon hatcheries and fish ladders, then later through installation of screens at turbine intakes and irrigation diversion screening, and finally barging and trucking of juvenile fish around the dams (*Williams et al, 2006*).

Due to the geographic range and historical importance of salmon and steelhead in the Columbia River Basin, local governments, industries, and private citizens became concerned with the recovery of the species' (*GAO, 2002*). Eleven federal agencies were tasked with developing salmon and steelhead recovery efforts, with the National Marine Fisheries Service being the lead federal agency. It is estimated that nearly $4 billion was spent on recovery efforts between 1982 and 2001 by the 11 federal agencies (*GAO, 2002*).

In addition to the federal agencies, many state and local governments, Indian tribes, private interest groups, and private citizens became involved with the recovery effort. These participants included the cities of Portland, Oregon and Yakima, Washington; local conservation districts like the Asotin County Conservation District in Washington, tribal entities such as the Confederated Tribes of the Umatilla Indian Reservation, Nez Perce Tribe, Confederated Tribes of the Warm Springs Reservation, and private interest groups/organizations like American Rivers, Columbia River Alliance, Ducks Unlimited, and Save our Wild Salmon (*GAO, 2002*), as well as industry providing technical, construction, and supply services.

During the implementation of the project, many competing priorities were encountered and these competing interests requiring trade-offs in order to make progress towards the salmon population restoration goals. As an example, the Northwest Power Act required the protection, mitigation, and enhancement of fish and wildlife while ensuring adequate, efficient, economical, and reliable power supply for the Pacific Northwest (*GAO, 2002*). During the drought of 2001, the Bonneville Power Administration (Department of Energy) found it difficult to meet its responsibilities under both the ESA and the Northwest Powers Act. As a result, Bonneville, in consultation with other federal agencies, determined that in order to maintain an adequate and reliable power supply during the declared power emergencies, available water had to be sent through dam turbines to generate electricity and, as a result, could not be released over the dam in an effort to aid juvenile fish passage past the dam, directly impacting survival rates of the salmon and steelhead fish populations (*GAO, 2002*).

This example of tradeoffs highlights the importance of viewing restoration within a Technology Delivery System. Tradeoffs requires project stakeholders (and in the case of the Columbia River Basin there are thousands of impacted stakeholders) to review the nature of the conflict and negotiate a compromise to satisfy the needs of the stakeholders while achieving the desired restoration objectives.

In addition to compromises regarding conflicting interests, manipulation of the technology inputs may also be required to achieve the intended outcomes. Table B1 presents a summary of the types of 'inputs' and 'technologies' developed as part of this Technology Delivery System to obtain the desired output of 5 million salmon returning to the Columbia River Basin annually. Inputs include factors such as interests of the project stakeholders (water supply, power generation, etc.), legislation (Clean Water Act, Endangered Species Act, National Environmental Protection Act, etc.), physical resources required to implement the selected restoration technologies, funds to cover the costs associate with the planning, design, construction, and operations/maintenance of the implemented restoration technologies, research and development to develop solutions to challenges associated with the restoration effort, as well as the actual mechanics of implementing the selected restoration efforts (which require planning, technical analyses, design plans and project specifications, construction), and scientific reviews and audits to evaluate the performance of the developed restoration technology.

For the Columbia River Basin case study, the primary restoration technologies that were developed to increase the annual salmon populations within the Basin from approximately 660,000 to 5 million include fish hatcheries, fish passage devices, screens installed on dam electricity generating turbines and irrigation intake structures, physical transportation of juvenile salmon around fish passage barriers via barges and transport truck, regulation of dam discharge frequency and duration to accommodate minimum water levels needed by salmon to spawn, improvements in physical habitats to increase potential spawing grounds for the salmon, and implementing 'best practices' for land use management to minimize non-point pollution into the waterways.

Table B1: Example Inputs, Technologies, and Outputs for the Columbia River Basin Technology Delivery System

Inputs	Technologies	Desired Output(s)
• Stakeholder Interests • Legislation • Physical Resources • Funding/Appropriations • Research & Development • Planning Efforts • Technical Designs • Reviews and Audits	• Fish Hatcheries • Fish Passage Devices • Turbine Intake Screens • Irrigation Diversion Screens • Barge/Truck Fish Bypass • River Flow Regulation • Habitat Improvements • Land Use "Best Practices"	• 5 million salmon returning annually to the Columbia River Basin

To evaluate the efficacy of the developed salmon restoration Technology Delivery System, annual fish counts have been performed. These fish count surveys have demonstrated that the actual salmon fish populations within the Columbia River Basin have not achieved the target fish population goals, nor has there been a steady increase in fish population in response to the implementation of the salmon restoration technology. Figure B3 shows the reported salmon counts at Bonneville Dam on the Columbia River between 1938 and 2003. Until about the year 2002, the annual fish counts were approximately 660,000 per year. An unusually high spike occurred in 2003, when nearly 2.5 million fish were counted (about half the target goal of 5 million salmon per year).

The cause for this spike in fish populations was unknown (*Williams et al, 2006*) and further data collection is underway to evaluate the longevity of these increased salmon counts.

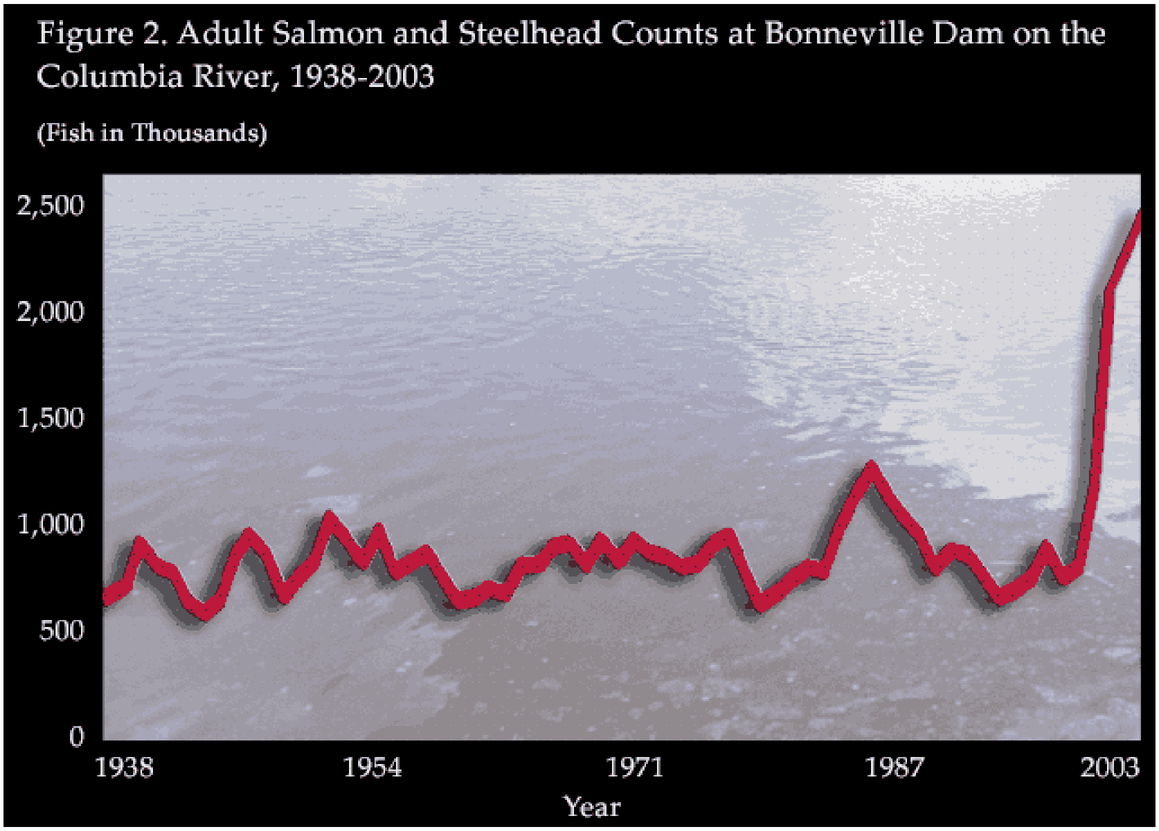

Figure B3: Reported fish counts between 1938 and 2004 (*NPCC, 2007*).

Although a spike in salmon populations was observed in 2003, within a longer historical context, dating back to the 1870s (shown in Figure B4 and as measured in tons of harvested salmon per year), the installation of dams on the river correspond to the onset of salmon population decreases. Some spikes in salmon populations appear to have occurred in the past, but the overall trend is a decrease in salmon populations, not an increase (*Williams et al, 2006*).

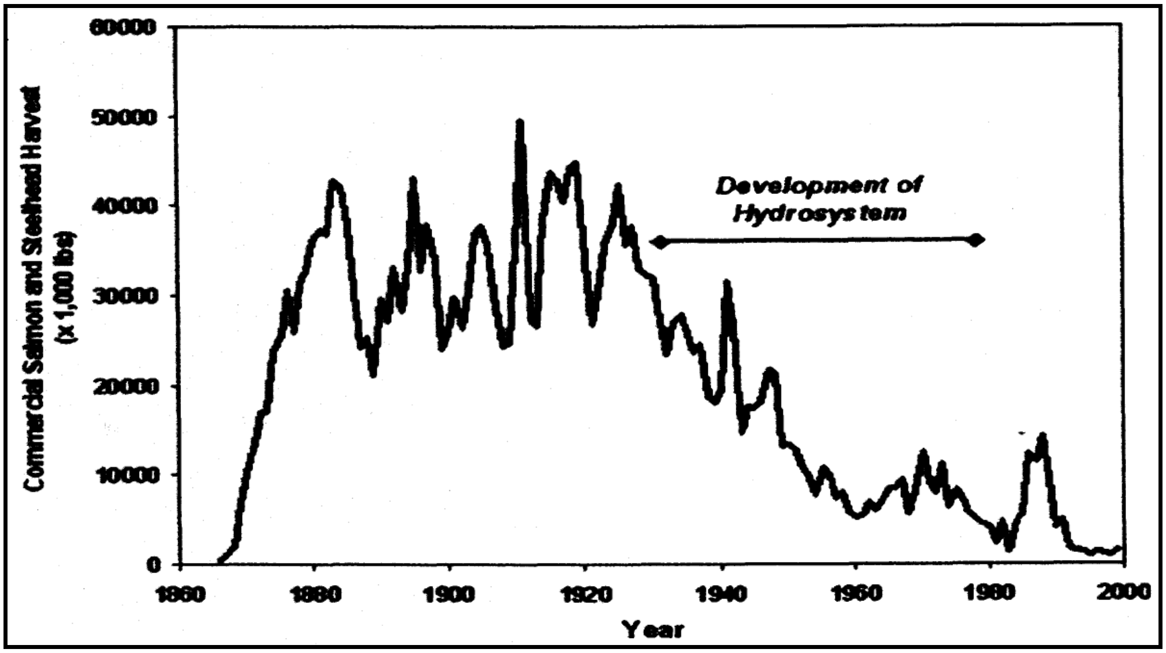

Figure B4: Historic salmon harvest (in thousands of pounds) between 1870 and 2000 (*Williams et al, 2006*).

The GAO (*2002*) found it very difficult to comment on the effectiveness of the restoration efforts because the data to isolate and quantify recovery efforts due to factors such as large natural yearly fluctuations in salmon and steelhead populations, changing weather and ocean conditions, the length of time it takes for project benefits to materialize, and the multiyear life cycles of the fish. The GAO (*2002*) concluded that actions that increase reproduction, improve passage and habitat conditions, reduce erosion and pollution, use hatcheries for recovery, ensure careful harvest management, and educate the public all improve salmon and steelhead survival rates. Although unable to quantify the improvements, federal officials were “confident” that the composite recovery actions had positive effects by generally improving the conditions for freshwater survival and ultimately resulting in higher numbers of returning adult salmon and steelhead than would have occurred otherwise (*GAO, 2002*).

Williams et al. (*2006*) argue that the existing restoration program has failed to curtail the decline of wild salmonid fishes within the Columbia River Basin as a result of reliance on a flawed set of assumptions and prevailing belief that that the primary problem for anadromous fish is mortality associated with juvenile passage through the mainstem dams and reservoirs. The "traditional" solution of hatchery technology (to maximize the number of smolts produced), flow augmentation, and juvenile transport via barges to move them as rapidly and efficiently as possible past the dams has not resulted in the target salmon repopulation goal of 5 million returning fishes per year (*Williams et al, 2006*).

In order to reconfigure the restoration technology so that the intended goal of 5 million returning fishes per year is attained, Williams et al. (*2006*) highlight that the Technology Delivery System must work as an integrated unit. "The region, through its policy representatives and the evaluative processes…must decide how far it is willing to restore the river based on its economic, cultural, and ecological values. If the region concludes it cannot or is unwilling to improve the ecological conditions needed to achieve the …current salmon recovery goals, then those goals must be changed. The challenge before the region is to reach agreement on the extent to which the numerous social and biophysical constraints on the Columbia River can be relaxed or removed. Defining what the river must be and moving the ecosystem to that point is the only way to bring about salmon recovery and to achieve the…restoration goals" (*Williams et al, 2006*).

In conclusion, the Columbia River Basin salmon and steelhead restoration case study was selected to illustrate the concept of a Technology Delivery System. The

Technology Delivery System provides an integrated approach to link stakeholders (public, government, and industry) to the development of a technology that will achieve a desired goal (or 'output'). Development of this technology requires cooperation between the stakeholders and inputs such as time, money and physical resources to achieve the desired goals. This process is iterative and not all technology developed yields immediate desired results. As demonstrated in the Columbia River Basin, some improvements have been realized as a result of the implementation of the TDS, but additional refinement is required in order to achieve the stated goal of 5 million returning salmon and steelhead annually.

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Appendix C

TABLE OF CONTENTS

C-1 INTRODUCTION

This appendix presents the background on the organizations I identified as being part of the river restoration Technology Delivery System (TDS). The organizations are presented in the following order: Federal, State, Local, and Other (non-profit, industrial, private, etc.). Although not fully complete and comprehensive, this TDS provides a basis and starting framework by which individual restoration projects can augment and add project-specific organizations applicable to their unique situation. Resources (design manuals, guides, software programs, data, etc.) identified for each of these organizations is presented in Appendix D.

C-2 FEDERAL AGENCIES

The United States federal government has eight primary departments that impact the field of river restoration. These departments include the U.S. Department of Agriculture, U.S. Department of Commerce, U.S. Congress, U.S. Department of Defense, U.S. Environmental Protection Agency, U.S. Department of Homeland Security, U.S. Department of Housing and Urban Development, U.S. Department of the Interior, and U.S. Department of Transportation. The role of the Executive branch with regards to policy, political appointments, etc has not been accounted for in this summary. Additionally, the role of the judicial branch with regards to interpretation of legislation and resulting impact to River Restoration has also not been directly accounted for in this summary. An examination of the Executive and Judicial branches will be a topic of future work.

Although these federal agencies are for the most-part separate, there have been collaborative efforts between the agencies related to river restoration. A guidance document was produced through the collaboration of fifteen federal agencies and other partners to produce a common reference on stream corridor restoration. The document, "Stream Corridor Restoration, Principles, Processes, and Practices," (*2001*) encapsulated the rapidly expanding body of knowledge related to stream corridors and their restoration (*FISRWG, 2001*). The original draft was first published in 1998 with a revision in 2001 and a new updated version is anticipated for publication in late 2008 or 2009.

This guidance document provides best practices on river restoration for both urban and rural settings and generally addresses all life-cycle phases of river restoration, (except requalification and decommissioning). Comprehensive processes and methods are presented for restoration practitioners to configure restoration projects that incorporate best practices.

The document also addresses a majority of restoration goals identified by the National River Restoration Science Synthesis group (*Bernhardt et al., 2005*). The primary NRRSS goals addressed in the guidance document include: bank stabilization, channel reconfiguration, floodplain reconnection, in-stream habitat management, in-stream species management, riparian management, and water quality management.

This federal working group has not produced any other guidance documents, nor is the working group tasked with the implementation or enforcement of any U.S. federal laws or regulations.

C-2.1 U.S. Department of Agriculture

The United States Department of Agriculture (USDA) is a diverse and complex organization with more than 100,000 employees that deliver more than $75 billion in public services through the USDA's more than 300 programs each year (*USDA, 2007*). The USDA was founded by President Abraham Lincoln in 1862 and today pursues six goals intended to mirror the USDA's commitment to provide "first-class service, state-of-the-art science and consistent management excellence" (*USDA, 2007*). The six goals identified by the agency include: enhancement of the international competitiveness of American agriculture; enhancement of the competitiveness and sustainability of rural and farm communities; supporting economic opportunities and improving the quality of life in rural America; enhancing the protection and safety of the Nation's agriculture and food supply; improving the Nation's nutrition and health; and protection and enhancement of the Nation's natural resource base and environment (*USDA, 2007*). The last goal (protection and enhancement of the Nation's natural resource base and environment) directly impacts the field of river restoration.

Mission areas further compartmentalize sub-departments within the USDA (Figure C1). The seven USDA mission areas are: Natural Resources and Environment; Farm and Agricultural Services; Rural Development; Food, Nutrition, and Consumer Services; Food Safety; Research, Education, and Economics; and Marketing and Regulatory programs (*USDA, 2007*). Two missions directly impact river restoration and these are Natural Resources and Environment (NRE) as well as Research, Education, and Economics. The NRE mission area consists of the Forest Service and the Natural Resources Conservation Service (NRCS). These agencies work to ensure the health of the land through sustainable management practices (*USDA, 2007*). The Forest Service manages 193 million acres of national forests and grasslands. NRCS assists farmers, ranchers and other private land owners in managing their acreage for environmental and economic sustainability (*USDA, 2007*). Both agencies work in partnership with Tribal, State and local Governments, communities, related groups and other Federal agencies to protect the Nation's soils, watersheds and ecosystems (*USDA, 2007*).

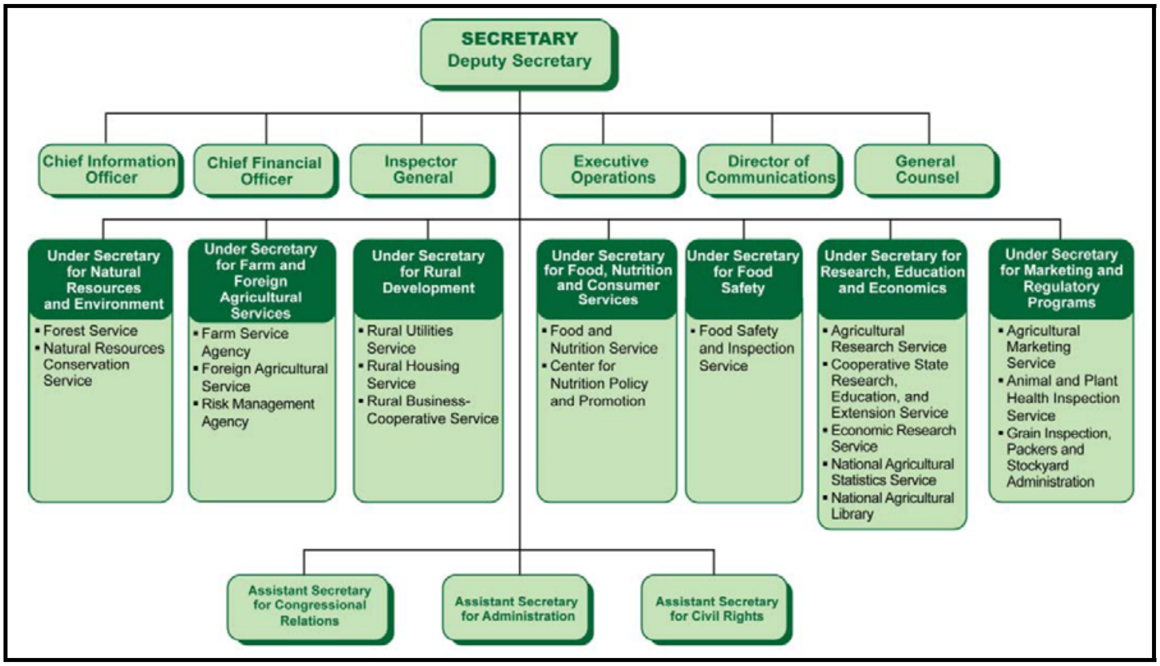

Figure C1: An organizational overview of the U.S. Department of Agriculture (*USDA, 2007*)

The Research, Education, and Economics (REE) mission area brings together all the USDA's active efforts to advance safe, sustainable, and competitive U.S. food and fiber system through science and the translation of science into real-world results (*USDA, 2007*). The REE is comprised of the Agricultural Research Service (ARS), the Cooperative State Research, Education and Extension Service (CSREES), the Economic Research Service (ERS), the National Agricultural Statistics Service (NASS), and the

National Agricultural Library (NAL). The ARS and CSREES are the two efforts within the REE that directly impact river restoration.

A more detailed discussion of the Forest Service, National Resource Conservation Service, Agricultural Research Service, and the Cooperative State Research, Education, and Extension Service and their interactions with river restoration are detailed below:

C-2.1.1 Forest Service

The United States Forest Service was established by Congress in 1905 to provide quality water and timber for the Nation's benefit (*USFS, 2008*). Today, the USFS manages over 192 million acres (equivalent to the size of Texas) to help the citizens of the United States share and enjoy the forest, while conserving the environment for "generations to come" (*USFS, 2008*).

The technical publications and guidance documents produced by the USFS that impact river restoration are directed primarily towards roadways, riparian zones, and water quality. The primary guidance document is "A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization," prepared by the USFS in October 2002. Another resource document is "Management and Techniques for Riparian Restorations," (*USFS, 2002a*).

C-2.1.2 Natural Resources Conservation Service

The National Resources Conservation Service (NRCS) was founded in 1935 (known initially as the Soil Erosion Service) through the efforts of Hugh Hammon Bennett. Bennet was a career soil scientist in the USADA and he was convinced that soil erosion was a national menace and that its only solution lay in tailoring conservation practices to fit the capability of the land and the desires of landowners (*NRCS, 2008*).

The NRCS began working with farmers in the Coon Creek watershed of southwestern Wisconsin to transform square, eroding fields into a conservation "showcase" consisting of contouring, strip-cropping, terracing, and "wise" land use. These soil conservation practices spread nationwide following the passage of the Soil Conservation Act in April of 1935, when the NRCS was established as a formal organization within the jurisdiction of the United States Department of Agriculture (*NRCS, 2008*). Today, the following principles guide the work of the NRCS: assessing the resources on the land, the conservation problems and opportunities; drawing on various sciences and disciplines and integrating all their contributions into a plan for the whole property; working closely with land users so that the plan for conservation meshes with their objectives; and contribute to the overall quality of life in the watershed through implementation of conservation on individual properties (*NRCS, 2008*).

The NRCS has a number of publications that are useful to the practice of river restoration. These documents and guides cover the areas of erosion, biology, conservation practices, ecology, engineering, environmental compliance, soils, and water resources.

C-2.1.3 Agricultural Research Service

The Agricultural Research Service (ARS) is the USDA's chief scientific research agency and conducts research to develop and transfer solutions to agricultural problems of high national priority, to provide information access and dissemination to ensure high-quality, safe food, and other agricultural products, to assess the nutritional needs of Americans, to sustain a competitive agricultural economy, to enhance the natural resource base and the environment, and to provide economic opportunities for rural citizens, communities, and society as a whole (*USDA-ARS, 2008a*).

Agricultural research (through the USDA) was first authorized by Congress through the passage of the Organic Act of 1862 which directed the Commissioner of Agriculture "…To acquire and preserve in his Department all information he can obtain by means of books and correspondence, and by practical and scientific experiments" (*USDA-ARS, 2007*). The scope of the agricultural research programs has been expanded and extended more than 60 times since the Department was created. During World War II, the USDA's various research components were brought together into the Agricultural Research Administration (ARA) and in 1953, the ARA was reorganized into the ARS (*USDA-ARS, 2007*). ARS is one of four component agencies of the Research, Education, and Economics (REE) mission area and the organizational structure of ARS is presented in Figure 2. One of the thrust areas for the ARS is technology transfer, and it should be noted that not only does the ARS have an office established to promote technology transfer (see Figure C2), but they also have an active listing of technologies that have been successfully transferred to industry.

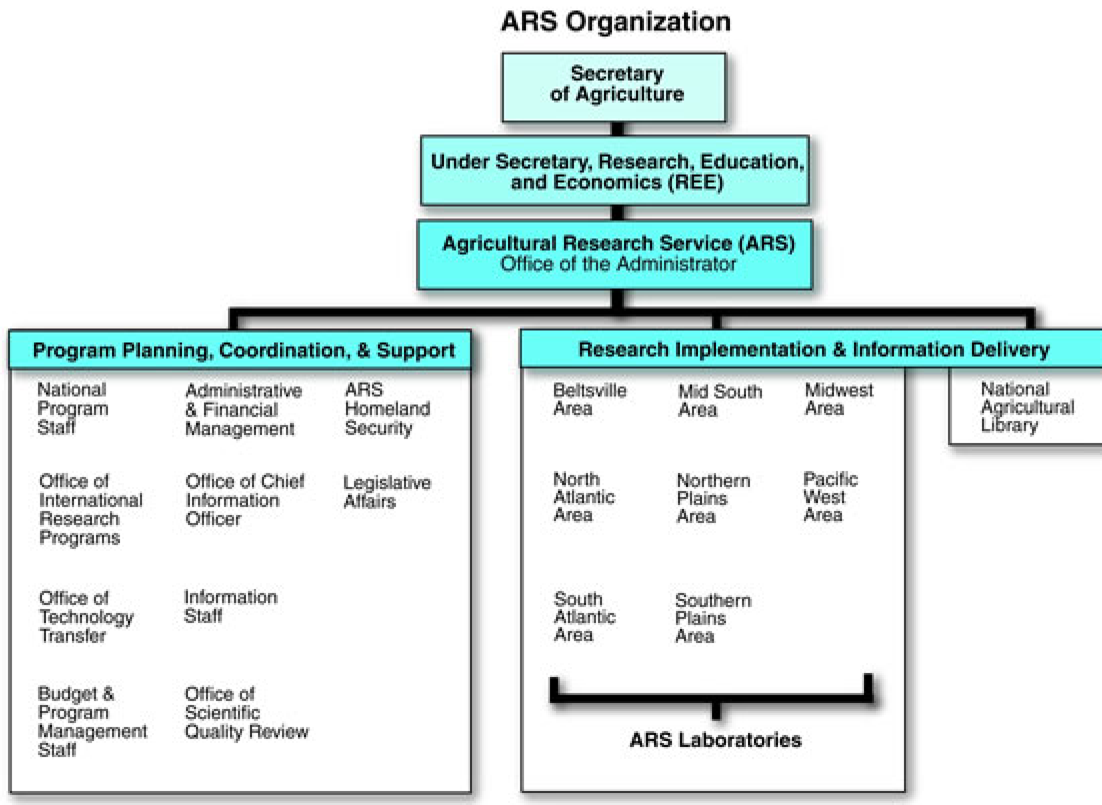

Figure C2: Organizational structure of the USDA Agricultural Resources Service (*USDA-ARS, 2008b*)

Within the ARS, there are a number of research groups that have specific emphasis on river restoration. Results from the research efforts are mainly disseminated via technical journal publications as opposed to agency manuals and guidelines, thus it is difficult to comprehensively summarize 'best practices' in this document. A listing of the restoration-related ARS research groups and a short description of their research emphasis are described below:

- **Grassland, Soil and Water Resources Laboratory (Temple, TX):** The mission of the Grassland Soil and Water Research Laboratory, which is achieved through simulation modeling and experimental research by a multi-disciplinary staff of scientists and engineers, is to develop technology for maximizing forage and crop production; reducing uncertainty regarding the effects of global change on agriculture; controlling non-economic brush and weeds; and solving problems relating to efficient use of soil and water, crop production, soil fertility, erosion, hydrology, and water quality (*USDA-ARS, 2008c*).

- **Hydraulic Engineering Research (Stillwater, OK):** The Hydraulic Engineering Research Unit (HERU) was established in 1940 and is recognized nationally and internationally as a significant contributor of sound design criteria for soil and water conservation structures and channels, with the most notable work performed on design concepts for vegetated waterways (*USDA-ARS, 2008d*). HERU conducts research to: develop criteria for the design and analysis of structures and channels for the conveyance, storage, disposal and measurement of runoff waters; develop fundamental knowledge of the hydraulics of surface flows for use in planning measures needed for control of water for flood prevention, pollution abatement, and/or assessing the safety of existing measures; and determine the ability of vegetation and/or various natural and manufactured materials to prevent erosion when used in the management of runoff waters (*USDA-ARS, 2008d*). HERU is situated on 40.5 hectares (100 acres) of open land with large gravity flow water supply and sufficient slope so that the fall required for experiments can be obtained (*USDA-ARS,* *2008d*). Water for experiments is drawn from adjoining Lake Carl Blackwell, through canals and pipelines, at rates from a trickle flow up to 3.7 cubic meters per second (130 cubic feet per second) and the facility has four model buildings where indoor experiments are conducted (*USDA-ARS, 2008d*).

- **Hydrology and Remote Sensing (Beltsville, MD):** The mission of the Hydrology and Remote Sensing Laboratory (HRSL) is to conduct nationally oriented basic and applied research on water resources and remote sensing concerns related to the production of food and fiber and the conservation of natural resources (*USDA-ARS, 2008e*). Specific research areas related to river restoration include: developing techniques for deriving local, regional, and global soil moisture, surface temperature, vegetation cover, crop yields and surface roughness distributions by integrating in-situ measurements, remote sensing observations and land surface modeling products; developing improved methods for evaluating subsurface water movement and chemical transport; developing methods to delineate plant available water zones within watersheds; and developing and evaluating protocols to identify water and chemical source areas of watersheds (*USDA-ARS, 2008e*).

- **Land Management and Water Conservation Research (Pullman, WA):** The Land Management and Water Conservation Research Unit (LMWCRU) conducts research to develop science-based information and technology that advances integrated agricultural systems for the sustained use of land, water, and air resources

(*USDA-ARS, 2008f*). Specific research related to river restoration includes soil resource management and water availability and water management.

- **National Soil Erosion Research (West Lafayette, IN):** The National Soil Erosion Research Laboratory (NSERL) is the focal point of the U.S. Government's national research program in soil erosion by water (*USDA-ARS, 2008g*). NSERL is located on the campus of Purdue University in West Lafayette, Indiana. The major thrust of the lab includes fundamental erosion process research, erosion control research, and delivery of improved erosion prediction technology. The mission of the NSERL is to develop the knowledge and technology needed by land users to conserve soil for future generations (*USDA-ARS, 2008g*). Based on a review of the NSERL main website, it appears that the primary knowledge dissemination approach for this organization is publication through peer-reviewed scientific journals.

- **National Sedimentation Laboratory (Oxford, MS):** The research program at the National Sedimentation Laboratory (NSL) emphasizes interdisciplinary research dealing with the processes of soil erosion; transport and deposition of sediment; movement of chemicals on upland areas and in streams; the impact of agricultural practices, in-stream structures, and bank protection on these processes; water quality; and the ecological well-being of streams (*USDA-ARS, 2008h*).

  Research ranges from basic and fundamental research to applied research and technology transfer for federal and state action agencies, especially the USDA-Natural Resources Conservation Service (NRCS) and the U.S. Army Corps of

Engineers (COE) in the multi-agency Demonstration Erosion Control (DEC) Project (*USDA-ARS, 2008h*). Much of the research conducted by the NSL is in cooperation with the University of Mississippi, Mississippi State University, the Mississippi Agricultural and Forestry Experiment Station, and other universities. This cooperation has allowed NSL to conduct research related to bio-indicators, numerical modeling, and acoustical measurements and to make progress that would not occur otherwise (*USDA-ARS, 2008h*).

Contributions NSL has made towards river restoration include numerous technical journal papers and software programs. Most notable are the Bank Stability and Toe Erosion Model, CONCEPTS and RUSLE, described below.

Bank Stability and Toe Erosion Model – The Bank Stability Model combines three limit equilibrium-method models that calculate the Factor of Safety for multi-layer streambanks (*USDA-ARS, 2008i*). The model accounts for the strength of up to five soil layers, the effect of pore-water pressure (both positive and negative), confining pressure due to streamflow and soil reinforcement and surcharge due to vegetation (*USDA-ARS, 2008i*).

CONCEPTS - The National Sedimentation Laboratory has developed the CONservational Channel Evolution and Pollutant Transport System (CONCEPTS) computer model to simulate the evolution of incised streams and to evaluate the long-term impact of rehabilitation measures to stabilize stream systems and reduce sediment yield (*USDA-ARS, 2008j*). CONCEPTS simulates unsteady, one-dimensional flow, graded sediment transport, and bank-erosion processes in stream corridors. It can predict the dynamic response of flow and sediment transport to in stream hydraulic structures. It computes channel evolution by tracking bed elevation changes and channel widening (*USDA-ARS, 2008j*). The bank erosion module accounts for basal scour and mass wasting of unstable cohesive banks. CONCEPTS simulates transport of cohesive and cohesionless sediments, both in suspension and on the bed, and selectively by size classes. CONCEPTS also includes channel boundary roughness varying along a cross section, for example due to varying vegetation patterns (*USDA-ARS, 2008j*).

RUSLE – The Revised Universal Soil Loss Equation (RUSLE) is a new, advanced, erosion prediction technology that uses the empirical Universal Soil Loss Equation (USLE) (*USDA-ARS, 2008k*). This erosion prediction technology (also referred to as an erosion model) are used to estimate rates of soil erosion caused by rainfall and associated overland flow. RUSLE can be used on cropland, disturbed forest land, rangeland, construction sites, mined land, reclaimed land, military training grounds, landfills, waste disposal sites, and other lands where rainfall and its associated overland flow cause soil erosion (USLE) (*USDA-ARS, 2008k*). RUSLE was developed in close coordination with NRCS and the University of Tennessee.

- **Northwest Watershed Management Research (Boise, ID):** The Northwest Watershed Research Center (NWRC) and the Reynolds Creek Experimental Watershed (RCEW) were established in 1960 to conduct long-term research in the areas of water supply, seasonal snow, soil freezing, water quality and rangeland hydrology (*USDA-ARS, 2008p*). The scope of NWRC and RCEW research has been subsequently broadened to include additional modeling and remote sensing objectives, and landscape-scale processes related to fire and invasive weeds. These new program areas, however, retain a core emphasis on hydrologic processes and the movement of heat and water within and through wildland ecosystems (*USDA-ARS, 2008p*). Current research topics under investigation at NWRC include: hydrologic modeling of snow distribution, accumulation and melt; frozen-soil effects on infiltration, runoff and erosion; characterization and modeling of heat and water flux within the soil-plant-atmosphere system; spatial and temporal variability in streamflow and water quality parameters of temperature and sedimentation; variability and modeling of weather and climatic variables; wild and prescribed-fire impacts on vegetation, soil and water resources; invasive weed management; emergency-fire rehabilitation; rangeland restoration; remote sensing; and development of decision support tools and models for sustainable management of rangeland ecosystems (*USDA-ARS, 2008p*).

NWRC conducts research at a range of scales from point, to field, to basin, and in diverse field sites in Idaho, Oregon, Washington, Montana, Colorado, Nevada, and western Canada. NWRC research, conducted under the ARS National Programs in Water Quality and Management; Rangeland, Pasture and Forages; and Global Change, is oriented towards interdisciplinary and systems approaches that address both long-term research needs and critical emerging problems in management of public and private wildlands (*USDA-ARS, 2008p*).

- **Southeast Watershed Research (Tifton, GA):** The mission of the Southeast Watershed Research Laboratory (SEWRL) is to develop the scientific understanding and associated technologies of watershed systems essential to maintaining/enhancing the environmental and natural resource base upon which a viable, sustainable, and productive agricultural economy depends (*USDA-ARS, 2008l*). The focus of the Laboratory is primarily on the Coastal Plain region of the southeastern U.S., a region with low-gradient drainage systems and extensive near stream riparian areas. Specific objectives are to develop: (a) conceptual understanding of responses in natural resource and environmental systems based on physical, chemical, and biological processes; (b) methodologies to direct optimal use of soil and water resources in the production of quality food and fiber, while maintaining short-and-long term productivity requirements, ecosystem stability, and environmental quality; and (c) models and information based systems to guide responsible management decisions for action and regulatory agencies at field, farm, and watershed scales (*USDA-ARS, 2008l*).

  The Laboratory's primary areas of research include (*USDA-ARS, 2008l*):

  1. Hydrologic processes as related to or affected by climate, soils, geology, watershed structure, and management. Development of integrating concepts with representation in models or information based systems to guide responsible management decisions at the field, farm, and watershed scales.
  2. Fate and transport of agrochemicals, nitrogen, phosphorus, and other environmentally significant water and sediment transported substances that are used in or have their mass and distribution affected by agriculture.

Development of predictive technology and the supporting science to provide environmentally sound, sustainable production systems.

3. Detachment, entrainment, and transport of sediments and associated chemicals as affected by soils, geology, climates, and management. Development of effective soil erosion control to sustain the productive capacity of soil and to prevent adverse downstream impacts from sedimentation in waterways, streams, ponds, buffers and wetlands within agricultural watersheds or agroecosystems.
4. Physical and biological structure and function of watershed ecosystems. Effects of watershed components (i.e., soils, stream segments, wetlands, upland field, etc.) on hydrology, sediment and chemical transport, and systems sustainability. Understanding of agricultural impacts (positive or negative) on biodiversity of wetlands; role of riparian and depressional wetlands in assimilating/attenuating potential pollutants; and role of riparian and depressional wetlands in hydrologic cycles (i.e., water budgets, storage groundwater recharge, etc.).
5. As an Index Site for the National Environmental Monitoring Initiative (http://www.epa.gov/cludygxb/Pubs/framewrk.pdf), conduct spatial and temporal analyses to understand the interactions between local, short-term processes and the behaviors of large watersheds over the long-term. SEWRL research will develop linkages between research sites and regional/national survey/monitoring programs in order to better characterize cause and effect

relationships between land management and environmental quality in Coastal Plain systems.

6. Development, evaluation, and integration of models and data bases at various scales from process level to watersheds, to facilitate research and transfer of technology to customers.

Contributions SEWRL has made towards river restoration include numerous technical journal papers and software programs. Most applicable to river restoration are FLOWNET, and REMM, described below.

FLOWNET - FLOWNET is a computer program developed to calculate hydraulic and topographic gradients for two-dimensional surfaces. Flow rates are calculated for saturated and unsaturated conditions based upon application of Darcy's law and the exponential hydraulic conductivity equation (*USDA-ARS, 2008m*). The FLOWNET program can be applied to evaluate flow in saturated and unsaturated porous media based upon observed pressure head data. In addition, the program can be used to evaluate slope direction and magnitude from topographic elevation data (*USDA-ARS, 2008m*). The central difference and Horn methods of determining gradients were incorporated into the program. Heterogeneity and anisotropy can be incorporated into the analysis by inputting variable saturated hydraulic conductivity (Ksat) and alpha, coefficients in the exponential hydraulic conductivity function (*USDA-ARS, 2008m*).

Two-dimensional problems in either the vertical or horizontal plane can be analyzed (*USDA-ARS, 2008m*). In the vertical plane, the method can be applied to examine saturated-unsaturated flow where observed pressure head data are available (*USDA-ARS, 2008m*). For these cases, the distribution of Ksat and alpha must be known as well as the angle of anisotropy. For problems in the horizontal plane, water table gradients, saturated flow rates, and land slope gradients can be calculated. For land slope analysis, input the land elevation in place of the pressure head and set Ksat values equal to 1.0 (*USDA-ARS, 2008m*).

REMM – The Riparian Ecosystem Management Model (REMM) is a computer simulation model that can be used to simulate hydrology, nutrient dynamics and plant growth for land areas between the edge of fields and a water body, allowing designers to develop buffer systems to help control non-point pollution (*USDA-ARS, 2008n*). REMM was developed to be used in the following application scenarios: determining buffer width for a given set of riparian conditions and upland loadings; determining buffer effectiveness under increased loads; evaluating influence of vegetation type on buffer effectiveness; determining impacts of harvesting on buffer effectiveness; investigating long term fate nutrients in riparian zones; and investigating Nitrogen/Phosphorous saturation in riparian buffers (*USDA-ARS, 2008n*).

- **Southwest Watershed Research (Tucson, AZ):** The Southwest Watershed Research Center (SWRC) is supported by the Walnut Gulch Experimental Watershed and features four major program areas: erosion and sedimentation, hydrology, decision support systems, and remote sensing (*USDA-ARS, 2008o*).

  Erosion and sediment research at SWRC is conducted to determine upland and channel erosion and sedimentation processes and their impact on water quality, semiarid landscape evolution, and the health and sustainability of rangeland ecosystems as well as to develop new technology to determine the rate of soil loss an ecosystem can endure and still remain economically and ecologically sustainable (*USDA-ARS, 2008o*).

  Hydrologic processes and global climate change are studied at SWRC to investigate hydrologic processes and related variability with special emphasis on modeling, scaling and global change issues to understand water supply, water quality, energy and CO2 fluxes from managed and natural semi-arid watersheds as well as on approaches to integrate interdisciplinary field experiments, simulation models, remote sensing and geographic information systems (GIS) to improve understanding (and expand databases) of the impacts of global change on semiarid watersheds (*USDA-ARS, 2008o*).

  SWRC is actively developing and transferring knowledge and technology related to decision support tools and systems that incorporate science into watershed decision making processes through integrated information systems that combine decision tools, databases, models, and expert opinion (*USDA-ARS, 2008o*). Two such programs developed include the Automated Geospatial Watershed Assessment

(AGWA) tool (which is a GIS-based hydrologic modeling tool to facilitate planning and assessment for land and water resource managers) and the Conservation Planning Support System (CPSS), which is a prototype web-based decision support system designed to automate and improve the science in the conservation process (*USDA-ARS, 2008o*).

Finally, SWRC's remote sensing research is directed towards four general activities: calibration and signal processing (sensor calibration, reflectance factor retrieval, bidirectional reflectance distribution function); algorithm and model development for evaporation, soil moisture, and vegetation; field experiments and inter-disciplinary programs, and maintaining a data archive.

C-2.1.4 Cooperative State Research, Education, and Extension Service

The Cooperative State Research, Education, and Extension Service (CSREES) was created by Congress through the 1994 Department Reorganization Act, by combining the USDA's Cooperative State Research Service (CSRS) and Extension Service (ES) into a single agency (*USDA-ARS, 2008q*). CSREES' mission is to advance knowledge for agriculture, the environment, human health and well-being, and communities by supporting research, education, and extension programs in the Land-Grant University System and other partner organizations. CSREES doesn't perform actual research, education, and extension but rather helps fund it at the state and local level and provides program leadership in these areas (*USDA-ARS, 2008q*).

CSREES' targeted areas of interest—its 60 identified programs—are grouped in the following National Emphasis Areas: Agricultural & Food Biosecurity; Agricultural Systems; Animals & Animal Products; Biotechnology & Genomics; Economics &

Commerce; Education; Families, Youth & Communities; Food, Nutrition & Health; International; Natural Resources & Environment; Pest Management; Plants & Plant Products; and Technology & Engineering (*USDA-ARS, 2008q*). Programs through the Natural Resources and Environment (NRE) are most applicable to river restoration.

NRE programs are aimed to strengthen the nation's capacity to address critical environmental priorities and contribute to improved air, soil, and water quality; fish and wildlife management; enhanced aquatic and other ecosystems; the sustainable use and management of forests, rangelands, watersheds, and other renewable natural resources; and a better understanding of global climate change, including its impact on the diversity of plant and animal life (*USDA-ARS, 2008q*). NRE programs also aim to demonstrate the benefits and opportunities of sustainable development, and contribute to the economic viability of agriculture and rural communities realizing the impact of environmental policies and regulations (*USDA-ARS, 2008q*).

C-2.2 U.S. Department of Commerce

The U.S. Department of Commerce (USDOC) was established by Congress in 1903 through the passage of the Organic Act (*USDOC, 2008*). The mission of the USDOC is to foster, promote, and develop the foreign and domestic commerce of the United States (*USDOC, 2008*). This mission is accomplished via the following: participating with other governmental agencies in the creation of national policy, through the President’s Cabinet and its subdivisions; promoting and assisting international trade; strengthening the international economic position of the U.S.; promoting progressive domestic business policies and growth; improving comprehension and uses of the physical environment and its ocean life; ensuring effective use and growth of the

Nation's scientific and technical resources; acquiring, analyzing, and disseminating information regarding the Nation and the economy to help achieve increased social and economic benefit; and assisting states, communities, and individuals with economic progress (*USDOC, 2008*). The organizational structure of the USDOC is presented in Figure C3.

U.S. DEPARTMENT OF COMMERCE

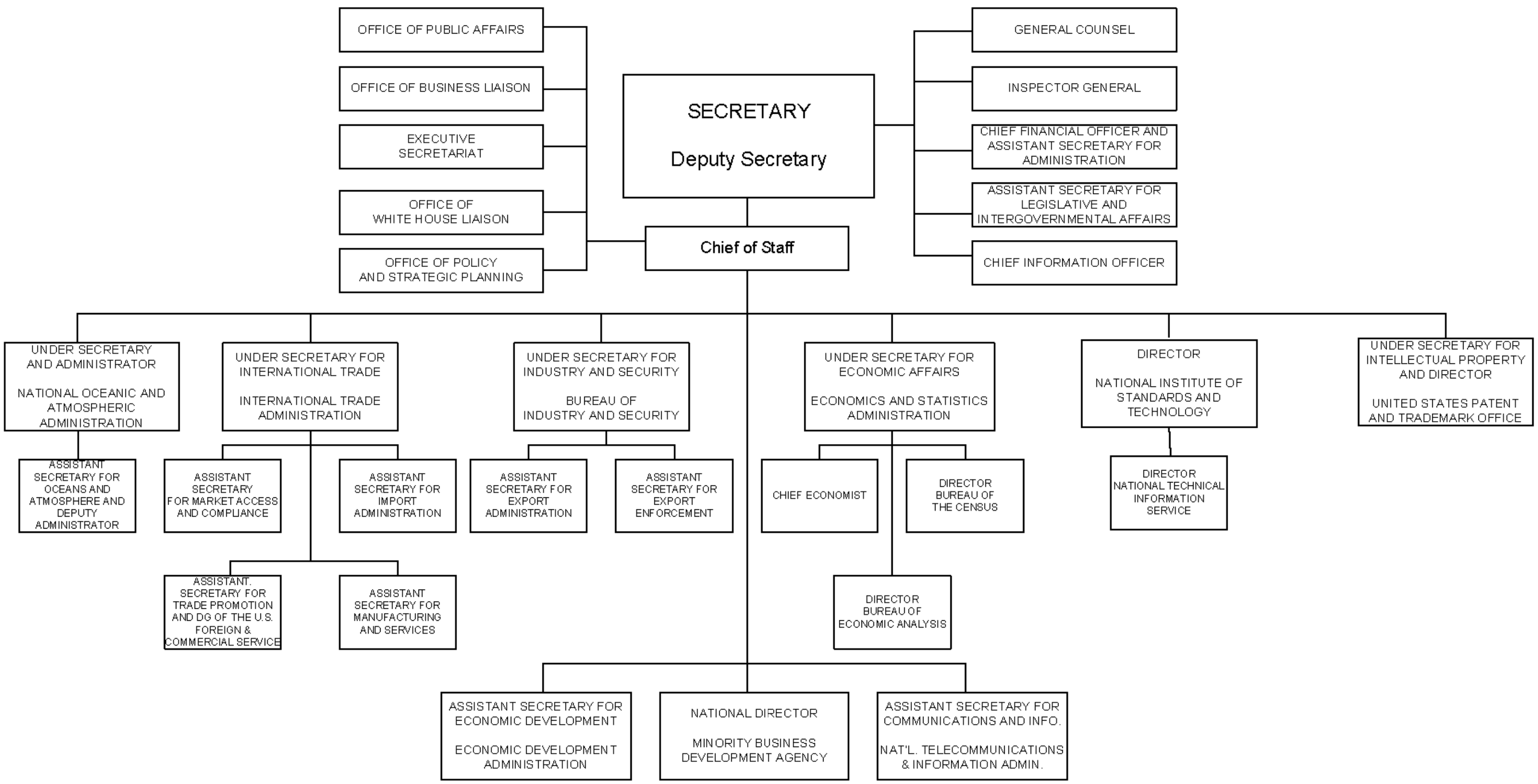

Figure C3: Organizational Chart for the U.S. Department of Commerce

There are ten commerce bureaus that comprise the USDOC: Bureau of Industry and Security; Economics and Statistics Administration; Economic Development Administration; International Trade Administration; Minority Business Development Agency; National Institute of Standards and Technology; National Oceanographic & Atmospheric Administration; National Technical Information Service; National Telecommunications and Information Administration; and Patent and Trademark Office (*USDOC, 2008*). Of these ten bureaus, the National Oceanographic & Atmospheric Administration (NOAA) has the greatest influence and contributions to river restoration.

NOAA was formed in 1970 through the combination of aspects of the United States Coast Guard (formed in 1807), the Geodetic Survey (formed in 1807), the Weather Bureau (formed in 1870), and the Bureau of Commercial Fisheries (formed in 1871) (*NOAA, 2008a*). The vision of NOAA is "an informed society that uses comprehensive understanding of the role of the oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions" and NOAA's mission statement is "to understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs" (*NOAA, 2008b*). Within NOAA, there are seven offices consisting of: National Environmental Satellite, Data, and Information Service; National Marine Fisheries Service; National Ocean Service; National Weather Service; Office of Marine and Aviation Operations; Office of Oceanic and Atmospheric Research; and Program Planning and Integration (*NOAA, 2008b*). Of these offices, the National Environmental Satellite, Data, and Information Service and the National Weather Service directly impact the field of river restoration.

C-2.2.1 National Environmental Satellite, Data, and Information Service

The National Environmental Satellite, Data, and Information Service (NESDIS) is oriented to provide timely access to global environmental data from satellites and other sources to promote, protect, and enhance the Nation's economy, security, environment, and quality of life (*NOAA, 2008c*). NESDIS acquires and manages the Nation's operational environmental satellites and provides access to the associated data and information services.

There are four data centers operated through NESDIS: Climate Data Center; Geophysical Data Center; Ocean Data Center; and Coastal Data Center (*NOAA, 2008d*). Of these centers, the National Climatic Data Center (NCDC) offers resources applicable to river restoration. The National Climatic Data Center offers a comprehensive archive of climate data including climate events (storms, tornadoes, hurricanes, etc.), satellite images, limited paleoclimatology data, and access to climate data (temperature, precipitation, etc.) at thousands of monitoring stations throughout the United States. To access this information, visit this website: http://www.ncdc.noaa.gov/oa/ncdc.html.

C-2.2.2 National Weather Service

NWS was authorized by through a joint resolution passed by Congress and signed by President Ulysses S. Grant in 1870 that allowed the Secretary of War to establish the National Weather Service. The mission of the NWS is to "provide weather, hydrologic, and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. NWS data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community (*NOAA, 2008e*).

The emphasis of the National Weather Service (NWS) is to provide information on real time climate conditions. The NWS also has access to some river stage monitoring locations (http://www.weather.gov/ahps/index.php) and precipitation data (http://water.weather.gov/). Both of these data sets have options for output to GIS shapefiles (where appropriate). In addition to the data archives, the NWS also produces several publications related to flood safety that are useful as planning and risk communication for public education related to river restoration activities.

C-2.3 U.S. Congress

The United States Congress is the bicameral legislature of the federal government of the United States of America, consisting of two houses, the Senate and the House of Representatives (*Wikipedia, 2008b*). Both senators and representatives are chosen through direct election. As provided by the United States Constitution, each of the 435 members of the House of Representatives represents a district and serves a two-year term (*Wikipedia, 2008b*). House seats are apportioned among the states by population and the 100 Senators (2 per state regardless of population) serve staggered six-year terms (*Wikipedia, 2008b*).

Article I of the Constitution vests all legislative power in the Congress and the House and Senate are equal partners in the legislative process (legislation cannot be enacted without the consent of both chambers); however, the Constitution grants each chamber some unique powers (*Wikipedia, 2008b*). The Senate is empowered to approve treaties and presidential appointments and revenue-raising bills must originate in the House of Representatives, which also has the sole power of impeachment, while the Senate has the sole power to try impeachment cases (*Wikipedia, 2008b*). The Congress meets in the U.S. Capitol in Washington, D.C. The term *Congress* actually refers to a particular meeting of the national legislature, reckoned according to the terms of representatives, therefore, a "Congress" covers two years (*Wikipedia, 2008b*).

The contribution the U.S. Congress makes to the field of River Restoration is through the enactment of legislation as well as the appropriation of funds to federally sponsored organizations and projects. A summary of relevant legislation to River Restoration is presented below.

