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Land and water resource planning using goal programming

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INTRODUCTION

The land and water of Iowa are two of its most important natural resources. How these two resources are used or misused will determine the legacy we leave to future generations. In the 1970's, Iowa's farmers produced more corn and soybeans than ever before as they met increased domestic and export demand. They responded as in times in the past, and produced an abundance of grain. This was done in spite of the two wettest years of record in 1973 and 1974, followed by a severe drought which plagued western Iowa in 1976 and central Iowa in the summer of 1977, and ending with abnormally wet harvest conditions in the fall of 1977.

Their success may possibly be overshadowed in both the short and long run from the side effects caused by this governmental and economic call for increased production. Corn and soybean prices presently are below their export peak values, yet thousands of acres of hay and pasture lands have been put to the plow, fence to fence planting has obliterated more of the wildlife habitat which enhances the quality of our rural areas, and millions of tons of the topsoil on which much of our prosperity depends have been carried down the Missouri River and the Mississippi River to enrich the delta region in Louisiana.

At the same time, Iowa's urban dwellers have maintained the characteristic American's love for an ever increasing standard of living. More comfort is demanded in the summer and winter. Electrical energy continues to be a major input to commercial and industrial growth and employment opportunities. Families use their automobiles, pulling camping trailers and boats, all of which require resources and energy to manufacture. Iowans travel to parks, lakes and amusement areas, all of which are becoming more and more crowded. To feed this appetite for water, energy and recreation, we use land on which to build the factories which produce the automobiles, trailers and boats. We use land to construct the generating plants which supply the electricity to the factories. We use land for the parks, lakes and amusement areas. We use land as routes to transport the goods which are produced and to travel to and from these leisure areas. We use land to house and support the people who work to produce all of the above.

To accomplish all of this, we use water to manufacture the automobiles, boats and trailers. We use water to produce the electricity. We use water to fill the recreation lakes. We use water to construct the transportation systems which move the goods and people. We use water to sustain the people who produce and use all of the above.

The foregoing overview indicates that the use of land and water are inseparable. One affects the other and both must be considered together rather than as two separate entities. Water allocation decisions always imply, directly or indirectly, land use decisions. The reverse is also true. Where water is plentiful, land decisions are less affected by water allocation. Where or when water shortages are real, water allocation will dictate land use decisions. When and where water allocations favor domestic use, land will be used for urban and rural residences. When water allocations favor industrial use, land will be used for manufacturing plants. Allocating scarce water supplies for energy production means land will be used for fossil fuel or nuclear power plants. Allocating water for irrigation means the use of land for agricultural crop production will be accelerated or intensified, as exemplified along the Missouri River in western Iowa. Allocating water for recreation means that rivers and lakes and their adjacent land areas will be used for recreation. The list could go on. This resource study is directed to the interrelated problems which arise in making future land use and water allocation decisions.

The land and water resources of Iowa are not infinite, but finite. However, some of our past actions do not indicate that we have given this fact serious consideration. This is especially true of soil erosion and of forest and timber depletions. As we place greater and greater demands on our resources in the future we must also place greater emphasis on their wise use so that future generations may continue to enjoy the bounty and beauty of this fertile prairie land.

In the past, most public works investments have been single purpose, such as to prevent floods, to build highways or to construct water supply systems. Since the 1930's, many water resources projects have encompassed multi-purpose concepts to better utilize our limited natural and financial resources. For example, a project may be constructed to prevent floods while at the same time provide an opportunity for recreation, improve water quality, aid navigation and/or generate power. The common objective of all the large-scale federal projects and programs was to increase national economic efficiency. In the future, water resources projects and programs must be multi-objective as well as multi-purpose. The U.S. Water Resources Council

(Federal Register, December 21, 1971) originally identified four objectives: national economic development, environmental quality, regional development and social well-being. Subsequently, the last two were dropped as formal objectives (Federal Register, September 10, 1973). However, since these multi-purposes and objectives are subject to many constraints, decision makers are in need of a systematic process which will allow them to combine all of these objectives, purposes and constraints in the planning process.

Any systematic, decision-analysis process involves three general steps: (1) identification of objectives, of goals which will implement and achieve these objectives, of constraints and of the activities which will contribute to the goals and objectives; (2) formulation of alternative courses of action to accomplish the goals and objectives; and (3) selection of one course of action among the many alternatives studied which satisfies the stated criteria most closely. This process allows for a comprehensive technical analysis of problems rather than the subjective decision-making process commonly pursued.

The national economic development objective is enhanced by increasing the value of the nation's output of goods and services and by improving national economic efficiency. The environmental quality objective is enhanced by managing, preserving, creating, restoring or improving the quality of certain natural and cultural resources and ecological systems. Constraints come in many forms: legal, financial, physical, social and technical as well as a myriad of institutional rules and regulations.

The following is an example of a portion of step 1 of the decision-analysis process. One objective is enhancing environmental quality. One goal which will implement this objective is a reduction in soil erosion. A technical and legal constraint in Iowa has quantified this goal by requiring that soil loss in rolling topography be no more than 5 tons per acre per year. This constraint also imposes a financial constraint by requiring that any costs incurred in meeting the 5 ton goal must be shared by the State of Iowa and the property owner. Several activities could contribute to meeting this particular goal within this one objective. These include changes in land use, changes in crop rotation, changes in tillage methods, changes in farming practices, construction of terraces and grassed waterways and implementation of erosion control measures as part of urban and rural construction programs.

The goals and objectives often are in conflict, and constraints limit the decision maker. Herein lies the basic difficulty of decision analysis: how these multiple, conflicting goals and objectives are to be treated, and how constraints are to be introduced in technical studies. In order to satisfy conflicting objectives as much as possible, decision makers must assign priorities to them. Priorities may be set in consultation with the various publics involved or by the decision makers' perception of what the publics' priorities are. Proper analysis of a water and related land resource program or project requires that each objective and constraint be considered. Goal programming is one method of accomplishing this.

Goal programming is a general mathematical optimizing formulation which gives the decision maker a flexible technique for handling problems which involve multiple conflicting objectives under many complex constraints (Lee, 1972; Ignizio, 1976). One special case of goal programming (GP) is linear programming (LP). While LP can handle only a single objective, GP is capable of handling decision problems that deal with multiple objectives having multiple subgoals, as well as problems with a single objective having a single or multiple subgoals. LP can do one thing, and one thing only, in the objective function (such as maximize profits, minimize costs, etc.) while GP can include many items within the objective function (minimize costs, maximize production, reduce soil erosion, increase recreational opportunities, reduce environmental problems, increase income, etc.). In the objective function of a LP problem, all variables must have the same units or be capable of being expressed in the same units (i.e., dollars, acres, bushels, etc.). In GP the objective function can include any and all kinds of units.

Rather than maximizing or minimizing the objective criterion directly as in LP, in GP the absolute deviations between (a) goals and (b) what can be achieved within the given set of constraints are minimized. This reflects the real world situation in which the best that can usually be done is to meet some of our goals, however expressed and in whatever units, and come as close as possible to meeting the rest while operating within the constraints of resource availability, governmental rules and regulations, etc. This minimization of deviations is carried out in conjunction with a set of preemptive priorities which ranks the goals and constraints into several ordinal levels. The solution to a GP problem is carried out by using some of the available resources to meet, if possible, the highest priority goal, using some of the remaining resources to attain the next highest priority goal insofar as is possible, and so on until all priority levels have been evaluated.

The purpose of this study is to explore the feasibility of using goal programming as a methodology for providing guidance to the solution of land and water resource planning problems involving multiple objectives with multiple subgoals. A GP model suitable for analyzing a state's land and water problems within the local-state-regional-national framework is developed to encompass both the physical spectrum of supply and demand and the social-institutional-environmental spectrum reflecting the multiple, conflicting objectives, goals and priorities of society.

An existing digital computer program for a linear GP algorithm is used, and is merged with additional computer code developed during this study which models the utilization of land and water resources for various purposes. The complete computer program is useful as a screening model for selecting from among several policies, programs and/or projects, those which contribute most to attaining the goals of a region's inhabitants. A 12-county region in Northwest Iowa is used to illustrate the effectiveness of GP in portraying the tradeoffs which would have to take place in order to attain, as closely as possible, the goals set by and for the people of the region.

This is a user-oriented study and the results are intended for those state and federal agencies and consulting firms who have need of improved planning methodology. It will permit them to evaluate the impacts of proposed solutions to complex land and water resource problems having many conflicting objectives and goals with which to contend. It should be of special interest to those agencies and resource interest groups in Iowa which will begin implementing the just-completed Phase I of the State Water Plan (Iowa Natural Resources Council, 1978). As they move into Phase II, seeking to implement the recommendations contained in Phase I, this study will provide them with the beginnings of a tool which can be used to assess the impacts of their decisions.

The investigations and results of this study are reported in several parts. After reviewing what has been done in the past, some comments are made on the sources, availability and uses of land and water, along with comments on the constraints which are always present. Then the data and the programming methodology are developed and applied to the 12-county region in Northwest Iowa, as shown in Fig. 1. This particular region of Iowa was chosen because it receives the lowest annual rainfall in the state and because it has a full complement of land and water related problems. Land and water use in both agricultural and urban enterprises are included in this case study. Water demands studied include water for agriculture, supplemental irrigation, municipal, industrial, recreation and urban domestic uses and regional rural systems. The application to a real-world situation (as opposed to a hypothetical, contrived scenario which neatly fits some assumed set of "facts") will provide concrete evidence of the effectiveness of goal programming. This water short region in Iowa will

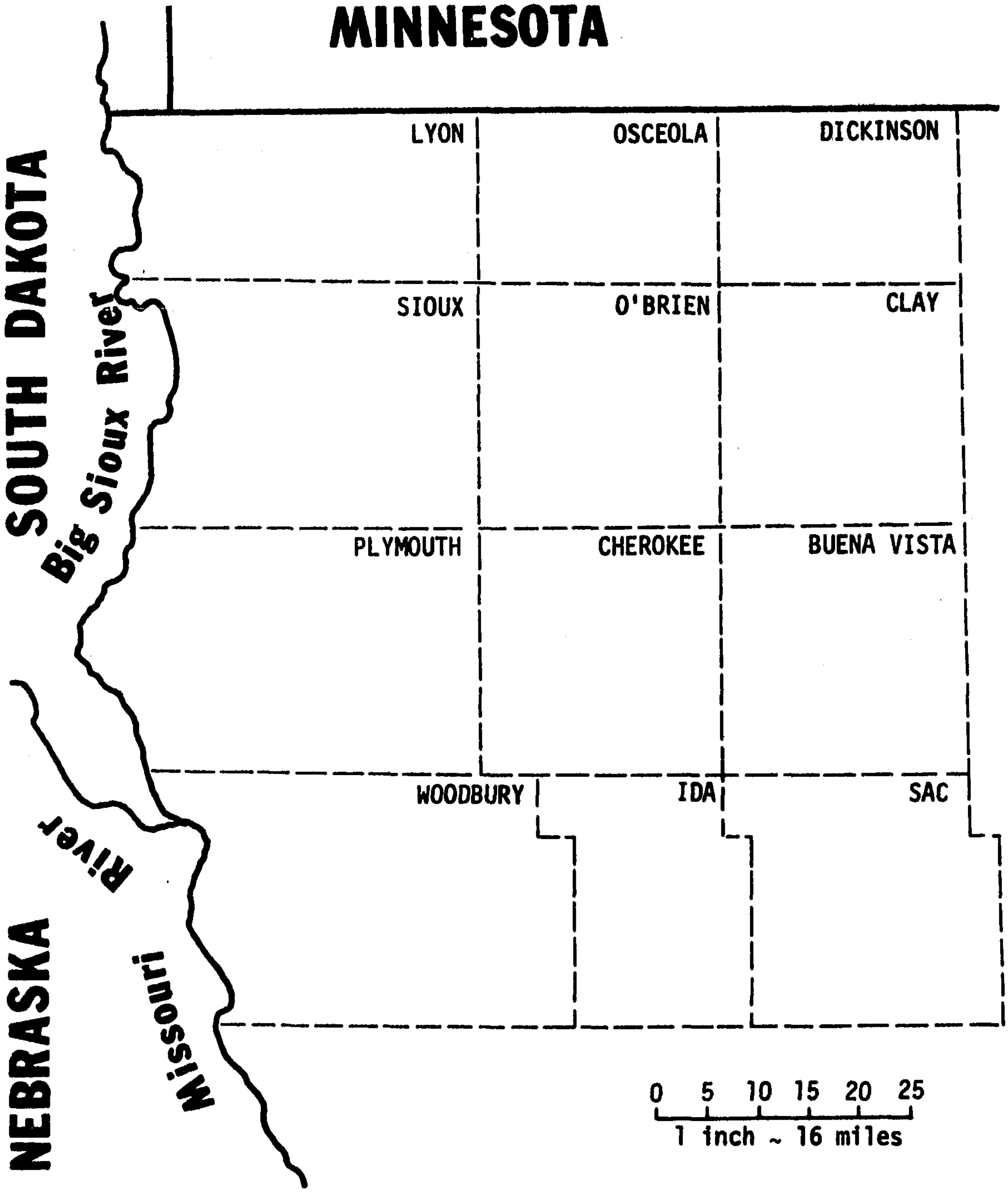


Fig. 1. Study area in Northwest Iowa

also benefit from such an application in its quest to remain economically competitive with other areas in Iowa and the Midwest.

THE INSTITUTIONAL SETTING AND PLANNING METHODOLOGIES

The Need

Our nation has reached the point where quality of life is achieving equal status with quantity of material goods and possessions. At the same time, the quantities of things demanded by our ever-increasing population is straining our capacity to provide them from our stock of natural resources. Whether collapse of our system is imminent, as some predict, or whether man's ingenuity will continue to provide new ways of providing and using our resources to meet our needs and desires remains to be seen. In the meantime, resolution of the present and future problems caused by public demands that are often conflicting will require new insights and flexibility on the part of those who plan the development and use of our natural resources.

One of the basic resources currently being stressed in some areas is water. Projections of our future water requirements, based on present technology and use patterns, indicate more widespread stress. As individual states and regions plan for the future, the quantity and quality of water available for use will play a large role in determining whether or not the quantity levels of goods and services and the quality of life desired by its citizens will be achieved. For this reason, the methodologies used by those who plan for the use of our water resources must be capable of reflecting these quantity and quality requests and the tradeoffs required to achieve them.

Inevitably, conflicts do now and in the future will continue to arise. In some areas there may not be sufficient water for all the intended uses by the people of that area. This will be especially true during drought periods. Conflicts do arise between uses such as the use of water and land for agriculture rather than as wetlands for various types of wildlife or waterfowl. Conflicts arise within the same user group such as recreation, with different types of water-oriented recreation competing for use of the same body of water. Conflicts also arise in which the water quality is degraded by one use so as to be unsuitable for another use. The public, agencies, and elected officials can seek to solve these conflicts by formulating general policy statements which establish priorities.

Once these policy statements have been formulated and resource needs identified, the next step is to carry out these policies and attempt to satisfy the various needs and resolve the conflicts through comprehensive planning. Many alternative solutions will be formulated. Which are the better ones? Which are better in a particular situation? Some will only solve a part of the problem. Is this the best in a particular situation?

Policies, priorities, resource availability and use data, and estimates of future demands provide the base from which solutions can be formulated. Until now, national economic efficiency has been the sole criterion on which alternative solutions to federal problems in resource development and allocation have been judged. In the future, alternative solutions will be judged on how well they satisfy the four objectives set forth in the original Principles and Standards of the U.S. Water Resources Council (Federal Register, December 21, 1971). These four objectives, stated in detail, are:

1) To enhance national economic development by increasing the value of the nation's output of goods and services and improving national economic efficiency;

2) To enhance the quality of the environment by the management, conservation, preservation, creation, restoration or improvement of the quality of certain natural and cultural resources and ecological systems in the area under study and elsewhere in the nation;

3) To enhance social well-being by the equitable distribution of real income, employment, and population with special concern for the incidence of the consequences of a plan on affected persons or groups, by providing educational, cultural, and recreational opportunities;

4) To enhance regional development through increases in the values of a region's income, increases in employment, and improvements in its economic base, environment, social well-being, and other specified components of the regional development objectives.

Planning emphasis is being placed currently on comprehensive state and regional water resources development. Gary Cobb (1975), then deputy director of the Federal Water Resources Council, had the following comments on this subject.

> Also under review now are policies relating to the Federal grant program established in the Water Resources Planning Act of 1965, P.L. 89-80. A ten year program of matching grants to the states was authorized under Title III to help the states in developing and participating in the development of comprehensive water and related land resources plans.
>
> During the first 8 years of the Title III program, considerable emphasis to this time was placed on state planning and on building planning staff capability within the states. The Council has reviewed the grant program and has determined that new direction is desirable. Greater importance is placed on activities aimed toward better state understanding of water and related land problems and on realizing comprehensive solutions. This new emphasis requires that planning activities be undertaken within a framework that provides for coordination with all federal, state and local agencies and nongovernmental entities having responsibilities in those fields affected by comprehensive planning, and that the full breadth of existing and prospective demands for

water and related land resources be fully considered in the planning process.

In this regard the State of Iowa has just completed a four year study to develop a comprehensive state water plan. The study team was composed of members of the various state natural resources agencies. They were organized into eleven task force groups, three dealing with data acquisition, retrieval, general population, socio-economic and legal-institutional information, and eight dealing with the various uses of water as listed below.

<u>Support Task Force Groups</u>

1. Basic data system
2. General availability of the water resource
3. Socio-economic and legal-institutional
    a. Social impact
    b. Population projections
    c. Economic growth
    d. Water law
    e. Institutional relationships

<u>Beneficial-Use Task Force Groups</u>

1. Water supply
2. Water quality control
3. Agriculture
4. Flood plain management
5. Water oriented recreation
6. Fish and wildlife resources
7. Navigation

8. Energy production

In a special report published in 1973, the concept of the state water plan was outlined in the following terms (Iowa Natural Resources Council, 1973).

> The basic framework plan will reflect a coordinated multiple use water resource policy. The plan will contain programs which will provide a basis for allocating water to all beneficial uses; it will also present programs for solving or mitigating water and related resource problems.
>
> The plan should guide development to satisfy the increasing demand for the water resources by our population and expanding economy. Its main objective is to provide a basis for the control, utilization, and protection of the state's water and related resources.
>
> In contrast to western arid states where water project facilities are the major or only concern of a state water plan, Iowa, which is in a humid region, needs to place greater emphasis on the program concept. First, definitive but broad programs should be developed and implemented for each major category of water problem and beneficial use. Development of broad programs and principles for water resource management takes precedence in this approach. Later, or as corollary measures, the need for additional projects can be considered and development of needed facilities can be recommended. Thus, the Iowa water plan should be program and policy oriented, rather than project oriented.

When implementing these policies and programs in Iowa, or in any other state, decisions must be made as to what management principles to pursue, what facilities to recommend and which projects to construct. If these decisions are made using inadequate or incomplete information, problems of many kinds may result. In order to obtain adequate information on which to base decisions, the proper accounting and inventory system must be developed as well as a methodology to utilize these data. This methodology must be comprehensive, flexible and permit one to keep an open mind — so to speak. People, natural resources, and decisions regarding their interactions are dynamic. Nothing remains the same over time. Peoples' needs and desires change, technologies change and institutions, hopefully, also change to meet new conditions. The examples which follow will illustrate the situations which will be evaluated by the goal programming model developed herein.

The future may bring about a real change in our present adherence to accepting or rejecting a water resources project or program on the basis of its economic benefit-cost ratio. Nonquantifiable objectives such as social well-being and environmental quality should share equal status with national economic efficiency. An increased flexibility in thinking and in planning methodologies will be required to incorporate these objectives into the planning process.

The time frame in Iowa for development of various sources of water (surface water reservoirs vs groundwater vs imported Missouri or Mississippi River water) will affect the decision as to what source is utilized. If the need is now and a reservoir requires 15 to 20 years to plan, overcome objections, design and construct, then an alternative source (even though it may be more costly) may become the solution selected for implementation. This could be used as one way to put a dollar value on constraints (social, legal, and/or institutional) which have in the past only been approached qualitatively, rather than quantitatively.

One typical problem in Iowa is the need for water for supplemental irrigation purposes. During the 1976-1977 drought, complete crop loss was experienced in some central and southern Iowa counties. In addition to the economic impact, there was also an institutional impact. The Iowa Natural Resources Council (INRC) was deluged with applications for irrigation permits during this period, and in April and May of 1977, there was a backlog of over 1,000 permit applications (James F. Wiegand, Iowa Natural Resources Council, Des Moines, Iowa, telephone interview, May 24, 1978). Besides the drought years, wet years can also have short-term impacts. This occurred when Iowa experienced two of its wettest years in 1973 and 1974 since records have been kept. However, because little or no rain fell during a critical portion of the growing season in these two years, yields in some areas having droughty soils were significantly lower than they might have been had sufficient water been available. Lower than average rainfalls are bound to occur in the future, as they did in 1976 and 1977, as well as short-term dry periods, as occurred in 1974 and 1975, and water for irrigation could be utilized in many areas to insure continuous high yields.

Large-scale water projects or delivery systems which will supply this water must already be in place when the need arises, since a period of 15 to 20 years is necessary to place a large engineering project on line. The costs of installing irrigation systems are great, but demand for Iowa's agricultural products in the world market is projected to remain high in the future. Presently, Iowa produces 20 percent of the nation's corn crop and exports 40 percent of what it produces (Nagadevera, Heady, and Nicol, 1975). Furthermore, since Iowa is blessed with an abundance of fertile soil in comparison to other states, national policy in the future may require that yields in Iowa be as large as possible. This could include an additional influx of federal funds or a revision of federal-state revenue participation to cover a portion of the cost of supplemental irrigation. Changing the funding constraints in the model could change the optimal solution.

Iowa also has many areas with clayey soils that experience reduced yields during wet years for various reasons because the soil is too wet: delayed planting, lack of air in the root zone, poor harvesting conditions. An alternative to the construction of projects for irrigation would be to use these same funds for the construction of drainage improvements and the maintenance of existing drainage systems. If sufficient financial resources were available, both could be accomplished.

The population of Iowa is well dispersed, the largest population center being Des Moines with a 1970 population of 201,404 and a total 1970 population in Polk County of 259,324. Many people, particularly in the more urban counties, are choosing to live in rural residences. In some areas regional rural water distribution systems, which include small communities, have been constructed and are required to meet present and future demands and drinking water standards. Also, effluent from community water pollution control systems could be used as a water supply for supplemental irrigation or for municipal, or industrial use. Approximately 1,100 acres of land could be irrigated with the effluent from a community of 10,000 people. Each acre could receive annually 12 inches of water, 72 pounds of nitrogen and 18 pounds of phosphorus (U.S. Army Corps of Engineers, 1975).

While water may be relatively abundant in most areas of Iowa and the Midwest (either as surface or ground water or both), localized conditions may be such that local demands or future demands will exceed existing or developable local supplies. When this occurs, supplementary water may need to be imported from other areas. The use of this imported water in local areas and the associated growth will need to be balanced against using the water in its original location and allowing the growth to occur there. This would save the costs (both monetary and environmental) of transferring the water.

Integrating these ideas and others into one all-encompassing planning model is a formidable task. A first step must be taken though if we are to come to grips with the complexities and the interrelationships between our environment, the quantities of goods and services, and the quality of life we desire. This project takes this first step and investigates the potential of goal programming as a planning methodology for addressing some of the priority objectives and concerns that have been expressed at the state, regional, and national levels.

The Call for Action

At the national level, mention has already been made of the Water Resources Council's priority for comprehensive planning for the "full breadth of existing and prospective demands for water and related land resources." In addition, two of the priority objectives of the Department of the Interior are (1) solving land use problems and (2) promotion of efficient allocation and conservation of scarce water and water-related resources in a manner compatible with environmental considerations. The agency within the Department of the Interior which funds interdisciplinary research dealing with water is the Office of Water Research and Technology (OWRT). Three of their priorities are (1) improvement of water resources planning, managerial, financial, operating and regulatory policies, (2) water resources policy and political institutions, and (3) analysis and evaluation of water resource projects.

The third priority area of OWRT listed above is especially pertinent to this project. OWRT's explanation of this objective is as follows:

> Benefit-cost analysis has been the principal tool for evaluation of public investment programs, including watershed and water resources programs. It has ranked projects and programs in terms of the objective of economic efficiency only. Research is needed to determine appropriate alternatives and multi-objectives which will insure that presently unquantified environmental amenities and values may be given appropriate considerations. Evaluations of methods to quantify values in terms of appropriate objectives and assigning weights to these values is needed so that alternative objectives and/or combinations of objectives can be compared.

On the regional level the institute directors associated with the Missouri River Basin Water Institute Consortium (MRBWIC) listed their twelve top priorities for fiscal year 1977 (Water Center Directors of the Missouri Basin States, 1975). Three of these are planning methodologies, water allocation problems, and planning and management operations.

On the state level, the Iowa State Water Resources Research Institute (ISWRRI) has developed a long-range research program which includes eight areas of emphasis. This program was developed in conjunction with the ISWRRI Advisory Board, which is made up of members of several state and federal agencies and other organizations interested in the planning and development of our water resources (Dougal and Rossmiller, 1974). Two of these objectives are (1) water resources planning technology — development and application of planning technology and multiobjective water resources planning procedures in the state water plan development and (2) water shortages, drought potential, water use efficiency, and supplemental water needs.

The Response from the Research Community

The literature is replete with articles concerning the various facets of the planning and development of our water resources. Volume 3 of "A Selected Annotated Bibliography on the Analysis of Water Resource Systems" contains 289 entries (Loucks, 1972). Volume 4 contains 323 entries. A recent bibliography on Multiobjective Water Resources Planning contains 112 entries (Loucks, 1975). The total number of entries in Selected Water Resources Abstracts in the past few years may be in the thousands (Water Resources Scientific Information Center, 1975–1978).

OWRT also has funded many projects dealing with several planning aspects of water resource activities. Shih and Dean (1973) used a multiattribute decision analysis model to plan and manage the water resources for an arid metropolitan center in Texas. Etzold, Williams, and Guice (1974) determined costs of developing groundwater in the Pat

Harrison Waterway, Mississippi. D'Arge (1970) gave emphasis to the potential for intrabasin water transfers between competitive users, locations, and points in time. Liner and Stepp (1974) studied the economics of water supply in South Carolina. They concluded that the least-cost plan was for the counties to have separate and different sources of supply. They also concluded that certain plausible political and legal developments could render a combined system desirable. A similar conclusion was reached by Austin and Patton (1975) in a study of rural water systems in southern Iowa. They concluded that "the best alternative for serving all water demands appears to be the development of county-wide water systems." Meier, Helm, and Curry (1973) sought to develop techniques to assist water planners in the optimum implementation of their plans. James, Benke, and Ragsdale (1975) developed a method to coordinate implementation of a number of structural and nonstructural flood control measures selected through the evaluation of a variety of hydrologic, economic, ecologic, social preference, and community well-being information. Keith, Anderson, and Clyde (1973) used mathematical programming techniques to determine the supply and demand relationships for agricultural water, given depletions for municipal, industrial and wetland requirements.

Some researchers have looked at the role of multiple objectives in water resource planning. Recommendations were made by Major (1969) on how instructions to federal water resource agencies could be broadened to permit them to use the appropriate formula for benefit-cost ratios of multiple objective projects. Wyckoff (1971) discussed the progress that has been made in including intangible benefits and costs in the usual benefit-cost analysis. He suggested that methodology for including proposed multiple objective functions in project analysis is a critical need. Schwartz and Major (1971) reviewed some of the innovative methods and models that were used to develop an effective planning process for the North Atlantic Regional Framework Study. They concluded that the use of systems techniques within a multi-objective framework is the best method for water resources planning. Andrews and Weyrick (1973) used linear programming to evaluate costs and benefits of surface water allocation. The incidence of benefits and costs was shown to shift depending on which objective was optimized. Cohon and Marks (1973) presented an application of multiobjective theory to the analysis of development alternatives for a large-scale river basin. They also discussed methods for handling more than one objective in a linear programming screening model.

A methodology for comprehensive evaluation of water resources development and use (Techcom) was developed as part of an OWRT Title II project (The Technical Committee of the Water Resources Research Centers of the Thirteen Western States, 1974). This computerized system provides comparisons of relative goal achievement and is based on an inversion of an input-output model interacting with social and environmental indicator connections. Three OWRT research projects have been funded in Iowa which have contributed to this research project. Timmons (1977) led a study entitled "Development and application of models for analyzing water resource use and development within a regional framework of economic growth and environmental quality." Dougal (1977) has conducted a study entitled "Identifying and classifying water allocation problems in Iowa for state water plan purposes." Berger and Austin (1977) led a study entitled "Use of technological forecasting in water resource planning." Austin and Patton (1975) have also completed a study for the Iowa Office for Programming and Planning entitled "A planning strategy for rural water systems: A case study in southern Iowa."

The limits of present benefit-cost methodology and the search for alternative approaches to water resource evaluation were discussed by Taylor, Davis, and North (1975). Their findings are presented in the following excerpt:

> Recently there has been increasing criticism of economic evaluations performed by water resource agencies. Critics argue that benefit cost analyses performed by the Corps of Engineers, Tennessee Valley Authority, etc., do not reflect a true evaluation of environmental and social objectives. Benefit-cost analysis as currently implemented is too limited to accommodate the complexities presented by a multiple objective approach to water resource development.
>
> It is the purpose of this article to review several alternatives and discuss advantages and limitations of each. In the mathematical programming area, two techniques will be reviewed, goal programming and the surrogate worth trade off method. In the value determination area, Environmental Evaluation Systems (EES) and personal value determination will be reviewed.
>
> The authors are of the opinion that no one methodology offers a complete solution to the evaluating problem. It is probable that a complete solution will not emerge unless a combination of the approaches is employed. However, of the four described, goal programming surfaces as the most workable. It considers all objectives within a single model framework, with a minimal degree of complexity. Also, the emphasis on subjective judgment (a factor existing

> to a varying degree in all the techniques) is minimal in goal programming.

Cohon and Marks (1975) evaluated the utility of several multiobjective programming techniques against three criteria: computational efficiency, explicitness of tradeoffs among objectives and the amount of information generated for decision making. They concluded that goal programming (GP) "is computationally efficient, but the value judgments it elicits, while they are certainly explicit, are the wrong ones, and they are requested from decision makers without prior knowledge of the tradeoffs."

Ignizio (1976) has authored the text Goal Programming and Extensions. When asked about the above critical statement (James P. Ignizio, Department of Industrial and Management Systems Engineering, The Pennsylvania State University, University Park, Pennsylvania, personal communication, April 12, 1978), his comment was:

> With regard to your last paragraph, I realize that goal programming has, like any other tool, some limitations. However, the two you cited (inability to set forth tradeoffs and insufficient information for decision making) came as a surprise to me. The three main reasons that I prefer goal programming are:
>
> (1) The effort required to develop the model forces one to better understand and appreciate the real problem.
>
> (2) Tradeoffs may be made in a logical manner.
>
> (3) A vast amount of information is available to the decision maker in the final tableau (including tradeoffs, sensitivity to changes and so forth).

Bishop, et al. (1976) examined a large variety of planning techniques and displayed their results in three tables: implementation characteristics, attributes relative to planning process technical content and attributes relative to planning process value content. They concluded that "multiobjective programming and goals evaluation methods offer a strong overall organizing concept for the process, and provide a good basis for the detailed and comprehensive analysis needed to generate the noninferior alternatives and describe their tradeoffs."

Taylor, Davis, and North (1975) also looked at two alternative approaches to water resource evaluation, mathematical programming and value determination methods, and discussed the advantages and limitations of each. They concluded that while no one method offered a complete solution, GP surfaced as the most workable since it considers all objectives within a single model framework, with a minimal degree of complexity.

Other writers have investigated the use of the GP methodology for water resource evaluation. Neely, North, and Forston (1976) developed a generalized model for selecting those projects from a larger list of proposed projects which best met economic and environmental objectives while operating under budgetary constraints. Panagiotakopolous (1975) presented a prescriptive framework for environmental management at the regional level using GP optimizing techniques. Bishop, et al. (1977) applied the GP techniques to a public investment planning situation — regional water quality management planning under Section 208 of PL 92-500. However, each of these studies used a hypothetical situation to illustrate the use of GP.

North, Neely, and Carlton (1977) applied GP to a restudy of the Cross Florida Barge Canal and indicated that "the main purpose of goal programming is to replace the inadequate benefit-cost ratio." A set of operational alternatives were defined, each of which produced a different mix of economic and environmental outputs (goal achievements). The preferred solution was then described in terms of "highest and best use" alternatives, with weights established on the basis of technical parameters. This is the only study found in the literature which used GP on an actual planning problem. Thus, little has been done to date to use the GP technique in a real-world planning situation. This project study is an attempt to close this gap.

With the foregoing as background, a general view of the GP methodology will be presented next, then comments made on the sources, uses and constraints on the utilization of our land and water resources and the study area in Northwest Iowa described. The GP methodology for the case study will then be developed in detail, applied to the study area, conclusions drawn concerning the GP methodology and some future water and land use implications made for Northwest Iowa.

A DESCRIPTION OF GOAL PROGRAMMING

Development of Goal Programming

Practitioners in the field of resource allocation have long recognized that real world problems are multiobjective and began their search for new methodologies almost two decades ago. One such methodology is GP and credit for the initial development of the concept is given to Charnes and Cooper (1961). They developed an approach for dealing with certain LP problems in which conflicting "goals of management" appeared as constraints. Because it might be impossible to satisfy all these goals, they attempted to minimize the sum of the absolute values of the deviations from these goals in the objective function. The problems were still in a LP form and were solved using the simplex method.

However, problems arose with this initial formulation. Deviation variables taken from different goals were not commensurable at times. Difficulties arose when attempts were made to find suitable multipliers (weighting factors) for these variables to construct a meaningful summation in the objective function. That is, $Z = n_1 + n_2$ was not a valid representation of $Z_1 = n_1$ and $Z_2 = n_2$. The goals of an organization might include stockholders' personal interests, profit, consumers' needs, product quality, obligations to employees, technical progress, duties and responsibilities to society, corporate growth, management efficiency, prestige and relations with suppliers and distributors. Many of these goals are conflicting and some are noncommensurable.

Ijiri (1965) described what he termed preemptive priority levels which treated goals according to their perceived importance. An objective or set of commensurable objectives would be assigned priority level one. The satisfaction of this objective (or objectives) was then preemptively preferred over any lower priority, i.e., $P_1 >> P_2$, regardless of any multiplier associated with P_2. This allowed more realistic models to be formulated but, unfortunately, these new models could not be solved as stated using the simplex method. The simplex method could only be used by solving a sequential series of GP problems, one for each priority level. However, the attainment levels of the deviation variables from each higher priority had to be included as new, rigid constraints before solving the next lower priority level.

In 1972, Lee (1972) presented a technique for solving GP problems with preemptive priority levels which involved a modification of the standard simplex method and was a substantial improvement over the sequential method listed above. His technique eliminated the need for the inclusion of a new constraint equation (or equations) at each new level. Work has also begun on solutions involving variables which are nonlinear and integer as detailed by Ignizio (1976). The present need in GP is for algorithms and computer codes which will bring this methodology up to the same level as LP.

A General Description of Linear Programming

Since many researchers are familiar with LP, this discussion will begin with a review of LP and then proceed to a description of GP and how it differs from LP. The basic requirements of LP are that the variables involved in the system be linear and homogeneous: linear in the sense that they are first order nonnegative variables and their relative properties do not change if they are multiplied by the same constant; homogeneous in the sense that the units of the variables (acres, dollars, pounds) can be made into a single compatible unit in the objective function. Also, the decision maker can do one thing and one thing only in the objective function, i.e., maximize profits, minimize costs or some one other objective.

Thus, one form of the linear programming model (Hillier and Lieberman, 1974) may be expressed as:

$$\text{Max} \quad Z = \sum_{j=1}^{n} c_j X_j \qquad (1)$$

$$\text{s.t.} \quad \sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad (i = 1, 2, \ldots, m) \qquad (2)$$

$$X_j \geq 0 \qquad (j = 1, 2, \ldots, n) \qquad (3)$$

where Z = overall measure of effectiveness

c_j = increase in Z that results from each unit increase in X_j $(j = 1, 2, \ldots, n)$

X_j = level of activity j

a_{ij} = amount of resource i consumed by each unit of activity j

b_i = amount of resource i available for allocation $(i = 1, 2, \ldots, m)$

m = number of limited resources

n = number of competing activities.

A General Description of Goal Programming

Lee (1972) described GP in the following manner:

> A formal decision analysis that is capable of handling multiple conflicting goals through the use of priorities may be a new frontier of management science. The goal-programming approach appears to be an appropriate, powerful, and flexible technique for decision analysis of the troubled modern decision maker who is burdened with achieving multiple conflicting objectives under complex environmental constraints. Goal programming allows a simultaneous solution of a system of complex multiple objectives. Goal programming is capable of handling decision problems that deal with a single goal with multiple subgoals, as well as problems with multiple goals with multiple subgoals. The goal-programming approach utilizes an ordinal hierarchy among conflicting multiple goals so that the low-order goals are considered only after the higher-order goals are satisfied or have reached the desired limit.

Some writers consider GP simply as an interesting modification and extension of LP. Other writers take the view that GP is a general formulation capable of solving "real world" problems and that LP is one special case of GP. Even though this difference of opinion exists as to the relationship between LP and GP, all agree that LP is capable of handling only one objective while GP is capable of handling multiple objectives.

Moreover, many "real world" decisions involve tradeoffs in order to satisfy two or more goals which at times are in conflict with each other. Goal programming is capable of handling situations which involve these multiple goals and subgoals. In addition, the objective function of a goal programming formulation may be expressed in non-homogeneous units (tons, dollars and miles). Lee (1972) explains other differences and advantages of goal programming in the following manner:

In goal programming, instead of trying to maximize or minimize the objective criterion directly as in linear programming, deviations between goals and what can be achieved within the given set of constraints are to be minimized. The objective function becomes the minimization of these deviations based on the relative importance or priority assigned to them. Management may be unable to specify the cost or utility of a goal or a subgoal, but often upper or lower limits may be stated for each subgoal.

When all constraints and goals are completely identified in the model, the decision maker must analyze each goal in terms of whether over or underachievement of the goal is satisfactory or not. Based on this analysis he can assign deviational variables to the regular and/or goal constraints. If overachievement is acceptable, positive deviation from the goal can be eliminated from the objective function. On the other hand, if underachievement of a certain goal is satisfactory, negative deviation should not be included in the objective function. If the exact achievement of the goal is desired, both negative and positive deviations must be represented in the objective function.

Lastly, Lee points out that the most important advantage of goal programming is its great flexibility, which allows model simulation with numerous variations of constraints and goal priorities.

Thus, one form of the goal programming model (Ignizio, 1978) may be expressed as:

Find $\overline{x} = x_1, \ldots, x_j, \ldots, x_J$ so as to minimize:

$$\overline{a} = g_1(\overline{n}, \overline{p}), \ldots g_k(\overline{n}, \overline{p}), \ldots, g_K(\overline{n}, \overline{p}) \quad (4)$$

such that:

$$f_i(\overline{x}) + n_i - p_i = b_i \qquad \text{for all } i = 1, \ldots, m \quad (5)$$

and $$\overline{x}, \overline{n}, \overline{p} \geq \overline{0} \quad (6)$$

where: x_j is the jth decision variable.

$\bar{a}$ is denoted as the <u>achievement function</u>; a row vector measure of the attainment of the objectives or constraints at each priority level.

$g_k(\bar{n}, \bar{p})$ is a function (normally linear) of the deviation variables associated with the objectives or constraints at priority level k.

K is the total number of priority levels in the model.

b_i is the right-hand side constant for goal (or constraint) i.

$f_i(\bar{x})$ is the left-hand side of the linear or nonlinear goal or constraint i.

n_i is the negative deviation from goal i (underachievement).

p_i is the positive deviation from goal i (overachievement).

Three possibilities exist for each goal or constraint equation: the left-hand side can be less than or equal to, greater than or equal to or exactly equal to the right-hand side. These three possibilities and how they are handled in a GP formulation are shown in Table 1. The contents of the last column, deviation variables to be minimized, must be included in the achievement function at some priority level.

Table 1. Goal programming model formulation[a]

Type	Goal or constraint type	Processed goal or constraints	Deviation variables to be minimized
1	$f_i(\bar{x}) \leq b_i$	$f_i(\bar{x}) + n_i - p_i = b_i$	p_i
2	$f_i(\bar{x}) \geq b_i$	$f_i(\bar{x}) + n_i - p_i = b_i$	n_i
3	$f_i(\bar{x}) = b_i$	$f_i(\bar{x}) + n_i - p_i = b_i$	$n_i + p_i$

[a]Source: Ignizio (1978).

An example of each of these possibilities in the context of a land and water resources planning problem would be as follows.

Type 1: water from a particular source could be used for a number of purposes but we cannot use more than is available. This constraint takes the form of

$$\sum_{j=1}^{n} x_{ij} + n_i - p_i = b_i \quad (i = 1, 2, \ldots, m) \tag{7}$$

where x_{ij} is the amount of water supplied from the ith source to the jth use location and p_i is included in the achievement function as a priority level one variable.

Type 2: one goal is to provide a certain number of acres for recreational purposes. We do not mind if we overachieve this goal but want to minimize its underachievement. This goal takes the form of

$$\sum_{j=1}^{n} RL_{ij} + n_i - p_i = b_i \quad (i = 1, 2, \ldots, m) \tag{8}$$

where RL_{ij} is the acres of recreation land at the jth location for the ith type of recreation and n_i is included in the achievement function at some priority level.

Type 3: all land must be used for some purpose, but no more or no less than exists. This constraint takes the form of

$$\sum_{j=1}^{n} \sum_{k=1}^{1} L_{ijk} + n_i - p_i = b_i \qquad (i = 1, 2, \ldots, m) \tag{9}$$

where L_{ijk} is the number of acres of land used for the jth land use on the kth capability class in the ith area and both n_i and p_i are included in the achievement function as priority level one variables.

Application of GP to Land and Water Resource Problems

One application area of goal programming is in the allocation of our land and water resources among competing uses. Sufficient quantities and qualities of land and water may not be available for all the desired uses in a state or region. Priorities will then have to be set in order to come as close as possible to meeting all the demands in the context of the multiple objectives set forth by the Water Resources Council. A partial disaggregation of the sources and uses of water and pertinent constraints are listed in Table 2 as a part of the goal, constraint and activity identification needed to transform the problem into the format necessary for solution by the GP methodology. The method used to list the various sources of water has been suggested by Bishop, Hendriks and Milligan (1971).

Because of the constraints listed in Table 2, no one solution will be able to satisfy all the desired objectives of the people living in a particular region. Conflicts will arise which will need to be resolved. The best that can probably be accomplished is to satisfy some of the objectives and come as close as possible to satisfying the others through a series of tradeoffs. Various alternative solutions can be presented to the decision makers which show the tradeoffs that must be made to achieve some level of satisfying all objectives (a measure of goal achievement).

With goal programming the optimal solution may achieve some goals (e.g., water supply is sufficient to meet all demands), underachieve some goals (water quality is poorer than required), and overachieve

Table 2. Water sources, uses and constraints

<u>Sources</u>

<u>Primary Supply</u>	<u>Secondary Supply</u>	<u>Supplementary Supply</u>
Surface water	Municipal effluent	Imported water
Ground water	Industrial waste	Desalination
	Agricultural return flow	

<u>Uses</u>

Water supply	Recreation
Water quality	Fish and wildlife enhancement
Flood control	Navigation
Flood plain management	Watershed management

<u>Constraints</u>

Economic	Technical
Social	Political
Legal	Physical
Institutional	Financial

Water supply could be subdivided into the following use sectors:

Domestic	Commercial	Livestock
Municipal	Rural	Energy
Industrial	Crops	Recreation

Water for energy could be subdivided into:

<u>Hydroelectric</u>	<u>Thermal-electric using water for cooling</u>	
Run-of-river plants	Once through	Spray canals
Storage projects	Dry towers	Ponds
Pumped storage	Wet towers	Others
Tidal plants		

other goals (more recreational opportunities are provided than demanded). In goal programming, differing priorities and weights can be assigned to the various goals and subgoals. By varying these priorities and weights, decision makers can observe by the degree of attainment of the various goals how well the objectives (e.g., those set forth by the Water Resources Council) have been satisfied. The goals could include such items as meat and grain production, reduction in soil erosion, rural and urban land and water demands, reduction of flood damages and recreation demands.

Physical constraints enter into the GP formulation in two ways: by becoming constraint equations and by providing limits on the coefficients to variables in constraint or goal equations. An example of the latter is the physical dimensions of a valley. Its length, width and depth provide a limit on the areas and volumes available if the valley were used as the site of a surface water reservoir. These limits become part of such equations as the number of acres available for land- and water-based recreation at that site, the volume of water available for various water supply purposes and the volume available to help reduce flood peaks. Two examples of the former have been given already: the total amount of water available from a particular source and the acres of land available in a certain area, such as a county. These appeared as Eqs. (7) and (9), respectively.

Cost constraints are a good illustration of how the GP methodology differs from LP. The allocation of water from various sources among competing uses and users is similar to the characteristic transportation problem of LP: the origins become the sources and the destinations become the demand locations of the various users. The objective function in LP for this problem would take the form

$$\text{minimize } z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}X_{ij} \text{ (total cost)} \tag{10}$$

where c_{ij} is the cost of supplying water from the ith source to the jth use location and X_{ij} is as defined before. However, since this is a goal programming problem, supplying water to all users at the least cost is only one goal we wish to satisfy. Thus in the goal programming format, the objective function of the linear programming problem simply becomes one of the goal equations and takes the following general form.

$$\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}X_{ij} + n_k - p_k = g_k \qquad (k = 1, 2, \ldots, G) \tag{11}$$

Since we are trying to minimize cost, the goal we would seek to reach is to have the cost of supplying water to the various demand locations equal to zero. Because both the c_{ij}s and the X_{ij}s are nonnegative for all i and j, the total cost can never be less than zero. Therefore, it is not possible to underachieve the kth goal of zero cost and the negative deviation, n_k, could be eliminated. Thus the final goal equation for supplying water at the least cost could be written as

$$\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}X_{ij} - p_k = 0 \qquad (k = 1, 2, \ldots, p) \tag{12}$$

The overachievement of the goal, p_k, becomes a part of the achievement function at some priority level and represents the minimum cost of meeting as many of the demands for water as possible from the available supplies.

One portion of the financial constraint would be the willingness-to-pay of the beneficiaries of the water supplies. In the GP context the right-hand side would be thought of as an upper limit rather than as a goal. The constraint equation for this portion of the problem would become

$$\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}X_{ij} + n_k - p_k = g_k \qquad (k = 1, 2, \ldots, G) \qquad (13)$$

where c_{ij} and X_{ij} are as defined before. The positive deviation, p_k, becomes part of the achievement function at some priority level and represents that amount of money which is greater than the people's willingness-to-pay.

Technical constraints find their way into constraint and goal equations in many ways: we can presently grow just so many bushels of corn per acre; the efficiency of pumps to lift and move water is limited; techniques for reducing soil erosion have only evolved to a certain point; techniques for removing pollutants from water have only evolved to a certain point; etc. Social, legal, political and institutional constraints are included in two ways, either as a right-hand side limitation (such as soil loss) or by the absence of some variable on the left-hand side (such as a source of water).

The supply of water from various sources for the several uses listed in Table 2 can be depicted as

$$\sum_{i=1}^{m} X_{ij} + n_j - p_j = b_j \qquad (j = 1, 2, \ldots, n) \qquad (14)$$

where X_{ij} is the amount of water supplied from the ith source to the jth use location and n_j is included in the achievement function at some priority level. The values given to b_j can be varied to portray the projected demands at various points in the future.

Recreation goals were already covered in Equation 13 but one other feature needs to be added. If a reservoir is constructed to provide water for irrigation, it could also provide land and water areas for recreation, along with other purposes such as flood control and low-flow augmentation. Since we cannot build half a reservoir, these variables take on the form of 0-1 integers. Thus the recreation goal equation takes the form

$$\sum_{j=1}^{n} RL_{ij}X_j + n_i - p_i = b_i \qquad (i = 1, 2, \ldots, m) \qquad (15)$$

where RL_{ij} is the acres of recreation land at the jth location for the ith type of recreation and

$$X_j = \begin{cases} 0 \text{ if the reservoir site is not selected} \\ 1 \text{ if the reservoir site is selected} \end{cases}$$

Flood plain management could be included in much the same way as the cost of water supply was included. We could look at all present and future flood plain uses and place a dollar value on the damage potential for each use. To minimize flood plain damage potential would mean that certain types of development (residential, commercial, industrial) would have to be removed from, adequately flood-proofed or kept off the flood plain. This would involve us in land use planning. In the goal programming format, the constraint would appear as follows:

$$\sum_{i=1}^{n} X_i + n_k - p_k = 0 \qquad (16)$$

Since the damage potential could never be less than zero, n_k could be eliminated from Equation 16 and the final equation would become

$$\sum_{i=1}^{n} X_i - p_k = 0 \qquad (17)$$

where X_i is the potential dollar damage of each of "n" flood plain uses. The overachievement of the goal, p_k, becomes a part of the achievement function at some priority level and represents the total potential flood plain damages.

Low-flow augmentation would contribute to two uses of water, water quality and fish and wildlife enhancement, by providing additional flow to dilute effluents and by providing more adequate flows for fish and those forms of wildlife who visit streams. Likewise, setting aside land and water areas for recreation, forest, wetlands and pasture would provide more habitat for fish and wildlife enhancement plus contribute also to watershed management. However, setting up meaningful goals and goal equations for the above is a difficult task, except to say that in this case more is better — which then is in conflict with other possible uses of the land.

The equation for the goal of reduction in soil erosion takes on the following form.

$$\sum_{j=1}^{n} \sum_{k=1}^{1} SE_{ijk} + n_i - p_i = b_i \qquad (i = 1, 2, \ldots, m) \qquad (18)$$

where SE_{ijk} is the tons of soil lost from the jth land use on the kth capability class in the ith area and p_i is included in the achievement at some priority level. The right-hand side is the allowable soil loss.

The goal equation for grain production has a form similar to that for soil erosion.

$$\sum_{j=1}^{n} \sum_{k=1}^{1} CS_{ijk} + n_i - p_i = b_i \qquad (i = 1, 2, \ldots, m) \qquad (19)$$

where CS_{ijk} is the number of bushels of the jth crop on the kth capability class in the ith area and n_i is included in the achievement function at some priority level. Some overachievement of the goal would be acceptable.

The foregoing has provided a description of the evolution of GP, how it differs from LP and some examples of how land and water uses, sources and constraints on their utilization are depicted in the GP format. The application of the GP methodology to a land and water resources problem is accomplished in the following series of steps. First, the problem and its scope must be defined. Existing and projected problems and needs are identified. The objectives and specific goals which will contribute to the achievement of the objectives are also identified. Second, the availability and capability of resources to meet the identified problems and needs, as well as the constraints on the utilization of the resources, are identified and evaluated. Third, each of the constraints, goals and resources are converted to an equation in the GP format as was illustrated above.

Fourth, the appropriate deviation (or deviations) from each of the equations is placed into a commensurate, ordinal priority level. All deviations in a given priority level must be commensurable, i.e., each deviation must have the same unit of measure or must be capable of being expressed in similar measures. However, simply because two goals are commensurable does not mean that they should be in the same priority level. One goal may be much more important than the other. Each priority level is designated by an ordinal number, i.e., priority level 2 is always preemptively preferred to priority level 3, no matter what multiplier might be associated with priority level 3. The decision as to which goals and constraints are placed in which priority levels is made by the analysts, the decision makers, the public or any combination of these groups. The manner in which priority levels are set and assignments to priority levels are made is important in order that the solution determined accurately reflects the desires of the affected population. The highest priority level, priority level one, is reserved for what Ignizio (1976) terms "absolute objectives." These are "objectives" which must be satisfied in order for the solution to be acceptable. All deviations in priority level one must be zero in order for the solution to be acceptable. These deviations may represent goals or constraints: corn production must be at a certain level, only so much land exists in a county, only so much water is available from a particular source.

Fifth, weights are assigned to the deviations within a given priority level. These weights are positive cardinal numbers which reflect the importance associated with the minimization of a deviation variable assigned to a given goal or constraint. These weights could be judgment values or they could reflect inherent features of the problem. The weighting factor could simply be a judgment that goal 3 is twice as important as goal 4. The weighting factor could also reflect the fact that the profit associated with product 3 is twice as much as the profit associated with product 4. The problem is then solved using a modified simplex method and the optimal solution determined.

Sixth, and last, the goals, limits on constraints, priority rankings and weights can be changed to determine the effects these changes will have on the original solution. This will give the decision makers added insight into the sensitivity and importance of these changes towards meeting the goals and objectives of the original problem and the tradeoffs involved in achieving these goals and objectives as closely as possible.

ROLE OF CONSTRAINTS

One underlying cause of the complexity of land and water resource development is that land and water are such basic necessities that they permeate all aspects of our lives. And since most aspects of our lives are constrained in one way or another, these constraints are also active in resource planning. A constraint is a restriction of some kind which inhibits our ability to solve problems and to satisfy our needs and desires. These constraints (legal, institutional, social, economic, financial, physical, technical and political) are discussed in this section, in varying degree of detail; however, each is given sufficient attention to indicate how it acts as a constraint on our actions as they relate to the utilization of our land and water resources.

Constraints are seldom independent. Rather they tend to overlap. Legal constraints merge into institutional constraints; a law is amplified by the rules and regulations written by the institution created by the law. The law itself or the resulting rules and regulations may include goals or limitations based on present or evolving technology. The law may also state that financial assistance will be forthcoming from some level of government only on presentation of proof that compliance with the law is based on implementation of the most cost-effective alternative investigated. These constraints also influence a GP or LP mathematical formulation by determining the coefficients and variables which appear on the left-hand sides of the equations and by influencing the values of the right-hand sides of the equations. Also, something which acts as a constraint on the actions of one group may serve as an opportunity for action by another group.

Legal Constraints

In the mid-60's we embarked on, and are still on, an environmental journey. People began to aspire to a higher quality of life. Some wished to also maintain a high material quantity to their lives; some were willing to reduce this as a tradeoff. This led to lobbying efforts on the part of many environmental groups requesting their elected representatives to improve the quality of our environment in several ways. Similar political efforts in the past have led to the introduction and passage of a series of federal laws affecting the utilization of our land and water resources, some of which are listed in Table 3.

These federal laws and subsequent state laws placed several legal constraints on the possible courses of action open to those decision makers who have responsibility for our land and water resources. However, these same laws also presented them with opportunities to achieve the changing goals and priorities of society.

The state-federal partnership necessary for an orderly progression towards realization of our goals was recognized in the Water Resources Planning Act of 1965. One provision of the Act provides for establishing River Basin Commissions. They are a good example of the state-federal partnership role; for instance, federal members on the Upper Mississippi River Basin Commission include the Departments of

Table 3. Some federal laws affecting land and water resources[a]

Date	Name
1899	River and Harbor Act
1902	River and Harbor Act
1902	Reclamation Act
1910	General Dam Act
1928	Boulder Canyon Act
1933	Tennessee Valley Act
1936	Flood Control Act
1944	Flood Control Act
1954	Watershed Protection and Flood Prevention Act
1956	Water Pollution Control Act
1958	Water Supply Act
1961	Federal Water Pollution Control Act
1963	Outdoor Recreation Act
1964	Land and Water Conservation Fund Act
1964	Water Resources Research Act
1965	Appalachian Regional Development Act
1965	Federal Water Project Recreation Act
1965	Water Resources Planning Act
1965	Water Quality Act
1965	Public Works and Economic Development Act
1966	Department of Transportation Act
1966	Clean Water Restoration Act
1968	National Flood Insurance Act
1968	National Water Commission Act
1968	Wild and Scenic Rivers Act
1969	Endangered Species Conservation Act
1970	National Environmental Policy Act
1970	Environmental Quality Improvement Act
1970	River and Harbor and Flood Control Act
1971	Uniform Relocations Assistance and Real Property Acquisition Policies Act
1972	National Dam Safety Act
1972	Rural Development Act
1972	Federal Water Pollution Control Act Amendments
1973	Flood Disaster Protection Act
1974	Water Resources Development Act
1974	Safe Drinking Water Act
1977	Federal Water Pollution Control Act Amendments
1977	Clean Water Act
1977	Land and Water Resource Conservation Act

[a]Source: U.S. Department of the Army (1975).

Agriculture, Transportation, Interior, Army, Commerce, Health, Education and Welfare, Housing and Urban Development, Energy and the Environmental Protection Agency. State members include representatives from Illinois, Iowa, Minnesota, Missouri, North Dakota and Wisconsin.

Legal constraints can also take the form of decisions rendered by the courts. Water rights are probably the most important aspect of this type of legal constraint. Decisions as to who owns the water, surface and subsurface, its allocation for various purposes and whether it can be transferred from one watershed to another or to another portion of the same watershed are items which can impose severe constraints on how and if water can be used for certain beneficial purposes. The various methods used in the United States to allocate water rights are discussed by Linsley and Franzini (1972) and by James and Lee (1971). In 1957, Iowa enacted legislation which declared that all water, both surface and subsurface, belonged to the state who holds it in trust for the beneficial use of all Iowans and which established a permit system for the allocation of water rights.

In a study of Iowa's experience with this legislation, Hines (1966) concluded that the permit system serves four important purposes: (1) "it establishes conclusively the principle that water use is an appropriate subject for regulation;" (2) "it takes the formulation of water rules away from the courts, and places it in the hands of a public agency which will presumably develop considerable expertise in handling the problems of water use;" (3) "it serves the very important function of gathering information;" and (4) it "provides for the public enforcement of the newly promulgated water rules."

Hines also concluded that "the most unusual characteristic of the Iowa system, at least as presently administered, is that it does not purport to do that which one normally suppose to be the purpose of water regulation — the establishment of priorities of use for times of scarcity."

Institutional Constraints

The law creating a federal or state agency spells out to some degree the mission of the agency. The agency is thus constrained from its inception to perform its mission within a given set of policy directives as outlined in the law and as later defined by the rules and regulations developed by the agency itself. As time passes new agencies (institutions) are created and new missions are given to existing institutions. More time passes and even more institutions are created to cope with newly identified problems. The end result is the confusing situation we find ourselves in today. A multiplicity of agencies abound to solve (theoretically) or at least cope with the complexities of modern society. Several agencies often are authorized to attack the same problem in different ways. Duties and responsibilities frequently overlap. Some agencies have activities which are complementary; some are competitive. A thick volume is required to simply give a one-page listing to each federal department, agency, bureau, board and commission (General Services Administration, 1978).

All things start with good intentions. Maybe if we had the gift of foresight, we probably (no — most assuredly) would not have the system we abide under today. Each law passed was done so with good intentions. Each department and agency formed was created with good intentions to fill some unmet public need. Each function or rule or regulation added to an existing agency or institution was done so with the good intention of providing some additional public service or answering some newly perceived or newly emerging public problem. The culmination of all these good intentions is a multi-million person local, state and federal bureaucracy which intertwines, overlaps, undermines — and which operates under a set of rules and regulations which at times seems to hinder the very people it is supposed to be helping — all with good intentions.

The various levels of government themselves are part of the problem. Some critics simply lump all their frustrations together and label them as "bureaucratic red tape." Each agency seems bent on fulfilling its own destiny with single-purpose plans and policies. We have transportation plans, housing policies, health plans, economic policies, urban development plans, agricultural policies, rural development plans, environmental policies and open space plans. Sadly, these several plans and policies appear destined to lead lonely existences for they seldom seem to become acquainted with each other. Highways are planned and constructed, land becomes accessible and suddenly new residential and commercial developments appear. However, community services are lacking and the open space for recreation and visual aesthetics somehow seems to have become lost in the shuffle.

While confusion and chaos do not yet reign supreme, we may be headed in that direction. Agencies abound to aid the poor. More arise to combat environmental degradation. Several exist to provide recreation of various types. Over a hundred are concerned with the various aspects of water. Some exist to prevent unfair competition in business while others put the federal government into business. Several have a finger in the energy pie. Some promote development of new energy supplies and new ways to use it while others promote conservation of energy. In relation to water quality, one agency demands zero discharge while another demands that certain flows be maintained in our rivers.

There is a consistent lack of coordination within and among our myriad institutions. The lack of a coherent set of national goals and priorities and the lack of a coordinated plan for accomplishing them between all federal and state institutions results in a costly waste of our capital and human resources as well as our other natural resources. There is a need for a unified plan for natural resource development, with a definition of the role that water resources development will play in the overall plan, which will lead to the realization of our national goals while attaining as nearly as possible the multiple objectives of national economic development, regional development, environmental quality and social well-being.

There presently exists an agency which has the potential for bringing order and direction to our quest for the realization of our goals. This is the U.S. Water Resources Council (WRC) created by the Water Resources Planning Act of 1965 (Public Law 89-80). On October 16, 1975, President Ford signed Public Law 94-112 which changed the Council membership to bring it into line with the present responsibilities of the executive branch of the federal government. Full membership on the Council now includes the Secretaries of the Interior, Army, Agriculture, Transportation, Energy, Commerce and Housing and Urban Development. Also included as a full member is the Administrator of the Environmental Protection Agency. Observers to the Council include the Secretary of Health, Education and Welfare, the Attorney General, the Director of the Office of Management and Budget, the Chairman of the Council on Environmental Quality, the Chairman of the Tennessee Valley Authority, the Chairmen of the River Basin Commissions and the Chairmen of the Interagency Basin Committees. Thus the governing body of one policy-making agency includes most of the major departments of the executive branch of the federal government. At the present time, however, the WRC appears to be a political liability and lacks strong support in Congress. Whether this situation will change and the WRC given the opportunity to fulfill its potential is a question which has yet to be answered.

Social Constraints

Social constraints come in many forms. Many times these constraints arise because preferential desires of one segment of the population conflict with the social desires of others. Mention has already been made of the social concern for the quality of our environment. The actions of the federal construction agencies to provide flood control, navigation, power, intensive-use recreation facilities, water for irrigation, etc. (all worthy goals), have drawn the wrath of several environmental interest groups because of their belief that the environment has been degraded by such actions.

At the same time these social concerns act as a constraint on the social well-being of others. Those who oppose the construction of flood control facilities inhibit the right of others to enjoy life free from the fear of floods. Those who oppose the construction of new power plants inhibit the right of others (and themselves) to enjoy the benefits of the many uses of electricity. Those who oppose the construction of irrigation projects inhibit the economic well-being of those who would use the irrigation water.

The social desires of various interest groups can also place constraints on and conflict with others, even within the same goal, such as recreation. The desires of flat-water enthusiasts may constrain and conflict with the desires of those who prefer free-flowing streams. The desires of the power boat and water skiing enthusiasts conflict with those of the sail boaters and swimmers. And the fishermen would prefer that all of the above would leave them alone and stop scaring the fish. All would be fine if there were enough water or sufficient lakes for separation of these activities. But real conflicts arise in water short areas.

A major social problem, one which causes many conflicts and which has given rise to the entire environmental movement, is the manner in which many Americans conceptually view land and the "rights" they have to use and abuse it. The early civilizations which flourished around the Mediterranean Sea held attitudes towards the environment which have helped shape our present-day attitudes (Hughes, 1975). In some instances a reverence towards land was engendered by imbuing it with religious significance. The land and water gave forth life in the form of grain and fruits for man and fodder for animals. The spring floods on the Nile River nourished the plains of Egypt with water and new layers of soil. Indeed, the Nile was called the River of Life. The Romans held a much different attitude towards land. As they conquered nations, so did they conquer land. Land was treated the same as a slave or a beast of burden — as a commodity to be exploited for the enrichment and the greater glory of the Roman Empire. Forests were given to deserving individuals who had them cut down and sold for timber and fuel as well as to open up new areas for grazing. In this way entire forests were removed and any new seedlings which attempted to grow were eaten by the sheep and the goats. Without a canopy of leaves and roots to protect the soil, massive erosion took place over a period of many centuries. This attitude, that land was a commodity to be bought and sold for personal gain rather than as a resource to be nurtured and renewed, has left us a legacy of bare rocks and desert where once cool green forests shaded the inhabitants from the hot Mediterranean sun.

With the fall of the Roman Empire and the Dark Ages which followed, a new attitude arose with the feudal system during the Middle Ages in Europe. Land was never regarded as the absolute property of any individual, but more positively as the source of collective sustenance and as the focus of reciprocal rights and responsibilities among lord, vassal and serf. The idea that rights in land are nested in "the crown," held in trust to serve the collective needs of people, evolved from the feudal system and underlies attitudes about control of land use in contemporary Europe (Stone, 1974).

The first emigrants to the new world brought these feudal concepts with them when they settled on the east coast of what was to become the United States of America. But slowly, over time, these concepts became swallowed up in the seemingly endless supply of land available in this new world. The individual became absolute sovereign over his land. Title to the land was vested in the owner in fee simple. The land became his to do with as he would. The concept of land being held in trust to serve the collective needs of people became transformed into the concept of "a man's home is his castle." Americans became the masters of their property rather than its stewards.

Property is viewed by many people as something physical. Cars, clothes, houses, boats, furniture, land — these are property. However, if property is viewed as the interests (rights) that people have in things (the right to use, buy, sell, trade, mortgage, build, tear down, plant crops on, dig minerals out of) — this is an entirely different concept. Using this idea air quality, water quality and a beautiful view become "property rights" which can be bought, sold and bargained for.

This is the approach used by Coase (1960) to handle externalities which cannot be handled normally in the market place. He suggests that air quality, etc. be made a property right and then have the parties get together and bargain with each other to solve their problems concerning these rights. Thus, if a manufacturer is creating air and water pollution which is affecting the aesthetic environmental qualities and health of the people surrounding the firm, they can then bargain with the manufacturer and bribe him to stop polluting, have him move somewhere else or whatever other alternative solution is mutually acceptable. Coase's fundamental concern is that the regulatory approach to externalities may result in massive economic costs greater than the economic costs of bargaining.

Also, the right to bargain presupposes the inherent right to create externalities. It can be argued that no one has the right to create externalities, yet our present system allows them. Setting emission standards allows industry of all types to create pollution in the forms of smoke, dust, noise, odor, visual aesthetics and degradation of the quality of our water. Land speculation allows one group to deny another group access to new housing. Allowing activities of many types forces the public to pay higher taxes and costs to alleviate the externalities created by these activities.

One unsuccessful solution to the problems with the Coase approach is to allow the use of certain land and water areas to be the common property of all citizens. This leads to "the tragedy of the commons" as delineated by Hardin (1968).

> Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. As a rational being, each herdsman seeks to maximize his gain ... [and] concludes that the only sensible course for him to pursue is to add another animal to his herd. But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit — in a world that is limited. Freedom in a commons brings ruin to all.

The National Parks present another instance of the working out of the tragedy of the commons. At present they are open to all, without limit. The parks themselves are limited in extent — there is only one Yosemite Valley — whereas population seems to grow without limit. The values that visitors seek in the parks are steadily eroded. Plainly, we must soon cease to treat the parks as commons or they will be of no value to anyone.

The laws of our society follow the pattern of ancient ethics and therefore are poorly suited to governing a complex, crowded, changeable world. Our epicyclic solution is to augment statutory law with administrative law. Since it is practically impossible to spell out all the conditions under which it is safe to burn trash in the back yard or to run an automobile without smog-control, by law we delegate the details to bureaus. The result is administrative law, which is rightly feared for an ancient reason — "Quis custodiet ipsos custodes?" — "Who shall watch the watchers themselves?" The great challenge facing us now is to invent the corrective feedbacks that are needed to keep custodians honest.

Perhaps the simplest summary of this analysis is this: the commons, if justifiable at all, is justifiable only under conditions of low population density. As the human population has increased, the commons has had to be abandoned in one aspect after another.

First we abandoned the commons in food gathering, enclosing farm land and restricting pastures and hunting and fishing areas. These restrictions are still not complete throughout the world.

Somewhat later we saw that the commons as a place for waste disposal would also have to be abandoned. Restrictions on the disposal of domestic sewage are widely accepted in the Western world; we are still struggling to close the commons to pollution by automobile, factories, insecticide sprayers, fertilizing operations, and atomic energy installations.

Every new enclosure of the commons involves the infringement of somebody's personal liberty. Infringements made in the distant past are accepted because no contemporary complains of a loss. It is the newly proposed infringements that we vigorously oppose; cries of "rights" and "freedom" fill the air. But what does "freedom" mean? Individuals locked into the logic of the commons are free only to bring on universal ruin; once they see the necessity of mutual coersion, they become free to pursue

> other goals. I believe it was Hegel who said, "Freedom is the recognition of necessity."

One part of this problem is contained in the following quote from Edwards (1969) as he was commenting on our coming post-industrial age where the struggle to make a living will be replaced by affluent societies, with many new choices of life-styles available.

> As long as scarcity, deprivation and the economic hustle were prime movers, the quality of the environment received scant attention at the national level. As long as the quest for individual material progress dominated society, the concept of community and the public interest suffered. As one conservationist summed it up, "If you scratch the heart of almost any American, you will find a trace of the land speculator."

Another aspect of the problem is contained in the following excerpts from a local newspaper, a report on a meeting and a letter to the editor.

> Several property owners whose land would be acquired by the [Iowa] Conservation Commission to develop a waterfowl management area said they will fight the Commission's plans. About 17 landowners would be affected by the proposal, which calls for the Commission to buy about 1,000 acres in the Mississippi-Maquoketa River bottoms. Under the plan, the agency would manage the area, along with 3,000 acres of Corps of Engineers land, to attract waterfowl and other aquatic wildlife. More than 100 residents met with Commission staff members — and most said they were opposed to the plan. One landowner said 48 of the 1,117 acres he farms would be taken by the project. "My land is not for sale — it will never be for sale," he shouted. "The price of freedom cannot be bought." His statement brought cheers and applause from the crowd. Another landowner who said 200 acres of his 400 acre farm would be affected, accused the Commission of trying to make the issue a landowners-versus-duck hunters dispute. "We are not opposed to duck hunters. The Conservation Commission is trying to make us look like we're fighting this — but we're not," he said. "We're fighting for our freedom" ("Vow to Fight Waterfowl Area Plans," February 11, 1976).

> At the land use meetings held at different parts of the state by the Extension Service, the question always came

> up, "Is our land a commodity or natural resource?" The term "our land" is a bold statement that implies that the land belongs to the state or to everybody. This is not true, but is dark pink socialist propaganda.... The [question of whether it is] a commodity or natural resource is almost as midleading. Privately-owned land that has been farmed, developed, and improved for a century or more, and on which the taxes have been paid by the titleholder annually, is not a natural resource in any way. Who pays taxes on air, sunshine, rain, or streams, just to mention a few natural resources?
>
> When the homesteaders and settlers came to Iowa they were given all development rights to improve their land. They could build homes and any other buildings necessary.... The government reserved only the right of eminent domain and the right to tax for public needs such as roads and county seats. The settlers had permanent siting permits and practically all development rights which are legal elsewhere.... ("Land Use Bill Criticized," March 10, 1976).

Until such time as Americans view land as a resource, held by them in trust for the common good, and not as a commodity to be used for whatever purpose the present owner decides, we will not achieve the quantity and quality of life we would wish for ourselves, our children and our grandchildren. This concept of land is not new. It is simply an affirmation of an old truth which man must apparently relearn over and over again. The pioneer spirit of carving a home out of the wilderness is still strong in Iowa. Its motto, "Our liberties we prize and our rights we will maintain," is a reflection of this. Hopefully, only a few more generations will be needed to relearn what history has taught us so many times — land cannot be exploited; it must be nurtured. The pioneer spirit needs to be maintained but must be channeled into the concept that we are the stewards of this good land, not its owners.

William Greiner (1977), past director of the Iowa Department of

Soil Conservation, made this same point when he stated that "there must be a recognition and acceptance of the importance of changing present values — from individual rights to stewardship regarding those aspects of the environment that transcend ownership."

Reflecting on the foregoing, social impacts and perceived rights of individuals, one is led to the following conclusions.

1. The present attitudes of most Americans toward land "ownership" are derived from those of the ancient Romans — land is a commodity to be exploited for the enrichment of its owner. In the west, water was placed in the same framework, will this expand to the eastern states?
2. These attitudes are reflected in our present laws and institutions and have led us to the present condition of many of our urban and rural areas — a condition that is less than desirable.
3. A better way exists — a path which will lead us to the quantity and quality of life we desire. The path includes many components of the current European land planning system such as the master plan-detailed plan concept, return of community created values in land back to the community and cooperative land use control measures involving all levels of government. Perhaps the same values can be placed on water. Will the Iowa water law be successful in the long run?
4. Many components of a better path can already be found in existing American law — if only our elected and appointed

officials had the fortitude to apply, and in some cases restructure, existing law to follow this path. Inherent in this path is the use of the community as the bargainer when attempting to reduce or eliminate externalities. This would apply to all resources, including land and water.

5. Our officials will acquire the fortitude to apply and restructure existing law and to act as the bargainer whenever the majority of Americans are persuaded that this is the type of path which must be followed; however, this persuasion must be preceded by a fundamental change in attitude towards resources. This brings us full circle back to the first conclusion. Our attitude must become one of stewardship towards rights in land and water as resources held in trust to serve the collective needs of people, rather than as commodities to be exploited for personal gain. How to accomplish this change in attitude is a question which must be answered — and soon — before the nation's resources are depleted or degraded beyond recovery.

Economic Constraints

Since the entrance of the federal government into multipurpose land and water resources development, economic considerations have been synonomous with the benefit-cost ratio (B:C ratio). This standard was first enunciated in the Flood Control Act of 1936 and stated that the "benefits to whomsoever they may accrue should be in excess of the estimated costs." An interesting comment was made by Maass (1966) on this point when he said that "this standard, you will note, does not specify efficiency benefits but benefits (of whatever kind) to whomsoever they may accrue."

Be that as it may, for almost forty years this passage in the 1936 Act was taken to mean national economic efficiency. Further, the entire gamut of water resource development evaluations have been predicted on this one sentence. Only since 1973 has environmental quality (EQ) been put on a par with national economic development (NED) (U.S. Water Resources Council, 1973). The Principles and Standards of the Water Resources Council are the latest effort to accommodate the publics' evolving attitudes and values toward growth and water resource development in the planning process; they are the conceptual basis for multiobjective planning.

Benefit-cost analysis can be interpreted in a number of ways as illustrated in Fig. 2. Note that in the following discussion, only economic costs and benefits are considered. Since the 1936 Act stated that benefits must exceed costs, the only portion of the curves shown in Fig. 2 that will be of interest is that portion which lies between points A and B. At any point at which costs are less than A or greater than B, costs exceed benefits and our primary criteria is not met, i.e., the benefit-cost ratio is less than one. Note also that the scale of project is changing when moving from point A to point B; a larger cost means a larger project size.

But at what point between A and B is the best scale of project which should be implemented? At all points between A and B the B/C

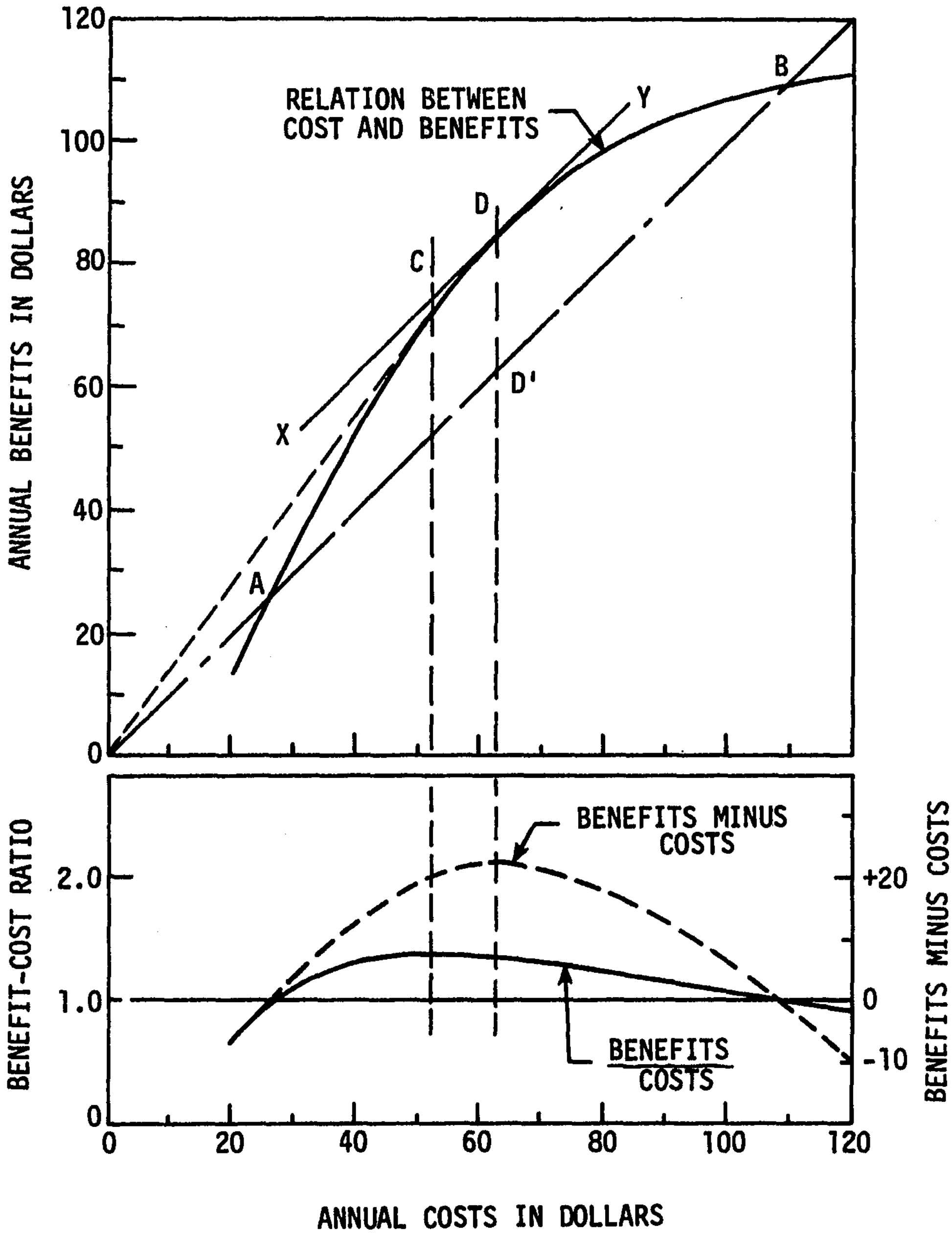


Fig. 2. Relation between benefits and costs for a water resources project

ratio is greater than one. However, three points are of special importance: points C, D and B. The portion of the curve between points A and C (and associated scale of project) is discarded because both the benefit-cost ratio and the net benefits (benefits minus costs) are increasing in this segment. At point C the benefit-cost ratio is a maximum; the rate of return on our investment is the greatest. This is true because the slope of line OC (B:C ratio) is the greatest of any line drawn through the origin to any point on the curve ACDB. However, between points C and D the rate of change of benefits is still greater than the rate of change of costs ($\Delta B > \Delta C$). Marginal benefits are still greater than marginal costs since one dollar of additional investment still brings a benefit of more than one dollar.

It is at point D that marginal costs and marginal benefits are equal. At point D we realize the maximum net benefits for the project. This is shown in Fig. 2 where point D is the point of tangency of line XY to the curve ADCB and line XY is parallel to and offset from line AB by the amount DD', the maximum net benefits. Beyond point D the rate of increase in benefits is less than the rate of increase in costs ($\Delta B < \Delta C$). However, total benefits still exceed total costs until we reach point B. We might reach for a scale of project equal to a level of B because this would create the largest scale of project and the greatest total dollar benefits for the people without violating the standard that benefits must exceed costs.

If money and other factors were not limiting, planners and engineers probably would prefer to construct all projects to the scale associated with point B. But here another factor must be brought into consideration, financial capability. There may be more economically acceptable projects that can be budgeted and thus a lesser scale of this example project must be selected. Economists would opt for a scale of project at point D where marginal benefits and costs are equal (maximum net benefits), $\Delta B = \Delta C$, then assign funds to the next project, but because of stringent budget limitations might be willing to settle for a scale of project somewhere between points C and D if scarce funds had to be "passed around."

Economists, engineers, resource planners and others have since 1936 been single-mindedly following the one path of NED, national economic development. There were other paths to follow but they became lost in NED methodology, improving it, refining it, molding it in various shapes to meet changing needs. There were other paths to follow in that clause in the Flood Control Act of 1936 but for almost forty years they chose but a single path. The clause does reveal other paths.

> It is hereby recognized that destructive floods upon the rivers of the United States, upsetting orderly processes and causing loss of life and property, including the erosion of lands, and impairing and obstructing navigation, highways, railroads, and other channels of commerce between the states, constitute a menace to national welfare; that it is the sense of Congress that flood control on navigable waters or their tributaries is a proper activity of the Federal Government in cooperation with States, their political subdivisions and localities thereof; that investigations and improvements of rivers and other waterways, including watersheds thereof, for flood-control purposes are in the interest of the general welfare; that the Federal Government should improve or participate in the improvement of navigable waters or their tributaries, including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected.

This reveals also a general welfare objective, a safety objective and a social well-being objective.

However, the requirement that benefits exceed costs is true for only those federal projects which are concerned with water resource development. Others are exempt. For example, in the 1960's Americans (through President Kennedy) decided to go to the moon. The National Aeronautics and Space Administration counted costs in the billions of dollars; the immediate benefits were counted in American prestige. In the period 1956-1978 the Department of Transportation counted the cost of the interstate highway system in the billions of dollars; benefits were counted in increased mobility and decreased highway deaths. Cost effectiveness then became the criterion, once the decision to build was made. The Department of Health, Education and Welfare counts the costs of education in the billions of dollars and the benefits in better educated children. The Department of Defense counts the cost of tanks, ships and planes in the billions of dollars and the benefits in national defense.

Likewise, in some areas of water resource development, an explicit enumeration of benefits exceeding costs is not required. One good example of this is water quality. We no longer consider a benefit-cost study of water quality per se, we only consider the most cost-effective way of achieving the water quality standards set by the Environmental Protection Agency (EPA). The American people, by way of Congress, have declared that "good" water quality is in the national interest. Thus, we assign a quality of water to existing or desired use conditions that should be achieved in a certain lake or stretch of a river. We then no longer calculate a true benefit-cost ratio for water quality; we simply assume that the benefits outweigh the costs and spend whatever amount is necessary (in the most cost-effective manner possible) to achieve the water quality standards set by the EPA and the appropriate state agencies.

Financial Constraints

As noted in the previous section, several projects may be economically justifiable, but if sufficient money is not available to pay for all of them, this then becomes a financial constraint. This type of constraint can also arise in another way. Local governments usually have limited financial resources; so most land and water resource development projects are beyond their capability to finance. To rectify this situation, a series of laws have been enacted over a period of years to provide financial assistance to the local populace. However, at times this assistance acts as a constraint because what has evolved is a series of laws and institutions which regulate water resources development in a most uneven fashion: some types of development are fully federally funded, some are shared equally with local interests and some must be entirely paid for by the local people.

In the early 1900's irrigation was declared to be a rightful federal responsibility. While users were charged a fee for the delivered water, this did little to reimburse the construction and maintenance costs of the dams and delivery systems. Flood damages in the 1930's became a national disaster and flood control on a national scale became the responsibility of the federal government with all costs borne by it. Dredging and lock maintenance costs for navigation continue to be the sole responsibility of the federal government, with 1978 being the first time Congress made a real attempt to introduce a measure of user payments.

However, with regard to recreation, specific cost allocation and cost sharing provisions were identified between the federal and state and local governments. The same was true for fish and wildlife enhancement. Water supply, however, was declared to be strictly a local responsibility. The effect of these federally imposed financial constraints is illustrated in the following example.

One conclusion that might be reached, based on the present financial role of the federal government, is that a flood is worse than a drought. Is an excess of water worse than a lack of water? Floods can destroy property, kill crops and people — but so can a drought. The economic losses caused by a flood can be estimated in terms of lost crops and livestock, decreased yields, bankrupt businesses and abandoned homes and farms.

Floods may now be given priority because they appear suddenly, are highly visible and dramatic, localized (even though a Mississippi River flood may extend over hundreds of miles), be over in a relatively short period of time and are readily amenable to countermeasures such as rescue, relief, loans and reconstruction. On the other hand, droughts are slow to develop, are not quite as visible and dramatic, may be widespread, extend over a much longer period of time and are not nearly as amenable to rehabilitation efforts. One possible reason for our country's massive involvement in a flood control program which began in the 1930's is given in the report of the National Water Commission (1973): a combination of the floods which occurred in the mid-1930's and the need to put the depression unemployed to work. The situation is not the same today but our massive involvement continues unabated.

Whatever the reasons for this historic dominance of flood control, the present rules and regulation of the Corps of Engineers and the Soil Conservation Service require that flood control compromises a significant portion of a proposed project (U.S. Department of the Army, 1975). The remainder of the project can be some combination of recreation, water supply, irrigation and fish and wildlife enhancement (such as increased wildlife habitat and/or improved low flow conditions in the river for fish).

Thus a community or a region which has a need for an increased water supply (for municipal, industrial, rural and supplemental irrigation uses) and has a desire for increased recreational opportunities could satisfy these needs and desires by constructing a reservoir. The cost of the project, however, may be beyond the financial capability of the people of the community or region. If flood control could be added as a purpose and comprise its required share of the total project, the federal government would now pay for a portion of the project. The local people would need to pay only for the incremental increase in size necessary for the water supply and recreation portion of the reservoir. If flood control would produce somewhat less than its required share, there would be no federal participation and, therefore, no reservoir and no water supply or recreation. The effects of these present financial constraints on lost opportunities to enhance regional development, environmental quality and social well-being have yet to be documented.

Physical Constraints

Land and water resource development is subject to many physical constraints. The total amount of land and water area in the world is finite, both spacially and temporally. The same is true for Iowa. However, over time the relative amounts of land and water areas can change slightly. Dams can be constructed across valleys to create water areas. Dikes can be constructed across water areas and land areas created by pumping out the water as has been done in Holland. While the number of acres of land and water can change slightly over time, the total number of surface acres which exist in a county, state or nation is fixed — unless its borders are changed. All the uses to which land and water areas can be put must come from the finite total acreage in a region. The number of acres devoted to one use can be increased only by decreasing the number of acres devoted to one or more other uses.

Land is fixed in place and its location cannot be transferred to any other place. Also, the surface of the land can be used for only one purpose at a time. This purpose can be changed but, at a single point in time, it is constrained to just one use. The volume beneath the surface can also be used for many purposes, but just one at a time;

aquifer, mine, utility corridor, wildlife habitat, etc. Air rights can be sold above the surface and this space also used for one purpose at a time. This physical constraint on use can also be accompanied by an institutional constraint such as zoning ordinances.

The physical dimensions of land can also act as a constraint. For example, assume that a dam is proposed in a valley to provide for flood control, recreation and water supply for various purpose. The dimensions of the valley are essentially fixed (its width, length and depth) except as they may be altered somewhat by such construction activities as excavation and filling. These dimensions place a limit on the area which can be used for recreation, on the volume which can be used to store water for various purposes and on the volume which can be used for the temporary storage of flood water.

The various attributes of land also place constraints on the uses to which it can be placed: elevation, slope and soil type which affects such items as internal drainage, ability to support crop growth and ability to support loads. Steep slopes and large differences in elevation combine into land forms which are aesthetically pleasing. Slope and soil type combine to form areas which are suitable for various rural uses: crops, pasture, orchards, forests.

Unlike land, the amount of water, both surface and subsurface, can vary both in time and space. The amount of participation falling on an area over some period of time can vary widely, resulting in floods and droughts. Also unlike land, water can be transported from one location to another. However, even with these possible variations, there is still a physical constraint on the total volume of water which can be made available at a certain location at some point in time. In addition to this physical constraint, there are also technical constraints which limit the total volume of water, both surface and subsurface, which can be made available at a certain location at some point in time. These will be discussed briefly in the next section. Further, unlike land, a body of water can be used for more than one purpose at a time: fish habitat, recreation, navigation and many water supply uses. However, there are physical limitations to these uses also.

The variables which make up our weather and climate, such as wind currents, temperature, precipitation, humidity and cloud cover, also act as physical constraints. Cloud cover determines the amount of sunshine available for photosynthesis and also acts as a blanket to retain heat near the earth's surface. Wind and humidity combine to determine the amount of evapotranspiration which takes place. Temperature and the amount of precipitation which occurs in the form of snow make possible the various forms of winter sports. Temperature also determines the length of the growing season for crops. Precipitation in the form of rainfall has already been discussed.

Physical constraints can also include physical processes such as soil erosion and the limited capacity of a stream to remove pollutants. Soil erosion is of concern because it removes the top layer of soil needed for crop growth and also forms gullys which creates difficulties for the efficient use of farm machinery. Eroded soil is carried to a stream where it becomes a pollutant. Congress has set a goal of zero discharge of pollutants by 1985. This is an admirable goal but physically, it is unattainable.

It is unattainable because we will not be able to completely eliminate sediment from our rivers and streams. When the first explorers traveled on the Missouri River, they nicknamed it "The Big Muddy." Erosion is a natural process in which mountains are eventually leveled and valleys are filled. Man has already spent billions of dollars in an attempt to stop erosion. He cannot stop the process; he can only slow it down. Assuming we were willing to spend enough money to completely capture all erosion from the land surface before it entered a stream, we would still have sediment in our streams.

Just as a stream with a certain cross section and slope has a capacity to carry a certain flow of water, this same stream of water has a capacity to carry a certain amount of sediment. If none is supplied to it, the stream will supply its own by eroding its banks and bed. This is evidenced downstream of dams where streambeds have been eroded several feet. The dam removes much or most of the sediment in the river upstream; so the water released from the reservoir is relatively clean and clear. This clear water picks up a new load of sediment by eroding the banks and bed of the river downstream from the dam. The banks and bed are also eroded by the velocity of flood waters. Thus there is no way to completely eliminate sediment from our rivers and streams.

Secondly, natural aeration of a stream will supply the oxygen needed to meet the biological, carbonaceous and nitrogenous demands of pollutants in a stream. If the pollutants are kept within certain limits, the stream will purify itself within a matter of a few miles.

At that location additional pollutants (within certain limits) could be delivered into the stream and the stream would purify itself again and again and again. This flow resource, if not stressed beyond its limits of irreversibility, could provide savings in pollution control amounting to tens of millions of dollars annually. These capital, labor, time, land, chemicals and other resources used for total pollution control could then be used for other purposes.

To carry this thought one step further, in a discussion to a paper by Schmid (1967), Haveman suggested the following:

> If questions, such as reasonable social alternatives in the water pollution area, were approached as Schmid recommends, it is not at all unlikely that the reservation of some streams solely for waste disposal would form an obvious and essential element in a socially optimum pattern of resource use.

Technical Constraints

Technical constraints are simply a reflection of the amount of intellectual progress which has been made in overcoming the physical constraints listed in the previous section. The progress to date is termed present-day technology. Corn yields of over 200 bushels per acre are now common due to the introduction of new seed varieties, higher plant populations, use of fertilizers, herbicides and insecticides and the timing of planting and supplemental irrigation. Waters polluted by human and industrial wastes can be restored to drinking water quality through the use of various physical, chemical and biological methods. Soil erosion can be reduced to levels such that new soil, through soil conservation and farming practices, is formed faster than it is being washed or blown away. This is accomplished through the use of terraces, contouring, grassed waterways, crop rotations and tillage systems incorporating organic residues into the soil. Water can be transported through mountains and across the plains. Many sources of energy can be used to produce electricity. Calculations that used to take hours can now be done in microseconds. And man has walked on the moon! All are evidences of an intellectual society, in a technology sense.

Ackerman and Löf (1959) have presented an indepth review of the technical advances which have played an important role in the development and utilization of our water resources. They grouped these advances under several headings: technical events which increase the demand for water, techniques capable of decreasing the demand for water, extending the services afforded by a given unit of water, technical improvements which promote economies of scale and techniques which improve the physical range of water recovery. Several examples of these technical advances are listed below.

Some advances have brought about an increase in the demand for water. The development of the refrigerated truck and railroad car allowed western farmers to vastly expand the market for their fruits and vegetables, both fresh and frozen. This in turn caused a large increase in the farmers' demands for irrigation water. Advances in the dependability of refrigeration techniques, from ice and salt to mechanical refrigeration equipment and the use of such precooling methods as chilled water and vacuum cooling, reduced spoilage and improved the appearance and flavor of the produce. More rapid air freight transportation today adds to this impact. The growth of the chemical and paper and pulp industries has also resulted in a large increase in water demand by these industries. The manufacture of paper products particularly requires huge volumes of water. The petro-chemical industry has led to a "plastic" world. For example, the production of acids, plastics, resins, synthetic fibers, synthetic detergents and products used in the automotive industry (antiknock compounds, additives to lubricants and greases, anti-freeze require large volumes of water.

The development of lightweight aluminum pipe and sprinkler attachments expanded the acreage which could be irrigated. Irrigation was no longer confined to flat land; slopes up to 15% can be irrigated using center pivot systems. This advance in irrigation technology ("push button" technology) greatly increased the demand for water in various regions of the United States, especially in the midwest. Also, the many advances made in the uses of electricity in both the industrial and residential sectors have caused a many fold increase in the volume of water needed for cooling purposes.

Some techniques are capable of decreasing the demand for water. This decrease in demand then allows the available water supply to be used for other purposes. In the western United States, large volumes of water are used for irrigated agriculture. This leads to progressive salt accumulation in the soil which is detrimental to crop production. Excess irrigation water has been applied to leach out the salts or more frequent irrigation has been used to dilute the salt concentration. However, the use of salt tolerant crops and the development of more salt tolerant crop varieties has resulted in less water being needed. Also, the development of crop varieties which are more tolerant of drought conditions has also reduced the volume of irrigation water needed. Food processing plants also use large volumes of water both within the plants and for disposal of wastes. One technique developed for waste disposal is the use of spray irrigation on land. Since the wastes are deposited directly on the land, higher waste concentrations can be used, thus reducing the volume of water needed for waste residue control. Other techniques have been developed in the paper and pulp industry which decrease the water requirements for waste disposal.

One method of extending the services afforded by a given unit of supply is the scheduling technique embodied in multipurpose reservoir operation. It involves the synchronization of water detention and release with two or more demands for water which rely on a single source of water. The objective is to arrange supply so as to reduce competition among uses and to increase complementarity among uses such as navigation, irrigation, flood prevention, power production, recreation and domestic and industrial water supply. One problem with the use of reservoirs is the loss of usable water to evaporation. In some areas, the available supply can be extended by underground storage of the water. Techniques and technology have developed over the years to recharge aquifers by water spreading and injection wells.

In the agricultural sector, water for plant growth can be conserved, through increased water use efficiency primarily. The use of the available supply has been extended by several techniques: through the use of mechanical means such as terracing, contouring and strip-cropping; through the reduction of surface evaporation by using mulches and leaving crop residues on the surface; through the elimination of weeds by using herbicides and crop rotations; through the use of various tillage methods to increase the volume of water retained in the system; through the use of more efficient irrigation systems which avoid waste and over-irrigation (trickle irrigation is an example); and through the use of windbreaks to protect crops against drying winds. A final technique, which extends the uses to which a given supply of water can be applied, is to reduce its hardness and allow its use for a wider range of purposes. This reduction in hardness or elimination of contaminants is accomplished by such methods as electrodialysis, reverse osmosis and ion exchange.

Several technical improvements have promoted economies of scale. The development and improvement of large-scale earth-moving equipment has enabled man to overcome the temporal fluctuations in water supply by allowing him to more economically construct large dams. The similar development of high-strength and reinforced concrete has also allowed the construction of these types of dams. Undesirable spacial distributions of water have been overcome by the development of machinery to construct canals and tunnels. Lining these canals and tunnels with concrete has greatly reduced seepage losses. Technological improvements have also allowed electricity to be transmitted over long distances. Electrical energy is lost in transmission, especially at low voltages. Through technological advances such as suspension-type insulators, high-capacity transformers and high-speed switches and circuit breakers, transmission voltages have increased from 22 kv to 330 kv. Direct current high voltage lines have replaced alternating current in some systems.

Finally, techniques have been developed which extend the physical range of ground water recovery. Improved drilling methods and equipment have extended the depths to which wells can be drilled. Improvements in pump design and efficiency have increased the depth from which water can be lifted. Also, the use of such techniques as acidizing, fracturing and surging can increase the yield of existing wells.

Where do we go from here? Recycling and reuse of water for industrial and domestic purposes has already begun and is expected to increase in the future. The recent drought has hastened the introduction of conservation: water-saving devices for domestic purposes. It has also given impetus to efforts in the industrial sector to refine and/or develop new processes to use less water per unit of output. Further increases in the efficiency of application of irrigation water and its use by plants are also foreseen. The future would seem to be limited only by the extent of man's imagination, ability to innovate and ability to achieve economies of scale to make such ideas profitable to private enterprise.

Political Constraints

Political constraints can take on many forms depending on the context in which the word is used. They include the actions of special interest groups to encourage or impede the passage of legislation, the implementation of certain policies and the construction of certain projects. They include the actions (or inactions depending on one's point of view) of federal and state bureaucracies. They include the workings of the various committees, subcommittees and their staffs who have responsibilities for land and water resources at the federal and state levels. They include the beliefs and attitudes of the major political parties on the degree of involvement that government should have in the activities of people and business. They include the actions and reactions of candidates seeking election to office, and elected officials, to special interest groups and other politicians. They generally include all the interactions of people seeking to influence people having influence. Many examples could be cited to illustrate each of the above, but only a few will be given here, simply to give the flavor of these political considerations.

An excellent example of how the political actions of a special interest group influenced the final development and operation of a newly constructed dam and reservoir in central Iowa is that of the "Save the Ledges" group (Environtology Council, 1973). The "Ledges" is a rock formation located in the valley of a small tributary just off the floodplain of the Des Moines River. The entire area is included in the Ledges State Park which is located about 33 river miles upstream of the Saylorville Dam and Reservoir. It is a popular park for picnicing and nature walks with annual visitations in excess of 500,000. The two purposes of the reservoir are flood control and recreation. The "Ledges" has been flooded naturally several times by the Des Moines River prior to construction of the dam but the original reservoir operating policy proposed by the Corps of Engineers would have increased the frequency, depth and duration of flooding. After several years of controversy which included court suits, independent studies by engineers and scientists and the involvement of several local and national special interest groups, state and federal agencies and elected state and federal officials, a compromise solution was reached. The "Ledges" was also an issue in the election campaigns of several candidates for local, state and federal offices.

The compromise solution included a revised reservoir operation policy which diminished flooding effects in the Ledges State Park. Because this revised policy increased downstream flows, Congress authorized the expenditure of over $6 million to purchase and develop a 3,000-acre greenbelt between the dam site and existing flood protection works in the city of Des Moines and for remedial measures at the Ledges State Park. The involvement of these special interest groups and the subsequent controversy had a positive impact on the Saylorville Reservoir project in that it shifted the final plan to an acceptable solution which gave a better balance between the NED and EQ objectives.

Another excellent example of the several connotations of political constraints is contained in a report on the background and passage of the Federal Water Pollution Control Act Amendments of 1972, PL 92-500 (Timothy Wolf, 1978, unpublished report, Civil Engineering Department, Iowa State University, Ames, Iowa). The passage of this bill involved interactions between several special interest groups, federal and state agencies, Congressional committees and subcommittees and politicians at the state and federal levels.

Control of water pollution essentially began in the late 1940's with the passage of the Water Pollution Control Act of 1948, PL 80-845, and its subsequent amendment in 1956 by PL 84-660. The 1960's saw much political activity centered on the quality of the environment involving several special interest groups and actions by Congress which passed much environmental legislation (see Table 3). Political activity in the area of pollution control in the 1970's began with a national outpouring of concern for cleaning up the environment which was expressed in the celebration of Earth Day on April 22, 1970.

In the two years prior to the passage of PL 92-500, both the Senate and the House held numerous hearings to obtain public input on this effort to clean up the nation's waters. In the Senate, the Subcommittee on Air and Water Pollution of the Public Works Committee devoted 33 days to public hearings on 18 bills concerning water pollution abatement and control. They heard a total of 181 witnesses, received 470 statements and compiled over 6,400 pages of testimony. During this period, the Subcommittee on Air and Water Pollution and the Committee on Public Works also conducted 45 executive sessions to develop the pending legislation. The final bill, S 2770, was passed on November 2, 1971 and sent to the House. During a 7-month period in the House, its Public Works Committee devoted 38 days to public hearings on over 200 bills which amended the existing Water Pollution Control Act. They heard a total of 295 witnesses, received 135 additional statements and compiled 4,144 pages of testimony. The final bill, HR 11896, was passed on March 29, 1972.

Because the bills passed by the Senate and House were different, a joint conference committee was formed. In fact, the two pieces of legislation were so divergent that some predicted the bill would die in conference. Between May 11 and September 14, 1972, the conference committee held 40 meetings before agreeing to file a conference report. The Senate and House both agreed to the report on October 4 and sent the final bill to the President for his signature. However, President Nixon vetoed the bill on October 17, 1972. Both the Senate and House voted to override the President's veto the next day and PL 92-500 became law.

This lengthy recitation of the enactment of PL 92-500 is an example of the political process at work to bring about passage of a piece of legislation at the federal level. The holding of public hearings gives the special interest groups and other interested persons a formal opportunity to present their cases to elected officials. This is in addition to the "politicing" which goes on in Congressmen's offices, in the corridors and cloakrooms and at meetings and parties. The following lists of special interest groups and other persons involved gives an idea of the diversity of interests which had input to the content of PL 92-500.

Those groups lobbying for a strong bill from the environmental viewpoint included the League of Women Voters, the Environmental Policy Center, Ralph Nader's Task Force on Water Pollution Control, Amalgamated Clothing Workers, Common Cause, Environmental Action, Friends of the Earth, Izaak Walton League, National Consumers League, Conservation Foundation, National Wildlife Federation, Sierra Club, Trout Unlimited, United Auto Workers, United Steelworkers, Wilderness

Society and Zero Population Growth. Groups from industry included the National Association of Manufacturers, American Petroleum Institute, Manufacturing Chemists Association, American Iron and Steel Institute, American Paper Institute and the Chamber of Commerce. Other groups included the National League of Cities, U.S. Conference of Mayors, Association of Metropolitan Sewage Agencies, Water Pollution Control Federation, Interstate Conference on Water Problems, Consulting Engineers Council and the National Association of Regulatory Utility Commissioners.

Several individuals from the federal and state governments also were involved. These included representatives of the EPA, HUD, CEQ, Treasury, Corps of Engineers, the President, New York Department of Environmental Conservation, New Hampshire Water Supply and Pollution Control Commission, Massachusetts Water Pollution Control Division, California Water Resources Control Board and Arkansas Public Service Commission. These individuals also included senators, congressmen, governors and mayors.

Another connotation of politics is illustrated in the following excerpt from the report by Wolf (1978).

> On July 20, 1971 the House passed HJ Res. 3 by voice vote, but the interesting item dealt with was the rejection of an amendment by H. R. Gross (R-Iowa) which would have prohibited any member of a proposed joint Senate-House committee on the environment from becoming a candidate for President until the committee's last press release was issued. The amendment was an obvious swipe at Sen. Edmund S. Muskie, an undeclared presidential contender and a leader of Senate forces to establish the new committee.

Another aspect of political constraints is the effect of the recommendations and policy statements made by various federal commissions and councils. These include the several recommendations made by the National Water Commission (1973) and the Principles and Standards of the U.S. Water Resources Council (1973). A recent recommendation by the President's Council on Environmental Quality (1978) in its latest annual report stated that federal farm programs should only be made available to those farmers who practice soil conservation and stop polluting streams. If this recommendation becomes formal federal policy, this political action would cause major impacts on farmers' incomes, financial requirements, crop production and quality of the environment.

The importance of these political constraints cannot be overemphasized. It is here in the political area, in its many varied forms as described above, that the future land and water resources policies of the United States will be hammered out. The direction of these policies, whether towards exploitation or conservation or some middle path, will be determined by the input, biases, persuasiveness and compromises agreed on by all these political groups. These political constraints, in concert with all the other types of constraints listed above need to be included in the GP formulation and will influence the manner in which the sources and uses of water discussed in the next section will be utilized and managed.

COMMENTS ON SOURCES AND USES OF WATER

Just as constraints are a part of the complexity of land and water resource planning, so also are the various sources of water and the uses to which it is put. Since water usually is available from more than one source, several questions must be answered concerning these sources of water in the planning of a water resource project or program. Which sources of water are or can be made available? Is a source of water available at more than one location? What quantity of water is or can be made available? What is the quality which is or can be made available? Will these quantities and qualities remain constant or change? Of those locations which are not now available, when might they be made available and how? Which area or areas should get priority over these sources and locations of water?

The same kinds of questions must be answered concerning the uses of water in the planning of a particular project or program. Which uses of water are or will be present? Are or will these uses be present in more than one location? What quantity of water is or will be needed (or desired) for each? What quality of water is or will be needed (or desired)? Will these needed quantities and qualities remain constant or change? When will the future needs occur? Will there be new locations of stress in some uses of water in the future? Will there be new uses demanding water in the future?

In this section, the various sources and uses of water will be discussed. In addition, the general pattern of source development and competition between and among uses will also be discussed. This will then lead to a detailed analysis of the Northwest Iowa study area.

Sources of Water

The present sources of water include the following: precipitation, surface water (streams, natural lakes, man-made reservoirs), ground water (surficial and bedrock aquifers and ground water recharge), municipal and industrial effluents, agricultural return flow and imported water from another region. The presently recognized beneficial use categories include water supply, water quality, flood control (including flood plain management), water-oriented recreation, fish and wildlife propagation, navigation, watershed management and instream flow needs. Water supply includes such present purposes as municipal, industrial, rural farmsteads and residences, livestock watering, irrigation and energy. Each of these are discussed in turn, to indicate its role as a source or use of water in illustrating the overall complexities of land and water resource planning.

Bishop, Hendriks and Milligan (1971) have suggested that the various sources of water be grouped under three headings: primary supply, secondary supply and supplementary supply. Surface water and ground water were included under primary supply. Municipal effluent, industrial waste and agricultural return flows represent the secondary supply, and imported water and desalination are the supplementary supply. Precipitation itself needs to be added as a primary supply in agricultural areas. It is the fundamental source of water for almost all crop production in Iowa and is the source of snow for such winter sports as skiing and tobogganing.

A region will first use its primary supply sources since they will be the least costly to develop. And depending on use, the cost of obtaining or developing it could be zero. For example, no cost is involved in using rainfall to provide water for growing crops; no cost is involved in using a natural lake to provide a body of water for swimming, fishing and boating; no cost is involved in using the assimilative capacity of a stream to eliminate a limited amount of the pollutants discharged to it.

When all of the primary sources of supply have been fully utilized or have become too expensive to develop (such as deep wells with low quantity or quality of water, or additional reservoirs whose cost per unit of water developed is greater than other alternatives), then the secondary sources of water will begin to be utilized. Other social, legal or institutional circumstances may also make the use of secondary supply sources attractive. These sources normally cost more to develop since their quality has usually been impaired to some extent from their previous use. However, in recent years federal and state laws and regulations have required that effluents and wastes be substantially upgraded in quality before they are released from the point of use. Thus, some or all of the increased cost has already been spent to satisfy some objective other than water supply, i.e., environmental quality.

When the needs or demands of the region exceed both primary and secondary supply sources, then the supplementary sources of supply will be utilized. These sources could be high salinity surface water, brackish ground water and importations from any primary or secondary supply source located outside of the region. These are usually the last to be developed because they have the high cost of desalination or the added cost of transportation from outside the region to the point of use in addition to all of the other costs of development.

Precipitation

All sources, primary, secondary and supplementary, have their origin in precipitation and each source, including precipitation, has the bothersome characteristic sometimes of (1) not being in the location that we want it, (2) not being there at the right time, (3) not being there in the needed quantity or (4) not being there with the correct quality. Iowans recently experienced a severe drought, and just prior to this drought, the state went through the wettest two years of recent record. Unless we learn to control the weather, we will repeat this cycle again — and again. Our chances of controlling the weather are slim at present, so preparations for the next drought or the next wet period should start now.

Since Iowa is an agricultural state, the amount of rainfall received is of paramount importance to the state's farmers and to all those workers who provide inputs to them and to all who process their crops. Annual precipitation over time has varied from less than half the average to about one and a half times the average. Precipitation in Iowa averages about 30 inches per year and statewide averages have varied from 19.9 inches in 1910 to 44.2 inches in 1881. This variation is even more pronounced at specific stations within the state where annual precipitation has varied from 12.1 inches at Clear Lake in 1910 to 74.5 inches at Muscatine in 1851 (Waite, 1970). In addition, the distribution of the precipitation throughout the year is far from uniform. This is crucial to farmers since they can experience a large reduction in yield if rain does not occur at critical times during the growing season, even though total annual rainfall is normal or above normal.

Thompson (1969) evaluated the influence of weather variables on corn yields. Figure 3 shows the influence of departure from normal precipitation from September to June on the yield of corn. In his words, "the curve indicates that a departure from normal of 40 cm of precpitation would have a greater adverse effect when more than normal than when less than normal. This can be explained in part by the fact that wet conditions in the spring delay planting and increase problems of weed control." Figure 4 shows the influence of departure from normal July rainfall on the yield of corn. This curve indicates a strong adverse effect on corn yield with below normal departures from July rainfall. Yields are increased by greater than normal July rainfall with yield increases leveling off at about twice normal July rainfall.

Thompson (1973) also has commented on the double sunspot cycle theory. This theory holds that the occurrence of droughts is related to a double cycle of sunspot activity. The average length of the double cycle has been 22 years since 1610, but only 20 years since 1914. A sunspot cycle starts with a few spots or groups of spots. The

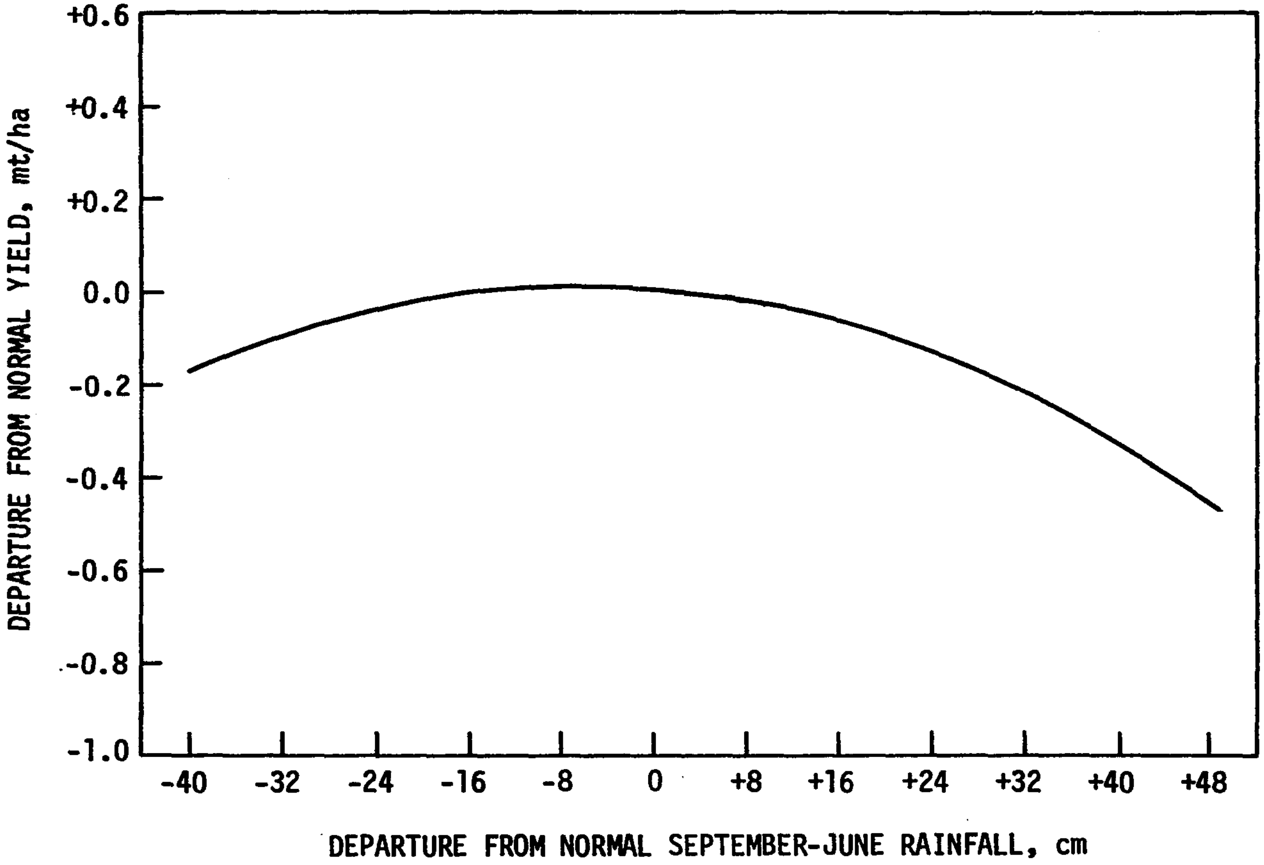


Fig. 3. Influence of departure from normal precipitation from September to June on the yield of corn

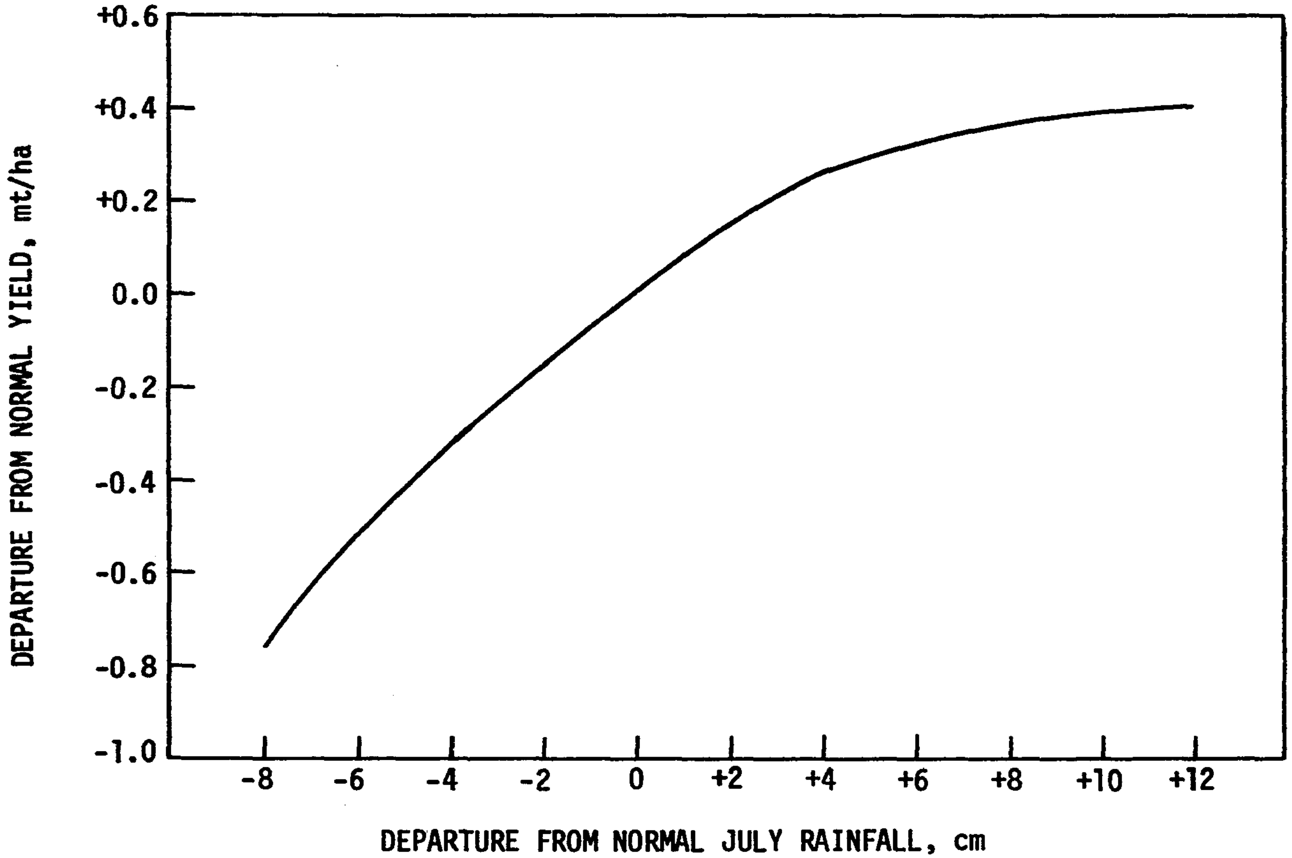


Fig. 4. Influence of departure from normal July rainfall on the yield of corn

spottiness increases to a maximum after three to five years and then subsides gradually until a new cycle begins every 10 or 11 years. Alternate cycles are labeled as "major" or "minor;" thus, a minor followed by a major cycle constitutes a full or double sunspot cycle of 20 to 22 years. A drought consists of below average rainfalls and above average temperatures. Figure 5 is a plot of average July-August temperature in the corn belt against the double sunspot cycle for the period 1900 to the early 1970's. Minor cycles are plotted below the zero line and major cycles are plotted above the zero line. The correlation is easily seen: warming trends occur after the peak of a minor cycle until the peak of a major cycle. Figure 6 is a plot of drought periods in Nebraska against the double sunspot cycle for the period 1740 to the early 1970's. Again the correlation is easily seen: drought occurred after the peak of the minor cycle until the peak of the major cycle.

Note that the last peak of the minor cycle occurred in 1969. We have just experienced the drought of the mid-1970's. Theoretically, we should not have to worry again until the middle 1990's; however, this may not be the case. In addition to the double sunspot cycle, Thompson (1975) has also investigated the effect of weather variability on grain production in five corn belt states: Illinois, Indiana, Iowa, Missouri and Ohio. One remarkable result of this work is the plot of the effect of weather on corn yield during the period 1891 to 1973, reproduced here as Fig. 7. The corn yields were calculated from the regression equation he developed and using the assumption of a 1973 level of technology throughout the period. The remarkable feature

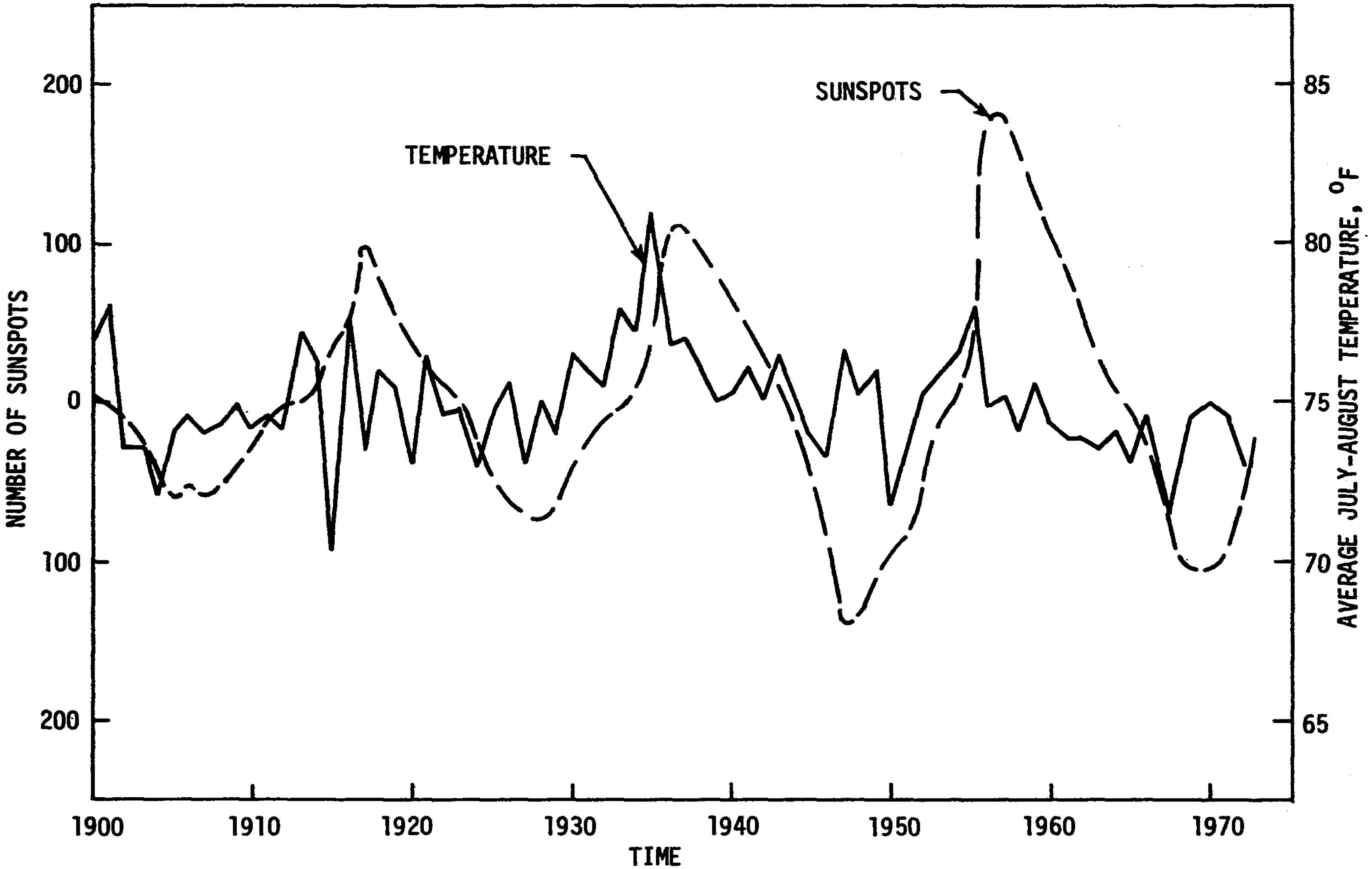


Fig. 5. Average July-August corn belt temperature plotted against double sunspot cycle from 1900 to 1973

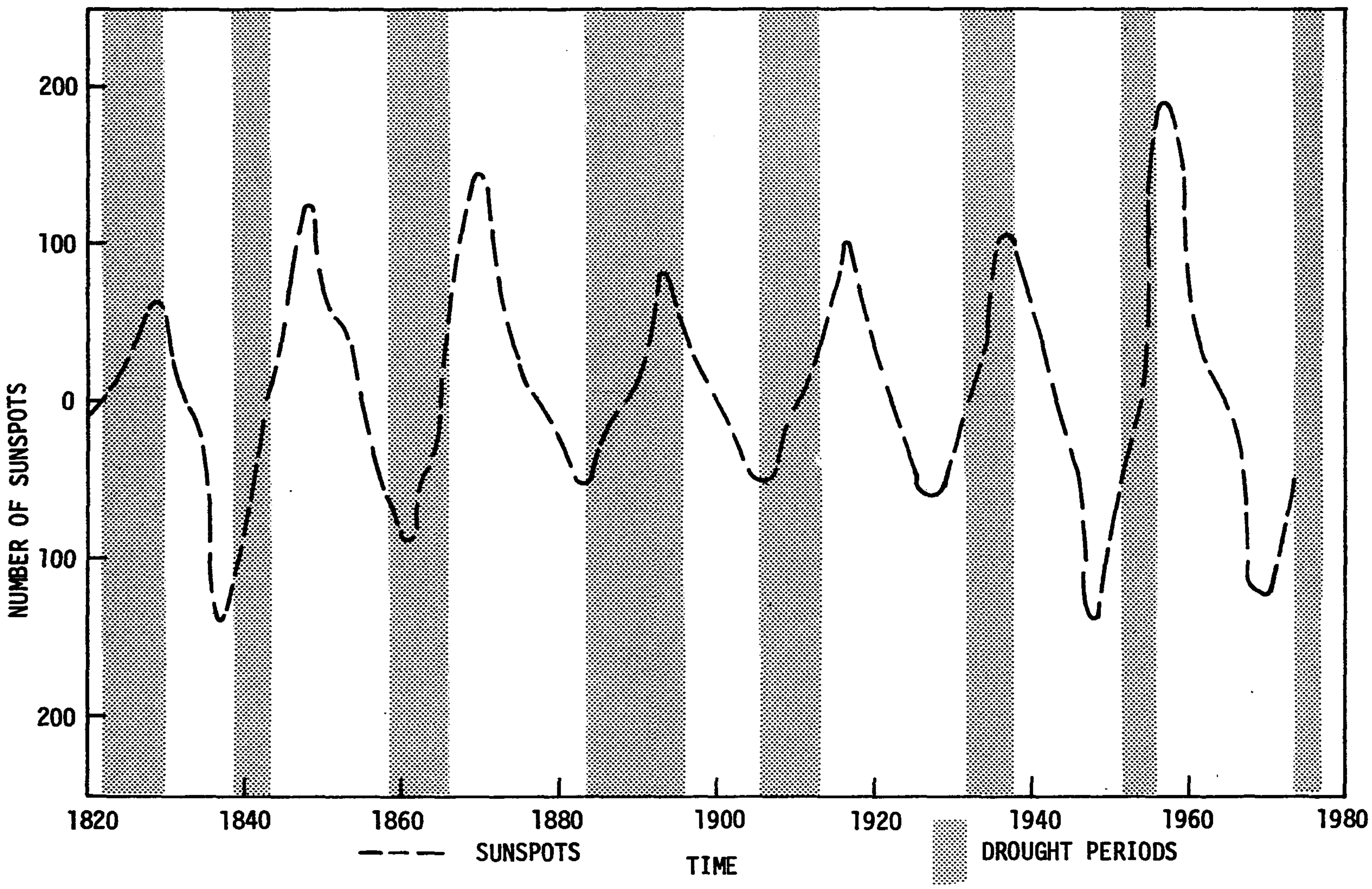


Fig. 6. Drought periods in Nebraska plotted against the double sunspot cycle from 1820 to 1977

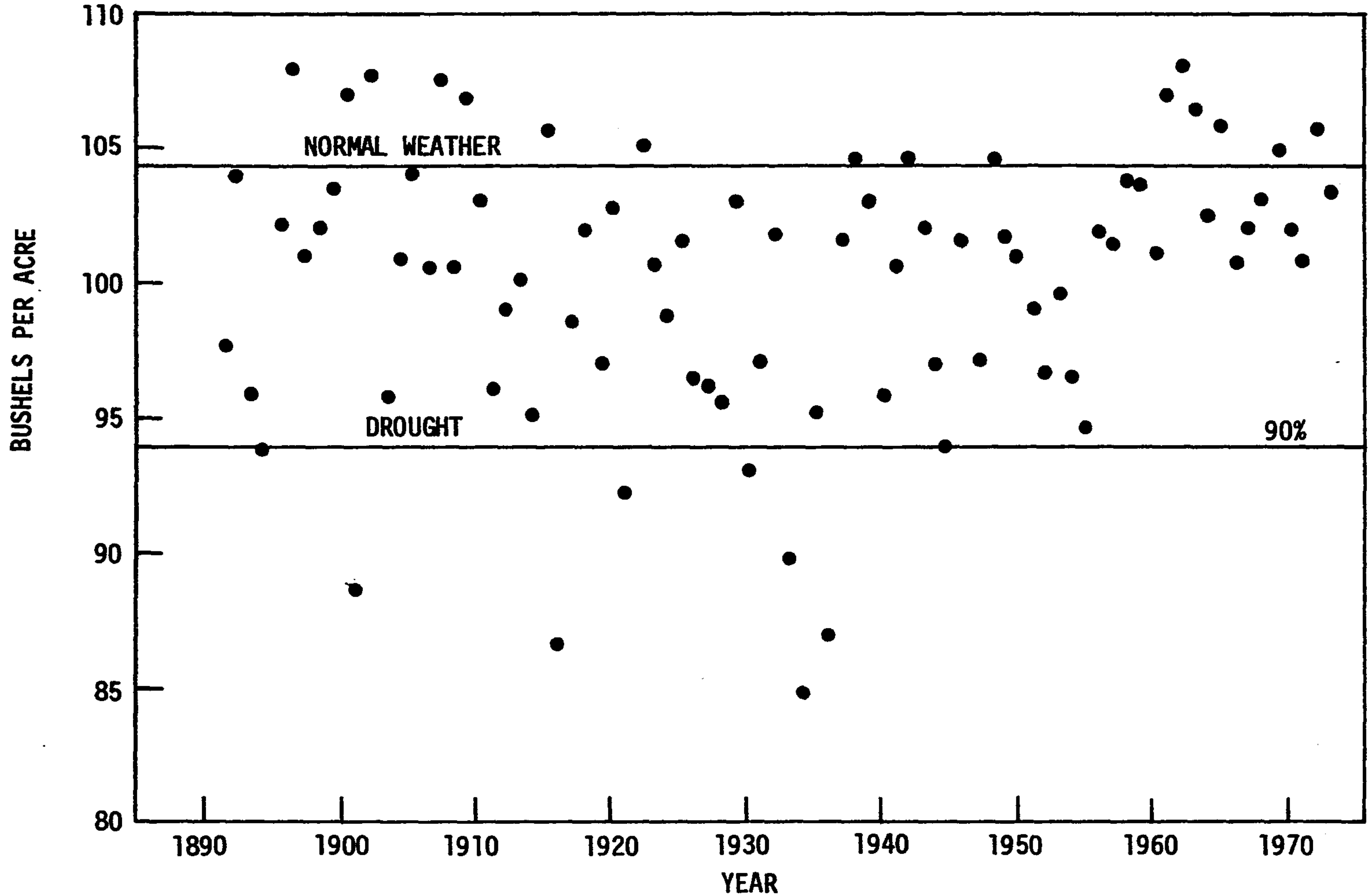


Fig. 7. Simulated five-state weighted average corn yields using 1973 technology and harvested acreage: Ohio, Indiana, Illinois, Iowa, Missouri

of this figure is the run of favorable years from 1956 to 1973 in which yields were 95% of normal or better every year. A glance at Fig. 5 shows that the average July-August temperature was below normal for this entire period. There is no reason to suspect that this 18-year sequence of excellent yields is going to continue. Indeed, the more likely prospect is that we will experience weather similar to that of the period from 1891 to 1956, a period in which yields were highly variable.