Year	Act Name	Statute	Section	Notes	Alternative Name
1884	Rivers and Harbors Act	23 Stat 133	33 §§ 5, 26 note	Navigable waterways, obstructions, structures, dredging	
1888	Rivers and Harbors Act	25 Stat 400	33 §§ 4, 500, 556, 601, 602, 604, 605, 608, 622, 623 note		
1892	Rivers and Harbors Act	27 Stat 88	33 §§ 628		
1894	Rivers and Harbors Act	28 Stat 338	33 §§ 1, 31, 443 to 448, 452, 499		
1899	Rivers and Harbors Act	30 Stat 1121	33 §§ 401, 403, 404, 406, 407, 408, 409, 411 to 416, 418, 502, 549 note, 686, 687		
1902	Rivers and Harbors Act	32 Stat 331	33 §§ 1, 4, 402, 418, 499, 541, 556, 558, 565, 602, 631		
1905	Rivers and Harbors Act	33 Stat 1117	33 §§ 417, 419		
1907	Rivers and Harbors Act	34 Stat 1073	33 §§ 605, 622 note, 629		
1909	Rivers and Harbors Act	35 Stat 815	33 §§ 2, 5, 604, 605		
1910	Rivers and Harbors Act	36 Stat 630	33 §§ 546, 564, 564 note, 643 note		
1911	Rivers and Harbors Act	36 Stat 933			
1912	Rivers and Harbors Act	37 Stat 206, 233	33 §§ 405, 553, 557 note, 581, 603 note, 609, 622, 625 note, 626, 645 note		
1913	Rivers and Harbors Act	37 Stat 801	33 §§ 26a, 453, 541, 542, 545, 556		
1914	Rivers and Harbors Act	38 Stat 725			
1915	Rivers and Harbors Act	38 Stat 1049	33 §§ 45, 471, 560, 562, 627		

Year	Act Name	Statute	Section	Notes	Alternative Name
1916	National Park Service Organic Act	39 Stat 535	16 §§ 1 to 4, 22, 43		
1916	Rivers and Harbors Act	39 Stat 391	33 §§ 7, 25, 28, 38, 424, 648 to 650		
1917	Flood Control Act	39 Stat 948	33 §§ 643 note, 701 to 703	General flood control; examinations and surveys (comprehensive study of watershed or watersheds); Board of Engineers for Rivers and Harbors	
1917	Rivers and Harbors Act	40 Stat 250	33 §§ 1, 22, 36, 43, 559, 567, 593, 607		
1918	Rivers and Harbors Act	40 Stat 904	33 §§ 550, 594, 595		
1919	Rivers and Harbors Act	40 Stat 1275	33 §§ 33, 551, 622, 624, 627 note		
1920	Rivers and Harbors Act	41 Stat 1009	33 §§ 547, 564 note		
1922	Rivers and Harbors Act	42 Stat 1038	33 §§ 555, 563 note, 568, 621, 630, 651		
1924	Oil Pollution Act	43 Stat 604	33 §§ 431 to 437	These address water quality issues, mainly oriented towards oil discharge into waters, but also recognized impact to wildlife	
1925	Rivers and Harbors Act	43 Stat 1191	33 §§ 424a, 548 note, 561, 583		
1928	Flood Control Act	45 Stat 534	33 §§ 702a to 702m, 704		Mississippi River Flood Control Act
1930	Rivers and Harbors Act	46 Stat 918	33 §§ 426, 465, 569a note, 603 note, 667a; 48 § 1399 note		
1934	Fish and Wildlife Coordination Act	48 Stat 401	16 §§ 661 to 666c	US Fish and Wildlife Service review of projects	
1935	Rivers and Harbors Act	49 Stat 1028, 1048	33 §§ 27a, 29a, 540 note, 546a, 558 note, 570		
1936	Flood Control Act	49 Stat 1570	33 §§ 701a to 701f		Overton-Whittington Flood Control Act

Year	Act Name	Statute	Section	Notes	Alternative Name
1937	Flood Control Act	50 Stat 876	33 §§ 701b-6, 701c, 701g, 702j-1		
1938	Flood Control Act	52 Stat 1215	33 §§ 701b to 701b-2, 701c note, 7-1c-1, 701f notes, 701f-1, 701i, 701j, 702a-11/2, 702a-11,706		
1938	Rivers and Harbors Act	52 Stat 802, 804, 805, 808	33 §§ 540, 540 note, 544a note, 558b, 558c, 571, 701k, 701l note		
1939	Flood Control Act	53 Stat 1414	33 §§ 558b-1, 701b-3, 701b-4, 701c-1, 701f note, 701g, 707		
1940	Rivers and Harbors Act	54 Stat 1200	33 §§ 603 note		
1941	Flood Control Act	55 Stat 638	33 §§ 642a, 701b, 701b-2, 701c note, 701c-2, 701c-3, 701f notes, 701f-1 note, 701g, 701j note, 701m, 701n, 702a-13/4, 702a-12		
1941	Rivers and Harbors Act				Flood Control Act of 1941
1944	Flood Control Act	58 Stat 887	16 §§ 460d, 825s; 33 §§ 701-1, 701a-1, 701b-1, 701c note, 708, 709; 43 §§ 390		
1945	Rivers and Harbors Act	59 Stat 10	33 §§ 544b, 603a		
1946	Flood Control Act	60 Stat 641	See 10 § 3296 et seq.; 16 § 460d; 33 §§ 701c-3, 701f-1 note, 701g, 701n to 701r; See 40 § 483; 43 § 931b		
1946	Rivers and Harbors Act	60 Stat 634			

Year	Act Name	Statute	Section	Notes	Alternative Name
1948	Federal Water Pollution Control Act	62 Stat 1155	33 §§ 1251 to 1263, 1265 to 1270, 1281 to 1299, 1311 to 1326, 1328 to 1330, 1341 to 1345, 1361 to 1377, 1381 to 1387	Restoration and maintenance of chemical, physical, and biological integrity of Nation's waters; natioanl goals for achievement of objective: (1) it is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985; (2) it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983; (3) it is the national policy that discharge of toxic pollutants in toxic amounts be prohibited; (4) it is national policy that Federal financial assistance be provided to construct publically owned waste treatment works; (5) it is the national policy that areawide waste treatment management planning processes be developed and implemented to assure adequate control of sources of pollutants in each State; (6) it is the national policy that a major research and demonstration effort be made to develop technology necessary to eliminate the discharge of pollutants into navigable waters, waters of the conti	
1948	Flood Control Act	62 Stat 1175	33 §§ 701c note, 701n, 701o, 701s, 701t		
1948	Rivers and Harbors Act	62 Stat 1172	22 § 275a; 33 §§ 572		
1950	Flood Control Act	64 Stat 170	33 §§ 701-1 note, 701b-1, 701b-8, 701c note, 701f-2, 701l-1, 701n, 701s, 701u, 701v, 702a-12c		
1950	Rivers and Harbors Act	64 Stat 163	33 §§ 534, 569a, 573		

Year	Act Name	Statute	Section	Notes	Alternative Name
1965	Rivers and Harbors Act	79 Stat 1089	22 § 275a; 33 §§ 59c, 59d, 426g, 540 note, 577, 610, 633		
1965	Water Quality Act	79 Stat 903	See 33 §§ 1151 et seq.		
1965	Water Resources Planning Act	79 Stat 244	42 §§ 1962, 1962-1, 1962a, 1962a-1 to 1962a-4, 1962b, 1962b-1 to 1962b-6, 1962c, 1962c-1 to 1962c-6, 1962d, 1962d-1 to 1962d-3	Comprehensive plans for development, utilization, and conservation of water and related resources. Liability indemnification for Federal Government. Cost-sharing guidelines. Future discount rates.	
1966	Flood Control Act	80 Stat 1418	33 §§ 642, 701-1 note, 701c note, 709a		
1966	Rivers and Harbors Act	80 Stat 1405			
1968	Flood Control Act	82 Stat 739	16 § 460d-3; 33 §§ 598, 701-1 note, 701c note; 42 § 1962d-5a		
1968	National Flood Insurance Act	82 Stat 572	42 §§ 1401, 2414, 4001 note, 4011 to 4027, 4041, 4051 to 4055, 4071, 4072, 4081 to 4084, 4101 to 4103, 4121 to 4127		
1968	Rivers and Harbors Act	82 Stat 731	33 §§ 59c-1, 59g to 59i, 426i, 562a		
1968	Wild and Scenic Rivers Act	82 Stat 906	16 §§ 1271 to 1285, 1285a, 1285b, 1286, 1287	Preserves select rivers to a free-flowing condition to protect the water quality of the rivers and to fulfil national conservation purposes	
1969	Endangered Species Conservation Act	83 Stat 275 to 278			See also Endangered Species Act of 1973
1969	National Environmental Policy Act	83 Stat 852	42 §§ 4321, 4331 to 4335, 4341 to 4347		

Year	Act Name	Statute	Section	Notes	Alternative Name
1970	Flood Control Act	84 Stat 1824	5 § 5315; 10 § 3013; 16 § 460d; 33 §§ 426e, 709a; 42 §§ 1962-2, 1962d-5b; 43 §1511a		
1970	Rivers and Harbors Act	84 Stat 1818	33 §§ 426-2 note, 426g, 569a, 577, 577a, 595a, 1161, 1165a		
1970	Water Quality Improvement Act	84 Stat 91	33 §§ 1151 note, 1152, 1155, 1156, 1158, 1160 to 1175		
1972	Federal Water Pollution Control Act Amendment	86 Stat 816	12 § 24; 15 §§ 633, 636; See 31 § 1305; 33 §§ 1251 to 1265, 1281 to 1292, 1311 to 1328, 1341 to 1345, 1361 to 1376		Clean Water Act
1972	Flood Control Act				
1973	Endangered Species Act	87 Stat 884	7 § 136; 16 §§ 460l-9, 460k-1, 668dd, 715i, 715a, 1362, 1371, 1372, 1402, 1531 to 1543	Congress finds and declares that (1) various species of fish, wildlife, and plants in the United States have ben rendered extinct as a consequence of economic growth and development untempered by adequate concern and conservation; (2) other species of fish, wildlife, and plants have been so depleted in numbers that they are in danger of or threatened with extinction; (3) these species of fish, wildlife, and plants are of esthetic, ecological, educational, historical, recreational, and scientific value to the Nation and its people; (4) the United States has pledged itself as a sovereign state in the international community to conserve to the extent practicable teh various species of fish or wildlife and plants facing extinction.	
1973	Oil Pollution Act Amendments	87 Stat 424	33 §§ 1001 to 1010, 1013, 1014, 1016		

Year	Act Name	Statute	Section	Notes	Alternative Name
1974	Water Resource and Development Act	88 Stat 16	16 §§ 460l-13, 460l-13 note, 460l-i14, 460ee; 22 § 275a; 33 §§ 59c-2, 59k, 579, 701b-11, 701g, 701n, 701r-1, 701s, 709a, 1165a, 1252a; 42 §§ 1962d-5 note, 1962d-5c, 1962d-5c note, 1962d-7 note, 1962d-15 to 1962d-17, 4482, 4482 note		
1976	Water Resource and Development Act	90 Stat 2917	16 § 460ee; 33 §§ 59l to 59o, 419a, 426j to 426m, 540 note, 544c, 547a, 577, 579, 701s; 42 §§ 1962d-5, 1962d-5d to 1962d-5g, 1962d-11a, 1962d-14a, 1962d-16, 1962d-18		
1977	Clean Water Act	91 Stat 1566	33 §§ 1251, 1252, 1254, 1255, 1256, 1259, 1262, 1263, 1281 to 1288, 1291, 1292, 1294 to 1297, 1311, 1314, 1315, 1317 to 1319, 1321, 1322, 1323, 1324, 1328, 1341, 1342, 1344, 1345, 1362, 1364, 1375, 1376	Point source and non-point source pollution, primarily focused on point-source pollutants	
1978	Endangered Species Act Amendment	92 Stat 3751	16 §§ 1531 note, 1532 to 1536, 1538 to 1540, 1542		
1978	Endangered Wilderness Act	92 Stat 40	16 §§ 1132 note	Establishment of wilderness areas for public use and enjoyment, protection, preservation, and gathering and dissemination of information	
1978	Sikes Act Amendments of 1978	92 Stat 921	16 §§ 670a note, 670f, 670o		

Year	Act Name	Statute	Section	Notes	Alternative Name
1982	Endangered Species Act Amendment	96 Stat 1411	16 §§ 1531 to 1533, 1535 to 1537a, 1538 to 1540, 1542		
1986	Water Resource and Development Act	100 Stat 4082	10 § 3036; 16 §§ 460d note, 460ll, 460tt, 1002, 1004 note; 26 §§ 4042, 4042 note, 4461, 4461 notes, 4462, 9505, 9505 note, 9506, 9506 note; 33 §§ 59, 59n-1 59w, 409, 414, 415, 426 notes, 426g, 426g note, 426i, 426j, 426m, 426n, 467, 467 note, 467b, 467f to 467n, 555, 555a, 577, 579a, 603a, 610, 652, 661 note, 701a-1, 701b-12, 701n, 701q, 701r, 701s, 709b, 984, 984 note, 1414a, 1414a note, 1801, 1802, 1804, 2201, 2201 notes, 2211 to 2219, 2231 to 2241, 2251, 2261 to 2267, 2281 to 2294, 2294 note, 2295 to 2311, 4260; 40 §§ 403b, 483d; 42 §§ 1962b-3 note, 1962d-5a, 1962d-5b, 1962d-5b note, 1962d-5d, 1962d-5f, 1962d-11b, 1962d-16, 1962d-20, 1962d-20 notes; 43 §§ 390, 390b, 390b note, 10301 note; 46 § 1121-1		

Year	Act Name	Statute	Section	Notes	Alternative Name
1987	Water Quality Act	101 Stat 7	33 §§ 1251, 1251 note, 1254, 1254a, 1256, 1262, 1267, 1268, 1281, 1281b, 1282 to 1284, 1284 note, 1285, 1287, 1288, 1291, 1311, 1311 note, 1312 to 1314, 1317, 1317 note,1318, 1319, 1319 notes, 1321, 1322, 1324, 1329, 1330, 1330 note, 1342, 1342 notes, 1344, 1345, 1345 notes, 1361, 1362, 1362 note, 1365, 1369, 1375, 1375 notes, 1376, 1377, 1381 to 1387, 1414a, 1414a note; 42 § 1926d-20 note		
1988	Water Resource and Development Act	102 Stat 4012	33 §§ 59j-1, 59y, 59z, 426, 579a note, 988 note, 1293a, 2201 notes, 2211, 2211 note, 2239, 2294, 2300, 2312 to 2314, 2314 note, 2315; 42 §§ 1962d-5a, 1962d-5g notes		
1990	Oil Pollution Act of 1990	104 Stat 484	33 §§ 2701		

Year	Act Name	Statute	Section	Notes	Alternative Name
1990	Water Resource and Development Act	104 Stat 4604	16 §§ 460d note, 460tt; 33 §§ 59bb, 426e note, 579, 579a, 652, 701n, 709a, 1252 note, 1268 note, 2201 notes, 2213, 2213 note, 2215, 2232, 2232 note, 2238, 2239, 2239 note, 2281, 2309a, 2313 note, 2314a, 2316, 2317, 2317 note, 2318, 2319, 2320, 2321, 2322, 2323, 2324; 42 § 1962d-16; 48 § 1405c note		
1992	Water Resource and Development Act	106 Stat 4797	10 § 3036; 16 §§ 460tt, 4702, 4711; 26 § 9505 note; 33 §§ 59gg, 426i-1, 426j, 467f, 467k, 467l, 541 note, 562, 569d, 569e, 569f, 652, 653, 1271, 1271 notes, 1342, 1412 to 1416, 1420, 1421, 2201 notes, 2211, 2211 note, 2213, 2239 note, 2267 note, 2268, 2281 note, 2309a, 2325 to 2328; 42 § 1962d-16; 43 §§ 390h-4 note, 390h-5 note		

Year	Act Name	Statute	Section	Notes	Alternative Name
1996	Water Resource and Development Act	110 Stat 3658	16 §§ 460d note, 460d-3, 3301 note, 3952; 25 § 3802; 26 § 9505; 33 §§ 59c-3, 411, 412, 415, 426e to 426g, 426g-1, 426h, 426h-1, 426i-1, 467, 467 notes, 467a to 467m, 576b, 579a note, 610, 622, 653a, 701-1, 701b note, 701b-11 note, 701b-12, 701b-12 note, 7-1b-13, 701n, 701n note, 701r, 701u, 1252 note, 1263 note, 1268 note, 1269, 1272, 1281 notes, 1293a note, 1412, 2201 notes, 2211, 2211 notes, 2213, 2213 notes, 2215, 2215 notes, 2239 notes, 2241, 2263, 2267 note, 2281, 2284a, 2284b, 2309a, 2313, 2313a, 2313b, 2319, 2321a, 2323a, 2325, 2326, 2326a, 2326b, 2328, 2328 note, 2330; 42 §§ 1962-2, 1962d-5a, 1962d-5b, 1962d-16, 9607 note		
1999	Water Resource and Development Act	113 Sta 269	33 §§ 426-2, 2331 to 2336; 42 § 1962d-21		
2000	Water Resource and Development Act	114 Sta 2572	33 §§ 2201		

Year	Act Name	Statute	Section	Notes	Alternative Name
2007	Water Resource and Development Act	121 Stat 1041	5 § 5343 note; 10 § 3036 note; 16 §§ 460d, 652 note, 668dd note, 1451 note, 3301 note, 3801 note; 33 §§ 59h-1, 59j-1, 426e-1, 426g, 426h, 426j, 426o-2, 467f-1, 574a, 577, 579a, 622, 652, 701b-13, 7-1b-13, 701b-14, 701r, 701s, 702a-12, 1268 note, 1273 note, 1412, 2201 note, 2213, 2215, 2222, 2242, 2263, 2267a, 2269, 2281, 2282, 2282a, 2283, 2295, 2309a, 2317a, 2317b, 2323a, 2326, 2326a, 2326b, 2330, 2330a, 2332, 2336, 2340 to 2348, 2901 to 2904, 2906 to 2909, 3301 to 3305; 42 § 1856a-1, 1962-3, 1962d-5b, 1962d-16, 1962d-21, 1962d-22		

C-2.4 U.S. Department of Defense

The U.S. Department of Defense traces its roots back to the Army, Navy, and Marine Corps, which were established in 1775 during the American Revolution (*USDOD, 2008a*). The War Department was established in 1789, the Department of the Navy was founded in 1798, and the Coast Guard (part of Homeland Security during peacetime) was created in 1790 (*USDOD, 2008a*). In 1947, Congress established a civilian Cabinet-level Secretary of Defense position to oversee the newly created National Military Establishment. During this time, the U.S. Air Force was created along with a new Department of the Air Force. The War Department was converted to the Department of the Army. The Army, Navy, and Air Force were placed under the direct control of the Secretary of Defense (*USDOD, 2008a*). In 1949, through further consolidation of the national defense structure, the Department of Defense was created (*USDOD, 2008a*).

Within the Department of Defense, the Army hosts the United States Army Corps of Engineers, which has significant influence on river restoration activities. An organizational overview of the DoD is presented in Figure C4.

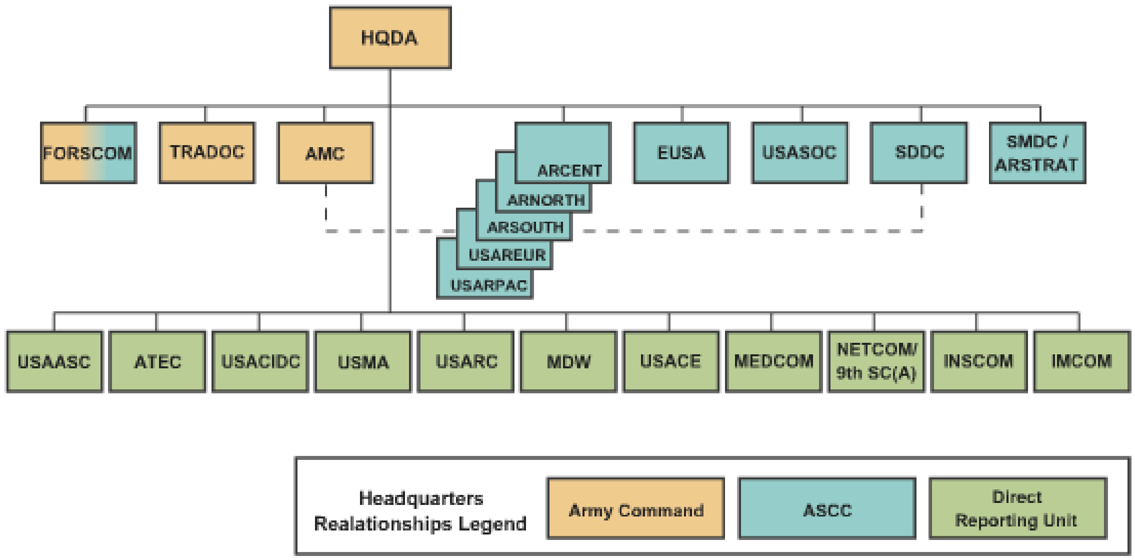

Figure C4: Organizational Structure of the U.S. Army (US*DOD, 2008b*)

C-2.4.1 Army Corps of Engineers

The USACE has a rich history that plays a major role in how the organization is structured and how it generates engineering solutions to infrastructure challenges. A brief review of the USACE's history is presented to provide some context on the development of the organization.

George Washington appointed the first engineer officer of the Army on June 16, 1775 during the American Revolution (*USACE, 2008a*). The Army established the Corps of Engineers as a separate, permanent branch in March of 1802 and gave engineers the responsibility for founding and operating the U.S. Military Academy at West Point (*USACE, 2008a*). Throughout the 19th century, the USACE built coastal fortifications, surveyed roads and canals, eliminated navigational hazards, constructed lighthouses, developed jetties and piers for harbors, mapped navigation channels, explored and mapped the Western Frontier, and constructed buildings and monuments in the Nation's

Capital (*USACE, 2008a*). The USACE worked closely with the Corps of Topographical Engineers until they were merged with the USACE in 1863 (*USACE, 2008a*).

In the 20th century, the USACE became the lead federal flood control agency and significantly expanded its civil works activities, becoming a major provider of hydroelectric energy and the Nation's leading provider of recreation. In 1980 the USACE began providing environmental restoration support services to the US EPA as a result of the passage of the Superfund Act (*USACE, 2008a*). This work was primarily limited to removal of hazardous materials from former military sites and the removal of unsafe buildings, ordnance, and other debris from both active and former military sites (*USACE, 2008a*). By 1984, the USACE assumed full control and management of the environmental restoration program for all former military sites, regardless of service branch. The organizational structure of the USACE is shown in Figure C5.

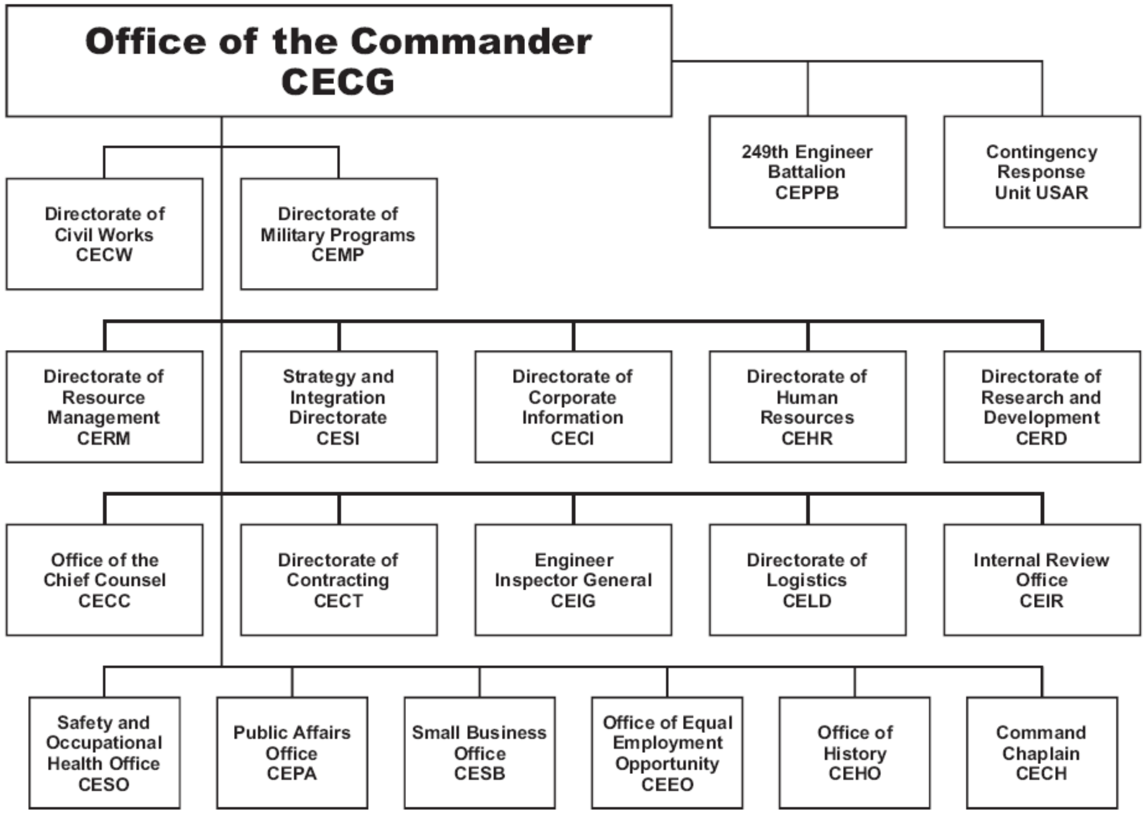

Figure C5: General Organizational Structure of the USACE (USACE, 2008b)

There are a number of acts, laws, and policies that impacts and influence the way in which the USACE approaches projects. These legal aspects include the Wilderness Act (1964), the Wild and Scenic Rivers Act (1968), and the National Environmental Policy Act (1969) testified to the strength of these new interests The eventual result was passage of the Water Resources Development Act of 1986, more simply called WRDA 86 (P.L. 99-662). In the Rivers and Harbors Act of 1899, Congress gave the Corps the authority to regulate most kinds of obstructions to navigation, including hazards resulting from effluents (under the so-called Refuse Act really Section 13 of the 1899 legislation) Oil Pollution Act of 1924 authorized the agency to apprehend those who discharged oil into tidal waters. Within its current regulatory program, the Corps of Engineers has authority over work on structures in navigable waterways under Section 10 of the Rivers and Harbors Act of 1899 and over the discharge of dredged or fill material under Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500). This latter requirement applies to wetlands and other valuable aquatic areas throughout the United States. The Rivers and Harbors Acts of 1890 and 1899 required that dam sites and plans be approved by the secretary of war and the Corps of Engineers before construction. The General Dam Act of 1906 empowered the federal government to compel dam owners to construct, operate, and maintain navigation facilities without compensation whenever necessary at hydroelectric power sites.

In the mid 1990s, the USACE was tasked with ecosystem restoration. Policies, laws, and regulations that enable USACE participation in ecosystem restoration include: 1) Section 1135, Project Modifications for Improvement of the Environment (Water Resources Development Act (WRDA) of 1986, as amended); 2) Section 206, Aquatic Ecosystem Restoration (WRDA 1996); 3) Section 204 Beneficial Uses of Dredged Material (WRDA 1992, as amended); and, 4) dredging of contaminated sediments under Section 312 of WRDA 1990, as amended (*USACE, 1999a*).

The purpose of Civil Works ecosystem restoration activities is to restore significant ecosystem function, structure, and dynamic processes that have been degraded (*USACE, 1999b*). Protection may be included as part of Civil Works ecosystem restoration initiatives, when such measures involve efforts to prevent future degradation of elements of an ecosystem's structure and functions (*USACE, 1999b*). Ecosystem restoration in the Civil Works program uses a ‘systems view’ in assessing and addressing restoration needs and opportunities. Recognition of the interconnectedness and dynamics of natural systems, along with human activities in the landscape, is integral and this philosophy promotes consideration of the effects of decisions over the long term and incorporates the ecosystem approach (*USACE, 1999b*).

The goal of USACE's ecosystem approach is to restore and sustain the health, productivity, and biological diversity of ecosystems and the overall quality of life through a natural resources management approach that is fully integrated with social and economic goals (*USACE, 1999b*). USACE's ecosystem approach recognizes and seeks to address the problems of habitat fragmentation and the piecemeal restoration and mitigation previously applied in addressing the Nation's natural resources (*USACE, 1999b*). The USACE recognizes that some restoration projects may only be able to address the symptoms of the disturbance or degradation, and not the cause(s), however, in these instances, the USACE recommends that "caution should be exercised" in these instances and consideration given as to whether the recommended action is a wise investment (*USACE, 1999b*). Addressing the symptoms without understanding causes of disturbance or degradation, may reduce the likelihood of achieving long-term success (resilience and persistence), and potentially increase the need for extensive operation and maintenance, rather than a functional, self-regulating system (*USACE, 1999b*). The USACE strongly recommends for restoration initiatives to be conceived in the context of broader watershed or regional water resources management programs and objectives, which may involve contributive actions by other Federal and non-Federal agencies and other stakeholders (*USACE, 1999b*).

Consideration of ecosystems within (or encompassing) a watershed provides a useful organizing tool to approach ecosystem-based restoration planning. Ecosystem restoration projects that are conceived as part of a watershed planning initiative or other regional resources management strategy are likely to more effectively meet ecosystem management goals than those projects and decisions developed independently (*USACE, 1999b*). Independently developed ecosystem restoration projects, especially those formulated without a system context, may only partially and temporarily address symptoms of a chronic systemic problem. Some restoration problems may only be addressed effectively through an integrated, collaborative, systematic, regional or ecosystem approach. The USACE's watershed perspective takes into account (1) the interconnectedness of water and land resources, (2) the dynamic nature of the economic and environmental factors, and (3) the variability of social interests over time (*USACE, 1999b*). It recognizes that watershed activities are not static, and that the strategy for managing the resources of the watershed needs to be adaptive (*USACE, 1999b*). Healthy and well functioning ecosystems are vital to the protection of our nation's biodiversity, to the achievement of quality of life objectives, and to the support of economies and communities (*USACE, 1999b*). The ecosystem approach recognizes the interrelationship between healthy ecosystems and sustainable economies. It is a common sense way for federal agencies to carry out their mandates with greater efficiency and effectiveness. The approach emphasizes (*USACE, 1999b*):

- Striving to consider all relevant and identifiable ecological and economic consequences (long term as well as short term).
- Improving coordination among federal agencies.
- Forming partnerships between federal, state, and local governments, Indian tribes, landowners, foreign Governments international organizations, and other stakeholders.
- Improving communication with the general public.
- Carrying out federal responsibilities more efficiently and cost-effective.
- Basing decisions on the best science.
- Improving information and data management.
- Adjusting management direction as new information becomes available.

In order to accomplish its ecosystem restoration work, the USACE relies on individual efforts from the Institute of Water Resource (IWR), the Engineering Research and Development Center (ERDC), and partially on the Navigation Data Center (NDC). A discussion of these sub-organizations is presented below:

Institute for Water Resources: The U.S. Army Institute for Water Resources (IWR) was formed in 1969 to provide the USACE with long-range planning capabilities to assist in improving the civil works planning process (*USACE, 2008c*). IWR hosts three facilities, the Hydrologic Engineering Center (HEC), the Navigation Data Center (NDC), and the Waterborne Commerce Statistics Center (WCSC). IWR has an extensive library of publications (http://www.iwr.usace.army.mil/inside/products/pub/publications.cfm) and software (http://www.iwr.usace.army.mil/inside/products/proj/software.cfm) that are available for free. The library contains a synthesis of all work produced by the two subgroups (HEC, NDC). A discussion of these two units is presented below (from *USACE, 2008d*).

Hydrologic Engineering Center (HEC): The primary goal of HEC from its inception in 1965 has been to support the Nation in its water resources management responsibilities by increasing the Corps technical capability in hydrologic engineering and water resources planning and management. An additional goal is to provide leadership for improving the state of the art in hydrologic engineering and analytical methods for water resources planning. Program efforts in research, training, planning analysis and technical assistance raise awareness of the problems and needs of the Corps and the Nation. HEC is committed to keep abreast of the latest developments throughout the water resources engineering profession and to make use of this information in a manner best suited to the needs of the USACE nationally and internationally.

HEC increases the effectiveness of the Corps and the profession by bridging the gap between the academic community, practicing hydrologic engineers and planning professionals. HEC responsibly incorporates state-of-the-art procedures and techniques into manuals and comprehensive computer programs. The procedures are made available to the USACE, United States government and international professionals through an effective technology transfer system of technical assistance, publications, DVD's and training.

Technical specialty areas addressed by HEC include: precipitation-runoff processes, reservoir regulation, reservoir systems analysis, hydrologic statistics and risk analysis, river hydraulics and sediment transport, groundwater hydrology, water quality and analytical aspects of water resources planning. Application areas include: flood damage reduction, real-time water control, water control management, hydroelectric power, navigation, erosion control, water supply, watershed studies and ecosystem restoration. Additional information about HEC and its software is available on its web site at www.hec.usace.army.mil.

Engineering Research and Development Center (ERDC): The Mission of the Engineer Research and Development Center (ERDC) is to provide science, technology, and expertise in engineering and environmental sciences in support of the Armed Forces and the Nation to make the world safer and better (*USACE, 2008e*). In 1999, the USACE consolidated its individual research laboratories into one organization, ERDC (*USACE, 2008e*). Seven laboratories are located in four geographic sites around the country: the Coastal and Hydraulics, Environmental, Geotechnical and Structures, and Information Technology Laboratories in Vicksburg, Miss.; the Construction Engineering Research Laboratory in Champaign, Ill.; the Cold Regions Research and Engineering Laboratory in Hanover, N.H.; and the Topographic Engineering Center in Alexandria, Va. (*USACE, 2008e*). A short discussion of the research laboratories is presented below:

Coastal and Hydraulics Laboratory (CHL): The U.S. Army Engineer Research and Development Center's Coastal & Hydraulics Laboratory (CHL) performs ocean, estuarine, riverine, and watershed regional scale systems analyses research support work for the U.S. Army Corps of Engineers and the DoD Task Force in support of the Ocean Commission (*USACE, 2008f*). CHL research and development addresses water resource challenges in groundwater, watersheds, rivers, reservoirs, lakes, estuaries, harbors, coastal inlets and wetlands, with physical facilities of approximately 1.7 million square feet are the basic infrastructure for producing cutting-edge products for successful coastal and inland water resources management (*USACE, 2008f*). Research projects range from design guidance to three-dimensional numerical models, with focus placed on inland and coastal navigation, military logistics over the shore, dredging, flood control, storm and erosion protection, waterway restoration, fish passage, hydro-environmental modeling, water/land management, and other water and sediment-related issues facing the nation. CHL work, although primarily in support of the Corp's divisions and districts, also interfaces with other federal, state and local agencies, academia, conservation groups, and the general public, as appropriate (*USACE, 2008f*).

Cold Regions Research & Engineering Laboratory (CRREL): The history of CRREL goes back to long before its inception in 1961. In the 124 years since Alaska was purchased from Russia, the U.S. Army Corps of Engineers has been involved in cold regions research and development (*USACE, 2008g*). During World War II, organizations were created which, in 1961, were brought together to form the Cold Regions Research and Engineering Laboratory at Hanover, New Hampshire (*USACE, 2008g*). The principal experimental and laboratory facilities operated by CRREL are located at the headquarters complex at Hanover, N.H. The main laboratory consists of 24 low temperature research cold rooms with a temperature range down to -35°C (*USACE, 2008g*). Separate facilities include -- the 73,000 square foot Ice Engineering Facility (IEF) houses three special-purpose research areas; a large low-temperature towing tank, a 100-foot-long refrigerated flume for modeling rivers, and a large hydraulic-model room for studying ice impacts on civil works facilities, primarily locks and dams (*USACE, 2008g*). The 27,000 square foot Frost Effects Research Facility (FERF) supports full-scale research on the impact of freeze-thaw cycles on pavements, foundations, and utility systems (*USACE, 2008g*). The

Civil Works Remote Sensing/Geographic Information Systems Center is involved in oil spill and flood mapping, and large area environmental assessments critical to emergency response efforts (*USACE, 2008g*). The Cold Regions Science and Technology Information Analysis Center serves as the nation's corporate repository for data generated within the cold regions area of science and engineering. CRREL also has special purpose ice test facilities, clean rooms, low temperature materials laboratories, a research permafrost tunnel in Fox, Alaska, and has access to a 133-acre permafrost research site on Ft. Wainwright, Alaska (*USACE, 2008g*). This research arm provides few contributions to River Restoration as a technology.

Construction Engineering Research Laboratory (CERL): CERL opened in 1969 at Champaign, Ill., to be co-located with the University of Illinois at Urbana-Champaign (UIUC) and capitalize on UIUC's science and engineering programs, experts, and facilities (*USACE, 2008h*) and CERL researchers work in collaboration with experts at the other ERDC labs as well as with multiple partners in government, industry and academia. The CERL program centers research around military installations sustainable ranges and lands. Specific focus areas for CERL are Sustainable Installations; Resilient Facilities and Infrastructure; Durable and Multi-Functional Materials; Installation Decision Support; Urban and Stability Operations; and Military Ranges and Lands (*USACE, 2008h*). CERL research in sustainable ranges and lands has two goals: provide knowledge, tools and improved practices to support sustained military use of lands, seas and airspace; and support military stewardship of natural and cultural resources on these lands (*USACE, 2008h*). CERL has state-of-the-art test facilities that include: Triaxial Earthquake and Shock Simulator; Paint Technology Center; Controlled Archeological

Test Site; Heating, Ventilation, and Air-Conditioning Test Facility; Environmental Processes Laboratory; Microbiology Laboratory; Structural Load Floor; Air Pollution Laboratory; Proton Exchange Membrane Fuel Cell with Electrolyzer; and Environmental Chemistry Laboratory (*USACE, 2008h*). This research arm provides few contributions to River Restoration as a technology.

Environmental Laboratory: The Environmental Laboratory conducts research in environmental science and engineering and development in support of environmental systems (*USACE, 2008i*). Environmental Laboratory research includes a network of expertise and facilities from other Engineer Research and Development Center (ERDC) and Corps Laboratories, other government agencies, academia, and private sector. Environmental Lab employees comprise a diverse workforce of biologist, ecologists, physical scientists and engineers with expertise and experience in the full spectrum of environmental science and engineering (*USACE, 2008i*). There are a number of facilities that comprise the Environmental Laboratory (*USACE, 2008i*): Aquatic and Wetlands Ecosystem Research and Development Center; Columbia River Research Facility; Eau Galle Aquatic Ecosystem Research Facility; Environmental Chemistry; Environmental Chemistry Laboratory; Geospatial Data Analysis Facility; Hazardous Waste Research Center; Lewisville Aquatic Ecosystem Research Facility; and Trotter's Shoals Limnological Research Facility. These facilities are described in more detail below:

- <u>Aquatic and Wetlands Ecosystems Research and Development Center</u> - The Aquatic and Wetlands Ecosystem Research and Development Center is a complex of laboratories, greenhouses, and ponds that are utilized to conduct research activities on a wide diversity of environmental problems (*USACE, 2008i*). The main facility

(18,100 sq. ft.) is comprised of five laboratories and two common research areas. Five greenhouses (7,000 sq. ft.) and ten research ponds surround the main facility. The research staff includes over 30 full-time employees with diverse backgrounds in areas such as botany, biology, marine biology, fisheries biology, entomology, malacology, phycology, pathology, plant ecology, statistics, and wildlife ecology (*USACE, 2008i*). The center has been utilized to conduct numerous studies such as: Sturgeon research; Biological control of invasive plants; control and management of zebra mussels; Native mussel biology; Development of plant pathogens; mosquito control and management; characterization of native invertebrate communities; characterization of native fish populations; shoreline erosion studies; lake revegetation; and marine biology (*USACE, 2008i*).

- Columbia River Research Facility - Located in North Bonneville, Washington near the Bonneville Dam and the Columbia River, the Fisheries Engineering Team (FET) conducts fish passage investigations in support of Portland and Walla Walla Districts' Anadromous Fish Evaluation Program and Seattle Districts' Lake Washington General Investigation Study (*USACE, 2008i*). The FET uses state-of-the-art hydroacoustic, video, and acoustic camera systems to monitor and evaluate juvenile salmon passage at Corps hydropower dams within the Columbia River Basin and a navigation lock on the Lake Washington Ship Canal in Seattle, WA (*USACE, 2008i*). The FET has extensive experience evaluating behavioral technologies (e.g., sound and light) and has developed capabilities for characterizing complex flow fields using Doppler-based instrumentation (*USACE, 2008i*). Additionally, the FET is developing a sophisticated computational tool that integrates hydrodynamic and aquatic biological concepts that will enable Computational Fluid Dynamics models to simulate detailed individual movements of fish species in three dimensions (*USACE, 2008i*).

- Eau Galle Aquatic Ecosystem Research Facility - The Eau Galle Aquatic Ecology laboratory (EGAEL) is located near Spring Valley, Wisconsin and specializes in field and experimental analysis of ecological and water quality processes essential for evaluating and implementing rehabilitation and management techniques for a variety of aquatic systems (*USACE, 2008i*). Areas of expertise include watershed nutrient transport and fate, nutrient dynamics and recycling, eutrophication diagnostics and modeling, sediment-nutrient interactions, macrophyte ecology and control, and rehabilitation and environmental management of aquatic systems (*USACE, 2008i*). The EGAEL has field capabilities for sampling sediments, water, and biota, onsite experimental facilities, and a complete 2,000-ft^2 laboratory facility for conducting a wide variety of chemical and physical analyses (*USACE, 2008i*).
- Environmental Chemistry - The analytical chemistry facility is located in Omaha, Nebraska and provides an extensive range of chemistry services to support Corps environmental programs (*USACE, 2008i*). Primary mission-functions are: environmental analytical chemistry research, quality assurance analysis, analytical chemistry in support of research projects, water quality analysis, analytical method development, and quality assurance program technical support (*USACE, 2008i*).
- Environmental Chemistry Laboratory - The Environmental Chemistry, located in Vicksburg, MS, is a center for research and methods development in the field of

environmental analytical chemistry with state of the art analysis in the areas of water quality, environmental restoration, and contaminated sediment and dredged material management; provide Quality Assurance (QA) support to the Corps' Hazardous, Toxic, Radiological Waste (HTRW) programs; site characterization and analysis penetrometer system (SCAPS); and support the Lower Mississippi Valley Division as the Division Laboratory (*USACE, 2008i*).

- Geospatial Data Analysis Facility (GDAF) - The GDAF supports a diverse array of environmental and natural resource research projects including wildlife habitat analysis, wetlands delineation and monitoring, flood modeling/mapping, emergency response activities, aquatic plant mapping, landscape analysis, image analysis and many other civil works areas (*USACE, 200*8i). The GDAF includes a research staff with diverse backgrounds in areas such as geography, computer science, mathematics, civil engineering, geodesy, modeling, landscape architecture, geology, remote sensing, photo interpretation, wildlife ecology, biology, statistics, and computer cartography. The facility also works closely with other ERDC scientists and engineers, therefore directly drawing on research expertise covering a broad spectrum within environmental sciences and a range of engineering disciplines (*USACE, 2008i*).
- Hazardous Waste Research Center - The HWRC provides research and development and innovative technology demonstration support to all Corps of Engineers Districts and Divisions, the ten Environmental Protection Agency (EPA) regions under the Resource Conservation and Recovery Act, the Superfund program and the Assessment and Remediation of Contaminated Sediments program under the Clean Water Act (*USACE, 2008i*). The HWRC conducts research at all levels, from initial

laboratory investigations to the development and application of new and innovative technologies on site (*USACE, 2008i*). Research is performed on a cost reimbursement basis and is executed through a variety of Federal funding arrangements, including work with the private sector under cooperative research and development agreements (CRDAs) to expedite transfer of remediation technologies to the governmental and private sector (*USACE, 2008i*).

- Lewisville Aquatic Ecosystem Research Facility - Lewisville Aquatic Ecosystem Research Facility (LAERF) in Lewisville, TX, is an experimental pond facility developed by the USACE Aquatic Plant Control Research Program (APCRP) (*USACE, 2008i*). LAERF supports studies on biology, ecology, and management of aquatic plants and provides an intermediate-scale research environment to bridge the gap between small-scale laboratory studies and large-scale field tests (*USACE, 2008i*). In addition to 53 earthen and 21 lined ponds, LAERF utilizes 18 flowing water raceways, 3 large outdoor mesocosm facilities, a research greenhouse, and several laboratories to conduct research activities (*USACE, 2008i*). APCRP research in progress includes: field testing of microbial pathogens and host-specific insects for biological control of submersed aquatic plants, studies of the efficacy of aquatic plant herbicides, studies of the effects of aquatic plants on fisheries, water quality, macro invertebrates, and native vegetation; studies of the biology of introduced aquatic weeds such as water hyacinth, Eurasian water milfoil, hydrilla, and giant salvinia; and studies of methods for promoting establishment of native aquatic plant species to prevent further spread of introduced weeds (*USACE, 2008i*).

- Trotter's Shoals Limnological Research Facility - Located on the shores of Richard B. Russell Lake on the Savannah River near Calhoun Falls of South Carolina, the Limnological Studies Team maintains an extensive field and laboratory capability to investigate reservoir, riverine, and wetland ecosystem processes (*USACE, 2008i*). State-of-the-art equipment and procedures are routinely used in the field at experiment sites to collect water, biological, and sediment samples while new methods are being developed to integrate water control and quality data; and to support project personnel in meeting multiple project objectives (*USACE, 2008i*).

Geotechnical and Structures Laboratory: The Geotechnical and Structures Laboratory (GSL) develops solutions to challenges in geotechnical and structural engineering and related disciplines (*USACE, 2008i*). GSL has a rich history, dating to the early 1930s, and is today a vital organization of more than 350 engineers, scientists, technicians, and administrative and support personnel (*USACE, 2008i*). Research conducted in GSL's nine branches encompasses the areas of soil mechanics, engineering geology, near-surface geophysics, earthquake engineering, pavements (both expedient and permanent), mobility and trafficability of military vehicles, weapons effects and blast mitigation, structural design and performance of structures under both static and dynamic loadings, earth dynamics, and the uses and performance of concrete, cement, and other construction materials (*USACE, 2008i*). Other investigations include measurement and analysis of seismic and acoustic signals to locate airborne and ground military targets and buried objects and to characterize earth media (*USACE, 2008i*).

Information Technology Laboratory: The Information Technology Laboratory (ITL) supports the research missions of U.S. Army Engineer Research and Development

Center (ERDC), other Corps activities, the Army, DoD, and other agencies by conceiving, planning, managing, conducting, and coordinating research and development (R&D) in high performance computing, computer-aided and interdisciplinary engineering, computer science, information technology, and instrumentation systems (*USACE, 2008i*). The ITL's CADD/GIS Technology Center for Facilities, Infrastructure, and Environment is currently developing the National Levee Database (*USACE, 2008i*).

Topographic Engineering Center: The Topographic Engineering Center (TEC) is located in Fort Belvoir, VA and its mission is to provide the warfight battlefield knowledge and to support the nation's civil and environmental initiatives through research, development, and the application of expertise in the topographic and related sciences (*USACE, 2008i*). This center offers very little accessible information that is available and/or of interest to River Restoration.

Navigation Data Center (NDC): NDC is the Corps designated center of expertise for the management of infrastructure, utilization and performance information for U.S. waterways and port and harbor channels. Because of the integrated nature of water resources, NDC also directly supports a range of related Civil Works business areas, including hydropower, recreation, environmental compliance, environmental stewardship, water supply, regulatory and homeland security, as well as other Federal, state and local agencies and the private sector. The primary operational arm of NDC is Waterborne Commerce Statistics Center (WCSC), which provides one-stop capability for national navigation information systems.

NDC also provides integrated business information in support of Corps decision making including financial output, performance measurements and performance-based budgeting processes. Additional information about NDC is available on its web site at www.ndc.iwr.usace.army.mil.

C-2.5 U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) was created in 1970 by President Nixon by 'reorganizing' 15 existing executive branch units into one independent organization (*EPA, 2008a*). Air, Solid Waste, Radiological Health, Water Hygiene, and Pesticide Tolerance functions and personnel had been transferred from the Department of Health, Education, and Welfare; Water Quality and Pesticide Label Review came from the Interior Department; Radiation Protection Standards came from the Atomic Energy Commission and the Federal Radiation Council; Pesticide Registration came from the Department of Agriculture (*EPA, 2008a*).

President Nixon declared that its mission would center on (*EPA, 2008a*):

- *The establishment and enforcement of environmental protection standards consistent with national environmental goals;*
- *The conduct of research on the adverse effects of pollution and on methods and equipment for controlling it; the gathering of information on pollution; and the use of this information in strengthening environmental protection programs and recommending policy changes;*
- *Assisting others, through grants, technical assistance and other means, in arresting pollution of the environment; and*
- *Assisting the Council on Environmental Quality in developing and recommending to the President new policies for the protection of the environment.*

Today, the EPA employs 17,000 people across the country, with offices in Washington, DC, 10 regional offices, and more than a dozen labs. The EPA staff is comprised of engineers, scientists, and policy analysts, as well as a large number of employees are legal, public affairs, financial, information management and computer specialists (*EPA, 2008b*). The EPA's organizational structure is shown in Figure C6.

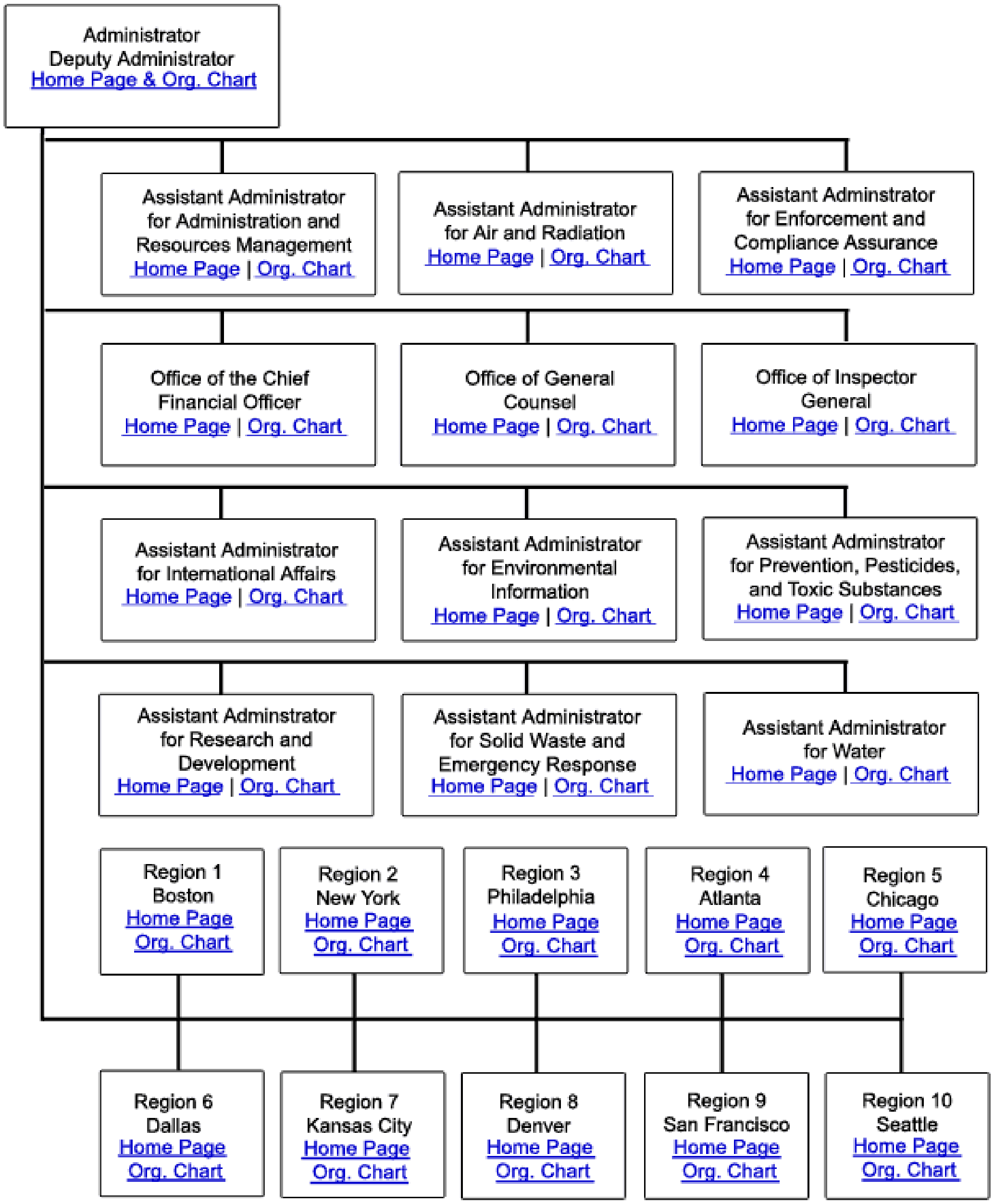

Figure C6: Organizational structure of the EPA (*EPA, 2008b*)

The primary means by which the EPA impacts River Restoration is through regulation and water quality and ecosystem health technology. The main mechanism that enables the EPA to influence River Restoration is the Clean Water Act (CWA). The primary divisions/offices/units that carry out the CWA mandate is the Office of Science and Technology, the Environmental Monitoring and Assessment Program, and National Exposure Research Laboratory. These areas are described in more detail below:

C-2.5.1 Clean Water Act

The Clean Water Act (CWA) establishes the basic structure for regulating discharges of pollutants into the waters of the United States and regulating quality standards for surface waters (*EPA, 2008i*). The basis of the CWA was enacted in 1948 and was called the Federal Water Pollution Control Act, but the Act was significantly reorganized and expanded in 1972 (*EPA, 2008i*). "Clean Water Act" became the Act's common name with amendments in 1977 and under the CWA, EPA has implemented pollution control programs such as setting wastewater standards for industry and setting water quality standards for all contaminants in surface waters (*EPA, 2008i*). The CWA made it unlawful to discharge any pollutant from a point source into navigable waters, unless a permit was obtained (*EPA, 2008i*). EPA's National Pollutant Discharge Elimination System (NPDES) permit program controls discharges.

Evolution of CWA programs over the last decade has also included something of a shift from a program-by-program, source-by-source, pollutant-by-pollutant approach to more holistic watershed-based strategies (*EPA, 2008k*). Under the watershed approach equal emphasis is placed on protecting healthy waters and restoring impaired ones. A full array of issues are addressed, not just those subject to CWA regulatory authority (*EPA, 2008k*). Involvement of stakeholder groups in the development and implementation of strategies for achieving and maintaining state water quality and other environmental goals is another hallmark of this approach (*EPA, 2008k*).

C-2.5.2 Water Science – Office of Science and Technology

The Office of Science and Technology (OST) is one of five water offices at EPA and is tasked with setting the national environmental baselines for the quality of the Nation's waters and ensures the latest water pollution science and best available control technologies to support the Office of Water program goals to keep water safe and clean (*EPA, 2008h*).

Every year under the Clean Water Act and Safe Drinking Water Act, OST produces regulations, guidelines, methods, standards, science-based criteria, and studies that are critical components of national programs that protect people and the aquatic environment (*EPA, 2008h*).

OST applies and sponsors water research and studies that help other EPA programs, states and tribes to protect their drinking water supplies and minimize the effects of pollutants on fish, wildlife, and the aquatic environment (*EPA, 2008h*). While OST's products form the scientific basis for most water programs that protect human health and the aquatic environment, it is the EPA's ten regional offices that are tasked with communicating the information to co-regulators and to the public (*EPA, 2008h*).

Within the Office of Science and Technology, there are three divisions, the Engineering and Analysis Division, the Standards and Health Protection Division, and Health and Ecological Criteria Division (*EPA, 2008h*).

The Engineering and Analysis Division (EAD) develops National technology-based Effluent Guidelines that control pollutant discharges from industry into surface waters and into wastewater treatment plants (*EPA, 2008h*). EAD regulations also control the intake of cooling water at many industrial facilities. Intake regulations keep fish and shellfish from being killed or injured as a result of being pulled into cooling systems or trapped against intake screens (*EPA, 2008h*). Additionally, EAD identifies and analyzes industrial processes and wastewater treatment technologies (*EPA, 2008h*). This division also develops laboratory analytical test methods that are the basis of national regulations and of thousands of discharge permits (*EPA, 2008h*). Many of the pollutants controlled by these regulations are persistent toxic compounds like lead or benzene, but the guidelines also address conventional pollutants like ammonia and phosphorous (*EPA, 2008h*).

The Standards and Health Protection Division (SHPD) directs the national program for adoption of state and tribal water quality standards (*EPA, 2008h*). It develops policies and guidance and provides assistance to EPA regional offices and states on adopting appropriate uses, water quality criteria, and antidegradation protection for specific water bodies (*EPA, 2008h*). SHPD also helps states and EPA Regions develop Total Maximum Daily Loads (TMDLs) to meet water quality standards (*EPA, 2008h*). SHPD runs the Agency's programs to limit the public's exposure to toxics and pathogens from swimming and consuming non-commercial fish (*EPA, 2008h*). It maintains the

National Listing of Fish Advisories, a database available to the public via the Internet, and develops technical documents and guidance materials that help states and tribes monitor, assess, and notify the public when and where non-commercial fish are not suitable to eat (*EPA, 2008h*). SHPD conducts environmental assessments to help evaluate the effects of regulations on water quality (*EPA, 2008h*). The Division also develops other tools—water quality models, flow and tissue analysis methods, and approaches for better understanding options for how to allocate pollutant loadings across sources—to help states, territories, and tribes effectively implement their Water Quality Standards (*EPA, 2008h*).

The Health and Ecological Criteria Division (HECD) conducts risk assessments and develops criteria for surface and drinking water to ensure they are safe for aquatic life and human use and consumption (*EPA, 2008h*). Division scientists also provide technical assistance to states, tribes, local governments and drinking water authorities on criteria implementation, site specific adjustment, data analysis, and drinking water health advisories (*EPA, 2008h*). To protect aquatic life, HECD develops and publishes nutrient criteria that protect waters from nutrient over-enrichment; biological criteria designed to describe and maintain the biological condition of aquatic communities; chemical criteria to define the chemical concentration below which aquatic life are protected; and clean sediment criteria that protect aquatic life from excessive non-contaminated sediment (*EPA, 2008h*).

C-2.5.3 Environmental Monitoring and Assessment Program (EMAP)

The Environmental Monitoring and Assessment Program (EMAP) is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources (*EPA, 2008c*). EMAP's goal is to develop the scientific understanding for translating environmental monitoring data from multiple spatial and temporal scales into assessments of ecological condition and forecasts of the future risks to the sustainability of our natural resources (*EPA, 2008c*). EMAP's research supports the National Environmental Monitoring Initiative (NEMI) of the Committee on Environment and Natural Resources (CENR) (*EPA, 2008c*).

The National Environmental Monitoring Initiative is an initiative in progress – one that is bringing together environmental monitoring and research organizations from across the United States (*EPA, 2008d*). It links large-scale survey information and remote sensing with ecological process research at a network of multi-resource, intensive monitoring areas, resulting in a greater understanding of what controls ecosystem health at the regional scale, where resource management decisions are made (*EPA, 2008d*). The objective of NEMI is to integrate and coordinate environmental monitoring and related research through government and private-sector collaboration, in order to enhance the utility of existing networks and programs (*EPA, 2008d*).

The Committee on Environment and Natural Resources Research (CENR) of the National Science and Technology Council (NSTC) and is the parent organization of the Subcommittee on Global Change Research (SGCR) (*NSTC, 2008*). The purpose of the CENR is to advise and assist the NSTC to increase the overall effectiveness and productivity of Federal R&D efforts in the area of the environment and natural resources.

CENR addresses science policy matters and R&D efforts that cut across agency boundaries and provide a formal mechanism for interagency coordination relevant to domestic and international environmental and natural resources issues.

CENR organizational members include: Department of Agriculture; Department of Commerce; Department of Defense; Department of Energy; Department of Health and Human Services; Department of Homeland Security; Department of the Interior; Department of Justice; Department of State; Department of Transportation; Environmental Protection Agency; National Science Foundation; National Aeronautics and Space Administration; Smithsonian Institution; Federal Emergency Management Agency; Office of Science and Technology Policy; Office of Management and Budget; National Economic Council; Council of Economic Advisors; Domestic Policy Council; and Council on Environmental Quality (*NSTC, 2008*).

EMAP objectives are to advance the science of ecological monitoring and ecological risk assessment, guide national monitoring with improved scientific understanding of ecosystem integrity and dynamics, and demonstrate the CENR framework through large regional projects (*EPA, 2008d*). EMAP aims to develop and demonstrate indicators to monitor the condition of ecological resources, and investigate multi-tier designs that address the acquisition and analysis of multi-scale data including aggregation across tiers and natural resources (*EPA, 2008d*).

As a result of peer reviews during its initial six years, EMAP has redefined its component structure (*EPA, 2008d*). The Information Management and Working Group components provide infrastructure for EMAP to carry out its mission with regional component working groups (*EPA, 2008d*). These component working groups consist of:

Aquatic Resource Monitoring – ARM is designed to provide information on integration issues associated with regional-scale assessments (*EPA, 2008e*). This information includes: introductory, conceptual and overview information on the overall approach, concepts and benefits; program level information on details of the approach, requirements, alternatives and examples; technical level information on the design and analysis details, including access to example data sets, results and statistical algorithms; implementation issues, indicators, and field manuals; presentation and training materials; reference information, internet links, brief descriptions of Federal, State, Tribal monitoring and research programs on aquatic resource monitoring; and related publications and documents and program links (*EPA, 2008e*).

Ecological Indicator Development – The Ecological Indicators workgroup was established to examine the characteristics that make indicators useful in order to improve the quality and utility of existing indicators and identify the need for new indicators of ecological condition (*EPA, 2008e*). The objectives of the workgroup are to (*EPA, 2008e*):

a) *develop a research strategy that focuses research efforts on the development of needed ecological indicators and reduces uncertainty associated with indicators already in use ;*
b) *define categories of information that are critical to the development of indicators to provide a consistent basis for research development and scientific review of ecological indicators; and*
c) *provide outreach and technology transfer to regional, state, and local groups who use ecological indicators in their regulatory and assessment programs as well as program offices and other agencies who have ongoing activities that influence the development and use of ecological indicators.*

Plans are underway to develop a research strategy with the assistance of a research strategy committee; review critical categories by assessing how well 6 specific ecological indicators selected for use in the Agency's Mid-Atlantic Integrated Assessment

Program (MAIA) meet identified needs in the areas of responsiveness, performance, and programmatic criteria; and establish a listing of regional contacts to assist in reviewing the array of critical categories for assessing ecological indicators prior to formal review. EMAP describes indicators as measurable characteristics of the environment, both abiotic and biotic, that can provide quantitative information on ecological resources (*EPA, 2008e*).

EMAP Information Management – EMAP's Information Management component develops the information management infrastructure that enables EMAP to achieve its program objectives (*EPA, 2008e*). Activities are guided by the EMAP Information Management Working Group, chaired by the Atlantic Ecology Division of the National Health and Environmental Effects Research Laboratory, Office of Research and Development, U. S. Environmental Protection Agency. Guidelines, procedures, and the EMAP Information Management Plan: 1998-2001 (*EPA, 2008e*).

EMAP National Coastal Assessment – The National Coastal Assessment surveys the condition of the Nation's coastal resources by creating an integrated, comprehensive monitoring program among the coastal states (*EPA, 2008e*). Estuarine and coastal data has been collected from thousands of stations along the continental US coastline to answer broad-scale questions on environmental conditions (*EPA, 2008e*). These data can be retrieved and stations mapped from applications under NCA Data (*EPA, 2008e*).

EMAP West – EMAP West was charged with demonstrating the value of the EMAP approach by applying it to specific environmental problems across a large and diverse geographical region, and to advance the science of ecosystem monitoring (*EPA,* *2008e*). EMAP West has 3 main research areas: coastal, rivers and streams, and landscapes and its objective is to assess the ecological condition of coastal waters and rivers and streams across the western United States (*EPA, 2008e*). EMAP is designed to monitor indicators of pollution and habitat condition and seek links between human-caused stressors and ecological condition (*EPA, 2008e*). Activities specific to rivers and streams include: Measurements of water column parameters, physical habitat structure, riparian vegetation, biota (benthic macro invertebrates and other organisms) and other data are combined to describe the current condition of rivers and streams. The collection of this environmental data from streams and rivers will be used to: describe the current ecological condition of flowing waters; build a database for the long-term monitoring; and to develop methodologies to advance the science of understanding the ecological function of aquatic ecosystems and the relation of human influence (*EPA, 2008e*).

The surface water indicators used in conducting the surface water assessments included biological, physical habitat, and water chemistry (*EPA, 2008e*). These indicators provide measurements of the environment by characterizing the habitat attribute and/or quantifying the level of stress (*EPA, 2008e*). Indicators to be measured are divided into three tiers: Tier 1 indicators are the core indicators, which were completed at all sites; Tier 2 and 3 indicators were measured at a subset of sites depending on local importance and resource availability.

Tier 1 (core) Indicators (*EPA, 2008e*)

- Water quality parameters
- Fish assemblage
- Macroinvertebrate assemblage
- Periphyton assemblage
- Physical habitat structure
- Riparian vegetation

Tier 2 (*EPA, 2008e*)

- Fish tissue chemistry/toxics
- Sediment metabolism
- Sediment chemistry

Tier 3 (*EPA, 2008e*)

- Amphibians
- Biomarkers
- Riparian birds

Great Rivers Study – The EPA is working on creating a 'report card' on river conditions on the following rivers: Ohio River, Missouri River (from Montana to Missouri), and the Mississippi River (from St. Paul Minnesota to Cairo, Illinois) (*EPA, 2008f*). Due to the size and complexity associated with the river systems, the EPA concluded it was impossible to measure everything, so a statistical process (similar to taking a public opinion survey) was employed (*EPA, 2008f*). Measurements at randomly selected sites will provide representative information about large sections of the river reach or an entire river within a state.

Landscape Ecology Working Group – The Landscape Ecology Program was founded as part of the Environmental Monitoring and Assessment Program in 1992 (*EPA, 2008e*). The primary goals of the program were: (1) to develop landscape pattern indicators of human activities and the environment that relate to observed conditions in ecological resources, including forests, wetlands, streams, lakes, estuaries, arid lands, and (2) to assess landscape pattern across broad areas through the use of comprehensive spatial databases.

The primary research and development goals of the Landscape Ecology Program are to: acquire and enhance spatial databases needed to conduct landscape assessments at multiple scales across large regions; develop new remote sensing techniques to detect landscape conditions; develop techniques to evaluate landscape change across multiple sensors; and quantify relationships between landscape metrics that measure the composition and spatial pattern of ecological resources and human activities and observed conditions of and risks to ecological resources and their associated processes

develop multi-metric statistical approaches (models) to assess the condition of and risks to ecological resources and their associated processes (*EPA, 2008e*).

The Landscape Ecology Program produces a number of products for a wide range of uses. These products include: Landscape assessment tools (ATtILA and AGWA); National assessments; Regional landscape assessments; Watershed-scale, landscape assessments; Journal articles highlighting research findings; Watershed-scale, landscape assessments; Landscape metric databases; and Specialized applications of the landscape approach (e.g., Environmental Justice) (*EPA, 2008e*).

<u>Mid-Atlantic Integrated Assessment</u> – The Mid-Atlantic Integrate Assessment (MAIA) is a multi-year project by EPA's Region III and the Office of Research and Development (ORD) are working jointly on an ecosystem-based evaluation of the Mid-Atlantic region and its watersheds (*EPA, 2008e*). MAIA also encapsulates activities associated with MAIA ORD.

MAIA will incorporate numerous state, regional, and national environmental monitoring programs into an assessment process specifically targeted to the management needs of Region III. Examples of programs with which there are specific plans for cooperative efforts include the Environmental Monitoring and Assessment Program (EMAP), the mid Atlantic Highlands Assessment, the National Biological Service's Gap Analysis Program, the Chesapeake Bay Program, the Delaware Estuary Program, the Virginia Coastal Bays Program, the U.S. Geological Survey's National Water Quality Assessment Program, the Forest Service's Forest Inventory and Analysis Program, and the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program (*EPA, 2008e*).

<u>Multi-Resolution Land Characteristics Interagency Consortium (MRCL) Project</u> – The Multi-Resolution Land Characteristics Interagency Consortium (MRLC) is a collaborative E-Government initiative where several federal agencies provide digital land-cover and ancillary data to the nation, with participating agencies including (*EPA, 2008e*): the Bureau of Land Management (BLM); Environmental Protection Agency

(EPA); the National Atmospheric and Space Administration (NASA); the National Oceanic and Atmospheric Administration (NOAA); National Park Service (NPS); the Natural Resource Conservation Service (NRCS); the Office of Surface Mining (OSM); U.S. Fish and Wildlife Service (USFWS); the U.S. Forest Service (USFS); and the U.S. Geological Survey (USGS).

The MRLC Consortium produces four different land-cover databases. The mapping efforts are not duplicative: all three use the same basic methods and data, and mapping done in one project supports the other two. The primary source of data for all three mapping efforts is Landsat, resulting in the following land cover data sets (*EPA, 2008e*):

- *The National Land Cover Database (NLCD) provides land-cover data for 1992, 2001, and change between the two dates (under development) for the United States and Puerto Rico. Land-cover products outside the conterminous Unites States are only available for 2001.*
- *The Coast Change Analysis Program (C-CAP) provides land-cover and land-cover change data for the coastal portions of the United States. Land-cover change, particularly as they affect coastal wetland resources, is an explicit objective of C-CAP.*
- *The Gap Analysis Project (GAP) provides habitat maps and combines these with wildlife models to determine where there are "gaps" in the network of U.S. conservation lands.*

- *Landscape Fire and Resource Management (LANDFIRE) provides vegetation and wildland fuel maps, and information on fire regimes for the U.S.*

Regional EMAP – REMAP was initiated to test the applicability of the EMAP approach to answer questions about ecological conditions at regional and local scales. Using EMAP's statistical design and indicator concepts, REMAP conducts projects at smaller geographic scales and in shorter time frames than the national EMAP program. The objectives of REMAP are to: Evaluate and improve EMAP concepts for state and local use; Assess the applicability of EMAP indicators at differing spatial scales; and Demonstrate the utility of EMAP for resolving issues of importance to EPA Regions and states. This effort is relatively new, as a result, data and documentation is in the process of being developed. Regional projects were initiated based on EPA Region delineations. Limited information is available, especially in Region 10 (Oregon and Washington) (*EPA, 2008e*). See http://www.epa.gov/emap/remap/index.html for more "up-to-date" information.

Parks Research and Intensive Monitoring of Ecosystems Networks (PRIMENet) Index Sites – The National Park Service and EPA's EMAP are establishing 14 sites to demonstrate appropriate site selection, measurements, and analyses for assessing local, regional, and national ecological condition. Information from these sites will also help to identify research hypotheses, particularly those related to process-level phenomena, for further investigation at the sites (*EPA, 2008e*).

STAR Estuarine and Great Lakes (EaGLe) – In 2000, the US EPA granted authority to establish up to five Estuarine Indicator Research Programs (*EPA, 2008e*). These Programs were designed to identify, evaluate, recommend and potentially develop a suite of new, integrative indicators of ecological condition, integrity, and/or sustainability that can be incorporated into long-term monitoring programs and which will complement ORD's intramural coastal monitoring program (*EPA, 2008e*). The proposed research of the EaGLe Program covers a large coastal area of the United States and will attempt to (*EPA, 2008e*):

1. *Develop indicators and/or procedures useful for evaluating the 'health' or condition of important coastal natural resources (e.g., lakes, streams, coral reefs, coastal wetlands, inland wetlands, rivers, estuaries) at multiple scales, ranging from individual communities to coastal drainage areas to entire biogeographical regions.*
2. *Develop indicators, indices, and/or procedures useful for evaluating the integrated condition of multiple resource/ecosystem types within a defined watershed, drainage basin, or larger biogeographical region of the U.S.*
3. *Develop landscape measures that characterize landscape attributes and that concomitantly serve as quantitative indicators of a range of environmental endpoints, including water quality, watershed quality, freshwater/estuarine/marine biological condition, and habitat suitability.*
4. *Develop nested suites of indicators that can both quantify the health or condition of a resource or system and identify its primary stressors at local to regional scales.*

The five study projects/areas are: the Atlantic Coast Environmental Indicators Consortium (University of North Carolina, Chapel Hill); the Atlantic Slope Consortium (Pennsylvania State University); Consortium for Estuarine Ecoindicator Research for the Gulf of Mexico (University of Southern Mississippi); Great Lakes Environmental Indicators Project (University of Minnesota, Duluth); and the Pacific Ecosystem Indicator Research Consortium (University of California, Davis) (*EPA, 2008e*).

C-2.5.4 National Exposure Research Laboratory

The Environmental Sciences Division (ESD) of Office of Research and Development's National Exposure Research Laboratory (NERL) conducts research, development, and technology transfer programs on environmental exposures to ecological and human receptors (*EPA, 2008g*). ESD, located on the campus of the University of Nevada, Las Vegas, develops methods for characterizing chemical and physical stressors, with special emphasis on ecological exposure.

Exposure is the contact of people (or other organisms) with an environmental stressor for a specific duration of time (*EPA, 2008g*). Stressors can include chemical pollutants, microbes or pathogens, or physical agents, like radiation or even processes such as alteration of wildlife habitat (*EPA, 2008g*).

NERL's environmental exposure assessment involves the following elements:

- *Characterizing sources of pollution, including mobile sources such as automobiles; point sources such as industrial plants; and non-point sources such as agricultural run-off and land-management practices.*
- *Understanding and modeling the processes that control the distribution, transport, transformation, and fate of these pollutants - stressors, as they move through the environment, from sources to "receptors" (the humans, plants, animals or ecosystems that may be exposed).*
- *Characterizing actual exposure - measuring and modeling how humans and ecosystems come into contact with pollutants - stressors. Since exposure involves both the pollutant - stressor and the "receptor" (e.g., the*

human or ecosystem) which is exposed, together with duration of exposure, exposure assessment requires a variety of efforts, including:

  - *measuring and modeling pollutants - stressors in various media - for example, measuring pollutant levels in the food people eat, in the water they drink, in the air they breathe, and on the things they touch; and*
  - *describing the behavior patterns of people or animals that affect their exposure - like the daily activities of people (the what, when, where and how long) that bring them into contact with pollutants or the distribution of sensitive ecosystems within a polluted watershed.*

- *Assessing the effectiveness of an exposure, including making measurements on receptors that provide evidence that they have been exposed. NERL's research includes: determination and modeling of uptake or transfer efficiencies or describing the dose to target organs; characterizing indicators of exposure, like measuring biological markers of exposure in people or animals; identifying antibodies in humans resulting from exposure to pathogens; characterizing changes in wetlands or forest cover; or measuring changes induced in the community composition in ecosystems.*

The Division develops landscape and regional assessment capabilities through the use of remote sensing and advanced spatial analysis techniques. ESD also conducts analytical chemistry research and applies advanced monitoring technology to issues involving surface and subsurface contamination (*EPA, 2008g*). To carry out its mission, the Division applies a multidisciplinary, multimedia approach in both laboratory and field settings.

C-2.5.5 EPA Models and Tools

EPA has developed a number of models and tools to be used for water quality management. Water quality models are tools for simulating the movement of precipitation and pollutants from the ground surface through pipe and channel networks, storage treatment units and finally to receiving waters (*EPA, 2008g*). Both single-event and continuous simulation may be performed on catchments having storm sewers and natural drainage, for prediction of flows, stages and pollutant concentrations (*EPA, 2008g*). Each water quality model has its own unique purpose and simulation characteristics and the reader is advised to thoroughly review downloading and data input instructions for each model (*EPA, 2008g*). A description of the models and tools is presented below:

- Allocating Loads and Wasteloads – A tool for developing TMDL standards (http://www.epa.gov/waterscience/models/allocation/);
- AQUATOX - AQUATOX is a freshwater ecosystem simulation model. It predicts the fate of various pollutants, such as nutrients and organic toxicants, and their effects on the ecosystem, including fish, invertebrates, and aquatic plants (http://www.epa.gov/waterscience/models/aquatox/);

- BASINS - A multi-purpose environmental analysis system that integrates a geographical information system (GIS), national watershed data, and environmental assessment and modeling tools into one convenient package (http://www.epa.gov/waterscience/BASINS/);
- Clean Water Act Analytic Methods - EPA publishes laboratory analytical methods that are used by industries and municipalities to analyze the chemical, physical and biological components of wastewater and other environmental samples that are required by regulations under the authority of the Clean Water Act (CWA). Methods are available from: http://www.epa.gov/waterscience/methods/;
- CORMIX - A mixing zone model that can be used to assess water quality impacts from point source discharges at surface or sub-surface levels. (http://www.epa.gov/waterscience/models/cormix.html);
- DFLOW - A tool to calculate design flow statistics. It also includes several pages explaining how to use the tool and provides detailed background information (http://www.epa.gov/waterscience/models/dflow/);
- EnviroMapper - EnviroMapper is an online mapping tool to spatially identify various types of environmental information, including air releases, drinking water, toxic releases, hazardous wastes, water discharge permits, and Superfund sites (*EPA, 2008n*) (http://www.epa.gov/enviro/html/em/index.html) .

- Mercury Maps - Mercury Maps is a tool that relates changes in mercury air deposition rates to changes in mercury fish tissue concentrations, on a national scale. Mercury Maps can be used to help identify those waterbodies expected to attain state water quality standards as a result of air deposition reductions, or to assist in Total Maximum Daily Load (TMDL) analyses for individual or multiple watersheds (http://www.epa.gov/waterscience/maps/);
- National Lake Fish Tissue Study - A screening-level study to estimate the national distribution of selected persistent, bioaccumulative and toxic chemical residues in fish tissue from lakes and reservoirs of the continental United States (http://www.epa.gov/waterscience/fishstudy/);
- QUAL2K - QUAL2K (or Q2K) is a river and stream water quality model that is intended to represent a modernized version of the QUAL2E (or Q2E) model. One dimensional. The channel is well-mixed vertically and laterally. Steady state hydraulics. Non-uniform, steady flow is simulated. Diurnal heat budget. The heat budget and temperature are simulated as a function of meteorology on a diurnal time scale. Diurnal water-quality kinetics. All water quality variables are simulated on a diurnal time scale. Heat and mass inputs. Point and non-point loads and abstractions are simulated (http://www.epa.gov/athens/wwqtsc/html/qual2k.html);
- STORET - The U.S. Environmental Protection Agency (EPA) maintains two data management systems containing water quality information for

the nation's waters: the Legacy Data Center (LDC), and STORET (*EPA, 2008l*). The LDC is a static, archived database and STORET is an operational system actively being populated with water quality data (*EPA, 2008l*). The LDC contains historical water quality data dating back to the early part of the 20th century and collected up to the end of 1998 and STORET contains data collected beginning in 1999, along with older data that has been properly documented and migrated from the LDC (*EPA, 2008l*). Both systems contain raw biological, chemical, and physical data on surface and ground water collected by federal, state and local agencies, Indian Tribes, volunteer groups, academics, and others and all 50 States, territories, and jurisdictions of the U.S. are represented in these systems (*EPA, 2008l*). Each sampling result in the LDC and in STORET is accompanied by information on where the sample was taken (latitude, longitude, state, county, Hydrologic Unit Code and a brief site identification), when the sample was gathered, the medium sampled (e.g., water, sediment, fish tissue), and the name of the organization that sponsored the monitoring (*EPA, 2008l*). In addition, STORET contains information on why the data were gathered; sampling and analytical methods used; the laboratory used to analyze the samples; the quality control checks used when sampling, handling the samples, and analyzing the data; and the personnel responsible for the data (*EPA, 2008l*) (http://www.epa.gov/storet/about.html);

- Surf Your Watershed - Surf Your Watershed gathers environmental information available by geographic units which includes state, watershed (Surf's primary focus), county, metro area, and tribe (*EPA, 2008m*). Surf integrates information gathered in associated databases by geographical unit. The databases include Environmental Websites, Adopt Your Watershed, River Corridor and Restoration, and more (http://cfpub.epa.gov/surf/locate/index.cfm) (*EPA, 2008m*);
- Water Quality Economics and Benefits - Estimating the benefits of water quality programs instituted under the 1972 Clean Water Act (CWA) is one of the requirements faced by the U.S. Environmental Protection Agency. It is also an integral part of the Agency's ongoing process to evaluate the contribution of its water quality programs to society. As a result, estimating the benefits of environmental regulation is one of the many procedural methods EPA uses to determine how it can be more effective in addressing the needs of society. To support these objectives, EPA has initiated a program to improve the data and methods used for estimating the benefits of its water quality programs (http://www.epa.gov/waterscience/economics/); and
- WASP7 - WASP7 is an enhanced version of the Water Quality Analysis Simulation Program (WASP). This version includes kinetic algorithms for eutrophication/conventional pollutants, organic chemicals/metals,

mercury, fecal coliform, and conservative pollutants (http://www.epa.gov/athens/wwqtsc/html/wasp.html);

C-2.6 U.S. Department of Homeland Security

The U.S. Department of Homeland Security (DHS) was formed in November of 2002 to primarily secure and protect the United States, it was also charged with preparing and responding to natural disasters (*DHS, 2008*). Within DHS, the Federal Emergency Management Agency (FEMA) has the most impact on the field of River Restoration through their policies and jurisdiction over flood protection systems. A discussion of FEMA is presented below.

C-2.6.1 Federal Emergency Management Agency

On March 1, 2003, the Federal Emergency Management Agency (FEMA) became part of the U.S. Department of Homeland Security (DHS) (*FEMA, 2008a*). The primary mission of the Federal Emergency Management Agency is to reduce the loss of life and property and protect the Nation from all hazards, including natural disasters, acts of terrorism, and other man-made disasters, by leading and supporting the Nation in a risk-based, comprehensive emergency management system of preparedness, protection, response, recovery, and mitigation (*FEMA, 2008a*). FEMA has more than 2,600 full time employees and also has nearly 4,000 standby disaster assistance employees who are available for deployment after disasters (*FEMA, 2008a*). An organizational structure is presented in Figure C7.

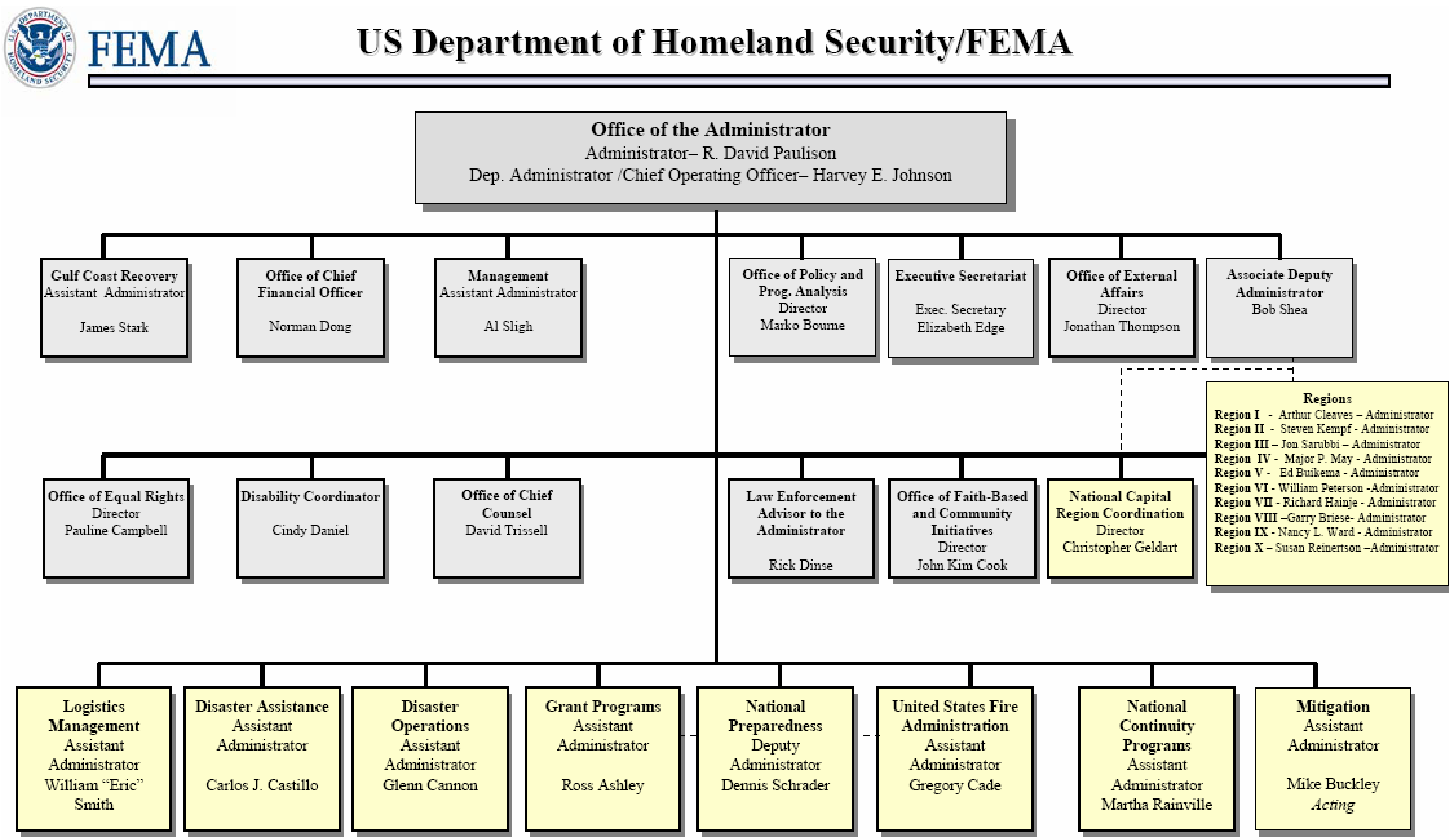

Figure C7:Organizational Structure of FEMA (*FEMA, 2008a*)

The Mitigation Directorate, a component of the Federal Emergency Management Agency (FEMA), manages the National Flood Insurance Program (NFIP). The three components of the NFIP are: Flood Insurance; Floodplain Management; and Flood Hazard Mapping (*FEMA, 2008a*).

Nearly 20,000 communities across the United States and its territories participate in the voluntary NFIP by adopting and enforcing floodplain management ordinances to reduce future flood damage, and in exchange, the NFIP makes Federally backed flood insurance available to homeowners, renters, and business owners in these communities (*FEMA, 2008b*).

Flood insurance is designed to provide an alternative to disaster assistance to reduce the escalating costs of repairing damage to buildings and their contents caused by floods (*FEMA, 2008b*). Flood damage is reduced by nearly $1 billion a year through communities implementing sound floodplain management requirements and property owners purchasing of flood insurance (*FEMA, 2008b*).

The U.S. Congress established the National Flood Insurance Program (NFIP) with the passage of the National Flood Insurance Act of 1968 (*FEMA, 2008c*). The NFIP is a Federal program enabling property owners in participating communities to purchase insurance as a protection against flood losses in exchange for State and community floodplain management regulations that reduce future flood damages (*FEMA, 2008c*). Participation in the NFIP is based on an agreement between communities and the Federal Government. If a community adopts and enforces a floodplain management ordinance to reduce future flood risk to new construction in floodplains, the Federal Government will make flood insurance available within the community as a financial protection against flood losses (*FEMA, 2008c*). This insurance is designed to provide an insurance alternative to disaster assistance to reduce the escalating costs of repairing damage to buildings and their contents caused by floods. Buildings constructed in compliance with NFIP building standards suffer approximately 80 percent less damage annually than those not built in compliance (*FEMA, 2008b*).

In addition to providing flood insurance and reducing flood damages through floodplain management regulations, the NFIP identifies and maps the Nation's floodplains (*FEMA, 2008b*). Mapping flood hazards creates broad-based awareness of the flood hazards and provides the data needed for floodplain management programs and to actuarially rate new construction for flood insurance (*FEMA, 2008b*).

C-2.6.2 Flood Plain Management

Floodplain management is the operation of a community program of corrective and preventative measures for reducing flood damage. These measures take a variety of forms and generally include requirements for zoning, subdivision or building, and special-purpose floodplain ordinances. The community must adopt and submit floodplain management regulations that meet or exceed the minimum flood plain management requirements of the NFIP.

The primary guidance document FEMA provides to communities to manage the floodplain is the "Floodplain Management in the United States, An Assessment Report (Full Report)," (*LRJA, 1992*). This document provides a background on floods and floodplains; hazards and common losses associated with floodplain development; an overview (including history) of the US floodplain management approaches, management frameworks, regulations, legal interpretations, and design standards; and future implications such as extrapolation uncertainties, land use changes, and impacts associated with climate change. However, the major contribution to floodplain management FEMA provides, is the identification of flood hazards, through their flood mapping project.

C-2.6.3 Flood Mapping

As administrator of the National Flood Insurance Program (NFIP), the Federal Emergency Management Agency (FEMA) is responsible for assessing flood hazards and related risks and providing appropriate flood hazard and risk information to communities nationwide. This information is provided to communities in the form of maps, called Flood Insurance Rate Maps (FIRMs). FEMA is updating and modernizing the FIRMs nationwide through its Flood Map Modernization (Map Mod) effort (*FEMA, 2008f*).

The Multi-Year Flood Hazard Identification Plan (MHIP) details FEMA's plan for prioritizing and delivering modernized flood maps for areas of the United States with the greatest flood risk (*FEMA, 2008d*). The MHIP provides detailed tables and graphs of projected flood map production sequencing and projected funding allocations (*FEMA, 2008d*). Actual funding levels for flood map and data production are determined as flood mapping projects are scoped and projects are further defined (*FEMA, 2008d*). The MHIP also includes a summary of FEMA's steps to enhance map quality (*FEMA, 2008d*).

This flood mapping is the foundation by which flood hazards (and the basis for determining associated flooding consequences) are identified and communicated to local communities living in the floodplain. The flood mapping has a direct and significant impact on land use policies in that it delineates spatial areas situated within (and outside) estimated flood zones. These flood maps are used by engineers, surveyors, architects, floodplain managers, homeowners, insurance professionals and lenders (*FEMA, 2008e*).

Levee systems, constructed as part of flood control measures, have been constructed in over one-fourth the counties that will receive modernized maps—Digital Flood Insurance Rate Maps (DFIRMs)—as part of Map Mod. Therefore, FEMA has noted that accurately identifying the flood risk in levee-impacted areas is an important element of their Map Mod effort (*FEMA, 2008f*). FEMA has no responsibility for building, maintaining, operating, or certifying levee systems (*FEMA, 2008f*). FEMA does, however, develop and enforce the regulatory and procedural requirements that are used to determine whether a completed levee system should be credited with providing 1-percent-annual-chance flood protection on a FIRM or DFIRM (*FEMA, 2008f*). These maps can be viewed online here: http://msc.fema.gov/.

C-2.7 U.S. Department of Housing and Urban Development

HUD's mission is to increase homeownership, support community development and increase access to affordable housing free from discrimination (*HUD, 2008a*). The Department was established as part of the U.S. Housing Act of 1937 and has six primary goals: increase homeownership opportunities; promote decent affordable housing; strengthen communities; ensure equal opportunity in housing; embrace high standards of ethics, management, and accountability; and to promote participation of faith-based and community organizations (*HUD, 2008b*). HUD has a staff of over 8,000 and manages a budget of over $36 billion each year. An organizational structure is presented in Figure C8.

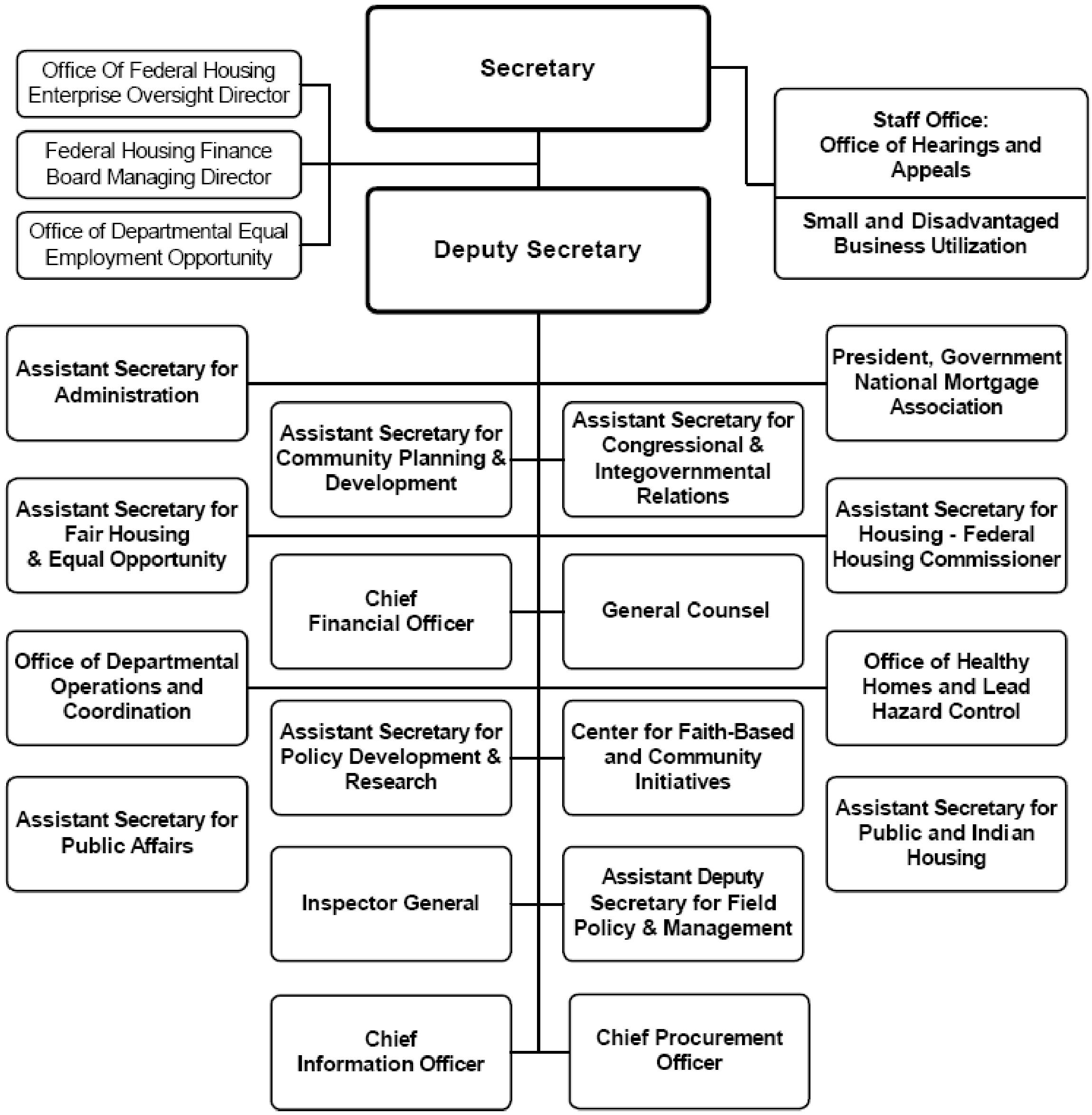

Figure C8: **HUD Organizational Structure (*HUD, 2008a*)**

The primary interaction HUD has with the River Restoration field is through flood hazard and floodplain management aspects that impact flood control in developed areas, implemented through Executive Order 11988 (floodplain management) and

Executive Order 11990 (Protection of Wetlands) (*HUD, 2008c*). Floodplain Management (Executive Order 11988) is defined "to avoid to the extent possible the long and short term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct or indirect support of floodplain development wherever there is a practicable alternative" (*HUD, 2008c*). - Protection of Wetlands (Executive Order 11990) is defined "to avoid to the extent possible the long and short term adverse impacts associated with wetlands and to avoid direct or indirect support of new construction in wetlands wherever there is a practicable alternative" (*HUD, 2008c*).

Information on where floodplains are located is available on Flood Insurance Rate Maps (FIRM) published by the Federal Emergency Management Agency (FEMA). The flood maps are available for public review at the local planning agency or building permit agency. Local appraisers and companies that make flood hazard determinations for banks and other lenders in connection with property loans also have access to these maps and data bases (*HUD, 2008c*). Information on where designated wetlands are located is available on the wetlands maps issued by the Department of the Interior (DOI) for the National Inventory of Wetlands and are available for public review at the local planning agency or State natural resources agency (*HUD, 2008c*).

C-2.8 U.S. Department of the Interior

The United States Department of the Interior (DOI) is a Cabinet department of the United States government that manages and conserves most federally owned land, and administers programs related to indigenous populations of the United States and its insular territories (*Wikipedia, 2008a*). It is administered by the United States Secretary of the Interior, has over 70,000 employees and an annual budget in excess of $10 billion. The organizational structure of the DOI is shown in Figure C9.

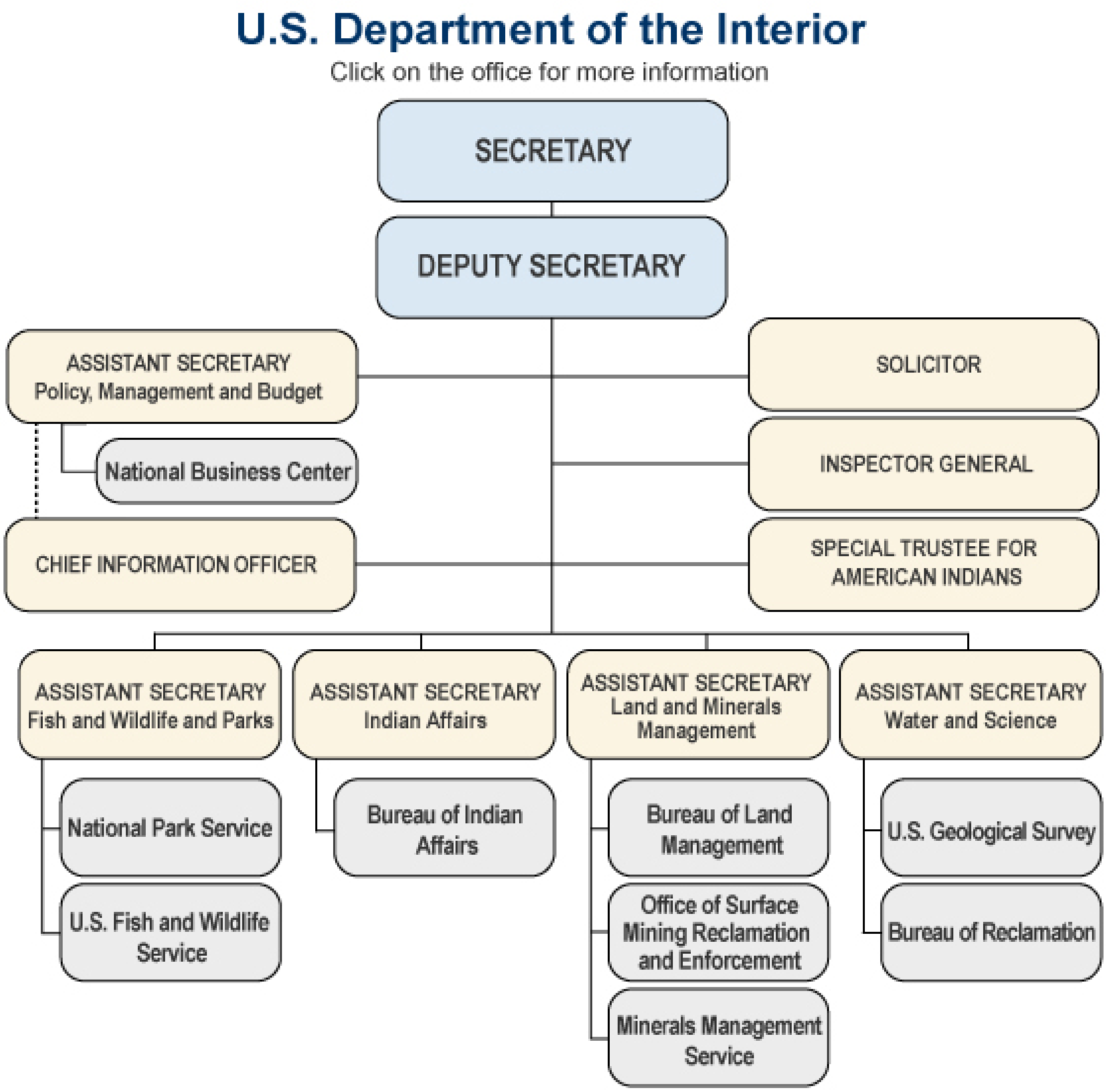

Figure C9: Organizational structure of the Department of Interior (*DOI, 2008a*).

There are eight bureaus within DOI and of these eight, five directly impact River Restoration: the Bureau of Land Management; the Bureau of Reclamation; the National Park Service, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. These Bureaus are discussed in more detail below:

C-2.8.1 Bureau of Land Management

The Bureau of Land Management (BLM) manages 264 million acres of surface acres of public lands located primarily in the 12 Western States, including Alaska (*DOI, 2008b*). The agency also manages 300 million acres of below ground mineral estate located throughout the country (*DOI, 2008b*). Originally, these lands were valued principally for the commodities extracted from them; today, the public also prizes them for their recreational opportunities and their natural, historical, and cultural resources they contain (*DOI, 2008b*).

The BLM is responsible for carrying out a variety of programs for the management and conservation, of resources on 258 million surface acres, as well as 700 million acres of subsurface mineral estate (*DOI, 2008c*). These public lands make up about 13 percent of the total land surface of the United States and more than 40 percent of all land managed by the Federal government (*DOI, 2008b*).

The Bureau has an active program of soil and watershed management on 175 million acres in the lower 48 states and 86 million acres in Alaska (*DOI, 2008b*). Practices such as revegetation, protective fencing, and water development are designed to conserve, enhance public land, including soil and watershed resources (*DOI, 2008b*). The BLM is also responsible for fire protection on public lands and on all Interior Department in Alaska, as well as for wildfire management on the public lands on the public lands in Alaska and the Western States (*DOI, 2008b*).

BLM is active in ecosystem evaluation and have developed tools to utilize quantitative geographic approach based on existing scientific principles to better understand the spatial distributions and relationships of natural structures and processes occurring on public land ecosystems (*DOI, 2008d*). BLM operates under the assumption that understanding these geographic patterns will permit development of better land management approaches to maintain the health of public lands. A number of GIS-based tools have been developed by BLM to aid in the quantification of ecosystem attributes and are available for download by the public (http://www.blm.gov/nstc/ecosysmod/index.html).

In addition to ecosystem attributes, BLM has an overview discussion of water policy in the western U.S. Water rights is a very complex issue and a critical component of the Bureau of Land Management's (BLM) water program (*DOI, 2008e*). The complexity is due to the fact that water rights are managed to a great extent under state law, therefore, it is critical to have a good understanding of the water right laws of each individual state (*DOI, 2008e*). The western states include: Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, and Wyoming. Special attention is paid to the states' water rights systems, especially the states' riparian and in stream flow programs (*DOI, 2008e*).

Riparian water rights occur as a result of landownership. The doctrine of riparian rights in the United States has its basis in case law which first involved Tyler v. Wilkinson in 1827 (*DOI, 2008e*). This case arose out of a dispute between mill owners over the right to use the flow of a river for mill power and the opinion in the case stated that all riparians had equal rights to the water in the river and that an upper proprietor could not diminish the quantity that would naturally flow to the lower proprietor (*DOI, 2008e*). However, the case opinion also recognized that such an absolute right would not be practical and held that an upper proprietor could make "reasonable use" of the water, including consumptive withdrawals (*DOI, 2008e*).

A landowner who owns land that physically touches a river, stream, pond, or lake has an equal right to the use of water from that source (*DOI, 2008e*). This water right, however, is only a usufructuary right and not a property right in the water (*DOI, 2008e*). The water may be used as it passes through the property of the land owner, but it cannot be unreasonably detained or diverted, and it must be returned to the stream from which it was obtained (*DOI, 2008e*). The use of riparian water rights is generally regulated by "reasonable use," where reasonable use allows for the consumptive use of water, but what actually constitutes reasonable use has varied widely from state to state and continues to evolve (*DOI, 2008e*).

Only certain waters are subject to riparian rights (*DOI, 2008e*). Riparian rights only attach to water in watercourses and not to diffuse surface waters (*DOI, 2008e*). Diffuse waters are waters that are spread over the surface, where as a watercourse has a definite natural channel and a bed with banks (*DOI, 2008e*). Diffuse waters are generally storm or flood drainage, and these do not constitute riparian rights (*DOI, 2008e*).

Riparian water rights are generally considered "part and parcel" to the land and are included if the property is sold (*DOI, 2008e*). The law, in most cases, forbids transfers of riparian rights for use on non-riparian lands (*DOI, 2008e*). This rule, however, has been amended in some instances to allow non-riparians to use the water so long as the use is "reasonable" with regards to other riparians (*DOI, 2008e*).

The general characteristics of riparian rights can be summarized as follows (*DOI, 2008e*):

- *Riparian rights are of equal priority.*
- *Unless adjudicated, the right is not quantified; rather it extends to the amount of water which can be reasonably and beneficially used on the riparian parcel.*
- *Riparian rights are correlative. During times of water shortage, the riparian proprietors share the shortage.*
- *Water may be used only upon that portion of the riparian parcel which is within the watershed of the water source.*
- *The riparian right does not extend to seasonal storage of water.*
- *The riparian right is part of the riparian land and cannot be transferred for use on other lands.*
- *The riparian rights remain with the land when riparian lands are sold.*
- *When riparian lands are subdivided, parcels which are severed from the adjacent water source lose their riparian rights unless the rights are reserved.*
- *A riparian right is not lost by non-use.*

The prior appropriation doctrine, or "first in time - first in right", developed in the western United States in response to the scarcity of water in the region (*DOI, 2008e*). The doctrine evolved during the California gold rush when miners in California needed to divert water from the stream to locations where it was needed to process ore (*DOI, 2008e*). Customs and principles relating to water diversion developed in the mining camps, and disputes were resolved by simple priority rule (*DOI, 2008e*). According to the rules of prior appropriation, the right to the full volume of water "related back" or had the priority date as of the time of first diverting the water and putting it to beneficial use (*DOI, 2008e*). In other words, those with earliest priority dates have the right to the use of that amount of water over others with later priority dates (*DOI, 2008e*).

Unlike a riparian right, an appropriative right exists without regard to the relationship between the land and water (*DOI, 2008e*). An appropriative right is generally based upon physical control and beneficial use of the water and these rights are entitlements to a specific amount of water, for a specified use, at a specific location with a definite date of priority (*DOI, 2008e*). An appropriative right depends upon continued use of the water and may be lost through non-use (*DOI, 2008e*). Unlike riparian rights, these rights can generally be sold or transferred, and long-term storage is not only permissible but common (*DOI, 2008e*). There are four essential elements of the prior appropriation doctrine: Intent, Diversion, Beneficial Use, and Priority (*DOI, 2008e*).

The hybrid doctrine recognizes both riparian and appropriative water rights (*DOI, 2008e*). Generally, states have this duel system because riparian rights were historically recognized, but the state has changed to an appropriative system (*DOI, 2008e*). Hybrid states have integrated riparian rights into the doctrine of prior appropriation by converting riparian rights to appropriative rights (*DOI, 2008e*). Generally, states have allowed riparian land owners to claim a water right by a certain time and incorporate it into the state's prior appropriation system (*DOI, 2008e*). The riparian rights tend to be superior to the prior appropriative rights even if the water was not put to beneficial use until much later (*DOI, 2008e*). Riparian rights are not recognized, however, if they are not claimed by a certain date (usually the date the state adopted the prior appropriation doctrine), or are not put to use within a certain number of years (*DOI, 2008e*). States that have a hybrid system include California, Kansas, Nebraska, North and South Dakota, Oklahoma, Oregon, Texas, and Washington (*DOI, 2008e*).

As public land managers, BLM must comply with a complex mix of federal and state water quality laws (*DOI, 2008e*). Federal laws provide an umbrella under which states must implement and enforce measures to meet or exceed federally established minimum standards and western states have differed in how they deal with water quality (*DOI, 2008e*). Key legislation that applies to water quality parameters for the BLM includes (*DOI, 2008e*):

- *The Clean Water Act and Corresponding USC Sections;*
- *Point Sources and NPDES Permits;*
- *Water Quality Standards and 303(d) Listing;*
- *The TMDL Program;*
- *Nonpoint Source Water Pollution, CWA § 319, and Best Management Practices;*
- *Wetlands and CWA § 404 Dredge and Fill Permits;*
- *The Oil Pollution Act and CWA §311*

A detailed discussion of water quality laws can be accessed on the BLM website at http://www.blm.gov/nstc/WaterLaws/ .

C-2.8.2 Bureau of Reclamation

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public (*DOI, 2008b*). Established in 1902, Reclamation is the largest wholesale water supplier in the country, delivering 10 trillion gallons of water to more than 31 million people (*DOI, 2008b*). Reclamation manages 457 dams, and its 348 reservoirs have more than 90 million recreation visits annually (*DOI, 2008b*). Reclamation is also the nation's second largest producer of hydropower and the tenth largest electric utility generating about 42 billion kilowatt hours a year (*DOI, 2008b*).

The Bureau of Reclamation operates a network of automated hydrologic and meteorological monitoring stations in the Great Plains and the Pacific Northwest (*USBR, 2008a*). Remote data collection platforms transmit water and environmental data via radio and satellite to provide cost-effective, near-real-time water management capability and other information, as available, is integrated to provide timely water supply status for river and reservoir operations (*USBR, 2008a*).

A number of studies, computer programs, and technical manuals are available from the U.S. Bureau of Reclamation related to river restoration, but the large majority of these resources are oriented towards conventional water transportation and dams.

C-2.8.3 National Park Service

Created by Congress on August 25, 1916, the National Park Service (NPS) preserves, unimpaired, the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations (*DOI, 2008b*). The National Park System of the United States comprises 388 areas covering more than 84 million acres in 49 States, the District of Columbia, American Samoa, Guam, Puerto Rico, Saipan, and the Virgin Islands (*DOI, 2008b*). These areas are of such national significance as to justify special recognition and protection in accordance with various acts of Congress (*DOI, 2008b*). The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world (*DOI, 2008b*).

The NPS is actively engaged in ecosystem restoration in those areas within park boundaries that have been degraded as a result of anthropogenic activities (*NPS, 2008a*). The NPS goal to do ecosystem restoration is to not only replace parts of a system, but conditions and underlying processes as well (*NPS, 2008a*).

Separate from the ecosystem restoration program, the NPS also has a water resources program, which addresses fisheries, hydrology, information management, ocean and coastal resources, planning, watershed condition, water quality, water rights, wetlands, and wild and scenic rivers (*NPS, 2008b*).

The Fisheries Management Program provides technical assistance and policy guidance on the management of recreational fisheries and the fish and aquatic resources under NPS control (*NPS, 2008c*). Fisheries program staff provides technical assistance to parks to evaluate threats to fish and aquatic resources, and to coordinate management and inventory projects (*NPS, 2008c*). Restoration of native fish stocks and recovery of threatened and endangered fishes are among the highest priorities for the Program (*NPS, 2008c*). Park fishing regulations are usually established in cooperation with adjacent states and often require the development of cooperative fishery management plans, and the Fisheries Management Program assists parks in developing these plans and restoring aquatic resources (*NPS, 2008c*).

The Hydrology Program provides technical and policy advice to parks on the management of hydrologic conditions and processes (*NPS, 2008d*). Program staff help address hydrologic issues such as ground-water protection and development, floodplain management, hydrologic monitoring, and fluvial geomorphology, as well as watershed, stream and riparian area condition management and restoration (*NPS, 2008d*). Other service areas include hydrologic modeling and assistance in the technical aspects of environmental regulation and compliance (*NPS, 2008d*). The Water Operations Branch (WOB) Hydrology Program provides technical assistance to parks in the following areas:

• *Surface water hydrologic and hydraulic modeling and assessment;*

• *Floodplain management, policy, and compliance;*

• *Ground water resource analysis, protection and development;*

• *Fluvial geomorphic assessment and sediment transport;*

• *Watershed, stream, and riparian area condition analysis and management; and*

• *Environmental assessment and compliance.*

Beginning in 2003, the Hydrology Program assumed responsibility for designing and administering a new service-wide program to assess the conditions of watershed in parks including uplands, wetlands, streams and riparian resources (*NPS, 2008d*). Development of a major review and analysis of existing methods used to assess the ecological conditions of watersheds at multiple scales was initiated during the program's first year (*NPS, 2008d*).

The NPS Information Management Program supports parks in the analysis and archiving of hydrologic data, including database design, data management, and GIS applications (*NPS, 2008e*). Program staff recommends standards for hydrographic data sets, compile waterbody inventories for parks, maintain a national water quality database, identify national water quality issues and assist in acquiring digital hydrographic data (*NPS, 2008e*). The NPS uses the STORET database (hosted by the EPA) for all of their water quality.

The NPS water resources planning process and its products assist in the development of park-wide management strategies and ensure that park managers and policy makers have adequate and timely information to protect, utilize and enhance water resources (*NPS, 2008f*). The 2004 Park Planning Program Standards provide a flow established through several levels of planning that become increasingly detailed and complementary by agreeing first on why a park was established and what resource conditions should exist, and then increasingly focused on how those conditions should be maintained or achieved (*NPS, 2008f*). Water Resources Management Plans are generated for NPS parks and serve as guidance for all restoration and conservation efforts within that park. Water resources planning reports can be accessed here: http://www.nature.nps.gov/water/planning/.

Through the Natural Resource Challenge, the NPS Water Resources Division was charged with the task of developing Watershed Condition Assessments on a system-wide basis (*NPS, 2008g*). Watershed Condition Assessment (WCA) involves applying a set of descriptive and/or quantitative technical methods to describe ecosystem health at the watershed scale and typically, these methods develop and integrate assessments of discrete ecosystem components at a variety of landscape scales (*NPS, 2008g*). The NPS considers the field of resource condition assessments as relatively new and rapidly expanding (*NPS, 2008g*). NPS identifies that there are no widely accepted definitions, approaches, or "methods" for conducting structured, replicable assessments of watershed resources, and a wide variety of methods are available depending upon such things as the assessment purpose or use, habitat type, scale, and degree of quantitative rigor (*NPS, 2008g*). Their first challenge for the program is to define the concept of watershed condition assessment for the National Park Service and to develop a framework and context for the systematic assessment of park watershed resource conditions (*NPS, 2008g*).

The Water Quality Program is designed to support NPS headquarters, regions, networks, and park-based managers and resource specialists by: providing national consistency in the acquisition and management of water quality information; synthesizing information on the quality of park waters at the national level; promoting effective use of regulatory initiatives to establish protective designations for critical park surface and ground water resources; coordinating and administering cooperating agency long-term monitoring programs in parks; transferring state-of-the-art information on aquatic contaminants and aquatic toxicity issues; and assuming responsibility for special studies requiring specialized technical or regulatory/policy skills, or which deal with significant issues of multi-park, regional or national scope (*NPS, 2008h*). In addition, the program provides technical assistance to parks without access to the specialized skills represented by the Water Quality Program staff. The water quality program provides program leadership and technical services in the following areas (*NPS, 2008h*):

- *Water Quality Baseline Inventories;*
- *Water Quality Vital Signs Monitoring (chemical, physical, biological);*
- *Aquatic contaminants and aquatic toxicity;*

- *The application of regulatory tools to water quality protection;*
- *Water quality strategic planning and reporting; and*
- *Water quality data management*

The NPS water rights program office, the Water Rights Branch, assists park management by providing scientific expertise concerning hydrologic systems and leadership in developing and implementing policy and procedures for legal and regulatory water rights processes under state and federal law (*NPS, 2008i*). The Water Rights Branch is organizationally located in the Water Resources Division of the Natural Resource Program Center under the Associate Director, Natural Resource Stewardship and Science (*NPS, 2008i*). Because of the legal nature of water rights, the NPS relies on legal expertise provided by attorneys in the Department of the Interior's Office of the Solicitor (*NPS, 2008i*). Water rights are created by Congressional action or through compliance with state law and they become fully established when their characteristics are determined and affirmed either by a court or state administrative official, such as a state engineer (*NPS, 2008i*). Characterization involves identifying the water-dependent purposes of a park unit, any other water uses necessary for park resources and visitors, and determining the quantity of water necessary to support those purposes and uses (*NPS, 2008i*). Once established, the NPS must participate in administrative and legal processes to protect its water rights against injury by existing or proposed water uses (*NPS, 2008i*).

The Wild and Scenic Rivers (WSR) Act was passed in 1968 and was specifically intended by Congress to balance the federal government's role in altering rivers for economic development (*NPS, 2008j*). It strived to meet this balance by establishing a new policy of protecting and enhancing designated rivers' free-flowing condition, water quality and "outstandingly remarkable values" (ORVs), which may include scenic, recreational, historical, cultural, fish, wildlife, ecological, geological, and hydrological values (*NPS, 2008j*). As of December 2006, the NPS has statutory management and regulatory responsibilities on 37 WSRs flowing more than 2,800 miles throughout the United States (*NPS, 2008j*). Of this total, 28 of the rivers are units of the National Park System or contained within a park, and nine are partnership rivers managed in cooperation with state and local governments (*NPS, 2008j*). Additionally, the NPS has a regulatory role on another 19 WSRs managed by states or tribes under Section 2(a)(ii) of the Act, totaling another 881 miles (*NPS, 2008j*). The NPS has significant responsibilities to ensure that WSRs under our care are fully preserved in their free-flowing condition, and that their water quality and ORVs are protected. The Act requires the NPS to (*NPS, 2008j*):

- *Prepare Comprehensive River Management Plans that identify how to protect and enhance the river and those characteristics for which the segment was designated.*
- *Establish boundaries and river classification for all designated segments.*
- *Serve in a regulatory capacity by evaluating and approving (or denying) proposed federally assisted water resources projects that could affect designated NPS segments and state managed and partnership federal wild and scenic river segments.*

- *Assist, advise and cooperate with the States in the designation and management of rivers, and seek opportunities for sharing management responsibilities with States and other partners.*

C-2.8.4 U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service (FWS) is the only agency of the U.S. Government whose primary responsibility is fish, wildlife, and plant conservation (*DOI, 2008b*). The Service helps protect a healthy environment for people, fish and wildlife, and helps Americans conserve and enjoy the outdoors (*DOI, 2008b*). The Service's major responsibilities are for migratory birds, endangered species, certain marine mammals, and freshwater and anadromous fish (*DOI, 2008b*). Specific programs relevant to River Restoration include: the environmental contaminants program and fisheries and habitat conservation.

The environmental contaminants program tackles contaminants prevention, contaminants identification and assessment, and contaminant cleanup and resource restoration. For contaminant prevention, USFWS review environmental documents, legislation, regulations, and permits and licenses with pollution potential to ensure that harmful effects on fish, wildlife, and plants are avoided or minimized (*USFWS, 2008a*).

For the contaminants identification and assessment, USFWS conduct field studies to determine sources of pollution, to investigate pollution effects on fish and wildlife and their habitat, and to investigate fish and wildlife die-offs (*USFWS, 2008a*). Sites typically assessed include those impacted by pesticides, industrial wastes, oil and hazardous waste spills, and drain water from agricultural irrigation and mining, as well as Superfund sites and other sites contaminated at some time in the past (*USFWS, 2008a*). Contaminants specialists have also developed tools such as the Contaminants Assessment Process (CAP), which was developed in cooperation with the US Geological Survey (*USFWS, 2008a*).