One last figure which provokes some intriguing questions is that shown in Fig. 8, a 35-year moving average of annual precipitation at Cedar Rapids with each point plotted at the end of the period. Is this a temporary aberration, just as our recent string of good weather could have been? Will this increase in annual precipitation continue? For how long? What are its implications for crop production, floods, etc.? Floods can also have an adverse effect on crop production, just as droughts do. Further investigation has indicated that this precipitation station record may not be an isolated case. This on-going study has also shown that some longer record stations may exhibit a long-term sinusoidal increase and decrease in a 35-year moving average of annual precipitation whose period is in excess of 100 years. This also provokes some intriguing questions for agricultural production.

But Iowa is not only agriculture, Iowa is also people — almost three million at the present. An excess of precipitation in the form of a flood or a lack of precipitation in the form of a drought has large adverse effects on the physical and mental well-being of the inhabitants of a region. The floods which occurred in the 1960's and

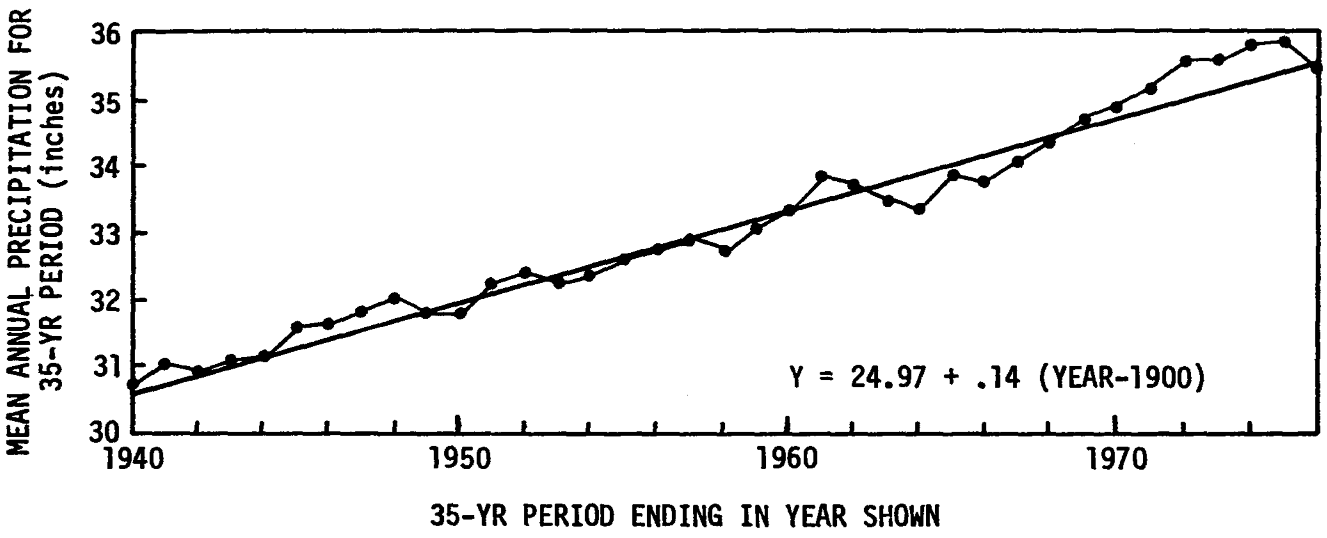


Fig. 8. 35-yr moving average of mean annual precipitation at Cedar Rapids, Iowa

the early 1970's, and the drought of the middle 1970's, have left their mark on both the rural and urban population of Iowa, marks which will not be erased for a long time to come.

Surface water

One visible effect of precipitation is surface runoff, the source of most of our surface water. This water is found in our rivers and streams, in our natural lakes, marshes and swamps and in our man-made reservoirs. The most perplexing aspects of surface water are the same as those for precipitation: its variability both in time and space. We usually have too much or too little and often in the wrong place at the wrong time. Billions of dollars have been spent in attempts to store surface water in order to make it available at the right place at the right time and to avoid an overabundance at the wrong place at the wrong time.

The U.S. Geological Survey and other federal and state agencies have been active for a number of years in gathering and publishing data on both the quantity and quality of streamflow. This network of gaging stations has proved invaluable in providing an historical record of streamflow and a data base from which numerous interpretations have been made. They have also provided an historical trace of the surface variation in many of our lakes and reservoirs. These data have given us a record of past floods (peak rates, stages, volumes) and of low-flow periods. We can estimate possible future flood and low-flow magnitudes. They have also provided us with a wealth of baseline data on such water quality parameters as suspended sediment, temperature, DO, BOD, pesticides, herbicides, heavy metals and others. This information has allowed us to answer many questions concerning the availability of water for beneficial use. Each of these purposes are discussed in some detail in a later section.

However, when using the data gathered by the USGS and others to determine the rates and volumes of water which could be available in the future, we must first be careful to eliminate the "noise" in the data. This "noise" results in either more or less discharge (either as a rate or a volume) occurring today from a certain amount of precipitation as opposed to what would have occurred from the same amount of precipitation 30, 60 or 100 years ago when the record began at some particular location.

These changes occur because conditions change over time, with most of these changing conditions being caused by man. A flood of a certain magnitude may not occur at the same depth of flow now as it did before. This could be due to the channel being straightened and enlarged, portions of the flood plain being filled to allow further development, levees being constructed or the streambed could be degrading or aggrading naturally. The magnitude of the flood itself and its volume could also be larger or smaller now than it was before. This could be caused by changes in land use, construction of dams to regulate the flow and diversions of flow from the river to meet various water supply demands. The situation has become so complex in some areas that the USGS has selected and labeled some stations as "benchmark" stations. These are stations which measure the flow from watersheds the USGS feels will remain in their natural state in the future and thus will maintain a baseline record which will be statistically significant.

The Missouri River is a good example of these complexities. During this century it has been straightened, reshaped, dammed and regulated. Upstream diversions have reduced the annual volume of flow at Sioux City by millions of acre-feet. Peak flood discharges up to 200,000 cfs (cubic feet per second) no longer occur. The streambed has degraded several feet in straightened reaches downstream of the dams. The flow in the river today is whatever man decides it will be, until sufficient flow from the unregulated tributaries enters the river to mask man's effect.

As indicated in Table 4, fresh surface water accounts for only about 0.01% of the world's supply of water: 0.009% in the fresh water lakes and only 0.0001% on the average in the world's rivers and streams. Over 99% of our water is contained in the world's oceans, icecaps and glaciers: 97.2% in the oceans and 2.15% in the icecaps and glaciers. The 0.0001% is equal to 300 cubic miles of water which may seem to be a lot, but when spread out to all the world's rivers and streams, we can readily understand how conflicts can arise as to how the water should be used. This situation is helped considerably each year as 24,000 cubic miles of precipitation falls over land areas. Of this total annual precipitation, 9,000 cubic miles flows to the rivers and 15,000 cubic miles becomes part of our ground water supply. This situation is also helped by the fact that as the surface water wends its way through the lakes and rivers on its way to the oceans, it can be used several times for many of the beneficial uses of water.

Table 4. Distribution of the world's estimated water supply

Location	Surface area sq. mi.	Volume cu. mi.[a]	Percent of total
Surface water			
Fresh-water lakes	330,000	30,000	0.0092
Saline lakes, inland seas	270,000	25,000	0.0077
Stream channels (average)	—	300	0.0001
Subsurface water	50,000,000		
Vados water (includes soil moisture)	—	16,000	0.0049
Ground water within depth of half a mile	—	1,000,000	0.3067
Ground water — deep lying	—	1,000,000	0.3067
Other water locations			
Icecaps and glaciers	6,900,000	7,000,000	2.1467
Atmosphere (at sea level)	197,000,000	3,100	0.0095
World's oceans	139,500,000	317,000,000	97.2172
Totals	—	326,000,000	100.0000

[a]One cubic mile of water equals 1.1 trillion gallons.

Ground water

Precipitation and streamflow can also be highly variable from one location to another. Ground water also has spatial and temporal variability but in a different sense than that of precipitation and surface water. Unlike precipitation and streamflow, in general, at any one location the amount of available ground water remains relatively constant over time. If an aquifer is capable of yielding 50 gpm (gallons per minute) or 500 gpm today, then the aquifer will have the same capacity tomorrow, next month and next year unless the withdrawal rate is such that the aquifer is being mined or the structure of the aquifer is changed somehow.

The ability of an aquifer to maintain a relatively uniform yield over a long period of time is a function of two properties, its porosity and its permeability. Porosity is the percentage of the total volume of the formation that is occupied by pore space or interstices. In an aquifer, the pores are completely filled with water. Original porosity is the porosity which existed at the time the material was formed while secondary porosity is the porosity which results from fractures and solution channels. A large porosity does not guarantee a large yield of water. On the contrary, while clay has a large porosity, it yields very little of its water due to its low permeability. Permeability is a measure of the ease with which water can move through an aquifer, a measure of how well the pore spaces are interconnected (Linsley, Kohler and Paulhus, 1975).

This is shown in Table 5 which lists the porosity, permeability and specific yield of several materials. Specific yield is the ratio, expressed as a percent, of the volume of water which will freely drain from the formation to the total volume of the formation. While clay has over half its volume in voids, its yield is only a few percent due to its low permeability. On the other hand, gravel has only half the void space of clay but will yield seven times the volume of water due to its high permeability.

As shown in Table 5, the properties of an aquifer are a function of the material or materials that make up the aquifer which leads us to look at the geology of the region. Ground water can be found near the surface or a half mile down; so we must investigate not only the

Table 5. Typical values of porosity, specific yield and permeability for various materials[a]

Material	Porosity %	Specific yield %	Permeability gpd/sq. ft.
Clay	55	3	1
Sand	35	25	800
Gravel	25	22	5,000
Gravel and sand	20	16	2,000
Sandstone	15	8	700
Dense limestone and shale	5	2	1
Quartzite and granite	1	0.5	0.1

[a]After Linsley, Kohler and Paulhus (1975).

unconsolidated materials near the surface but also the layers of bedrock which underlie the region. This vertical variation divides aquifers into two general classifications: surficial and bedrock.

Surficial aquifers can be subdivided into three main types: alluvial, buried channel and drift aquifers. Alluvial aquifers are those which lie adjacent to and beneath streams and are composed of the materials deposited by the streams. Ancient stream channels which were carved by preglacial or interglacial streams and then buried beneath the current landscape by later deposits are called buried channel aquifers. Drift aquifers are those which are located in the uplands and are composed of materials deposited by glaciers. These surficial aquifers are not uniform or continuous in occurrence. They can be missing in some areas, patchy in others and thick and widespread in others.

Conversely, bedrock aquifers are normally continuous and underlie large areas. They are usually composed of sedimentary rocks occurring in layers and thus some areas will have two or more bedrock aquifers separated by confining layers. Portions of Iowa are underlain by three bedrock aquifers which slope from the northeast to the southwest: the Mississippian, the Silurian-Devonian and the Cambrian-Ordivician aquifers. Along the bottom edge of the Cambrian-Ordivician aquifers is a layer of rock known as the Jordan Sandstone which is quite productive, but occurs at a depth of 2,000 feet or more. In Northwest Iowa a bedrock aquifer known as the Dakota Sandstone is present and is found at a depth of only a few hundred feet.

Aquifers can also be defined as confined or unconfined. The differences between the two are that in an unconfined aquifer (also known as a water table aquifer) the pressure at the water surface is atmospheric and there is a confining bed only along the bottom edge of the aquifer. In a confined aquifer there is a confining bed on both the top and bottom and the piezometric head in the formation can be many hundreds of feet. The depth to the water table or piezometric surface is of great economic importance because this determines to a large extent how high the water must be lifted. The other factor which must be known is the drawdown at the well, the number of feet the original water surface or piezometric surface has been depressed when a pump is operating.

Also of great economic importance is the yield of each well, for this will determine how many wells must be dug or drilled in order to meet demands. Some wells will yield only a few gallons per minute while others will yield a few thousand gallons per minute. The difference lies in the characteristics of the aquifer, how many other wells are in the vicinity, the rates at which these wells are being pumped and their collective interference effect.

Municipal and industrial effluent

Whether municipal or industrial water is withdrawn from a surface water or ground water source, the effluent is almost always returned to a water-receiving body on the surface. Invariably, both the quantity and the quality of the effluent is reduced from its original condition. The quantity of municipal water is reduced due to food preparation, car washing and lawn and garden irrigation. Its quality is impaired due to the addition of human wastes, kitchen residues and laundry water. The quantity of industrial water is reduced both by being consumed by various manufacturing processes and by being evaporated when used for cooling purposes. Its quality is impaired due to the addition of chemicals, organic materials, heavy metals and/or heat.

There are seldom technical difficulties in upgrading the quality of effluent for a particular use. All that is required is the commitment of the various inputs (capital, land, labor, materials) to construct and operate the needed facilities. However, the direct reuse of treated wastewater as potable water has met with public resistance because of the psychological inhibitions to drinking reclaimed sewage. Denver is conducting a two-year public relations campaign to persuade its population to accept recycled effluent for direct reuse as drinking water because it is presently the most economical and politically feasible source of water to meet Denver's near future demands.

Potable water is just one aspect of the reuse of municipal and industrial effluent. Other present uses include sewer main flushing, irrigation of parks, golf courses and cemeteries, fountains, cooling water for energy production, ground water recharge and irrigation of farm land for forage and grain crops.

This last use has received increased attention since October 1977. Section 201(d) of PL 92-500 indicates that the Administrator should encourage the recycling of wastewater pollutants through the production of agriculture, silviculture and aquaculture products. In compliance with this, on October 3, 1977, Douglas Costel, current EPA Administrator, sent a policy memorandum to the Assistant and Regional Administrators stating that during consideration of land treatment for municipal facilities planning that "... if a method that encourages water conservation, wastewater reclamation and reuse is not recommended, the applicant shall be required to provide complete justification for the rejection of land treatment." In order to ensure that state and local requirements do not discriminate against land treatment, such as requiring secondary effluent quality prior to application, then the cost of the unnecessary facilities will not be funded by EPA. The following excerpts from the memorandum convey the scope, justification and impact of this new position:

> At the time P.L. 92-500 was enacted, it was the intent of Congress to encourage to the extent possible the development of wastewater management policies that are consistent with the fundamental ecological principle that all materials should be returned to the cycles from which they are generated. Particular attention should be given to wastewater treatment processes which renovate and reuse wastewater as well as recycle the organic matter and nutrients in a beneficial manner.
>
> ... Land treatment systems involve the use of plants and

> the soil to remove previously unwanted contaminants from wastewaters. Land treatment is capable of achieving removal levels comparable to the best available advanced wastewater treatment technologies while achieving additional benefits. The recovery and beneficial reuse of wastewater and its nutrient resources through crop production, as well as wastewater treatment and reclamation, allow land treatment systems to accomplish far more than most conventional treatment and discharge alternatives.
>
> ... Because land treatment processes contribute to the reclamation and recycling requirements of P.L. 92-500, they should be preferentially considered as an alternate wastewater management technology. Such consideration is particularly critical for smaller communities. While it is recognized that acceptance is not universal, the utilization of land treatment systems has the potential for saving billions of dollars. This will benefit not only the nationwide water pollution control program, but will also provide an additional mechanism for the recovery and recycling of wastewater as a resource.

Subsequent guidelines (The Bureau of National Affairs, Inc., 1978) indicate that the cost of land treatment can be a maximum of 15% greater than conventional treatment and still be the preferred alternative. The additional cost would be borne by EPA. The Clean Water Act of 1977 also emphasizes the evaluation and construction of land treatment systems.

In accordance with these laws, policies and guidelines, each facilities plan must include an evaluation of the following land treatment systems: slow rate (irrigation), rapid rate (infiltration-percolation) and overland flow (McAllister and Soderbeck, 1978). The slow rate system includes ridge and furrow, border strip flooding and surface spraying. The wastewater is treated as it flows through the soil with a portion taken up by the vegetation and the remainder percolating to the ground water. This system should be used in areas with a maximum land slope of 5%, a maximum anticipated ground water table 5 feet below the ground surface and have soils with a minimum percolation rate of 0.6 inches per hour. The design application rates on areas with perennial crop cover such as woodland, pasture, golf courses, etc. should not exceed 20 inches per year, 10 inches per month, 5 inches per week or 3 inches per day. The design application rates on areas with seasonal crops should not exceed 15 inches per year, 8 inches per month, 5 inches per week or 3 inches per day. In no case should the application rate exceed one-half the design percolation rate or be greater than 1 inch per hour.

The rapid-rate land application system is based on the percolation capacity of the soil with the wastewater moving into the ground at a relatively higher rate than either the irrigation or overland flow systems. This system should be used in areas where the wastewater can be contained in basins which are relatively flat to allow uniform distribution of the water over the surface, a maximum anticipated ground water surface ten feet below the ground and have soils whose permeabilities are described as moderately rapid to very rapid (2 to greater than 20 inches per hour). The basins may be covered with vegetation or have bare soil. A recovery system must be planned to withdraw the renovated water and reuse it for irrigation, for recreation or to augment streamflow. The recovery method could be an underdrain system, pumped withdrawal or natural drainage to a watercourse.

The overland flow system applies wastewater uniformly over relatively impermeable sloped surfaces which are vegetated. A portion of the flow percolates into the ground while the remainder is collected and reapplied to the land or discharged to a stream. This system should be used in areas where land slopes are in the range of 2 to 8% with the slopes being plane surfaces at least 200 feet long, a maximum anticipated ground water elevation at least two feet below the ground surface and have soils with a percolation rate no greater than 0.2 inches per hour.

Young (1978) has concluded that in many instances land application is a cost-effective method of advanced wastewater treatment, especially for smaller communities applying less than 5 mgd (million gallons per day). Aerated lagoons improve the cost effectiveness of land application and provide sufficient pretreatment. Chlorination may be used in addition to the aerated lagoons and does not add appreciably to the cost. Crops grown on the irrigated land produce revenue, the amount depending on which crops are grown. The increased cost of nearby land can be offset by the increased pumping costs to cheaper, more-distant land. Buffer zones around the irrigation site or the use of chlorination to pretreat the effluent can be effective in minimizing health problems. Application rates and application days per year are important in determining the volume of storage required. This adds to costs, especially in the northern climates where winter weather is a problem.

Numerous examples of the use of wastewater for irrigation can be cited. The city of Lubbock, Texas (Pilgrim, 1975) began irrigating a 200-acre farm in the early 1930's with their daily flow of 1.5 mgd. In 1975 their flow of 16 mgd irrigated 5,000 acres and supplied water to a public utility for cooling purposes. Nutrients in the effluent have eliminated the need for commercial fertilizers and yields have been 8 times those of dryland farming and 2 times those of land irrigated with Ogallala-formation ground water.

Muskegon, Michigan (Dobrzynski, 1975) irrigates 6,000 acres with 44 mgd of wastewater given secondary treatment with aeration and chlorination. Raw sewage enters the system at 325 ppm of suspended solids and 220 ppm of BOD; conventional treatment reduces these concentrations 70 to 90%. After filtration through the soil, the water collected in a series of drain pipes and wells has zero suspended solids and 2.2 ppm BOD. The soil also removes ammonia and phosphate; the corn is fertilized with the nutrients. The ammonia content, 9 ppm in the influent, is reduced to 0.04 ppm. Phosphates enter at 6.5 ppm and leave at 0.05 ppm. Operating costs of the $42 million system is $143 per million gallons, excluding the revenue from the corn. Comparable operating costs for conventional secondary treatment only are about $200 per million gallons.

Near Sioux Center, Iowa (Valmont Industries, Inc., 1975), the Sioux-Preme Packing Company is irrigating 72 acres with 20 million gallons of water used in processing 500,000 hogs annually using a center pivot irrigation system supplied with water treated in 4 lagoons. When asked about the cost of this system compared with other systems for treatment of packing plant wastewater the company president's reply was "No comparison. You start with a half million dollars and go up from there with other systems." Effluent from the slaughtering operation passes through a solids separator that skims off floating waste and then moves into two, one-quarter acre anaerobic lagoons. Wastewater from the anaerobic lagoons is passed over an iron filings bed to neutralize hydrogen sulfide and then into two holding lagoons with surface areas of 11.7 and 3.3 acres. The 9-foot depths in these two holding ponds provide sufficient volume to store the wastewater during the colder months of the year.

Storm Lake, Iowa (Roskopf, 1976) began a pilot project in 1975 which irrigates a 33-acre corn field with a center pivot system using water from an aerated lagoon. If the system works as well as expected, the city plans to expand the system at a cost of $3 to $6 million to irrigate about 3,600 acres. The city was put on notice in 1972 by the Iowa Department of Environmental Quality (IDEQ) to stop polluting Outlet Creek from Storm Lake. A new conventional treatment plant would have cost between $8 and $10 million so city officials began looking at other alternatives. The yearly effluent from the Storm Lake plant was about 1.2 billion gallons and irrigation use of the wastewater would provide benefits both in terms of increased yields and reduced needs for commercial fertilizer. "Analysis of the effluent shows that with a twelve-inch-per-acre application during the growing season, the fertilizer content would be about 100 pounds of nitrogen, 9 pounds of phosphate and 34 pounds of potassium."

The use of municipal wastewater for irrigation purposes could cause some instream problems in some localities. Since irrigation in Iowa is an almost 100% consumptive use of the water, problems may arise in the watercourse downstream of the treatment plant because historically, the effluent may have been the major portion of the flow in the stream at some times during the year.

Imported water

As noted before, imported water is a supplementary source of water and includes all primary and secondary sources located outside the region and transported to a point or points of use or uses inside the region. Since the beginning of the 20th century, the western United States has been involved in the large-scale transfer of water from one region to another. Most of these transfers have been for irrigation purposes but some have been for urban purposes. The most notable of these is the provision of water for the greater Los Angeles area in California. These efforts began with the Owens River Aqueduct and the Colorado River aqueduct and most recently with the California Water Project. Another recent example is the Arizona Water Project which is presently being constructed.

One common feature shared by almost all large-scale transfers of water is that they are controversial and cause social, political and legal battles. The Owens River aqueduct was completed only after many of the settlers in the Owens River valley actually were killed by an "army" from Los Angeles. The California Water Project was completed only after serious attempts by some state legislators to divide California into two separate states in order to thwart the movement of water from Northern California to Southern California. The Colorado River has long been the site of several legal battles between the western states as to who had the right to what percentage of the water in the river.

Legal controversy is almost a certainty in the future as the states in the entire Missouri River basin contend for the ownership of the water in the river for use in many locations adjacent to and away from the river for many beneficial purposes. Not only the surface water in the river but also the ground water in the alluvial aquifer adjacent to the river will be involved because large-scale pumping of the aquifer will induce flow from the river into the aquifer.

This point was raised by Dr. Merwin D. Dougal, Director of the Iowa State Water Resources Research Institute (letter dated August 30, 1977 to the Missouri River Basin Commission) concerning the prioritization of water resources research. He said:

> There is a need for both legal-institutional and social-economic research attention to the problem of allocating the waters of the main channel of the Missouri River. This is an item of concern both to the upper states as well as to the lower states. We have estimated that large scale irrigation of the Iowa flood plain lands, from Sioux City to Hamburg, Iowa, could utilize from 1-2 percent or up to 2 percent of the annual yield of the Missouri River at Sioux City, during an extended drought period. We understand that there are several counties in southeast Nebraska who are considering making some large transfers of water from the Missouri River Valley westward into the interior counties, presumably for irrigation purposes. A considerable amount of this could use up the 10 or 20 percent of the average annual yield of the river, as has been posed in the preliminary consideration of such transfers. It would appear then that large scale transfers would have quite an impact in the lower states, Nebraska, Iowa, Kansas and Missouri. Therefore, the continued studies regarding these allocation problems within the total basin structure need to be fostered. The decisions made at the last Missouri Basin Commission meeting to further support the transfers of water through the Garrison and Oahe diversion projects shows that there is continued stress in this allocation picture, and if some of this is added to the energy situation which has been presented previously, then we are observing a greatly increased use-stress on the waters of the Missouri. Additional technical studies may be needed also in this water allocation framework, so that as we look at water transfers away from the main valley we might better consider the possibilities of having additional surface water storage in the tributary valleys. Therefore, the

trade-off from surface vs ground water needs to be part of the water transfer and water allocation studies.

More controversy will arise when efforts are made on a smaller scale to transfer water from one watershed to another watershed, both being tributary to a major river such as the Missouri River. Controversy may also arise when efforts are made to transfer water from one portion of a watershed to another portion of the same watershed. Most transfers are from water surplus areas to water deficient areas. However, whether an area has a surplus or a deficiency of water is simply a function of the time and space demands on the available supply of water. Conditions could change in the future and an area which presently has a surplus may need it all in the future. Thus when water transfers are being planned, future needs and the point raised in the following paragraph will have to be taken into consideration.

Americans have always been free to live and work where they please. This one fact has been the cause of much of the "need" for water transfers. Americans have settled areas where they chose to live and as the population and demands for water increased, the water was brought to these areas. In the future the costs, both economic and environmental, of bringing water to the people may no longer be supportable and people may have to move closer to the sources of water. This movement will also have its economic and environmental costs and may result in the loss of some freedom of choice as to where we live. Other possible solutions to this problem are to intensify our efforts towards zero population growth and to intensify our efforts towards the conservation of water used for all purposes.

In Iowa, all water, both surface and subsurface, belongs to the state who holds it in trust for the beneficial use of all Iowans. Thus, any transfer of water from whatever source(s) to whatever location(s) for whatever purpose(s) must first receive the approval of the state in the form of a permit from the Iowa Natural Resources Council (INRC). The Council is given the duty and authority under Iowa law "to establish and enforce an appropriate state-wide program for the control, utilization, and protection of the surface and ground-water resources of the state." Therefore, the INRC must decide if these transfers are in the interest of the state and must evaluate the impacts and trade-offs involved in both allowing proposed transfers to be made and in not allowing any proposed transfer to be made (Iowa Code, 1979).

Desalination

There are four sources of salt water which can be desalinated: sea water, salt lakes such as the Great Salt Lake in Utah and the Dead Sea in Israel, rivers made salty by irrigation return flows such as the Colorado River and brackish ground water aquifers such as the Jordan Sandstone aquifer in southern Iowa. Desalination is classed as a supplementary source of water because of the costs involved in separating the salt from the water.

Ships at sea have used desalting for many years on a small scale to avoid the necessity of storing a large volume of fresh water aboard ship. Southern California has experimented with using the heat from a small nuclear power plant to evaporate sea water and then condense the steam to obtain fresh water. Several years of research data generated at the Yuma, Arizona desalination pilot plant have culminated in the onset of construction of a full scale 95 mgd desalting plant using the reverse osmosis system. The Yuma plant will treat agricultural return flows which are contributing high total desolved solids (TDS) loads to the Colorado River and limiting irrigation usage in Mexico. Based on October 1975 indices, the plant, billed as the largest desalting facility in the world, is expected to have a capital cost of $150 million with operation and maintenance expenditures running over $20 million per year (AWWA, 1977a).

In Iowa Laverentz (1974) has reported on the economic feasibility of desalting systems for municipal water supply. Water with less than 500 mg/l TDS is considered good quality water, from 500 to 1,000 mg/l TDS is considered fair quality water and over 1,000 mg/l TDS is considered brackish water. Iowa has 160 of its almost 1,000 communities with municipal water supplies having in excess of 1,000 mg/l TDS. Ten of these communities were selected for study representing conditions all over the state. Methods of desalting evaluated for each study community were reverse osmosis (RO), electrodialysis (ED), ion exchange (IX) and combinations of these. The most economical method in six communities was RO, IX in three and ED in one. Laverentz described these three methods and methods of brine disposal in some detail, repeated here.

Electrodialysis

Electrodialysis utilizes electrical energy to drive dissolved ionized solids through semi-permeable membranes, thus creating a purer residual water stream. Dissolved minerals are ionized; that is, each molecule is separated into positive ions (cations) such as Na^{+}, Ca^{++}, Mg^{++} and negative ions (anions) such as Cl^{-}, HCO_3^{-}, $SO_4^{=}$. The cations in solution are attracted to the negative electric pole (cathode) and the anions are attracted to the positive pole (anode).

The basic ED unit consists of an inlet water channel, two semi-permeable membranes, and two electrodes. One membrane is cathodic; it will allow the passage of positively charged ions, but is impermeable to negatively charged ions. The other membrane is anodic, and will allow only the passage of negatively charged ions. Each electrode is connected to a source of DC electrical energy. The brackish water is introduced between the cation-permeable and anion-permeable membranes and an electric potential is applied across the cell. Under the influence of the electric potential difference, cations move toward the cathode and anions toward the anode, passing through the charge-selective membrane enroute. The water between the membranes is thus gradually reduced in salinity and becomes the product water while water on the other side of the membranes becomes more concentrated with ions and becomes the waste brine.

Reverse osmosis

When saline waters of different concentrations are separated by a semi-permeable membrane, water from the less concentrated side will migrate through the membrane to the more concentrated side in an attempt to equalize the concentrations. The semi-permeable membrane allows water, but not dissolved solids to pass through it. This physical chemical phenomenon is known as osmosis. During osmosis the volume of the more concentrated solution will increase with a resulting pressure increase. There is an effective pressure gradient across the membrane in the direction of flow of the water which can be as high as 400 pounds per sq. in. as for sea water salt concentrations. This driving pressure for the flow of pure water is known as osmotic pressure. By putting sufficient hydraulic pressure on the more concentrated side, the osmotic pressure gradient can be overcome and an effective pressure gradient in the opposite direction can be imposed. This creates a flow of water in the direction opposite of normal osmosis thus it is referred to as reverse osmosis.

In RO desalting processes brackish water is pressurized and piped into the RO unit where relatively pure water diffuses through the semi-permeable membrane and becomes the product water, leaving a concentrated brine. The desalted product water is withdrawn at essentially atmospheric pressure while the brine remains at a high pressure.

Ion exchange

When a saline water is passed through a resin bed containing certain active chemical exchange sites, there can be an effective exchange of chemically equivalent ions. This is the principle used in water softening in which calcium and magnesium ions (the chief hardness ions) are exchanged in a zeolite or similar bed for sodium ions, which form more soluble salts. Water softening does not reduce the amount of dissolved solids but merely exchanges less desirable ions (those causing hardness) for more desirable ones.

When ion exchange is used for desalting both cations and anions must be removed. A cation exchanger is an acid resin that exchanges its hydrogen ions (H^+) for cations (Na^+, Ca^{++}, Mg^{++}, etc.) in the in-coming solution. The anion exchanger is a basic resin that exchanges its hydroxyl ions (OH^-) for anions (Cl^-, $SO_4^=$, HCO_3^-, etc.) in the in-coming solution. The hydrogen and hydroxyl ions are subsequently combined to form water.

As the conversion process continues, the resins progressively become saturated until finally they lose their ability to remove mineral anions and cations from the feed-water. When this point is reached, the conversion process must be halted while the resins are regenerated. Regeneration is accomplished by washing the resin beds with acids or bases that restore the original ion-exchange properties to the exchange media.

Brine disposal

The means of disposal of brine from a desalting plant is a very important consideration. The brine waste stream from a desalting plant contains 6,000-18,000 mg/l TDS depending on the raw water composition, degree of treatment, and product water recovery rate. Several means of handling this brine have been used for desalting systems.

Pond evaporation. This consists of pumping brine into lined ponds where solar rays evaporate it. Such a pond must have a surface area such that the net evaporation from it equals a year influent of brine, where the net evaporation is the total volume evaporated minus the total evaporation for the year. This method of brine disposal is not feasible for Iowa, however. The net evaporation is such that pond sizes required would be extremely large, also the ponds would have to have the capacity for storing the entire winter months brine flow because there would be essentially no evaporation during these periods.

Deep well brine injection. Deep well brine injection involves pumping waste brine back into the ground. Abandoned wells or new wells penetrating unused aquifers could be used for such a process. This method of brine disposal is especially applicable to areas which contain abandoned oil wells. The abandoned oil wells provide ideal locations for returning liquid into the ground. The old oil wells have the capacity to absorb the waste brine without the problem of polluting any resource. However deep well injection is not as suitable for Iowa. Here deep well injection would mean adding highly concentrated saline water into an aquifer thus lowering the quality of the water in the aquifer. Even though the aquifer into which the brine would be injected may not be used as a source at this time, sometime in the future it may be necessary to tap the aquifer. In addition, although an aquifer into which brine could be injected may not be used as a water source in the immediate area, the same aquifer may be a source of water in other areas. The flow of water in the aquifer could eventually take this lower quality water caused by brine injection to other areas where the aquifer is used as a source of water supply. In accordance with a policy determination by the Iowa Department of Environmental Quality, deep well brine injection was determined to be unacceptable as a means of waste brine disposal in Iowa.

Discharge into surface waters. Discharging waste brine along with city waste water into surface waters has a minimal effect on the surface waters. The effect of the high concentration of dissolved solids in the waste brine will be offset to a large extent by the reduction in dissolved solids of the municipal waste waters.

For this study we will assume brine effluents from all desalting plants, except Holstein, Oakland and Leon, will be piped to the discharged stream of the municipal waste water treatment plant for dilution with the waste plant effluent before piping to a surface stream.

The brine from Holstein, Oakland and Leon will be piped to the inlet of the waste water lagoon. (Leon does not presently have waste water lagoons but tentative plans call for the construction of such facilities.) In this manner

> no additional hydraulic load will be placed on the waste water treatment facilities, and the quality of the waste water discharged into surface waters will not change significantly from present waste water quality.

One desalination unit was installed at Greenfield, Iowa in the late 1960's. Today it is being discarded and a second reservoir added as a source of supply. Operational problems, economics and brine disposal problems are the key factors in its retirement. Desalination may not be an economic solution in Iowa.

Uses of Water

As noted in a previous section, Iowa law established a permit system for the regulation of the use of both surface water and ground water. However, this water law also established four nonregulated uses which require no permit. These are:

1. "The use of water for ordinary household purposes, poultry, livestock, and domestic animals."
2. "The beneficial use of surface flow from rivers bordering the state of Iowa."
3. "Existing beneficial uses of water within the territorial boundaries of municipal corporations on May 16, 1957."
4. "Any other beneficial use of water by any person of less than 5,000 gallons per day."

Beneficial use is defined in the law as "the application of water to a useful purpose that inures to the benefit of the water user and subject to his dominion and control but does not include the waste or pollution of water." With the exception of the above-noted uses, all uses of water of more than 5,000 gallons per day require a permit. The law specifically requires a permit for the following:

> 1. "Any municipal corporation or person supplying same, which increases its water use in excess of 100,000 gallons or 3 percent, whichever is greater, per day more than its highest per day beneficial use prior to the effective date of this act. Such corporation or person must make reasonable provision for storage of water when daily use is less than the amount specified above."
>
> 2. "Except for nonregulated uses, any person using in excess of 5,000 gallons of water per day diverted, stored, or withdrawn from any source of supply except a municipal water system or any other source specifically exempted by this act."
>
> 3. "Any person who diverts water or any material from the surface directly into any underground watercourse or basin. Provided, however, that any such diversion existing on the effective date of this act shall not require a permit if no waste or pollution is created."
>
> 4. "Industrial users of water having their own water supply within the territorial boundaries of municipal corporations shall be regulated when such water use exceeds 3 percent more than the highest per day beneficial use prior to the effective date of this act."

A water storage permit is required to store more than 18 acre-feet of water in a farm pond or any other artificial reservoir filled by natural runoff.

Thus in Iowa, all uses of water, with the exception of those listed above, are regulated by the INRC. These uses include urban domestic, municipal, commercial, industrial, rural domestic, livestock, irrigation, power generation, water quality, recreation, navigation, flood plain management and watershed management. Each of these uses is discussed in turn in the following sections.

Urban domestic

Iowa law gives highest priority to domestic uses of water. But this is the only guidance given as to how water should be allocated; no mention is made as to how other uses should be ranked or any methodology given to determine how water should be allocated during periods of drought. A recent study by the INRC (Task Force on Water Supply and Use, 1977) estimated average urban residential water use in Iowa as 46 gpcd (gallons per capita per day) with a range of 33 to 53 gpcd. These estimates were based on actual metered use in eleven of Iowa's larger communities. The purposes for which residential water is used are listed in Table 6.

Table 6. Average residential water usage for various purposes in the United States

Use	Percent of total
Toilet flushing	34
Bathing	26
Lawn sprinkling, car washing	15
Laundry	13
Dishwashing	4
Drinking, cooking	4
Personal	4

During the drought that plagued the United States in the past few years, residential customers were called on to conserve water. They did so in outstanding fashion. A glance at Table 6 shows several areas in which substantial reductions were possible. Toilets were flushed less often and weighted plastic bags filled with water or rock pebbles were used to cut down on the amount of water used per flush.

Television commercials and billboards in California proclaimed that "if its yellow, let it mellow; if its brown, flush it down." People took fewer and shorter showers and put devices in the shower head to reduce the rate of flow, then used this water to flush the toilet. They stopped watering their lawns and washing their cars. They washed only full loads of laundry and then used this water on their gardens.

The residents of Alameda County, California responded to a mandated cutback of 25% by reducing usage 57%. The citizens of San Francisco responded to a mandatory cutback of 25% with a 40% decrease in use. In hard-hit Marin County, California where penalty rates were tied to a mandatory 57% cutback, some additional moisture was evoked in the form of tears. The Martin Luther King school in Sausalito saw its normal two-month bill of $400-$500 skyrocket to $16,289 despite turning off all drinking fountains and using only recycled water for irrigating its lawns. The same was true in Ames, Iowa where penalty rates nine times normal rates caused problems for a few customers while overall use was reduced measurably.

Along with this very positive response for a reduction in use came a negative impact in the form of smaller revenues to the utility companies. Alameda County officials saw revenues fall to only 40 to 50% of normal. San Francisco's water department manager estimated that unless use returned to normal a 49% rate increase would have to be instituted in order to offset a projected $4.5 million decrease in revenue (AWWA, 1977b).

Municipal

The community itself can also be a large water user. In the course of performing its many functions for operating and maintaining the infrastructure of the community, the various city departments can use large quantities of water. The street and sewer departments will use water for street washing, dust control and sewer main flushing. The parks and recreation department can consume large volumes of water in irrigating golf courses, parks and other public grounds and filling and maintaining city swimming pools. The fire department will use whatever water is needed to fight fires. The schools and hospitals will use large amounts of water. Probably the largest user of water will be the city electric utility department as it uses water for both cooling and ash control. One estimate of the amount of water used for municipal purposes is 30% of total residential water use.

Commercial and industrial

Water use in the commercial and industrial sectors can be viewed in two ways: (1) on a per capita or per unit basis or (2) on the gross amount of water used in a particular commercial enterprise or in a particular industrial sector. Neither gives a completely satisfactory answer by itself as illustrated in the following tables. Table 7 outlines typical water usage in various types of commercial buildings (offices, hospitals, stores and hotels) (AWWA, 1978) while Table 8 lists the amounts of water necessary to manufacture several industrial products (Linsley and Franzini, 1972). Table 9 lists the total

Table 7. Typical building water usage

Type of structure	Average consumption		Percent of total use for	
	gal/ft^2/day	l/m^2/day	Flushing	Cooling
Large office	0.22	8.8	30-50	25
Small office	0.21	8.5	50-80	25
Hospital	0.66	26.9	20-30	30-40
Department store	0.53	21.7	15-35	30-50
Hotel	0.52	21.1	20	—

Table 8. Use of water for selected industrial products

Product	Unit of production	Typical water use	
		gal/unit	l/unit
Beer	Barrel	470	1,780
Canned apricots	Case of #2 cans	80	300
Canned lima beans	Case of #2 cans	250	950
Coke	Ton	3,600	13,600
Oil refining	Barrel	770	2,900
Paper	Ton	39,000	147,600
Leather (tanned)	Ton	16,000	60,600
Rayon hosiery	Ton	18,000	68,100
Woolens	Ton	140,000	530,000
Steel	Ton	35,000	132,500
Electricity-steam	Kw-hr	80	300

estimated volume of water used in Iowa in 1970 for all purposes (Miesner, 1975). All three tables present useful information but several questions could be asked about each. Barnard and Dent (1976) have assumed that in areas of the commercial sector such as communications, radio and TV broadcasting, finance and insurance and areas of the manufacturing sector such as apparel, printing and publishing, ordnance and miscellaneous fabricated textile products where water

Table 9. Estimated annual water usage in Iowa in 1970

Sector	Intake water billion gallons	Percent of total use
Power plant cooling water	864	72.0
Municipal[a]	96	8.0
Agriculture		
Livestock	42	3.5
Crop irrigation	25	2.1
Rural domestic	17	1.4
Mining, sand and gravel	5	0.4
Manufacturing		
Food products	68	5.7
Foundries	25	2.1
Machinery	22	1.8
Chemicals	17	1.4
Cement, concrete, plaster	12	1.0
Others	7	0.6
Total	1,200	100.0

[a]Includes public, residential, commercial and institutional.

use is only for personal purposes of the employees that a value of 23 gpcd be used, half of the urban domestic daily value.

All of the above is good, useful information but yet it does not give the complete picture. Knowing the per unit or per capita use of water is fine, but how many square feet of office space or hospital space are there? How many barrels of beer, cases of lima beans and tons of woolens are produced? A total of 1,200 billion gallons of water is difficult to visualize. It is about 36,800 acre-feet which is a depth of about one-hundredth of an inch over the entire state of Iowa. Do we consume all of the 1,200 billion gallons of water per year? Here we need to define four terms (Barnard and Dent, 1976).

1. Intake water. Water intake is the water withdrawn from the ground, stream, lake or reservoir for use in any industry sector or domestic residential use.
2. Gross water used. Total water intake plus recirculation. Water may be recycled a number of times in a production process for such activities as cooling, cleaning or transporting materials.
3. Water discharged. Water used and returned to a body of water where it may be used again.
4. Consumption. Net depletion of water through evaporation or in a form not returnable to a body of water to be used again. Consumption includes water incorporated into products and water essentially consumed such as in the case of water consumed by livestock or used for irrigation.

From these definitions we can conclude that the 42 billion gallons used for livestock and the 25 billion gallons used for irrigation is consumed. But what portion of the 68 billion gallons is incorporated into the beer, lima beans and other food products? About 99% of the 864 billion gallons used for cooling purposes in energy production is discharged and can be used again. This is almost three times as much as is used for all other purposes. Much of the power generation for Iowa takes place along the Missouri and Mississippi River and so is not available presently for use again in the interior of the state. Recent institutional rules and regulations have stated a preference for cooling towers rather than once-through cooling due to environmental considerations. Towers are expensive and in addition to the direct increase in consumptive losses shown in Table 10 more water is needed for blowdown purposes and must be upgraded in quality (more expense) before it can be discharged to receiving waters.

Table 10. Water use in electric power generation for selected systems, gallons per kilowatt-hour[a]

Type	Intake	Gross	Discharge	Consumption
Once through cooling	51.65	51.65	50.93	0.72
Cooling towers	1.18	59.00	0.00	1.18

[a]After Barnard and Dent (1976).

Kollar and Brewer (1977) have commented on the impact of industrial water use on public water supplies based on their analysis of the Second National Assessment of Water and Related Land Resources by the U.S. Water Resources Council. They concluded that although reliance on public water supplies will increase in the future, the growth of recycling will reduce industrial water use. In 1975 U.S. manufacturers had a gross demand of 120 bgd (billion gallons per day), however, they withdrew or purchased only 42 bgd. The difference of 78 bgd represented the demand met by recycling of water and treated effluents. About 12,000 large water-using plants accounted for about 99% of gross demand and 98% of total intake. Municipal plants provided them with about 4.7 bgd. On the other hand, municipal plants provided essentially 100% of the intake and gross demand of the 290,000 small water-using manufacturing plants. Their demand was about 520 mgd.

The Second National Assessment projects gross water demand for manufacturing to triple by the year 2000 but because of the large projected increase in recycling, water intake is projected to decline to 20 bgd in the year 2000 from the 42 bgd in 1975. Rather than declining in volume, water supplied to manufacturers by municipal utilities is forecast to increase 30 to 70% during the next 25 years. This is due to the following factors:

> Since EPA has mandated advanced treatment of discharges, water costs can be reduced considerably by heavy recycling of treated effluents combined with the purchase of make-up water, as opposed to advanced treatment of once-through discharges; municipally supplied water is dedicated most often to classes of internal use least capable of being met by recycled water; because water-intake requirements per plant and per unit production will be reduced greatly by the substitution of recycled water in other classes of use, water obtained from municipal water systems will be priced more competitively on a unit-cost basis relative to the costs of self-supplied water (Kollar and Brewer, 1977).

This same tripling of gross water use between the years 1975 and 2000 is forecast for Iowa by Barnard and Dent (1976) as shown in Fig. 9. They also projected an additional quadrupling in the 20-year period from 2000 to 2020. Figure 9 is somewhat misleading in that it indicates that water intake will become greater than the average annual surface runoff in about the year 2010. As mentioned before, much of Iowa's intake occurs on the Missouri and Mississippi Rivers. Their present average annual runoff is 23,200,000 acre-feet at Sioux City on the Missouri River and 24,400,000 acre-feet at McGregor on the Mississippi River (U.S. Geological Survey, 1978). Thus the total average annual surface runoff flowing through and past the state of Iowa is about 66,000,000 acre-feet per year. This represents

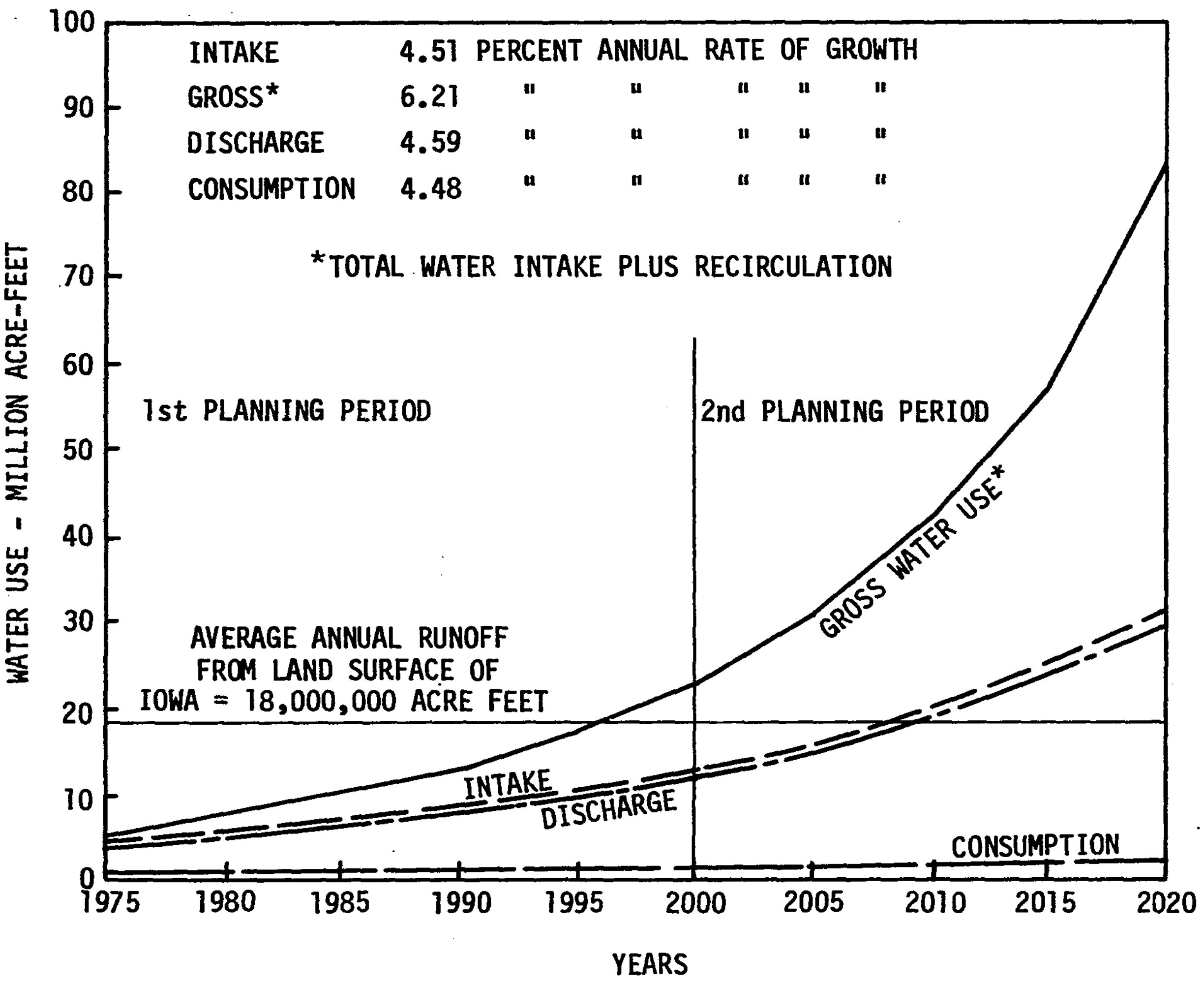


Fig. 9. Summary of projections of water use in Iowa, 1975-2020 (after Barnard and Dent)

25+ acre-feet per capita annually for Iowa, although not all can be demanded or used by Iowans, but must be shared with other states.

Rural domestic

Rural is defined in this section as those areas occupied by people not classified as "urban" by the U.S. Bureau of the Census. Its definition of "urban" is "all persons living in (a) places of 2,500 inhabitants or more incorporated as cities, villages, boroughs (except in Alaska) and towns (except in the New England States, New York, and Wisconsin), but excluding those persons living in the rural portions of extended cities; (b) unincorporated places of 2,500 inhabitants or more; and (c) other territory, incorporated or unincorporated, included in urbanized areas." The Farmers Home Administration (FmHA), the federal agency which funds rural water supply systems, is authorized to define "rural" as all places with less than 10,000 inhabitants. In Iowa this would include all rural areas and almost all of its nearly 1,000 cities.

In the past people living on farms and in small towns have had to contend with water supplies which many times were deficient in both quantity and quality. This fact is amply demonstrated in the following excerpts from a report on drinking water supplies in rural America by the National Demonstration Water Project (NDWP, 1977). The problems that are described have several social, economic, political, financial, physical, legal and institutional overtones.

> These two counties of Windham and Windsor, located in Southeastern Vermont, have the highest number of homes without adequate water or plumbing in Vermont. There are cases in these two counties of contaminated well and

surface water, citations against families for bad septic systems, broken down systems, and cases where there was no source of water at all for houses and trailers. Trailers are a particular dilemma. In the community of Bellows Falls, there is a trailer park with thirty families. Four months out of the year, they cannot drink the water because it is contaminated (it is surface water).

The community of Lyeffion, located in Conecuh County, Alabama, has a population of about 160 families. Few of these people can afford deep wells and concern has been expressed by local citizens about the health effects of bad water. The community has an elementary school and a high school, both of which are continually being condemned by the local and state health officials. Lack of an adequate supply of water — many of the residents have to haul water from springs or streams — has also led to other health problems. What little water they do haul must be used for drinking. The lack of water for bathing has led to spread of infection of skin diseases and virus diseases.

The Big Sioux Water Association — located in Moody, Lake, and Brookings Counties in South Dakota — is a non-profit association serving approximately 900 homes. Many people in this area who are not presently served by central systems are hauling water because of inadequate supplies of ground water. To deal with this problem, the state of South Dakota has appropriated money to provide grants to rural areas that qualify for FmHA financing. To finance the Big Sioux Association, $300,000 was obtained from the state and $200,000 from FmHA in grant money. This was coupled with a $2,300,000 loan. The system is presently operating at capacity.

Residents of the small rural community of Bald Knob, located in Frankfort County, Kentucky, have tried for 15 years to obtain running water for their homes, so far without success. Some residents have water hauled to their homes at a cost of $7 to $10 per truckload. Others, who cannot afford to pay the hauling cost, haul water themselves. Still others capture rain water from the roof tops and store it in outdoor cisterns. A majority of all dwellings in Bald Knob are without clean drinking water or indoor plumbing. The nearly 100 persons who live in Bald Knob are forced to bathe in galvanized wash tubs, boil drinking water, and use outdoor bathrooms.

The community of Northboro, in Page County, Iowa, has been trying to get water service for at least two years, and it still has a long wait ahead, even under optimum circumstances. The community has requested a connection with Page County Rural Water District #1 and in March of 1976 filed another application with FmHA (a previous proposal was deemed too expensive and was rejected). Even with a 50 percent grant, which is unlikely, the minimum monthly bill would be $11.20 (based upon the debt service). Assuming a water use of 4,000 gallons per month, the average monthly bill would be $14.20. Over 25 percent of the county's population is below the poverty line, and median family income is $6,778. So far the mayor has not heard from FmHA concerning Northboro's application.

The small community of Matadore, Texas, located in Motley County, will have to meet the new interim Safe Drinking Water Standards in the Spring of 1977. Like many small Texas towns this community may encounter difficulties or added expense in meeting these new regulations. For example, one resident was told that he would have to make a percolation test on his septic system. The added expense made it more difficult for him to build his home and sewage disposal facilities. In another instance, a small water development on Lake Whitney may be required to have a certified operator on duty and may also be required to take regular water samples. This development serves only 15 customers and is used only a few weeks a year.

The community of Seboyeta, New Mexico, located in Valencia County, is made up of mostly elderly, low-income families, with some young people who are finding work in the new uranium industry. During the recent inspection of the water system, the Environmental Improvement Agency of New Mexico found that the water serving the 57 families contained high levels of arsenic and selenium. High levels of coliform were also found. The community obtained its water from a spring, which produced only 7 gallons of water per minute; and from an open stream, from which water is carried through a small plastic line to a storage tank. The stream is in constant danger of being contaminated from animals, and the community has been informed that the raw water from the stream is unfit to drink.

Mayor Harry Palmer of Mount Auburn, Iowa estimates that three-fourths of the wells that provide drinking water for Mount Auburn's 200 residents are yielding water "that's not fit to drink." Each of the approximately 80 homes in Mount Auburn has its own well, and all but a handful are "shallow 60-footers," the mayor said. Some are going dry because of the low water table. The others have such high sulfur and iron contents that the taste and smell makes the water undrinkable. Palmer said the water situation here gets worse each year. He said the water quality has deteriorated throughout the 15 years that he has lived in Mount Auburn. Today, the people with bad wells are hauling water from the few wells that are still good.

Marquette County, located in the upper peninsula of Michigan, did not have a health department until 1966. In 1967, the Health Department tabulated the results of the individual water wells sampled in the eighteen townships. From this sample, it was found that 25% of the wells were bacteriologically unsafe for drinking. In one community, 120 homes were found with particularly severe problems of contaminated shallow wells and multiple sewage failures. These homes were owned or rented primarily by low-income families and retired people.

There are seven rural water systems in Lauderdale County, Mississippi (some of the best rural systems in the state), but there is only one person available to work each system. In most cases, the people who do the maintenance and operations are volunteers, who work a maximum of probably five hours per week on the systems. This is the case for much of Mississippi. There is an insufficient amount of funds available for O&M on the existing systems. This has become of special concern with the passage of the Safe Drinking Water Act. By 1977, communities must comply with the act or face fines. Many of these communities do not have the certified personnel necessary to insure that the systems would meet the new standards (e.g., chlorinators need to be maintained properly by trained personnel in order to insure a minimum water quality).

Four towns in Ripley County, Indiana, are in the process of obtaining FmHA financing for an integrated water system. Up to this point they have been relying on poor quality individual systems, and generally have outgrown their water supplies. The system will be centered at Osgood, which will sell water to the other three towns. The reasons for this upgraded system include the following: (1) imminent implementation of the Safe Drinking Water Act which will force small towns to upgrade and expand, (2) low density populations and poor water supplies resulting in high rates, and (3) the inability or unwillingness of present systems to expand (owing to the impact on rates). Average monthly bills will be about $16.

A 1974 study by the Iowa Farm Bureau Federation (Anderson, 1974) found that similar conditions exist in Iowa as shown in the following excerpts from the study.

> The most severe water problems were reported in the southern three tiers of counties. Hamilton County also reported a large number of farmers hauling water, mainly because of poor quality.
>
> Underground water-bearing formations in Southwest Iowa have a limited supply of water. Many shallow wells in this area are contaminated with nitrates and bacteria while many of the deeper wells often contain high mineral contents.
>
> In Northwest Iowa, Lyon, Sioux, O'Brien, Clay, Cherokee, Buena Vista, Osceola and Sac Counties reported large numbers of farmers hauling water regularly with as many as three-fourths of the farmers in the far northwest counties hauling water during dry years. The survey showed that at least one person is fully employed just hauling water to farmers in some cities located in these counties. Some city water supplies are equipped with coin operated meters to measure purchased water.

The recent drought in the midwest has also added to the water supply problems of rural America. A symposium on the drought in mid-America was a featured part of the 22nd Quarterly Meeting of the Upper Mississippi River Basin Commission held May 9-10, 1977 in St. Louis, Missouri. Some of the major impacts mentioned by the speakers were as follows: (1) there were reduced crop yields and harvest and crop failures in hundreds of counties; (2) thousands of shallow domestic wells went dry; (3) rural and farm residents numbering in the tens of thousands had to haul domestic and livestock water supplies; (4) many towns and villages had to haul municipal water supplies; (5) normal municipal water services, including fire reserves, were threatened in several small cities; (6) there was widespread conservation and rationing of community water supplies; and (7) there was increased interest in irrigation and state agencies were besieged with requests for irrigation permits.

Given the foregoing statement of the water supply problem in rural areas, how should this problem be remedied? One step towards its solution was the passage of the Safe Drinking Water Act (PL 93-523) on December 16, 1974 whose purpose was "to assure that the public is provided with safe drinking water." The Act empowered the EPA to develop a set of national drinking water standards which would apply to all community water supplies. A community water supply was defined as "a system for the provision of piped water for human consumption, if such water has at least 15 service connections or regularly supplies water to at least 25 individuals. Such term includes any water supply, treatment, storage, and distribution facilities under the control of the operator of such system."

As an indication that Congress intended that safe drinking water should be available to all Americans, rural as well as urban, Section 3(a) of the Act stated:

> Sec. 3(a) The Administrator of the Environmental Protection Agency shall (after consultation with the Secretary of Agriculture and the several States) enter into arrangements with public or private entities as may be appropriate to conduct a survey of the quantity, quality, and availability of rural drinking water supplies. Such survey shall include, but not be limited to the consideration of the number of residents in each rural area —
>
> (1) presently being inadequately served by a public or private drinking water supply system, or by an individual home drinking water supply system;
>
> (2) presently having limited or otherwise inadequate access to drinking water;
>
> (3) who, due to the absence or inadequacy of a drinking water supply system, are exposed to an increased health hazard; and
>
> (4) who have experienced incidents of chronic or acute illness, which may be attributed to the absence or inadequacy of a drinking water supply system.

How should we define "quantity, quality and availability?" The NDWP report (1977) examined this question and answered it in the following manner.

> Congress asked that the "quantity, quality, and availability" or rural water supplies be surveyed. Quantity and quality are not difficult to define since they can be identified and measured in terms of hard figures — so many gallons per minute, so many parts per million of a given chemical or mineral or bacteriological contaminant, etc. To be sure, there is disagreement regarding how much quantity or what type of quality is acceptable or nonacceptable in a water supply, but there is little disagreement regarding what is covered by the terms themselves. One task of the rural water survey, therefore, is to determine by appropriate sampling and testing procedures what the quantity and quality of rural water supplies are.
>
> "Availability" is a different matter. Some sort of water supply is obviously available to all living persons. The Congressional use of the term implies that some sort of qualitative judgment will be made about the adequacy of the water supplies that are available. It also implies that the mere presence or absence of water, or even of a facility, does not mean that a water supply is available. For example, if someone lives on the bank of a river, a water supply is, technically, available. But if the water cannot be used without treatment, and if there is no way to treat the water or the resident cannot afford the treatment, the water supply is not available in any reasonable sense.
>
> Nor is availability synonymous with good quantity and quality. If a family drives 30 miles to obtain a sufficient quantity of bottled water for household use, the water may be high in quality, but it is difficult to call this an available water supply.

The "what type of quality" is answered by the new national drinking water standards set by EPA. This quality of water should be available to everybody, whether they live in a large city or on an isolated farm. The "how much quantity" cannot be defined so precisely. Two items need to be discussed: the uses to which the water will be put and the adequacy of the supply during extended drought periods. "It is questionable if, in a rural area, all demands should be met during the most severe drought conditions. There has to be an economic tradeoff between the cost of designing and building a system with no chance of failure and the willingness of the consumer to ration water and reduce his consumption during the very infrequent events" (Austin, Rossmiller and Wehrmann, 1976). The uses will be discussed in the next paragraph. Another aspect of "availability" is the cost of the water to the user. A water supply with adequate quantity and quality may be present but if the cost of the water is beyond the user's ability to pay, then that water supply is not available to the consumer unless some sort of subsidy is instituted.

What uses should be included in a rural water supply? Water which is actually drunk must obviously be included. Normal home usage also includes washing clothes and dishes, bathing, cooking and cleaning. Most farms also have small or large gardens which must be watered. People with adequate water supplies also sprinkle their lawns and wash their cars. Another use is for fire protection. The FmHA encourages fire protection capacity in the community systems it funds. Another frequent use of water in rural Iowa is livestock watering. The rural water systems in Iowa funded by FmHA thus far have included water for cattle, hogs and poultry.

Most or all of the above must be included in order to provide rural residents with an "adequate" water supply. The NDWP report had the following to say on this subject.

> All persons, obviously, have some facility for obtaining drinking water. The question is whether they are adequate. Adequacy in America's rural areas can be determined by comparing the situation there with the situation elsewhere, such as that in America's urban areas or in the rural areas of other countries. Or a more abstract standard can be applied if it is a standard that is totally or largely socially acceptable. For example, it can be asserted that all persons, rural or urban, should have a water supply that is safe (not injurious to health), plentiful (sufficient for household purposes), and convenient (not far away or otherwise difficult to use). Probably most Americans would subscribe to this standard as an objective, though they would disagree on how to achieve the objective. Meeting that standard would mean not only the presence of a good water supply but also effective indoor plumbing, since most people, certainly if they are talking about their own needs, would regard this as necessary to meet the "convenience" test.

One definition of an adequate rural water supply which has been presented is a supply in which "there was a sufficient quantity of water available to meet minimum requirements during severe drought periods, the water was piped into the home under pressure, the water would meet the national interim primary drinking water standards, and the cost was within the ability of the user to pay" (Austin, Rossmiller and Wehrmann, 1976).

Two impacts of the provision of adequate water supplies to rural consumers under the 1974 Safe Drinking Water Act must be mentioned. One is an economic impact and the other concerns land use. As rural water systems expand and become more prevalent, larger and larger segments of the rural areas in each state will have access to adequate water supplies. This proliferation of rural water systems could lead to the unwise spread of rural subdivisions, individual residences and other nonfarming activities unless strong land use controls are instituted. The economic impact is contained in the following excerpt from an article by Kimm on the effects of EPA regulations (Kimm, 1977).

> Among the major tasks facing EPA in the months ahead is the need to understand better the cost and economic impact of the new regulations. Of special concern are the problems facing small systems encountering water quality problems. Where they cannot reasonably develop a higher quality alternative source or interconnect to some nearby system, they may face unrealistic per capita costs to upgrade treatment. While variances and exemptions offer some flexibility in the short run, the true magnitude of the problem needs to be assessed as quickly as the system monitoring data becomes available. The Congress is also concerned about this matter and legislation currently before the House would mandate a detailed study of costs as well as an assessment of how costs might be funded, including the strengths and weaknesses of various types of federal subsidies.

<u>Livestock</u>

As indicated in the previous section, water for livestock must sometimes be hauled by truck because of insufficient quantities and qualities of the water source. The amount of nitrates and total dissolved solids in a water supply adversely affect cattle and hogs just as they have an adverse effect on humans. A study by Rossmiller for Page County, Iowa (Rossmiller, 1976) indicated that the annual volume of water needed for cattle and hogs exceeded the volume of water needed by the entire rural population of the county which included all small towns, rural residences and farms. Page County is not one of the major cattle or hog producing counties in Iowa.

There are four possible sources of water for livestock: ground water, surface water in streams, surface water in farm ponds and water from a rural supply system which may have its source in either surface or ground water. The ground water resources in many regions of Iowa are deficient in both quantity and quality. The quality of its surface water has also been degraded by both point and nonpoint sources of pollution. Streamflow is highly variable and the low-flow characteristics of many streams in Iowa are such that during those months of the year when rainfall is low, the streams are dry or carry very little flow. This is especially true for those streams in the western two-thirds of Iowa. During drought periods, many streams have zero flow for a period of several months. The same is true for farm ponds. Those ponds whose original volumes were not large enough and those whose volumes have been reduced due to the deposition of sediment tend to dry up during mild as well as severe droughts. The recent spread of rural water systems, which include water for livestock, has alleviated these conditions for farmers involved in these systems. Some farmers claim that, because of the better water quality in these systems, a larger percentage of their animals are reaching maturity, but no research studies have yet been done to verify these claims (Gieseke, 1972).

The INRC has jurisdiction over all water resources in Iowa and issues permits to withdraw water from streams. During low-flow periods, holders of permits to withdraw water from streams can be ordered to stop these withdrawals. This is done whenever the flow in the stream is at the 84% point on the flow-duration curve, i.e., the protected flows are those flows which will be equalled or exceeded about 84% of the time during the April 1 to September 30 period. Recession curves have been derived for the streams in Iowa and when flow conditions are such that the 84% level will be reached in about a week, permittees are notified in order to give them time to make other arrangements for water. Thus, at the exact time when water need is the greatest, some livestock raisers may be cut off from their source of supply.

The total water needs of livestock in Iowa are large since many counties in Iowa market between 50,000 and 100,000 cattle and over 200,000 hogs every year. Combining these numbers with the daily consumptions shown in Table 11 give an idea of the total volumes involved. Table 11 was taken from the projections of future water use in Iowa for the State Water Plan by Barnard and Dent (1976).

Table 11. Daily water requirements for various species of livestock[a]

Specie	Gallons of water per head per day
Cattle	
All cows	10.0
Other cattle	6.0
Hogs	
Sows	5.0
Other hogs	3.5
Sheep	
Ewes 1 year +	1.5
Other sheep	1.0
Horses (all kinds and all ages)	8.0
Poultry	
Hens and pullets of laying age	0.05
Turkeys and broilers	0.10

[a]After Barnard and Dent (1976).

Irrigation

In those regions of the United States where annual rainfall is low, irrigation must be used to sustain agricultural production. Barnes (1973) estimated that over 34 million acres were being irrigated in the 18 western states and that these acres accounted for about 10% of the total crop land in the United States. On much of this acreage from 50 to 100% of the crop production is dependent upon the application of irrigation water. In a study by Williams and Chancellor (1974), they found that for nine crop types grown extensively in California, the application of irrigation water was by far the single most important factor affecting crop production. They estimated that a 50% reduction in the amount of irrigation water applied would result in a 49% yield reduction for the nine crop types considered with over a $1 billion loss in crop value.

The situation in the midwest is much different. Because annual rainfall amounts are much higher than in the west, only supplemental amounts of water are needed to ensure high yields. The need in the midwest is to make sure the soil profile has sufficient water prior to planting, at critical stages during plant growth (such as the silking stage of corn) and to reduce stress due to high temperatures and low humidity. The students majoring in crop production at Kirkwood Community College in Cedar Rapids, Iowa found this out as evidenced by the following excerpt from a newspaper article which appeared in the Des Moines Register (Muhm, 1977).

> Students at Kirkwood Community College in Cedar Rapids have found out how much a couple of timely rains can mean to a farmer's pocketbook. The college's corn crop averaged 115 bushels per acre — and a net profit of nearly $70 an acre — last year. The 1975 crop was only 89 bushels an acre, with a loss of nearly $10 an acre, despite the fact that rainfall was nearly as much as in 1976.
>
> Jim Hynek, a Kirkwood agronomist, said this illustrates how important it can be for farmers to have "timely rains." He said his records show that the big difference was that

> although the total rainfall at the Kirkwood field was just slightly more in 1976 than in 1975, the totals during June and July was 5.8 inches last year and just over 4 inches in 1975.

Well-timed applications of irrigation water can replace the rains which do not fall when needed. The water can be applied using one of several methods as evidenced by the ways in which over 1.9 million acres of crop land in Oregon were irrigated in 1975 as documented by Shearer (1975).

> Gravity irrigation is the predominant type, covering 1,120,000 acres. Hand move sprinkler systems are the second most popular type, irrigating 500,000 acres, while side roll sprinkler systems account for 175,000 acres, center pivot sprinkler systems for 110,000 acres, solid set sprinkler systems for 20,000 acres, big gun sprinkler systems for 12,000 acres, and trickle irrigation systems for 1,000 acres. In many areas of the state the water source is surface water, developed by government-financed irrigation projects. When ground water is the source, or when the surface water supply lies below the land to be irrigated, more than 99 percent of the pumping plants used to lift irrigation water are powered by electric motors.

Good descriptions of the various irrigation systems used in the midwest were presented by Eisenhauer and Fischbach (1976) at an irrigation short course held in Lincoln, Nebraska. These descriptions are given below.

> Skid-tow line sprinklers
>
> The system consists of rigidly coupled laterals connected to a mainline by flexible joint. The mainline is positioned in the center of the field. Laterals are towed end-ways over the mainline from one side of the mainline to the other by a tractor. The mainline should be buried or partially buried to protect it from wear and abuse when moving the lateral over it. If it is not buried, the mainline can be taken apart and moved from one side of the lateral to the other.
>
> Although it can be longer, the maximum length of the lateral is recommended to be not over 1,320 feet. Outriggers keep the lateral in an upright position. The system works well in

most crops. It is best adapted to square fields and nearly level to slightly rolling terrains, and to soils with medium to low intake rates. It is not well adapted to the shallow sandy soils which require irrigation every three to five days. Some sandy soils may also cause excessive wear on the pipe. Operating pressures are about 40 to 60 pounds per square inch.

Center pivot sprinklers

The center pivot sprinkler systems are automatically propelled through pneumatic, mechanical, hydraulic or electric power. They move around a center pivot to irrigate a field. The system is engineered to apply water at a fairly uniform rate throughout the length of the line by increasing nozzle size progressively from the pivot to the end of the line. The center pivot system will apply water in amounts of less than 1/4 inch up to two inches per acre per revolution. The amount of water applied is determined by the rate of travel of the system and the amount of water pumped through the system. Customary length of the system for a quarter section of land is 1,285 feet to 1,299 feet. Because the center pivot sprinkler irrigates in a circle, approximately 128 to 134 acres can be irrigated by it in a quarter section of land. Shorter and longer length systems are available. Center pivot sprinkler systems are well adapted to a sandy soil with flat to gently sloping topography. Operating pressures are about 60 to 80 pounds per square inch. The center pivot sprinkler system is growing very rapidly in use. Its ability to irrigate frequently and its automation feature has made it a favorite for large farming operators on the less expensive sandy soils. Recent developments to increase the rate of travel and flexibility of the system have made them more adaptable to medium textured soils and to steeper slopes.

Traveling guns

The traveling gun systems use a cable and winch arrangement powered with a water motor or an internal combustion engine to propel itself across a field. A 660 foot flexible hose is used to connect the system with the mainline which allows for travel distances up to 1,320 feet. Travel lanes are spaced from 250 to 300 feet which allows the system to cover from 7.6 to 9.1 acres per set. Particularly adaptable to various crop heights, variable travel speeds, odd-shaped fields, and rough terrain, the traveling gun requires a moderate initial investment, medium labor, and high operating pressures.

<u>Gated pipe with a reuse system</u>

This system consists of a solid set of gated pipe along the upper end of the irrigation and a reuse system to pick up the runoff water and enough pipe to put it back into the system. The slope of the field should not exceed 1.0 foot per 100 feet or less than 0.2 foot per 100 feet. The system may or may not utilize some buried pipelines.

This system is adaptable to soils that can be leveled economically to a slope of less than 1.5 percent, and soils that have medium to low water-intake rates. This type of surface irrigation system can be operated manually or completely automatic. Operating pressures usually do not exceed 9.0 pounds per square inch at the pumping plant and less than 1.0 pounds per square inch at the gates on the gated pipe. Water application efficiency can be as high as 85 to 92 percent with proper management.

Some of the older irrigation methods were not described above because there has been an increasing trend away from the use of labor to a greater dependence on technology, mechanization and automation. Here again we are substituting capital and energy for labor. The labor requirements for the four systems described above are listed in Table 12. Application efficiencies are 75% for the skid-tow and traveling gun methods, 85% for the center pivot system and 70% for the gated pipe surface method. However, as stated above, the application efficiency for the gated pipe method can range from 85 to 92% with proper management.

<u>Costs</u> The costs of these four systems are shown in Tables 13 and 14 and were taken from the study by Eisenhauer and Fischbach (1976). The costs for the center pivot system are based on irrigating 130 acres out of a 160-acre quarter section as shown in Table 13. Recent improvements have incorporated an end gun in a corner system so that now a center pivot can reach 150 of the 160 acres. In addition, the

Table 12. Labor requirements for various irrigation distribution systems[a]

Type of system	Fixed labor per acre per year (hr)	Variable labor per acre per irrigation (hr)	No. of irrigations	Total labor per acre
Gated pipe with reuse (not solid set)	0.23	0.42	4	1.9
Gated pipe with reuse (solid set)	0.23	0.20	4	1.0
Skid-tow	0.23	0.21	5	1.3
Traveling gun	0.23	0.24	7	1.9
Center pivot	—	—	10	0.5

[a]From Eisenhauer and Fischbach (1976).

Table 13. Initial costs and annual fixed costs for various irrigation distribution systems[a]

Item	Expected life	Gated pipe with reuse	Skid-tow	Traveling gun	Center pivot
Well — 150 feet	25 yrs.	3,300	3,300	3,300	3,300
Pump	18	4,100	4,700	4,900	4,700
Diesel power unit	12	5,000	6,500	7,000	6,500
Gearhead	12	1,000	1,250	1,250	1,250
Fuel tank	20	375	375	375	375
Pipe	15	2,925	4,335	2,595	—
Distribution system[b]	15	13,000	9,200	10,000	30,000
Reuse system	15	3,190	—	—	—
Total initial cost	—	32,890	29,660	29,420	46,125
Acres irrigated	—	145	140	100	130
Initial cost per acre	—	227	212	294	355
Fixed costs per acre per year including taxes and insurance[c]		$30.10	$30.56	$41.15	$47.61

[a]From Eisenhauer and Fischbach (1976).

[b]Does not include land leveling.

[c]Based on 9% interest note.

systems can now operate using less pressure which saves pumping costs. Which system is used is dependent on many factors: soil type, land slope, size and shape of fields, land cost, water availability, energy

Table 14. Estimated operating costs and total costs per acre for irrigation with various systems[a]

Item	Gated pipe with reuse	Skid-tow	Traveling gun	Center pivot
Inches of water applied per year	15	13	13	12
Fuel — 35¢/gallon	\$11.98[b]	\$15.55	\$23.87	\$15.52
Oil	1.43	1.84	2.83	1.84
Maintenance and repairs	2.74	2.88	4.11	3.70
Labor — \$3.00/hour	3.00[c]	3.90	5.70	1.50
Total operating costs per year	19.15	24.17	36.51	22.56
Total irrigation costs per year	\$49.25	\$54.73	\$77.66	\$70.17

[a]From Eisenhauer and Fischbach (1976).

[b]Includes costs of pumping reuse water with electric pump at 2¢/kwhr.

[c]Based on solid set of gated pipe.

availability, total block of land to be irrigated, type and availability of labor and owner's likes and dislikes.

Future What is the future of supplemental irrigation in Iowa? There is no clear-cut answer because it is dependent on a number of factors: future weather variability, availability of water for irrigation, demand for crops, crop prices, the long-term economic feasibility of supplemental irrigation. Hallberg, Koch and Horick of the Iowa Geological Survey (1976) examined the various facets of this question.

They projected an increase in the number of irrigated acres to the year 2000 as shown in Table 15. They felt that the figure for 1977 might be too low and that the figure for the year 2000 might be too high. Soils with low moisture-holding capacity, the sandier soils, will show a much greater response to irrigation than those with high moisture-holding capacities. Figure 10 lists the percentage of "coarse" textured soils in Northwest Iowa.

Table 15. Historic and projected use of land and water for irrigation in Iowa[a]

Year	Authorized number of permits	Acres irrigated	Acre-feet of water used or authorized
1949	—	7,500	—
1956	—	27,000	—
1969	649	93,200	99,300
1976	837	131,300	146,000
1977	1,150[b]	185,000[b]	225,000[b]
2000	7,000[b]	1,300,000[b]	1,425,000[b]

[a]After Hallberg, Koch and Horick (1976).

[b]Estimated.

Hallberg, Koch and Horick (1976) have detailed the several problems and conflicts which must be solved, at least partially, before larger-scale supplemental irrigation can claim a share of the land and water resources of Iowa. These problems and conflicts are described in the following excerpts from their report.

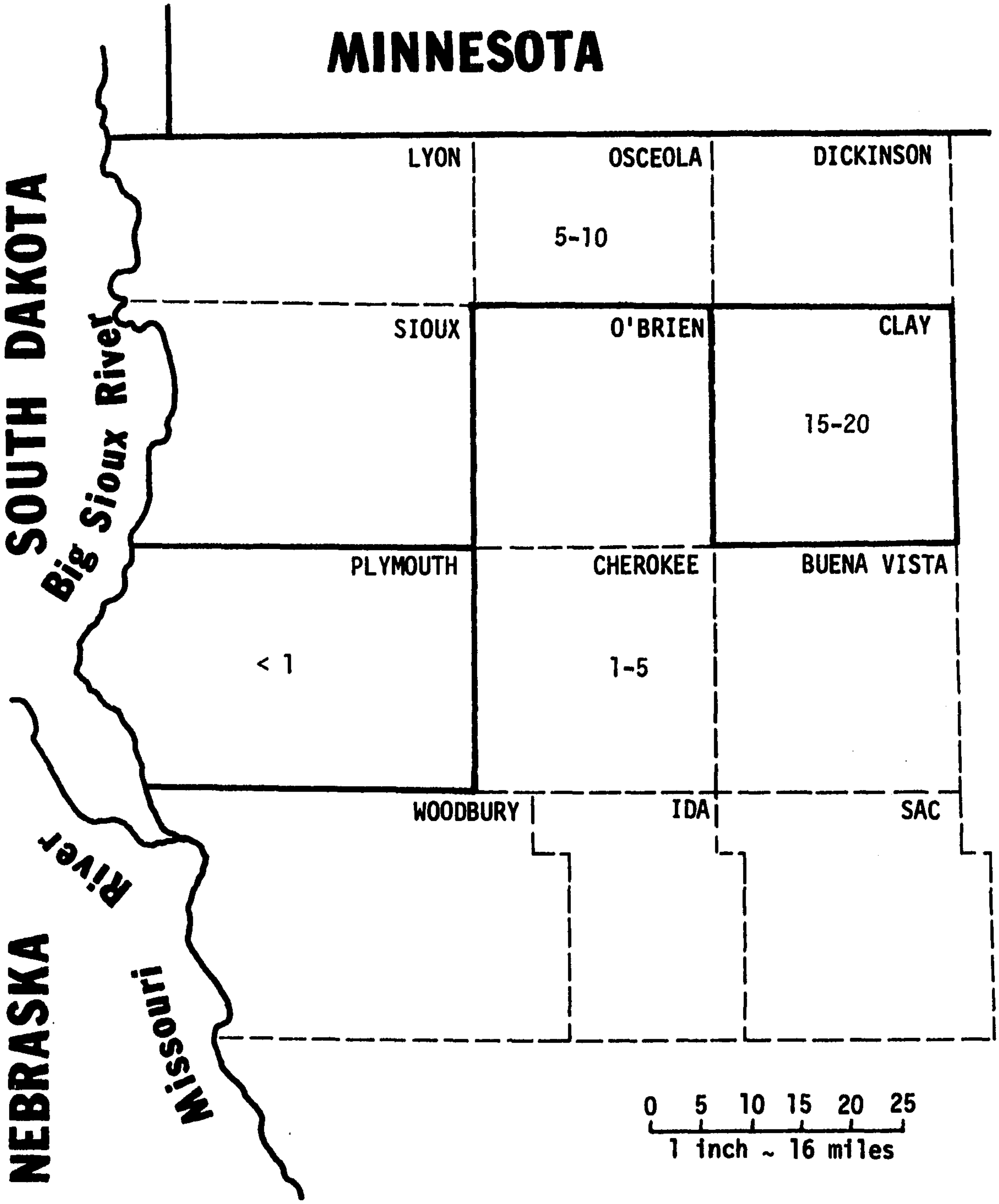


Fig. 10. Percentage of "coarse" textured soils of low water-holding capacity by county in Northwest Iowa (from Iowa Cooperative Soil Survey Data)

Historically, by far the greatest use of water for irrigation has been in western Iowa, especially on the bottomlands of the Missouri River. During the last three years, applications for irrigation permits received by the Iowa Natural Resources Council for upland sites in west-central and northwestern Iowa have increased markedly. As irrigation expands in an area it may also be necessary to require more detailed testing as part of the permitting procedure, to ascertain the necessity of conservation measures.

One center-pivot system applying one acre-foot of water to a 160-acre tract (about 133 acres irrigated) will consume as much water as a town of 10,000-12,000 people per year. Obviously, this issue is of serious magnitude and conflicts in water use will arise. The expansion of irrigation must be carefully managed to avoid serious depletion of water resources.

Nevertheless, the present consumption for irrigation does present potential conflicts in water use. The overriding element here is the question of water availability. Few problems are anticipated for the Missouri bottomlands region where tremendous volumes of water are available from thick alluvial sand and gravel aquifers. Even some reaches of Iowa's interior streams contain highly productive sand and gravel aquifers that will support at least moderate withdrawals for irrigation. It is the upland areas, distant from alluvial aquifer sources, that present the greatest number of problems which require resolution.

Some stream irrigators in drought prone Northwest Iowa have not renewed their irrigation permits because the protected flow of streams does not allow them to take water from streams during droughts, which is precisely the period they most need the water. Many irrigators are turning to wells, or a combination of wells and streams to obtain the large quantities of water needed.

The Dakota Sandstone is the only other potential aquifer of northwestern Iowa for developing irrigation supplies, at least at comparatively shallow depths. The sandstone is fine grained and poorly cemented which can result in sand-pumping problems when wells are pumped at high rates. In addition, water from the Dakota aquifer in parts of northwestern Iowa has such a high concentration of dissolved solids it may be objectionable for its effects on crops and soils.

These exceptionally good climatic years of the 1960's and early 1970's present a further problem. Much of our modern agricultural research was conducted during this period.

Irrigation studies conducted during this time may or may not be indicative of the costs and/or benefits that might be derived. Even if the long-term economics of irrigation are marginal, it may be attractive to reduce year-to-year yield variations, providing a more uniform cash flow and reducing the impact of sharp "economic valleys" of bad years.

The greatest increase in irrigation will be in western and northwestern Iowa. However, in much of this area it may be difficult to produce wells which will yield sufficient quantities of water for efficient operation of sprinkler irrigation systems. In these areas, if irrigation is to be implemented, it may be necessary to use combinations of wells, reservoirs, and streams for water supplies. This will present additional problems and expense to developing irrigation.

Power generation

In the introduction notice was taken of the growing use and demand for energy. At the present time Iowans import 98% of their total energy use and assuming that past trends continue into the future, this percentage will increase also unless Iowa further develops its coal reserves and electrical generating capacity. Figure 11 portrays the growth in energy consumption in Iowa for the 20-year period from 1953 to 1973. Figure 12 shows the dramatic rise in electricity sales in Iowa during this same time period. This increase in sales is projected to continue as shown in Fig. 13. Each of these three figures was taken from the annual reports of the Iowa Energy Policy Council (1975 and 1977).

A report by Butterfield and Dougal (1975) indicated that about 24% of total energy use in Iowa in 1973 was for the purpose of producing electricity. Total production capacity in Iowa in 1974 was just over 6,050 megawatts with 55% of this capacity in fossil fuel plants and 23% in nuclear plants. Additions of over 3,000 megawatts

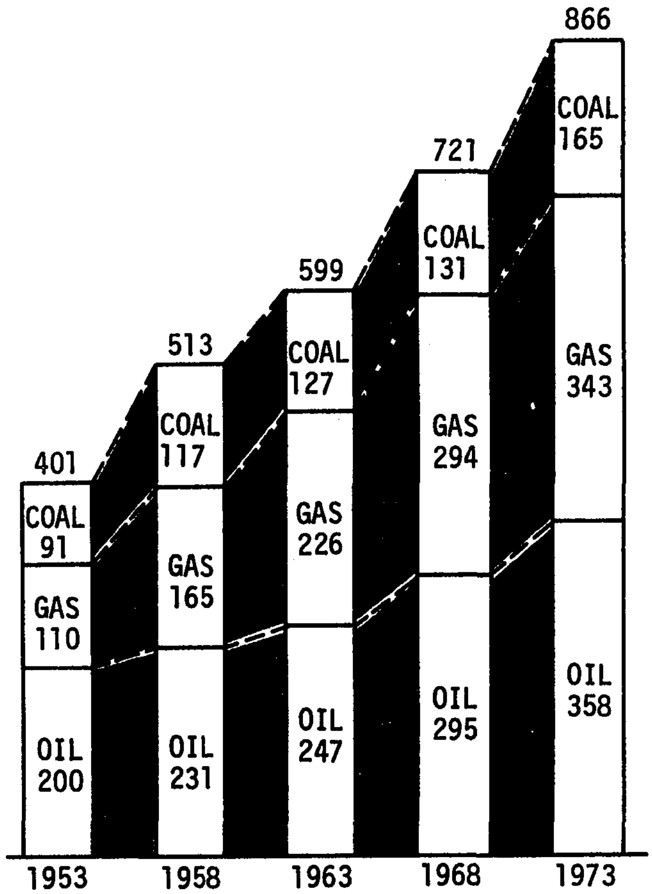


Fig. 11. Growth of energy consumption in Iowa from 1953 to 1973, trillion Btu (after Iowa Energy Policy Council)

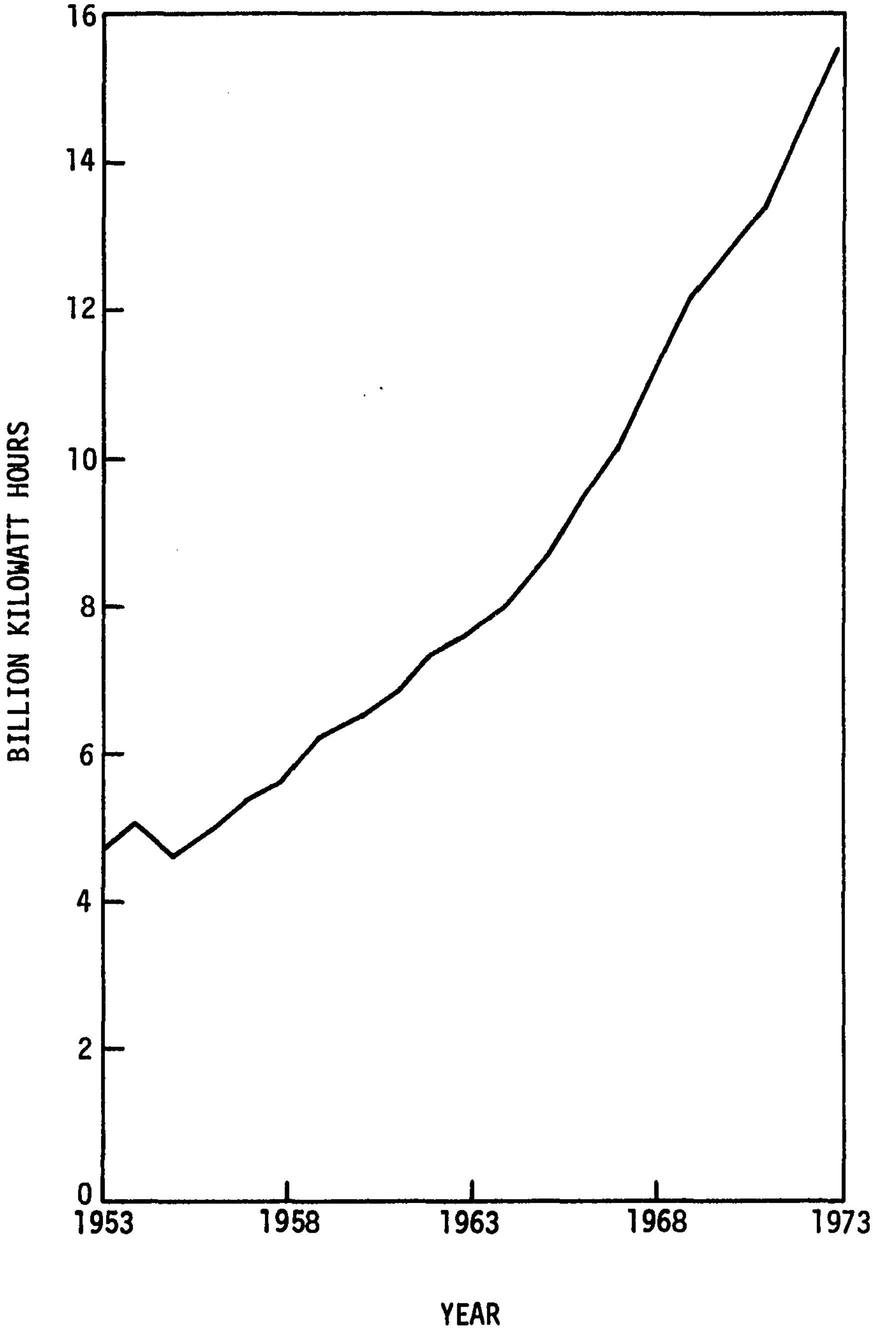


Fig. 12. Electricity sales in Iowa from 1953 to 1973 (after Iowa Energy Policy Council)

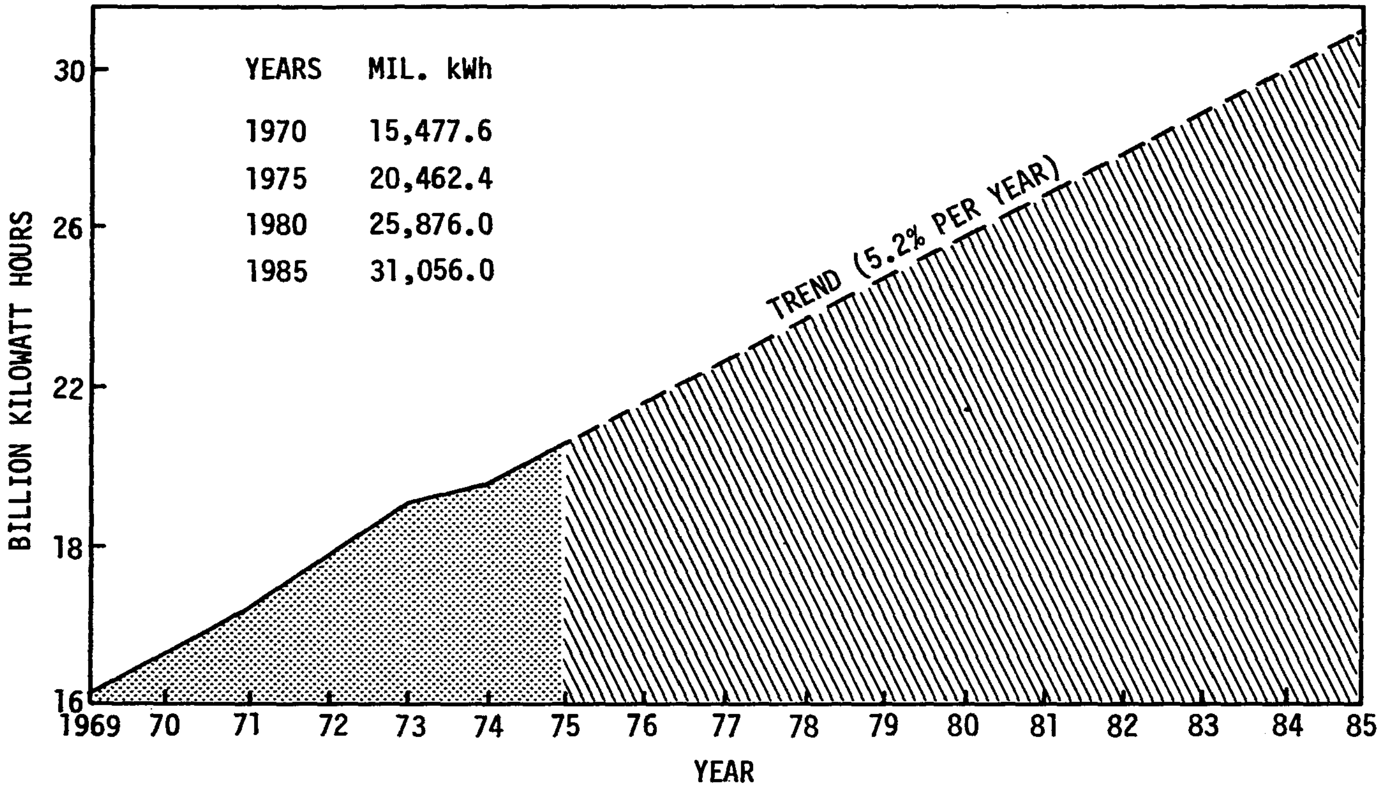


Fig. 13. Historic and projected electricity sales in Iowa (after Iowa Energy Policy Council)

are committed to be on line by 1985 with about 90% of this additional capacity to be fossil or nuclear. Since the efficiencies of most modern plants are in the range of 30 to 40%, this means that 60 to 70% of the heat generated in a steam-electric plant must be wasted to the air or, as is the case in most all plants, to the cooling tower. One proposed 600 megawatt plant in Iowa will need 720 million gallons of water per day (mgd). By way of contrast, each day the residents of Des Moines, Iowa use about 35 mgd, Davenport uses nearly 17 mgd, Council Bluffs almost 9 mgd and Ames about 6 mgd. This difference in the amount of water required is the reason that power generation accounts for over 70% of the water used in Iowa — and 90% of the water needed for power generation is used for cooling purposes. There are various cooling methods used for dissipating the waste heat such as once-through systems, cooling ponds, spray ponds and canals, wet towers, dry towers and combinations of these methods.

The consumptive loss of water used for cooling purposes is dependent on the type of fuel used and the method used for cooling as shown in Table 16. While the actual values vary, the consumptive loss is least with once-through systems and fossil fuel plants consume less water than nuclear plants. Butterfield and Dougal (1975) also estimated future consumptive losses to the year 2025 based on four growth trends for energy requirements in Iowa. These are shown in Table 17. Using these and the above figures as a guide, additional power plants for Iowa will need to be sited on the border rivers or if some are sited on or near interior rivers, additional water will have

Table 16. Consumptive water loss, gal/kwh, from a 1,000 kw fossil fuel or nuclear fuel plant using three cooling methods[a]

Source	Fossil fuel			Nuclear fuel		
	Once-through	Cooling pond	Wet tower	Once-through	Cooling pond	Wet tower
Upper Mississippi River Commission Basin Study	0.300	0.358	0.479	0.358	0.430	0.573
Thompson & Young	0.340	0.670	0.517	0.425	0.843	0.646
National Water Commission	0.331	0.497	0.663	0.531	0.797	1.064

[a]After Butterfield and Dougal (1975), based on a heat rate of 9,500 Btu/kwh, and a temperature rise of 18°F across the condensers.

Table 17. Estimated future consumptive losses in power plants for selected energy growth trends in Iowa, million acre-feet per year[a]

Condition	Source[b]	1985		2000		2025	
		Once-through	Wet tower	Once-through	Wet tower	Once-through	Wet tower
I	NWC	0.045	0.090	0.091	0.184	0.394	0.798
	UMRBC	0.036	0.057	0.074	0.125	0.316	0.505
II	MWC	0.045	0.090	0.162	0.334	0.436	0.872
	UMRBC	0.036	0.057	0.123	0.198	0.332	0.532
III	NWC	0.053	0.106	0.109	0.218	0.294	0.588
	UMRBC	0.043	0.069	0.090	0.144	0.243	0.389
IV	NWC	0.064	0.128	0.138	0.276	0.372	0.744
	UMRBC	0.046	0.074	0.065	0.157	0.266	0.425

[a]After Butterfield and Dougal (1975).

[b]NWC — National Water Commission formula; UMRBC — Upper Mississippi River Basin Commission formula.

to be made available through either surface water reservoirs or ground water well fields.

Water quality

The quality of water can vary depending on the use or uses to which it will be put. Not all water must be of drinking water quality. Some industrial processes require a higher quality than that of drinking water. Other uses, such as irrigation and fishable and swimmable rivers and lakes, require a lesser quality water. Some uses, such as navigation and hydroelectric power generation, do not require any particular water quality.

Since the mid-1960's water quality has no longer been subject to benefit-cost determination, rather water quality has been declared a national "good" and the only proviso now is that the required water quality be achieved in the most cost-effective manner. Whatever this cost is is assumed to be less than the benefits derived from the increase in water quality. Since the advent of the environmental movement in the mid-1960's, water quality has become institutionalized with the creation of the federal Environmental Protection Agency (EPA) and the several state agencies such as the Iowa Department of Environmental Quality (IDEQ).

The EPA has recently set drinking water standards in compliance with the 1974 Safe Drinking Water Act. It has also recently called for increased attention to the land disposal of municipal and industrial wastewater as called for in the Water Pollution Control Act Amendments of 1972. The IDEQ has set standards and issued regulations on such items as quality standards for the various stream classifications, rules affecting animal feeding operations and waste load allocations for the streams in Iowa. They have also issued new standards to protect lakes and streams that "constitute an outstanding natural resource" and others with "high quality waters" which are to be protected from further degradation.

The need for higher quality drinking water in our rural areas has been documented in a previous section. Americans, through Congress, have declared that the continuing pollution of our rivers and lakes must cease and that they be returned to a semblance of their former condition. The reason for this declaration is the realization that we must provide the climate for the existence of a wide range of species diversity which is so vital to the continuation of a healthy, stable environment.

Recreation

Water-based recreation comes in many sizes: active and passive, contact and noncontact, summer and winter, flat water and white water, natural lakes and man-made pools. It runs the gamut from shooting the rapids to sitting on shore and watching the sun glisten off the surface of a lake. During the winter one normally thinks of water-based recreation as being limited to ice skating and ice fishing. But there is also snowmobiling, sledding, tobogganing and all types of skiing.

During the summer there is stream fishing, lake fishing and deep sea fishing. There is swimming, diving and water skiing. There are canoes, kayaks, rowboats, motorboats and sailboats. You can fish from shore, off a dock, in hip boots or in many kinds of boats in a stream, lake, reservoir and ocean.

Many people have written about the increasing affluence and leisure time of Americans and how they are using some of this increased leisure time and affluence for water-based recreation. Also many more Americans than previously are using the existing recreational facilities. This leads to increased pressure on these facilities which has two effects. First, the quality of the recreational experience is diminished because of the overload of people and boats. Water skiers interfere with sailboats and fishing boats. Parking lots overflow; waste receptacles overflow; increased wave action erodes the shoreline; grass, shrubs and trees get trampled, mangled and broken. Second, to relieve the pressure on the existing facilities, new water-based recreation areas are developed. This conflicts with the existing land use and social, political and legal hassles arise as to where the new facilities should be located.

In order to resolve these hassles, outdoor recreation planners inventory the existing facilities, count the numbers of people involved in the various activities, take polls and make determinations as to how much land and water is needed for each activity. People taking nature walks near the shore of a lake do not want to be disturbed by hunters' shotguns. Water skiers do not want to get tangled up with other boaters. With these conflicts in mind, recreation planners have set up a variety of standards to determine the number of acres necessary to provide adequate space on both land and water for the wide array of outdoor recreational activities and to provide the related aesthetics, buffering and screening between activities.

The Bureau of Outdoor Recreation (BOR) in the U.S. Department of the Interior has compiled these various standards into a handy source booklet for use by outdoor recreation planners in both urban and rural areas (USDI, Bureau of Outdoor Recreation, 1967). The provision of water-based recreation involves not only the use or creation of a body of water but also the necessary land resources to support and enhance the water-based activities. These include boat launching ramps, parking lots, beaches, bathhouses, picnic areas, camping areas, access roads and trails, marshy areas, maintenance facilities and sanitation facilities.

Navigation

Navigation on inland waters involves problems which are not present in ocean navigation. On the oceans of the world there is an abundance of deep water which is present at all times. On inland rivers the depth of water is dependent on both the rate of flow and the cross-sectional area of flow. The rate of flow is highly variable on most rivers at various times during the year and many rivers flow wide and shallow rather than narrow and deep. Man has used two methods to rectify this situation. He has confined the river between walls and jetties to make it flow deeper and has dammed the river upstream so that he can control the rate of flow at all times. The other method is to construct low-head dams at invervals along the length of the river which creates pools of sufficient depth to allow navigation.

Locks in the dams allow boats to be raised or lowered from one level to another.

Both these systems are present on the border streams of Iowa. The Missouri River which forms most of the western border of Iowa is an example of the first method. The Mississippi River which forms Iowa's eastern border is an example of the second method. By confining the flow in the Missouri River to a narrow channel, the velocity of the water is high and maintains the needed depth of flow by scouring the bottom. On the other hand, because the Mississippi River is essentially a series of slack-water pools, constant dredging is required to maintain the navigation channel at the required depth. The disposal of this dredged material is a constant problem because of the environmental problems which arise wherever the dredged material is placed.

These two methods of providing navigation on inland waterways also have positive and negative effects on the recreational uses of the rivers. The swift current in the Missouri River precludes most recreational uses of the river. Swimming is dangerous as is water skiing. Only those boats with powerful motors can use the river and sailing is out of the question. By way of contrast, the Mississippi River provides an opportunity for all types of water activity. Swimming, fishing and boating of all kinds can be enjoyed in the wide expanses of flat water. At the upper ends of the pools, marshes abound which support a variety of wildlife. At times recreational boating and barges vie for the use of the locks and cause some interference.

Be that as it may, the use of Iowa's border rivers for navigation forms a necessary part of Iowa's transportation system for the movement of goods. Barges are well-suited to the transportation of bulk goods such as carrying corn and soybeans to markets around the world and bringing back such items as coal, petroleum, cement, stone, sand, gravel, sulphur, iron ore, iron and steel products, industrial chemicals and agricultural chemicals (Task Force on Commercial and Recreational Navigation, 1977).

<u>Flood plain management</u>

Flood plain management is obviously not a use of water but it plays a large role in water resource development because of the way man has misused flood plains in the past and continues to do so at the present time. This abuse has not been deliberate but was simply a consequence of how man develops an area for his convenience. When the white man first began to colonize what is now the United States, he settled along the eastern seaboard. As the early explorers moved westward across the Allegheny Mountains, they used the only two transportation systems available to them: the trails that they blazed and the rivers and streams that flowed westward. Travel was much swifter with the water routes. In time the rivers became the highways for the settlers who built villages along their banks. Large communities blossomed on the flood plains at the confluences of many of the major rivers and these rivers became the main arteries for commerce in the newly settled territories.

In 1973 Iowa celebrated the tercentenary of the exploration of the Mississippi River by Marquette and Joliet. A glance at a map of Iowa shows the important role that its rivers have played in the lives of its first European settlers. Their small settlements have become Iowa's largest cities — and each of them is situated on the banks of one of its rivers. The history of these cities and rivers is, in large part, the history of the development of Iowa.

While these cities were growing to their present sizes, their rivers provided water for navigation, for all domestic and commercial uses, for agriculture, for power for mills and later on for electricity, for recreation, for food in the form of fish and for the disposal of wastes. In order to conveniently use the rivers for these many purposes, man built his towns on the banks and flood plains of the rivers. These uses of rivers are not unique to Iowa, they are common throughout the history of mankind. Then, as now, water meant life. At times, however, water also meant death and destruction. But again, throughout history, man has accepted floods as a necessary evil when compared to the perceived benefits of using flood plains.

For these many reasons, man has built his cities on the flood plains of rivers. In recent times he has become more active in attempting to protect them from floods. Through structural measures and programs, levees, floodwalls, dams and bypass channels have been constructed. These attempts have not always been successful so now nonstructural methods are coming into use to reduce flood losses. These include land use planning, zoning, flood plain regulations, utility controls, tax adjustments and other legal and economic controls over urbanization of flood plain areas.

The time has come to reflect on what we have wrought and seek to live in harmony with nature rather than bend it to our will. Let us finally learn that the flood plain belongs to the river for the conveyance of water and that when we occupy the flood plain, we do so with full knowledge of the consequences involved and use it for only those purposes which are compatible with periodic inundation.

Structural flood control efforts on the federal level had their greatest impetus with the passage of the Flood Control Act of 1936 (PL 74-738) which gave the Corps of Engineers the authority to implement a flood control program at federal expense. This and subsequent acts have provided billions of dollars for structural flood control works. The legacy of these actions has been increased occupancy of the flood plains and increasing flood damages.

More recently impetus has been given to nonstructural solutions by the passage of (and subsequent amendments to) the National Flood Insurance Act of 1968 (PL 90-448) which provides that in order for individuals to be eligible for flood insurance, state and local governments must adopt acceptable arrangements for land use regulations in flood-prone areas. This Act created the Flood Insurance Administration (FIA) within the U.S. Department of Housing and Urban Development (HUD, 1978). A community qualifies for the program in two separate phases — the emergency program and the regular program. Under the initial emergency phase, limited amounts of flood insurance are available to local property owners at subsidized rates. Under the regular program, the full limits of flood insurance coverage become available locally using actuarially determined rates. These rates and coverages are shown in Table 18.

The minimum flood plain management standards necessary for a community to qualify for the emergency program are as follows. A community must require building permits for all proposed construction or other development in the community and review the permit to assure that sites are reasonably free from flooding. For its flood-prone sites, the community must also require: the proper anchoring of structures, the use of construction materials and methods that will minimize flood damage, adequate drainage for new subdivisions and design of new or replacement utility systems to prevent flood loss.

To enter the regular program, the community must require that all new construction and substantial improvements to existing structures in HUD-identified flood-prone areas be elevated or floodproofed to the level of the base flood. The "base flood" is a term used to describe the intermediate level of flooding the FIA program is geared to protect against. It is a flood with a 1% chance of occurring in any given year. Over a 30-year period, the life of most mortgages, there is about one chance in four (26%) that this magnitude of flood will occur in a given area.

Any owner of property (a building or its contents) located in a community approved for the sale of flood insurance may purchase a flood insurance policy. Tenants in eligible communities may also insure their personal property against flood loss. Almost every type of walled and roofed building above ground can be insured. This would include a mobile home on a foundation. The contents of a fully enclosed

Table 18. Emergency and regular coverage and rates under the National Flood Insurance Program

Type	Emergency program: Total amount available (first layer)[a]	Emergency program: Subsidized rate per $100 of coverage	Regular program: Second layer	Regular program: Actuarial rate per $100 coverage based on risk	Regular program: Total amount available 1st & 2nd layers[b]	Regular program: Maximum required
Single family residential	$ 35,000	$0.25	150,000	Rate varies	185,000	70,000
Other residential	$100,000	0.25	150,000	Rate varies	250,000	200,000
Contents, residential	$ 10,000	0.35	50,000	Rate varies	60,000	20,000
Small business	$100,000	0.40	150,000	Rate varies	250,000	200,000
Contents, small business	$100,000	0.75	200,000	Rate varies	300,000	200,000
Other nonresidential	$100,000	0.40	100,000	Rate varies	200,000	200,000
Contents, other nonresidential	$100,000	0.75	100,000	Rate varies	200,000	200,000

[a] Only the first layer of coverage is available under the Emergency Program. Slightly higher imits of coverage are available for purchase under the Emergency Program in Hawaii, Alaska, the U.S. Virgin Islands, and Guam.

[b] (1) Full coverage is available under the Regular Program for all structures in the community; (2) New construction and substantial improvements are charged actuarial rates for all coverage; (3) All existing structures are charged actuarial rates for the second layer of coverage and property owners have the option of paying either the subsidized or actuarial rate for the first layer, whichever is lower.

building are also eligible. The insurance provides coverage at replacement cost but only for single-family dwellings and only for those which are insured for 80% of the structure's replacement value at the time of loss or are insured to the maximum amount of insurance required.

All direct losses from floods are covered. A flood is defined as "a general and temporary condition of partial or complete inundation of normally dry land areas, from overflow of inland or tidal waters, or from the unusual and rapid accumulation of runoff of surface waters from any source, or from mud flows." Losses resulting from flood-related erosion are also covered.

The law requires HUD to notify every flood-prone community that it has one or more flood-prone areas. The reason for this mapping effort is to help communities better manage their flood-prone areas, avoid future losses and alert citizens of these communities to the hazards they face. FIA publishes a "Flood Hazard Boundary Map" which labels the flood-prone areas within the community as "special flood hazard areas" and marks them as an "A" zone. These areas are subject to inundation from the intermediate level of flooding which was defined earlier. On the community's Flood Insurance Rate Map, the "A" zone is refined into numbered zones (A1, A2, A3, etc.) that reflect the degree of flood risk for that area. The risk zones are used for the rating of new properties to be insured under the regular program. Also, the community enrolled in the regular program must use the flood elevations shown on the rate map as the minimum building elevations for new construction.

Watershed management

Just as flood plain management was not a use of water as such, either is watershed management. However, how we manage our watersheds has a great influence on both the quantity and quality of the water we use. By removing the natural cover from the soil as we do in agriculture and by making the surface impervious as we do in many activities, water has less chance to infiltrate and replenish our ground water supplies. And since less water infiltrates, more is available to run off on the surface carrying with it fertile topsoil, herbicides, pesticides, fertilizers and other surface wastes.

When the white man first came to Iowa, he found a good land covered with prairie grasses and dotted with many forests. Today only remnants of prairie remain and the forests have all but disappeared in many areas. Because of the fertile soil found throughout most of Iowa, we have denuded its surface and become the bread basket of the world. Feeding the world is a good role for Iowa to play but the manner in which we have played this role in the past one hundred years plus leaves much to be desired. Half of the topsoil has been transported out of the state, fouling our rivers as it flows to the Gulf of Mexico (Drake, 1977). If Iowa is to continue to play its present role on into the foreseeable future — and beyond — then the proper steps must be taken immediately to reduce soil erosion to the point where new soil is formed at least as fast as it is removed. Not only will these steps considerably reduce our soil erosion problem, they will also improve the physical, chemical and aesthetic quality of our environment.

Some tentative steps have already been taken but as yet the proper follow-up steps have not occurred. In 1971 the Iowa Conservancy Act was passed which divided the state into the six conservancy districts shown in Fig. 14. These districts have set soil loss limits ranging from 3 to 5 tons per acre per year. They have also taken a few baby steps towards the fulfillment of Chapter 467D.1 of the Iowa Code which states:

> It is hereby declared to be the policy of the state of Iowa and the objectives of this chapter to preserve and protect the public interest in the soil and water resources of this state for future generations, and for the purpose to encourage, promote, facilitate, and where such public interest requires, to mandate the conservation and proper control and use of the soil and water resources of this state, by measures including but not limited to the control of floods, the control of erosion by water or by wind, the preservation of the quantity and quality of recreational, industrial, and domestic purposes, all of which shall be presumed conducive to the public health, convenience and welfare, both present and prospective.

However, before the above policy can become reality, two proper steps must be taken. The first step is called money. The people, the state government and the federal government must come to the realization that soil and water conservation is not an out-of-pocket expense that farmers should be forced to bear by themselves. These are national natural resources on which our very lives depend and must be preserved and enhanced by all. The Iowa Conservancy Act recognizes this fact in its provision for 75% cost sharing but succeeding legislatures have appropriated little money to implement this law. Similar inaction is also the rule at the federal level. Total costs throughout the United States will surely run into the billions of dollars but it

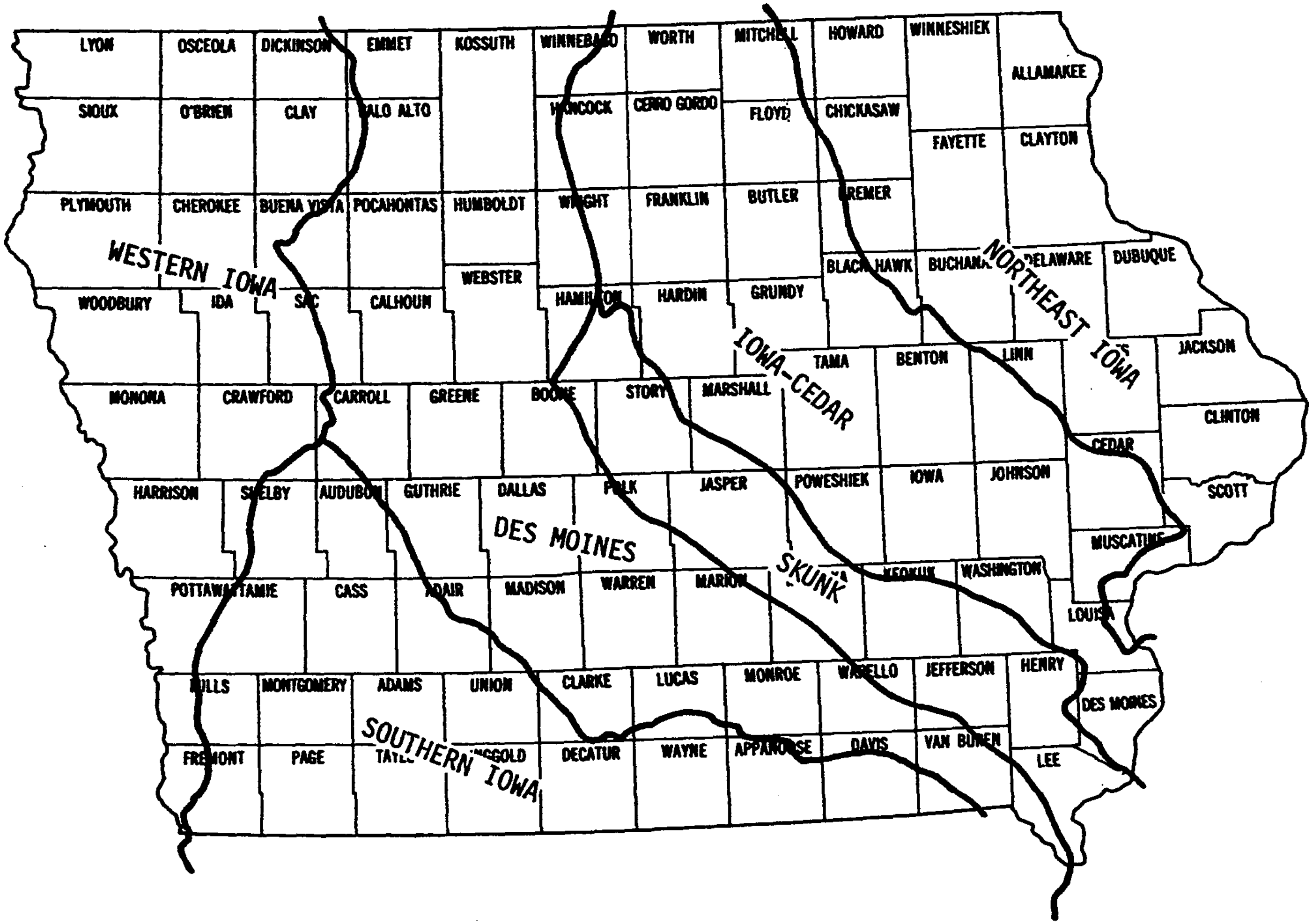


Fig. 14. Iowa conservancy districts

is an expenditure which must be made. Past research, construction and farm management efforts have shown that there are no technical problems to be overcome. The techniques are known and available; we lack only the appropriation of the money and the will to implement these techniques.

This leads us to the second proper step: the will to do the things which must be done. The wasting of our soil resources is simply a reflection of present societal values. This is a throw-away society. Planned obsolescence of our goods is the norm. The second proper step is literally an about-face in how Americans view their land and other resources. They must change from conquerors to stewards. We have the know-how; we have the necessary inputs; we lack only the will to do what we should be doing. Once this will is acquired and communicated to the politicians, the money will be forthcoming and we will be able to get on with the management of our watersheds in earnest, rather than the few efforts which are presently taking place.

The more fragile lands can be returned to forests and pastures; the more productive soils can be protected from excessive erosion either by structural means or by crop management practices. These things can be done and still maintain the total production called for by the federal government. The cost will be high, far beyond the ability of the farmers to pay, but well within the ability of the people to pay (through the federal government). The only ingredients required are the realization that these things must be done and the reordering of priorities, especially at the federal level, to get these things done.

Summary

In these sections, comments have been made on the sources and uses of water and the constraints under which they must operate. These constraints were legal, institutional, social, economic, financial, physical, technical and political in nature. The sources of water included precipitation, surface and ground water, municipal and industrial effluents, agricultural return flow and desalination. The uses of water ranged from water supply for all purposes to watershed management.

As one attempts to combine all of the above facets into one integrated whole, the mind boggles at the attempt and is reminded anew of the complex nature of land and water resource development and use. At times the above comments may have appeared disjointed and unrelated to one another. If so, they were merely reflecting reality. The real world is complex and disjointed. Resources are finite and choices and trade-offs must be made. Decisions in seemingly unrelated areas do impact on each other. The obvious becomes obvious only after events have occurred. The best we can do is plan for the future based on what we know or suspect to be the facts now and the trends, needs and desires we project will be present in the future.

We plan for the future by documenting what has occurred in the past, what is occurring now and estimating what will occur in the future by building on current and emerging trends. This then is what will be done. The next section will document the past, present and emerging future of Northwest Iowa. Then we will build on these data set by attempting to combine in a single model the complexities of land and water resource use discussed above and to portray the impacts and trade-offs that will occur and that must be made in order to fulfill our future goals and desires as nearly as possible.

RESOURCES OF THE NORTHWEST IOWA REGION

The case-study location selected for this application of goal programming is the 12-county area in Northwest Iowa shown in Fig. 15. This region is bounded on the north by Minnesota and the western border is formed by the Missouri and Big Sioux Rivers which separate Iowa from Nebraska and South Dakota. This region was chosen because it contains most of the elements which should be considered in a water resources planning study and because it has many water-related problems. Annual rainfall is the lowest in the state, ranging from 25 to 28 inches per year. Ground water is available but not in sufficient quantities for many uses. Some soils in the area are highly susceptible to erosion. Most of Iowa's natural lakes are located in the region but lack of public access to some and overuse of others by vacation homes and recreation developments (the Iowa Great Lakes region in Dickinson County) are major problems. Continued out-migration of persons from the rural areas due to increasing farm mechanization and a lack of job opportunities in the urban areas to keep young people in the region is a problem common to many parts of Iowa.

Table 19 gives an indication of the size and population of the 12 counties in this northwest region of Iowa compared to the 99 counties in the state. While this 12-county region contains 12.8% of the total area of the state, it contains only 10.2% of the population. The 11-county region (without Woodbury County) contains 11.2% of the total state area but only 6.6% of the population. Population

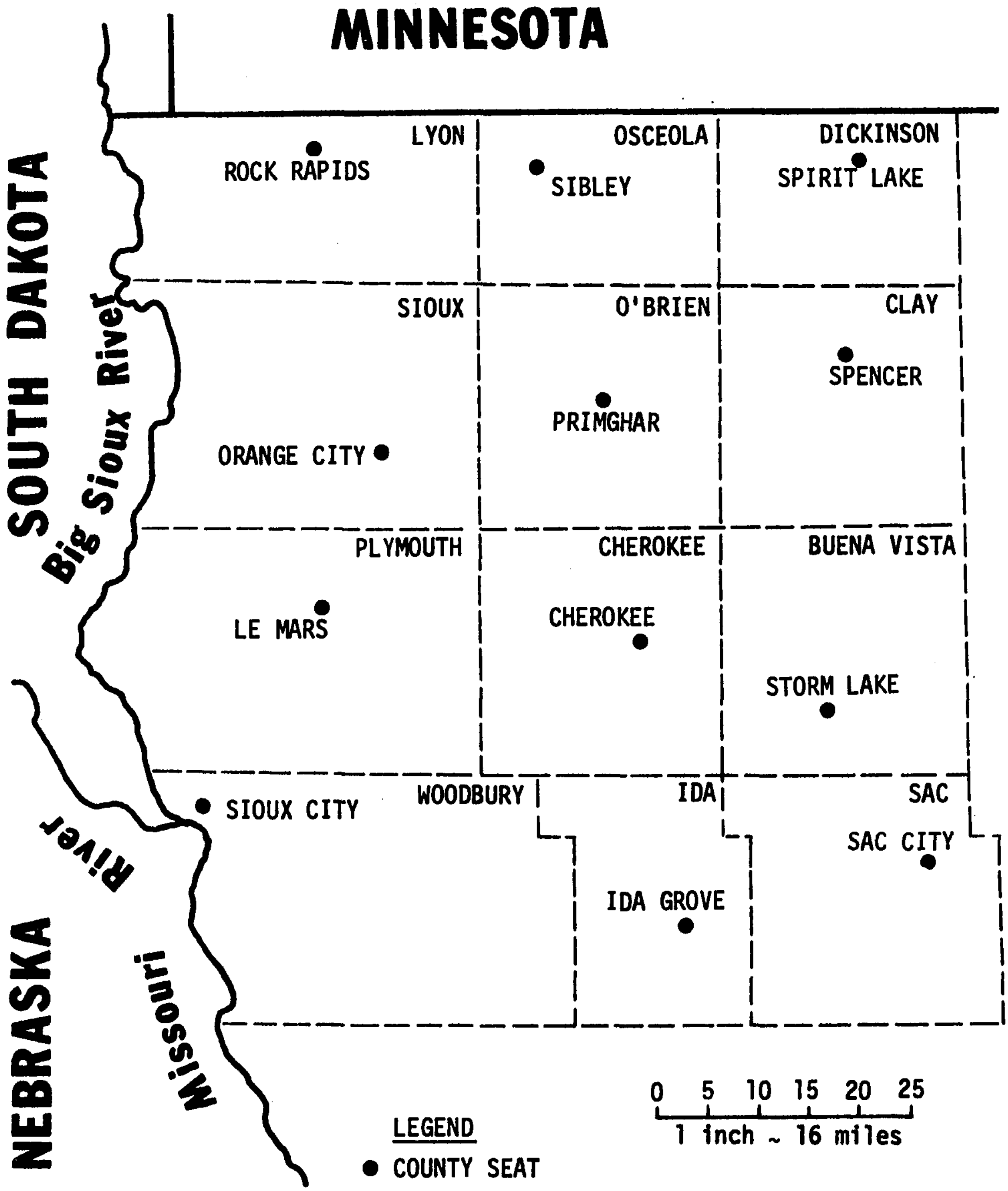


Fig. 15. Study area in northwest region of Iowa

Table 19. Size and population of Northwest Iowa as compared to the State of Iowa[a]

County	Area sq. mi.	Population 1970 census[b]	Density people/sq. mi.
Buena Vista	572	20,693	36.2
Cherokee	573	17,269	30.1
Clay	570	18,464	32.4
Dickinson	380	12,565	33.1
Ida	431	9,283	21.5
Lyon	588	13,340	22.7
O'Brien	575	17,522	30.5
Osceola	398	8,555	21.5
Plymouth	863	24,322	28.2
Sac	578	15,573	26.9
Sioux	766	27,996	36.5
Woodbury	871	103,052	118.3
12-county region	7,165	288,634	40.3
11-county region (without Woodbury Co.)	6,294	185,582	29.5
State	55,941	2,825,368	50.5

[a]U.S. Department of Commerce, Bureau of the Census (1973).

[b]Includes all corrections to the 1970 Census made subsequent to the release of the official counts.

density in the 11 more rural counties varies from 21 to 36 people per square mile, much less than the state average density of 50 people per square mile. The one exception to this is Woodbury County which has a population density of 118 people per square mile. Sioux City, the largest city in the region, is located in Woodbury County and had a 1970 population of 85,925, almost 30% of the 12-county population (Johnson and Tait, 1972).

Knowing the size and population of the region is just a small part of the total volume of information needed concerning an area as we prepare to analyze some alternative futures for its people, land, water and other resources. But before we can project into the future, we must examine the past and present. We must examine demographic variables, land use patterns and changes, topography, soils, surface and subsurface water supply and availability, and agricultural crop and livestock production. In summary, we need to know what demands society has placed on the people, land and water resources in the past.

Using these data, and evaluating current and emerging trends, we can project the demands which will be placed on these resources in the future. These demands can then be matched against the existing and developable resources of the area to determine how close we can come to satisfying all the projected demands and desires. Population and farm production trends will be based on the OBERS projections (U.S. Water Resources Council, 1974). A rather complete synopsis of these projections is also given in the dissertation by Gibson (1976). These OBERS projections will be used to serve as the proxy for the exogenous variables which will influence the study area of Northwest Iowa.

The resources of Northwest Iowa are described in the following order: its climate and water resources, its people and their incomes and finally, its land resources and how they are used.

Climate

The climate of an area includes such weather phenomena as snowfall, temperature, rainfall, number of sunny and cloudy days, number of frost-free days, wind speed and direction, evaporation and transpiration. Waite (1974) indicated that Iowa's climate, because of its latitude and interior continental location, is characterized by marked seasonal variations. "During the 6 warm months of the year the prevailing moist, southerly air flow from the Gulf of Mexico produces a summer rainfall maximum. The prevailing northwesterly flow of dry Canadian air in the winter causes this season to be cold and relatively dry."

Monthly and yearly variations in precipitation are documented in the next section. Severe hailstorms are slightly more frequent in Northwest Iowa than in the remainder of the state. Iowa averages 58 damaging hailstorms a year with each locality experiencing from 2 to 6 each year, reaching a maximum frequency in early summer. The hail usually accompanies thunderstorms as do tornadoes. Tornado frequency is highest in May and June in the afternoon and early evening. In Iowa tornadoes average 15 per year on 8 days. Snow has occurred in Iowa as early as September 25 (1942) and as late as May 28 (1947). Average annual snowfall in Iowa ranges from 20 inches at Keokuk to 35-45 inches in the northern counties. Figure 16 depicts the average annual snowfall in Northwest Iowa. The largest average statewide snowfall occurred during the winter of 1961-62 when 58.3 inches was recorded. Of this total 22.2 inches fell in February and 10.6 inches fell in March of 1962. The greatest flood threat from accumulated snow on the ground occurred in March 1969. The water equivalent of the snow in Northwest Iowa ranged from 5 to 8 inches. Since just 1 or 2 inches of rapid runoff from a watershed will cause a flood, a rapid melt of this snow pack

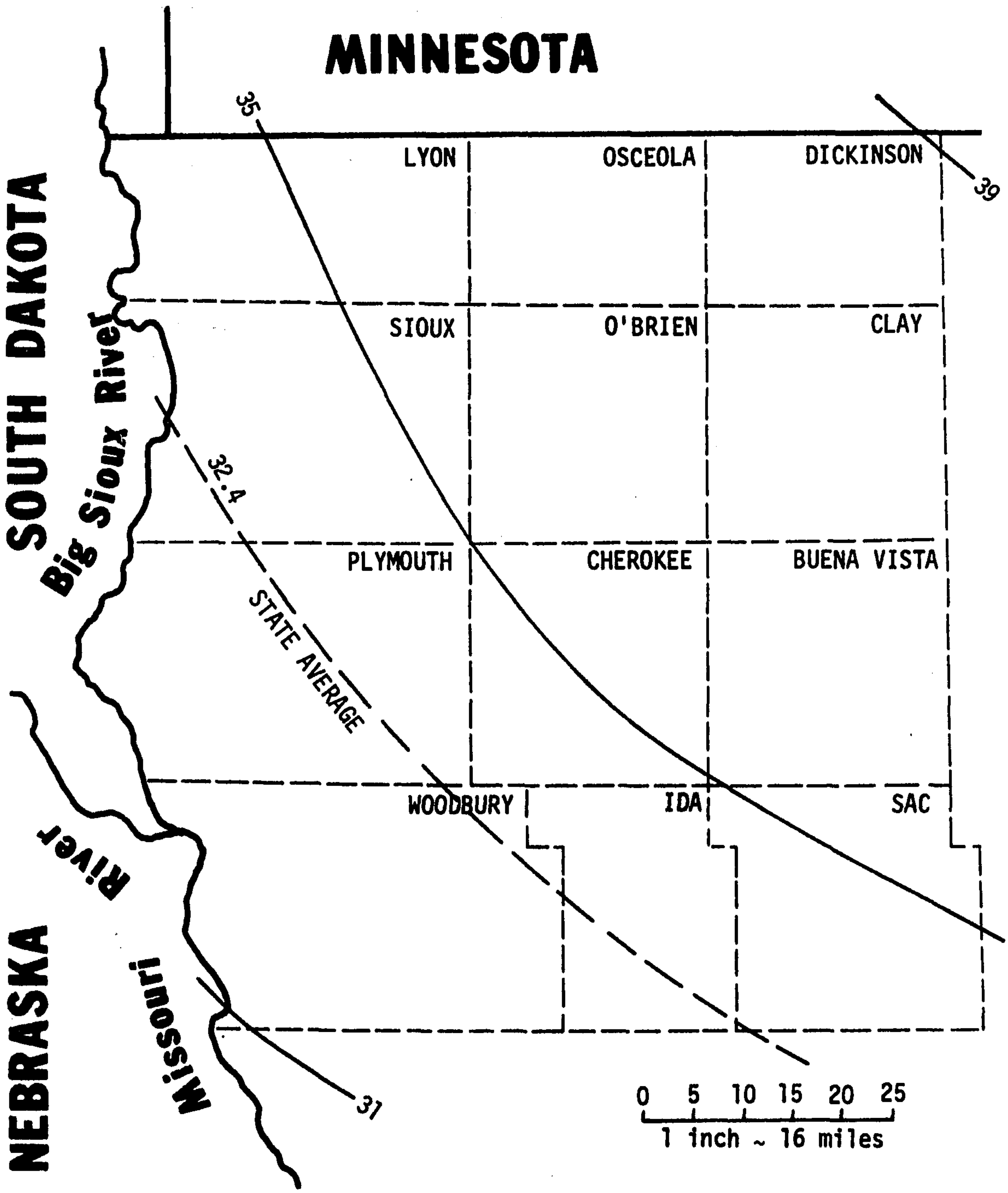


Fig. 16. Average seasonal snowfall in Northwest Iowa, inches (after Shaw, Thom and Barger)

constituted a major flood threat.