For the contaminant cleanup and resource restoration, USFWS collects contaminants assessment data used to secure compensation for resources lost or degraded by hazardous waste releases or spills. These efforts are part of the Natural Resource Damage Assessment and Restoration Program (Restoration Program) (*USFWS, 2008a*). USFWS also takes part, through contaminants identification, assessment, planning and restoration, in the Department of Interior's National Irrigation Water Quality Program (NIWQP) (*USFWS, 2008a*). Contaminant specialist are often called in by the US Environmental Protection Agency (EPA), US Coast Guard, or various other Federal or State agencies responsible for cleaning up a contaminated area, to ensure that fish and wildlife and their habitat are adequately protected during, and upon completion of, the cleanup (*USFWS, 2008a*). Contaminants specialists also work closely with National Wildlife Refuge managers to design and implement actions to cleanup oil and hazardous material on refuge lands (*USFWS, 2008a*).

The Fisheries and Habitat Conservation Program works with partners to achieve: Healthy fish and wildlife; Healthy habitats; Healthy people; and a Healthy economy (*USFWS, 2008b*). The Fisheries and Habitat Conservation Program is unique within the US Fish and Wildlife Service in its capabilities to apply a multifaceted approach to resource management (*USFWS, 2008b*). The Program conserves and restores habitat to ensure that fish and wildlife populations are sustained for the benefit of current and future generations of Americans (*USFWS, 2008b*). Fisheries and Habitat Conservation relies on collaboration with State agencies, Tribes, private landowners, industry, other federal agencies, and the public to achieve its conservation goals and objectives (*USFWS, 2008b*). Expertise areas within the Program include (*USFWS, 2008b*):

- *Habitat restoration*
- *Contaminant assessment and remediation*
- *Genetics*
- *Population dynamics and management*
- *Fish culture and fish health*
- *Fish passage*
- *Invasive species management*
- *Wetlands inventory, monitoring and mapping*
- *Water quality, development and management*
- *Wildlife management, and*
- *Permitting in energy, transportation, and other activities.*

USFWS identifies that habitat is a combination of environmental factors that provides food, water, cover and space that a living thing needs to survive and reproduce (*USFWS, 2008b*). There are many different types of habitats, including: coastal and estuarine, rivers and streams, lakes and ponds, wetlands, riparian areas, deserts, grasslands/prairie, forests, coral reefs, marine, perennial snow and ice, and urban (*USFWS, 2008b*). Fisheries and Habitat Conservation programs are dedicated to improving the health all types of habitat so that they are able to support healthy fish and wildlife, healthy people, and a healthy economy (*USFWS, 2008b*). Fisheries and Habitat Conservation programs are involved in habitat protection and restoration; partnerships, grants, and financial assistance; assessment and monitoring; project planning, permits, technical assistance and review; and public awareness and education (*USFWS, 2008b*).

C-2.8.5 U.S. Geological Survey

The U.S. Geological Survey (USGS) serves the Nation as an independent fact-finding agency that collects, monitors, analyzes, and provides scientific understanding about natural resource conditions, issues, and problems (*DOI, 2008b*). The value of the USGS to the Nation rests on its ability to carry out studies on a national scale and to sustain long-term monitoring and assessment of natural resources (*DOI, 2008b*). Because it has no regulatory or management mandate, the USGS provides impartial science that serves the needs of a changing world (*DOI, 2008b*). The diversity of scientific expertise enables the USGS to carry out large-scale, multi-disciplinary investigations that build the base of knowledge about the Earth and in turn, decision makers at all levels of government-and citizens in all walks of life- have the information tools they need to address pressing societal issues (*DOI, 2008b*). The USGS is an important organization for River Restoration and provides a large majority of data used in the proper configuration of restoration projects. The main science areas where the USGS provides valuable contributions include: Biology; Geography; Geology; Geospatial; and Water.

Due to the extensive programs, only a surficial overview will be presented in this appendix.

Biology - The Biological Resource Division (BRD) works with others to provide the scientific understanding and technologies needed to support the sound management and conservation of biological resources. The following general principles guide the implementation of our mission and form the basis of our strategic planning (*USGS, 2008a*):

- *BRD develops scientific and statistically reliable methods and protocols to assess the status and trends of the Nation's biological resources.*
- *BRD utilizes tools from the biological, physical, and social sciences to understand the causes of biological and ecological trends and to predict the ecological consequences of management practices.*
- *BRD leads in the development and use of the technologies needed to synthesize, analyze, and disseminate biological and ecological information.*
- *BRD strives for quality, integrity, and credibility of its research and technology by constantly improving its scientific programs through internal quality control, external peer review, and competitive funding.*
- *BRD enters into partnerships with scientific collaborators to produce high-quality scientific information and partnerships with the users of scientific information to ensure this information's relevance and application to real problems.*

- *BRD provides reliable scientific information to all American citizens while recognizing a special obligation to serve the biological information needs of Department of the Interior bureaus.*
- *BRD strives for a diverse, safe, healthy, and productive workforce, and provides opportunities for the continuing education and professional development of its employees.*

There are eight programs within the BRD: biological informatics; contaminant biology; cooperative research units; ecosystems; wildlife, terrestrial and endangered resources; status and trends of biological resources; invasive species; and fisheries, aquatic and endangered resources. A large number of individual publications are available on this topic and are available via the online USGS publications website (http://library.usgs.gov/).

Geography - USGS Geography observes the Earth with remote sensing satellites, USGS geographers monitor and analyze changes on the land, study connections between people and the land, and provide society with relevant science information to inform public decisions (*USGS, 2008b*). Within the Geography Division, there are six science centers: Earth Resources Observations and Science (EROS) Center; the Eastern Geographic Science Center (EGSC); the Mid-Continent Geographic Center (MCGSC), the Rocky Mountain Geographic Science Center (RMGSC), the Western Geographic Science Center (WGSC), and the Alaska Science Center (ASC). The primary (general) center that provides valuable information for River Restoration is EROS. Region-specific information can be found within the regional science centers (EGSC, MCGSC, RMGSC, WGSC, and ASC).

Earth Resources Observation and Science (EROS) is a data management, systems development, and research field center (*USGS, 2008b*). EROS opened in the early 1970's with a handful of employees and the largest mainframe computer in the State of South Dakota and now houses one of the largest computer complexes in the Department of the Interior (*USGS, 2008b*). Data can be accessed via the USGS Global Visualization Viewer, Earth Explorer, Photo Finder, Map Finder, and EOS Data (*USGS, 2008b*). The most powerful data collection site maintained by the USGS and EROS is the National Map Seamless Server (www.seamless.usgs.gov).

Geology - USGS Geology efforts address major societal issues that involve geologic hazards and disasters, climate variability and change, energy and mineral resources, ecosystem and human health, and ground-water availability and characterizes the geological landscape and provides the US with fundamental geochemical and geophysical data (*USGS, 2008d*). Primary areas that the geology program contributes to River Restoration are: landslides, climate change, and geologic mapping.

The primary objective of the National Landslide Hazards Program (LHP) is to reduce long-term losses from landslide hazards by improving our understanding of the causes of ground failure and suggesting mitigation strategies (*USGS, 2008e*). The LHP has operated since the mid-1970's in gathering information, conducting research, responding to emergencies and disasters, and producing scientific reports and other products for a broadly based user community including geologists and engineers in government, academia and private practice, planners and decision makers from governmental entities at all levels, and the general public (*USGS, 2008e*). Landslide susceptibility maps are available from http://landslides.usgs.gov/learning/nationalmap/.

The USGS Global Change Research activities strive to achieve a whole-system understanding of the interrelationships among earth surface processes, ecological systems, and human activities (*USGS, 2008f*). Activities of the program focus on documenting, analyzing, and modeling the character of past and present environments and the geological, biological, hydrological, and geochemical processes involved in environmental change so that future environmental changes and impacts can be anticipated (*USGS, 2008f*).

The National Cooperative Geologic Mapping Program (NCGMP) provides accurate geologic maps and three-dimensional framework models that help to sustain and improve the quality of life and economic vitality of the U.S. and to mitigate natural hazards. The NCGMP represents over a decade of successful cooperation among Federal (FEDMAP), State (STATEMAP), and university (EDMAP) partners to deliver digital geologic maps to customers (*USGS, 2008g*). Each of these three components has a unique role, yet all work cooperatively to select and map high-priority areas for new geologic maps (*USGS, 2008g*). Geologic mapping data from all of North America is presented via the National Geologic Map Database and a common set of geologic map standards is being developed by the NCGMP in cooperation with the North American Geologic Map Data Model Steering Committee (*USGS, 2008g*). The National Geologic Map Database can be accessed here: http://ngmdb.usgs.gov/.

The Water Resources Discipline's mission is to provide reliable, impartial, timely information that is needed to understand the Nation's water resources and WRD actively promotes the use of this information by decision makers to (*USGS, 2008h*):

- *Minimize loss of life and property as a result of water-related natural hazards, such as floods, droughts, and land movement.*
- *Effectively manage ground-water and surface-water resources for domestic, agricultural, commercial, industrial, recreational, and ecological uses.*
- *Protect and enhance water resources for human health, aquatic health, and environmental quality.*
- *Contribute to wise physical and economic development of the Nation's resources for the benefit of present and future generations.*

Water Resource Programs include: cooperative water program, national streamflow information program, national water quality assessment program, toxic substances hydrology (toxics) program, ground water resources program, hydrologic networks and analysis, hydrologic research and development, state water resources research institute program, international water projects, and water information program. The majority of these programs provide valuable resources for River Restoration. In particular, the following programs are of special interest:

National Streamflow Information Program – The USGS operates and maintains approximately 7,500 stream gages which provide long-term, accurate, and unbiased information on streamflow (*USGS, 2008i*). NSIP is designed with five goals, one of which is to provide a "backbone" or core of stream gages that are critical to national stream flow information needs and that would be funded totally with Federal funds. The

NSIP was created in response to Congressional and stakeholder concerns about (1) a loss of stream gages, (2) a disproportionate loss of stream gages with a long period of record, (3) the inability of the USGS to continue operating high-priority stream gages when partners discontinue funding and (4) the increasing demand for streamflow information due to new resource-management issues and new data-delivery capabilities (*USGS, 2008i*). Streamflow information can be found here: http://waterdata.usgs.gov/nwis/sw/.

National Water Quality Assessment (NAWQA) Program - The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to develop long-term consistent and comparable information on streams, rivers, ground water, and aquatic systems in support of national, regional, State, and local information needs and decisions related to water-quality management and policy (*USGS, 2008j*). The NAWQA program is designed to address the following objectives and answer these questions (*USGS, 2008j*): *What is the condition of our Nation's streams, rivers, and ground water? How are these conditions changing over time? How do natural features and human activities affect these conditions, and where are those effects most pronounced?* From 1991-2001, the NAWQA Program conducted interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units. Descriptions of water-quality conditions in streams and ground water were developed in more than a thousand reports (*USGS, 2008j*). Non-technical Summary Reports, written primarily for those interested or involved in resource management, conservation, regulation, and policymaking, were completed for each of the 51 Study Units (*USGS, 2008j*). Non-technical national summary reports on pesticides, nutrients, and volatile organic compounds (VOCs) also were completed, in which water-quality conditions were compared to national standards and guidelines related to drinking water, protection of aquatic life, and nutrient enrichment (*USGS, 2008j*). The USGS National Water Quality Assessment Data Warehouse can be accessed at: http://infotrek.er.usgs.gov/traverse/f?p=NAWQA:HOME:0:.

In addition to these USGS programs, there are a plethora of USGS research efforts that have valuable contributions to the field of River Restoration. Some of these research efforts include:

Columbia Environmental Research Center (CERC) – The Columbia Environmental Research Center (CERC) addresses contaminant research in support of sound natural resource management of aquatic and terrestrial ecosystems (*USGS, 2008l*). CERC takes an integrated approach for complex resource problems, such as complexities that encompass several factors associated with the biological significance of degraded water quality that often includes physical landscape alterations, invasive species, and ecosystem restoration activities (*USGS, 2008l*).

Biomonitoring of Environmental Status and Trends Program (BEST) - The Biomonitoring of Environmental Status and Trends (BEST) Program was initiated, in part, as a revision and expansion of the National Contaminant Biomonitoring Program (NCBP) (*USGS, 2008m*). One aspect of the BEST program focuses on monitoring contaminants and effects across broad geographic areas and is currently being evaluated in the Mississippi, Columbia, Rio Grande, and Yukon River basins (*USGS, 2008m*). The overall objectives of the BEST program are to describe the occurrence and distribution of contaminants and their effects on fish in large US river basins; to quantitatively evaluate the performance of aquatic methods used by the BEST program; and to evaluate potential collaborations with the National Stream Quality Accounting Network (NASQAN) and the National Water Quality Assessment (NAWQA) programs of the USGS-Water Resources Division (*USGS, 2008m*).

Geomorphology and Sediment Transport Laboratory - The Geomorphology and Sediment Transport Laboratory (GSTL) is a new U.S. Geological Survey (USGS) facility that conducts research in three primary categories: basic research on fluid and sediment-transport mechanics governing the morphodynamics of rivers; applied research dealing with specific issues in American rivers; and software development, verification and dissemination for models of physical processes in rivers (*USGS, 2008n*). Most GSTL projects comprise field, laboratory, and computational components. GSTL has the expertise and equipment to carry out field studies in rivers and streams, with a majority of field work tied to laboratory and computational research, typically to collect basic data such as bathymetry for the application of numerical flow, sediment transport, bed evolution and/or habitat models or to collect data for model testing and verification (*USGS, 2008m*). GSTL staff develops software for modeling flow, sediment transport, and bed evolution in a wide variety of situations, with modeling techniques ranging from relatively simple 1-D or 2-D vertically averaged steady flow models to direct numerical simulation models based on the Navier-Stokes equations (*USGS, 2008m*). Some GSTL models are freely distributed within the Multi-dimensional Surface Water Modeling System (MD_SWMS). This software programs allows for 1, 2, and 3 dimensional modeling of flow.

C-2.9 U.S. Department of Transportation

The U.S. Department of Transportation (USDOT) is a federal cabinet department of the United States responsible for federal transportation issues (*USDOT, 2008*). It was established by an act of Congress on October 15, 1966 and began operations in April of 1967 (*USDOT, 2008*). The mission of USDOT is to serve the United States by ensuring a fast, safe, efficient, accessible and convenient transportation system that meets the vital national interest and enhances the quality of life of the American people (*USDOT, 2008*). An organizational chart of the USDOT is presented in Figure C10.

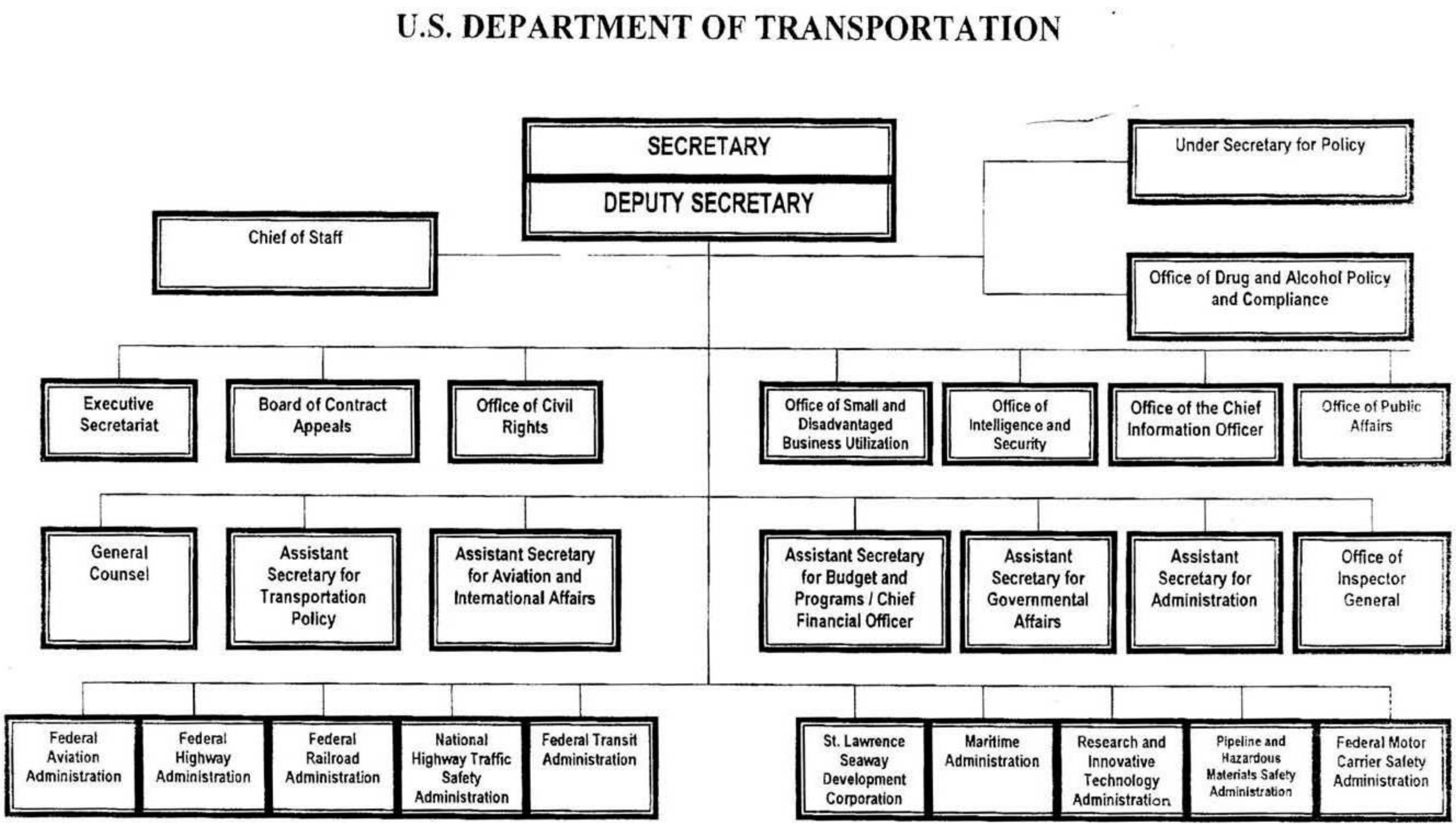

Figure C10: Organizational structure of the USDOT (*USDOT, 2008*).

There are thirteen divisions within the USDOT (*USDOT, 2008*): Federal Aviation Administration; Federal Highway Administration; Federal Motor Carrier Safety Administration; Federal Railroad Administration; Federal Transit Administration; Maritime Administration; National Highway Traffic Safety Administration; Office of Inspector General; Office of the Secretary of Transportation; Pipeline and Hazardous Materials Safety Administration; Research and Innovative Technology Administration; Saint Lawrence Seaway Development Corporation; and Surface Transportation Board. Of these divisions, the Federal Highway Administration makes direct contributions to the practice of River Restoration.

C-2.9.1 Federal Highway Administration (FHWA)

The Federal Highway Administration (FHWA) coordinates highway transportation programs in cooperation with states and other partners to "enhance the country's safety, economic vitality, quality of life, and the environment" (*FHWA, 2008a*). Major program areas include the Federal-Aid Highway Program, which provides federal financial assistance to the States to construct and improve the National Highway System, urban and rural roads, and bridges, providing funds for general improvements and development of safe highways and roads (*FHWA, 2008a*). The Federal Lands Highway Program provides access to and within national forests, national parks, Indian reservations and other public lands by preparing plans and contracts, supervising construction facilities, and conducting bridge inspections and surveys (*FHWA, 2008a*). The FHWA also manages a comprehensive research, development, and technology program.

A relatively new program is the Ecosystem Initiatives effort. In 2002 the FHWA identified ecosystem conservation as one of three performance objectives under the agency's "vital few" goal of Environmental Streamlining and Stewardship (*FHWA, 2008b*). FHWA promotes actions that take advantage of opportunities to enhance environmental protection and encourage partnerships that promote eco-system conservation or encourage broader mitigation strategies that seek corridor or watershed based approaches (*FHWA, 2008b*). The Vital Few Environmental Streamlining and Stewardship goal (Environment VFG) sets expectations, measures, and methods for advancing an improved and efficient environmental review process and for demonstrating environmental stewardship (*FHWA, 2008b*).

C-3 CALIFORNIA STATE AGENCIES

There are a number of State of California agencies that influence the practice of River Restoration. The primary knowledge base used in California stems from the Federal agencies, with adaptation due to site-specific conditions in California. The primary agencies that influence River Restoration in California are the Bay Conservation Development Commission, the California Coastal Commission, the Department of Water Resources, the Department of Fish and Game, the Department of Transportation, and the State Water Resources Quality Control Board. A more detailed discussion of these organizations is presented below.

C-3.1 Bay Conservation and Development Commission

The Bay Conservation and Development Commission (BCDC) is the federally-designated state coastal management agency for the San Francisco Bay segment of the California coastal zone (*BCDC, 2008a*). This designation empowers the Commission to use the authority of the federal Coastal Zone Management Act to ensure that federal projects and activities are consistent with the policies of the Bay Plan and state law (*BCDC, 2008a*). The mission of BCDC is to protect and enhance San Francisco Bay and to encourage responsible use of the Bay (*BCDC, 2008b*).

Alarmed by the fact that between 1850 and 1960 an average of four square miles of the Bay were filled each year, in 1961 citizens in the Bay Area formed the Save San Francisco Bay Association, now called Save the Bay (*BCDC, 2008a*). At the urging of this organization, state legislation--the McAteer-Petris Act--was passed in 1965 to establish the San Francisco Bay Conservation and Development Commission (BCDC) as a temporary state agency (*BCDC, 2008a*).

Today, there are four main areas within BCDC (*BCDC, 2008c*): Planning, Dredging and sediment management, Permits, and Enforcement.

The Planning unit is responsible for conducting major planning studies, specialized research and policy development, and developing amendments to the San Francisco Bay Plan (*BCDC, 2008c*).

The Dredging and Sediment Management unit works with its federal, state and local partners in the Long Term Management Strategy for the Placement of Dredged

Material in the San Francisco Bay Region (LTMS) to manage dredging and disposal activities in the Bay Area (*BCDC, 2008c*).

The Permit unit includes a small team of planners, analysts, an engineer, a designer, a biologist and secretaries who oversee the permit process for any work in the Bay or within 100 feet of the shoreline, including filling, dredging, shoreline development and other work (*BCDC, 2008c*).

The Enforcement unit ensure adherence to the laws protecting the San Francisco Bay region and deal with violations (*BCDC, 2008c*). Highest priority is given to those violations that involve potential harm to the Bay's natural resources or failure to provide public access or mitigation required by a BCDC permit (*BCDC, 2008c*). Anyone can report alleged violations to BCDC's staff for investigation (*BCDC, 2008c*). Permits are routinely monitored to ensure that the conditions of authorization have been met and BCDC staff members conduct site visits to ensure that the public access has been built and maintained as required by permits (*BCDC, 2008c*). The most serious violations are referred to the Commission's Enforcement Committee or to the Attorney General's Office for prosecution (*BCDC, 2008c*). However, the majority of the violations can be resolved at the staff level using the standardized fines provided in BCDC's regulations (*BCDC, 2008c*).

BCDC impacts River Restoration in those areas where the river drains to the ocean and falls within the designated San Francisco Bay zone.

C-3.2 Coastal Commission

The California Coastal Commission was established by voter initiative in 1972 (Proposition 20) and later made permanent by the Legislature through adoption of the California Coastal Act of 1976 (*California Coastal Commission, 2008a*). The mission of the Coastal Commission is to protect, conserve, restore, and enhance environmental and human-based resources of the California coast and ocean for environmentally sustainable and prudent use by current and future generations (*California Coastal Commission, 2008a*).

The Commission is an independent, quasi-judicial state agency. The Commission is composed of twelve voting members, appointed equally (four each) by the Governor, the Senate Rules Committee, and the Speaker of the Assembly (*California Coastal Commission, 2008a*). Six of the voting commissioners are locally elected officials and six are appointed from the public at large (*California Coastal Commission, 2008a*). Three ex officio (non-voting) members represent the Resources Agency, the Business, Transportation and Housing Agency, and the State Lands Commission (*California Coastal Commission, 2008a*).

The coastal zone, which was specifically mapped by the Legislature, covers an area larger than the State of Rhode Island (*California Coastal Commission, 2008a*). On land the coastal zone varies in width from several hundred feet in highly urbanized areas up to five miles in certain rural areas, and offshore the coastal zone includes a three-mile-wide band of ocean (*California Coastal Commission, 2008a*). The coastal zone established by the Coastal Act does not include San Francisco Bay, where development is regulated by the Bay Conservation and Development Commission (*California Coastal Commission, 2008a*)

Along with the Bay Conservation and Development Commission (BCDC), the Coastal Commission is one of California's two designated coastal management agencies for the purpose of administering the federal Coastal Zone Management Act (CZMA) in California (*California Coastal Commission, 2008a*). The most significant provisions of the federal CZMA give state coastal management agencies regulatory control (federal consistency review authority) over all federal activities and federally licensed, permitted or assisted activities, wherever they may occur (i.e., landward or seaward of the respective coastal zone boundaries fixed under state law) if the activity affects coastal resources (*California Coastal Commission, 2008a*). Examples of such federal activities include: outer continental shelf oil and gas leasing, exploration and development; designation of dredge material disposal sites in the ocean; military projects at coastal locations; U.S. Army Corps of Engineers fill permits; certain U.S. Fish and Wildlife Service permits; national park projects; highway improvement projects assisted with federal funds; and commercial space launch projects on federal lands (*California Coastal Commission, 2008a*).

The primary programs of the California Coastal Commission include (*California Coastal Commission, 2008b*): Coastal access program; ReCAP and local coastal program periodic reviews; Local coastal programs, Water quality program; Enforcement program; Federal consistency; Oil spill program; and Public education and volunteer programs.

The California Coastal Commission impacts River Restoration in those areas where the river drains to the ocean and falls within the designated 'coastal zone.'

C-3.3 Coastal Conservancy

The California Coastal Conservancy, established in 1976, is a State of California agency that uses entrepreneurial techniques to purchase, protect, restore, and enhance coastal resources, and to provide access to the shore and works in partnership with local governments, other public agencies, nonprofit organizations, and private landowners (*California Costal Conservancy, 2008a*).

To date, the Conservancy has undertaken more than 1,800 projects along the 1,100 mile California coastline and around San Francisco Bay, frequently accomplishing multiple goals (*California Costal Conservancy, 2008a*). Through these projects, the Conservancy (*California Costal Conservancy, 2008a*):

- *protects and improves coastal wetlands, streams, and watersheds;*
- *helps people get to coast and bay shores by building trails and stairways and by acquiring land and easements. The Conservancy also assists in the creation of low-cost accommodations along the coast, including campgrounds and hostels;*
- *works with local communities to revitalize urban waterfronts;*
- *helps to solve complex land-use problems;*
- *purchases and holds environmentally valuable coastal and bay lands;*
- *protects agricultural lands and supports coastal agriculture; and*
- *accepts donations and dedications of land and easements for public access, wildlife habitat, agriculture, and open space.*

The Coastal Conservancy has a staff of about 77 and a current annual budget of $140 million (*California Costal Conservancy, 2008a*). Since 1976, the Conservancy has used almost $1.5 billion to complete its projects, with funds coming from state general obligation bonds and from the state's general fund (*California Costal Conservancy, 2008a*).

The Legislature created the Coastal Conservancy as a unique entity with flexible powers to serve as an intermediary among government, citizens, and the private sector in recognition that creative approaches would be needed to preserve California's coast and San Francisco Bay lands for future generations (*California Costal Conservancy, 2008a*). The Coastal Conservancy's non-regulatory, problem-solving approach complements the work of the California Coastal Commission, a distinct agency that regulates land use along the coast and issues development permits (*California Costal Conservancy, 2008a*). The Coastal Conservancy also coordinates its work with the San Francisco Bay Conservation and Development Commission (BCDC), an agency created to protect and enhance San Francisco Bay and encourage the responsible use of its resources (*California Costal Conservancy, 2008a*).

The California Coastal Conservancy impacts River Restoration in those areas where the river drains to the ocean and falls within the coastal zone. It has one active program area in Santa Cruz County called "Integrated Watershed Restoration Program for Santa Cruz County" or IWRP.

C-3.3.1 Integrated Watershed Restoration Program (IWRP)

Beginning in the late 1990s, eight separate watershed restoration plans and a number of other related assessments were developed for seven watersheds located within Santa Cruz County and it was recognized that watershed restoration would be more effective as a coordinated county-wide effort (*IWRP, 2008*). In May 2002, the concept for the Integrated Watershed Restoration Program (IWRP) for Santa Cruz County was developed (*IWRP, 2008*). The goal of IWRP is to support local watershed partners in developing projects and to coordinate agencies that provide technical assistance, permits, and funds, reducing staff time required while helping to ensure that critical projects are identified, funded, and permitted (*IWRP, 2008*).

IWRP aims to improve the effectiveness of watershed restoration through a variety of approaches (*IWRP, 2008*). For local organizations and individuals doing watershed restoration, IWRP will ease the process by providing technical assistance, facilitating the design and permitting of projects, and providing clear priorities and guidance to help develop more competitive proposals (*IWRP, 2008*). In order to ease the burdens of dwindling agency staff, IWRP provides a framework to coordinate state watershed priorities and funding (*IWRP, 2008*). To evaluate project successes and identify future needs, IWRP supports the creation of a county-wide restoration monitoring program, and as a complement to physical projects, IWRP supports watershed outreach and education endeavors (*IWRP, 2008*). These targets and the mechanisms are summarized below in the IWRP "Objectives" (*IWRP, 2008*).

1. Coordinate agencies on the identification, funding, and implementation of watershed restoration projects.

2. Target proposals to critical projects supported by the resource agencies.

3. Facilitate higher quality designs at lower cost.

4. Simplify the permit process for watershed restoration projects.

5. Effect institutional change to improve watershed restoration efforts.

6. Develop a countywide outreach and education program.

7. Develop a countywide watershed restoration monitoring program geared toward future project identification needs.

8. Develop additional assessments and plans as needed.

9. Serve as a watershed restoration information hub for Santa Cruz County.

C-3.4 California Environmental Protection Agency

The California Environmental Protection Agency (Cal/EPA) was created in 1991 by Governor's Executive Order within the Cal/EPA "umbrella" to create a cabinet level voice for the protection of human health and the environment and to assure the coordinated deployment of State resources (*Cal/EPA, 2008a*). The mission of Cal/EPA is to restore, protect and enhance the environment, to ensure public health, environmental quality and economic vitality (*Cal/EPA, 2008a*). The term "Cal/EPA" is used both to refer to the Office of the Secretary and to the entire agency (the Office of the Secretary and the constituent entities) (*Cal/EPA, 2008a*).

The Cal/EPA departments consist of: the Office of the Secretary; the Air Resources Board; the Department of Pesticide Regulation; the Department of Toxic

Substances Control; the Integrated Waste Management Board; the Office of Environmental Health Hazard Assessment; and the State Water Resources Control Board. The State Water Resources Control Board has a direct impact on River Restoration and a discussion of this organization is presented below.

C-3.4.1 State Water Resources Control Board

The State Water Resources Control Board (SWRCB) is a five-member board that was created by the California Legislature in 1967, charged with setting statewide policy, coordinating and supporting the Regional Water Boards efforts, and reviewing petitions that contest Regional Board actions (*SWRCB, 2008a*). The mission of SWRCB is to preserve, enhance, and restore the quality of California's water resources and ensure their proper allocation and efficient use for the benefit of present and future generations. SWRCB is solely responsible for allocating surface water rights (*SWRCB, 2008a*).

There are nine regional water quality control boards statewide (1-North Coast; 2-San Francisco Bay; 3-Central Coast; 4-Los Angeles; 5-Central Valley; 6-Lahontan; 7-Colorado River Basin; 8-Santa Ana; and 9-San Diego) and these regional boards are semi-autonomous and are comprised of nine part-time Board members appointed by the Governor and confirmed by the Senate (*SWRCB, 2008a*). Regional boundaries are based on watersheds and water quality requirements are based on the unique differences in climate, topography, geology, and hydrology for each watershed (*SWRCB, 2008a*). Each Regional Board makes water quality decisions for its region, including setting standards, issuing waste discharge requirements, determining compliance with those requirements, and taking appropriate enforcement actions (*SWRCB, 2008a*).

There are four major SWRCB programs (*SWRCB, 2008a*):

- *Water Quality* – *SWRCB works in coordination with the Regional Water Boards to preserve, protect, enhance, and restore water quality, with focus areas consisting of: Stormwater; Wastewater treatment; Water quality monitoring; Wetlands protection; Ocean protection; Environmental education; Environmental justice; Clean up contaminated sites, including brownfields; Low-impact development;*
- *Financial Assistance* – *SWRCB provides loans and grants for constructing municipal sewage and water recycling facilities, remediation for underground storage tank releases, watershed protection projects, and for nonpoint source pollution control projects. SWRCB has several financial programs to help local agencies and individuals prevent or clean up pollution of the state's water;*
- *Water Rights* – *Anyone wanting to divert water from a stream or river not adjacent to their property must first apply for a water right permit from SWRCB. SWRCB issues permits for water rights specifying amounts, conditions, and construction timetables for diversion and storage. Decision-making stems from water availability, prior water rights, and flows needed to preserve in stream uses, such as recreation and fish habitat;*
- *Enforcement* – *SWRCB and the nine Regional Water Quality Control Boards are responsible for swift and fair enforcement when the laws and*

regulations protecting waterways are violated. SWRCB has recently created an Office of Enforcement to assist and coordinate enforcement activities statewide. The Water Boards also work with federal, state, and local law enforcement, as well as other environmental agencies to ensure a coordinated approach to protecting human health and the environment.

There are a number of important resources available through the SWRCB and the Regional Water Boards for the practice of River Restoration. These resources include the California Integrated Water Quality System Project (CIWQS), the Watershed Management Initiative (WMI); the Total Maximum Daily Load Program; the Construction Storm Water Program; and Educational and Public Outreach.

The California Integrated Water Quality System (CIWQS) is a computer system used by the State and Regional Water Quality Control Boards to track information about places of environmental interest, manage permits and other orders, track inspections, and manage violations and enforcement activities (*SWRCB, 2008b*). CIWQS also allows online submittal of information by Permittees within certain programs and makes data available to the public through reports. Currently, individual National Pollutant Discharge Elimination System permit holders and enrollees under the statewide general sanitary sewer overflow (SSO) order and industrial stormwater permit may be able to submit information to CIWQS (*SWRCB, 2008b*). The Water Boards have developed a number of reports that display the regulatory data that CIWQS contains (SWRCB, 2008b).

The Water Management Initiative (WMI) was approved as part of the 1995 Strategic Plan and established a broad framework overlying the numerous federal and state mandated priorities (*SWRCB, 2008b*). As such, the WMI helps the Water Board to achieve water resource protection, enhancement and restoration while balancing economic and environmental impacts (*SWRCB, 2008b*). The goals and objectives include (*SWRCB, 2008b*): Use water quality to identify and prioritize water resource problems within individual watersheds. Involve stakeholders to develop solutions; Better coordinate point source and nonpoint source regulatory efforts. Establish working relationships between staff from different programs; and Better coordinate local, state and federal activities and programs, especially those relating to regulations and funding, to assist local watershed groups.

Through the WMI effort, the Regional Boards developed watershed management strategies that consider local conditions and pollution sources for their priority watersheds (*SWRCB, 2008c*). Each Regional Board's WMI Chapter contains these strategies and identifies priorities, where baseline resources will be spent, and where more resources are needed and each WMI chapter is updated as needed by the Regional Board or by a directive from the State Water Board (*SWRCB, 2008c*). The WMI chapters can be accessed here: http://www.waterboards.ca.gov/water_issues/programs/watershed/.

TMDLs in California are developed either by RWQCBs or by USEPA (*SWRCB, 2008f*). TMDLs developed by RWQCBs are designed as Basin Plan amendments and include implementation provisions (*SWRCB, 2008f*). TMDLs developed by USEPA typically contain the total load and load allocations required by Section 303(d), but do not contain comprehensive implementation provisions; this stems from the fact that USEPA authorities related to implementation of nonpoint source pollution control measures are generally limited to education and outreach as provided by CWA Section 319 (*SWRCB, 2008f*). Although the abbreviation stands for "Total Maximum Daily Load," the limitations contained in a TMDL may be other than "daily load" limits (*SWRCB, 2008f*). There also can be multiple TMDLs on a particular water body, or there can be one TMDL that addresses numerous pollutants (*SWRCB, 2008f*). The basis for grouping is whether or not there can be a common analytical approach to the assessment or a common management response to the impairment (*SWRCB, 2008f*).

SWRCB regulates earthwork construction projects that disturb one or more acres of soil (or whose projects disturb less than one acre but are part of a larger common plan of development that in total disturbs one or more acres) as part of their nonpoint source stormwater pollution control program, and a General Permit for Discharges of Storm Water Associated with Construction Activity (Construction General Permit, 99-08-DWQ) must be obtained (*SWRCB, 2008g)*. Activities subject to this permit includes clearing, grading and disturbances to the ground such as stockpiling, or excavation, but does not include regular maintenance activities performed to restore the original line, grade, or capacity of the facility (*SWRCB, 2008f*).

The Construction General Permit requires the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP), which should contain a site map(s) which shows the construction site perimeter, existing and proposed buildings, lots, roadways, storm water collection and discharge points, general topography both before and after construction, and drainage patterns across the project (*SWRCB, 2008f*). The SWPPP must list Best Management Practices (BMPs) the discharger will use to protect storm water runoff and the placement of those BMPs (*SWRCB, 2008f*). Additionally, the SWPPP must contain a visual monitoring program; a chemical monitoring program for "non-visible" pollutants to be implemented if there is a failure of BMPs; and a sediment monitoring plan if the site discharges directly to a water body listed on the 303(d) list for sediment (*SWRCB, 2008f*).

Through the Education program, SWRCB has developed educational curriculum and outreach tools and materials ("Erase the Waste") to inform the public and its varied stakeholders about the Board and its mission and to involve them in water quality decisions and pollution prevention efforts (*SWRCB, 2008d*). Through the Public Outreach program, SWRCB educates the general public about water quality issues, and water pollution prevention with information, tools and activities designed to reach out to municipalities, service clubs, civic organizations, watershed groups, youths and other members of the general public (*SWRCB, 2008e*).

C-3.5 California Resources Agency

C-3.5.1 CALFED Bay-Delta Program

The CALFED Bay-Delta Program is a collaboration among 25 state and federal agencies that came together with a mission to improve California's water supply and the ecological health of the San Francisco Bay/Sacramento-San Joaquin River Delta (*CALFED, 2008a*). CALFED was created because of the importance of the Delta to California, with the majority of the state's water running through the Delta and into aqueducts and pipelines that distribute water to 25 million Californians throughout the state, making it the single largest and most important source of water for drinking, irrigation and industry (*CALFED, 2008a*).

The CALFED agencies include (*CALFED, 2008g*): the California Bay-Delta Authority; California State Parks; Department of Water Resources; Department of Fish and Game; the Reclamation Board; the Delta Protection Commission; the Department of Conservation; the San Francisco Bay Conservation and Development Commission; the State Water Resources Control Board; the Department of Health Services; the Department of Food and Agriculture; the Bureau of Reclamation; the U.S. Fish and Wildlife Service; the U.S. Geological Survey; the Bureau of Land Management; the Environmental Protection Agency; the U.S. Army Corps of Engineers; the Natural Resources Conservation Service; the U.S. Forest Service; NOAA Fisheries; and the Western Area Power Administration.

As an ecosystem, the Delta is unique as the largest estuary on the Pacific Coast and home to more than 750 species of flora and fauna, as well as being a home to more than 500,000 people, a major recreation destination, and a crossroads for Northern California infrastructure (*CALFED, 2008a*). Finally, the importance of the Delta has made it a politically-charged battleground that has compounded the issue of finding solutions to its problems as an aging and increasingly fragile system susceptible to the forces of land subsidence, seasonal flooding, a future of climate change and sea level rise, the specter of earthquake and the collapse of its ecosystem (*CALFED, 2008a*).

There are four primary program objectives for CALFED, consisting of: water quality, levee integrity, water supply, and ecosystem restoration. All of these program objectives impact River Restoration and a brief summary of these programs is presented below.

C-1.1.1.1 Water Quality

The Water Quality Program focuses on drinking water quality, and has invested in projects supporting goal six of the Strategic Plan to "Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed; and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife and people" (*CALFED, 2008b*). There are three objectives that support this goal: reduced loadings and concentrations of toxic contaminants; reduced loadings of oxygen-depleting substances from human activities; and reduced fine sediment loadings from human activities into rivers and streams to levels that do not cause adverse ecological effects (*CALFED, 2008b*).

The Water Quality Program emerged with the beginning of CALFED in 2000, stemming from historical conflicts over water in California and the struggle to optimize water supply while minimizing impacts to fish and water quality within the Delta (*CALFED, 2008b*). The CALFED Water Quality Program coordinates the many agency roles and responsibilities for Delta water quality. In California, source water quality has been regulated by the State Water Resources Control Board and its nine Regional Water Quality Control Boards through controls on discharges and water rights (*CALFED, 2008b*). Both treated drinking water quality and source water quality are regulated to protect many beneficial uses, including household, fish, agricultural, municipal and recreational. Treated drinking water is regulated by the California Department of Public

Health. The California Department of Fish and Game, the National Marine Fisheries Service, and the U.S. Fish and Wildlife Service regulate impacts on fish and formulate plans to recovery endangered and threatened species (*CALFED, 2008b*). The California Department of Water Resources and the U.S. Bureau of Reclamation operate large water supply projects that deliver Delta water to its agricultural, municipal and industrial uses throughout California. The U.S. Geological Survey monitors, assesses and researches water flow and quality throughout the Delta watershed (*CALFED, 2008b*).

The water quality efforts of CALFED directly impact the quantity and quality of the water for ecological components of River Restoration.

C-1.1.1.2 Levee Integrity

CALFED's Levee System Integrity Program aims to provide long-term protection for resources in the Delta by maintaining and improving the integrity of the estuary's extensive levee system (*CALFED, 2008c*). These resources include the quality of the Delta's water and the health of its ecosystem, but the 500,000 people who call the Delta home, the many towns and villages in the Delta, infrastructure such as utilities and transportation corridors, and economic assets of thriving agriculture and recreational industries (*CALFED, 2008c*). The goal of the Levee System Integrity Program is to reduce risk to land use and associated economic activities, water supply, agriculture and residential use, infrastructure and the ecosystem from the effects of catastrophic breaching of Delta levees (*CALFED, 2008c*).

Specific actions for the levee integrity program include (*CALFED, 2008d*): providing a base level of protection; implementing special improvement projects to enhance protection beyond the base level protection for key levees that protect public benefits such as water quality, life, personal property, as well as local and state infrastructures; implementing a levee subsidence control plan and developing 'best management practices' to minimize levee integrity risk; implementing an emergency management and response plans to enhance the emergency preparedness of local, State, and Federal agencies; and finally an evaluation of levees in the Suisun marsh.

C-1.1.1.3 Water Supply

CALFED's Water Supply Reliability Program is achieved through five program elements: Conveyance, Storage, Environmental Water Account, Water Use Efficiency and Water Transfers (*CALFED, 2008e*). Through partnerships with local and regional agencies, these programs seek to increase water supplies, ensure efficient use of water resources and add flexibility to California's water system (*CALFED, 2008e*). This program seeks to reduce the mismatch between Delta water supplies, and current and projected beneficial uses dependent upon the Bay-Delta system (*CALFED, 2008e*).

The Water Supply Reliability Program emerged with the beginning of CALFED in 2000, stemming from historical conflicts over water in California, where the majority of the state's population lives in the southern and western parts of the state and the majority of its precipitation occurs in the northern and eastern parts of the state (*CALFED, 2008e*). Conflicts over this mismatch intensified as Southern California emerged as a population center, and whenever the state faced drought conditions (*CALFED, 2008e*). The conflict over sending water from north/east to south/west has also intensified with discussions of a peripheral canal (*CALFED, 2008e*). Since inception of the Water Supply

Reliability Program, more water has been reliably delivered than in the years of crisis before the establishment of CALFED (*CALFED, 2008e*).

To that overall success, the Environmental Water Account was credited in its first year of existence (2001) with helping to protect winter-run salmon, Delta smelt and splittail, while continuing water deliveries that otherwise would have been curtailed (*CALFED, 2008e*). In that year, approximately 290,000 acre-feet of EWA water was released at key times (*CALFED, 2008e*). EWA proved its worth again in 2007, when it made up for shortages due to state pumping halts to save threatened Delta smelt (*CALFED, 2008e*).

The Storage Program dates back to the late 1960s, when the majority of California's reservoirs were built (*CALFED, 2008e*). Designed to provide water for 20 million Californians, they are deemed inadequate for the state's expected 50 million population projected by 2020 (*CALFED, 2008e*). State and federal agencies have considered 52 potential locations for increased surface storage in California, narrowing the list down to five sites based on numerous factors: estimated size, cost, and environmental impacts (*CALFED, 2008e*).

The Conveyance Program is the history of the two largest conveyance projects in California -- the SWP and the federal Central Valley Project (CVP) (*CALFED, 2008e*). Construction of CVP began in the late 1930s and SWP followed some 20 years later and both were multi-year projects that included numerous phases (*CALFED, 2008e*). They allowed vast tracts of previously uninhabitable land to become prosperous farms and bustling cities and fueled the population and economic growth of California (*CALFED, 2008e*).

The Water Transfers Program evolved from a 1976 report of the Governor's Commission on Water Rights that recognized water transfers as important to the future of California's water supply (*CALFED, 2008e*). Through CALFED, the roles of the state and federal agencies in the water transfer process changed and they assumed added responsibilities (*CALFED, 2008e*). Water transfers for irrigation and drinking are unlike those of CALFED's Environmental Water Account that focuses on environmental needs to benefit Delta fisheries when CALFED agencies invoke export reductions (*CALFED, 2008e*).

The Water Use Efficiency Program, with a three-pronged approach through conservation, desalination and recycling, was created in 2000 with the signing of the CALFED Record of Decision (*CALFED, 2008e*). Recycling has been the best funded of the three program components, but all have made progress toward goals (*CALFED, 2008e*).

C-1.1.1.4 Ecosystem Restoration

CALFED's Ecosystem Restoration Program is implemented through the ERP and Watershed Program Elements and works to improve the ecological health of the Bay-Delta watershed through restoring and protecting habitats, ecosystem functions and native species (*CALFED, 2008f*). The Watershed Program Element specifically works in tandem with the Ecosystem Restoration Program Element to ensure that ecological health of the Delta is restored and that water management is improved by working with communities at the watershed level (*CALFED, 2008f*).

The goal of the Ecosystem Restoration Program Element is to improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species (*CALFED, 2008f*). The goals of the Watershed Program Element are to provide financial and technical assistance for watershed activities that help achieve the mission and objectives of CALFED, and to promote collaboration and integration among community-based watershed efforts (*CALFED, 2008f*).

Both the Ecosystem Restoration and Watershed Program Elements have focused on areas upstream from the Delta, where the greatest level of investment has taken place and these areas are showing the strongest results (*CALFED, 2008f*). Significant investments made there in fish screens, temperature control, fish passage improvements and upstream habitats have resulted in an improved outlook for salmon throughout the Central Valley (*CALFED, 2008f*). Additionally, watershed funding, training and staffing has been a strong focus, primarily upstream from the Delta (*CALFED, 2008f*). Unfortunately, efforts have been less successful at acquiring and protecting important lands in the Delta along its tributary rivers and streams (*CALFED, 2008f*). The decline of pelagic organisms, most notably Delta smelt, and the increasing proliferation of non-native, invasive species in the Delta, has made it one of the most invaded ecosystems in the world (*CALFED, 2008f*).

C-1.1.1.5 Science Initiatives

The long-term goal of the Science Program of CALFED is to establish a body of knowledge relevant to CALFED actions and their implications. Presenting information that is ‘unbiased’ both in perception and reality, relevant, authoritative, integrated across program elements, and communicated to the scientific community, CALFED agency managers, stakeholders, and the public (*CALFED, 2008h*).

The California Bay Delta Authority’s Science Program integrates the best available knowledge across CALFED by strategic involvement at three different scales (*CALFED, 2008i*):

- *At the CALFED-wide level--define and invest in critical unknowns at the system-wide scale, fill monitoring gaps (cost share), invest in analyses that integrate information across scales, support system-wide evaluations of CALFED performance, and clarify the state of knowledge related to cross-program goals and management decisions*
- *At the regional level, where several individual CALFED programs interact, support integrated "signature" studies which address cross-program questions through active involvement in scientific questions and design, cost-sharing, and organizing collaborative groups to carry out the work*
- *Provide advice and guidance to individual CALFED programs on specific science elements, including monitoring and performance assessment, using expert panels, peer review, and defining critical unknowns.*

To date, no summary planning, design, construction or monitoring guidelines have been developed and made publicly available from CALFED. CALFED does have a rich database of research reports, studies, and conference proceedings. The organization of these information sources is disparate and site-specific and/or goal-specific searches area required. Searches can be conducted through their Library (http://www.calwater.ca.gov/calfed/library/index.html) or the CALFED Science Product Library (http://www.science.calwater.ca.gov/library/library_index.html).

A number of conceptual model guidelines are available (*CALFED, 2008,j*) as part of the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Overview program. The current "scientific input" phase of DRERIP applies the adaptive management approach by developing a suite of ecosystem conceptual models and species life history models that incorporate the most recent scientific information on the system (*CALFED, 2008,j*). These models are valuable tools themselves, but were designed to evaluate proposed restoration actions using the DRERIP scientific evaluation process (*CALFED, 2008,j*). The actions that are refined through the scientific evaluation process are aimed to inform public policy decisions within the Delta, and to be useful for other Delta planning efforts such as the Bay-Delta Conservation Plan (BDCP) and Delta Vision (*CALFED, 2008,j*). The ecosystem conceptual models include:

- *Aquatic Vegetation Conceptual Model*
- *Chemical Stressors Conceptual Model*
- *Fish Habitat Linkage Conceptual Model*
- *Floodplain Conceptual Model*
- *Mercury Conceptual Model*
- *Pyrethroids Conceptual Model*
- *Sediment Conceptual Model*

- *Selenium Conceptual Model*
- *Tidal Marsh Conceptual Model*

C-3.5.2 California Conservation Corps

The California Conservation Corps (CCC) is the oldest and largest conservation corps in the nation and it was modeled after the original federal Civilian Conservation Corps created in 1933 by President Franklin Roosevelt (*CCC, 2008a*). The program was signed into law by Governor Jerry Brown on July 7, 1976 and the program was envisioned by Governor Brown as "a combination Jesuit seminary, Israeli kibbutz and Marine Corps boot camp" (*CCC, 2008a*). The mission of the CCC is for the "young women and men of the CCC to work hard protecting and restoring California's environment and responding to disasters, becoming stronger workers, citizens, and individuals through their service" (*CCC, 2008b*).

The CCC has a number of programs for its personnel, but there are two programs within the CCC that are oriented explicitly towards River Restoration; the salmon restoration program and the watershed stewards program.

The salmon restoration program began as a partnership between the CCC, California Department of Fish and Game, and private and public landowners and a partnership with the National Oceanographic and Atmospheric Administration enabled the CCC and DFG to build capacity for additional collaborative efforts and expand the CCC's fisheries restoration activities from California's remote North Coast south to Ventura County in Southern California (*CCC, 2008c*).

All salmon restoration projects begin with a stream assessment that is conducted by California Conservation Corps fish habitat specialists, Fish and Game biologists, CCC/AmeriCorps Watershed Stewards and other watershed restoration experts (*CCC, 2008c*). A second, more detailed survey is conducted if initial findings determine a stream or watershed will benefit from restoration and the scientific data collected during these visits is then used to develop a site-specific restoration plan (*CCC, 2008c*).

Guided and supervised by California Department of Fish and Game and California Conservation Corps habitat staff, the CCC Fisheries Restoration crews implement the restoration site plan. Once completed, biologists check the site, add it to the restoration database, and monitor it for effectiveness and structural integrity for up to ten years (*CCC, 2008c*). Typical CCC restoration projects include modifying barriers to fish passage, planting trees in the riparian zones, reducing upslope sediment sources, stabilizing stream banks through bioengineering and log/ boulder structures, building livestock exclusion fences, constructing in-stream habitat structures for pool development and spawning gravel retention, and installing logs and root wads that serve as cover structures in pool and flat water habitats (*CCC, 2008c*). Restoration work is focused on streams and watersheds that have the greatest ability to increase threatened and endangered salmonid populations over the long term (*CCC, 2008c*).

The Watershed Stewards Project (WSP) is a comprehensive, community-based watershed restoration and education program with a mission to conserve, restore and sustain anadromous watersheds for future generations through education and high quality scientific practices (*CCC, 2008d*). Established in 1994, biologists and educators created

WSP to fill critical information gaps in scientific and education communities (*CCC, 2008d*).

In collaboration with the commercial and sport fishing industry, timber companies, teachers, nonprofit organizations and public agencies, WSP members and the WSP partnership work to revitalize watersheds inhabited by endangered and threatened species through the use of the WSP "Real Science" environmental education curricula and state-of-the-art data collection and watershed techniques (*CCC, 2008d*). WSP activities include: dissemination of advanced monitoring and analysis techniques; presentation of WSP "Real Science" curricula to students in grades K-12; participation in stream and upslope restoration activities; tutoring of K-12 students in math and science; conduct environmentally-based public outreach; and to conduct environmental education workshops and symposiums (*CCC, 2008d*). WSP has a library with resources aimed at educating the public on a number of watershed issues (http://watershedstewards.com/wsp-library).

C-3.5.3 California Department of Conservation

The Department of Conservation administers a variety of programs pertaining to California's public safety, environment and economy (*DOC, 2008a*). The services DOC provides are designed to balance today's needs with tomorrow's obligations by fostering the wise use and conservation of energy, land and mineral resources (*DOC, 2008a*). The programs within the Department of Conservation include: Beverage Container Recycling, Land Resources Protection, Mine Reclamation, Geological Survey, Oil, Gas & Geothermal, and State Mining and Geology Board. Of these departments, the Land

Conservation and Geological Survey have significant impacts on the practice of River Restoration and are described in more detail below (*DOC, 2008a*).

C-1.1.1.6 Land Conservation

The Division of Land Resource Protection provides information, maps, funding and technical assistance to local governments, consultants, Resource Conservation Districts and non-profit organizations statewide with the goal of conserving the state's agricultural and natural resources (*DOC, 2008b*). The Land Resource Protection division has an active watershed program, with a purpose to advance sustainable watershed-based management of natural resources through community–based strategies (*DOC, 2008c*). The program offers a manual for assessing California watersheds as well as a comprehensive list of resources for watershed-related activities. These resources can be accessed at: http://cwam.ucdavis.edu/.

C-1.1.1.7 California Geological Society

The California Geological Society (CGS) is the primary source of geological and seismological information in California. The mission of CGS is to provide scientific products and services about the state's geology, seismology and mineral resources including their related hazards that affect the health, safety, and business interests of the people of California (*CGS, 2008a*). The CGS objective are to (*CGS, 2008a*): Increase the use of CGS products and services in order to improve the quality of decision-making by local jurisdictions, professional consultants, and private persons regarding the public's health and safety, its economy, and its business decisions; Develop and maintain the highest technical and professional expertise of CGS staff through formal training programs, scientific and technical conferences, and continuing education activities; and Develop and maintain a succession planning program to actively transfer institutional knowledge, promote current staff, and recruit new talent.

The primary program that impacts River Restoration is the Forest and Watershed Geology Program. The Forest and Watershed Geology Program (FWGP) provides technical information and advice about landslides, erosion, sedimentation and other geologic hazards to the California Department of Forestry and Fire Protection (CDF), the Board of Forestry and Fire Protection, the Department of Fish and Game (DFG), Department of Parks and Recreation and other agencies, industries and the public that make land-use decisions on California's forested lands and in watersheds where proposed activities may affect water quality and fish habitat (*CGS, 2008b*).

The FWGP sponsors the Watershed Restoration Project, which provides site specific landslide mapping, engineering geologic review, and analysis of geomorphic processes for various state agencies (*CGS, 2008b*). The Watershed Restoration Project provides advice and technical information to various state agencies in their decision-making for future site-specific restoration project planning issues related to sediment sources, slope stability, water quality, cumulative watershed effects and fish habitat (*CGS, 2008b*). All the information (reports, maps, and GIS data) prepared by CGS is available to the public through their maps (http://www.consrv.ca.gov/cgs/maps/Pages/Maps.aspx) and their publications (http://www.consrv.ca.gov/cgs/publications/Pages/index.aspx) websites.

C-3.5.4 Department of Fish and Game

The Department of Fish and Game (CDFG) is charged with maintaining native fish, wildlife, plant species and natural communities for their intrinsic and ecological value and their benefits to people, which includes habitat protection and maintenance in a sufficient amount and quality to ensure the survival of all species and natural communities (CDFG, 2008a). The department is also responsible for the diversified use of fish and wildlife including recreational, commercial, scientific and educational uses (CDFG, 2008a). The Mission of the Department of Fish and Game is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public (CDFG, 2008a).

There are seven CDFG regions: Northern, North Central, Bay Delta, Central, South Coast, Inland Deserts, and Marine and the CDFG programs involve regulation of fish and wildlife related recreation, marine resource management, oil spill response, enforcement of fish and wildlife laws, as well resource management. CDFG's Resource Management program include: aquatic bioassessment, conservation planning, environmental reviewing and permitting, lands program, resource assessment program, wildlife, fish and plant information program, and the fisheries restoration grant program. These areas are discussed in more detail below.

C-1.1.1.8 Aquatic Bioassessment

The mission of the aquatic bioassessment laboratory is to support the use of biology in California's water quality management and assessment programs (*CDFG,* *2008b*) and has four parts: a laboratory where samples are logged in, processed, taxonomic classification is assigned, data is quality controlled, and reported; field data collection where sampling protocols include targeted riffle and multiple habitat sampling of macro invertebrates, fish and algae as well as associated physical habitat and chemical monitoring; an active research program throughout California with current research efforts focused on developing IBIs for different regions, developing objective reference condition selection methods and establishing quantitative tolerance values; and Benthic macroinvertebrate (BMI) data often provide a critical component to enforcement of state water regulations.

C-1.1.1.9 Conservation Planning

The Conservation Planning Program is responsible for statewide oversight of various approaches used to balance the needs of threatened, endangered, and sensitive species and habitats with the needs of land users (*CDFG, 2008c*). The primary focus is to provide policy guidance to large-scale, multi-species planning approaches that are partnerships between state, federal and local governments and private interest groups (*CDFG, 2008c*). Habitat acquisition is also coordinated in associated with plans, local assistance grants for conservation planning and implementation, conservation and mitigation banking, and voluntary integrated resource management plans (*CDFG, 2008c*).

C-1.1.1.10 Environmental Review and Permitting

The Environmental Review and Permitting Programs are responsible to fulfill the mission of the State to encourage the preservation, conservation and maintenance of wildlife resources under the jurisdiction and influence of the State, including the conservation, protection and management of fish, wildlife, native plants, and habitat necessary for biologically sustainable populations of those species (*CDFG, 2008d*). Environmental legislation and acts that are overseen include (*CDFG, 2008d*):

- *California Endangered Species Act Permitting (CESA) - The California Endangered Species Act (CESA) allows CDFG to authorize project proponents to take state- listed threatened, endangered, or candidate species if certain conditions are met. The permitting program administers the incidental take provisions of CESA to ensure regulatory compliance and statewide consistency;*
- *California Environmental Quality Act Review (CEQA) - CDFG consults with lead and responsible agencies and provides the requisite biological expertise to review and comment upon environmental documents and impacts arising from project activities under the California Environmental Quality Act;*
- *Lake and Streambed Alteration Program (LSA) - The Lake and Streambed Alteration Program determines whether an agreement is needed for an activity that will substantially modify a river, steam or lake. Notification is required by any person, business, state or local government agency, or public utility that proposes an activity that will:*
    - *substantially divert or obstruct the natural flow of any river, stream or lake;*

- *substantially change or use any material from the bed, channel, or bank of, any river, stream, or lake; or*
- *deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake.*

The notification requirement applies to any work undertaken in or near a river, stream, or lake that flows at least intermittently through a bed or channel. This includes ephemeral streams, desert washes, and watercourses with a subsurface flow. It may also apply to work undertaken within the flood plain of a body of water. If CDFG determines that the activity may substantially adversely affect fish and wildlife resources, a Lake or Streambed Alteration Agreement will be prepared. The Agreement includes reasonable conditions necessary to protect those resources and must comply with the California Environmental Quality Act (CEQA); and

- *Timberland Conservation Program - Timber harvesting in California is overseen by multiple state agencies to address the variety of potential impacts logging has on the environment. CDFG may issue permits for road construction across streams and incidental lake permits when endangered species habitat is involved.*

C-1.1.1.11 Lands Program

The Lands Program is responsible for assisting Regional CDFG staff in the management of over 1,000,000 acres of fish and wildlife habitat (*CDFG, 2008e*). In total, CDFG manages 711 properties throughout the state that provide habitat for a rich diversity of fish, wildlife, and plant species and comprise habitats from every major ecosystem in the state (*CDFG, 2008e*). In addition, the Lands Program also administers several private lands conservation programs designed to assist landowners with the management of wetlands, riparian habitats, native grasslands and wildlife-friendly farmlands (*CDFG, 2008e*).

C-1.1.1.12 Resource Assessment Program

The goal of the Resource Assessment Program is to develop and implement a long-term and strategic program to inventory, monitor, and assess the distribution and abundance of priority species, habitats, and natural communities in California (*CDFG, 2008f*). The program synthesizes many of CDFG's varied data collection, compilation, and dissemination efforts under the "umbrella" of a systematic and more comprehensive effort and will more effective resource assessment priority evaluations and refocus many CDFG existing efforts in the collection, analysis, and use of data on native fish, wildlife, plants, and communities (*CDFG, 2008f*).

C-1.1.1.13 Wildlife, Fish and Plant Information and Programs

The general wildlife conservation policy of the State is to encourage the conservation and maintenance of wildlife resources under the jurisdiction and influence of the State (Section 1801, Fish and Game Code) (*CDFG, 2008g*). The policy includes several objectives which include (*CDFG, 2008g*):

- *To provide for the beneficial use and enjoyment of wildlife by all citizens of the State;*
- *To perpetuate all species of wildlife for their intrinsic and ecological values, as well as for their direct benefits to man;*
- *To provide for aesthetic, educational, and non-appropriative uses of the various wildlife species;*
- *To maintain diversified recreational uses of wildlife, including hunting, as proper uses of certain designated species of wildlife, subject to regulations consistent with public safety, and a quality outdoor experience;*
- *To provide for economic contributions to the citizens of the State through the recognition that wildlife is a renewable resource of the land by which economic return can accrue to the citizens of the State, individually and collectively, through regulated management. Such management shall be consistent with the maintenance of healthy and thriving wildlife resources and the public ownership status of the wildlife resource;*
- *To alleviate economic losses or public health and safety problems caused by wildlife; and To maintain sufficient populations of all species of wildlife and the habitat necessary to achieve the above-state objectives.*

The Wildlife Branch Nongame Program includes native mammals, birds, reptiles and amphibians (except in circumstances where these are considered nuisance species;

they then become the responsibility of the appropriate regional DFG office) (*CDFG, 2008g*). Nongame Program conservation actions focus on Threatened and Endangered species and Species of Special Concern, and include: planning and implementing species conservation and recovery, preparing and reviewing listing/delisting petitions, developing conservation strategies, overseeing research contracts, writing research permits, and developing regulations (*CDFG, 2008g*).

C-1.1.1.14 Fisheries Restoration Grant Program

The Fisheries Restoration Grant Program (FRGP) was established in 1981 in response to rapidly declining populations of wild salmon and steelhead trout and deteriorating fish habitat in California (*CDFG, 2008h*). The grant program has invested over $180 million to support projects from sediment reduction to watershed education throughout coastal California (*CDFG, 2008h*). Contributing partners include CDFG, federal and local governments; tribes, water districts, fisheries organizations, watershed restoration groups, the California Conservation Corps, AmeriCorps, and private landowners (*CDFG, 2008h*).

Restoring anadromous salmon and steelhead habitat is a commitment this program and partners have embraced and with population of some salmon at critically low levels, there are many opportunities for restoration projects that will directly benefit the salmon and steelhead trout in California (*CDFG, 2008h*). Specific accomplishments over the last seven years (2000-2006) include (*CDFG, 2008h*):

- *895 miles of stream have been treated;*
- *53 miles of stream bank have been stabilized;*

- *122 miles of in stream habitat has been restored;*
- *661 miles of stream have been opened to fish passage by removing 440 barriers;*
- *5,467 acres of riparian habitat have been restored;*
- *1,283 miles of road have been treated to reduce sediment in salmonid streams; and*
- *1,000s of children and adults educated about habitat necessary for anadromous fish to thrive.*

C-3.5.5 Department of Water Resources

The California Department of Water Resources (DWR) is a department within the California Resources Agency responsible for the State of California's management and regulation of water usage. The department was created in 1956 by Governor Goodwin Knight following severe flooding across Northern California in 1955, combining the Division of Water Resources of the Department of Public Works with the State Engineer's Office, the Water Project Authority, and the State Water Resources Board (*Wikipedia, 2008c*).

Though DWR was formed in 1956 with the purpose to build and operate the State Water Project, as a State organization responsible for the development and protection of water resources, DWR has since been subject to numerous legislative, judicial, and administrative orders that dictate how DWR should protect the public trust (*Wikipedia, 2008c*). Like any other water user, DWR must apply for water rights permits from the State Water Resources Control Board. The water rights decisions of the Control Board limit the amount of water that the Department can provide to communities and also are responsible for many of the legal, administrative, and environmental projects that the Department has adopted (*Wikipedia, 2008c*). Unlike most other users, DWR also must answer to the Governor's Office and State Legislature (*Wikipedia, 2008c*). Flood control and local assistance programs often have a basis in DWR's role as a resource trustee, while water supply, environmental mitigation, and electricity generation are often related to DWR's role as a water permittee (*Wikipedia, 2008c*).

There are a number of programs that have implications to River Restoration, including: Aquatic restoration planning and implementation; Fish passage improvement; Flood protection corridor program; Mitigation and Restoration; Restoration, Planning, Monitoring, and Implementation; Urban Streams Restoration Program, and Water Quality Monitoring. These programs are discussed in more detail below.

C-1.1.1.15 Aquatic Restoration Planning and Implementation

The Aquatic Restoration Planning and Implementation Section was established to support the CALFED Ecosystem Restoration Program by developing habitat enhancement and fish passage improvement in the Yolo Bypass (*DWR, 2008a*). The section collaborates with the Yolo Basin Foundation and other local groups to identify, study, and work to implement such opportunities on public lands and the lands of willing participants (*DWR, 2008a*). The Aquatic Restoration Planning and Implementation Section supports efforts to create regionally significant improvements in riparian, tidal marsh, and seasonal floodplain habitats in the Yolo Bypass and this effort is compatible with maintaining or improving seasonal flood flow capacity of the bypass while improving habitat diversity and quality (*DWR, 2008a*).

C-1.1.1.16 Fish Passage Improvement Program

The Fish Passage Improvement Program (FPIP) identifies and evaluates the potential to modify or remove structures in waterways that impede migration of anadromous fish, primarily Chinook salmon (Oncorhynchus tshawytscha) and steelhead (Oncorhynchus mykiss), within the Central Valley (*DWR, 2008b*). The program provides (*DWR, 2008b*): feasibility studies (fish passage with reliable water supply); prioritization, evaluation, and development of fish passage enhancement projects; environmental documentation; coordination and consultation with stakeholders and the public; interdisciplinary teams of fish biologists, hydrologists, engineers, and environmental scientists to conduct barrier inventories. FPIP plans and implements fish passage projects to modify or remove in stream barriers which impede migration and spawning of anadromous fish. These barriers include: dams, road crossings, bridges, culverts, canal and pipeline crossings, flood control channels, and erosion control structures (*DWR, 2008b*).

C-1.1.1.17 Flood Protection Corridor Program

The Flood Protection Corridor Program (FPCP) was established when California voters passed Proposition 13, the "Safe Drinking Water, Watershed Protection and Flood Protection Act" in March of 2000 (*DWR, 2008c*). This proposition provided funding for nonstructural flood management projects that include wildlife habitat enhancement and/or agricultural land preservation and was first made available for direct expenditure projects during the fiscal year of 2001-2002, followed by a competitive solicitation for grant-funded project proposals in fiscal year 2002 -2003 (*DWR, 2008c*). Proposition 84, The Safe Drinking Water, Water Quality & Supply, Flood Control, River & Coastal Bond Act of 2006, provides renewed funding for the Flood Protection Corridor Program. Proposition 84 provides the sum of $40,000,000 be made available to continue the Flood Protection Corridor Program (*DWR, 2008c*).

C-1.1.1.18 Mitigation and Restoration Branch

The Mitigation and Restoration Branch is responsible for analysis and evaluation of ecological, water resource, and restoration projects for the State Water Project and State of California (*DWR, 2008d*). Branch staff members support the planning and implementation of the Bay Delta Conservation Plan as well as CALFED Record of Decision projects such as the Environmental Water Account and Prospect Island (*DWR, 2008d*). Branch staff also manages mitigation projects for the State Water Project such as the Delta Fish Agreement, survey biological and geomorphic resources, and design and implement monitoring and restoration programs for Department of Water Resources and California Bay Delta Authority (*DWR, 2008d*). The Branch is organized into four sections (*DWR, 2008d*): Restoration Planning, Monitoring, & Implementation; Delta Fish Agreement (Four Pumps), Bay Delta Conservation Plan; and Special Investigations; where staff members participate in a wide variety of projects.

C-1.1.1.19 River Parkways and Urban Streams Restoration Program

The River Parkways and Urban Streams Restoration stemmed from the passage of the California Safe Drinking Water, Water Quality and Supply, Flood Control, River and

Coastal Protection Bond Act of 2006. The legislation appropriated $62 million for the acquisition, restoration, protection and development of river parkways in accordance with the California River Parkways Act of 2004 and $18 million for the Urban Stream Restoration program (*DWR, 2008e*).

The goals of the River Parkways Program is to: protect and restore riparian and riverine habitat; and to directly improve the quality of life in California by providing important recreational, open space, wildlife, flood management, water quality, and urban waterfront revitalization benefits to communities in the State (*DWR, 2008e*). The goals of the Urban Streams Restoration Program (USRP) are to (*DWR, 2008e*): reduce property damage caused by flooding or erosion; restore, enhance, or protect the natural ecological values of streams; promote community involvement, education, and stewardship.

Since 1985, the program has provided over 240 grants ranging from $1,000 to $1 million to communities throughout California and these projects have included stream cleanups, bank stabilization projects, revegetation efforts, recontouring of channels to improve floodplain function and occasional acquisition of strategic floodplain properties or easements (*DWR, 2008e*). For more detailed information on many projects that the program has funded, visit the University of California, Davis Natural Resource Project Inventory. Project names followed by "DWR Z*****" have received funding from the Urban Streams Restoration Program (*DWR, 2008e*).

C-1.1.1.20 <u>Water Quality Monitoring</u>

The mission of the Office of Water Quality (OWQ) is to meet the overall water quality needs of DWR and to provide a central focal point for the collection and dissemination of water quality information for DWR and stakeholders (*DWR, 2008f*). This mission is accomplished through comprehensive water quality monitoring, analysis, and assessment; applied research; implementation of a rigorous quality assurance and control program; and, data management and dissemination (*DWR, 2008f*). While the geographic focus is the Sacramento-San Joaquin Delta and the State Water Project, the Office also provides support to other departmental organizations and stakeholders throughout the State in meeting their water quality-related needs, including providing water quality data and information in support of such activities as long-range planning, regulatory compliance, project operations, scientific research and policy development (*DWR, 2008f*).

There are three main areas of focus for the OWQ (*DWR, 2008f*): Municipal Water Quality (Drinking Water Quality); Environmental Water Quality; and Operational Water Quality (SWP). The Bryte Chemical Laboratory also supports all three of these focus areas through maintaining the highest level of analytical capability.

The objective of the Municipal Water Quality focus is to determine and examine the sources of constituents that effect drinking water quality of the Sacramento-San Joaquin Delta, and to provide information necessary for planning Delta water quality improvements (*DWR, 2008f*).

The objective of the Environmental Water Quality focus is to document the environmental water quality conditions affected by operation of the SWP and the federal Central Valley Project through the monitoring and assessment of various physical, chemical and biological constituents throughout the Delta (*DWR, 2008f*). This objective is met through implementation of the Bay-Delta Environmental Monitoring Program and the Interagency Ecological Program and the various water quality programs carried out through the department's district offices (*DWR, 2008f*).

The objective of the Operational Water Quality focus is to provide the water quality information necessary for operational needs of both the SWP and the State Water Contractors, and to identify opportunities to provide the best water quality possible for our customers (*DWR, 2008f*).

C-1.1.1.21 Watersheds

The DWR Watershed Program works with locally led stewardship efforts to integrate the needs of communities, urban and rural, with resource management that sustains watershed ecology (*DWR, 2008g*). The program seeks to cultivate and nurture collaborative management that expands the natural, financial, and social capital that supports watershed management throughout the state and strives to inform and educate people about their watersheds and the benefits and values that those watersheds provide (*DWR, 2008g*).

C-3.5.6 California State Parks and Recreation

The California Department of Parks and Recreation (CPR) manages more than 270 park units, which contain the finest and most diverse collection of natural, cultural, and recreational resources to be found within California (*CPR, 2008a*). The mission of CPR is to provide for the health, inspiration and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources, and creating opportunities for high-quality outdoor recreation (*CPR, 2008a*).

CPR has many policies, guidelines, programs, and activities that support its natural resource mission, which includes funding programs used to support CPR's wide variety of management activities, including habitat restoration, prescribed fire management, corrective and ongoing maintenance, and monitoring (*CPR, 2008b*). In addition, information on many of the major subject areas of resource management planning and action is provided, such as geographic information systems (GIS), exotic species control, marine areas, and watershed management (*CPR, 2008b*).

Natural Resource Acquisition Program – CPR's acquisition program focuses on three core areas: natural resources, cultural resources and recreational opportunities (*CPR, 2008c*). The most acreage acquired is for natural resource purposes and normally, these acquisitions include significant contributions by other agencies and nonprofits (*CPR, 2008c*). The overall goal is to protect and sustain the most important natural resources within the State Park System which is accomplished by acquiring linkages (connection key parks to other protected areas), lands within the keystone watersheds, and true and effective buffers (*CPR, 2008c*).

Inventory, Monitoring, and Assessment – The Inventory, Monitoring, and Assessment Program (IMAP) provides goals, guidance, and standards for CPR's efforts to systematically evaluate the vegetation, wildlife, and physical natural resources of the State Park System (*CPR, 2008d*). Evaluations consist of collecting data through various scientific means in each State Park System unit (*CPR, 2008d*). Data is generally quantitative and consists of counts and measures of natural resources and examples include measuring stream water quality, the distribution of various species of plants in an area, and counting the number of offspring of endangered animals (*CPR, 2008d*). The data can be used to make status assessments of a unit's natural resources, such as what resources are present, where the resources are distributed, and how much of a resource is present (*CPR, 2008d*). Data is also used to detect changes in resources over time so that trends in the unit's health can be ascertained and corrective management action can be taken (*CPR, 2008d*).

Policy – The Natural Resources Division is responsible for providing leadership and policy direction that contributes to protection and improved management of natural resources in the State Park System (*CPR, 2008e*).

Environmental Compliance – Environmental compliance in the Department of Parks and Recreation includes both the review and preparation of necessary environmental documents under the California's Environmental Quality Act (CEQA) (*CPR, 2008f*).

Restoration – CPR is active in implementing restoration efforts that attempt to heal disturbed areas and ecological relationships, returning them to their original biological diversity and ecosystem function (*CPR, 2008g*). To effect such a change and to maintain the restored condition, a long-term commitment to resource management is necessary (*CPR, 2008g*). Natural community restoration and management in state parklands involves a variety of techniques (*CPR, 2008g*).

C-3.6 Central Valley Flood Protection Board (Reclamation Bureau)

The State Central Valley Flood Protection Board (Board), under Section 8609 of the Water Code, has the authority to designate floodways in the Central Valley. The Central Valley includes the following counties (*Board, 2008a*): Butte; Calaveras;

Colousa; Fresno; Glenn; Kern; Kings; Madera; Mariposa; Merced; Placer; Plumas; Sacramento; San Joaquin; Shasta; Stanislaus; Tehema; Tulare; Tuolumne; Yolo; and Yuba. Designated Floodway refers to the channel of the stream and that portion of the adjoining floodplain reasonably required providing for the passage of a design flood; it is also the floodway between existing levees as adopted by The Board or the Legislature (Board, 2008a) and these areas are generally managed via an Adopted Plan of Flood Control.

An Adopted Plan of Flood Control is a flood control or Central Valley Flood Protection strategy for a specific area that has been adopted by the Board or the Legislature (*Board, 2008b*). It includes the natural stream channel and overbank area at design flood levels or a 100-year flood elevation, areas between and including the project levees, areas where there are flowage easements, and up to ten (10) feet landward from the landside toe of a Federal flood control project levee (*Board, 2008b*).

A permit is required from the Board for any project that proposes to work in a regulated stream, designated floodway on federal flood control project levee slopes or within 10 feet of the levee toe. Such activities might include but are not limited to: boat docks, ramps, bridges, sand and gravel mining, placement of fill, fences, landscaping and irrigation facilities (*Board, 2008b*). Additionally, the Board requires a permit be obtained for any work that (*Board, 2008b*): is within federal flood control project levees and within a Board easement; may have an effect on the flood control functions of project levees; is within a Board designated floodway; and/or is within regulated Central Valley streams listed in Table 8.1 in Title 23 of the California Code of Regulations. Detailed technical criteria for work within zones is designated in Title 23, but the U.S. Army

Corps of Engineers design guidelines are specified. Streams regulated by the Board are presented in Table C1.

Table C1: Summary of Regulated Streams and Rivers

Alta Main Canal	Dry Creek	Lindsey Slough
American River	Duck Creek	Little Chico Creek
Antelope Creek	Duck Creek South Branch	Little Chico Diversion Canal
Angel Slough	Duck Slough	Little Cow Creek
Arcade Creek	Dutch John Cut Slough	Littlejohns Creek
Ash Creek	Dye Creek	Lone Tree Creek
Ash Slough	East Sand Slough	Lwr San Joaquin Rvr Fld Ctrl Chnl
Atherton Cove	Eastside Bypass	Magpie Creek
Auburn Ravine	Edendale Creek	Main Drain Canal
Beacon Creek	Elder Creek	Mariposa Bypass
Battle Creek	Elk Bayou	Mariposa Creek
Bear Creek	Elk Slough	Markham Creek
Bear River	Fahrens Creek	Mayberry Slough
Berenda Slough	Feather River	McClure Creek
Best Slough	Feather River North Fork	McCoy Creek
Big Chico Creek	Five Mile Slough	Merced River
Black Rascal Creek	Fourteenmile Slough	Middle Creek
Butte Basin	French Camp Slough	Miles Creek
Butte Creek	Fresno River	Mill Creek
Butte Creek Diversion Canal	Fresno River South Fork	Miners Ravine
Butte Slough	Fresno Slough	Miner Slough
Byrd Slough	Georgiana Slough	Mokelumne River
Cache Creek	Globe Slough	Moody Slough
Cache Slough	Gold Run Creek	Mormon Slough
Calaveras River	Haas Slough	Morrison Creek
Cameron Slough	Hastings Cut	Mosher Slough/Creek
Canal Creek	Honcut Creek	Moulton Bypass and Weir
Cherokee Creek	Hughes Creek	Mud Creek
Chowchilla Canal Bypass	Hutchison Creek	Mud Slough Creek
Chowchilla River	Ida Island	Murphy Slough
Churn Creek	Inside Creek	Natomas Cross Canal
Cirby Creek	James Bypass	Natomas East Main Drainage Canal
Clarks Fork	Jack Slough	Oak Run Creek
Clear Creek	Kaweah River	Old River
Clover Creek	Kaweah River North Fork	Outside Creek
Cole Slough	Kaweah River Middle Fork	Owens Creek
Colousa Bypass	Kaweah River South Fork	Paddy Creek
Colousa Basin Draiun and Canal	Kern River South Fork	Paradise Cut
Colousa Trough	Kern River	Paynes Creek
Coon Creek	Kern River Bypass Channel	Pixley Slough
Consumnes River	Kings River	Pleasant Grove Creek Canal
Cottonwood Creek	Kings River, North Fork	Porter Slough
Cottonwood South Fork	Kings River, South Fork	Putah Creek
Cow Creek	Knights Landing Ridge Cut	Putah Creek South Fork
Crescent Bypass	Laird Slough	Red Bank Creek
Cross Creek	Laquna Creek	Reeds Creek

Table C-1: Summary of Regulated Streams and Rivers (Cont'd)

Davis Drain	Laurel Creek	Sacramento Bypass
Dead Horse Slough	Ledgewood Creek	Sacramento Deep Water Channel
Deer Creek	Linda Creek	Sacramento River
Dog Creek	Lindo Channel	Salt Creek
Sand Creek	Sutter Bypass	Wadsworth Intercepting Canal, East
Sandy Gulch	Sutter Slough	Wadsworth Intercepting Canal, West
San Joaquin River	Sycamore Creek	Walker Slough
Scotts Creek	Sycamore Slough	Walthall Slough
Secret Ravine	Thomes Creek	Western Pacific Interceptor Channel
Shag Slough	Threemile Slough	West Side Canal
Smith Canal	Tisdale Bypass	Willow Creek
Sevenmile Slough	Torm Paine Slough	Willow Slough and Bypass
Simmerly Slough	Tule River	Wright Cut
St. Johns River	Tule River North Fork	Yankee Slough
Stanislaus River	Tule River Middle Fork	Yokohl Creek
State Main Drain	Tule River South Fork	Yolo Bypass
Steamboat Slough	Tuolomne River	Yuba River
Stockton Diverting Canal	Ulatis Creek	
Stony Creek	Wadsworth Canal	

C-3.7 Department of Transportation

The California Department of Transportation (Caltrans) manages more than 45,000 miles of California's highway and freeway lanes, provides inter-city rail services, permits more than 400 public-use airports and special-use hospital heliports, and works with local agencies (*Caltrans, 2008*). Caltrans carries out its mission of improving mobility across California with six primary programs: Aeronautics, Highway Transportation, Mass Transportation, Transportation Planning, Administration and the Equipment Service Center. Caltrans has been active in moving the people and commerce of California for more than 100 years from a loosely connected web of footpaths and rutted wagon routes to the sophisticated system that today serves the transportation needs of more than 30 million residents.

As part of roadway construction projects, Caltrans frequently impacts rivers and streams and they actively manage stormwater that both runs onto their freeway systems as well as the stormwater running from their projects. The Caltrans Highway Design Manual has excellent technical design information related to hydrologic characteristics of rivers and streams. They also have a construction-related stormwater Best Management Practices manual to minimize nonpoint source pollution runoff during earthwork related construction activities. Caltrans also has a technical manual on fish passage through culverts. Some cost information is also available through the Cost Data Information database, an annual publication of construction costs (by Caltrans Item Number) for the previous year (available from: http://www.dot.ca.gov/hq/esc/oe/awards/).

C-4 LOCAL AGENCIES

There are a number of local agencies that impact the practice of River Restoration. The intent of this dissertation is not to generate a complete and comprehensive listing of all local agencies, rather highlight the topic and provide some examples of the types of local agencies to be aware of as possible 'stakeholders' in the development of restoration projects. In the greater San Francisco Bay Area, some notable agencies include: the Association of Bay Area Governments; various Counties and Cities; Flood Control Districts; and the Sacramento Area Flood Control Agency.

C-4.1 Association of Bay Area Governments (ABAG)

The Association of Bay Area Governments (ABAG) is the official comprehensive planning agency for the San Francisco Bay region and its mission is to strengthen cooperation and coordination among local governments and in doing so, ABAG addresses social, environmental, and economic issues that transcend local borders (*ABAG, 2008a*). The Bay Area is defined as the nine counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma (*ABAG, 2008a*). The 101 cities and all nine counties within the Bay Area are voluntary members of ABAG, representing nearly all of the region's population (*ABAG, 2008a*).

ABAG works with a variety of agencies and institutions to advance regional environmental management objectives (*ABAG, 2008b*). The Water and Land Use Program joins environmental planning and land use planning to help ABAG members meet water quality and other regulatory program goals (*ABAG, 2008b*). Two technical working groups have helped address Delta and groundwater issues and ABAG has contributed to the State's Water Plan Update, the Bay Area Integrated Regional Water Management Plan, legislative discussions related to flooding and levees, and a State funded and U.C. Berkeley-based Delta planning and visioning effort (*ABAG, 2008b*). ABAG is partnering with the S.F. Estuary Institute to assist with the State's Critical Coastal Areas Project, and additionally assist the State of California with a proposed Stream Protection Policy (*ABAG, 2008b*). To aid local governments and professional planners, a technology survey and GIS maps of the region's water districts, the region's watersheds and selected areas of the coastline has been created and is accessible to the public (*ABAG, 2008b*). An excellent summary of water-related resources is available on their Water Web pages, available from: http://www.abag.ca.gov/water/.

C-4.2 Counties/Cities

Some cities and/or counties may have specific criteria that must be addressed as part of a River Restoration project. It has become common in the past few years for cities to adopt creek ordinances that regulate in-stream activities and configurations. For example, the City of Berkeley established a policy to preserve and restore natural watercourses which regulates the issuance of permits for culverting open creeks, the rehabilitation and restoration of natural waterways, and the management of watersheds.

The policy declares the following regarding the management of culverts in creeks:

- *Public health and safety requires creek and watershed management and planning in order to control flood and erosion damages. Maintenance of natural channels, including removal of debris and erosion control;*
- *A dependence on structural solutions for reduction of property damage such as creek channelization, culverting and channel riprapping, often has been found to result in the loss of property from unanticipated problems associated with their design. Channelization can result in changes in stream meander, bank erosion, channel filling and channel degradation, causing damages by the undercutting of bridges, homes and other structures or by the over-the-bank flows caused by channel filling. Culverts can result in upstream and downstream bank erosion problems and, because debris removal from them is difficult, they can back up flows and cause floods. Undersized culverts and culverts installed at the wrong slope can also cause flooding and serious bank erosion;*

- *The use of riprap or other debris to stabilize banks can result in the erosion of streambanks up and downstream of the riprap. Riprap and other debris may decrease channel capacity contributing to potential flood damages;*
- *Streams managed as close to a natural system as possible without interference from structures, maintain a geomorphic equilibrium or watercourse best suited for carrying stream flows, and carrying and depositing suspended bed loads;*
- *Natural streams provide the most environmental amenities to the community and riparian owners;*
- *Streams and their riparian environment should be held as an important public asset in an increasingly endangered environment that provides an usual urban ecological habitat with recreational and aesthetic value;*
- *Culverting or channelization of existing open creeks should only occur if there is an extreme hazard to public health or safety an no other alternatives can prevent the hazard; and*
- *It is in the interest of the City of Berkeley to encourage the removal of culverts and channels, prevent channel riprapping, and to restore natural watercourses whenever safely possible.*

C-4.3 Flood Control Districts/Agencies (SAFCA)

The Sacramento Area Flood Control Agency (SAFCA) was formed in 1989 to address the Sacramento area's vulnerability to catastrophic flooding, which was exposed during the record flood of 1986 when Folsom Dam exceeded its normal flood control storage capacity and several area levees nearly collapsed under the strain of the storm (*SAFCA, 2008a*). In response, the City of Sacramento, the County of Sacramento, the County of Sutter, the American River Flood Control District and Reclamation District 1000 created SAFCA through a Joint Exercise of Powers Agreement to provide the Sacramento region with increased flood protection along the American and Sacramento Rivers (*SAFCA, 2008a*).

The major levees protecting Sacramento are part of a system of a Federally authorized and State of California authorized levees and reservoirs which protect the flood-prone lowlands of the Sacramento Valley (*SAFCA, 2008b*). Improvements to this flood control system are typically cost-shared with both the Federal government and the State of California in an evolving partnership framed by Federal and State laws (*SAFCA, 2008b*).

SAFCA's geographic boundaries include the City of Sacramento, the County of Sacramento except the incorporated cities of Folsom, Galt and Isleton; and portions of Sutter County south of the Natomas Cross Canal in the Natomas Basin (*SAFCA, 2008c*). The Agency's planning and project implementation activities are primarily concentrated in the flood water conveyance corridors along the American and Sacramento Rivers (*SAFCA, 2008c*). Today these river corridors, bounded by earthen flood protection levees, support the remnants of a once extensive riparian forest and marsh ecosystem (*SAFCA, 2008c*). Consistent with its flood protection imperative, SAFCA works to conserve and protect valuable habitats and crucial ecosystem functions that sustain our regional fish and wildlife resources, and provide other public trust benefits to water quality, nature recreation, and the visual and cultural resources of the Sacramento River and American River Parkway (*SAFCA, 2008c*).

The California Environmental Quality Act (CEQA) is a foundational law that requires governmental actions that affect the environment to be adequately analyzed, so that such actions are designed to avoid or reduce damage to the environment (*SAFCA, 2008c*). Where impacts cannot be avoided, governmental agencies like SAFCA are obliged to compensate for environmental impacts through reasonable and feasible mitigation measures (*SAFCA, 2008c*).

Other environmental laws and regulations which often intersect with SAFCA's flood management actions include the Federal and State Endangered Species Acts (ESA); Migratory Bird Treaty Act; provisions under the federal Clean Water and Clean Air Acts, the Federal Rivers and Harbors Act; Fish & Game Code Section1602 (Streambed Alteration Agreements) and applicable Federal and State Archaeological Resource Protection laws (*SAFCA, 2008c*). As a local agency, SAFCA is also obliged to comply with various local resource ordinances such as heritage tree preservation codes and water codes (*SAFCA, 2008c*).

Habitats and their species most often affected and mitigated by SAFCA's actions are terrestrial and aquatic species associated with river ecosystems and protected by state or federal ESA status (*SAFCA, 2008c*). These species have included: Swainson's hawk (Buteo swainsoni), valley elderberry longhorn beetle (Desmocerus californicus dimorphus), giant garter snake (Thamnophis gigas), and ESA-listed anadromous fish species, including Chinook salmon (winter and spring run) (Oncorhynchus tshawytscha) and steelhead (Oncorhynchus mykiss) and species associated with vernal pool wetlands (*SAFCA, 2008c*).

Throughout its jurisdiction, SAFCA has planned, designed and implemented numerous habitat restoration projects including innovative stream bank protection designs that also benefit juvenile salmon and steelhead, perennial native grassland projects, fish passage improvements and invasive plant control programs (*SAFCA, 2008c*). The Agency has also implemented successful habitat compensation and enhancement projects for burrowing owls and vernal pool species (*SAFCA, 2008c*). Over the past decade, SAFCA in partnership with the California Department of Water Resources, the US Army Corps of Engineers and other agencies have successfully completed a multitude of riparian and aquatic habitat projects along the Sacramento and American Rivers, and Steelhead and Dry Creeks, including planting thousands of native riparian trees and shrubs (*SAFCA, 2008c*). SAFCA is recognized as a statewide leader and innovator of natural resource planning and habitat restoration design integrated with levee protection and floodway management to protect public safety (*SAFCA, 2008c*).

SAFCA is a sponsor and participant in several collaborative planning forums that promote coordination, cooperation and mutual assistance among local, state, and federal flood management and natural resource agencies, tribal representatives, neighborhood groups and business and environmental organizations with an interest in flood management and river and stream corridor issues (*SAFCA, 2008c*). The Agency sponsors two active collaborative groups including the Lower American River Task Force (LAR Task Force) founded in 1994, and the North Area Round Table (Round Table) (*SAFCA, 2008c*). SAFCA staff members are or have recently been actively involved in supporting the California Levees Roundtable, American River Parkway Plan Update, Sacramento River Corridor Planning Forum, Natomas Joint Vision, and other interagency flood management and natural resource collaborative groups (*SAFCA, 2008c*).

C-5 NON-GOVERNMENT AGENCIES (NGOS)

In addition to government-sponsored agencies, there are a number of non-governmental organizations (NGOs) that contribute to the practice of River Restoration. It is not possible to include all the NGOs actively involved in River Restoration, but a number of active groups in the greater Bay Area have been highlighted in this section. These groups include the Center for Ecosystem Management and Restoration, Friends of Creek groups, the San Francisco Bay Joint Venture, the Urban Creeks Council, and the Watershed Project.

C-5.1 American Rivers

American Rivers is a national organization promoting healthy rivers through national advocacy, innovative solutions and our growing network of strategic partners (*American Rivers, 2008a*). Founded in 1973, American Rivers has more than 65,000 members and supporters nationwide, with offices in Washington, DC and the Mid-Atlantic, Northeast, Midwest, Southeast, California and Northwest regions (*American Rivers, 2008a*).

American Rivers takes a pragmatic, science-based approach to solving problems facing rivers and assure credibility in their research and communications (*American Rivers, 2008b*). They work closely with grassroots river and watershed groups across the country, as well as other conservation groups, sporting and recreation groups, local citizens and businesses, and various federal, state, and tribal agencies to build strong coalitions across the United States (*American Rivers, 2008b*). They have four main campaigns, consisting of Healthy Waters, Water for Life, River Renewal, and River Heritage.

C-5.1.1 Healthy Waters

American Rivers works with community leaders, public health officials and local partners to advocate for state and federal Community Right-to-Know legislation that warns citizens when sewage is being dumped into rivers (*American Rivers, 2008c*). Sewage spills and polluted water that runs off streets, driveways and other paved surfaces after rains pose a health hazard for people, as well as fish and wildlife and American Rivers educates developers, local governments and partners about natural stormwater management techniques, such as permeable paving and rain gardens, to help restore the natural water cycle and reduce pollutants that would flow into rivers and streams (*American Rivers, 2008c*).

C-5.1.2 Water For Life

The Water for Life is a campaign that explores new approaches for providing communities with reliable water supplies that sustain a river's ability to protect public health, provide recreational opportunities, support habitat and sustain economic development (*American Rivers, 2008d*). American Rivers is working with the U.S. Environmental Protection Agency to promote WaterSense, a new program that will set national water efficiency standards for plumbing fixtures, appliances and landscape irrigation systems (*American Rivers, 2008d*).

C-5.1.3 River Renewal

American Rivers argues that dams, levees and other man-made structures disrupt the natural flow of rivers, leaving many of them lifeless or cut off from their communities and they cite that the nation's annual flood damages have more than doubled from the first half of the 20th century to more than $6 billion per year in the past decade (*American Rivers, 2008e*). For decades, structural flood prevention strategies (dams, levees and concrete-lined riverbeds) have been the primary mechanism used to protect homes and businesses from floods, but American Rivers highlights that the traditional protection approaches create a false sense of security for people in the floodplain, often increase flood heights, and typically damage the river's natural ability to minimize flooding (*American Rivers, 2008e*).

American Rivers is championing new approaches to river management that restore natural river functions, floodplains and wetlands by providing communities with technical and financial assistance, as well as advancing new policies that show communities that our best hopes lie in working with nature rather than against it when relying upon engineering to "protect" communities from flooding (*American Rivers, 2008e*).

For more than ten years, American Rivers has led a national effort to educate the public about the option of restoring rivers through selective dam removal, which has enabled a gradual shift in society's view of dams, and dramatically increased consideration of dam removal as a reasonable and beneficial option for restoring rivers, with American Rivers experts providing communities with the technical and financial assistance they need to turn rivers from afterthoughts to assets, and to promote awareness and appreciation of healthy rivers as both an economic and environmental benefit (*American Rivers, 2008e*).

C-5.1.4 River Heritage

The final American Rivers Campaign is that of River Heritage. American Rivers is working to increase protection of the nation's remaining free-flowing rivers by advancing the listing of 40 new rivers as Wild and Scenic in celebration of the 40th anniversary of the national Wild and Scenic Rivers Act in 2008 (*American Rivers, 2008f*). Additionally, they have established Blue Trails, a means by which to connect people to their local rivers while boosting tourism, civic pride and a conservation ethic (*American Rivers, 2008f*).

C-5.2 Center for Ecosystem Management and Restoration

The Center for Ecosystem Management and Restoration (CEMAR) was founded by environmental scientists who are committed to bridging the gap between environmental research and policy (*CEMAR, 2008a*). The purpose of CEMAR is to refine and clarify the implications of scientific research for policy development and resource management, and to assist policy makers in the effective use of scientific information (*CEMAR, 2008a*). The goal of these activities is to promote greater respect for ecological systems and processes, as well as the restoration and sustainable management of natural ecosystems for the benefit of present and future generations (*CEMAR, 2008a*).

CEMAR undertakes research, planning, and stakeholder facilitation projects with the intent of balancing conservation and restoration with other beneficial uses such as water supply and flood protection and works across the public sector with individual jurisdictions, interest-based coalitions, and State and Federal agencies to establish scientifically-sound management directions (*CEMAR, 2008b*).

CEMAR's current focus is the restoration of steelhead and salmon in California, where they are developing scientific information for collaborative decision-making to identify durable strategies for sustainable management of California's coastal watersheds (*CEMAR, 2008b*). CEMAR is also working to educate all sectors of our society about the science of climate change and the need to take action now to prevent major human and economic consequences in the future (*CEMAR, 2008b*).

CEMAR has published some excellent references on salmon habitat in the greater San Francisco Bay Area, all of which are available on their website (http://www.cemar.org/).

C-5.3 Environmental Defense Fund

Environmental Defense Fund (EDF) is a national nonprofit organization representing more than 500,000 members (*EDF, 2008a*). Since 1967, EDF has linked science, economics and law to create innovative, equitable and cost-effective solutions to society's most urgent environmental problems (*EDF, 2008a*). Environmental Defense Fund dedicates itself to protecting the environmental rights of all people, including future generations, among these rights are access to clean air and water, healthy and nourishing food, and flourishing ecosystems (*EDF, 2008a*).

Guided by science, Environmental Defense Fund evaluates environmental problems and works to create and advocate solutions that win lasting political, economic and social support because they are nonpartisan, cost-efficient and fair (*EDF, 2008a*).

EDF believes that a sustainable environment will require economic and social systems that are equitable and just (*EDF, 2008a*). They have four major programs (*EDF, 2008a*): global warming; land, water and wildlife; oceans; and health. Of these, the land, water and wildlife program has a direct relation to River Restoration and is described in more detail below.

C-5.3.1 Land, Water and Wildlife

Environmental Defense works with landowners, businesses, indigenous groups and others to restore ecosystems and protect biodiversity, seeking to leverage market incentives and other innovative financing options to drive billions of dollars in government and private funds towards rehabilitating major rivers and coastal delta systems, reversing the decline of rare habitats and bringing endangered species back from the brink of extinction (*EDF, 2008b*). The EDF Center for Rivers and Deltas, staffed by leading economists, policymakers, attorneys and hydrologists, seeks to reform federal policy and modernize water laws in key states to (*EDF, 2008b*):

- *Provide incentives for water conservation in cities and on farms;*
- *Promote voluntary water rights markets to avoid the need for new environmentally harmful dams;*
- *Establish laws and incentives to protect the flows needed to sustain healthy streams and rivers;*
- *Build resiliency to climate change into water supply systems; and*
- *Improve flood control by establishing a strong national policy to restore wetlands and reconnect rivers to their natural floodplains.*

EDF has positioned the Center for Rivers and Deltas to work with partners to bring the nation's mighty river system back to life, so there will be enough water for everyone (*EDF, 2008b*).

C-5.4 Friends of Creeks Groups

Many communities have local grass-roots volunteer organizations that work to promote clean water and healthy watersheds. The groups conduct trash cleanup walks, riparian planting, water quality monitoring and testing, and water resources testing. These groups tend to have a wealth of background knowledge on their creek of interest and should be viewed as a great source of information as well as project collaboration for any restoration activities. It may, in fact, be surprising how much assistance these groups can supply and how numerous they are. Some Friends of Creeks groups in the greater Bay Area include:

Alameda County

- Friends of Five Creeks (Codornices Creek, Cerrito Creek, Marin Creek, Blackberry Creek, Village Creek, and Schoolhouse Creek);
- Friends of Strawberry Creek;
- Friends of Temescal Creek;
- Piedmont Avenue Neighborhood Improvement League (Glen Echo Creek);
- Friends of Sausal Creek;
- Butters Land Trust (Peralta Creek);
- Friends of Capistrano Creek;

- Friends of San Leandro Creek;
- Friends of Ward Creek Watershed;
- Alameda Creek Alliance;
- Friends of Baxter Creek;

Contra Costa County

- Friends of Baxter Creek;
- San Pablo Watershed Neighbors Education and Restoration Society (San Pablo, Bear Creek, Lauterwasser Creek, Castro Ranch Creek, Appian Creek, Wilkie Creek);
- Friends of Garrity Creek;
- Friends of Pinole Creek;
- Friends of the Rodeo and Carquinez Watersheds;
- Friends of Orinda Creeks;
- Friends of Lafayette Creeks;
- Friends of Alhambra Creek;
- Friends of Grayson Creek;
- Kirker Creek Watershed Partners;
- Friends of Mount Diablo Creek;
- Friends of Marsh Creek;

North Bay

- Mill Valley StreamKeepers;
- Friends of Corte Madera Creek Watershed;

- Friends of Miller Creek;
- Friends of Novato Creek;
- Salmon Protection and Watershed Network (Lagunitas Creek, San Geronimo Valley Creek);
- Students and Teachers Restoring a Watershed (STRAW) Project (Stemple Creek and Tributaries);
- Dutch Bill Creek Watershed Group;
- Friends of the Russian River;
- Atascadero and Green Valley Creek Watershed Council;
- Blucher Creek Watershed Group;
- Cotati Creek Critters (Laguna de Santa Rosa);
- Friends of Petaluma River;
- Save the Bay (Tolay Creek);
- Friends of the Napa River;
- Vallejo Watershed Alliance;
- Save Suisun Creek Alliance;
- Putah Creek Council;

<u>San Francisco/Peninsula</u>

- Friends of Glen Canyon Park;
- Friends of Islais Creek;
- Friends of Lobos Creek;
- Mission Creek Conservancy;

- San Pedro Creek Watershed Coalition;
- Friends of Cordilleras Creek;
- San Francisquito Watershed Council;
- Friends of Calabazas Creek;
- Friends of Stevens Creek Trail;
- Friends of Guadalupe River Park and Gardens;
- Friends of Los Alamitos Creek; and
- Coyote Creek Alliance.

C-5.5 The National Academies

The National Academies perform an unparalleled public service by bringing together committees of experts in all areas of scientific and technological endeavor and all the experts serve *pro bono* to address critical national issues and give advice to the federal government and the public (*National Academies, 2008*). Four organizations comprise the Academies (*National Academies, 2008*): the National Academy of Sciences, the National Academy of Engineering, the Institute of Medicine and the National Research Council. Of these, the National Academy of Engineering, National Academy of Sciences, and the National Research Council directly impact the practice of River Restoration and these two organizations are described in more detail below.

C-5.5.1 National Academy of Engineering

Founded in 1964, the National Academy of Engineering (NAE) provides engineering leadership in service to the nation, operating under the same congressional act of incorporation that established the National Academy of Sciences, signed in 1863 by President Lincoln (*NAE, 2008*). Under this charter the NAE is directed "whenever called upon by any department or agency of the government, to investigate, examine, experiment, and report upon any subject of science or art" (*NAE, 2008*). The NAE is a private, independent, nonprofit institution and in addition to its role as advisor to the federal government, the NAE also conducts independent studies to examine important topics in engineering and technology (*NAE, 2008*).

The NAE has more than 2,000 peer-elected members and foreign associates, senior professionals in business, academia, and government who are among the world's most accomplished engineers who provide the leadership and expertise for numerous projects focused on the relationships between engineering, technology, and the quality of life (*NAE, 2008*). The NAE provides advisory services to the federal government, primarily through studies and projects executed by the National Research Council (NRC). In a typical year, more than 900 NRC study committees are in operation (*NAE, 2008*).

In addition to NRC activities, the NAE also conducts an independent study program using its own funds (*NAE, 2008*). In these studies the NAE addresses important topics in engineering and technology that have significant economic and social implications (*NAE, 2008*). In recent years the work of the NAE has focused on establishing a balance between economic growth and environmental protection; ensuring national prosperity in era of global economic and technological interdependence; and supporting an education system that can provide both a literate, well-trained workforce (*NAE, 2008*).

C-5.5.2 National Academy of Sciences

The National Academy of Sciences (NAS) is an honorific society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare (*NAS, 2008*). The NAS was signed into being by President Abraham Lincoln on March 3, 1863, at the height of the Civil War (*NAS, 2008*). As mandated in its Act of Incorporation, the NAS has, since 1863, served to "investigate, examine, experiment, and report upon any subject of science or art" whenever called upon to do so by any department of the government (*NAS, 2008*).

The NAS provides a public service by working outside the framework of government to ensure independent advice on matters of science, technology, and medicine (*NAS, 2008*). NAS enlists committees of the nation's top scientists, engineers, and other experts, all of whom volunteer their time to study specific concerns and the results of their deliberations have inspired some of America's most significant and lasting efforts to improve the health, education, and welfare of the population (*NAS, 2008*). The Academy's service to government has become so essential that Congress and the White House have issued legislation and executive orders over the years that reaffirm its unique role.

The Academy membership is composed of approximately 2,100 members and 380 foreign associates, of whom nearly 200 have won Nobel Prizes (*NAS, 2008*). Members and foreign associates of the Academy are elected in recognition of their distinguished and continuing achievements in original research; election to the Academy is considered one of the highest honors that can be accorded a scientist or engineer (*NAS, 2008*). The Academy is governed by a Council consisting of twelve members (councilors) and five officers, elected from among the Academy membership (*NAS, 2008*).

C-5.5.3 National Research Council

The National Research Council (NRC) was established in 1916, with a mission to improve government decision making and public policy, increase public education and understanding, and promote the acquisition and dissemination of knowledge in matters involving science, engineering, technology, and health (*NRC, 2008*). The institution takes this charge seriously and works to inform policies and actions that have the power to improve the lives of people in the U.S. and around the world (*NRC, 2008*).

The NRC is committed to providing elected leaders, policy makers, and the public with expert advice based on sound scientific evidence (*NRC, 2008*) The NRC does not receive direct federal appropriations for its work, rather individual projects are funded by federal agencies, foundations, other governmental and private sources, and the institution's endowment (*NRC, 2008*). The work is made possible by 6,000 of the world's top scientists, engineers, and other professionals who volunteer their time without compensation to serve on committees and participate in activities (*NRC, 2008*). The NRC is administered jointly by the NAS, NAE, and the IOM through the NRC Governing Board (*NRC, 2008*).

The core services involve collecting, analyzing, and sharing information and knowledge. The independence of the institution, combined with its unique ability to convene experts, allows it to be responsive to a host of requests (*NRC, 2008*). The portfolio of activities includes (*NRC, 2008*):

- *Consensus Studies: These comprehensive reports focus on major policy issues and provide recommendations for solving complex problems.*
- *Expert Meetings and Workshops: By convening symposia, workshops, meetings, and roundtables, the NRC connects professionals as well as the interested public and stimulates dialogue on diverse matters.*
- *Program and Research Management: At the request of state and federal agencies, the NRC manages and evaluates research programs, conducts program assessments, and reviews proposals.*
- *Fellowships: The NRC administers several postdoctoral fellowship programs.*

The results of the findings are generally available as free scientific reports. Publishing more than 200 reports and related publications each year, the institution is one of the largest providers of free scientific and technical information in the world (*NRC, 2008*). Most of it is now on the Web at www.nap.edu.

C-5.6 The Natural Heritage Institute

The Natural Heritage Institute (NHI) is a non-governmental, non-profit organization founded in 1989 by a group of experienced conservation lawyers and scientists who foresaw the need for a toolkit for the next era of environmental problem-solving: where the technical challenges are more complex, the solutions more elusive, the economics more central, the ramifications more global, and the conventional pathways less efficacious (*NHI, 2008*). NHI's core mission is to restore and protect the natural functions that support water-dependent ecosystems and the services they provide to sustain and enrich human life (*NHI, 2008*).

As a public interest law firm that advocates as an engine for social change, NHI acts as both a representative of environmental interests and a counselor to the ultimate custodians, managers and regulators of water resource assets, representing conservation interests in complex, multi-party negotiations over the allocation of natural resources (*NHI, 2008*). NHI operates both within and outside of the policy-making institutions, typically bridging across institutional boundaries, working in creative partnerships with other governmental and non-governmental organizations (*NHI, 2008*). Whereas these government agencies and the private resource custodians are often absorbed by the urgent at the expense of the important, NHI has the advantage of being able to take the longer view and illuminate the transformational solutions that loom beyond the conventional planning horizon (*NHI, 2008*). NHI endeavors to keep a seat at every table and a voice in every forum, recognizing that constructive engagement with the custodians and managers of both public and private resources is indispensable (*NHI, 2008*). NHI consciously predicates its action agenda on a sound technical and scientific foundation, even when that may lead NHI in unfamiliar directions (*NHI, 2008*). NHI addresses the economic incentive structures that tend to discount future values in favor of present ones in resource management decisions (*NHI, 2008*). Their belief is that if the incentives can be rectified, the custodians, consumers, managers and regulators will make the right decisions, thus, market mechanisms and the elimination of perverse subsidies are important tools, and distributional impacts of resource policies are necessary considerations (*NHI, 2008*).

NHI works in watersheds worldwide, including transboundary systems, that have been significantly altered and those where intact aquatic systems of exceptional ecological value are subject to imminent development pressure (*NHI, 2008*). NHI pursues an integrated systems approach that includes entire water-centered landscapes from headwaters, to floodplains, to wetlands, to estuarine systems, to the near shore environment, and includes both groundwater and surface water systems and their interactions (*NHI, 2008*). NHI targets systemic improvements and tool development rather than place-based or species-specific conservation actions (*NHI, 2008*).

C-5.7 The Nature Conservancy

The Nature Conservancy's mission is to preserve the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive (*TNC, 2008a*). The Nature Conservancy's work has been guided by a Conservation by Design framework; a systematic approach that determines where to work, what to conserve, what strategies to use and their effectiveness (*TNC, 2008b*). Conservation by Design marries a collaborative, science-based approach with key analytical methods that we use to assess and plan their actions (*TNC, 2008b*). In the more than 30 countries in which we work, Conservation by Design enables the Conservancy to preserve healthy ecosystems that support people and host the diversity of life on Earth (*TNC, 2008b*). The Nature Conservancy applies their science-based conservation approach in multiple scales to reflect patterns in nature as well as socio-political and economic realities. The basic concepts of Conservation by Design consist of

(*TNC, 2008d*): setting goals and priorities, developing strategies, taking action and measuring results.

C-5.7.1 Setting Goals and Priorities

Conservation goals describe the results TNC wants to achieve for biodiversity (*TNC, 2008d*). Based on the best available scientific information, TNC sets long-term goals for the abundance and geographic distribution of species and ecological systems necessary to ensure the long-term survival of all biodiversity on Earth (*TNC, 2008d*).

TNC also set near-term goals, such as their current goal of conserving at least 10 percent of every major habitat type on Earth by 2015, as "stepping stones" toward TNC's global mission (*TNC, 2008d*). To make the most effective progress toward their conservation goals, TNC established priorities, those places, threats to biodiversity and strategic opportunities that are most in need of conservation action or promise the greatest conservation return on investment (*TNC, 2008d*).

C-5.7.2 Developing Strategies

Guided by those priorities, TNC works with others to design innovative conservation strategies to meet their goals, strategies tailored to the understanding of ecology and critical threats to biodiversity as well as to the social, political and economic forces at play (*TNC, 2008d*). TNC seeks solutions that will meet the needs of species and ecosystems as well as people (*TNC, 2008d*).

C-5.7.3 Taking Action

TNC is committed to place-based results by taking action locally, regionally and globally (*TNC, 2008d*). The bulk of their resources, human and financial, are spent executing the developed strategies with partners. These actions are varied and agile, but typically include (*TNC, 2008d*):

- *Investing in science to inform decision-making;*
- *Protecting and managing land and waters, as we did with the largest forest conservation deal in the United States;*
- *Forging strategic alliances with a variety of groups from all sectors;*
- *Creating and maintaining supportive public policies, practices and incentives;*
- *Strengthening the institutional capacity of governments and non-governmental organizations to achieve conservation results, through programs such as the Amazon Indigenous Training Center;*
- *Developing and demonstrating innovative conservation approaches, such as our work to create resilient networks of protected marine areas;*
- *Building an ethic and support for biodiversity conservation, such as we do with community restoration projects; and*
- *Generating private and public funding, including through innovative debt-for-nature swaps.*

C-5.7.4 Measuring Results

TNC measures effectiveness by answering two questions (*TNC, 2008d*): "How is the biodiversity doing?" and "Are our actions having the intended impact?" Tracking progress toward goals and evaluating the effectiveness of strategies and actions provide the feedback needed to adjust TNC goals, priorities and strategies and chart new directions (*TNC, 2008d*).

TNC uses three complementary analytical methods (*TNC, 2008c*): global habitat assessments, ecoregional assessments and conservation action planning.

C-5.7.5 Global Habitat Assessments

To establish goals and priorities in a global context, TNC works with others to assemble, improve and disseminate global data on the distribution and status of biodiversity, habitat condition, current and future threats to that biodiversity and the socio-political conditions that influence conservation success. These data are used to estimate the current level of effective conservation within and across ecoregions in each major habitat type on Earth, and to set 10-year goals for advancing effective conservation (*TNC, 2008c*). TNC uses these global habitat assessments to help identify conservation gaps and establish priorities for allocating resources on a global scale, which specific ecoregions, threats to biodiversity and strategic opportunities affect one or more major habitat types and demand immediate attention (*TNC, 2008c*).

C-5.7.6 Ecoregional Assessments

To establish goals and priorities for the highly ranked ecoregions identified in a global habitat assessment, TNC works with others to develop and disseminate finer-scale data on the distribution and status of biodiversity, habitat condition, current and future threats and the socio-political conditions that influence conservation success within those ecoregions (*TNC, 2008c*).

C-5.7.7 Conservation Action Planning

TNC translates global and ecoregional priorities into conservation strategies and actions through Conservation Action Planning (*TNC, 2008c*). This method is used to design and manage conservation projects that advance conservation at any scale, from efforts to conserve species and ecosystems in a single watershed or landscape to efforts to reform regional or multi-national policies (*TNC, 2008c*).

The Nature Conservancy has seven priority conservation initiatives to address the principal threats to conservation (*TNC, 2008e*). Through these initiatives, TNC advances conservation science, developing multi-site strategies, catalyzing global partnerships and improving policies in each of these key conservation areas (*TNC, 2008e*): global marine imitative; freshwater conservation; global climate change initiative; global fire initiative; global invasive species initiative; protected areas; and the global forest partnership. Of these initiatives, the freshwater conservation initiative has direct implications to River Restoration.