As mentioned above, the climate in Northwest Iowa is characterized by marked seasonal variations. This is especially true of temperature. Extreme temperatures have varied from 117°F at Logan to -46°F at Inwood. The average annual temperature in Northwest Iowa is about 47°F. Normal temperatures at Rock Rapids and Sioux City are shown in Figs. 17 and 18, respectively. Normal monthly temperatures at 6 locations in Northwest Iowa are listed in Table 20 (Shaw and Waite, 1964). Because Iowa is an agricultural state, the occurrence of freezing temperatures and the number of frost-free days are of prime importance (Shaw, Thom and Barger, 1954). Figure 19 indicates that the average date of the last 32°F freeze in spring is between May 4 and May 10 but it has occurred as late as May 31. Table 21 lists the percent chance that 32°F will occur on or after the date shown in spring. Figure 20 shows that the average date of the first 32°F freeze in fall is between September 25 and October 5 but it has occurred as early as August 20. Table 22 lists the percent chance that the first 32°F freeze in fall will occur on or before the date shown. Figure 21 indicates that the average length of the freeze-free season in Northwest Iowa ranges from 135 to 152 days.

Northwest Iowa is the sunniest and least cloudy part of Iowa, as reflected in its lower annual precipitation. The sunniest time occurs during the long summer days in July while the cloudiest time occurs in the latter part of November and first part of December. The percent of possible sunshine varies from 44% in December to over 74% in July. The average daily solar radiation is about 340 Langleys with available

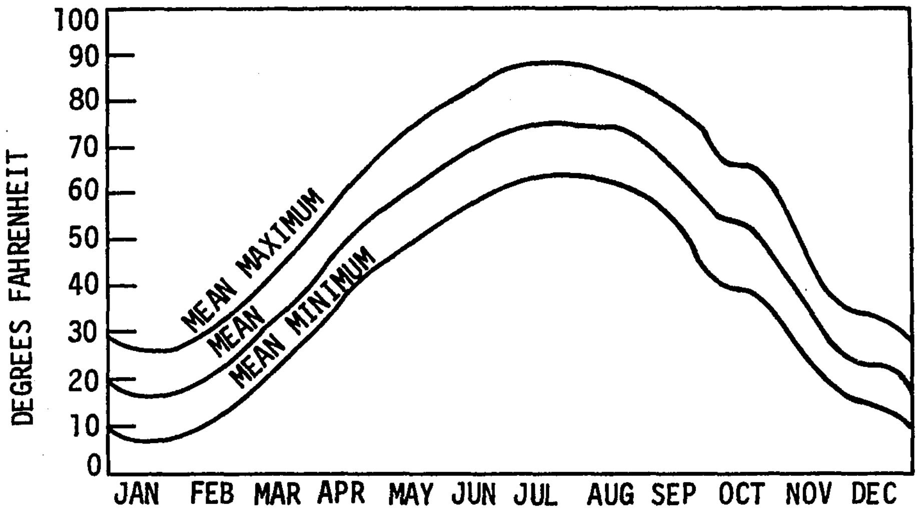


Fig. 17. Normal temperature distribution at Rock Rapids

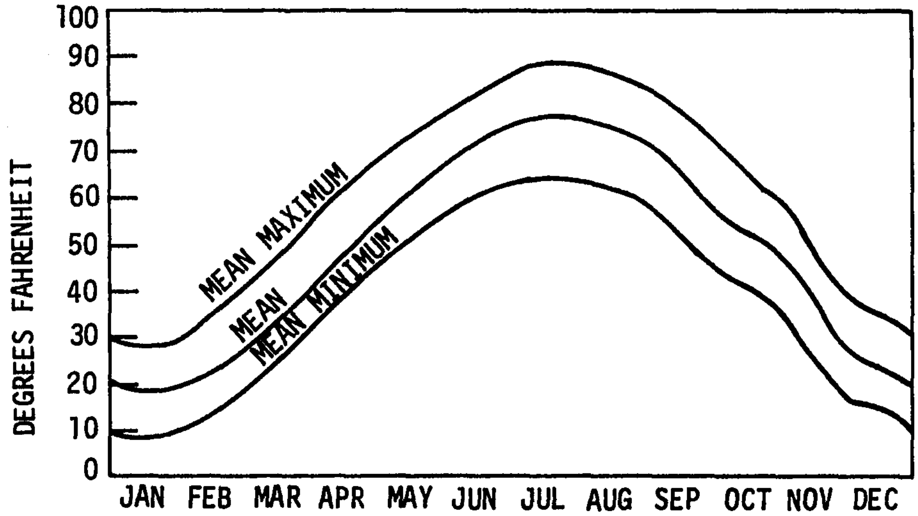


Fig. 18. Normal temperature distribution at Sioux City

Table 20. Normal monthly and annual temperatures at Lake Park, LeMars, Rock Rapids, Sac City, Sioux City and Storm Lake, °F[a]

Month	Lake Park	Le Mars	Rock Rapids	Sac City	Sioux City	Storm Lake
January	15.7	18.8	16.3	19.2	18.7	17.5
February	19.3	22.9	20.2	23.2	22.7	21.2
March	29.9	33.6	31.3	33.8	33.6	31.6
April	45.8	48.9	46.9	48.9	48.9	47.3
May	58.4	60.7	59.4	61.0	60.9	59.4
June	67.9	70.4	68.8	70.7	70.9	69.1
July	73.2	75.7	74.3	75.8	76.4	74.3
August	71.2	73.7	72.4	73.7	74.1	72.2
September	62.2	64.5	62.7	65.2	64.5	63.6
October	51.0	52.9	50.9	53.7	53.0	52.3
November	33.3	35.6	33.5	36.1	35.6	34.8
December	21.4	24.7	22.0	24.9	24.5	23.2
Annual	45.8	48.5	46.6	48.9	48.7	47.6

[a] Shaw and Waite (1964).

solar energy four times as abundant in July as in December. Southerly winds prevail from April to October with northwesterly winds prevailing from November to March. The average wind speed is about 12 miles per hour (mph). High winds at 15 feet above the ground reach 50 mph in about half the years. Winds to 75 mph at the 15-foot level can be expected once in 50 years.

The average Class A land pan evaporation is about 50 inches per year with lake evaporation averaging about 35 inches per year. Evapotranspiration is the loss of water by evaporation from surface water bodies, surface soil moisture and the surfaces of vegetation and man-made objects plus transpiration through plant leaves. Since most of Iowa's land is used for agricultural purposes such as row and

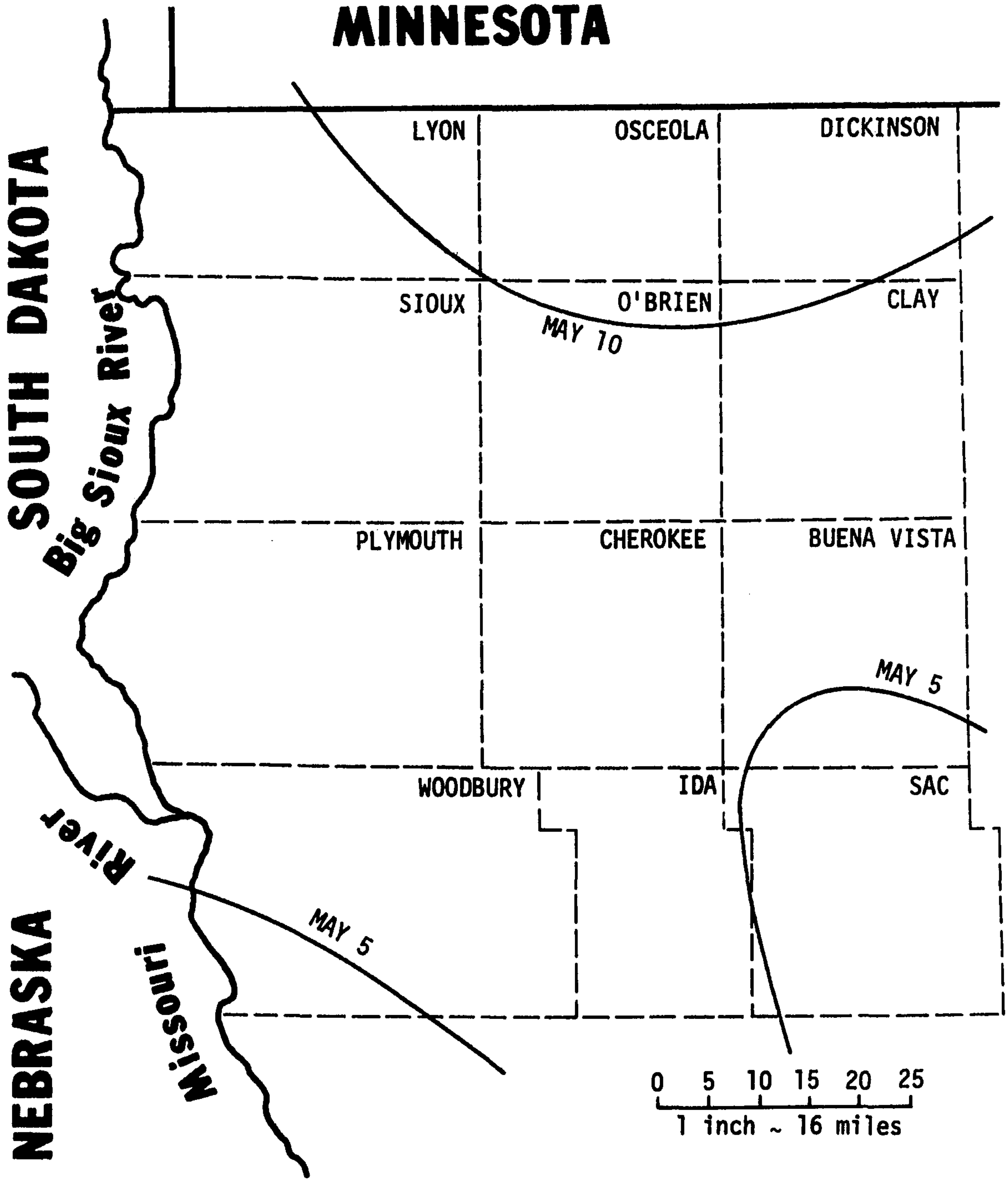


Fig. 19. Mean date of last 32°F freeze in spring in Northwest Iowa (after Shaw, Thom and Barger)

Table 21. Percent chance of 32°F occurring on or after given dates at several locations in Northwest Iowa

Station	Percent chance					
	75	50	25	10	5	1
Alta	Apr. 28	May 6	May 14	May 21	May 25	June 2
Alton	Apr. 29	May 7	May 15	May 22	May 26	June 3
Inwood	May 1	May 9	May 17	May 24	May 28	June 5
Le Mars	Apr. 29	May 7	May 15	May 22	May 26	June 3
Sac City	Apr. 25	May 3	May 11	May 18	May 22	May 30
Sibley	May 4	May 12	May 20	May 27	May 31	June 8
Sioux City	Apr. 20	Apr. 28	May 6	May 13	May 17	May 25

Table 22. Percent chance of 32°F occurring on or before given dates at several locations in Northwest Iowa

Station	Percent chance					
	1	5	10	25	50	75
Alta	Sept. 6	Sept. 15	Sept. 19	Sept. 27	Oct. 5	Oct. 13
Alton	Sept. 2	Sept. 11	Sept. 15	Sept. 23	Oct. 1	Oct. 9
Inwood	Aug. 30	Sept. 8	Sept. 12	Sept. 20	Sept. 28	Oct. 6
Le Mars	Sept. 1	Sept. 10	Sept. 14	Sept. 22	Sept. 30	Oct. 8
Sac City	Sept. 4	Sept. 13	Sept. 17	Sept. 25	Oct. 3	Oct. 11
Sibley	Aug. 24	Sept. 2	Sept. 6	Sept. 14	Sept. 22	Sept. 30
Sioux City	Sept. 11	Sept. 20	Sept. 24	Oct. 2	Oct. 10	Oct. 18

close-grown crops and pasture, more than three-fourths of annual evapotranspiration occurs during the growing season. The normal evapotranspiration process utilizes most of the precipitation which infiltrates into the soil profile and is responsible for the growth of the high-yielding crops in the state.

The availability of soil moisture for plant growth in Iowa has been documented by Shaw, Felch and Duncan (1972). Records are available for 5 stations in Northwest Iowa at the locations shown in Fig. 22.

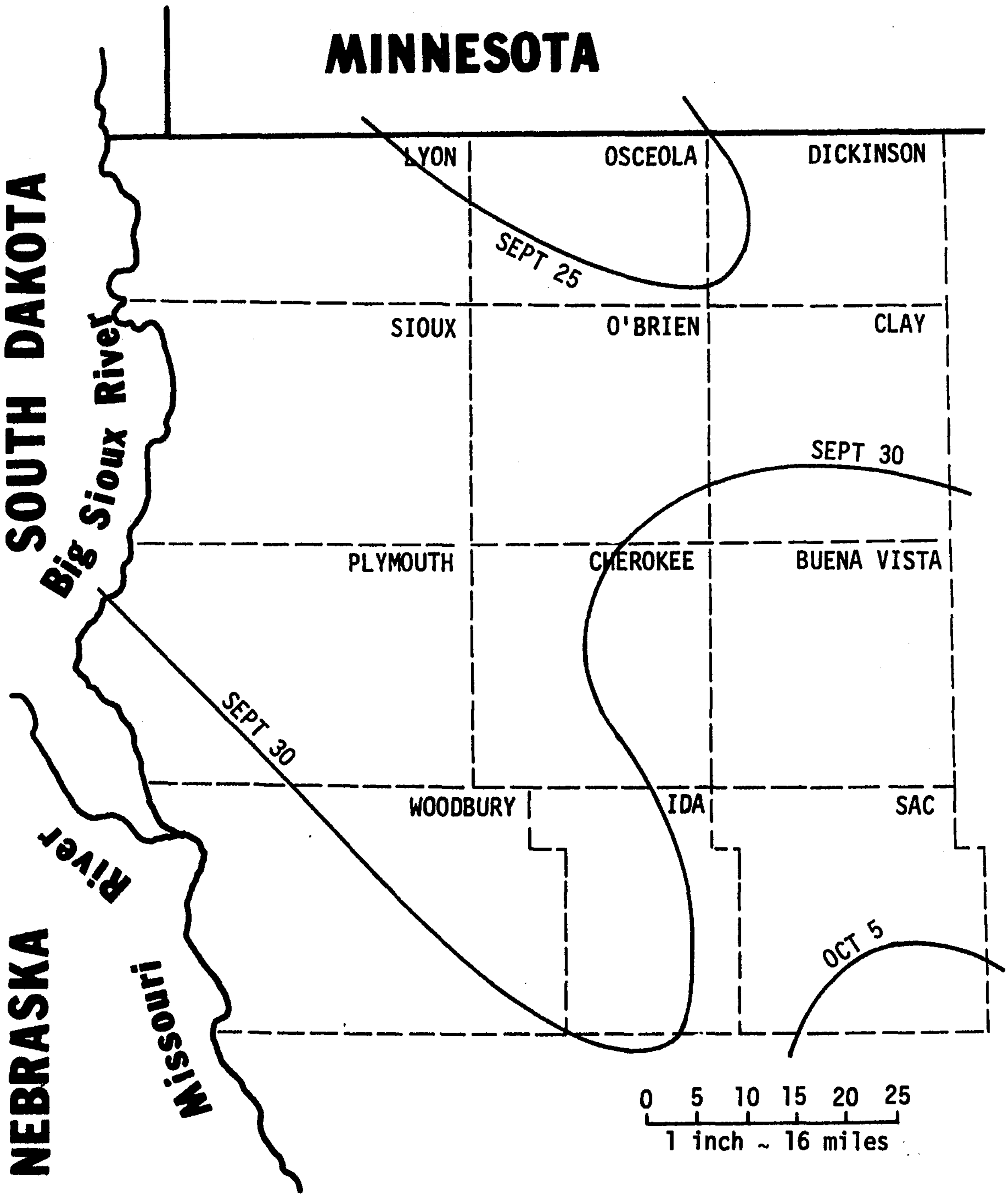


Fig. 20. Mean date of first 32°F freeze in fall in Northwest Iowa (after Shaw, Thom and Barger)

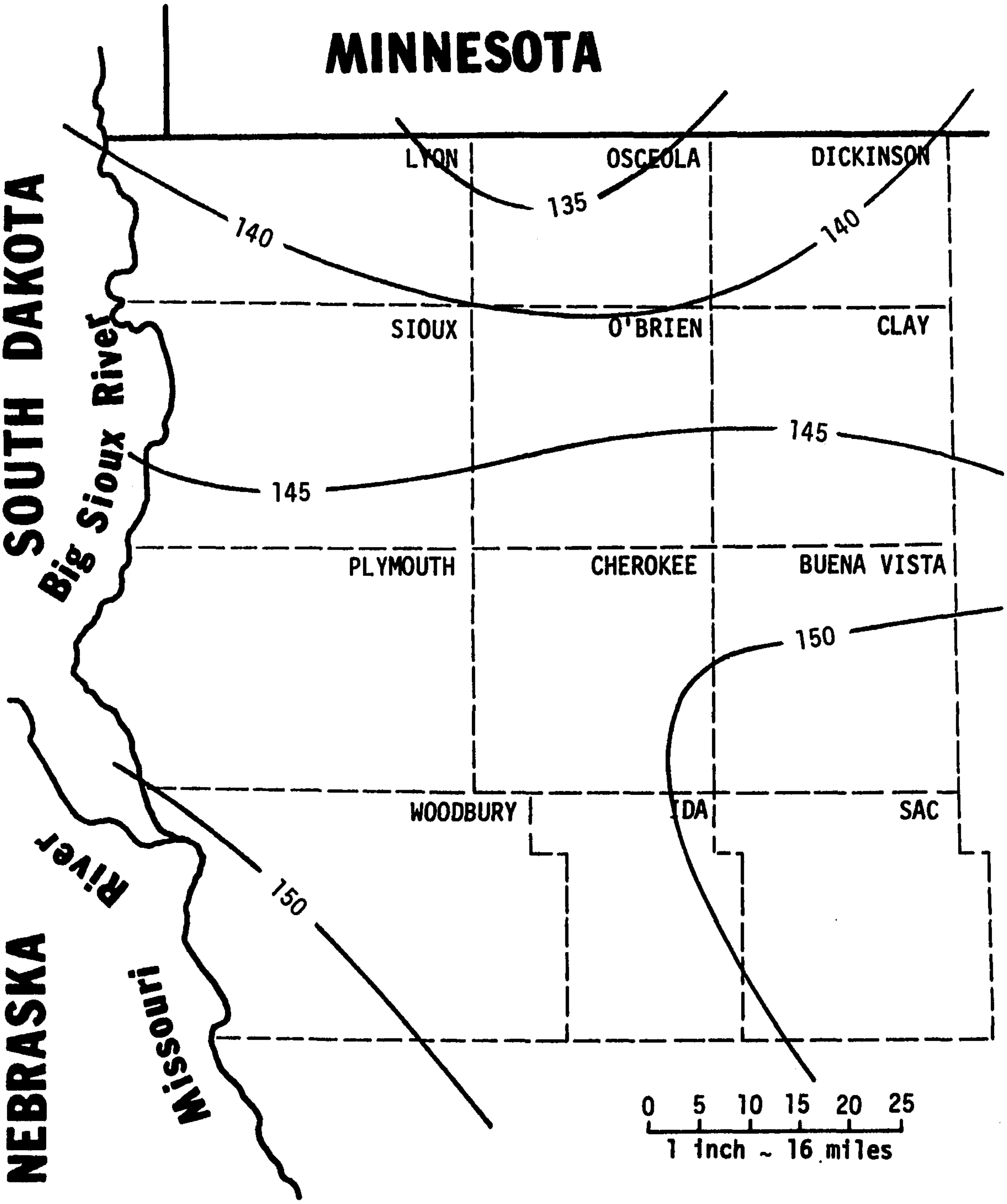


Fig. 21. Average length of freeze-free season in Northwest Iowa, days (after Shaw, Thom and Barger)

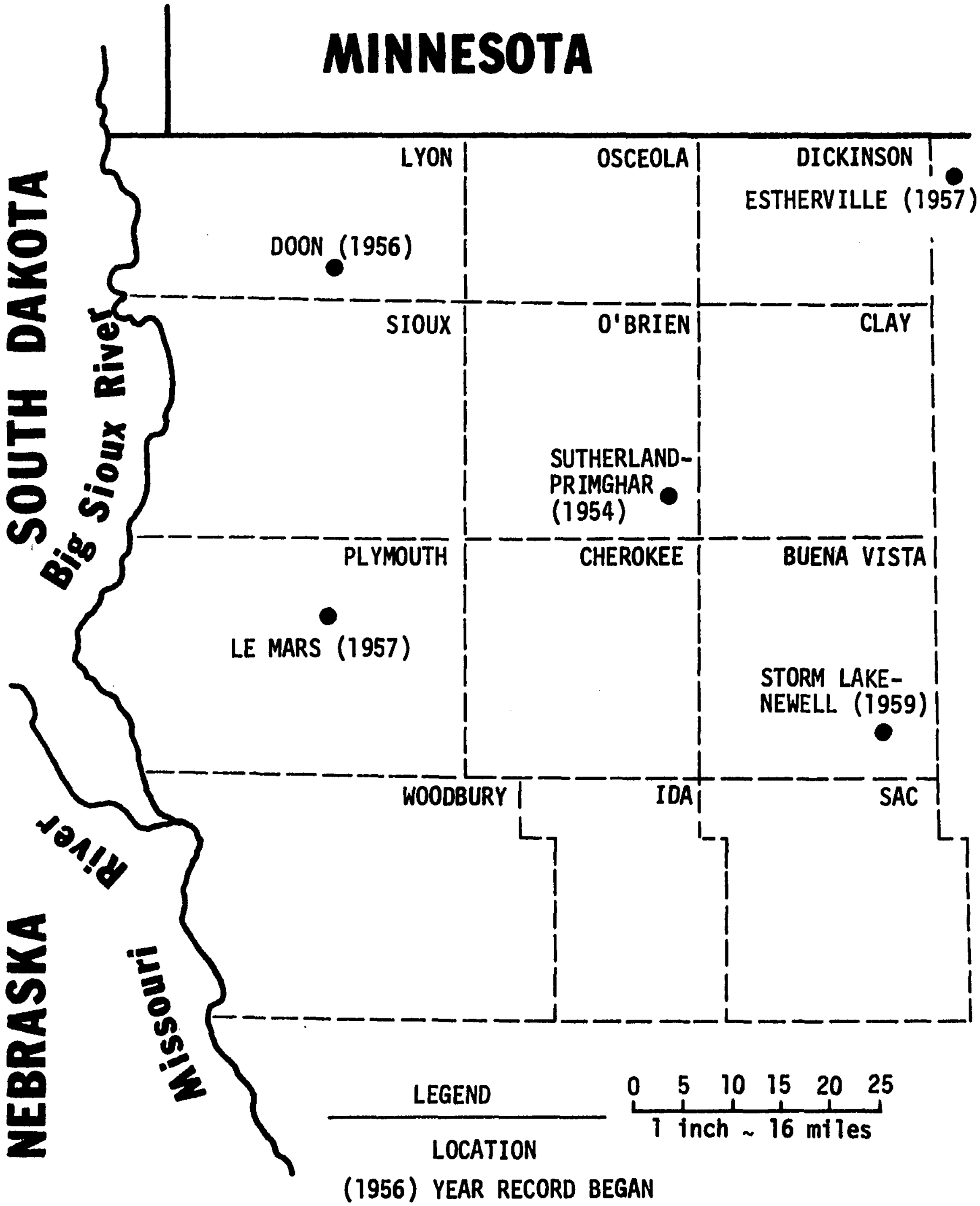


Fig. 22. Location of soil-moisture sampling sites in Northwest Iowa

Average soil moisture values at various dates and depths for the period of record at each station and the state average are listed in Table 23. All of these data are for corn following corn and are averages for the period of record through 1970. These average values and other information contained in the report by Shaw, Felch and Duncan (1972) indicate that Northwest Iowa has the lowest soil-moisture content in the state. The variability in soil moisture from the average is also a reason for the annual variations in crop yields in the study area. This variability is shown in Table 24 for the stations at Doon and Le Mars.

Precipitation

As mentioned in a previous section, the source of all surface and ground water is precipitation. Measuring stations for precipitation have been maintained for a number of years and are the responsibility of the National Weather Service, an agency presently within NOAA (U.S. Department of Commerce, 1891-1977). There are 23 long-term stations located in Northwest Iowa as shown in Fig. 23. Table 25 indicates that their lengths of record range from 33 years at Merrill to 88 years at Sioux City (U.S. Department of Commerce, 1956, 1964, 1891-1977).

The average annual precipitation over the entire state is 32 inches, varying from about 25 inches in the northwest to 35 inches in the southeast. In Northwest Iowa the range is from 25 to 29 inches as shown in Fig. 24. About three-fourths of the annual precipitation, from 19 to 21 inches, falls during the crop season which extends from

Table 23. Average amount of plant-available water in the top 5 feet of the soil profile, by 1-foot increments, for several dates at 5 locations in Northwest Iowa. Period of record through 1970[a]

Station	Depth feet	Plant-available water in inches for designated date							
		April 15	May 1	June 1	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1
Doon	0-1	1.6	1.3	1.6	1.5	0.7	1.1	1.5	1.4
	1-2	1.3	1.3	1.4	1.2	0.5	0.3	0.6	1.0
	2-3	0.7	0.8	0.9	1.1	0.6	0.3	0.4	0.6
	3-4	0.6	0.6	0.7	0.8	0.6	0.3	0.3	0.4
	4-5	0.5	0.5	0.6	0.6	0.6	0.5	0.4	0.5
	0-5	4.7	4.5	5.2	5.2	3.0	2.5	3.2	3.9
Le Mars	0-1	1.4	1.1	1.5	1.2	0.5	0.9	1.3	1.4
	1-2	1.2	1.2	1.4	0.8	0.3	0.2	0.6	0.8
	2-3	0.9	1.0	1.2	1.1	0.5	0.2	0.3	0.5
	3-4	0.9	0.9	1.2	1.3	0.9	0.5	0.5	0.6
	4-5	1.0	1.0	1.1	1.2	1.1	0.8	0.8	0.8
	0-5	5.4	5.2	6.4	5.7	3.3	2.6	3.5	4.1
Sutherland -Primghar	0-1	1.7	1.3	1.7	1.6	0.8	1.2	1.5	1.6
	1-2	1.4	1.5	1.7	1.3	0.6	0.4	1.0	1.0
	2-3	1.1	1.2	1.3	1.4	0.8	0.5	0.6	0.9
	3-4	1.1	1.1	1.1	1.2	0.9	0.6	0.7	0.9
	4-5	0.9	0.9	0.9	1.0	0.9	0.8	0.7	0.7
	0-5	6.2	6.0	6.7	6.5	4.0	3.5	4.5	5.1
Estherville	0-1	1.8	1.3	1.8	1.7	0.9	1.0	1.6	1.6
	1-2	1.5	1.5	1.7	1.2	0.6	0.4	0.9	1.2
	2-3	1.1	1.1	1.4	1.4	0.7	0.4	0.6	0.9
	3-4	1.1	1.1	1.3	1.5	1.0	0.7	0.7	0.9
	4-5	1.3	1.3	1.5	1.6	1.5	1.1	1.0	1.2
	0-5	6.8	6.3	7.7	7.4	4.7	3.6	4.8	5.8

Storm Lake -Newell	0-1	1.8	1.4	1.7	1.3	0.8	1.0	1.7	1.6
	1-2	1.5	1.6	1.7	1.4	0.7	0.5	0.9	1.2
	2-3	1.2	1.3	1.6	1.6	0.9	0.5	0.8	0.9
	3-4	1.0	1.0	1.4	1.6	1.0	0.8	0.8	1.0
	4-5	1.1	1.1	1.2	1.5	1.5	1.3	1.1	1.1
	0-5	6.5	6.4	7.6	7.4	4.9	4.1	5.3	5.8
State average	0-1	1.9	1.7	1.8	1.6	1.1	1.2	1.8	1.8
	1-2	1.7	1.8	1.9	1.5	1.0	0.7	1.2	1.5
	2-3	1.4	1.5	1.6	1.6	1.0	0.6	0.8	1.1
	3-4	1.3	1.3	1.5	1.6	1.2	0.8	0.8	1.0
	4-5	1.3	1.3	1.4	1.5	1.4	1.3	1.2	1.3
	0-5	7.6	7.6	8.2	7.8	5.7	4.6	5.8	6.7

[a]Shaw, Felch and Duncan (1972).

Table 24. Variability in amount of plant-available water in inches in the top 5 feet of the soil profile for several dates at Doon and Le Mars. Period of record through 1970[a]

Date	Doon			Le Mars		
	Low	Average	High	Low	Average	High
April 15	1.2	4.7	10.2	2.3	5.4	7.7
May 1	0.8	4.5	9.3	2.3	5.2	7.6
June 1	1.5	5.2	9.6	2.8	6.4	8.8
July 1	0.9	5.2	9.8	2.5	5.7	8.9
Aug. 1	0.4	3.0	7.2	0.8	3.3	6.4
Sept. 1	0.2	2.5	4.5	0.7	2.6	4.3
Oct. 1	0.5	3.2	8.6	1.2	3.5	6.9
Nov. 1	0.0	3.9	8.3	1.4	4.1	6.1

[a]Shaw, Felch and Duncan (1972).

April through September as shown in Fig. 25. On 165 days of the year, a trace or more of precipitation falls at all Northwest Iowa locations. A rainfall of more than 0.1 inch per day falls on each of about 50 days and on an average of 16 days per year, a rainfall of greater than 0.5 inch per day occurs in Northwest Iowa. The annual variability of precipitation in the state is considerable. In Iowa the record low state-average value is 19.9 inches in 1910 and the high is 44.2 inches in 1881. Spatially, the annual precipitation has varied from 12.1 inches at Clear Lake in 1910 to 74.5 inches at Muscatine in 1851 (Waite, 1970). Precipitation is also highly variable throughout the year as depicted in Fig. 26 through Fig. 31 which show the average monthly precipitation at six stations in Northwest Iowa.

Annual precipitation plus rainfall during the months of June, July and August for the period of record at the gaging stations shown in Fig. 23 are listed in Tables F-1 through F-23 in Appendix F. These

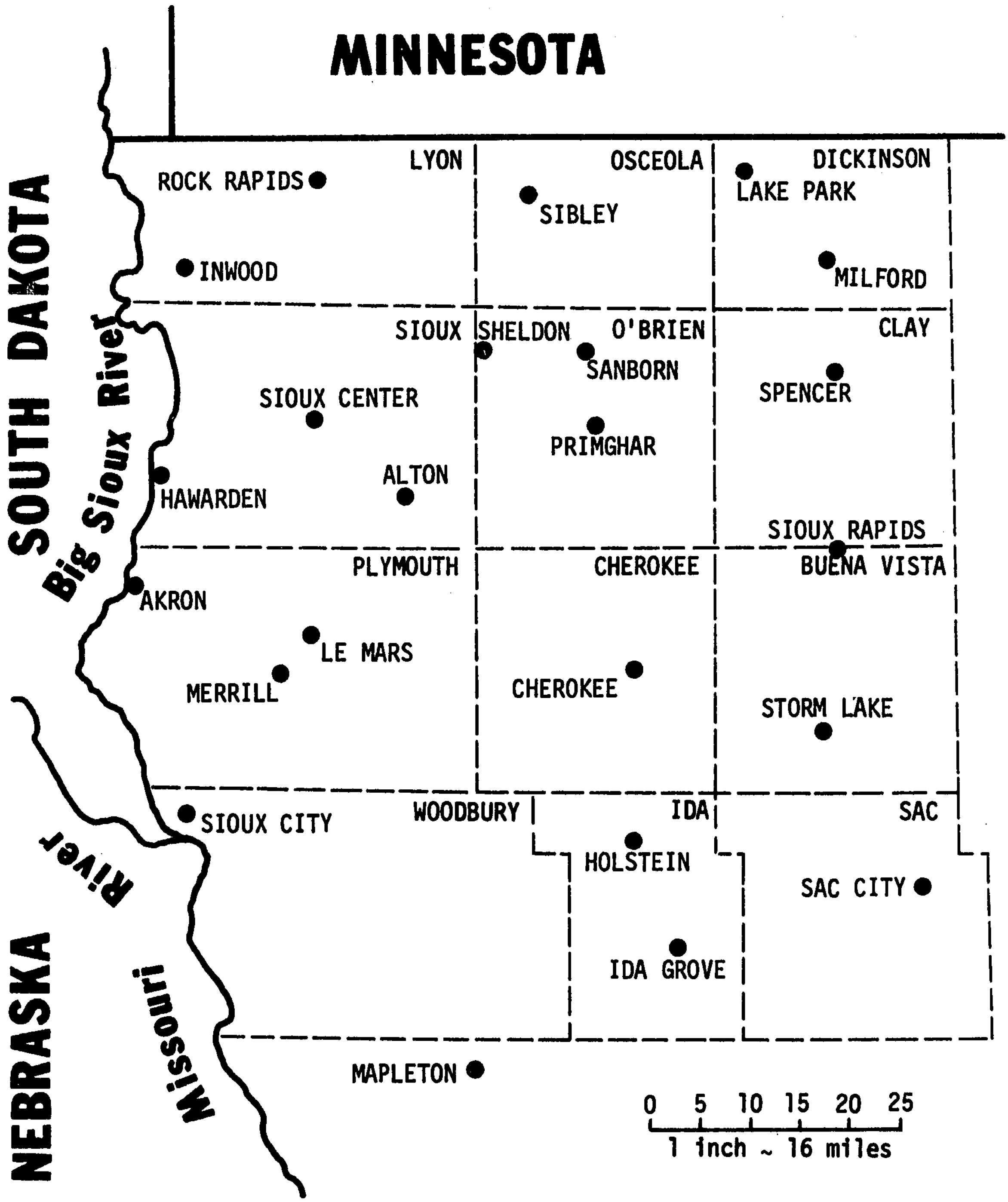


Fig. 23. Location of precipitation gaging stations in Northwest Iowa

Table 25. Location and period of record of long-term precipitation gaging stations in Northwest Iowa

Location	Period of record From	To	Length years
Akron	1928	Present	51
Alton	1906	Present	73
Cherokee	1922	Present	57
Hawarden	1927	Present	52
Holstein	1934	Present	45
Ida Grove	1945	Present	34
Inwood	1904	1972	69
Lake Park	1927	Present	52
Le Mars	1897	Present	82
Mapleton	1938	Present	41
Merrill	1946	Present	33
Milford	1939	Present	40
Primghar	1937	Present	42
Rock Rapids	1904	Present	75
Sac City	1893	Present	86
Sanborn	1915	Present	64
Sheldon	1926	Present	53
Sibley	1936	Present	43
Sioux Center	1900	Present	79
Sioux City	1891	Present	88
Sioux Rapids	1942	Present	37
Spencer	1912	Present	67
Storm Lake	1899	Present	80

data are also ranked from high to low values in Tables F-24 through F-46 in Appendix F. As shown in Table 26, the average annual precipitation in the region is 27.0 inches, ranging from 24.9 inches at Inwood to 29.4 inches at Ida Grove. The minimum annual precipitation was 12.1 inches at Cherokee in 1958 and ranged up to 16.4 inches at Sibley in 1955. The maximum annual precipitation was 51.6 inches at Ida Grove in 1951 and ranged down to 35.9 inches at Lake Park in 1938. The maximum annual precipitation was recorded at 14 of the 23 stations

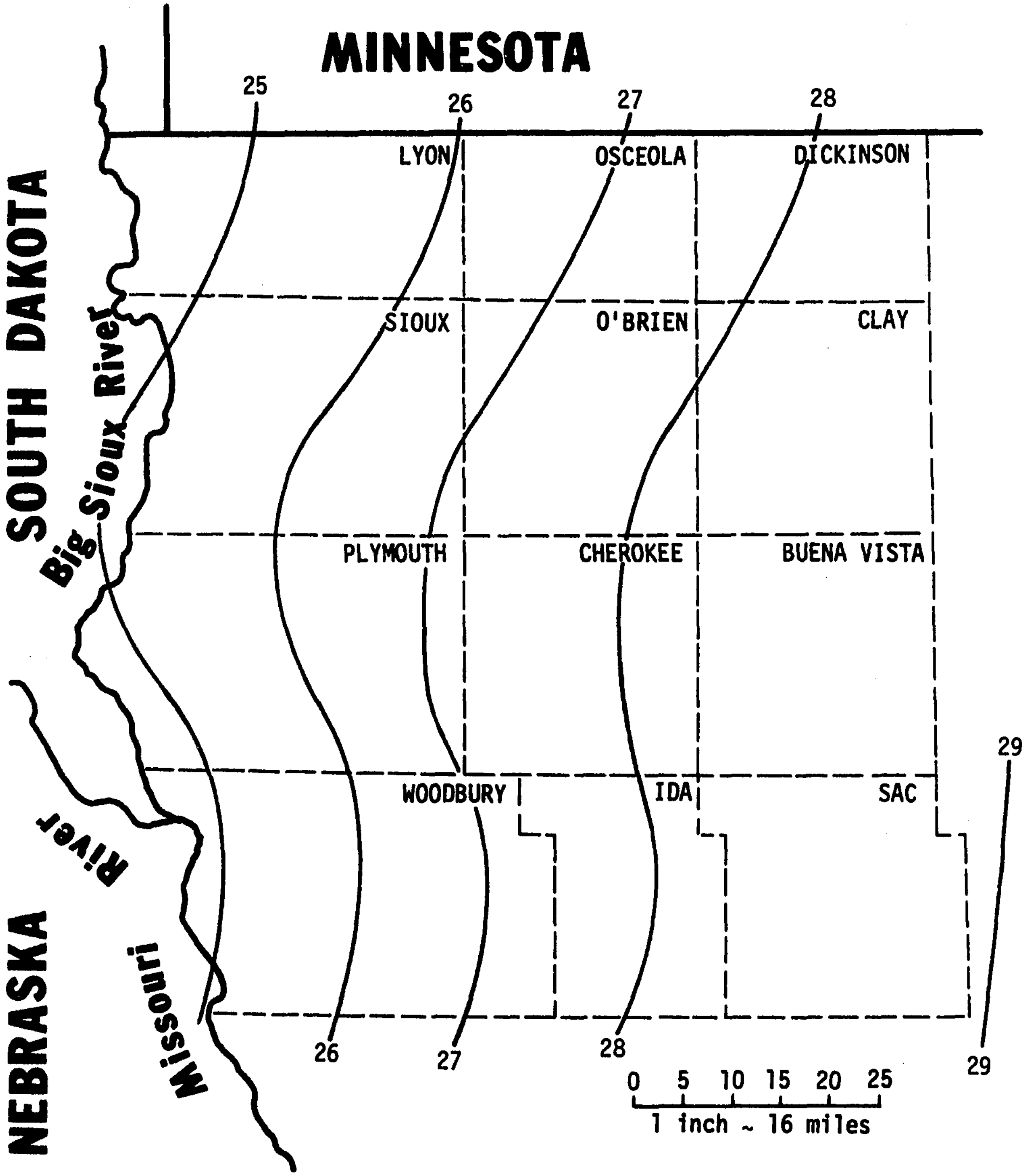


Fig. 24. Normal annual precipitation in inches (after Waite)

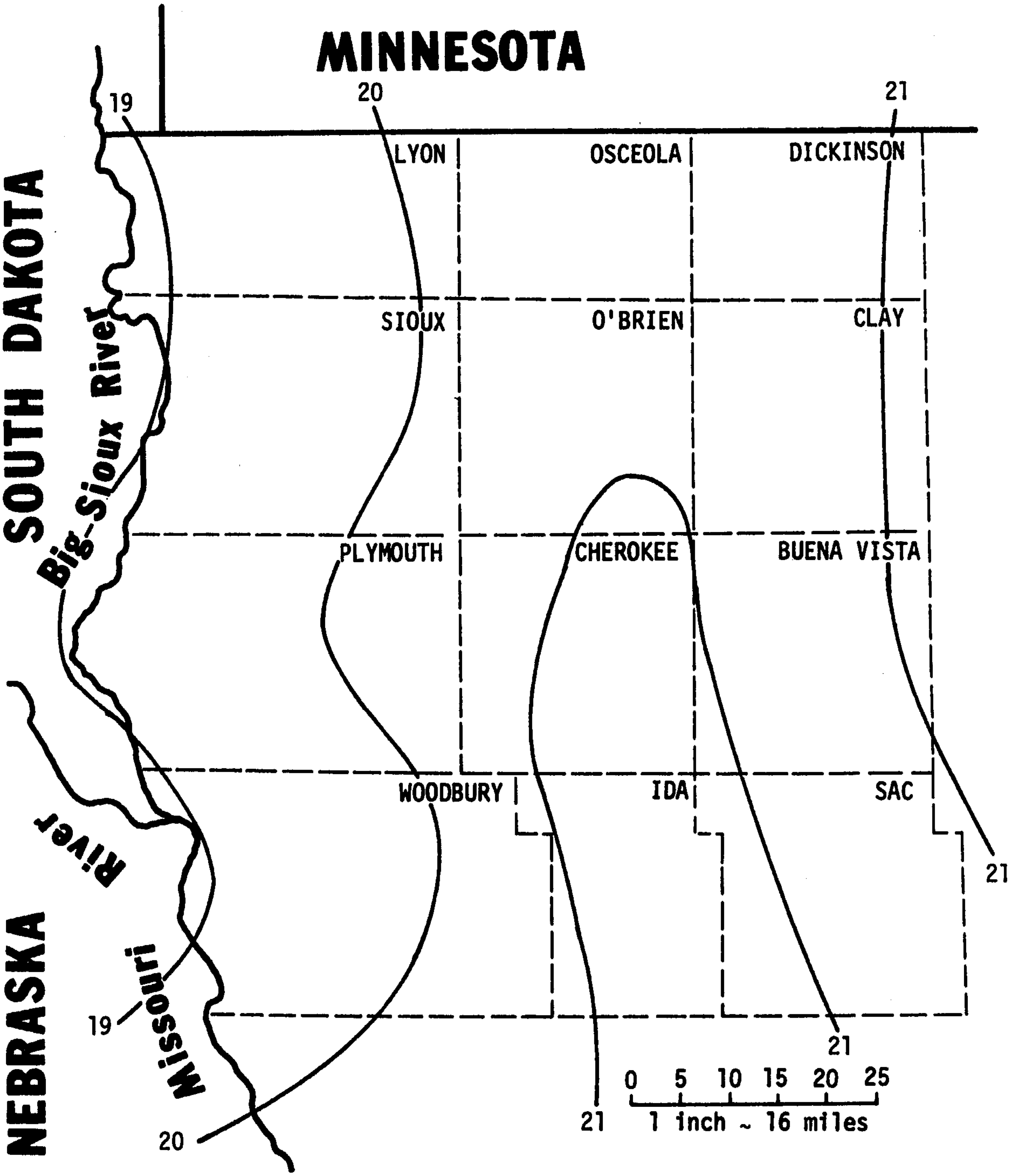


Fig. 25. Normal crop season precipitation in inches (April through September) (after Waite)

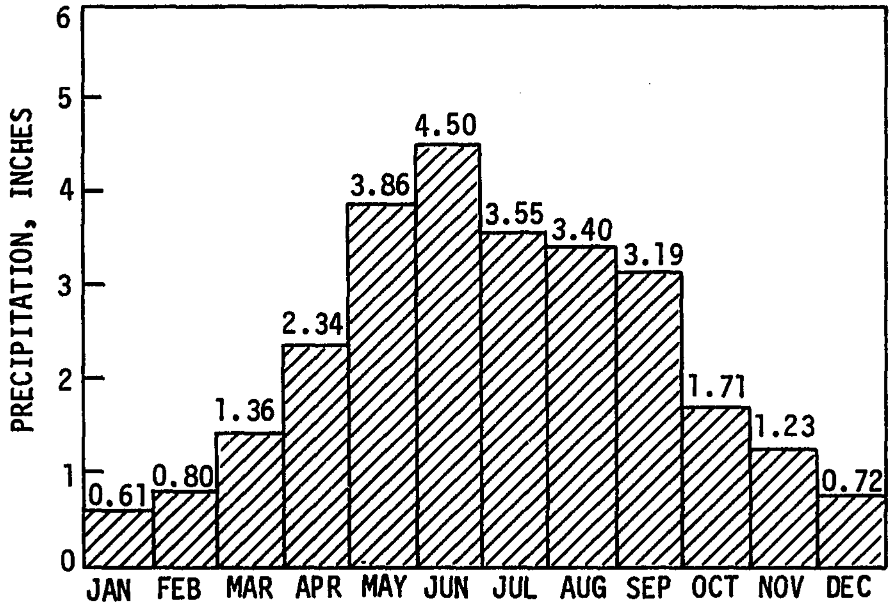


Fig. 26. Normal monthly precipitation at Cherokee

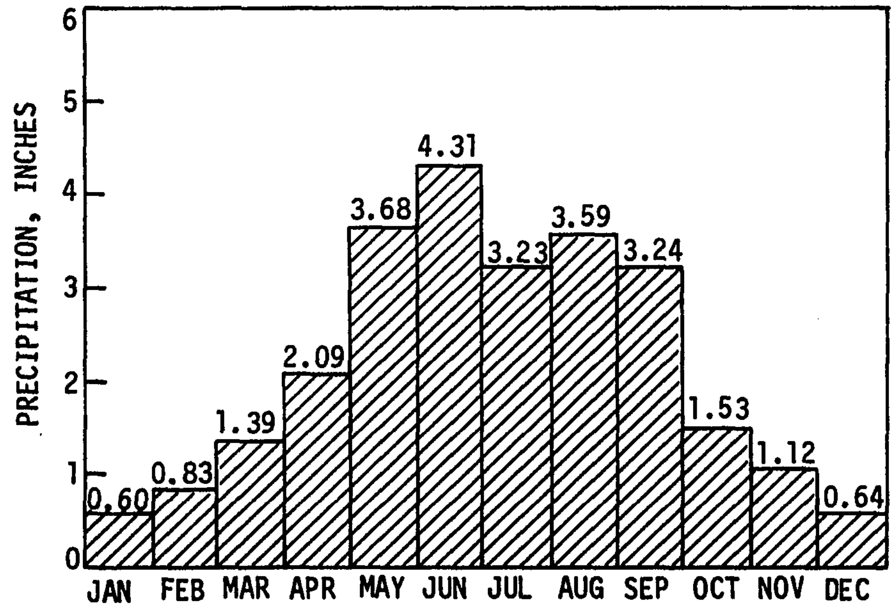


Fig. 27. Normal monthly precipitation at Lake Park

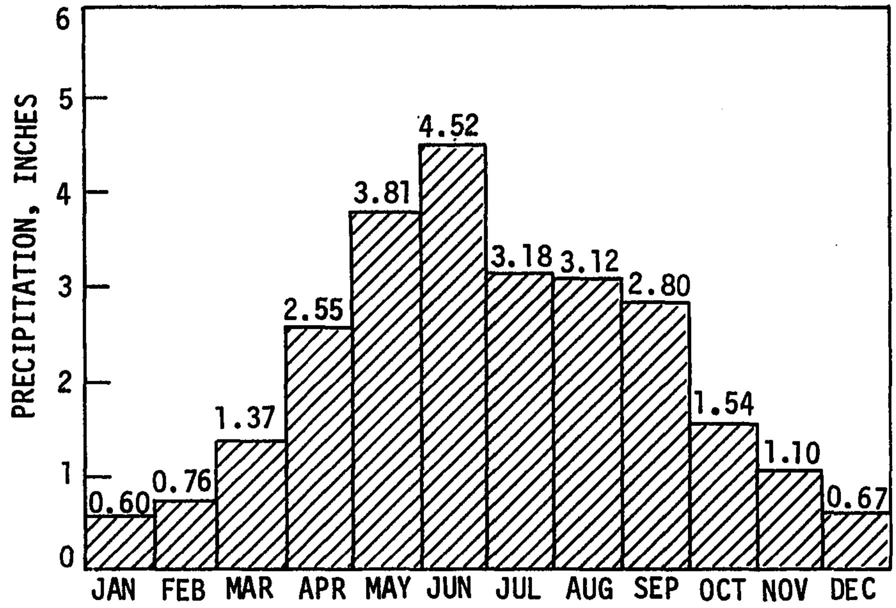


Fig. 28. Normal monthly precipitation at Rock Rapids

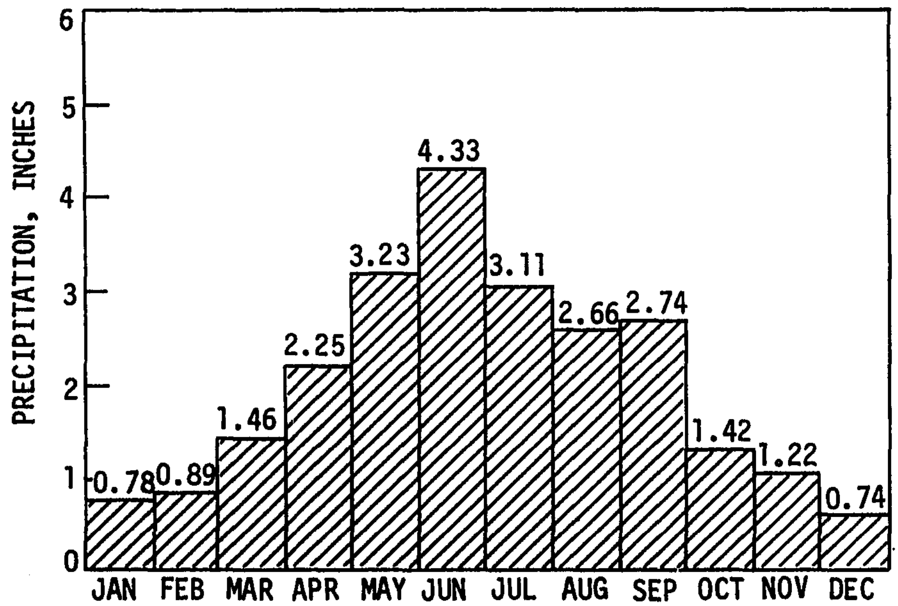


Fig. 29. Normal monthly precipitation at Sioux City

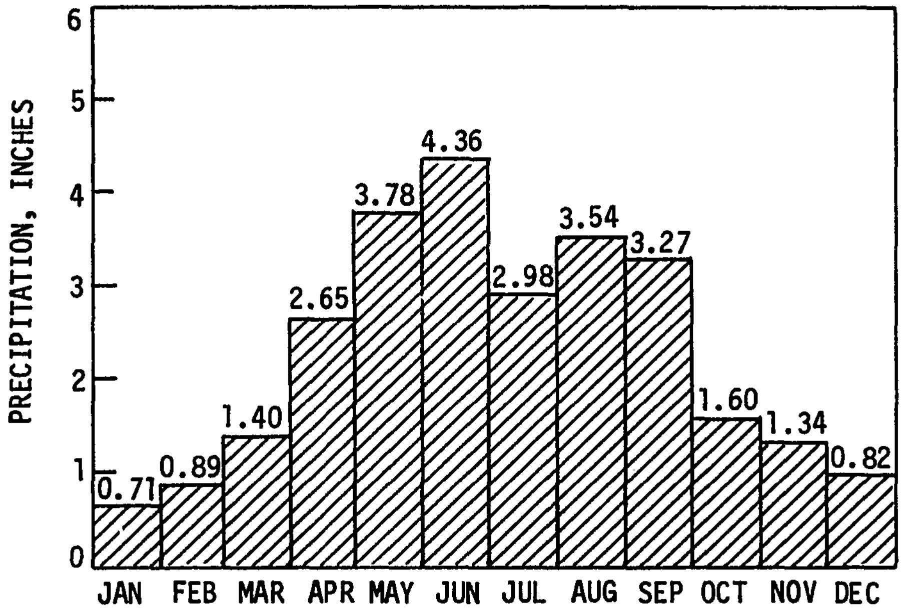


Fig. 30. Normal monthly precipitation at Spencer

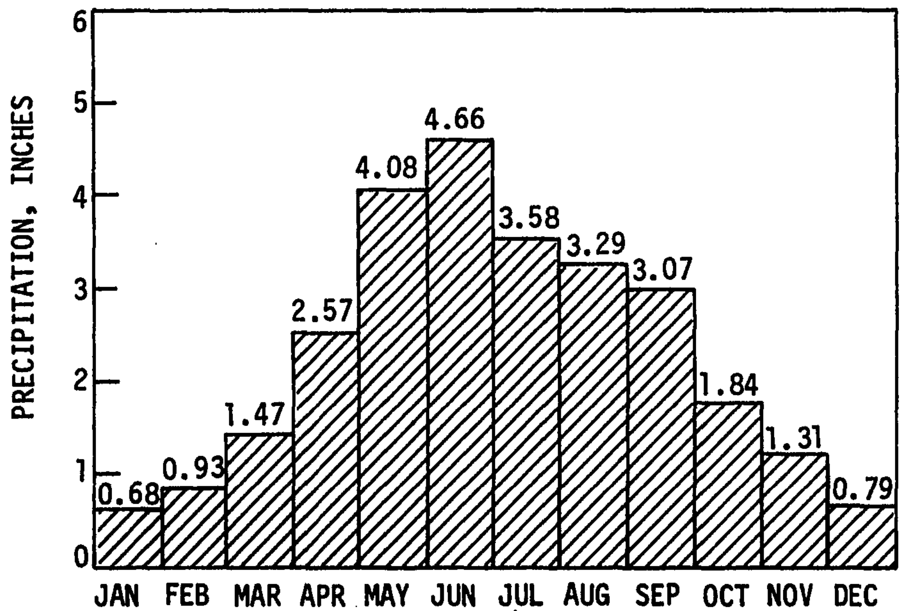


Fig. 31. Normal monthly precipitation at Storm Lake

Table 26. Mean, minimum and maximum annual precipitation at various locations in Northwest Iowa, inches

County	Location	N, years	Mean	Minimum	Maximum
Buena Vista	Sioux Rapids	35	28.10	14.17	39.11
	Storm Lake	78	28.41	13.90	45.94
Cherokee	Cherokee	55	27.12	12.11	42.86
Clay	Spencer	65	27.69	14.41	44.15
Dickinson	Lake Park	50	26.53	13.43	35.91
	Milford	36	26.78	12.70	37.21
Ida	Holstein	43	28.43	15.54	43.10
	Ida Grove	32	29.43	16.02	51.62
Lyon	Inwood	69	24.92	12.65	37.61
	Rock Rapids	73	25.78	13.58	41.69
O'Brien	Primghar	40	27.83	14.96	43.54
	Sanborn	62	27.87	13.77	46.02
	Sheldon	51	26.57	15.41	46.02
Osceola	Sibley	41	27.55	16.38	37.60
Plymouth	Akron	49	25.67	12.75	42.95
	Le Mars	80	26.48	13.02	42.35
	Merrill	31	25.42	13.14	38.84
Sac	Sac City	84	28.63	14.75	44.51
Sioux	Alton	71	25.82	13.29	38.25
	Hawarden	50	25.33	13.97	39.34
	Sioux Center	77	27.02	14 83	41.14
Woodbury	Sioux City	86	25.38	14.33	41.10
Monona	Mapleton	39	27.50	15.90	40.73
Regional average			26.97	14.13	41.81

in 1958. The minimum annual precipitation was recorded at another 8 stations in 1976 and the second lowest annual precipitation was recorded at 7 stations also in 1976. The statistical parameters for the annual precipitation are shown in Table 27. These values were used with the Pearson Type III distribution to determine the annual precipitation amounts for the six recurrence intervals shown in Table 28.

Table 27. Statistical parameters of annual precipitation in Northwest Iowa, inches

Location	N years	Mean	Standard deviation	Skew	Coeff. of variation
Akron	49	25.67	5.93	0.004	0.23
Alton	71	25.82	5.31	- 0.247	0.20
Cherokee	55	27.12	6.45	0.121	0.24
Hawarden	50	25.33	5.56	0.131	0.22
Holstein	43	28.43	6.30	- 0.059	0.22
Ida Grove	32	29.43	7.33	0.702	0.25
Inwood	69	24.92	5.27	0.154	0.21
Lake Park	50	26.53	5.45	- 0.247	0.20
Le Mars	80	26.48	5.93	0.166	0.22
Mapleton	39	27.50	6.08	- 0.058	0.22
Merrill	31	25.42	5.43	- 0.079	0.21
Milford	38	26.78	5.75	- 0.508	0.21
Primghar	40	27.83	5.97	0.023	0.21
Rock Rapids	73	25.78	5.68	0.171	0.22
Sac City	84	28.63	6.58	0.347	0.23
Sanborn	62	27.87	5.62	0.166	0.20
Sheldon	51	26.57	5.59	0.711	0.21
Sibley	41	27.55	5.50	- 0.162	0.20
Sioux Center	77	27.02	5.74	0.044	0.21
Sioux City	86	25.38	5.32	0.233	0.21
Sioux Rapids	35	28.10	7.01	- 0.435	0.25
Spencer	65	27.69	5.81	0.136	0.21
Storm Lake	78	28.41	6.29	- 0.161	0.22

Table 28. Minimum annual precipitation in inches for several recurrence intervals at various locations in Northwest Iowa

Location	Minimum annual precipitation in inches for indicated recurrence interval in years					
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr
Akron	25.67	20.68	18.07	15.29	13.49	11.88
Alton	26.04	21.43	18.89	16.09	14.22	12.50
Cherokee	26.99	21.66	18.94	16.10	14.30	12.60
Hawarden	25.21	20.62	18.28	15.86	14.30	12.95
Holstein	28.49	23.15	20.31	17.27	15.29	13.50
Ida Grove	28.58	23.15	20.76	18.52	17.24	16.19
Inwood	24.79	20.47	18.26	15.97	14.53	13.25
Lake Park	26.76	22.02	19.42	16.54	14.62	12.86
Le Mars	26.32	21.45	19.00	16.45	14.84	13.42
Mapleton	27.56	22.40	19.67	16.73	14.82	13.09
Merrill	25.50	20.88	18.42	15.76	14.04	12.47
Milford	27.26	22.14	19.17	15.78	13.47	11.30
Primghar	27.81	22.80	20.19	17.43	15.64	14.05
Rock Rapids	25.62	20.96	18.62	16.19	14.65	13.31
Sac City	28.25	23.01	20.48	17.94	16.36	15.03
Sanborn	27.72	23.10	20.78	18.36	16.84	15.49
Sheldon	26.00	21.78	19.87	18.05	16.99	16.10
Sibley	27.70	22.97	20.42	17.63	15.79	14.11
Sioux Center	26.97	22.18	19.70	17.07	15.38	13.86
Sioux City	25.17	20.85	18.71	16.56	15.13	13.93
Sioux Rapids	28.60	22.40	18.85	14.85	12.13	9.60
Spencer	27.56	22.76	20.33	17.79	16.17	14.75
Storm Lake	28.58	23.18	20.25	17.06	14.96	13.04
Regional average	26.92	22.00	19.45	16.75	15.01	13.45

Similar information was obtained for June, July and August and combinations of these three months for use in estimating irrigation needs. The combinations of these three months are ranked from high to low values in Tables F-47 through F-69 in Appendix F. Statistical parameters for these three months and their combinations are listed in Tables F-70 through F-75 in Appendix F. These values were then used with the Pearson Type III distribution to determine the amounts at the various recurrence intervals shown in Tables F-76 through F-81 in Appendix F. The average values of the various combinations of June, July and August rainfall at each of the 23 locations in Northwest Iowa are listed in Table 29. The regional values of these various combinations of rainfall for recurrence intervals from 2- to 100-yr are summarized in Table 30.

Table 29. Average values of various combinations of June, July and August precipitation at several locations in Northwest Iowa, inches[a]

Location	N years	June	July	August	June and July	July and August	June through August
Akron	49	4.64	3.15	3.41	7.79	6.56	11.20
Alton	71	4.07	3.29	3.36	7.36	6.65	10.72
Cherokee	55	4.50	3.54	3.33	8.04	6.88	11.38
Hawarden	50	4.39	3.11	3.27	7.50	6.38	10.77
Holstein	43	4.84	3.54	3.38	8.38	6.93	11.77
Ida Grove	32	4.83	3.50	3.76	8.33	7.26	12.09
Inwood	69	4.51	3.04	2.97	7.55	6.00	10.51
Lake Park	50	4.56	3.46	3.33	8.03	6.80	11.36
Le Mars	80	4.22	3.42	3.06	7.64	6.48	10.70
Mapleton	39	4.89	3.34	3.40	8.23	6.74	11.63
Merrill	31	4.06	3.33	3.23	7.39	6.57	10.62
Milford	38	4.66	3.56	3.18	8.23	6.75	11.41
Primghar	40	4.60	3.29	3.89	7.89	7.18	11.78
Rock Rapids	73	4.42	3.20	3.19	7.62	6.39	10.81
Sac City	84	4.35	3.49	3.56	7.84	7.05	11.40
Sanborn	62	4.30	3.32	3.67	7.62	6.99	11.30
Sheldon	51	4.43	3.19	3.56	7.62	6.75	11.18
Sibley	41	4.82	3.61	3.59	8.43	7.20	12.02
Sioux Center	77	4.44	3.44	3.23	7.88	6.67	11.12
Sioux City	86	4.11	3.25	2.85	7.36	6.10	10.21
Sioux Rapids	35	4.78	3.49	3.86	8.27	7.35	12.13
Spencer	65	4.24	3.26	3.57	7.50	6.84	11.07
Storm Lake	78	4.57	3.60	3.52	8.17	7.12	11.69
Region		4.49	3.37	3.40	7.86	6.77	11.26

[a]See Tables F-70 through F-75 in Appendix F.

Table 30. Regional values of various combinations of June, July and August precipitation for several recurrence intervals in Northwest Iowa, inches[a]

Recurrence interval years	June	July	August	June and July	July and August	June through August
2	4.22	3.18	3.07	7.66	6.48	10.94
5	2.67	1.71	1.63	5.41	4.33	7.99
10	2.00	0.99	1.04	4.28	3.42	6.62
25	1.38	0.39	0.51	3.19	2.20	5.26
50	1.02	0.13	0.28	2.53	1.71	4.44
100	0.74	0.08	0.16	1.96	1.22	3.75

[a]See Tables F-76 through F-81 in Appendix F.

While June rainfall averages 4.5 inches in Northwest Iowa, it has ranged from 0.15 inches at Sioux Center in 1933 to 14.05 inches at Ida Grove in 1967. The regional average July precipitation is 3.4 inches and has varied from 0.01 inches at Akron in 1930 to 12.61 inches at Sac City in 1902. The average August rainfall is also 3.4 inches but has ranged from 0.01 inches at Lake Park in 1948 to 14.85 inches at Ida Grove in 1951. June-July precipitation averages 7.9 inches in Northwest Iowa and has varied from a low of 1.49 inches at Holstein in 1936 to a high of 18.24 inches at Sac City in 1902. Precipitation in July and August has averaged 6.8 inches but has ranged from 0.69 inches at Primghar in 1947 to 21.27 inches at Ida Grove in 1962. The average rainfall during the three summer months in Northwest Iowa is 11.3 inches. The driest three summer months occurred in 1976 when only 2.55 inches of rain were recorded at Sioux City. The three wettest summer months occurred at Ida Grove in 1951 when 29.03 inches of rain were recorded.

Streamflow

Drainage patterns in Northwest Iowa are well-defined as shown in Fig. 32. The drainage areas of these watersheds are shown in Table 31. Streamflow data in Iowa is gathered and published by the U.S. Geological Survey. The cost of maintaining this widespread network of stream gaging stations is borne by the federal government in cooperation with the Iowa Geological Survey plus such agencies as the Corps of Engineers, Iowa Natural Resources Council, Iowa Department of Transportation and others. Currently in Northwest Iowa there are about 20 continuous-record stations, 73 low-flow partial-record stations and 13 crest-stage partial-record stations. The length of record at these stations varies from 4 to 79 years. These records provide the data that show this region of Iowa to be the most deficient in surface water runoff, averaging about 3 inches annually, half the state average. These data also indicate that the flow is highly variable; many streams have a 7-day, 10-year low flow near or at zero flow, yet these rivers also are subject to large floods.

This flow variability is shown in Table 32 which lists the average, peak and minimum flows plus the average annual runoff in inches and acre-feet for the period of record at the continuous stream gaging stations. For example, the Rock River has experienced flows ranging from zero to 40,400 cfs while on the Floyd River at James,

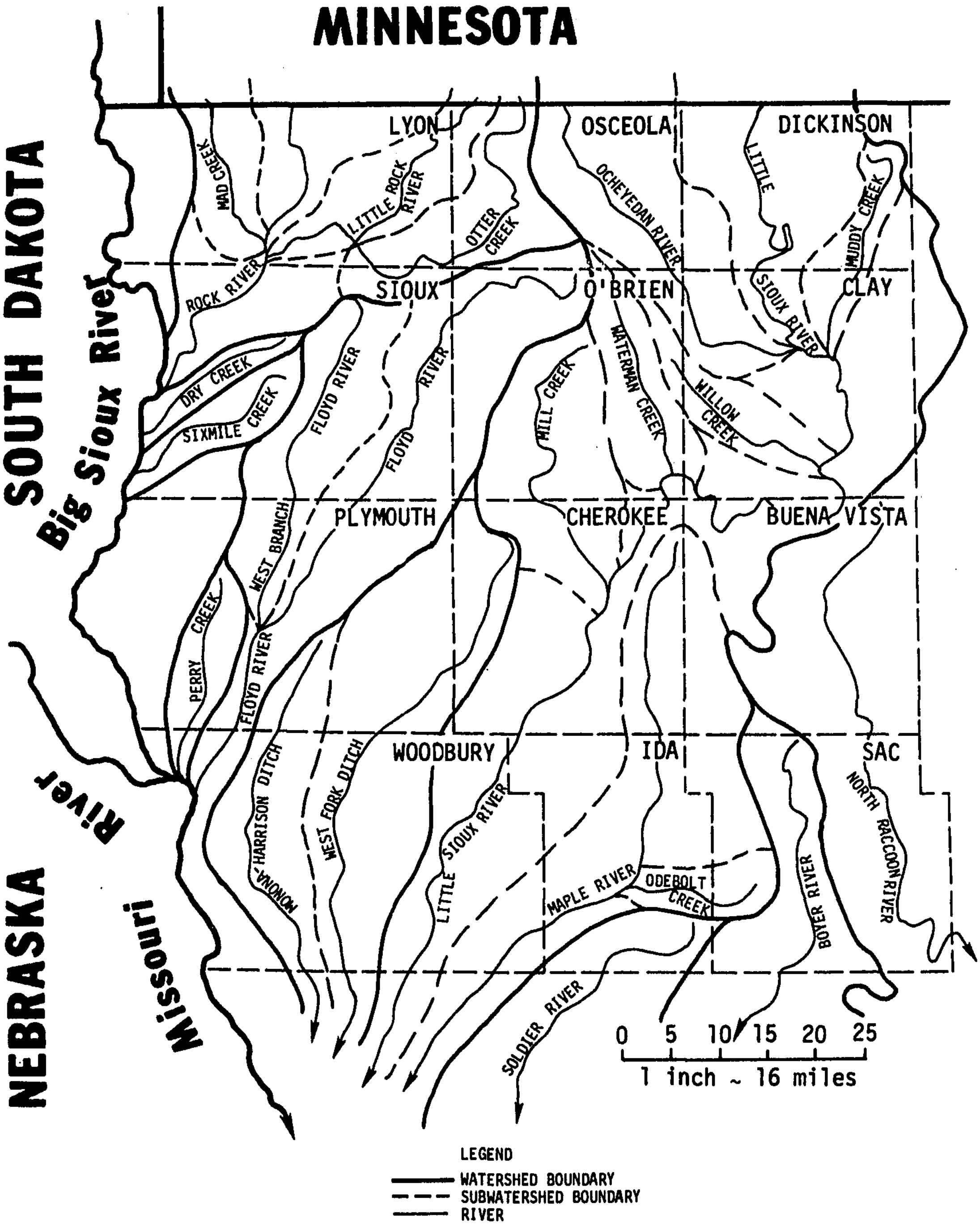


Fig. 32. Rivers and river basins in Northwest Iowa

Table 31. Drainage areas of streams in Northwest Iowa

Name	Drainage area, sq. mi.			
	Minnesota state line	Mouth	Parent river upstream of trib.	Southern county line
Big Sioux River				
Rock River	558	1,688		
Mud Creek	31	138	911	
Little Rock River	92	474	1,052	
Otter Creek	11	210	206	
Dry Creek		50		
Sixmile Creek		108		
Broken Kettle Creek		99		
Missouri River				
Perry Creek		73		
Floyd River		921		
West Branch Floyd River		281	530	
Monona-Harrison Ditch				190
West Fork Ditch				410
Little Sioux River	100			2,697
Ocheyedan River	50	434	556	
Muddy Creek		103	999	
Willow Creek		92	1,400	
Waterman Creek		140	1,803	
Mill Creek		294	2,163	
Maple River				628
Odebolt Creek		61	428	
Soldier River				59
Boyer River				210
North Raccoon River				852

flows have varied from 1.0 to 71,500 cfs. This table also indicates that the average annual runoff at the long-term stations in the 12-county region ranges from 2 to 5 inches as shown in Fig. 33.

An interesting point to note in Table 32 is the average annual runoff at the two stations on the Missouri River, Sioux City and Omaha. Even though the drainage area is smaller at Sioux City, its average

Table 32. Continuous stream gaging station records in Northwest Iowa through September 30, 1977[a]

Stream	Number	Location	D.A. sq. mi.
North Raccoon River	5-4823.00	Near Sac City	713
Big Cedar Creek	5-4821.70	Near Varina	80
Missouri River	6-4860.00	At Sioux City	314,600
Missouri River	6-6100.00	At Omaha	322,800
Big Sioux River	6-4855.00	At Akron	9,030
Rock River	6-4832.70	At Rock Rapids	788
Rock River	6-4835.00	Near Rock Valley	1,592
Dry Creek	6-4840.00	At Hawarden	48
Perry Creek	6-6000.00	At 38th St., Sioux City	65
Floyd River	6-6001.00	At Alton	265
Floyd River	6-6005.00	At James	882
W. Br. Floyd River	6-6003.00	Near Struble	181
West Fork Ditch	6-6020.20	At Hornick	403
Monona-Harrison Ditch	6-6024.00	Near Turin	900
Little Sioux River	6-6056.00	At Gillette Grove	1,334
Little Sioux River	6-6058.50	At Linn Grove	1,548
Little Sioux River	6-6066.00	At Correctionville	2,500
Little Sioux River	6-6067.00	Near Kennebec	2,738
Little Sioux River	6-6075.00	Near Turin	3,526
Maple River	6-6072.00	At Mapleton	669
Odebolt Creek	6-6070.00	Near Arthur	39
Soldier River	6-6085.00	At Pisgah	407
Boyer River	6-6095.00	At Logan	871

[a]Water Resources Data for Iowa (U.S. Geological Survey, 1978).

Record length years	Recorded flows Mean cfs	Peak cfs	Minimum cfs	Average annual runoff Inches	Ac. ft.
19	274	10,800	0.0	5.22	198,500
18	32.8	2,080	0.0	5.57	23,760
80	31,970	441,000	2,500	1.38	23,160,000
49	29,350	396,000	2,200	1.23	21,260,000
49	820	80,800	4.0	1.23	594,100
15	164	29,000	0.8	2.83	118,800
29	288	40,400	0.0	2.44	208,700
21	8.0	12,500	0.0	2.26	5,820
24	15.1	9,600	0.0	3.15	10,940
22	44.5	45,500	0.0	2.28	32,240
42	173	71,500	0.9	2.66	125,300
22	28.5	8,060	0.0	2.14	20,650
33	92.4	12,400	0.2	3.11	66,940
19	206	19,900	8.5	3.27	149,200
15	380	24,000	1.0	3.87	275,300
5	405	8,620	0.7	3.55	293,400
50	685	45,000	2.6	3.72	496,300
30	780	29,700	11.0	3.87	565,100
19	1,041	30,000	17.0	4.01	754,200
36	225	15,700	2.5	4.57	163,000
18	15.7	5,200	0.2	5.42	11,370
37	123	22,500	2.0	4.10	89,110
45	303	31,000	1.5	4.72	219,500

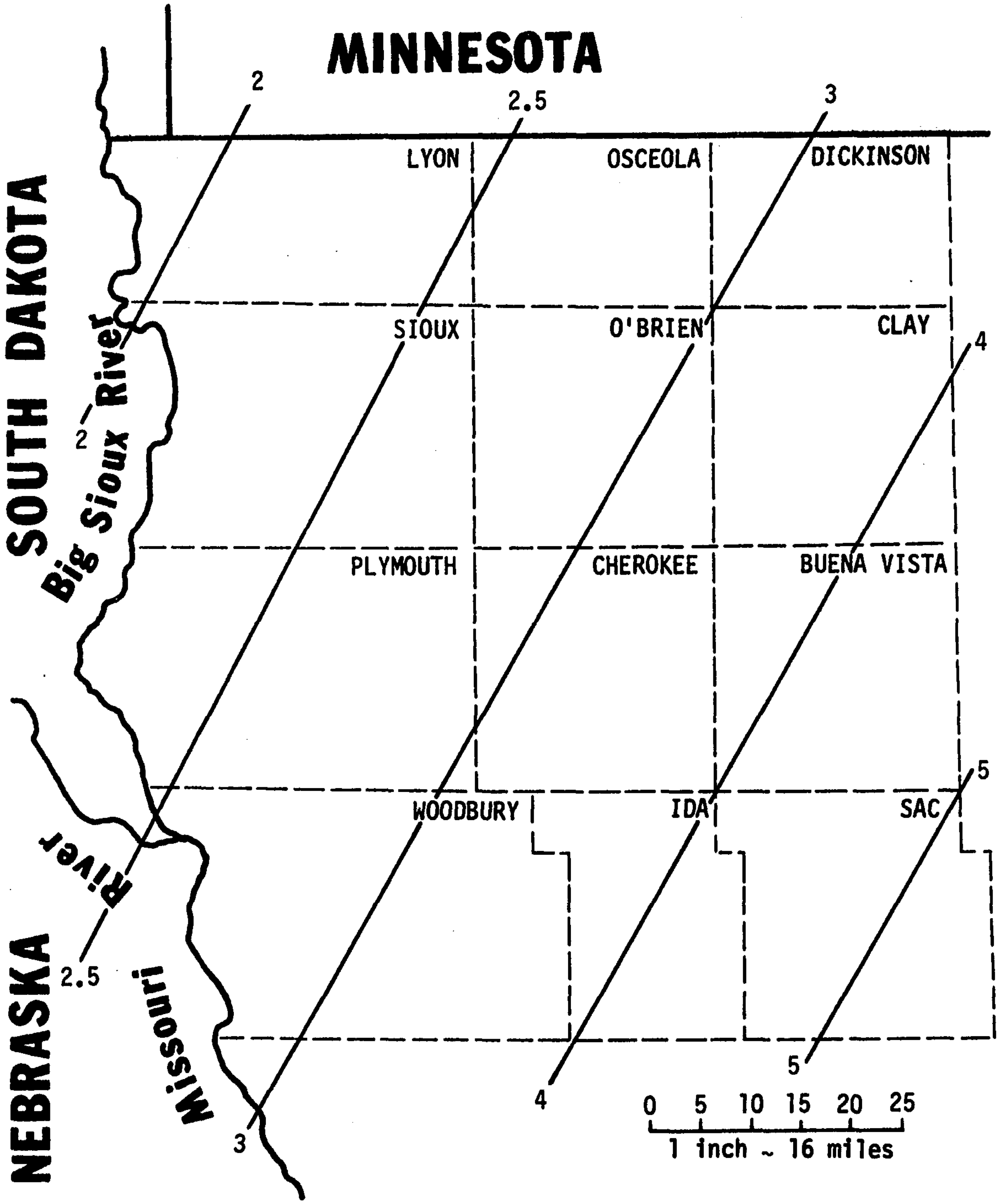


Fig. 33. Average annual runoff in inches

annual runoff is almost two million acre-feet greater than at Omaha. The reason for this is that the flow records are 31 years longer at Sioux City and thus include many more years when the flow depletions (caused by upstream consumptive withdrawals) were less than they are now. Historic and future flows and depletions for each of the Missouri River subbasins above Sioux City are shown in Table 33 and plotted in Fig. 34 (Missouri Basin Inter-Agency Committee, 1971b).

Table 33. Historic and future average annual streamflow depletions and available water supply in the Missouri River subbasins above Sioux City

Subbasin	1910 flow mil. ac. ft.	Cumulative depletions to indicated year, million acre-feet 1910-1949	1970	1980	2000	2020
Upper Missouri	8.5	0.7	1.3	1.7	2.1	2.3
Yellowstone	9.4	0.3	0.6	1.2	1.6	2.2
Western Dakota	2.8	0.1	0.4	0.7	1.1	1.6
Eastern Dakota	3.6	0.1	0.3	0.3	0.5	0.6
Total	24.3	1.2	2.6	3.9	5.3	6.7
Net flow	24.3	23.1	21.7	20.4	19.0	17.6

[a]The Missouri River Basin Comprehensive Framework Study (Missouri Basin Inter-Agency Committee, 1971b).

The 6.7 million acre-feet in 2020 represents a depletion of 27.6% of the total runoff existing in 1910. Included in these depletions are municipal, industrial and rural consumptive uses, irrigation, energy production and reservoir evaporation. These upstream depletions reduce the flow available for in-stream uses and also for off-stream uses by the downstream states.

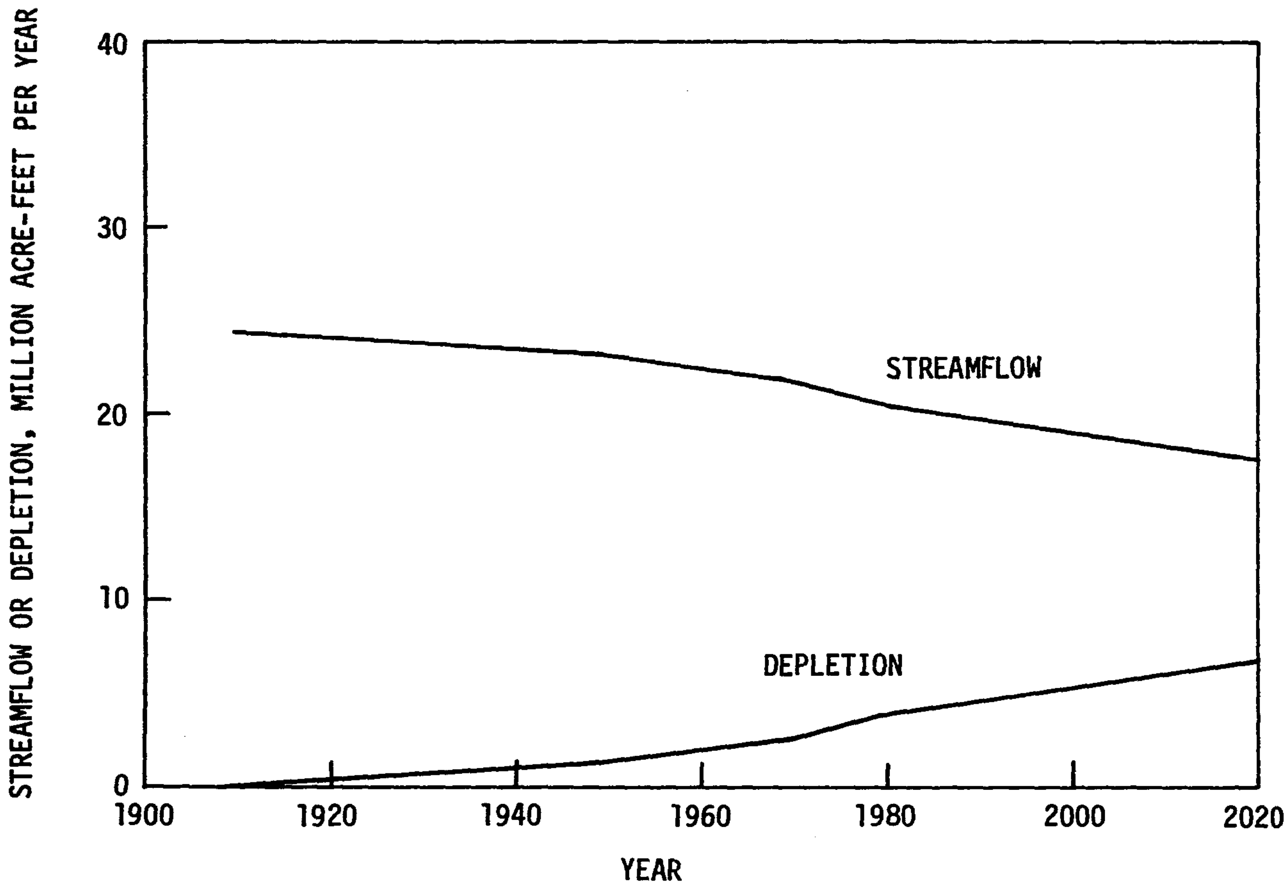


Fig. 34. Historic and future average annual streamflow depletions and available water supply in the Missouri River above Sioux City

Using the data in Table 32, the mean and peak flows in cfs per square mile at the continuous streamflow gaging stations in Northwest Iowa were calculated. The results are shown in Table 34. The mean flows for the various periods of record vary from 0.16 to 0.43 cfs per square mile and their locations are plotted in Fig. 35. The U.S. Geological Survey has developed the following regression equation for calculating the mean flow of an interior stream in Iowa (Heinitz, 1970).

$$\bar{Q} = 0.0000007063A^{1.013}P^{3.88} \tag{20}$$

where $\bar{Q}$ = 1941-1966 average discharge in cfs

A = drainage area in square miles

P = normal annual precipitation in inches for the period 1931-1960. This value is an average for the basin above the point of determination.

Using this equation the average annual streamflow would vary from 0.19 to 0.37 cfs per square mile in Northwest Iowa.

In addition to the continuous streamflow gaging stations, the U.S. Geological Survey also maintains a network of crest-stage partial-record stations. The peak flows in cfs and cfs per square mile for these stations located in Northwest Iowa are shown in Table 35. Combining these data with those listed in Table 34 indicate that peak flows in this region of Iowa have ranged up to almost 1,000 cfs per square mile in one small drainage area of 4.35 square miles. These peak flows have been plotted versus their drainage areas in Fig. 36. The envelope curve to these points represents the regional flood which

Table 34. Mean and peak flows in cfs per square mile for continuous stream gaging stations in Northwest Iowa through September 30, 1977[a]

Stream	Location	Record length years	D.A. sq. mi.	Mean flow cfs/sq. mi.	Peak flow cfs/sq. mi.
North Raccoon River	Near Sac City	19	713	0.38	15.1
Big Cedar Creek	Near Varina	18	80	0.41	26.0
Missouri River	At Sioux City	80	314,600	0.10	1.4
Missouri River	At Omaha	49	322,800	0.09	1.2
Big Sioux River	At Akron	49	9,030	0.09	8.9
Rock River	At Rock Rapids	15	788	0.21	36.8
Rock River	Near Rock Valley	29	1,592	0.18	25.4
Dry Creek	At Hawarden	21	48	0.17	227.1
Perry Creek	At 38th St., Sioux City	24	65	0.23	147.7
Floyd River	At Alton	22	265	0.17	171.7
Floyd River	At James	42	882	0.20	81.1
W. Br. Floyd River	Near Struble	22	181	0.16	44.5
West Fork Ditch	At Hornick	33	403	0.23	30.8
Monona-Harrison Ditch	Near Turin	19	900	0.23	22.1
Little Sioux River	At Gillette Grove	15	1,334	0.28	18.0
Little Sioux River	At Linn Grove	5	1,548	0.26	5.6
Little Sioux River	At Correctionville	50	2,500	0.27	18.2
Little Sioux River	Near Kennebec	30	2,738	0.28	10.8
Little Sioux River	Near Turin	19	3,526	0.30	8.5
Maple River	At Mapleton	36	669	0.34	23.5
Odebolt Creek	Near Arthur	18	39	0.40	133.3
Soldier River	At Pisgah	37	407	0.30	55.3
Boyer River	At Logan	45	871	0.35	35.6

[a]Water Resource Data for Iowa (U.S. Geological Survey, 1978).

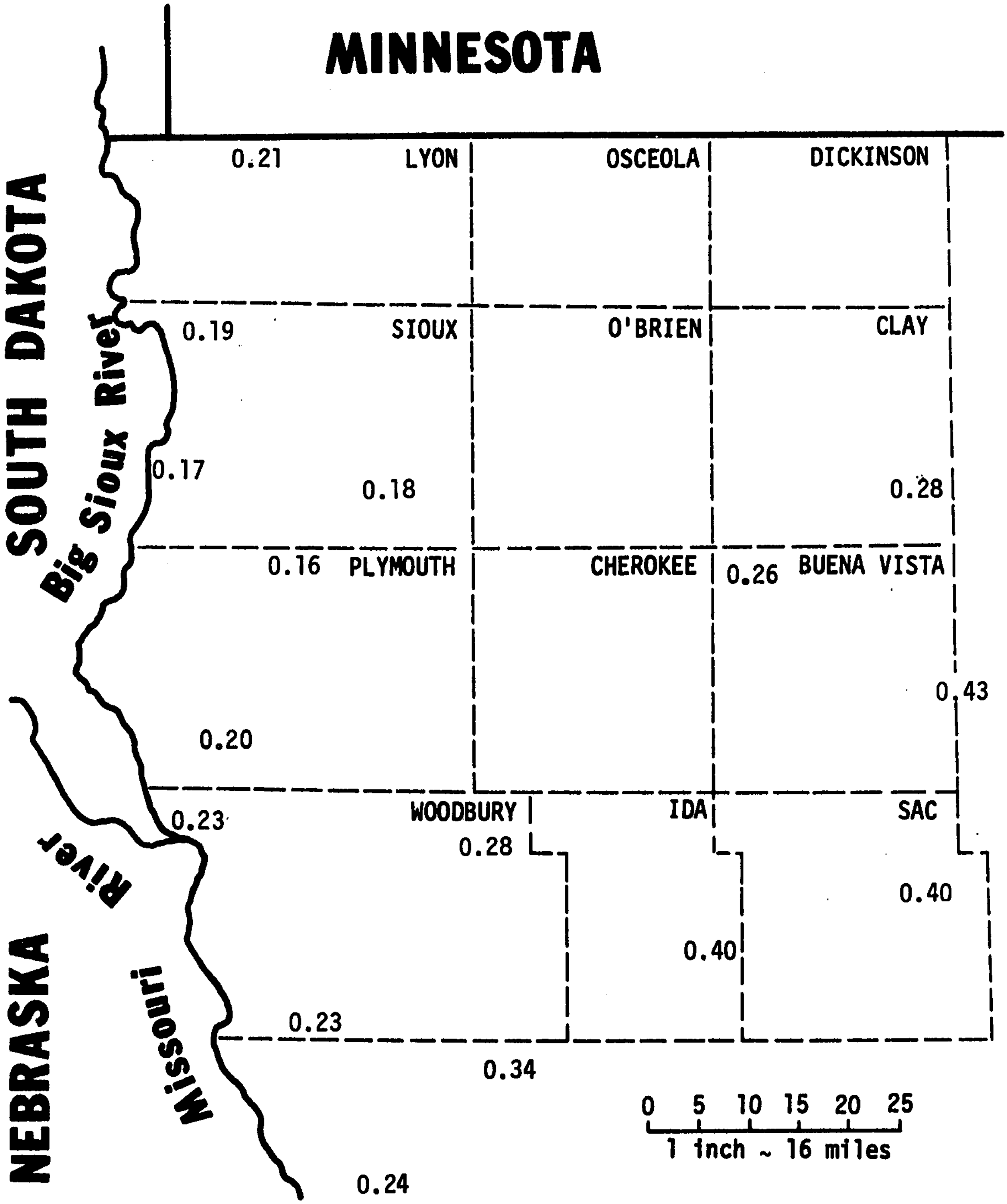


Fig. 35. Average stream flows in Northwest Iowa in cfs per square mile, based on continuous streamflow records

Table 35. Peak flows in cfs and cfs per square mile for crest-stage partial-record stream gaging stations through September 30, 1977[a]

Stream	Number	Location	Record length years	D.A. sq. mi.	Peak flow cfs	Peak flow cfs/sq. mi.
Big Sioux River						
Otter Creek	6-4834.10	North of Sibley	26	11.9	1,730	145.4
Schutte Creek	6-4834.20	Near Sibley	26	1.43	503	351.7
Otter Creek	6-4834.30	At Sibley	26	29.9	5,400	180.6
Dawson Creek	6-4834.40	Near Sibley	26	4.35	4,290	986.2
Wagner Creek	6-4834.50	Near Ashton	26	7.09	2,840	400.6
Otter Creek	6-4834.60	Near Ashton	26	88.0	17,400	197.7
Perry Creek	6-5998.00	Near Merrill	25	8.17	2,540	310.9
Perry Creek	6-5999.50	Near Hinton	25	30.8	4,980	161.7
Monona-Harrison Ditch						
Elliott Creek	6-6021.90	At Lawton	13	34.8	2,810	80.7
Little Sioux River						
Prairie Creek	6-6053.40	Near Spencer	13	22.3	2,200	98.6
Willow Creek	6-6057.50	Near Cornell	13	78.6	1,650	21.0
Waterman Creek	6-6058.90	At Hartley	13	28.7	2,100	73.2
Maple Creek	6-6067.90	Near Alta	13	15.5	5,300	341.9

[a]Water Resources Data for Iowa (U.S. Geological Survey, 1978).

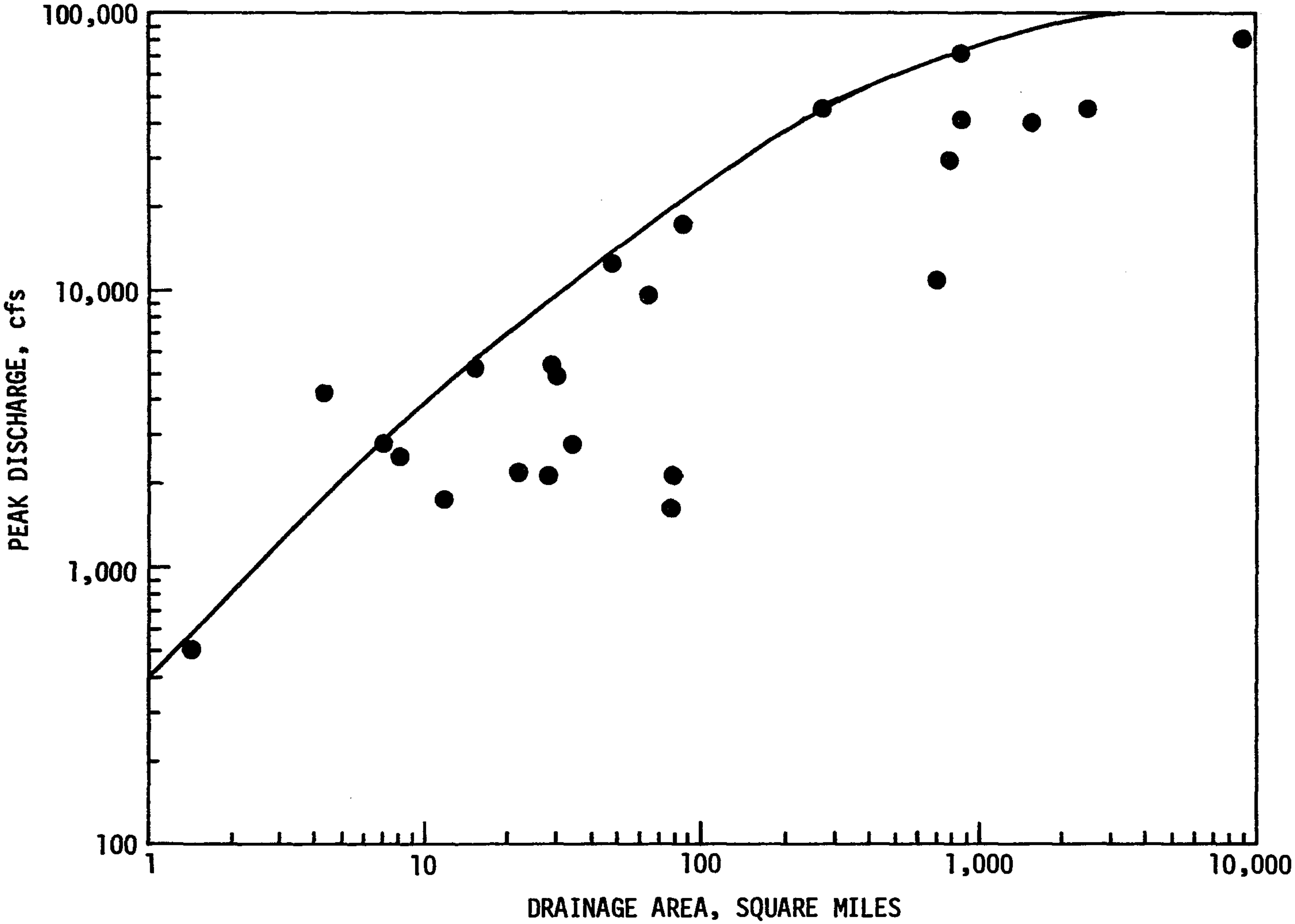


Fig. 36. Envelope curve for maximum experienced streamflow in Northwest Iowa based on gaging station records

could be expected to occur on streams with drainage areas up to 3,000 square miles in Northwest Iowa. The regional flood is defined as the flood caused by the greatest rainfall and/or snowmelt previously experienced and recorded at some location in the area. In Northwest Iowa the regional flood would have a magnitude of 400 cfs on a 1 sq. mi. watershed, 4,000 cfs on a 10 sq. mi. watershed, 22,000 cfs on a 100 sq. mi. watershed, 78,000 cfs on a 1,000 sq. mi. watershed and 100,000 cfs on a 3,000 sq. mi. watershed.

For those who depend on streamflow for either in-stream or off-stream uses, the effects of a lack of streamflow can be just as devastating as those from a flood. To this end the U.S. Geological Survey also maintains a network of low-flow partial-record stations. These records are published annually (U.S. Geological Survey, 1978) and were analyzed in a document published by the Iowa Natural Resources Council (Heinitz, 1970). The results of this analysis are shown in Table E-1 in Appendix E. This table lists the lowest discharge measured, the average flow computed from Eq. (20), the computed 7-day, 2-year low-flow and the computed 7-day, 10-year low-flow for each of the low-flow partial-record stream gaging stations located in Northwest Iowa. Since these stations only had a record length of eight or nine years at the time of the analysis, the 7-day, 10-year low-flow is not shown for most stations. However, since the 7-day, 2-year low-flow is less than 4 cfs for most of the stations, the 7-day, 10-year low-flow will probably be less than 1 cfs. This 1970 publication is presently being updated but no results are available at this time.

Analysis of the continuous stream gaging station records provides a variety of low-flow information (Heinitz, 1970). Table 36 lists the lowest discharge measured, the average flow computed from equation 20, the computed 7-day 2-year low-flow and the computed 7-day 10-year low-flow for those continuous stations located in Northwest Iowa. Table 37 contains the minimum average flows for periods of 1-, 7-, 30-, 60-, 120- and 183-days during the period of record. Table 38 lists annual flow-duration data, the discharge, which was equalled or exceeded 50, 70, 90, 95, 98 and 99% of the time. Finally, Table 39 contains the amount of net storage required in 1,000 acre-feet for various draft rates and recurrence intervals. In order to obtain the total storage required at a site, to these net storage requirements must be added storage for sediment, storage for losses due to seepage and evapotranspiration plus storage for such other purposes as recreation, flood control, low-flow augmentation and surcharge requirements.

The quality of the water in the rivers and streams located in Northwest Iowa is well-documented in two publications, one by the Iowa Department of Environmental Quality (Planning and Analysis Section, 1976) and the other by the Task Force on Water Resources Availability for the state water plan (1976). Data is presented on the Missouri, Big Sioux, Rock, Floyd, Little Sioux, Boyer and Soldier Rivers. Some of the water quality parameters which are discussed are temperature, dissolved oxygen, ammonia nitrogen, fecal coliform, pesticides, dissolved solids and heavy metals. Almost 200 point sources of pollution were identified: 100 municipal, 33 semi-public and 62 industrial sources.

Table 36. Average discharge and low-flow data for continuous stream gaging stations in Northwest Iowa[a]

Stream	Number	Location	Record length years
Big Cedar Creek	5-4821.70	Near Varina	7
North Raccoon River	5-4823.00	Near Sac City	8
Rock River	6-4832.70	At Rock Rapids	7
Rock River	6-4835.00	Near Rock Valley	18
Dry Creek	6-4840.00	At Hawarden	18
Perry Creek	6-6000.00	At 38th St., Sioux City	21
Floyd River	6-6001.00	At Alton	11
W. Br. Floyd River	6-6003.00	Near Struble	11
Floyd River	6-6005.00	At James	31
West Fork Ditch	6-6020.00	At Holly Springs	27
Little Sioux River	6-6056.00	At Gillette Grove	8
Little Sioux River	6-6066.00	At Correctionville	39
Little Sioux River	6-6067.00	Near Kennebec	27
Odebolt Creek	6-6070.00	Near Arthur	9
Maple River	6-6072.00	At Mapleton	25
Little Sioux River	6-6075.00	Near Turin	8
Soldier River	6-6085.00	At Pisgah	26
Boyer River	6-6095.00	At Logan	34

[a]Low-Flow Characteristics of Iowa Streams through 1966 (Heinitz, 1970).

[b]7-day 2-year low-flow.

[c]7-day 10-year low-flow.

[d]Not determined.

D.A. sq. mi.	Computed average Q cfs	Lowest Q measured cfs	Computed low-flow $7Q_2$[b] cfs	$7Q_{10}$[c] cfs
80.0	27.2	0.00	0.5	–[d]
713	236	1.00	6.5	–
788	177	0.80	2.2	–
1,600	379	0.00	11.0	0.2
48.4	10.0	0.00	0.0	0.0
65.1	14.4	0.00	0.5	$<$ 0.1
265	76.6	0.00	0.4	$<$ 0.1
181	41.9	0.00	0.0	0.0
882	232	1.00	11.0	2.5
399	103	0.20	8.1	1.4
1,334	398	1.00	21.0	4.0
2,500	774	2.60	52.0	10.0
2,738	836	11.00	77.0	23.0
39.3	11.7	0.20	0.8	–
669	192	2.50	23.0	5.8
3,526	1,045	22.00	130.0	–
407	119	2.00	14.0	3.0
871	276	1.50	30.0	4.9

Table 37. Minimum average flow for various numbers of days for continuous stream gaging stations in Northwest Iowa[a]

Stream	Location	Record length years	D.A. sq. mi.
Big Cedar Creek	Near Varina	7	80.0
North Raccoon River	Near Sac City	8	713
Rock River	At Rock Rapids	7	788
Rock River	Near Rock Valley	18	1,600
Dry Creek	At Hawarden	18	48.4
Perry Creek	At 38th St., Sioux City	21	65.1
Floyd River	At Alton	11	265
W. Br. Floyd River	Near Struble	11	181
Floyd River	At James	31	882
West Fork Ditch	At Holly Springs	27	399
Little Sioux River	At Gillette Grove	8	1,334
Little Sioux River	At Correctionville	39	2,500
Little Sioux River	Near Kennebec	27	2,738
Odebolt Creek	Near Arthur	9	39.3
Maple River	At Mapleton	25	669
Little Sioux River	Near Turin	8	3,526
Soldier River	At Pisgah	26	407
Boyer River	At Logan	34	871

[a]Low-Flow Characteristics of Iowa Streams through 1966 (Heinitz, 1970).

[b]Not determined.

Period of days					
1-day cfs	7-day cfs	30-day cfs	60-day cfs	120-day cfs	183-day cfs
0.0	0.0	0.0	0.1	—	—
1.0	1.0	—	—	—	—
0.8	1.0	1.6	2.6	5.6	13.1
0.0	0.0	0.1	0.4	2.9	3.1
0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.1	0.1	0.4	0.5
0.0	0.0	0.0	0.1	0.1	0.1
0.0	0.0	0.0	0.0	0.1	0.1
1.0	1.0	1.1	1.5	2.7	3.1
0.2	0.5	1.7	2.1	2.7	2.9
1.0	1.0	1.0	1.4	—[b]	—
4.0	4.6	6.3	7.8	14.0	14.0
11.0	12.1	15.0	19.2	25.6	25.9
0.2	0.2	0.2	0.2	0.3	0.6
2.5	2.6	2.7	3.1	6.8	8.3
22.0	22.0	22.6	24.2	32.1	36.7
2.0	2.0	3.3	3.9	7.0	9.7
1.5	2.0	2.7	3.3	5.8	8.3

Table 38. Annual flow-duration data for continuous stream gaging stations in Northwest Iowa[a]

Stream	Location	Record length years	D.A. sq. mi.
Big Cedar Creek	Near Varina	7	80.0
North Raccoon River	Near Sac City	8	713
Rock River	At Rock Rapids	7	788
Rock River	Near Rock Valley	18	1,600
Dry Creek	At Hawarden	18	48.4
Perry Creek	At 38th St., Sioux City	21	65.1
Floyd River	At Alton	11	265
W. Br. Floyd River	Near Struble	11	181
Floyd River	At James	31	882
West Fork Ditch	At Holly Springs	27	399
Little Sioux River	At Gillette Grove	8	1,334
Little Sioux River	At Correctionville	39	2,500
Little Sioux River	Near Kennebec	27	2,738
Odebolt Creek	Near Arthur	9	39.3
Maple River	At Mapleton	25	669
Little Sioux River	Near Turin	8	3,526
Soldier River	At Pisgah	26	407
Boyer River	At Logan	34	871

[a]Low-Flow Characteristics of Iowa Streams through 1966 (Heinitz, 1970).

[b]Not determined.

Discharge, in cfs, equalled or exceeded for percentage of time indicated					
50	70	90	95	98	99
7.0	2.8	1.1	0.65	0.15	—
62.0	31.0	12.0	7.4	2.6	1.2
32.0	19.0	8.0	5.1	3.0	2.0
69.0	34.0	9.0	3.7	1.4	0.70
0.66	0.13	—[b]	—	—	—
3.1	1.6	0.65	0.41	0.22	0.11
5.0	2.2	0.31	0.18	0.11	—
2.8	1.1	0.19	—	—	—
46.0	23.0	9.1	588	3.4	2.5
30.0	17.0	6.7	4.2	2.5	1.7
85.0	43.0	21.0	9.6	3.0	1.2
265.0	125.0	42.0	26.0	15.0	11.0
315.0	160.0	61.0	39.0	26.0	21.0
5.8	3.3	1.5	0.90	0.33	0.25
90.0	50.0	21.0	14.0	7.0	4.6
420.0	245.0	140.0	57.0	28.0	26.0
51.0	30.0	13.0	8.5	5.6	4.3
130.0	70.0	27.0	16.0	9.0	6.0

Table 39. Storage requirements for various draft rates and recurrence intervals for continuous stream gaging stations in Northwest Iowa[a]

Stream	Location	D.A. sq. mi.	Draft rate cfs	Net storage required, in 1,000 ac. ft., for recurrence intervals indicated		
				5-yr	10-yr	20-yr
Rock River	Near Rock Valley	1,600	10	0.69	1.49	—[b]
			15	1.59	2.72	—
			20	2.38	4.17	—
Perry Creek	At 38th St., Sioux City	65.1	1	0.05	0.09	—
			2	0.29	0.43	—
			3	0.66	0.85	—
Floyd River	At James	882	10	0.40	0.99	1.88
			15	1.19	2.38	3.77
			20	2.38	4.13	5.95
West Fork Ditch	At Holly Springs	399	5	—	0.14	0.44
			7	0.12	0.44	0.95
			10	0.50	1.19	1.98
Little Sioux River	At Correctionville	2,500	30	—	1.39	2.98
			40	—	2.58	6.15
			50	—	4.96	9.92
Little Sioux River	Near Kennebec	2,738	40	—	0.81	2.98
			50	—	1.98	5.55
			60	—	3.57	9.12

Maple River	At Mapleton	669	15	—[b]	0.44	1.39
			20	0.44	1.25	2.68
			25	0.99	2.48	4.46
Soldier River	At Pisgah	407	15	0.79	1.23	1.79
			20	1.49	2.38	3.27
			25	2.38	3.87	5.06
Boyer River	At Logan	871	30	0.81	1.98	3.47
			40	2.18	3.97	6.35
			50	3.57	6.55	9.32

[a]Low-Flow Characteristics of Iowa Streams through 1966 (Heinitz, 1970).

[b]Not determined.

All of the rivers were found to have water quality problems to some degree, especially during winter and times of low-flow.

Lakes and Ponds

Northwest Iowa is blessed in one respect in that it contains many of the natural lakes in Iowa. However, even here there are problems since the lakes are concentrated in the northeastern portion of the region as shown in Fig. 37 and are thus not readily accessible to many of the people living in the region. The size of these lakes are listed in Table 40. Due to the number of lakes in Dickinson County, they have been shown separately in Fig. 38 and their sizes listed in Table 41. These lakes were formed following the recession of the glaciers which covered north central Iowa. These most recent glaciers extended only into the eastern portion of Northwest Iowa resulting in the concentration of lakes in that area. The only other natural lakes in Northwest Iowa are those found in Woodbury County which are cut-off oxbows of the Missouri River. As shown in Tables 40 and 41 the total area of all lakes is about 26,500 acres.

In addition to these natural lakes, several marshes, ponds, gravel pits and off-stream impoundments are located in Northwest Iowa. These are shown in Fig. 39 and listed in Table 42. The total area of these water bodies in the 12-county region is about 1,100 acres. Numerous farm ponds are scattered throughout each of the 12 counties in the region. Their numbers, surface areas and volumes are listed in Fig. 40. These farm ponds have an aggregate area of about 3,000 acres.

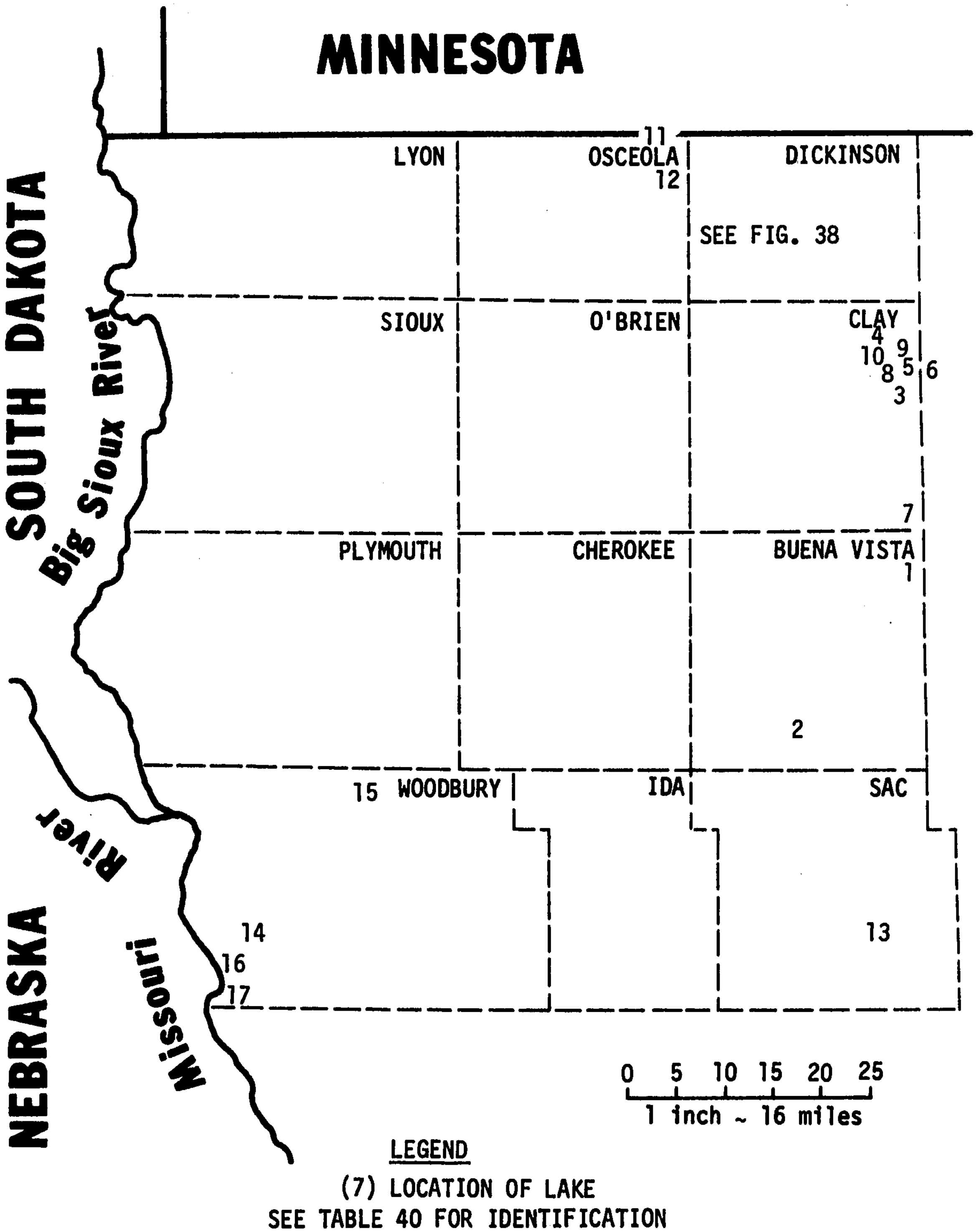
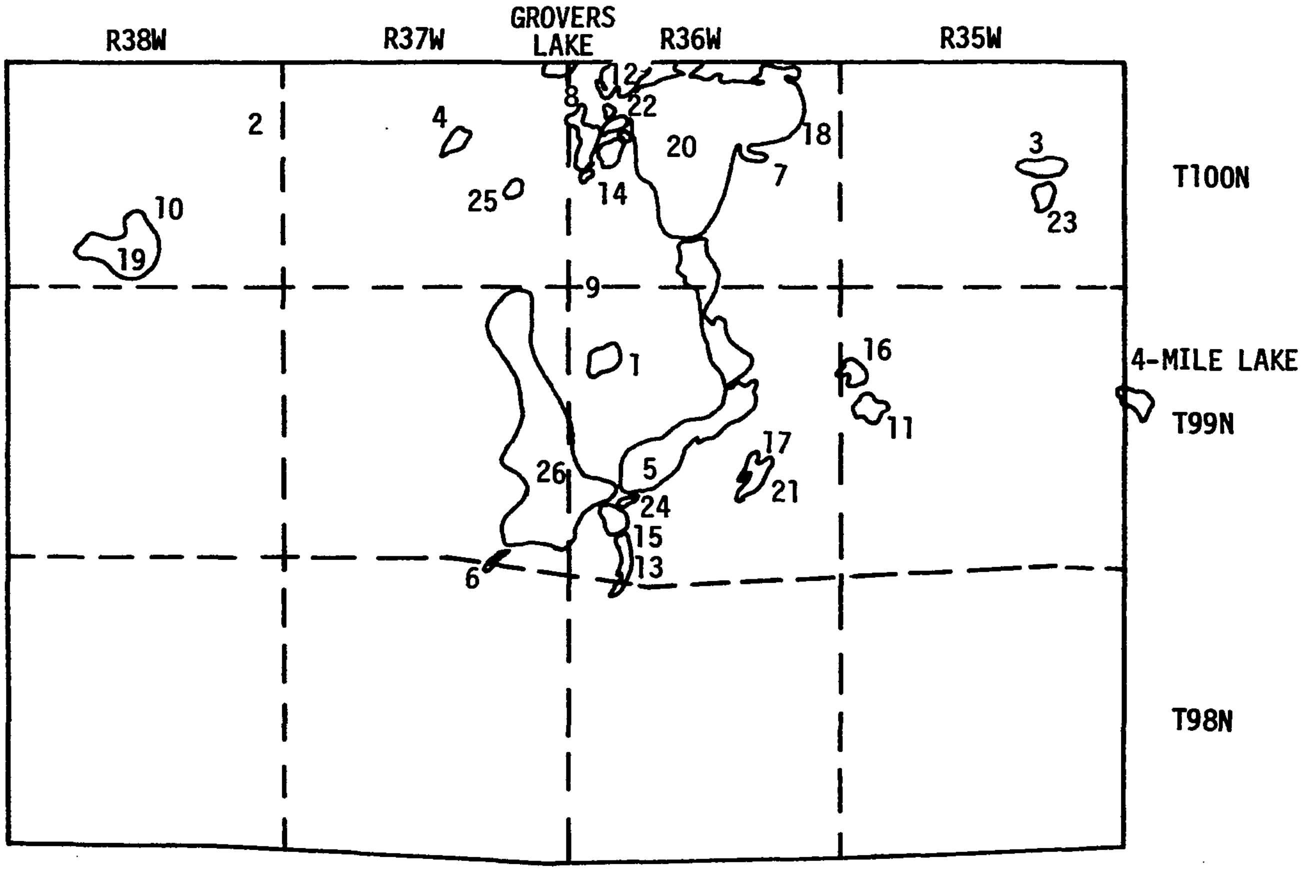


Fig. 37. Natural lakes and oxbow lakes in Northwest Iowa

Table 40. Natural lakes and oxbow lakes in Buena Vista, Clay, Osceola, Sac and Woodbury Counties[a]

No.	County	Name	Acres	Total
1	Buena Vista	Pickeral Lake	176	
2		Storm Lake	3,097	3,273
3	Clay	Barringer Slough	778	
4		Dan Green Slough	311	
5		Elk Lake	261	
6		Lost Island Lake	1,260	
7		Mud Lake	252	
8		Round Lake	438	
9		Smith Slough	236	
10		Trumbull Lake	1,185	4,721
11	Osceola	Iowa Lake	114	
12		Rush Lake	314	428
13	Sac	Black Hawk Lake	957	957
14	Woodbury	Browns Lake	325	
15		Midway Park	2	
16		Snyder Bend	375	
17		Winnebago Bend	555	1,257
				10,636

In total, the natural lakes, marshes, ponds, gravel pits, off-stream impoundments and farm ponds cover about 30,500 acres which would appear to be adequate for the approximately 288,500 people living in the region in 1970. However, as shown in Table 85, these acres of surface water are not well distributed throughout the region. While the required average is 106 acres of water for every 1,000 people, the county average ranges from a low of 3 acres per 1,000 people in Sioux County to a high of 1,267 acres per 1,000 people in Dickinson County, the site of the Iowa Great Lakes. Nine of the 12 counties have less than 100 acres of water per 1,000 people. This poor distribution of surface water will become an important factor in



<u>LEGEND</u>

17 LOCATION OF LAKE
SEE TABLE 41 FOR IDENTIFICATION

Fig. 38. Natural lakes in Dickinson County

Table 41. Natural lakes in Dickinson County[a]

No.	County	Name	Acres	Total
1	Dickinson	Center Lake	329	
2		Cory Marsh	30	
3		Christopherson Slough	171	
4		Diamond Lake	166	
5		East Okoboji Lake	1,873	
6		Garlock Slough	100	
7		Hales Slough	59	
8		Hottes Lake	378	
9		Jemmerson Slough	88	
10		Lake Park Pond	5	
11		Lily Lake	60	
12		Little Spirit Lake	214	
13		Lower Gar Lake	252	
14		Marble Lake	183	
15		Minnewashta Lake	122	
16		Pleasant Lake	77	
17		Prairie Lake	100	
18		Sandbar Slough	30	
19		Silver Lake	1,058	
20		Spirit Lake	5,684	
21		Spring Run	370	
22		Sunken Lake	62	
23		Swan Lake	371	
24		Upper Gar Lake	43	
25		Welsh Lake	75	
26		West Okoboji Lake	3,939	15,839

[a]Outdoor Recreation in Iowa (Planning and Coordination Section, Iowa Conservation Commission, 1972).

the social well-being of the people insofar as water-based recreation is concerned.

Water Plan '78 (Iowa Natural Resources Council, 1978) indicates that flat-water recreation should be provided in larger lakes whose sizes are dependent on the scope of the project and the following acreages per 1,000 population: statewide, 40 acres; regional, 20 acres; county, 10 acres. The situation in Northwest Iowa is even

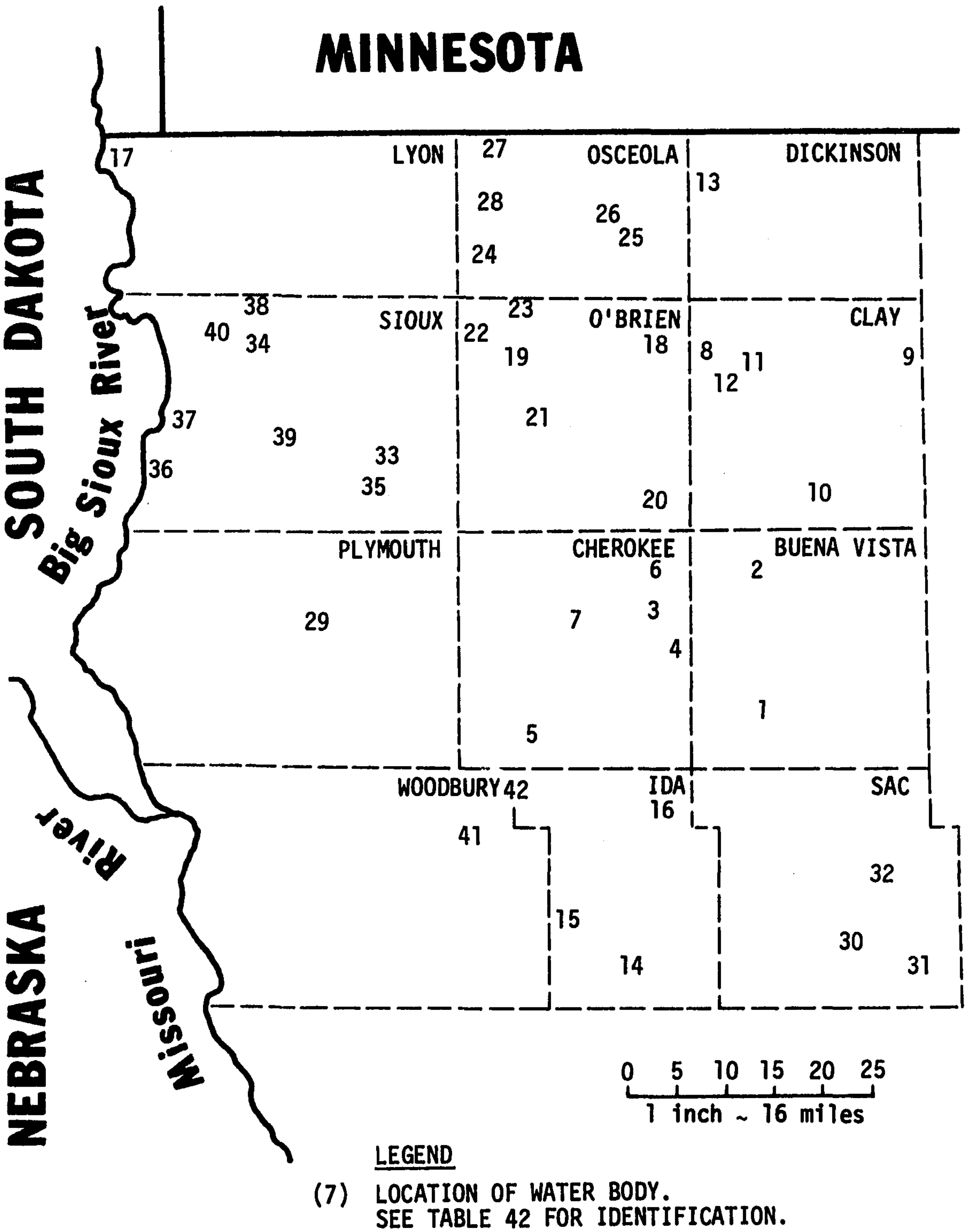


Fig. 39. Marshes, ponds, gravel pits and off-stream impoundments in Northwest Iowa

Table 42. Existing marshes, ponds, gravel pits and off-stream impoundments in Northwest Iowa[a]

No.	County	Name	Type[b]	Acres	Total
1	Buena Vista	Storm Lake Shooting Area	M	264	
2		Linn Grove Park	P	2	266
3	Cherokee	Barnes Access	M	4	
4		Larson Lake	P	4	
5		Stieneke Access	M	1	
6		Soo Access	M	1	
7		Spring Lake	P	18	28
8	Clay	Brugeman Park	GP	8	
9		Deweys Pasture	M	161	
10		Kindlespire Park	P	5	
11		Ocheyedan Area	M	25	
12		Scharnberg Park	GP	10	209
13	Dickinson	Arnold's Pond	P	14	14
14	Ida	Moorhead Park	OSI	12	
15		School Pond	FP	3	
16		Town and County	OSI	12	27
17	Lyon	Gitche Manitou Monument	P	1	1
18	O'Brien	Bruegman Area	P	10	
19		Dauma Park	GP	10	
20		Dog Creek Park	OSI	35	
21		Mill Creek	OSI	35	
22		Van Nyhuis #1	GP	315	
23		Van Nyhuis #2	GP	4	399
24	Osceola	Ashton Pits	GP	11	
25		May City Pit Area	GP	1	
26		Ocheyedan Pit Area	GP	2	
27		Peters Pit Area	GP	3	
28		Sibley Pit	GP	2	19
29	Plymouth	Le Mars Pit	GP	3	3
30	Sac	Black Hawk Marsh	M	56	
31		Grant Park	P	5	
32		Sac City Access	M	2	63
33	Sioux	Alton Wayside	P	2	
34		County Hiway Pond	GP	15	
35		Floyd Park Pit	GP	2	
36		Hawarden Pit	GP	?	
37		Oak Grove	GP	5	

[a]Outdoor Recreation in Iowa (Planning and Coordination Section, Iowa Conservation Commission, 1972).

[b]FP = farm pond; GP = gravel pit; M = marsh; OSI = off-stream impoundment; P = pond.

Table 42. Continued

No.	County	Name	Type[b]	Acres	Total
38		Rock Valley Access	M	4	
39		Sioux Center Pit	GP	5	
40		Van Zee Pit	GP	7	40
41	Woodbury	Little Sioux Park	GP	3	
42		Park Pits	OSI	14	17

worse based on these criteria. The regional average is 94 acres per 1,000 population, ranging from zero acres in 5 counties to 1,252 acres per 1,000 population in Dickinson County.

The situation is more acute in Lyon and Sioux Counties than it appears in Table 43. In Lyon County, 92 of the 93 acres are located in farm ponds as are 337 of the 340 acres in Sioux County. Since farm ponds are normally not available for use by the public, the people in these two counties must travel outside the county to enjoy most types of water-based recreation. Both counties, as well as Sioux County, are adjacent to the Missouri River, but it provides only limited opportunities for a few water-based activities. These three counties have the lowest per-capita incomes in the region (see Table 77); so the people living in these counties are the least able to travel to other locations for recreational activities.

Ground Water

A discussion of the ground water resources of the region is best preceeded by a description of the geology of the region since the

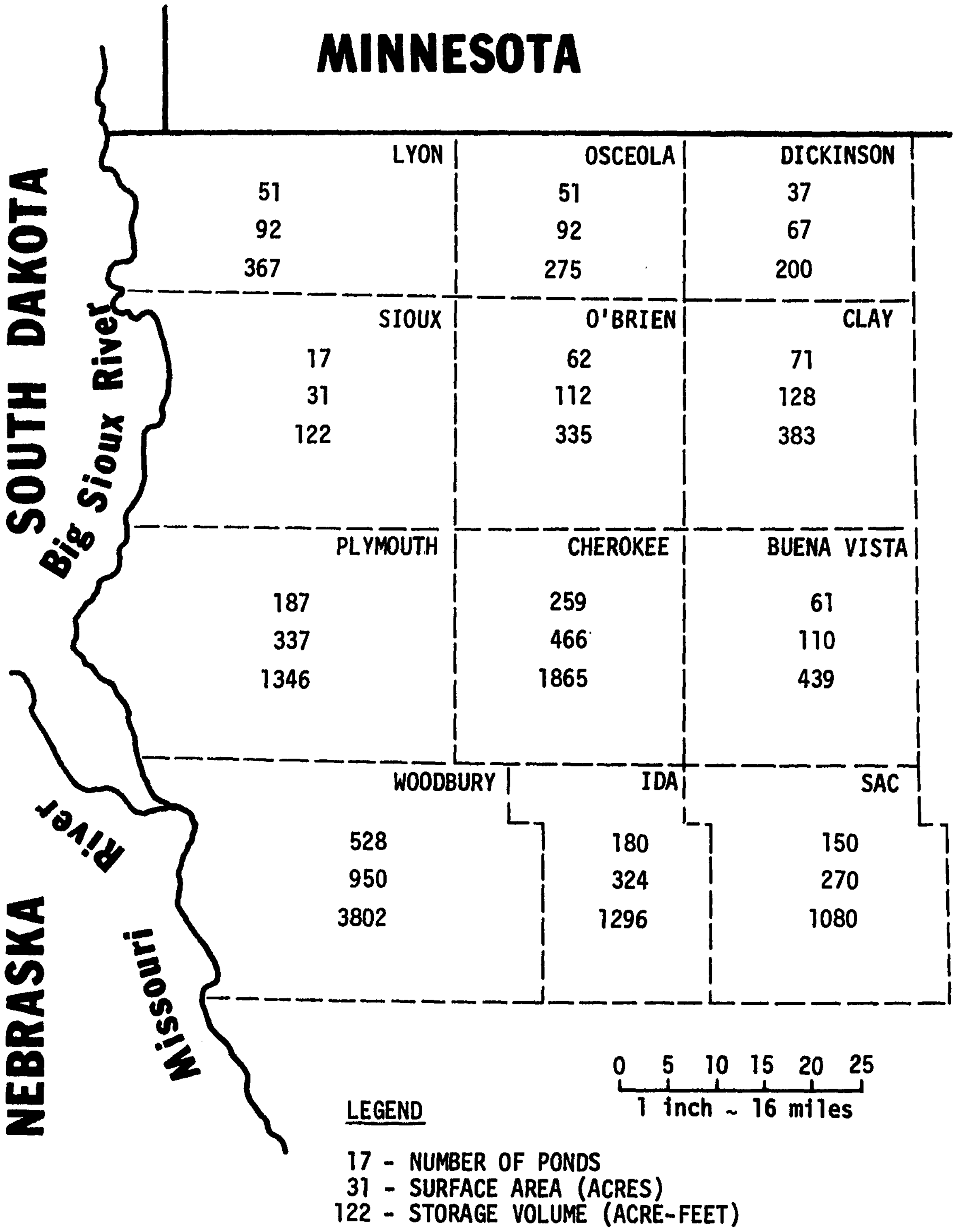


Fig. 40. Farm ponds in Northwest Iowa

Table 43. Distribution of surface water and population in Northwest Iowa in 1970[a]

County	1970 population[d]	Surface water[b] Total water acres	Larger lakes[c] acres	Acres of water per 1,000 people Total water	Larger lakes[c]
Buena Vista	20,693	3,649	3,537	176	171
Cherokee	17,269	494	0	29	0
Clay	18,464	5,058	4,882	376	363
Dickinson	12,565	15,920	15,731	1,267	1,252
Ida	9,190	351	0	38	0
Lyon	13,340	93	0	7	0
O'Brien	17,522	511	315	29	18
Osceola	8,555	539	428	63	50
Plymouth	24,312	340	0	14	0
Sac	15,573	1,290	1,013	83	65
Sioux	27,996	71	0	3	0
Woodbury	103,052	2,224	1,255	22	12
Region	288,531	30,540	27,161	106	94

[a]Excludes surface area of rivers and streams.

[b]See Tables 40-42 and Fig. 40.

[c]Includes only those water bodies larger than 50 acres.

[d]Bureau of the Census (1973).

quantity and quality of ground water available is dependent on the geologic history of the region. The surface topography and soils of Iowa were developed mostly on unconsolidated sediments of glacial origin. During the past million years several glaciers have advanced into and across Iowa and then receded again to the north with each succeeding event covering over the surface of the previous advance as shown in Fig. 41. Interspersed amongst these glacial drifts are large and small pockets of sand and gravel which can produce small

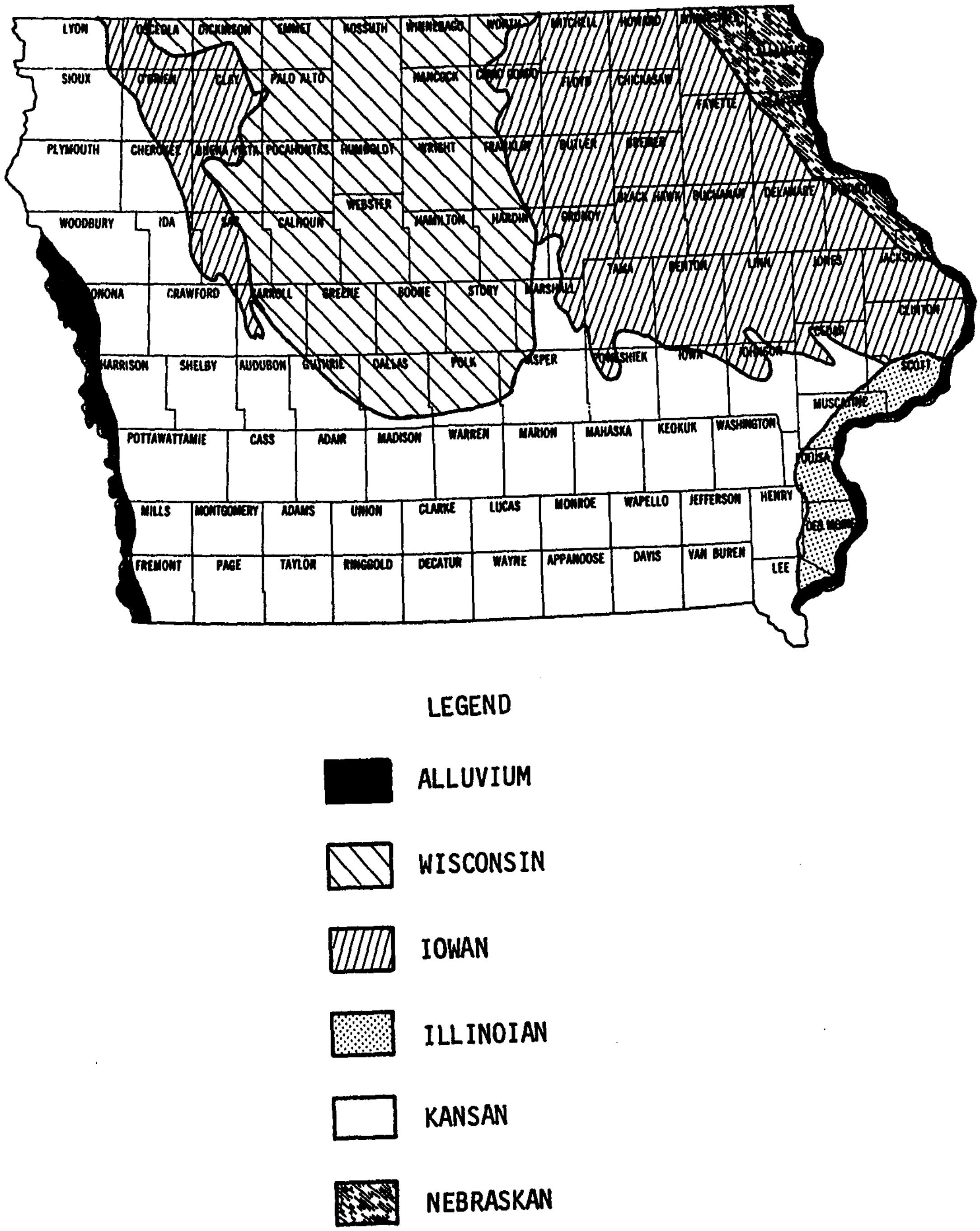


Fig. 41. Generalized sketch map of the glacial geology of Iowa

quantities of water. Underlying this glacial surface are old river valleys carved into the older surface and filled with sand and gravel. These buried channels are capable of producing small to large quantities of water. On the surface where the products of erosion have been deposited in and along stream valleys, these alluvial deposits can also produce small to large quantities of water, depending on their composition and thickness.

Underlying these unconsolidated glacial deposits are several sequences of layered rock formations. Several of these will produce water and all are found in Northwest Iowa. The uppermost formation is the Dakota Sandstone aquifer. It has an average thickness of 50 to 75 feet but has a maximum thickness of about 260 feet in the vicinity of Sioux City and lies from 200 to 600 feet beneath the surface. Beneath the Dakota Sandstone aquifer is the Mississippian aquifer. It has an average thickness of about 350 feet and is found from 600 to 900 feet below the surface in the southern tier of counties in Northwest Iowa. Beneath this aquifer is the Silurian-Devonian aquifer system. This system underlies most of Iowa and varies in thickness from a thin edge in the east to a maximum thickness of 650 feet in Southwestern Iowa. In Northwest Iowa it occurs at depths from 500 to 1,000 feet under the southern half of the region. Beneath this system is the Cambro-Ordivician aquifer system. It underlies almost all of Iowa and in the west ranges from 0 to 400 feet in thickness. It is found in every county except Lyon County in Northwest Iowa and occurs from less than 1,000 feet to more than 2,000 feet beneath the surface.

The yields from these various formations vary greatly. In the unconsolidated aquifers, the glacial drift aquifers produce the lowest yields. Wells will range from 15 to 20 to as much as 400 feet deep. Generally, these wells yield only a few gallons per minute (gpm) but with favorable conditions and proper well design, they will yield as much as 10 to 20 gpm. These glacial drifts are used as a source of supply for livestock, rural domestic and small towns when it is the only source of acceptable water quality at a reasonable depth. Because these are generally shallow wells, they tend to go dry during drought periods. Total storage in the drift aquifers in Northwest Iowa is estimated to range from 0.9 to 4.0 million acre-feet with annual recharge ranging from 0.1 to 1.0 million acre-feet (Task Force on Water Resources Availability, 1976).

Buried channel aquifers, when they are overlain by alluvial aquifers and are in hydraulic communication with each other, will yield 500 gpm and more in some instances. When these aquifers are confined beneath relatively thick, impermeable, glacial materials, yields to individual wells will range from 10 to 100 gpm. The thickness of alluvial aquifers in Northwest Iowa range from a few feet on interior streams, to 30 to 70 feet along the major interior rivers, to 100 to 160 feet along the Missouri River. Yields will range from less than 50 gpm, to 200 to 300 gpm along the interior rivers, to 1,000 to 2,000 gpm along the Missouri River valley. Some individual wells have yielded over 2,000 gpm on a sustained basis. Total storage in the alluvial aquifers along the major rivers in Iowa is estimated to range from 1.6 to 8.0 million acre-feet with annual recharge ranging from 0.24 to 0.96 million acre-feet; total storage in the Missouri

River alluvial system is estimated to range from 5 to 25 million acre-feet with annual recharge ranging from 0.43 to 1.7 million acre-feet (Task Force on Water Resources Availability, 1976).

The Dakota Sandstone aquifer is the principal bedrock aquifer used for water supply in Northwest Iowa. The variation in yield from this aquifer is documented in the following excerpt from the water quality management plan by the Iowa Department of Environmental Quality (Planning and Analysis Section, 1976).

> Yields from the sandstone aquifer are somewhat erratic, varying from a few ten to a few hundred gallons per minute. The aquifer generally can be counted on to produce sufficient water for rural and many municipal requirements. Even where the aquifer is only moderately thick, many wells have been developed to yield 50 to 100 gpm. However, municipal wells in Osceola, O'Brien, Sioux and Cherokee Counties have been tested at 350 to 750 gpm. At Sioux City, where the Dakota Sandstone is recharged by water from the overlying alluvial sands and gravels, yields in excess of 1,500 gpm have been obtained.

Total storage in the Northwest Iowa bedrock aquifer system which includes the Dakota Sandstone aquifer and the other underlying bedrock aquifers is estimated to range from 0.3 to 7.0 million acre-feet with annual recharge ranging from 0.001 to 0.03 million acre-feet (Task Force on Water Resources Availability, 1976).

The quality of ground water in Northwest Iowa is generally not good. Many wells located in the glacial drift aquifers contain high nitrate concentrations. Most of this contamination is the result of improper well construction and/or well location. The same is true of those wells where high coliform bacteria counts are present. The water quality in buried channels is variable but generally tends to be of poorer quality than other nonbedrock aquifers. It is usually hard and may be highly mineralized. The total dissolved solids in buried channel aquifers ranges from somewhat less than 500 mg/l to over 2,000 mg/l. Water quality in the alluvial aquifers is also quite variable and is dependent on a number of factors: aquifer thickness, depth of wells, underlying aquifer or confining bed and whether the water is coming from storage, induced infiltration or local precipitation. Total dissolved solids can range from 300 to over 1,000 mg/l as shown in Fig. 42. The quality of water in the Dakota Sandstone aquifer is also not good. Over much of its area, the water is high in dissolved solids, objectionably hard and contains significant amounts of sulfate. The variation in total dissolved solids is shown in Fig. 43. Total hardness ranges from 500 to over 1,500 mg/l throughout the entire Northwest Iowa region.

Population

In any analysis of water resource development, the number of people (past, present and future) in an area will have a large impact on the quantities of water needed or desired and the various ways in which the water will be used. Large numbers of people imply large quantities of water needed for personal and municipal use (e.g., southern California). A large population implies a large labor force which in turn implies a large demand for water for various industrial uses. A large, presumably well-paid labor force also implies a demand for water-oriented recreation. And since this large population needs to be fed, there will be a demand for water for agriculture. In

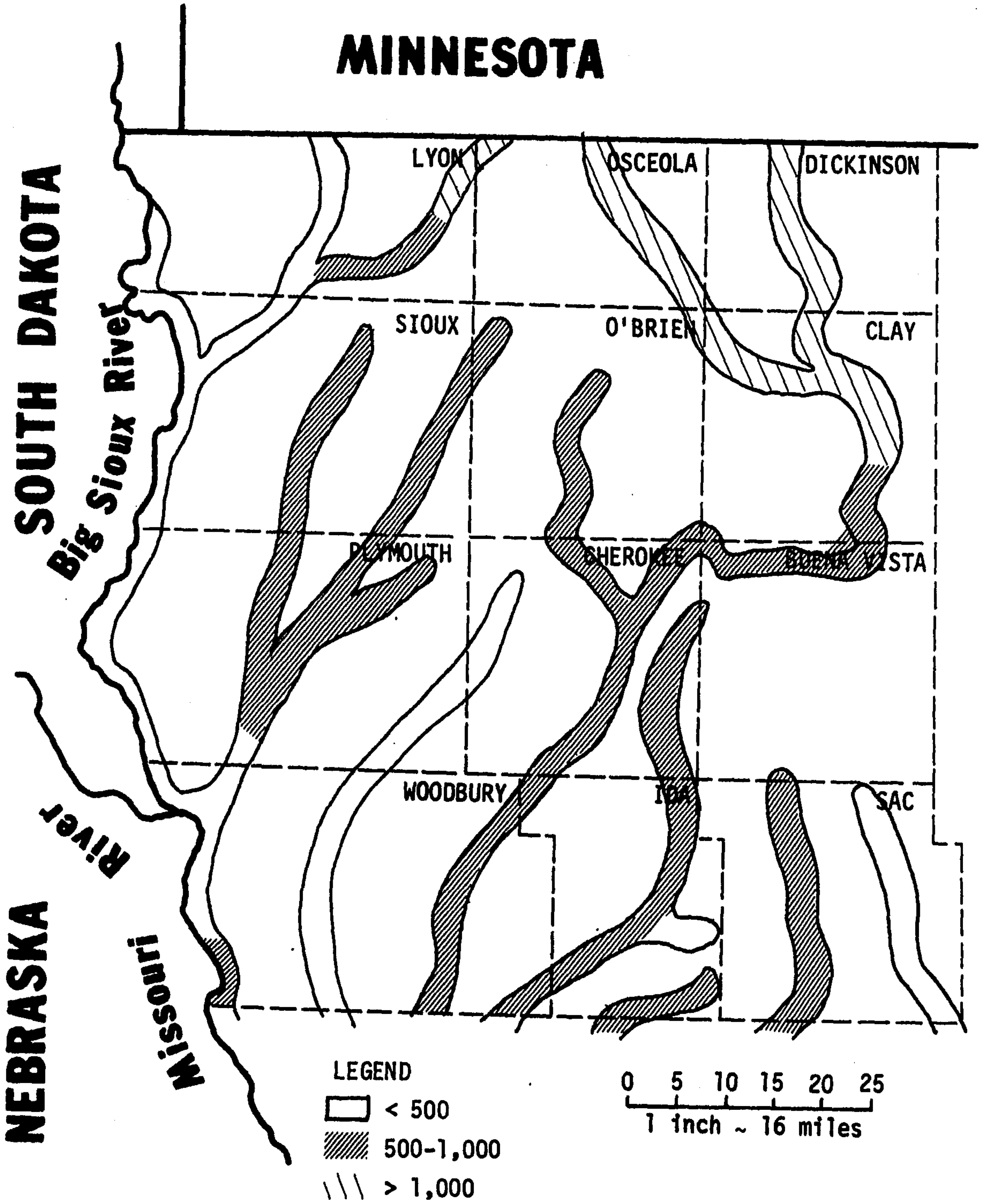


Fig. 42. Total dissolved solids in the alluvial aquifers in Northwest Iowa, milligrams per liter

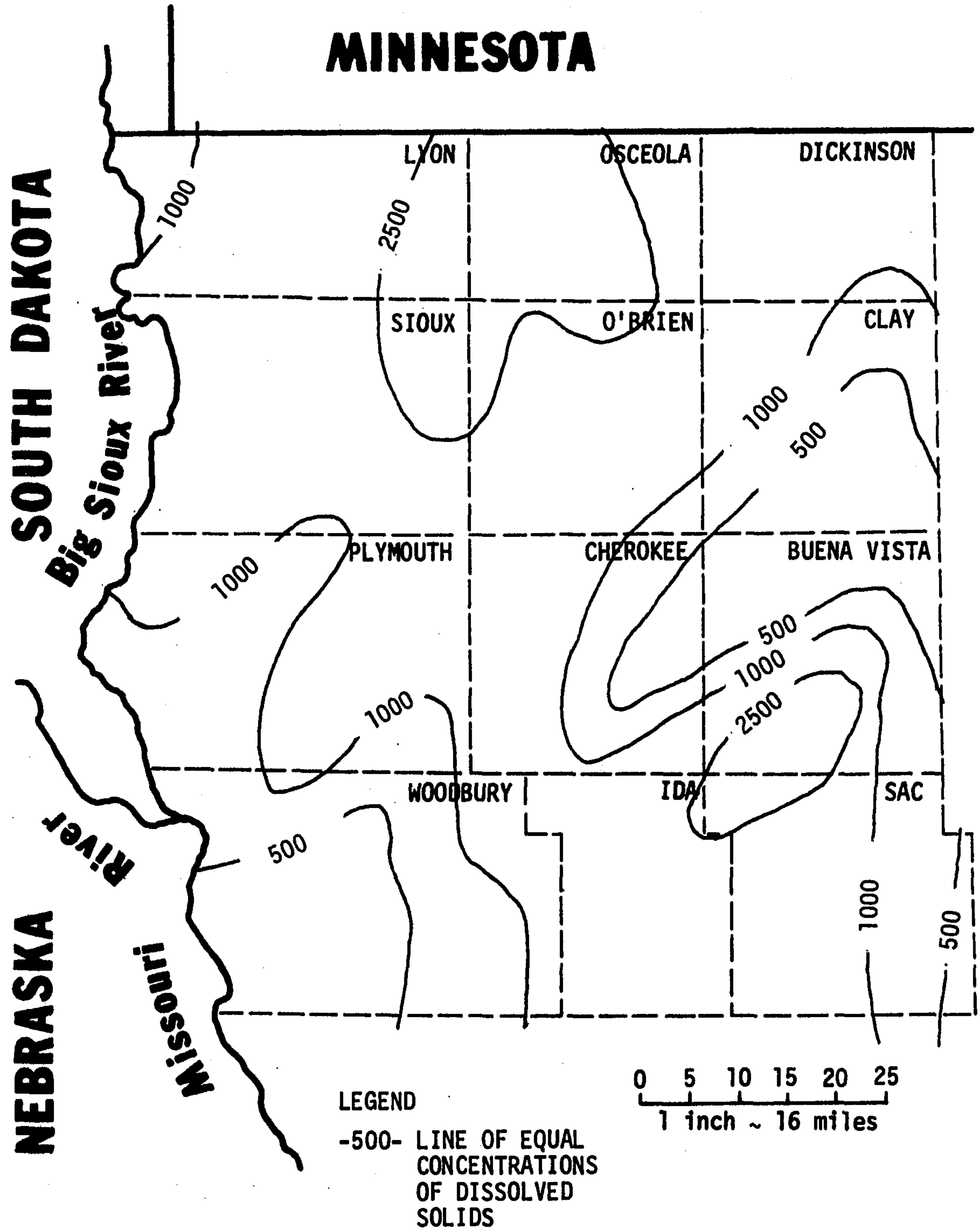


Fig. 43. Total dissolved solids in the Dakota Sandstone aquifer in Northwest Iowa, milligrams per liter

addition, there may well be a need for water for navigation, power generation and for pollution control and water quality enhancement. Thus the size of the existing or future population of an area can give us some insight as to the amounts of water which may be required. Agriculture and mining activities may be exceptions; these are large consumers of water with increasingly fewer labor inputs required.

By examining the past and present population of an area, we may also glean some insights into trends which have developed or are developing. Carrying these trends or modifications of these trends into the future provides one basis for estimating the future population of an area. One such trend used by the U.S. Water Resources Council is the lower birth rates currently being recorded which in some areas is already at zero population growth (ZPG). This trend is reflected in the Council's present use of Series E' in their OBERS projections (U.S. Water Resources Council, 1974 and 1975) for the growth of population and economic activity in the United States to the year 2020.

<u>Historic population</u>

While the first census for the United States was taken in 1790, it was not until 1860 that the first census was taken in Northwest Iowa. The early growth of the 12-county study area, compared to Iowa and the nation is depicted in Table 44. This charts the growth from 1840 through 1900. These population figures were obtained from a summary in the Twelfth Census of the United States by the Census Office which at that time was located in the U.S. Department of the Interior (Census Office, 1901).

Table 44. Historic population of Northwest Iowa, Iowa and Nation, 1840-1900[a]

Area	1840	1850	1860	1870	1880	1890	1900
Buena Vista	—[b]	—	57	1,585	7,537	13,548	16,975
Cherokee	—	—	58	1,967	8,240	15,659	16,570
Clay	—	—	52	1,523	4,248	9,309	13,401
Dickinson	—	—	180	1,389	1,901	4,328	7,995
Ida	—	—	43	226	4,382	10,705	12,327
Lyon	—	—	—	221	1,968	8,680	13,165
O'Brien	—	—	8	715	4,155	13,060	16,985
Osceola	—	—	—	—	2,219	5,574	8,725
Plymouth	—	—	148	2,199	8,566	19,568	22,209
Sac	—	—	246	1,411	8,774	14,522	17,639
Sioux	—	—	10	576	5,426	18,370	23,337
Woodbury	—	—	1,119	6,172	14,996	55,632	54,610
Region	—	—	1,921	16,461	72,412	188,955	223,938
Iowa	43,112	192,214	674,913	1,194,020	1,624,615	1,911,896	2,231,853
Nation	17,069,453	23,191,876	31,443,321	38,558,371	50,155,783	62,622,250	75,994,575

[a]U.S. Department of the Interior (Census Office, 1901).

[b]No census taken.

In 1840 the number of inhabitants in the entire state of Iowa totaled only 43,112, less than the current enrollment in the two state universities in Iowa. In 1860 the entire population of the 12-county Northwest Iowa study area totaled 1,921, about equal to the current enrollment of a single high school in one of our larger cities. However, by 1900, just 40 years later, almost a quarter million people lived in Northwest Iowa, attesting to the rapid settlement and development of the area. In the 60-yr period from 1840 to 1900, the state population grew from 43,112 to 2,231,853. This westward movement by these early settlers rapidly changed the face of Iowa, from a full beard of tall, thickly-rooted prairie grasses and some forests to a clean-shaven one, dotted with the stubble of grain, hay and corn fields, countless farmsteads, almost a thousand communities, a few forests and only tiny, isolated fragments of prairie.

In contrast to the 60-yr period prior to 1900, the 70-yr period after 1900 was one of much slower growth. This is depicted in Table 45 which lists the historic populations of the 12 counties in Northwest Iowa, and for Iowa and the Nation for the period 1900 through 1970. These data were obtained from the records of the Bureau of the Census which is now a part of the Social and Economic Statistics Administration in the U.S. Department of Commerce (1973). During this 70-yr period Iowa had a net gain of about 600,000 inhabitants in contrast to the almost 2,200,000 gain the previous 60 years. Northwest Iowa had a net gain of only 64,500 people in the 70-yr period from 1900 to 1970 while in the previous 40-yr settlement period, the gain was over 220,000 persons. Indeed, 3 counties had fewer inhabitants in 1970 than they

Table 45. Historic population of Northwest Iowa, Iowa and Nation, 1900-1970[a]

Area	1900	1910	1920	1930
Buena Vista	16,975	15,981	18,556	18,667
Cherokee	16,570	16,741	17,760	18,737
Clay	13,401	12,766	15,660	16,107
Dickinson	7,995	8,137	10,241	10,982
Ida	12,327	11,296	11,689	11,933
Lyon	13,165	14,624	15,431	15,293
O'Brien	16,985	17,262	19,051	18,409
Osceola	8,725	8,956	10,223	10,182
Plymouth	22,209	23,129	23,584	24,159
Sac	17,639	16,555	17,500	17,641
Sioux	23,337	25,248	26,458	26,806
Woodbury	54,610	67,616	92,171	101,669
Region	223,938	238,311	278,324	290,585
Iowa	2,231,853	2,224,771	2,404,021	2,470,939
Nation	75,994,575	91,972,266	105,710,620	122,775,046

[a]U.S. Department of Commerce, Bureau of the Census (1973).

1940	1950	1960	1970
19,838	21,113	21,189	20,693
19,258	19,052	18,598	17,269
17,762	18,103	18,504	18,464
12,185	12,756	12,574	12,565
11,047	10,697	10,269	9,190
15,374	14,697	14,468	13,340
19,293	18,970	18,840	17,522
10,607	10,181	10,064	8,555
23,502	23,252	23,906	24,312
17,639	17,518	17,007	15,573
27,209	26,381	26,375	27,996
103,627	103,917	107,849	103,052
297,341	296,637	299,643	288,531
2,538,268	2,621,073	2,757,537	2,825,041
131,669,275	150,697,361	179,323,175	203,184,772

did in 1900, 3 counties increased in population by less than 700 people during this 70-yr period, 5 counties gained less than 5,000 inhabitants and only one county, Woodbury County, recorded a gain of 48,500 persons. Included in this growth of 48,500 was an increase in the population of Sioux City of almost 53,000 people, reflecting a decrease in the rural parts of the county.

The number of incorporated cities and towns in the 12-county study area increased from 82 to 114 between 1900 and 1970. Their locations are shown in Fig. 44. The populations of each of these incorporated communities from 1900 through 1970 are listed in Appendix A, Tables A-1 through A-12, and were obtained from a publication by Johnson and Tait (1972). Of the 82 incorporated communities in existence in 1900, 24 had fewer inhabitants in 1970 than they did in 1900, 7 gained less than 100 people, 14 gained less than 250, 11 gained less than 500, 13 gained less than 1,000, 7 gained less than 2,500 and only 6 gained more than 2,500 people. Of the 32 communities incorporated after 1900, 5 increased less than 100 inhabitants in the 70-yr period from 1900 to 1970, 15 gained less than 250 people, 10 increased less than 500 and only 2 gained more than 500 people between 1900 and 1970.

The historic population of the 12 counties shown in Tables A-1 through A-12 in Appendix A has been separated into three components: urban population, rural farm population and the rural nonfarm population. The definition used in this study for the "urban" population is all persons living in incorporated towns and cities of whatever size. This differs from the Bureau of the Census definition which is "all persons living in (a) places of 2,500 inhabitants or more incorporated

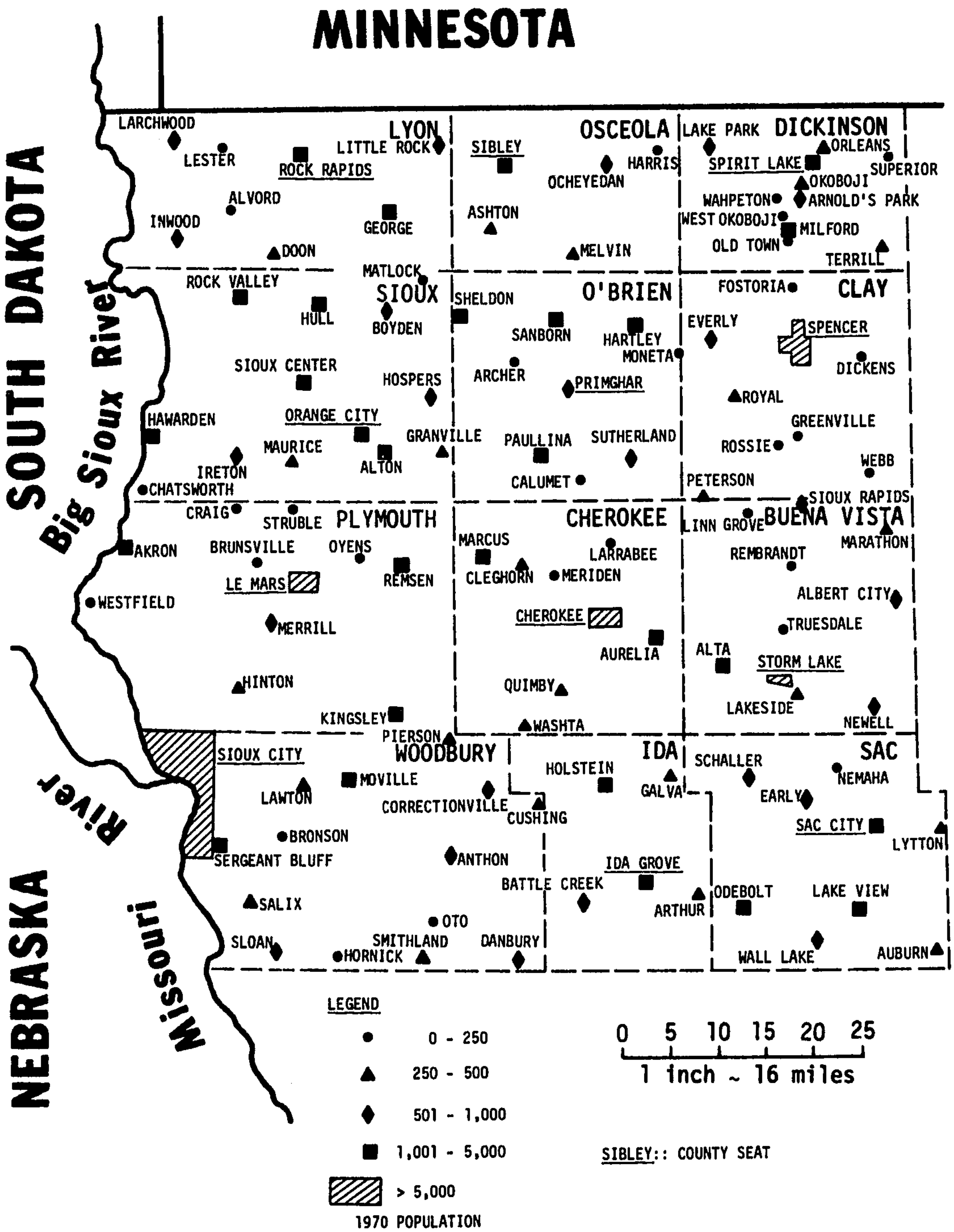


Fig. 44. Incorporated cities and towns in Northwest Iowa

as cities, villages, boroughs (except in Alaska) and towns (except in the New England States, New York, and Wisconsin), but excluding those persons living in the rural portions of extended cities; (b) unincorporated places of 2,500 inhabitants or more; and (c) other territory, incorporated or unincorporated, included in urbanized areas." The definition used for the "rural farm" population is the same as that used by the Bureau of the Census which is all "persons living on places of 10 or more acres from which sales of farm products amounted to $50 or more in the preceeding calendar year or on places of fewer than 10 acres from which sales of farm products amounted to $250 or more in the preceeding year." All persons not included in the "urban" or "rural farm" population are included in the "rural nonfarm" population. All persons living in small unincorporated towns are included in this "rural nonfarm" population category.

The number of people in each county in each of the three categories as shown in Tables A-1 through A-12 in Appendix A and summarized in Table 46 for the year 1970 were determined in the following manner. The number of inhabitants in each incorporated community and the total urban population were taken from the publication by Johnson and Tait (1972) which is based on census data. The rural farm population and the total county population were obtained from the census records. The total rural population was determined by subtracting the total urban population from the total county population. The rural nonfarm population was then determined by subtracting the rural farm population from the total rural population. Prior to 1930 the Bureau of the Census did not separate out the rural farm population from the total

Table 46. Urban, rural nonfarm and rural farm populations in Northwest Iowa in 1970

County	Urban	Rural nonfarm	Rural farm
Buena Vista	14,103	1,288	5,302
Cherokee	10,931	1,416	4,922
Clay	12,816	1,287	4,361
Dickinson	8,246	1,251	3,068
Ida	5,228	293	3,669
Lyon	6,491	665	6,184
O'Brien	11,215	841	5,466
Osceola	4,297	571	3,687
Plymouth	13,800	1,848	8,664
Sac	9,162	1,001	5,410
Sioux	17,283	1,141	9,572
Woodbury	93,540	2,699	6,813
Region	207,112	14,301	67,118

rural population; so prior to 1930 these two population categories were assumed to be equal. As can be seen from the data, the use of this assumption is reasonable.

Historic and current population trends

Examination of the census records indicate a number of trends at the state, regional and local level. The most evident trend at the state level is the rate of population growth in Iowa compared to the national growth rate. These rates are shown in tabular form in Table 47 and pictorially in Fig. 45. The national and state population growth rates were calculated using Eq. (21).

$$GR = 100(P_{i+10} - P_i)/P_i \tag{21}$$

where GR = decennial population growth rate in percent

Table 47. Decennial population growth rates in Iowa and nation, 1840-1970

Decade	National growth rate, percent	Iowa growth rate, percent
1840-1850	35.87	345.84
1850-1860	35.58	251.12
1860-1870	22.63	76.91
1870-1880	30.08	36.06
1880-1890	24.86	17.68
1890-1900	21.85	16.73
1900-1910	21.02	- 0.32
1910-1920	14.94	8.06
1920-1930	16.14	2.78
1930-1940	7.24	2.72
1940-1950	14.45	3.26
1950-1960	19.00	5.21
1960-1970	13.31	2.45

P_i = population in census year i

P_{i+10} = population in census year i plus 10

These state and national population growth rates indicate quite clearly that except for the period from 1840 to 1880 when Iowa was being settled, the rate of population growth in Iowa (for almost the last 100 years) has lagged far behind the national population growth rate.

Using Eq. (21) the population growth rate in Northwest Iowa was also determined. This regional growth rate is compared with the state growth rate in Table 48 and is shown pictorially in Fig. 46. Here again the growth rate is greater for Northwest Iowa only during its period of settlement. For the past 50 years, the growth rate for Northwest Iowa has lagged behind the state growth rate.

Another way of looking at the relative growth rate is through the use of Eq. (22) and (23).

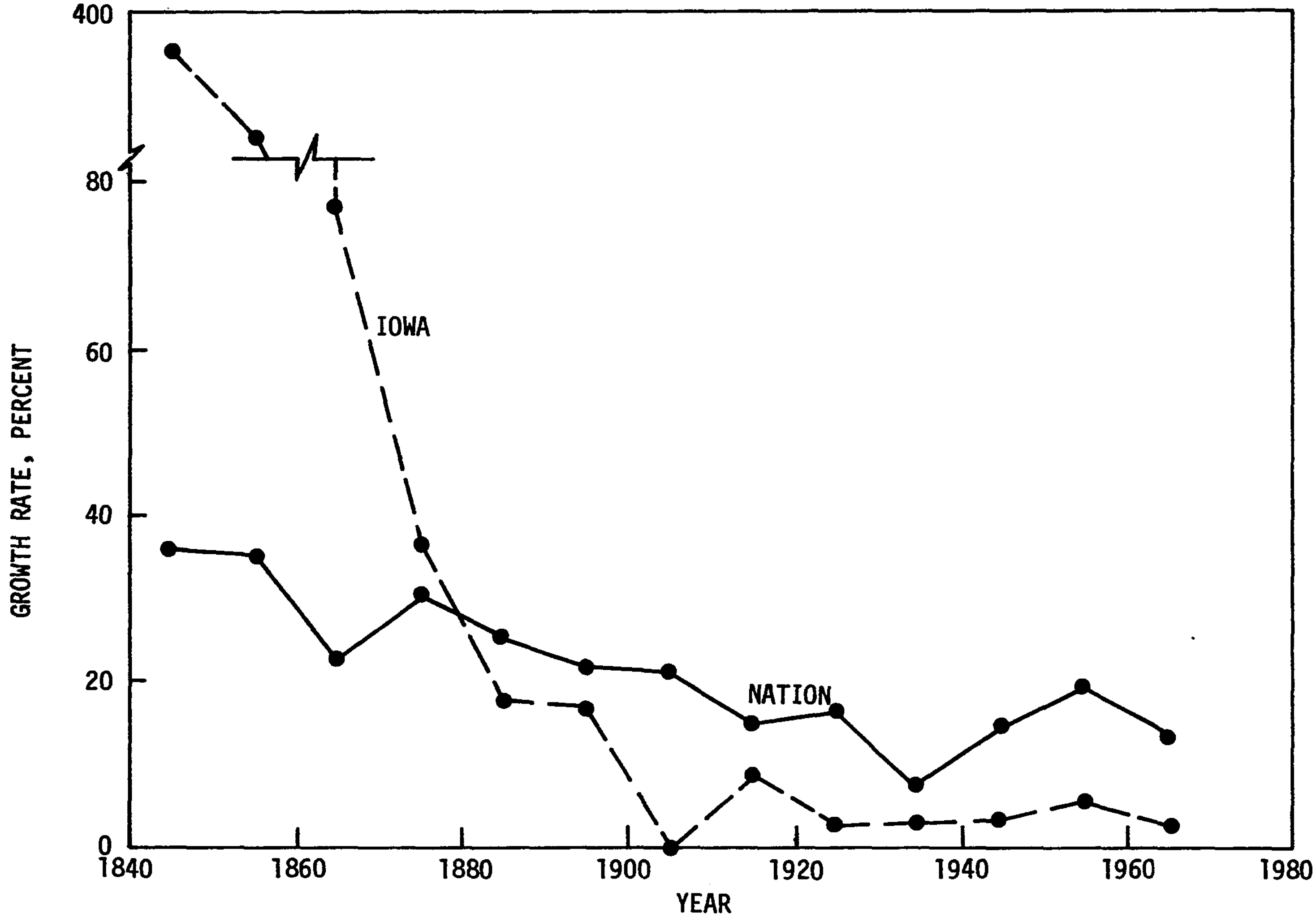


Fig. 45. Decennial growth rates in Iowa and the nation, 1840–1970

Table 48. Decennial population growth rates in Iowa and Northwest Iowa, 1860-1970

Decade	Iowa growth rate, percent	Northwest Iowa growth rate, percent
1860-1870	76.91	756.90
1870-1880	36.06	339.90
1880-1890	17.68	160.94
1890-1900	16.73	18.51
1900-1910	- 0.32	6.42
1910-1920	8.06	16.79
1920-1930	2.78	4.40
1930-1940	2.72	2.32
1940-1950	3.26	- 0.24
1950-1960	5.21	1.01
1960-1970	2.45	- 3.71

$$RP_{IN_i} = 100PI_i/PN_i \quad (22)$$

$$RP_{RI} = 100\ PNI_i/PI_i \quad (23)$$

where RP_{IN_i} = relative population in Iowa to that of the nation in year i in percent

RP_{RI_i} = relative population in the Northwest Iowa region to that of Iowa in year i in percent

PN_i = population of the nation in year i

PI_i = population of Iowa in year i

PNI_i = population of Northwest Iowa in year i

By looking at these relative percentages over time, a trend in relative growth rates can be determined. These percentages are shown for Northwest Iowa to Iowa, and Iowa to the nation, in Table 49 for the period 1840 through 1970 and are illustrated graphically in Fig. 47. This figure clearly shows that the number of people residing in Iowa as a

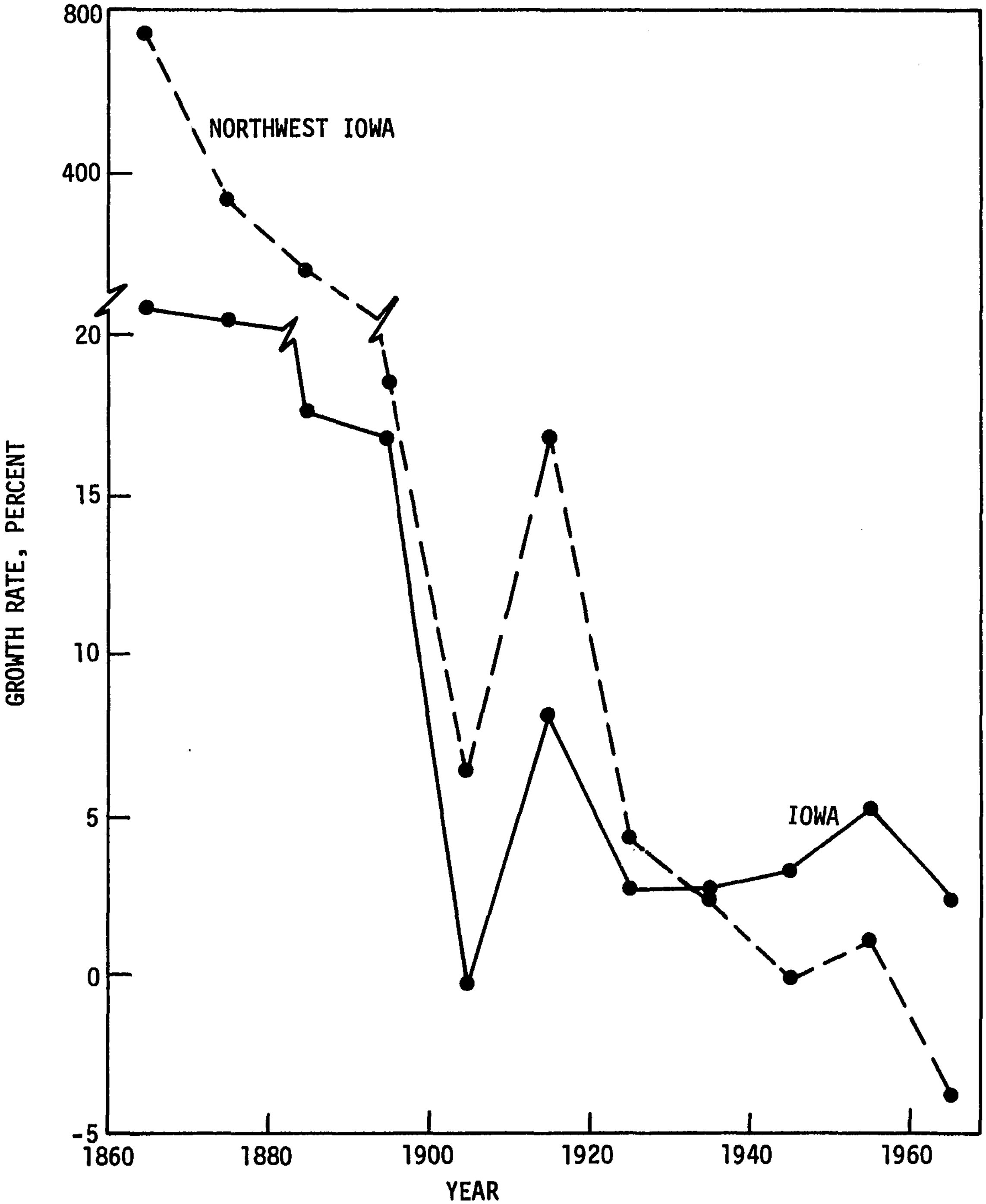


Fig. 46. Decennial growth rates in Northwest Iowa and Iowa, 1860-1970

Table 49. Relative percentages of population in Northwest Iowa and Iowa, 1840-1970

Year	Percentage of population: (Pop. of Iowa / Pop. of Nation) x 100	Percentage of population: (Pop. of NW Iowa / Pop. of Iowa) x 100
1840	0.25	–[a]
1850	0.83	–
1860	2.15	0.28
1870	3.10	1.38
1880	3.24	4.46
1890	3.05	9.88
1900	2.94	10.03
1910	2.42	10.71
1920	2.27	11.58
1930	2.01	11.76
1940	1.93	11.71
1950	1.74	11.32
1960	1.54	10.87
1970	1.39	10.21

[a]Data not available.

percentage of those living in the United States has been declining for almost a hundred years. Likewise, the number of people living in Northwest Iowa as a percentage of those living in Iowa has been declining for almost fifty years. If this trend continues into the future, Northwest Iowa will increase in population (if it increases at all) at a much slower pace than either Iowa or the nation.

The main reason for this slow rate of population growth in Iowa, and the actual decline in population in Northwest Iowa, is the net out-migration which has become a long, well-established trend. During any time period, such as the 10-year intercensal period, people are constantly moving into and out of a region or state. If more people move into the area than leave the area during a given time

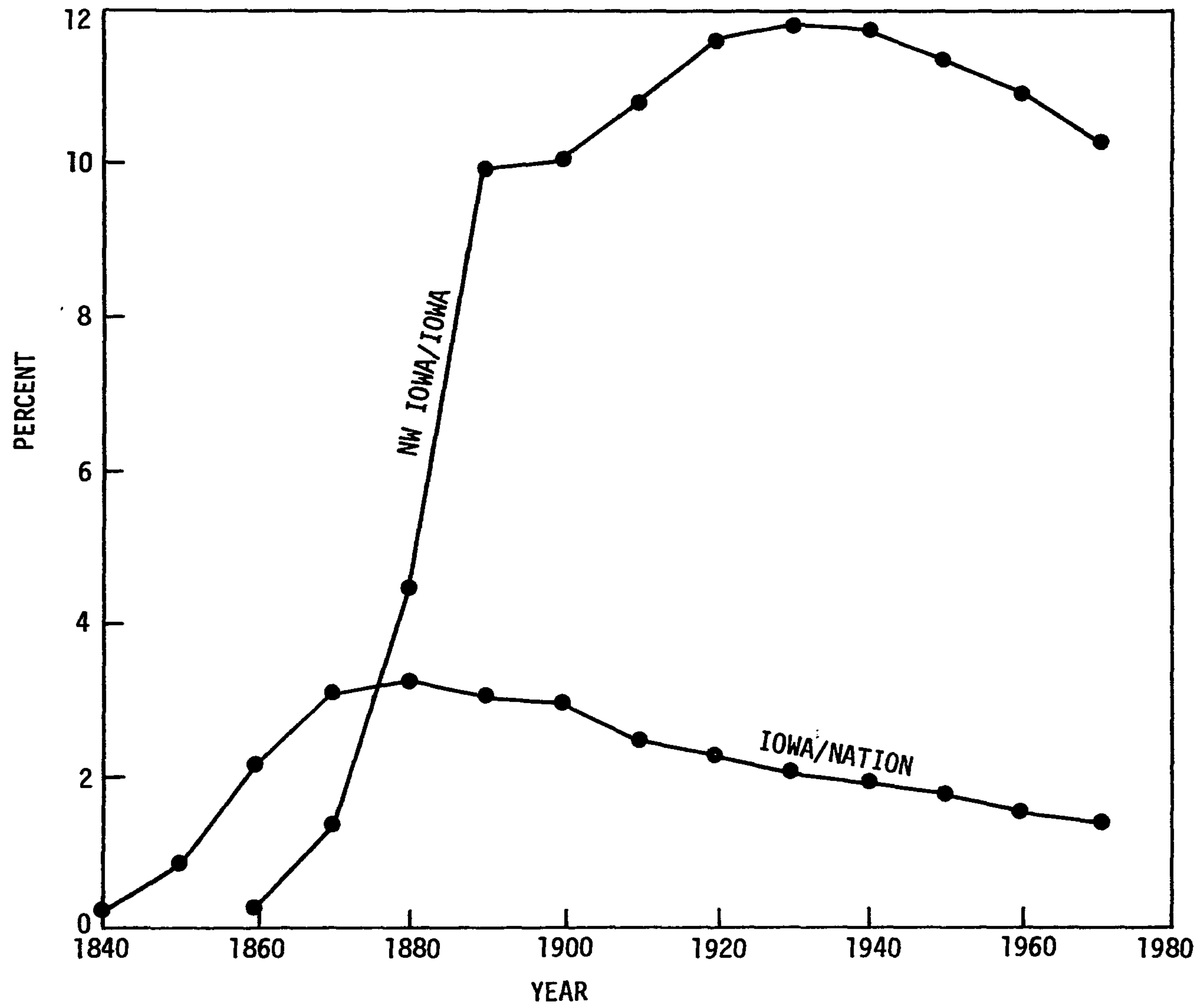


Fig. 47. Relative percentages of population in Northwest Iowa and Iowa, 1840–1970

period, then we have a net in-migration; if more people leave the area than move into the area during a given time period, then we have a net out-migration.

Net migration can be determined by using census data and birth and death records in the following manner. Natural increase is the excess of births over deaths and is calculated using Eq. (24). If deaths exceed births, then NI_j will have a minus (-) sign and we will have a natural decrease.

$$NI_j = B_j - D_j \tag{24}$$

where NI_j = natural increase during time period j, such as the 10-year intercensal period

B_j = number of births during time period j

D_j = number of deaths during time period j

If the borders of an area were closed so that no one could move into or out of the area, then the population of the area at the end of time period j would be equal to the population at the beginning of time period j plus the natural increase or decrease. However, since our borders are not closed and people are free to move into and out of the area at will, then the population at the end of the period, assuming the period is the 10-year intercensal period, can be calculated using Eq. (25).

$$P_{i+10} = P_i + NI_j + NM_j \tag{25}$$

where P_{i+10} = population in year i + 10

P_i = population in year i

NI_j = natural increase during the 10-year period j

NM_j = net migration during the 10-year period j, (positive or negative)

P_{i+10} and P_i are taken from the various census records and NI_j is calculated from Eq. (24). B_j and D_j are simply the summation of births and deaths recorded during each year of the 10-year period. In Iowa these birth and death records are obtained from the Iowa Summary of Vital Statistics (Iowa Department of Health, 1970). By solving Eq. (25) for NM_j, we derive Eq. (26) which can be used to determine the net migration during any 10-year period.

$$NM_j = (P_{i+10} - P_i) + NI_j \qquad (26)$$

By grouping P_{i+10} and P_i together, we can determine whether the population of the area increased or decreased during the period by observing whether the sign is positive or negative. The sign on NI_j can also be positive or negative. If the sign of NM_j is positive, then we experienced a net in-migration during the period; if the sign is negative, there was a net out-migration during the period.

Tables A-13 through A-16 in Appendix A list the annual births and deaths recorded in Iowa and the 12 Northwest Iowa counties during the period 1940-1969. The data listed is for resident births and deaths for the calendar year rather than total births and deaths occurring in the specific county or state. This eliminates a bias from the data by removing all persons just visiting the area when the birth or death occurred. Census data for the period 1940-1970 have already been presented in Table 45. Using Eq. (26) the net migration from each of the

12 counties, the region and the state was calculated for the decades of 1940-1950, 1950-1960 and 1960-1970. These data and results are shown in Tables 50, 51 and 52. Using the same methodology, Chang (1973) calculated the net migrations for the State of Iowa for each decade from 1870 to 1970. These results are shown in Table 53. There are two reasons for the small differences in net migration between the author's and Chang's work for the three most recent decades: census data is taken in April while Chang used an estimated July 1 population; the author used calendar year births and deaths while Chang used data from July through June.

The results of these calculations are very informative. At the state level, in the ten census periods since 1870 eight have shown a net out-migration. Every decade since 1900 has resulted in a net out-migration with the 70-yr total amounting to 1,065,900 people. This is over a third of the 1970 Iowa population of 2,825,041. The results are the same at the regional and county level. In all three decades, in every one of the 12 counties, the result is a net out-migration. During this same 30-yr time period, 53 of the 114 incorporated communities decreased in population and 29 others increased by less than 100 people.

One reason for this continuing net out-migration is the trend towards bigger farms and the increasing use of larger farm machinery which results in fewer farm workers being needed. Another reason is the failure to create enough urban, nonfarm jobs to employ these excess farm workers as well as the urban dwellers seeking employment. These excess workers and their families leave the region or state and

Table 50. Net migration during 1940-1950 from Northwest Iowa and Iowa

Area	Births	Deaths	Natural increase	1940 pop.	1950 pop.	Change in pop.	Net migration
Buena Vista	3,873	1,849	2,024	19,838	21,113	1,275	- 749[b]
Cherokee	3,618	1,606	2,012	19,258	19,052	- 206[a]	- 2,218
Clay	3,730	1,499	2,231	17,762	18,103	341	- 1,890
Dickinson	2,318	1,033	1,285	12,185	12,756	571	- 714
Ida	2,071	945	1,126	11,047	10,697	- 350	- 1,476
Lyon	3,098	1,142	1,956	15,374	14,697	- 677	- 2,633
O'Brien	3,966	1,842	2,124	19,293	18,970	- 323	- 2,447
Osceola	2,205	734	1,471	10,607	10,181	- 426	- 1,897
Plymouth	4,970	2,031	2,939	23,502	23,252	- 250	- 3,189
Sac	3,581	1,452	2,129	17,639	17,518	- 121	- 2,250
Sioux	6,031	1,958	4,073	27,209	26,381	- 828	- 4,901
Woodbury	22,118	10,077	12,041	103,627	103,917	290	- 11,751
Region	61,579	26,168	35,411	297,341	296,637	- 704	- 36,115
Iowa	519,272	256,832	262,440	2,538,268	2,621,073	82,805	- 179,635

[a]Minus sign indicates a decrease in population from 1940 to 1950.

[b]Minus sign indicates a net out-migration.

Table 51. Net migration during 1950-1960 from Northwest Iowa and Iowa

Area	Births	Deaths	Natural increase	1950 pop.	1960 pop.	Change in pop.	Net migration
Buena Vista	5,000	2,084	2,916	21,113	21,189	76	- 2,840[b]
Cherokee	4,277	1,730	2,547	19,052	18,598	- 454[a]	- 3,001
Clay	4,489	1,662	2,827	18,103	18,504	401	- 2,426
Dickinson	2,874	1,212	1,662	12,756	12,574	- 182	- 1,844
Ida	2,326	977	1,349	10,697	10,269	- 428	- 1,777
Lyon	3,685	1,156	2,529	14,697	14,468	- 229	- 2,758
O'Brien	4,626	1,822	2,804	18,970	18,840	- 130	- 2,934
Osceola	2,651	788	1,863	10,181	10,064	- 117	- 1,980
Plymouth	5,905	2,179	3,726	23,252	23,906	654	- 3,072
Sac	4,020	1,581	2,439	17,518	17,007	- 511	- 2,950
Sioux	7,112	2,247	4,865	26,381	26,375	- 6	- 4,871
Woodbury	27,891	10,884	17,007	103,917	107,849	3,932	- 13,075
Region	74,856	28,322	46,534	296,637	299,643	3,006	- 43,528
Iowa	635,334	269,149	366,185	2,621,073	2,757,537	136,464	- 229,721

[a]Minus sign indicates a decrease in population from 1950 to 1960.

[b]Minus sign indicates a net out-migration.

Table 52. Net migration during 1960-1970 from Northwest Iowa and Iowa

Area	Births	Deaths	Natural increase	1960 pop.	1970 pop.	Change in pop.	Net migration
Buena Vista	3,469	2,287	1,182	21,189	20,693	- 496[a]	- 1,678[b]
Cherokee	3,178	1,806	1,372	18,598	17,269	- 1,329	- 2,701
Clay	3,151	1,817	1,334	18,504	18,464	- 40	- 1,374
Dickinson	2,037	1,413	624	12,574	12,565	- 9	- 633
Ida	1,499	1,152	347	10,269	9,190	- 1,079	- 1,426
Lyon	2,611	1,293	1,318	14,468	13,340	- 1,128	- 2,446
O'Brien	3,269	1,928	1,341	18,840	17,522	- 1,318	- 2,659
Osceola	1,741	858	883	10,064	8,555	- 1,509	- 2,392
Plymouth	4,518	2,308	2,210	23,906	24,312	406	- 1,804
Sac	2,713	1,887	826	17,007	15,573	- 1,434	- 2,260
Sioux	5,372	2,510	2,862	26,375	27,996	1,621	- 1,241
Woodbury	21,635	11,266	10,369	107,849	103,052	- 4,797	- 15,166
Region	55,193	30,525	24,668	299,643	288,531	- 11,112	- 35,780
Iowa	542,544	291,005	251,539	2,757,537	2,825,041	67,504	- 184,035

[a]Minus sign indicates a decrease in population from 1960 to 1970.

[b]Minus sign indicates a net out-migration.

Table 53. Estimated net intercensal migration of total Iowa population, 1870-1970[a]

Decade	Net migration number of persons
1870-1880	85,100
1880-1890	- 5,600[b]
1890-1900	21,700
1900-1910	- 207,500
1910-1920	- 18,300
1920-1930	- 167,200
1930-1940	- 73,400
1940-1950	- 182,500
1950-1960	- 236,300
1960-1970	- 180,700

[a]H. C. Chang (1973).

[b]Minus sign indicates a net out-migration.

form the group which searches for work elsewhere.

This trend towards larger farms and fewer farmers is documented in Tables A-17 through A-28 in Appendix A. These data for the period 1952 through 1973 were obtained from the Iowa Annual Farm Census (Iowa Department of Agriculture, 1952-1973) and are summarized in Table 54. Here again all 12 counties were totally consistent throughout the 22-yr period: the total farm population decreased; the number of farms decreased; the average number of farm inhabitants per square mile decreased and the average farm size increased. In the region as a whole, the total farm population decreased from 93,530 to 68,438; the number of farms decreased from 23,321 to 16,401; the average number of farm inhabitants per square mile decreased from 13.1 to 9.6 and the average farm size increased from 194 to 273 acres in the 22-yr period from 1952

Table 54. Farm population and density, number and size of farms in Northwest Iowa, 1952-1973[a]

County	Population living on farms		Number of farms		Average farm size, acres		Area sq. mi.	Rural farm population density, persons/sq. mi.	
	1952	1970	1952	1973	1952	1973	1970	1952	1970
Buena Vista	7,570	5,448	1,973	1,352	183	259	572	13.4	10.1
Cherokee	6,922	5,354	1,768	1,213	205	292	573	12.2	9.7
Clay	6,898	4,431	1,792	1,120	198	308	570	12.4	8.2
Dickinson	4,340	2,775	1,156	728	202	310	380	11.9	7.9
Ida	5,133	3,663	1,344	973	203	278	431	12.0	8.7
Lyon	7,843	6,212	1,820	1,432	203	254	588	13.6	10.9
O'Brien	7,500	5,627	1,856	1,352	194	260	575	13.3	10.2
Osceola	5,285	3,696	1,274	905	198	272	398	13.4	9.7
Plymouth	10,980	8,413	2,727	2,016	199	265	863	12.9	10.0
Sac	7,823	5,531	1,934	1,280	186	284	578	13.9	9.7
Sioux	12,156	9,375	2,812	2,103	171	228	766	16.2	12.6
Woodbury	11,080	7,913	2,865	1,927	185	265	871	13.4	9.9
Region	93,530	68,438	23,321	16,401	194	273	7,165	13.1	9.6

[a]Iowa Annual Farm Census (1952-1973).

to 1973. Table 55 lists the rural farm population density from 1900 to 1970 based on census data.

Table 55. Historic rural farm population density, persons per square mile[a]

County	1900	1910	1920	1930	1940	1950	1960	1970
Buena Vista	20.1	17.6	17.2	16.4	15.4	14.5	12.3	9.3
Cherokee	18.1	15.8	15.0	15.7	14.6	13.2	12.1	8.6
Clay	17.2	14.9	15.4	14.9	14.4	12.8	10.4	7.6
Dickinson	13.2	13.3	14.7	14.9	14.9	12.5	10.2	8.1
Ida	19.3	17.1	15.8	15.9	13.8	12.7	11.5	8.5
Lyon	14.7	16.0	16.2	15.9	15.1	13.5	12.6	10.5
O'Brien	17.7	16.0	16.3	15.9	15.4	13.5	12.3	9.5
Osceola	15.3	15.3	16.3	16.2	15.5	13.5	12.6	9.3
Plymouth	17.3	16.6	16.0	16.0	14.7	13.1	11.7	10.0
Sac	19.2	17.8	16.6	15.6	15.2	14.2	11.6	9.4
Sioux	19.0	20.0	19.8	20.2	19.2	16.8	14.2	12.5
Woodbury	18.8	16.1	16.1	16.9	15.1	12.8	10.7	7.8
Region	17.5	16.4	16.3	16.2	14.1	13.6	11.8	9.2

[a]U.S. Department of Commerce, Bureau of the Census (1973).

Other trends also developed at the regional, county and local levels. Using the historic population data, the percentage of the total urban, rural farm, rural nonfarm and total rural population to the total county population was determined. In addition, the percentage of population in each county to the total regional population was calculated. Similarly, the percentage of population in each town to the total urban population in each county was determined. The results of these calculations for the period 1900-1970 are shown in Tables A-29 through A-40 in Appendix A and are summarized in Tables 56 and 57.

Table 56. Historic population percentages in Northwest Iowa and Iowa, 1900-1970

Area	1900	1910	1920	1930	1940	1950	1960	1970
Buena Vista[a]	7.58	6.71	6.67	6.42	6.67	7.12	7.07	7.17
Cherokee[a]	7.40	7.03	6.38	6.45	6.48	6.42	6.21	5.99
Clay[a]	5.98	5.36	5.63	5.54	5.97	6.10	6.17	6.40
Dickinson[a]	3.57	3.41	3.68	3.78	4.10	4.31	4.19	4.35
Ida[a]	5.50	4.74	4.20	4.11	3.72	3.61	3.43	3.19
Lyon[a]	5.88	6.14	5.55	5.26	5.17	4.95	4.83	4.62
O'Brien[a]	7.58	7.24	6.84	6.34	6.49	6.40	6.29	6.07
Osceola[a]	3.90	3.76	3.67	3.50	3.57	3.43	3.36	2.96
Plymouth[a]	9.92	9.70	8.47	8.31	7.90	7.84	7.98	8.43
Sac[a]	7.88	6.95	6.29	6.07	5.93	5.90	5.68	5.40
Sioux[a]	10.42	10.59	9.51	9.22	9.15	8.89	8.80	9.70
Woodbury[a]	24.39	28.37	33.11	34.99	34.85	35.03	35.99	35.72
Region[b]	10.03	10.71	11.58	11.76	11.71	11.32	10.87	10.21
Iowa[c]	2.94	2.42	2.27	2.01	1.93	1.74	1.54	1.39

[a]As percent of region.

[b]As percent of Iowa.

[c]As percent of nation.

The regional population, as a percentage of the total state population, rose from 10.03 in 1900 to a maximum of 11.76 in 1930 and then steadily declined to 10.21 in 1970. The 12-county region contains 7,165 sq. mi. or 12.74% of the total land area in Iowa which is 56,239 sq. mi. In terms of total population, while the state increased from 2.2 to 2.8 million during this 70-year period, the region increased from 224,000 in 1900 to 290,000 in 1930 and has remained fairly constant at that level to the present time.

At the county level only three counties increased in percentage, as a percentage of total regional population, in the period from 1900

Table 57. Historic percentages for the total urban, rural farm, rural nonfarm, total rural and total county populations in Northwest Iowa, 1900 and 1970

County	Total urban[a]		Rural farm[a]		Rural nonfarm[a]		Total rural[a]		Total county[b]	
	1900	1970	1900	1970	1900	1970	1900	1970	1900	1970
Buena Vista	32.14	68.16	67.86	25.62	0.00	6.22	67.86	31.84	7.58	7.17
Cherokee	37.37	63.30	62.63	28.50	0.00	8.20	62.62	36.70	7.40	5.99
Clay	26.98	69.41	73.02	23.62	0.00	6.97	73.02	30.59	5.98	6.40
Dickinson	37.42	65.63	62.58	24.41	0.00	9.96	62.58	34.37	3.57	4.35
Ida	32.42	56.89	67.58	39.92	0.00	3.12	67.58	43.11	5.50	3.19
Lyon	34.22	48.66	65.78	46.36	0.00	4.98	65.78	51.34	5.88	4.62
O'Brien	40.04	64.01	59.96	31.19	0.00	4.80	59.96	35.99	7.58	6.07
Osceola	30.01	50.23	69.99	43.10	0.00	6.67	69.99	49.77	3.90	2.96
Plymouth	32.83	56.74	67.17	35.64	0.00	7.60	67.17	43.24	9.92	8.43
Sac	37.09	58.83	62.91	34.74	0.00	6.43	62.91	41.17	7.88	5.40
Sioux	37.65	61.73	62.35	34.19	0.00	4.08	62.35	38.27	10.42	9.70
Woodbury	69.97	90.77	30.03	6.61	0.00	2.62	30.03	9.23	24.39	35.72

[a]As a percent of total county.

[b]As a percent of the region.

to 1970: Clay County which contains Spencer, the second largest city in the region; Dickinson County which contains the Iowa Great Lakes area and Woodbury County which contains Sioux City, the largest city in the region. In terms of total population for the other nine counties, three decreased in population, three gained fewer than 700 people each and the other three increased less than 4,700 persons each.

The most apparent trend at the county level was the movement from the rural to the urban areas. This is clearly shown in Table 57 and Fig. 48 and is typical of the trend experienced throughout Iowa and the nation. In 1900 all Northwest Iowa counties, with the exception of Woodbury County, had from 60% to 73% of their inhabitants living in rural areas. These percentages have steadily declined over the years so that by 1970 only 24% to 46% of the population lived on farms. The rural farm population in Woodbury County, which contains Sioux City, has declined from 30% to 9% in this same 70-yr period.

Another trend which has developed in the last 40 years is that segment of the population classified as rural nonfarm. These are urban dwellers who have found the "good life" to be in isolated homes or small subdivisions located in rural areas away from the "problems" of the larger cities. Figure 49 indicates this trend in terms of population in order to give a feel for the number of persons involved rather than in terms of a percent of total county population. For example, while Woodbury County had the largest rural nonfarm population in 1970, 2,699 persons, it had the smallest percentage of all 12 counties simply because over 83% of the county population, 103,052 persons, lived in Sioux City in 1970. While Fig. 49 indicates the

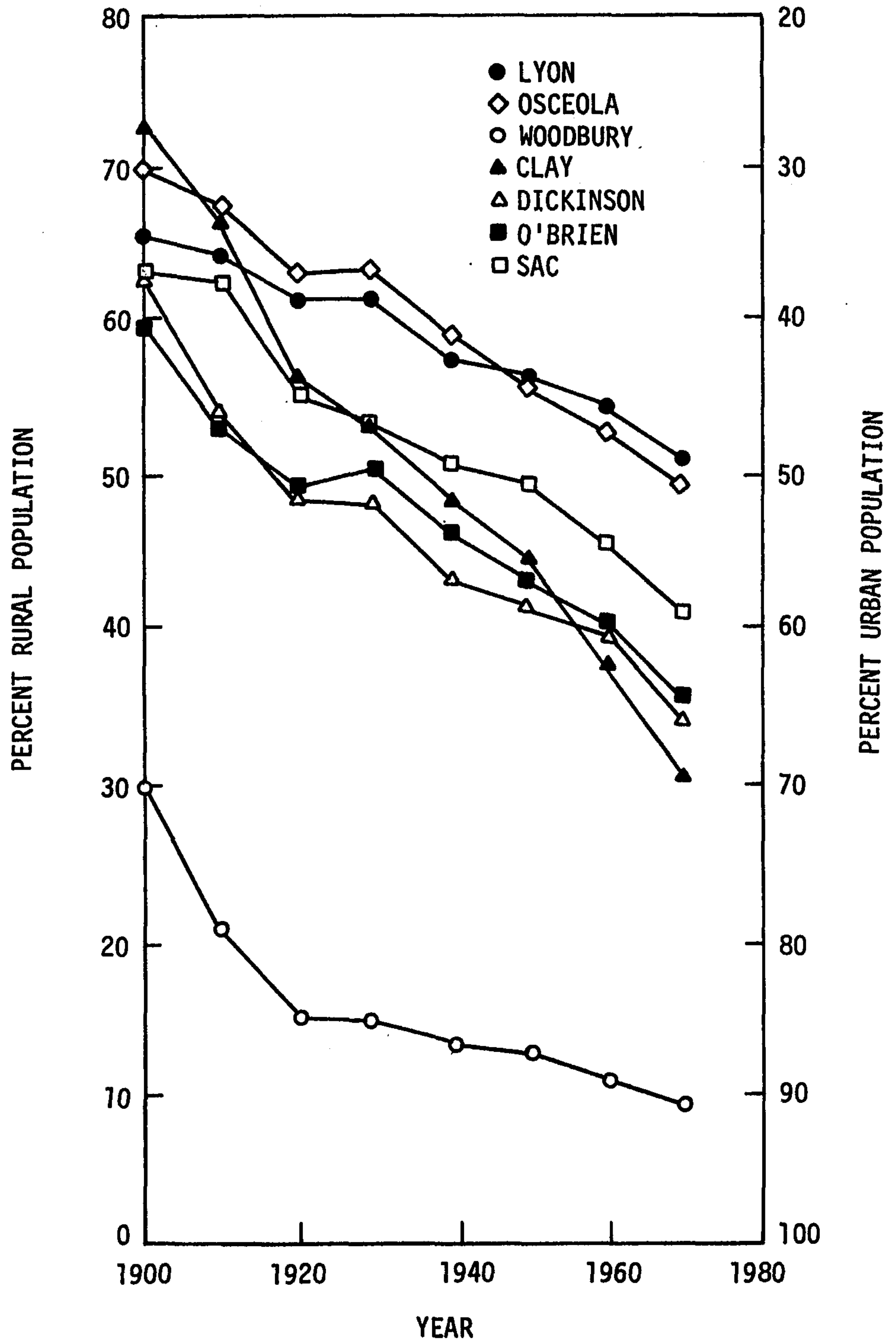


Fig. 48. Decrease in rural and increase in urban population in several Northwest Iowa counties, 1900-1970

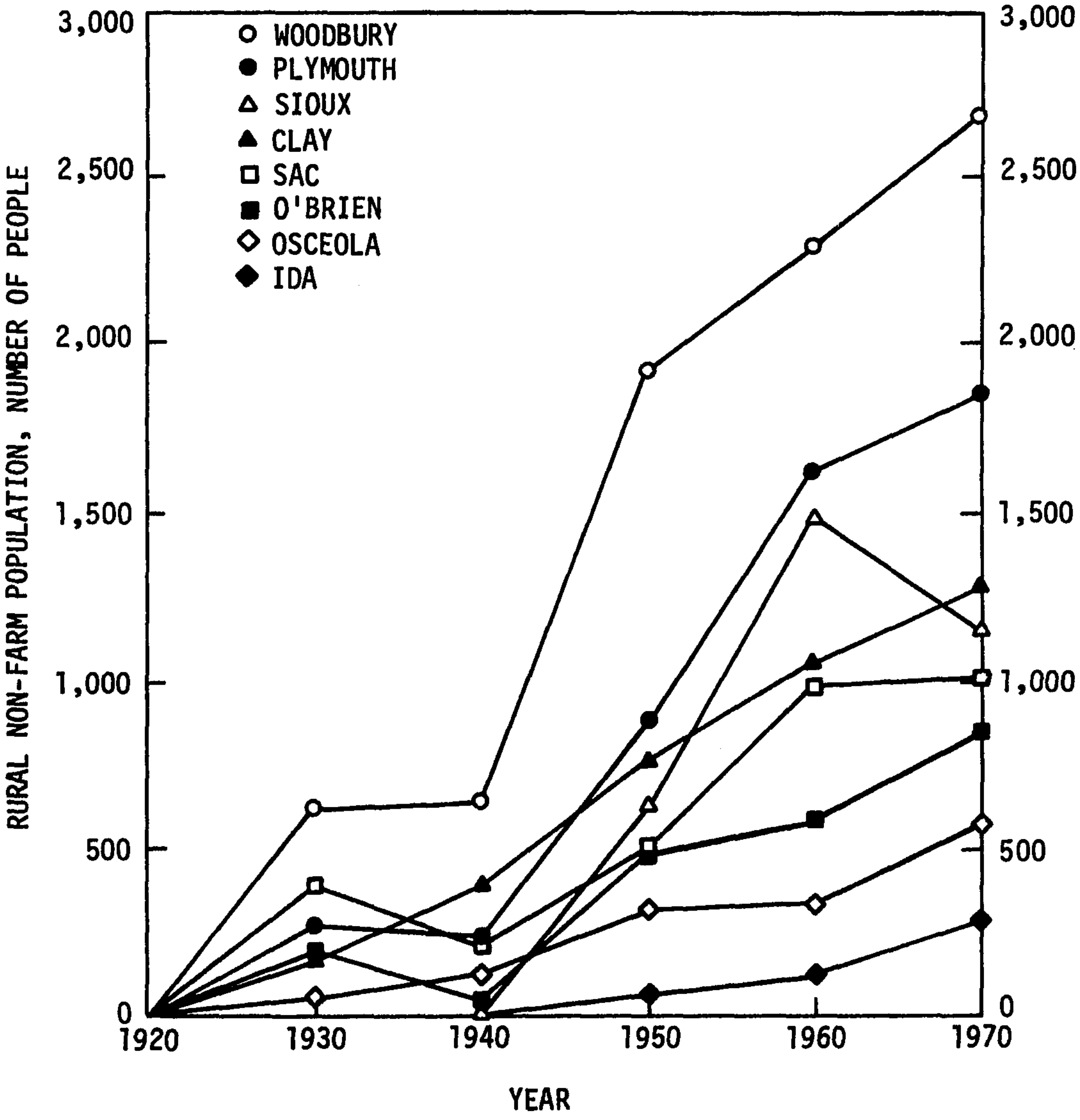


Fig. 49. Increase in rural nonfarm population in several Northwest Iowa counties, 1920-1970

general upward trend in the rural nonfarm or suburban dweller, the total numbers of people may not be accurately reflected because the data has not been corrected to include those who had previously lived in a suburban area but are now included in the urban category due to annexation during this period.

The most notable trends at the local level were that the total urban population in each county consistently increased, the ten largest cities consistently claimed a larger and larger percentage of the total regional population, the larger communities tended to get larger and the smaller cities tended to get smaller. Table 57 and Fig. 48 show the growth of the urban population in Northwest Iowa: from an average of 34.4% in 1900 to an average of 60.3% in 1970, excluding Woodbury County. In this county the urban portion of the population rose from 70% to almost 91% in the same time period. Thus, at the present time, over seven out of every ten persons in Northwest Iowa live in an urban area.

And as shown in Table 58 and Fig. 50, almost five of these seven persons lived in just 10 out of the 114 incorporated communities in Northwest Iowa in 1970 with three of these five people living in Sioux City. Even though Iowa contains hundreds of small communities and is thought to be a rural state (census definition: farms and communities less than 2,500), the majority of Iowans live in incorporated cities (urban in this study).

Table 59 indicates quite clearly that the larger communities tended to get larger and the smaller towns tended to get smaller between 1900 and 1970. Fifty of the 114 incorporated communities

Table 58. Population of the ten largest cities in Northwest Iowa and the region, 1900-1970

Area	1900	1910	1920	1930	1940	1950	1960	1970
Sioux City	33,111	47,828	71,227	79,183	82,364	83,991	89,159	85,925
Spencer	3,095	3,005	4,599	5,019	6,599	7,446	8,864	10,278
Storm Lake	2,169	2,428	3,658	4,157	5,274	6,954	7,728	8,591
Le Mars	4,146	4,157	4,683	4,788	5,353	5,844	6,767	8,159
Cherokee	3,865	4,884	5,824	6,443	7,469	7,705	7,724	7,272
Sheldon	2,282	2,941	3,488	3,320	3,768	4,001	4,251	4,535
Orange City	1,457	1,374	1,632	1,727	1,920	2,166	2,707	3,572
Sioux Center	810	1,064	1,389	1,497	1,680	1,860	2,275	3,450
Sac City	2,079	2,201	2,630	2,854	3,165	3,170	3,354	3,268
Spirit Lake	1,219	1,169	1,701	1,778	2,161	2,467	2,685	3,014
Total of 10 cities	54,233	71,051	100,831	110,766	119,753	125,604	135,514	138,064
Regional population	223,938	238,311	278,324	290,585	297,341	296,637	299,643	288,531
Sioux City[a]	14.8	20.1	25.6	27.2	27.7	28.3	29.8	29.8
Ten cities[b]	24.2	29.8	36.2	38.1	40.3	42.3	45.2	47.8

[a]Population of Sioux City as a percentage of total regional population.

[b]Population of the ten communities as a percentage of total regional population.

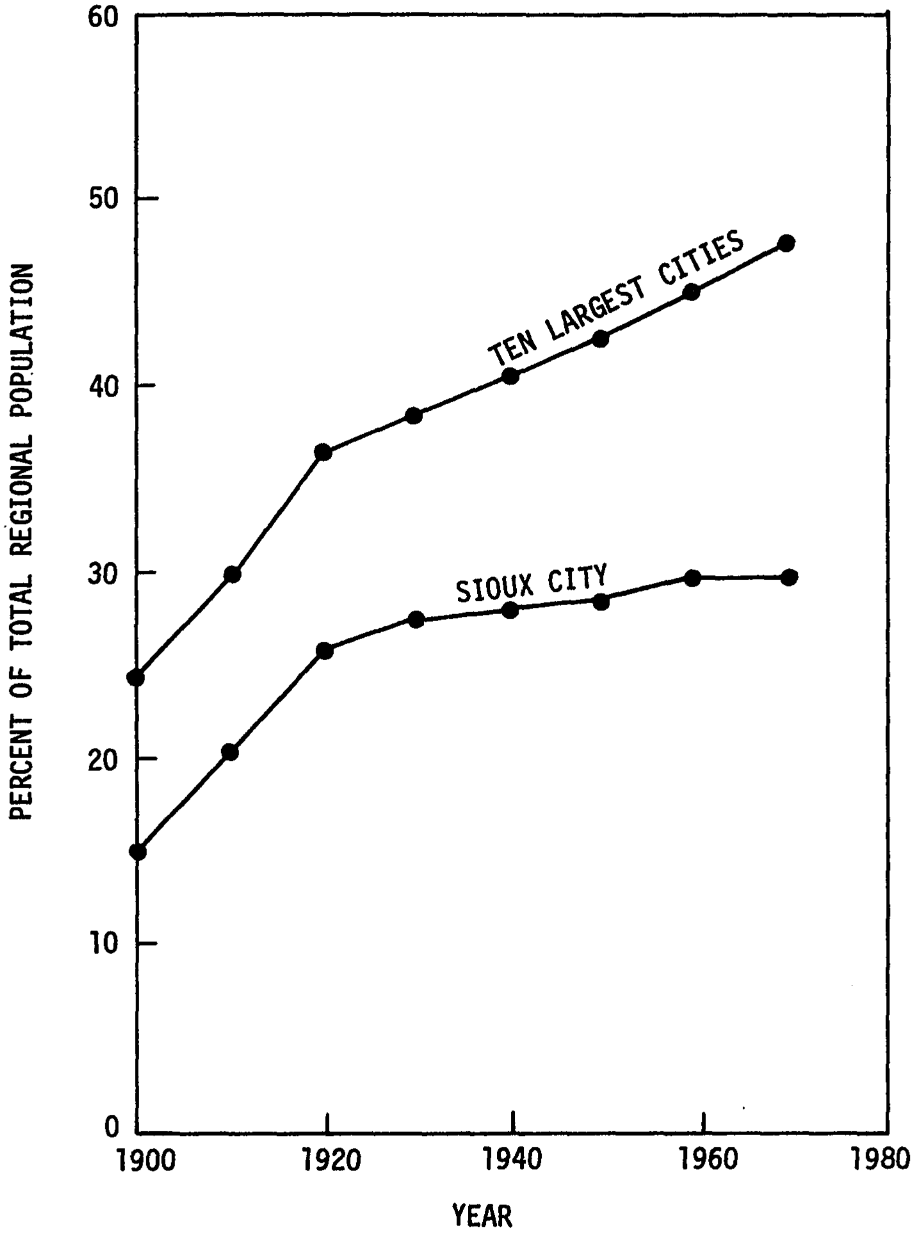


Fig. 50. Growth of Sioux City and the ten largest cities in Northwest Iowa as a percentage of the total regional population, 1900-1970

Table 59. Number of cities in Northwest Iowa which increased or decreased in population during the period 1900-1970

1970 population	Increased in population	Decreased in population
0- 250	5	28
251- 500	12	12
501-1,000	14	10
1,001-2,500	20	0
2,501-5,000	8	0
> 5,000	5	0
Total	64	50

decreased in population while 64 increased or maintained a fairly stable population. All cities whose 1970 population was over 1,000 increased in size while about 85% of those whose 1970 population was less than 250 decreased in size. In the size range from 251 to 1,000 people, slightly more than half increased in size. This could be due to the location of small industries, and thus employment opportunities, in these larger communities or in nearby cities.

Projections by the State of Iowa

The State of Iowa has made population projections to the year 2020 for state planning purposes. These projections were made by the Statistics Division of the Iowa State Department of Health for the Iowa Office for Planning and Programming (Taylor, 1976) and are shown in Table 60. The methodology and assumptions on which these projections are based are as follows.

> Three components are calculated by age and sex groups. Fertility rates are computed for each appropriate age-group of women, and male and female survival and

Table 60. Department of Health population projections for Northwest Iowa[a]

County	1970	1980	1990	2000	2010	2020
Buena Vista	20,693	21,302	22,030	22,151	22,117	21,921
Cherokee	17,269	16,363	16,455	16,836	17,313	17,740
Clay	18,464	19,237	20,254	20,579	20,685	20,641
Dickinson	12,565	14,778	16,757	17,470	17,859	18,071
Ida	9,283	8,733	8,690	8,693	8,744	8,839
Lyon	13,340	13,018	13,528	14,274	15,284	16,566
O'Brien	17,522	17,998	18,913	19,325	19,637	19,974
Osceola	8,555	8,719	9,288	9,776	10,465	11,264
Plymouth	24,322	23,948	24,524	25,250	25,895	26,455
Sac	15,573	15,112	15,287	15,419	15,729	16,116
Sioux	27,996	30,117	32,389	33,755	34,635	35,403
Woodbury	103,052	108,600	114,948	120,144	124,802	128,251
Region	288,634	297,925	313,063	323,672	332,445	341,241
State	2,825,368	2,932,716	3,088,197	3,203,015	3,293,502	3,355,763

[a]Taylor (1976).

migration rates are calculated by age-groups. These rates are called age-specific and sex-specific rates. Because each specified age and sex group comprises a cohort, this method is called a cohort-survival component method; since these projections are based on the age-sex specific rates of three components of population (live birth, death, migration). This method produces a sensitive projection because it is a highly refined procedure involving detailed calculations.

The age-sex-specific death and fertility rates and migration rates for each county are determined. According to assumptions about change between 1970 and 1975, each rate for each cohort in each county is applied to revised 1970 population of that cohort, resulting in a projected cohort population to July 1, 1975 for all 99 counties. The procedure is repeated for each projected period, each new projection being calculated from the previously projected figure and according to assumptions about the change in rates of the components.

The period from 1969 to 1971 provides the base for determining the fertility and the survival rates, and the census decade 1960 to 1970 provides the base for calculating the net migration rates.

Survival rates: Five year survival rates for Iowa males and females by age were calculated and tied-in with the United States projected rates. The state age and sex specific survival rates are not statistically different from and are applicable to all 99 counties.

Fertility rates: Age-specific rates calculated for each county were adjusted to follow the national trend for Series III (white). Series III (white) assumes an ultimate completed fertility of 1.9 children per woman.

Net migration rates: County rates by age and sex based on the 1960-1970 net migration experience were adjusted to conform with the 1970-1975 county trends. These trends were incremented to a zero net migration by 2000. In other words, from 2000 on the total in-migration will equal the total out-migration for each county.

This set of assumptions creates an entirely different future for Northwest Iowa when compared to the historic trend as shown in Fig. 51 through 55. Another set of projections, based on OBERS, is developed which tends to continue the historic trend of the last 30 to 50 years

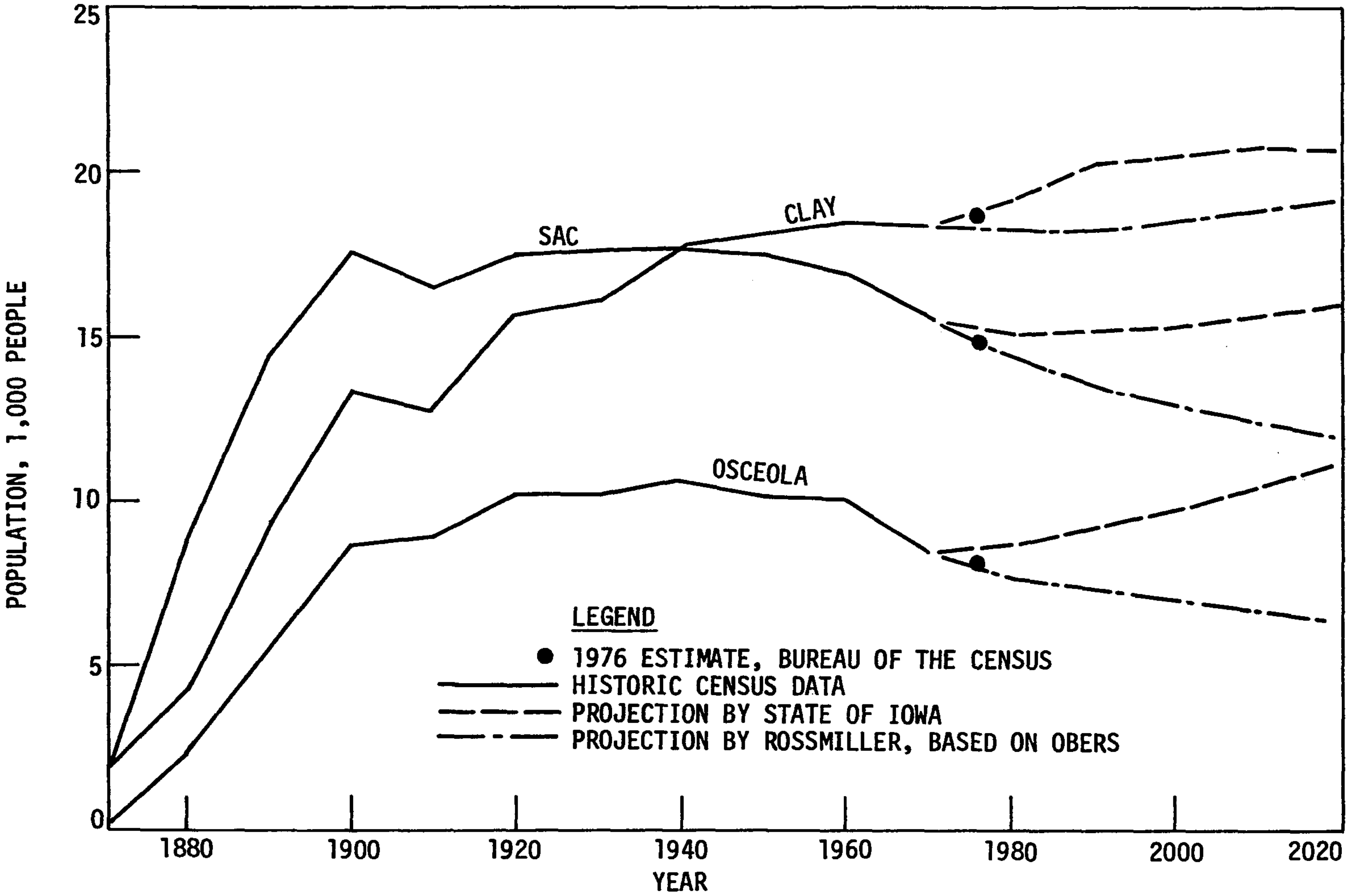


Fig. 51. Historic and projected populations in Clay, Osceola and Sac Counties, 1870-2020

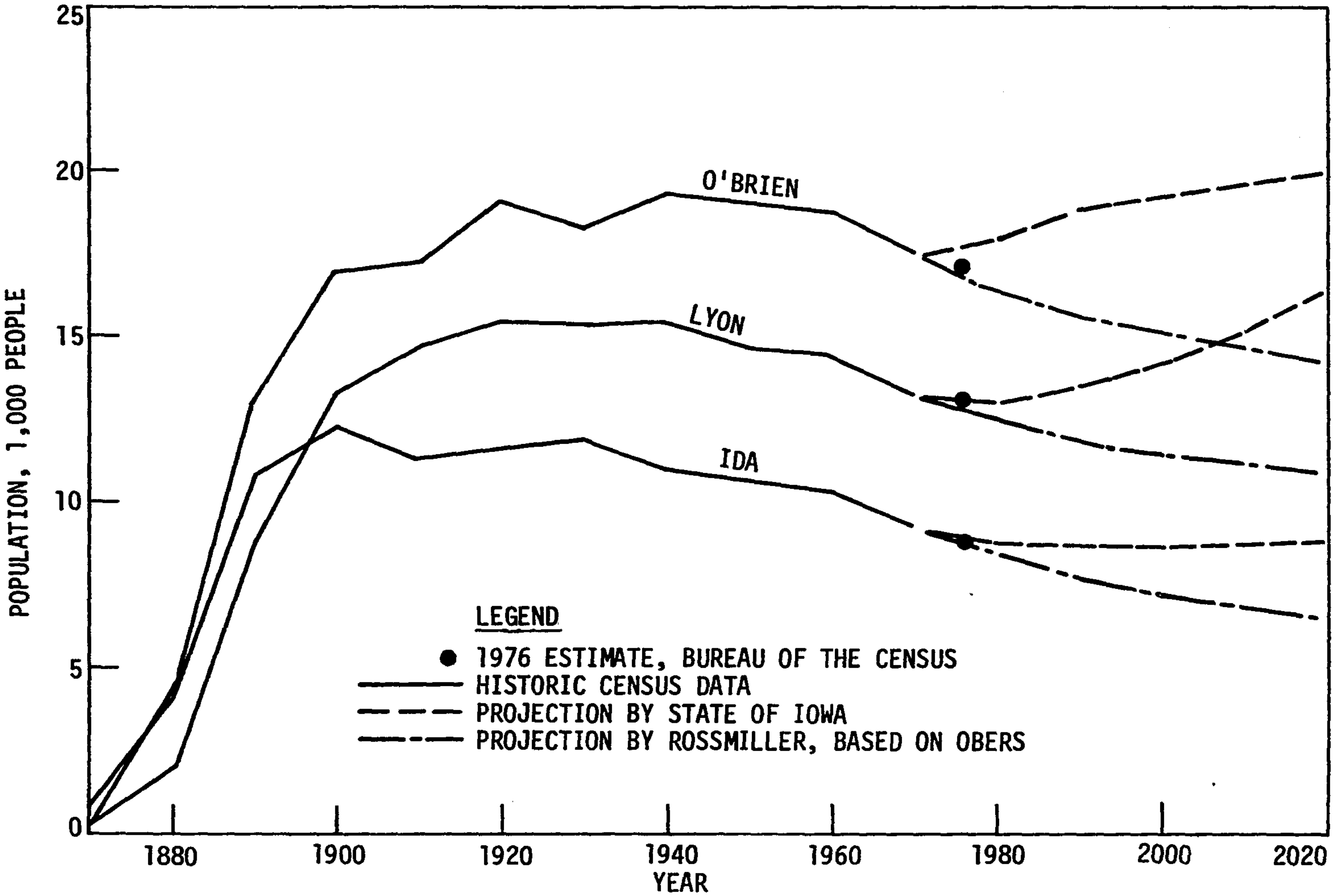


Fig. 52. Historic and projected populations in Ida, Lyon and O'Brien Counties, 1870-2020

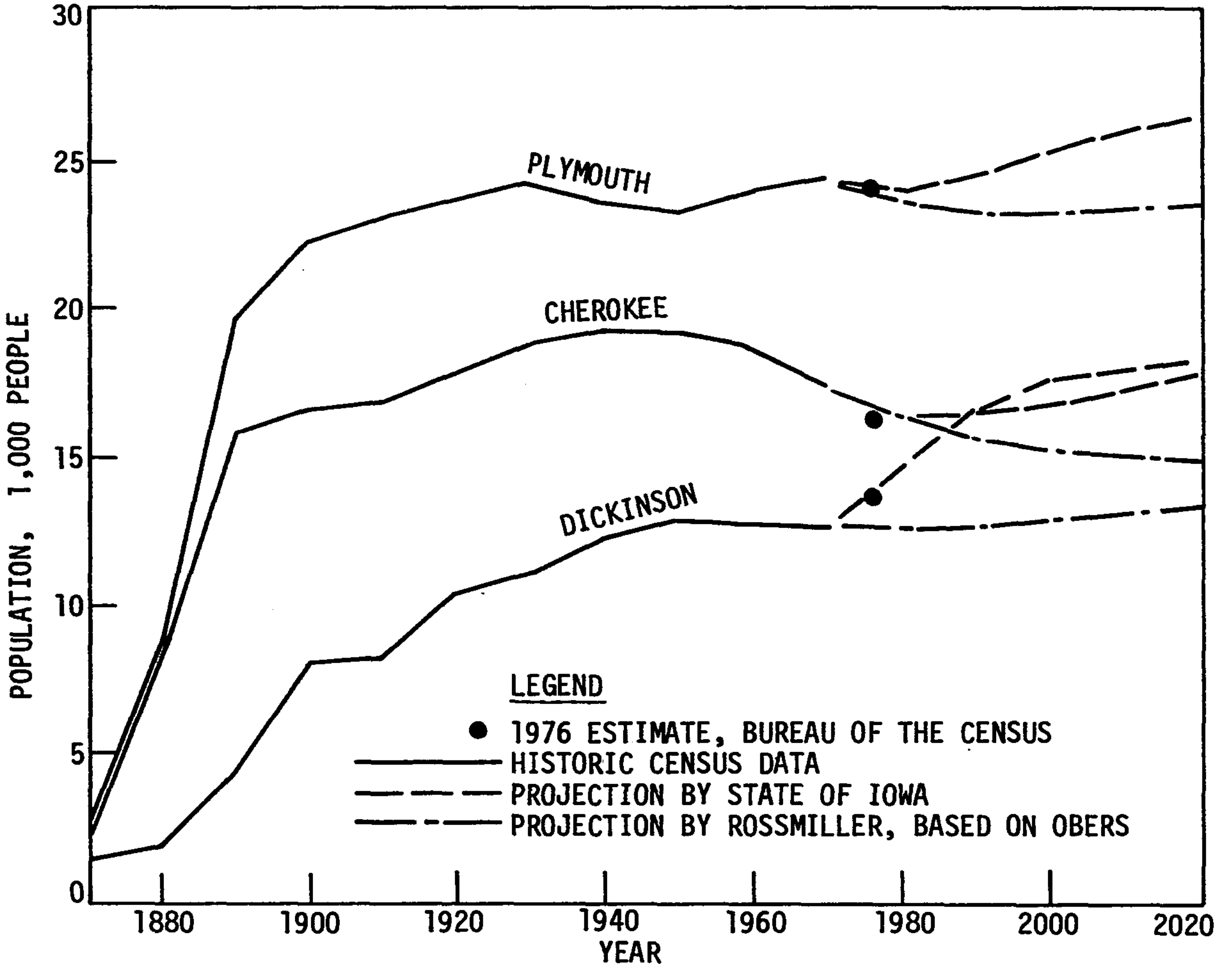


Fig. 53. Historic and projected populations in Cherokee, Dickinson and Plymouth Counties, 1870-2020

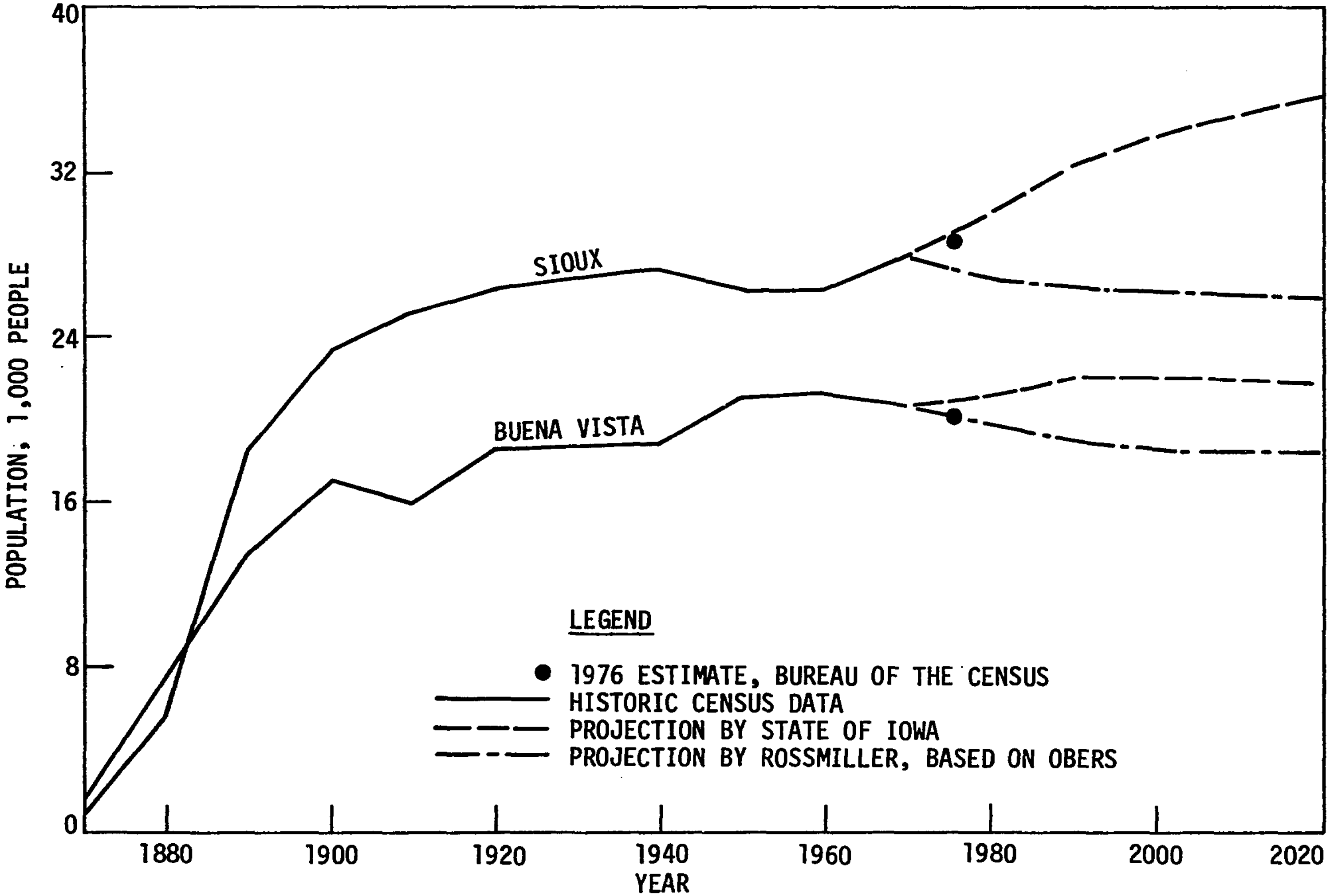


Fig. 54. Historic and projected populations in Buena Vista and Sioux Counties, 1870-2020

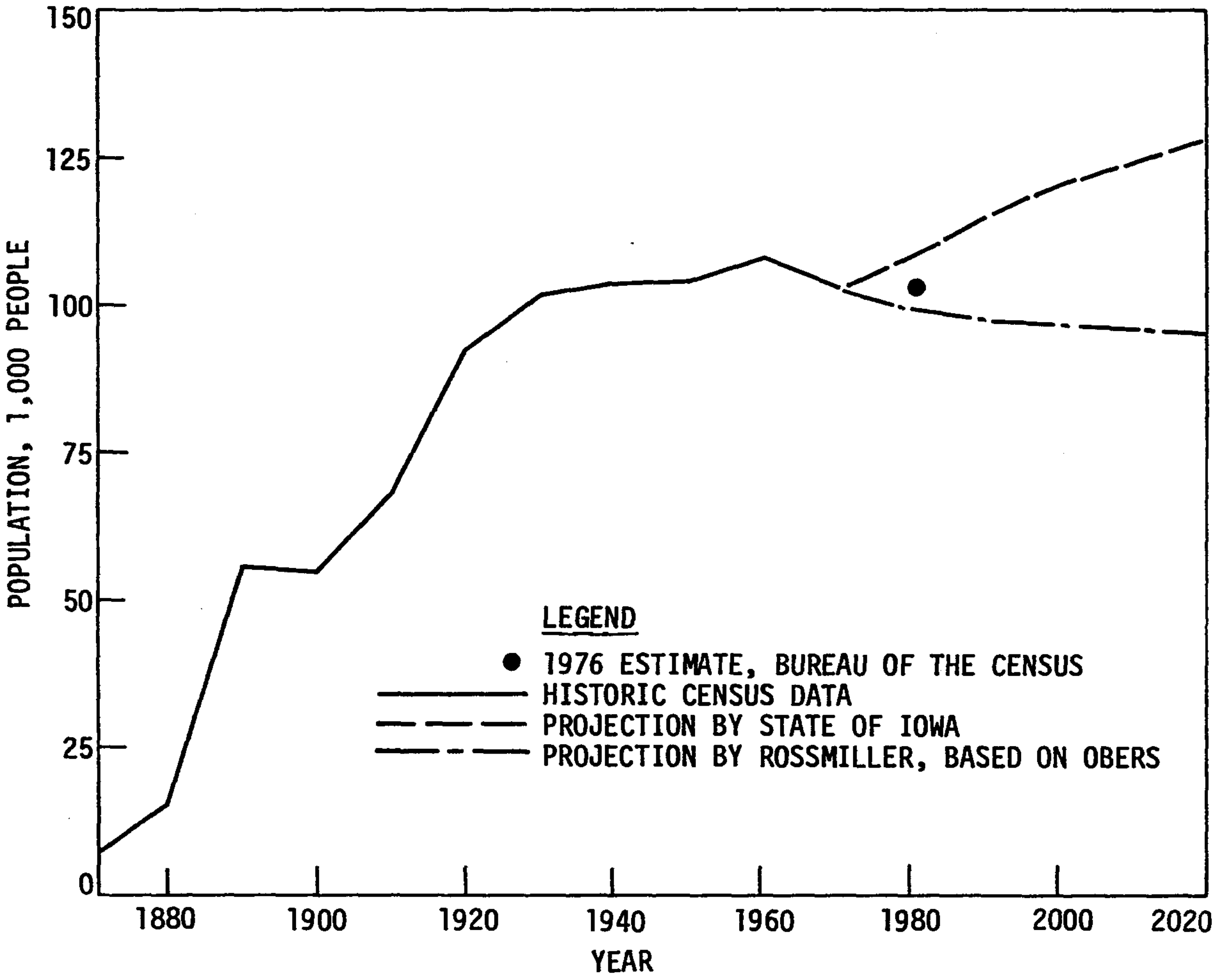


Fig. 55. Historic and projected population in Woodbury County, 1870-2020

of declining county populations. This is felt to be a more realistic projection than the State projection which dramatically reverses this trend. Time will certainly tell which set of projections is the more accurate. As stated by Taylor (1976), "a projection is an 'if-then' statement. If certain specified trends continue, then the population will be as projected."

The main difference between the two sets of projections is the assumption concerning net migration. During the 1970-1975 period, many counties in Iowa experienced a reversal in the historic net out-migration rate: The state OPP projections assume that this current net in-migration trend will continue but will become zero in the year 2000. The OBERS projections assume a continuation of the historic out-migration trend. The assumption of a net in-migration means a reversal of the long-term decline in Iowa's rural population and/or a reversal of the long-term failure in Iowa to provide jobs for those who leave the rural areas. Again, only time and actual commercial and industrial employment opportunities will tell which net migration assumption is more accurate. Farming trends appear to be well-established. Largeness is expected to continue, although perhaps at a decreasing rate.

For purposes of estimating the future impacts of OPP's set of population projections on the land and water resources of Northwest Iowa, the following assumptions are made. The rural farm population will decline at the same rate as projected in the following section. The remainder of the projected county population is split between the urban and rural nonfarm components in the same ratios as projected in the following section. The results of these assumptions are shown in Table 61. These projections are developed more fully in Appendix A. Tables A-65 through A-76 in Appendix A depict the future population percentages in Northwest Iowa as projected by the State of Iowa. These percentages are then used to develop the future urban and rural populations in Northwest Iowa as projected by the State of Iowa shown in Tables A-77 through A-88 in Appendix A.

Population projection methodology used in this study

Population projections can be performed in a number of ways. Historic trends, modifications of past trends, new trends or a combination of these can be used to estimate the future population of an area. We might use assumed future birth, death and migration rates broken down by sex and age cohorts to project the population of an area at several points in the future. We might also use the component method wherein the population is broken down into major components such as urban, rural, dominant commercial, industrial and/or governmental firms in an area, students, nonstudents, etc. and then estimate the future population of the area by using perceived trends for each of the components. Population projections can also be made by first projecting the future employment of the area in all fields and then relating employment to population by using past, present or perceived ratios of employment to population. Whichever method or combination of methods is used to project future population, however, the estimate will only be as good as how accurately the assumptions used in the projection match what actually occurs in the future unless certain

Table 61. Future total urban, rural farm and rural nonfarm populations in Northwest Iowa based on the projection made by the State of Iowa for the years 1980, 2000 and 2020[a]

County	Total urban			Rural farm			Rural nonfarm		
	1980	2000	2020	1980	2000	2020	1980	2000	2020
Buena Vista	15,090	16,520	16,770	4,770	3,930	3,300	1,440	1,700	1,850
Cherokee	10,450	11,260	12,200	4,440	3,760	3,300	1,470	1,820	2,240
Clay	13,680	15,100	15,340	4,080	3,660	3,300	1,480	1,820	2,000
Dickinson	10,270	12,680	13,290	2,840	2,470	2,100	1,670	2,320	2,680
Ida	5,090	5,440	5,830	3,300	2,780	2,400	340	470	610
Lyon	6,870	8,930	11,630	5,400	4,260	3,410	750	1,080	1,520
O'Brien	12,140	13,950	14,930	4,850	3,960	3,300	1,010	1,410	1,740
Osceola	4,720	5,920	7,310	3,270	2,700	2,250	730	1,160	1,700
Plymouth	14,210	16,500	18,570	7,760	6,360	5,100	1,980	2,390	2,790
Sac	9,190	10,060	11,080	4,830	3,970	3,300	1,090	1,390	1,740
Sioux	20,420	25,620	28,770	8,310	6,290	4,500	1,390	1,850	2,130
Woodbury	99,190	110,630	118,380	6,320	5,560	5,120	3,090	3,950	4,750
Region	221,320	252,610	274,130	60,170	49,700	41,380	16,440	21,360	25,750

[a]Taylor (1976).

factors compensate for others inadvertently.

The method used in this study to project the future population of Northwest Iowa is a combination of three of the above methods. The state and regional population and the population of Woodbury County were obtained from the OBERS projections which estimates future population based on national fertility rates and economic activity. The total population of the other eleven counties was estimated by extending the historic trend of the percentage of the total regional population living in each county and then adjusting these slightly to match the regional population obtained from the OBERS projections. The future populations of the incorporated communities were estimated using the component method and modifications of historic trends. The county population was divided into three components: rural farm, rural non-farm and urban. The rural components were estimated using a modification of the historic trends for these two components. The residual became the urban population. The future population of each town was then estimated by using a modification of the historic trend of the percentage of the total urban population residing in each town. All of the above are discussed in detail in the following paragraphs.

OBERS is a combination of the names of two federal agencies: the Office of Business Economics (OBE) and the Economic Research Service (ERS). The OBERS projections are made for the U.S. Water Resources Council and are to be used for planning purposes as set forth in the following excerpt from the Forward to the OBERS publications (U.S. Water Resources Council, 1974).

> The OBERS projections are intended as a planning tool, as a contribution to planning decisions. Wherever water and related land development problems may be solved by alternative levels of growth, through more or less resource development, full consideration should be given to such action, uninhibited by the projections contained in this report.

The present OBERS projections are based on the Census Bureau's 1972 "Series E" national population projection. This is a much lower rate of growth than used in the 1972 OBERS projections which used "Series C." The differences between these two series and some insights into their projection methodology are given in the following excerpt from the Forward to the OBERS projections (U.S. Water Resources Council, 1974).

> Significant population, personal income and cropland harvested differences between the "Series C" and "Series E" projections for the year 2000 are shown in the following table.

Item	"Series C"	"Series E"	Change	Percent difference
	Year 2000 projections (millions)			
Population (domestic)	306.8	263.8	- 43.0	- 14.0
Total personal income (domestic) (1967 dollars)	2,542,849	2,154,266	- 388,583	- 15.3
Cropland harvested (acres)	309.7	271.9	- 37.8	- 12.2

> These differences are caused primarily by changes in the national population growth rate assumptions. However, the following additional changes also contributed to differences in the two reports.
>
> o The hours worked per year are projected to decline at the rate of 0.35 percent per year. The "Series C"

report used a 0.25 percent rate.

- o The projected rate of increase in product per man per hour in the private economy is lowered from 3.0 percent to 2.9 percent.
- o Earnings per worker in the individual industries at the national level are projected to converge toward the all-industry rate more slowly than in the "Series C" report.
- o Income data for 1970 and 1971 and total employment data for 1970 have been included in this report. Use of this additional information, which was not available for the first report, has caused significant changes in some area projections.
- o On the basis of the President's 1974 budget message to Congress, a smaller military establishment has been assumed.
- o The method for projecting population as a function of projected employment has been revised to treat each of three age groups separately.

Tables 62 and 63 present the OBERS projections for the Sioux City Standard Metropolitan Statistical Area (SMSA) and either two economic areas or two water resources subareas which include the non-SMSA portions of the study area in Northwest Iowa. The Sioux City SMSA includes Woodbury County, Iowa and Dakota County, Nebraska. Most of these projections predict a gradual decline in the population of the area, a continuation of the historic and recent trends. The future population of Woodbury County was estimated by calculating the ratio of the 1970 county population to the 1970 SMSA population, assuming that this was also the ratio which would occur in 2000 and 2020 and then prorating the future populations for the other decades.

Table 64 presents the current OBERS projections for Iowa and the United States. In Table 65 the population of Iowa as a percentage of

Table 62. OBERS projections for the water resources subareas which include most of the study area in Northwest Iowa

Year	SMSA 212 Sioux City, Iowa-Nebr.[a]	Non-SMSA portion of water resources subarea 1023, Missouri-Sioux City-Omaha[b]	Non-SMSA portion of water resources subarea 1017, Missouri-Big Sioux[c]
1950	114,487	219,455	293,529
1970	116,431	206,023	272,719
1980	111,300	197,000	270,500
1990	109,400	189,500	260,300
2000	109,600	186,900	252,300
2020	108,300	183,500	241,000

[a]Includes Woodbury County, Iowa and Dakota County, Nebraska.

[b]Includes 13 counties in Iowa and 4 counties in Nebraska.

[c]Includes 2 counties in Iowa, 3 counties in Minnesota and 15 counties in South Dakota.

Table 63. OBERS projections for the economic areas which include most of the study area in Northwest Iowa

Year	SMSA 212 Sioux City, Iowa-Nebr.[a]	Non-SMSA portion of economic area 103 Sioux City, Iowa-Nebr.[b]	Non-SMSA portion of economic area 104 Fort Dodge, Iowa[c]
1950	114,487	367,074	282,802
1970	116,431	338,820	266,531
1980	111,300	335,400	270,100
1990	109,400	323,800	271,800
2000	109,600	321,300	271,800
2020	108,300	313,600	275,800

[a]Includes Woodbury County, Iowa and Dakota County, Nebraska.

[b]Includes 8 counties in Iowa, 16 counties in Nebraska and 7 counties in South Dakota.

[c]Includes 15 counties in Iowa.

Table 64. OBERS population projections for Iowa and the United States

Year	Iowa	United States	Percent of national
1950	2,621,073	150,697,361	1.74
1960	2,757,537	179,323,175	1.54
1970	2,825,041	203,184,772	1.39
1980	2,913,400	223,532,000	1.30
1990	2,992,700	246,039,000	1.22
2000	3,053,500	263,830,000	1.16
2010	3,123,200	281,368,000	1.11
2020	3,187,400	297,146,000	1.07

Table 65. Projected population percentages of Northwest Iowa and Iowa

Area	1970	1980	1990	2000	2010	2020
Buena Vista[a]	7.17	7.12	7.08	7.05	7.02	7.00
Cherokee[a]	5.99	5.89	5.79	5.72	5.68	5.65
Clay[a]	6.40	6.60	6.80	7.00	7.20	7.40
Dickinson[a]	4.35	4.52	4.67	4.80	4.94	5.05
Ida[a]	3.19	3.05	2.91	2.75	2.63	2.50
Lyon[a]	4.62	4.52	4.42	4.33	4.27	4.20
O'Brien[a]	6.07	5.94	5.80	5.68	5.60	5.50
Osceola[a]	2.96	2.85	2.76	2.66	2.57	2.50
Plymouth[a]	8.43	8.53	8.64	8.76	8.87	9.00
Sac[a]	5.40	5.23	5.05	4.89	4.75	4.60
Sioux[a]	9.70	9.75	9.80	9.85	9.90	9.95
Woodbury[a]	35.72	36.00	36.28	36.51	36.57	36.65
	100.00	100.00	100.00	100.00	100.00	100.00
Region[b]	10.21	9.50	9.00	8.70	8.45	8.20
Iowa[c]	1.39	1.30	1.22	1.16	1.11	1.07

[a]As a percent of regional population.

[b]As a percent of state population.

[c]As a percent of national population.

the national population is shown. This percentage has declined from 2.94% in 1900 to 1.39% in 1970 and is projected to further decline to 1.07% in 2020. In total population Iowa has grown from 2.2 million in 1900 to 2.8 million in 1970 and is projected to increase to 3.2 million in 2020. On the regional level the number of people in the study area as a percentage of the state population has increased from 10.03% in 1900 to 11.76% in 1930, declined to 10.21% in 1970 and is projected to further decline to 8.2% in 2020. In total population the region has grown from 224,000 in 1900 to a maximum of almost 300,000 in 1960, declined to 288,000 in 1970 and is projected to further decline to 261,400 in 2020. Thus, the OBERS projections anticipate a continuation of the historic trend on both the state and regional levels to contain a smaller and smaller percentage of the national and state population, respectively. These declines are shown pictorially in Fig. 56.

The figure of 8.2% was determined in the following manner. The ratio of the 1970 Northwest Iowa regional population to the average of the 1970 OBERS non-SMSA areas, excluding Fort Dodge, was determined. This ratio was applied to the average of the 2020 populations of these non-SMSA areas and a population of 261,400 was obtained for the region in 2020. Expressing this population as a percent of the projected state population in 2020, yielded the value of 8.2%. The other values of regional percentages shown in Table 65 were obtained by prorating between 10.21% in 1970 and 8.2% in 2020.

The percentages for Woodbury County were calculated by dividing the projected populations previously determined by the projected

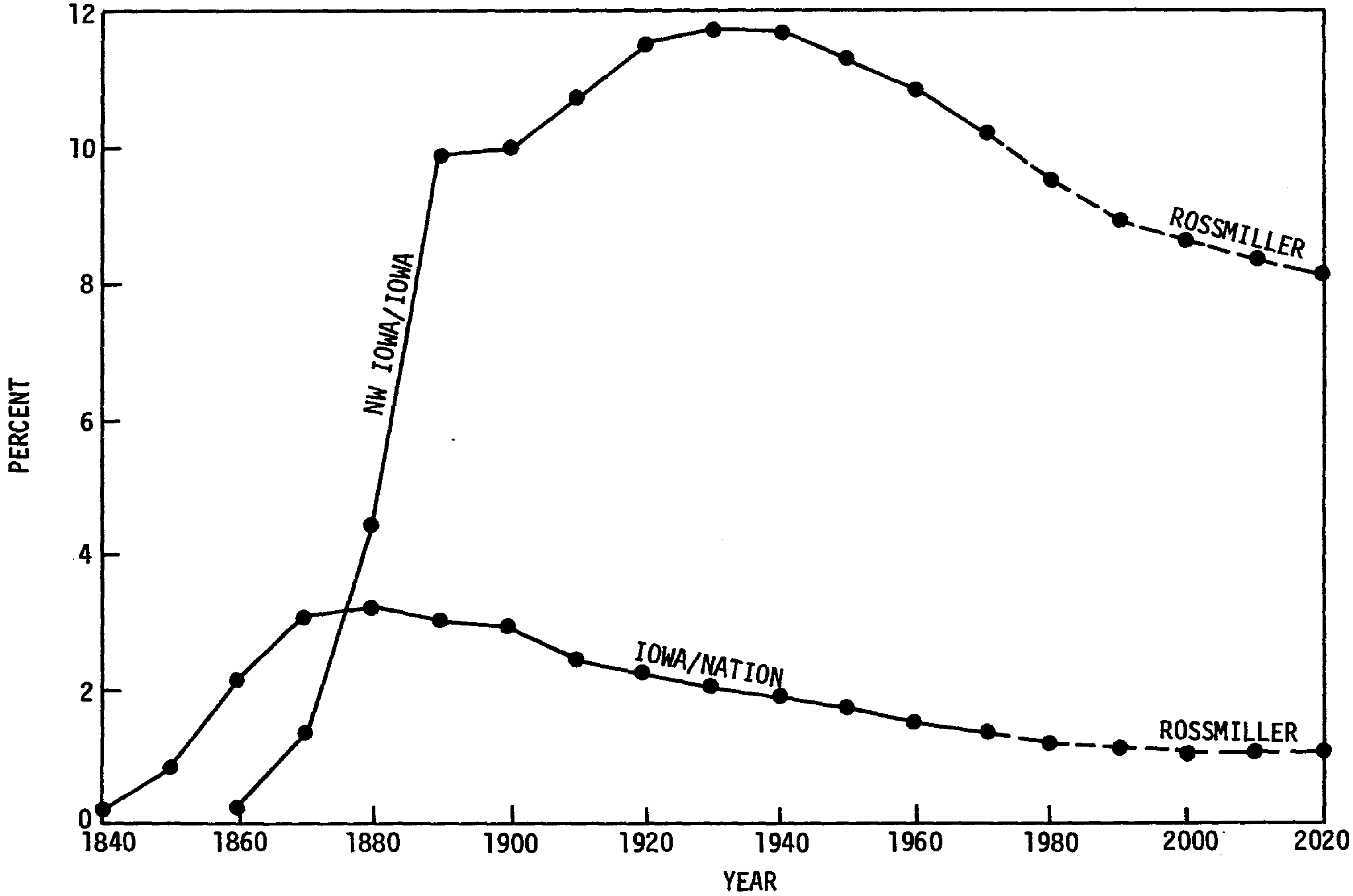


Fig. 56. Relative percentages of population in Northwest Iowa and Iowa, 1840-2020

regional populations for each decade. Percentages for the other counties were determined by modifying the historic trends shown in Table 56. Clay and Dickinson Counties were projected to continue to increase their percentage of regional population based on the presence of Spencer and the Iowa Great Lakes recreational area. Plymouth County was also projected to increase in anticipation of some population spillover from Sioux City. The percentage in Sioux County was projected to remain fairly stable. The other seven counties were projected to continue to decrease as more people migrated from farms to the larger cities in and out of the region. These assumptions were used to set the percentages for each county in 2020. The percentages for the other decades were determined by prorating between the percentages in 1970 and 2020, making sure that each decade added up to 100%.

Within each county the population was divided into three components: rural farm, rural nonfarm and urban. The assumptions were made that the average farm size would continue to increase to at least 320 acres per farm-family unit, the rural farm population density would continue to decrease to about 6 people per square mile and that these levels would be reached in 2020. The further assumption was made that the rate of decline would steadily decrease as we approached the year 2020. For each county the rural farm population in 2020 was determined by multiplying the area of the county in square miles by six. This figure was divided by the 2020 county population to determine the percentage of people in the rural farm component in 2020. The percentages for the other decades were determined by prorating between the 1970 and 2020 percentages using the assumption listed above. These future rural farm population percentages for all 12 counties are shown in Tables A-41 through A-52 in Appendix A.

The future rural nonfarm population was determined in a somewhat similar fashion. The assumption was made that this component of the population would increase in total numbers in the future as more and more people sought a suburban or rural area setting in which to live. A subjective judgment was made as to the number of persons in this category in 2020 in each county after examining the historic rate of growth and rural nonfarm population in each county in 1970. The percentages for the other decades were determined by using a straight line proportion between the 1970 and 2020 percentages. The total future rural population percentages for each county were calculated by adding the percentages for the future rural farm and the future rural nonfarm components. These two sets of percentages are also shown in Tables A-41 through A-52 in Appendix A.

The future total urban population percentages for each decade in each county were calculated by subtracting the future total rural population percentages from 100, the total county population. The future populations of each of the incorporated communities were determined in the following manner. The basic assumption used was that the historic trends would continue: the larger cities (over 1,000 in 1970) would tend to get larger, the smaller communities (under 250 in 1970) would tend to get smaller and those in the 250 to 1,000 range could get larger or smaller. Using this as the basis, another subjective judgment was made as to the 2020 population of each city. These values were revised again until the total 2020 population of the towns in a county matched the projected total urban population in 2020 for that county. These final populations were then expressed as percentages of the total urban population in each county in 2020. The percentages for the other decades were determined by using a straight line proportion between the 1970 and 2020 percentages. These percentages are also shown in Tables A-41 through A-52 in Appendix A.

The projected percentages for the total urban, rural farm, rural nonfarm, total rural and total county for each county in 1990 and 2020 are summarized in Table 66. The historic percentages (1900 and 1970) for these components were previously summarized in Table 57.

Projected populations

Table 67 lists the projected populations for the period 1970 to 2020 for each county in Northwest Iowa, the region, the state and the nation. These estimated future populations and those which follow for the cities and rural populations should be viewed in the following manner: these estimates are indicative of the future population of the areas described only insofar as the assumptions on which they are based accurately reflect the trends and conditions which actually occur in the future; if the present trends and conditions change somewhat, then these figures will be inaccurate to that degree. In an integrated regional sense, these projections reflect what is expected if past population trends, birth rates, death rates, and economic and industrial growth patterns continue. One very large industry locating in the region, perhaps governmentally supported or related, could easily

Table 66. Projected percentages for the total urban, rural farm, rural nonfarm, total rural and total county populations in Northwest Iowa, 1990 and 2020

County	Total urban[a]		Rural farm[a]		Rural nonfarm[a]		Total rural[a]		Total county[b]	
	1990	2020	1990	2020	1990	2020	1990	2020	1990	2020
Buena Vista	70.45	73.90	22.55	17.95	7.00	8.15	29.55	26.10	7.08	7.00
Cherokee	64.30	65.70	26.00	22.30	9.70	12.00	35.70	34.30	5.79	5.65
Clay	70.85	73.30	21.00	17.10	8.15	9.60	29.15	26.70	6.80	7.40
Dickinson	67.35	70.00	21.00	15.90	11.65	14.10	32.65	30.00	4.67	5.05
Ida	56.98	57.10	38.70	36.90	4.32	6.00	43.02	42.90	2.91	2.50
Lyon	53.70	61.00	40.10	31.00	6.20	8.00	46.30	39.00	4.42	4.20
O'Brien	66.00	69.00	27.90	22.90	6.10	8.10	34.00	31.00	5.80	5.50
Osceola	51.35	53.10	39.70	34.60	8.95	12.30	48.65	46.90	2.76	2.50
Plymouth	61.20	68.10	30.10	21.70	8.70	10.20	38.80	31.90	8.64	9.00
Sac	60.30	62.70	31.90	27.50	7.80	9.80	39.70	37.30	5.05	4.60
Sioux	67.85	77.00	27.40	17.30	4.75	5.70	32.15	23.00	9.80	9.95
Woodbury	90.87	91.00	6.09	5.35	3.04	3.65	9.13	9.00	36.28	36.65

[a]As a percent of total county.

[b]As a percent of the region.

Table 67. Projected populations of Northwest Iowa, Iowa and the Nation, 1970-2020

Area	1970	1980	1990	2000	2010	2020
Buena Vista	20,693	19,800	19,100	18,700	18,600	18,400
Cherokee	17,269	16,300	15,600	15,200	15,000	14,800
Clay	18,464	18,300	18,300	18,600	19,000	19,300
Dickinson	12,565	12,500	12,600	12,800	13,000	13,200
Ida	9,190	8,400	7,800	7,300	6,900	6,500
Lyon	13,340	12,500	11,900	11,500	11,300	11,000
O'Brien	17,522	16,400	15,600	15,100	14,800	14,400
Osceola	8,555	7,900	7,400	7,100	6,800	6,500
Plymouth	24,312	23,600	23,300	23,300	23,400	23,500
Sac	15,573	14,500	13,600	13,000	12,500	12,000
Sioux	27,996	27,000	26,400	26,200	26,100	26,000
Woodbury	103,052	99,600	97,700	97,000	96,500	95,800
Region	288,531	276,800	269,300	265,800	263,900	261,400
Iowa[a]	2,825,041	2,913,400	2,992,700	3,053,500	3,123,200	3,187,400
Nation[a]	203,184,772	223,532,000	246,039,000	263,830,000	281,368,000	297,146,000

[a]OBERS Projections, Series E'(U.S. Water Resources Council, 1974).

upset the estimates of any one county, but the regional impact would be low.

The populations shown in Table 67 were calculated in the following manner. The state and national populations were taken directly from the OBERS projections. The regional population in each decade was obtained by multiplying the projected state population by the regional percentages shown in Table 65. The county populations in each decade were determined by multiplying the projected regional population by the county percentages also shown in Table 65.

The projections for the urban, rural farm and rural nonfarm populations in each county are contained in Tables A-53 through A-64 in Appendix A. The total urban, rural farm, rural nonfarm and total rural populations were determined by multiplying the projected county population in each decade by the component percentages shown in Tables A-41 through A-52 in Appendix A. The future population of each town was obtained by multiplying the projected total urban population for each county in each decade by the appropriate percentages listed in Tables A-41 through A-52 in Appendix A. The 1980, 2000, and 2020 components of each county's population are summarized in Table 68.

Implications for the study

In addition to the tables presented above, five other tables have been prepared which indicate the impacts of the population projections. Table 69 displays the historic and estimated regional populations for the various components at several points in time between 1900 and 2020. Table 70 lists these various populations as percentages of the total

Table 68. Future total urban, rural farm and rural nonfarm populations in Northwest Iowa based on the OBERS projection for the years 1980, 2000 and 2020

County	Total urban			Rural farm			Rural nonfarm		
	1980	2000	2020	1980	2000	2020	1980	2000	2020
Buena Vista	13,720	13,390	13,600	4,770	3,930	3,300	1,310	1,380	1,500
Cherokee	10,400	9,850	9,720	4,440	3,760	3,300	1,460	1,590	1,780
Clay	12,830	13,330	14,150	4,080	3,660	3,300	1,390	1,610	1,850
Dickinson	8,310	8,730	9,240	2,840	2,470	2,100	1,350	1,600	1,860
Ida	4,780	4,160	3,710	3,300	2,780	2,400	320	360	390
Lyon	6,400	6,460	6,710	5,400	4,260	3,410	700	780	880
O'Brien	10,660	10,120	9,940	4,850	3,960	3,300	890	1,020	1,160
Osceola	4,010	3,680	3,450	3,270	2,700	2,250	620	720	800
Plymouth	13,900	14,800	16,000	7,760	6,360	5,100	1,940	2,140	2,400
Sac	8,640	7,930	7,520	4,830	3,970	3,300	1,030	1,100	1,180
Sioux	17,500	18,570	20,020	8,310	6,290	4,500	1,190	1,340	1,480
Woodbury	90,460	88,190	87,180	6,320	5,560	5,120	2,820	3,150	3,500
Region	201,610	199,210	201,240	60,170	49,700	41,380	15,020	16,790	18,780

Table 69. Urban and rural population in Northwest Iowa, 1900-2020

Location	1900	1940	1970	2000	2020
Sioux City	33,111	82,364	85,925	80,890	79,890
Other urban	63,897	102,766	121,187	118,320	121,350
Total urban	97,008	185,130	207,112	199,210	201,240
Rural farm	126,930	110,235	67,118	49,800	41,380
Rural nonfarm	0	1,976	14,301	16,790	18,780
Total rural	126,930	112,211	81,419	66,590	60,160
Total region	223,938	297,341	288,531	265,800	261,400

Table 70. Urban and rural population percentages in Northwest Iowa, 1900-2020

Location	1900	1940	1970	2000	2020
Sioux City[a]	14.79	27.70	29.78	30.44	30.56
Other urban[a]	28.53	34.56	42.00	44.51	46.42
Total urban[a]	43.32	62.26	71.78	74.95	76.98
Rural farm[a]	56.68	37.08	23.26	18.73	15.83
Rural nonfarm[a]	0.00	0.66	4.96	6.32	7.19
Total rural[a]	56.68	37.74	28.22	25.05	23.02
Total region[b]	10.03	11.71	10.21	8.70	8.20

[a]As percent of total region.

[b]As percent of Iowa.

regional and state population. Table 71 shows the variation in number of cities of various sizes from 1900 to 2020. Table 72 presents this same information as percentages of the total number of cities at each point in time. Finally, Table 73 lists the change in regional population of the various sizes between 1970 and 2020.

Table 71. Number of incorporated cities in Northwest Iowa of various sizes, 1900-2020

Size of town	1900	1940	1970	2000	2020
0- 250	14	23	33	36	38
251- 500	21	29	24	21	21
501-1,000	27	27	24	24	22
1,001-2,500	16	24	20	20	19
2,501-5,000	3	4	8	8	9
Over 5,000	1	5	5	5	5
Total	82	112	114[a]	114	114

[a]Gained communities of Bronson and Old Town.

Table 72. Percentages for incorporated cities of various sizes in Northwest Iowa, 1900-2020

Size of town	1900	1940	1970	2000	2020
0- 250	17.1	20.5	28.9	31.6	33.3
251- 500	25.6	25.9	21.1	18.4	18.4
501-1,000	32.9	24.1	21.1	21.1	19.3
1,001-2,500	19.5	21.4	17.5	17.5	16.7
2,501-5,000	3.7	3.6	7.0	7.0	7.9
Over 5,000	1.2	4.5	4.4	4.4	4.4
Total	100.0	100.0	100.0	100.0	100.0

Table 73. Change in population and number of cities in Northwest Iowa of various sizes, 1970 and 2020

	1970		2020		
Size of city	Number of cities	Total population	Number of cities	Total Population	Net change
0- 250	33	5,132	38	4,350	- 782
251- 500	24	9,161	21	7,910	- 1,251
501-1,000	24	18,090	22	15,650	- 2,440
1,001-2,500	20	28,495	19	25,420	- 3,075
2,501-5,000	8	26,009	9	30,570	4,561
Over 5,000	5	120,225	5	117,340	- 2,885
Total	114	207,112	114	201,240	- 5,872

The most noticable impact is the general decline in population from 1970 to 2020 with the region decreasing over 10%, from 288,500 to 261,400. Ten of the 12 counties decreased in population, ranging from 3.4% in Plymouth County to 41.4% in Ida County. Clay and Dickinson Counties increased about 4.5%, a total of less than 1,500 people. By decreasing the rural farm population density to about 6 people per square mile, this component of the regional population declined from 67,100 to 41,400 between 1970 and 2020, a total of 25,700 people. However, the rural nonfarm population in the region increased from 14,300 to 18,800 people during this same time period, an increase of 4,500. Thus, the net decline in the rural area was 21,200. Instead of the urban areas increasing by this amount, they also decreased from about 207,000 to 201,000, a decline of 6,000 people, so the net out-migration from the region is forecast to continue.

In terms of regional percentages, the urban population was forecast to increase from 71.8% to 77.0%, the rural nonfarm component to increase from 5.0% to 7.2% and the rural farm population to decrease from 23.2% to 15.8% between 1970 and 2020. These small percentage changes indicate a further shift to a more urban population, but at a much slower pace than in the previous 50 years.

The same thing is true concerning the shifts in number and percentage of cities of various sizes between 1970 and 2020: the shifts are small compared to the previous 50-yr period. Because of the net out-migration from the region, 5 of the 6 size of community categories decrease in total regional population. Of the 114 communites forecast to be in existence in 2020, 41 are projected to increase and 73 are projected to decrease in population from their 1970 levels. Even so more and more of the total population will live in incorporated communities. Sioux City alone is projected to contain 30.6% of the regional population in 2020, 51.9% in the 10 largest towns and 77.0% in the 114 incorporated communities. Yet, 59 of these communities will have populations less than 500 people, and 100 will have populations less than 2,500 people. This assumes that there will be no new incorporated places or amalgamations of one by another.

Summary

What are the implications of these projections for this study of Northwest Iowa? Most far reaching and important is that there will be fewer people. Fewer to be employed on farms or in the cities, to pay for local and county services, to maintain and improve the school systems, to maintain and improve the transportation systems, to maintain and improve the water supply and pollution control systems, to maintain and improve the recreational facilities, to pay for all the other services we have come to expect as essential services of government. Two counties will have fewer than 10,000 inhabitants and 9 of the 12 counties will contain less than 20,000 people. And while there will be fewer people, they will still be as widely scattered as they are at present.

The 73 cities projected to decrease in size may become less viable and 22 of the 41 cities projected to increase will have 2020 populations of less than 1,000 people. While numerous communities in the region declined in population during the 1960-1970 decade, 29 communities increased more than 10% during this same decade. However, even by decreasing the rural farm population to a minimum and increasing the rural nonfarm population by only a few thousand, the urban population can increase only slightly if the OBERS projections are to be realized in 2020. Thus, the OBERS projections require that the rural population be minimized and urban growth must be stifled or at least held to a slow rate of increase. This could be brought about for the reasons discussed below.

With fewer persons constituting the labor force, industry will have less incentive to locate in the region. As a corollary impact, since new industries and businesses are not locating in the region, the excess labor that does exist is migrating elsewhere to find work, thus continuing the downward trend in population. Here then is another important implication for this study. Unless and until the state and federal governments take a more active role in rural development, the present trend of out-migration will continue. Their success to this point in time has not been overwhelming. The projections used in this study assume at most a modest degree of success. Presently, federal regulations classify communities under 10,000 population as rural for certain types of support. This would include 112 of the present 114 communities in the region since only Spencer and Sioux City have populations greater than 10,000. Thus the opportunity exists for future improvement.

Assuming that the trend to bigger farms continues, the rural farm population in 2020 will be one-third of what it was in 1900 and just 60% of what it was in 1970, some 25,700 farmers less. With 25,000 fewer customers in the future, many firms will go out of business and those remaining will most likely be concentrated in the larger cities. If new jobs are not created locally for these people, both the 25,000 farmers and the employees of those firms which go out of business, they will have no other choice but to leave the region and seek employment elsewhere. Some of those who are nearing retirement may decide to remain in the region. However, a percentage of these retirees may not have sufficient funds to see them through their retirement years and they will impose further stress on county and state social service programs. Some with adequate funds may move to warmer winter climates, supporting the decline in population forecast by OBERS.

While these lower population numbers do have negative aspects, they also have positive connotations in terms of water resource utilization. Lesser volumes of water will be required in the future for all user groups than would have been the case if population had increased. The total volume of water needed in the future will probably still be greater than it is today due to increased per capita use and expanded usage by some user groups. The same is true for energy. But in terms of water supply, pollution control, recreation and energy, lesser volumes of water will be needed in the future than if the population had increased.

The above comments are true if, and only if, these projections that are based on OBERS are accurate, i.e., county population levels in Northwest Iowa will be lower than they are today. Table 74 lists the estimated populations in Northwest Iowa as of July 1976 which were made by the Bureau of the Census (U.S. Department of Commerce, 1977).