C-5.7.8 Freshwater Conservation

The Nature Conservancy has been designing and implementing strategies to protect earth's fresh waters for decades (*TNC, 2008f*). To improve the health of freshwater resources, TNC's focus is on practical, science-based solutions to help society meet today's and tomorrow's water needs for nature and people (*TNC, 2008f*). Their efforts include (*TNC, 2008f*):

- *Reducing the Ecological Impact of Dams;*
- *Reconnecting Floodplains with Rivers;*
- *Protecting Watersheds and Water Supplies for Cities;*
- *Changing Water Policies to Protect Environmental Flows;*
- *Promoting Sustainable Agricultural Practices;*
- *Protecting Coastal Rivers and Estuaries;*
- *Guarding Freshwater Ecosystems from Invasive Species; and*
- *Sustaining Ecosystem Resilience to Climate Change.*

Deep investment in over 600 freshwater projects around the world informs these efforts and TNC works with local communities, build alliances to support new approaches, share innovations with others, and establish meaningful and productive partnerships with some of the world's most influential water, energy and agricultural companies and organizations to accomplish their work (*TNC, 2008f*).

C-5.8 San Francisco Bay Joint Venture

The San Francisco Bay Joint Venture (SFBJV) is one of eighteen Joint Ventures established under The Migratory Bird Treaty Act and funded under the annual Interior

Appropriations act and SFBJV brings together public and private agencies, conservation groups, development interests, and others to restore wetlands and wildlife habitat in San Francisco Bay watersheds and along the Pacific coasts of San Mateo, Marin and Sonoma counties (*SFBJV, 2008a*). The goal of the San Francisco Bay Joint Venture is to protect, restore, increase and enhance all types of wetlands, riparian habitat and associated uplands throughout the San Francisco Bay region to benefit birds, fish and other wildlife. SFBJV has very explicit habitat goals which are to (*SFBJV, 2008b*):

- *Protect 63,000 acres, restore 37,000 acres, enhance another 35,000 acres of San Francisco Bay's tidal flats, marshes, and lagoons to benefit waterfowl, shorebirds, and other wildlife;*
- *Protect 37,000 and restore and/or enhance 30,000 acres of seasonal wetlands for breeding waterfowl and migrating shorebirds; and*
- *Restore and/or enhance approximately 1000 miles of creeks and protect 40,000 acres of riparian corridors for resident and migratory songbirds.*

The San Francisco Bay Joint Venture is composed of a Management Board and four Working Committees established to accomplish specific SFBJV objectives (*SFBJV, 2008b*). These committees include diverse representation from state and federal agencies, environmental organizations, hunting and fishing groups, the business community, landowners, public utilities and local government. Members of each of these groups are expected to assist with external communications at national, state and local levels, help secure funding for projects supported by the Joint Venture and bring new initiatives to it (*SFBJV, 2008b*).

The Management Board consists of 26 agencies and private organizations whose members agree to support and promote the goal and objectives of the Joint Venture and who represent the diversity of wetlands interests found in the San Francisco Bay Region (*SFBJV, 2008b*). The SFBJV offers the opportunity to acquire and restore more wetlands than was previously thought possible because of the leveraging capacity available through organizational cooperation (*SFBJV, 2008b*).

Working Committees of the SFBJV help accomplish the specific objectives of the Joint Venture and can be established at any time by the Management Board. The SFBJV Working Committees include (*SFBJV, 2008b*): Restoration Strategy/Technical (subcommittee: Regional Creeks); the Legislative Committee; and the Public Outreach Committee.

C-5.8.1 Restoration Strategy/Technical

The Restoration Strategy/Technical Committee identifies restoration opportunities for SFBJV by (*SFBJV, 2008c*): developing a list of potential acquisition, restoration and enhancement opportunities and specific projects that will further the goals of the Joint Venture, based on technical review and evaluation; developing prioritization criteria, and recommend projects to the Management Board, integrating marshland and creek issues; providing technical information and assistance to the Management Board and members; recommending monitoring mechanisms and protocols to measure progress; tracks accomplishments of Joint Venture projects; convenes Marshlands subcommittee and

Creeks subcommittee, for information exchange, project identification, partnership development, trouble-shooting and coordination; drafts Implementation Strategy to guide acquisition and restoration activities; recommends to the Management Board the creation of new Working Committees as need arises; provides technical information to the Management Board to set and achieve habitat objectives; performs work assignments as directed by the Management Board; and coordinates Joint Venture Implementation Strategy with Regional Wetlands Ecosystem Goals Project.

C-5.8.2 Legislative Committee

The Legislative Committee Develops and implements a legislative strategy to secure funding and otherwise support projects promoted by SFBJV, tracks current and developing legislative issues, and advises the Management Board on appropriate actions (*SFBJV, 2008c*).

C-5.8.3 Public Outreach Committee

SFBJV has an active public outreach committee that is responsible for developing a public outreach strategy for external communications at the national, state and local levels as well as designing brochures, web site and other publications as directed by the Management Board (*SFBJV, 2008c*). The Committee helps facilitate public involvement and promoting the goals of Restoring the Estuary, hosts tours and events for legislators and key decision makers, serves as a liaison between partners and other wetlands protection efforts, and develops and implements strategies and tools for informing the community about the mission of the joint venture (*SFBJV, 2008c*).

C-5.9 San Francisco Estuary Institute

The San Francisco Estuary Institute (SFEI) was founded as a non-profit organization in 1986 (formerly known as the Aquatic Habitat Institute) to foster the development of the scientific understanding needed to protect and enhance the San Francisco Estuary (*SFEI, 2008a*). SFEI is governed by a Board of Directors composed of Bay Area scientists, environmentalists, regulators, local governments, and industries (*SFEI, 2008a*).

SFEI fills the niche between environmental science and environmental management and policy for San Francisco Estuary and its watershed, by conducting science studies, synthesizing data and information, and collaborate with other scientists to provide a holistic integration of information from many disciplines that supports management activities or demonstrates the potential implications of different management scenarios to environmental management agencies and other stakeholders (*SFEI, 2008a*). SFEI's work is relevant to the primary issues currently facing the ecosystem, including industrial and municipal discharge, non-point source pollution, biological invasions, and watershed and wetlands restoration (*SFEI, 2008a*).

Their programs include (*SFEI, 2008b*): Aquatic Pesticides Monitoring Program; Biological Invasions Program; Contaminant Monitoring and Research; EcoAtlas; Historical Ecology; Regional Monitoring Program for Water Quality; Watersheds Science Program; and Wetlands Science Program. These are described in more detail below:

C-5.9.1 Aquatic Pesticides Monitoring Program

The Aquatic Pesticides Monitoring Program designed and implemented a monitoring plan to determine the potential effects of aquatic pesticides on environments throughout California (*SFEI, 2008c*). This data was used by the State Water Resources Control Board in its development of new aquatic pesticide NPDES permits.

The APMP arose from the fallout of a 2001 legal decision in the U.S. Ninth Circuit court (Headwaters, Inc. v. Talent Irrigation District) which was interpreted as requiring that aquatic pesticide users obtain a National Pollution Discharge Elimination System (NPDES) permit prior to discharging pesticides to U.S. waters (*SFEI, 2008c*). Previously, pesticide use was governed only under federal pesticide law (FIFRA) and in order to keep aquatic pesticide users legal under the recent court decision, last July the State Water Resource Control Board (SWRCB) issued an emergency permit (*SFEI, 2008b*). However, the advocacy group Waterkeepers felt that this permit did not require adequate monitoring and challenged the permit in court (*SFEI, 2008c*). As a settlement with Waterkeepers, the SWRCB agreed to fund two years of research and monitoring to provide the state with enough information to develop a good general NPDES permit when the current emergency permit expires (*SFEI, 2008c*).

C-5.9.2 Biological Invasions Program

Biological invasions, the introduction and spread of exotic organisms in regions outside of their native range, has emerged as a major environmental, economic and public health problem tied to the rapid, ongoing expansion in international trade and travel (*SFEI, 2008d*). Recent studies have found that exotic organisms constitute the second greatest threat to biological diversity, ranking below habitat loss and degradation but far above pollution and over harvesting (*SFEI, 2008d*). SFEI's Biological Invasions program conducts scientific and policy research and provides information and analyses on the introduction of exotic organisms into marine and freshwater ecosystems (*SFEI, 2008d*).

C-5.9.3 Contaminant Monitoring and Research

SFEI's Contaminant Monitoring and Research Program (CMR) include all contaminant-related activities of the Institute (*SFEI, 2008e*). A variety of monitoring and research projects are coordinated by CMR staff to produce an overall understanding of contamination sources, fate, and effects in the Estuary (*SFEI, 2008e*). Monitoring data stimulates the formulation of hypotheses about processes and identifies gaps in understanding that may be addressed by research (*SFEI, 2008e*). Research may provide better interpretations of monitoring data or may produce better monitoring methods and indicators (*SFEI, 2008e*).

C-5.9.4 EcoAtlas

The EcoAtlas provides public access to a large collection of objective scientific data and information about the San Francisco Estuary and its watersheds, including (*SFEI, 2008f*):

- *Wetland Project Tracker (interactive map of Bay Area wetland projects);*
- *Ecoatlas (interactive maps and monitoring program information);*
- *PCBs in the Bay (Interactive map of PCB concentrations in the Bay); and*
- *EcoAtlas Baylands Maps.*

C-5.9.5 Historical Ecology

Historical ecology is the documentation of landscape change and has become an essential tool for understanding both current conditions and restoration potential (*SFEI, 2008g*). The Historical Ecology Program creates this information using a range of innovative methods to recover and synthesize diverse historical data sources, providing essential information for the management of creeks, wetlands, and terrestrial environments (*SFEI, 2008g*).

The objectives of the historical ecology effort is to (*SFEI, 2008g*): develop information about historical landscape change to support natural resource agencies and environmental groups involved in local and regional ecological planning and restoration; develop and disseminate new methods for the synthesis and analysis of historical data into reliable technical information; coordinate technically consistent and comparable historical ecology studies of California coastal watersheds to guide long term strategic planning for habitat restoration, endangered species recovery, and response to climate change; and contribute SFEI research about landscape history to the larger public arena through art and education.

Historical Ecology Projects are carried out in collaboration with local organizations, other SFEI programs, and an extended group of archivists, historians, and scientists (*SFEI, 2008g*). Key components of the program include the analysis of historical document accuracy, the synthesis of historical data into composite maps, and the visualization of landscape change through a variety of media (*SFEI, 2008g*).

C-5.9.6 Regional Monitoring Program for Water Quality

The Regional Monitoring Program for Water Quality (RMP) has combined shared financial support, direction, and participation by regulatory agencies and the regulated community in a model of collective responsibility (*SFEI, 2008h*). The RMP has established a climate of cooperation and a commitment to participation among a wide range of regulators, dischargers, industry representatives, community activists, and scientists and the RMP provides an open forum for interested parties to communicate about contaminant issues facing the Bay (*SFEI, 2008h*). The RMP works in close collaboration with the recently established Clean Estuary Partnership (CEP), a group of representatives from wastewater treatment plants, stormwater agencies, and the Regional Board (*SFEI, 2008h*). The CEP was formed in 2001 to provide information to facilitate the development of Total Maximum Daily Loads (TMDL) and other water quality attainment strategies for the Bay (*SFEI, 2008h*).

The RMP provides information targeted at the highest priority questions faced by managers of the Bay (*SFEI, 2008h*). The RMP produces an Annual Monitoring Report that summarizes the current state of the Estuary with regard to contamination, a summary report (Pulse of The Estuary), a quarterly newsletter, technical reports that document specific studies and synthesize information from diverse sources, and journal publications that disseminate RMP results to the world's scientific community (*SFEI, 2008h*). The RMP web site provides access to RMP products and links to other sources of information about water quality in San Francisco Bay (*SFEI, 2008h*).

C-5.9.7 Watersheds Science Program

The watershed program at SFEI was founded in 1998 to assist local and regional environmental management and the public to understand, characterize and manage environmental resources in the watersheds of the Bay Area (*SFEI, 2008i*). Most projects are carried out collaboratively with other scientists or technical managers from universities, private consulting firms, agencies, or local environmental groups and SFEI often works with field volunteers and local community or place based environmental groups (*SFEI, 2008i*). SFEI helps local groups to build capacity, passing on methods and philosophies, and increasing the scientific validity of their work and we often assist them with grant writing (*SFEI, 2008i*).

The Watershed Program at SFEI provides Bay Area environmental managers with quality science information in the context of the whole system (watersheds, the airshed, wetlands, and the Bay) and it is their intent is to help develop a regional picture of watershed condition and downstream effects through a solid foundation of literature review and peer-review and the application of a range of quality science methodologies, empirical data collection and interpretation in watersheds around the Bay Area (*SFEI, 2008i*).

C-5.9.8 Wetlands Science Program

SFEI's wetland science program coordinates the design and implementation of a regional program to monitor the status and trends of the wetland ecosystem of the San Francisco Estuary, with specific objectives that include (*SFEI, 2008j*): contributing to the scientific basis for wetland conservation, to the assessment of the success (or failure) of wetland restoration projects, and to the assessment of the ecological effects of wetland management including restoration; creating and maintaining a regional public access information system about wetlands in the region; enhancing coordination of wetland research within the region between and among state and federal agencies and academia; and enhancing coordination of monitoring and research that regards wetlands as transitional landscapes between terrestrial and aquatic systems.

C-5.10 Sierra Club

The Sierra Club is the oldest and largest grassroots environmental organization in the United States and was founded on May 28, 1892 in San Francisco, California by the well-known conservationist and preservationist John Muir, who became its first president (*Wikipedia, 2008c*). The Sierra Club has hundreds of thousands of members in chapters located throughout the US. The mission of the Sierra Club is to explore, enjoy, and protect the wild places of the earth; To practice and promote the responsible use of the earth's ecosystems and resources; To educate and enlist humanity to protect and restore the quality of the natural and human environment; and to use all lawful means to carry out these objectives (*Wikipedia, 2008c*).

The Sierra Club has official policies on a number of conservation issues, which they group into 17 categories (*Wikipedia, 2008c*): agriculture, biotechnology, energy, environmental justice, forest and wilderness management, global issues, government and political issues, land management, military issues, nuclear issues, oceans, pollution and waste management, precautionary principle, transportation, urban and land use policies, water resources, and wildlife conservation. One long-standing goal of the Sierra Club has been opposition to dams it considers inappropriate (*Wikipedia, 2008c*). In the early 20th century, the organization fought against the damming and flooding of the Hetch Hetchy Valley in Yosemite National Park (*Wikipedia, 2008c*). Despite this lobbying, Congress authorized the construction of O'Shaughnessy Dam on the Tuolumne River (*Wikipedia, 2008c*). The Sierra Club continues to lobby for removal of the dam, urging that San Francisco's water needs be accommodated instead by the re-engineering of the Don Pedro Reservoir downstream (*Wikipedia, 2008c*).

C-5.11 Urban Creeks Council

The Urban Creeks Council is a non-profit organization located in Berkeley, California, working to preserve, protect, and restore urban streams and their riparian habitats (*UCC, 2008*). UCC facilitates programs that protect streams, restore riparian habitats to urban areas and give people the chance to experience nature in the urban context, and offer support and technical service to agencies, creeks groups and landowners (*UCC, 2008*).

The restoration projects implemented are designed to preserve the natural form and function of creeks, increase biodiversity and habitat for native species, and serve as a recreational and educational resource for the public (*UCC, 2008*). The projects are funded through grants from federal and state agencies as well as private foundations, with foundation grants and donations supporting many local programs and riparian advocacy activities (*UCC, 2008*).

UCC advocates low-cost, effective methods of bank stabilization and revegetation using geotechnical soil-bioengineering techniques, or plant-based systems, for stream bank and slope restoration (*UCC, 2008*). Soil-bioengineering provides both immediate and long-term slope protection and erosion reduction, while California native riparian plants offer excellent wildlife habitat (*UCC, 2008*).

In addition to our hands-on restoration work, UCC works to educate citizens and agencies about creeks, and advocates for creek protection through public process (*UCC, 2008*). The Urban Creeks Council (UCC) implements both specific restoration projects, as well as ongoing programs for creek restoration and education (*UCC, 2008*).

C-5.12 The Watershed Project

The Watershed Project helps homes, schools, and communities protect water resources throughout the San Francisco Bay Area through their programs to prevent pollution, save water, reduce waste, and protect local birds and wildlife (*Watershed Project, 2008*). The mission of the Watershed Project is to educate and inspire communities to protect their local watersheds (*Watershed Project, 2008*). The Watershed Project hosts a number of workshops and serves as a facilitator to link community members with activities within their watershed of interest.

The Watershed Project takes an innovative approach to protecting our water resources by giving people the practical skills they need to reduce pollution and protect the health of the San Francisco Bay (*Watershed Project, 2008*).

Since 1997, the Watershed Project (formerly the Aquatic Outreach Institute) has assisted hundreds of teachers and thousands of students in preventing pollution and protecting and restoring local natural resources (*Watershed Project, 2008*). They have involved thousands of members of the general public in education, restoration, and outreach projects (*Watershed Project, 2008*). By sharing information on the environment in and around the San Francisco Bay--and by providing citizens with the means to act on this information--the Watershed Project empowers present and future stewards of the San Francisco Bay with the confidence and skills they need to actively participate in decisions affecting the protection and use of local natural resources (*Watershed Project, 2008*).

C-6 PRIVATE/COMMERCIAL AGENCIES

There are hundreds, if not thousands, of private and commercial agencies and firms that participate in developing and implementing technologies related to River Restoration. However, to highlight the contributions of these private agencies, I have listed common types of professions involved with River Restoration:

- *Planners;*
- *Landscape Architects;*
- *Civil Engineers;*
- *Geologists (Engineering, Fluvial, Geomorphologists);*
- *Hydrologists;*
- *Lawyers;*
- *Chemists;*
- *Biologists;*
- *Ecologists; and*
- *Farmers.*

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Federal Interagency Stream Restoration Working Group

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Stream Corridor Restoration (2002)	X	X		X	X				X	X			X		X	X		X		X
Software																					

U.S. Forestry Service

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	A Soil Bioengineering Guide (2002)	X	X		X					X	X										
	A Framework for Analyzing the Hydrologic Condition of Watersheds	X								X	X		X	X		X			X	X	X
	Management and Techniques for Riparian Restorations (2002)	X			X														X	X	
Software	WinXSPro (Cross Sections)																				

National Resource Conservation Service

Type	Name	Life-Cycle Phase: Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	NRRSS Goal: Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws	Soil Conservation Act (1935)	X								X										X	
	Farm Bill (1985)	X																			
	Farm Bill (1996)	X																			
	USDA Departmental Policy for the National Environmental Policy Act	X																			
	GENERAL MANUAL : TITLE 190 - ECOLOGICAL SCIENCES : PART 410 - COMPLIANCE WITH NEPA - Part 410 - Compliance with NEPA	X																			
	Watershed Protection and Flood Prevention Act	X																			
Document	TR-28-1 Clay Minerals		X							X											
	National Engineering Handbook	X	X	X	X	X				X	X	X		X		X					
	Engineering Field Handbook		X	X						X	X	X		X		X					
	PSIAC - Erosion and Sediment Yield	X								X	X	X		X		X					
	Water Quality Guide	X																			X
	Water Quality Indicator's Guide	X																			X
	Design of Open Channels	X	X							X	X	X		X							
	Stream*A*Syst	X							X	X	X		X	X		X			X	X	X
	Stream Corridor Inventory and Assessment Techniques	X							X	X	X		X	X		X			X	X	X
	Watershed_Condition-Biotic_Condition_Indicators_Tech_Note_1	X														X					X
	Watershed_Condition-Index_of_Biotic_Integrity_Tech_Note_2	X														X					X
	Engineering Layout Notes Staking and Calculations			X						X	X			X							
	Geologic Investigations for Watershed Planning	X								X	X	X		X							
	Hood Inlets for Culvert Spillways		X								X		X								
	Hydraulic Design of Riprap Gradient Control Structures		X								X		X								
	Index of SCS National Engineering Technical Materials	X	X							X	X	X		X							
	Investigating Engineering Structural Problems and Deficiencies		X		X	X				X	X										
	Procedure for Computing Sheet and Rill Erosion on Project Areas		X		X																
	Lateral Earth Pressures		X																		
	Riprap for Slope Protection Against Wave Action		X							X											

National Resource Conservation Service

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Document	Tables of Percentage Points of the Pearson Type III Distribution		X							X	X		X								
	The Characterization of Rock for Hydraulic Erodibility		X																		
	Urban Hydrology for Small Watersheds	X	X							X	X	X	X	X						X	
	Water Surface Profiles and Tractive Stresses for Riprap Grade Control Structures		X								X										
	Guide for the Use of Geotextiles		X							X	X										
	Input Data for Design Unit Programs		X																		
	Guide to Organization and Operation of Independent Review Boards	X	X																		
	Probability of Occurrence for Certain Design Events	X	X																		
	Engineering Standard Drawings		X																		
	Color Codes for Sediment Yield Maps	X	X																		
	Geologic Investigation	X	X																		
	Prediction of Fine Sediment in Channels from Single Storm Events		X								X										X
	Soil Sample Size Requirements for Soil Mechanics Laboratory Testing		X																		
	Dispersive Clays		X																		
	Flow Net Construction and Use		X																		
	Permeability of Selected Clean Sands and Gravels		X																		
	The Mechanics of Seepage Analyses		X																		
	Estimates of Peak Rates of Runoff Using Measured Stream Flow Data		X							X	X	X	X	X						X	
	n-Value Guide		X							X	X	X	X	X						X	
	Handbook of Channel Design for Soil and Water Conservation	X	X							X	X	X	X	X						X	
	National Catalog of Erosion and Sediment Control and Stormwater Management Guidelines for Community Assistance	X	X																	X	
	Stability Design of Grass Lined Open Channels		X							X	X										
	The Bed-Load Function for Sediment Transport in Open Channel Flows	X	X							X	X	X	X	X						X	X
	Watershed-and-Stream-Mechanics	X	X																		
	Ecosystem Indicators Report	X														X					
	Principles and Guidelines for Water Resource Projects	X																			
	EFOTG!!	X																			

National Resource Conservation Service

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Document	National Environmental Compliance Handbook	X																			
Software	DRAINMOD (groundwater)		X												X						
	FLDWY		X								X				X						
	Websoil Survey 2.0	X	X							X	X								X	X	
	Cross-Section Analyzer		X							X	X			X							
	NRCS Geo-Hydro	X	X							X	X	X	X	X						X	
	WinTR-55 (Small Watershed Hydrology)	X	X							X	X	X	X	X						X	
	FreqCurves_ver209	X	X							X	X	X	X	X						X	
	EFH2	X	X							X	X	X	X	X						X	

Agricultural Resource Service

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document																					
Software	Snowmelt-Runoff Model (WinSRM)	X	X							X	X	X	X	X		X			X	X	X
	WinTR-55 is a single-event rainfall-runoff small watershed hydrologic model	X	X							X	X	X	X	X		X			X	X	X
	Geostatistical software package for analyzing spatially correlated data		X																		
	The purpose of this tool is to estimate latitude and longitude from a user inputted zip code.	X	X																		
	SamplePoint is a manual image-analysis program designed to facilitate vegetation cover measurements from nadir digital images of any scale.	X																		X	
	Water Erosion Prediction Project	X	X							X	X									X	
	RUSLE	X	X								X		X			X				X	
	Bank Stability and Toe Erosion Model	X	X							X	X										
	FLOWNET	X	X							X	X				X				X		
	Riparian Ecosystem Management Model	X	X																X	X	X
	Automated Geospatial Watershed Assessment	X	X												X					X	X
	Soil Water Assessment Tool (SWAT)	X	X																	X	X
	KINematic Runoff and EROSion (KINEROS2)	X	X							X	X									X	X

U.S. Army Corps of Engineers

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws	Wilderness Act (1964)	X							X										X		
	Wild and Scenic Rivers Act (1968)	X																			
	National Environmental Policy Act (1969)	X							X	X	X	X	X	X	X	X	X	X	X	X	X
	Flood Control Act of 1917	X																			
	Flood Control Act of 1928	X																			
	Flood Control Act of 1936	X																			
	Flood Control Act of 1937	X																			
	Flood Control Act of 1938	X																			
	Flood Control Act of 1939	X																			
	Flood Control Act of 1941	X																			
	Flood Control Act of 1944	X																			
	Flood Control Act of 1946	X																			
	Flood Control Act of 1948	X																			
	Flood Control Act of 1950	X																			
	Flood Control Act of 1954	X																			
	Flood Control Act of 1958	X																			
	Flood Control Act of 1960	X																			
	Flood Control Act of 1962	X																			
	Flood Control Act of 1965	X																			
	Flood Control Act of 1966	X																			
	Flood Control Act of 1968	X																			
	Flood Control Act of 1970	X																			
	Water Resources Development Act of 1974 (Section 22) and amendments	X							X	X	X										
	Water Resources Development Act of 1976	X																			
	Water Resources Development Act of 1986 (Section 206, 1103, 1135) and amendments	X																			
	Water Resources Development Act of 1988	X																			

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Type	Name	Life-Cycle Phase: Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	NRRSS Goal: Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws	Water Resources Development Act of 1990	X																			
	Water Resources Development Act of 1992 (Section 204) and amendments	X																			
	Water Resources Development Act of 1996	X																			
	Water Resources Development Act of 1999	X																			
	Water Resources Development Act of 2000	X																			
	Water Resources Development Act of 2007	X																			
	Rivers and Harbors Act of 1899	X																			
	Rivers and Harbors Act of 1917	X																			
	Rivers and Harbors Act of 1945	X																			
	Rivers and Harbors Act of 1948	X																			
	Rivers and Harbors Act of 1958	X																			
	Rivers and Harbors Act of 1960	X																			
	Rivers and Harbors Act of 1962	X																			
	Rivers and Harbors Act of 1965	X																			
	Rivers and Harbors Act of 1968	X																			
	Oil Pollution Act of 1924	X																			
	Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500)	X																			
	Rivers and Harbors Acts of 1890	X																			
	General Dam Act of 1906	X																			
Document	CPD-10 Hydraulics Graphics Package, User's Manual (HGP)	X	X							X	X			X	X					X	
	"Assessment of fish-plant interactions," Miscellaneous Paper A-97-6	X	X		X								X			X	X				
	"CE-QUAL-R1: A numerical one-dimensional model of reservoir water quality; User's manual (Revised Edition)," Instruction Report E-82-1		X		X											X					X
	"CE-QUAL-W2: A numerical two-dimensional, laterally averaged model of hydrodynamics and water quality; User's manual," Instruction Report E-8		X		X								X	X		X	X				X
	"Environmental effects of dikes and revetments on large riverine systems," Technical Report E-86-5	X	X							X	X			X		X			X		
	"Environmental features for streambank protection projects," Technical Report E-84-11	X	X							X	X								X		
	"Environmental features for streamside levee projects," Technical Report E-85-7	X	X							X	X								X		

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Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Document	"Environmental guidelines for dike fields," Technical Report E-84-4	X	X							X	X			X					X		
	"Environmental value of riparian vegetation," Technical Report EL-96-16	X	X																X		
	"Flood tolerance in Plants: A State-of-the-Art Review," Technical Report E-79-2	X	X											X		X			X		
	"Formulation of water quality models for streams, lakes, and reservoirs: Modeler's perspective," Miscellaneous Paper E-89-1	X	X																		X
	"Handbook of environmental quality measurements and assessment: Methods and techniques," Instruction Report E-82-2	X	X		X											X					X
	"Handbook on reservoir releases for fisheries and environmental quality," Instruction Report E-86-3	X	X		X								X		X						X
	"Incremental effects of large woody debris removal on physical aquatic habitat," Technical Report EL-92-35	X	X							X	X		X			X					
	"Inventory and assessment of aquatic plant management methodologies," Technical Report A-83-2	X	X		X	X										X	X				
	"Literature review of economic valuation of aquatic plant control," Miscellaneous Paper A-91-1	X	X		X	X										X	X				
	"Low-flow aquatic habitat restoration evaluation, the RCHARC Methodology, Goose Creek, Colorado," Technical Report EL-97-1	X	X		X	X										X	X				
	"Physical habitat analysis using the riverine community habitat assessment and restoration concept (RCHARC): Missouri River case history," Tech	X	X		X											X	X				
	"Proceedings of the U.S. Army Corps of Engineers riparian zone restoration and management workshop, 24-27 February 1986," Miscellaneous Pap	X	X		X	X													X		
	"RECOVERY, a Mathematical Model to Predict the Temporal Response of a Surface Water to Contaminated Sediments," Technical Report W-94-4		X		X																X
	"Relationships between fish and aquatic: A plan of study," Miscellaneous Paper A-93-1	X	X		X											X	X				X
	"Sampling design software; User's manual," Instruction Report W-93-1		X		X											X	X				X
	"Simplified procedures for eutrophication assessment and prediction: User Manual," Instruction Report W-96-2		X		X	X															X
	"Simplified, steady-state temperature and dissolved oxygen model: User's guide," Instruction Report E-86-4		X		X	X															X
	"Species selection for habitat assessments," Miscellaneous Paper EL-85-8	X	X													X	X				
	"Studies of water movement in vegetated and unvegetated littoral areas," Technical Report A-95-3	X	X		X	X				X	X			X					X		
	"Techniques for evaluating aquatic habitats in rivers, streams, and reservoirs; Proceedings of a workshop," Miscellaneous Paper W-91-2	X	X		X	X										X					
	"The effects of vegetation on the structural integrity of sandy levees," Technical Report REMR-E1-5	X	X		X	X				X									X		
	"Use of field techniques to assess the environmental effects of commercial navigation traffic," Technical Report EL-92-12	X			X											X					X
	"Water quality, macroinvertebrates, larval fishes, and fishes of the lower Mississippi River -- A synthesis," Technical Report E-86-12	X	X		X	X										X	X				X
	"WESTEX: A numerical one-dimensional reservoir thermal model; Report 1: User's manual," Instruction Report W-93-2		X		X	X															X
	"Workshop on riverine water quality modeling," Miscellaneous Paper E-81-1	X	X		X	X															X
	(IHD) Volume 1, Requirements and General Procedures	X	X							X	X										

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Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Document	(IHD) Volume 10, Principles of Ground-Water Hydrology		X							X	X			X		X			X		
	(IHD) Volume 11, Water Quality Determinations		X										X			X					X
	(IHD) Volume 12, Sediment Transport		X		X	X				X	X		X	X		X					X
	(IHD) Volume 2, Hydrologic Data Management		X		X	X															
	(IHD) Volume 3, Hydrologic Frequency Analysis		X							X	X		X	X		X			X		
	(IHD) Volume 4, Hydrology Analysis		X							X	X		X	X		X			X	X	
	(IHD) Volume 5, Hypothetical Floods		X							X	X		X	X		X			X	X	
	(IHD) Volume 6, Water Surface Profiles		X		X					X	X		X	X		X			X		
	(IHD) Volume 7, Flood Control by Reservoirs		X		X										X						
	(IHD) Volume 8, Reservoir Yield		X		X										X						
	(IHD) Volume 9, Reservoir System Analysis for Conservation	X	X		X										X						
	A conceptual framework for the evaluation of coastal habitats	X														X	X				
	A Metric and GIS Tool for Measuring Connectivity Among Habitat Patches Using Least-Cost Distances	X	X											X		X			X		
	A Regional Guidebook for Conducting Functional Assessments of Forested Wetlands and Riparian Areas in the Ozark Mountains Region of Arkai	X			X														X		
	A Regional Guidebook for Conducting Functional Assessments of Forested Wetlands in the Arkansas Valley Region of Arkansas	X			X														X		
	A Study of Vegetation on Revetments, Sacramento River Bank Protection Project - Phase 1: Literature Review and Pilot Study	X	X		X					X									X		
	A Watershed Assessment Tool for Evaluating Ecological Condition, Proposed Impacts, and Restoration Potential at Multiple Scales	X	X											X		X	X		X		
	Advantages and Disadvantages of Aquatic Plant Management Techniques	X			X	X										X	X				
	Algorithm Considerations for Evaluating Phosphorus Transport and Environmental Management Strategies Using a Grid-Based Spatial Watershed M		X		X																X
	Assessment of Environmental and Economic Benefits Associated with Streambank Stabilization and Phosphorus Retention	X	X							X						X					X
	Availability of an ArcGIS Wetland Restoration Spatial Decision Support System (SDSS) Tool	X	X													X					
	Avian Line Transect Methods	X			X														X		
	Avian Plot Methods	X			X														X		
	Avian Territory Mapping	X			X														X		
	Bioengineering for Streambank Erosion Control-Report 1: Guidelines	X	X	X						X	X								X		
	Boulder Clusters	X	X	X	X	X					X		X			X					

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Type	Name	Life-Cycle Phase: Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	NRRSS Goal: Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Document	Brush Mattresses for Streambank Erosion Control	X	X	X	X	X				X									X		
	Brush Piles	X	X	X															X		
	Catalog of Community Habitat Models	X														X			X		
	Channel Maintenance by Training Structures; Guidance for Numerical Model Mesh Development		X			X				X	X										
	Channel Rehabilitation: Processes, Design, and Implementation	X	X							X	X			X		X					
	Coastal Engineering Manual	X	X		X																
	Coir Geotextile Roll and Wetland Plants for Streambank Erosion Control	X	X	X	X	X				X	X					X					
	Computing Scour		X								X					X					
	Conceptual Models to Support Environmental Planning and Operations	X	X		X											X			X		
	Corridors and Vegetated Buffer Zones: A Preliminary Assessment and Study Design	X	X																X		
	Corridors and vegetated buffer zones—Guidelines for Corps projects	X	X																X		
	CPD-11 Thermal Simulation of Lakes, User's Manual (THERMS & HEATX)	X	X										X			X	X				X
	CPD-12 Statistical & Graphical Analyses of Stream Water Quality Data, User's Manual (SGSWQ)	X	X										X			X	X				X
	CPD-13 Flood Flow Frequency Analysis, User's Manual (HEC-FFA)	X	X							X	X			X	X					X	
	CPD-15 Geometric Elements from Cross Section Coordinates, User's Manual (GEDA)	X	X							X	X			X	X					X	
	CPD-27 Regional Frequency Computation, User's Manual (REGFQ)	X	X							X	X			X	X					X	
	CPD-28 Reservoir Temperature Stratification, User's Manual (RSTEMP)	X	X										X			X	X				X
	CPD-30 Expected Annual Flood Damage Computation, User's Manual (EAD)	X	X							X	X			X	X					X	
	CPD-31 Interior Flood Hydrology Package, User's Manual (HEC-IFH)	X	X							X	X			X	X					X	
	CPD-32 Multiple Linear Regression, User's Manual (MLRP)	X	X							X	X			X	X					X	
	CPD-33 Resource Information and Analysis, User's Manual (RIA)	X	X							X	X			X	X					X	
	CPD-34 Hydrologic Parameters, User's Manual (HYDPAR)	X	X							X	X			X	X					X	
	CPD-35 Damage Reach Stage - Damage Calculation, User's Manual	X	X							X	X			X	X					X	
	CPD-4 HEC-4, Monthly Streamflow Simulation, User's Manual	X	X							X	X			X	X					X	
	CPD-42 Streamflow Routing Optimization, User's Manual (OPROUT)	X	X							X	X			X	X					X	
	CPD-44 Structure Inventory for Damage Analysis Edit Program	X	X							X	X			X	X					X	

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Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Document	CPD-46 Probable Maximum Storm (Eastern United States), User's Manual (HMR52)	X	X							X	X			X	X					X	
	CPD-48 Agricultural Flood Damage Analysis, User's Manual	X	X							X	X			X	X					X	
	CPD-53 Interactive Paired-Function Data Input Program For Flood Damage Data, User's Manual (PIP)	X	X							X	X			X	X					X	
	CPD-54 Stream Hydraulics Package, User's Manual (SHP)	X	X							X	X			X	X					X	
	CPD-5Q Appendix on Water Quality Analysis, Simulation of Flood Control and Conservation Systems, User's Manual	X	X										X			X	X				X
	CPD-61 Preliminary Analysis System for Water Surface Profile Computations, User's Manual (PAS)	X	X							X	X			X	X					X	
	CPD-63 Statistical Analysis of Time Series Data, User's Manual (Preliminary) (STATS)	X	X							X	X			X	X					X	
	CPD-66 UNET, One-Dimensional Unsteady Flow Through a Full Network of Open Channels, User's Manual	X	X							X	X			X	X					X	
	CPD-67 HEC-PBA, Project Benefit Accomplishments, User's Manual	X	X							X	X			X	X					X	
	CPD-7 Storage, Treatment, Overflow, Runoff Model, User's Manual (STORM)	X	X							X	X			X	X					X	
	CPD-8 Water Quality for River-Reservoir Systems, User's Manual (WQRRS)	X	X										X			X	X				X
	Creating a Wetland Restoration Decision Support System Using GIS Tools	X	X													X					
	Decision Support for Water Resource Management: Integration of Water Control and Water Quality Data	X	X		X	X										X					X
	Description of the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) and Application to Watershed Studies	X																			
	Design of Low-Flow Channels	X	X							X	X			X		X					
	Design Recommendations for Riparian Corridors and Vegetated Buffer Strips	X	X							X	X								X		
	Determining Drag Coefficients and Area for Vegetation		X		X					X	X			X							
	Determining Optimal Degree of Soil Compaction for Balancing Mechanical Stability and Plant Growth Capacity		X	X						X									X		
	Field methods to measure aquatic plant treatment method efficacy and site variables				X	X										X	X				
	Fixed area plot sampling for forest inventory: Section 6.2.4, U.S. Army Corps of Engineers Wildlife Resources Management Manual	X			X	X													X		
	Flood-Control Channel National Inventory	X												X					X		
	Functional Objectives for Stream Restoration	X	X																		
	Gabions for Streambank Erosion Control		X	X						X	X										
	Glossary of Stream Restoration Terms	X	X	X	X	X															
	Guidelines for Establishing Monitoring Programs to Assess the Success of Riparian Restoration Efforts in Arid and Semi-Arid Landscapes	X	X		X														X		
	Habitat Equivalency Analysis: A Potential Tool for Estimating Environmental	X	X													X					

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Document	Habitat Requirements for Freshwater Fishes	X	X		X								X			X	X				X
	Habitat value of aquatic plants for fishes	X	X		X								X			X	X				
	Handbook for obtaining and using aerial photography to map aquatic plant distribution	X	X		X											X	X				
	Hydraulic Impacts of Riparian Vegetation; Summary of the Literature Technical Report EL-97-9	X	X		X					X	X		X	X		X	X				
	Hydraulic Losses in River Meanders	X	X		X					X	X		X	X		X	X				
	Impacts of Stabilization Measures	X	X		X					X	X					X					
	Irrigation Systems for Establishing Riparian Vegetation	X	X	X	X					X									X		
	Landscape Metrics to Assess Habitat Suitability for Conservation Bird Species in the Southeastern United States	X	X		X														X		
	Landscaping Considerations for Urban Stream Restoration Projects	X	X		X	X			X										X		
	Library of Habitat Models to Evaluate Benefits of Aquatic Restoration Projects on Fishes	X	X										X			X	X				
	Line intercept: Section 6.2.5 U.S. Army Corps of Engineers Wildlife Resources Management Manual	X	X		X	X													X		
	Linking Biological Models and Spatial Descriptions of Environmental Complexity with Coupled Models	X	X													X	X				
	Live and Inert Fascine Streambank Erosion Control	X	X	X						X	X								X		
	Live Stake and Joint Planting for Streambank Erosion Control	X	X	X						X	X								X		
	Nutrient Criteria: Considerations for Corps of Engineers Reservoirs	X	X		X	X															X
	Overview of Prairie Planting Techniques and Maintenance Requirements	X	X		X	X													X		
	Overview of stream restoration technology: State of the science	X																			
	P-154 Modeling Water-Resource Systems for Water-Quality Management		X																		X
	Spatial Interpolation Techniques for Water Quality Analysis	X	X																		X
	Plant Material Selection and Acquisition	X	X		X	X													X		
	Point sampling: Section 6.2.1 U.S. Army Corps of Engineers Wildlife Resources Management Manual	X	X		X	X													X		
	Preliminary Watershed Assessment	X	X						X	X	X	X	X	X	X	X	X	X	X	X	X
	Prism sampling: Section 6.2.3 U.S. Army Corps of Engineers Wildlife Resources Management Manual	X	X		X	X													X		
	Proceedings of the workshop on aquatic ecosystem modeling and assessment techniques for application within the U.S. Army Corps of Engineers	X	X													X	X				
	Propagation and establishment of aquatic plants: A handbook for ecosystem restoration projects	X	X		X	X										X	X				
	Quantifying Habitat Benefits of Restored Backwaters	X	X													X	X				

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Document	RD-10 Estimating Costs and Benefits for Nonstructural Flood Control Measures	X	X																		
	RD-11 Physical and Economic Feasibility of Nonstructural Flood Plain Management Measures	X	X																		
	RD-15 National Economic Development Benefits for Nonstructural Measures	X	X																		
	RD-16 Guide Manual for Preparation of Water Balances	X	X										X		X						
	RD-26 Accuracy of Computed Water Surface Profiles		X							X	X		X	X	X	X					
	RD-26A Accuracy of Computed Water Surface Profiles, Commercial Survey Guidelines for Water Surface Profiles, Supplement		X							X	X		X	X	X	X					
	RD-29 Remote Sensing Technologies and Spatial Data Applications	X	X																		
	RD-36 Application of a Geographic Information System to Rainfall-Runoff Modeling	X	X							X	X			X	X					X	X
	RD-46, HEC-FDA Sensitivity and Uncertainty Analysis	X	X																		
	RD-47, Application of Paleohydrology to Corps Flood Frequency Analysis	X	X		X	X	X			X	X		X	X		X				X	X
	RD-7 Determination of Land Use from LANDSAT Imagery; Applications to Hydrologic Modeling	X																X	X		
	Reconnection of Floodplains with Incised Channels	X	X		X	X	X			X	X			X							
	Recreation Enhancements for Urban Streams	X							X												
	Resistance Due to Vegetation	X	X		X	X				X	X			X		X					
	Restoration and enhancement of aquatic habitats	X	X													X					
	Restoration of Delta Streams: A Case History and Conceptual Model	X	X																		
	Review of watershed water quality models	X																			X
	Riparian Habitat Management for Mammals on Corps of Engineers Projects	X																	X		
	Riparian Terminology: Confusion and Clarification	X	X	X	X	X	X												X		
	Rootwad Composites for Streambank Erosion Control and Fish Habitat Enhancement	X	X	X	X	X										X			X		
	Sediment Sampling and Analysis for Stream Restoration Projects	X								X	X					X					X
	Shoreline Protection Using Naturally Occurring Vegetation	X	X		X	X				X											
	Simulating Population Dynamics in an Ecosystem Context Using Coupled Eulerian-Lagrangian Hybrid Models (CEL HYBRID Models)		X													X					
	Stability Thresholds for Stream Restoration Materials		X							X	X			X		X					
	Stream Management	X	X							X	X	X	X	X		X	X		X	X	X
	Streambank Habitat Enhancement with Large Woody Debris	X	X							X	X					X					

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		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Document	Streams Above the Line: Channel Morphology and Flood Control	X	X							X	X					X					
	TD-11 Adoption of Flood Flow Frequency Estimates at Ungaged Locations		X		X		X			X	X		X	X		X					X
	TD-14 Hydrologic Engineering in Planning	X								X	X		X	X		X				X	X
	TD-16 Analytical Instruments for Formulating and Evaluating Nonstructural Measures		X																		
	TD-17 Mixed-Population Frequency Analysis		X																		
	TD-36 Application of Methods and Models for Prediction of Land Surface Erosion and Yield		X		X		X				X					X					X
	Techniques for Measuring Substrate Embeddedness		X		X	X					X					X					
	Technologies for urban stream restoration and watershed management	X																			
	The Application of Conceptual Models to Ecosystem Restoration	X	X						X	X	X	X	X	X	X	X	X	X	X	X	X
	The Ecosystem Concept and Linking Models of Physical-Chemical Processes to Ecological Responses: Introduction and Annotated Bibliography	X	X													X					X
	The Ecosystem Functions Model (EFM): A Tool for Restoration Planning	X	X													X					
	The Ecosystem Functions Model: A Tool for Restoration Planning	X	X													X					
	The habitat value of aquatic macrophytes for macroinvertebrates	X	X													X	X				
	The Stream Investigation and Streambank Stabilization Handbook	X	X		X	X				X									X		
	Total Maximum Daily Loads (TMDLs): A Perspective	X	X		X	X	X														X
	TP-103 Engineering and Economic Considerations in Formulating Nonstructural Plans	X	X																		
	TP-105 Use of a Two-Dimensional Flow Model to Quantify Aquatic Habitat, Apr 85		X		X	X	X				X					X					
	TP-11, Survey of Programs for Water Surface Profiles		X							X	X		X	X	X	X					
	TP-113 Modeling and Managing Water Resource Systems for Water Quality	X	X		X	X	X									X			X		X
	TP-12, Hypothetical Flood Computation for a Stream System	X	X		X	X				X	X	X	X	X	X	X					
	TP-13, Maximum Utilization of Scarce Data in Hydrologic Design		X							X	X	X	X	X	X	X					X
	TP-130 Estimating Sediment Delivery and Yield on Alluvial Fans		X							X	X			X		X					X
	TP-18, Estimating Monthly Streamflows Within a Region	X	X		X	X				X	X		X	X		X					X
	TP-19, Suspended Sediment Discharge in Streams	X	X		X	X	X			X	X		X	X	X	X					X
	TP-38, Water Quality Evaluation of Aquatic Systems	X	X		X	X	X									X					X
	TP-48, Direct Runoff Hydrograph Parameters versus Urbanization	X	X		X	X	X			X	X		X	X		X				X	X

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		Life-Cycle Phase							NRRSS Goal												
Document	TP-5, Streamflow Synthesis for Ungaged Rivers	X	X		X	X	X			X	X		X	X		X				X	X
	TP-6, Simulation of Daily Streamflow	X	X		X	X	X			X	X		X	X		X				X	X
	TP-77, Investigation of Soil Conservation Service Urban Hydrology Techniques	X	X		X	X	X			X	X		X	X		X				X	X
	TP-93, Flood Routing Through a Flat, Complex Floodplain Using a One-dimensional Unsteady Flow computer Program		X		X	X	X				X			X							
	TP-97 Prediction of the Effects of a Flood Control Project on a Meandering Stream	X	X		X	X	X			X	X			X		X					
	Units and Conversions for Stream Restoration Projects	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X
	Update to the Propagation and Establishment of Aquatic Plants Handbook	X	X		X	X										X	X				
	Using Soil Amendments to Improve Riparian Plant Survival in Arid and Semi-arid Landscapes	X	X		X	X	X												X		
	Variations in Field-Scale Nitrogen and Phosphorus Concentrations in Runoff as a Function of Land-Use Practice	X	X		X	X	X									X					X
	Vegetated Reinforced Soil Slope Streambank Erosion Control	X	X	X	X	X				X											
	Vegetation Impacts Upon Stream Width	X	X								X								X		
	Visual obstruction: Section 6.2.6 U.S. Army Corps of Engineers Wildlife Resources Management Manual	X	X		X	X	X												X		
	Water Quality Additions to CASC2D TAPS	X	X		X	X	X									X					X
	Water Quality Manual References	X	X		X	X	X									X					X
	Watershed Analysis with the Hydrologic Engineering Center's River Analysis System (HEC-RAS)	X	X		X	X	X			X	X	X	X	X	X	X			X	X	X
	Watershed Modeling System Hydrological Simulation Program; Watershed Model User Documentation and Tutorial	X	X		X	X	X			X	X	X	X	X	X	X			X	X	X
	Geotechnical reliability of dam and levee embankments (GSL CR-04-1)	X	X							X	X			X							
	Technical Memorandum No. 3-357 The unified soil classification system	X	X		X	X	X			X	X					X			X		
	Width of Riparian Zones for Birds	X	X		X	X	X												X		
	Willow Stake Installation: Example Contract Specifications		X	X						X									X		
Software	Hydrologic Modeling System (HEC-HMS)	X	X		X					X	X	X	X	X	X	X	X			X	
	Statistical Software Package (HEC-SSP)	X	X							X	X	X	X	X	X	X	X			X	
	Reservoir System Simulation (HEC-ResSim)	X	X							X	X	X	X	X	X	X	X			X	
	River Analysis System (HEC- RAS)	X	X							X	X	X	X	X	X	X	X			X	
	HEC-GeoRAS	X	X							X	X	X	X	X	X	X	X			X	
	Geospatial Hydrologic Modeling Extension (HEC-GeoHMS)	X	X							X	X	X	X	X	X	X	X			X	

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Software	Regime Prescription Tool (HEC-RPT)	X	X		X					X	X	X	X	X	X	X	X			X	
	Ecosystem Functions Model (HEC-EFM)	X	X							X	X	X	X	X	X	X	X	X	X	X	
	Flood Damage Analysis (HEC-FDA)	X	X							X	X			X	X					X	
	Data Storage System (HEC-DSS)	X	X		X					X	X	X	X	X	X	X	X			X	
	Corps Water Management System (CWMS)	X	X							X	X	X	X	X	X	X	X			X	
	Geospatial Floodplain Inventory Tool (IWR-GeoFIT)	X																			
	IWR-MAIN Water Demand Management Suite	X																			
	IWR-PLAN Decision Support Software	X							X	X	X	X	X	X	X	X	X	X	X	X	X
	Scour and Deposition in Rivers and Reservoirs (HEC-6)	X	X							X	X	X	X	X	X	X	X			X	
	Contaminant Model for Streams (CMS)	X	X		X	X	X														X

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Laws	Clean Water Act (1972)	X																			
	National Environmental Protection Act (1969)	X																			
References	Ecological Condition of Wadeable Streams of the Interior Columbia River Basin	X	X		X	X							X			X					X
	Guidelines for Ecological Risk Assessment	X	X		X											X					X
	An Ecological Assessment of Western Streams and Rivers	X	X		X	X							X			X					X
	Field Operations Manual for Streams	X	X		X	X							X	X		X			X		X
	Field Operations and Methods for Measuring the Ecological Condition of Non Wadable Rivers and Streams	X	X		X	X							X	X		X			X		X
	Field Operations and Methods for Measuring the Ecological Condition of Wadable Streams	X	X		X	X							X	X		X			X		X
	Quantifying Physical Habitat in Wadable Streams	X	X		X	X							X	X		X			X		X
	Environmental Monitoring and Assessment Program Great River Ecosystems Field Operations Manual	X	X		X	X							X	X		X			X		X
	Mid-Atlantic Integrated Assessment (MAIA)	X	X		X	X							X	X		X			X		X
	The Consequences of Landscape Change on Ecological Resources An Assessment of the United States Mid-Atlantic Region 1973-1993	X	X		X	X							X	X		X			X		X
	Handbook for Developing Watershed Plans to Restores and Protect Our Waters	X	X													X			X		X
	Clean Watersheds Needs Survey 2004 Report to Congress	X																		X	X
Software	Watershed Plan Builder	X	X						X	X	X	X	X	X	X	X	X		X	X	X
	Watershed Assessment of River Stability & Sediment Supply (WARSSS)	X	X		X	X				X	X		X	X		X					
	Better Assessment Science Integrating Point & Nonpoint Sources (BASINS)	X	X																	X	X
	River and Stream Water Quality Model (QUAL2K)		X																		X
	Water Quality Analysis Simulation Program (WASP)		X		X															X	X
	Aquatox		X		X								X			X				X	X
	One Dimensional Riverine Hydrodynamic and Water Quality Model (EPD-RIV1)		X		X								X			X				X	X
	Environmental Fluid Dynamics Code (EFDC)		X		X					X	X		X			X				X	X
	Loading Simulation Program in C++ (LSPC)	X	X		X					X	X	X	X	X		X				X	X
	Watershed Assessment Model (WAM)	X	X		X								X			X				X	X
	Storm Water Management Model (SWMM)	X	X																	X	
	Water Resources Database (WRDB)	X	X													X				X	X

U.S. Environmental Protection Agency

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Software	Allocating Loads and Wasteloads	X	X		X											X					X
	DFLOW	X	X		X					X	X	X	X	X		X					
	HSPF Toolkit for BMP Modeling Applications	X	X		X	X														X	X
	Bioaccumulation in Aquatic Systems Simulator (BASS)	X	X		X								X			X					X
	Riparian Ecosystem Management Model (REMM)	X	X		X														X		
	Habitat Suitability Index Calculator	X	X													X					
	Stream Fish Assemblage Predictor (SFAP)	X	X													X					
	Estimated and Projected Impervious Cover in the Southeastern United States	X								X	X		X	X		X				X	X
	Surf Your Watershed	X	X		X	X				X	X	X	X	X	X	X			X	X	X
	STORET Data Warehouse	X	X		X	X										X					X

Federal Emergency Management Agency

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Laws																					
Document	Addressing Your Community's Flood Problems	X			X		X														
	Alluvial Fans: Hazards and Management	X			X		X														
	A Unified National Program for Floodplain Management	X			X		X														
	Design Guidelines for Flood Damage Reduction	X			X		X														
	Floodplain Management in the United States: An Assessment Report, Volume 1: Summary	X			X		X							X						X	
	Floodplain Management in the United States: Assessment Report, Volume 2: Full Report	X			X		X							X						X	
	Protecting Floodplain Resources - A Guidebook for Communities	X			X		X							X						X	
	Reducing Losses in High Risk Flood Hazard Areas: A Guidebook for Local Officials	X			X		X							X						X	
	Report of the Floodplain Management Forum	X																			
	Modernizing FEMA's Flood Hazard Mapping Program: Recommendations for Using Future-Conditions Hydrology for the NFIP	X																			
	FEMA's Multi-Hazard Identification and Risk Assessment (MHIRA)	X	X							X	X										
	Riverine Erosion Hazard Areas Mapping Feasibility Study	X								X	X										X
	Guidelines and Specifications for Flood Hazard Mapping Partners	X																			
	Multi-Year Flood Hazard Identification Plan (MHIP)	X																			
Software	CHAMP	X	X																		
	CHECK-2	X	X							X	X		X	X						X	
	CHECK-RAS	X	X							X	X		X	X						X	
	FISPLOT	X	X							X	X		X	X						X	
	QUICK-2	X	X							X	X		X	X						X	
	RASPLOT	X	X							X	X		X	X						X	
	HAZUS-MH	X	X		X	X	X				X			X						X	

U.S. Department of Housing and Urban Development

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document																					
Software																					

U.S. Department of Interior

Type	Name	Life-Cycle Phase							NRRSS Goal															
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																						
Document	Adaptive Management The U.S. Department of the Interior Technical Guide	X	X	X	X	X				X	X	X	X	X	X	X	X		X	X	X
Software																						

U.S. Bureau of Land Management

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							**NRRSS Goal**												
Laws	Western States Water Laws	X	X	X	X	X	X	X		X	X	X	X	X	X	X			X		
Document	The National Environmental Policy Act Handbook	X																			
Document	Hydraulic Considerations for Pipelines Crossing Stream Channels																				
Document	Roads and Trails Terminology	X																			
Document	Passive Treatment Systems for Acid Mine Drainage	X	X		X																X
Document	Wildlife water catchment construction in Nevada	X																			
Document	Evaluating Bighorn habitat: A Landscape Approach	X																			
Document	TN380_Interpretation of aerial photographs	X																			
Document	TN379_Soil Landscape Analysis Project (SLAP) methods in soil surveys	X																			
Document	TN378_ Simulation of storm runoff in the Oregon Coast Range	X																			
Document	TN372_Stream discharge measurement using a modified technique	X	X							X	X	X	X	X							
Document	TN371_ Determining hydrologic properties of soil	X	X							X	X	X	X	X							
Document	TN370_A predictive model for estimating maximum summer stream temperatures in western Oregon	X	X							X	X	X	X	X		X					
Document	TN369_Considerations in rangeland watershed monitoring	X				X															
Document	TN368_ A runoff and soil-loss monitoring technique using paired plots	X																			
Document	TN366_ Gully erosion	X								X											
Document	TN365_ Hydrology and USLE: application to rangelands	X																			
Document	TN363_Willow planting for riparian habitat improvement	X	X	X															X		
Document	TN361_The use of remote sensing for soils investigations on BLM lands	X																			
Document	TN346_Erosion condition classification system																				
Document	TN342_ The use of gabions to improve aquatic habitat	X								X	X										
Document	TN337_Hydrologic risk and return period selection of water related projects	X																			
Document	TN331_Sampling theory, examples and rationale	X																			
Document	TN325_ The use of large scale color infrared photography for stream habitat inventory	X														X					
Document	TN322_Indexed bibliography on stream habitat improvement	X														X					
Document	TN283_ Techniques for conducting stream habitat survey on national resource land	X														X					