Personal Income

Details concerning the total personal and per capita incomes of the residents of Northwest Iowa were obtained from a publication of the U.S. Department of Commerce, Bureau of Economic Analysis (1977). Per capita income is computed by dividing the residence-adjusted total personal income by population estimates. The population data are provided by the Bureau of the Census for July 1 of each year. Total personal income is determined based on the following definition used by the Department of Commerce.

> Personal income is the current income of residents of an area from all sources. It is measured after deduction of personal contributions to Social Security, government retirement, and other social insurance programs, but before deduction of income and other personal taxes. It includes income received from business; Federal, State, and local governments; households; institutions; and foreign governments. It consists of wages and salaries (covering all employee earnings, including executive salaries, bonuses, commissions, payments in kind, incentive

Table 74. County populations and components of change, 1970-1976[a]

County	April 1970 census	Births[b]	Deaths[b]	Net migration[c]	July 1976 estimate
Buena Vista	20,693	1,700	1,400	- 500	20,500
Cherokee	17,269	1,500	1,100	- 1,400	16,200
Clay	18,464	1,600	1,200	100	18,900
Dickinson	12,565	1,100	1,000	1,100	13,800
Ida	9,263	700	800	- 400	8,900
Lyon	13,340	1,200	700	- 700	13,200
O'Brien	17,522	1,400	1,400	- 300	17,300
Osceola	8,555	700	600	- 600	8,200
Plymouth	24,322	2,200	1,500	- 900	24,200
Sac	15,573	1,200	1,200	- 700	14,900
Sioux	27,996	2,900	1,600	- 100	29,200
Woodbury	103,052	10,800	6,800	- 3,700	103,400
Region	288,634	27,000	19,300	- 8,100	288,700
State	2,825,368[d]	263,000	181,000	- 38,000	2,870,000

[a]Bureau of the Census (U.S. Department of Commerce, 1977).

[b]Births and deaths are based on reported vital statistics from April 1, 1970 to December 31, 1975 with extrapolations to June 30, 1976.

[c]Net migration is the difference between net change and natural increase.

[d]Includes all corrections to the 1970 census made subsequent to the release of the official counts. The official 1970 census count for Iowa was 2,825,041.

payments, and tips); various types of supplementary earnings termed "other labor income" (the largest item being employer contributions to private pension, health, and welfare funds); the net incomes of owners of unincorporated businesses (farm and nonfarm, with the latter including the incomes of independent professionals); net rental income; royalties; dividends, interest; and government and business transfer payments (consisting, in general, of disbursements to persons for which no services are rendered currently, such as unemployment benefits, Social Security payments, Medicare benefits, retirement pay of governmental programs, and welfare and relief payments).

Total personal income by major sources for each county in Northwest Iowa for the years 1970 through 1975 is shown in Tables B-1 through B-12 in Appendix B. A summary of these data for the years 1970, 1973 and 1975 is given in Table 75. These three years were selected because they illustrate the trends which exist in the region. While total incomes varied widely between the counties, each county showed consistent growth in the nonfarm and government categories. Both increased about 50% during the 5-yr period, nonfarm income increasing from $506.4 to $792.1 million and government increasing from $91.1 to $139.0 million in the region. Conversely, net income from farms fluctuated greatly during this period, increasing from $183.2 million in 1970 to $459.0 million in 1973 and then declining to $337.1 million in 1975 in the region.

The percent of total income derived from various sources in each of the twelve counties are shown in Table 76. Farming is the largest single source of income in the region, accounting for about one-fourth of the total. If Woodbury County is eliminated, the farming share increases to over one-third. The 1975 percentage for each county is shown in Fig. 57. Farming was also the only category which increased its percentages during the period 1970 to 1975. Declines were registered in the other four categories: manufacturing, wholesale and retail trade, services and government. The importance of agriculture to the region is illustrated in another way. The above figures are based on net farm income and not total farm income. The difference between total and net becomes income to the other four categories as the farmers purchase the various inputs and services for their farming

Table 75. Personal income in Northwest Iowa by major sources in 1970, 1973 and 1975, millions of dollars

County	1970				1973				1975			
	Farm	Non-farm	Govt.	Total	Farm	Non-farm	Govt.	Total	Farm	Non-farm	Govt.	Total
Buena Vista	15.9	36.2	6.2	58.3	48.6	43.5	7.4	99.5	38.3	45.1	9.1	92.5
Cherokee	10.4	30.8	9.3	50.5	36.0	34.6	11.8	82.4	28.0	40.4	14.2	82.6
Clay	13.5	33.6	7.0	54.1	37.8	41.9	9.0	88.7	29.1	58.1	11.1	98.3
Dickinson	10.3	17.5	4.0	31.8	23.9	26.9	5.1	55.9	17.6	33.5	6.3	57.4
Ida	10.8	12.2	2.6	25.6	25.1	13.4	3.3	41.8	21.5	16.9	4.0	42.4
Lyon	13.3	11.4	3.2	27.9	31.7	14.5	4.0	50.2	20.7	17.6	4.9	43.2
O'Brien	16.5	21.3	4.9	42.7	40.0	28.2	6.4	74.6	33.0	34.0	7.7	74.7
Osceola	13.4	10.4	2.3	26.1	26.1	12.1	3.1	41.3	18.5	14.4	3.9	36.8
Plymouth	17.3	27.2	6.4	50.9	47.8	34.2	8.2	90.2	26.4	42.7	10.0	79.1
Sac	17.0	19.4	4.0	40.4	41.0	24.8	5.0	70.8	32.9	31.9	6.0	70.8
Sioux	29.0	34.6	6.3	69.9	52.9	47.3	8.1	108.3	34.1	58 6	9.8	102.5
Woodbury	15.8	251.8	34.9	302.5	48.1	334.1	43.0	425.2	37.0	398.9	52.0	487.9
Each categories % of total regional personal income	23.5	64.8	11.7	100.0	37.4	53.3	9.3	100.0	26.6	62.4	11.0	100.0

Table 76. Percent of total personal income in each county in Northwest Iowa from selected sources in 1970 and 1975

County	Farm		Manufacturing		Wholesale & retail trade		Services		State and local govt.	
	1970	1975	1970	1975	1970	1975	1970	1975	1970	1975
Buena Vista	27.3	41.4	19.7	9.8	18.0	16.5	11.7	10.3	8.4	7.8
Cherokee	20.6	33.9	21.0	16.5	15.8	12.3	10.9	8.7	16.6	15.5
Clay	25.0	29.6	13.9	16.2	20.3	19.6	8.3	8.3	10.5	9.2
Dickinson	32.4	30.7	16.4	18.5	18.9	19.7	9.4	9.6	10.1	9.2
Ida	42.2	50.7	6.6	7.5	15.6	12.0	9.0	7.3	7.4	6.8
Lyon	47.7	47.9	2.3	6.9	10.6	14.4	5.6	10.0	6.2	9.5
O'Brien	38.6	44.2	3.7	6.6	21.3	17.9	11.7	8.6	9.4	8.3
Osceola	51.3	50.2	8.8	5.5	13.8	11.2	5.4	3.9	6.5	5.5
Plymouth	34.0	33.4	9.0	8.2	19.2	19.6	11.2	11.8	9.6	9.9
Sac	42.1	46.5	8.7	11.4	17.1	13.8	7.9	7.9	8.2	6.8
Sioux	41.5	33.2	12.9	16.1	15.2	18.3	10.9	11.1	7.3	7.8
Woodbury	5.2	7.6	22.4	20.0	22.6	20.0	17.0	15.9	7.9	7.5
Region	23.5	26.6	16.2	15.1	19.5	18.0	12.7	11.8	8.9	8.5

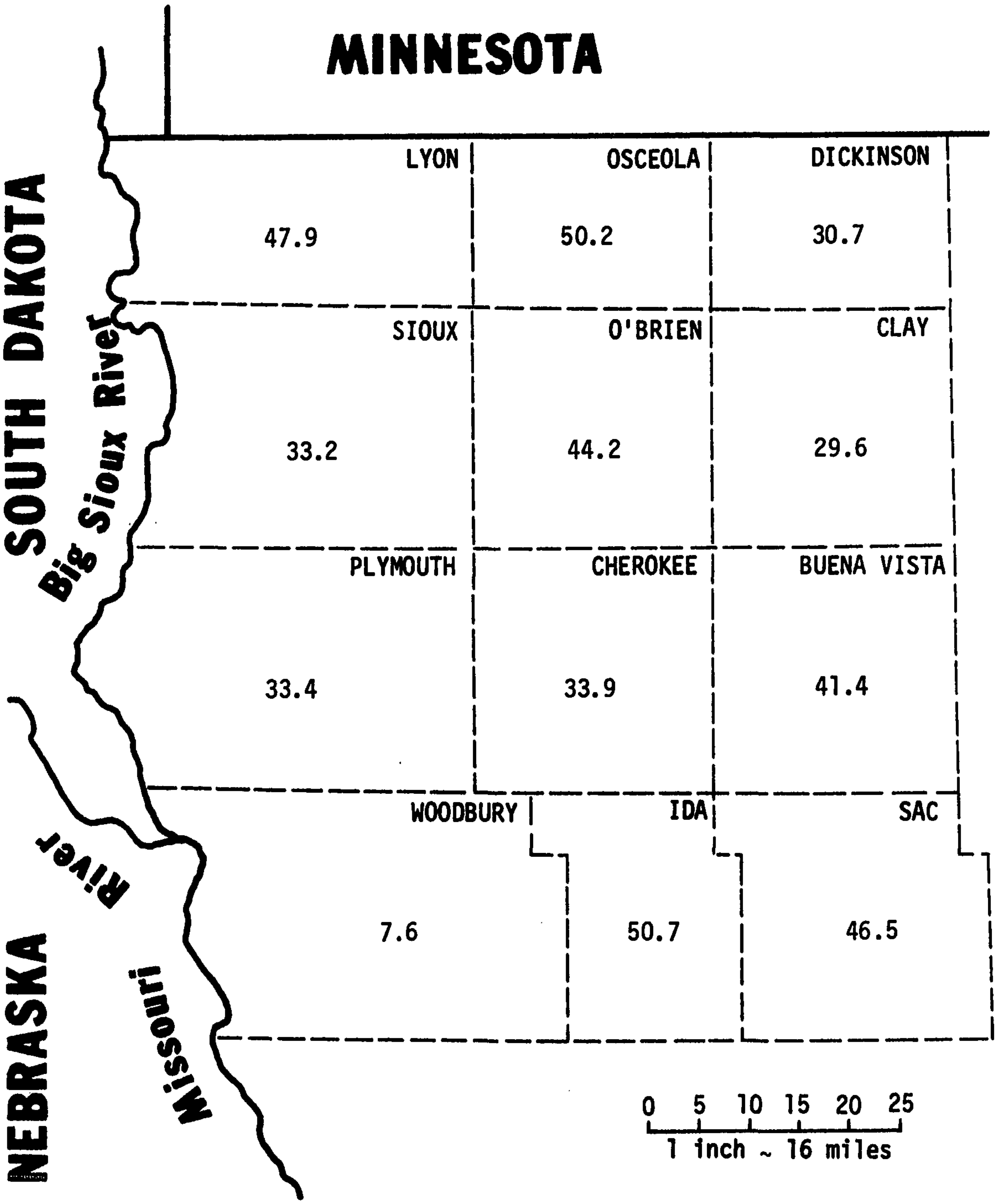


Fig. 57. Net farm income as a percent of total 1975 county personal income in Northwest Iowa

operations. This is illustrated in the following excerpt from the Department of Commerce publication (1977):

> Farm proprietors' income was based mainly on the 1969 Census of Agriculture. County distributions of 35 components of gross income and about 45 items of farm production expenses were used to allocate State totals of the corresponding series. These State totals were provided by the U.S. Department of Agriculture. Subtraction of total production expenses from the total gross farm income, county by county, yielded total net farm income. Estimates of corporate farm income were subtracted from total net farm income to obtain farm proprietors' income. Estimates for postcensal years were prepared by modifying the county distributions of the various income and expense items by modifying the county distributions of the various income and expense items by information obtained from the individual States wherever possible. Other distributions were held constant or moved forward by a related series for which data were available.
>
> To those accustomed to gauging the importance of farming by the size of cash receipts, farm earnings (labor and proprietors' income) in a given county may seem low. However, two points must be considered. First, farm earnings do not measure receipts from farming, but only the net personal income generated in the industry; that is, farm earnings are the sum of farm wages, supplementary farm labor income, and net profits of farm operation. A large part of total farm receipts is used to purchase supplies and services — such as fertilizer, machinery, and fuel — produced by other industries.
>
> Second, in areas where corporate farms predominate, labor and proprietors' earnings will be comparatively small, since the only part of corporate farm income included in labor earnings is wages and salaries and other labor income. No corporate farm profits are included in labor earnings. Indeed, only a small part of corporate profits — dividends paid to stockholders — is included in personal income, and dividends are not identified by industry or county of origin.

Per capita annual incomes at the county level were also taken from the Department of Commerce publication (1977). Annual per capita incomes at the state level were obtained from a 1978 report of the Resource and Support Division of the Iowa Development Commission

(1978b). These per capita incomes are shown in Table 77 for the years 1970, 1972, 1973 and 1975. The county incomes generally increase from 50 to 70% during the 5-yr period. The average regional income is roughly the same as the average state income, varying from about 5% less in 1970 to about 2% more in 1975. The variation in incomes between counties was about $850 in 1970 (28%) and $1,870 in 1975 (38%). These variations in income are explained in part by the following excerpt from the Department of Commerce publication (1977).

Table 77. Average annual county and state per capita income in Northwest Iowa in 1970, 1972, 1973 and 1975, dollars[a]

Area	1970	1972	1973	1975
Buena Vista	3,827	4,427	6,224	6,433
Cherokee	3,623	4,305	5,883	6,451
Clay	3,496	4,025	5,210	5,460
Dickinson	3,772	4,329	5,967	6,417
Ida	3,896	4,517	5,979	6,760
Lyon	3,077	3,793	5,074	5,120
O'Brien	3,490	4,039	5,750	6,206
Osceola	3,925	4,380	6,152	6,032
Plymouth	3,169	3,922	5,300	5,278
Sac	3,617	4,268	6,119	6,652
Sioux	3,249	3,669	4,857	4,890
Woodbury	3,640	4,197	5,026	5,963
Region	3,565	4,156	5,628	5,972
State[b]	3,751	4,297	5,168	5,867

[a]Department of Commerce (1977).

[b]Iowa Development Commission (1978b).

> Per capita income can vary widely from county to county. Those with either extremely high or low per capita incomes are generally the small counties. In many instances, an unusually high (or low) level of per capita income is temporary and results from unusual conditions such as a bumper crop, a major construction project (i.e., a defense facility, a nuclear plant, or a dam), or a catastrophe (i.e., flood, tornado, or drought). In some cases, a high per capita income is illusory (for example, when a construction project brings in a large number of high-paid workers who live near the site and are included in the population count, but who send a substantial portion of their wages to their dependents living at their permanent homes in other counties). Conversely, counties with heavy institutional populations may show unusually low per capita incomes.
>
> In addition, because population is measured as of one date, whereas income is measured as a flow over the calendar year, a significant change in population during the year, particularly after July 1, can cause a distortion in the per capita figure.

Several conclusions can be drawn from the above data. Farm sector income is much more variable than income in the other sectors. As shown in Table 75, the dollar value of nonfarm income rises steadily during the 1970-1975 period while net farm income fluctuates greatly. Figure 58 plots net farm income, expressed as a percentage of total county income, as a function of the 1970 farm population, expressed as a percentage of total county population. The exponent in the regression equation indicates almost a one-to-one relationship between farm income and farm population. This would tend to indicate that the farm sector has not fared any worse than the other employment sectors in Northwest Iowa. Or stated in another way, the nonfarm sectors have not fared any better economically than the farm sector.

Figure 57, taken in conjunction with the 1970 farm populations shown in Table 57, indicate that the health of Northwest Iowa's economy is based on the health of its farm sector. This conclusion

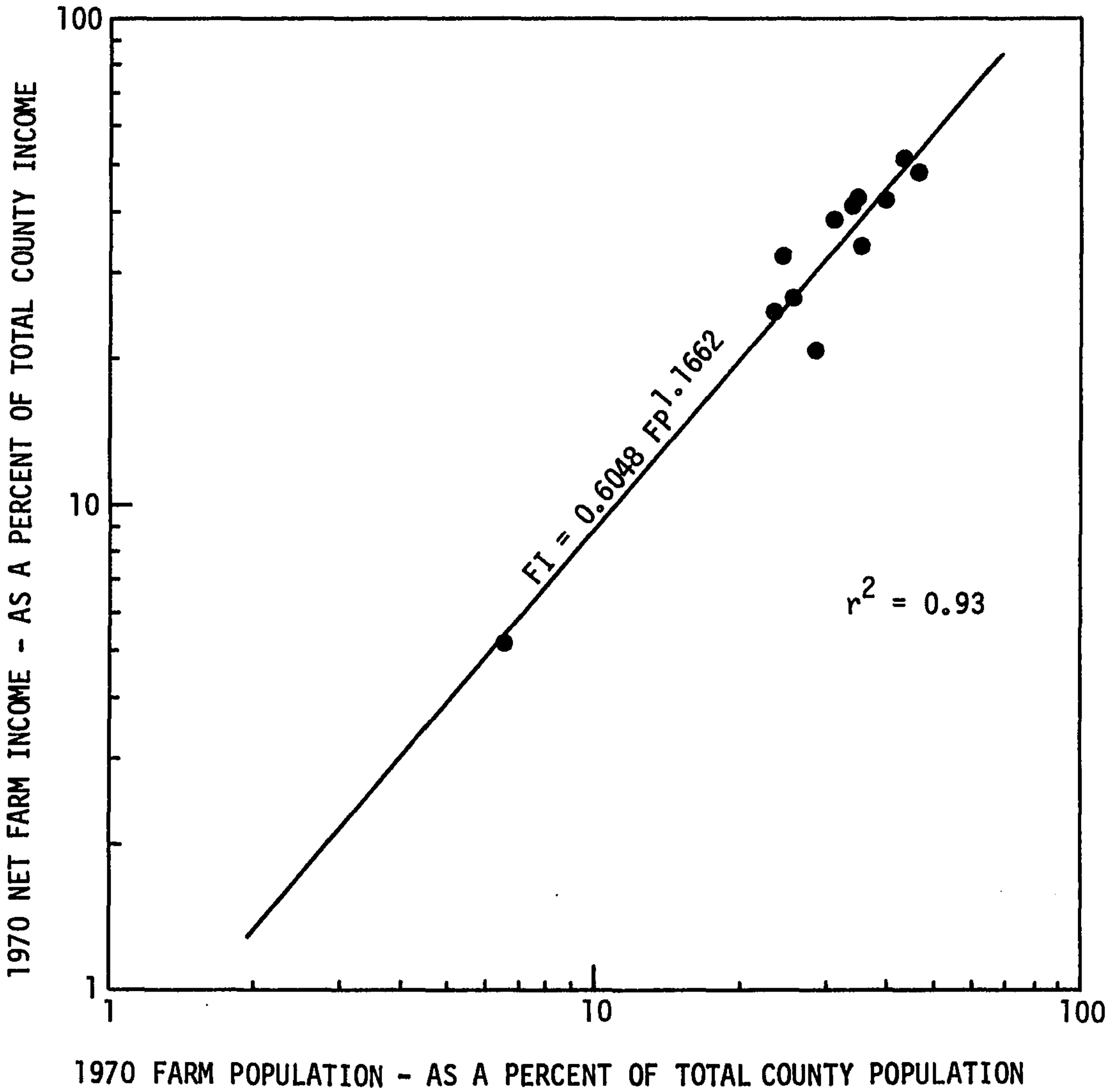


Fig. 58. Variation in net farm income with farm population

is enhanced by the fact that the difference between gross and net farm income provides a good portion of the income to the other sectors. Thus, the farm sector could act to set a ceiling on total county income. To rise above this limitation, the region would need to move vigorously to a more urbanized-industrialized economy. Another way to increase total county income would be to add irrigation to the region to increase total farm income plus its multiplier effect in the other sectors. Irrigation would tend to smooth out somewhat the fluctuations in farm income, making them less volatile. It would also add an increment to the nonfarm sectors since it would create jobs in retail outlets, salesmen, repairmen and possibly in the manufacturing of irrigation equipment.

Land Use in Northwest Iowa

The pattern of land uses in Northwest Iowa is reflected in Tables 78 and 79 which list the number of acres in various uses during 1958 and 1967, respectively. These data were taken from the Iowa Conservation Needs Inventory (Iowa Conservation Needs Committee, 1970) and are shown in more detail in Tables D-1 through D-12 in Appendix D. The use of Iowa's land for agricultural purposes is carried over into Northwest Iowa as 4.2 million of the 4.6 million acres in the region are used for crops and pasture. These two uses account for over 90% of the total area as shown in Table 80. This overwhelming use of the land for crop production is the principal reason why soil erosion in Iowa is such a large problem. And the problem is accelerating. By

Table 78. 1958 land use in Northwest Iowa, acres[a]

County	Cropland	Pasture	Urban and built-up	Water area	Forest	Other	Total
Buena Vista	285,963	41,345	15,237	3,540	10,217	9,778	366,080
Cherokee	276,718	56,989	13,294	300	8,551	10,868	366,720
Clay	299,524	36,555	12,790	4,930	674	10,327	364,800
Dickinson	171,756	34,778	10,126	15,850	792	9,898	243,200
Ida	227,723	31,834	9,046	364	42	6,831	275,840
Lyon	305,578	49,812	11,180	400	0	9,350	376,320
O'Brien	292,571	46,771	13,301	400	2,971	11,986	368,000
Osceola	206,464	30,076	8,536	430	1,012	8,202	254,720
Plymouth	441,969	66,740	16,920	1,000	12,000	13,691	552,320
Sac	296,426	38,676	17,095	1,020	4,006	12,697	369,920
Sioux	398,792	61,290	17,910	810	0	11,438	490,240
Woodbury	438,162	63,835	27,212	1,470	8,921	17,840	557,440
Region	3,641,646	558,701	172,647	30,514	49,186	132,906	4,585,600

[a]Iowa Conservation Needs Committee (1970).

Table 79. 1967 land use in Northwest Iowa, acres[a]

County	Cropland	Pasture	Urban and built-up	Water area	Forest	Other	Total
Buena Vista	307,437	24,771	15,998	3,540	5,015	9,319	366,080
Cherokee	273,717	57,222	13,548	310	11,000	10,923	366,720
Clay	300,105	23,579	13,795	4,930	8,000	14,391	364,800
Dickinson	178,592	25,118	10,128	15,850	4,047	9,465	243,200
Ida	228,298	29,690	9,261	364	1,205	7,022	275,840
Lyon	304,955	44,721	11,491	425	4,000	10,728	376,320
O'Brien	311,230	26,812	14,093	400	4,000	11,465	368,000
Osceola	217,506	17,250	8,630	430	2,000	8,904	254,720
Plymouth	431,448	75,269	16,997	1,050	12,000	15,556	552,320
Sac	306,360	25,396	17,590	1,020	6,000	13,554	369,920
Sioux	417,882	33,615	17,902	810	3,000	17,031	490,240
Woodbury	431,474	59,842	27,217	1,470	25,000	12,437	557,440
Region	3,709,004	443,285	176,650	30,599	85,267	140,795	4,585,600

[a]Iowa Conservation Needs Committee (1970).

Table 80. 1958 and 1967 land use in Northwest Iowa, percent of county and regional total

County	Cropland		Pasture		Urban and built-up		Water area		Forest		Other		Total	
	1958	1967	1958	1967	1958	1967	1958	1967	1958	1967	1958	1967	1958	1967
Buena Vista	78.1	84.0	11.3	6.7	4.1	4.4	1.0	1.0	2.8	1.4	2.7	2.5	100	100
Cherokee	75.5	74.6	15.5	15.6	3.6	3.7	0.1	0.1	2.3	3.0	3.0	3.0	100	100
Clay	82.1	82.3	10.0	6.5	3.5	3.8	1.4	1.3	0.2	2.2	2.8	3.9	100	100
Dickinson	70.6	73.4	14.3	10.3	4.2	4.2	6.5	6.5	0.3	1.7	4.1	3.9	100	100
Ida	82.6	82.8	11.5	10.8	3.3	3.4	0.1	0.1	0.0	0.4	2.5	2.5	100	100
Lyon	81.2	81.0	13.2	11.9	3.0	3.1	0.1	0.1	0.0	1.1	2.5	2.8	100	100
O'Brien	79.5	84.6	12.7	7.3	3.6	3.8	0.1	0.1	0.8	1.1	3.3	3.1	100	100
Osceola	81.0	85.4	11.8	6.8	3.4	3.4	0.2	0.1	0.4	0.8	3.2	3.5	100	100
Plymouth	80.0	78.1	12.0	13.6	3.1	3.1	0.2	0.2	2.2	2.2	2.5	2.8	100	100
Sac	80.1	82.8	10.5	6.9	4.6	4.7	0.3	0.3	1.1	1.6	3.4	3.7	100	100
Sioux	81.3	85.2	12.5	6.8	3.7	3.7	0.2	0.2	0.0	0.6	2.3	3.5	100	100
Woodbury	78.6	77.4	11.4	10.7	4.9	4.9	0.3	0.3	1.6	4.5	3.2	2.2	100	100
Region	79.4	80.9	12.2	9.7	3.7	3.8	0.7	0.7	1.1	1.8	2.9	3.1	100	100

comparing the 1958 and 1967 data about 70,000 additional acres were placed in crop production while over 115,000 acres were converted from pasture to some other use, including urban growth.

About 4% of the land in Northwest Iowa is used for urban and built-up purposes, about 2% for forest and 3% for other uses. These other uses include farmsteads, farm roads, feedlots, ditch banks, fence rows, hedge rows, rural nonfarm residences and investment tracts. Urban and built-up areas include cities, villages, built-up areas of more than 10 acres, industrial sites, railroad yards, cemetaries, airports, golf courses, etc.

Table 81 indicates that about 1 to 2 acres are used at present for each urban inhabitant. If population increases in the future, one would expect that additional acreage would be needed for urban purposes. However, a study by Gibson (1976) indicated that most Iowa communities have sufficient land within their present corporate limits to absorb population until the year 1990 or 2000. In this study we will assume that neither increases nor decreases in urban population will affect the amount of land used for urban purposes until the year 2000. Then one-half acre of land will be needed for each new urban resident. On the other hand, land for new rural nonfarm residents will be needed immediately at the rate of one acre per resident based on the study by Gibson.

Table 82 subdivides the cropland acreage in Northwest Iowa into five categories: row crops, close-grown crops, rotation hay and pasture, hay land, and conservation use. Row and close-grown crops account for over 2.8 million of the 3.7 million acres of land used for

Table 81. Determination of unit urban acreage

County	1967 urban acreage[a]	1970 urban population[b]	Acres per urban person
Buena Vista	15,998	14,103	1.13
Cherokee	13,548	10,931	1.24
Clay	13,795	12,816	1.08
Dickinson	10,128	8,246	1.23
Ida	9,261	5,228	1.77
Lyon	11,491	6,491	1.77
O'Brien	14,093	11,215	1.26
Osceola	8,630	4,297	2.01
Plymouth	16,997	13,800	1.23
Sac	17,590	9,162	1.92
Sioux	17,902	17,283	1.04
Woodbury	27,217	93,540	0.29

[a]Iowa Conservation Needs Committee (1970).

[b]Bureau of the Census (1973).

Table 82. 1967 cropland acreage in Northwest Iowa, acres

County	All row crops	Close-grown crops	Rotation hay and pasture	Hay land	Conservation use only	Total
Buena Vista	219,933	17,583	31,611	4,864	37,626	311,617
Cherokee	188,364	21,459	28,641	1,030	34,223	273,717
Clay	233,543	2,050	26,861	0	43,221	305,675
Dickinson	131,533	10,236	25,301	579	24,530	192,179
Ida	142,636	18,658	29,892	1,003	36,109	228,298
Lyon	202,418	30,240	31,985	1,595	38,717	304,955
O'Brien	234,477	19,439	29,679	684	27,351	311,630
Osceola	161,454	11,500	17,648	0	26,904	217,506
Plymouth	266,353	42,541	53,025	10,484	59,045	431,448
Sac	209,621	37,088	19,615	0	41,056	307,380
Sioux	303,352	51,943	18,761	0	43,826	417,882
Woodbury	250,796	29,000	61,336	855	90,759	432,746
Region	2,544,480	291,737	374,355	21,094	503,367	3,735,033

crop production in 1967. These two uses account for about 76% of all cropland as shown in Table 83. Note that with only a few exceptions, land use in the various categories in each county is very similar, varying by only a few percentage points.

Table 83. 1967 cropland acreage in Northwest Iowa, percent of total

County	All row crops	Close-grown crops	Rotation hay and pasture	Hay land	Conservation use only	Total
Buena Vista	70.6	5.6	10.1	1.6	12.1	100.0
Cherokee	68.8	7.8	10.5	0.4	12.5	100.0
Clay	76.4	0.7	8.8	0.0	14.1	100.0
Dickinson	68.4	5.3	13.2	0.3	12.8	100.0
Ida	62.5	8.2	13.1	0.4	15.8	100.0
Lyon	66.4	9.9	10.5	0.5	12.7	100.0
O'Brien	75.3	6.2	9.5	0.2	8.8	100.0
Osceola	74.2	5.3	8.1	0.0	12.4	100.0
Plymouth	61.7	9.9	12.3	2.4	13.7	100.0
Sac	68.2	12.1	6.4	0.0	13.3	100.0
Sioux	72.6	12.4	4.5	0.0	10.5	100.0
Woodbury	57.9	6.7	14.2	0.2	21.0	100.0
Region	68.1	7.8	10.0	0.6	13.5	100.0

All land is divided into eight capability classes, depending on the magnitude of the restrictions involved in using the land for various plants. Table 84 contains a description of each capability class and the range of slopes associated with each class. As the class number increases, its suitability for crop production decreases and its susceptibility to erosion increases. Tables D-1 through D-12 in Appendix D list the number of pasture, forest and other cropland acres by capability classes in each county in Northwest Iowa in 1967. These data are summarized in Tables 85 and 86 and indicate that almost 400,000

Table 84. Description of land capability classes and range of slopes associated with each

Class	Slopes, %	Description
I	0-2	Soils with few limitations that restrict their use
II	2-5	Soils with moderate limitations that reduce the choice of plants or that require moderate conservation
III	5-14	Soils with severe limitations that reduce the choice of plants, require special conservation practices, or both
IV	14-18	Soils with very severe limitations that reduce the choice of plants, require very careful management, or both
V	0-2	Soils which are subject to little or no erosion, but have other limitations, impractical to remove, that limit their use largely to pasture, range, woodland or wildlife habitat
VI	18-25	Soils with severe limitations that make them generally unsuited to cultivation and limit their use largely to pasture or range, woodland or wildlife habitat
VII	25+	Soils with very severe limitations that make them unsuited to cultivation and that restrict their use largely to pasture or range, woodland or wildlife habitat
VIII	40+	Soils and landforms with limitations that preclude their use for commercial plant production and restrict their use to recreation, wildlife habitat, water supply or to aesthetic purposes

acres of Class I and II land were being used for pasture and hay in 1967.

Over 100,000 acres of Class IV through VII land were used to grow row and close-grown crops in 1967. This included 28,000 acres in Woodbury County, with much rolling loess-covered topography. This implies much trouble with regard to erosion. All of this land could be used better for permanent pasture, for conservation purposes or be terraced if used for crops. However, if the only land a farmer has

Table 85. 1967 cropland acreage by groups of land capability classes in Northwest Iowa, acres[a]

County	All row and close-grown crops			Hay and pasture			Conservation use only		
	Class I & II	Class III	Class IV-VII	Class I & II	Class III	Class IV-VII	Class I & II	Class III	Class IV-VII
Buena Vista	210,500	25,200	1,800	30,000	4,900	1,600	29,100	7,400	1,100
Cherokee	149,700	52,800	7,600	17,700	11,000	900	15,000	16,500	2,700
Clay	214,100	20,900	600	24,200	2,300	400	38,600	4,200	400
Dickinson	108,200	30,300	3,300	15,500	9,300	1,200	16,200	7,300	1,000
Ida	55,800	85,900	19,700	10,600	17,700	2,600	9,200	20,700	6,200
Lyon	182,200	44,600	5,400	24,300	7,500	1,800	27,400	9,300	2,100
O'Brien	241,400	8,100	4,400	27,100	2,900	400	25,800	1,200	400
Osceola	152,100	15,400	5,400	12,500	4,200	1,000	22,000	3,600	1,300
Plymouth	132,600	160,400	16,000	21,400	34,300	7,900	18,400	33,800	6,800
Sac	194,000	47,200	5,400	12,100	5,900	1,700	29,800	10,700	500
Sioux	251,200	97,300	6,800	12,600	6,000	200	24,100	19,100	600
Woodbury	101,100	150,700	28,000	9,800	40,600	11,800	17,200	59,600	14,000
Region	1,992,900	738,800	104,400	217,800	146,600	31,500	272,800	193,400	37,100

[a]Iowa Conservation Needs Committee (1970).

Table 86. 1967 pasture, forest and other acreage by groups of land capability classes in Northwest Iowa, acres[a]

County	Pasture			Forest			Other		
	Class I & II	Class III & IV	Class V-VII	Class I & II	Class III & IV	Class V-VII	Class I & II	Class III & IV	Class V-VII
Buena Vista	5,650	5,215	13,906	456	1,064	3,495	8,104	1,215	0
Cherokee	15,444	12,870	28,908	1,047	2,881	7,072	8,244	2,267	412
Clay	14,557	4,511	4,511	4,940	1,530	1,530	10,360	3,840	191
Dickinson	8,650	10,147	6,321	1,395	1,635	1,017	5,408	4,057	0
Ida	11,234	10,833	7,623	402	803	0	3,009	3,611	402
Lyon	25,043	9,108	10,570	2,959	830	211	8,047	2,475	206
O'Brien	10,439	5,524	10,849	1,451	0	2,549	11,055	205	205
Osceola	7,535	2,776	6,939	1,750	250	0	7,965	741	198
Plymouth	22,950	29,952	22,367	462	6,461	5,077	8,762	5,917	877
Sac	12,698	6,248	6,450	1,154	231	4,615	9,818	2,929	807
Sioux	18,567	7,817	7,231	2,031	863	106	2,238	3,619	6,174
Woodbury	16,670	38,897	4,275	5,005	19,995	0	6,396	5,329	712
Region	169,437	143,898	129,950	29,052	36,543	25,672	94,406	36,205	10,184

[a]Iowa Conservation Needs Committee (1970).

is Class IV or worse, he stills knows he must make a living. If it must be used for row crops, it should be regraded into level or nearly level terraces. This will still place hardships on the farmer in terms of terrace construction costs and reduced net income. The trade-offs here are reduced erosion with reduced production and large cash outlays or high erosion with some production and no cash outlays (the present situation) or reduced erosion with no production and some cash outlay or some solution between the extremes. If the 28,000 acres in Woodbury County were converted from row crops to permanent pasture, erosion would be reduced from 2,833,000 tons per year to only 21,000 tons per year. The loss of production on this acreage would be about 1.4 million bushels of corn.

One method of making up for this lost corn production is to irrigate land which is less susceptible to erosion and increase corn production on it. Table 87 lists the Class I and II acreage in Northwest Iowa used for row crops in 1967. This land is the least susceptible to erosion and would be the land most suitable for irrigation. Class I land totals about 500,000 acres; Class IIe land would add another 900,000 acres; Class IIw land would add an additional 400,000 acres. These are just the acreages for these classes that were planted to row crops in 1967. They do not represent the total acreages of these classes available in Northwest Iowa.

Since soybeans are more tolerant of droughty conditions, except on sandy soils, we will assume that corn is the primary crop to be irrigated. Using the assumption that the ratio of corn acreage to all row crop acreage in 1967 was the same for all land capability classes,

Table 87. Potential 1967 row crop acreage suitable for irrigation by land capability class in Northwest Iowa, acres

County	Class I	Class IIe	Total	Class IIw	Total
Buena Vista	41,577	83,995	125,572	65,684	191,256
Cherokee	27,999	88,515	116,514	20,135	136,649
Clay	77,096	28,501	105,597	91,449	197,046
Dickinson	33,221	36,698	69,919	29,745	99,664
Ida	3,211	38,317	41,528	8,025	49,553
Lyon	43,155	99,845	143,000	15,657	158,657
O'Brien	69,957	116,410	186,367	36,379	222,746
Osceola	52,849	68,558	121,407	21,804	143,211
Plymouth	14,644	74,499	89,143	28,515	117,658
Sac	30,435	88,686	119,121	46,358	165,479
Sioux	47,259	143,052	190,311	23,417	213,728
Woodbury	43,641	35,351	78,992	16,168	95,181
Total	485,044	902,427	1,387,471	403,357	1,790,828

the acres of corn suitable for irrigation were determined and are listed in Table 88. A sample calculation for the corn acreage in Buena Vista County suitable for irrigation is shown in Table 89. Table 88 indicates that there are about 1.1 million acres of irrigable land for corn in Northwest Iowa if no changes in land use are made: about 295,000 acres of Class I land, 575,000 acres of Class IIe land and 245,000 acres of Class IIw land.

Flood Problems

An earlier section detailed man's involvement with flood plains as sites to live, work and play. This close proximity to the water's edge has brought many benefits but the price of these benefits has been high at times in terms of economic loss and human suffering.

Table 88. Potential 1967 row crop acreage suitable for irrigation of corn by land capability class in Northwest Iowa, acres

County	Class I	Class IIe	Total I & IIe	Class IIw	Total I & II
Buena Vista	25,400	51,300	76,700	40,100	116,800
Cherokee	17,500	55,400	72,900	12,600	85,500
Clay	40,200	14,900	55,100	47,700	102,800
Dickinson	19,300	21,400	40,700	17,300	58,000
Ida	2,200	26,100	28,300	5,500	33,800
Lyon	29,400	67,900	97,300	10,700	108,000
O'Brien	39,600	65,900	105,500	20,600	126,100
Osceola	29,800	38,700	68,500	12,300	80,800
Plymouth	11,400	58,000	69,400	22,200	91,600
Sac	19,200	56,000	75,200	29,300	104,500
Sioux	31,300	94,800	126,100	15,500	141,600
Woodbury	30,900	25,100	56,000	11,500	67,500
Region	296,200	575,500	871,700	245,300	1,117,000

Table 89. Sample calculations for potential 1967 row crop acreage suitable for irrigation of corn in Buena Vista County, acres

Corn acreage = 134,220 (from Table D-1)

All row crops = 219,933 (from Table 82)

Assume that the ratio of corn acreage to all row crop acreage was the same for all land capability classes.

Class I = 41,577 (from Table D-1) x 134,220/219,933 = 25,373
use 25,400

Class IIe = 83,995 (from Table D-1) x 134,220/219,933 = 51,260
use 51,300

Class IIw = 65,684 (from Table D-1) x 134,220/219,933 = 40,085
use 40,100

Summary:

Class	I	IIe	Subtotal	IIw	Total
Acreage	25,400	51,300	76,700	40,100	116,800

Structural approaches to solving flood problems began in the 1930's with current emphasis now going to nonstructural solutions. This approach is embodied in the National Flood Insurance Act of 1968 (PL 90-448) and its subsequent amendments which require that state and local governments adopt acceptable arrangements for land use regulations in flood-prone areas using the results of a flood insurance study in order for individuals to be eligible for flood insurance.

In order to set priorities for flood insurance studies in Iowa, a flood susceptibility rating was devised by the INRC which was determined as follows (Task Force on Flood Plain Management, 1977).

> The flood hazard rating list for Iowa cities was compiled based upon Flood Hazard Boundary Maps for the respective communities issued by the Federal Insurance Administration as required by the Flood Disaster Protection Act of 1973, and was developed solely for the purpose of establishing priorities for Flood Insurance Studies. The rating assigned to each city is no more than a dimensionless parameter which is an attempt to reflect the severity of a community's existing flood problem and the potential for future problems as a result of flood plain development. It should be cautioned that the listing is not necessarily complete and the rating may be in error for some communities due to the inaccuracies on the Flood Hazard Boundary Maps which are, in most instances, a crude approximation of the 100-year flood inundation limits. For the purpose of assigning priorities for flood insurance studies, the rating list is utilized as a guide and is considered along with any other relevant information.

Table 90 lists the susceptibility ratings of those cities and towns located in Northwest Iowa along with their counties, populations and sources of flooding. The locations of these 41 communities are shown in Fig. 59. The ratings range from 0.7 at Larchwood in Lyon County to 343.7 at Sioux City in Woodbury County. The range of the 392 listed communities in Iowa is from zero at Muscatine in Muscatine

Table 90. Flood-susceptibility ratings of communities located in Northwest Iowa

County	Community	1970 pop.	Source of flooding	D.A., sq. mi.	Rating
Buena Vista	Linn Grove	240	Little Sioux River	1,548	1.1
	Sioux Rapids	813	Little Sioux River	1,548	9.8
Cherokee	Cherokee	7,272	Little Sioux River	2,175	65.4
	Marcus	1,272	Unnamed creek	4	1.0
	Washta	319	Little Sioux River	2,380	1.9
Clay	Spencer	10,278	Little Sioux River	555	85.5
			Ocheyedan River	434	—
Dickinson	Milford	1,668	Okoboji Lake Outlet	145	1.9
Ida	Battle Creek	837	Maple River	515	0.9
	Galva	412	Halfway Creek	20	1.2
	Ida Grove	2,261	Odebolt Creek	60	13.6
Lyon	Doon	437	Rock River	910	0.9
	George	1,194	Little Rock River	195	4.8
	Larchwood	611	Klondike Creek	5	0.7
	Little Rock	531	Little Rock River	125	1.6
	Rock Rapids	2,632	Rock River	778	15.8
			Tom Creek	62	—
			Moon Creek	11	—
O'Brien	Hartley	1,694	Sewer Creek	5	4.1
	Sheldon	4,535	Little Floyd River	59	2.4
	Sutherland	875	Murray Creek	5	10.5
Osceola	Ashton	483	Otter Creek	105	1.1
	Sibley	2,749	Otter Creek	40	5.5
Plymouth	Akron	1,324	Big Sioux River	9,030	5.3
	Hinton	488	Floyd River	860	0.9
	Le Mars	8,189	Floyd River	322	5.3
			Deep Creek	156	—
	Merrill	790	Floyd River	811	1.0
	Westfield	148	Westfield Creek	25	1.5

Sac	Early	727	Boyer River	70	1.5
	Lake View	1,249	Indian Creek	40	2.9
	Sac City	3,268	North Raccoon River	349	4.9
	Wall Lake	936	Lime Creek	10	6.5
Sioux	Alton	1,018	Floyd River	265	3.8
	Hawarden	2,789	Big Sioux River	9,000	3.3
			Dry Creek	50	—
	Ireton	582	Indian Creek	6	1.2
	Rock Valley	2,205	Rock River	1,591	10.2
	Sioux Center	3,450	Unnamed creek	5	2.6
Woodbury	Anthon	711	Little Sioux River	2,575	2.2
	Correctionville	870	Little Sioux River	2,500	10.4
	Hornick	250	West Fork Ditch	410	15.0
	Moville	1,198	West Fork Ditch	343	7.3
	Pierson	421	Pierson Creek	7	1.9
	Sioux City	85,925	Missouri River	—	343.7
			Big Sioux River	—	—
			Floyd River	921	—
			Perry Creek	73	—
	Smithland	293	Little Sioux River	2,695	1.8

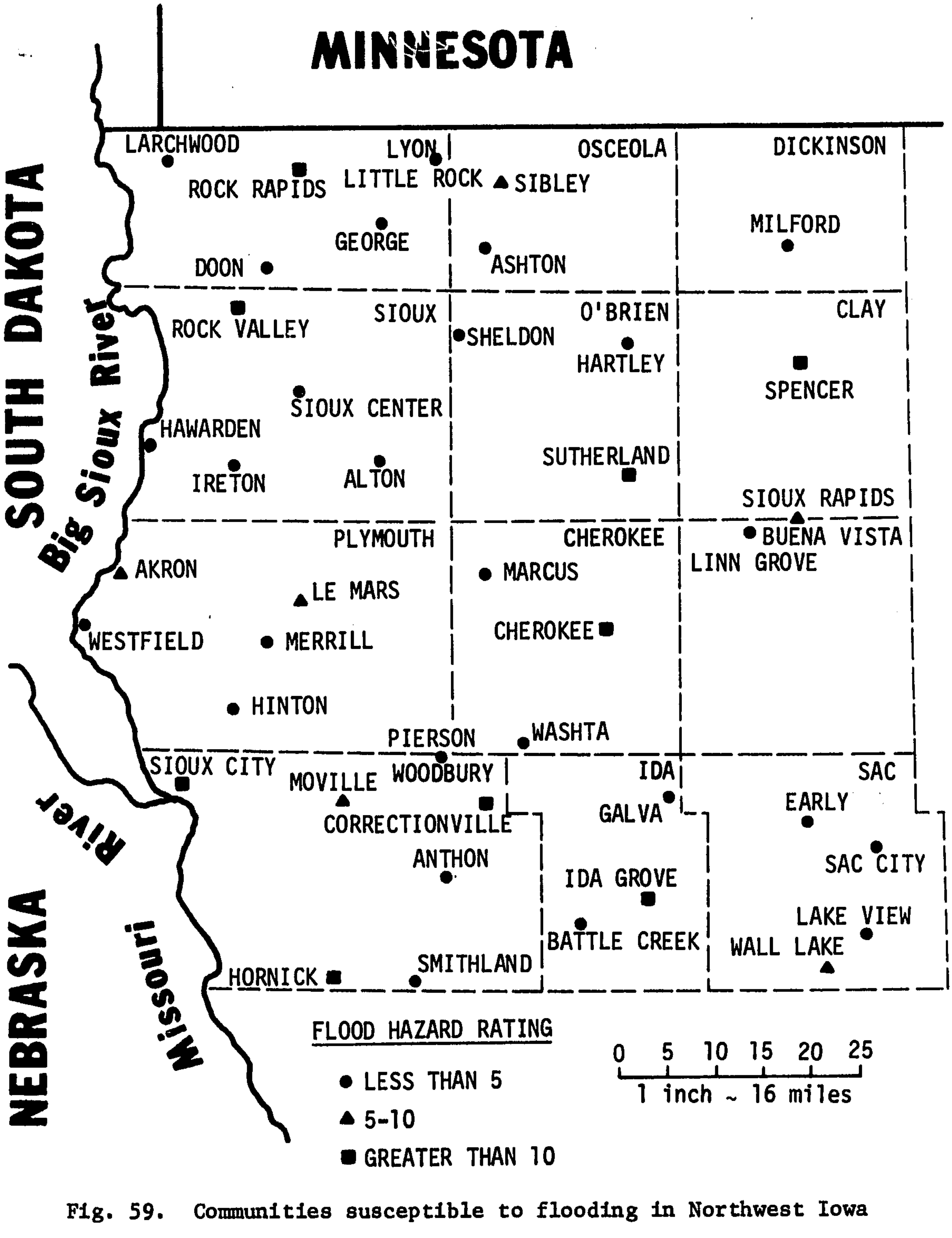


Fig. 59. Communities susceptible to flooding in Northwest Iowa

County to 1,232.0 at Council Bluffs in Pottawattamie County. There are only 9 communities in Northwest Iowa with a rating over 10 and just 3 with a rating over 16. These are Cherokee (65.4) in Cherokee County, Spencer (85.5) in Clay County and Sioux City. The other 6 are Ida Grove (13.6) in Ida County, Rock Rapids (15.8) in Lyon County, Sutherland (10.5) in O'Brien County, Rock Valley (10.2) in Sioux County and Correctionville (10.4) and Hornick (15.0) in Woodbury County.

Just because there are only 9 communities in Northwest Iowa with a rating over 10 does not mean that there are no flood problems in the region. A flood is devastating to those involved even if their community's rating is only 0.9. Nor does it require a major river to create a potential flood problem. Many of the sources of flooding have drainage areas which are considerably less than 100 square miles. The source of most of the present flood problem in Sioux City is Perry Creek with a drainage area at its mouth of just 73 square miles. Both the Missouri River and the Floyd River are also listed for Sioux City because even though extensive flood control works have been constructed on these rivers, future floods of large magnitudes could cause additional damage.

Previously constructed flood control works have reduced the flooding problems in Sioux City primarily to those caused by Perry Creek. Records show that 22 floods have occurred on Perry Creek in Sioux City since 1892. The most damaging flood occurred in July 1944 causing over a million dollars in damage while inundating a 330-block area containing 914 residences and 222 businesses. Water rose to a height of about 5 feet above the first floor levels of some homes.

Gardens and yards were covered with mud and debris up to a depth of 2 feet. Normal business operations were disrupted for several days. Several city bridges were destroyed and many streets, sewers, parks and golf courses were severely damaged (Omaha District, Corps of Engineers, 1973). A system of reservoirs in the rural area north of Sioux City was proposed in 1970 to provide flood control and recreation benefits but was met with opposition by some of the local residents (Omaha District, Corps of Engineers, 1970). About 50 landowners and residents of Plymouth County felt they would be adversely affected by the proposed construction. A petition signed by 224 persons was presented at the public hearing stating that they felt that the flood potential was overstated and protection could be obtained by conservation measures.

In Spencer 13 floods have occurred on the Little Sioux and Ocheyedan Rivers since 1936 (Omaha District, Corps of Engineers, 1971). The greatest flood of record took place in June 1953 with damages estimated at $252,000. Portions of about 20 blocks on the south side of Spencer were flooded, 100 homes and 25 businesses were damaged, 225 families were evacuated and the city park and swimming pool were heavily damaged. U.S. Highways 71 and 18 were closed for several days. Several other floods have occurred in Spencer with varying amounts of damage as shown in Table 91. Two smaller communities also are impacted by floods on the Ocheyedan River, Everly and May City.

Other urban flood damages could be reported in communities such as Cherokee, Ida Grove, Le Mars, Rock Rapids and others. However, floods do not only cause damages in urban areas, but can and do cause damages in rural areas as well. Damages occur to crops, livestock,

Table 91. Urban flood damages in Spencer[a]

Month-year	Damages, dollars
June 1947	$ 13,000
April 1951	47,900
June 1953	252,000
March 1960	1,000
April 1965	18,700
April 1969	40,000

[a]Omaha District Corps of Engineers (1971).

farm buildings and machinery, highways and bridges and to the land itself. Table 92 summarizes the rural flood damages which have been sustained in Northwest Iowa during the period 1944-1974 (Task Force on Flood Plain Management, 1977).

Manufacturing

The number, types and locations of manufacturers in the region can give us an estimate of their diversity or dependence on agriculture. The most recent edition of the Directory of Iowa Manufacturers (Iowa Development Commission, 1978a) was used to obtain these data. Tables C-1 through C-12 in Appendix C list the locations, number of employees, names and products of the manufacturers located in Northwest Iowa. Firms were located in 75 of the 114 incorporated communities. There were 18 cities with only one firm, 18 with two firms and 9 with three firms. Of the total of 446 firms, 238 or about 53% were located in the ten largest cities.

Table 92. Rural flood damages in the Big Sioux, Floyd and Little Sioux River basins during the period 1944 to 1974, 1,000 dollars[a]

Year	Big Sioux	Floyd	Little Sioux
1944	282.2	46.1	768.5
1945	—[b]	1.6	1,357.7
1946	—[b]	—[b]	3.0
1947	230.0	1,123.9	1,450.4
1948	365.8	—[b]	46.8
1949	26.6	1.5	447.9
1950	—[b]	58.3	412.8
1951	2,215.6	121.5	3,416.1
1952	540.1	306.6	—[b]
1953	966.9	25,432.0	3,103.4
1954	1,192.5	235.5	3,520.0
1955	—[b]	—[b]	—[b]
1956	—[b]	—[b]	—[b]
1957	4,090.7	—[b]	—[b]
1958	—[b]	—[b]	—[b]
1959	228.0	—[b]	343.7
1960	2,307.0	438.0	454.0
1961	—[c]	—[c]	—[c]
1962	2,852.0	680.0	1,412.1
1963	—[b]	—[b]	—[b]
1964	—[b]	—[b]	—[b]
1965	553.0	—[b]	1,311.2
1966	—[c]	—[c]	—[c]
1967	—[b]	—[b]	130.0
1968	—[c]	—[c]	—[c]
1969	—[b]	—[b]	36.9
1970	—[c]	—[c]	—[c]
1971	—[c]	—[c]	—[c]
1972	—[b]	—[b]	—[b]
1973	—[c]	—[c]	—[c]
1974	—[c]	—[c]	—[c]

[a]Task Force on Flood Plain Management (1977).

[b]No records of damaging floods.

[c]No damage estimates were made.

The 446 firms were divided into 28 categories as shown in Table 93. The manufacturing of feed was the most popular business with 58 firms. The newspaper business was also active and well in Northwest Iowa numbering 52 firms. Steel products manufacturing had the third largest number of firms with 43 while ready-mixed concrete and concrete products manufacturing totaled 48 plants. There were 165 firms directly involved with agriculture with another 50 firms less involved with the agricultural sector. Thus almost half the firms in Northwest Iowa depend wholly or in major part on agriculture. By using the midpoint of each employee size category as the number of employees in each firm, it was estimated that 9,500 manufacturing jobs were directly dependent on agriculture while 11,600 jobs were not ag-related. Such firms as newspapers, printing, ready-mixed concrete, concrete products, steel products, wood products, clothing, welding and soft drink bottlers were assumed not to be ag-related firms even though some of their customers will be farmers or people with ag-related jobs.

Recreation

At first glance Northwest Iowa would seem to be blessed with an abundance of water-based recreation opportunities since it is the site of most of the natural lakes in Iowa and it contains many rivers and streams. However, as in most cases, there are pockets of scarcity within the midst of plenty and problems with use even where the resource is most plentiful. The natural lakes are all located in the eastern tier of 4 counties plus one lake in Osceola County on the

Table 93. Number and types of manufacturing firms in Northwest Iowa in 1977[a]

No. of firms	Category
58	Feed
52	Newspaper
43	Steel products
33	Miscellaneous
25	Agricultural machinery
24	Ready-mixed concrete
24	Concrete products
20	Wood products
19	Livestock and poultry packers
19	Fertilizer
18	Printing
14	Clothing
11	Plastic products
9	Feed and fertilizer
8	Milk products
8	Electronic equipment
7	Livestock by-products
7	Bakery
6	Popcorn
6	Welding and machine
5	Seed corn
5	Fences and gates
5	Furniture
5	Truck parts
4	Livestock products
4	Bottlers – soft drinks
4	Paper products
3	Signs

[a]Iowa Development Commission (1978a).

Minnesota border. Five of the other 7 counties have a total of just 99 acres devoted to flat water recreation while a sixth has 399 acres in 3 gravel pits and 3 off-stream impoundments. The seventh county has 1,274 acres of water but 1,257 acres are contained within 4 oxbow lakes and due to low water levels and siltation problems, they usually are used only for wildlife areas and river access. The 7 Iowa Great Lakes occupy 12,149 acres in Dickinson County, the northeasternmost county in the region. However, the shoreline on some of them, especially West Okoboji, have been preempted by private cottages, year-round homes and resorts so that the general public has access to the lakes in only a relatively few locations.

State, county, local and private interests have developed 162 recreation areas in Northwest Iowa, exclusive of golf courses, swimming pools and city parks. Information on the 85 water areas is contained in Table G-1 in Appendix G and the data on the 77 areas which do not include bodies of water are shown in Table G-2 in Appendix G. These data were compiled by the Iowa Conservation Commission and published in Outdoor Recreation in Iowa (Planning and Coordination Section, 1972). The locations of the water areas are shown in Figs. 60 and 61. The locations of the other recreation areas are shown in Figs. 62 and 63. These figures clearly indicate that the distribution of existing outdoor recreation areas in Northwest Iowa creates some serious gaps both in areal location and proximity to population centers.

The data contained in Tables G-1 and G-2 in Appendix G are summarized in a series of four tables. Table 94 lists all 162 recreation areas (both water and nonwater) broken down by county into nine use categories: fishing access, lake access, river access, wildlife areas, rest areas, natural lakes, general outdoor recreation areas, natural environment areas, and reserved open spaces and undeveloped areas. Table 95 presents the same information for just the 85 water areas. Table 96 lists these 85 areas broken down into six types of water:

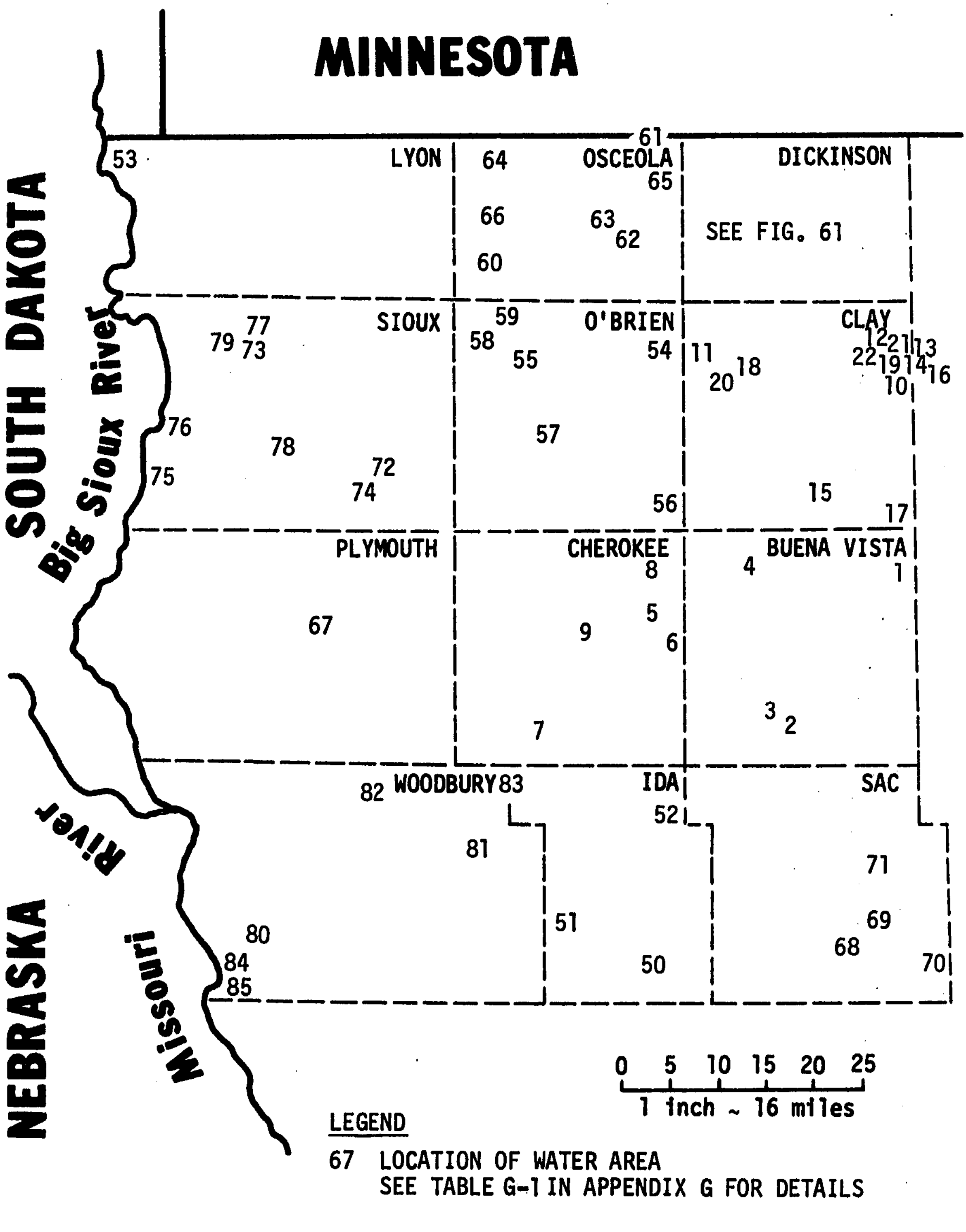
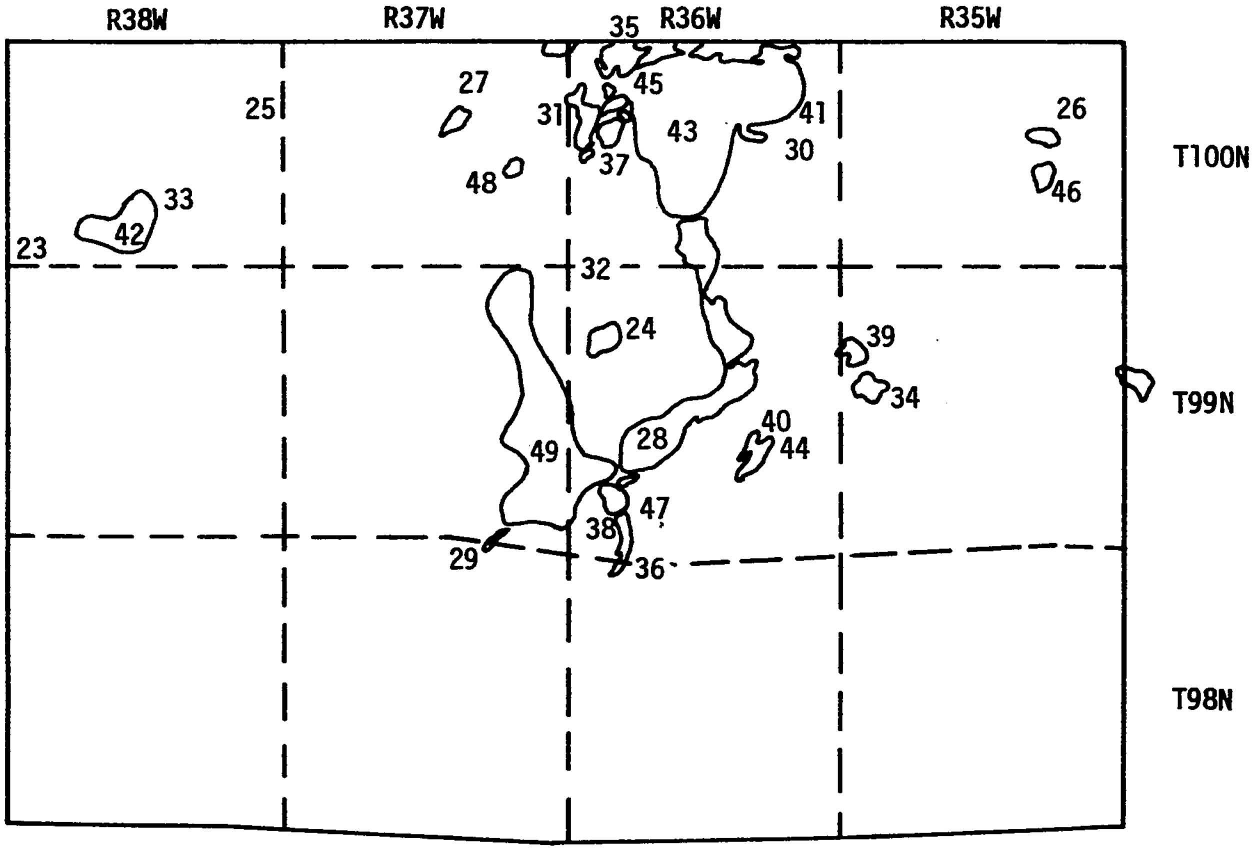


Fig. 60. Location of natural and artificial water areas in Northwest Iowa



LEGEND

40 LOCATION OF WATER AREA
SEE TABLE G-1 IN APPENDIX G FOR DETAILS

Fig. 61. Natural water areas in Dickinson County

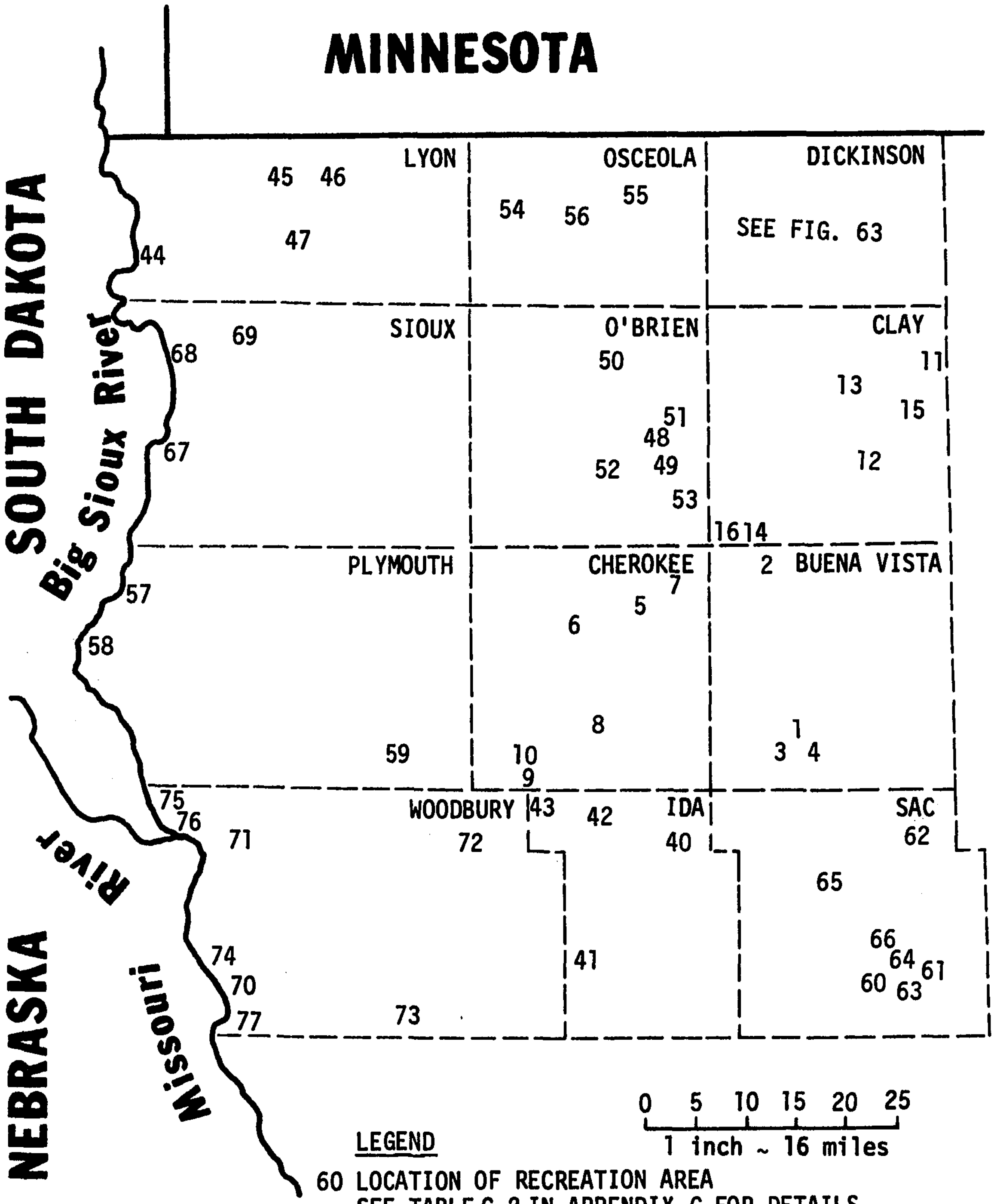
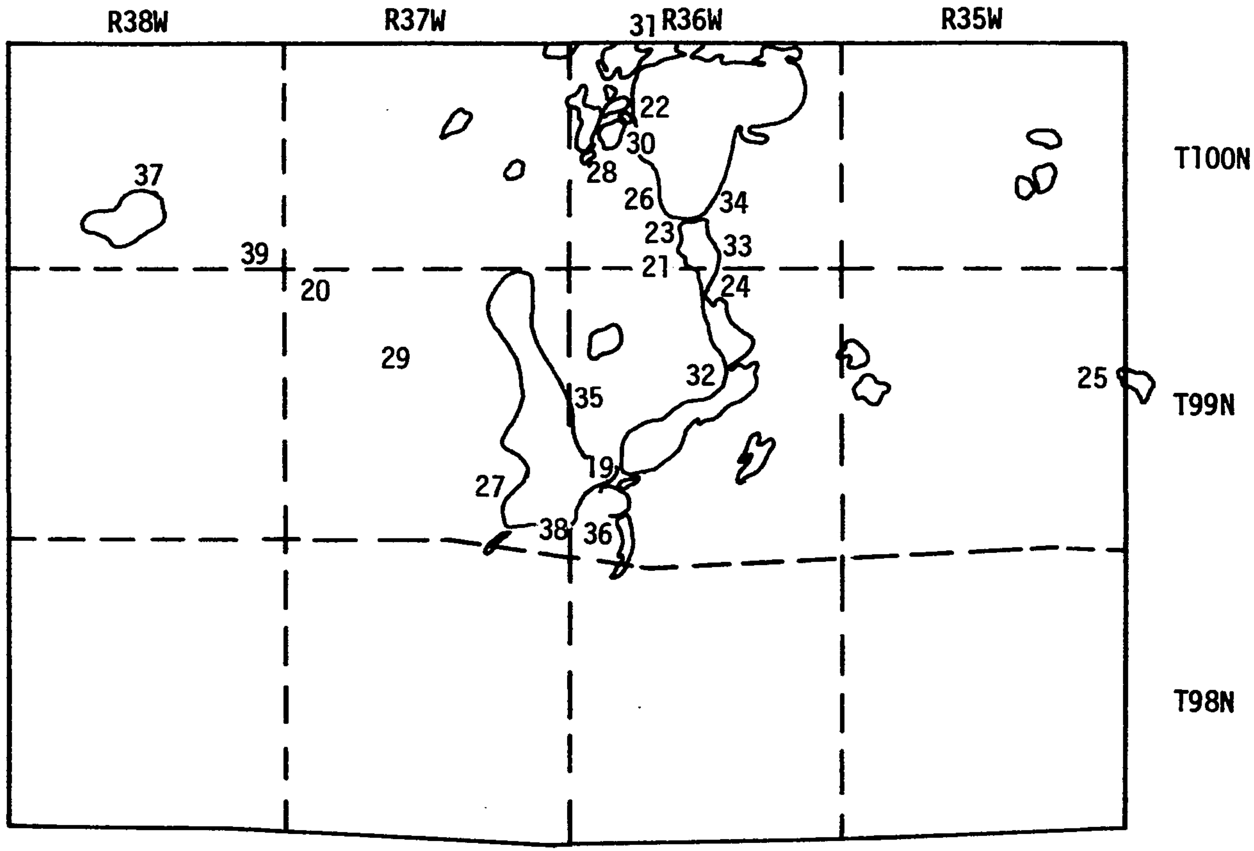


Fig. 62. Location of outdoor recreation areas in Northwest Iowa without bodies of water



LEGEND

38 LOCATION OF RECREATION AREA
SEE TABLE G-2 IN APPENDIX G FOR DETAILS

Fig. 63. Location of outdoor recreation areas in Dickinson County without bodies of water

Table 94. Summary of use, number and size of existing private, county and state outdoor recreation areas in Northwest Iowa[a]

County	Fishing access		Lake access		River access		Wildlife area		Rest area	
	No.	Acres[b]	No.	Acres[b]	No.	Acres[b]	No.	Acres[b]	No.	Acres[b]
Buena Vista	0	0	1	0	0	0	1	276	0	0
Cherokee	1	11	0	0	8	311	0	0	1	16
Clay	0	0	0	0	0	0	6	2,104	0	0
Dickinson	0	0	7	158	1	24	12	2,970	0	0
Ida	0	0	0	0	2	57	0	0	1	4
Lyon	0	0	0	0	0	0	1	435	2	11
O'Brien	0	0	0	0	0	0	0	0	1	1
Osceola	4	45	0	0	1	16	0	0	2	2
Plymouth	0	0	0	0	1	23	3	285	0	0
Sac	0	0	0	0	1	23	3	285	0	0
Sioux	0	0	0	0	3	104	0	0	1	11
Woodbury	1	17	0	0	4	1,056	2	786	2	7
Region	6	73	8	162	20	1,591	27	6,895	10	52

[a]Planning and Coordination Section, Iowa Conservation Commission (1972).

[b]Total acreage: land plus water.

Table 94. Continued

County	Natural lake		Class II[c]		Class III[d]		Class VII[e]		Total	
	No.	Acres[b]	No.	Acres[b]	No.	Acres[b]	No.	Acres[b]	No.	Acres[b]
Buena Vista	2	3,273	2	310	0	0	2	26	8	3,889
Cherokee	0	0	1	18	0	0	0	0	11	356
Clay	6	3,818	3	204	1	160	3	12	19	6,298
Dickinson	16	14,901	12	195	2	161	0	0	50	18,409
Ida	0	0	1	4	3	275	0	0	7	340
Lyon	0	0	0	0	1	91	1	5	5	542
O'Brien	0	0	8	630	1	4	2	6	12	641
Osceola	2	450	0	0	0	0	0	0	10	536
Plymouth	0	0	0	0	1	3	2	69	4	88
Sac	1	957	3	450	2	236	1	28	11	1,979
Sioux	0	0	7	188	0	0	0	0	11	303
Woodbury	0	0	3	486	2	915	0	0	14	3,267
Region	27	23,399	40	2,485	13	1,845	11	146	162	36,648

[c]Class II: general outdoor recreation areas.

[d]Class III: natural environment areas.

[e]Class VII: reserved open spaces and undeveloped areas.

Table 95. Summary of use, number and size of existing water areas in Northwest Iowa[a]

County	Natural lake		Class II & III[b]		Wildlife area		Fishing access		River access		Total	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Buena Vista	2	3,273	1	2	1	264	0	0	0	0	4	3,539
Cherokee	0	0	1	18	0	0	1	4	3	6	5	28
Clay	6	3,707	3	23	4	1,200	0	0	0	0	13	4,930
Dickinson	16	14,758	2	19	9	1,076	0	0	0	0	27	15,853
Ida	0	0	3	27	0	0	0	0	0	0	3	27
Lyon	0	0	1	1	0	0	0	0	0	0	1	1
O'Brien	0	0	6	399	0	0	0	0	0	0	6	399
Osceola	2	428	0	0	1	11	4	8	0	0	7	447
Plymouth	0	0	1	3	0	0	0	0	0	0	1	3
Sac	1	957	1	5	1	56	0	0	1	2	4	1,020
Sioux	0	0	7	36	0	0	0	0	1	4	8	40
Woodbury	0	0	2	17	2	327	0	0	2	930	6	1,274
Region	27	23,123	28	550	18	2,934	5	12	7	942	85	27,561

[a]Planning and Coordination Section, Iowa Conservation Commission (1972).

[b]Class II: general outdoor recreation areas.

[c]Class III: natural environment areas.

Table 96. Summary of type, number and size of existing water areas in Northwest Iowa[a]

County	Natural lake		Oxbow lake		Gravel pit		Pond		Marsh		Off-stream impoundment		Total	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Buena Vista	2	3,273	0	0	0	0	1	2	1	264	0	0	4	3,539
Cherokee	0	0	0	0	0	0	2	22	3	6	0	0	5	28
Clay	8	4,721	0	0	2	18	1	5	2	186	0	0	13	4,930
Dickinson	26	15,839	0	0	0	0	1	14	0	0	0	0	27	15,853
Ida	0	0	0	0	0	0	1	3	0	0	2	24	3	27
Lyon	0	0	0	0	0	0	1	1	0	0	0	0	1	1
O'Brien	0	0	0	0	3	329	1	10	0	0	2	60	6	399
Osceola	2	428	0	0	5	19	0	0	0	0	0	0	7	447
Plymouth	0	0	0	0	1	3	0	0	0	0	0	0	1	3
Sac	1	957	0	0	0	0	1	5	2	58	0	0	4	1,020
Sioux	0	0	0	0	6	34	1	2	1	4	0	0	8	40
Woodbury	0	0	4	1,257	1	3	0	0	0	0	1	13	6	1,274
Region	39	25,218	4	1,257	18	406	10	64	9	518	5	98	85	27,561

[a]Planning and Coordination Section, Iowa Conservation Commission (1972).

natural lakes, oxbow lakes, gravel pits, ponds, marshes and off-stream impoundments. Finally, Table 97 shows the ownership of the 162 outdoor recreation areas. In addition to these outdoor areas, the rivers themselves present opportunities for boating and canoeing. Figure 64 shows those rivers in Northwest Iowa which the Iowa Conservation Commission deems suitable for canoeing and for power boats up to 10 horsepower. Many of these streams are canoeable early in the year, but become increasingly difficult as the water depth decreases over the summer.

Table 97. Ownership of existing outdoor recreational facilities in Northwest Iowa excluding city parks and golf courses[a]

County	State	County	Local	Private	Total
Buena Vista	6	2	0	0	8
Cherokee	2	8	1	0	11
Clay	13	6	0	0	19
Dickinson	43	0	0	7	50
Ida	3	3	0	1	7
Lyon	3	1	1	0	5
O'Brien	3	7	0	2	12
Osceola	5	4	0	1	10
Plymouth	1	3	0	0	4
Sac	7	4	0	0	11
Sioux	4	6	0	1	11
Woodbury	9	5	0	0	14
Region	99	49	2	12	162

[a]Planning and Coordination Section, Iowa Conservation Commission (1972).

A recreation experience is affected not only by the quantity of land and/or water available but also by the kinds of recreation offered and the quality of the experience. Low water levels and

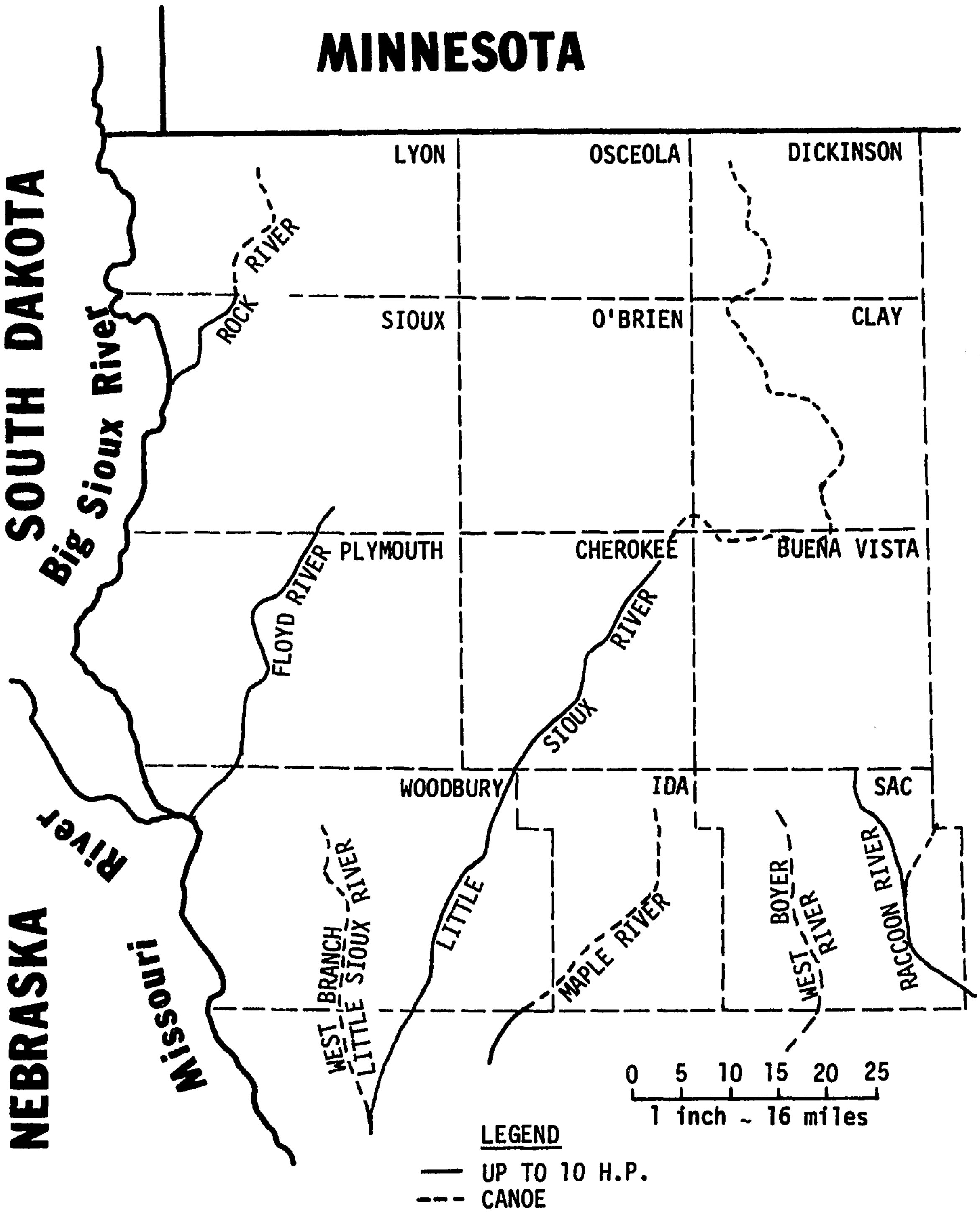


Fig. 64. Stream boating resource in Northwest Iowa

siltation problems in oxbow lakes lower their quality and restrict their use for many kinds of recreation. Gravel pits normally are deep and have steep sides which causes severe safety problems to swimmers and other contact and noncontact varieties of water-based recreation. Simple overcrowding can also cause a deterioration in the quality of a recreation experience. Many kinds of outdoor recreation are available in Northwest Iowa: picnicking, swimming, boating, fishing, hiking, camping and hunting. Tables 98 and 99 summarize the number of opportunities available in each county for enjoying these various types of recreation. Table 100 lists the number of counties which have inadequate recreational opportunities.

These tables show the wide disparity in facilities provided and adequacies in some of the counties. Dickinson County provides 113 opportunities while Plymouth and Lyon Counties provide only 5 and 6, respectively. Fishing is provided at 78 locations, followed closely by hunting and picnicking. However, opportunities for swimming are provided at only 16 locations (9 lakes, 3 ponds, 2 off-stream impoundments, 1 gravel pit and 1 river access) and hiking trails are found in only 20 locations. Six counties provide no swimming facilities at all while three others provide only one. About the same is true for hiking trails. Three counties provide no boating opportunities while two others provide only one facility. If river accesses were excluded, then three more counties would provide no lake boating. Figure 65 shows the counties which do not provide the facilities listed at the present time or provide only one such facility. Woodbury County has two swimming facilities; however, one

Table 98. Number and type of existing outdoor recreation facilities in Northwest Iowa[a]

County	Picnicking	Swimming	Boating	Fishing	Hiking	Camping	Hunting	Total
Buena Vista	3	1	5	5	2	2	3	21
Cherokee	10	0	4	11	0	6	11	42
Clay	2	1	3	6	1	2	14	29
Dickinson	10	7	25	28	8	13	22	113
Ida	5	0	0	3	1	3	1	13
Lyon	3	0	0	1	0	1	1	6
O'Brien	8	4	1	4	0	6	0	23
Osceola	2	0	0	5	0	0	6	13
Plymouth	2	0	1	1	0	0	1	5
Sac	5	1	3	3	1	3	3	19
Sioux	4	0	3	5	2	3	2	19
Woodbury	8	2	4	6	5	6	3	34
Total	62	16	49	78	20	45	67	337

[a]Planning and Coordination Section, Iowa Conservation Commission (1972).

Table 99. Summary of number and type of existing outdoor recreation facilities in Northwest Iowa

Type of activity	Number of facilities
Fishing	78
Hunting	67
Picnicking	62
Boating	49
Camping	45
Hiking	20
Swimming	16

Table 100. Number of counties in Northwest Iowa with inadequate outdoor recreation facilities

Type of activity	Number of counties with	
	No facilities	Only one facility
Swimming	6	3
Hiking	5	3
Boating	3	2
Camping	2	1
Hunting	1	3
Fishing	0	2
Picnicking	0	0

is a river access and the other is a 3-acre pond, scarcely adequate for a county population of over 100,000 people. Previously, Table 43 listed the variation in water acres per 1,000 people in each county.

Table 101 lists the number of city parks and their total acreages in each of the 12 counties for three ranges of community size. They total about 300 parks with about 2,500 acres. Almost every community in Iowa has a city park so it is not surprising that the 114 communities in Northwest Iowa have almost 300 parks. Table 102 lists

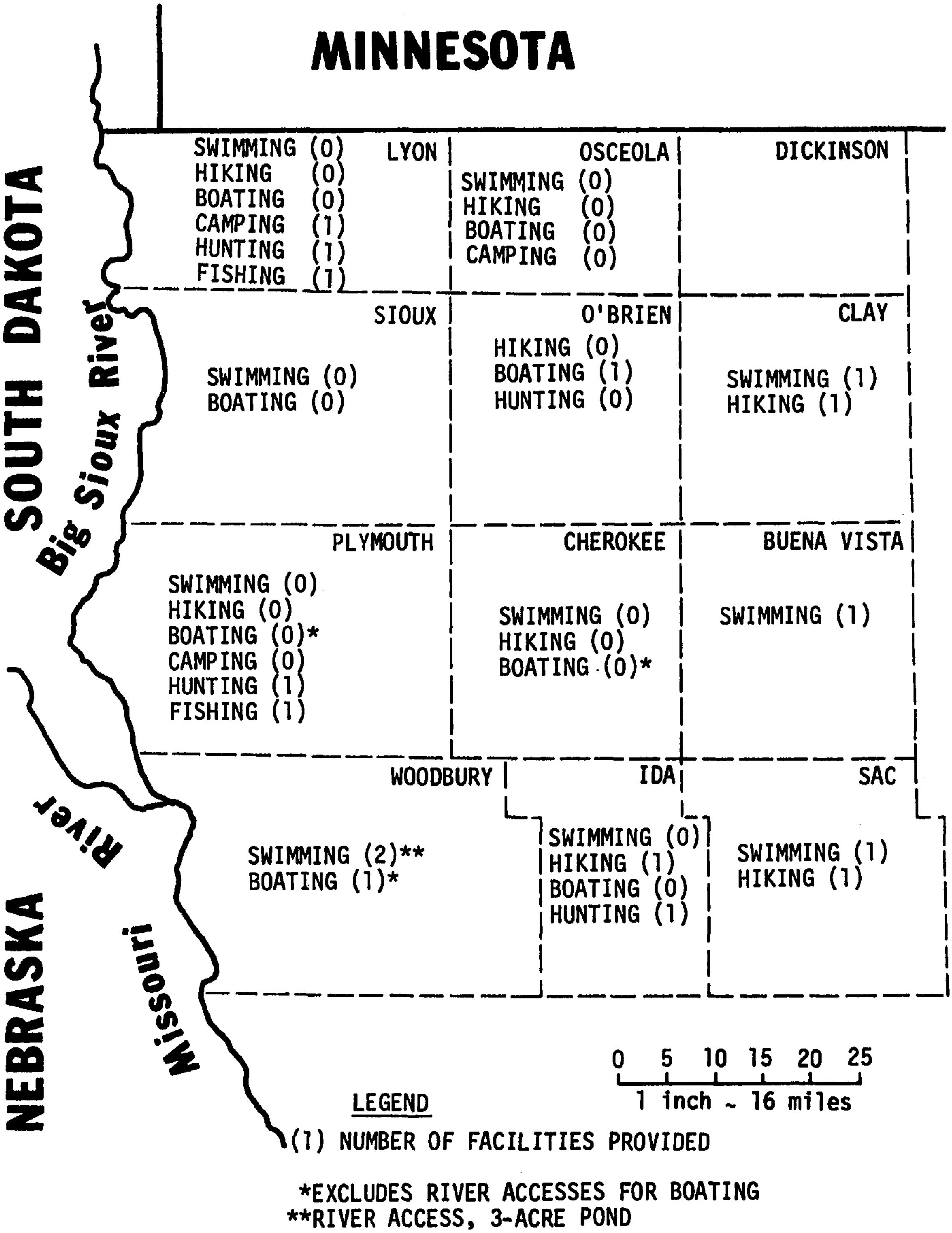


Fig. 65. Counties which lack or provide only one of the facilities listed

Table 101. Summary of existing municipal outdoor recreational areas in Northwest Iowa[a]

County	0-2,500 pop.			2,501-10,000 pop.			Over 10,000 pop.		
	No. of areas	Other areas[b]	Total acres	No. of areas	Other areas[b]	Total acres	No. of areas	Other areas[b]	Total acres
Buena Vista	9	7	123	1	5	61	—[c]	—	—
Cherokee	7	5	12	1	3	113	—	—	—
Clay	8	7	15	—	—	—	1	6	25
Dickinson	10	9	39	1	2	12	—	—	—
Ida	5	7	25	—	—	—	—	—	—
Lyon	7	9	30	1	5	44	—	—	—
O'Brien	8	9	41	1	2	22	—	—	—
Osceola	4	6	12	1	2	9	—	—	—
Plymouth	10	15	46	1	7	127	—	—	—
Sac	7	11	30	1	1	10	—	—	—
Sioux	10	14	40	3	7	51			
Woodbury	14	13	75	—	—	—	1	29	546
Total	99	112	488	11	34	449	2	35	571

[a]Planning and Coordination Section, Iowa Conservation Commission (1972).

[b]Number of areas for which acreage is not known.

[c]No communities in this population range.

Table 102. Number and location of existing golf courses and municipal swimming pools in Northwest Iowa[a]

County	Golf course 9-hole	Golf course 18-hole	Swimming pool
Buena Vista	4	0	5
Cherokee	3	0	3
Clay	1	1	2
Dickinson	3	3	0
Ida	2	0	2
Lyon	1	0	2
O'Brien	3	0	3
Osceola	1	0	1
Plymouth	2	0	2
Sac	2	0	3
Sioux	4	0	5
Woodbury	5	4	7
Region	31	8	35

[a]Planning and Coordination Section, Iowa Conservation Commission, (1972).

the number of 9- and 18-hole golf courses and swimming pools in the region. Figures 66 and 67 show the locations of the golf courses and swimming pools, respectively. Only Dickinson County has no municipal swimming pool, but this may be due to the abundance of natural lakes in the county. The number and distribution of golf courses and swimming pools would appear to be adequate for the region.

Several assumptions must be made in order to estimate the future need for land and water areas to be used for recreational purposes. In this study provision of recreational facilities will be based on the largest county population attained during the period 1970-2020 as shown in Tables A-53 through A-64 in Appendix A. Only the inhabitants of the county will use the facilities within the county and each person

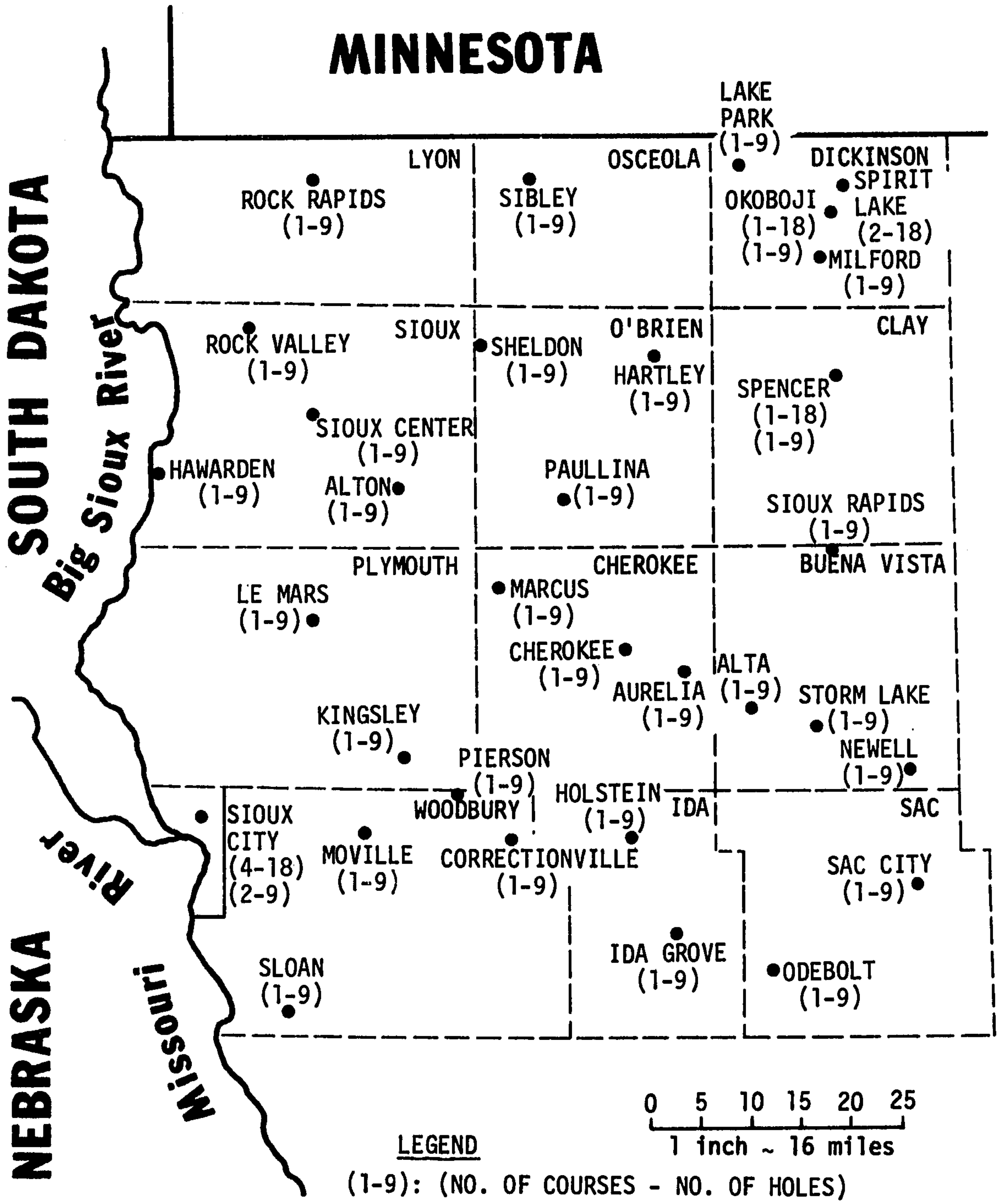


Fig. 66. Location of existing golf courses in Northwest Iowa

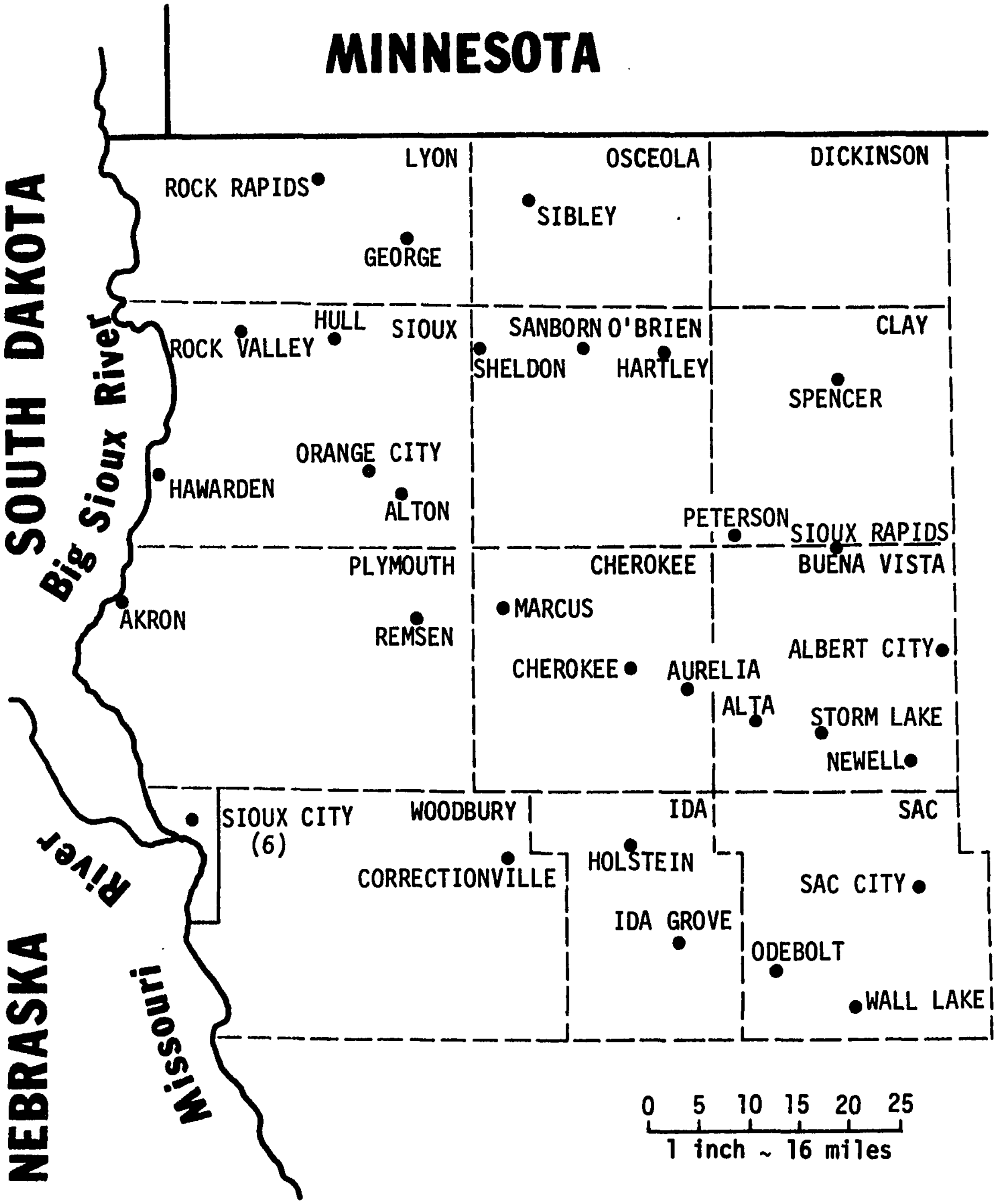


Fig. 67. Location of existing swimming pools in Northwest Iowa

will make six visits per year. Of the total annual visitations, 80% will occur during the summer season, 60% of the total weekly visitations will occur on Sunday, there are 14 Sundays during the summer season and the turnover rate is 1.5. The design load for each county then becomes:

$$\text{D.L.} = \frac{6 \times 0.8 \times 0.6}{14 \times 1.5} \text{(Co. Pop.)} = 0.137\text{(Co. Pop.)} \qquad (27)$$

The results for each county are shown in Table 103. These design loads and populations for each county are then used to calculate the number of acres of land and water which would be desirable in each county in the future for recreational purposes. These acreages are based on standards developed by the Bureau of Outdoor Recreation for each type of land- and water-based recreational activity and support facility.

Tables G-3 through G-14 in Appendix G depict the results of these calculations for each county. The factors in these tables include 3 additional acres per acre required for land-based activities to provide proper buffering, screening and aesthetics. The results shown in Tables G-3 through G-14 are summarized in Table 104. This table indicates that while 36,650 acres are presently used for various types of outdoor recreation and only 8,255 acres are needed, a total of an additional 3,960 acres would be desirable in 8 of the 12 counties. This is due to a lack of acreage in some land and water categories and an overabundance in others. For example, in Lyon County 205 acres of water should be provided but there presently exists only a single 1 acre pond. The same is true in Sioux County where 370 acres of

Table 103. Determination of recreational design loads in Northwest Iowa through the year 2020

County	Population[b]	Factor[c]	Design load[a] number of people
Buena Vista	20,700	0.137	2,840
Cherokee	17,300	0.137	2,370
Clay	19,300	0.137	2,650
Dickinson	13,200	0.137	1,810
Ida	9,200	0.137	1,260
Lyon	13,300	0.137	1,820
O'Brien	17,500	0.137	2,400
Osceola	8,500	0.137	1,160
Plymouth	24,300	0.137	3,330
Sac	15,600	0.137	2,140
Sioux	28,000	0.137	3,840
Woodbury	103,000	0.137	14,120

[a]Design load = population x factor.

[b]Largest county population during the period 1970-2020. See Tables A-53 through A-64 in Appendix A.

[c]See text for details: $(6 \times 0.8 \times 0.6) \div (14 \times 1.5)$.

water are recommended but only 40 acres of water presently exist in 6 gravel pits, 1 pond and 1 marsh.

The provision of these additional acres for recreation would serve many purposes. Outdoor recreational facilities would become more accessible to the people in each county. This is especially true of Lyon, Sioux and Plymouth Counties where the inhabitants have the lowest per capita incomes in the region. Since all the people would live closer to recreational facilities, they would need to use less energy in the form of gasoline in order to enjoy these activities. Properly located water areas could also be used for flood control, water supply and irrigation purposes.

Table 104. Summary of acreage desirable for recreation in Northwest Iowa through the year 2020

County	Recommended Land	Recommended Water	Recommended Total	Presently available[b]	Additional desirable[c]
Buena Vista	275	315	590	3,890	0
Cherokee	230	265	495	355	340
Clay	255	295	550	6,300	0
Dickinson	175	200	375	18,410	0
Ida	120	140	260	340	230
Lyon	175	205	380	540	350
O'Brien	235	265	500	640	100
Osceola	115	130	245	535	100
Plymouth	320	370	690	90	600
Sac	205	240	445	1,980	0
Sioux	370	425	795	305	540
Woodbury	1,365	1,565	2,930	3,265	1,700
Region	3,840	4,415	8,255	36,650	3,960

[a]See Tables G-3 through G-14 in Appendix G.

[b]See Table 94.

[c]Additional acreage needed because of an existing lack in some land and water categories and an overabundance in others.

Energy

Northwest Iowa is similar to the remainder of the state in that it imports most of its energy requirements. Figure 68 shows the locations of the natural gas pipelines in Northwest Iowa. Figure 69 is a similar map showing the locations of the petroleum products pipelines in Northwest Iowa. Both of these figures were obtained from the 1975 annual report of the Iowa Energy Policy Council (1975). In addition to these two sources of energy, millions of tons of coal are shipped into Iowa from states located both to the east and west of Iowa. Some

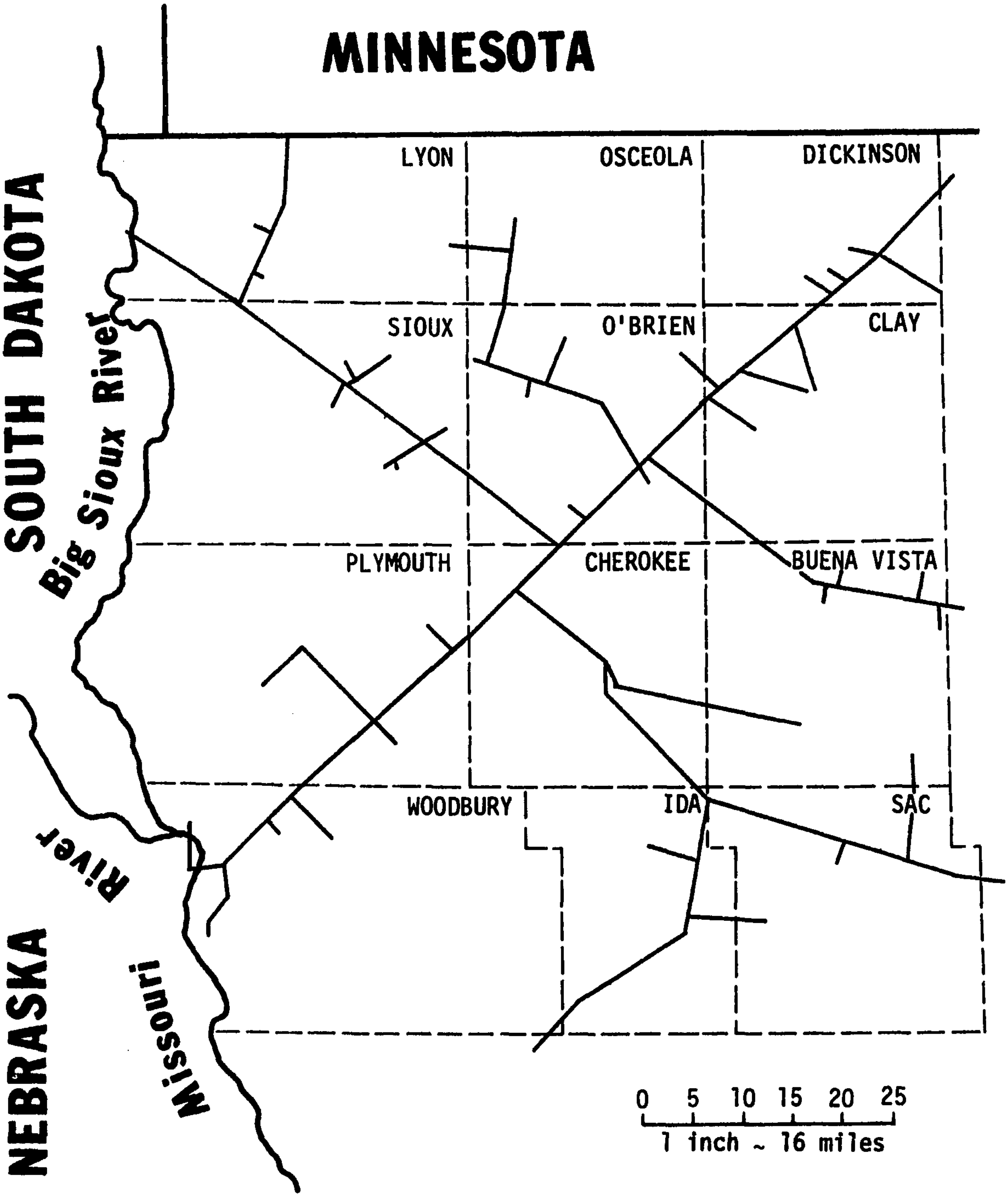


Fig. 68. Natural gas pipelines in Northwest Iowa

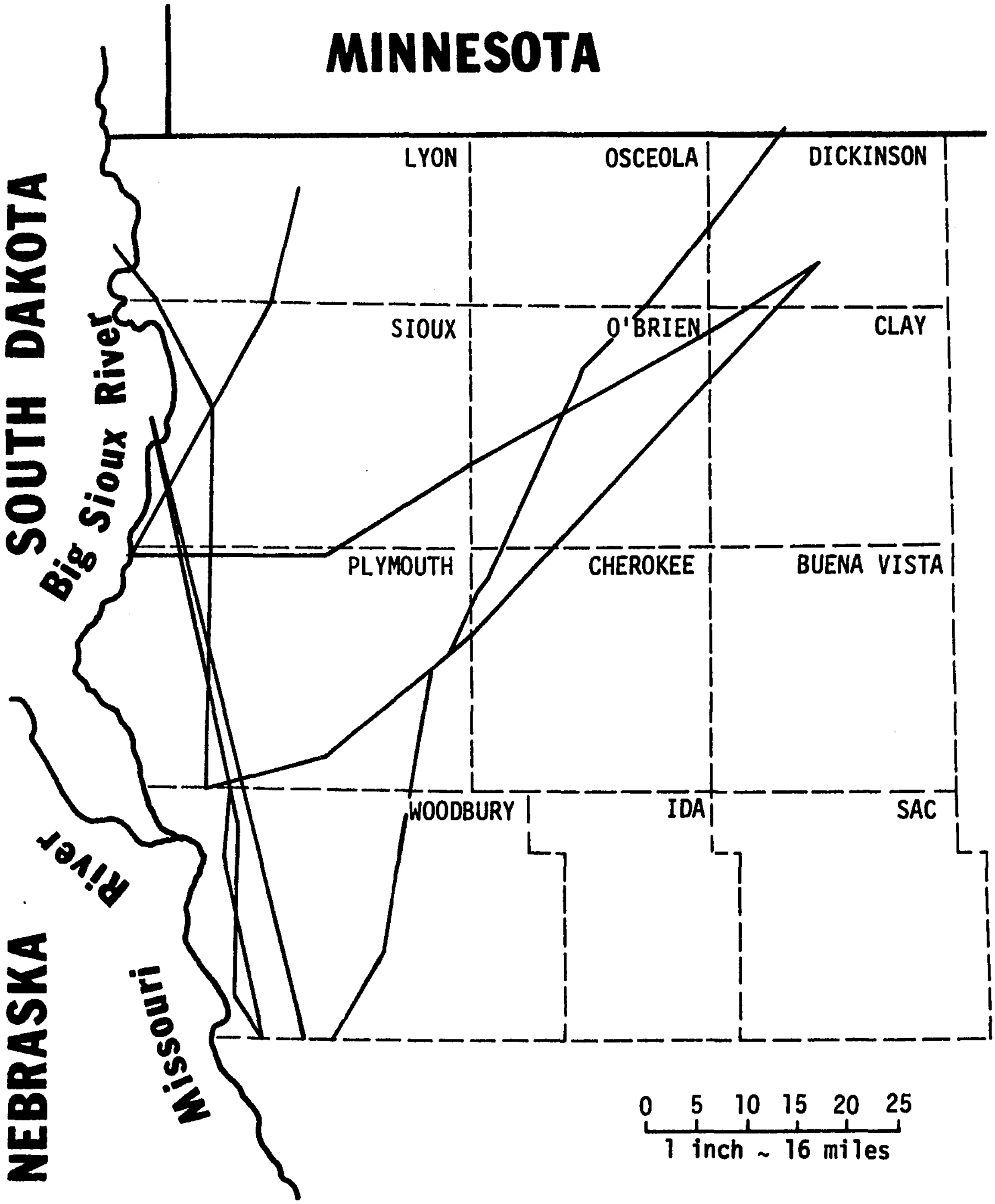


Fig. 69. Petroleum products pipelines in Northwest Iowa

of these energy resources are used to produce electricity at several locations throughout Northwest Iowa. These locations, sizes and types of plants are listed in Table 105 and are shown in Fig. 70. This set of data was obtained from the 1977 annual report of the Iowa Energy Policy Council (1977).

Table 105. Municipal electric plants in Northwest Iowa[a]

County	City	Type[b]	K.W. cap.
Buena Vista	Alta	IC	1,250
Clay	Spencer	IC, S	38,500
Dickinson	Lake Park	IC	1,300
	Milford	IC	1,530
Lyon	Rock Rapids	IC	2,750
O'Brien	Hartley	IC	2,353
	Paullina	IC	1,540
	Primghar	IC	1,580
	Sanborn	IC	1,484
Osceola	Sibley	IC, S	4,570
Plymouth	Akron	IC	1,306
	Remsen	IC	1,440
Sioux	Hawarden	IC	2,650
	Orange City	IC	3,625
	Sioux Center	IC	1,465
Woodbury	Sioux City	S	763,900

[a]Iowa Energy Policy Council (1977).

[b]IC: internal combustion; S: steam.

Besides the power plants shown in Fig. 70, much of western Iowa's electricity is generated from hydroelectric plants at the main stem dams on the Missouri River in South Dakota and from power plants in Nebraska. Almost all of the water needed for power production in Northwest Iowa is taken from the border streams which are not regulated under Iowa law. The plant in Spencer uses ground water for

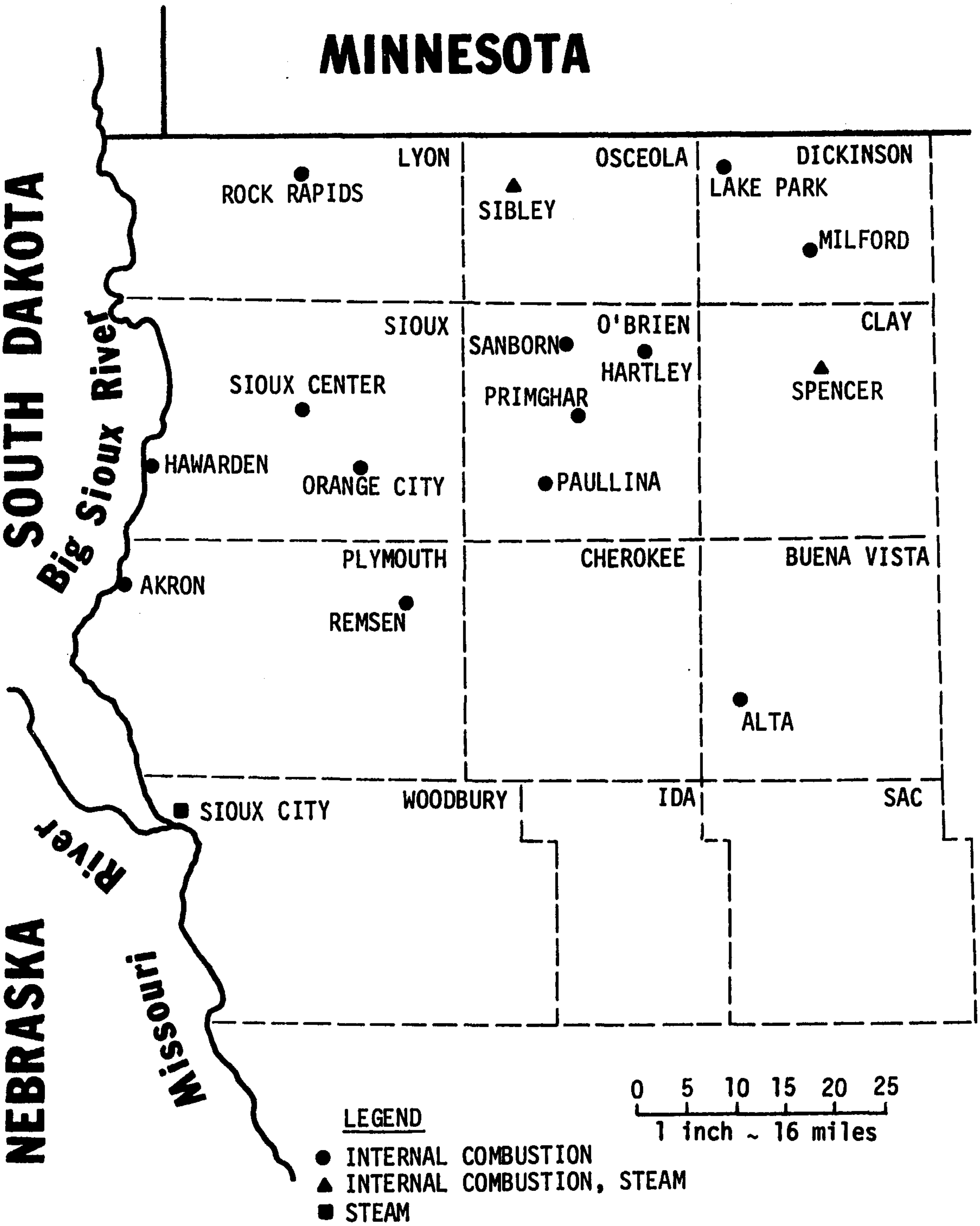


Fig. 70. Location of municipal power plants in Northwest Iowa

cooling tower make-up. The other plants use internal combustion which require very little water. Thus power production in Northwest Iowa is not one of the uses of water which must be considered at this time.

Most if not all of the internal combustion plants are on emergency standby; these communities normally draw their electrical energy needs from the main stem dams on the Missouri River.

Soils

The soils of Northwest Iowa were formed from loess and the till left by the glaciers as shown in Fig. 41. The maturely dissected Kansan drift plain in northwestern Iowa was covered by the earlier substage of the Wisconsin ice advance, the Iowan. The Iowan drift is present at the surface or beneath wind-blown deposits in the western part of the basin. Much of Northwest Iowa was covered with loess during the melting of the Iowan ice sheet and the interval before the advance of the Tazewell substage of the Wisconsin advance. The Tazewell covered what are now the headwaters of the Floyd River and the eastern tributaries of the Rock River. A small part of the region in the extreme northeast was covered by the Cary substage of the Wisconsin stage (Planning and Analysis Section, Iowa Department of Environmental Quality, 1976).

The topography resulting from this glacial activity, loess deposition and subsequent erosion is a plain sloping from northeast to southwest. The Cary region of the extreme northeast is marked by youthful glacial moraine country. Present are isolated steep-sided hills, undrained basins and land virtually unaltered by erosion. The Tazewell drift is better drained but still fairly youthful. Drainage systems are better developed in the Iowan drift. The erosion over much of the uplands has been so uniform that there are few gullies and the loess cover has been cut through in only a few places. Incision increases towards the Big Sioux and Missouri Rivers, however, with the valleys located some 200 feet below the general plain. From the vicinity of Sioux City southward, there are steep bluffs which are the result of a deep accumulation of loess modified by stream erosion. Here the bluffs drop sharply 200 feet and more towards the rivers (Planning and Analysis Section, Iowa Department of Environmental Quality, 1976).

Several major soil types exist in Northwest Iowa as shown in Fig. 71. In the north where the Cary and Tazewell glacial-related soils exist at the surface and in those areas only thinly covered by loess, the land is underlain by relatively impermeable materials inhibiting the downward movement of water. In the thicker loess regions, drainage varies from good to excessive in many places due to poor water-holding capability and steep slopes. Erosion problems are severe in some parts of the region due to low moisture-holding capacity, and steepness of slope. The Monona-Ida-Hamburg association soils have low moisture-holding capacity. Many of the other soil types are subject to severe erosion where steep slopes exist, but are not particularly vulnerable where the land is more level. The Galva-Primghar-Sac and the Clarion-Nicollet-Webster association in the eastern part of the region are not subject to any severe erosion hazard (Planning and Analysis

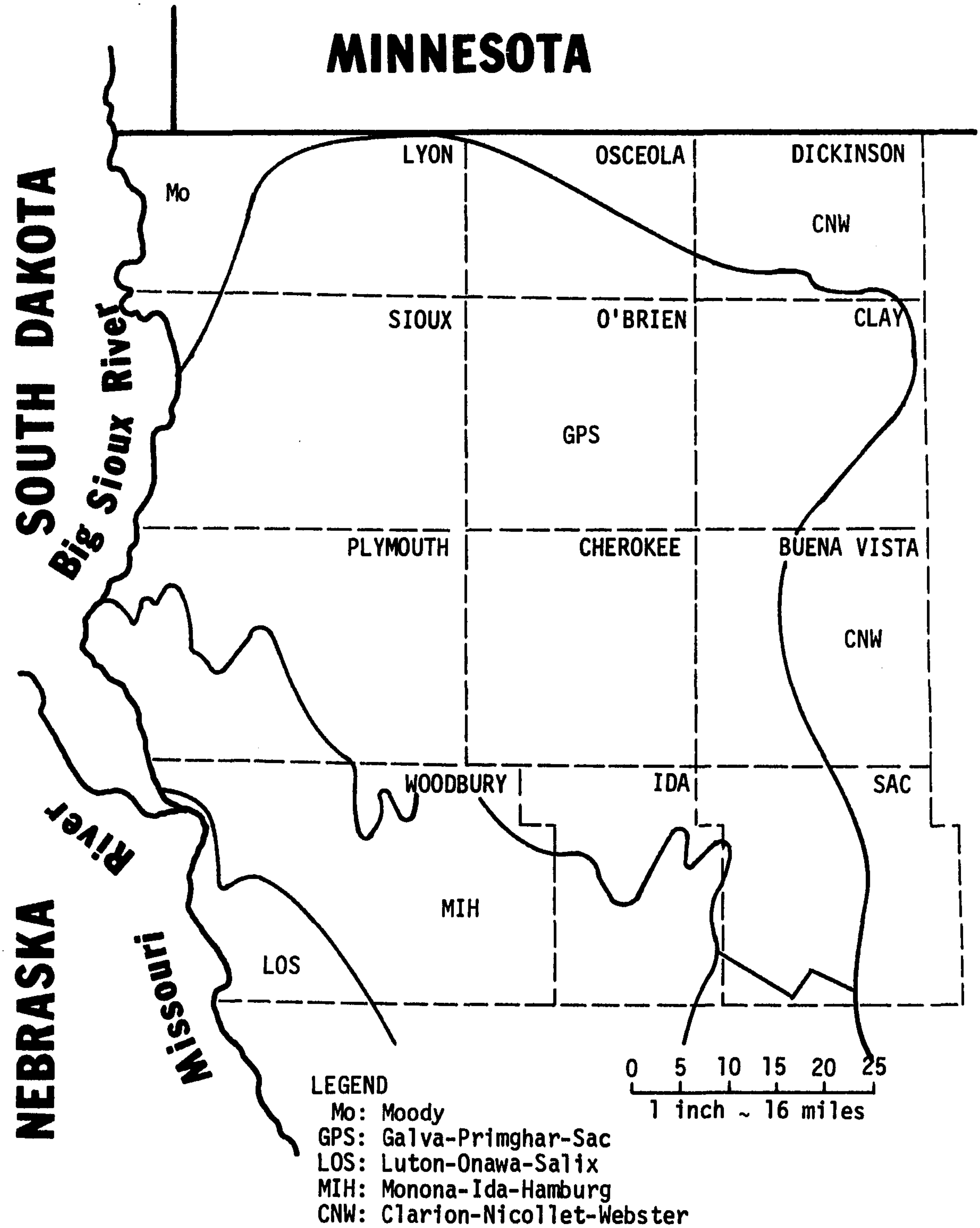


Fig. 71. Principal soil association areas in Northwest Iowa

Section, Iowa Department of Environmental Quality, 1976).

General information about the major soil types in Northwest Iowa is given in Table 106. Most of the columns are self-explanatory, but the last three need further clarification. Erosion hazard is separated into four classes: none, slight, severe and very severe. For a soil classed as subject to a severe erosion hazard, the rate of surface soil loss is estimated to be high enough that corn yields cannot be maintained or the soil "conserved" without additional erosion control practices. Soils with a slight erosion hazard require some attention to erosion control through either the cropping system or erosion control measures. Practices such as terracing and contouring may be needed on the steeper slopes in this class, especially when used intensively for row crops. Natural internal drainage is the soil characteristic related to the downward movement of excess water through the soil profile. It indicates the frequency and length of time the soil is saturated with water under natural conditions, i.e., without tile drains. Not all the water in the soil profile is available for use by plants. The upper limit of water usable by plants is called "field capacity" and the lower limit is termed the "wilting point." The difference between these two is an estimate of water available to plants and is called the available moisture content. As a general guide, it can be assumed that "very low" is less than 3 inches, "low" is 3 to 5 inches, "medium" is 6 to 9 inches and "high" is more than 9 inches of plant-available water in the top 5 feet of soil (Oschwald et al., 1965).

Table 107 lists the land use, fertility levels and corn production

Table 106. General information about the major soil types in Northwest Iowa[a]

Soil type	Slope, %		Land position	Parent material
	Typical	Range		
Moody silty clay loam	2-5	1-15	Upland ridges and side slopes	Loess
Clarion loam	2-5	2-30	Upland highs and ridges	Glacial till
Nicollet loam	1-3	0-5	Upland middle highs	Glacial till
Webster silty clay loam	0-2	0-3	Upland flats	Glacial till
Galva silty clay loam	2-5	1-15	Upland ridges and side slopes	Loess $>$ 40" thick on till
Primghar silty clay loam	1-3	0-5	Uplands	Loess $>$ 40" thick on till
Sac silty clay loam	2-5	2-14	Upland side slopes	Thin loess on till
Monona silt loam	2-5	1-30	Upland ridges and side slopes	Loess
Ida silt loam	10-20	6-30	Upland ridges and side slopes	Loess
Hamburg silt loam	30-60	30-60	Catstep slopes	Loess
Luton silty clay	0-1	0-1	Bottomland	Alluvium
Onawa silty clay	0-1	0-1	Bottomland	Alluvium
Salix silty clay loam	0-1	0-1	Bottomland	Alluvium

[a]Oschwald et al. (1965).

Table 106. Continued

Soil type	Original vegetation	Erosion hazard	Natural internal drainage	Plant-available water-holding capacity to 5 feet
Moody silty clay loam	Prairie	Slight to severe	Good	High
Clarion loam	Prairie	Slight to severe	Good	High
Nicollet loam	Prairie	Slight	Somewhat poor	High
Webster silty clay loam	Prairie	None	Poor	High
Galva silty clay loam	Prairie	Slight to moderate	Good	High
Primghar silty clay loam	Prairie	Slight	Moderately good to somewhat poor	High
Sac silty clay loam	Prairie	Severe	Good	High
Monona silt loam	Prairie	Slight to severe	Good	High
Ida silt loam	Prairie	Severe	Good	High
Hamburg silt loam	Prairie	Very severe	Good	Medium
Luton silty clay	Prairie-sedges	None	Poor to very poor	High
Onawa silty clay	Prairie, forest	None	Somewhat poor	High
Salix silty clay loam	Prairie	None	Moderately good	High

Table 107. Land use, fertility levels and corn production potentials of the major soil types in Northwest Iowa[a]

Soil type	Phase		Lime needs	Average soil test			Maximum corn use with conservation practices	Corn yield potential bu/ac[b]	Land capability class and subclass
	Slope, %	Erosion	T/ac	N	P	K			
Moody silty clay loam	2-5	1	0-3	L to M	L to M	M to H	Often	85	IIe
Moody silty clay loam	5-9	2	0-3	L	L to M	M to H	Occasionally	77	IIIe
Clarion loam	2-5	1	0-3	L to M	VL to L	L to M	Often	110	IIe
Clarion loam	5-9	2	0-3	L	VL to L	L to M	Occasionally	102	IIIe
Nicollet loam	1-3	0	0-4	L to M	VL to L	L to M	Often	118	I
Webster silty clay loam	0-2	0	0-4	L to M	VL to L	VL to M	Often	110	IIw
Galva silty clay loam	2-5	1	0-4	L to M	VL to L	M to H	Often	95	IIe
Galva silty clay loam	5-9	2	0-4	L	VL to L	M to H	Occasionally	93	IIIe
Primghar silty clay loam	1-3	0	0-4	L to M	VL to L	M to H	Often	103	I
Sac silty clay loam	2-5	1	0-4	L to M	L to M	M to H	Often	89	IIe
Sac silty clay loam	5-9	2	0-4	L	L to M	M to H	Occasionally	81	IIIe
Monona silt loam	2-5	1	0-3	L	VL to L	M to H	Often	98	IIe
Monona silt loam	5-9	2	0-3	VL to L	VL to L	M to H	Occasionally	90	IIIe
Monona silt loam	9-14	3	0	VL	VL to L	M to H	Seldom	82	IIIe
Ida silt loam	5-9	2	0(ex)	L	VL	M to H	Occasionally	83	IIIe
Ida silt loam	9-14	3	0(ex)	VL to L	VL	M to H	Seldom	68	IIIe
Ida silt loam	14-18	3	0(ex)	VL	VL	M to H	Seldom	50	IVe
Hamburg silt loam	30+	3	0(ex)	VL	VL	H	Never	0	VIIe
Luton silty clay	0-1	0	0-2	L	L to M	H	Often	65	IIIw
Onawa silty clay	0-1	0	0(ex)	L	L to M	H	Often	90	IIw
Salix silty clay loam	0-1	0	0-2	L to M	M to H	H	Often	114	I

[a]Oschwald et al. (1965).

[b]Fenton et al. (1971).

potentials of the major soil types in Northwest Iowa. Again, some of the columns need further explanation. Four erosion phases are used: 0 is slight erosion, over 12 inches of surface soil remains; 1 is slight to moderate erosion, 7 to 12 inches of surface soil remaining; 2 is moderate to severe erosion, 3 to 7 inches of surface soil remaining and includes areas of surface soils mixed with areas of exposed subsoil; 4 is severe erosion including erosion of the subsoil, less than 3 inches of surface soil remaining. The average soil tests indicate that the amounts of nitrogen (N), phosphorus (P) and potassium (K) in the soil are very low (VL), low (L), medium (M) or high (H), which will require the use of varying amounts of fertilizer to make the soil more productive. The frequency that corn may be grown is divided into four classes: never, seldom, occasionally and often. "Never" implies that the soils are best suited for permanent vegetation such as pasture or trees. "Seldom" implies planting corn not more than once every 6 years, "occasionally" means planting corn from one-fifth to two-thirds of the time and "often" over two-thirds of the time (Oschwald et al., 1965). The potential corn yields in bushels per acre were obtained from the most recent update available (Fenton et al., 1971). An explanation of the various land capability classes was previously given in Table 84.

Table 106 indicated that almost all of the soils in Northwest Iowa have high water-holding capabilities. This is shown in Table 108 which lists the plant-available water and the average, maximum and minimum June 1 soil moistures to a depth of 5 feet for various soil types located in and around Northwest Iowa. These data were obtained from Special Report No. 70 of the Cooperative Extension Service at

Table 108. Plant-available water and June 1 soil moistures to 5 feet for various soil types in and around Northwest Iowa, inches[a]

Location	Soil type	Available water[b]	June 1 soil moisture[b] Average	Maximum	Minimum
Doon	Moody S.L.	10.5	5.2	9.6	1.5
Le Mars	Galva S.L.	8.8	6.4	8.8	2.8
Castana	Ida S.L.	10.0	6.8	10.0	1.4
Sutherland	Galva S.L.	11.9	6.7	11.9	0.4
Primghar	Primghar S.L.	10.7	6.4	10.7	0.4
Denison	Monona S.L.	11.7	8.4	11.6	2.1
Estherville	Nicollet L.	9.3	7.7	9.2	3.5
Storm Lake	Webster S.C.L.	10.2	7.6	9.4	4.2
Kanawha	Webster S.C.L.	10.2	8.0	10.2	5.9
Blairsburg	Nicollet S.C.L.	10.4	8.5	10.1	4.5
Average		10.4	6.5	(NW Iowa only)	

[a]Shaw et al. (1972).

[b]Total soil moisture to a depth of 5 feet.

Iowa State University (Shaw et al., 1972). The average values of 10.4 inches of available water and 6.4 inches of soil moisture on June 1 indicate a good potential for crop production as long as this soil moisture is replaced, as it is utilized by the crops, by adequate rainfall and/or irrigation water.

Crops and Livestock

As noted previously, land use in Northwest Iowa is dominated by agricultural uses. Most of the crop acreage is devoted to corn and soybeans while cattle and hogs account for the vast majority of the livestock marketed from the region. Tables H-1 through H-16 in

Appendix H indicate for each of the 12 counties in Northwest Iowa the number of acres and yields in bushels per acre of corn and soybeans, the acres of hay and pasture and the number of cattle and hogs marketed during the period 1952 through 1977. These data were obtained from the Iowa Annual Farm Census as compiled by the Iowa Crop and Livestock Reporting Service (Iowa Department of Agriculture, 1952-1973).