U.S. Bureau of Land Management

Type	Name	Life-Cycle Phase: Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	NRRSS Goal: Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Document	TN174_ Log Sills--A solution to a fish passage problem	X	X										X								
	TN173_A barrier panel to prevent the upstream migration of fish	X	X										X								
	TN160_ Codes for ties on BLM tree seedlings			X	X														X		
	TR1730-2_Biological Soil Crusts Ecology and Management	X																			
	TR1730-1_Measuring and Monitoring Plant Populations				X	X													X		
	TR1734-7_Ecological Site Inventory	X	X		X	X													X		
	TR1734-4_Sampling Vegetation Attributes	X	X		X	X													X		
	TR1737-22_Riparian Restoration	X	X		X	X													X		
	TR1737-21_Riparian and Wetland Classification	X	X		X	X													X		
	TR1737-19_Riparian-Wetland Soils	X	X		X	X													X		
	TR1737-18_Managing for enhancement of riparian and wetland areas of the Western United States An annotated bibliography	X	X		X	X													X		
	TR1737-14_Grazing management for riparian-wetland areas riparian area management	X	X		X	X													X		
	TR1737-13_Observing physical and biological change through historical photographs	X	X		X	X													X		
	TR1737-12_Using aerial photographs to assess proper functioning condition of riparian wetland areas	X	X		X	X													X		
	TR1737-10_The use of aerial photography to manage riparian-wetland areas Riparian area management	X	X		X	X													X		
	TR1737-9_Process for assessing proper functioning condition Riparian area management	X	X		X	X													X		
	TR1737-8_Greenline riparian-wetland monitoring Riparian area management	X	X		X	X													X		
	TR1737-8_Monitoring the vegetation resources in riparian areas	X	X		X	X													X		
	TR1737-7_Procedures for ecological site inventory with special reference to riparian-wetland sites Riparian area management	X	X		X	X													X		
	TR1737-6_Management techniques in riparian areas - Riparian area management	X	X		X	X													X		
Software	XSPRO : a channel cross-section analyzer		X							X	X			X							
	Peak/risk/culvert									X	X		X								
	Hydrologic terrain analysis: watershed (catchment) and stream network delineation	X	X		X	X				X	X	X	X	X	X	X				X	X
	The Spatial Terrain Analysis Resource Toolset (START)	X	X		X	X				X	X	X	X	X	X	X				X	X
	Sheet and rill erosion evaluation with the Revised Universal Soil Loss Equation (RUSLE) – GIS Interface	X	X		X	X				X	X	X	X	X	X	X				X	X

U.S. Bureau of Reclamation

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Laws																					
Document	Earth Manual — Part 1	X																			
	Measuring the Influence of Water Management Practices on the Economic Benefits of Commercial Fishing	X																			
	Public Involvement Manual	X							X												
	Resource Management Plan Guidebook—Planning for the Future	X																			
	Engineering Geology Field Manual	X								X	X			X							
	Erosion and Sedimentation Manual	X	X							X	X			X							
	Water Measurement Manual	X	X							X	X		X	X		X					
	Fish Protection at Water Diversions	X	X										X								
	Hydraulic and Excavation Tables		X	X						X	X			X							
	Hydraulic Laboratory Techniques		X	X						X	X			X							
	EM31_Ground Water Movement		X	X						X	X			X					X		
	Mechanics of the Hydraulic Jump		X								X		X								
	Instrumentation for Hydraulic Measurements in Laboratory and Field				X	X															
	Canal Bank Erosion by Surface Water Waves Generated in a Laboratory		X							X											
	Studies of Tractive Forces of Cohesive Soils in Earth Canals		X							X											
	Culvert Hydraulics - A Library Study		X										X								
	Progress Report No. 1 - Canal Bank Erosion Due to Wind-generated Water Waves		X							X											
	Progress Report No.3 - Canal Erosion and Tractive Force Study		X							X											
	Friction Factors for Large Conduits Flowing Full		X																		
	Measuring Seepage Loss in Irrigation Canals		X		X																
	Some Effects of Suspended Sediment on Growth of Submersed Pondweeds		X																		X
	Hydraulic Studies of Fish Collecting Facilities		X		X								X								
	Field and Laboratory Tests to Develop the Design of a Fish Screen		X										X								
	The Importance of Fluvial Morphology in Hydraulic Engineering		X																		
	Stable Channel Profiles	X	X								X										

U.S. Bureau of Reclamation

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Document	Angle of Repose of Non-Cohesive Material		X							X											
Document	Critical Tractive Forces which Start Movement of Sediment in a Channel		X							X	X										
Document	Critical Tractive Forces on Channel Side Slopes		X							X	X										
Document	Proposed Program of Studies to Develop Methods of Design of Stable Channels in Erodible Material		X							X											
Document	Principles of Design of Stable Channels in Erodible Material		X							X	X										
Document	The Stable Channel Problem of Coarse Material		X							X	X										
Document	The Flow of Water in Open Channels with High Gradients		X							X	X										
Document	Design Guidance for Coanda-Effect Screens		X										X								
Document	Hydraulic Performance of Coanda-Effect Screens		X										X								
Document	Laboratory Testing and Numerical Modeling of Coanda-Effect Screens		X		X								X								
Document	Hydraulic Testing of Static Self-Cleaning Inclined Screens				X								X								
Software	WinFlume		X								X										
Software	Wall Gage Creator	X	X							X	X		X	X		X					
Software	Estimating construction quantities		X	X																	
Software	Drop structures and stilling basins		X																		
Software	BFI - Automated base flow separation		X																		
Software	CTAC - water surface profiles		X																		
Software	Coanda - Hydraulic performance of Coanda-effect screens used for low-maintenance screening of fish and fine debris		X										X								
Software	RiverWare - Generalized river basin modeling environment		X																		
Software	SAMS - Stochastic Analysis, Modeling and Simulation		X																		
Software	USBRWeir.xls - Rating tables and equations for common sharp-crested weirs		X																		

National Park Service

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Laws																					
Document	Evaluation of Stream Temperature Regimes for Juvenile Coho Salmon in Redwood Creek using Infrared	X																			X
	A Field Manual for the Use of Antimycin A for Restoration of Native Fish Populations	X															X				X
	Plant Toxicity Testing with Sediment and Marsh Soils	X			X	X															X
	Water Resources Instrumentation	X			X																
	Part A: Identification of priority impaired and pristine waters for the water quality vital signs monitoring component	X																			
	Part B: Planning Process Steps. Issues to consider and then to document in a detailed study plan that includes a Quality Assurance Project Plan (Q	X																			
	Part B Lite QA/QC Review Checklist for Aquatic Vital Signs Monitoring Protocols and SOPs	X			X																X
	Part C: Draft guidance of WRD required and other field parameter measurements, general monitoring methods, and some design considerations i	X		X	X																X
	Part D: Draft guidance on laboratory analytes/measurements and their consideration in preparation of a detailed study plan (Table of Contents /	Poss	X		X																X
	Part E: Draft guidance on data reporting and archiving in STORET		X		X																X
	Recommendations for Core Water Quality Monitoring Parameters				X																X
	Recommendations for Core Water Quality (Vital Signs) Monitoring Parameters for Marine and Coastal National Parks	X	X		X																X
	WRD Comments on First 12 Monitoring Plans and new guidance	X	X		X																X
	Park Water Quality Questionnaire	X			X																X
	Table of Water Body Protected Uses	X																			
	Summary Tables of Aquatic Life Exceedences & Threats	X	X		X	X															X
	Sample Design & Protocol Development SOW	X	X		X																X
	Environmental Contaminants Encyclopedia	X																			X
Software	NPSTORET	X	X		X					X	X										X

U.S. Fish and Wildlife Service

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Aquatic Animal Health Procedures and Protocols	X	X		X												X				
	Construction Inspection Handbook			X																	
	Endangered Species Consultation Handbook	X																			
	Habitat Conservation Planning Handbook	X																			
	Habitat Evaluation Procedures Handbook	X														X					
	National Environmental Policy Act Handbook (Federal Assistance)	X																			
	National Environmental Policy Act Reference Handbook	X																			
	Preliminary Planning and Integrated Data Collection	X																			
	Tactical Planning in Fish and Wildlife Management and Research	X																			
Software																					

U.S. Geologic Survey

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Laws																					
Document	Ground Water	X																	X		
	Basic ground-water hydrology	X																	X		
	What is Ground Water	X																			
	Ground Water and Surface Water A Single Resource	X																			
	Ground-Water Availability in the United States	X																			
	Water Budgets Foundations for Effective Water-Resources and Environmental Management	X																			
	Estimated Withdrawals from Principal Aquifers in the United States	X																			
	Estimated Use of Water in the United States in 2000	X																			
	Evolving Issues and Practices in Managing Ground-Water Resources Case Studies on the Role of Science	X																			
	Assessing Ground-Water Vulnerability to Contamination: Providing Scientifically Defensible Information for Decision Makers	X																			
	Ground-Water-Level Monitoring and the Importance of Long-Term Water-Level Data	X																			
	Sustainability of Ground-Water Resources	X																			
	Land Subsidence in the United States	X																			
	Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program Selection, Installation, and Docume	X																			
	Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program: Collection and Documentation of \	X																			
	National Field Manual for the Collection of Water-Quality Data	X																			X
	Revised Methods for Characterizing Stream Habitat in the National Water-Quality Assessment Program	X														X					X
	Revised Protocols for Sampling Algal, Invertebrate, and Fish Communities as Part of the National Water-Quality Assessment Program	X	X		X											X					X
	Guidelines for quality assurance and quality control of fish taxonomic data collected as part of the National Water-Quality Assessment Program	X			X																X
	Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory-- Processing, taxonomy, and quality control of benthic mac	X			X											X					X
	Protocols for the Analysis of Algal Samples Collected as Part of the U.S. Geological Survey National Water-Quality Assessment Program	X			X											X					X
	Protocols for Mapping and Characterizing Land Use/Land Cover in Riparian Zones	X																	X		
Software	Analysis of Aquifer-Test and Slug-Test Data	X																			
	ANNIE Interactive Hydrologic Analyses and Data Management	X	X																		
	Blossom Statistical Software	X	X																		

U.S. Geologic Survey

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Software	BRANCH Branch-Network Dynamic Flow Model		X																		
	BSDMS Bridge Scour Data Management System		X								X										
	CAP Culvert Analysis Program		X								X										
	CFP: Documentation of a Conduit Flow Process for MODFLOW-2005		X																		
	CloseTest		X																		
	Coupled Ground-water and Surface-water FLOW model (GSFLOW)		X																		
	DOTABLES Dissolved oxygen saturation tables		X																		X
	DR3M Distributed Routing Rainfall-Runoff Model--version II		X																		
	Full Equations (FEQ) Model		X																		
	GLSNet Regional hydrologic regression and NETwork analysis using Generalized Least Squares		X																		
	GW_Chart		X																		
	Habitat Evaluation Procedures (HEP)		X													X					
	Habitat Suitability Index (HSI)		X													X					
	HSPexp Expert System for Calibration of HSPF		X																		
	HST3D:A Computer Code for Simulation of Heat and Solute Transport in Three-Dimensional Ground-Water Flow Systems		X																		
	HYDROTHERM:A Computer Code for Simulation of Two-Phase Ground-Water Flow and Heat Transport in the Temperature Range of 0 to 1200 Degr		X																		
	HYSEP Hydrograph Separation Program		X																		
	INFIL3.0		X																		
	IOWDM Input and Output for a Watershed Data Management (WDM)		X																		
	Legal Institutional Analysis Model (LIAM)	X																			
	LIBANNE A collection of related libraries for use in hydrologic applications	X																			
	LIBUTL Utility libraries for interactive prompting, device-independent graphics, and time-dependent data base access	X																			
	Load Estimator (LOADEST): A Program for Estimating Constituent Loads in Streams and Rivers	X																			X
	MEASERR A Program for Determination of Error in Individual Discharge Measurements		X		X																
	MF2005-GWM Three-dimensional ground-water flow simulation with Ground-Water Management capability using optimization		X																		
	MF2K-GWT Three-dimensional ground-water flow and solute-transport model integrated with MODFLOW-2000		X																		

U.S. Geologic Survey

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Software	MFI Data input program for MODFLOW, MODPATH, and MOC3D		X																		
	MOC Two-dimensional method-of-characteristics ground-water flow and transport model		X																		
	MOCDENSE A two-constituent solute transport model for ground water having variable density		X																		
	MODBRNCH Ground-Water/Surface-Water Coupled Flow Model using USGS MODFLOW and BRANCH Models		X																		
	Model Viewer		X																		
	MODFLOW-2005		X																		
	MODFLOW-GUI		X																		
	MODPATH Version 5.0 A particle-tracking postprocessing model for MODFLOW-2000 and MODFLOW-2005		X																		
	National Hydrologic Assessment Tool (NATHAT)	X	X																		
	National Streamflow Statistics program		X																		
	NCALC Manning's n value calculation program		X							X	X										
	NFF - National Flood Frequency program	X								X	X										
	One-dimensional transport with inflow and storage (OTIS): A solute transport model for streams and rivers		X																		X
	OPR-PPR A Computer Program for Assessing Data Importance to Model Predictions Using Linear Statistics		X																		
	PART: A computerized method of base-flow-record estimation		X																		
	PeakFQ Flood Frequency Analysis Based on Bulletin 17B		X							X	X	X	X	X		X					X
	Physical Habitat Assessment Model	X	X													X					
	PRMS Precipitation-Runoff Modeling System	X	X																		
	PULSE: Model-Estimated Ground-Water Recharge and Hydrograph of Ground-Water Discharge to a Stream	X	X																		
	SAC Slope-Area Computation Program		X																		
	Salmonid Population Model (SALMOD)		X														X				
	SEDDISCH Computation of fluvial sediment discharge		X																		
	SEDSIZE Particle-size statistics of fluvial sediments		X																		
	Stream Network and Stream Segment Temperature Models Software		X																		
	SWSTAT Surface-Water Statistics		X																		
	Time Series Library Software (TSLIB)		X																		

U.S. Geologic Survey

Type	Name	Life-Cycle Phase							NRRSS Goal															
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Software	ZONEBUDGET		X																		
	WSPRO A computer model for Water-Surface PROfile computations		X																		
	TRIGRS landslide assessments and modeling		X																		
	Multidimensional Surface-Water Modeling System		X																		

U.S. Federal Highway Administration

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Environmental Guidebook	X																			
	Report of the Secretary of Transportation to the US Congress on Preservation of Transportation Corridors	X																			
	Highway Corridor Preservation and Early Right of Way Acquisition	X																X			
	Right of Way Activities During Planning and Project Development	X																X			
	Eco-Logical - An Ecosystem Approach to Developing Infrastructure Projects	X																			
	Hydraulics Engineering Publications	X	X							X	X										
	Introduction to Highway Hydraulics	X	X							X	X										
	Hydraulic Design of Highway Culverts	X	X							X	X		X								
	River Engineering for Highway Encroachments	X	X							X	X										
	Debris Control Structures Evaluation and Countermeasures	X	X		X	X					X										
	Design of Riprap Revetment		X							X											
	Hydraulic Design of Energy Dissipators for Culverts and Channels	X	X							X	X		X								
	Design of Roadside Channels with Flexible Linings, Third Edition	X	X							X	X										
	The Design of Encroachments on Flood Plains Using Risk Analysis	X	X								X										
	Evaluating Scour at Bridges, Fourth Edition		X		X						X										
	Stream Stability at Highway Structures Third Edition	X	X							X	X										
	Urban Drainage Design Manual Second Edition	X	X		X	X				X	X									X	
	Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance Second Edition		X		X						X										
	Assessing Stream Channel Stability at Bridges in Physiographic Regions		X		X						X										
	Effects of Inlet Geometry on Hydraulic Performance of Box Culverts	X	X							X	X		X								
	Best Management Practices for Erosion and Sediment Control	X	X							X	X		X								X
	Culvert Inspection Manual	X	X		X	X				X	X		X								
	Bottomless Culvert Scour Study: Phase I Laboratory Report	X	X							X	X		X								
	Bottomless Culvert Scour Study: Phase II Laboratory Report	X	X							X	X		X								
	Bridge Scour in Nonuniform Sediment Mixtures and in Cohesive Materials: Synthesis Report	X	X							X	X										

U.S. Federal Highway Administration

Type	Name	Life-Cycle Phase: Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	NRRSS Goal: Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Document	Enhanced Abutment Scour Studies For Compound Channels	X	X							X	X			X							
	Field Observations and Evaluations of Streambed Scour at Bridges	X	X								X										
	Design for Fish Passage at Roadway-Stream Crossings: Synthesis Report	X	X								X		X								
Software	WSPRO		X																		
	HY-8		X																		
	HDS 5 Appendix D Chart Calculator		X																		
	FESWMS		X																		
	Visual Urban (HY-22) Urban Drainage Design Programs		X																		
	BRI-STARS		X																		

Bay Conservation and Development Commission

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Laws	McAteer-Petris Act	X																			
	Suisun Marsh Preservation Act	X																			
Document	San Francisco Bay Plan	X																			
	Suisun Marsh Protection Plan	X																			
	Shoreline Spaces Design Guidelines	X																			
	Shoreline Signs Design Guidelines	X							X												
	Shoreline Plants Design Guidelines	X																	X		
	Water Quality Protection and Nonpoint Source Pollution Control in San Francisco Bay	X			X															X	X
Software																					

California Coastal Commission

Type	Name	Life-Cycle Phase							NRRSS Goal												
Type		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws	California Coastal Act	X																			
	McAteer-Petris Act	X																			
	Coastal Zone Management Act	X																			
	Coastal Zone Management Act Regulations	X																			
	State Coastal Conservancy Law	X																			
Document	LCP (Local Coastal Program) Update Guide	X																			
	California Coastal Commission's Plan for Controlling Polluted Runoff (Coastal CPR Plan)	X																			
	Model Urban Runoff Program	X																		X	
	California Coastal Commission Strategic Plan	X																			
	Overview of Sea Level Rise and Some Implications for Coastal California: Briefing to the California Coastal Commission on Sea Level Rise (June 2(	X																			
	Waves, Wetlands, and Watersheds	X																			
Software																					

California Coastal Conservation

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws	California Public Resource Code, Division 21, State Coastal Conservancy	X																			
Document	Watershed Planning Guide	X																			
	IWRP Design & Permitting Coordination Process Guidelines Manual	X																			
Software																					

CALFED

Type	Name	Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
		Life-Cycle Phase							NRRSS Goal												
Laws	California Bay-Delta Act of 2003	X																			
Document	CALFED Bay-Delta Program. Levee Systems Integrity, Program Plan Year 8	X	X											X							
Document	Aquatic Vegetation Conceptual Model	X	X														X				
Document	Chemical Stressors Conceptual Model	X	X																		X
Document	Fish Habitat Linkage Conceptual Model	X	X													X					
Document	Floodplain Conceptual Model	X	X											X							
Document	Mercury Conceptual Model	X	X																		X
Document	Pyrethroids Conceptual Model	X	X																		X
Document	Sediment Conceptual Model	X	X																		X
Document	Selenium Conceptual Model	X	X																		X
Document	Tidal Marsh Conceptual Model	X	X																		
Software																					

State Water Regional Control Boards

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Watershed Management Initiative (WMI)	X																			
	The California Storm Water Toolbox	X	X		X															X	
	Site Specific Water Quality Objectives	X	X		X																X
	Water Quality Assessments Report on the Condition of California Coastal Waters and Wadeable Streams	X	X		X																X
	Impaired Waters Guidance and Policy	X																			X
	A Primer on Stream and River Protection for the Regulator and Program Manager	X								X	X		X	X					X	X	
	Construction Activities Storm Water General Permit Order No. 99-08-DWQ	X	X	X																X	
Software																					

California Department of Conservation

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	California Watershed Assessment Manual	X	X							X	X		X	X		X		X	X	X	X
	Watershed Assessments	X	X							X	X		X	X		X		X	X	X	X
	Watershed Modeling	X	X							X	X		X	X		X		X	X	X	X
	Watershed Assessment Tools	X	X							X	X		X	X		X		X	X	X	X
Software																					

California Department of Fish and Game

	Name	Life-Cycle Phase							NRRSS Goal												
Type		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws	Fish and Game Code (Section 1602)	X								X	X	X	X	X		X			X		
Document	A Manual of California Vegetation	X																	X		
	Rapid Assessment Protocol	X																	X		
	Rapid Assessment Field Form	X																	X		
	California Salmonid Stream Habitat Restoration Manual	X	X	X	X	X				X	X	X	X	X		X			X	X	X
	Protocols for Monitoring the Response of Anadromous Salmon and Steelhead to Watershed Restoration in California				X											X					
	Culvert Criteria for Fish Passage		X										X								
	Anadromous Fishes of California	X																			
	2007 swamp bioassesment procedure	X	X		X											X					X
Software	California Wildlife Habitat Relationships	X	X		X																
	California Natural Diversity Database	X	X		X																
	RareFind 3	X	X		X														X		
	Biogeographic Information and Observation System	X	X		X														X		
	The Vegetation Classification and Mapping Program	X	X		X														X		

California Department of Parks and Recreation

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Acquisition Guidelines 2008-09 Natural Resources and Sustainable Ecosystems	X																			
Software																					

California Department of Water Resources

Type	Name	Life-Cycle Phase							NRRSS Goal													
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws	Proposition 13	X																			
Laws	Proposition 84	X																			
Laws	California Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coasta Protection Bond Act of 2006	X																			
Laws	California River Parkways Act of 2004	X																			
Document	CALIFORNIA RIVER PARKWAYS AND URBAN STREAMS RESTORATION GRANT PROGRAMS	X	X	X																	
Software																					

California Department of Transportation

Type	Name	Life-Cycle Phase: Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	NRRSS Goal: Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Highway Design Manual	X	X	X	X	X				X	X			X					X	X	X
	Storm Water Quality Handbook - Project Planning and Design Guide	X	X	X																X	X
	Fish Passage Design for Road Crossings	X	X										X								
	California Bank and Shore Rock Slope Protection Design	X	X							X											
	Cost Data Information	X	X	X						X	X									X	
	Construction Site BMP Manual March 2003			X																X	
	SWPPP/WPCP Preparation Manual March 2007	X	X	X																X	
	SWPPP/WPCP Review Guidance Manual	X	X	X																X	
	Construction Site Stormwater Quality Sampling Guidance Manual	X	X	X																X	
	11x17 Non-Visible WPCDs	X	X	X																X	
	11x17 Sediment WPCDs	X	X	X																X	
	Stormwater Management Enforcement Guidance Manual	X	X	X																X	
	Guidance for Temporary Soil Stabilization	X	X	X																X	
	BMP Field Manual and Troubleshooting Guide	X	X	X																X	
	Field Guide for Construction Dewatering	X	X	X							X									X	
Software																					

Center for Ecosystem Management and Research

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Steelhead/Rainbow Trout (Oncorhynchus mykiss) Resources South of the Golden Gate, California	X	X																		
	San Francisco Estuary Watersheds Evaluation: Identifying Promising Locations for Steelhead Restoration in Tributary Streams	X	X																		
	Historical Distribution and Current Status of Steelhead/Rainbow Trout in Streams of the San Francisco Estuary, California	X	X																		
	Historical Status of Coho Salmon in Streams if the Urbanized San Francisco Estuary, California	X	X																		
	Evaluating the Ecological Condition of the South Bay:A Potential Assessment Approach	X	X														X					
	Conceptual Design and Feasibility of a Natural Fishway at the Fremont BART Weir, Alameda Creek, California	X	X										X								
Software																					

San Francisco Bay Joint Venture

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Riparian Habitat Joint Venture Conference: Integrating Riparian Habitat Conservation & Flood Management in California December 4-6, 2007	X																	X		
	San Francisco Bay Joint Venture — Regional Creeks Subcommittee: Riparian Buffers Resource Library	X																	X		
Software																					

American Rivers

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Catching the rain: a Great Lakes resource guide to natural stormwater management	X																		X	
	Where rivers are born: the scientific imperative for defending small streams and wetlands	X																			
	Hidden Reservoir: Why Water Efficiency is the Best Solution for the Southeast	X																			
	Local Water Policy Innovation: A Road Map for Community Based Stormwater Solutions	X																			
	Using Green Infrastructure in Karst Regions	X																			
	Dam Removal and Historic Preservation: Reconciling Dual Objective	X										X									
	What's In Your Water: The State of Public Notification in 11 U.S. States	X																			
	Protecting Wisconsin's Waters: Better Oversight of Development is Necessary to Prevent Runoff Pollution	X																		X	
	Greening Stormwater	X																		X	
	Unnatural Disasters, Natural Solutions: Lessons from the Flooding of New Orleans	X																			
	Follow the Money: An Agenda for Smarter Infrastructure Funding in the Great Lakes	X																			
	Waterways at Risk: How Low-Impact Development Can Reduce Runoff Pollution in Michigan	X																			
	Beyond Dams: options and alternatives	X										X									
	Ecological Riverfront Design: restoring rivers, connecting communities	X																			
	A handbook on nature-like fishways	X											X								
	Exploring Dam Removal: a decision making guide	X	X									X									
	Ecology of Dam Removal	X	X									X									
	Restoring Riverfronts: a guide to selected funding sources	X																			
	Stranded Midstream: causes and consequences for hydropower regulatory delay	X																			
	River of Renewal: connecting communities to a living Mississippi River	X																			
	Paying for Dam Removal	X										X									
	Dam removal success stories	X										X									
	Significant River Events in the United States	X																			
Software																					

The National Academy of Sciences

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Science and the Greater Everglades Ecosystem Restoration: An Assessment of the Critical Ecosystem Studies Initiative (2003)	X																			
	Adaptive Monitoring and Assessment for the Comprehensive Everglades Restoration Plan	X	X		X																
	First Report from the NRC Committee on the Review of the Louisiana Coastal Protection and Restoration (LACPR) Program	X																			
	Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy	X																			
	River Science at the U.S. Geological Survey	X																			
	River Basins and Coastal Systems Planning Within the U.S. Army Corps of Engineers	X																			
	Analytical Methods and Approaches for Water Resources Project Planning	X	X																		
	The Science of Instream Flows: A Review of the Texas Instream Flow Program	X																			
	The Geological Record of Ecological Dynamics: Understanding the Biotic Effects of Future Environmental Change	X																			
	Adaptive Management for Water Resources Project Planning	X	X		X																
	U.S. Army Corps of Engineers Water Resources Planning: A New Opportunity for Service	X																			
	Valuing Ecosystem Services: Toward Better Environmental Decision-Making	X																			
	Endangered and Threatened Species of the Platte River	X																			
	A Century of Ecosystem Science: Planning Long-Term Research in the Gulf of Alaska	X																			
	New Directions in Water Resources Planning for the U.S. Army Corps of Engineers	X																			
	Riparian Areas: Functions and Strategies for Management	X																	X		
	New Strategies for America's Watersheds	X																			
	Watershed Research in the U.S. Geological Survey	X																			
	Biodiversity	X																			
	Flood Risk Management and the American River Basin: An Evaluation	X																			
	Engineering Within Ecological Constraints	X	X																		
	Cooperating with Nature: Confronting Natural Hazards with Land-Use Planning for Sustainable Communities	X																			
	Assessing the National Streamflow Information Program	X																			
	Managing the Columbia River: Instream Flows, Water Withdrawals, and Salmon Survival	X																			
	Review Procedures for Water Resources Project Planning	X																			

The National Academy of Sciences

Type	Name	Life-Cycle Phase							NRRSS Goal													
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Document	Assessing the TMDL Approach to Water Quality Management	X																			X
Document	Report of a Workshop on Predictability & Limits-To-Prediction in Hydrologic Systems	X																			
Document	Envisioning the Agenda for Water Resources Research in the Twenty-First Century	X																			
Document	Hydrologic Science Priorities for the U.S. Global Change Research Program: An Initial Assessment	X																			
Document	Improving American River Flood Frequency Analyses	X																			
Document	Peer Review in Environmental Technology Development Programs	X																			
Document	Ecological Risks: Perspectives from Poland and the United States	X																			
Software																					

The Natural Heritage Institute

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Mt. Diablo Creek Watershed Inventory	X																			
	Marsh Creek Report	X																			
	The Rheem Creek Watershed: An Analysis of Current Conditions and Future Opportunities	X																			
	Guadalupe Flood Control Project Settlement	X																			
	Guadalupe, Coyote, and Stevens Creeks Water Rights Settlement	X																			
	Guadalupe and Coyote Creeks Homeless Encampment Complaint	X							X												
	Corridor Width Report, Parcel Inventory, and Conceptual Stream Corridor Master Plan for Marsh, Sand, and Deer Creeks - Brentwood	X																			
	Where Property Rights and Biodiversity Converge: Lessons from Experience in Habitat Conservation Planning	X																			
	Habitat Improvement for Native Fish in the Yolo Bypass	X																			
Software																					

The Nature Conservancy

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Rivers for Life: Managing Water for People and Nature	X																			
	A Practitioner's Guide to Freshwater Biodiversity Conservation	X																			
	Managing Freshwater Inflows to Estuaries: A Methods Guide	X																			
	A Spatial Assessment of Hydrologic Alteration Within a River Network	X																			
	A Working Classification of Terrestrial Ecological Systems in the Coterminous United States	X																			
	Conservation by Design: A Framework for Mission Success	X																			
	DRAFT: Using Conceptual Models	X																			
	The 5S Framework for Site Conservation: A Practitioner's Handbook for Site Conservation Planning	X																			
	The National Vegetation Classification System	X																	X		
	Watershed Management	X																			
	Plant Guide for Riparian Reforestation: Medium to Large Trees	X																	X		
	Plant Guide for Riparian Reforestation: Small Trees and Shrubs	X																	X		
	Planting Riparian Bare Root Trees and Shrubs	X																	X		
Software	Indicators of Hydrologic Alteration (IHA)	X																			
	Conservation Action Planning	X																			
	Guidelines for Developing and Selecting Conservation Strategies	X																			
	Including Aquatic Targets in Ecoregional Portfolios:Guidance for Ecoregional Planning Teams	X	X																		
	Protected Area Tools for ArcGIS 9.2 (SP4)	X	X																		
	Socio-Economic Buffer Analysis ArcView Extension	X	X																		

San Francisco Estuary Institute

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Final Report South Santa Clara Valley Historical Ecology Study	X																			
	Napa River Watershed Historical Ecology Project	X																			
	Historical Ecology of Contra Costa County	X																			
	Final Report Coyote Creek Watershed Historical Ecology Study	X																			
	Inventory of Monitoring Programs in the San Francisco Bay and Delta	X																			
	A Survey of User Needs for Data Relating to Environmental and Water Quality in the San Francisco Estuary	X																			X
	Assessment of Potential Aquatic Herbicide Impacts to California Aquatic Ecosystems.	X																			X
	The Regional Monitoring Program: Science in Support of Managing Water Quality in San Francisco Bay	X																			X
	Setting Goals and Defining Watershed and Stream "Health" to Better Integrate Policies, Programs, and Projects	X																			
	Bay Area Watersheds Science Approach	X																			
Software																					

Association of Bay Area Governments (ABAG)

Type	Name	Life-Cycle Phase							NRRSS Goal												
		Planning	Design	Construction	Operations	Maintenance	Requalification	Decommissioning	Aesthetics/Recreation/Education	Bank Stabilization	Channel Reconfiguration	Dam Removal/Retrofits	Fish Passage	Floodplain Reconnection	Flow Modification	Instream Habitat Improvement	Instream Species Management	Land Acquisition	Riparian Management	Stormwater Management	Water Quality Management
Laws																					
Document	Manual of Standards for Erosion and Sediment Control Measures	X	X	X																X	
Software																					

Appendix E

As part of the National River Restoration Science Synthesis (NRRSS), a national effort to assess the state of the River Restoration practice (in 2003-2005), Kondolf et al (2007) performed a Post Project Appraisal (PPA) of forty completed River Restoration projects in California. Projects were selected based primarily on availability of data and based on construction methods that involved some physical reconstruction of the channel, to provide a better basis for comparability among projects. The PPAs spanned a wide range of watershed scale, agencies, and intents. Generally, projects were at least 4 years old so that the project would likely have already experienced at least one significant flow.

For each PPA project, a background on the project was developed and the goals (explicitly stated or inferred where not explicit) were identified. Based on the project goals, a standard set of evaluation criteria (based on NRRSS goal category) were applied. The degree of success to achieve the stated project goals were then evaluated based on the standard evaluation criteria. This appendix presents a short summary of the PPA case studies, extracted from Kondolf et al, (*2007*). For more detailed background on these projects, see Kondolf et al (*2007*).

A detailed description of the PPA method is presented in Chapter 3. Table E1 presents a summary of the forty PPA projects, including geographic location, county, watershed, and PPA rating. Figures E1 and E2 show locations of these projects.

Table E1 Summary of NRRSS PPA Case Study Projects

Project Name	County	PPA Rating	Latitude	Longitude
Ackerman Creek	Mendocino	2	39.185	-123.296
Alameda Creek Niles	Alameda	2	37.597	-121.952
Alameda Creek Sunol	Alameda	2	37.595	-121.919
Alamo Creek	Contra Costa	2	37.763	-121.909
Alamo Creek East	Contra Costa	2	37.759	-121.902
Arroyo de la Laguna	Alameda	2	37.616	-121.882
Arroyo Mocho	Alameda	2	37.694	-121.849
Arroyo Viejo Creek	Alameda	2	37.763	-122.176
Baxter Creek BookerTAnderson	Contra Costa	2	37.919	-122.326
Baxter Creek Gateway	Contra Costa	3	37.931	-122.321
Baxter Creek Poinsett Park	Contra Costa	2	37.935	-122.317
Bear Creek	Modoc	4	41.121	-121.570
Blackberry Creek	Alameda	2	37.892	-122.282
Brandy Creek	Shasta	2	40.601	-122.584
Carmel River (deDampierre)	Monterey	2	36.480	-121.742
Carmel River (Schulte Road)	Monterey	2	36.523	-121.830
Castro Valley Creek	Alameda	1	37.694	-122.072
Cerrito Creek	Contra Costa	2	37.898	-122.299
Chorro Flats	San Luis Obispo	2	35.359	-120.823
Clarks Creek	Plumas	1	40.136	-120.508
Clear Creek	Shasta	3	40.495	-122.456
Cold Creek	Tahoe	2	38.911	-119.967
Crocker Creek	Sonoma	2	38.773	-122.965
Cuneo Creek	Humboldt	1	40.334	-124.030
Green Valley Creek	Solano	4	38.221	-122.148
Lower Guadalupe River	Santa Clara	1	37.401	-121.942
Lower Ritchie Creek	Napa	1	38.553	-122.519
Lower Silver Creek	Santa Clara	4	37.355	-121.873
Martin Canyon Creek	Alameda	1	37.706	-121.949
Miller Creek	Marin	5	38.036	-122.591
Redwood Creek	Marin	3	37.870	-122.581
Sausal Creek	Alameda	2	37.809	-122.216
Strawberry Creek	Alameda	1	37.868	-122.286
Tassajara Creek	Alameda	5	37.706	-121.879
Tennessee Hollow	San Francisco	2	37.802	-122.454

Table E-1 Continued

Project Name	County	PPA Rating	Latitude	Longitude
Uvas Creek	Santa Clara	2	37.001	-121.590
Village Creek	Alameda	2	37.886	-122.302
Wildcat Creek Alvarado	Contra Costa	1	37.952	-122.322
Wildcat Creek Flood Control	Contra Costa	2	37.961	-122.365
Wilder Creek	Santa Cruz	2	37.966	-122.082

Project-specific information can be found on the California NRRSS website, available at: http://landscape.ced.berkeley.edu/~kondolf/NRRSS/.

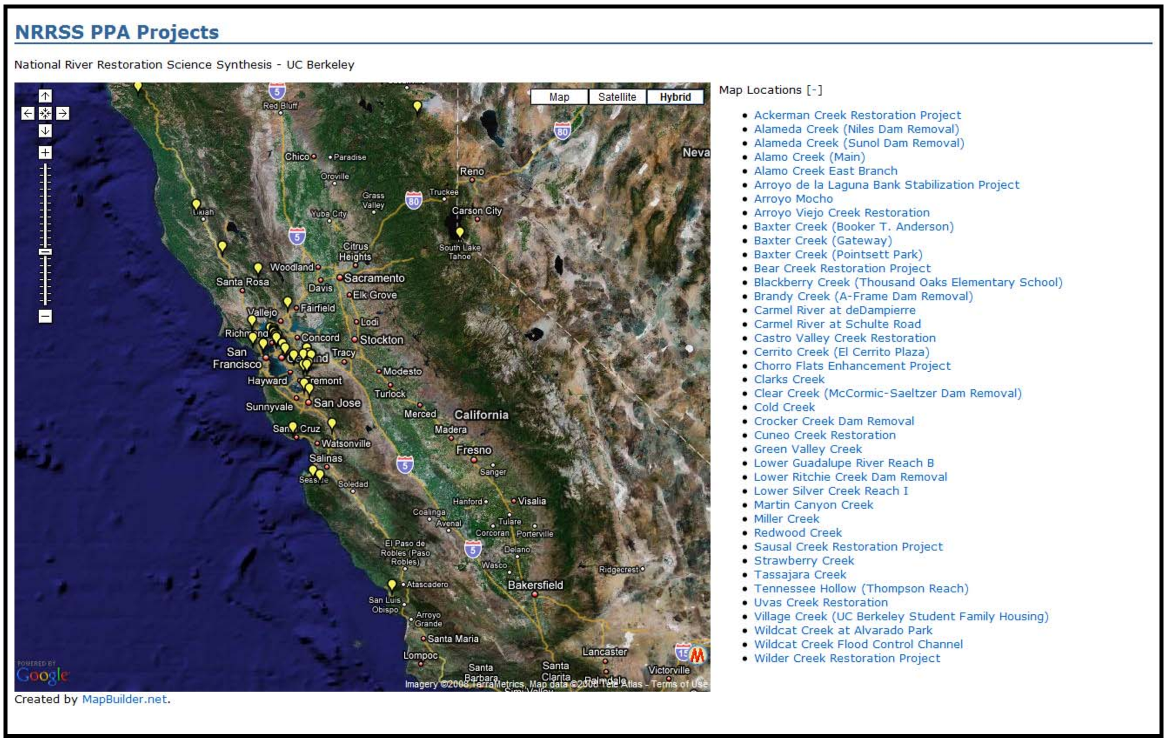

Figure E1: Website interface to access NRRSS PPA project documentation.

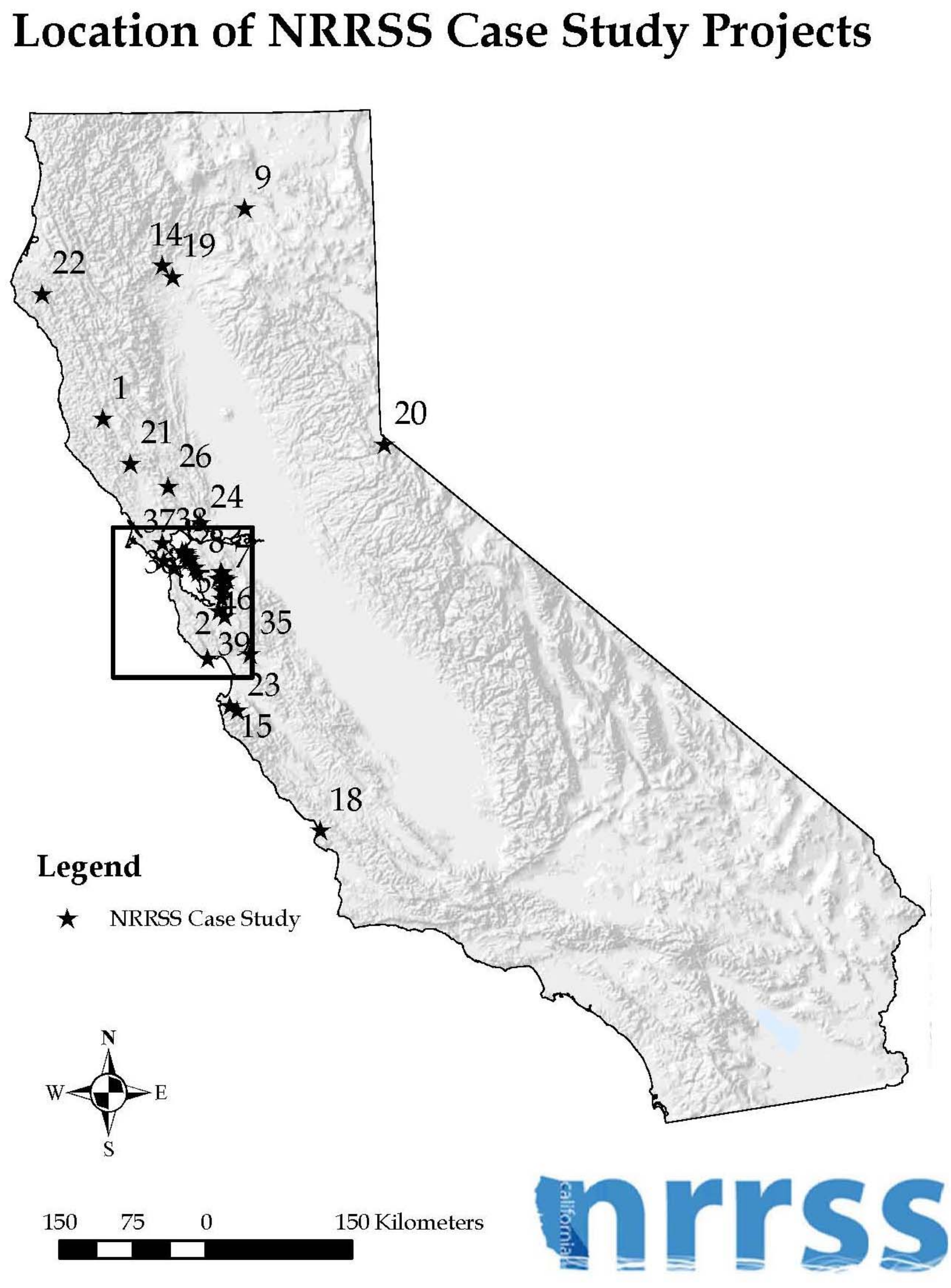

Figure E2: An overview map of NRRSS PPA projects throughout California.

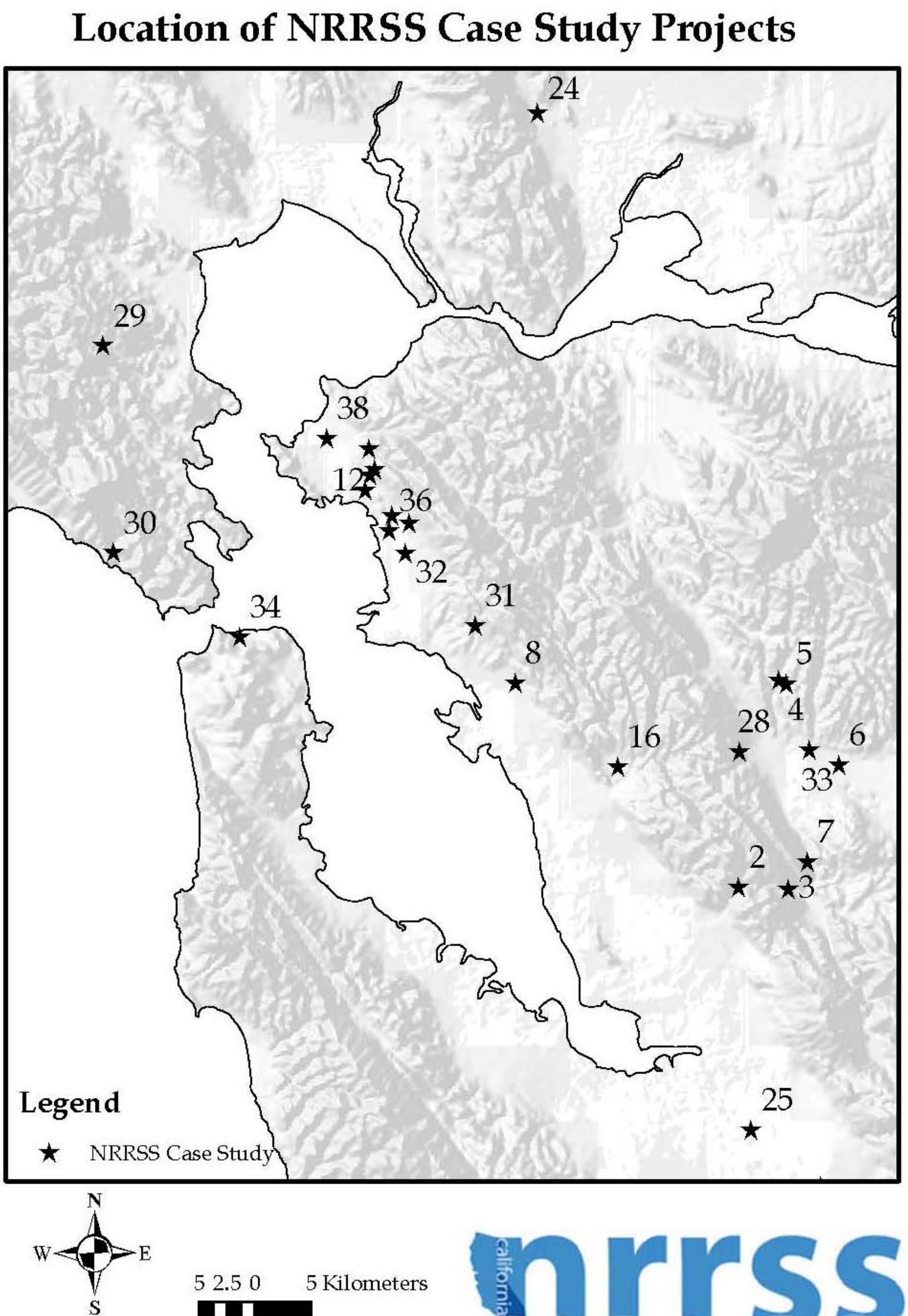

Figure E-3: An overview map of NRRSS PPA projects in the SF Bay Area.

E1 ACKERMAN CREEK

The Ackerman Creek watershed has an area of approximately 39 km^2 that is located in Mendocino County, west of Ukiah, California and discharges into the Russian River. The restoration project is located on a 250 m reach west of Masonite Road. A 1995 California Department of Fish and Game stream inventory report identified a 1 km reach above the Masonite Road crossing on Ackerman Creek as degraded steelhead habitat. An undersized culvert at the road crossing caused a backwater effect that resulted in an extensive zone of deposition and pool infilling upstream. Scouring below the culvert created a deep pool and drop between the culvert and low flow water levels, presenting an obstacle for steelhead migration.

In 2000, the Mendocino Redwood Company replaced the culvert with a single span bridge. They installed an exclusion fence to limit access to the creek by livestock, and willow mattresses and rock rip-rap to stabilize the creek banks and aid in establishing a riparian corridor. The total length of creek improvements was approximately 250 m. High stream flows occurred in the fall of 2001 and spring of 2002 that significantly scoured the recently completed stream grading activities, and the site was re-graded in the summer of 2002.

The project goals included bank stabilization (explicit), channel reconfiguration (inferred), fish passage (explicit), habitat improvement (explicit), livestock exclusion (explicit), and riparian management (explicit). Based on these goals, it was found that only about 22% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 30% goal attainment. Table E2 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E2: Summary of completed evaluation parameters for Ackerman Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✗	✓	✗				✓		✗	✗	✗
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✗				✓		✗	✗	✗
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✓		✗	✗	✗
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✓		✗	✗	✗
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✗				✓		✗	✗	
Livestock Exclusion		R						R	R					R	R	R	R
		✗						✓	✗					✗	✗	✗	✗

E2 ALAMEDA CREEK (NILES DAM REMOVAL)

Niles Dam is located in southern Alameda County along Niles Canyon Road on Alameda Creek about 3.2 km above the historic site of Vallejo's Mill. In 1887, the Spring Valley Water Company (predecessor to the San Francisco Public Utilities Commission [SFPUC]) constructed Niles Dam to divert water into an aqueduct. From the aqueduct the water was fed into a variety of conveyance systems and eventually reached San Francisco as a water source. After 1900 Sunol Dam and aqueduct came into use and the Niles Dam only served to supply downstream riparian rights. In the 1930s, the dam's use was discontinued as a result of the completion of Hetch Hetchy reservoir and delivery system. The dam acted as a barrier to the potential upstream migration of central California coast steelhead (*Onchorynchus mykiss*), a federally listed threatened species. In addition, the dam created pools that attracted trespassers and posed risk and liability concerns for the City and County of San Francisco.

In 2006, the SFPUC removed Niles dam to improve fish passage, restore a self-sustaining population of steelhead to the Alameda Creek watershed, and minimize an existing public safety hazard. According to the Environmental Impact Report for the Niles Dam Removal, the release of sediment stored behind the dam would occur gradually over a period of decades and would not significantly affect the sediment load of Alameda Creek. The estimated volume of sediment behind Niles Dam was 2,200 m^3.

The project goals included fish passage (explicit), dam removal (explicit), and other – public safety (explicit). Based on these goals, it was found that only about 80% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 90% goal attainment. Table E3 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E3: Summary of completed evaluation parameters for Alameda Creek (Niles)

Goal/ Objective	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Dam Removal / Retrofit	R	R	R		R	R	R	R	R				R	R	R	R	R
	✓	✓	✓		✗	✓	✓	✓	✓				✓	✓	✓	✓	✓
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✗	✗	✓	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓

(Column group header: Evaluation Parameters)

E3 ALAMEDA CREEK SUNOL DAM REMOVAL

In 1900, the Spring Valley Water Company (predecessor to the San Francisco Public Utilities Commission [SFPUC]) constructed Sunol Dam on Alameda Creek as a water source for the city of San Francisco. In the 1930s, the water company discontinued the dam's use as a drinking water supply as a result of the completion of Hetch Hetchy reservoir and delivery system. Sunol Dam acted as a barrier to the potential upstream migration of central California coast steelhead (*Onchorynchus mykiss*), a federally listed threatened species. In addition, the dam created pools that attracted trespassers and posed risk and liability concerns for the City and County of San Francisco.

In 2006, the SFPUC partially removed Sunol dam to improve fish passage, restore a self-sustaining population of steelhead to the Alameda Creek watershed, and reduce or eliminate an existing public safety hazard. In association with the removal of Sunol dam, impounded sediment was left in place to move downstream naturally over a period of several decades.

The project goals included fish passage (explicit), dam removal (explicit), and other – public safety (explicit). Based on these goals, it was found that only about 80% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 90% goal attainment. Table E4 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E4: Summary of completed evaluation parameters for Alameda Creek (Sunol)

Goal/ Objective		Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Dam Removal / Retrofit		R	R	R		R	R	R	R	R				R	R	R	R	R
		✓	✓	✓		✗	✓	✓	✓	✓				✓	✓	✓	✓	✓
Fish Passage		R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
		✓	✓	✗	✗	✓	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓

(Column heading spanning all parameters: Evaluation Parameters)

E4 ALAMO CREEK MAINSTEM

Alamo Creek drains approximately 15.7 km^2 immediately upstream of its confluence with the East Branch of Alamo Creek. Prior to the project, Alamo Creek was highly incised, primarily due to past grazing practices in the watershed, and reduction of the vegetative cover on the upper banks combined with the dislodging of soil particles by livestock hooves over a period of several decades resulted in significant erosion in the entire watershed.

Project design was initiated in 1999. The entire project covered a 1.6 km long and a deeply incised reach of Alamo Creek was reconstructed in a compound channel configuration as part of a 9.4 km^2 mixed-use development in Dougherty Valley in south-central Contra Costa County. The low flow channel was left in place, and a broad floodplain terrace was excavated on the west side of the channel. The conceptual design drawings and memoranda showed the basic design for Alamo Creek as an excavated floodplain "terrace" within a widened corridor adjacent to the intact low flow channel. The design also included numerous grade control structures at knick points to prevent further incision, and the floodplain surfaces and riparian zones were vegetated with California native riparian species. Because this project was conceived and initiated prior to urbanization, a wide corridor 43 to 92 m was maintained for flood conveyance.

The project goals included bank stabilization (explicit), channel reconfiguration (explicit), floodplain reconnection (explicit), and riparian management (explicit). Based on these goals, it was found that only about 80% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E5 presents a summary of the parameters that were

evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E5: Summary of completed evaluation parameters for Alamo Creek (Main)

Goal/ Objective	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓				✓		✓	✓	✓
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓				✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✗	✗		✓		✓	✓				✓		✓	✓	

E5 ALAMO CREEK EAST BRANCH

The East Branch of Alamo Creek drains a 4.7 km^2 watershed near San Ramon, California. From the early 1800s, cows grazed the Alamo Creek watershed and numerous gullies and shallow landslides are still present in the surrounding hills. In the late 1980s, the City of San Ramon annexed the Dougherty Valley, rezoning it from agricultural to residential land uses. To guide new development, the City prepared the Dougherty Valley Specific Plan (drafted in 1989, updated in 2005). This plan specified that any new development in the Dougherty Valley required restoration of the upper Alamo Creek watershed.

As part of the residential development, the East Branch of Alamo Creek was physically abandoned and the creek was relocated in a new drainage configuration to accommodate the land development plans. Because of the existing channel's degradation, permitting agencies allowed the relocation. The East Branch was moved approximately 100 m south and set at an angle to the existing channel. Following excavation of the new bed, the original channel was filled. The relocated East Branch Alamo Creek was designed as a step-pool channel with several bank stabilization measures to prevent erosion and delivery of sediment into the creek, including rip-rap, erosion control fabric, and irrigated native riparian vegetation plantings (installed along the entire length of the project).

The project goals included bank stabilization (explicit), channel reconfiguration (explicit), and riparian management (explicit). Based on these goals, it was found that only about 85% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 90% goal attainment. Table E6 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red “x”).

Table E6: Summary of completed evaluation parameters for Alamo Creek (East)

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✓	✗	✗	✓	✓	✓	✓				✓		✓	✓	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✗	✗	✓	✓	✓	✓				✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✓	✗		✓		✓	✓				✓		✓	✓	

E6 ARROYO DE LA LAGUNA

The Arroyo de la Laguna watershed has an area of approximately 1,114 km^2 and is located in Alameda County. Arroyo de la Laguna joins Alameda Creek and eventually drains to San Francisco Bay. Streambank erosion on the outer bends of an "S" curve of the Arroyo de la Laguna Creek resulted in land loss for the residents adjacent to the creek. The project area, which is approximately 210 m in length, has vertical banks six to nine m in height.

Watershed hydrology and channel function have been historically impacted by urbanization (including drainage and flood control), roads, railroads, gravel mining, and the construction of Del Valle Reservoir, resulting in channel incision on the order of six m. The restoration efforts utilized soil bioengineering methods to stabilize the streambank, including regarding the vertical banks and re-vegetation with native plants. The creek thalweg was relocated and vegetated spurs and rock barbs with perpendicular root wads were installed to increase roughness and stabilize the banks.

The project goals included bank stabilization (explicit) and channel reconfiguration (explicit). Based on these goals, it was found that only about 56% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 70% goal attainment. Table E7 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E7: Summary of completed evaluation parameters for Arroyo de la Laguna

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✓	✓	✓				✓		✓	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✓	✓	✓				✓		✓	✗	✓

E7 ARROYO MOCHO

The Arroyo Mocho project is located within the Alameda Creek watershed in Alameda County. This site is situated north of the Livermore gravel pits and south of Interstate 580 in the town of Livermore, California. The Arroyo Mocho watershed is approximately 150 km^2 in size and drains to Arroyo de la Laguna, then to Alameda Creek before finally discharging into San Francisco Bay.

To accommodate the combined flood waters of the Arroyos Mocho and Las Positas, the Zone 7 Water Agency widened and deepened a 640 m reach of Arroyo Mocho, between the existing confluence and El Charro Road. The new channel configuration is similar to a newly constructed channel in Arroyo Las Positas, with a meandering low-flow channel, flood terraces, and access roads. To match grades with the existing downstream reach of Arroyo Mocho and the upstream reaches of the Mocho and Las Positas, restoration included removal of an existing concrete confluence drop structure and replacement with a new, fish-passage friendly drop structure. Construction began in April 2003 and was completed in January 2004.

Baseline biological resource surveys of the project reach were performed in 1993, 1995, and 2002, providing very useful information of pre-project performance in the project area. These baseline surveys found that prior to the implementation of the restoration project, Arroyo Mocho supported an intermittent vegetative cover of wetland and upland, native and non-native plant species. Post project monitoring was performed by Davis Environmental Consulting in 2004 and 2005.

The project goals included channel reconfiguration (explicit), fish passage (explicit), in-stream habitat improvement (explicit), and riparian management (explicit).

Based on these goals, it was found that only about 76% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 80% goal attainment. Table E8 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E8: Summary of completed evaluation parameters for Arroyo Mocho

Goal/Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓				✓		✓	✓	✓
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓	✗	✓	✓	✓		✓	✓	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓	✗	✓	✓	✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✗	✗		✓		✓	✓				✓		✓	✓	

E8 ARROYO VIEJO

The Arroyo Viejo Creek improvement project is located in the City of Oakland in Alameda County. The Arroyo Viejo watershed has an area of approximately 16 km^2 and drains to San Francisco Bay. The City of Oakland and the Alameda county Public Works Agency implemented the Arroyo Viejo Creek Improvement Project in 2001-2002 to enhance an approximately 230 m reach of urban creek in Arroyo Viejo Park. The project included partial removal of concrete channel walls in the eastern half of the project area, re-grading and re-vegetation of channel banks, and installation of park enhancement features. These modifications were intended to provide environmental benefits like habitat improvement, long-term bank stability, and improved water quality, as well as enhancing public safety and access.

The project goals included aesthetics/recreation/education (explicit), bank stabilization (inferred), channel reconfiguration (explicit), in-stream habitat improvement (explicit), and riparian management (explicit). Based on these goals, it was found that only about 41% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 65% goal attainment. Table E9 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E9: Summary of completed evaluation parameters for Arroyo Viejo

Goal/ Objective	Evaluation Parameters: Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✗	✗	✗	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✗	✓	✓				✓		✗	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✓				✓		✗	✗	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✗	✓		✗	✗	✓
Riparian Management	✓	R	R	R		R		R	R				R		R	R	
		✗	✗	✗		✗		✓	✓				✓		✗	✗	

E9 BAXTER CREEK AT BOOKER T WASHINGTON

Baxter Creek originates in the Richmond and El Cerrito Hills and flows southwesterly to the San Francisco Bay. Much of the creek is culverted, with few open and public reaches in the lower watershed. One of these reaches flows through Booker T. Anderson Jr. Park in southwest Richmond, California. This section of the park has experienced numerous disturbances including cattle grazing, frog pond construction, and failed "restoration" attempts in 1970 and 1988. The result of long-term land uses was a widened creek with abundant weeds and algae that lacked woody riparian vegetation and dissolved oxygen levels needed to support diverse wildlife. In addition, erosion undermined bridges across the creek and exposed subsurface drainage pipes. Concrete and boulders from the 1970 and 1988 restoration projects have also fallen into the creek.

In 2000, the Urban Creeks Council (UCC) restored a 259-m reach of Baxter Creek at Booker T. Anderson Jr. Park to improve water quality, provide wildlife habitat, provide a more functional hydraulic geometry, and enhance human use and understanding of the creek. The restoration project consisted of re-grading sections of the creek and planting woody riparian vegetation, with maintenance and monitoring of the project to be handled by volunteer citizens and students. The construction of the project occurred in 2000.

The project goals included aesthetics/recreation/education (explicit), channel reconfiguration (explicit), riparian management (explicit), and water quality (explicit). Based on these goals, it was found that only about 41% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 65% goal attainment. Table E10 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red “x”).

Table E10: Summary of completed evaluation parameters for Baxter Creek at Booker T. Anderson

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✗	✗	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✓		✓				✓		✓	✗	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✓				✓		✗	✗	
Water Quality Management			R		R	R	R		R	R					R	R	R
			✗		✓	✗	✓		✓	✗					✗	✗	✓

E10 BAXTER CREEK AT GATEWAY

The Baxter Creek at Gateway project is located in the City of El Cerrito in Contra Costa County. The project watershed has an area of approximately 1 km^2 and drains to San Francisco Bay. The project is situated on 0.7 hectares with approximately 213 m of improved creek.

Baxter Creek has concrete culverts above and below the restoration site and drains a heavily urbanized watershed. The restoration project consisted of reconfiguring the creek channel planform to introduce sinuosity, importation of gravel and cobble to recreate processes of deposition and erosion, floodplain grading, planting of native riparian vegetation, extension of a public pathway, and installation of educational signs. Construction of the project began in the summer of 2005 and was completed in September 2006.

The project goals included aesthetics/recreation/education (explicit), channel reconfiguration (inferred), riparian management (explicit), and water quality (explicit). Based on these goals, it was found that only about 41% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 70% goal attainment. Table E11 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red “x”).

Table E11: Summary of completed evaluation parameters for Baxter Creek at Gateway

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✗	✗	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✓		✓				✓		✓	✗	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✓				✓		✗	✗	
Water Quality Management			R		R	R	R		R	R					R	R	R
			✗		✓	✗	✓		✓	✗					✗	✗	✓

E11 BAXTER CREEK AT POINTSETT PARK

The Baxter Creek watershed, approximately 11.0 km^2, begins in the El Cerrito Hills and flows through Richmond to its mouth at the San Francisco Bay. The restoration project site is located on a 70 m reach at the east end of Poinsett Park in El Cerrito. In the 1940s, like many urban creeks in the San Francisco Bay Area, this segment of Baxter Creek was put underground in a concrete culvert to address flooding and sanitation concerns. Previously a grassy lawn, the formerly culverted creek emerges at the tip of a triangular park and flows west before it goes back underground beneath a playground, maintenance building, and large cemented basketball court at the west end of the park.

In 1992, the El Cerrito City Council conducted a financial analysis of a broken culvert beneath Poinsett Park. The Council determined that it was more cost effective to “daylight” or open a 70 m section of underground culvert at the east end of Poinsett Park than to repair it over time. The Waterways Restoration Institute (WRI) designed and managed the restoration project.

The restoration project ‘re-created’ pre-culvert conditions by restoring sinuosity and riparian vegetation to the newly opened channel. The new channel’s cross-section, width, and depth were determined using regional hydraulic geometry relationships between channel sizes and drainage areas. Step pools (designed to be 30 cm high to avoid undercutting) were created with salvaged rocks from the excavation. Bank and riparian modifications included soil bioengineering approaches: fascines (bundles of willows) and willow posts (1 m long, 10–15 cm wide).

The project goals included channel reconfiguration (inferred) and riparian management (inferred). Based on these goals, it was found that only about 40% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 80% goal attainment. Table E12 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red “x”).

Table E12: Summary of completed evaluation parameters for Baxter Creek at Pointsett Park

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✓				✓		✗	✗	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✓				✓		✗	✗	

E12 BEAR CREEK

The Bear Creek restoration project is located east of Ted Elder Road and north of McArthur Road in Shasta County. The project has a drainage area of approximately 458 km^2. The project was originally conceived in 1994 to reduce erosion and improve fish habitat for the deeply incised Bear Creek channel. In consultation with Dr. Luna Leopold and Dave Rosgen, Wildland Hydrology, the sponsors instituted a system of data collection and monitoring to provide design level data and baseline conditions of streamflow and sediment.

The chosen design alternative was a meadow re-watering via the pond and plug technique. This design entailed relocating the channel into a system of constructed and remnant channels on top of the meadow. Relocating the channel back to meadow elevation reconnects the channel to its naturally developed, functional floodplain, greatly reducing the stresses of floods on the riparian system. Concurrently the meadow groundwater table rises to match the new channel base level, providing enhanced meadow vegetation. This project was constructed in 1999.

Extensive post project monitoring occurred on this project. Monitoring included longitudinal thalweg and cross sectional surveys, water table piezometer surveys, vegetation transects, photo documentation, sediment transport data collection, hydrograph analyses, and macro invertebrate studies.

The project goals included channel reconfiguration (explicit), fish passage (explicit), floodplain reconnection (explicit), and in-stream habitat improvement (explicit). Based on these goals, it was found that 69% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a

90% goal attainment. Table E13 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E13: Summary of completed evaluation parameters for Bear Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓				✓		✓	✓	✓
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓				✓		✓	✓	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✗	✗	✗	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓

E13 BLACKBERRY CREEK

Blackberry Creek is located in northern Berkeley, California (Alameda County) and drains from the Berkeley Hills to San Francisco Bay. The restoration site is located south of Tacoma Avenue and east of Ensenada Avenue. The drainage area for the restoration site is approximately 1 km^2.

Prior to restoration, the stream was contained in a culvert that ran beneath Thousand Oaks Elementary School. The culvert had a history of flooding during large storms and following the 1989 Loma Prieta Earthquake, there was a community desire to mitigate the poor condition of the culvert and increase storm water conveyance. A $144,000 grant from the California Department of Water Resources Urban Stream Restoration Program was used to fund the daylighting project.

Post Project Appraisals were performed by Askew in 1996, Imanishi in 2000, and Gerson et al. in 2005. Askew surveyed cross sections and a long profile, observed plant survival, conducted photo documentation, and conducted personal interviews. Imanishi surveyed cross sections and a long profile, observed plant survival, and conducted photo documentation. Gerson et al. surveyed cross sections and a long profile, observed plant survival, conducted photo documentation, analyzed rainfall data, and evaluated community perception and use.

The project goals included channel reconfiguration (explicit), fish passage (explicit), floodplain reconnection (explicit), and in-stream habitat improvement (explicit). Based on these goals, it was found that 23% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 75% goal attainment. Table E14 presents a summary of the parameters that were

evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E14: Summary of completed evaluation parameters for Blackberry Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✗	✗	✗	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✗		✗	✗	✗	✗	✗	✗	✓				✓		✗	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✗	✗	✗	✗	✗	✗	✗	✗	✓				✓		✗	✗	✓
Stormwater Management			R		R		R			R					R		R
			✗		✗		✗			✗					✗		✓

E14 BRANDY CREEK

In 1960, a recreational dam was constructed within the Whiskeytown National Recreation area (operated by the National Park Service, NPS) on a small tributary to Brandy Creek near Redding, California. The dam was an earthen A-Frame Dam, reaching 9 m high and 30 m wide; impounding over 22,203 m^3.

The A-Frame Dam became unstable after two floods in the late 1980's and 1990's overtopped it and created a partial breach on the downstream face. NPS was concerned that another overtopping flood could cause the dam to fail catastrophically. Although there were no toxicity concerns within the sediment deposit, the material mobilized downstream could partially block Brandy Creek, creating a situation primed for a larger, more catastrophic debris flow, which might threaten the downstream bridges and any visitors present along Brandy Creek or in the downstream beach area at the Whiskeytown Lake Reservoir.

The NPS Maintenance, Operations and Safety of Dams Program evaluated the A-Frame's condition and gave it an unsatisfactory rating, ranking it third highest on the Department of the Interior Technical Priority Rating List for the Pacific West Region. Congress appropriated $400,000 which allowed the NPS to remove the A-Frame Dam to prevent catastrophic failure. NPS wanted to restore natural topography, the estimated cost of repair was just as great as the removal costs, and dam removal enabled them to discontinue the maintenance requirements and the A-Frame Dam was removed on 1993.

The project goals was dam removal (explicit) and based on this goal, it was found that 77% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E15 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E15: Summary of completed evaluation parameters for Brandy Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Dam Removal / Retrofit	R	R	R		R	R	R	R	R				R	R	R	R	R
	✓	✗	✗		✓	✓	✓	✓	✓				✗	✓	✓	✓	✓

E15 CARMEL RIVER AT DEDAMPIERRE

The deDampierre restoration site on the Carmel River is located in Monterey County. Carmel River drains the Carmel Valley region and discharges into the Pacific Ocean. The restoration site is approximately 20 km upstream of the coast and located south of Rosie's bridge at Robles del Rio, east of East Garzas Road and west of East Carmel Valley Road, near the town of Carmel Valley. The drainage area associated with the restoration site is 529 km^2.

Following widespread bank erosion in the early 1980's, the Carmel River Management Program undertook a series of river restoration projects to stabilize the river banks (for a design flood with a 10-year return period). The projects emphasized riparian vegetation for bank stabilization over hard structural elements, thereby promoting improved riparian and aquatic habitats.

Kondolf and McBain (*1995*) and James and Sereno (*1999*) conducted post project appraisals on this site. Kondolf and McBain conducted field surveys (cross-sectional and longitudinal thalweg surveys), historical analyses (flood frequency and aerial photograph review), and a geomorphic analysis (meander wavelength, channel sinuosity, and floodway width). James and Sereno interviewed project participants, reviewed historical photos, and surveyed cross-sections.

The primary project goal was bank stabilization (inferred) and based on this goal, it was found that 50% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 50% goal attainment. Table E16 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E16: Summary of completed evaluation parameters for Carmel River at deDampierre

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✓	✓	✓				✓		✗	✗	✓

E16 CARMEL RIVER AT SCHULTE ROAD

The Schulte Road restoration site on the Carmel River is located in Monterey County. Carmel River drains the Carmel Valley region and discharges into the Pacific Ocean. The restoration site is approximately 20 km upstream of the coast and located southeast of the Schulte Road bridge. The drainage area associated with the restoration site is 636 km^2.

The bottomlands of Carmel Valley have been heavily urbanized in the last three decades and water table drawdown by municipal well pumps promoted increased bank erosion and channel instability. Near the Schulte road bridge, the channel width increased from approximately 24 m to as much as 65 m between 1965 and 1982. In an attempt to reverse the severe erosion, the Schulte Road restoration project was implemented in 1988, which consisted of channel realignment, construction of pool-riffle sequences and restoration of the riparian vegetation.

Post project evaluations were performed by Byrd (*1996*) who analyzed vegetation establishment and diversity, Eischeid (*1998*) who evaluated pebble counts, Pacca (*1998*) who conducted cross sectional field surveys and pebble counts, and Graham Matthews & Associates performed cross sectional and longitudinal field surveys.

The project goals included bank stabilization (explicit) and riparian management (explicit). Based on these goals, it was found that 77% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E17 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E17: Summary of completed evaluation parameters for Carmel River at Schulte Road

Goal/ Objective	Evaluation Parameters: Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✓	✗	✓	✓	✗	✓				✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✓	✗	✓	✓	✗	✓				✓		✓	✓	□

E17 CASTRO VALLEY CREEK

Castro Valley Creek runs from the Contra Costa hills through Castro Valley, before joining Chabot Creek as a tributary to San Lorenzo Creek. Approximately 50% of Castro Valley Creek is either culverted or channelized. One section of the creek, just off Interstate 580 through a commercial strip in Castro Valley, remained undeveloped and relatively natural.

Over the years, parking lots and driveways were built to the edge of the creek along most of the west bank with slightly less encroachment on the east bank. Bank erosion threatened to undermine the business adjacent to the channel. In 1995, the Alameda County Public Works Agency stabilized approximately 198 m of creek with cribwalls of redwood timbers (instead of concrete), which allow streamside vegetation to grow, and animal habitat to be maintained.

The project goals included aesthetics/recreation/education (inferred), bank stabilization (explicit), channel reconfiguration (explicit), riparian management (inferred), and in-stream habitat management. Based on these goals, it was found that 50% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 70% goal attainment. Table E18 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E18: Summary of completed evaluation parameters for Castro Valley Creek

Goal/ Objective	Evaluation Parameters: Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✗	✓	✗	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✓	✓	✓				✓		✓	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✓	✓	✓				✓		✓	✗	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗	✓		✓	✗	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✓				✓		✓	✗	

E18 CERRITO CREEK

Cerrito Creek drains a portion of the East Bay hills and flows westward to San Francisco Bay. The creek delineates the border between Alameda and Contra Costa Counties and the cities of Albany and El Cerrito. Like many other creeks in the San Francisco Bay Area, large stretches of Cerrito Creek are underground or contained within engineered channels. The scope of the Cerrito Creek restoration project is a three-block daylighted section starting at Talbot Avenue and extending approximately 213m down to Kains Avenue in El Cerrito. Cornell Avenue runs over the reach to the parking lot so the stream flows through a box culvert at that juncture. This splits the reach into a downstream section extending from Kains to Cornell and an upstream section from Cornell to Talbot.

The El Cerrito Plaza shopping center borders Cerrito Creek to the north, and dense residential units (mainly apartments) border the project to the south. As part of a renewal project for El Cerrito Plaza, the property owner agreed to condense the parking lot by allowing approximately 7 additional meters of width for a new stream channel and flood terrace system. Despite the additional width available to the stream, space constraints limited the number of meanders initially considered for the design. Rock weirs and in-stream boulders were installed in lieu of meanders to dissipate energy and reduce velocities during high flow conditions. Large boulder rip-rap installed along most of the reach was intended to provide increased bank strength and stability.

The project goals included aesthetics/recreation/education (inferred), bank stabilization (explicit), channel reconfiguration (explicit), and riparian management (inferred). Based on these goals, it was found that 50% of the parameters identified in the

Requirements Matrix were evaluated, and it was estimated that the project achieved a 65% goal attainment. Table E19 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E19: Summary of completed evaluation parameters for Cerrito Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✗	✓	✗	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✓	✓	✓				✓		✓	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✓	✓	✓				✓		✓	✗	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗	✓		✓	✗	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✓				✓		✓	✗	

E19 CHORRO FLATS

The Chorro Flats restoration project is located in San Luis Obispo County on Chorro Creek, approximately 2.5 km upstream from Morro Bay, with a drainage area of approximately 111 km^2. The site is located east of South Bay Boulevard and South of Highway 1.

The Chorro Flats restoration project was a floodplain reconnection project that eliminated flood control levees in order to allow sediment deposition within the Chorro Creek floodplain, upstream of Morro Bay. The Soil Conservation Service prepared a report in 1989 that identified the Chorro Flats site as suitable for sediment control from Chorro Creek. On this recommendation, the Coastal San Luis Resource Conservation District purchased the Chorro Flats site. Funds to purchase the site were provided by the California Transportation Commission (Proposition 111 gas tax revenues) and the State of California Coastal Conservancy.

The Coastal San Luis Resource Conservation District (CSLRCD) performed a post-project appraisal in 2002. CSLRCD collected data on sediment transport, precipitation, vegetation, water temperature, fish habitat, bird surveys and performed cross sectional surveys to evaluate channel form stability. The field monitoring was based on their Maintenance and Management plan, created in 1998.

The project goals included floodplain reconnection (explicit) and land acquisition (explicit). Based on these goals, it was found that 89% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E20 presents a summary of the parameters that were

evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E20: Summary of completed evaluation parameters for Chorro Flats

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✗	✓	✗	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✓	✓	✓				✓		✓	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✓	✓	✓				✓		✓	✗	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗	✓		✓	✗	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✓				✓		✓	✗	

E20 CLARKS CREEK

Clarks Creek drains a 48 km^2 watershed that receives 99cm of annual precipitation predominately as snow. A geomorphic reconstruction of land use history indicated that a cattle trail during historic overgrazing (~1900) likely caused channel down-cutting. In addition to incision, the existing shallow meadow water table lowered and subsequently converted the floodplain from mesic (moist) site plants to a xeric (dry) site vegetative community. In 1990, the Plumas National Forest (PNF) began restoration efforts on Clarks Creek with the development of the Clarks 2000 plan, which entailed road closure/rehabilitation, channel stabilization, and grazing management changes throughout the watershed.

The Clarks Creek restoration final design was a collaborative effort between PNF, the FR-CRM Technical Advisory Committee (TAC) and the grazing permittee. The Clarks Creek meadow system has numerous archaeological sites along the meadow/hillslope margins, as well as sensitive plant occurrences and willow flycatcher habitat in the lower reaches. These resource constraints in combination with continued grazing in the area limited the project effort to two of the three meadows targeted for restoration. The project entailed obliteration of 1,067 m of gully, while redirecting stream flow into a well-defined remnant channel throughout the meadow. The gully obliteration resulted in the excavation and placement of approximately 17,585 m^3 creating ten small ponds and ten plugs.

The primary project goal was floodplain reconnection (explicit) and based on this goal, it was found that 62% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 80% goal attainment. Table

E21 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E21: Summary of completed evaluation parameters for Clarks Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✓	✗	✗	✗	✓	✓				✓		✓	✓	✓

E21 CLEAR CREEK SAELTZER DAM

Draining 591 km^2, Clear Creek is a 56-km long west bank tributary to the Sacramento River; the first major tributary to the Sacramento downstream of the Shasta Dam with the confluence just south of Redding, California. Clear Creek has been severely degraded over the years by human land use practices. In particular, mining activities have been heavy on Clear Creek since 1848. Historic dredge-mining for gold and gravel has altered the channel form by removing point bars, floodplains and riparian vegetation. In some areas, the stream is straight and highly entrenched; in others, multiple flow channels and open extraction pits exist.

In 1992, the Central Valley Project Improvement Act authorized the Bureau of Reclamation to increase anadromous fish populations in the Central Valley within 10 years. Specific actions identified included improving fish access above Saeltzer Dam. The Central Valley Project Improvement Act and the California Bay-Delta Authority were the primary funders of more than $21 million dollars in restoration efforts focused on five primary activities, including: a major rehabilitation project on the Lower Clear Creek Floodway increasing the minimum instream flow, spawning gravel augmentation, erosion control projects, and fish passage. Project costs, from design through construction, totaled $3.5 million dollars. An additional $2.5 million was also paid to the Townsend Flat Water Ditch Company for the water rights and property interests, bringing the total to $6 million, not including post-project monitoring.

The project goals included dam removal (explicit), fish passage (explicit), flow modification (inferred), in-stream habitat improvement (inferred), and other – public safety (explicit). Based on these goals, it was found that 85% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E22 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E22: Summary of completed evaluation parameters for Clear Creek

Goal/ Objective	Evaluation Parameters: Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✓												✓	✓	✓	✓
Dam Removal/Retrofit	R	R	R		R	R	R	R	R				R	R	R	R	R
	✓	✓	✓		✓	✓	✓	✓	✓				✓	✓	✓	✓	✓
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓
Flow Modification							R						R		R		R
							✓						✓		✓		✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓

E22 COLD CREEK

The Cold Creek restoration project is located in El Dorado County, east of the town of South Lake Tahoe. The project site is located northwest of Pioneer Trail, southwest of Black Bart Court, and northeast of Pioneer Circle. The drainage area associated with the Cold Creek restoration site is approximately 34 km^2.

The City of South Lake Tahoe acquired the property on which the Cold Creek restoration project was completed in 1983. A dam had been built across Cold Creek in order to create Lake Christopher, which was constructed as part of a nearby subdivision development. An effort was launched in 1989 to breach the dam, drain the lake, and restore the Cold Creek channel. This initial restoration effort resulted in an unstable channel configuration yielding several head cuts and poor water quality. In 1992, the City of South Lake Tahoe contracted with the Tahoe Resource Conservancy District to remove the remnants of the original Lake Christopher dam and to construct a naturalized channel to restore natural channel and wetland functions. A final design for the project was issued in 1994 and construction was completed in October 1994.

The project goals included channel reconfiguration (explicit) and floodplain reconnection (explicit). Based on these goals, it was found that 85% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E23 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red “x”).

Table E23: Summary of completed evaluation parameters for Cold Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✓	✗	✓	✓	✓				✓		✓	✗	✓
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✓	✗	✓	✓	✓				✓		✓	✗	✓

E23 CROCKER CREEK

Crocker Creek drains approximately 8.5 km^2 of oak woodland, chaparral, and grassland habitat environments, and flows westward into the Russian River near Cloverdale. It is a second order, perennial creek with over 19 km of stream channel, flowing mostly through incised v-shaped canyons. The Crocker Creek Dam, which was approximately 9 m high and 30 m wide, was located in a narrow gorge area of Crocker Creek, about 0.8 km upstream from the confluence with the Russian River.

Crocker Creek Dam began to show signs of failure in 1974 and in 1995, the entire northern portion of the dam failed, with the exception of the original base, and further failure occurred in the high flow events of 1997. At the time of failure, the impounded area was nearly full of sediment, but still served as a recreational pond In 2002, with project funding from the California Department of Fish and Game, Sonoma County Water Agency removed the Crocker Creek Dam.

The primary construction aspect of the dam removal was sediment containment and bank stabilization. The north abutment was anchored and the steep banks were re-graded to a 2:1 slope "match existing grades" and bank protection was installed. The south abutment and spillways were demolished and removed. This project was constructed starting in fall 2002 and was completed in fall 2003.

The project goals included bank stabilization (explicit), fish passage (explicit), and riparian management (inferred). Based on these goals, it was found that 75% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 85% goal attainment. Table E24 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red “x”).

Table E24: Summary of completed evaluation parameters for Crocker Creek

Goal/ Objective		Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
		Evaluation Parameters																
Bank Stabilization		R		R	R	R	R	R	R	R				R		R	R	R
		✓		✗	✗	✓	✗	✓	✓	✓				✓		✓	✓	✓
Dam Removal/Retrofit		R	R	R		R	R	R	R	R				R	R	R	R	R
		✓	✓	✗		✓	✗	✓	✓	✓				✓	✓	✓	✓	✓
Fish Passage		R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
		✓	✓	✗	✗		✗	✓	✓	✓	✗	✗	✓	✓		✓	✓	✓
Riparian Management		R	R	R	R		R		R	R				R		R	R	
		✓	✓	✗	✗		✗		✓	✓				✓		✓	✓	

E24 CUNEO CREEK

The Cuneo Creek restoration project is located within the Humboldt Redwoods State Park Cuneo Campground, approximately 9.5 km west of Weott in Humboldt County, California. The restoration site has a drainage area of 13 km^2. Cuneo Creek drains to Bull Creek, then to the Eel River, and finally discharges to the Pacific Ocean past the town of Ferndale, California.

The Cuneo Creek basin's climate and geology, combined with the effects of logging in the 1950's and '60's, created a high susceptibility to erosion and consequently high sediment loads into the creek. High intensity storms hit the region in 1955 and 1964, causing extensive erosion in the headwaters of Cuneo Creek and massive channel widening and aggradation in lower Cuneo Creek as a result of sediment deposition. In the late 1960's, the Humboldt Redwood State Park purchased all of the land and, in 1991, a reach of lower Cuneo Creek was reconstructed into a sinuous meandering channel in an effort to develop a 'stable' configuration that would minimize sediment transport.

The project goals included bank stabilization (explicit) and channel reconfiguration (explicit). Based on these goals, it was found that 44% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 0% goal attainment. Table E25 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E25: Summary of completed evaluation parameters for Cuneo Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✗	✓	✓				✗		✓	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✗	✗	✗	✗	✓	✓				✗		✓	✗	✓

E25 GREEN VALLEY CREEK

Green Valley Creek drains 57 km^2 in Solano County, California, and flows for 22 km, from the Vaca Mountains through the town of Cordelia, where it becomes the Cordelia Slough. The creek is characterized by a relatively deep canyon in the upper reaches, before it enters a broad agricultural plain near the project reach. Upstream, active hill-slope, mass movement processes, (notably earth flows) contribute sediment in the upper watershed. Downstream bank erosion (due to channel incision) contributes sediment to the stream. In the lower reaches of Green Valley Creek, fine grained sediment has been continually dredged from the channel in order to maintain conveyance of flood waters over the past few decades. The initial motivation for restoring Green Valley Creek was development in the floodplain, as developers could not build housing subdivisions without flood control provisions, and mitigation for wetland lost to housing.

The restoration project maintained the original low flow channel and excavated an "overflow terrace" (i.e. a floodplain surface) along the west bank of the channel to carry seasonal high flows and to allow development of seasonal marsh and native grass habitats. The floodplain terrace was excavated at the estimated 5-year flow surface elevation and connectivity between low flow channel and floodplain was not continuous throughout the restored reach. High terrace elevations were undisturbed around mature oak trees along the west bank of the channel such that higher-elevation "islands" remained along the low flow channel in some locations.

The project goals included floodplain reconnection (explicit) and riparian management (inferred). Based on these goals, it was found that 83% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the

project achieved a 90% goal attainment. Table E26 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E26: Summary of completed evaluation parameters for Green Valley Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✓	✓	✗	✓	✓	✓				✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✗	✓		✗		✓	✓				✓		✓	✓	

E26 LOWER GUADALUPE RIVER

The Lower Guadalupe River Flood Protection Project (LGRP) was proposed for construction by the Santa Clara Valley Water District (SCVWD) on the Guadalupe River between Interstate 880 and the community of Alviso and on Alviso Slough from the UPRR bridge to the terminus of Alviso Slough with San Francisco Bay in San Jose and Santa Clara, California. The drainage area associated with the project site is approximately 408 km^2.

The LGRP was authorized by SCVWD to provide flood protection, environmental protection and public access opportunities and was designed and constructed to ensure that the channel improvements are operated and managed to convey design flood flows in the Guadalupe River from Interstate 880 to the UPRR bridge where Section 104 improvements currently exist and through the bay lands to San Francisco Bay. The LGRP is also incorporating measures to avoid existing fish and wildlife habitat, to protect special status species (e.g. steelhead trout and chinook salmon under the Endangered Species Act, and the Magnuson-Stevens Act, respectively) and to meet conditions for water quality certification under the Clean Water Act. Construction of the LGRP occurred in phases, with substantial completion by 2005.

Construction of the LGRP occurred in phases. The "Reach B" phase, which is the focal point of this PPA, was completed in 2005. Post project evaluations were completed by Tompkins (2005), following the completion of the restoration activities. These evaluations included longitudinal profile surveys and review of historical aerial photographs.

The primary project goal was channel reconfiguration (explicit) and based on this goal, it was found that 83% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 90% goal attainment. Table E27 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E27: Summary of completed evaluation parameters for Lower Guadalupe River (Reach B)

	Evaluation Parameters																
Goal/ Objective	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✗	✓	✗	✓	✓	✓				✓		✓	✓	✓

E27 LOWER RITCHIE CREEK DAM REMOVAL

Ritchie Creek, a tributary of the Napa River, is a perennial stream approximately 6 km in length and drains an area of 6.7 km^2 that joins the Napa River 0.8 km northwest of Bale, California. The upper two-thirds of Ritchie Creek's watershed lie entirely within Bothe-Napa Valley State Park, which has a total of approximately 8 km^2 and is located along Highway 29 between Saint Helena and Calistoga.

In 1912, a 1.8-meter high, 0.3-meter thick dam was built on Ritchie Creek, approximately 1.6 km upstream from its confluence with the Napa River to divert water for agriculture. After the land was acquired by the Park in the 1960s, staff began to advocate removal of the dam to facilitate fish passage. Park staff also wanted the dam removed because it was believed to cause fish habitat degradation and downstream channel cutting, degraded archeological sites, and created a visual blight on the Park. Water rights and dam ownership issues delayed dam removal for 30 years. These issues were eventually resolved, and in August 1993, over 80 years after installation, the dam was removed. Part of the dam still remained after initial removal. Two years later in 1995, the Park removed the rest of the dam. The January 1997 flood damaged a water system and septic facilities at the park and caused significant bank erosion. In response, park staff removed two upstream culverts. The park also installed four bank stabilization treatments, three of which are located within the study reach.

The project goals included aesthetics/education/recreation (inferred), channel reconfiguration (inferred), dam removal (inferred), and fish passage (inferred). Based on these goals, it was found that 53% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 80% goal attainment. Table E28 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E28: Summary of completed evaluation parameters for Green Valley Creek

Goal/ Objective	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
	Evaluation Parameters																
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✓	✓	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✓	✗	✗	✗	✗	✓	✓				✓		✓	✗	✓
Dam Removal/Retrofit	R	R	R		R	R	R	R	R				R	R	R	R	R
	✓	✗	✓		✗	✗	✗	✓	✓				✓	✓	✓	✗	✓
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✓	✗	✗	✗	✗	✓	✓	✗	✗	✗	✓		✓	✗	✓

E28 LOWER SILVER CREEK

Lower Silver Creek drains 111 km^2 of highly urbanized areas (95% urban in 1998) in Santa Clara County. The Lower Silver Creek compound channel project is managed by the Santa Clara Valley Water District (SCVWD). The project includes 7.4 km of channel reconstruction designed to achieve flood protection and ecosystem restoration objectives.

The project is divided into six reaches beginning at the downstream end of lower Silver Creek at its confluence with Coyote Creek. The lower Silver Creek project was conceived in 1975, and after many changes to meet evolving regulatory requirements and stakeholder concerns, construction of Reach 1 was completed in 2003. Reach 1 extends from the Coyote Creek confluence upstream to the Union Pacific Railroad bridge. The lower Silver Creek compound channel project is located near the downstream end of the storage / transport geomorphic zone.

The project goals included aesthetics/education/recreation (explicit), bank stabilization (explicit), channel reconfiguration (explicit), floodplain reconnection (explicit), in-stream habitat improvement (explicit), riparian management (explicit), and stormwater management (explicit). Based on these goals, it was found that 73% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 80% goal attainment. Table E29 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E29: Summary of completed evaluation parameters for Lower Silver Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✓												✓	✓	✗	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✓	✗	✗	✓	✓	✓	✓				✓		✓	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✗	✗	✓	✓	✓	✓				✓		✓	✗	✓
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✗	✗	✓	✓	✓	✓				✓		✓	✗	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✓	✗	✗	✓	✓	✓	✓	✗	✗	✗	✓		✓	✗	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✓	✗		✓		✓	✓				✓		✓	✗	
Stormwater Management			R		R		R			R					R		R
			✓		✗		✓			✗					✓		✓

E29 MARTIN CANYON CREEK

Located in Dublin, California, Martin Canyon Creek is a small tributary draining 4.7 km^2 in the Alameda Creek watershed. Martin Canyon Creek borders Hanson Hills and flows into the J-3 flood control channel, which is managed by the Alameda County Flood Control and Water Conservation District (ACFCWCD). Prior to development of Hansen Hills, the J-3 was experiencing sedimentation problems. Also other creeks in close proximity and of similar land use context had experienced channel incision and subsequent widening. Therefore the City of Dublin and Alameda County Flood Control and Water Conservation District required the developer to "prevent the oversupply of sediment to downstream reaches, or threats to adjacent structures through channel erosion."

A restoration design was developed by Philip Williams and Associates (PWA). PWA conducted a sediment budget, which concluded that most of the incision, areas of extreme slope, erodable soil, and large nick points were upstream of the project reach. The final design was based on accomplishing four main goals: minimizing sedimentation in the downstream flood canal, protecting structures near stream meanders, maintaining the creek's natural character and ecology, and minimizing costs of long-term maintenance. Grade control structures (GCS) were employed to reduce sedimentation in the downstream flood control system through creation of the dynamic equilibrium slope and rock lined scour pools to reduce cascading water energy.

The project goals included bank stabilization (explicit) and channel reconfiguration (explicit). Based on these goals, it was found that 92% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the

project achieved a 95% goal attainment. Table E30 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E30: Summary of completed evaluation parameters for Martin Creek

Goal/ Objective		Evaluation Parameters																
		Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization		R		R	R	R	R	R	R	R				R		R	R	R
		✓		✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓
Channel Reconfiguration		R	R	R	R	R	R	R	R	R				R		R	R	R
		✓	✓	✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓

E30 MILLER CREEK

The Miller Creek compound channel project in southeast Marin County was completed in 1990 as part of the Lucas Valley Estates housing development, making it one of the oldest compound channel projects in California. Prior to the project, Miller Creek had incised and widened extensively, mostly due to intensive cattle grazing, with vertical banks as high as 6 m in some locations. Miller Creek flows through a narrow valley underlain by quaternary alluvium, and its watershed receives mean annual rainfall of 86 cm. The climate in the region of this project is Mediterranean, meaning that 80% of annual precipitation typically occurs between November and May.

The project goals included aesthetics/education/recreation (explicit), bank stabilization (explicit), channel reconfiguration (explicit), floodplain reconnection (explicit), in-stream habitat improvement (explicit), and riparian management (explicit). Based on these goals, it was found that 95% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E31 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E31: Summary of completed evaluation parameters for Miller Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✓												✗	✓	✓	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✓	✓		✓		✓	✓				✓		✓	✓	
Stormwater Management			R		R		R			R					R		R
			✓		✓		✓			✗					✓		✓

E31 REDWOOD CREEK

The Redwood Creek drainage basin (22.7 km^2) is located in Marin County, California approximately 20 km north of San Francisco. Redwood Creek originates in steep headwaters of Mt. Tamalpais, flows through Muir Woods National Monument, Mount Tamalpais State Park, and empties into the Pacific Ocean at Muir Beach.

Redwood Creek is important spawning and rearing environment for two anadromous salmonid species of conservation interest: steelhead trout (*Oncorhynchus mykiss*) and endangered coho salmon (*O. kisutch*). The Banducci restoration project site, named for its former owners, is located on a 69-hectare parcel adjacent to Redwood Creek, about 1 km upstream of the mouth of Redwood Creek.

In fall of 2003, the NPS completed the first phase of the Banducci Site restoration project, constructing artificial log jams using downed Eucalyptus trees and breaching the constraining levees to reconnect the floodplain in the artificially-straightened "bowling alley" reach of Redwood Creek. The primary purpose of the instream project was to increase channel complexity, and specifically to create rearing pools for juvenile salmonids. NPS also removed invasive, non-native vegetation in the riparian corridor, and replaced it with native vegetation to enhance nesting habitat for resident and migrant riparian songbirds.

The project goals included floodplain reconnection (explicit), in-stream habitat improvement (explicit), and riparian management (explicit). Based on these goals, it was found that 100% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E32 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E32: Summary of completed evaluation parameters for Redwood Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✓	✓	✓	✓	✓	✓				✓		✓	✓	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✓	✓		✓		✓	✓				✓		✓	✓	

E32 SAUSAL CREEK

Sausal Creek is an urban creek in the City of Oakland in Alameda County, California. The creek runs through a mixture of preserved open space and highly developed residential and commercial areas. It begins in the Oakland hills and drains to the Oakland Estuary, situated between Alameda Island and the City of Oakland. The restoration site is located north of El Centro Avenue, east of Benevides Avenue, and west of Arden Place. The drainage area associated with the restoration site is approximately 8 km^2.

A local community group, Friends of Sausal Creek, formed in 1996 to restore the creek with a focus on native plant revegetation, erosion control, bank stabilization, and water quality monitoring. In 2000, the Waterways Restoration Institute and Wolfe Mason and Associates were contracted to design a restoration project for a 183-m reach of the creek in the lower portion of Dimond Canyon. The designed restoration had multiple key objectives, which included restoring a stable channel profile and meander sequence within the restoration reach, stabilizing channel banks, restoring native riparian plant species and improving the quality of habitat for terrestrial species. The project was funded by the City of Oakland, California Coastal Conservancy, and the Alameda County Flood Control District, and was implemented in the summer of 2001.

The project goals included bank stabilization (explicit), channel reconfiguration (explicit), in-stream habitat improvement (explicit), and riparian management (explicit). Based on these goals, it was found that 65% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 80% goal attainment. Table E33 presents a summary of the parameters that were

evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E33: Summary of completed evaluation parameters for Sausal Creek

	Evaluation Parameters																
Goal/ Objective	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✓	✓	✓				✓		✓	✓	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✓	✓	✓				✓		✓	✓	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✓				✓		✓	✓	

E33 STRAWBERRY CREEK

Strawberry Creek is located in West Berkeley along Addison and West Street. Before the creek restoration, the surrounding area was an existing right of way for the trains, and the creek ran below the tracks in a culvert. The design of the creek began in 1981 and construction began in 1983. The restoration was the first of its kind in the Bay Area. Prior to this restoration, the City of Berkeley was opposed to creek restoration projects because they were concerned with potential liabilities.

Doug Wolfe, the City of Berkeley planner at the time, designed the restoration and daylighting project. Wolfe used all native plantings, protected existing trees, and was able to recycle and incorporate hardscape materials already on site into the project. The concrete that existed prior to the restoration was broken up and re-used along the creeks banks in order to stabilize the steep banks. The only new installation was a pedestrian bridge. The creek restoration was one element of the design of this area. Other design features completed at this time included tennis courts, a children's playground, and a large lawn area adjacent to the creek. The project withstood the 1982 El Nino year, which occurred just after construction. During a storm in 1997, however, the water overtopped the banks.

The project goals included aesthetics/recreation/education (explicit) and channel reconfiguration (explicit). Based on these goals, it was found that 50% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 65% goal attainment. Table E34 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red “x”).

Table E34: Summary of completed evaluation parameters for Strawberry Creek

Goal/ Objective		Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education			R												R	R	R	R
			✗												✗	✓	✗	✓
Channel Reconfiguration		R	R	R	R	R	R	R	R	R				R		R	R	R
		✓	✗	✗	✗	✗	✓	✗	✓	✓				✓		✓	✗	✓

(Column group header: Evaluation Parameters)

E34 TASSAJARA CREEK

Tassajara Creek flows from the southeastern slopes of Mount Diablo and drains approximately 60 km^2 at the compound channel project reach in northern Alameda County, just east of downtown Dublin, CA. Climate in the Tassajara Creek watershed is Mediterranean, with mean annual precipitation of 43 cm at the project site. The project reach is in a moderately high energy transport zone, although local areas of deposition along the creek are not uncommon. Reviews of historical aerial photography indicated that the project reach of Tassajara Creek has remained in essentially the same location and planform orientation for at least the past 150 years.

The restoration consisted of improvements in two reaches. In Reach 1 (from Highway 580 north to Dublin Boulevard), the entire channel was reconstructed with a low flow channel designed to convey the 2-year flow before overtopping onto the floodplain, situated within a leveed flood corridor designed to convey the 100-year flow. In Reach 2 (from Dublin Boulevard north to Gleason Road), the existing low flow channel was left mostly intact (except where it was relocated to protect mature oak trees) and the floodplain surface was excavated to the 5-year flow water surface elevation in the low flow channel. Reach 2 was also designed to convey the 100-year flow through the broader flood corridor.

The project goals included aesthetics/education/recreation (explicit), bank stabilization (explicit), channel reconfiguration (explicit), floodplain reconnection (explicit), in-stream habitat improvement (explicit), riparian management (explicit), and stormwater management. Based on these goals, it was found that 86% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the

project achieved a 95% goal attainment. Table E35 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E35: Summary of completed evaluation parameters for Tassajara Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✓												✗	✓	✓	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✓	✗		✓		✓	✓				✓		✓	✓	
Stormwater Management			R		R		R			R					R		R
			✓		✓		✓			✗					✓		✓

E35 TENNESSEE HOLLOW

The Tennessee Hollow restoration site is located on the Presidio in the City and County of San Francisco, California. The site is situated northeast of Lincoln Boulevard, southeast of Halleck Street, and northwest of Girard Road. The site drains the hills within the Presidio and discharges to Crissy Field, before finally draining to San Francisco Bay. The drainage area associated with the site is approximately 1 km^2.

In fall 2005, the Presidio Trust restored an approximately 150 m reach of Tennessee Hollow, a perennial stream draining into the restored Crissy Field wetland. This reach, informally known as Thompson Reach was formerly contained in a culvert buried under a landfill. Excavation and removal of the historic artificial fill placed in the old creek channel provided an opportunity to restore a surface stream and plan a riparian corridor. The completed creek daylighting effort resulted in excavation of approximately 1.2 hectares, removal of about 935 m^3 of fill contaminated with mercury and PCBs, planting of approximately one hectare of native vegetation, and construction of a restored creek channel.

Post project activities were performed by Storesund et al (*2007*) that included Terrestrial LiDAR scanning, a longitudinal thalweg and cross sectional surveys, Features Mapping, stream flowrate and water quality instrumentation installation (with the collected data being posted to an online database), vegetation plot samples, BMI surveys, bird monitoring, and photo documentation.

The project goals included bank stabilization (explicit), channel reconfiguration (explicit), in-stream habitat improvement (explicit), and riparian management (explicit). Based on these goals, it was found that 86% of the parameters identified in the

Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E36 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E36: Summary of completed evaluation parameters for Tennessee Hollow

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✓	✗	✓	✓	✓	✓				✓		✓	✓	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✓	✗	✓	✓	✓	✓				✓		✓	✓	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✗	✓		✓		✓	✓				✓		✓	✓	

E36 UVAS CREEK

This channel reconstruction project is located in the Uvas Creek Park Preserve in the City of Gilroy (Santa Clara County, California). The project site is situated southeast of Uvas Park Drive and northwest of Miller Avenue. Uvas Creek drains from the Santa Cruz Mountains into the Pajaro River, then discharges into the Pacific Ocean. The project site has a drainage area of approximately 187 km^2 and Uvas Creek is partially regulated due to the Uvas Reservoir, located 13.5 km upstream of the restoration site.

The 1992 Master Plan for the Uvas Creek Park Preserve called for channel reconstruction to "establish a more stable and natural channel" after significant alteration of the creek from historic gravel mining activities. The primary project goal was to restore stability to the channel through the recreation of stable hydraulic geometry relationships. The project was constructed in November 1995.

The project goals included bank stabilization (explicit) and channel reconfiguration (explicit). Based on these goals, it was found that 44% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 0% goal attainment. Table E37 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E37: Summary of completed evaluation parameters for Uvas Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✗	✗	✓				✓		✓	✗	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✗	✗	✗	✗	✗	✗	✓				✓		✓	✗	✓

E37 VILLAGE CREEK

Village Creek, located in Albany, California, is the lower tributary of Marin Creek. The restoration site is located south of Buchanan Street, west of 8th Street, and north of Riley Drive. Village Creek is situated in a highly urbanized watershed and has a drainage area of approximately 1 km^2.

Prior to the restoration, the creek was contained in a 610 m long concrete culvert that discharged into the San Francisco bay tidal marsh near the Golden Gate Fields race track. In 1998, the University of California, Berkeley daylighted a 274 m stretch of the Creek and restored it to a 343 m long open channel flanked by 3116 m^2 of riparian and aquatic habitat.

A post project evaluation was performed by Asher and Atapattu (*2005*) where the authors conducted a longitudinal thalweg survey, cross sectional surveys, and a vegetation survey.

The project goals included channel reconfiguration (explicit), in-stream habitat improvement (explicit), riparian management (explicit), and stormwater management (explicit). Based on these goals, it was found that 52% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 60% goal attainment. Table E38 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red “x”).

Table E38: Summary of completed evaluation parameters for Village Creek

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✓				✓		✓	✓	✓
In-Stream Habitat Improvement	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✗	✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✗	✗	✗		✗		✓	✓				✓		✓	✓	
Stormwater Management			R		R		R			R					R		R
			✗		✗		✓			✗					✓		✓

E38 WILCAT CREEK AT ALVARADO

Wildcat Creek runs from Tilden Regional Park 22 km down through the Berkeley hills to the City of Richmond, where it discharges into the San Francisco Bay. The reach that runs through Alvarado Park drains a watershed of approximately 18 km^2. Through the Alvarado Park reach, the channel of Wildcat Creek is a canyon with very steep slopes characterized by active slumps and bank erosion, both of which deposit substantial amounts of colluvial material into the creek. Because much of the upper watershed of the creek is underlain by highly erosive bedrocks, there is also a substantial quantity of alluvial material flowing into this reach.

The East Bay Regional Park District (EBPRD) chose to restore an approximately 490 m long reach of Wildcat Creek in order to stabilize the banks, remove barriers to fish migration, and protect historic masonry walls immediately adjacent to the channel. The initial restoration project was design by Dr. David Rosgen and consisted of removing concrete sills and dams throughout the project reach and installation of a stable step/pool morphology and protect the historic rock walls through the use of vortex rock weirs. The project was implemented in 1993. In 1995, flows estimated at between 900 and 1200 m^3/s eroded banks in near the upstream end of the project reach, undermining some of the historic walls the project had intended to protect. In 1997, EBRPD hired William Vandiveere of Clearwater Hydrology to repair and reshape an approximately 120 m reach just upstream of the historic stone bridge.

The project goals included aesthetics/recreation/education (explicit), bank stabilization (explicit), and fish passage (explicit). Based on these goals, it was found that 42% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 65% goal attainment. Table E39 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E39: Summary of completed evaluation parameters for Wildcat Creek (Alvarado)

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Aesthetics, Recreation, Education		R												R	R	R	R
		✗												✗	✓	✗	✓
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✗	✗	✗	✗	✗	✓	✓				✓		✓	✗	✓
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✗	✗	✗	✗	✗	✗	✓	✓	✗	✗	✗	✓		✓	✗	✓

E39 WILCAT CREEK FLOOD CONTROL CHANNEL

The Wildcat Creek watershed, 22.5 km^2, is located at the north end of the East Bay Area. The watershed consists of two distinct sections, a gently sloping alluvial fan and a steeper canyon. It flows northward through its canyon where it turns westward on its alluvial fan as it flows to the San Pablo baylands, and ends at the tidal marshlands northeast of the Richmond Protrero. The alluvial fan for Wildcat Creek ranges in elevation from sea level to about 36.5 m.

Lower Wildcat Creek has had numerous flood control projects proposed since the 1940s but for various reasons none were implemented until 1989 when the U.S. Army Corps of Engineers, in cooperation with Contra Costa County, constructed a 'green flood control project', conceived as an alternative to traditional flood control channel (i.e. concrete trapezoid). The project replaced an existing trapezoidal channel with a compound channel reconnecting the low flow channel with floodplain with the 100-year flow, a riparian reserve area, a floodplain, setback berms and regional trial.

As early as 1996 it became apparent that the low-flow channel was filling with vegetation and sediment, and had to be excavated to accommodate winter flows. In 2000, this alternative flood-control channel was reconfigured by deepening the existing low-flow channel and restoring proper functioning to 457 m of stream. The banks were replanted with native willows and cottonwoods. Enhancements also included adding an upstream sediment basin and fish ladder just upstream from Verde School.

The project goals included channel reconfiguration (explicit), fish passage (explicit), floodplain reconnection (explicit), and riparian management (explicit). Based on these goals, it was found that 87% of the parameters identified in the Requirements

Matrix were evaluated, and it was estimated that the project achieved a 90% goal attainment. Table E40 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E40: Summary of completed evaluation parameters for Wildcat Creek (Flood Control Channel)

Goal/ Objective	Evaluation Parameters																
	Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓
Floodplain Reconnection	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓
Riparian Management	R	R	R	R		R		R	R				R		R	R	
	✓	✓	✓	✗		✓		✓	✓				✓		✓	✓	

E40 WILDER CREEK

Wilder Creek, situated in Santa Cruz County, is a coastal stream draining a 6 km^2 watershed into the Pacific Ocean. Within the Wilder Ranch, now a state park of the same name, a dam was built in 1956 to impound water for agriculture. By 1985, the dam's reservoir was completely filled with sediment, with approximately 300 m^3 being added to the impoundment every year. Furthermore, during the high flow events in the winter of 1994-1995, the creek migrated around the sediment-filled dam, carving a large gully in an adjacent field and exposing 2 pipelines. The dam also proved to be a migratory barrier to steelhead (even though the reservoir provided excellent, though artificial, red-legged frog habitat).

In the fall of 2000, the California State Parks and Department of Fish and Game hired a contractor to remove the dam and restore a 610 m reach of the creek. The plan focused on correcting the channel's instability and re-burying the exposed pipelines. Contractors removed the dam, planted willows, installed log-and-rock structures to reduce bank erosion, placed boulders to control the creek's gradient, and filled the bypass gully with sediment removed from the dam's reservoir. Species of special concern in this project were the anadromous steelhead trout and the red-legged frog.

The project goals included bank stabilization (explicit), channel reconfiguration (explicit), dam removal (explicit), and fish passage (explicit). Based on these goals, it was found that 87% of the parameters identified in the Requirements Matrix were evaluated, and it was estimated that the project achieved a 95% goal attainment. Table E41 presents a summary of the parameters that were evaluated (black check mark) and those parameters that should have been evaluated, but were not (red "x").

Table E41: Summary of completed evaluation parameters for Wilder Creek

Goal/ Objective	Evaluation Parameters: Channel Form	Connectivity	Erosion/Scour	Groundwater	Sediment Transport	Soil/Geology	Stream Discharge	Structures	Topography	Water Quality	Aquatic Species	Food Web Support	Riparian Vegetation	Community Value	Documentation	Land Use	Permits/Regulatory
Bank Stabilization	R		R	R	R	R	R	R	R				R		R	R	R
	✓		✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓
Channel Reconfiguration	R	R	R	R	R	R	R	R	R				R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓				✓		✓	✓	✓
Dam Removal/ Retrofit	R	R	R		R	R	R	R	R				R	R	R	R	R
	✓	✓	✓		✓	✓	✓	✓	✓				✓	✗	✓	✓	✓
Fish Passage	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✗	✗	✓		✓	✓	✓

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Appendix F

Heuristic evaluation is a systematic inspection of a user interface design for usability and involves having a small set of evaluators examine the interface and judge its compliance with recognized usability principles. Evaluators were asked to review and judge the validity of the developed Restoration Evaluation Checklist. Evaluators were obtained from Federal, State of California, and City governments; from private industry; and from public citizen groups. The evaluators were ensured anonymity, but a summary of their comments and review is presented in this Appendix. All heuristic evaluators confirmed the validity of the developed Restoration Evaluation Checklist and strongly encouraged further refinement of the NRRSS Goal categories (Goal definition was not part of this dissertation effort).

Reviewer 1 (Biologist)

United States Geological Survey

Overall I think it is a very useful compilation of data and ways to improve the entire process of river restoration. The adaptive management section is good and although the adaptive management process takes longer and costs more, it is often a very good and transparent process when there is public opposition (i.e., Everglades restoration).

Ecologists say that restoration monitoring is the equivalent of financial accounting in business. Establishing a monitoring plan and developing baseline conditions is important to assess the success of a restoration project.

No other comments or critiques were submitted. Verbal discussions with the reviewers identified that they were in substantial agreement with the presented Restoration Evaluation Checklist.

Reviewer 2 (Biologist & Water Resource Engineer)

California Department of Fish and Game (CDFG)

As I understand it, your scheme would have multiple possible goals for each project. There are other biological communities, including riparian understory native plants and riparian birds that should be, and are, monitored for several types of restoration (and are in many other States). Riparian Management, Livestock Exclusion, Bank Stabilization minimally for birds, and Livestock Exclusion should include Riparian Vegetation. If restoration is ultimately for organisms, "Aquatic Species" should be monitored for all type of restoration.

No other comments or critiques were submitted. Verbal discussions with the reviewers identified that they were in substantial agreement with the presented Restoration Evaluation Checklist.

Reviewer 3 (Assistant City Civil Engineer)

City of San Ramon, California

Firstly, I like the concept and think it could be useful, particularly in the hands of an informed and interested and open minded regulator (if there is such a thing) and anyone trying to do a better job with planning. I could see such a matrix as morphing into a hyperlinked system that led to various documents.

As I understand it the 'Restoration Evaluation Checklist' would serve to identify the various critical items (Recommended) that must be considered in planning a project and evaluating its success. The particulars of the criteria will, of course, vary with every project. That seems all well and good to me but I was thinking about how the concept of "first do no harm" fits into this. This general idea often seems high in the mind of the regulatory community and I was imagining a matrix where many of the blanks are filled in the NH. Thus a recreation project must not adversely impact aquatic species etc. Similarly, tied into the above discussion is the idea of striking the right balance to achieve the greater good. It would seem to me that allowing some harm in some categories is appropriate if there is an overarching benefit that more than counter balances it. I think in principle regulators accept this but in practice tend not to. So I think that a matrix can help planners and regulators to focus on what is important (required) for each project but I am wondering if there is a way to blend the "no-harm" or minimize harm and the overall project balance considerations into your concept and thus make it something that might more easily facilitate discussions with regulators. Perhaps this is another part of your work that I have not looked at.

In looking some of the details I came up with the following:

- I would anticipate that water temperature is included in the water quality. Thus it would become a required feature for dam and flood plain projects.
- I thought the species and food chain considerations would be important to any dam project.
- I thought Dam Removal and Retrofit projects were sufficiently different to be on separate lines
- the fish passage item seems very broad, in many projects a lot of items might not be required
- I anticipate water quality as a required issue of concern on many floodplain reconstruction projects
- I would have viewed land acquisition and livestock exclusion as being tools to other more substantive goals and objectives
- Would channel form, erosion and sediment transport be typically required items for flow modification?

Reviewer 4 (Consulting Civil Engineer)

CH2M Hill Corporation

No written comments or critiques were submitted. Verbal discussions with the reviewers identified that they were in substantial agreement with the presented Restoration Evaluation Checklist and no modifications were recommended.

Reviewer 5 (Community Restoration Participant)

Community Friends of Creeks Organization

Some of the choices of appropriate evaluation parameters based on project goals and objectives appear to me to be incomplete or arbitrary, as follows:

1. Aesthetics, Recreation, Education: If one's goal is aesthetics, recreation, and/or education, it would seem to lack common sense to fail to evaluate, at some reasonable level, water quality and existing, potential, and post-project aquatic species, food web support, and riparian vegetation. Smelly, ugly, dangerous waters with no plants, frogs, fish, or birds don't do the job. The same would be true for failure to evaluate erosion, sediment, and discharge, as these could undermine the success of any project in multiple ways, from looks to safety.
2. Flow modification: Among the major effects of flow modification (basically, releases from impoundments) are those on erosion, sediment transport, temperature, and aquatic species. These issues are among the major ones in California's ongoing water wars – consider Friant Dam and the San Joaquin River. Thus, I do not see how these can be omitted from evaluations.
3. In-stream species management (defined as direct transportation, stocking, or removal): If removal of exotics includes removal of invasive vegetation, I can tell you from experience, if it is not obvious from common sense, that you had better evaluate soil, erosion, sediment

transport, and the like. Depending on the animal species, you also would be foolhardy not to evaluate such things as erosion, groundwater, sediment, and stream discharge, since these clearly could sweep away, desiccate, or bury your transplanted species or their habitat

4. Livestock exclusion: "Livestock exclusion" is not in the glossary. One may exclude livestock for a variety of reasons. These include limiting compaction and erosion, protecting varying aspects of water quality, or protecting specific species that may be eaten, trampled, or out-competed, for example by seeds brought in dung. Depending on the goal(s), the factors appropriate for evaluation would vary – though why they would always include "community value" is beyond me.
5. Stormwater management: Even though stormwater management is defined as dealing with quantity only, and not quality, I believe that one would exclude considerations of groundwater contamination in an urban area at one's peril.
6. Water quality management: Water quality management appears to be treated in a way that excludes temperature, although the definitions in the glossary would seem to include it. And I think that only very traditional engineers would exclude consideration of riparian vegetation as having no effect.

There may also be a problem of scoring and overlap in the parameters. That is, if some parameters depend on others and are thus not independent, I don't believe it is valid to give each equal weight. As an example, you are from academia, so you give "documentation" universal value, but others might simply include this is "community value." (I am not arguing one way or the other.) The same could be true of "land use." Channel form, erosion, sediment transport, soils, and stream discharge are not independent of one another.

I note that there is no goal of "flood control." (This cannot be totally subsumed in "stormwater management.") Without arguing whether floods are good or bad, this is one of the most common rationales for restoration and perhaps the source of the largest amount of money.

I read with interest the chapters and tables reviewing and evaluating various projects. I have two comments, one specific and one more general:

(a) I am not sure about the validity of including the daylighting of part of Tennessee Hollow Creek. First, this project is not old enough to be evaluated, much less declared a success. Second, I believe there was a major slope failure that greatly increased the cost of the project. This may have been due to poor landscaping and irrigation in the adjacent land to the east not under control of the project (I believe you know that Presidio land management is complex). But I don't think you can ignore it.

(b) It is important to avoid post-hoc errors and to consider alternative explanations for one's findings. In looking at Table 24, upon which much of the argument rests, it seems clear to me that the low-scoring projects are the small urban restorations which did not consider long reaches or entire watersheds. I am not sure that evaluating more factors would have made any difference – these tend to be factors that one couldn't do anything about anyway. Without defending such projects – they tend to be high cost, with limited value considering ecosystems as a whole – I think maybe the thesis, and the system, is not realistic about why such projects are undertaken and how they should be valued. That is, the answer may not be more (expensive) studies, but rather just recognizing that what these projects are out to do is create parks of various sorts, and that in cities, one has to settle for what one can get.