Table 109 is a sample of the above data for a single county, Cherokee County, at various times during the entire period. The trends in Cherokee County are typical of those for this region of Iowa. Corn acreage has tended to fluctuate widely but always within some defined range. Corn yields have risen steadily during the entire period, pausing recently as the effects of the drought have been felt. Soybean acreage has generally quadrupled during the past 25 years. Soybean yields have also increased but at a slower pace than corn yields. The increase in soybean acreage has been at the expense of hay and pasture acreage, both of which declined during this period. The number of cattle marketed each year has generally doubled or quadrupled during the past 25 years, fluctuating yearly as the demand rises and falls. The number of hogs sent to market each year shows why Iowa has long been a leader in pork production in the United States. In 1976 this region of Iowa alone sent over 2,200,000 hogs to market with two counties, Plymouth and Sioux Counties, each marketing over 400,000 hogs.

Because Northwest Iowa has less rainfall than the rest of the state, corn and soybean yields tend to be lower in this region than

Table 109. Changes in acreages and yields of corn, soybeans, hay and pasture and numbers of cattle and hogs marketed in Cherokee County from 1952 through 1975

Item unit	1952	1960	1968	1975
Corn acres	119,993	145,096	106,918	141,598
Corn yields bushels per acre	66.5	70.9	89.4	91.1
Soybeans acres	22,218	29,588	65,530	75,825
Soybean yields bushels per acre	28.1	29.9	28.3	38.1
Hay acres	36,124	31,140	19,598	15,733
Pasture acres	79,935	68,891	65,122	57,906
Cattle numbers	41,562	87,714	114,098	93,368
Hog numbers	—[a]	—	223,933	200,787

[a]Data not available.

the state average. This is shown in Tables 110 and 111 which list the corn and soybean yields, respectively, for the region and state from 1952 through 1977. There is also much variability in corn yields from year to year. State yields ranged from 48.4 bushels per acre in 1955 to 110.6 in 1972. In the region they ranged from 36.9 bushels of corn per acre in 1956 to 110.2 in 1972. Soybean yields in Iowa as a state average ranged from 19.8 bushels per acre in 1955 to 35.9 in 1972. In

Table 110. Variation in corn yields in bushels per acre from 1952 through 1977 in the state and northwest region of Iowa

Year	State average	Regional average	High yield Amount	High yield County	Low yield Amount	Low yield County
1952	62.2	61.1	66.6	Ida, Sac	51.7	Lyon
1953	52.9	55.0	61.7	O'Brien	46.7	Woodbury
1954	53.9	57.6	62.2	Cherokee	44.0	Woodbury
1955	48.4	44.7	54.2	O'Brien	31.0	Woodbury
1956	52.8	36.9	56.7	Osceola	19.1	Plymouth
1957	62.1	58.9	65.3	Cherokee	55.2	Plymouth
1958	66.0	55.7	70.5	Sac	42.4	Lyon
1959	64.2	57.4	69.1	Buena Vista	40.3	Dickinson
1960	63.2	66.1	76.9	Sac	50.8	Plymouth
1961	75.4	74.1	83.0	Buena Vista	64.6	Lyon
1962	77.1	75.0	83.7	Ida	63.2	Dickinson
1963	81.1	72.8	82.7	Buena Vista	56.4	Sioux
1964	78.7	75.0	85.6	Sac	63.9	Plymouth
1965	82.3	71.2	84.0	Sioux	57.6	Dickinson
1966	89.0	84.5	90.6	Ida	71.8	Lyon
1967	88.6	81.2	93.5	Buena Vista	72.5	Dickinson
1968	92.3	79.8	102.0	Buena Vista	59.0	Woodbury
1969	97.6	102.8	116.9	O'Brien	89.4	Plymouth
1970	85.8	68.9	90.2	Dickinson	51.4	Lyon
1971	99.8	93.1	103.0	Buena Vista	83.0	Plymouth
1972	110.6	110.2	117.0	O'Brien	105.0	Dickinson
1973	103.9	105.2	120.1	O'Brien	95.3	Plymouth
1974	77.7	70.2	90.8	Buena Vista	47.1	Lyon
1975	86.2	85.3	97.6	Buena Vista	65.3	Plymouth
1976	91.4	67.8	91.7	O'Brien	52.8	Plymouth
1977	88.0	103.8	118.5	Buena Vista	88.2	Sac

the region, soybean yields have ranged from 14.0 bushels per acre in 1956 to 37.5 in 1972.

This variability in yields is also evident in the region, not only from year to year but within any one year. Tables 110 and 111 indicate this quite clearly. During the drought year of 1956, Osceola County yielded 56.7 bushels of corn per acre while Plymouth County produced only 19.1 bushels per acre. During 1974, the beginning of the next drought, the difference was even greater: Buena Vista

Table 111. Variation in soybean yields in bushels per acre from 1952 through 1977 in the state and northwest region of Iowa

Year	State average	Regional average	High yield		Low yield	
			Amount	County	Amount	County
1952	25.3	24.0	28.2	Ida	18.9	Dickinson
1953	21.4	22.8	27.9	Cherokee	16.1	Woodbury
1954	26.0	27.0	30.2	Cherokee	20.3	Woodbury
1955	19.8	18.2	21.0	Cherokee	12.2	Woodbury
1956	19.9	14.0	20.1	Clay	7.3	Plymouth
1957	26.7	26.6	29.3	Cherokee	23.1	Dickinson
1958	25.1	22.0	26.9	Ida	17.7	Lyon
1959	26.1	25.4	30.3	Buena Vista	19.5	Woodbury
1960	25.7	26.8	29.9	Cherokee	22.9	Dickinson
1961	28.5	28.7	33.0	Sac	23.3	Dickinson
1962	27.4	27.6	30.3	Cherokee	21.1	Woodbury
1963	30.4	30.0	33.0	Ida	26.9	Woodbury
1964	28.5	28.7	32.5	Sac	24.9	Osceola
1965	26.1	23.8	27.3	Sioux	19.2	Dickinson
1966	29.3	30.2	32.7	Cherokee	26.5	Lyon
1967	27.4	26.2	31.1	Sac	19.4	Dickinson
1968	31.7	24.4	33.2	Buena Vista	18.9	Lyon
1969	32.3	33.2	37.5	O'Brien	30.0	Buena Vista
1970	32.5	25.9	29.2	Dickinson	20.7	Lyon
1971	32.3	30.6	35.0	O'Brien	27.0	Woodbury
1972	35.9	37.5	42.0	O'Brien	34.0	Woodbury
1973	33.9	35.9	40.1	O'Brien	31.2	Woodbury
1974	27.2	29.0	32.5	Plymouth	23.6	Osceola
1975	32.8	35.5	38.1	Cherokee	31.1	Dickinson
1976	30.7	28.5	33.9	O'Brien	24.8	Woodbury
1977						

County produced 90.8 bushels of corn per acre while Lyon County could only manage 47.1. While the differences in soybean yields between counties were not as great as they were for corn, they still existed. In 1956 Clay County yielded 20.1 bushels per acre, Plymouth County only 7.3. In 1968 Buena Vista County produced 33.2 bushels of soybeans per acre while Lyon County could only manage 18.9 bushels per acre.

The variations in corn and soybean yields for each year from

1952 through 1977 between the region and the state and within the region are shown in Table 112. Regional corn yields for the period averaged 4.5 bushels per acre less than the state average while regional soybean yields averaged only 0.8 bushels per acre less than the state average. The greatest variation occurred during the recent drought. The drought peaked in Northwest Iowa in 1976 and so the regional average corn yield was 23.6 bushels per acre less than the state. Overall the state suffered the worst stress in 1977 while Northwest Iowa enjoyed good rainfall at critical times; thus in 1977 the regional average was 15.8 bushels of corn per acre higher than the state average.

Within the region itself, the average variability in yield for the 26-yr period was 25.6 bushels of corn per acre and was 9.0 bushels per acre for soybeans. The variability in corn yield was greater than 30 bushels per acre in 7 of the years and was greater than 20 bushels per acre in 19 of the 26 years.

However, while this variability persisted each year during this 26-yr period, the average yields of corn and soybeans showed steady improvement. This is shown in Table 113 which lists the 5-year moving averages for corn and soybeans in Northwest Iowa and the state from 1952 through 1977. This steady increase in yields is portrayed much more vividly in Fig. 72. Here the persistent climb is quite evident, broken only by the drought which occurred in the middle 1970's. During this period the 5-yr average corn yield in the state almost doubled, increasing from 54.0 to 99.5 bushels per acre. Soybean yields in the state rose at a slower pace, increasing from 22.5 to 33.4 bushels per

Table 112. Variation of average corn and soybean yields in bushels per acre between Northwest Iowa and the state from 1952 through 1977

Year	Corn: Region − state	Corn: Range in region	Soybeans: Region − state	Soybeans: Range in region
1952	- 1.1	14.9	- 1.3	9.3
1953	2.1	15.0	1.4	11.8
1954	3.7	18.2	1.0	9.9
1955	- 3.7	23.2	- 1.6	8.8
1956	- 15.9	37.6	- 5.9	12.8
1957	- 3.2	10.1	- 0.1	6.2
1958	- 10.3	28.1	- 3.1	9.2
1959	- 6.8	28.8	- 0.7	10.8
1960	2.9	26.1	1.1	7.0
1961	- 1.3	18.4	0.2	9.7
1962	- 2.1	20.5	0.2	9.2
1963	- 8.3	26.3	- 0.4	6.1
1964	- 3.7	21.7	0.2	7.6
1965	- 11.1	26.4	- 2.3	8.1
1966	- 4.5	18.8	0.9	6.2
1967	- 7.4	21.0	- 1.2	11.7
1968	- 12.5	43.0	- 7.3	14.3
1969	5.2	27.5	0.9	7.5
1970	- 16.9	38.8	- 6.6	8.5
1971	- 6.7	20.0	- 1.7	8.0
1972	- 0.4	12.0	1.6	8.0
1973	1.3	24.8	2.0	8.9
1974	- 7.5	43.7	1.8	8.9
1975	- 0.9	32.3	2.7	7.0
1976	- 23.6	38.9	- 2.2	9.1
1977	15.8	30.3	—	—
Average	- 4.5	25.6	- 0.8	9.0

acre. Regional corn yields also increased but in any one year were always less than the state yield. Soybean yields in the region were closer to the state yield and in four instances the regional 5-year average yield was greater than the state average.

To determine if there was any consistency in the variability of

Table 113. Five-year moving averages for corn and soybeans in Northwest Iowa and the state from 1952 through 1977[a]

Year	Corn		Soybeans	
	State	Region	State	Region
1954	54.0	51.1	22.5	21.2
1955	54.0	50.6	22.8	21.7
1956	56.6	50.8	23.8	21.6
1957	58.7	50.7	23.5	21.2
1958	61.7	55.0	24.7	23.0
1959	66.2	62.4	26.4	25.9
1960	69.2	65.7	26.6	26.1
1961	72.2	69.1	27.6	27.7
1962	75.1	72.6	28.1	28.4
1963	78.9	73.6	28.2	27.8
1964	81.6	75.7	28.3	28.1
1965	83.9	76.9	28.3	27.8
1966	86.2	78.3	28.6	26.7
1967	90.0	83.9	29.4	27.6
1968	90.7	83.4	30.6	28.0
1969	92.8	85.2	31.2	28.1
1970	97.2	91.0	32.9	30.3
1971	99.5	96.0	33.4	32.6
1972	95.6	89.5	32.4	31.8
1973	95.6	92.8	32.4	33.7
1974	94.0	87.7	32.1	33.3
1975	89.4	86.5	–	–

[a]5-yr average listed at middle of period.

yields, the data contained in Tables 110 and 111 were used to develop Figs. 73 and 74, high and low corn and soybean yields, respectively, in Northwest Iowa for the period 1952 through 1977. These figures show that for both corn and soybeans the western and northern tiers of counties consistently had the lowest yields in the region while the six counties grouped in the southeastern corner of the region always had the highest yields.

This consistency was checked by calculating the average corn and

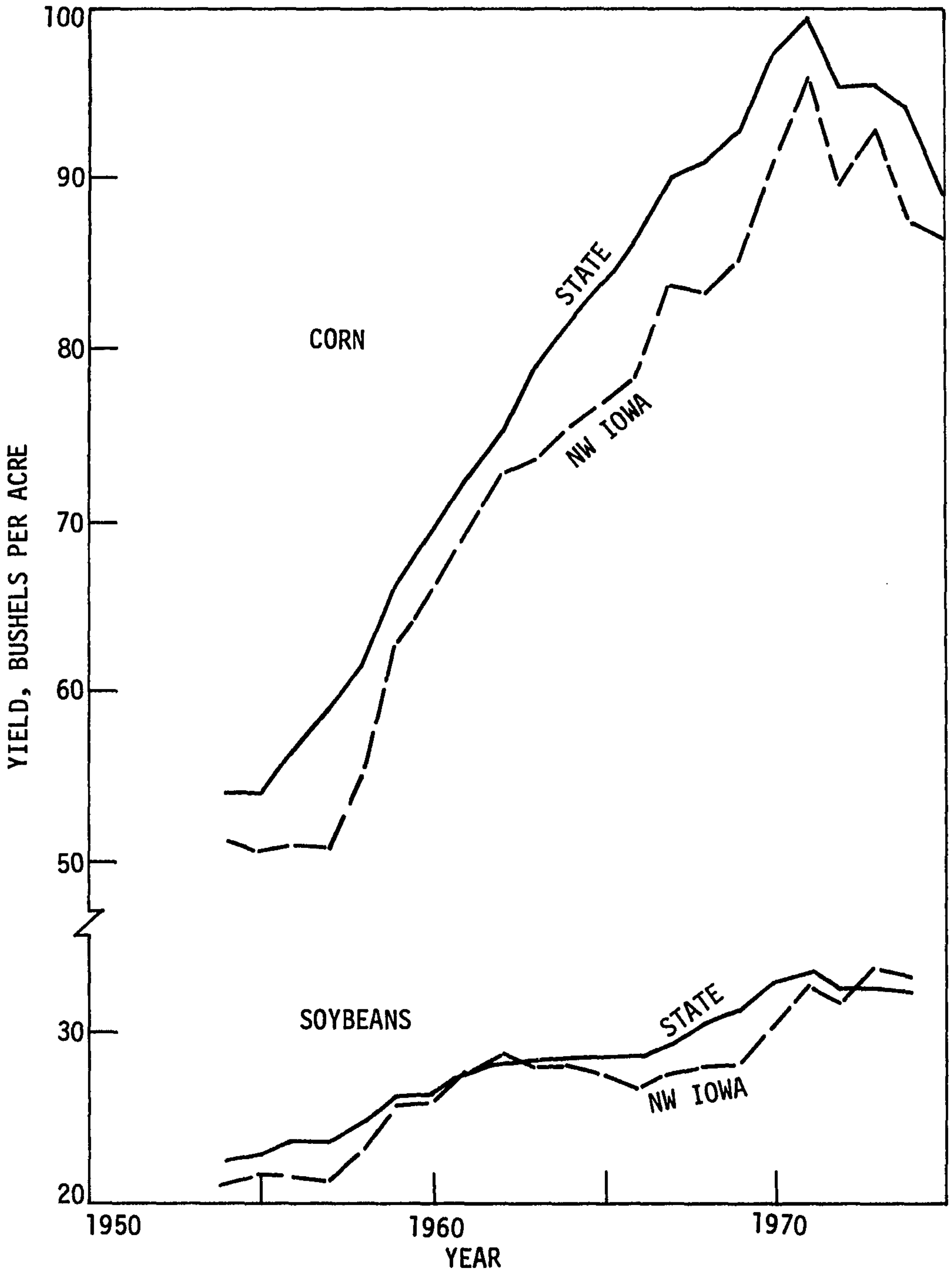


Fig. 72. Five-year moving averages for corn and soybeans in Northwest Iowa and the state from 1952 through 1977

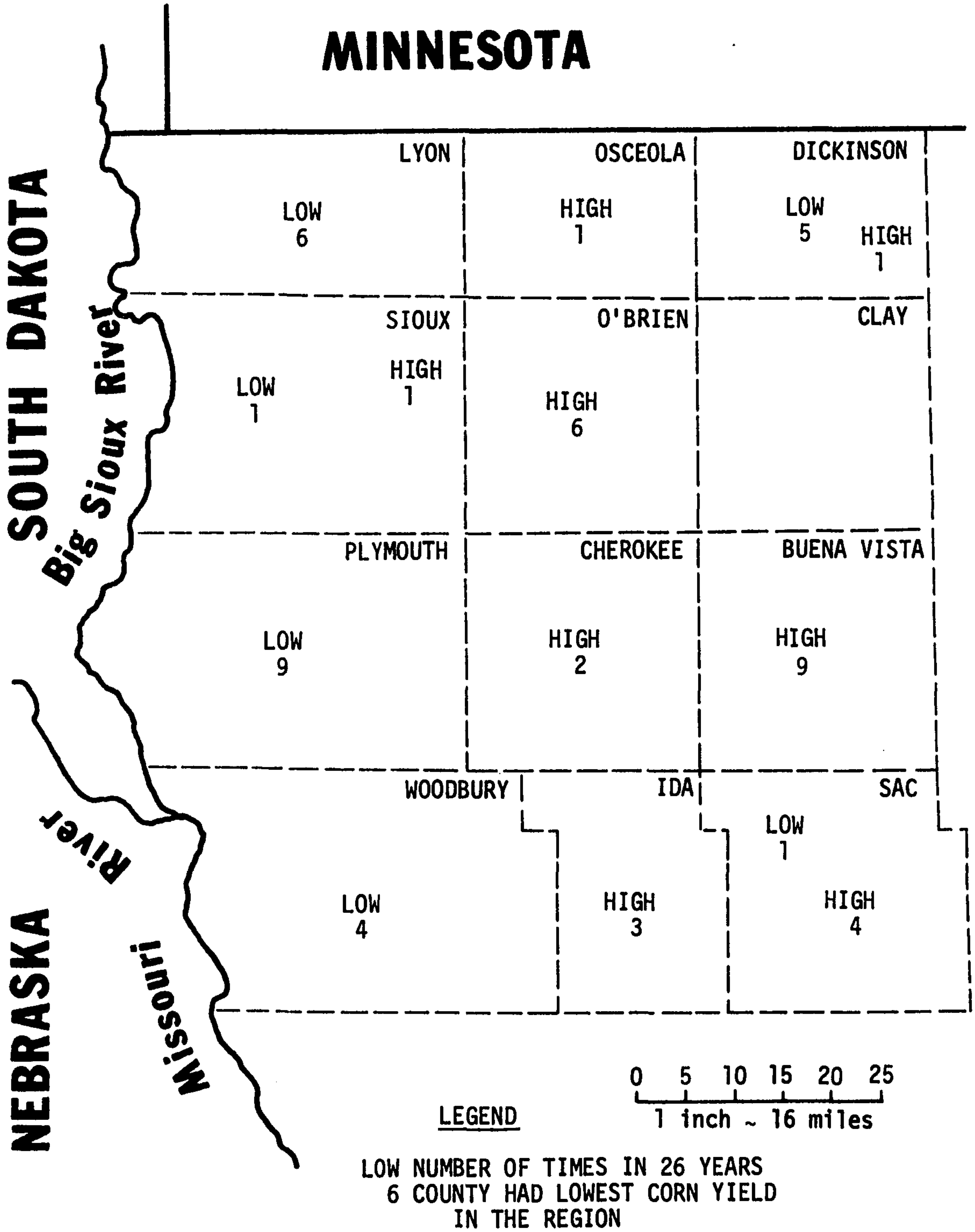


Fig. 73. High and low corn yields in Northwest Iowa from 1952 through 1977

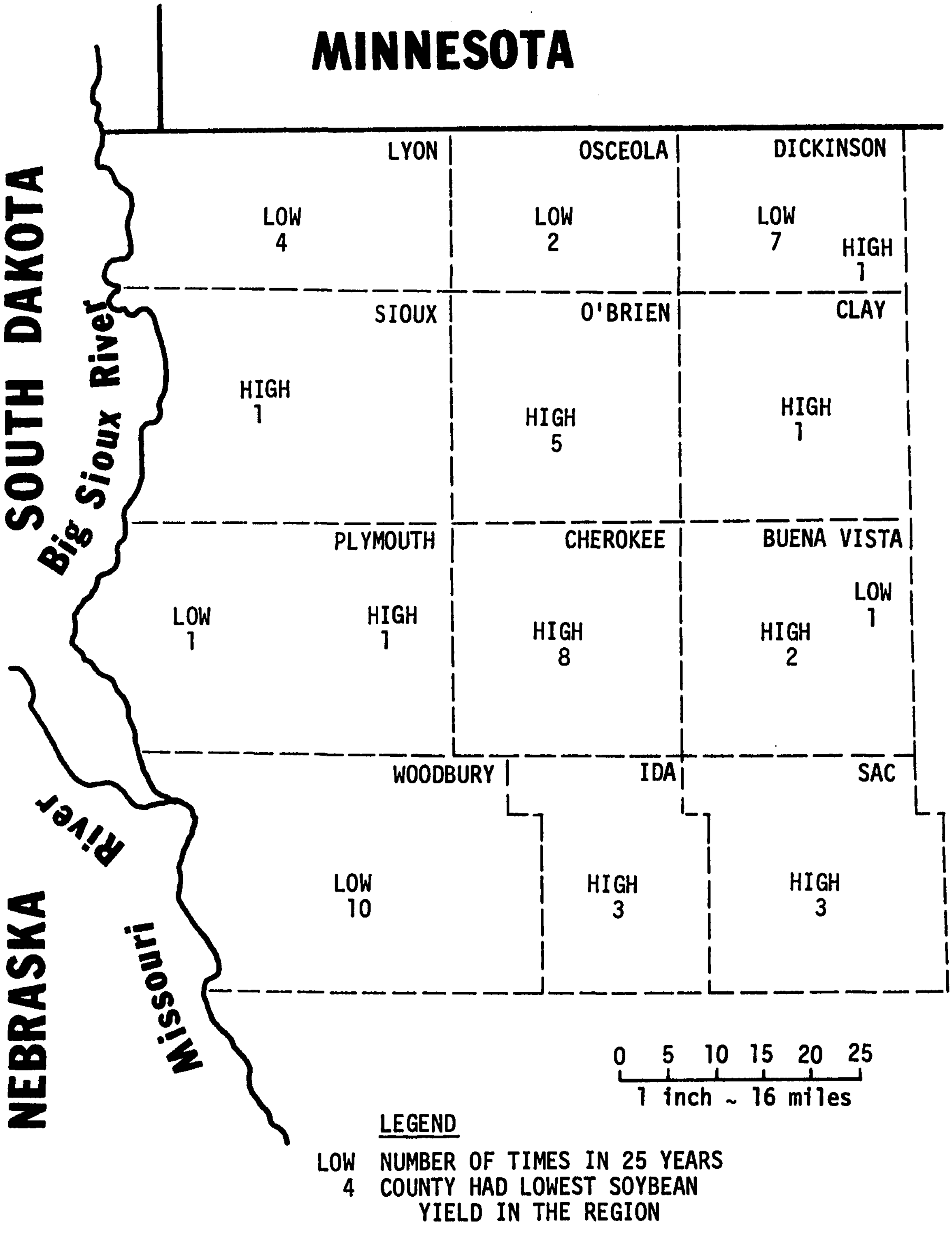


Fig. 74. High and low soybean yields in Northwest Iowa from 1952 through 1976

soybean yields for the 26-year period and then ranking them from high to low as shown in Table 114. These rankings and average yields are plotted in Figs. 75 and 76 for corn and soybeans, respectively. These two figures indicate exactly the same results as before: the western and northern tiers of counties have the lowest yields for both corn and soybeans and the southeastern group of six counties have the highest yields.

Table 114. Average corn and soybean yields in bushels per acre and rank of counties in Northwest Iowa for the period 1952 through 1977[a]

	Corn		Soybeans	
Rank	Yield	County	Yield	County
1	80.7	Buena Vista	29.6	Cherokee
2	79.1	O'Brien	29.1	O'Brien
3	77.7	Clay	28.7	Buena Vista
4	77.5	Cherokee	28.7	Sac
5	76.6	Ida	28.6	Ida
6	76.6	Sac	27.8	Clay
7	73.9	Osceola	27.7	Sioux
8	72.4	Dickinson	26.9	Plymouth
9	69.8	Sioux	25.9	Osceola
10	67.3	Woodbury	25.8	Lyon
11	66.2	Lyon	24.1	Dickinson
12	65.7	Plymouth	24.0	Woodbury

[a]Note: Average state yields for this same period were 78.1 and 27.7 bushels per acre for corn and soybeans, respectively.

In order to determine if these rankings held true for the most recent period of record, the average corn and soybean yields for each county in Northwest Iowa were calculated for the period 1970 through 1977 and then ranked high to low. These rankings and average yields are shown in Table 115. For corn the southeastern group of six

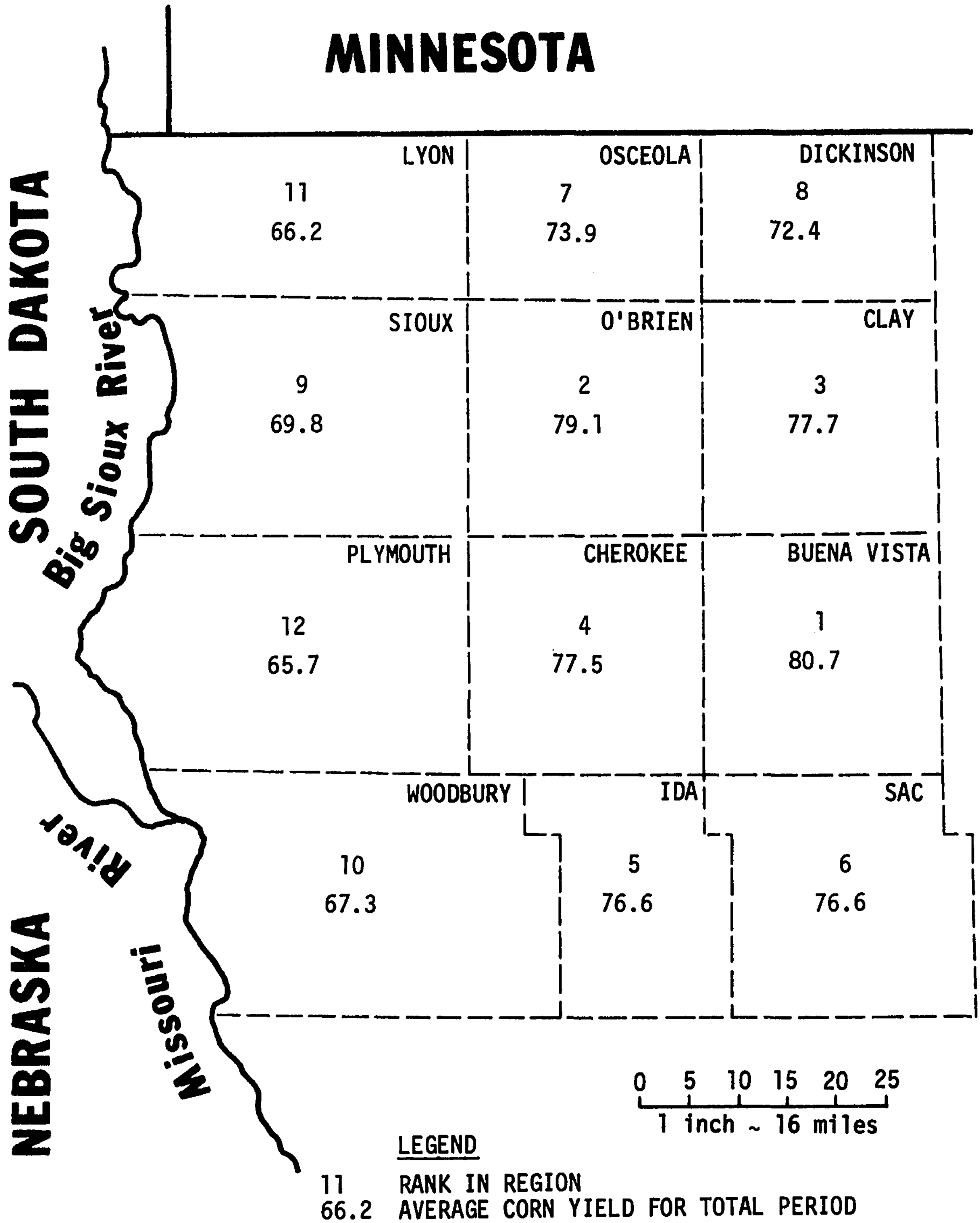


Fig. 75. Average corn yields in bushels per acre and rank of counties in Northwest Iowa for the period 1952 through 1977

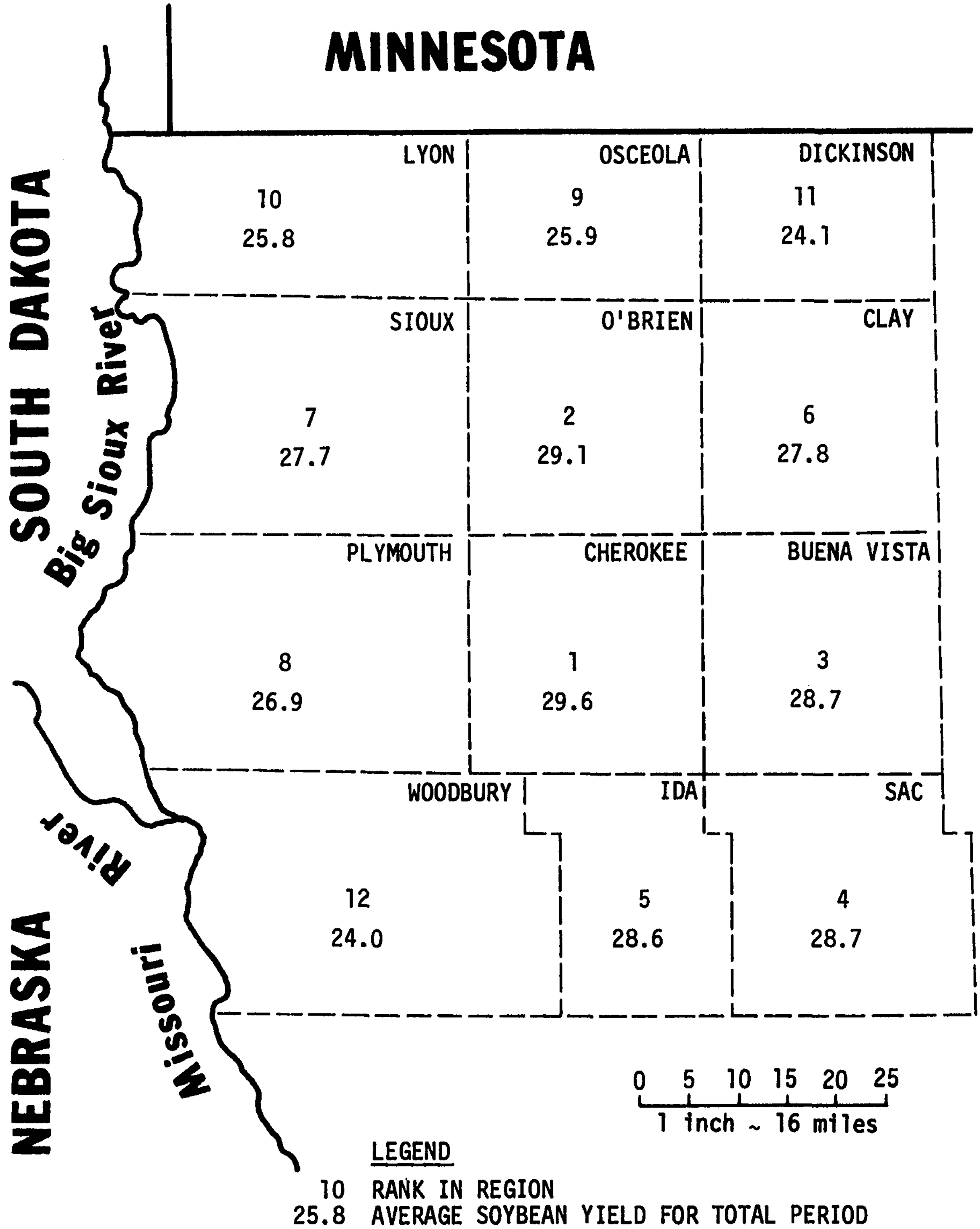


Fig. 76. Average soybean yields in bushels per acre and rank of counties in Northwest Iowa for the period 1952 through 1976

Table 115. Average corn and soybean yields in bushels per acre and rank of counties in Northwest Iowa for the period 1970 through 1977[a]

	Corn		Soybeans	
Rank	Yield	County	Yield	County
1	99.0	O'Brien	34.9	O'Brien
2	98.9	Buena Vista	33.5	Cherokee
3	95.8	Clay	32.9	Sioux
4	93.2	Cherokee	32.7	Buena Vista
5	90.8	Ida	32.4	Clay
6	90.2	Osceola	32.2	Ida
7	88.2	Dickinson	31.7	Osceola
8	85.9	Sac	31.1	Plymouth
9	81.3	Woodbury	30.9	Lyon
10	80.6	Sioux	30.7	Sac
11	76.6	Plymouth	30.6	Dickinson
12	76.1	Lyon	28.5	Woodbury

[a]Note: Average state yields for this same period were 92.9 and 32.2 bushels per acre for corn and soybeans, respectively.

counties again had the highest yields with the exception of Sac County which fell to eighth place, probably due to being particularly hard hit by the drought. The same grouping was also true for soybean yields, again with the exception of Sac County which fell to tenth place.

A similar ranking of the counties was made for cattle and hog production. This was done by calculating the average number of cattle and hogs marketed from each county for the 10-yr period from 1967 through 1976. The results of these calculations are shown in Table 116. Sioux County ranked first in number of cattle marketed and second in hog production while Plymouth County ranked first in hog production and second in number of cattle sent to market. Sac County ranked third in cattle marketed and fourth in hog production. Four counties averaged over 100,000 cattle sent to market annually while eight

Table 116. Average number of cattle and hogs marketed annually and rank of counties in Northwest Iowa for the period 1967 through 1976

	Cattle		Hogs	
Rank	Number	County	Number	County
1	236,420	Sioux	396,390	Plymouth
2	131,470	Plymouth	389,790	Sioux
3	108,820	Sac	241,330	Buena Vista
4	102,640	Cherokee	230,990	Sac
5	98,780	Lyon	228,130	O'Brien
6	92,720	O'Brien	226,370	Woodbury
7	91,960	Woodbury	213,740	Cherokee
8	77,980	Ida	207,180	Lyon
9	55,640	Clay	170,550	Ida
10	50,540	Osceola	129,410	Clay
11	48,580	Buena Vista	111,980	Osceola
12	30,310	Dickinson	80,080	Dickinson

counties sent over 200,000 hogs to market annually during the 10-yr period. In total these 12 counties averaged over 1.1 million cattle and over 2.6 million hogs sent to market annually during this 10-yr period.

As shown in Tables 75 and 76, the economic health of Northwest Iowa is highly dependent on the economic health of the region's farmers. If they can sell their crops at prices which give them a reasonable return on their investment, then the farmers will prosper as well as those who sell the farmers the inputs they need and those who process the farmers' outputs. Table 117 develops estimates for corn and soybean production costs in 1977. These costs range from $201 to $234 per acre for corn and from $154 to $181 per acre for soybeans depending on whether the acquisition or current cost of land is used,

Table 117. Estimated 1977 corn and soybean production costs, dollars per planted acre[a]

Cost item	Corn	Soybeans
Variable – subtotal	$ 88.49	$ 42.93
Seed	9.52	6.40
Fertilizer	30.90	2.67
Lime	0.85	0.47
Chemicals	13.74	9.84
Custom operations	4.91	2.44
All labor	8.66	8.68
Fuel and lubrication	5.19	5.45
Repairs	6.24	5.68
Drying	5.54	0.05
Interest	2.94	1.25
Machinery ownership – subtotal	24.93	22.82
Replacement	16.15	15.09
Interest	6.48	6.08
Taxes and insurance	1.76	1.65
General farm overhead	9.61	6.50
Management	13.74	12.56
Total – excluding land	136.23	84.81
Land – current cost	97.38	96.39
acquisition cost	65.24	69.18
Grant total – w/current	233.61	181.20
w/acquisition	201.47	153.99

[a]Iowa Crop and Livestock Reporting Service (1977).

respectively. Table 118 then lists the breakeven yields for several prices of unirrigated corn and soybeans.

Table 118. Breakeven point for unirrigated corn and soybean production based on 1977 estimated costs[a]

Corn			Soybeans		
Price $	Low[b] bu/ac	High[c] bu/ac	Price $	Low[b] bu/ac	High[c] bu/ac
1.80	112	130	4.00	38.5	45.3
2.00	101	117	5.00	30.8	36.3
2.20	92	106	6.00	25.7	30.2
2.40	85	97	7.00	22.0	25.9
2.60	77	90	8.00	19.2	22.7
2.80	72	83	9.00	17.1	20.1
3.00	67	78	10.00	15.4	18.1

[a]Iowa Crop and Livestock Reporting Service (1977).

[b]Based on total costs with land included at acquisition cost.

[c]Based on total costs with land included at current cost.

Corn and Soybean Yields at Experimental Farms

In the mid-1950's two experimental farms were obtained by Iowa State University in Northwest Iowa. One is a 40-acre farm in Lyon County, located 9 miles south of Rock Rapids on U.S. Highway No. 75. The soil is all Moody silt loam except for a small area, is quite permeable and has slopes ranging from 2 to 5%. The other farm is an 80-acre tract in O'Brien County, located near Sutherland on the Sutherland-Hartley blacktop road. Table 119 lists the various soil types and depths of loess found on this farm. The slopes also range from 2 to 5%.

No attempt was made to determine the average annual yields at these two farms since they both are involved in conducting continuous

Table 119. Acreages of the various soil types and depth of loess found on the Sutherland experimental farm in O'Brien County

Soil type	Acres	Inches of loess
Primghar silt loam	33	40 to 80
Galva silt loam	27	> 36
Sac silt loam	10	10 to 36
Marcus silty clay loam	6	None

tests and experiments on such variables as seed variety, tillage treatment, plant population, planting date, level of fertilizer application, pesticide treatment and herbicide treatment. However, the annual reports of the experimental farms (Vogel, 1957-1977) were searched to determine the maximum corn and soybean yields obtained each year since this would give us an idea of the soil's capabilities. The results of this search are shown in Table 120. The maximum yields obtained at the Doon farm during the 21-yr period of record (1957-1977) were 159 bushels of corn per acre and 61 bushels of soybeans per acre. Maximum yields at the Sutherland farm during this same period were 163 bushels of corn per acre and 62 bushels of soybeans per acre.

The total rainfall during the growing season (April through October) at each farm is also shown in Table 120. Comparison of these amounts with the corn yields listed for each year is shown in Fig. 77. The large scatter indicates that the 7-month rainfall total is not a good variable to use as a predictor of corn yield. For example, at the Doon farm in 1968, rainfall was over 3 inches above normal but the yield was the lowest on record. This year had been

Table 120. Maximum corn and soybean yields with growing season rainfall at the Doon and Sutherland experimental farms in Northwest Iowa from 1957 through 1977

	Doon: Moody soil			Sutherland: Galva-Primghar soil		
	Yield, bu/ac		Rain, in.[a]	Yield, bu/ac		Rain, in.[b]
Year	Corn	Soybeans		Corn	Soybeans	
1957	94	37.5	25.22	110	46.8	27.55
1958	66	29.0	10.76	84	33.2	10.85
1959	82	25.8	24.77	107	41.5	28.42
1960	122	30.6	27.55	121	38.1	22.56
1961	90	31.7	20.50	147	40.9	19.52
1962	89	34.7	20.92	128	38.9	26.26
1963	86	39.7	14.79	139	51.1	18.09
1964	116	36.2	28.01	120	32.6	24.55
1965	116	43.7	28.18	106	25.5	24.29
1966	103	31.8	16.90	136	32.4	15.11
1967	70	25.3	15.93	121	35.5	17.26
1968	50	Low	23.98	85	24.2	25.29
1969	159	43.2	18.71	163	55.7	25.25
1970	61	23.3	16.74	112	40.1	19.33
1971	84	33.3	18.51	152	52.0	22.14
1972	148	56.0	26.51	150	54.0	22.27
1973	151	52.2	22.17	150	48.0	28.56
1974	100	42.2	15.82	143	46.2	19.52
1975	111	48.0	21.71	153	49.9	26.34
1976	76	39.3	10.08	140	44.0	12.24
1977	124	61.1	27.23	154	62.0	23.70

[a]Rainfall from April 1 through October 31. Normal rainfall at Inwood for this period is 20.6 inches.

[b]Rainfall from April 1 through October 31. Normal rainfall at Primghar for this period is 23.6 inches.

preceeded by two years of below average rainfall and a note in the annual report for 1968 indicates that rainfall was below average until mid-August. Thus rainfall in the latter part of August and in September and October must have been above average to bring the season average to 3 inches above average. In 1969 rainfall at Doon was almost 2

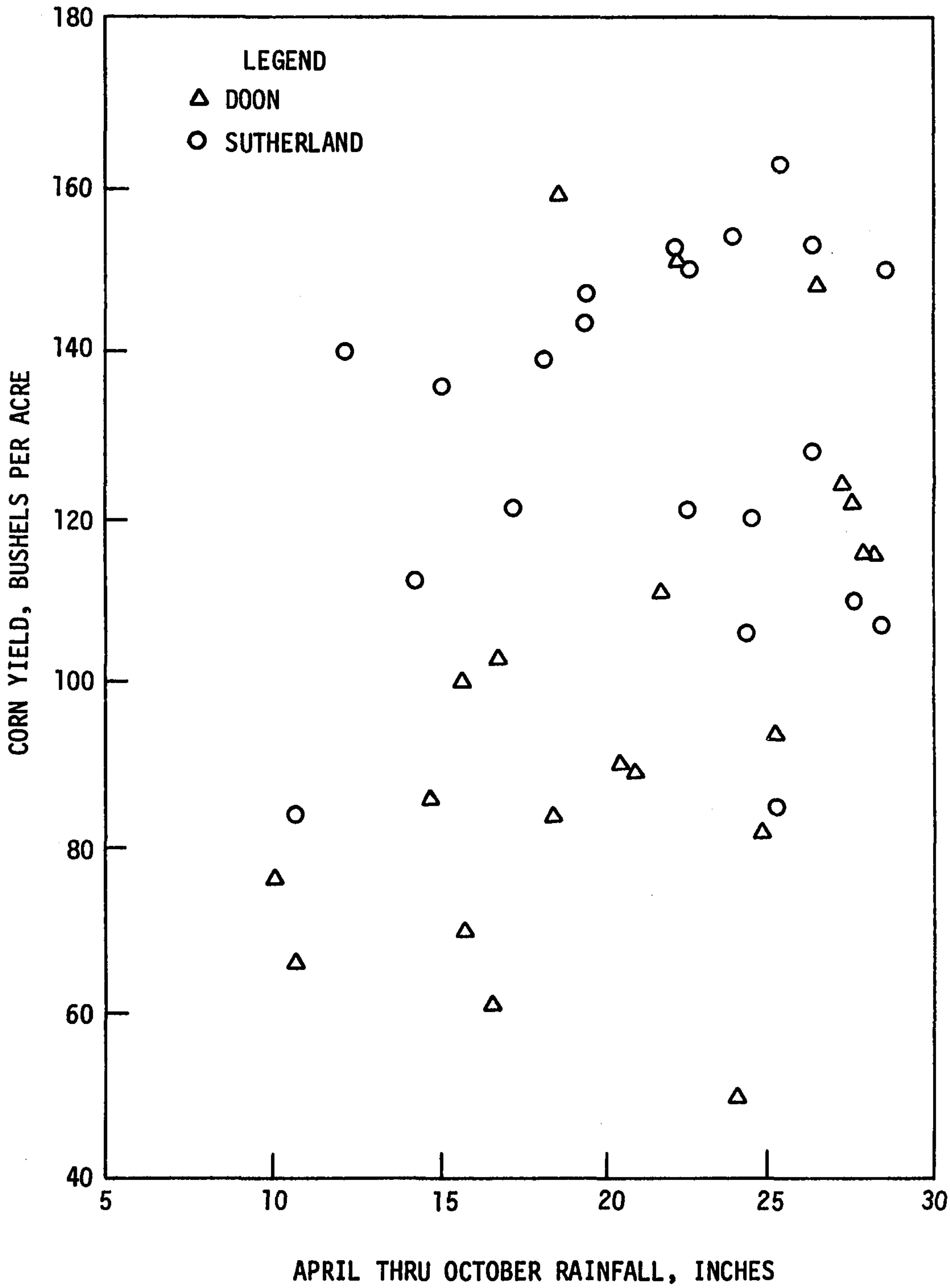


Fig. 77. Comparison of corn yield with April through October rainfall at the Doon and Sutherland experimental farms in Northwest Iowa from 1957 through 1977

inches below normal but the highest yield on record was obtained. This was due to above average soil moisture at planting and rainfall occurring when needed during the growing season. In 1976 rainfall at the Sutherland farm was almost 11 inches below normal, but a respectable yield was obtained. A note in the 1976 annual report indicates that the soil moisture at planting was above normal, all soil moisture was used to meet plant needs during the critical silking and grain filling period and soil moisture below the five foot level was used.

The 1972 annual report contained an interesting table which showed corn yield as a function of soil moisture at planting. These data are shown in Table 121. The effect of soil moisture at planting on corn yield is obvious. The other principal weather variables which affect corn yields are the monthly rainfalls during the growing season and the number of days above 90°F.

Table 121. Variation in corn yield with soil moisture available at planting at the Doon farm from 1958 through 1972

Soil moisture available at planting, inches	Number of observations	Corn yields, bushels/acre		
		High	Low	Average
0.0-2.0	9	51	0	25
2.1-4.0	19	114	0	62
4.1-6.0	8	140	46	96
> 6.0	9	159	99	121

Based on the yields obtained at the Doon and Sutherland experimental farms, the long-term average corn yield in Northwest Iowa could be 185 bushels per acre with irrigation in 1980 on the better soils. Preplanting irrigation could be used to bring soil moisture to 70 or 80% of field capacity. Further irrigation during the growing season could maintain these soil moisture levels so that stress would be minimized. However, since the irrigation systems may not be able to respond quickly enough to eliminate stress from all parts of all fields, farm management may not be as good as it should be and since hail damage, late and early frosts and pest damage will continue, the long-term average county corn yield in Northwest Iowa with irrigation will more likely be about 165 bushels per acre in 1980 on the better soils.

Table 122 indicates the increase in yields which might be expected in Northwest Iowa with irrigated corn on all land capability classes (LCC) when compared with the most recent 10-yr average corn yield (1968-1977). This increase in yields ranges from 61.7 to 75.6 bushels per acre with an average of 67.3 bushels. Assuming that an increase of 40 to 45 bushels per acre (at $2.00 per bushel) is needed to make irrigation profitable, then irrigation would be profitable in all counties. The percentage increase in yields ranges from 69 to 86 with an average increase of 76. One interesting item of information to be gleaned from Table 122 is that the four counties which form the western border of Iowa, Lyon, Sioux, Plymouth and Woodbury Counties, show the largest percentage increases in yield ranging from 77% to 81% with an average increase of 79.5%.

The implications of these increases are far reaching. We might simply be satisfied with the 76% increase in yield and accept the increase in regional income since the small increase in total national

Table 122. Comparison of potential irrigated corn yields in Northwest Iowa with 10-yr (1968-1977) average nonirrigated yields, bushels per acre[a]

County	Long-term average: Irrigated[b]	Long-term average: 10-yr nonirrigated	Increase in yield	Increase in yield, %[c]
Buena Vista	170	99.5	70.5	71
Cherokee	164	94.0	70.0	74
Clay	166	96.6	69.4	72
Dickinson	154	89.3	64.7	72
Ida	162	90.8	71.2	78
Lyon	141	78.1	62.9	80
O'Brien	166	98.4	67.6	69
Osceola	157	90.5	66.5	73
Plymouth	139	77.1	61.9	80
Sac	164	88.4	75.6	86
Sioux	147	81.3	65.7	81
Woodbury	142	80.3	61.7	77
Region	156	88.7	67.3	76

[a]Based on yields from all land capability classes (LCC).

[b]1980 irrigated corn yields from Table 134 divided by corn ratio in Table 132.

[c]% = 100(irrigated yield - 10-yr nonirrigated yield)/10-yr yield.

corn production should have little if any effect on the price of corn. However, the possibility also exists to use this yield increase to retire some acreage from row crop production and keep total corn production about the same as now. Those acres to be retired would be those which cause most of the soil erosion. These areas could be returned to pasture, meadow or forest and add to our stock of public land for recreation or simple aesthetics while significantly reducing the pollution load in our streams.

In 1976 about 1,800,000 acres were planted to corn in Northwest

Iowa. Assuming the 10-yr average corn yield of 89 bushels per acre were obtained, total corn production from these 1.8 million acres would have been 160 million bushels. Using irrigation to produce 156 bushels per acre, only 1.03 million acres would have been needed to equal this same total production, thus almost 800,000 acres would have been freed to return to less polluting uses. Based on the Conservation Needs Inventory (Iowa Conservation Needs Committee, 1970), there were, coincidentally, 1,117,000 acres of Class I and Class II land used for corn production in Northwest Iowa in 1967. Therefore, by using only those lands least susceptable to erosion for corn, we could maintain production at present levels. The total stock of Class I and Class II land in Northwest Iowa is 2.43 million acres.

While it is physically and economically possible to effect this shift in land use, the social and political implications must also be considered. Some farmers may not like being told that they no longer can plant corn because they have no Class I or Class II land on their farm. Since the conversion of land use may not be voluntary, then laws may need to be passed to make sure these changes are made. The politicians who vote for these bills may become former legislators. However, since Iowa has lost half its topsoil in its first hundred years, the last half may go in less than another hundred years (Drake, 1977). The physical, economic, social, political and environmental consequences to Iowa are rather mind boggling, so a start must be made now to preserve our remaining soil resources even though the immediate effects on some people may be quite painful. Other alternatives are available for reducing erosion while maintaining corn production and these will be explored in the goal programming model.

Estimated Future Crop Production Needs and Yields

Future crop and livestock requirements in Iowa have been estimated by OBERS (U.S. Water Resources Council, 1975a) and are listed in Table 123. Both historic and projected needs are shown for the period 1959 to 2020 for the four principal agricultural commodities in Iowa: corn, soybeans, beef and pork. The amounts of each commodity needed in the future increase but by varying amounts. Table 124 lists these same commodities and time periods as percentages of the production in 1964 in order to get a better idea of the size of these increases. Between 1964 and 2020, beef and pork production is forecast to about double, corn production is projected to increase over two and a half times and soybean production is expected to more than quadruple. These increases suggest that Iowa will be expected to continue in its present role of fulfilling a significant portion of the nation's and world's demands for agricultural production. These exogenous demands will in turn place great demands on Iowa's land in order to meet these expectations. Iowans will have to manage their soil resources with great care in order to maintain and improve the soil's productivity over the next 40 years. Since the last inventory of land use in Iowa was done in 1967, the percentages shown in Table 124 have been changed to those listed in Table 125 which uses 1967 as its base. These values in Table 125 are used as inputs to the goal programming model.

Table 123. OBERS Iowa agricultural production by commodity groups, historical and projected for the period 1959 to 2020[a]

Year	Corn million bushels	Soybeans million bushels	Beef million pounds	Pork million pounds
1959	795.9	62.8	2508.7	4743.3
1964	759.1	121.2	2990.0	4873.6
1980	1319.4	286.2	3812.7	5665.6
1985	1448.9	344.2	4152.3	6111.5
2000	1813.3	463.2	5117.2	7418.0
2020	2037.3	511.9	5874.4	8808.2

[a]U.S. Water Resources Council (1975a).

Table 124. OBERS Iowa agricultural production by commodity groups, historical and projected for the period 1959 to 2020, percent of 1964 production[a]

Year	Corn	Soybeans	Beef	Pork
1959	104.8	51.8	83.9	97.3
1964	100.0	100.0	100.0	100.0
1980	173.8	236.1	127.5	116.2
1985	190.9	284.0	138.9	125.4
2000	252.0	382.2	171.1	152.2
2020	268.4	422.4	196.5	180.7

[a]U.S. Water Resources Council (1975a).

Historic yields of corn and soybeans are a matter of record but what these yields will be in the future becomes a matter of educated guesses and pure speculation. The yield of a particular crop at a specific time and locale is determined by climate, soils, other environmental factors, and a variety of economic factors including output price and input cost variables (Gibson, 1976). Some of the climatic

Table 125. OBERS Iowa agricultural production by commodity groups, historical and projected for the period 1967 to 2020, percent of 1967 production[a]

Year	Corn	Soybeans	Beef	Pork
1967	100.0	100.0	100.0	100.0
1980	138.8	198.4	99.1	90.3
1985	152.5	238.6	107.9	97.4
2000	201.3	321.1	133.0	118.3
2020	214.4	354.9	152.7	140.4

[a]U.S. Water Resources Council (1975a) and ratio of 1967 to 1964 regional production.

and environmental factors are amounts and timing of rainfall, temperatures, planting date, type and amounts of fertilizers, herbicides and insecticides, plant populations and cropping practices. Table 126 lists the corn and soybean yields used in the OBERS projections (U.S. Water Resources Council, 1975a). A 106% increase in corn yields and a 38% increase in soybean yields are forecast for the 45-yr period from 1975 to 2020.

Table 126. OBERS projected corn and soybean yields for Iowa for the period 1975 to 2020, bushels per acre[a]

Year	Nonirrigated corn	Soybeans
1975	90	34.0
1980	124	36.0
1985	132	38.0
2000	155	42.6
2020	185	46.9

[a]U.S. Water Resources Council (1975a).

Another set of estimates of future corn and soybean yields are those by Gibson (1976). These are shown in Table 127. He used ordinary least squares regression to regress historical state yield data against time for the 27-yr period from 1947 to 1973. Again using 1975 as the base, he projects that there will be a 150% increase in corn yields and a 76% increase in soybean yields for the 45-yr period from 1975 to 2020. Gibson also used a "low trend" in which he assumed that "the rapid rate of increase in research and resource development in agriculture that occurred in the 1947 to 1973 period will continue at a slower rate of increase in the 1970 to 2020 period. Low trend projected state commodity yields are equal to the trend projected state commodity yields minus two corresponding estimated standard deviations. Given the regression procedure, the low trend projected state corn yields delimit those minimum crop yields which there is at least a 9 out of 10 chance of being less than or equal to actual state yields, assuming normal yield distributions."

Table 127. Gibson's projected trend average state corn and soybean yields for the period 1980 to 2020, bushels per acre[a]

	Corn		Soybeans	
Year	Yield	Standard deviation	Yield	Standard deviation
1980	122.648	7.982	37.765	2.586
1990	148.222	8.882	43.333	2.878
2000	173.795	10.007	48.900	3.240
2010	199.369	11.290	54.468	3.658
2020	224.943	12.683	60.036	4.109

[a]Gibson (1976).

The author discussed these two projections of corn and soybean yields with two specialists from Iowa State University. Their opinion was that any projection of future corn yields was essentially a guess but they felt that Gibson's projections were too high. They indicated that since many of the yield variables such as planting date, plant population, fertilizer, weed and pest control and farming operations had already been incorporated into present farm practices that yield increases would come mainly from genetic improvements and that no breakthroughs were foreseen at this time. Based on this the author selected the corn and soybean yields listed in Table 128. No objections were received to these estimates; they are as good a guess as any other. Irrigated corn yields were assumed to average 50 bushels per acre greater than nonirrigated yields. This figure is much higher than those recently reported by Babula (1978) and Colbert (1978). However, the author feels that the 50 bushel per acre increase is justified for the following reasons. Babula's study used yield data from the period 1957 to 1977 while Colbert's study used yield data from the period 1959 to 1976. Both of these studies include the period of remarkably good weather for crop production shown in Fig. 7 and thus do not reflect the yield increase that would arise from a normal variability in the weather resulting in more variable crop yields. Since water will be available on demand, plant populations can be increased from 10% to 25% or more and additional applications of fertilizer can be made at appropriate times during the growing season.

These estimated future yields are statewide averages and must be

Table 128. Projected average state corn and soybean yields to be used in the goal programming study for the period 1967 to 2020, bushels per acre[a]

Year	Corn: Irrigated[b]	Corn: Nonirrigated	Soybeans
1967	–	88.6	27.4
1980	165.0	115.0	36.0
2000	195.0	145.0	44.0
2020	225.0	175.0	52.0

[a]Based on conversations with Drs. Howard Johnson and William Shrader of Iowa State University.

[b]Restricted to LCC I and IIe only.

adjusted to reflect the soil productivity levels in each county and the several land capability classes (LCC) within each county. The maximum yield potential relations for each land capability class for both corn and soybeans are listed in Table 129 and were taken from the study by Gibson (1976). Table 114 listed the average county and state corn and soybean yields in Northwest Iowa for the period 1952 through 1977. These data were used to calculate the long-term ratio of average county to state corn and soybean yields in each county in Northwest Iowa. These ratios are shown in Table 130.

One of the items of input data to the goal programming model is the projected LCC I future corn yields in each county. In order to obtain this input, the relative LCC I corn yield and its ratio to the average county yield had to be determined. This was done by combining several variables: number of row crop acres on each LCC, total number of corn acres, average county yield and yield ratio of each LCC to

Table 130. Iowa maximum corn and soybean yield potential relations by land capability classes[a]

Crop	LCC	Maximum relative yield potential relationships[b]
Corn	I	1.00
	IIE, IIW, IIIE	0.90
	IIIW	0.70
	IIS, IVE, IVW, all VI	0.60
	IIIS, all V and VII	0.50
	IVS	0.40
Soybeans	I	1.00
	All II	0.95
	IIIE	0.87
	IIIS, IIIW	0.80
	IVE	0.75
	IVS, IVW	0.62
	All V, VI and VII	0.40

[a]Gibson (1976).

[b]Ratio of LCC_k to LCC_I.

Table 130. Ratio of average county to state corn and soybean yields in Northwest Iowa for the period 1952 to 1977[a]

County	Corn	Soybeans
Buena Vista	1.03	1.04
Cherokee	0.99	1.07
Clay	1.00	1.00
Dickinson	0.93	0.87
Ida	0.98	1.03
Lyon	0.85	0.93
O'Brien	1.01	1.05
Osceola	0.95	0.94
Plymouth	0.84	0.97
Sac	0.99	1.04
Sioux	0.89	1.00
Woodbury	0.86	0.87

[a]See Table 114.

LCC I land. A sample calculation for the relative yield ratio for corn in Sac County in 1967 is shown in Table 131. Similar calculations were made for each county for both corn and soybeans. These results are shown in Table 132. The relative corn yield ratios range from 1.08 to 1.17 while the relative soybean yield ratios range from 1.05 to 1.16. The closer the ratio is to unity is an indication that more and more land in the county is better suited to farming.

Table 131. Calculation of the relative corn yield ratio for LCC I land in Sac County in 1967 based on average county yield, total acres planted to corn, acres of row crops on each LCC and yield ratio of LCC_k to LCC_I[a]

LCC	Number of row crop acres[b]	Yield ratio[c]	Relative number of LCC I corn acres
I	30,440	1.00	19,220
IIe	88,690	0.90	50,410[d]
IIIe	33,460	0.90	19,020
IVe	1,010	0.60	380
VIe	400	0.60	150
IIw	46,360	0.90	26,350
IIIw	4,430	0.70	1,960
Vw	2,420	0.50	760
IIs	2,020	0.60	760
IVs	400	0.40	100
Total	209,620		119,110

Relative yield on LCC I = 90.9 x 132,380/119,110 = 101.0 bu/ac
Relative yield ratio: LCC I/county average = 101.0/90.9 = 1.11

[a]Acres planted to corn in 1967 = 132,380 (Table H-2 in Appendix H); average county yield in 1967 = 90.9 bu/ac (Table H-4 in Appendix H).

[b]Iowa Conservation Needs Committee (1970).

[c]See Table 129.

[d]50,410 = 88,690 x 0.9 x 132,380/209,620.

Table 132. 1967 relative LCC I corn and soybean yield in bushels per acre and ratio to average county yields[a]

County	Corn			Soybeans		
	LCC I	County	Ratio	LCC I	County	Ratio
Buena Vista	103.4	93.5	1.11	31.8	30.1	1.06
Cherokee	97.9	88.0	1.11	33.1	30.5	1.09
Clay	83.2	75.2	1.11	23.2	22.2	1.05
Dickinson	79.9	72.5	1.10	20.8	19.4	1.07
Ida	107.8	92.4	1.17	34.1	29.4	1.16
Lyon	83.2	75.6	1.10	26.0	24.4	1.07
O'Brien	79.2	73.0	1.08	24.6	23.4	1.05
Osceola	87.1	80.0	1.09	26.0	24.5	1.06
Plymouth	93.4	82.8	1.13	33.9	30.3	1.12
Sac	101.0	90.9	1.11	33.4	31.1	1.07
Sioux	81.3	73.3	1.11	27.3	25.4	1.08
Woodbury	89.3	76.6	1.17	26.4	23.4	1.13

[a]See Table 131 for sample calculations.

The projected LCC I future corn and soybean yields were then determined using the values contained in Tables 128, 130 and 132. The results of these calculations for nonirrigated corn, irrigated corn and soybeans are shown in Tables 133, 134 and 135, respectively. The values in these three tables are inputs to the goal programming model. These values also preserve the variation in historic yield between the various counties since such factors as soil types, land slopes, temperature, etc., will not change over time. Similar values for Gibson's projections for nonirrigated corn, irrigated corn and soybeans are shown in Tables 136, 137 and 138, respectively. They also serve as input data to the goal programming model and serve to test the sensitivity of the model to different crop yield assumptions.

Table 133. Rossmiller's projected LCC I nonirrigated corn yields in Northwest Iowa for the period 1980 to 2020, bushels per acre[a]

County	1980	2000	2020
Buena Vista	132	166	200
Cherokee	126	159	192
Clay	128	161	194
Dickinson	118	148	179
Ida	132	166	201
Lyon	108	136	164
O'Brien	125	158	191
Osceola	119	150	181
Plymouth	109	138	166
Sac	126	159	192
Sioux	114	143	173
Woodbury	116	146	176

[a]LCC I yield = projected average state yield in some year x ratio of county to state average yield x ratio of LCC I to average county yield.

Table 134. Rossmiller's projected LCC I irrigated corn yields in Northwest Iowa for the period 1980 to 2020, bushels per acre[a]

County	1980	2000	2020
Buena Vista	189	223	258
Cherokee	182	214	248
Clay	184	217	250
Dickinson	169	199	231
Ida	189	223	258
Lyon	155	182	210
O'Brien	179	212	245
Osceola	171	202	233
Plymouth	157	185	214
Sac	182	214	248
Sioux	163	193	223
Woodbury	166	196	226

[a]LCC I yield = projected average state yield in some year x ratio of county to state average yield x ratio of LCC I to average county yield.

Table 135. Rossmiller's projected LCC I soybean yields in Northwest Iowa for the period 1980 to 2020, bushels per acre[a]

County	1980	2000	2020
Buena Vista	39.7	48.5	57.3
Cherokee	41.9	51.3	60.6
Clay	37.8	46.2	54.6
Dickinson	33.4	41.0	48.4
Ida	43.0	52.6	62.1
Lyon	35.8	43.8	51.8
O'Brien	39.7	48.5	57.3
Osceola	35.9	43.8	51.8
Plymouth	39.1	47.8	56.5
Sac	40.0	48.9	57.8
Sioux	38.8	47.6	56.2
Woodbury	35.4	43.3	51.2

[a]LCC I yield = projected average state yield in some year x ratio of county to state average yield x ratio of LCC I to average county yield.

Table 136. Gibson's projected LCC I nonirrigated corn yields in Northwest Iowa for the period 1980 to 2020, bushels per acre[a]

County	1980	2000	2020
Buena Vista	141	199	257
Cherokee	134	190	247
Clay	136	193	249
Dickinson	126	177	230
Ida	141	199	258
Lyon	115	163	211
O'Brien	133	189	246
Osceola	127	180	233
Plymouth	116	165	213
Sac	134	190	247
Sioux	122	171	222
Woodbury	124	175	226

[a]LCC I yield = projected average state yield in some year x ratio of county to state average yield x ratio of LCC I to average county yield.

Table 137. Gibson's projected LCC I irrigated corn yields in Northwest Iowa for the period 1980 to 2020, bushels per acre[a]

County	1980	2000	2020
Buena Vista	198	256	315
Cherokee	190	246	303
Clay	192	249	305
Dickinson	177	228	282
Ida	198	256	315
Lyon	162	209	257
O'Brien	187	243	299
Osceola	179	232	285
Plymouth	164	212	262
Sac	190	246	303
Sioux	170	221	272
Woodbury	174	225	276

[a]LCC I yield = projected average state yield in some year x ratio of county to state average yield x ratio of LCC I to average county yield.

Table 138. Gibson's projected LCC I soybean yields in Northwest Iowa for the period 1980 to 2020, bushels per acre[a]

County	1980	2000	2020
Buena Vista	41.6	53.9	66.2
Cherokee	44.0	57.0	70.0
Clay	39.6	51.3	63.0
Dickinson	35.0	45.6	55.9
Ida	45.1	58.4	71.7
Lyon	37.6	48.7	59.8
O'Brien	41.6	53.9	66.2
Osceola	37.7	48.7	59.8
Plymouth	41.0	53.1	65.2
Sac	42.0	54.3	66.7
Sioux	40.7	52.9	64.9
Woodbury	37.1	48.1	59.1

[a]LCC I yield = projected average state yield in some year x ratio of county to state average yield x ratio of LCC I to average county yield.

Soil Erosion

Man's activities on the earth's surface, especially his farming activities, have consistently and annually caused massive amounts of soil erosion. During the centuries of the Roman Empire, entire forests were removed with the result that in many areas today the soils are either very thin or entirely removed. Somewhat over a century ago, the white man began plowing the prairie sod covering Iowa in order to grow crops. Today only scattered fragments of prairie remain and on the average, half the depth of topsoil has been lost to soil erosion. With present farming methods, the other half will be gone in less than another 100 years (Brune, 1978; Drake, 1977).

This statement has been made verbally and in print many times, but only a few people seem to be aware of what this means to the future of Iowa. Most people simply do not believe that the topsoil will be gone. Others do not want to give up some short-term profits for long-term productivity.

The knowledge and techniques to slow down the erosion process to tolerable levels are available now. The two things which are lacking are the will to get on with the job which must be done and the commitment of the large amounts of money needed from the state and federal governments and the private sector.

All of the topsoil in Iowa will not be gone in another 100 years. All of the topsoil will be gone in certain portions of Iowa within the next 100 years if present farming methods continue. The loess mantle in western Iowa is 200 feet thick in some areas and its productivity does not decrease appreciably as the top surface is washed away. The Class I soils in Iowa have little susceptibility to erosion by water but must be protected against wind erosion. Soils become more prone to erosion in progressing from Class II through Class VII lands. Those lands on the steeper slopes will lose all their topsoil if they continue to be used for agricultural production.

The techniques are available to reduce soil erosion to a rate at which soil is being formed at least as fast as it is being washed or blown away. The best long-term predictor of soil erosion by water in existence today is the Universal Soil Loss Equation (USLE) which was first introduced in 1958. This empirical equation is based on several thousands of plot years of data collected and analyzed by many researchers. The usual formulation of the USLE is shown in Eq. (28).

$$A = RKLSCP \tag{28}$$

where A = average annual soil loss in tons per acre

R = rainfall factor, a summation of the rainfall and runoff erosivity index over a one-year period

K = soil erodibility factor, average annual soil loss in tons per acre per unit of R, for a given soil on a unit plot which is defined as 72.6 feet long with a 9% slope, continuously fallow and tilled parallel to the slope

L = slope length factor, a ratio of soil loss from a given length of slope to the unit length of 72.6 feet

S = slope steepness factor, a ratio of soil loss from a given percent slope to the unit slope of 9%

C = cropping and management factor, a ratio of soil loss with a specific cover and agronomic practices to that from continuous fallow

P = conservation practice factor, a ratio of soil loss with some supporting practice to that with straight row farming parallel to the slope.

Erosion and the production of sediment is a function of two processes, detachment and transport. The kinetic energy of moving water is the mechanism by which both processes take place. First the kinetic energy in falling raindrops detaches the soil particles. Then the kinetic energy in the velocity of moving water entrains the detached particles and moves them off the site. The erosive power of water is measured by the rainfall factor, R. This factor varies from an annual value of 143 in Northwest Iowa to 191 in Southeast Iowa.

Some soils are more susceptible to erosion than others. This susceptibility is affected by the physical properties of a soil such as soil texture, size and stability of soil structure, soil permeability and infiltration, organic matter content and soil depth. The K factor measures this susceptibility to erosion and in Iowa its value ranges from 0.17 for a loamy fine sand to 0.49 for a silty clay loam.

Long, steep slopes lose more soil than short, gentle slopes. If the length of slope is doubled, erosion is increased 1.5 times. If the steepness of slope is doubled, erosion is increased 2.5 times.

The cropping and management factor, C, takes into account two major variables: crop rotations and methods used to grow the crops.

Crop rotation accounts for what crops are grown (row, small grain, meadow) and the sequence in which they are grown. The methods include when the soil is plowed, the type and timing of tillage operations and the handling of crop residues. The residue can be turned under, left on the surface, mixed in the plow layer or removed from the field. C factors range from 0.01 for a cropping system which uses grass most of the time with all residue left on the surface to 0.46 for a corn-soybean rotation with all residue removed. The C factor for mixed hay and pasture is 0.007 and for good grass it is 0.003. Annual soil loss in forested areas in Iowa is about 0.3 tons per acre (Harmon and Duncan, 1978; Soil Conservation Service, 1977).

The practice factor, P, involves contouring, contour strip-cropping and terracing as opposed to plowing up and down slope. The factor ranges from 0.0 when level, parallel terraces are used to 0.9 when contouring is used on very steep slopes.

Sufficient experience and data have been incorporated into the USLE to make good estimates of the effects of several conservation measures and management practices on the long-term rates of erosion by water. These estimates are shown in the following tables. Tables 139 and 140 show the calculations for the development of the cropping-management factor, C, in the USLE with conventional tillage and minimum tillage, respectively, for a corn-corn-soybean rotation. The use of minimum tillage cuts the rate of erosion by somewhat more than half. Table 141 shows the computed annual erosion rates by land capability class for the C-C-S rotation under the two tillage systems and contouring. The allowable long-term erosion rate in Northwest Iowa is 5 tons

Table 139. Development of cropping-management factor (C) for C-C-S rotation with conventional tillage[a]

(1) Operation[b]	(2) Crop stage	(3) Date	(4) Reading, curve No. 2[c]	(5) EI in period %	(6) Soil-loss ratio, %	(7) Cols. (5) x (6)	(8) C value Σcol. (7)
Corn after soybeans							
TP-corn	S4	4/15	4	–	–	–	
P-corn	F	5/01	6	2	43[d]	0.009	
	C1	6/01	18	12	76	0.091	
	C2	7/01	42	24	60	0.144	
HV-corn	C3	10/20	98	56	31	0.174	
TP-corn	C4	4/15	104	6	36	0.022	0.440
Corn after corn							
TP-corn	C4	4/15	4	–	–	–	
P-corn	F	5/01	6	2	36[e]	0.007	
	C1	6/01	18	12	63	0.076	
	C2	7/01	42	24	50	0.120	
HV-corn	C3	10/20	98	56	26	0.146	
TP-beans	C4	4/25	105	7	30	0.021	0.370
Soybeans after corn							
TP-beans	C4	4/25	5	–	–	–	
P-beans	F	5/15	11	6	36[f]	0.022	
	S1	6/15	29	18	63	0.113	
	S2	7/15	24	25	50	0.125	
HV-beans	S3	10/15	98	44	26	0.114	
TP-corn	S4	4/15	104	6	30	0.018	0.392
Rotation average =							0.400

[a]As per example in Wischmeier and Smith (1965).

[b]TP = turn plow; P = plant; HV = harvest.

[c]Values from Curve No. 2 in Wischmeier and Smith (1965).

[d]Values from Table 2 in Wischmeier and Smith (1965) times 1.2. An adjustment indicated by Moldenhauer and Wischmeier (1969) for increased soil loss with corn following soybeans.

[e]Values from Table 2 in Wischmeier and Smith (1965) as representative of continuous corn.

[f]Values for soybeans assumed the same as continuous corn.

Table 140. Development of cropping-management factor (C) for C-C-S rotation with minimum tillage[a]

(1) Operation[b]	(2) Crop stage	(3) Date	(4) Reading, curve No. 2[c]	(5) EI in period %	(6) Soil-loss ratio, %	(7) Cols. (5) x (6)	(8) C value Σcol. (7)
Corn after soybeans — residue: 1500-2000 lb/ac							
P-corn	S4	5/1	6	—	—	—	
	C1	6/1	18	12	48[d]	0.058	
	C2	7/1	42	24	38	0.091	
HV-corn	C3	10/20	98	56	22	0.123	
P-corn	C4	5/1	106	8	30	0.024	0.296
Corn after corn — residue: 3000-4000 lb/ac							
P-corn	C4	5/1	6	—	—	—	
	C1	6/1	18	12	20[e]	0.024	
	C2	7/1	42	24	16	0.038	
HV-corn	C3	10/20	98	56	9	0.050	
P-beans	C4	5/15	111	13	15	0.020	0.132
Soybeans after corn — residue: 3000-4000 lb/ac							
P-beans	C4	5/15	11	—	—	—	
	S1	6/15	29	18	20[f]	0.038	
	S2	7/15	54	25	16	0.040	
HV-beans	S3	10/15	98	44	9	0.040	
P-corn	S4	5/1	106	8	15	0.012	0.130
Rotation average =							0.186

[a]As per example in Wischmeier and Smith (1965).

[b]P = plant; HV = harvest.

[c]Values from Curve No. 2 in Wischmeier and Smith (1965).

[d]Values from Table 1 in Wischmeier (1968) times 1.2. An adjustment indicated by Moldenhauer and Wischmeier (1969) for increased soil loss with corn following soybeans.

[e]Values from Table 1 in Wischmeier (1968) for corn following corn.

[f]Values for soybeans assumed the same as continuous corn.

Table 141. Computed annual erosion rates by land capability class for C-C-S rotation under two tillage systems and contouring[a]

Capability class	Slope length ft	Slope gradient %	R	K	LS	C	P	A = RKLSCP tons/acre
Conventional tillage								
I	300	1.0	150	0.32	0.18	0.400[b]	1.0[c]	3.5
II	300	3.5	150	0.32	0.51	0.400	1.0	9.8
III	600	9.5	150	0.32	3.20	0.400	1.0	61.4
IV	600	16.0	150	0.32	7.00	0.400	1.0	134.4
VI	600	22.0	150	0.32	11.60	0.400	1.0	222.7
VII	600	30.0	150	0.32	19.00	0.400	1.0	364.8
Minimum tillage								
I	300	1.0	150	0.32	0.18	0.186[d]	1.0[c]	1.6
II	300	3.5	150	0.32	0.51	0.186	1.0	4.5
III	600	9.5	150	0.32	3.20	0.186	1.0	28.6
IV	600	16.0	150	0.32	7.00	0.186	1.0	62.5
VI	600	22.0	150	0.32	11.60	0.186	1.0	103.6
VII	600	30.0	150	0.32	19.00	0.186	1.0	169.6
Conventional tillage + contouring								
I	300	1.0	150	0.32	0.18	0.400[b]	0.6[c]	2.1
II	300	3.5	150	0.32	0.51	0.400	0.5	4.9
Minimum tillage + contouring								
I	300	1.0	150	0.32	0.18	0.186[d]	0.6[c]	1.0
II	300	3.5	150	0.32	0.51	0.186	0.5	2.3

[a]As per example in Wischmeier and Smith (1965).

[b]From Table 139.

[c]From Wischmeier and Smith (1965).

[d]From Table 140.

per acre per year. Only Class I land can meet this criterion with conventional tillage. Class II land can meet the criterion in one of two ways: by using minimum tillage or by using conventional tillage with contouring. None of these cropping systems requires any capital investment, so Class I and II land can be farmed for maximum row crop production and meet erosion standards without any additional capital investment. The same is true of Class V land.

All other land capability classes must use terraces if farmed for crop production. Terraces can be constructed in many combinations: broad-based or grassed back slope, level or graded, open- or closed-end, parallel or nonparallel, surface or subsurface drained (American Society of Agricultural Engineers, 1978). Broad-based terraces take no land out of production but are limited to slopes of 8% or less. Grassed back slope terraces do take some land out of production but can be used on much steeper slopes. Level terraces require more earth moving than graded terraces. Open-ended terraces drain on the surface around the end of the terrace. Surface drainage of terraces utilizes grassed waterways which must be maintained and which also take land out of production. Subsurface drainage uses tile lines which take no land out of production and require little maintenance but are more expensive to install. Farmers prefer parallel graded terraces with tile outlets because they allow for the best farming operations with the least maintenance and the least land taken out of production. However, they are more expensive to construct.

The terrace layout on each field is different and in some cases not all of the land is upslope of a terrace. This results in some portion of the land not being protected. For this reason other cultural practices such as contouring and minimum tillage should also be employed. Research has indicated that soil loss from a surface drained graded terrace is about 0.30 the amount calculated using the USLE while soil loss from a subsurface drained graded terrace is about 0.06 the amount calculated using the USLE (Bondurant and Laflen, 1978; Laflen et al., 1972). Grassed back slope terraces remove about 10% of the land from production on Class III land and about 20% on Class IV land. Table 142 lists the computed annual erosion rates by land capability class for the C-C-S rotation, two tillage systems, contouring and two types of terraces with tile outlets. All of these alternative systems easily meet the 5 ton per acre limitation.

Tables D-1 through D-12 in Appendix D list the acres of land in each county devoted to each of the ten land use categories on each of the land capability classes as they existed in Northwest Iowa in 1967. Erosion rates for corn and soybeans are listed in Tables 141 and 142. Computed erosion rates for rotation hay and pasture and permanent pasture are given in Table 143 while the erosion rates for close grown crops and forest are listed in Table 144. Water areas do not erode so an erosion rate of zero is used in the goal programming model for water. The three remaining categories are urban and built-up, other and conservation use only. These three categories are assumed to have the same erosion potential as rotation hay and pasture on each land capability class (John Laflen, Agricultural Engineering Department, Iowa State University, personal interview, December 15, 1978).

The existing and future erosion rates for each land use and land

Table 142. Computed annual erosion rates by land capability class for C-C-S rotation, two tillage systems, broadbased terraces and grassed backslope terraces with tile outlets[a]

Capability class	Slope length[b] ft	Slope gradient %	R	K	LS	C	P[b]	A = RKLSCP tons/acre
Conventional tillage + broadbased terraces								
II	300	3.5	150	0.32	0.51	0.400[c]	0.03	0.3
III	120	8.0	150	0.32	1.00	0.400	0.04	0.8
Minimum tillage + contouring + broadbased terraces								
II	300	3.5	150	0.32	0.51	0.186[d]	0.015	0.1
III	120	8.0	150	0.32	1.00	0.186	0.024	0.2
Conventional tillage + contouring + grassed backslope terraces								
III	120	9.5	150	0.32	1.45	0.400[c]	0.012	0.3
IV	90	14.0	150	0.32	2.10	0.400	0.015	0.6
Minimum tillage + contouring + grassed backslope terraces								
III	120	9.5	150	0.32	1.45	0.186[d]	0.012	0.2
IV	90	14.0	150	0.32	2.10	0.186	0.015	0.3

[a]As per example in Wischmeier and Smith (1965).

[b]From (Laflen et al., 1972; Soil Conservation Service, 1977).

[c]From Table 139.

[d]From Table 140.

capability class are listed in Tables 145 and 146, respectively, and are used as inputs to the GP model.

In order to meet the 5 ton per acre per year standard set in compliance with the Iowa Conservancy District Act, some changes in land use and large capital investments will have to be made. All

Table 143. Computed annual erosion rates by land capability class for permanent pasture and rotation hay and pasture[a]

Capability class	Slope length ft	Slope gradient %	R	K	LS	C	P	A = RKLSCP tons/acre
Permanent pasture								
I	300	1.0	150	0.32	0.18	0.004[b]	1.0	0.1
II	300	3.5	150	0.32	0.51	0.004	1.0	0.2
III	600	9.5	150	0.32	3.20	0.004	1.0	0.6
IV	600	16.0	150	0.32	7.00	0.006	1.0	2.0
V	300	1.0	150	0.32	0.18	0.004	1.0	0.1
VI	600	22.0	150	0.32	11.60	0.006	1.0	3.3
VII	600	30.0	150	0.32	19.00	0.010	1.0	9.1
VII	150	30.0	150	0.32	10.00	0.010	1.0	4.8
Rotation hay and pasture								
I	300	1.0	150	0.32	0.18	0.009[c]	1.0	0.1
II	300	3.5	150	0.32	0.51	0.009	1.0	0.2
III	600	9.5	150	0.32	3.20	0.009	1.0	1.4
IV	600	16.0	150	0.32	7.00	0.014	1.0	4.7
V	300	1.0	150	0.32	0.18	0.009	1.0	0.1
VI	600	22.0	150	0.32	11.60	0.014	1.0	7.8
VII	600	30.0	150	0.32	19.00	0.023	1.0	21.0

[a]As per example in Wischmeier and Smith (1965).

[b]From Table 2 in Wischmeier and Smith (1965).

[c]From Table 4.2-4 in Harmon and Duncan (1978).

VI and VII land should be converted to either permanent pasture or forest. Broad-based or grassed back slope terraces should be constructed on all Class III and IV land used for crop purposes. Current construction costs for graded terraces with tile outlets are assumed to be $360 per acre on Class III land and $420 per acre on Class IV land (John Laflen, Agricultural Engineering Department, Iowa State University, personal interview, December 15, 1978).

Table 144. Computed annual erosion rates by land capability class of close grown crops and forest[a]

Capability class	Slope length ft	Slope gradient %	R	K	LS	C	P	A = RKLSCP tons/acre
Close grown crops — minimum tillage								
I	300	1.0	150	0.32	0.18	0.066[b]	1.0	0.6
II	300	3.5	150	0.32	0.51	0.066	1.0	1.6
III	600	9.5	150	0.32	3.20	0.066	1.0	10.1[c]
IV	600	16.0	150	0.32	7.00	0.066	1.0	22.2[c]
V	300	1.0	150	0.32	0.18	0.066	1.0	0.6
VI	600	22.0	150	0.32	11.60	0.066	1.0	36.7[c]
VII	600	30.0	150	0.32	19.00	0.066	1.0	60.2[c]
Forest[d]								
I								0.1
II								0.2
III								0.6
IV								1.0
V								0.1
VI								1.6
VII								2.0

[a]As per example in Wischmeier and Smith (1965).

[b]From Table 2 in Wischmeier and Smith (1965).

[c]To meet 5 ton/acre standard, use broad-based terrace on Class III land (A = 0.6 tons/acre) and use grassed backslope terrace on Class IV land with contouring (A = 1.3 tons/acre). Convert Class VI and VII land to permanent pasture.

[d]From Soil Conservation Service (1977) and Harmon and Duncan (1978).

Table 145. Existing erosion rates by land use and capability class in Northwest Iowa for 1967 and 1980, tons per acre per year

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas	Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture
I	0.1	0.1	0.1	0.1	0.0	3.5	3.5	0.6	0.1	0.1
IIe	0.2	0.2	0.2	0.2	0.0	9.8	9.8	1.6	0.2	0.2
IIw	0.2	0.2	0.2	0.2	0.0	9.8	9.8	1.6	0.2	0.2
IIs	0.2	0.2	0.2	0.2	0.0	9.8	9.8	1.6	0.2	0.2
IIIe	1.4	0.6	1.4	1.4	0.0	61.4	61.4	10.1	1.4	0.6
IIIw	1.4	0.6	1.4	1.4	0.0	61.4	61.4	10.1	1.4	0.6
IIIs	1.4	0.6	1.4	1.4	0.0	61.4	61.4	10.1	1.4	0.6
IVe	4.7	1.0	4.7	4.7	0.0	134.4	134.4	22.2	4.7	2.0
IVw	4.7	1.0	4.7	4.7	0.0	134.4	134.4	22.2	4.7	2.0
IVs	4.7	1.0	4.7	4.7	0.0	134.4	134.4	22.2	4.7	2.0
Vw	0.1	0.1	0.1	0.1	0.0	3.5	3.5	0.6	0.1	0.1
VIe	7.8	1.6	7.8	7.8	0.0	222.7	222.7	36.7	7.8	3.3
VIs	7.8	1.6	7.8	7.8	0.0	222.7	222.7	36.7	7.8	3.3
VIIe	21.0	2.0	21.0	21.0	0.0	364.8	364.8	60.2	21.0	9.1
VIIw	21.0	2.0	21.0	21.0	0.0	364.8	364.8	60.2	21.0	9.1
VIIs	21.0	2.0	21.0	21.0	0.0	364.8	364.8	60.2	21.0	9.1

Table 146. Future erosion rates by land use and capability class in Northwest Iowa for 2000 and 2020, tons per acre per year

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas	Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture
I	0.1	0.1	0.1	0.1	0.0	3.5	3.5	0.6	0.1	0.1
IIe	0.2	0.2	0.2	0.2	0.0	4.6	4.6	1.6	0.2	0.2
IIw	0.2	0.2	0.2	0.2	0.0	4.6	4.6	1.6	0.2	0.2
IIs	0.2	0.2	0.2	0.2	0.0	4.6	4.6	1.6	0.2	0.2
IIIe	1.4	0.6	1.4	1.4	0.0	0.2	0.2	0.6	1.4	0.6
IIIw	1.4	0.6	1.4	1.4	0.0	0.2	0.2	0.6	1.4	0.6
IIIs	1.4	0.6	1.4	1.4	0.0	0.2	0.2	0.6	1.4	0.6
IVe	4.7	1.0	4.7	4.7	0.0	0.3	0.3	1.3	4.7	2.0
IVw	4.7	1.0	4.7	4.7	0.0	0.3	0.3	1.3	4.7	2.0
IVs	4.7	1.0	4.7	4.7	0.0	0.3	0.3	1.3	4.7	2.0
Vw	0.1	0.1	0.1	0.1	0.0	3.5	3.5	0.6	0.1	0.1
VIe	3.3	1.6	3.3	3.3	0.0	103.6	103.6	36.7	7.8	3.3
VIs	3.3	1.6	3.3	3.3	0.0	103.6	103.6	36.7	7.8	3.3
VIIe	4.8	2.0	4.8	4.8	0.0	169.6	169.6	60.2	21.0	4.8
VIIw	4.8	2.0	4.8	4.8	0.0	169.6	169.6	60.2	21.0	4.8
VIIs	4.8	2.0	4.8	4.8	0.0	169.6	169.6	60.2	21.0	4.8

PRESENT AND FUTURE SOURCES OF WATER SUPPLY

In Northwest Iowa and in the other areas of Iowa, water used for various beneficial purposes in the future will for the most part come from the sources presently being utilized. These include the interior and border streams, surface water reservoirs and the various ground water aquifers. As discussed initially in a previous section, many of these sources have quantity limitations and/or quality problems and thus are not reliable nor adequate sources of water as required under the 1974 Safe Drinking Water Act. The existing uses of water, their sources and water rights allocation are discussed in three parts: municipal water supplies, rural water systems and the Iowa Natural Resources Council permit system. This is followed by a discussion of the yields which can be expected from the various aquifers and the potential yields from several reservoir sites.

These sources, as presently used and as they may serve future uses, provide the supply side to the goal programming model. The development costs of these various sources will be detailed in a later section.

Existing Municipal Water Supplies

Data on sources of water for municipal supplies were obtained from Iowa Public Water Supply Data (Iowa Department of Health, 1964) and are shown in Tables J-2 through J-13 in Appendix J. This document was published in 1964 so does not contain data on wells installed since then. The Iowa Department of Environmental Quality is currently updating this publication, but no information is available yet. Of the 114 communities in existence in 1960, 13 were not listed indicating that there was no municipal system. These are all small communities of about a hundred inhabitants of less and presumably they use individual wells. Three cities purchase their water from another community. Five cities use a surface water source and are all located around the Iowa Great Lakes in Dickinson County. The other 92 communities use one or more ground water aquifers as their source of supply. These aquifers and the number of wells in each are shown in Table 147. Some of the bedrock wells obtain water from more than one bedrock aquifer, having open boreholes through several formations.

Table 147. Aquifers used for municipal water supply in Northwest Iowa and number of wells in each[a]

Number of wells	Aquifer[b]
88	Pleistocene (glacial deposits and outwash) sands and gravels
70	Recent (alluvial) sands and gravels
57	Dakota sandstone
5	Jordan sandstone
4	St. Peter sandstone
3	Galena dolomite
3	Prairie du Chien dolomite
2	Cedar Valley
2	Mississippian limestone
2	St. Lawrence dolomite
1	Maquoketa dolomite
1	Wapsipinicon dolomite

[a]Iowa Department of Health (1964).

[b]Not all of these aquifers are physically present throughout the region.

Of the 222 wells, 158 are located either in the more recent alluvial sands and gravels along the rivers or the older and deeper glacial sand and gravel deposits in the till. The wells in the recent deposits range from 15 to 65 feet in depth while those in the glacial till deposits range from 20 to 470 feet deep. The 57 wells in the Dakota sandstone aquifer vary from 203 to 749 feet in depth while the wells in the other bedrock aquifers range from 450 to 2,200 feet deep. The age of these wells also varies considerably as shown in Table 148. These dates indicate that 44 of the wells are at least 50 years old. In addition the installation dates of 14 of the older wells were not given. Another 44 wells are 40 years old and a total of 133 wells were installed more than a quarter century ago. Some of these probably have been replaced in the last 15 years. If not, the reliability of some of these older wells must be questioned.

Table 148. Date of installation of wells used for municipal water supply in Northwest Iowa[a]

Decade	Number of wells
1890-1899	3
1900-1909	6
1910-1919	14
1920-1929	21
1930-1939	44
1940-1949	31
1950-1959	82
1960-1961	7

[a]Iowa Department of Health (1964).

Those wells located in the sand and gravel aquifers are especially vulnerable. Most of these are recharged by the surface streams and/or by rainfall or snowmelt infiltrating through the overburden. During droughts, recharge is reduced or eliminated for a period of time. The resultant lowering of the water surface or piezometric head could cause some of the wells to go dry or reduce their capacity below that needed to adequately supply the community. There is cause for concern here since 41 communities have a total of 99 wells which have depths of less than 50 feet. Quality problems arising from fertilizers and bacterial contamination have been severe in these shallow well systems also.

Amounts withdrawn from these sources per well vary from 10 to 50 gpm in the small cities to 1,000 to 1,500 gpm in Sioux City.

Rural Water Systems

Location and description of systems

Because of quantity shortages and quality problems associated with water from the more economical shallow aquifer sources, many residents in the rural areas and small communities in Iowa have turned to rural water systems as the answer to both their quantity and quality problems. This is especially true of southern and western Iowa. Figure 78 shows the location and status of the active rural water systems in Northwest Iowa through March 1978. The names and descriptions of these systems are given in Table 149 (U.S. Farmers Home Administration, 1978).

A glance at Fig. 78 shows that most rural water systems in Iowa

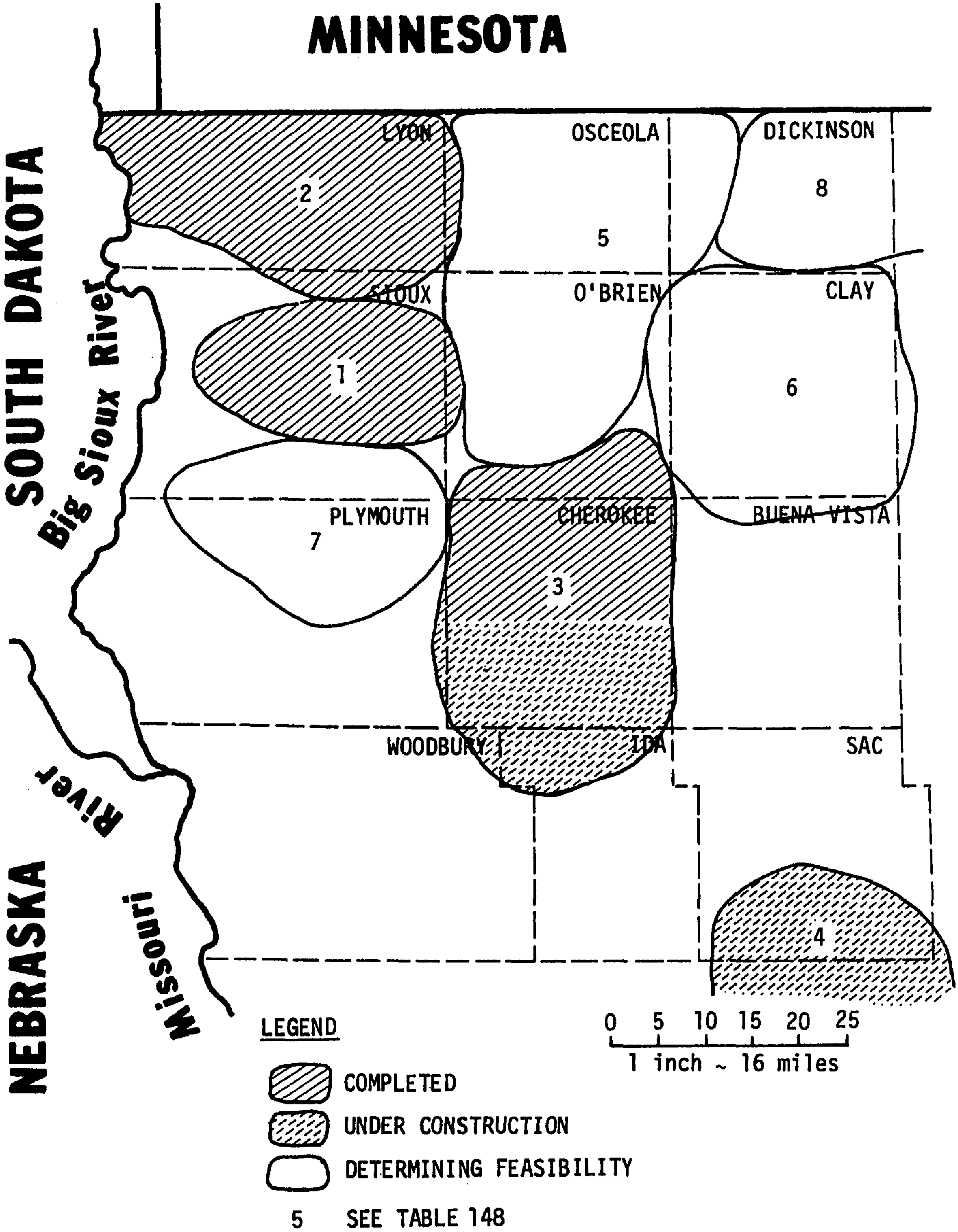


Fig. 78. Approximate location and status of rural water systems in Northwest Iowa in March 1978

Table 149. Rural water systems in Northwest Iowa, as of March 1978

Number	Name and description
1	Rural Water System No. 1, Hospers, Iowa All or portions of 9 townships in Sioux County and portions of 3 townships in O'Brien County. About 650 rural connections with service to 4 unincorporated communities. Project construction completed.
2	Lyon and Sioux Rural Water System, Inc., George, Iowa All or portions of 17 townships in Lyon County, 6 townships in Sioux County and 1 township in O'Brien County. Approximately 820 rural connections. Project construction completed.
3	Cherokee County Rural Water District No. 1, Cherokee, Iowa All or portions of 16 townships in Cherokee County and 6 townships in surrounding counties. About 740 connections. The northern Mill Creek subsystem is completed and selling water to about 350 users. The southern Cherokee subsystem is under construction.
4	West Central Iowa Rural Water Association, Manning, Iowa All or portions of 19 townships in Carroll, Crawford, Shelby, Audubon and Sac Counties. About 850 rural connections plus service to 6 communities. Southern Nishnabotna subsystem is completed and selling water to 425 users plus 3 towns. The northern Boyer subsystem is under construction.
5	Osceola County Rural Water Association, Melvin, Iowa All of Osceola County, most of O'Brien County and portions of east Lyon and west Dickinson County. 2,759 rural users plus bulk water to 14 communities and water service to 6 other communities. North and South Ocheyedan subsystems funded for a total of $7 million. Little Creek, Mill Creek and Stony Creek subsystems funded for $13 million. Final plans and specifications being prepared.
6	Clay County Rural Water Association, Spencer, Iowa All of Clay County. 1,037 rural users plus bulk water to 5 communities. Project funded for $6.9 million. Final plans and specifications being prepared.
7	Southern Sioux Rural Water Association, Ireton, Iowa All or parts of 16 townships in southern Sioux County and northern Plymouth County. About 850 rural users. Project funded for $5.1 million. Final plans and specifications being prepared.
8	Dickinson County Rural Water Association, Spirit Lake, Iowa All or portions of 11 townships in eastern Dickinson County and a portion of Emmet County. Signup of 626 to date. Survey is still being completed. Estimated cost is about $4.5 million.

tend to be large, varying from a half county to two counties in size. Completion of these systems involve the laying of hundreds of miles of pipe at a cost of millions of dollars per county. Since there are only a few customers per mile, user costs are higher than those paid by urban dwellers. In addition, Table 149 indicates that some of the systems do not include all the rural residents and communities within their service areas. However, with the growth of rural water systems in Iowa and the requirements of the 1974 Safe Drinking Water Act, the assumption could be made that most, if not all, of the people living in Northwest Iowa will be served by a municipal or rural water system within the next one or two decades.

Livestock needs for water as well as rural domestic and urban uses are presently included in the purposes for which these rural systems have been designed. Improvement of animal health is a key objective in increasing agricultural livestock profits using higher quality water (Gieseke, 1972). The Farmers Home Administration (FmHA) also encourages the inclusion of some capacity for fire fighting purposes in the system. However, water for irrigation of farm or specialty crops is not included in any of these rural water districts.

To date all the systems in Northwest Iowa have or will be using ground water as their water supply source. Hopefully, the existence of these rural water supply systems will put an end to the social and economic disadvantages borne by rural residents in the past because of inadequate water supplies. Also, hopefully, the county officials will institute land use practices which will discourage the unwise spread of rural residences when adequate water becomes available.

These interrelationships of land and water are increasingly becoming of concern to planners and legislators.

Costs of various types of systems

While the total cost of these systems is high, Austin (1977) has shown that they are comparable in monthly user cost to individual and small cluster systems. For this rough comparison he assumed an area in north central Iowa where an adequate supply of water (8,000 gallons per month per family) was available for 8 families in the Dakota Sandstone aquifer 200 feet below the surface. However, this water is very hard and has a high iron content. Table 150 shows the cost of individual systems for this hypothetical area. The total monthly cost of $26.22 does not include any funds set aside for repair or maintenance of equipment. Table 151 shows the cost calculations for the cluster well system. The per user cost of $25.34 per month is somewhat less than the cost of the individual systems. To represent the cost of a regional rural water system, Austin used the amount which would be charged for using 8,000 gallons per month from 3 regional rural water systems in Iowa. These amounts are shown in Table 152. Their average cost, $28.28, is higher than either the individual or cluster systems.

Austin (1977) also indicated that the benefits of centralized management need to be evaluated. A regional system can employ full-time personnel to operate and maintain the system. This eliminates the need for the user to spend any of his time to run and repair the system, as he would if he had an individual system. This should result in the regional system being able to provide a more dependable supply

Table 150. Cost analysis of individual well systems[a]

Item	Unit cost	Cost/user	Total cost
Well, casing, pump[b] and controls	$15.00/ft	$3,000	$24,000
Storage tank	$85 each	85	680
Water softener	$290/each	290	2,320
Iron removal filter	$200/each	200	1,600
Total capital cost		$3,575	$28,600
Annual capital cost (5% for 40 years)		$ 208.35	$ 1,666.80
Annual power cost[c]	$0.05/kw-hr	$ 60.92	$ 487.36
Salt[d]	$0.02/lb	$ 16.70	$ 133.60
Potassium permanganate[e]	$2.39/bottle	$ 28.68	$ 228.44
Total annual cost		$ 314.65	$ 2,516.20
Monthly cost		$ 26.22	$ 209.68

[a]After Austin (1977).

[b]Well is 4-inch diameter, 200 feet deep with casing sealed with concrete grout.

[c]Power cost based on 2 hours operation per day; pump power requirement of 1670 watts.

[d]Salt requirements based on 0.45 lb NaCl/1000 grains hardness removed.

[e]Based on one recharge cycle per month.

of water and also possibly a higher quality water, both of which are requirements of the 1974 Safe Drinking Water Act. Another advantage of the regional system mentioned by Austin (1977) is that "the federal

Table 151. Cost analysis of cluster well systems[a]

Item	Unit cost	Total cost
Well[b]	$14/ft	$ 2,800
30 gpm pump and[c] controls	$1,200/each	1,200
Storage tank	$500/each	500
Interconnecting piping[d]		
10,560 ft of 1-1/2"	$0.60/ft	6,336
21,120 ft of 1-1/4"	$0.55/ft	11,616
Package treatment plant[e]	$15,000/each	15,000
Total capital cost		$37,452.00
Annual capital cost		2,182.70
Power[f]	$0.05/kw-hr	134.98
Chemicals	$0.15/1000 gal	115.20
Total annual cost		$ 2,432.88
Monthly cost/user		$ 25.34

[a]After Austin (1977).

[b]Well cost for 6" diameter well, 200 feet deep includes casing and grouting.

[c]Pump with total dynamic head of 300 feet.

[d]Pipeline class 160 PVC pipe. Cost includes installation.

[e]Treatment includes oxidation with potassium permanganate, horizontal pressure filters and zeolite softening with automatic controls.

[f]Power requirements based on 2 hours operation per day; pump power requirements of 3700 watts.

funding program does not generally provide the capability for loans to individuals for improving their own systems, but it will provide loans for the individual's share of the capital cost of regional rural water

Table 152. Capital cost and average monthly user charge for rural water systems in Iowa[a]

System	Capital cost/user	Monthly cost[b]
Hospers Rural Water System (660 connections)	$5,000	$31.78
Lyon-Sioux Rural Water System (820 connections)	$6,000	$26.05
Rathbun Rural Water System	$4,780[c]	$27.00[c]

[a]After Austin (1977).

[b]Monthly cost based on rate schedule for the system supplying 8,000 gallons/month.

[c]Estimated per user cost. Rathbun is currently under construction.

systems. Also, state and federal grant funds are often available for regional rural water systems making these systems more economical."

In a recent discussion (T. Al Austin, Civil Engineering Department, Iowa State University, Ames, Iowa, personal interview, November 1, 1978), Austin pointed out that the above comment on federal funding would change the economic analysis made in his paper (Austin, 1977). The FmHA currently funds regional systems with loans at 5% interest for a period of 40 years. These are the rates and terms used in his analysis of individual and cluster systems as shown in Tables 150 and 151. More likely the farmers and rural residents, for individual supplies or cluster systems, would have to obtain their loans from private lenders whose current rates are 10% for a period of 10 years. Using these rates and terms rather than those provided by the federal government yields the results shown in Table 153. With the more

Table 153. Monthly user costs for various types of rural water systems and loan terms

Type of system	Loan terms %	Loan terms Years	Monthly cost dollars
Cluster wells	5	40	25.34
Individual	5	40	26.22
Regional	5	40	28.28
Individual	10	10	57.34
Cluster wells	10	10	66.10

favorable loan terms, the average monthly cost for a user involved in a regional system is only one-half the cost of those involved in individual or cluster well systems. Another way of refining the rough estimates shown in Tables 150 and 151 is to include the useful lives of the components of each system, such as the pumps, tanks, softeners, etc., in the economic analysis.

Existing Water Use Permit Status

Two computer listings of water use permits in Northwest Iowa were obtained from the Iowa Natural Resources Council in April 1978. The first listing contained 670 permits for seven general uses: commercial, industrial, irrigation, municipal, recreational, rural and storage. The second listing contained more detailed information on two categories: the use was designated as "storage" and the source involved a "reservoir." These permits do not cover all uses of water in Northwest Iowa because the law excludes the following uses from the permit requirements.

1. The use of water for ordinary household purposes, poultry, livestock and other domestic animals.

2. The beneficial use of surface flow from rivers bordering the State of Iowa.

3. Existing beneficial uses of water within the territorial boundaries of municipal corporations on May 16, 1957, except those that increase their water use in excess of 100,000 gallons or 3 percent, whichever is greater, per day more than its highest per day beneficial use prior to the above date.

4. Any other beneficial use of water by any person of less than 5,000 gallons per day.

Table 154 indicates that most of the 670 permits issued were for irrigation and storage purposes. These two will be discussed in following paragraphs. The sources of water for the other five uses are listed in Table 155. The surficial sand and gravel aquifers are the source for about half the uses with the other half divided roughly equally between the Dakota Sandstone aquifer and surface water reservoirs. Streams are the source for about 6% of the uses. The number and distribution of these sources through the 12-county region indicate that no one locality is overstressed. However, as mentioned before, many of these sources have quantity and quality problems, especially during periods of drought.

Table 156 shows that 291 permits have been issued to irrigate 57,369 acres in Northwest Iowa through April 1978. By far the most

Table 154. Number of water permits issued by the Iowa Natural Resources Council for various uses in Northwest Iowa

County	Commercial	Industrial	Irrigation	Municipal	Recreational	Rural	Storage
Buena Vista	0	2	4	2	0	0	2
Cherokee	1	3	3	2	0	2	15
Clay	0	10	23	4	0	0	1
Dickinson	1	2	7	5	2	0	2
Ida	0	1	4	1	1	0	26
Lyon	0	1	16	2	0	3	4
O'Brien	2	2	6	2	0	0	7
Osceola	1	5	24	3	0	0	2
Plymouth	3	2	32	2	0	0	62
Sac	1	8	12	2	0	1	0
Sioux	2	9	63	8	0	2	5
Woodbury	0	16	97	4	1	0	132
Region	11	61	291	37	4	8	258

Table 155. Sources of water in Northwest Iowa for commercial, industrial, municipal, recreational and rural purposes

Purpose	Aquifers: Sand and gravel	Aquifers: Dakota sandstone	Aquifers: Other	Streams	Reservoirs
Commercial	4	6	0	1	0
Industrial	19	15	2	5	20
Municipal	25	7	0	0	5
Recreational	1	1	0	1	1
Rural	7	1	0	0	0
Total	56	30	2	7	26

Table 156. Source of supply for irrigation water, number of permits and total number of acres irrigated in Northwest Iowa

County	Wells in the sand and gravel aquifers		Wells in the Dakota sandstone aquifer		Reservoirs		Streams	
	No.	Acres	No.	Acres	No.	Acres	No.	Acres
Buena Vista	1	300	0	0	1	152	2	520
Cherokee	0	0	0	0	0	0	3	355
Clay	12	1,689	0	0	1	85	10	1,676
Dickinson	3	263	0	0	2	39	2	260
Ida	2	165	0	0	0	0	2	311
Lyon	12	1,438	1	100	2	163	1	6
O'Brien	3	215	3	390	0	0	0	0
Osceola	18	2,670	0	0	4	505	2	600
Plymouth	26	4,270	4	742	1	80	1	77
Sac	2	315	0	0	5	355	5	840
Sioux	53	11,099	3	538	2	390	5	745
Woodbury	85	24,457	3	619	0	0	9	940
Region	217	46,881	14	2,389	18	1,769	42	6,330

used source is the surficial sand and gravel aquifers which account for 217 permits and about 46,900 acres. The three southern counties along the western border of the region make up the bulk of this use with 164 permits and about 39,800 acres. The 42 permits which use a stream as their source are vulnerable to being cut off just when their need is the greatest. The shallow wells in the sand and gravel aquifers may also be vulnerable to drought conditions due to lowering of the ground water table, especially those which are not located on the Missouri River flood plain in Woodbury County.

The second computer listing revealed that 344 reservoirs, combined into 6 types of water bodies, were used to provide water for 10 uses under the categories of "reservoir" and "storage." The 6 types were natural lakes, artificial lakes for recreation, farm ponds, gravel pits, quarries and dug reservoirs in the form of pit wells. The 10 uses were dewatering and/or processing of sand and gravel, irrigation of farm crops, specialty crops and golf courses, municipal, recreation, commercial feedlot and storage for livestock watering and watershed management. The following detailed listing of permits in each county illustrate the lengths to which the residents of Northwest Iowa must go in order to meet the demands placed on the available water resources in the region.

Buena Vista County had 2 farm ponds used for watershed management and/or livestock watering and 5 gravel pits, 2 of which were used for dewatering and processing sand and gravel, 1 for irrigating farm crops and 2 for irrigating a golf course. In Cherokee County water users used 1 gravel pit for processing sand and gravel and 15 farm ponds for watershed management and/or livestock watering. In Clay County 2 farm ponds were used for irrigating farm crops, 1 farm pond used for watershed management and/or livestock watering, 3 dug reservoirs for irrigating farm crops and 7 gravel pits, 4 used for dewatering and/or processing sand and gravel and 3 for irrigation of farm crops.

In Dickinson County 8 permit holders used natural lakes as the source of water: 1 for irrigating specialty crops, 1 for irrigating a golf course, 1 for recreational purposes and 5 for municipal uses. One farm pond was used for irrigating a golf course and 2 other farm ponds were utilized for watershed management and/or livestock watering. One gravel pit was used for dewatering and processing sand and gravel and one other was used for irrigating farm crops. In Ida County 1 farm pond was used for irrigating a golf course and another 26 for watershed management and/or livestock watering. One artificial lake in Lyon County was used for recreational purposes, 3 farm ponds were utilized for watershed management and/or livestock watering, 1 gravel pit was used for irrigating a golf course and 1 gravel pit and 2 dug reservoirs were used for irrigating farm crops.

Two artificial lakes in O'Brien County were used for recreational purposes, 5 farm ponds were used for watershed management and/or livestock watering, 3 farm ponds and 3 gravel pits were used for irrigating farm crops and 1 gravel pit was dewatered and used for processing sand and gravel. In Osceola County 3 gravel pits were used for dewatering and/or processing sand and gravel, 2 farm ponds were utilized for watershed management and/or livestock watering and 8 gravel pits and 2 dug reservoirs were used for irrigating farm crops. Plymouth County had 1 farm pond serving a commercial feedlot, 1 gravel pit dewatered to process sand and gravel, 1 gravel pit used for irrigating farm crops and 62 farm ponds used for watershed management and/or livestock watering purposes.

Sac County had 1 quarry used to irrigate a golf course and 12 gravel pits, 7 dewatered for processing sand and gravel and 5 for irrigating farm crops. Five farm ponds in Sioux County were used for watershed management and/or livestock watering, 2 gravel pits used for dewatering and processing sand and gravel and 1 farm pond, 1 dug reservoir and 6 gravel pits used for irrigating farm crops. In Woodbury County 2 gravel pits were used to dewater sand and gravel, 4 dug reservoirs were used to irrigate specialty crops and 132 farm ponds were used for watershed management and/or livestock watering.

Future Availability of Ground Water

Yields from the aquifers located in Northwest Iowa vary from just a few gallons per minute to more than 2,000 gpm. The yields of just a few gpm are obtained from the glacial drift aquifers while 2,000 gpm can be obtained from the surficial aquifer at some points in the Missouri River floodplain. Other yields between these two extremes can be obtained from the surficial aquifers along the Big Sioux River and the interior streams and the various bedrock aquifers.

Kriz and Johnson (1963) have reported on the results of pumping tests on two wells in the Missouri River floodplain located near the town of Hornick in Woodbury County. The nonconsolidated materials consist of a 10-20 inch surface layer of black clay. Lenses of sand are scattered throughout the upper 40 feet of the clayey alluvial material. A deep layer of sand and gravel which is about 80 feet thick lies between this top layer and the bedrock which is about 120 feet below the surface. The wells were tested at rates ranging from 1,650 to 2,325 gpm for durations of 16 to 40 hours. At the end of 40 hours with a discharge of 2,325 gpm, drawdowns were 8.9 feet at a distance of 43 feet from the pumped well, 2.2 feet at a distance of 1,690 feet and about 1.5 feet at 2,952 feet.

The records of several wells along the floodplain of the Big Sioux River were made available to the author (Richard Hunter, Layne-Western Co., Omaha, Nebraska, private communication, May 23, 1978). These records included 2 wells in the town of Akron in Plymouth County, 6 wells for the city of Hawarden in Sioux County and 2 wells drilled near Klondike in Lyon County for the Lyon-Sioux Rural Water District. In Akron, at one well the aquifer consisted of 44 feet of gravel and coarse sand underlying 12 feet of brown clay. The well was tested for 3 hours at a rate of 429 gpm with a resulting drawdown of 3.5 feet. The aquifer of the other well consisted of 44 feet of material ranging from coarse sand to boulders underlying 4 feet of top-soil. This well was pumped at various rates: 185 gpm with 1.1 feet of drawdown, 300 gpm with 1.8 feet of drawdown, 492 gpm with 3.5 feet and 610 gpm with 4.5 feet of drawdown. Full recovery was experienced in 5 minutes.

The aquifer at Hawarden consists of material ranging from coarse sand to boulders whose thickness varies from 24 to 35 feet. The aquifer is underlain by blue shale and is covered by a surface layer of 5 to 8 feet of soil ranging from sandy loam to clay. Pumping rates and drawdowns at each of the 6 wells varied considerably: 154 gpm with 5.7 feet of drawdown, 201 gpm with 2.9 feet of drawdown, 204 gpm with 6.9 feet, 212 gpm with 3.1 feet, 264 gpm with 5.7 feet, 328 gpm with 7.0 feet and 349 gpm with 5.0 feet of drawdown. All wells had fully recovered within 30 minutes after pumping had ceased. The aquifer of one well at Klondike consisted of 35 feet of material ranging from fine sand to boulders. It was overlain with 3 feet of topsoil and 7 feet of brown clay. The well was tested at 200 gpm for 24 hours with a drawdown of 7.0 feet. The aquifer of the other well consisted of 49 feet of coarse gravel and rock overlain by 1 foot of topsoil and 9 feet of fine sand. This well was also tested at 200 gpm for 24 hours with a drawdown of 3.5 feet. Both wells had essentially fully recovered within 30 minutes. At all three locations, Akron, Hawarden and Klondike, all wells fully penetrated the aquifer and ranged in depth from 31 to 59 feet.

Three wells have been developed in Big Sioux River alluvium west of Larchwood in Lyon County for the Lyon-Sioux Rural Water District (Donald Gordon, Iowa Geological Survey, Iowa City, Iowa, private communication, May 16, 1978). These wells were tested between 200 and 250 gpm with 6 to 8 feet of drawdown and cones of influence of about 600 foot radius. The wells were developed in alluvial sands and gravels, two strata separated by intervening impermeable soils, with a combined thickness of about 20 feet. He indicated that these yields were probably comparable with yields from the Rock River alluvium as well as for the alluvial aquifers of most interior Iowa streams.

Gibbs (1978a, 1978b) has recently completed two studies on the location of some possible buried channel aquifers in Northwest Iowa as a part of the overall planning for three new rural water systems. These locations are shown in Fig. 79 and listed in Table 157. Only a few of these sites have been verified by pumping tests but for this study the assumption is made that all locations have the yield characteristics listed in Table 157. This is the first study to be done on possible buried channel aquifers in Northwest Iowa. Whether these are all buried channel aquifers needs to be verified. Some may be alluvial valley aquifers. If some or most of these sites are productive, then additional exploration programs can be undertaken to map other buried channel aquifers throughout Northwest Iowa and bring needed water supplies to the farmers and other residents of the region.

As noted in a previous section, yields from the Dakota Sandstone aquifer vary over a wide range, from about 50 gpm to 750 gpm. At Sioux City, where it is recharged from the overlying alluvial aquifer, yields in excess of 1,500 gpm have been obtained. The quality of the water is not good, containing significant amounts of sulphates with total hardness ranging from 500 to 1,500 mg/1. However, it occurs at shallow depths, ranging from 200 to 600 feet below the surface, and is the principal bedrock aquifer used in Northwest Iowa. Other bedrock aquifers exist below the Dakota Sandstone aquifer, but they also

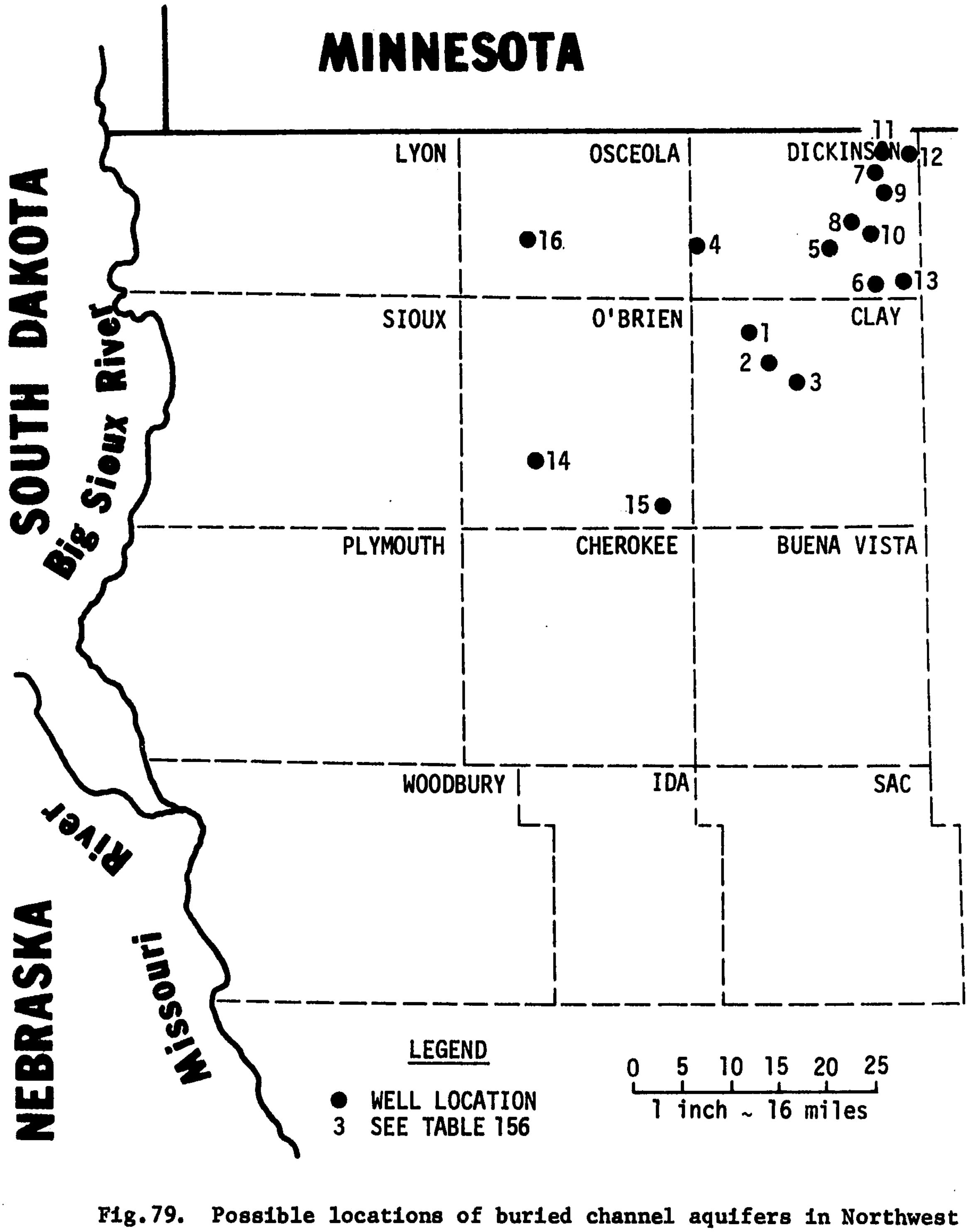


Fig. 79. Possible locations of buried channel aquifers in Northwest Iowa

Table 157. Locations, yields and well data of possible buried channel aquifers in Northwest Iowa[a]

No.	County	Location sec.-twp.-range	Yield per well, gpm	Number of wells[b]	Depth of wells, ft
1	Clay	19-97-38	1,000	4	50
2		30-97-37	1,000	6	100
3		2-96-37	500	4	80
4	Dickinson	6-98-38	1,000	7	100
5		33-99-36	500	4	150
6		29-98-35	500	3	150
7		28-100-35	500	3	150
8		24-99-36	500	4	150
9		4-99-35	500	3	150
10		31-99-35	500	2	150
11		15-100-35	500	4	150
12		13-100-35	500	2	150
13		26-98-35	500	2	150
14	O'Brien	29-95-41	500	4	150
15		23-94-39	500	4	100
16	Osceola	31-99-41	500	4	100

[a]Gibbs (1978a, 1978b).

[b]All wells are assumed to be drilled wells finished in sand and gravel formations, and screened and gravel packed.

have quality problems. And since they occur at deeper depths, they are more expensive to develop.

Reservoir Storage for Future Water Supply

Streamflow in Northwest Iowa is highly variable as shown by the gaging station records in a previous section. Because of this, the only way that a substantial portion of this streamflow can be made available as a source of water for both urban and rural purposes is through the use of impoundments. Sufficient storage must be made available so that an adequate volume of water is present in the reservoir to carry the people in the area through a prolonged drought while supplying all their needs. Yucel (1971) derived the following regression equation for net reservoir storage requirements in Iowa. The equation is applicable to the broad, relatively shallow impoundments constructed in Iowa and yields storage volumes adequate to maintain a flow equal to some percentage of the average annual flow through a drought with roughly a 50-year recurrence interval. The exponents to the slope and length variables were added by the writer to obtain more "reasonable" results for Northwest Iowa.

$$V/VMAF = 2.5676 + 2.7544\ D/QM - 0.01662S^{1.3} - 0.04475P - 0.0006E - 0.04318L^{0.9} \qquad (29)$$

where V = volume of net storage required, ac. ft.

VMAF = volume of average annual flow, ac. ft.

D = demand, cfs

QM = average annual flow, cfs

S = slope of mainstream channel, ft/mi. Defined as the slope between the points 10% and 85% along the main channel upstream of the point of interest

P = normal annual rainfall for the period 1931-1960, inches

E = average elevation of the watershed, 1,000 ft

L = length of mainstream channel from point of interest to watershed divide, miles

The average annual flow, QM, is determined from Eq. (30) as derived by Heinitz (1970). The volume of the average annual flow, VMAF, is calculated by multiplying QM in cfs by 365 days and multiplying this product by 1.98 to change the units to acre-feet.

$$QM = 0.0000007063A^{1.013}P^{3.88} \tag{30}$$

where QM = average annual flow, cfs

A = drainage area of watershed, sq. mi.

P = normal annual rainfall for the period 1931-1960, inches

The variables used in Yucel's equation were taken from a study by Burmeister (1970) which was an evaluation of the streamflow data program in Iowa. Precipitation, P, is obtained from Fig. 80. The drainage area, A, stream length, L, and slope, S, are determined from available maps or taken from compiled data. The average elevation of the watershed, E, is obtained by laying a grid over a map, determining the elevation of each grid intersection, averaging these elevations and dividing the average elevation by 1,000. The grid spacing should be selected so that at least 25 grid boundaries fall within the basin boundary.

The maximum possible demand on a stream on a long-term basis is the average annual flow. However, since some of the stored water will evaporate, the maximum possible demand will be only about 80% of the average annual flow. During a drought which lasts for 2 years, the net evaporation (total evaporation minus total precipitation) can approach 3 feet in Iowa. This net evapotranspiration is time dependent. During a severe, prolonged drought which lasts for 5 or 6 years, the net evaporation can approach 5 feet. For this study we will assume that net storage will be provided for a demand equal to 0.4-0.7 QM

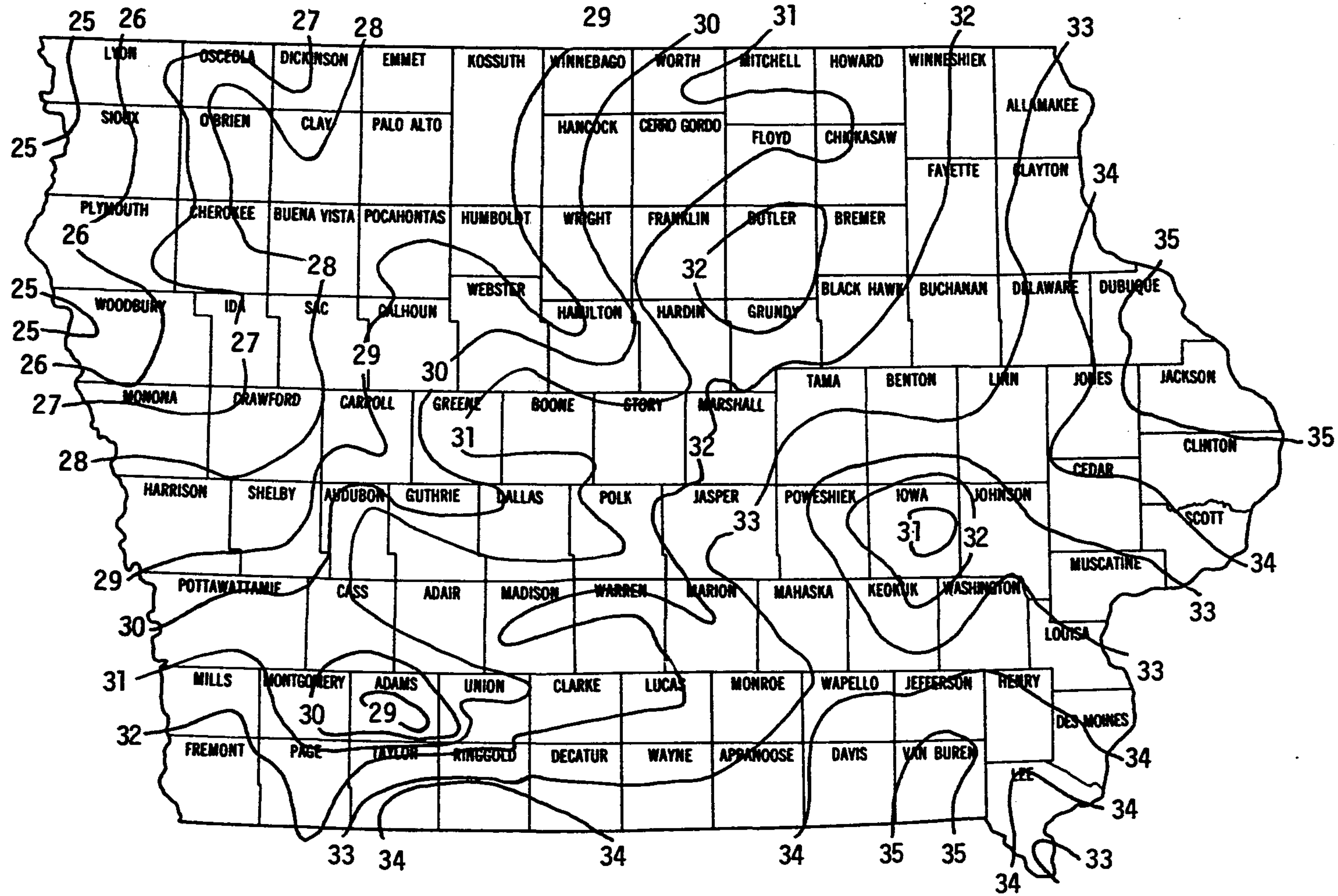


Fig. 80. Normal annual precipitation in Iowa, inches (after Burmeister, 1970)

and then add a volume equal to 3 feet times the average surface area of the reservoir in acres to obtain the gross storage needed for water supply.

Table 158 lists the locations and drainage areas of several potential reservoir sites in Northwest Iowa. These locations are also shown in Fig. 81 and were identified by the Corps of Engineers for flood control studies done in the late 1960's. The variables needed in Yucel's equation for each of these sites are listed in Table 159 and the net storages required for water supply for whatever purpose are shown in Table 160.

In order to arrive at a total storage volume and height of dam at each site, the following assumptions were made. Sediment storage would be that determined by the Corps of Engineers. Storage for water supply purposes would be that calculated using Yucel's equation, based on a range of demand to average annual flow ratios of 0.4 to 0.7, depending on the volume of storage available at a particular site. Three feet of storage would be added for evaporation on top of the sediment and water supply pools. The top of the flood surcharge pool would contain either 4 or 8 inches of runoff from the watershed depending on the storage available at a particular site. The top of the dam would be 7 feet above the flood surcharge pool elevation. The results of these assumptions are shown in Table 161 for each site. Note that if sediment production could be cut to one-third to one-half of the present rate, several thousand acre-feet of additional storage would become available for water supply purposes. Surface areas and elevations for each pool level as well as the streambed and

Table 158. Locations of potential reservoir sites in Northwest Iowa

County	Stream	Location sec.-twp.-rng.	Drainage area sq. mi.
Buena Vista	Brooke Creek	14-93-38	43
Cherokee	Mill Creek	10-92-40	283
	Silver Creek	09-90-40	40
Clay	Big Muddy Creek	34-97-36	61
	Willow Creek	11-94-37	50
Dickinson	Stony Creek	14-97-38	50
Ida	Battle Creek	11-87-41	49
	Maple River	11-87-40	362
Lyon	Little Rock River	21-98-45	486
O'Brien	Little Floyd River	09-96-42	47
	Waterman Creek	14-94-39	138
Plymouth	Deep Creek	32-93-43	50
	Johns Creek	12-90-44	41
	Plymouth Creek	05-91-45	34
	Willow Creek	30-93-44	64
Sac	Boyer River	33-88-37	112
	Indian Creek	17-87-36	32
Sioux	W. Br. Floyd River	28-95-45	113
Woodbury	Big Whiskey Creek	30-88-45	60
	Elliott Creek	28-88-45	58
	Mud Creek	31-89-44	66
	Reynolds Creek	20-86-42	19
	W. Fk. Little Sioux River	04-86-45	395
	Wolf Creek	01-86-45	106

top of dam elevations are shown in Table 162. The normal water surface elevation in each reservoir would be that of the water supply pool.

These various sources of surface and ground water and their potential yields which have been described above will provide the supply of water for the several demands discussed in the next section.

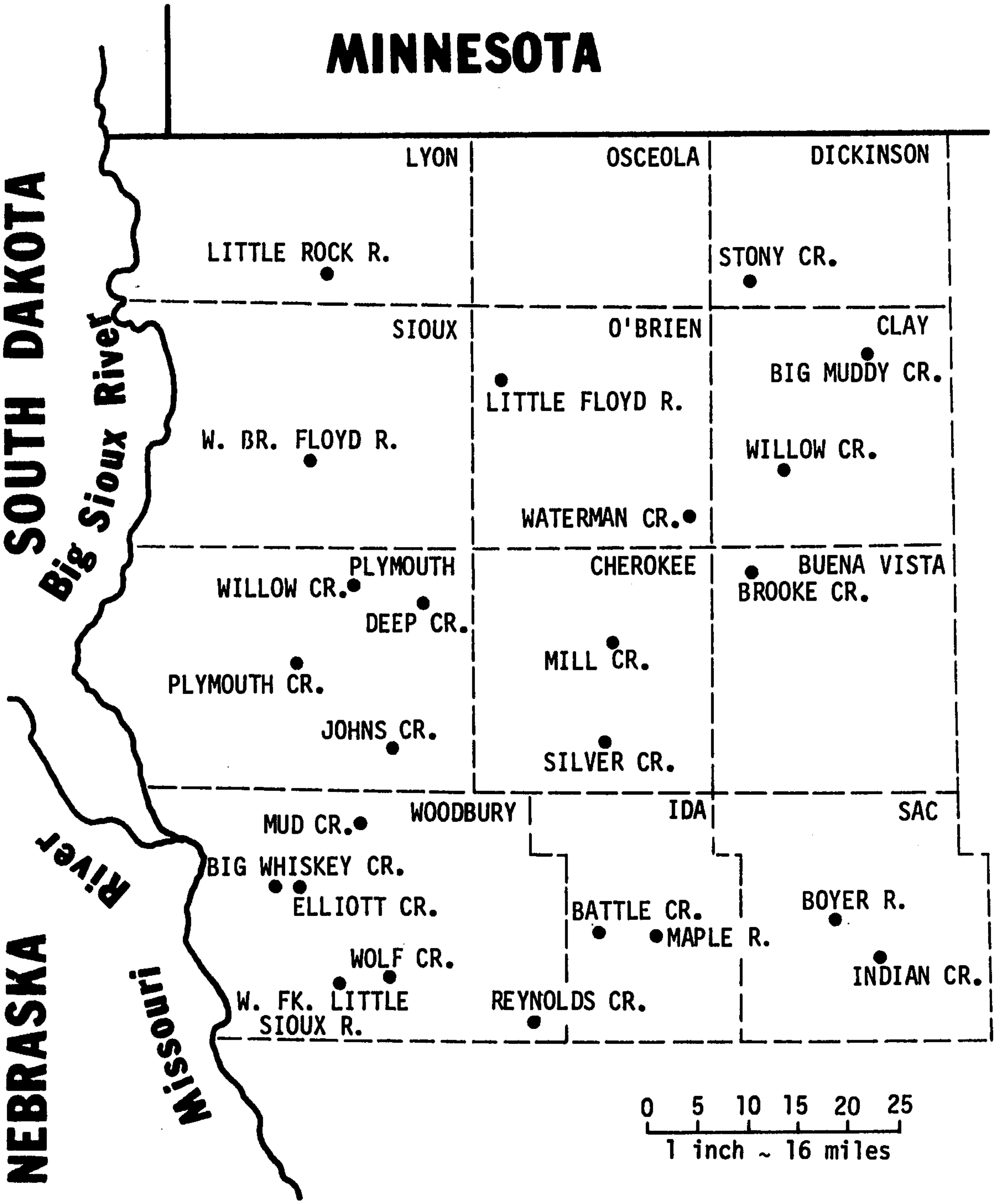


Fig. 81. Locations of potential reservoir sites in Northwest Iowa

Table 159. Data needed to determine storage volumes required for water supply purposes at potential reservoir sites in Northwest Iowa

County	Stream	D.A. sq. mi.	S ft/mi	L mi	P in./yr	E 1,000 ft	D/QM
Buena Vista	Brooke Creek	43	15.0	18	28.3	1.4	0.6
Cherokee	Mill Creek	283	9.7	41	28.1	1.4	0.6
	Silver Creek	40	18.0	13	27.0	1.4	0.6
Clay	Big Muddy Creek	61	5.0	23	27.9	1.5	0.5
	Willow Creek	50	5.0	23	28.3	1.4	0.7
Dickinson	Stony Creek	50	11.0	14	27.2	1.5	0.7
Ida	Battle Creek	49	22.2	14	27.0	1.4	0.6
	Maple River	362	7.4	38	27.6	1.4	0.4
Lyon	Little Rock River	486	4.5	57	27.3	1.5	0.4
O'Brien	Little Floyd River	47	11.0	14	27.5	1.5	0.7
	Waterman Creek	138	9.0	30	28.3	1.4	0.7
Plymouth	Deep Creek	50	8.0	16	27.2	1.4	0.6
	Johns Creek	41	8.0	17	26.5	1.4	0.4
	Plymouth Creek	34	17.0	12	26.0	1.3	0.7
	Willow Creek	64	9.0	23	26.4	1.4	0.6
Sac	Boyer River	112	10.0	24	28.0	1.3	0.5
	Indian Creek	32	10.0	11	28.2	1.4	0.6
Sioux	W. Br. Floyd River	113	7.5	21	26.1	1.5	0.6
Woodbury	Big Whiskey Creek	60	22.0	24	25.8	1.4	0.6
	Elliott Creek	58	22.0	18	25.8	1.4	0.6
	Mud Creek	66	17.0	20	26.0	1.4	0.7
	Reynolds Creek	19	26.0	9	26.7	1.4	0.7
	W. Fk. Little Sioux River	395	6.5	56	27.0	1.3	0.4
	Wolf Creek	106	17.7	29	25.7	1.4	0.5

Table 160. Net storage volumes required for water supply purposes at potential reservoir sites in Northwest Iowa

Stream	QM cfs	VMAF ac. ft.	D/QM	Annual demand volume ac. ft.	V/VMAF	Volume required ac. ft.
Brooke Creek	13.7	9,900	0.6	5,900	1.11	11,000
Mill Creek	90.0	65,000	0.6	39,000	1.42	92,300
Silver Creek	10.6	7,700	0.6	4,600	1.27	9,800
Big Muddy Creek	18.5	13,400	0.5	6,700	1.07	14,300
Willow Creek	15.9	11,500	0.7	8,100	1.60	18,400
Stony Creek	13.7	9,900	0.7	6,900	1.82	18,000
Battle Creek	13.0	9,400	0.6	5,600	1.61	15,100
Maple River	107.0	77,400	0.6	46,400	1.62	125,400
Little Rock River	139.0	100,400	0.4	40,200	0.69	69,300
Little Floyd River	13.4	9,700	0.7	6,800	1.80	17,500
Waterman Creek	44.6	32,200	0.7	22,500	1.14	36,700
Deep Creek	13.7	9,900	0.6	5,900	1.59	15,700
Johns Creek	10.1	7,300	0.4	2,900	1.04	7,600
Plymouth Creek	7.8	5,600	0.7	3,900	1.76	9,500
Willow Creek	15.7	11,300	0.6	6,800	1.30	14,700
Boyer River	34.6	25,000	0.5	12,500	0.83	20,800
Indian Creek	10.0	7,200	0.6	4,300	1.65	11,900
W. Br. Floyd River	26.7	19,300	0.6	11,600	1.47	28,400
Big Whiskey Creek	13.5	10,000	0.6	6,000	1.39	13,900
Elliott Creek	13.0	9,400	0.6	5,600	1.56	14,700
Mud Creek	15.2	11,000	0.7	7,700	1.36	15,000
Reynolds Creek	4.8	3,400	0.6	2,000	1.56	5,300
W. Fk. Little Sioux River	108.0	78,000	0.6	46,800	1.20	93,600
Wolf Creek	23.5	17,000	0.6	10,200	1.48	25,200

Table 161. Total storage volumes required at potential reservoir sites in Northwest Iowa, acre-feet

County	Stream	100-yr sediment	Water supply	Evaporation	Flood control	Total volume
Buena Vista	Brooke Creek	3,900	11,000	1,900	9,200	26,000
Cherokee	Mill Creek	34,600	92,300	10,000	120,700	257,600
	Silver Creek	3,600	9,800	1,900	8,500	23,800
Clay	Big Muddy Creek	5,700	14,300	6,300	13,000	39,300
	Willow Creek	4,700	18,400	3,500	21,300	47,900
Dickinson	Stony Creek	4,600	18,000	7,400	21,300	51,300
Ida	Battle Creek	4,400	15,100	4,000	20,900	44,400
	Maple River	45,200	125,400	27,000	154,500	352,100
Lyon	Little Rock River	10,000	69,300	13,500	103,700	196,500
O'Brien	Little Floyd River	1,700	17,500	7,800	20,000	47,000
	Waterman Creek	14,800	36,700	4,500	58,900	114,900
Plymouth	Deep Creek	1,800	15,700	4,000	21,300	42,800
	Johns Creek	3,600	7,600	3,500	8,800	23,500
	Plymouth Creek	1,200	9,500	2,800	14,500	28,000
	Willow Creek	2,200	14,700	3,600	27,300	47,800
Sac	Boyer River	4,000	20,800	2,800	23,900	51,500
	Indian Creek	1,200	11,900	3,500	13,600	30,200
Sioux	W. Br. Floyd River	4,000	28,400	8,500	48,200	89,100
Woodbury	Big Whiskey Creek	5,800	13,900	3,700	25,600	49,000
	Elliott Creek	5,400	14,700	4,300	24,700	49,100
	Mud Creek	6,500	15,000	5,200	28,200	54,900
	Reynolds Creek	1,500	5,300	1,100	8,100	16,000
	W. Fk. Little Sioux River	49,400	93,600	17,500	168,500	329,000
	Wolf Creek	10,900	25,200	7,000	45,200	88,300
Total		230,700	704,100	155,300	1,009,900	2,100,000

Table 162. Pertinent elevations and areas at the potential reservoir sites in Northwest Iowa

Stream	Stream-bed elev. ft	Sediment pool Elev. ft	Sediment pool Area ac	Water supply pool Elev. ft	Water supply pool Area ac	Flood pool Elev. ft	Flood pool Area ac	Top of dam Elev. ft	Top of dam Area ac
Brooke Creek	1,232	1,271	200	1,302	620	1,317	810	1,324	1,030
Mill Creek	1,195	1,244	1,300	1,288	3,400	1,310	5,800	1,317	7,000
Silver Creek	1,198	1,228	210	1,256	740	1,267	940	1,274	1,030
Big Muddy Creek	1,320	1,341	690	1,357	1,860	1,363	2,300	1,370	2,800
Willow Creek	1,300	1,322	480	1,347	1,390	1,359	2,240	1,366	3,050
Stony Creek	1,360	1,377	620	1,394	2,500	1,401	4,050	1,408	5,200
Battle Creek	1,217	1,245	500	1,265	1,400	1,277	2,000	1,284	2,500
Maple River	1,210	1,253	3,200	1,278	9,500	1,295	15,600	1,302	18,500
Little Rock River	1,271	1,30-	900	1,336	4,800	1,353	9,500	1,360	12,000
Little Floyd River	1,380	1,403	880	1,415	2,400	1,422	3,700	1,429	5,200
Waterman Creek	1,230	1,277	810	1,310	1,770	1,336	2,750	1,343	3,100
Deep Creek	1,313	1,323	370	1,348	1,440	1,359	2,350	1,366	3,100
Johns Creek	1,210	1,237	360	1,255	820	1,264	1,250	1,271	1,800
Plymouth Creek	1,198	1,205	150	1,230	830	1,244	1,350	1,251	1,700
Willow Creek	1,243	1,262	330	1,285	1,300	1,300	2,600	1,307	3,200
Boyer River	1,265	1,270	260	1,295	1,580	1,307	3,000	1,314	4,200
Indian Creek	1,245	1,251	240	1,265	750	1,277	1,200	1,284	1,450
W. Br. Floyd River	1,296	1,312	600	1,333	3,000	1,344	6,000	1,351	8,000
Big Whiskey Creek	1,089	1,121	500	1,142	1,400	1,157	2,200	1,164	2,700
Elliott Creek	1,090	1,128	600	1,147	1,500	1,160	2,400	1,167	3,000
Mud Creek	1,158	1,184	520	1,205	1,450	1,221	2,300	1,228	2,850
Reynolds Creek	1,170	1,196	140	1,222	400	1,238	650	1,245	780
W. Fk. Little Sioux River	1,062	1,115	3,100	1,137	6,200	1,159	10,300	1,166	12,000
Wolf Creek	1,070	1,100	1,000	1,119	2,400	1,136	3,500	1,143	3,900

WATER SUPPLY DEMANDS FOR NORTHWEST IOWA

In order to test the adequacy of the water resources in the region, including both ground water and surface water sources, the future demands which will be made upon these sources must be known or estimated. Average per capita demand, the amount of water use assessed to each person in a designated period, has been evaluated in water-use studies nationally, using records of municipal water use and population data for the area served. Average daily use, computed from an annual average basis, is the most common reference level. Total daily demands in the community are then obtained by multiplying the amount of water used by a person (measured in gpcd, gallons per capita per day) by the number of people being served. Future demands are estimated by projecting both the per capita demand rates and population, accounting for expansion of area served, commercial and industrial growth, etc.

These techniques are used to estimate the future urban water demands in Northwest Iowa. This permits aggradation of data more easily than more detailed breakdowns by manufacturing or commercial categories, as used in economic input-output models such as that of Barnard and Dent (1976) for the Iowa Water Plan. Similar aggradation techniques are also used to determine the demands for such other uses as irrigation, rural domestic and livestock production.

These future water demands become another portion of the input data needed for the proposed goal programming model.

General Relationships for Water Demand in Iowa

Variations in use

The rate of water use on a daily per capita basis varies widely throughout the United States and is dependent upon many factors: climate, local economy, urbanization, water distribution facilities, cost to consumer, availability and variability of the water source, and kinds of commercial and industrial establishments supplied from the municipal system (U.S. Water Resources Council, 1968). People in hot, arid climates will tend to use more water than people in cooler, more humid climates. The degree of affluence of the population will be reflected in the amount of water used: a higher standard of living will result in more water being used for lawn watering, for car washing, for baths and showers, in automatic clothes washers and in dishwashers. Urban areas will use water for such public purposes as park and golf course watering, fire fighting, schools, hospitals, air-conditioning, cooling water for power generation and waste disposal. Scarcity of water, poor quality, and/or higher cost of water may result in decreased use. The amounts of water required by different commercial and industrial activities varies many fold.

Since the water supply can be utilized for many purposes, one needs to define exactly what beneficial uses will be included in the per capita use rate, gpcd. Langbein and Kammerer (1969), writing on water supply trends in the United States, listed three categories which were most commonly referred to in water resources studies. These three categories are listed in Table 163. The definition of Category 2

Table 163. Categories of water usage in the United States[a]

Category	Use	1965 nationwide average, gpcd
1	Municipal supplies, domestic household use only	63
2	Municipal supplies, all uses (domestic, public, commercial and municipally supplied industrial)	155
3	Municipal, rural, irrigation, and self-supplied industrial uses (excluding water for hydroelectric power)	1,600

[a]Langbein and Kammerer (1969).

will be used in this study.

Langbein and Kammerer (1969) also found that the increase in the rate of per capita use of water in the United States (Category 2) prior to 1930 amounted to about one gpcd annually, or 100 gallons per century, but the increase had begun to taper off slightly in recent years.

Data on present use and future requirements of municipal water supplies on a national, regional, state and local basis have been presented by many researchers and various governmental agencies and committees (Schroepfer et al., 1948; Seidel et al., 1953; Seidel and Baumann, 1957; Future Water Requirements, 1960; Csallany, 1965; Seidel and Cleasby, 1966; U.S. Water Resources Council, 1968; Seidel, 1978). Per capita use rates derived from these and other studies can then be combined with the population projections prepared previously to determine the future water supply demands for Northwest Iowa.

Other water demand studies with data applicable to Northwest Iowa

Recent federal studies In August 1966, a federal study was completed on the needs for water supply and water quality control in the Skunk River basin, Iowa (Federal Water Pollution Control Administration, 1966). One excerpt from this report stated that

> "The present per capita use of water for domestic purposes is about 65 gpd (gallons per day). In larger cities, domestic use per person may range as high as 85 gpd, whereas in communities of less than 500, it may be as low as 48 gpd. These are direct use figures that were calculated from water bills. The per capita use of water in municipalities is generally much greater, considering commercial and light industrial water uses. On this basis, the current per capita use, ordinarily supplied through municipal systems, is estimated to be about 135 gpd. For projections of future use, it is estimated that increased industrialization and increased standards of living will raise the per capita consumption to 150 gpd by 2020 and 200 gpd by 2070."

In 1970 six volumes of the Upper Mississippi River Comprehensive Basin Study were published (UMRCBS Coordinating Committee, 1970). Appendix H dealt with water supply and quality control. Base and projected water use rates taken from this study are shown in Table 164. Central supplies include both domestic and commercial usage. Industry includes only that portion which is municipally supplied.

Table 164. Base and projected municipal and industrial water use, gpcd[a]

Year	Central supplies	Industrial	Total
1960	78	32	110
1980	93	35	128
2000	109	44	153
2020	115	55	170

[a]UMRCBS Coordinating Committee, 1970.

In 1971 seven volumes of the Missouri River Basin Comprehensive Framework Study were published (Missouri Basin Inter-Agency Committee, 1971a). Volume 5 dealt with present and future needs. Within the basin historic per capita use rates varied from 11 to 720 gallons per day. The following criteria were set for that portion of the basin which includes Iowa. In cities over 10,000 population where present use was over 125 to 150 gpcd, a check was made of industrial water use and unit values adjusted accordingly. These adjusted values then became the future per capita demand for these communities. The future demand criteria for rural homes and communities with populations less than 10,000 are listed in Table 165. A constant demand was assumed for the entire planning period. The per capita use rates include domestic, municipal, commercial and municipally-supplied industrial uses.

Table 165. Projected water use rates in the Iowa portion of the Missouri River Basin, gpcd[a]

Population	Demand
2,500-10,000	125[b]
Less than 2,500	80[b]
Rural homes	
With pressurized system	50[c]
Without pressurized system	10[c]

[a]Missouri Basin Inter-Agency Committee (1971a).

[b]Includes domestic, municipal, commercial and industrial uses.

[c]Domestic only.

Every five years the U.S. Geological Survey (USGS) publishes national, regional and state estimates of water use for several purposes. The results of the 1975 study (Murray and Reeves, 1977) for Iowa are shown in Table 166. Public supplies include domestic, public, commercial and municipally-supplied industrial uses. Of the total daily use of 296 MG, the domestic and public categories accounted for 210 MG and the commercial and industrial categories accounted for 86 MG. The average per capita use was given as 146 gpd.

Table 166. Water withdrawn for various uses and consumed in Iowa during 1975 as estimated by the USGS

Use category	Ground water MGD	Surface water MGD	Total MGD	Fresh water consumed	
				MGD	%
Public supplies[b]	216	80	296	44	14.9
Rural use					
Domestic	51	0.1	51	20	39.1
Livestock		22	116	116	100.0
Self-supplied industrial					
Thermoelectric power	2	2,700	2,702	15	0.6
Other uses	183	132	315	63	20.0
Irrigation	21	3	24	24	100.0
Total	567	2,937	3,504	282	8.0

[a]Murray and Reeves (1977).

[b]Includes domestic, public, commercial and municipally-supplied industrial.

Total water use in Iowa in 1975 was 3,500 MGD of which 16% was ground water and 84% was surface water. If thermoelectric power use of water is neglected, then only 800 MGD was used. Ground water was the source of 70% of the water while surface water accounted for the other 30%. Fresh water consumption was either 6.4% or 26.3% depending on whether thermoelectric power use is or is not included. Consumption in each use category varied from 0.6% to 100%.

While these amounts and percentages are only percentages, they give a good idea of the relative magnitudes of use by each category and the source of water for that use. For instance water for irrigation and rural domestic use is almost exclusively ground water as is the majority of water used for livestock. Irrigation presently uses the smallest amount of water of all categories but is third highest in total amount of water consumed. And while Iowa is generally considered an agricultural state, this use accounts for only 191 MGD, 5.5% of the total but accounts for 71.1% of all water consumed in the state.

A comparison of the above values with the years 1960, 1965 and 1970 as estimated by the USGS for public supplies, rural domestic and livestock use and self-supplied industrial uses are given in Tables 167 through 172 (Task Force on Water Supply and Use, 1977).

Table 167. Water withdrawn and consumed for public use in Iowa as estimated by the USGS for the period 1960 through 1975

Year	Ground water MGD	Surface water MGD	Total MGD	Fresh water consumed MGD	Fresh water consumed %
1960	91	68	159	16	10.1
1965	150	47	197	19	9.6
1970	180	73	253	37	14.6
1975	216	80	296	44	14.9

Table 168. Water delivered for public use in Iowa as estimated by the USGS for the period 1960 through 1975

Year	Domestic & public use MGD	Commercial & industrial use: Air cond. MGD	Commercial & industrial use: Other MGD	Commercial & industrial use: Total MGD	Total MGD	Per capita use gpd
1960	88	5.1	67	72	160	106
1965	140	1.2	56	57	197	104
1970	190	NA[a]	NA	63	253	123
1975	210	NA	NA	86	296	145

Table 169. Water withdrawn and consumed for rural domestic use in Iowa as estimated by the USGS for the period 1960 through 1975

Year	Surface water MGD	Ground water MGD	Total MGD	Fresh water consumed MGD	Fresh water consumed %
1960	0.5	55	56	14	25.0
1965	0.3	41	41	7	17.1
1970	0.1	47	47	19	40.4
1975	0.1	50	50	20	40.0

Table 170. Water withdrawn and consumed for livestock use in Iowa as estimated by the USGS for the period 1960 through 1975

Year	Surface water MGD	Ground water MGD	Total MGD	Fresh water consumed MGD	Fresh water consumed %
1960	69	69	138	138	100
1965	20	130	150	150	100
1970	25	110	135	135	100
1975	22	94	116	116	100

Table 171. Water withdrawn and consumed for self-supplied electric utility uses in Iowa as estimated by the USGS for the period 1960 through 1975

Year	Surface water MGD	Ground water MGD	Total MGD	Fresh water consumed MGD	%
1960	1,500	0	1,500	2	0.1
1965	1,500	2	1,502	21	1.4
1970	1,400	0	1,400	20	1.4
1975	2,700	2	2,702	15	0.6

Table 172. Water withdrawn and consumed for self-supplied industrial uses (except electric utility) in Iowa as estimated by the USGS for the period 1960 through 1975

Year	Surface water MGD	Ground water MGD	Total MGD	Fresh water consumed MGD	%
1960	37	74	111	11	9.9
1965	55	130	185	19	10.3
1970	130	150	280	53	18.9
1975	132	183	315	63	20.0

Recent Iowa studies In 1973 the Ames Reservoir Environmental Study was completed for the Corps of Engineers. Chapter 3 of Appendix 5 dealt with the future water supply requirements and alternative sources of supply at Ames (Rossmiller et al., 1973). The projected use rates adopted in that study are reproduced here as Table 173 and include water for domestic, public, commercial and municipally-supplied industrial purposes.

Austin and Patton (1975) conducted a rural water systems study for the Southern Iowa Council of Governments (SICOG). Their report

Table 173. Projected per capita use rates for the City of Ames, gpcd[a]

Water usage projection	Year	Use rate	Increase each 5 years
Low	1970	130	2
	2020	150	
Medium	1970	130	5
	1990	150	0
	2020	150	
High	1970	130	5
	1990	150	3
	2020	168	

[a]Rossmiller et al. (1973).

included a study of water consumption rates of towns in the Kaskaskia River basin in west central Illinois which included a large number of towns with populations of 200 to 3,000. This study found that the curve (reproduced here as the lowest curve in Fig. 82) known as the 1967 Illinois State Water Survey curve "showed with reasonable accuracy the relationship between community size and per capita water consumption." Using this curve and projections of the U.S. Water Resources Council (1968), the other three curves shown in Fig. 82 were developed. The formulas on this figure were used to develop a table of water use rates by year and community size which is included here as Table 174.

They cautioned that "since each community is unique in its makeup of homes, commercial establishments, schools, industries, and public utilities, the generalized relationship between community size and

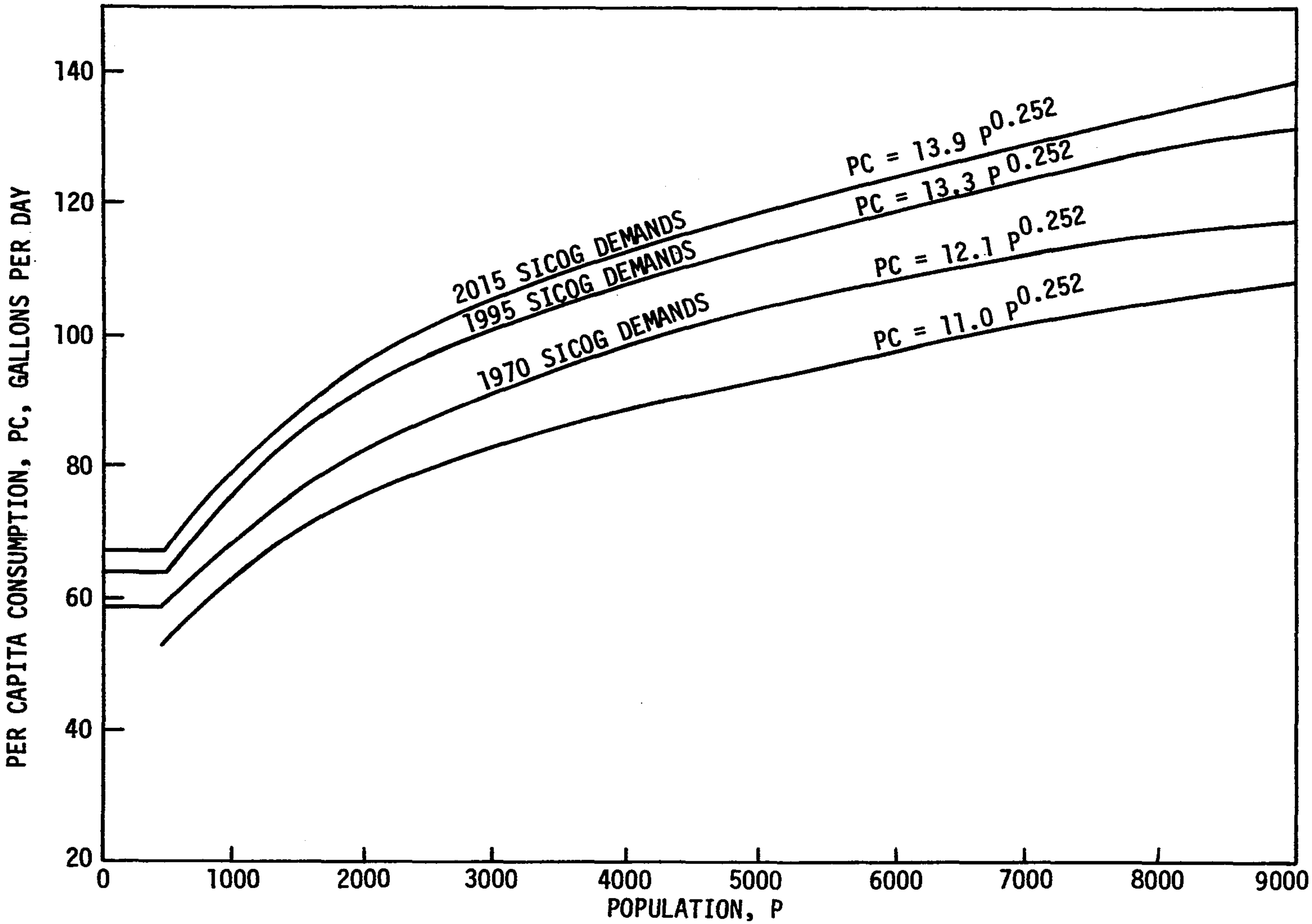


Fig. 82. Per capita water consumption vs. community size (after Austin and Patton)

Table 174. Water demand by year and community size in the SICOG region[a]

User category	Water demand in gpcd 1970	1995	2015
Individual rural households and unincorporated communities	40	50	60
Incorporated communities			
Population 500 and below	58	64	67
Population 750	64	71	74
Population 1,000	69	76	79
Population 1,500	76	84	88
Population 2,000	82	91	95
Population 3,000	91	100	105
Population 5,000	103	114	119
Population 10,000	123	136	142

[a]Austin and Patton (1975).

water consumption just developed cannot be expected to predict the consumption level for every community accurately. Therefore, caution should be exercised against the unsubstantiated use of these consumption estimates and projections for anything but preliminary planning purposes."

In 1974 several state agencies began work on a water plan for the State of Iowa. One task force group has published a preliminary report on water supply and use (Task Force on Water Supply and Use, 1977). Urban water use in 1974 was determined from three sources. Questionnaires were sent to the 27 largest cities in Iowa. All were completed to varying degrees and returned. These data represent about 44% of the state's population and about 62% of the people served by municipal water supply systems. The INRC files produced water use data for another 91 cities. These 118 cities were plotted on a map and geographic gaps became apparent. These gaps were filled in by obtaining operational data on another 64 communities from the files of the IDEQ.

Iowa had an estimated population of 2,855,000 in 1974. About 2,054,000 people, which is approximately 72% of the state's population, are supplied with water distributed by 765 public water supply systems. The 182 communities surveyed in 1974 serve water to about 1,692,000 people. This represents about 59% of the state's population and about 82% of the people supplied from municipal water systems. The sample communities were divided into three groups: over 10,000 population, between 2,500 and 10,000 and under 2,500. "The 10,000 population limit was chosen since it was a criterion for assessing a city's ability to respond to the questionnaire. The limit of 2,500 was chosen to separate intermediate-sized cities from small cities that are normally considered as rural communities." A population of 10,000 is also the upper limit for a city to qualify for Farmer's Home Administration (FmHA) loans for water supply systems.

The survey data on urban water use are plotted as histograms in Fig. 83. For communities under 2,500 people the most frequent water production values were in the range of 90-100 gpcd. The most frequent range for cities between 2,500 and 10,000 was 120-130 gpcd and for cities over 10,000, it was 130-140 gpcd. Tables 175 and 176 indicate the per capita production and total group production, respectively, in each group for Iowa municipalities in 1974. Only for communities below 2,500 does production drop off appreciably. The overall mean

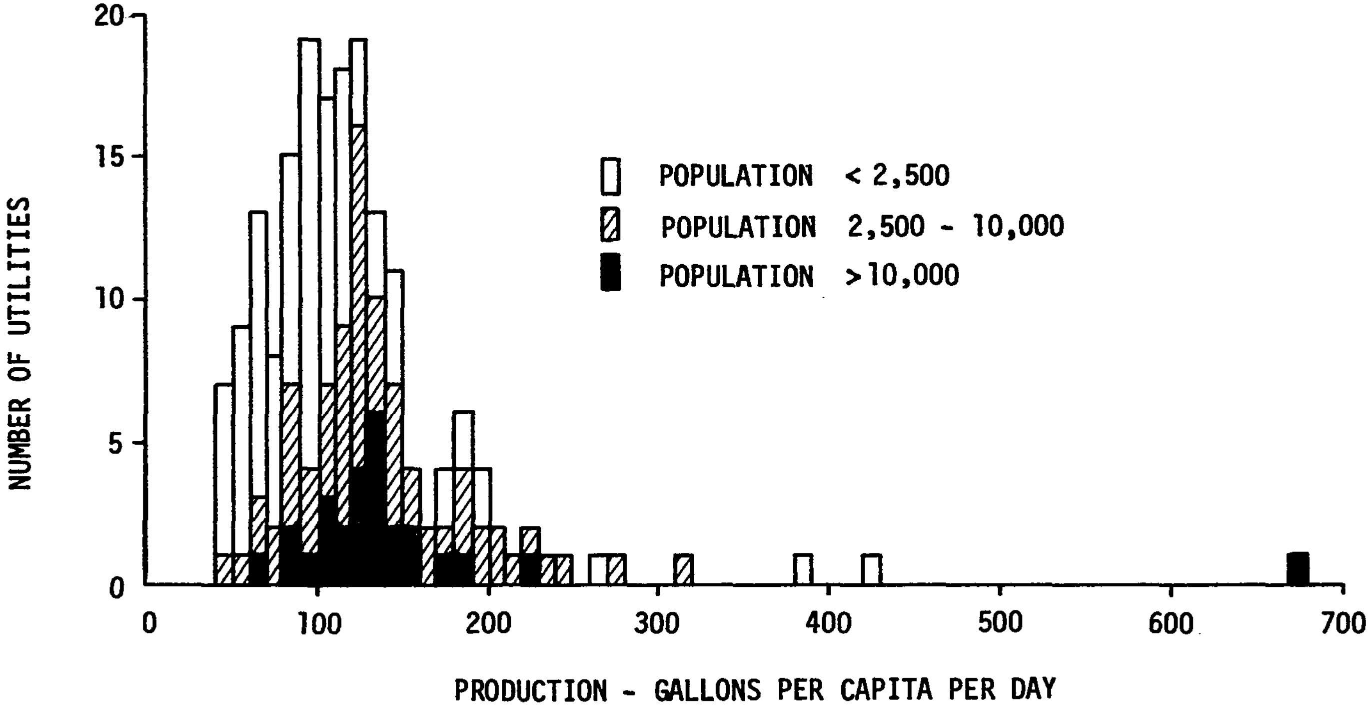


Fig. 83. Frequency distribution of water production in Iowa in 1974 (after Task Force on Water Supply and Use)

Table 175. Per capita water production for Iowa municipalities in 1974[a]

Population served, 1,000's	No. of cities	Water production — gpcd			
		Min.	Max.	Mean	Median
<2.5	91	41	423	105	95
2.5-10	64	49	312	137	124
>10	27	66	676	150	131
Total	182	41	676	122	110

[a]Task Force on Water Supply and Use (1977).

Table 176. Total group water production for Iowa municipalities in 1974[a]

Population served 1,000's	No. of cities	Total group production MG/yr	Total group population	Per capita production gpd
<2.5	91	3,720	93,250	109
2.5-10	64	17,050	330,300	141
>10	27	66,420	1,268,800	143
Total	182	87,190	1,692,350	141

[a]Task Force on Water Supply and Use (1977).

value of per capita production is given as 122 gpd while the overall mean value for total group production is listed as 141 gpcd. The difference arises in the method used to calculate the mean. In Table 175 the per capita mean is determined by giving each city equal weight in its group. This method ignores the population in each city. The group mean in Table 176 includes population by using both the total group production and the total group population to calculate the mean.

Table 177 shows metered water use in 22 of Iowa's largest cities

Table 177. Breakdown of municipal water use for major cities in Iowa in 1974[a]

City	Total production gpcd	Metered customer water use, gpcd				
		Residential	Commercial	Industrial	Other[b]	Notes
Ames	127[c]	78	12	26	11	d
Boone	131	55	17	14	45	
Cedar Falls	116	48	27	17	24	
Cedar Rapids	157		152		5	
Clinton	130	51	22	29	28	
Council Bluffs	141	53	66		22	
Davenport-Bettendorf	122	45	23	28	26	
Des Moines	132		106		26	
Dubuque	125	33	35	26	31	
Fort Dodge	159	39	39	67	14	
Fort Madison	108	39	22	16	31	
Keokuk	221		151		70	
Marion	85	63	7		15	d,e
Mason City	136	63	37	5	31	d
Muscatine	676	82		428	330	
Newton	171	57	24	59	31	
Oskaloosa	104	42	33		29	
Ottumwa	124	73	17	21	13	d

Sioux City	134	37	45		22	30	d
Urbandale	66	50		12		4	e
Spencer	133	45	29		29	30	d
Waterloo	186	52		106		28	

[a]Task Force on Water Supply and Use (1977).

[b]Includes resale, unaccounted for water, and other minor uses.

[c]Adjusted data, Iowa State University neglected in original report.

[d]Breakdown numbers are estimated.

[e]Part of water is purchased.

[f]All water is purchased.

in 1974 broken down into residential, commercial, industrial and other purposes. It is assumed that "other" also includes public uses. The mean values for total production and each purpose were calculated giving each city equal weight. Only those values were used which listed a separate number for that purpose. The city of Muscatine was excluded from all calculations. The following mean values were determined: total production — 132 gpcd; residential — 50 gpcd; commercial — 25 gpcd; industrial — 13 gpcd; other — 26 gpcd.

Twenty-four cities in the northwest study area were included in the 182 city sample and are listed in Table 178. The mean values for the three population groups were again determined giving each community equal weight. The calculated means were 165 gpcd for communities under 2,500 population, 182 gpcd for communities between 2,500 and 10,000 and 134 gpcd for cities over 10,000. The means for the two population groups under 10,000 are much higher than the state average. Nine cities account for the greater than average water use. Four of these communities (Wahpeton, Okoboji, Milford and Spirit Lake) are located around the Iowa Great Lakes in Dickinson County and their high use rates undoubtedly reflect the influx of summer tourists who are not reflected in the city's population. The same is true of Lake View in Sac County which is located alongside Blackhawk Lake and of Storm Lake in Buena Vista County which is situated next to Storm Lake. The city of Storm Lake also supplies water to a meat packing business and a Wilson packing plant is located in Cherokee. The average per capita use in these nine communities is 265 gpd. While the per capita rates in the last three cities mentioned above should be included in the

Table 178. Northwest Iowa communities included in 1974 survey of municipal water use in Iowa as part of the state water planning effort

City	County	Population[a]	1974 use MGY[b]	1974 gpcd
Wahpeton	Dickinson	153	11.00	197
Dickens	Clay	243	3.92	44
Auburn	Sac	309	10.93	97
Lytton	Sac	357	50.61	388
Okoboji	Dickinson	375	57.96	423
Quimby	Cherokee	399	10.58	73
Ocheyedan	Osceola	530	12.67	65
Early	Sac	684	29.50	118
Lake View	Sac	1,186	77.73	180
Paullina	O'Brien	1,215	51.75	117
Marcus	Cherokee	1,269	57.25	124
Milford	Dickinson	1,612	107.99	184
Ida Grove	Ida	2,268	115.37	139
Hawarden	Sioux	2,568	189.35	202
Rock Rapids	Lyon	2,580	96.34	102
Spirit Lake	Dickinson	3,154	258.42	224
Orange City	Sioux	3,532	117.51	91
Sioux Center	Sioux	3,706	201.63	149
Sheldon	O'Brien	4,673	218.32	128
Cherokee	Cherokee	7,052	803.13	312
Le Mars	Plymouth	7,601	427.86	154
Storm Lake	Buena Vista	8,948	894.75	274
Spencer	Clay	10,800	522.39	133
Sioux City	Woodbury	92,000	4,500.00	134

[a]Estimated population as of July 1, 1973.

[b]Million gallons per year.

overall average, the six cities with the large summer tourist trade should be omitted. With these explanations the average water use in Northwest Iowa may not be much different than that of the entire state.

Detailed Water Demand Projections for Northwest Iowa

Municipal and rural domestic demands

Based on the foregoing information, one is faced with selecting between high or low per capita use rates. However, the purpose in this study is not to determine what a precise per capita use rate might be in the future for some particular community but rather the total annual demands for water which will be imposed on the water resources of Northwest Iowa both now and in the future for several different purposes. However, per capita use rates are needed so that they can be combined with population in order to estimate these total future demand volumes.

Four items argue in favor of higher per capita use rates. Since this region has the lowest annual rainfall of any area of the state, general household lawn and garden watering will probably be higher here. The presence of summer visitors at the Iowa Great Lakes and other lakes in the region creates a higher demand for water although this is confined to only a few counties. Because so many cattle and hogs are raised in the region, several packing plants have located here and impose their demands for water on the local water utilities.

There is a fourth item which argues in favor of higher per capita use rates. If we assume that, as stated in the 1974 Safe Drinking Water Act, every American is entitled to adequate quantities of good quality water and that this concept will become a reality in the future, then water resource planners should plan on the high side to insure that adequate supplies of water will be available in the future.

Two items argue in favor of lower per capita use rates. Both are especially true in the rural sector. As commented on previously, many of the shallow aquifers in the region are prone to drought stress and residents must haul water for domestic and livestock purposes. This results in their using water in a conservative manner which translates into low per capita use rates. One solution to this problem has been the creation of rural water districts. These districts have provided their customers with a more adequate quantity and a better quality water. But the cost of the water has been high and this also translates into lower per capita use rates.

Based on the above, municipal per capita use rates will be set on the high side. Rural domestic use rates will be set somewhat lower. Municipal rates are assumed to include domestic, public, commercial and municipally-supplied industrial uses. Per capita use rates will also be assumed to increase somewhat in the future but at a lower rate of growth than has been experienced. These higher per capita use rates will also be a hedge against the possibility that the future population of the region will be higher than projected. Adequate supplies should still be available but each person would have to make do with less. The concept of conservation of our resources will require much education before Americans accept it as a way of life and thus conservation of water has not been explicitly incorporated into these future projections.

Table 179 lists the per capita use rates which will be used in this study. Use rates are given for rural areas and for communities of less than 2,500, between 2,500 and 10,000 and over 10,000 population

Table 179. Estimated future water use rates in Northwest Iowa, gpcd

Community size	1980	2000	2020
Rural farm	50	60	70
Rural nonfarm	70	80	90
Community use:			
< 2,500	120	130	140
2,500-10,000 pop.	140	150	160
> 10,000 pop.	150	160	170

for the years 1980, 2000 and 2020. Peak daily use rates are assumed to be 1.85 times the average daily use (Seidel and Cleasby, 1966; Seidel, 1978). Double the average use rates will be used in Buena Vista, Cherokee, Dickinson and Sac Counties to account for the conditions presently existing in these counties.

The above per capita use rates have been multiplied by each of the projected populations listed in Tables A-53 through A-64 in Appendix A. The results of these calculations are shown in Tables I-1 through I-12 in Appendix I. Summaries of these results are shown in Tables 180 and 181.

The most striking feature of the data in Table 180 is that water use in the future will not be much greater than it is now. Ida, Osceola and Sac Counties are projected to have no increase at all. Plymouth County is projected to have the maximum increase, about 35%, from 2.3 to 3.1 MGD. The total regional increase is 14.5%, from 37.2 to 42.6 MGD. Current use in the greater Des Moines area is about 32 MGD. Thus if present sources are capable of providing adequate water at all times, then they will also be able to provide water through

Table 180. Rossmiller's projected average rural domestic and urban water demands for Northwest Iowa in 1980, 2000 and 2020, MGD[a]

County	Year	City	Other urban	Total urban	Total rural	Total county
Buena Vista		Storm Lake				
	1980	2.4	1.2	3.6	0.3	3.9
	2000	2.6	1.2	3.8	0.4	4.2
	2020	2.9	1.3	4.2	0.4	4.6
Cherokee		Cherokee				
	1980	1.9	0.9	2.8	0.3	3.1
	2000	1.9	0.9	2.8	0.4	3.2
	2020	2.0	1.0	3.0	0.4	3.4
Clay		Spencer				
	1980	1.6	0.3	1.9	0.3	2.2
	2000	1.8	0.3	2.1	0.4	2.5
	2020	2.0	0.3	2.3	0.4	2.7
Dickinson		Spirit Lake				
	1980	0.9	1.2	2.1	0.2	2.3
	2000	1.0	1.4	2.4	0.3	2.7
	2020	1.1	1.6	2.7	0.3	3.0
Ida						
	1980		0.6	0.6	0.2	0.8
	2000		0.6	0.6	0.2	0.8
	2020		0.5	0.5	0.2	0.7
Lyon		Rock Rapids				
	1980	0.4	0.4	0.8	0.3	1.1
	2000	0.4	0.5	0.9	0.3	1.2
	2020	0.5	0.5	1.0	0.3	1.3
O'Brien		Sheldon				
	1980	0.6	0.7	1.3	0.3	1.6
	2000	0.7	0.7	1.4	0.3	1.7
	2020	0.8	0.7	1.5	0.3	1.8
Osceola						
	1980		0.5	0.5	0.2	0.7
	2000		0.5	0.5	0.2	0.7
	2020		0.5	0.5	0.2	0.7
Plymouth		Le Mars				
	1980	1.2	0.6	1.8	0.5	2.3
	2000	1.4	0.7	2.1	0.6	2.7
	2020	1.7	0.8	2.5	0.6	3.1

[a]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table 180. Continued

County	Year	City	Other urban	Total urban	Total rural	Total county
Sac		Sac City				
	1980	0.9	1.3	2.2	0.3	2.5
	2000	0.9	1.3	2.2	0.3	2.5
	2020	0.9	1.3	2.2	0.3	2.5
Sioux		Sioux Center				
	1980	0.5	1.8	2.3	0.5	2.8
	2000	0.6	2.0	2.6	0.5	3.1
	2020	0.7	2.4	3.1	0.4	3.5
Woodbury		Sioux City				
	1980	12.5	0.9	13.4	0.5	13.9
	2000	12.9	1.0	13.9	0.6	14.5
	2020	13.6	1.0	14.6	0.7	15.3
Region						
	1980	22.9	10.4	33.3	3.9	37.2
	2000	24.2	11.1	35.3	4.5	39.8
	2020	26.2	11.9	38.1	4.5	42.6

Table 181. Rossmiller's projected peak rural domestic and urban water demands for Northwest Iowa in 1980, 2000 and 2020, MGD[a]

County	Year	City	Other urban	Total urban	Total rural	Total county
Buena Vista		Storm Lake				
	1980	4.4	2.3	6.7	0.6	7.3
	2000	4.8	2.3	7.1	0.6	7.7
	2020	5.4	2.4	7.8	0.7	8.5
Cherokee		Cherokee				
	1980	3.6	1.5	5.1	0.6	5.7
	2000	3.6	1.6	5.2	0.7	5.9
	2020	3.7	1.8	5.5	0.7	6.2
Clay		Spencer				
	1980	2.9	0.6	3.5	0.6	4.1
	2000	3.3	0.6	3.9	0.6	4.5
	2020	3.7	0.6	4.3	0.7	5.0
Dickinson		Spirit Lake				
	1980	1.6	2.3	3.9	0.4	4.3
	2000	1.8	2.6	4.4	0.5	4.9
	2020	2.1	2.9	5.0	0.6	5.6
Ida						
	1980		1.1	1.1	0.3	1.4
	2000		1.0	1.0	0.4	1.4
	2020		0.9	0.9	0.4	1.3
Lyon		Rock Rapids				
	1980	0.7	0.8	1.5	0.6	2.1
	2000	0.7	1.0	1.7	0.6	2.3
	2020	0.8	1.0	1.8	0.6	2.4
O'Brien		Sheldon				
	1980	1.2	1.3	2.5	0.6	3.1
	2000	1.3	1.3	2.6	0.6	3.2
	2020	1.4	1.4	2.8	0.6	3.4
Osceola						
	1980		1.0	1.0	0.4	1.4
	2000		1.0	1.0	0.4	1.4
	2020		1.0	1.0	0.4	1.4
Plymouth		Le Mars				
	1980	2.2	1.2	3.4	1.0	4.4
	2000	2.6	1.3	3.9	1.0	4.9
	2020	3.2	1.5	4.7	1.1	5.8

[a]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table 181. Continued

County	Year	City	Other urban	Total urban	Total rural	Total county
Sac		Sac City				
	1980	1.6	2.5	4.1	0.6	4.7
	2000	1.7	2.3	4.0	0.6	4.6
	2020	1.7	2.4	4.1	0.6	4.7
Sioux		Sioux Center				
	1980	0.9	3.4	4.3	0.9	5.2
	2000	1.1	3.8	4.9	0.9	5.8
	2020	1.3	4.4	5.7	0.8	6.5
Woodbury		Sioux City				
	1980	23.0	1.7	24.7	1.0	25.7
	2000	23.9	1.8	25.7	1.1	26.8
	2020	25.1	1.9	27.0	1.3	28.3
Region						
	1980	42.1	19.7	61.8	7.6	69.4
	2000	44.8	20.6	65.4	8.0	73.4
	2020	48.4	22.2	70.6	8.5	79.1

2020 with only minor expansion. However, this is not true throughout the region.

Two other items in Table 180 are worthy of mention. The ten largest cities account for 60% of the water demand in the region. In most counties the largest city accounts for the majority of the water demanded in the county. Rural domestic use, both farm and rural residences, account for only about 10% of the water demand. However, this 10% is the most susceptible to drought stress when many rural residents must resort to hauling water for their domestic needs. Some must haul water every year. Rural water systems are one answer to this problem. Some farmers must also haul water for their livestock. These needs are discussed in the next section.

Another set of future municipal and rural domestic water demands were generated using the per capita use rates listed in Table 179 and the population projections by the State of Iowa contained in Tables A-77 through A-88 in Appendix A. This was done in order to determine the effect this would have on the need for new water supplies in the region since the demands projected by the author would pose little stress on existing water sources. The results of these calculations are shown in Table 182. The variation between the author's estimated demands shown in Table 180 and the State of Iowa estimated demands shown in Table 182 is considerable. The total regional demand is about one-third higher in 2020 for the State of Iowa estimate. On the county level, however, the State of Iowa estimates vary from 10% to 100% greater than the author's estimates.

Table 182. Projected average rural domestic and urban water demands for Northwest Iowa in 1980, 2000 and 2020 using the state population estimates, MGD[a]

County	Year	City	Other urban	Total urban	Total rural	Total county
Buena Vista		Storm Lake				
	1980	2.6	1.4	4.0	0.3	4.3
	2000	3.2	1.5	4.7	0.4	5.1
	2020	3.8	1.6	5.4	0.4	5.8
Cherokee		Cherokee				
	1980	1.9	0.9	2.8	0.3	3.1
	2000	2.2	1.0	3.2	0.4	3.6
	2020	2.5	1.2	3.7	0.4	4.1
Clay		Spencer				
	1980	1.7	0.3	2.0	0.3	2.3
	2000	2.0	0.3	2.3	0.4	2.7
	2020	2.2	0.4	2.6	0.4	3.0
Dickinson		Spirit Lake				
	1980	1.1	1.5	2.6	0.3	2.9
	2000	1.4	2.2	3.6	0.3	3.9
	2020	1.6	2.4	4.0	0.4	4.4
Ida						
	1980		0.6	0.6	0.2	0.8
	2000		0.7	0.7	0.2	0.9
	2020		0.9	0.9	0.2	1.1
Lyon		Rock Rapids				
	1980	0.4	0.5	0.9	0.3	1.2
	2000	0.6	0.6	1.2	0.4	1.6
	2020	0.8	0.9	1.7	0.4	2.1
O'Brien		Sheldon				
	1980	0.7	0.9	1.6	0.3	1.9
	2000	0.9	1.0	1.9	0.4	2.3
	2020	1.1	1.1	2.2	0.4	2.6
Osceola		Sibley				
	1980	0.4	0.2	0.6	0.2	0.8
	2000	0.6	0.2	0.8	0.3	1.1
	2020	0.8	0.3	1.1	0.3	1.4
Plymouth		Le Mars				
	1980	1.2	0.7	1.9	0.5	2.4
	2000	1.6	0.8	2.4	0.6	3.0
	2020	2.0	0.9	2.9	0.6	3.5

[a]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table 182. Continued

County	Year	City	Other urban	Total urban	Total rural	Total county
Sac		Sac City				
	1980	0.9	1.4	2.3	0.3	2.6
	2000	1.1	1.7	2.8	0.3	3.1
	2020	1.4	1.9	3.3	0.4	3.7
Sioux		Sioux Center				
	1980	0.6	2.1	2.7	0.5	3.2
	2000	0.8	2.9	3.7	0.5	4.2
	2020	1.0	3.5	4.5	0.5	5.0
Woodbury		Sioux City				
	1980	13.7	0.9	14.6	0.6	15.2
	2000	16.2	1.2	17.4	0.7	18.1
	2020	18.4	1.4	19.8	0.8	20.6
Region						
	1980	25.2	13.4	36.6	4.1	40.7
	2000	30.6	14.1	44.7	4.9	49.6
	2020	35.6	16.5	52.1	5.2	57.3

Packing plant water demands

It was assumed, in making the urban water demands estimated in the previous section, that all industrial demands are municipally-supplied. The one industrial sector which could upset this assumption is livestock processing (slaughtering, cutting, packaging, by-products). Since large numbers of cattle and hogs are marketed each year in Northwest Iowa, several packing plants have located in the region. These are listed in Table 183 and are shown in Fig. 84. The volumes of water demanded by these plants in the future could be a large portion of the total water demand in the cities in which they are located. Thus it becomes necessary to ensure that these future urban water demands include the packing plant demands.

Several factors must be known in order to determine the future packing plant water demands: number of cattle and swine to be processed, their average weights and number of gallons of water used per unit weight. The average weight of cattle and hogs at slaughtering is 1,100 pounds and 240 pounds, respectively; each requires about 950 gallons of water per 1,000 pounds of live weight for processing (Stewart Melvin, Agricultural Engineering Department, Iowa State University, personal interview, March 26, 1979). The latest supplement to the 1972 OBERS projections (U.S. Water Resources Council, 1975a) lists the projected increases in cattle and hog production in Iowa to the year 2020. These estimates are listed in Table 184 as a percentage of 1964 production.

Table 184 indicates that cattle and hog production in Iowa will roughly double by the year 2020. The assumption is made that this

Table 183. Location, size and products of packing plants and livestock products and by-products plants in Northwest Iowa[a]

County	City	Size[b]	Products
Buena Vista	Linn Grove	A	Meat and bone meal, grease, hides
	Storm Lake	E	Hog slaughter, products and by-products
		E	Frozen eviserated turkeys and parts
Cherokee	Cherokee	A	Beef steaks, roasts, patties, ground beef
		F	Pork and beef and by-products
Clay	Spencer	E	Dressed beef carcasses and by-products
		A	Meat and bone meal, inedible tallow, hides
O'Brien	Hartley	C	Ground beef, primal cuts, retail portions
Osceola	Sibley	C	Dressed poultry
Plymouth	Le Mars	D	Carcass beef, beef offal
		C	Portioned meat products
Sac	Wall Lake	A	Dry rendered tankage, animal feeding fat
Sioux	Alton	A	Meat meal, inedible tallow
	Boyden	C	Dressed beef, beef portion cuts
	Hawarden	C	Carcass beef, beef variety meats
	Hospers	B	Beef by-products, dressed beef
		A	Wieners, bologna, pressed ham, ground beef
	Orange City	C	Portioned meat products
	Sioux Center	C	Carcass hogs and by-products
Woodbury	Sergeant Bluff	A	Sausage, ham and bacon
		C	Grease, skin residue, gelatin
	Sioux City	B	Wieners, sausage, luncheon meats
		B	Beef, pork and lamb products, corned beef
		B	Processed hides, tankage, grease
		B	Beef slaughtering, dressed beef, hides, offal
		C	Dressed beef carcass, offal products

[a]Iowa Development Commission (1978).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table 183. Continued

County	City	Size[b]	Products
Woodbury	Sioux City	E	Pork cuts and by-products
		D	Dressed turkeys
		D	Pork
		E	Meat products

Table 184. Increase in cattle and hog production in Iowa to the year 2020 as projected by OBERS, percent[a]

Year	Cattle	Hogs
1964	100	100
1980	127	116
2000	171	152
2020	196	181

increase in production will occur uniformly throughout Iowa, i.e., each county will increase its livestock production in proportion to the above table so each county's portion of total production will remain as it is presently. Using this assumption, the future production of cattle and hogs in Northwest Iowa will be as shown in Tables 185 and 186, respectively.

Two other assumptions which will be made are that the packing plants will operate 260 days per year and that one-half of the livestock marketed will be slaughtered within the region. The assumption of only one-half of the livestock being processed in the region is based on the existence of multiple packing plant centers at Fort Dodge, Denison and Council Bluffs in Iowa, Omaha, South Sioux City and

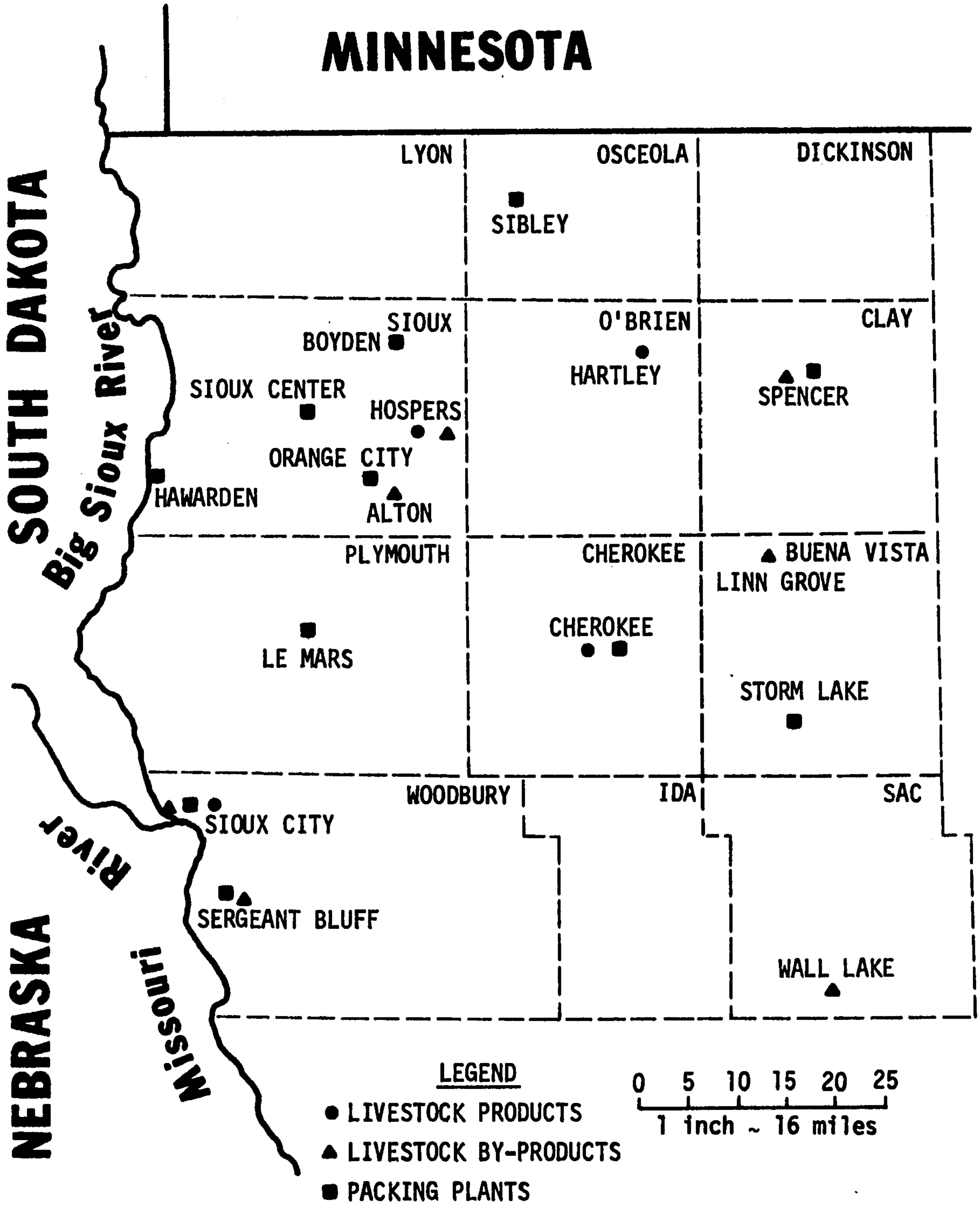


Fig. 84. Location of packing plants and livestock products and by-products plants in Northwest Iowa

Table 185. Number of cattle in Northwest Iowa as projected by OBERS for the years 1980, 2000 and 2020

County	1980	2000	2020
Buena Vista	59,700	80,400	92,100
Cherokee	123,700	165,500	190,900
Clay	65,400	88,000	100,900
Dickinson	29,500	39,700	45,500
Ida	83,900	113,000	129,600
Lyon	86,500	116,400	133,500
O'Brien	78,100	105,200	120,500
Osceola	47,200	63,600	72,900
Plymouth	130,800	176,100	201,900
Sac	101,300	136,500	156,400
Sioux	166,900	224,700	257,500
Woodbury	97,500	131,300	150,500
Region	1,070,500	1,440,400	1,652,200

Table 186. Number of hogs in Northwest Iowa as projected by OBERS for the years 1980, 2000 and 2020

County	1980	2000	2020
Buena Vista	250,100	327,700	390,200
Cherokee	210,000	275,300	327,700
Clay	155,000	203,100	241,800
Dickinson	87,500	114,600	136,500
Ida	155,400	203,800	242,600
Lyon	225,500	295,500	351,900
O'Brien	256,100	335,600	399,600
Osceola	105,100	137,700	164,000
Plymouth	421,300	552,100	657,400
Sac	219,600	287,700	342,600
Sioux	419,500	549,600	654,500
Woodbury	248,500	325,600	387,700
Region	2,754,600	3,608,300	4,296,500

Dakota City in Nebraska, Sioux Falls in South Dakota and several in southwestern Minnesota. All are within easy trucking distance of the Northwest Iowa region. Using the above assumptions and estimates, the amount of water demanded by packing plants in Northwest Iowa in some future year can be determined using Eq. (31).

$$WD_y = \frac{950}{1,000 \times 2 \times 260} \times NO_{xy} \times WT_x \qquad (31)$$

where WD_y = water demanded in year Y, MGD

NO_{xy} = number of animal type X in year Y, million animals

WT_x = weight of each animal type X, pounds

Using Eq. (31), the total amount of water demanded by packing plants in Northwest Iowa in the future is shown in Table 187.

Table 187. Packing plant water demand in Northwest Iowa in the years 1980, 2000 and 2020, MGD

Year	Cattle	Hogs	Total
1980	2.15	1.21	3.36
2000	2.89	1.58	4.47
2020	3.32	1.88	5.20

The total water demand shown in Table 187 is the total for the entire region. To determine the volume demanded in each city, the following assumption is made: the volume of water used in each plant is directly proportional to the number of employees in each plant. Using the mid-range of employees listed in Table 183, the percentages shown in Table 188 were determined. These percentages were combined with the totals shown in Table 187 to yield the daily volumes for each

Table 188. Packing plant water demand in ten cities in Northwest Iowa in the years 1980, 2000 and 2020, MGD

City	Percent[a]	1980	2000	2020
Storm Lake	20	0.67	0.89	1.04
Cherokee	19	0.64	0.85	0.99
Spencer	10	0.33	0.45	0.52
Sibley	2	0.07	0.09	0.10
Le Mars	7	0.23	0.31	0.38
Boyden	2	0.07	0.09	0.10
Hawarden	2	0.07	0.09	0.10
Orange City	2	0.07	0.09	0.10
Sioux Center	2	0.07	0.09	0.10
Sioux City	34	1.14	1.52	1.77
	100	3.36	4.47	5.20

[a]Percentage of total number of packing plant employees in Northwest Iowa working in listed city.

city listed in Table 188 for the period 1980 to 2020.

The water demand by packing plants in each of the ten cities is shown as a percentage of the total urban demand in each city in Table 189 for the period 1980 to 2020. These percentages range from one-tenth to one-half of the total urban water demand. These values appear to be reasonable, with the possible exception of Cherokee. One factor not taken into account in these figures is the trend towards increasing reuse of process water in order to reduce the volume of waste water which must be treated in order to meet water quality standards. For these reasons, the values listed in Table 180 are presumed to be reasonable estimates of future urban water demands in Northwest Iowa.

Table 189. Ratio of packing plant demand to total urban demand in ten cities in Northwest Iowa for the years 1980, 2000 and 2020, percent

City	1980	2000	2020
Storm Lake	28	34	36
Cherokee	33	45	49
Spencer	21	25	26
Sibley	19	24	25
Le Mars	19	22	22
Boyden	43	50	50
Hawarden	18	21	22
Orange City	14	16	15
Sioux Center	14	15	14
Sioux City	9	12	13

Self-supplied industrial demands

The assumption has been made in this study that all industrial demands are municipally-supplied. For this and the following three reasons, no self-supplied industrial water needs will be included in this study. First, as noted in the data presented by the USGS (Murray and Reeves, 1977), the overwhelming majority of the self-supplied industrial water is used for the production of electrical energy. Electrical energy is supplied to Northwest Iowa from three sources: main stem dams on the Missouri River, publicly-owned plants located on the Missouri River and municipally-owned plants located within Northwest Iowa. The main stem dams are located in South Dakota and thus are not a part of this study. The investor-owned utilities are located on the Missouri River in the vicinity of Sioux City and use the water in the river for cooling purposes. The flow in the river is controlled by the dams located in South Dakota and so the water used by these utilities are also not a part of this study. The small amount of water used by the municipally-owned utilities has already been included as part of the urban water needs. Thus all water used in the production of electrical energy is either already accounted for or is not a part of this study.

Second, little data is available on the volume of self-supplied water used by industry for purposes other than power production. The Task Force for Water Supply and Use (1977) as part of the water plan for the State of Iowa, stated in the section of their report on industrial water use that "the statistics cited above are rough estimates since, time and again, water use data is extremely lacking [and is] particularly apparent among the numerous small industrial operations that rely on private wells and other supplies." From what data is available on industry in Northwest Iowa, only a small portion is self-supplied.

Third, the word "self-supplied" indicates that the water is taken from a single source and is used only by that particular industrial plant. In order to have any impact on the local water resources, several plants would need to take water from the same source in such volumes that the quantity of water available to other users of the same source is significantly reduced. There is no available evidence that self-supplied industrial water users are creating any adverse effect at the present time in Northwest Iowa.

Livestock demands

Water demands for livestock, principally cattle and hogs, are calculated in the same manner as urban and rural domestic needs: daily per capita use rates are multiplied by the total number of livestock to obtain the total volume of water needed each day. Schulz and Austin (1976) have estimated stock water use in rural water systems. Relationships developed by them yielded the daily use rates for cattle and hogs listed in Table 190. No water demands for sheep and poultry have been included since the data indicates that their numbers have declined significantly in the last 20 years and their water usage is low compared to cattle and hogs.

Table 190. Livestock water consumption[a]

Livestock type	Consumption, gpd	
	Average	Peak
Cattle	6.6	9.0
Hogs	1.5	2.1

[a]Schulz and Austin (1976).

The water use rates in Table 190 were then combined with the number of cattle and hogs listed in Tables 185 and 186. This yielded the average and peak volumes of water needed in the future for cattle and hogs shown in Tables 191 and 192, respectively. The assumption was made that the livestock would be kept for 120 days so that only one-third of the livestock marked during the year would be drinking water at any one time.

Table 191. Estimated average and peak demands for water by cattle in Northwest Iowa in 1980, 2000 and 2020, MGD

County	Average			Peak		
	1980	2000	2020	1980	2000	2020
Buena Vista	0.13	0.18	0.20	0.18	0.24	0.28
Cherokee	0.27	0.36	0.42	0.37	0.50	0.57
Clay	0.14	0.19	0.22	0.20	0.26	0.30
Dickinson	0.06	0.09	0.10	0.09	0.12	0.14
Ida	0.18	0.25	0.28	0.25	0.34	0.39
Lyon	0.19	0.26	0.29	0.26	0.35	0.40
O'Brien	0.17	0.23	0.26	0.23	0.32	0.36
Osceola	0.10	0.14	0.16	0.14	0.19	0.22
Plymouth	0.29	0.39	0.44	0.39	0.53	0.61
Sac	0.22	0.30	0.34	0.30	0.41	0.47
Sioux	0.37	0.49	0.57	0.50	0.67	0.77
Woodbury	0.21	0.29	0.33	0.29	0.39	0.45
Region	2.33	3.17	3.61	3.20	4.32	4.96

Table 192. Estimated average and peak demands for water by hogs in Northwest Iowa in 1980, 2000 and 2020, MGD

County	Average			Peak		
	1980	2000	2020	1980	2000	2020
Buena Vista	0.13	0.16	0.20	0.18	0.23	0.27
Cherokee	0.10	0.14	0.16	0.15	0.19	0.23
Clay	0.08	0.10	0.12	0.11	0.14	0.17
Dickinson	0.04	0.06	0.07	0.06	0.08	0.10
Ida	0.08	0.10	0.12	0.11	0.14	0.17
Lyon	0.11	0.15	0.18	0.16	0.21	0.25
O'Brien	0.13	0.17	0.20	0.18	0.23	0.28
Osceola	0.05	0.07	0.08	0.07	0.10	0.11
Plymouth	0.21	0.28	0.33	0.29	0.39	0.46
Sac	0.11	0.14	0.17	0.15	0.20	0.24
Sioux	0.21	0.27	0.33	0.29	0.38	0.46
Woodbury	0.12	0.16	0.19	0.17	0.23	0.27
Region	1.37	1.80	2.15	1.92	2.52	3.01

Irrigation demands for corn

In a recent paper, Shaw (1976) makes a point that it takes a large amount of water to produce a crop of corn and that as the total amount of water used increases, so does the yield. This is illustrated in Table 193 which summarizes data gathered by Shaw in 1958. Technology has increased yields by almost 30 bushels/acre in the last 20 years so current data should show even greater yields.

Table 193. Water use versus corn yield in Iowa in 1958

Actual water availability[a] inches	Average 5-yr yield bushels/acre	Efficiency bushels/inch
< 17.5	46.0	2.6
17.5-19.9	48.0	2.6
20.0-22.4	77.7	3.7
22.5-24.9	90.7	3.8
> 25.0	95.3	> 3.8

[a]From April 15 to November 1 and includes all water lost by evapotranspiration, runoff and percolation.

Research in Iowa has also shown that corn yields are increased with earlier planting (Benson and Thompson, 1974). Table 194 summarizes the effect of the planting date on corn yield based on research at the experimental farm near Sutherland in O'Brien County. Since top yields were achieved with early May planting, the experiment was changed to study the effects of April planting dates. These results are shown in Table 195. The late May planting dates show a marked decrease in yield while there is little if any yield difference for planting dates from April 16 to May 12.

Table 194. Effect of planting date on corn yield and maturity, Galva-Primghar Experimental Farm, Sutherland, 1961-1965

Planting date	Emergence date	Silking date	Percent grain moisture Oct. 4[a]	Percent grain moisture Oct. 25[b]	Yield bu/ac
May 2	May 14	July 23	29.1	18.8	130
May 10	May 21	July 25	31.3	19.8	128
May 20	May 30	July 31	36.4	22.9	120
May 30	June 7	Aug. 5	40.7	26.9	111

[a]Normal freeze date.

[b]Harvest date.

Table 195. Effect of planting date on corn yield and maturity, Galva-Primghar Experimental Farm, Sutherland, 1966-1973

Planting date	Emergence date	Silking date	Percent grain moisture Oct. 4[a]	Percent grain moisture Oct. 25[b]	Yield bu/ac
April 16	May 10	July 23	31.8	22.6	126
April 24	May 14	July 24	32.6	22.9	124
May 3	May 18	July 26	33.4	23.9	122
May 12	May 24	July 28	36.1	26.1	123

[a]Normal freeze date.

[b]Harvest date.

Shaw (1976) has also presented Fig. 85 which shows the water use patterns for both irrigated and nonirrigated corn based on data from Iowa, Minnesota, Tennessee and Washington. The two curves represent what he terms an unlimited and limited water supply after tasseling. The limited water supply could be due either to a lack of rainfall or an insufficient amount of irrigation water. The monthly and total

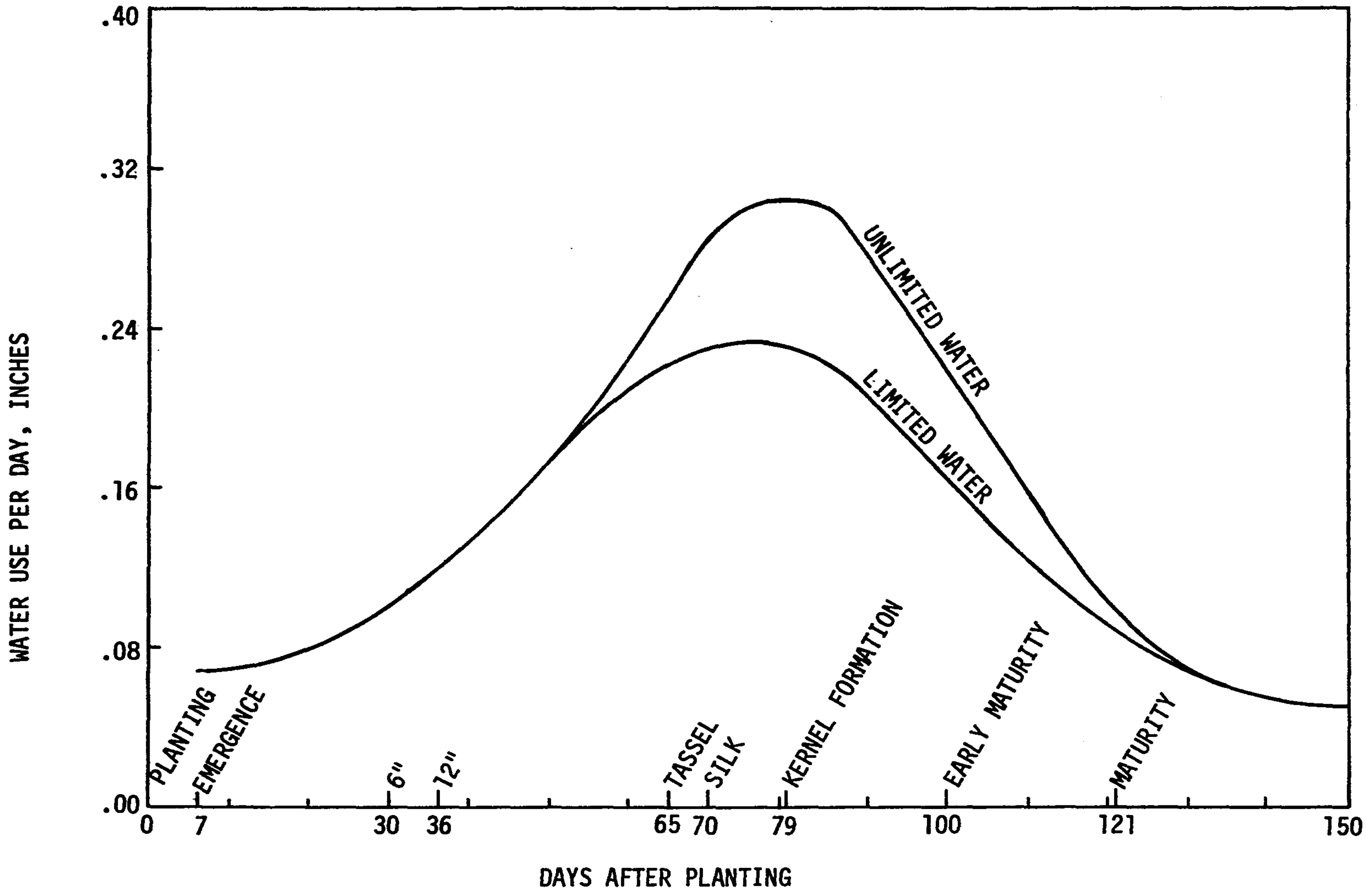


Fig. 85. Water use patterns for corn.(after Shaw)

plant water use for an unlimited and limited water supply are shown in Tables 196 and 197, respectively, and represent the areas beneath the curves shown in Fig. 85 assuming a May 1 planting date. The total water use (24.8 and 21.7 inches) is just evapotranspirtation. In order to be comparable with Table 193, an adjustment must be made for runoff and percolation.

Corn yields are reduced when the plants are subjected to moisture stress. Plants go under stress whenever the available soil moisture is not adequate to meet the transpiration demands caused by high radiation, low humidity, winds, high temperature, etc. Figure 86 is a summary presented by Shaw (1976) of the work of several researchers on the reduction in yield caused by stress. Yield reduction at 50 days after planting averages about 3% per day of stress. A sharp increase in yield reduction occurs around the tasseling-silking stage, averaging about 7% per day of stress. During the early grain-filling period, the yield reduction averages about 4% per day of stress and then gradually decreases as maturity approaches.

Stress can be reduced or eliminated if adequate moisture is maintained in the soil profile (either by timely precipitation or irrigation). "Adequate soil-moisture is not a constant value but varies depending on the potential evapotranspiration (PET) demand." This is illustrated in Fig. 87. With a high demand rate of 6 mm per day, PET can be maintained to higher and higher soil-moisture potentials (lower and lower soil moistures). Purportedly, if the soil moisture level was at least 70% of the total available water value for a particular soil, most all moisture stress would be eliminated, even under high demand rates. On the other hand, if soil moisture was only 40% of total available water, stress would undoubtedly occur.

Northwest Iowa contains a number of different soil types with varying moisture-holding capacities. Table 108 listed the plant available water and average, maximum and minimum June 1 soil moistures to a depth of 5 feet for various soil types at several locations in and around Northwest Iowa (Shaw et al., 1972). The average values listed in Table 108 are used to calculate irrigation requirements.

If all of the foregoing information is combined with the rainfall data previously compiled and analyzed for Northwest Iowa, the amount of seasonal irrigation water required for various return periods can be determined. The calculations for these requirements are shown in Tables 198 and 199. Before explaining each of the columns in these tables, four assumptions inherent in the calculations should be mentioned. First, sufficient snow and rainfalls occur during the winter and early spring so that the soil profile has 6.5 inches of water available on June 1. Second, planting date is May 1. Third, total plant-available water is 10.4 inches with soil moisture reducing to 7.3 or 4.2 inches during the growing season. Fourth, from September 1 until the corn is picked, precipitation for all return periods is again sufficient to meet evapotranspiration demands.

Column 1 in Tables 198 and 199 is the return periods considered: 2-, 5-, 10-, 25- and 50-years. Column 2 is the major portion of the growing season, June 1 to September 1, broken into three monthly periods. Column 3 is the monthly rainfall for each return period. The value for June is the average of the 23 precipitation gaging

Table 196. Water use pattern for corn in inches with unlimited water after tasseling

Plant stage	Days after planting	Date		Water use per day	Avg. use per day	Total water use during period	Total water use since planting	Monthly total
Planting	0	May	1	0.07			0.00	
					0.070	0.49		
Emergence	7		8	0.07			0.39	
					0.075	0.98		
	20		21	0.08			1.47	
					0.090	0.90		
6" high	30		31	0.10			2.37	2.4
					0.115	1.15		
	40	June	10	0.13			3.52	
					0.150	1.50		
	50		20	0.17			5.02	
					0.195	1.95		
	60		30	0.22			6.97	4.6
					0.235	1.18		
Tassel	65	July	5	0.25			8.15	
					0.265	1.32		
Silk	70		10	0.28			9.47	
					0.290	1.45		
	75		15	0.30			10.92	
					0.300	1.20		
Kernel Formation	79		19	0.30			12.12	
					0.300	1.80		
	85		25	0.30			13.92	
					0.290	1.45		
	90		30	0.28			15.37	8.4
					0.250	2.50		
Early Maturity	100	Aug.	9	0.22			17.87	
					0.190	1.90		
	110		19	0.16			19.77	
					0.130	1.43		

Maturity	121		30	0.10			21.20	5.9
					0.083	0.75		
	130	Sept.	8	0.66			21.95	
					0.061	0.61		
	140		18	0.56			22.56	
					0.053	0.69		
	152		30	0.50			23.20	2.0
					0.050	1.55		
	183	Oct.	31	0.50			24.75	1.5

Table 197. Water use pattern for corn in inches with limited water after tasseling

Plant stage	Days after planting	Date	Water use per day	Avg. use per day	Total water use during period	Total water use since planting	Monthly total
Planting	0	May 1	0.07			0.00	
				0.070	0.49		
Emergence	7	8	0.07			0.49	
				0.075	0.98		
	20	21	0.08			1.47	
				0.090	0.90		
6" high	30	31	0.10			2.37	2.4
				0.115	1.15		
	40	June 10	0.13			3.52	
				0.150	1.50		
	50	20	0.17			5.02	
				0.190	1.90		
	60	30	0.21			6.92	4.5
				0.215	1.08		
Tassel	65	July 5	0.22			8.00	
				0.225	1.12		
Silk	70	10	0.23			9.12	
				0.232	1.16		
	75	15	0.234			10.28	
				0.233	0.93		
Kernel Formation	79	19	0.232			11.21	
				0.229	1.37		
	85	25	0.226			12.58	
				0.218	1.09		
	90	30	0.210			13.67	6.8
				0.187	1.87		
Early Maturity	100	Aug. 9	0.164			15.54	
				0.145	1.45		

	110		19	0.126			16.99	
					0.108	1.19		
Maturity	121		30	0.090			18.18	4.5
					0.078	0.70		
	130	Sept.	8	0.066			18.88	
					0.061	0.61		
	140		18	0.056			19.49	
					0.053	0.64		
	152		30	0.050			20.13	2.0
					0.050	1.55		
	183	Oct.	31	0.050			21.68	1.5

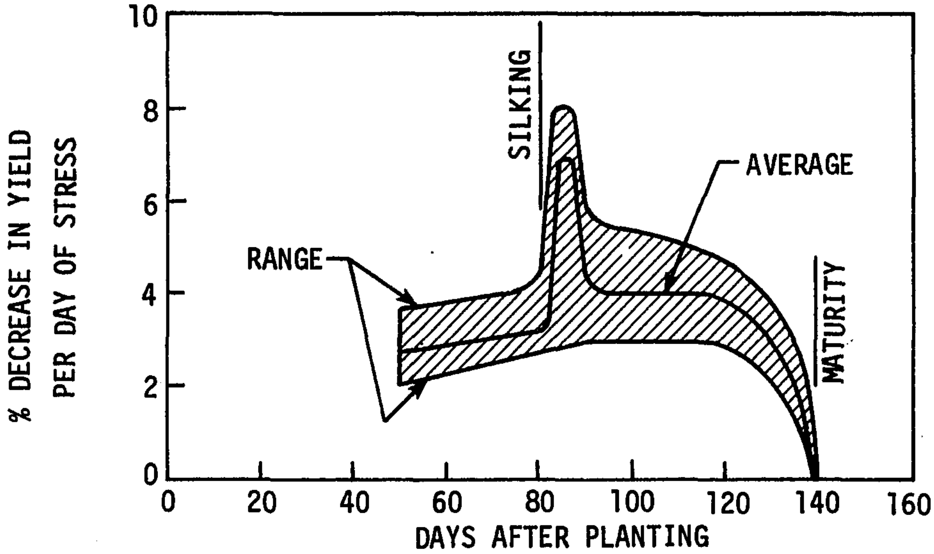


Fig. 86. Relationship between age of crop and percentage yield decrease per day of moisture stress

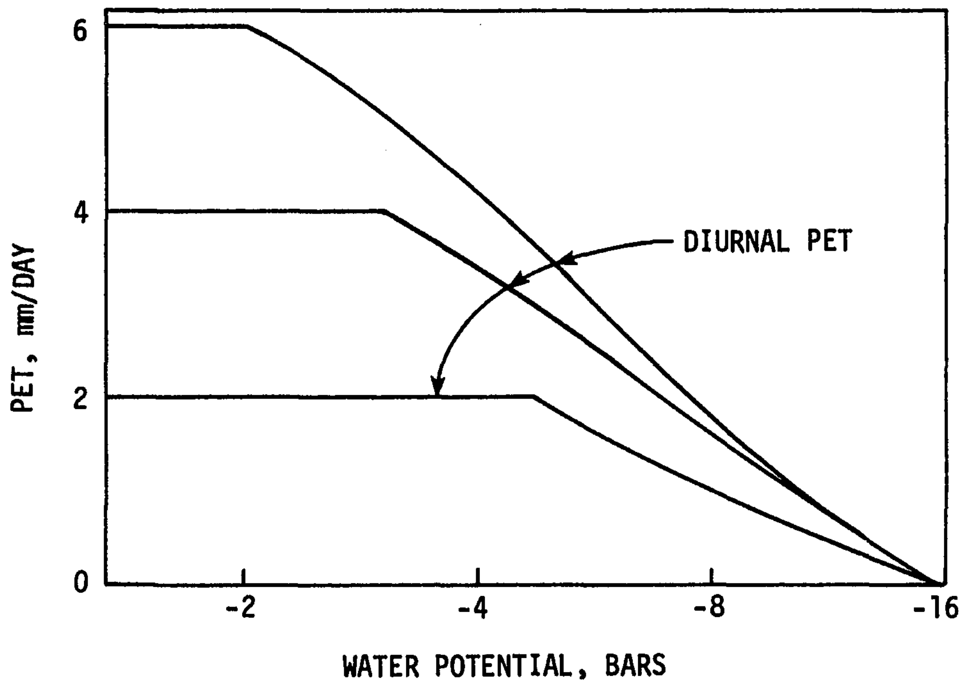


Fig. 87. Expected daily crop transpiration and soil water potential with various levels of PET (after Cowan, 1965)

Table 198. Net irrigation water requirements for corn for various return periods with limited water after tasseling for a soil with 10.4 inches of available water in the root zone

Return period years	Date	Rainfall inches	Total water needed inches	Water needed from soil profile inches	Irrigation water required inches	Soil moisture remaining inches
2	June 1					6.5
		4.2	4.5	0.3	0.0	
	July 1					6.2
		3.5	6.8	3.3	1.3	
	Aug. 1					4.2
		3.2	4.5	1.3	1.3	
	Sept. 1					4.2
					Total = 2.6	
5	June 1					6.5
		2.7	4.5	1.8	0.0	
	July 1					4.7
		2.7	6.8	4.1	3.6	
	Aug. 1					4.2
		2.6	4.5	1.9	1.9	
	Sept. 1					4.2
					Total = 5.5	
10	June 1					6.5
		2.0	4.5	2.5	0.2	
	July 1					4.2
		2.3	6.8	4.5	4.5	
	Aug. 1					4.2
		2.3	4.5	2.2	2.2	
	Sept. 1					4.2
					Total = 6.9	
25	June 1					6.5
		1.4	4.5	3.1	0.8	
	July 1					4.2
		1.8	6.8	5.0	5.0	
	Aug. 1					4.2
		2.1	4.5	2.4	2.4	
	Sept. 1					4.2
					Total = 8.2	

Table 198. Continued

Return period years	Date	Rainfall inches	Total water needed inches	Water needed from soil profile inches	Irrigation water required inches	Soil moisture remaining inches
50	June 1					6.5
		1.0	4.5	3.5	1.2	
	July 1					4.2
		1.5	6.8	5.3	5.3	
	Aug. 1					4.2
		1.9	4.5	2.6	2.6	
	Sept. 1					4.2
					Total = 9.1	

Table 199. Net irrigation water requirements for corn for various return periods with unlimited water after tasseling for a soil with 10.4 inches of available water in the root zone

Return period years	Date	Rainfall inches	Total water needed inches	Water needed from soil profile inches	Irrigation water required inches	Soil moisture remaining inches
2	June 1					6.5
		4.2	4.6	0.4	1.2	
	July 1					7.3
		3.5	8.4	4.9	4.9	
	Aug. 1					7.3
		3.2	5.9	2.7	2.7	
	Sept. 1					7.3
					Total = 8.8	
5	June 1					6.5
		2.7	4.6	1.9	2.7	
	July 1					7.3
		2.7	8.4	5.7	5.7	
	Aug. 1					7.3
		2.6	5.9	3.3	3.3	
	Sept. 1					7.3
					Total = 11.7	
10	June 1					6.5
		2.0	4.6	2.6	3.4	
	July 1					7.3
		2.3	8.4	6.1	6.1	
	Aug. 1					7.3
		2.3	5.9	3.6	3.6	
	Sept. 1					7.3
					Total = 13.1	
25	June 1					6.5
		1.4	4.6	3.2	4.0	
	July 1					7.3
		1.8	8.4	6.6	6.6	
	Aug. 1					7.3
		2.1	5.9	3.8	3.8	
	Sept. 1					7.3
					Total = 14.4	

Table 199. Continued

Return period years	Date	Rainfall inches	Total water needed inches	Water needed from soil profile inches	Irrigation water required inches	Soil moisture remaining inches
50	June 1					6.5
		1.0	4.6	3.6	4.4	
	July 1					7.3
		1.5	8.4	6.9	6.9	
	Aug. 1					7.3
		1.9	5.9	4.0	4.0	
	Sept. 1					7.3
					Total = 15.3	

stations analyzed in Northwest Iowa. The value for July is the 23-station average for the 2-month period, June and July, minus the value for June. The value for August is the 23-station average for the 3-month period, June through August, minus the sum of the values listed for June and July. Column 4 is the total water needed each month as determined in Table 196 or 197. Column 5 is the water needed from the soil profile and is equal to column 4 minus column 3, total water needed minus rainfall. These values were always positive, indicating that the water demand always exceeded the rainfall. Column 6 is the amount of irrigation water required each month (and total seasonal requirement) such that the remaining soil moisture is always equal to or greater than some minimum value. Column 7 is the amount of moisture remaining in the soil profile and is equal to the previous value in column 7 minus column 5 plus column 6.

Table 200 summarizes the seasonal net irrigation water requirements from Tables 198 and 199. These data indicate that some water for irrigation could be used almost every year in order to reduce or eliminate moisture stress. To these net requirements must be added an allowance for irrigation efficiency and for losses incurred in the storage and transmission of the irrigation water in order to obtain the gross amount of water needed for irrigation.

As noted before, the values listed in Table 200 are seasonal requirements. These values should be used rather than the monthly values calculated in Tables 198 and 199. The reason is that the monthly rainfall values listed in these two tables are not true monthly values (except for June) but were determined as explained in a previous

Table 200. Summary of seasonal net irrigation water requirements for corn for various return periods with limited and unlimited water after tasseling, inches

Return period	Available water = 10.4 in.	
	Limited	Unlimited
2	2.6	8.8
5	5.5	11.7
10	6.9	13.1
25	8.2	14.4
50	9.1	15.3

paragraph. The 3-month, 2-year average rainfall in Northwest Iowa is 10.9 inches but may not fall in a sequence of 4.2, 3.5 and 3.2 inches. There are a large number of possible rainfall amounts which could be recorded in June, July and August which total 10.9 inches. Thus, while the monthly amounts could vary considerably, the seasonal total is correct.

Table 201 indicates the variation in soil moisture present during the growing season with varying amounts of irrigation water applied. The "no irrigation" column is the current situation in Northwest Iowa and shows that almost all moisture is depleted by September 1 about 10% of the time. One other comment should be made about the remaining soil moisture. By maintaining the soil moisture at 70% of field capacity with irrigation, there is still room in the root zone to store about 3 inches of rain depending on soil type when a storm occurs. Thus little if any precipitation is wasted.

The analysis indicates that about 12 inches of net irrigation water could be used to supplement rainfall about once every 5 years to

Table 201. Moisture remaining in the soil profile for various dates, return periods and amounts of irrigation water for a soil with 10.4 inches of available water in the root zone, inches

Return period years	Date	Full irrigation inches	Limited irrigation inches	No irrigation[a] inches
2	June 1	6.5	6.5	6.5
	July 1	7.3	6.2	6.2
	Aug. 1	7.3	4.2	2.9
	Sept. 1	7.3	4.2	1.6
5	June 1	6.5	6.5	6.5
	July 1	7.3	4.7	4.7
	Aug. 1	7.3	4.2	0.6
	Sept. 1	7.3	4.2	0.0
10	June 1	6.5	6.5	6.5
	July 1	7.3	4.2	4.0
	Aug. 1	7.3	4.2	0.0
	Sept. 1	7.3	4.2	0.0
25	June 1	6.5	6.5	6.5
	July 1	7.3	4.2	3.4
	Aug. 1	7.3	4.2	0.0
	Sept. 1	7.3	4.2	0.0
50	June 1	6.5	6.5	6.5
	July 1	7.3	4.2	3.0
	Aug. 1	7.3	4.2	0.0
	Sept. 1	7.3	4.2	0.0

[a]Based on total water needed with limited water after tasseling.

eliminate most if not all stress. The rainfall records were searched to determine the least amount of summer rainfall which fell from June through August, thus requiring the greatest amount of irrigation in order to produce a good crop of corn. The lowest summer rainfall occurred at Sioux City in 1976 and amounted to 2.55 inches: 0.75 inches fell in June, 1.50 inches in July and 0.30 inches in August. The

Sioux City station has the longest continuous record in Northwest Iowa, beginning in 1891. With this rainfall and assuming a soil with 10.4 inches of available water in the root zone, with unlimited water after tasseling and 6.5 inches of water available on June 1, 17.2 inches of net irrigation water would have been needed to produce a good crop of corn: 4.7 inches in June, 6.90 inches in July and 5.60 inches in August.

With this background the volumes of water needed for irrigation of corn can be estimated. The upper limit is about two feet of water on every acre with less than a 10% to 15% slope. The lower limit of course is zero. The "correct" answer is that amount of water which is physically, economically, financially, environmentally, politically, socially and institutionally feasible. The "correct" answer is whatever volume society, collectively, decides it should be. Before we can decide what it should be, we should determine the physical, economic, financial, environmental, political, social and institutional consequences of making available various amounts of water for irrigation.

To do this we need to establish some limits on how much land will be irrigated and how much water will be applied during any one year. In order to eliminate many of the impacts, only that land labeled as Class I or Class IIe will be considered for irrigation. To provide some flexibility in total volume required, application rates for several recurrence intervals will be considered. Table 202 lists the acres of Class I and Class IIe land in Northwest Iowa planted to corn in 1967. Table 203 lists the number of inches of gross irrigation

Table 202. Number of acres planted to corn in 1967 and suitable for irrigation of corn by land capability class in Northwest Iowa

County	Class I	Class IIe	Total
Buena Vista	25,400	51,300	76,700
Cherokee	17,500	55,400	72,900
Clay	40,200	14,900	55,100
Dickinson	19,300	21,400	40,700
Ida	2,200	26,100	28,300
Lyon	29,400	67,900	97,300
O'Brien	39,600	65,900	105,500
Osceola	29,800	38,700	68,500
Plymouth	11,400	58,000	69,400
Sac	19,200	56,000	75,200
Sioux	31,300	94,800	126,100
Woodbury	30,900	25,100	56,000
Region	296,200	575,500	871,700

Table 203. Average gross irrigation water requirements for corn for various return periods with limited and unlimited water after tasseling for a soil with 10.4 inches of available water in the root zone[a]

Return period years	Limited water inches	Unlimited water inches
2	3.2	11.0
5	6.9	14.6
10	8.6	16.4
25	10.2	18.0
50	11.4	19.1

[a]Application efficiency is assumed to be 80%.

water needed for several recurrence intervals with limited and unlimited water after tasseling. Application efficiency is assumed to be 80%.

Tables 204 and 205 were derived by multiplying the depths in Table 203 by the acreages in Table 202 and changing the units from acre-inches per year to million gallons per year (MGY). These values differ from those for urban, rural domestic and livestock in that they have units of MGY rather than MGD. The reason for this is irrigation water is not needed every day but is spread out over some portion of the year between April and September. A comparison of these last two tables with Tables 180, 191 and 192, water for people, cattle and hogs, clearly indicates the tremendous volumes of water demanded for irrigation as compared to the volumes of water demanded by people and livestock.

Summary

In this section the future water demands for all urban uses, identified industrial uses, rural domestic, livestock and irrigation have been detailed. Using the population projections made for this study by the author, future urban water demands in Northwest Iowa will not be much larger than they are today. In 3 of the 12 counties, total urban water demand remains the same as today. In the other 9 counties, the maximum increase is 39%. The same is true for total county demands which include urban, rural residential and livestock demands. Here the maximum increase is 35%. However, if the population

Table 204. Estimated average gross water requirements for irrigation in Northwest Iowa for various return periods and land classes with limited water after tasseling, MGY

County	Class I return period - years					Class IIe return period - years				
	2	5	10	25	50	2	5	10	25	50
Buena Vista	2,200	4,800	5,900	7,000	7,900	4,500	9,600	12,000	14,200	15,900
Cherokee	1,500	3,300	4,100	4,800	5,300	4,800	10,400	12,900	15,300	17,100
Clay	3,500	7,500	9,400	11,100	12,400	1,300	2,800	3,500	4,100	4,600
Dickinson	1,700	3,600	4,500	5,300	6,000	1,900	4,000	5,000	5,900	6,600
Ida	200	400	500	600	700	2,300	4,900	6,100	7,200	8,100
Lyon	2,600	5,500	6,900	8,100	9,100	5,900	12,700	15,900	18,800	21,000
O'Brien	3,400	7,400	9,200	11,000	12,300	5,700	12,300	15,400	18,300	20,400
Osceola	2,600	5,600	7,000	8,300	9,200	3,400	7,200	9,000	10,700	12,000
Plymouth	1,000	2,100	2,700	3,200	3,500	5,000	10,900	13,500	16,100	18,000
Sac	1,700	3,600	4,500	5,300	5,900	4,900	10,500	13,100	15,500	17,300
Sioux	2,700	5,900	7,300	8,700	9,700	8,200	17,800	22,100	26,300	29,300
Woodbury	2,700	5,800	7,200	8,600	9,600	2,200	4,700	5,900	7,000	7,800
Region	25,800	55,500	69,200	82,000	91,600	50,100	107,800	134,400	159,400	178,100

Table 205. Estimated average gross water requirements for irrigation in Northwest Iowa for various return periods and land classes with unlimited water after tasseling, MGY

County	Class I return period — years					Class IIe return period — years				
	2	5	10	25	50	2	5	10	25	50
Buena Vista	7,600	10,100	11,300	12,400	13,200	15,300	20,300	22,800	25,100	26,600
Cherokee	5,200	6,900	7,800	8,600	9,100	16,500	22,000	24,700	27,100	28,700
Clay	12,000	15,900	17,900	19,600	20,800	4,400	5,900	6,600	7,300	7,700
Dickinson	5,800	7,700	8,600	9,400	10,000	6,400	8,500	9,500	10,500	11,100
Ida	660	870	980	1,080	1,140	7,800	10,300	11,600	12,800	13,500
Lyon	8,800	11,700	13,100	14,400	15,200	20,300	26,900	30,200	33,200	35,200
O'Brien	11,800	15,700	17,600	19,400	20,500	19,700	26,100	29,300	32,200	34,200
Osceola	8,900	11,800	13,300	14,600	15,500	11,600	15,300	17,200	18,900	20,100
Plymouth	3,400	4,500	5,100	5,600	5,900	17,300	23,000	25,800	28,300	30,100
Sac	5,700	7,600	8,500	9,400	10,000	16,700	22,200	24,900	27,400	29,000
Sioux	9,300	12,400	13,900	15,300	16,200	28,300	37,600	42,200	46,300	49,200
Woodbury	9,200	12,200	13,800	15,100	16,000	7,500	9,900	11,200	12,300	13,000
Region	88,400	117,400	131,900	144,900	153,500	171,800	228,000	256,000	281,400	298,400

projections made by the State Health Department for the State of Iowa are used, water demands are greater. The total regional demand is about one-third higher. On the county level, these estimates range from 10% to 100% greater than the author's estimates.

However, these urban and rural demands are small when compared to future potential irrigation demands. Total annual regional water demands for all urban, rural residential and livestock uses are estimated to be 13,600 MG in 1980 and 15,500 MG in 2020. Potential annual regional irrigation demands range from 172,000 MG for a 2-yr recurrence interval to 298,000 MG for a drought with a 50-yr recurrence interval, assuming that only those Class I and IIe lands used for corn and soybeans in 1967 are used for irrigated corn.

These then are the projected regional water demands. The previous section detailed the various sources of water and their potential yields. Other sections have described the land resources of Northwest Iowa, the present and future demands which could be placed on their utilization, and the constraints which are always active on the development and utilization of our land and water resources: legal, institutional, social, economic, financial, physical, technical and political. And through all of these sections, many of the conflicts which arise among competing users of these resources have been enumerated. Thus, the stage is set for the final objective: to combine all of these facets into a single goal programming model. This is presented in the next section.

DEVELOPMENT OF GOAL PROGRAMMING MODEL

Principles and Standards

The U.S. Water Resources Council formulated its Principles and Standards for Planning Water and Related Land Resources in 1973. These provide the conceptual basis for multiobjective planning (U.S. Water Resources Council, 1971 and 1973). A manual on the application of the Principles and Standards was developed for the U.S. Water Resources Council by Colorado State University (Caulfield et al., 1974). Schaefer (1975) has reported on the Bureau of Reclamation's experience with the new Principles and Standards. These publications serve as the early experience record for the federal multiobjective planning technique.

The six steps in the process of formulating the recommended plan are shown in Fig. 88. Step 1 states that the planner should "specify components of the objectives relevant to the planning setting" (U.S. Water Resources Council, 1973). Two objectives are recognized in the present form of the Principles and Standards and are stated as follows:

A. To enhance national economic development (NED) by increasing the value of the Nation's output of goods and services and improving national economic efficiency.

B. To enhance the quality of the environment (EQ) by the management, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

The NED components are divided into two parts. The first is concerned with actual outputs of goods and services desired by the

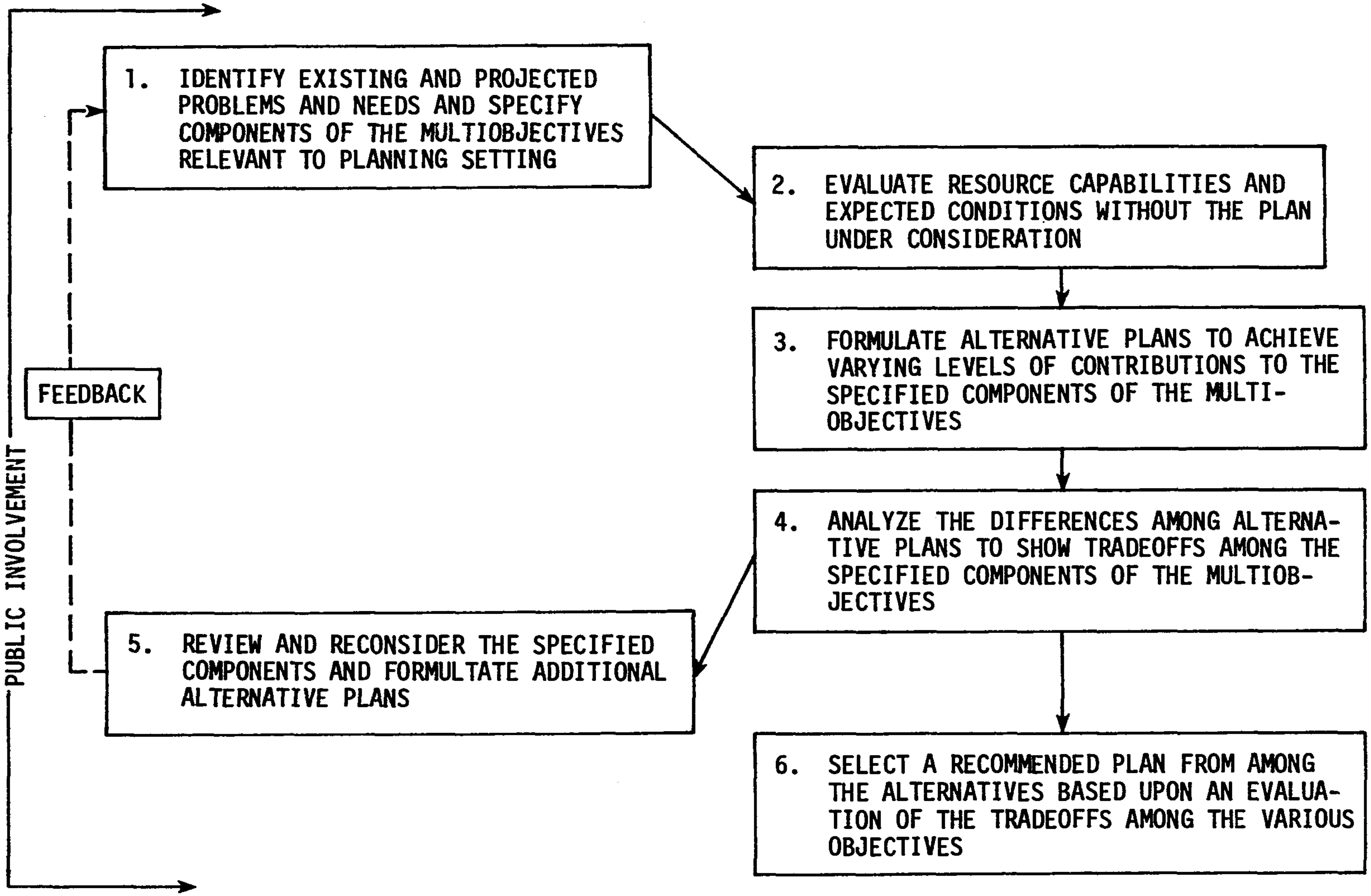


Fig. 88. Plan formulation process (after Schaefer)

people. These are expressed in terms of increasing outputs or more efficiently producing goods and services in the following categories (Schaefer, 1975).

A. Municipal and industrial water supply

B. Energy

C. Recreational services including fish and wildlife

D. Flood protection

E. Transportation

F. Land stability and drainage

G. Food and fiber

H. Industrial output

I. Other

The second part involves translating these desires into specific needs for:

A. Water and land for irrigation and recreation including fish and wildlife purposes

B. Hydroelectric power

C. Navigation or deep draft harbors

D. Provision of flood-free or stabilized lands

E. Water supplies for domestic, municipal, rural and/or industrial use

F. Other

The EQ objective includes three components. These are:

A. Identifying the need for miles or acres of:

1. Open space and greenbelts

2. Streams and stream systems

3. Lakes and reservoirs
4. Beaches and shores
5. Wilderness, primitive and natural areas
6. Estuarine and wetland areas
7. Other areas of natural beauty

B. Identifying the number of kinds of archaeological, historical, cultural, biological, geological and ecological sites that should be preserved or investigated and salvaged.

C. Identifying those quality parameters in the following categories that should be maintained or improved

1. Water
2. Air
3. Land
4. Sound
5. Visual

Step 2 states that the planner should evaluate resource capabilities and expected conditions without any plan. In this step the available resources are inventoried and their capability assessed to meet the needs identified in Step 1 without any further development. If the present and future needs can be met with the existing available resources, then no further action is needed, presuming there is no adverse environmental impact. If the present and future needs cannot be met with the existing available resources, however, then the planner "is requested to inventory and identify the management, development or other actions that, if implemented, could possibly meet component needs" (Schaefer, 1975).

In Step 3 the planner begins to develop alternative courses of action. Step 3 states that the planner should "formulate alternative plans to achieve varying levels of contributions to the specified components of the objectives" (U.S. Water Resources Council, 1973). The Principles and Standards require that the planner formulate several plans and that one plan optimize contributions to the NED objective while another plan should optimize contributions to the EQ objective. They also provide four tests against which each plan must be measured (Caulfield et al., 1974).

Acceptability — the plan must be acceptable to the public and compatible with known institutional constraints.

Effectiveness — the plan must be technically effective in meeting component needs and must make significant, rather than marginal, contributions to meeting the component needs of the objectives.

Efficiency — the plan must demonstrate that it represents the least-cost means of achieving those component needs included in the plan.

Completeness — the plan must account for all investments and other required inputs or actions to achieve those component needs included in the plan.

If the plan which optimizes contributions to the NED objectives is not acceptable to environmental groups, then that particular alternative plan may not be acceptable (at that point in time) because it does not meet the acceptability test. A second look could be taken at the institutional constraints included in the acceptability test. This second look would be directed towards the feasibility of changing or removing some of the institutional constraints in order to open up the choices and tradeoffs on the components of the objectives.

Step 4 states that the planner should "analyze the differences among alternative plans to show tradeoffs among the specified components of the objectives" (U.S. Water Resources Council, 1973). To accomplish this, the Principles and Standards include a 4-account system for measuring, evaluating, and displaying beneficial and adverse effects by which each plan is measured (Schaefer, 1975). These four accounts include not only NED and EQ, but Regional Development (RD) and Social Well-Being (SWB) as well. The factors to be included in NED and EQ have already been listed in Step 1. RD effects are measured in both monetary and nonmonetary terms and include such factors as:

1. Regional income
2. Regional employment
3. Population distribution
4. Regional economic base and stability
5. Environmental conditions of special regional concern

SWB effects are usually measured in nonmonetary terms and include such factors as:

1. Distribution of real incomes
2. Security of life, health and safety
3. Educational, cultural and recreational opportunities
4. Emergency preparedness
5. Other

Step 5 emphasizes the iterative nature of the planning process. Step 5 instructs the planner to "review and reconsider, if necessary, the specified components for the planning setting and formulate additional alternative plans as appropriate" (U.S. Water Resources Council, 1973). Because of the complexity of land and water resource planning due to the several constraints listed in Table 206, many iterations may be necessary before the final acceptable plan is formulated.

Step 6 concludes that <u>someone</u> will or must "select a recommended plan from among the alternatives based upon an evaluation of the trade-offs between the objectives of national economic development and environmental quality" (U.S. Water Resources Council, 1973). This step, as all other steps in the process, should be done in concert with the affected publics as indicated in Fig. 88 which fulfills the requirement in the Principles and Standards which states that "efforts to secure public participation should be pursued vigorously through appropriate means such as public hearings, public meetings, information programs, citizens' committees, etc." (U.S. Water Resources Council, 1973). Final decision-making may reside ultimately in the political process, e.g., the elective legislative bodies authorizing programs or projects and appropriating funds.

Model Development Rationale

Land use and use of water are inseparable as stated before. A model which purports to allocate water must also include a land use component. And any model which purports to reflect the real world must at least attempt to somehow include most of the items listed in Table 206.

Since the passage of NEPA in early 1970, Americans have been trying to determine how we can maintain or increase our standard of living while at the same time improving the quality of the environment in which we live. If we insist on increasing our demands for goods and services, then we must commit more of our land and water resources to their production. By insisting on a high level of economic development, many conflicts have already arisen because of the items listed in Table 206.

If we attempt to resolve some of the environmental problems caused by increasing demands, new conflicts arise because of other constraints. For example, Heady et al. (1972) published a study on the shifts in production which would take place if erosion were reduced to acceptable limits. Much of western Iowa would revert to grass and crop production is shifted to southern states. Their linear programming model is large, complex and contains many physical, technical and economic variables — but it does not do much for the farmers trying to make a living in western Iowa or for those companies supplying inputs to these farmers or for those companies processing their output.

What is it that we are attempting to do? We are attempting to use goal programming (GP) in a screening model to help us understand the consequences of decisions made on the use of our land and water resources. It is aimed at improving the quantity and quality of our lives in a multiobjective and multipurpose framework, subject to the

Table 206. Objectives, purposes, uses and constraints considered in the land and water resources planning model for Northwest Iowa

Objectives	Purposes[a]	Water supply uses[b]	Constraints[c]
1. National Economic Development	1. Land and Water Quality	1. Urban Domestic	1. Physical
2. Environmental Quality	2. Water Supply	2. Commercial	2. Technical
3. Regional Development	3. Agricultural Production	3. Municipal	3. Economic
4. Social Well-Being	4. Employment Opportunities	4. Industrial	4. Financial
	5. Flood Control	5. Rural Domestic	5. Social
	6. Recreation	6. Livestock	6. Institutional
	7. Fish and Wildlife Enhancement	7. Irrigation	7. Legal
	8. Watershed Management	8. Power	8. Political

[a]These purposes are a partial listing of the components of the objectives.

[b]Each purpose could be disaggregated into a similar, more specific set of items, such as those listed for water supply.

[c]Each constraint could apply to each item in each purpose.

constraints on the system and the conflicts which will arise. Conversely, we could say that we are using goal programming to make a "first stab" at giving decision-makers a comprehensive multiobjective tool. This new tool will show them the conflicts which will arise and the tradeoffs which will occur when certain decisions are made on how to best use the land and water resources of a region in order to meet most of the inhabitants' conflicting goals. What is meant by the "first stab" is that the most difficult part of any problem is to address it and formulate a potential solution the first time. Improvement comes easier, then it is much easier to change, add to, refine and generally improve the initial approach or solution.

How will we do this? As stated before, the objective function of GP is the minimization of deviations from goals. The physical distribution of water from sources to uses and users can be handled as a transportation problem of linear programming which minimizes the cost of distributing the water to all users. This will tend to satisfy <u>the goal</u> of providing an adequate and dependable supply of water for all urban and rural purposes. It can also be used to satisfy <u>the goal</u> of providing water at the least cost. If some of the sources are reservoirs, they will tend to test that part of the recreation goal which desires flat water. Water quality and watershed management goals may be met by a reduction in erosion. Flood plain management goals can be met by either structural or nonstructural measures. Land use changes to less intensive uses will tend to satisfy fish and wildlife enhancement goals.

The attainment of the goals for the purposes listed above will also simultaneously satisfy the four objectives listed in Table 206. Goals are defined as specific values assigned to the components of the objectives. Increases in output will tend to satisfy the NED and RD objectives. Changes in land use and reductions in erosion will tend to satisfy the EQ objective. The SWB objective will tend to be met by the provision of equity of access to opportunities for income, recreation, quality of surroundings and freedom from the physical and mental anguish caused by a lack or excess of water.

Some of the constraints have already been discussed. Financial constraints in a GP context can be viewed from three standpoints: ability- and willingness-to-pay and provision of subsidies. Physical, technical and economic constraints are bound up in the coefficients used to describe each of the purposes and objectives. Legal, political, institutional and some social constraints can be handled as sensitivity elements. Tradeoffs will become evident as attempts are made to satisfy the goals set forth, as constraints are changed and as priorities are rearranged.

Several linkages exist which will quantify the impacts on both the land and water resources of the region. Increases in population will create demands for more land and water to be used for urban purposes. Increases in livestock and crop production as projected by OBERS will place increased demands on the land and water resources for rural purposes. Demands for enhancement of the quality of the environment will place financial burdens on the people of the region and nation. Some of the impacts are complementary and some are conflicting. Land converted to urban uses may take land out of crop production.

If some of the water sources involve surface water reservoirs, more land may be taken out of crop production. Need for more pasture could take land out of crop production. Land needed for fish and wildlife enhancement could utilize land presently used for pasture and crops. In order to reduce erosion, steep slopes may be converted to conservation uses and terraces may be constructed which will take more land out of production. However, urban land covered by rooftops, streets and grass does not erode very much. Land covered by water does not erode at all. Land converted to pasture or conservation uses produces much less erosion than cropland. The loss in crop production could be made up by irrigating lands less susceptible to erosion.

Farmers may be affected in one of two ways: their income could be reduced and capital outlays will be necessary to construct terraces. But existing laws and institutional regulations allow for grants and subsidies to pay a percentage of the terrace construction costs and make up for the income lost by setting aside acreage and not raising crops. The magnitude of the subsidies and grants needed to achieve the goals of the region (as one output of the GP model) will indicate whether present state and federal funding levels are adequate. Undoubtedly, the existing funding levels will be found to be woefully inadequate. That portion of Sec. 208 of PL 92-500 which addresses nonpoint source pollution problems could be the mechanism for the additional funding requirements. PL 92-500 authorized $16 billion for the reduction of <u>point</u> source pollution. The Clean Water Act of 1977, PL 95-217, authorizes an additional $25 billion for <u>point</u> source pollution. Industry estimates that in order to meet the 1984 goal of

Best Available Technology (BAT), it will need to invest an additional $60 billion dollars, over and above what it has already spent to date, to achieve only an incremental improvement in water quality. Similar or even greater sums will be needed to reduce nonpoint source pollution to acceptable levels.

Such linkages serve to indicate the kinds of tradeoffs which will need to take place to attain the several perceived goals of the region listed in Table 207. The attainment of these goals will in turn satisfy the four objectives listed in the Principles and Standards. Some of these goals obviously conflict with others while some are complementary. Provision of land for people, industry, water supplies, recreation, watershed management, timber resources and fish and wild-life enhancement may easily diminish the availability of land for crop and livestock production. At the same time, provision of land for these purposes will reduce the amount of soil erosion in the region. Construction of terraces and changes in land use to reduce erosion will require subsidies and grants to farmers. All of these shifts in land use may require that less erosion-prone land be irrigated in order to meet crop and livestock production goals. If some of this water is provided from surface water reservoirs, more land will be taken out of production but erosion will also be decreased.

All of the above linkages and planning factors must be combined into the goal programming screening model if it is to be effective for decision-makers in selecting for more detailed study those policies and/or projects which best achieve the several conflicting goals of the people living in a region.

Table 207. Perceived goals of Northwest Iowa

Number[a]	Goal
1	Provide dependable water supplies of adequate quantity and quality for all urban and rural uses
2	Reduce soil erosion to the extent indicated by the state Soil Conservancy District Act
3	Increase crop and livestock production to the levels projected by OBERS
4	Make water-based recreation more accessible to the people of the region
5	Provide increased opportunity for fish and wildlife enhancement
6	Maintain income levels commensurate with those in other regions of Iowa
7	Reduce threat of flooding to both urban and rural areas
8	Improve management of the many watersheds in the region
9	Provide a pleasing environment for the people of the region in which to work and play
10	Generate from the national, state and local economic levels sufficient money to pay for the changes to be made in the present distribution of human, land and water resources

[a]Not listed in any order of preference.

NED and EQ in Terms of Goal Programming

Several items must be evaluated in order to assess improvements in the two objectives set forth by the U.S. Water Resources Council and the tradeoffs involved when using a GP model:

1. the components which make up the objectives,

2. the goals set by or for the people of the region for each of the components in order to improve NED and EQ,

3. the existing and developable resources needed for the attainment of these goals, and

4. the equations which translate these components, goals and

resources into the GP format.

The economy of Northwest Iowa is largely dependent on agriculture and a major percentage of the jobs and income are directly or indirectly related to it. These include the jobs and income of the farmers themselves and their families and employees, the jobs and income of those who manufacture, sell and transport inputs to the farmers and the jobs and income of those who transport, process and market the farmers' output. These also include the jobs and income of these people in the service industries who provide banking, educational, health, municipal, recreational, governmental, publishing and other services to those involved in all phases of agriculture. Thus if the economic health of agriculture in the region is improved, then the entire economic health of the region will be improved. Likewise, since most of the land resources of the region are devoted to agriculture, if the environmental health of the agricultural land and adjacent water resources of the region are improved, then the quality of the entire regional environment will be improved.

Environmental quality

Soil erosion is used as the major component of the environmental quality objective, the rationale being that the less sediment that there is in streams, the better the quality of land and water areas will be. However, the effects of soil erosion also spill over into the socio-economic accounts. Loss of soil due to sheet and gully erosion in the fields leads to decreased soil fertility, loss of tillable acreage and loss of access to fields due to land voiding.

Deposition of sediment in road ditches, culverts and drainage ditches leads to increased maintenance costs. All of these impair the visual quality of the landscape and reduce the public's enjoyment of the rural scene. Sediment deposited in a stream reduces its capacity to carry water and results in swamping of flood plain land and deposition of infertile overwash on it, both of which reduce the productivity of farmland located there.

Sediment in a stream or lake also causes several water quality problems. It can carry pesticides, toxic materials and plant nutrients adsorbed on the soil particles which are harmful to aquatic organisms. Deposition of this material retains the pollutants in the stream and impairs or eliminates fish spawning areas. Suspended sediment affects light penetration and reduces plant and insect growth as food for fish. Human enjoyment of water areas is also reduced by suspended sediment. The aesthetic experience of both contact and noncontact activities such as swimming, fishing and boating are impaired by sediment-laden waters. Sediment deposited in beach areas ruins them, sediment deposited in reservoirs reduces their useful lives and effectiveness and a sediment-laden stream increases the cost of using it as a water supply.

All soil which is eroded does not appear as sediment in a stream. Gross erosion is first estimated by the Universal Soil Loss Equation (USLE), discussed previously and shown as Eq. (28), and is then multiplied by a delivery ratio in order to obtain a value for the sediment which actually appears in a stream. Some of the variables which affect the gross erosion rate also influence the delivery ratio. For this study it will be assumed that the delivery ratio will remain the same under all conditions. Thus, if erosion from a watershed is cut in half, we will assume that the sediment in the stream will also be cut in half. This assumes little change in the stream channel network, which would tend to be true if environmental quality is maintained.

Since it is being assumed that a reduction in soil erosion yields an improvement in the EQ objective, then the USLE must be examined to determine how erosion may best be reduced. Two items become apparent immediately: man has no control over some of the variables at the present time, and the amount of reduction in erosion varies considerably for those variables over which man does have some control. Presently, man cannot control either the rainfall factor, R, or the soil erodibility factor, K. The only thing man can do is time his planting so that the soil has some cover when the erosive rains occur. However, this solution is not workable in Iowa since half the erosive rains occur from April 21 to July 20 and during this 3-month period crop canopy is either nonexistent or is relatively ineffective in controlling erosion.

Man can control the other four variables to some extent. The length and steepness of slope can be reduced by grading operations to develop terraces. New crop rotations, conservation tillage methods and contouring and strip cropping can be used. Land use on the farm can be altered. Some of these changes require a capital investment such as the construction of terraces and farm ponds. Other changes result in a loss of income, such as changing from continuous corn to a rotation which includes grass three years out of five or changing to permanent pasture. Social, economic, fiscal, legal, institutional and political problems arise out of these attempts to increase EQ by reducing soil erosion.

The amount of reduction in soil erosion is dependent on the variable involved. Soil loss on a 10% slope is 7 times as much as that on a 2% slope and is 18 times greater than that on a 0.2% slope. Soil loss from a 400-foot long slope is 2 to 4 times greater than that from a 20-foot long slope. Soil loss from a corn-soybean rotation is 150 times as much as that from a good grass cover. Soil loss from plowing parallel to a mild slope is about 2 times greater than that from contouring or conventional terraces and about 4 times as much as that from strip cropping with alternate meadows. As a result, the two most promising candidates for reducing erosion are a reduction in slope by terracing and crop rotations (including changes in land use). Changes in land use can imply a variety of changes: from continuous corn to permanent pasture and vice versa, from a corn-soybean rotation to forest land and from farmland to rural residential.

Thus the components and their directions for the EQ objective in Northwest Iowa are decreases in soil erosion and increases in land and water areas available for open space, fish and wildlife enhancement and watershed management. The components and their direction for the NED objective in Northwest Iowa are increases in livestock production, increases in corn and soybean production, and increases in recreational opportunities.

In conclusion, the components and their directions of change for the EQ objective in Northwest Iowa are (1) decreases in soil erosion and (2) increases in land and water areas available for open space, fish and wildlife enhancement and watershed management. The erosion goal is 5 tons per acre per year, set in compliance with the Iowa Soil Conservancy District Act. Land and water goals for open space and fish and wildlife enhancement are difficult to set. However, in this case more is better, so the goal is set at not losing any existing land and water areas already set aside for this purpose and adding additional areas wherever possible.

National economic development

The components and direction of change for the NED objective in Northwest Iowa are increases in livestock production, increases in corn and soybean production, increases in recreational opportunities, decreases in flood damages and decreases in shortages of water for all purposes. Conflicts and competition immediately arise for the use of the finite amount of land available to satisfy both the NED and EQ objectives. However, there is some complementary land use since the land devoted to rowcrops and pasture could be considered open space as long as the public has some access (roads and parks) to enjoy the views.

Goals for these components can also be set. Corn, soybean and livestock goals are meeting those productions projected by OBERS for the years 1980, 2000 and 2020. Recreational goals are measured by the number of acres of land and water set by various guidelines. The goal for flood damages is to reduce them to zero even though this may be impossible to attain. The goal for water shortages is to meet the projected demands for all purposes.

The existing and developable land and water resources of the region, used to attain the goals of the above components, are input to the goal programming model which is developed in greater detail in a later section.

Priorities for Land and Water in Iowa

Iowa is fortunate in having people who are interested in the state's future. What should Iowa be like in the future? This is the essence of the Iowa 2000 program first proposed by then U.S. Representative John Culver in 1972. The latest in this series of state-wide discussions was held at Iowa State University on May 24, 1978 and had for its theme "Iowa 2000: Land, Water, and Energy — An Examination of Policies and Issues" (Iowa 2000 Committee, 1978).

Beverly Everett of New Sharon, a member of the Iowa 2000 Committee, had the following reflections on the views expressed at the conference.

1. We need to work on achieving a positive attitude. A positive attitude toward problems is a great leveler between mandatory and voluntary action. If we listen positively, we can find a solution.
2. We ought to be aware of the views of those who are developers and those who are farmers. Developers ask: If we have to do things to protect the environment, why shouldn't other persons?
3. With the amount of agricultural land already within incorporated places, shouldn't emphasis on new development be placed upon that land before moving farther out of the city?
4. If Iowa is to help feed the world now and in the future, should we consider 'capping' some Iowa farmlands for the future, analogous to OPEC's 'capping' of oil wells for future use?

5. We need to remember that the 'local level' is ourself. Conflicts regarding resource allocations have to be made locally, otherwise state and federal agencies will be involved.
6. Democracy moves slowly. As citizens, we need to keep 'nagging' in order to get policies we want.

A major goal of the conference was to involve the almost 400 participants in small group discussions for the purpose of identifying needed public policies. "The following summaries, organized by issue areas, serve more to report the discussions than to propose specific policy statements. It should be remembered that the issues were complex and the time was relatively short. As is often the case in such discussions, contradictory positions were advanced — sometimes by the same person, often by the same group. No attempt has been made to resolve those contradictions in this report; they were not resolved by the discussants. Indeed, some contradictions can be resolved only through the political process or the exigencies of crises."

Land

Consideration of two related issues — farmland retention and urban sprawl — centered on a discussion of answers to the following questions: How much farmland should be retained? What quality of land should be protected? What means should be used to achieve farmland retention? And what land should be used for economic development?

Those groups which discussed land issues expressed the belief that preserving all farmland is neither realistic nor necessary, but prime land should be retained for crops. In addition, participants said that property rights are important and if they are altered at all, the changes should be made carefully. The groups thought that any regulations pertaining to farmland retention should be flexible and tied to an indexing of productivity.

Cultural land-use practices (terracing, reduced tillage, etc.) need as much attention as land-use questions arising from economic developments, participants said. They stated that local land-use control was the most desirable, but agreed that it might have to be backed up by state policy.

While the above statements represent a consensus, in several instances, individuals pressed for more absolute policy positions. For example, some participants thought the marketplace should be the sole determinant of land use; others believed mandatory zoning was necessary.

The following preferred methods were recommended for the development of "better" land-use practices:

1. State land-use policy guidelines put into effect by local governments and based upon the work of the temporary county and state land preservation policy commissions and the deliberations of the general assembly;

2. incentives for retaining farmland through such means as preferential taxes; and

3. comprehensive planning and zoning, based on state guidelines with local control.

Water

Discussion groups dealt with five water issues: pollution, irrigation, impoundment, allocation, and, indirectly, conservation.

Water pollution

Those participants who discussed water pollution saw a two-fold, complementary concern — the prevention of soil loss along with the reduction of nonpoint water pollution. They cited the need for variable standards for surface water and for reconciliation of contradictory national policies, such as "all-out production" and "soil conservation."

The emphasis should be on voluntary actions and incentives, participants said, but they also recognized the probable need for some levels of mandatory controls.

There was considerable scope to the goals and means suggested by group members. Many argued for a change in farming practices, particularly in the goal of reduced tillage. Some individuals wanted tax incentives to reduce use of the moldboard plow. Others wanted to consider an "effluent charge," which would be present depending upon such factors as soil type, slope, and cultivation practices.

In general, participants judged the standards for the 1983 goal of fishable and swimmable waters as too restrictive. They called for flexibility and technological solutions to achieve the needed water quality at the point of use.

There was nearly unanimous agreement that some form of cost-sharing would be necessary to get operators to invest in land-treatment practices, such as terracing.

Irrigation

Only a few groups addressed this area. But there was general agreement that irrigation should be regulated as it is now. The view also was expressed that irrigation for agriculture should not be encouraged in Iowa, with the possible exception of areas which could draw from the border rivers. Moreover, there was a call for increased irrigation research and education to use water available for irrigation more efficiently.

Water impoundment

Most participants who discussed this issue thought it was being handled well in Iowa. There was some sentiment for an increased number of smaller impoundments to serve rural water system needs. The overall posture toward water impoundment was viewed as being subject to a goal of avoiding the flooding of prime land due to dam construction.

Water allocation and conservation

On the issue of allocation, perhaps more than on any other, the groups expressed clear priorities for use during water shortages. The following order of highest to lowest priorities was generally agreed upon:

1. Residential use

2. Normal agricultural use

3. Industrial use

4. Municipal use

Some groups placed industrial use ahead of agriculture. All groups agreed that irrigation and recreation should have the lowest priorities.

In addition, methods for achieving water conservation were suggested. These included progressive water pricing (i.e.,

> charging more, the more water is used) and, for rural areas, the establishment of annual water-withdrawal permits.

Quality of life

Inherent in many of the discussions on land and water was the theme of the future quality of life in Iowa. This was usually expressed as the conflict between economic development and the quality of the environment. This dilemma was best expressed in the following excerpt from the comments made by James Hearst, professor emeritus of creative writing at the University of Northern Iowa, during the conference wrap-up.

> But I keep coming back to what I think is the important question: Are we willing to pay for what we want? (Is what we get worth the cost?)
>
> Which road shall we take — over the hills and far away or stay and tend our garden? If we go over the hills, we say to coming generations: 'We made what profit we could out of this place. We milked her dry. You do what you can with what's left.' If we stay and tend our garden, we turn over our stewardship with the feeling that we have made Iowa a good place to live.

Summary

Based on the above, the following set of priorities for the utilization of the land and water resources of Northwest Iowa have been formulated. The content and order of these priorities are taken from the Iowa 2000 program, but they also reflect the biases of the author on what the future ought to be.

1. Supply all water needed for urban, rural residential and livestock purposes.

2. Continue to increase farm production to meet national and

world-wide demands.

3. Reduce erosion in the region to acceptable limits.

4. Use irrigation as needed to meet crop demands.

5. Provide additional water-based recreational opportunities.

6. Do all of the above at the least cost.

These serve as the basic set of priorities for the region. The detailed equations needed to express these general priorities in the GP format are developed in the following sections. These equations also embody the author's biases: no more trees are cut down to obtain land for crop production; no land presently used for conservation purposes is converted to crop production; prime farmland contiguous to urban areas may be converted to urban uses in preference to the problems caused by "leapfrogging."

General Form of the Goal Programming Model

The general form of the goal programming model is depicted in Figs. 89 and 90. Figure 89 illustrates the interrelationships between land and water resources, their uses, society's objectives and the constraints under which all must operate. No one facet is independent of another; each affects the others to a greater or lesser extent. Shapes are indistinct because of the complexities of the interrelationships.

The generalized flowchart of the goal programming model is shown in Fig. 90. The model is input intensive since most of the facets shown in Fig. 89 can change over time and will vary from problem to

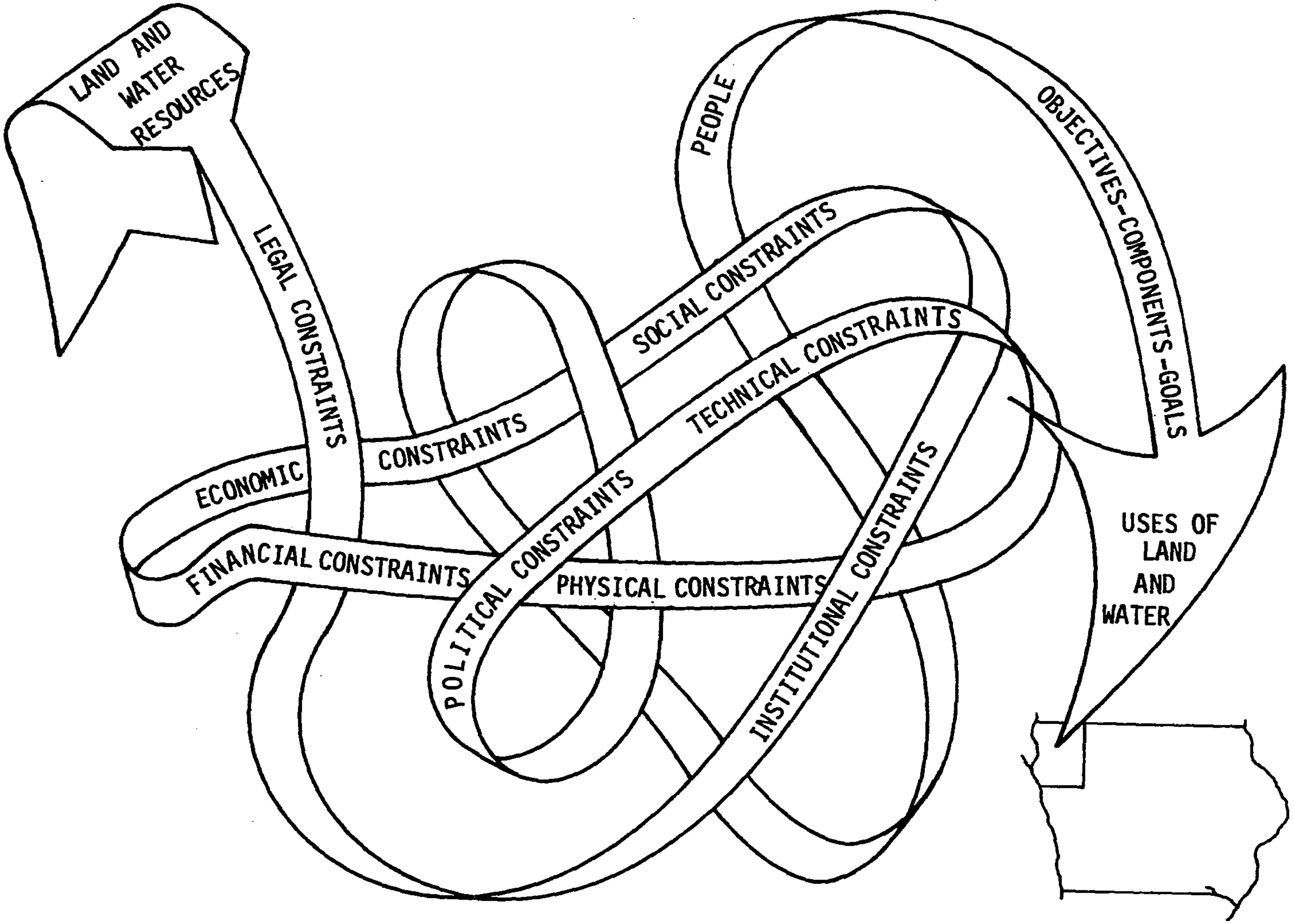


Fig. 89. General form of the goal programming model

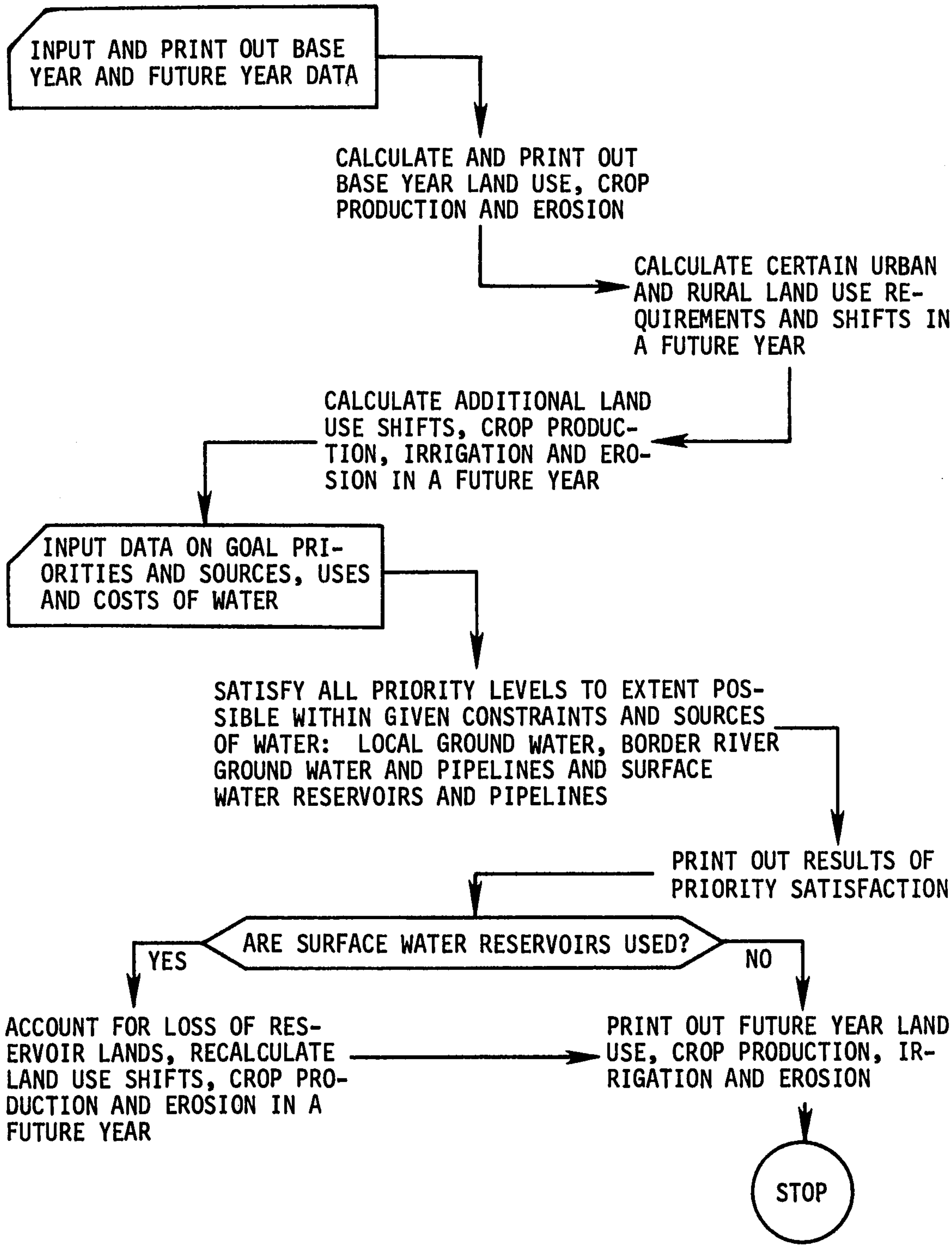


Fig. 90. Generalized flowchart of the goal programming model

problem. Some of the constraints have been built into the model which reduces its flexibility. Future versions of this GP model could be made more flexible by changing these to input items. It is a static model in that it depicts the state of the system at only one point in time. Separate runs are required to depict the system at different points in time.

A run progresses in the following manner. Several items of input are read: run identification data, land use in the base year, relative yield potential of corn and soybeans on each land capability class (LCC), relative corn and soybean yields on Class I land, average annual erosion rates per acre on each LCC for each land use with no erosion control measures and possible reservoir sites. Several items are also read in for some future year: additions to urban and rural residential land use, OBERS increases in corn and soybean production, relative yields on Class I land of nonirrigated corn, irrigated corn and soybeans, how many inches, if any, of water for irrigation will be applied, which crop planting scenario will be used and whether or not erosion control measures will be used. If they will, then new average annual erosion rates per acre on each LCC for each land use are read in. The input data is then printed.

Corn and soybean production and total erosion in the base year are calculated and printed. Land use changes are made: additions to urban and rural residential, all Class VI and VII land used for crops in the base year (1967) is changed to permanent pasture. Corn and soybean production, land use and volume of irrigation water needed in some future year are determined and stored.

Data on sources of water, uses of water other than irrigation, costs and priorities are read. Calculations are made for all priority levels and the results output. If some of the sources of water are surface water reservoirs, the necessary adjustments are made to land use in the affected counties. Corn and soybean production, amount of land irrigated, land use and total erosion in each county in some future year are calculated and output. This completes a run.

Several options are available when using the model: amount of irrigation water to be applied, whether or not erosion control measures are to be used, crop planting scenario, urban land use based on population projections, crop production demands, crop yield estimates, water sources and water demands. The detailed equations used in the model are developed in the next several sections.

Land Use

The acres of land listed in Tables D-1 through D-12 in Appendix D are those used in each of the 12 counties in Northwest Iowa for 10 categories of land use on each of 16 land capability classes as they existed in 1967 (Iowa Conservation Needs Committee, 1970). The names of these counties, land use categories and land capability classes (LCC) as they are used in the GP model are shown in Table 208. $LUTCCY_{ijk}$ is the number of acres of the jth land use on the kth capability class in the ith county in some year. Thus, $LUTCCY_{262}$ = 62,250 indicates that 62,250 acres would be planted to corn on LCC IIe in Cherokee County in 1980.

Table 208. Counties, land use categories and land capability classes used in the goal programming model

County index number	County (i)	Land use index number	Land use category (j)	LCC index number	Land capability class (k)[a]
1	Buena Vista	1	Urban and built-up	1	I
2	Cherokee	2	Forest	2	IIe
3	Clay	3	Other	3	IIw
4	Dickinson	4	Conservation use only	4	IIs
5	Ida	5	Water areas	5	IIIe
6	Lyon	6	Corn	6	IIIw
7	O'Brien	7	Soybeans	7	IIIs
8	Osceola	8	Close grown crops	8	IVe
9	Plymouth	9	Rotation hay and pasture	9	IVw
10	Sac	10	Pasture	10	IVs
11	Sioux			11	Vw
12	Woodbury			12	VIe
				13	VIs
				14	VIIe
				15	VIIw
				16	VIIs

[a]See Table 84.

Since all land in a county must be used for some purpose and no more land can be utilized than there is in a county, the form of the equation in the GP format is a Type 3 equation as shown previously in Table 1. The land use equation takes the general form shown in Eq. (32).

$$\sum_{j=1}^{10} \sum_{k=1}^{16} LUTCCY_{ijk} + n_n - p_n = LUCA_i \quad (i = 1, 2, \ldots, 12) \tag{32}$$

where $LUTCCY_{ijk}$ is as defined above and $LUCA_i$ is the total number of acres in the ith county. Both n_n and p_n, the negative deviation and positive deviation, respectively, would appear in the achievement function as priority level one variables and both would equal zero in all iterations. In this instance the deviation variables could be omitted from Eq. (31) since they <u>must</u> equal zero in order for this constraint to be met.

Three equations for land use are included in the GP model. Equation (33) indicates that the summation of all land uses on a particular LCC in a certain county must exactly equal the total number of acres of that LCC in that county. Like the total area of a county, the number of acres of a LCC in a county is a constant, $LUCC_{ik}$, and all acres in that LCC must be utilized for some land use. Thus, Eq. (33) is also a Type 3 equation and both n_n and p_n must appear in the achievement function as priority level one variables and both must equal zero in each iteration.

$$\sum_{j=1}^{10} LUTCCY_{ijk} + n_n - p_n = LUCC_{ik} \quad (i = 1, 2, \ldots, 12), \quad (k = 1, 2, \ldots, 16) \tag{33}$$

Equation (34) states that the total number of acres of the jth land use in the ith county in some year, $LUTY_{ij}$, is the summation of that land use on all land capability classes in that county.

$$\sum_{k=1}^{16} LUTCCY_{ijk} = LUTY_{ij} \quad (i = 1, 2, \ldots, 12), \quad (j = 1, 2, \ldots, 10) \qquad (34)$$

$LUTY_{ij}$ is not a constant. The total number of acres devoted to some land use in a county in any year will change depending on which objective and components are given higher priority. Thus, this variable will trace the shifts in land use that will take place as emphasis is given to certain goals of the people in the region. However, since no more land can be used than is available in a county, Eq. (35) is included in the GP model to assure that this condition is met.

$$\sum_{j=1}^{10} LUTY_{ij} + n_n - p_n = LUCA_i \quad (i = 1, 2, \ldots, 12) \qquad (35)$$

Equation (35) is also a Type 3 equation and both n_n and p_n must appear in the achievement function as priority level one variables and both must equal zero in each iteration.

Several assumptions on land use have been built into the GP model. These assumptions have been made to reflect some social, institutional and political realities. For example, it is physically and technically possible to drain existing marshlands and convert them to rowcrop production. It is also possible to cut down forests and convert the land to agricultural purposes. However, the present and foreseeable future socio-institutional-political climate does not indicate that these are desirable or socially feasible alternatives.

Therefore, the assumption is made that the number of acres devoted to the following four land use categories will not decrease from the 1967 base level throughout the projection period to the year 2020: forest, other, conservation use only and water areas. This represents an arbitrary but reasonable environmental quality constraint.

<u>Urban and rural residential</u>

As previously noted, priority is given to devoting whatever land is needed in the future for urban and rural residential growth. In rural areas one acre of land will be used for each additional rural nonfarm resident beginning in the year 1980. In urban areas one-half acre of land will be used for each additional urban resident beginning in the year 2000. This assumption reflects the findings of Gibson (1976). If a town's population decreases in future years, its acreage will remain the same. If a town's population increases, its acreage will increase. Equal amounts of land are used from LCC I, IIe, IIw and IIIe. Increases in urban and rural nonfarm populations over the 1970 levels are shown in Tables 209 and 210 for the author's and the State of Iowa's projections, respectively. Tables 211 and 212 list the additional acres needed to support this increase in population for the years 1980, 2000 and 2020 based on these two sets of projections.

Some land use problems could arise if the State of Iowa's population projections more accurately reflect the region's future population than the projections made in this study. These latter projections forecast a need for an additional 5,000 and 10,000

Table 209. Increase in urban and rural nonfarm population from 1970 levels in Northwest Iowa in 1980, 2000 and 2020 based on Rossmiller's projections, number of persons

County	Urban[a]			Rural		
	1980	2000	2020	1980	2000	2020
Buena Vista	40	184	824	20	92	212
Cherokee	20	104	200	40	172	360
Clay	120	800	1,760	100	320	560
Dickinson	100	624	1,240	100	352	612
Ida	0	0	0	32	72	100
Lyon	20	160	480	32	112	212
O'Brien	0	0	160	52	180	320
Osceola	0	0	0	52	152	232
Plymouth	220	1,240	2,544	92	292	552
Sac	0	0	0	32	100	180
Sioux	260	1,360	2,840	52	200	340
Woodbury	120	480	840	120	452	800
Region	900	4,952	10,888	724	2,496	4,480

[a]Urban increases based on population increases only in each community.

acres of urban and rural built-up acreage in the years 2000 and 2020, respectively. If the State of Iowa's projections are used, it indicates a need for an additional 30,000 and 46,000 acres in these same two years. Most of these additional acres will probably come from present agricultural uses and this could cause problems in meeting future agricultural production needs.

Urban acreage is added to the existing "urban and built-up" land use category. Rural nonfarm acreage is added to the "other" land use category since that is where it was included in the 1967 conservation needs inventory of land use in Iowa (Iowa Conservation Needs Committee, 1970). These increases in urban and rural built-up

Table 210. Increase in urban and rural nonfarm population from 1970 levels in Northwest Iowa in 1980, 2000 and 2020 based on the State of Iowa's projections, number of persons

County	Urban[a] 1980	Urban[a] 2000	Urban[a] 2020	Rural 1980	Rural 2000	Rural 2020
Buena Vista	1,040	2,704	3,504	152	412	560
Cherokee	0	304	1,344	48	400	820
Clay	880	2,408	2,872	192	528	712
Dickinson	1,968	4,440	5,112	420	1,072	1,432
Ida	0	344	824	48	176	316
Lyon	392	2,448	5,160	88	420	860
O'Brien	928	2,808	3,888	172	568	900
Osceola	432	1,632	3,040	160	592	1,132
Plymouth	464	2,768	4,920	132	540	940
Sac	104	1,000	1,968	92	392	740
Sioux	3,144	8,360	11,520	252	708	992
Woodbury	5,648	17,160	25,144	392	1,252	2,052
Region	15,000	46,376	69,296	2,148	7,060	11,456

[a]Urban increases based on population increases only in each community.

acreage are included in the GP model as indicated in Eqs. (36) and (37) and have been divided equally between LCC I, IIe, IIw and IIIe.

$$LUTCCY_{i1k} = LUTCCY_{i1k} + LUUR_i/4 \quad (i = 1, 2, \ldots, 12) \quad (k = 1, 2, 3, 5) \qquad (36)$$

$$LUTCCY_{i3k} = LUTCCY_{i3k} + LURUR_i/4 \quad (i = 1, 2, \ldots, 12) \quad (k = 1, 2, 3, 5) \qquad (37)$$

where $LUUR_i$ = future additional urban acreage in ith county

$LURUR_i$ = future additional rural residential acreage in ith county

Table 211. Increase in urban and rural built-up acreage in Northwest Iowa in 1980, 2000 and 2020 based on Rossmiller's projections, acres of land[a]

County	Urban			Rural		
	1980	2000	2020	1980	2000	2020
Buena Vista	0	92	412	20	92	212
Cherokee	0	52	100	40	172	360
Clay	0	400	880	100	320	560
Dickinson	0	312	620	100	352	612
Ida	0	0	0	32	72	100
Lyon	0	80	240	32	112	212
O'Brien	0	0	80	52	180	320
Osceola	0	0	0	52	152	232
Plymouth	0	620	1,272	92	292	552
Sac	0	0	0	32	100	180
Sioux	0	680	1,420	52	200	340
Woodbury	0	240	420	120	452	800
Region	0	2,476	5,444	724	2,496	4,480

[a]Based on 0.5 acre per additional resident in urban areas beginning in the year 2000 and 1.0 acre per additional nonfarm resident in rural areas beginning in 1980.

Pasture on Class VI and VII land

In most alternatives, all Class VI and VII land presently used for row crops, close grown crops and rotation hay and pasture is converted to permanent pasture. These are the lands which are most susceptible to erosion and the least capable of producing crops. By converting Class VII land from row crops using conventional tillage to permanent pasture, the rate of erosion is reduced from 365 tons per acre per year to just 9 tons per acre per year as shown in Tables 141 and 143. On Class VI lands, the erosion rate is reduced from 223 to 3 tons per acre per year. These land use changes are effected in the GP model as shown in Eqs. (38) and (39).

Table 212. Increase in urban and rural built-up acreage in Northwest Iowa in 1980, 2000 and 2020 based on the State of Iowa's projections, acres of land[a]

County	Urban 1980	Urban 2000	Urban 2020	Rural 1980	Rural 2000	Rural 2020
Buena Vista	0	1,352	1,752	152	412	560
Cherokee	0	152	672	48	400	820
Clay	0	1,204	1,436	192	528	712
Dickinson	0	2,220	2,556	420	1,072	1,432
Ida	0	172	412	48	176	316
Lyon	0	1,224	2,580	88	420	860
O'Brien	0	1,404	1,944	172	568	900
Osceola	0	816	1,520	160	592	1,132
Plymouth	0	1,384	2,460	132	540	940
Sac	0	500	984	92	392	740
Sioux	0	4,180	5,760	252	708	992
Woodbury	0	8,580	12,572	392	1,252	2,052
Region	0	23,188	34,648	2,148	7,060	11,456

[a]Based on 0.5 acre per additional resident in urban areas beginning in the year 2000 and 1.0 acre per additional nonfarm resident in rural areas beginning in 1980.

$$\sum_{j=6}^{10} \sum_{k=12}^{16} LUTCCY_{ijk} = LUTCCY_{i10k} \quad (i = 1, 2, \ldots, 12) \quad (38)$$

$$\sum_{i=1}^{12} \sum_{j=6}^{9} \sum_{k=12}^{16} LUTCCY_{ijk} = 0 \quad (39)$$

<u>Potential reservoir sites</u>

In some alternatives land will be devoted to surface water reservoirs for irrigation, flood control and recreational purposes. The land and water areas needed for these purposes and their locations were listed in Table 162. The normal water surface area is that of the water supply pool and the total land area required is that of the flood pool. The additional land and water areas needed at each of the 24 locations identified in Northwest Iowa are summarized in Table 213 and are used as inputs to the GP model. The acreage devoted to water is added to the "water areas" land use category and the land acreage is added to the "conservation use only" land use category. As in the case of additional land for urban and residential uses, the assumption is made that equal amounts of land are used from LCC I, IIe, IIw and IIIe. A detailed examination of each of the sites would need to be made in order to refine this estimate.

Unlike the additional land for urban and rural residential uses which <u>will</u> be used in the future, the land for surface water reservoirs is used <u>only</u> if it is needed for irrigation. The present situation in Northwest Iowa with regards to flooding problems and opportunities for water-based recreation is not so critical that reservoirs <u>must</u> be constructed for these purposes. However, if a surface water reservoir is needed for irrigation and is a part of the final tableau, then it should also be considered for flood control and recreation use also.

Table 161 indicates that the 24 sites provide about 700,000 acre-feet of storage for water supply. Table 214 lists the total acres of LCC I and IIe land in Northwest Iowa devoted to corn, soybeans, close grown crops, rotation hay and pasture and permanent pasture in 1967. This table shows that over 586,000 acres of Class I land and 1,197,000 acres of Class IIe land were used for these purposes in 1967. If at some future time, this land was used for irrigated corn and all 24 sites were developed, each Class I Acre could receive about 14 inches of water or if all 1,783,000 acres were used for irrigated corn, each acre could receive about 5 inches of water. Based on Table 200, these

Table 213. Additional land and water areas needed at potential reservoir sites in Northwest Iowa, acres

County	Stream	Land	Water
Buena Vista	Brooke Creek	190	620
Cherokee	Mill Creek	2,400	3,400
	Silver Creek	200	740
Clay	Big Muddy Creek	440	1,860
	Willow Creek	850	1,390
Dickinson	Stony Creek	1,550	2,500
Ida	Battle Creek	600	1,400
	Maple River	6,100	9,500
Lyon	Little Rock River	4,700	4,800
O'Brien	Little Floyd River	1,300	2,400
	Waterman Creek	980	1,770
Plymouth	Deep Creek	910	1,440
	Johns Creek	430	820
	Plymouth Creek	520	830
	Willow Creek	1,300	1,300
Sac	Boyer River	1,420	1,580
	Indian Creek	450	750
Sioux	West Branch Floyd River	3,000	3,000
Woodbury	Big Whiskey Creek	800	1,400
	Elliott Creek	900	1,500
	Mud Creek	850	1,450
	Reynolds Creek	250	400
	West Fork Little Sioux River	4,100	6,200
	Wolf Creek	1,100	2,400

depths of irrigation water correspond to drought recurrence intervals of 25 years and less than 2 years, assuming unlimited water available after tasseling.

If all this land <u>were</u> needed for irrigated corn production in order to meet the OBERS crop production projections, then additional water could be made available from ground water sources.

Land used for surface water reservoirs is incorporated in the GP model as shown in Eqs. (40) and (41). The acreage devoted to water is added to the "water areas" land use category and the land

Table 214. Total acres of LCC I and IIe land in Northwest Iowa devoted to corn, soybeans, close grown crops, rotation hay and pasture and permanent pasture in 1967

County	LCC I	LCC IIe
Buena Vista	49,370	107,960
Cherokee	34,970	115,920
Clay	87,350	35,880
Dickinson	42,110	50,350
Ida	3,610	56,770
Lyon	54,200	138,080
O'Brien	92,130	143,050
Osceola	60,380	82,240
Plymouth	17,860	110,390
Sac	39,290	118,140
Sioux	54,400	181,300
Woodbury	50,550	57,040
Region	586,220	1,197,120

acreage is added to the "conservation use only" land use category. The range of "i" is 1 to 12 and "m" is 1 to 24.

$$LUTCCY_{i4k} = LUTCC_{i4k} + LUR_{mi} \times LURL_{mi} \quad (k = 1, 2, 3, 5) \qquad (40)$$

$$LUTCCY_{i5k} = LUTCC_{i5k} + LUR_{mi} \times LURW_{mi} \quad (k = 1, 2, 3, 5) \qquad (41)$$

where LUR_{mi} = 1 or 0 depending on whether that particular reservoir is or is not included

$LURL_{mi}$ = acres of land used in the reservoir area for recreation and temporary storage of water

$LURW_{mi}$ = acres of land used in the reservoir area for permanent storage of water

The final assumption concerning land use is that all Class I through V lands presently used for row crops, close grown crops, rotation hay and pasture and permanent pasture are eligible for redistribution to some other use. Some of these other uses have been discussed above. Future use of land in Northwest Iowa for crops and pasture is discussed in the next section.

Crops and Pasture

Since the economic health of Northwest Iowa is dependent on a healthy agricultural sector, a high priority must be given to ensuring continued corn, soybean and livestock production as projected by OBERS. This priority could conflict with the preference expressed in the Iowa 2000 program to reduce erosion. Whether this will or will not be accomplished is dependent on the willingness of farmers to adapt their present farming methods to meet goals set at the regional, state and national levels, the price of crops and levels of government programs and subsidies. Production goals have been set at the national level in the various OBERS publications. Stream water quality goals have been set at both the state and national levels. The attainment of these water quality goals is dependent to a great extent on how well nonpoint sources of pollution are brought under control. Runoff from agricultural land is a major contributor of nonpoint source pollution. State and regional goals and desires concerning equity in opportunities for work, housing and recreation, with all of these located in an environmentally pleasing setting, may also require that farmers alter or relocate their farming operations.

Farmers have long conducted their businesses while operating under a variety of legal, institutional, social and fiscal constraints. One current institutional constraint prohibits the use of water from a particular ground water aquifer for crop production. Another institutional constraint prohibits the use of water from certain locations of another ground water aquifer for crop production. Some groups of people do not want any surface water reservoirs to be constructed. Thus, another potential source of water for increased crop production may be eliminated.

How should the acreage devoted to corn, soybeans and close grown crops be distributed over the various land capability classes? Under the present system the decisions are made by the individual landowners based on their perceptions of future crop demands, prices and weather and their involvement in various government programs. The present system will undoubtedly change somewhat in the future but it is doubted that the government will ever decide which crops and in what amounts will be planted on each capability class. Some, and perhaps a great deal of, discretion will be left to the farmer. Assuming this to be true, there is no way to predict exactly which crops will be planted where in the future. The best which can be done is to model the range of planting scenarios, along with the attendant range of erosion control measures, water needs and some possible government programs and costs, and estimate the results of these several actions while attempting to meet the various goals of the region. These results will indicate the impacts that will occur in some areas when decisions are made in other areas.

For instance, allowing crops to continue to be raised as they are now will also continue the massive soil erosion now in progress. Restricting row crops to just Class I and II land would reduce soil erosion but would eliminate most of the income for those farmers who own only Class III and IV land. Allowing these farmers to grow row crops, but with appropriate erosion control measures, may require government grants and/or loans to pay for the installation of these erosion control facilities. Some scenarios may require that land be irrigated in order to meet OBERS future production estimates. Who would or should pay for the construction and installation of the needed irrigation facilities? Some farmers may elect to place a portion of their land in the set-aside program. This would require the continuation of this program and the commitment of government funds to it.

Crop planting scenarios

All of these goals and constraints have been combined into a series of seven scenarios. One goal included in all seven is to meet the future production volumes projected by OBERS. The scenarios run the gamut from almost allowing farmers to plant as they please (which has not been a desired objective if EQ goals are violated) to full control of what crops are planted where, from no erosion control to full erosion control, from no irrigation to full irrigation. These scenarios also take into account two characteristics of corn and soybeans. First, soybeans are more tolerant of drought conditions than corn, i.e., during a drought soybean yields decrease less than corn yields decrease. Thus, it would be preferable to have only corn receive supplemental irrigation water. Second, when these two crops are planted on steeper and steeper slopes, the reduction in soybean yields is less than the reduction in corn yields. Thus, it would be preferable to have corn planted on the flatter slopes and soybeans planted on the steeper slopes.

These scenarios also take into account two other items. Some scenarios include various erosion control measures. Since some of these measures take cropland out of production, this is accounted for in the model. Some scenarios include surface water reservoirs. Since these remove some land from production, this is also accounted for in the model.

A general description of these scenarios follows. A complete listing of the computer code for each of them is given in Appendix L. Scenario 1 is the "do nothing" alternative which allows farmers to continue planting as they desire without irrigation. This has resulted in row crop acreage in Northwest Iowa increasing from 1.86 million acres in 1952 to 2.45 million acres in 1967 to 2.70 million acres in 1976. Scenario 2 is similar to 1 but removes LCC VI and VII from crop production and allows for some irrigation. Scenario 3 modifies 2 in that less sloping land is favored for corn production. Scenario 4 continues modifying 2 with more restrictions and more irrigation. Scenario 5 further continues modifying 2, initially utilizing only those lands used for row and close grown crops in 1967 with irrigation of all necessary Class I and IIe land for corn. Scenario 6 is essentially complete control using only the less sloping lands for row crops with irrigation of all necessary Class I and IIe land for corn.

Scenario 7 is similar to 1 but more land use categories are allowed to be used for crops, so all crop production demands can be met without irrigation. These seven scenarios are described more fully in Table 215.

Equations for crop planting scenarios

The equations used to describe these seven scenarios in the GP model are similar in each scenario, so the equations listed in the following paragraphs do not describe each of the seven in detail but do give the sense of how the important variables are included in the model. Only corn is discussed but soybeans are included in the same manner. Simply exchange the word "soybeans" for "corn," and in each variable, use the letter "s" rather than "c."

Nonirrigated corn Land use as it existed in 1967 is input and totaled as described previously in Eqs. (33), (34) and (35). Two other inputs are the relative yields of corn and soybeans on LCC I which were listed in Table 132 and the relative yield potential of corn and soybeans on each LCC which are listed in Table 216. Corn production on each LCC and total corn production in each county in 1967 are calculated using Eqs. (42) and (43).

$$KCCP_{ik} = \sum_{k=1}^{16} LUTCC_{i6k} \times RCYCC1_i \times CCCRYP_k \quad (i = 1, 2, \ldots, 12) \tag{42}$$

$$KTCP_i = \sum_{k=1}^{16} KCCP_{ik} \quad (i = 1, 2, \ldots, 12) \tag{43}$$

where $LUTCC_{i6k}$ = acres of land devoted to corn in the ith county on the kth capability class in 1967

Table 215. General descriptions of crop planting scenarios

Number	Description
1	Allow row crop acreage to expand onto land presently used for close grown crops, hay and pasture with each land capability class (LCC) claiming the same percentage of total production as it had in 1967, planting corn first and then soybeans on Class I through VII land without any irrigation
2	Allow row crop acreage to expand onto land presently used for close grown crops, hay and pasture with each LCC claiming the same percentage of total production as it had in 1967, planting corn first and then soybeans on Class I through V land using irrigation as needed
3	Utilize all land used for row and close grown crops, hay and pasture in 1967 with the same percentage of land utilized in 1967 for row and close grown crops used first for corn and then soybeans on Class I through V land using irrigation as needed
4	Only allow corn and soybeans on those Class I through V lands which were planted to row crops in 1967; use full irrigation on Class I land for corn and irrigate Class IIe land as needed; use all Class I land before using Class II land, etc., growing corn first, then soybeans, then close grown crops, with all remaining land to be in hay and pasture
5	Only allow corn and soybeans on those Class I through V lands which were planted to row and close grown crops in 1967; use full irrigation on Class I land for corn and irrigate Class IIe land as needed; use all Class I land before using Class II land, etc., growing corn first, then soybeans, then close grown crops, with all remaining land to be in hay and pasture
6	Allow corn and soybeans on all Class I through V lands which were planted to row and close grown crops, hay and pasture in 1967; use full irrigation on Class I land for corn and irrigate Class IIe land as needed; use all Class I land before using Class II land, etc., growing corn first, then soybeans, then close grown crops, with all remaining land to be in hay and pasture
7	Allow row crop acreage to expand onto land presently used for close grown crops, hay, pasture, other and conservation use only with each land capability class (LCC) claiming the same percentage of total production as it had in 1967, planting corn first and then soybeans on Class I through V land using no irrigation

Table 216. Relative yield potential of corn and soybeans on each land capability class as input to the GP model[a]

LCC	Corn	Soybeans
I	1.00	1.00
IIe	0.90	0.95
IIw	0.90	0.95
IIs	0.60	0.95
IIIe	0.90	0.87
IIIw	0.70	0.80
IIIs	0.50	0.80
IVe	0.60	0.75
IVw	0.60	0.62
IVs	0.40	0.62
Vw	0.50	0.40
VIe	0.60	0.40
VIs	0.60	0.40
VIIe	0.50	0.40
VIIw	0.50	0.40
VIIs	0.50	0.40

[a]Gibson (1976).

$RCYCC1_i$ = relative corn yield on LCC I, bushels per acre

$CCCRYP_k$ = relative yield potential of corn on the kth capability class

$KCCP_{ik}$ = total corn production on kth capability class in ith county in 1967, bushels

$KTCP_i$ = total corn production in ith county in 1967, bushels

$KTCP_i$ is also equal to the product of the acres of land devoted to corn in the ith county in 1967 times the average corn yield in bushels per acres in the ith county in 1967 as listed in Appendix H.

The goal of total corn production in some future year as projected by OBERS is included as Eq. (44). The percentage increases in corn production in the years 1980, 2000 and 2020 as projected by OBERS based on total corn production in 1967 were previously listed in Table 125.

$$KTCPY_i = KTCP_i \times OBERSC \qquad (44)$$

where $KTCPY_i$ = total corn production in bushels in the ith county in some future year

$KTCP_i$ = total corn production in bushels in the ith county in 1967

OBERSC = OBERS future increase in corn production as a percentage of 1967 production

Total corn production in a county in some future year is equal to the summation of the production from those number of acres on each capability class devoted to corn in each county. The seven scenarios allow several variations on how much acreage on various capability classes can be devoted to corn in future years. The following equations illustrate this process and were taken from scenario 3.

$$RATIOC_i = RAT/TIO \qquad (45)$$

where $RATIOC_i$ = ratio for corn of RAT to T10 in the ith county

RAT = $LU610_{ik}$ = total acres devoted to land uses 6 through 10 in 1967 on the kth capability class in the ith county

TIO = $LU68_{ik}$ = total acres devoted to land uses 6 through 8 in 1967 on the kth capability class in the ith county

This ratio is used to determine the total acres which could be devoted to corn for that particular scenario as illustrated in Eq. (46). "k" ranges from 1 to 11 or 1 to 16.

$$LUTCCY_{i6k} = LUTCC_{i6k} \times RATIOC_i \quad (i = 1, 2, \ldots, 12) \qquad (46)$$

where $LUTCCY_{i6k}$ = acres devoted to corn in some future year on the kth capability class in the ith county

$LUTCC_{i6k}$ = acres devoted to corn in 1967 on the kth capability class in the ith county

Corn production from each of the capability classes is determined using Eq. (47).

$$KCCPY_{ik} = LUTCCY_{i6k} \times ICY1_i \times CCCRYP_k \quad (i = 1, 2, \ldots, 12) \qquad (47)$$

where $KCCPY_{ik}$ = total corn production in bushels on the kth capability class in the ith county in some future year

$ICY1_i$ = relative corn yield on LCC I in some future year, bushels per acre

$CCCRYP_k$ = relative yield potential of corn on the kth capability class, see Table 216

The corn production from each capability class is subtracted from the total corn production in each county in some future year as shown in Eq. (48).

$$KTCPY_i = KTCPY_i - KCCPY_{ik} \quad (i = 1, 2, \ldots, 12) \qquad (48)$$

where $KTCPY_i$ = total corn production in bushels in the ith county in some future year

If the $KTCPY_i$ on the left side of the equation becomes negative, then the corn production goal has been exceeded. When this occurs, the acreage used for corn on the last LCC used is reduced so that the goal is just met.

If the corn production goal is not met ($KTCPY_i$ on the left side of the equation does not become negative) after all land initially allowed for corn in that scenario is utilized, then the program cycles back to LCC I and uses whatever land is necessary to meet the goal. First, however, the amount of land not yet utilized on each LCC must be determined. This is done through the use of Eqs. (49) and (50).

$$LUCC16_{ik} = \sum_{j=1}^{6} \sum_{k=1}^{11} LUTCCY_{ijk} \quad (i = 1, 2, \ldots, 12) \tag{49}$$

where $LUCC16_{ik}$ = total acreage devoted to land uses 1 through 6 on the kth capability class in the ith county in some future year

Land uses 1 through 6 include urban and built-up, forest, other, conservation use only, water areas and corn.

$$LLO = LUCC_{ik} - LUCC16_{ik} \quad (k = 1, 2, \ldots, 11), \quad (i = 1, 2, \ldots, 12) \tag{50}$$

where $LUCC_{ik}$ = total acreage of the kth capability class in the ith county

LLO = land left over, acres

If LLO is equal to zero, then the program goes on to the next LCC.

The volume of additional corn production required is determined using Eq. (51).

$$KPRA = KTCP_i \times OBERSC - KTCPY_i \quad (i = 1, 2, \ldots, 12) \quad (51)$$

where KPRA = additional corn production required, bushels

Then the additional land needed for corn is calculated using Eq. (52).

$$LNFCA = KPRA/ICY1_i/CCCRYP_k \quad (i = 1, 2, \ldots, 12), \quad (k = 1, 2, \ldots, 11) \quad (52)$$

where LNFCA = additional land needed for corn, acres

If LNFCA is less than or equal to LLO, this means that sufficient additional land exists on that capability class to meet the total corn production goal. If LNFCA is greater than LLO, this means that all remaining land on that LCC must be used for corn plus additional land from other capability classes. This is accomplished in Eqs. (53), (54) and (55), then the program goes on to the next LCC. The range of "i" is 1 to 12 and "k" from 1 to 11.

$$LUTCCY_{i6k} = LUTCCY_{i6k} + LLO \quad (53)$$

$$KCCPY_{ik} = LUTCCY_{i6k} \times ICY1_i \times CCCRYP_k \quad (54)$$

$$KTCPY_i = KTCPY_i + LLO \times ICY1_i \times CCCRYP_k \quad (55)$$

If the corn production goal is still not met, then the program cycles back and begins irrigating corn on LCC I and LCC IIe as necessary. Soybean production is determined in a similar manner. Land not utilized for land uses 1 through 6 is determined. Some portion of this land is utilized for soybean production, depending on the particular scenario. If soybean production goals are not met, then the amount of land not yet utilized is determined and this land is used for soybean production. If soybean production goals are still not met, then the program cycles back to corn production. Class I and IIe land is used for irrigated corn production (again depending on the scenario) which releases land for soybean production. If soybean production goals are still not met, then the GP model stores this information and goes on to meet goals of lower priority.

Irrigated corn   Irrigation is confined to corn on LCC I and IIe only for two reasons. These lands are the least susceptible to erosion and have the greatest potential to increase yields due to irrigation. The assumption is also made that only center pivot irrigation systems are used. This is based on the further assumption that the trend towards the substitution of capital for labor will continue throughout the projection period. There has been some irrigation using gated pipe and land leveling on the Missouri River floodplain. Even here the growth of center pivot irrigation has been great.

The equations used to incorporate irrigation into the GP model for crop production in the various scenarios are listed below. The particular equations used here are taken from scenario 4. The corn production goal is determined as before by using Eq. (44). Irrigated corn production on LCC I is calculated as shown in Eq. (56). The range of "i" is 1 to 12.

$$KCCPY_{i1} = LU67Y_{i1} \times IICY1_i \times 0.94 + LU67Y_{i1} \times ICY1_i \times 0.06 \quad (56)$$

where $KCCPY_{i1}$ = total corn production in bushels on LCC I in the ith county in some future year

$LU67Y_{i1}$ = total number of acres used for corn and soybeans in 1967 minus acres used for urban and rural residential purposes and surface water reservoirs in some future year on LCC I

$IICY1_i$ = relative irrigated corn yield on LCC I in some future year, bushels per acre

0.94 = 150.4/160 = that portion of a quarter section of land which can be irrigated using a center pivot system with corner attachments

If $KCCPY_{i1}$ is equal to $KTCPY_i$, then the corn production goal is met. If $KCCPY_{i1}$ is greater than $KTCPY_i$, then corn production is more than met and acreage used for irrigated corn is reduced so that the goal is just met. If $KCCPY_{i1}$ is less than $KTCPY_i$, then the corn production goal is not met, all LCC I land is used for irrigated corn and additional land on other capability classes must also be used for corn. Equation (57) records the number of acres used for irrigated corn on LCC I.

$$LUICY1_i = LUTCCY_{i61} \quad (i = 1, 2, \ldots, 12) \tag{57}$$

where $LUTCCY_{i61}$ = acres of land used for corn on LCC I in some future year in the ith county

$LUICY1_i$ = acres of irrigated corn on LCC I in some future year in the ith county

If the corn production goal cannot be met without irrigation on the other capability classes or if the soybean production goal cannot be met, then irrigation is also used for corn on LCC IIe as shown in Eqs. (58) and (59).

$$ICPR = KTCP_i \times OBERSC - KTCPY_i \quad (i = 1, 2, ..., 12) \qquad (58)$$

where ICPR = additional irrigated corn production required, bushels

$$LUICY2_i = ICPR/CCCRYP_2/(IICY1_i - ICY1_i)/0.94 \quad (i = 1, 2, ..., 12) \qquad (59)$$

where $LUICY2_i$ = acres of land used for irrigated corn production on LCC IIe in some future year in the ith county

This value of $LUICY2_i$ is then checked against the available acreage on LCC IIe and the appropriate adjustments made if needed.

<u>Close grown crops, hay and pasture</u> When all irrigation needs are determined in the various scenarios, and the corn and soybean goals are either met or not met, then the land still not utilized on each LCC in that scenario is devoted to land uses 8, 9 and 10, close grown crops, rotation hay and pasture and permanent pasture, respectively. The goal for each of these three uses is to maintain, as a minimum, that amount of land used for that purpose in 1967. This is accomplished as indicated in the following equations.

First, the remaining land on each capability class not yet utilized for some other purpose is determined as shown in Eqs. (60) and (61).

$$LUCC17_{ik} = \sum_{j=1}^{7} \sum_{k=1}^{11} LUTCCY_{ijk} \quad (i = 1, 2, ... 12) \qquad (60)$$

where $LUCC17_{ik}$ = total acreage devoted to land uses 1 through 7 on the kth capability class in the ith county in some future year

$$LUCC80_{ik} = LUCC_{ik} - LUCC17_{ik} \quad (i = 1, 2, \ldots, 12) \quad (k = 1, 2, \ldots, 11) \qquad (61)$$

where $LUCC80_{ik}$ = total acreage available for land uses 8 through 10 on the kth capability class in the ith county in some future year

$LUCC_{ik}$ = total acres of the kth capability class in the ith county

Second, $LUCC80_{ik}$ is compared with the land devoted to close grown crops in 1967 on that LCC and then the acreage devoted to close grown crops in some future year is set initially to the smaller of these two values. The total initial acreage devoted to close grown crops and the additional acreage needed is determined as shown in Eqs. (62) and (63).

$$LUTY_{i8} = \sum_{k=1}^{11} LUTCCY_{i8k} \quad (i = 1, 2, \ldots, 12) \qquad (62)$$

where $LUTY_{i8}$ = total acreage devoted to close grown crops in the ith county in some future year

$$LU8N = LUT_{i8} - LUTY_{i8} \qquad (63)$$

where LUT_{i8} = total acres used for close grown crops in the ith county in 1967

LU8N = additional acres of land-use 8 (close grown crops) needed in some future year

LU8N is then compared with the acreage still not utilized in the various capability classes, LU90, and the appropriate amount of acreage added to land use 8 in each LCC until the goal of LUT_{i8} is met.

Third, a similar procedure is used to determine the number of acres devoted to land use 9, rotation hay and pasture, in attempting to meet the goal of at least the same acreage utilized for land use 9 in some future year as there was in 1967. Finally, all remaining acreage is utilized for land use 10, permanent pasture. Similar procedures to all of the above are used for each of the seven scenarios. By comparing the degree of attainment of the goals for corn and soybeans and the other land uses for each of the scenarios, those scenarios which best meet the goals can be identified. These goals are included in the model as shown in the following equations. These are all Type 2 equations so the negative deviations, n_n, are included in the achievement function at some priority level and minimized.

$$\text{corn:} \quad KTCPY_i + n_n - p_n = KTCP_i \times OBERSC \quad (i = 1, 2, \ldots, 12) \qquad (64)$$

$$\text{soybeans:} \quad KTSPY_i + n_n - p_n = KTSP_i \times OBERSS \quad (i = 1, 2, \ldots, 12) \qquad (65)$$

$$\text{LU8:} \quad LUTY_{i8} + n_n - p_n = LUT_{i8} \quad (i = 1, 2, \ldots, 12) \qquad (66)$$

$$\text{LU9:} \quad LUTY_{i9} + n_n - p_n = LUT_{i9} \quad (i = 1, 2, \ldots, 12) \qquad (67)$$

$$\text{LU10:} \quad LUTY_{i10} + n_n - p_n = LUT_{i10} \quad (i = 1, 2, \ldots, 12) \qquad (68)$$

Soil Erosion

Total soil erosion in a county is equal to the summation of the erosion from each capability class on each land use in the county. The average annual erosion rates in tons per acre for each type of land use on each capability class without and with erosion control measures were previously summarized in Tables 145 and 146, respectively. These two tables are input to the GP model as are the acres utilized for each type of land use on each LCC in each county in 1967. The determination of acreage devoted to the various land uses in the future was detailed in the previous section. These values are used in the following equations to determine the total soil erosion in a county.

$$KCE_{ijk} = LUTCCY_{ijk} \times AETCC_{jk} \quad (i = 1, 2, \ldots, 12), \; (j = 1, 2, \ldots, 10), \; (k = 1, 2, \ldots, 16) \qquad (69)$$

where $LUTCCY_{ijk}$ = acres devoted to the jth land use on the kth capability class in the ith county in some future year

$AETCC_{jk}$ = average annual rate of erosion on each land use and capability class, tons per acre

KCE_{ijk} = total erosion in tons per year from the kth capability class on the jth land use in the ith county in some future year

$$LUTE_{ij} = \sum_{k=1}^{16} KCE_{ijk} \quad (i = 1, 2, \ldots, 12), \; (j = 1, 2, \ldots, 10) \qquad (70)$$

where $LUTE_{ij}$ = total erosion in tons per year from the jth land use in the ith county in some future year

$$KCTE_{ik} = \sum_{j=1}^{10} KCE_{ijk} \quad (i = 1, 2, ..., 12), (k = 1, 2, ..., 16) \tag{71}$$

where $KCTE_{ik}$ = total erosion in tons per year from the kth capability class in the ith county in some future year

$$KTE_i = \sum_{j=1}^{10} LUTE_{ij} \quad (i = 1, 2, ..., 12) \tag{72}$$

where KTE_i = total erosion in tons per year from the ith county in some future year

By comparing LUTE for each land use and KCTE for each capability class, those land uses and capability classes which contribute the most to the total erosion in a county can be identified. By comparing these and KTE in each county for each of the scenarios, those scenarios which best meet the soil erosion goal can be identified. This is determined using Eq. (73).

$$KTE_i + n_n - p_n = 5.0 \times LUCA_i \quad (i = 1, 2, ..., 12) \tag{73}$$

Recreation

Table 217 lists the additional acreage devoted to recreation which would be desirable in Northwest Iowa through the year 2020. The four counties which have no need for additional acreage are those which contain natural lakes. Due to the low priority placed on recreation, no surface water reservoirs will be constructed solely for recreation.

Table 217. Summary of additional acreage desirable for recreation in Northwest Iowa through the year 2020

County	Additional acreage[a]
Buena Vista	0
Cherokee	340
Clay	0
Dickinson	0
Ida	230
Lyon	350
O'Brien	100
Osceola	100
Plymouth	600
Sac	0
Sioux	540
Woodbury	1,700
Region	3,960

[a]See Table 104.

If a reservoir is constructed for irrigation purposes, then it will also be used for recreation. The acres of land and water at each potential reservoir site were previously listed in Table 213.

A comparison of the acreages listed in Tables 213 and 217 indicate that much more potential acreage is available than would be needed for recreational purposes if most of the reservoirs were constructed. If this possibility becomes a fact, then consideration can be given to developing the recreation potential of only those sites which offer the best recreational opportunities.

The acreages shown in Table 217 become the goals for the recreation component of the environmental quality objective and are incorporated in the GP model in the form shown in Eq. (74). The range of "i" is 1 to 12 and "m" is 1 to 24.

$$LUR_{mi}(LURL_{mi} + LURW_{mi}) + n_n - p_n = IARA_i \quad (74)$$

where LUR_{mi} = 1 or 0 depending on whether the mth reservoir is or is not included

$LURL_{mi}$ = acres of land used in the mth reservoir for recreation and temporary storage of water

$LURW_{mi}$ = acres of land used in the mth reservoir for the permanent storage of water

$IARA_i$ = additional recreation acres needed in the ith county

Equation (74) is a Type 2 equation and n_n becomes a part of the achievement function and is minimized. Since there is some likelihood that more reservoirs could be constructed than are needed for recreation, p_n could have some positive integer value other than zero. In this case more could be better for the following reason. The goals were set assuming only those people living within the county would use the recreational facilities. At present, the Iowa Great Lakes in Dickinson County are becoming overused, especially Lake West Okoboji, from people visiting the lakes from all over Iowa and the surrounding states, including the Omaha-Council Bluffs area. The newly constructed reservoirs could relieve some of this pressure and thus "over-construction" or over-investment could be desirable. This would be included in the GP model by introducing p_n into the achievement function preceded by a minus sign.

The various potential reservoirs should also have their recreational potential modified by a weighting factor. Additional recreational lakes in Dickinson, Clay, Buena Vista and Ida Counties are not needed. However, new recreational lakes in Lyon, Sioux, Plymouth and Woodbury Counties are urgently needed since they have the greatest present need for recreational facilities and these four counties have the lowest per capita incomes in the region. New reservoirs would mean the residents of these counties would not have to travel as far to enjoy water-based recreation and could enjoy this type of recreation more frequently. These reservoirs would also provide new job opportunities in the county. Based on the above, the assumption is made that new recreational opportunities at reservoirs located in the four counties which form the western border of Iowa are 4 times as desirable as those which form the eastern border of the region and new recreational opportunities in the middle tier of counties are twice as desirable as those in the eastern tier of counties. Both n_n and p_n appear in the achievement function with the weighting factors shown in Table 218.

Table 218. Weighting factors for the recreation component of the achievement function

County	n_n	p_n
Buena Vista	1	- 1
Cherokee	2	- 2
Clay	1	- 1
Dickinson	1	- 1
Ida	2	- 2
Lyon	4	- 4
O'Brien	2	- 2
Osceola	2	- 2
Plymouth	4	- 4
Sac	1	- 1
Sioux	4	- 4
Woodbury	4	- 4

Water Supply

The allocation of water among competing uses is similar to the transportation problem of linear programming as shown in Fig. 91. A product is available in amounts a_1, a_2, ..., a_m from each of m shipping origins and is needed in amounts b_1, b_2, ..., b_n at each of n shipping destinations. X_{ij} is the amount shipped from the ith origin to the jth destination. The shipping cost of a unit amount from each source to each destination is c_{ij} and must be known. The objective is to determine the amounts, X_{ij}, to be shipped over all routes so as to meet all needs at the minimum total cost, TC. Thus, the objective function in a linear programming format is:

$$\text{Min. TC} = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}X_{ij} \qquad (75)$$

$$\text{s.t.} \sum_{j=1}^{n} X_{ij} = a_i \quad (i = 1, 2, \ldots, m) \qquad (76)$$

$$\sum_{i=1}^{m} X_{ij} = b_j \quad (j = 1, 2, \ldots, n) \qquad (77)$$

$$X_{ij}, c_{ij} \geq 0 \qquad (78)$$

In terms of water allocation, the transportation problem can be reformulated such that the origins become the sources and the destinations become the use demands. X_{ij} becomes the amount of water supplied from the ith source to the jth use. Equation (76), the row sum of Fig. 91 is the amount supplied from each source. Equation (77), the column sum of Fig. 91, is the amount of water demanded by each use sector.

DESTINATIONS

ORIGINS

$i \backslash j$	(1)	(2)			(j)			(n)	
(1)	x_{11}	x_{12}			x_{ij}			x_{in}	a_1
(i)	x_{i1}	x_{i2}			x_{ij}			x_{in}	a_i
(m)	x_{m1}	x_{m2}			x_{mj}			x_{mn}	a_m
	b_1	b_2			b_j			b_n	

Fig. 91. Transportation problem tableau of LP

Equations (75) through (78) in a LP format become Eqs. (79) through (82), respectively, in the GP format.

$$\sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij}X_{ij} + n_n - p_n = 0 \qquad (79)$$

$$\sum_{j=1}^{n} X_{ij} + n_n - p_n = a_i \quad (i = 1, 2, \ldots, m) \qquad (80)$$

$$\sum_{i=1}^{m} X_{ij} + n_n - p_n = b_{\cdot j} \quad (j = 1, 2, \ldots, n) \qquad (81)$$

$$X_{ij},\ c_{ij},\ n_n,\ p_n \geq 0 \qquad (82)$$

The right-hand side of Eq. (79) is now zero and represents the minimum possible total cost of supplying water. While there is no possibility of achieving this, it does represent the lower limit for total cost. p_n is made a part of the achievement function at some priority level and is minimized. Thus, p_n in Eq. (79) represents the minimum total cost of supplying water. Since as noted in Eq. (82), both c_{ij} and X_{ij} must be equal to or greater than zero, the minimum possible summation of $c_{ij}X_{ij}$ is zero, so n_n in Eq. (79) could be omitted from the equation.

Equation (80) represents the amounts of water supplied to various uses from source a_i. Since it is a physical impossibility for the summation of X_{ij} to be greater than a_i, p_n in Eq. (80) must be included as an absolute objective in the achievement function as a priority one variable and must equal zero. N_n represents the unused portion of water available at source a_i. Equation (81) represents the amounts of water demanded by use sector b_j. Since the goal is to provide all the water needed by each use sector, n_n in Eq. (81) is included in the achievement function at some priority level and is minimized. p_n represents the amount of water supplied to the jth use sector over and above the quantity demanded, b_j.

To apply the transportation problem to Northwest Iowa, several items must be identified and quantified: the sources and destinations of water, the supplies of and demands for water and the cost per unit of water distributed from each source to each destination. The types and locations of the various sources and the amounts of water available from each have been discussed previously. The cost of developing and distributing these supplies are determined in detail in the next section. The demands for water by the various use sectors have also been discussed previously and are summarized below.

Urban demands

Future average and peak urban water demand estimates for both low and high population projections (Rossmiller's and the State of Iowa's projections, respectively) are contained in Appendix I. The peak demands for the low and high population projections for the years 1980, 2000 and 2020 are summarized in Table 219. Urban water use in some counties is divided into two categories, a large community and others, for the following reason. The assumption is made that only the large communities have the present facilities and the future capabilities to meet the requirements of the 1974 Safe Drinking Water Act which call for water supplies which meet the new quality standards, which are adequate in quantity even during prolonged droughts, which are available and convenient to use and which have costs that are

Table 219. Summary of peak urban water demands for the low and high population projections for 1980, 2000 and 2020 in Northwest Iowa, MGD

County	Location	Low 1980	Low 2000	Low 2020	High 1980	High 2000	High 2020
Buena Vista	Storm Lake	4.42	4.79	5.38	4.86	5.92	7.07
	Others	2.31	2.31	2.38	2.51	2.84	2.87
Cherokee	Cherokee	3.57	3.57	3.72	3.57	4.07	4.66
	Others	1.57	1.65	1.79	1.55	1.88	2.21
Clay	Spencer	2.89	3.26	3.72	3.07	3.68	4.05
	Others	0.59	0.60	0.61	0.61	0.63	0.67
Dickinson	Great Lakes	3.21	3.66	4.21	3.95	5.53	6.28
	Others	0.73	0.76	0.82	0.88	1.12	1.18
Ida	Others	1.06	1.02	0.95	1.12	1.31	1.61
Lyon	Rock Rapids	0.68	0.74	0.83	0.72	1.02	1.44
	Others	0.84	0.92	1.01	0.92	1.27	1.78
O'Brien	Sheldon	1.15	1.26	1.39	1.31	1.72	2.09
	Others	1.37	1.37	1.39	1.58	1.83	2.06
Osceola	Sibley	0.68	0.70	0.74	0.81	1.15	1.57
	Others	0.30	0.28	0.24	0.35	0.43	0.50
Plymouth	Le Mars	2.16	2.55	3.22	2.20	3.03	3.74
	Others	1.26	1.36	1.53	1.29	1.51	1.70
Sac	Sac City	1.63	1.66	1.74	1.72	2.11	2.57
	Others	2.46	2.36	2.39	2.60	3.02	3.49
Sioux	Orange City	0.94	1.07	1.26	1.11	1.48	1.79
	Sioux Center	0.93	1.09	1.30	1.07	1.50	1.87
	Others	2.41	2.72	3.17	2.86	3.80	4.65
Woodbury	Sioux City	23.05	23.94	25.12	25.27	30.04	34.13
	Others	1.69	1.78	1.87	1.76	2.17	2.56

within the ability of the users to pay. Those small communities included in the "others" category will become part of a rural water system. In most cases the one large community in the county represents the majority of the water used for urban purposes in the county.

Six communities in Dickinson County presently obtain their water supplies from the Iowa Great Lakes. These six communities are Arnold's Park, Milford, Okoboji, Orleans, Spirit Lake and West Okoboji. Because of current institutional constraints, if and when these communities require additional water, they will need to procure these new supplies from sources other than the Iowa Great Lakes and tie these new supplies into their existing systems. The Iowa Natural Resources Council is currently (1979) holding hearings on minimizing future withdrawals to prevent additional adverse economic impacts on recreation.

<u>Rural demands</u>

Future average and peak rural water demand estimates for both low and high population projections (Rossmiller's and the State of Iowa's projections, respectively) are also contained in Appendix I. These estimates include both rural farm and rural nonfarm residential uses. The peak demands for the low and high population projections for the years 1980, 2000 and 2020 are summarized in Table 220. The same assumption is made here as was made for urban demands. No rural household or group of homes has the capability to meet the requirements of the 1974 Safe Drinking Water Act. Therefore, all rural residences will also become part of rural water systems.

<u>Livestock demands</u>

Average and peak water demands by cattle and hogs in Northwest Iowa were estimated in a previous section and were presented in Tables 191 and 192, respectively. The peak demands for water by cattle and hogs for the years 1980, 2000 and 2020 are summarized in Table 221. The normal sources of supply for these livestock needs are farm ponds, wells and water hauled in trucks. These have proved inadequate in the past with ponds and wells going dry and the quality of the water being

Table 220. Summary of peak rural water demands for the low and high population projections for 1980, 2000 and 2020 in Northwest Iowa, MGD

County	Low			High		
	1980	2000	2020	1980	2000	2020
Buena Vista	0.61	0.64	0.69	0.62	0.70	0.73
Cherokee	0.60	0.67	0.73	0.59	0.67	0.79
Clay	0.56	0.65	0.74	0.59	0.67	0.75
Dickinson	0.43	0.52	0.59	0.48	0.61	0.72
Ida	0.35	0.37	0.38	0.34	0.38	0.40
Lyon	0.59	0.59	0.59	0.59	0.65	0.70
O'Brien	0.55	0.59	0.63	0.57	0.64	0.72
Osceola	0.37	0.41	0.43	0.39	0.47	0.58
Plymouth	0.98	1.01	1.08	1.00	1.05	1.13
Sac	0.57	0.61	0.63	0.59	0.64	0.72
Sioux	0.93	0.90	0.83	0.96	0.98	0.94
Woodbury	0.96	1.07	1.26	1.00	1.20	1.47

Table 221. Summary of peak demands for water by cattle and hogs for 1980, 2000 and 2020 in Northwest Iowa, MGD

County	1980	2000	2020
Buena Vista	0.36	0.47	0.55
Cherokee	0.52	0.69	0.80
Clay	0.31	0.40	0.47
Dickinson	0.15	0.20	0.24
Ida	0.36	0.48	0.56
Lyon	0.42	0.56	0.65
O'Brien	0.41	0.55	0.64
Osceola	0.21	0.29	0.33
Plymouth	0.68	0.92	1.07
Sac	0.45	0.61	0.71
Sioux	0.79	1.05	1.23
Woodbury	0.46	0.62	0.72

low at various locations, therefore these demands will also become part of rural water systems.

The total demand on a rural water system is the sum of small urban, rural residential and livestock demands. These total peak demands on rural water systems in Northwest Iowa for the low and high population projections for the years 1980, 2000 and 2020 are listed in Table 222.

Table 222. Summary of peak rural water systems demands for the low and high population projections for 1980, 2000 and 2020 in Northwest Iowa, MGD[a]

County	Low			High		
	1980	2000	2020	1980	2000	2020
Buena Vista	3.28	3.42	3.62	3.44	4.01	4.15
Cherokee	2.69	3.01	3.32	2.66	3.24	3.80
Clay	1.46	1.65	1.82	1.51	1.70	1.89
Dickinson	1.31	1.48	1.65	1.51	1.93	2.14
Ida	1.77	1.87	1.89	1.82	2.17	2.57
Lyon	1.85	2.07	2.25	1.93	2.48	3.13
O'Brien	2.33	2.51	2.66	2.56	3.02	3.42
Osceola	0.88	0.98	1.00	0.95	1.19	1.41
Plymouth	2.92	3.29	3.68	2.97	3.48	3.85
Sac	3.48	3.58	3.73	3.64	4.27	4.92
Sioux	4.13	4.67	5.23	4.61	5.83	6.82
Woodbury	3.11	3.47	3.85	3.22	3.99	4.70

[a]Rural water systems include demands for small communities, rural residences, farms and livestock.

Tables 219 and 222 summarize the peak water demands in future years for urban and rural water systems, respectively. While these systems must be designed with sufficient capacity to deliver these peak flows, the total volume required over the course of a year will be the average daily demand times 365. As noted previously, peak daily demands in this study are assumed to be 1.85 times average daily demands. This relationship is used to determine the proper annual volume of water demanded for these purposes.

Irrigation demands

The volume of irrigation water demanded is dependent on four items: the number of acres to be irrigated, the inches of water stored in the soil at planting, whether limited or unlimited water is supplied after tasseling and the severity of the drought to be overcome. The number of acres of corn to be irrigated is a function of meeting the OBERS production goals for corn and soybeans and the scenario being investigated. The 1972 annual report of the Doon experimental farm in Lyon County contained a table which showed corn yield as a function of the soil moisture available at planting and is presented here as Table 223. Table 224 indicates the average gross amounts of irrigation water needed for corn for various recurrence intervals and with limited and unlimited water after tasseling. These values were determined for soils with 10.4 inches of available water in the root zone and 6.5 inches of water available on June 1, the average available in Northwest Iowa for the period of record. Planting normally occurs about May 1 so some irrigation water may be needed in addition to the amounts listed in Table 224 if rainfall during the month of May is insufficient to bring soil moisture up to 6.5 inches by June 1. Irrigation efficiency is assumed to be 80% for center pivot systems.

Table 223. Variation in corn yield with soil moisture available at planting at the Doon farm from 1958 through 1972

Soil moisture available at planting, inches	Number of observations	Corn yields, bushels per acre		
		High	Low	Average
0.0-2.0	9	51	0	25
2.1-4.0	19	114	0	62
4.1-6.0	8	140	46	96
> 6.0	9	159	99	121

Table 224. Average gross irrigation water requirements for corn for various return periods with limited and unlimited water after tasseling for a soil with 10.4 inches of available water in the root zone[a]

Return period years	Average rainfall[b] inches	Limited water inches	Unlimited water inches
2	10.9	3.2	11.0
5	8.0	6.9	14.6
10	6.6	8.6	16.4
25	5.3	10.2	18.0
50	4.4	11.4	19.1

[a]Based on an available amount of soil moisture of 6.5 inches on June 1 and using center pivot systems with irrigation efficiencies of 80%.

[b]Average total rainfall during the months of June, July and August.

The demand for irrigation water is included in the GP model as follows.

$$LUICYT_i = LUICY1_i + LUICY2_i \quad (i = 1, 2, ..., 12) \qquad (83)$$

where $LUICYT_i$ = total acres of irrigated land required in the ith county

$LUICY1_i$ = acres of irrigated land on LCC I in the ith county

$LUICY2_i$ = acres of irrigated land on LCC IIe in the ith county

$$IVR_i = LUICYT_i \times IWR/12 \quad (i = 1, 2, \ldots, 12) \qquad (84)$$

where IVR_i = volume of irrigation water required in the ith county in acre-feet

IWR = depth of irrigation water needed in inches. Values taken from Table 224

Cost Factors

Having determined the amounts of water available from all sources and the amounts of water demanded at all use locations, the last remaining task is to estimate the unit costs of supplying water from each source to each use. These costs include not only the transmission and distribution costs but the costs related to the development of the sources, costs related to the treatment of the water to make it suitable for human consumption and costs related to the operation and maintenance of all the systems' components. This will satisfy the completeness test.

Several assumptions are made to reduce the number of unit costs which must be determined and which take into account social preferences, political, institutional and financial feasibility and common sense:

a large reservoir will not be constructed to serve a small rural water system, a few wells will not irrigate an entire county, an adequate source close to a user location will be used rather than an equal source further away due to lower transmission costs, bedrock aquifers will not be used for irrigation, people would prefer not to construct reservoirs, wells take little if any land out of production while reservoirs do. These assumptions will satisfy the acceptability test of the U.S. Water Resources Council's Principles and Standards. To these ends, water from surficial aquifers will be used as much as possible and reservoirs will be constructed only for irrigation purposes (if needed).

Several equations have been developed to estimate the various costs listed above (Dawes and Wathne, 1968; Gibb and Sanderson, 1969; Austin and Patton, 1975; Bovet, 1975) and are discussed below under the general headings of surface water and ground water.

Surface water

The cost of each reservoir is the sum of land and construction costs. Construction costs include not only the dam and all outlet works but also relocations, engineering and contingencies. These costs, as used by the Corps of Engineers in 1967 for some of the potential reservoir sites in Northwest Iowa, were plotted on log-log paper against several variables in an attempt to derive a simple regression equation which could be used for all sites. The variables included the height of dam, length of dam at the crest, total cost, embankment and outlet costs, relocation costs and storage volumes at various pool elevations. The best fit occurred when total cost was plotted as a function of the storage volume at the top of the flood pool. This function is shown in Fig. 92 and has the form shown in Eq. (85).

$$C = 50{,}000 S_{FP}^{0.4} \tag{85}$$

where C = total project cost of dam, 1967 dollars

S_{FP} = total reservoir storage volume at top of flood pool, ac. ft.

The Engineering News Record construction cost index (Hannon, 1978) was used to update the coefficient in Eq. (85) to 1977 prices. The final equation used in this study is Eq. (86) where C now represents the total project cost of the dam without land, in 1977 dollars.

$$C = 112{,}000 S_{FP}^{0.4} \tag{86}$$

Equation (86) is used in this study since it represents an upper envelope cost curve as determined by the Corps of Engineers, in 1977 dollars. The lowest curve shown in Fig. 92 represents the "better" sites in the region, those with low relocation costs and those whose site characteristics are such that large storage volumes are obtained with lower embankment and spillway costs.

Another reservoir construction cost curve used by some investigators (Austin and Patton, 1975; Bovet, 1975) was developed by the Illinois State Water Survey (Dawes and Wathne, 1968) and has the form shown in Eq. (87).

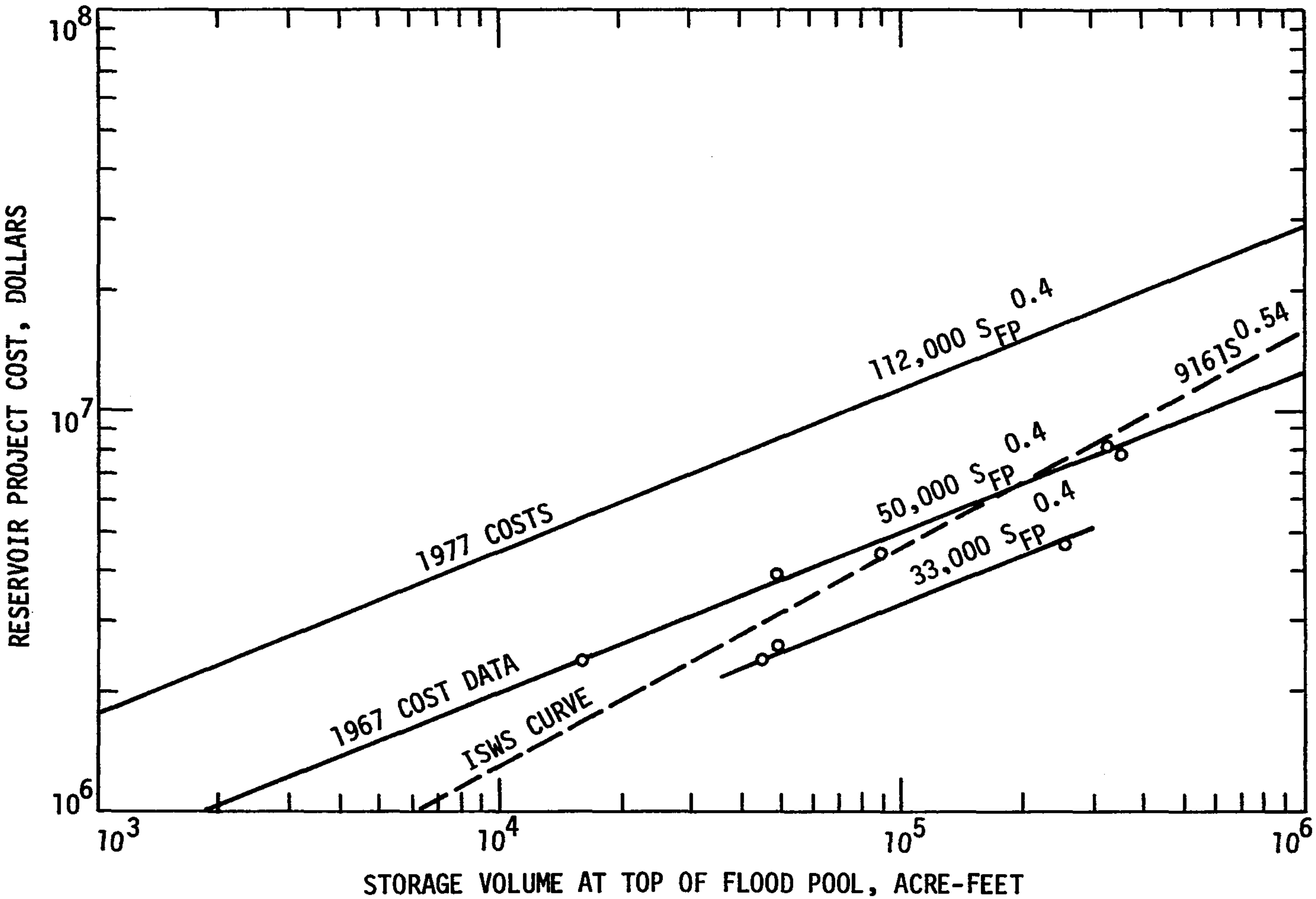


Fig. 92. Reservoir project cost without land versus flood pool storage volume

$$P_c = 9161S^{0.54} + 0.49S^{0.87}K \quad (87)$$

where P_c = total cost in dollars

S = storage volume of normal pool in acre-feet

K = land cost in dollars per acre

Equation (87) is plotted as a dashed line in Fig. 92 and yields relatively good agreement with the Corps of Engineers' data.

Current land costs were taken from a study by Harris et al. (1978). Average land values used by the Corps of Engineers in their 1967 study were $338 per acre while the average 1977 value of farmland in Northwest Iowa was $1,628 per acre. The general increase in farmland prices during this century in Iowa is shown in Fig. 93. Current land values in Northwest Iowa are listed in Fig. 94. The point to be made here is that in the past 10 years land values have increased 480%. If reservoirs are to be constructed in the future, then one way to reduce total costs would be to buy the land now and lease it back until construction takes place.

The combination of these two factors, land and project construction costs, yields the total cost of a reservoir. Table 225 lists the variables used, costs of land and construction and total costs of the reservoirs. If all 24 reservoirs were to be constructed, the total cost at 1977 prices would be 367 million dollars: 135 million dollars for 88,800 acres of land and 232 million dollars in construction costs. The types of trade-offs involved become evident. Here we are trading off land for water, water for irrigation, recreation and various other purposes. Some farmland would be sacrificed so that more desirable

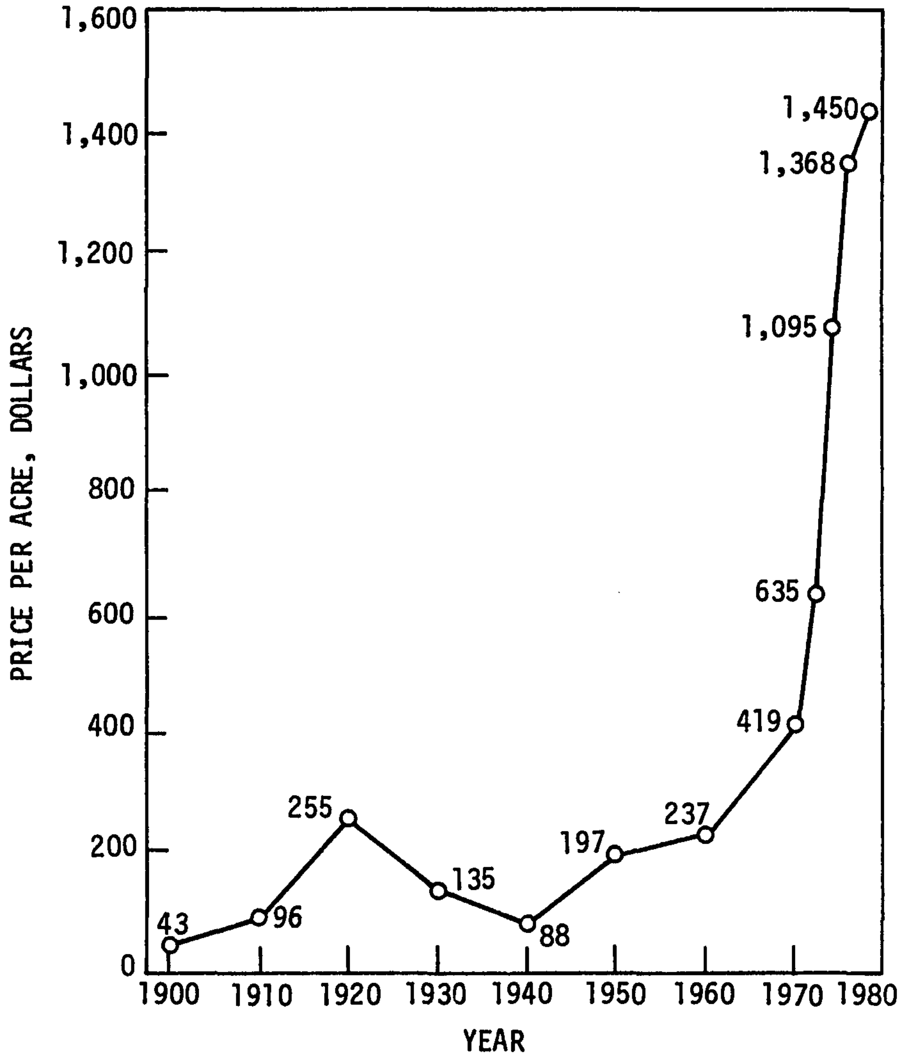


Fig. 93. Average value per acre of Iowa farm land, 1900-1977

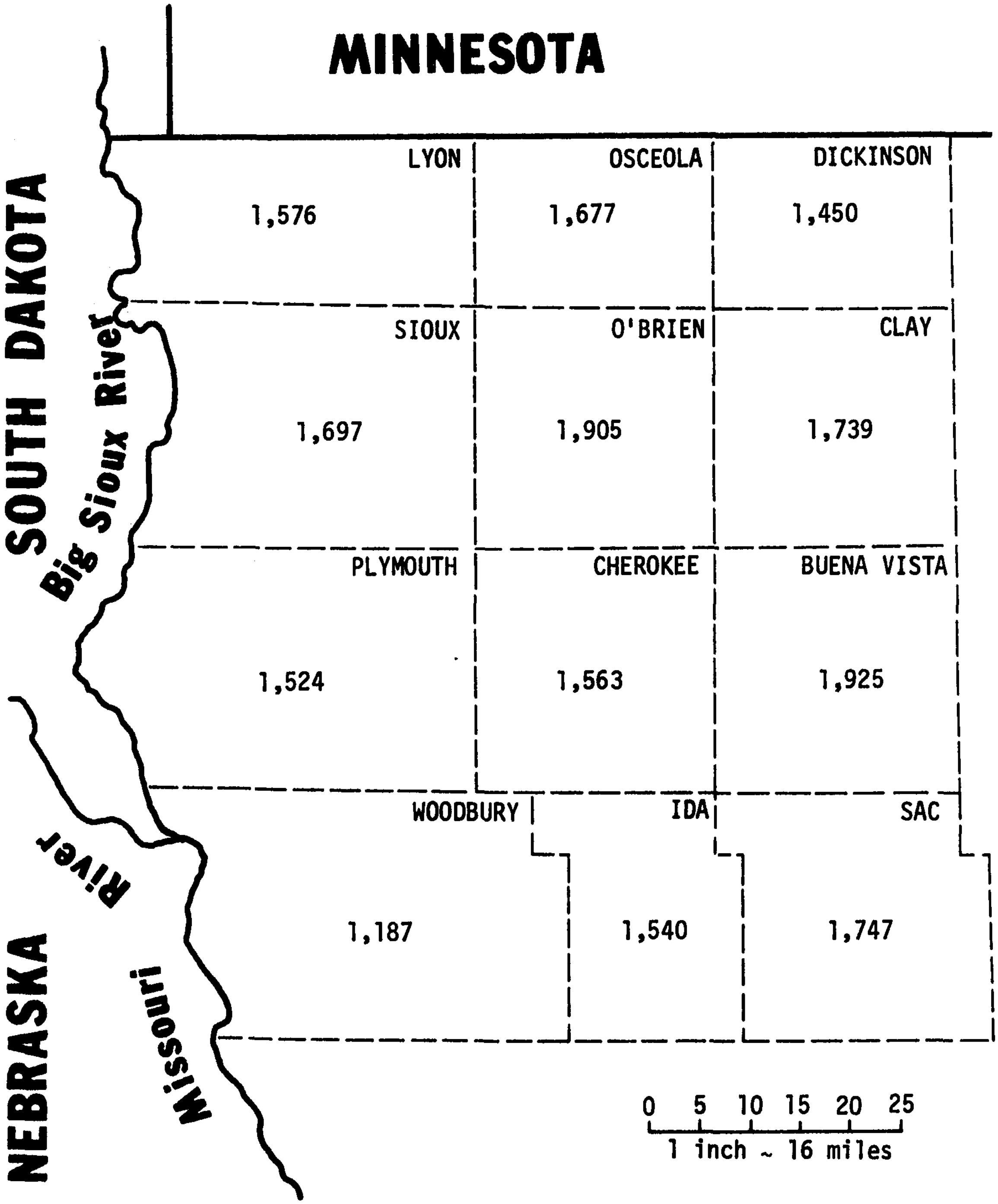


Fig. 94. Average value per acre of Northwest Iowa farm land as of November 1977, dollars (after Harris, Lord and Grove)

Table 225. Total estimated 1977 costs of developing the potential reservoir sites in Northwest Iowa

Stream	Storage volume ac. ft.	Land area ac.	Project cost dollars	Land cost dollars	Total cost dollars
Brooke Creek	26,000	810	6,600,000	1,560,000	8,160,000
Mill Creek	257,600	5,800	16,500,000	9,065,000	25,565,000
Silver Creek	23,800	940	6,400,000	1,470,000	7,870,000
Big Muddy Creek	39,300	2,300	7,800,000	4,000,000	11,800,000
Willow Creek	47,900	2,240	8,400,000	3,895,000	12,295,000
Stony Creek	51,300	4,060	8,600,000	5,885,000	14,485,000
Battle Creek	44,400	2,000	8,200,000	3,080,000	11,280,000
Maple River	352,100	15,600	18,800,000	24,025,000	42,825,000
Little Rock River	196,500	9,500	14,800,000	14,970,000	29,770,000
Little Floyd River	47,000	3,700	8,400,000	7,050,000	15,450,000
Waterman Creek	114,900	2,750	11,900,000	5,240,000	17,140,000
Deep Creek	42,800	2,350	8,000,000	3,580,000	11,580,000
Johns Creek	23,500	1,250	6,300,000	1,905,000	8,205,000
Plymouth Creek	28,000	1,350	6,800,000	2,055,000	8,855,000
Willow Creek	47,800	2,600	8,400,000	3,960,000	12,360,000
Boyer River	51,500	3,000	8,600,000	5,240,000	13,840,000
Indian Creek	30,200	1,200	7,000,000	2,095,000	9,095,000
W. Br. Floyd River	89,100	6,000	10,800,000	10,180,000	20,980,000
Big Whiskey Creek	49,000	2,200	8,500,000	2,610,000	11,110,000
Elliott Creek	49,100	2,400	8,500,000	2,850,000	11,350,000
Mud Creek	54,900	2,300	8,900,000	2,730,000	11,630,000
Reynolds Creek	16,000	650	5,400,000	770,000	6,170,000
W. Fk. Little Sioux River	329,000	10,300	18,100,000	12,225,000	30,325,000
Wolf Creek	88,300	3,500	10,800,000	4,150,000	14,950,000
Total	2,100,000	88,800	232,500,000	134,590,000	367,090,000

farmland could be irrigated. We would also be reducing the erosion potential on the 88,800 acres of land and increasing the erosion potential somewhat on land which is less susceptible to erosion.

As noted above, surface water reservoirs will only be used for irrigation purposes. For this reason no treatment of the water is necessary. In fact some of the pollutants in the water aid crop growth. The development costs of these reservoirs are listed in Table 225. Amortization of these costs is assumed to be at a rate of 5% per year over a 40-year period. Annual operation and maintenance costs of a reservoir are estimated from Eq. (88).

$$MOR_m = 0.015ITC_m + 12,500 \quad (m = 1, 2, \ldots, 24) \qquad (88)$$

where MOR_m = annual operation and maintenance cost of the mth reservoir in dollars

ITC_m = initial total cost of the mth reservoir in dollars

Transmission costs include the annual costs of pipelines, pumping stations, power, operation and maintenance. All of these costs were combined into a single figure, Fig. C-5 in Austin and Patton (1975), which is presented here as Fig. 95. Since peak flows are about double average flows, the 0.45 load factor is used. Water from the reservoirs is transmitted through pipelines to the centers of the assumed demand areas as indicated in Fig. 96. Final distribution to individual farms is not included because of a lack of data on the locations of the Class I and IIe lands in each county.

A total of 74 combinations of the 24 potential reservoir sites and the 12-county use areas were selected for evaluation based on volume of

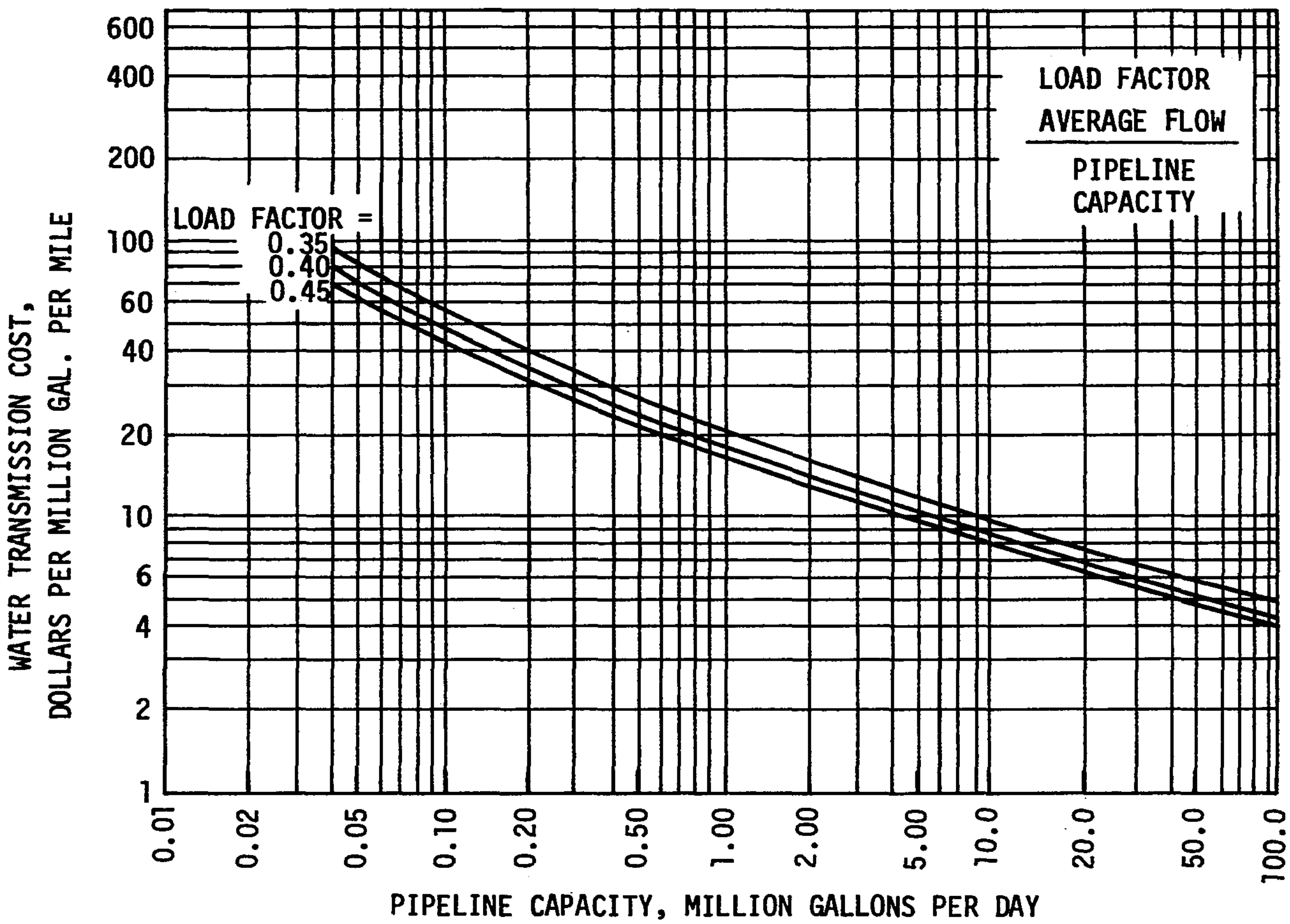


Fig. 95. Water transmission cost vs pipeline capacity

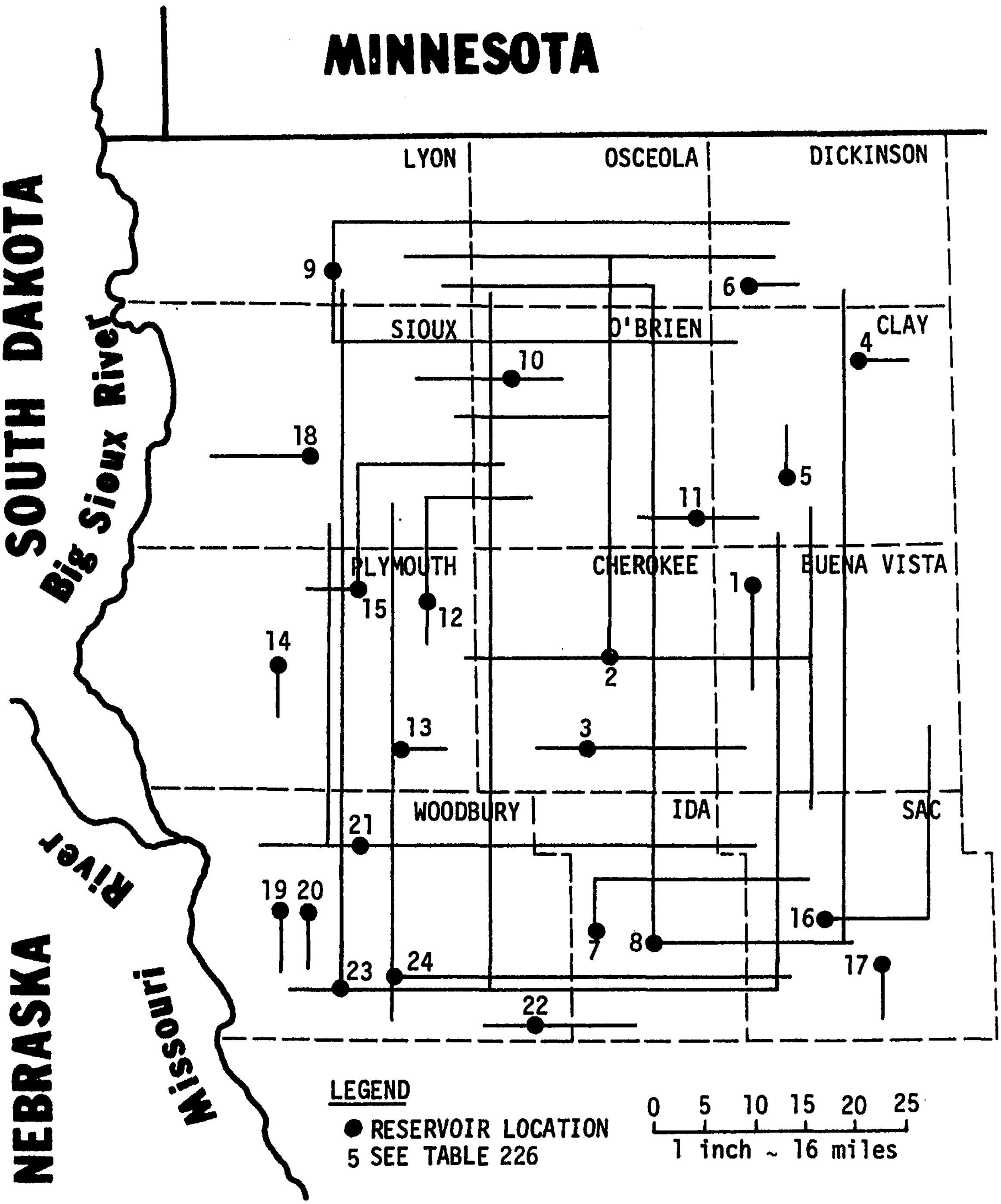


Fig. 96. Locations of potential reservoir sites and pipelines to potential use areas in Northwest Iowa

reservoir storage and need for irrigation water in the counties. The lengths of pipelines in miles for each of these 74 combinations are shown in Fig. 96 and listed in Table 226. Reservoir construction and maintenance costs are divided equally between the potential use areas. Transmission costs are taken from Fig. 95 and are based on the following assumptions: volume of irrigation water in reservoir, an irrigation season of 120 days (May through August), pipeline flow based on number of pipelines from reservoir and areas to be served and costs increased by 22.5% to account for inflation since 1975. The total annual costs per million gallons (MG) of water for irrigation from each of the potential reservoirs to the several use locations in Northwest Iowa are developed in Tables K-1 through K-4 in Appendix K and are summarized in Table 227. These costs are input to the GP model and serve as the c_{ij} in Eq. (79).

Ground water

The development costs for wells in alluvial and buried channel aquifers can be estimated using the following equations which were developed by the Illinois State Water Survey (Gibb and Sanderson, 1969). The coefficients in these equations have been updated to 1977 prices using the Engineering News Record construction cost index (Hannan, 1978). Equation (89) is the cost of gravel-packed wells and Eq. (90) is the cost of the pump. The total development cost is the sum of Eqs. (89) and (90).

$$W.C. = 1,720D^{0.408} \qquad (89)$$

Table 226. Locations of potential reservoirs in Northwest Iowa and pipeline distances in miles to counties of potential use

No.	Location	Buena Vista	Cherokee	Clay	Dickinson
1	Brooke Creek	10			
2	Mill Creek	20	5	35	55
3	Silver Creek	15	5		
4	Big Muddy Creek			5	
5	Willow Creek			5	
6	Stony Creek				5
7	Battle Creek				
8	Maple River	40	20	60	85
9	Little Rock River			50	50
10	Little Floyd River				
11	Waterman Creek			6	
12	Deep Creek				
13	Johns Creek				
14	Plymouth Creek				
15	Willow Creek				
16	Boyer River	30			
17	Indian Creek				
18	W. Br. Floyd River				
19	Big Whiskey Creek				
20	Elliott Creek				
21	Mud Creek				
22	Reynolds Creek				
23	W. Fk. Little Sioux River	65	40	90	
24	Wolf Creek				

Ida	Lyon	O'Brien	Osceola	Ply-mouth	Sac	Sioux	Wood-bury
	60	20	40	15	35	40	
5					25		
5	85	40	65		20		
	5	25	25			7	
		5				10	
		10					
		20		5		10	
				5			
				5			
		25		5		12	
					10		
					5		
						10	
							5
							5
20				10	40	35	10
10							5
25	70	60	85	25	42	50	5
20				20	40	48	5

Table 227. Locations of potential reservoir sites, counties of use and total annual costs for development and transmission of water for irrigation in Northwest Iowa

No.	Location	Buena Vista	Cherokee	Clay	Dickinson
1	Brooke Creek	400			
2	Mill Creek	135	45	225	345
3	Silver Creek	361	252		
4	Big Muddy Creek			442	
5	Willow Creek			383	
6	Stony Creek				518
7	Battle Creek				
8	Maple River	463	243	683	958
9	Little Rock River			328	328
10	Little Floyd River				
11	Waterman Creek			127	
12	Deep Creek				
13	Johns Creek				
14	Plymouth Creek				
15	Willow Creek				
16	Boyer River	324			
17	Indian Creek				
18	W. Br. Floyd River				
19	Big Whiskey Creek				
20	Elliott Creek				
21	Mud Creek				
22	Reynolds Creek				
23	W. Fk. Little Sioux River	429	269	579	
24	Wolf Creek				

Ida	Lyon	O'Brien	Osceola	Ply-mouth	Sac	Sioux	Wood-bury
	375	135	255	105	210	254	
274					445		
79	958	463	738		243		
	58	178	178			70	
		310				360	
		155					
		350		200		249	
				697			
				469			
		389		189		259	
					192		
					530		
						480	
							464
							507
252				161	437	391	161
510							435
173	461	397	557	174	283	334	96
255				256	455	536	162

where W.C. = cost of well in 1977 dollars

D = depth of well in feet

$$P.C. = 18.5Q^{0.453}H^{0.642} \quad (90)$$

where P.C. = installed cost of pump in 1977 dollars

Q = pumping rate in gallons per minute

H = total pumping head in feet

The total yields and total development costs of the 16 potential buried channel aquifers are listed in Table 228. The assumption was made that the total pumping head was equal to 200 feet plus the depth of the well. Estimates of the yields and costs of wells in the alluvial aquifers of the Missouri and Big Sioux Rivers were also made. Yields and costs of wells in the alluvium of the other major rivers in Northwest Iowa are assumed to be comparable to those of the Big Sioux River. Yields were set at 1,750 gpm and 300 gpm per well for the Missouri and other rivers, respectively, to reduce the drawdown and resulting well interference from closely spaced wells. Well depths are 120 feet for the Missouri River aquifer and 50 feet for all others. Total pumping head is the depth of the well plus 200 feet. Using these values in Eqs. (89) and (90), the total cost of a well in the Missouri River alluvial aquifer is $34,200 and $17,000 for wells in the alluvial aquifers of the other rivers in Northwest Iowa. A yield of 1,750 gpm is equal to 2.5 MGD and 7.7 ac. ft. per day. A yield of 300 gpm is equal to 0.4 MGD and 1.3 ac. ft. per day.

Existing wells in the Dakota Sandstone aquifer range in depth from 200 to 750 feet deep and their yields range from 50 to over 750

Table 228. Total yields and development costs of the potential buried channel aquifers in Northwest Iowa

No.	County	Location Sec.-twp.-range	Total yields GPM	MGD	AF/day	Development costs Wells	Pumps	Total
1	Clay	19-97-38	4,000	5.8	17.7	34,000	58,000	92,500
2		30-97-37	6,000	8.6	26.5	67,800	98,800	166,600
3		2-96-37	2,000	2.9	8.8	41,000	46,000	87,000
4	Dickinson	6-98-38	7,000	10.1	31.0	79,100	115,200	194,300
5		33-99-36	2,000	2.9	8.8	53,000	53,100	106,100
6		29-98-35	1,500	2.2	6.6	39,800	39,800	79,600
7		28-100-35	1,500	2.2	6.6	39,800	39,800	79,600
8		24-99-36	2,000	2.9	8.8	53,000	53,100	106,100
9		4-99-35	1,500	2.2	6.6	39,800	39,800	79,600
10		31-99-35	1,000	1.4	4.4	26,500	26,500	53,000
11		15-100-35	2,000	2.9	8.8	53,000	53,100	106,100
12		13-100-35	1,000	1.4	4.4	26,500	26,500	53,000
13		26-98-35	1,000	1.4	4.4	26,500	26,500	53,000
14	O'Brien	29-95-41	2,000	2.9	8.8	53,000	53,100	106,100
15		23-94-39	2,000	2.9	8.8	45,200	48,100	93,300
16	Osceola	31-99-41	2,000	2.9	8.8	45,200	48,100	93,300

gpm. For this study an average yield of 400 gpm, a depth of 500 feet and a total pumping head of 700 feet will be assumed. Using these values in Eqs. (90) and (91), the total cost of a well in the Dakota Sandstone aquifer is $35,500.

$$W.C. = 2.13D^{1.45} \quad (91)$$

where W.C. = cost of well in Dakota Sandstone aquifer in 1977 dollars

D = depth of well in feet

Annual operation and maintenance costs per well in all of the above aquifers are estimated from Eq. (92) as $425 plus power costs of 2.5 cents per kilowatt-hour and a wire to water efficiency of 50%. Equation (93) estimates the annual operation and maintenance costs of wells used for irrigation.

$$WORM = 0.0826Q(D + 200) + 425 \quad (92)$$

where WORM = annual ORM per well in dollars

Q = pumping rate in gpm

D = depth of well in feet

$$IWORM = 0.0272Q(D + 200) + 150 \quad (93)$$

where IWORM = annual ORM per irrigation well in 1977 dollars

Treatment costs are estimated from Eq. (94). The annual operation and maintenance costs of these plants are estimated from Eq. (95).

$$TPC = 285,000(PC)^{0.63} \quad (94)$$

where TPC = construction cost of a water treatment plant in 1977 dollars

PC = plant capacity in MGD

$$PORM = 33{,}500(PC)^{0.63} \qquad (95)$$

where PORM = annual ORM cost of a treatment plant in 1977 dollars

Transmission costs are again taken from Fig. 95. Water for rural water systems is transmitted through pipelines to the centers of the assumed demand areas. Final distribution to individual farms and rural residences is not included because of a lack of data on their locations. The same is true for the transmission of water for irrigation from the border rivers to inland counties. A nominal distance is used for new supplies for the larger communities.

Development costs for the existing water supplies of the larger communities listed in Table 219 are assumed to be zero since they are already in place but they will have annual operation and maintenance costs. These existing supplies are assumed adequate to meet the 1980 high population demands. Additional future supplies for the communities are developed as needed and their costs are determined in Table K-5 and K-6 in Appendix K. Amortization of these costs is assumed to be at a rate of 10% per year over a 25-year period.

Supplies for rural water districts are developed for each county regardless of whether or not a district already exists since some of them do not serve all the inhabitants of their areas. The total annual costs for these districts in 1980 are developed in Tables K-7 and K-8 in Appendix K. Amortization of these costs is assumed to be at a rate of 5% per year over a 40-year period. The supplies for Clay, Dickinson, O'Brien and Osceola Counties are developed from buried channel aquifers; the others are developed in alluvial aquifers. Additional future supplies are developed as needed and their costs taken from the appropriate column in Tables K-5 or K-6 in Appendix K.

Water for irrigation is kept separate from the other uses and is left untreated. Determination of the total annual costs for the development of water for irrigation from buried channel aquifers in Northwest Iowa is shown in Tables K-9 and K-10 in Appendix K. Amortization of these costs is assumed to be at a rate of 5% per year over a 40-year period. Large numbers of wells are developed in the alluvial aquifers of the border and interior streams for irrigation. Total annual costs for the development of water for irrigation used at its point of origin are determined in Table K-11 in Appendix K. Table K-12 in Appendix K determines the total annual cost of water developed for irrigation which is used in the same or another county.

The total annual costs per MG listed in Tables K-5 through K-12 in Appendix K are input to the GP model and serve as the c_{ij} in Eq. (79).

Summary

In this section the general form of the GP model has been developed, taking into account the planning process and objectives of the U.S. Water Resources Council as well as the priorities suggested by the Iowa 2000 program. In addition, detailed equations and data have also been developed for such aspects of the total problem as land use, crops and pasture, soil erosion, recreation, water sources, water demands and cost factors.

The result is a model capable of analyzing several aspects of both the physical spectrum of supply and demand and the social-institutional-environmental spectrum reflecting the multiple conflicting goals and priorities of society. It also displays the tradeoffs which would occur when certain decisions are made as to how the land and water resources of a region are to be developed. The results obtained from using this GP model are summarized in the next section.

However, these results must be viewed from the standpoint of the following land use restrictions which were built into the model and influence the results. The effect of these restrictions is to change the original order of priorities. Meeting the future OBERS demands for crop and livestock production, a component of the NED objective, had originally been given priority over the EQ objective. By building these land uses restrictions into the model, EQ gained top priority and meeting the OBERS projections dropped to a lower priority. This decision was made after considering the comments made by those participating in the Iowa 2000 program.

The restrictions built into the model are as follows. All Class VI and VII land used for crop production in 1967 is converted to permanent pasture to reduce soil erosion. A common restriction in each crop planting scenario (CPS) is that all counties cannot produce more than that share of total regional production in the future than they did in

1967, regardless of the potential for additional production in a county.

Only that acreage used for corn, soybeans, close grown crops, rotation hay and pasture and pasture are eligible to produce row crops in the future in CPS 1-6. The other five land use categories, urban and built-up, forest, other, conservation use only and water areas, cannot be converted to agricultural uses. This restriction is not imposed in CPS 7. Urban and water areas are obviously not suitable for row crops. Land presently devoted to forests and conservation uses could be converted but this would not be a socially or environmentally acceptable alternative. The "other" land use category includes land devoted to farmsteads, farm roads, feedlots, ditch banks, fence rows, hedge rows, rural nonfarm residences and investment tracts. Some of this land could be converted to row crops.

Two other restrictions are built into the model. First, corn is planted on the less sloping land and the demand for it must be met before land is used for soybeans. Second, only corn is irrigated and only on Class I and IIe land. These restrictions are based on the fact that soybeans withstand drought conditions better than corn. Also, the percentage reduction in yield for soybeans on steeper land is less than the percentage reduction in corn yield. Only Class I and IIe lands are irrigated for corn because they respond most to irrigation and they are the least prone to erosion.

ANALYSIS OF RESULTS — IMPLICATIONS FOR NORTHWEST IOWA

The goal programming model was applied to Northwest Iowa to trace the shifts in use of the land and water resources of the region and how these shifts would impact on the NED and EQ objectives when subjected to several combinations of the following types of inputs. Two sets of population projections, the author's and the state of Iowa's, could be used in conjunction with two sets of crop yield projections, the author's and Gibson's, in each of three years, 1980, 2000 and 2020. This is a total of 12 separate runs. Each of these 12 could be used in combination with one of seven crop planting scenarios, which raises the total number of runs to 84. Each of these runs could be made with or without erosion control measures, raising the total to 168 runs. Five of the seven crop planting scenarios involve irrigation and each of these five could reflect five different magnitudes of droughts. This brings the total to 648 runs. To display the results of each of these runs for each of the 12 counties included in each run, with each display including the amount of land and water used for all purposes and degrees of goal attainment (water quantity, crops, livestock, soil erosion, several socio-economic aspects), would require a total of 7,776 tables.

Since both time and money would run out before most of these alternatives could be investigated, the decision was made to concentrate on a smaller number of runs using the more "reasonable" estimates plus enough other runs to determine the probable impacts of the other estimates and variables. This led to using the author's estimates for both population and yields with erosion control measures for all seven crop planting scenarios in the years 1980, 2000 and 2020 as the basic set of results, a total of 21 runs. Irrigation demands for the 50-yr drought plus all other urban and rural demands were used with this basic set of runs to stress the water resources of the region as much as possible. Many of these runs were duplicated using no erosion control measures. Several other runs were made using the other variables listed above.

Trade-offs and impacts are evident in each of these runs. However, as these trade-offs and impacts are traced through the institutional, social, financial, physical and political aspects for each and every run, one can become lost. For this reason the analysis is conducted in two major parts: (1) each scenario is presented with its attendant impacts and trade-offs for the basic set of runs; this is followed by a similar analysis of the other alternatives for which runs were made; and (2) several aspects are examined individually across all alternatives to analyze their implications for Northwest Iowa, the state and the nation.

All land uses in Northwest Iowa have been aggregated into ten categories: urban built-up, forest, other, conservation use only, water areas, corn, soybeans, close grown crops, rotation hay and pasture and permanent pasture. The first five categories are not allowed to decrease from their 1967 levels in the first six scenarios. Scenario 7 allows categories 3 and 4 to also be used for corn and soybean production in some future year.

Each scenario analysis contains summary tables which portray regional results and results for Buena Vista County, for the following types of goal satisfaction: water for urban, rural and irrigation uses, corn and soybean production, livestock production, soil erosion, land use categories 6 through 10 and recreation. Costs are discussed in detail in a later section as well as which sources of water are used since they are somewhat similar for various scenarios.

Before beginning this summary of each of the scenarios with and without erosion control measures, a brief overall summary of the results is listed to give the flavor of the impacts and trade-offs which would have to take place. Some of these are discussed in more detail later.

Summary

Two population projections are presented in this study. One continues the present trend of out-migration from the region and estimates that the regional population will decrease from 288,600 in 1970 to 261,400 in 2020. The other projection envisions an increase in population to 341,200 in 2020. Both projections forecast a further decline in the farm population of about 27,500, from 69,000 in 1970 to 41,400 in 2020.

These two projections have important implications for the economic health of the region in the future. The majority of the jobs in the region are directly or indirectly dependent on agriculture. Thus the value of future farm income will determine to a large extent the economic health of the region. As shown in the various crop planting scenarios, the use of supplemental irrigation could increase farm income by $250 million annually. However, if the higher populations become a fact, this will have to be accompanied by an increase in job opportunities in the urban areas of the region. Success to date in creating new jobs has been limited.

If the lower population projection becomes a fact, then businesses will lose about 27,000 customers. The economic viability of several small communities could be jeopardized. The decline in population will also mean that fewer people will be available to maintain and improve the services provided by governmental agencies on which they depend: schools, transportation systems, water supply, sanitation facilities, recreation and all the social services.

These future population estimates also impact on the land and water resources of the region. Additional demands for all urban plus rural residential purposes will require the conversion of 10,000 acres for the lower estimate and 46,000 acres for the higher projection. All demands for water for all urban, rural residential and livestock purposes can be met without stressing the water resources of the region for either population projection. An additional 44 new wells would be needed in the sand and gravel aquifers located throughout the region for the lower projection. The higher set of projections would require an additional 110 wells. These include new wells for the urban areas and for the county-wide rural water systems.

There are sufficient water resources in Northwest Iowa to meet all demands to the year 2020 _if_ the necessary funds are committed to their development. This includes the construction of 24 reservoirs, the drilling of several thousand wells and the laying of several hundred miles of pipeline. This investment of roughly a billion dollars is necessary to meet all demands including the demand for irrigation water on over a million acres of land during a drought with a 50-yr recurrence interval lasting for two years. If the decision is made to not irrigate on a large scale, then an investment of less than $100 million is necessary to meet all remaining demands.

However, if irrigation of corn is not used extensively, then Northwest Iowa must use so much land to meet corn production requirements that it will not be able to meet its share of soybean production as projected by OBERS. All corn, cattle and hog demands can be met in all years. These projections are shown in Table 229. The greatest deficit is 35 million bushels of soybeans in the year 2000, based on an OBERS demand of 74 million bushels. Even if full irrigation is used, there is still a deficit of 2 million bushels in the year 2000. These deficits are based on the assumption that only those lands used for crops, hay and pasture in 1967 will be used for crop production in the future.

Table 229. OBERS agricultural production by commodity groups in Northwest Iowa, historical and projected for the period 1967 to 2020

Commodity	1967	1980	2000	2020
Corn, million bushels	134.3	186.4	270.3	287.9
Soybeans, million bushels	23.0	45.6	73.9	81.6
Beef, million head	1.1	1.1	1.5	1.7
Pork, million head	2.6	2.3	3.1	3.7

Based on this assumption and using full irrigation of Class I and IIe land, land used for crop production in Northwest Iowa will increase from 2.84 million acres in 1967 to 3.51 million acres in 2000 while land used for hay and pasture will decrease from 0.84 to 0.17 million acres in these same two years. If irrigation is not used, then land used for crop production increases to 3.60 million acres in 2000 while land used for hay and pasture decreases to 0.08 million acres. This is a shift of only 90,000 acres but the soybean deficit is cut from 35 to 2 million bushels. All crop and livestock demands can be met in all years without irrigation by converting another 34,000 of the 703,000 acres currently utilized for forest, conservation and other uses, excluding urban uses, to crop production. The total stock of land in Northwest Iowa is 4.6 million acres.

These increases in crop production can be accomplished while at the same time reducing soil erosion in the region by a significant amount. Soil erosion in the region was about 66 million tons in 1967. This can be reduced in the future to 10 to 12 million tons per year by using erosion control measures. These measures include using minimum tillage and/or contouring on Class I, II and V land, constructing terraces on Class III and IV land and converting all Class VI and VII land used for crops to permanent pasture. Depending on the crop planting scenario used, terraces would be needed on from 0.8 to 1.3 million acres of Class III and IV land at a cost ranging from $290 to $405 million. If these changes in farming practices are not made and no terraces are constructed, then soil erosion will increase from the 66 million tons in 1967 to from 86 to 95 million tons per year in some future year, depending on the crop planting scenario used. The choice is between 10 and 86 million tons of soil lost to erosion each year. If we opt for less soil erosion, the cost will be between $300 and $400 million.

Other decisions must also be made. How much, if any, land should be irrigated? Who should pay for the cost of the irrigation systems? Who should pay for the terrace construction? If full irrigation of corn is used, terrace construction costs will be $100 million less. How will, or should, the farmers be persuaded to irrigate, plant certain crops on certain land capability classes, and install erosion control measures? How, or who, should decide which sources of water will be developed in the future? Generally, water from ground water sources is less expensive to develop and transport. However, there are some reservoir sites which are usually a part of the final tableau. These reservoirs are useful not only as a source of water for irrigation, but also can be used for recreational purposes and flood control.

In conclusion, the economic and environmental health of the region can be maintained and possibly improved in the future if certain decisions are made and these decisions are backed up by two items: (1) sufficient funds from the local, state and federal levels and (2) changes in farming methods and types of crops produced on the various land capability classes.

Crop Planting Scenarios with Erosion Control

Crop planting scenario 1

CPS-1 allows row crop acreage to expand onto land presently used for close grown crops, hay and pasture with each land capability class (LCC) claiming the same percentage of total production as it had in 1967, planting corn first and then soybeans on Class I through V land using no irrigation. This is the "do nothing" alternative which does not interfere with people's desire to develop land as they wish and the farmers' preference to plant as they please subject only to current and the most probable new laws and regulations. One change was included — to require erosion control measures. This is deemed to be the likely future course as Iowans and Congress become convinced that steps must be taken to prevent the loss of one of their most important natural resources. This scenario also allows most of the farmers to share in the potential growth in crop production, except those who own only Class VI or VII land. It also continues the current trend of no large investment by Iowa's farmers in supplemental irrigation.

A summary of the results of this set of assumptions for Northwest Iowa is shown in Table 230. The results for one of the counties, Buena Vista County, are shown in Table 231. This county was chosen because its land resources are impacted the most heavily of all 12 counties in the study area; most of its land resources would be converted to row crop production. Only five land uses are shown in these tables because the assumption is made in CPS 1 through 6 that the amount of land used for urban and built-up, forest, other, conservation use only

Table 230. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 1 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	12.5	4.0
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	No	No	No	No
Soil erosion, million tons/yr	66.2	11.2	12.0	11.7
Terraces				
Class III, 1,000 acres	0	958.7	991.8	984.8
Class IV, 1,000 acres	0	104.7	116.9	113.8
Cost, million dollars	0	389.1	406.1	402.3
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	1,664.0	1,824.5	2,097.1	1,853.5
Soybeans	880.5	1,324.1	1,473.9	1,562.5
Close grown crops	291.7	238.8	18.2	123.5
Rotation hay and pasture	395.4	172.4	0.1	44.8
Pasture	443.3	114.4	80.6	80.6

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

and water areas will not be decreased from their 1967 levels. This assumption is relaxed in CPS-7.

Regional results Except for soybeans, crop and livestock demands are met for all years. In the years 2000 and 2020, soybean production deficits are 12.5 and 4.0 million bushels, respectively.

Table 231. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 1 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	3.0	1.9
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	1.2	1.2	1.2
Terraces				
Class III, 1,000 acres	0	33.6	33.6	33.6
Class IV, 1,000 acres	0	3.7	3.7	3.7
Cost, million dollars	0	13.6	13.6	13.6
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	134.2	149.1	171.9	152.0
Soybeans	85.7	142.5	120.4	139.9
Close grown crops	17.6	0.9	0.0	0.0
Rotation hay and pasture	36.5	0.0	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

The deficit in the year 2020 is less than in 2000 because the assumed percentage increase in soybean yield per acre between 2000 and 2020 is greater than the projected percentage increase in demand for soybeans from 2000 to 2020.

All urban and rural water demands, excluding irrigation, can be met from ground water sources. Total average urban demands range from 33.3 MGD in 1980 to 38.1 MGD in 2020. Total average rural demands, which include livestock demands, range from 3.9 MGD in 1980 to 4.5 MGD in 2020. These increases in resource use occur even though the regional population is projected to decrease from 291,900 in 1967 to 261,400 in the year 2020. Urban demands include only the largest cities in each county. All of the smaller communities, rural subdivisions and farmsteads are assumed to be included in county-wide rural water districts.

This was done to assure that the entire population would be served with adequate quantities and qualities of water as required by the new drinking water standards. Table 230 indicates that rural water demands are not met in 1967 and 1980. This is because all rural water districts will not be in operation by 1980. These urban and rural water demands, excluding irrigation, are identical for all seven crop planting scenarios, so they will not be repeated again. Water for irrigation is not used in this scenario.

Because no irrigation is used, the land resources allocated to agriculture in the region are not sufficient to meet the projected demands for corn and soybeans in the future. This is true even though the average state corn yields are assumed to increase from 115 bushels per acre in 1980 to 175 bushels per acre in 2020. Soybean yields are assumed to increase from 36 bushels per acre in 1980 to 52 bushels per acre in 2020. As shown in Table 230, land used for corn and soybeans increases from 2.54 million acres in 1967 to 3.57 million acres in the year 2000, an increase of just over one million acres. However, even this increase in row crop acreage was not enough to meet the projected demands. This 3.57 million acres of land is 78% of the total area of Northwest Iowa.

The increase in corn and soybean acreage takes place at the expense of land devoted to close grown crops, rotation hay and pasture and permanent pasture. These uses decrease from 1,130,000 acres in 1967 to just 99,000 acres in the year 2000. The 80,600 acres of permanent pasture is the Class VI and VII land in the region which had been used previously for agricultural purposes. Only 18,000 acres are devoted to close grown crops in the year 2000 and none to hay.

Even with this massive conversion to row crops, soil erosion can be reduced to less than 20% of the present rate, from 66 to 12 million tons per year. This can be accomplished by constructing terraces on about 1.1 million acres of Class III and IV land at a cost of about $400 million and by using practices such as contouring and minimum tillage. These terraces are closed-end, broad based and grassed backslope terraces with tile outlets. Problems will undoubtedly arise when discussions begin on who is to pay what portion of the terrace costs: the farmers and/or the local, state and federal governments.

Recreation and structural flood control benefits are not enhanced since no reservoirs are constructed. However, some aspects of environmental quality should be enhanced due to the large reduction in soil erosion.

<u>County results</u> The results for Buena Vista County are given in Table 231 and reflect the regional results. All agricultural demands are met with the exception of soybeans. The deficit comprises one-fourth to one-half of the regional deficit in 2000 and 2020,

respectively. All water demands for urban and rural purposes are met. These total average demands, without irrigation, are 3.9 MGD in 1980 and 4.6 MGD in 2020 with the population declining from 20,800 in 1967 to 18,400 in 2020. Water-based recreation demands are also met because the county contains a large natural lake. However, almost all the land devoted to agricultural purposes in 1967 must be converted to row crops in order to attain, as closely as possible, the production goals for corn and soybeans. Only about 6,300 acres of Class VI and VII land are devoted to permanent pasture.

The remaining agricultural land, about 292,000 acres, is devoted to corn and soybeans. This is almost 80% of the total area of the county. The other uses (urban and built-up, forest, other, conservation use only and water areas) total only about 67,000 acres. Even with this almost total conversion to row crops, soil erosion can be reduced to one-third of its present rate, from 3.4 to 1.2 million tons per year. This is accomplished by constructing terraces on 37,300 acres at a cost of $13.6 million and by using practices such as contouring and minimum tillage.

<u>Summary</u> CPS-1 is the reflection of what could happen in the future if present trends are allowed to continue. Row crop acreage in Northwest Iowa has expanded from 1.9 million acres in 1958 to 2.7 million acres in 1976 and could expand further to 3.6 million acres by the year 2000. During this same period of time, land devoted to hay and pasture would decrease drastically.

These changes would also affect livestock production. Over 350,000 acres of pasture would be converted to row crops. This would require most livestock production to be limited to feedlots and confinement units, increasing environmental problems and production costs. The loss of almost 400,000 acres of hay land would also increase livestock production costs.

While this "do nothing" alternative may appeal to some because no one is asked to do anything differently than he is doing now, especially if the erosion control measures also are ignored, its overall impact on agriculture and the region would not make this the preferred alternative, in the author's viewpoint.

Crop planting scenario 2

CPS-2 allows row crop acreage to expand onto land presently used for close grown crops, hay and pasture with each land capability class (LCC) claiming the same percentage of total production as it had in 1967, planting corn first and then soybeans on Class I through V land using irrigation as needed. CPS-2 is similar to CPS-1, with one exception: irrigation of corn is allowed on Class I and IIe land, if needed to meet row crop production goals. Results for the northwest region of Iowa are listed in Table 232 while those for Buena Vista County are shown in Table 233.

Regional results Crop and livestock demands are met in all years except soybeans in the year 2000. The deficit has been reduced from 12.5 million bushels in CPS-1 to just 2.1 million bushels in this scenario. In the year 2020 the deficit has been reduced from 4.0 million bushels to almost zero. This was accomplished by irrigating almost 1.1 million acres of corn in 2000 and about 0.5 million acres

Table 232. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 2 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	2.1	0.1
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	99.8	1,073.6	459.2
Recreation needs met?	No	No	Yes	Yes
Soil erosion, million tons/yr	66.2	11.1	11.9	11.6
Terraces				
Class III, acres	0	903.1	967.3	946.5
Class IV, acres	0	103.3	81.8	111.4
Cost, million dollars	0	368.5	382.6	387.5
Reservoirs needed?	No	No	Yes	Yes
Land use, 1,000 acres				
Corn	1,664.0	1,772.9	1,620.8	1,675.9
Soybeans	880.5	1,325.4	1,758.0	1,675.8
Close grown crops	291.7	238.7	162.7	140.4
Rotation hay and pasture	395.4	194.2	77.9	58.2
Pasture	443.3	143.7	81.2	80.7

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

in 2020. Both ground water sources and surface water sources (through reservoir storage) would be needed to meet these irrigation demands. As before, all other demands for water could be met from ground water sources.

Even though over a million acres of corn are irrigated, the land

Table 233. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 2 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.0	0.1
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	0	122.4	112.0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	1.2	1.2	1.2
Terraces				
Class III, 1,000 acres	0	33.6	33.6	33.6
Class IV, 1,000 acres	0	3.7	3.7	3.7
Cost, million dollars	0	13.6	13.6	13.6
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	134.2	149.1	122.4	112.0
Soybeans	85.7	142.5	169.9	179.9
Close grown crops	17.6	0.9	0.0	0.0
Rotation hay and pasture	36.5	0.0	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

resources devoted to agriculture in this scenario are not sufficient to meet the projected demands for soybeans. However, since irrigation is used, one trade-off here is that additional land is available for close grown crops and rotation hay and pasture. This is especially true in the year 2000 where land devoted to these two land use categories increases from 18,300 acres in CPS-1 to 240,600 acres in CPS-2. Another trade-off is that fewer acres requires terraces. The greatest decrease, 60,000 acres, occurs in the year 2000 at a savings of $23.5 million dollars. Erosion in the region remains about the same for both scenarios at about 12 million tons per year, down from 66 million tons per year in 1967. Recreation needs are also met due to the construction of reservoirs. These will also provide some flood control benefits.

County results   Table 233 depicts the results for Buena Vista County. Half the regional deficit in soybean production occurs in this county even though 122,400 acres of corn are irrigated in the year 2000. Agricultural land use for this scenario is exactly the same as in CPS-1. All agricultural land is converted to the production of corn and soybeans except Class VI and VII land which is converted to permanent pasture. The only thing that is accomplished by irrigation is to reduce the soybean deficit from 3.0 to 1.0 million bushels in the year 2000 and from 1.9 to 0.1 million bushels in the year 2020. A total of 37,300 acres again are terraced at a cost of $13.6 million and soil erosion also remains the same.

Crop planting scenario 3

CPS-3 utilizes all land used for row and close grown crops, hay and pasture in 1967 with the same percentage of land utilized in 1967 for row and close grown crops used first for corn and then for soybeans on Class I through V land using irrigation as needed. CPS-3 differs from CPS-2 in the manner in which corn and soybean acreage on the various land capability classes (LCC) is determined. This begins the movement towards growing row crops only on the less sloping lands and having someone other than the farmers deciding (dictating?) which crops should be planted and on which lands. The results for Northwest Iowa and Buena Vista County are shown in Tables 234 and 235, respectively.

Regional results Again, crop and livestock production goals are met in all years with the exception of soybeans in the years 2000 and 2020. The deficit is 2.0 and 0.1 million bushels, respectively, the same as in CPS-2. The main difference in these two scenarios is that the need for any irrigation is now delayed until the year 2000 with slightly over a million acres of corn being irrigated. This use of irrigation for corn and of the less sloping lands for row crops has two impacts: somewhat less acreage needs to be terraced and slightly more land is devoted to close grown crops, hay and pasture. Soil erosion is again about 12 million tons per year.

Both ground water and surface water storage withdrawals are needed to meet irrigation demands in the year 2000, but only ground water sources would be sufficient in the year 2020. This raises the possibility that if this scenario were adopted, only the ground water sources might be utilized for irrigation purposes, irrigation of corn would be limited and the region would accept the increased soybean deficit which would occur in the year 2000. This would mean that recreation, flood control and low flow augmentation benefits would have to be foregone.

County results As indicated in Table 235, the results for CPS-3 are almost exactly the same as for CPS-2. The only improvement

Table 234. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 3 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	2.0	0.1
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	19.1	19.1
Acres, 1,000	0	0	1,023.1	459.2
Recreation needs met?	No	No	Yes	Yes
Soil erosion, million tons/yr	66.2	11.9	12.0	11.9
Terraces				
Class III, 1,000 acres	0	882.1	964.5	934.4
Class IV, 1,000 acres	0	56.7	113.6	101.3
Cost, million dollars	0	341.4	394.9	378.9
Reservoirs needed?	No	No	Yes	Yes
Land use, 1,000 acres				
Corn	1,664.0	1,723.8	1,609.4	1,605.9
Soybeans	880.5	1,361.3	1,803.4	1,712.8
Close grown crops	291.7	244.4	130.7	149.1
Rotation hay and pasture	395.4	213.0	44.9	72.3
Pasture	443.3	132.4	81.5	80.6

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

is in the amount of land devoted to close grown crops in 1980. Otherwise, the soybean deficit, land use, irrigation demands, terrace costs, and soil loss is the same as in CPS-2.

Table 235. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 3 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.0	0.1
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	19.1	19.1
Acres, 1,000	0	0	122.4	112.0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	1.2	1.2	1.2
Terraces				
Class III, 1,000 acres	0	33.6	33.6	33.6
Class IV, 1,000 acres	0	3.7	3.7	3.7
Cost, million dollars	0	13.6	13.6	13.6
Reservoirs needed?	No	No	Yes	No
Land use, 1,000 acres				
Corn	134.2	143.5	122.4	112.0
Soybeans	85.7	146.8	169.9	179.9
Close grown crops	17.6	2.2	0.0	0.0
Rotation hay and pasture	36.5	0.0	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

Crop planting scenario 4

CPS-4 only allows corn and soybeans to be planted on those Class I through V lands which were planted to row crops in 1967; uses full irrigation on Class I land for corn; and uses all Class I land before using Class II land, etc., growing corn first, then soybeans, then close grown crops, with all remaining land to be in hay and pasture. CPS-4 differs radically from the first three scenarios in two ways: all Class I land used for corn must be irrigated, and Class IIe land used for corn can also be irrigated, and (2), more importantly, only those Class I through V lands utilized for corn and soybeans in 1967 can be used for corn and soybeans in some future year. This scenario is an attempt to hold the line on any future conversions of hay and pasture land and close grown crops to row crops. It is also an attempt to keep soil erosion to a minimum while maintaining the present capability to raise crops. The results of this alternative future are shown in Table 236 for Northwest Iowa and in Table 237 for Buena Vista County.

Regional results The most apparent, severe impact of this constraint on land utilization is that the soybean production deficit in the years 2000 and 2020 increases to 34.9 and 28.5 million bushels, respectively. At a price of $7.00 per bushel, this would amount to a potential future loss of income of almost $250 million annually. Irrigated corn acreage increases to 1.2 million in the year 2000 and then decreases to somewhat over 1.1 million acres in the year 2020. A deficit of 6.5 million bushels of soybeans in 1980 also appears for the first time.

The land devoted to close grown crops and rotation hay and pasture remains constant at the 1967 level of use throughout the entire projection period. Land utilized for permanent pasture increases almost 100,000 acres in 1980 but then declines to almost the 1967 level for the remainder of the period. The cost of terraces declines to about

Table 236. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 4 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	6.5	34.9	28.5
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	986.7	1,209.0	1,128.9
Recreation needs met?	No	Yes	Yes	Yes
Soil erosion, million tons/yr	66.2	9.9	10.0	10.0
Terraces				
Class III, 1,000 acres	0	698.7	736.4	736.1
Class IV, 1,000 acres	0	53.0	58.6	59.8
Cost, million dollars	0	273.8	289.7	290.1
Reservoirs needed?	No	Yes	Yes	Yes
Land use, 1,000 acres				
Corn	1,664.0	1,265.8	1,555.2	1,405.0
Soybeans	880.5	1,178.9	977.3	1,122.7
Close grown crops	291.7	291.7	291.7	291.7
Rotation hay and pasture	395.4	395.4	395.4	395.4
Pasture	443.3	542.5	450.4	450.4

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

$290 million, over $100 million less than the other scenarios. Soil erosion also decreases to a level of about 10 million tons per year, 2 million tons less than the other scenarios and only 15% of the 1967 level of 66.2 million tons per year. The 10 million tons per year represents an average of 2.2 tons per acre per acre in the region.

Table 237. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 4 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	0.8	4.1	3.6
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	99.7	123.2	112.9
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	1.0	1.0	1.0
Terraces				
Class III, 1,000 acres	0	25.2	25.2	25.2
Class IV, 1,000 acres	0	1.0	1.0	1.0
Cost, million dollars	0	9.5	9.5	9.5
Reservoirs needed?	No	Yes	Yes	Yes
Land use, 1,000 acres				
Corn	134.2	99.7	123.2	112.9
Soybeans	85.7	119.8	96.1	106.0
Close grown crops	17.6	17.6	17.6	17.6
Rotation hay and pasture	36.5	36.5	36.5	36.5
Pasture	24.8	25.2	25.2	25.2

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

Both surface and ground water sources must be used to satisfy the irrigation demands which range from about 1.0 to 1.2 million acres. Thus, benefits from recreation, flood control and low flow augmentation would also be realized.

County results   Deficits in soybean production occur in all future years, ranging from 0.8 to 4.1 million bushels, even though over 100,000 acres of corn are irrigated. Again, land used for close grown crops and rotation hay and pasture remain at their 1967 levels throughout the projection period while land devoted to permanent pasture increases slightly. Terraces are needed on only 26,200 acres at a cost of $9.5 million. Soil erosion also decreases to 1.0 million tons per year, as opposed to 1.2 million tons per year in the other scenarios, from the 1967 level of 3.4 million tons.

Crop planting scenario 5

CPS-5 only allows corn and soybeans on those Class I through V lands which were planted to row and close grown crops in 1967; uses full irrigation on Class I land for corn; and uses all Class I land before using Class II land, etc., growing corn first, then soybeans, then close grown crops, with all remaining land to be in hay and pasture. CPS-5 differs from CPS-4 in that land used for close grown crops in 1967 can also be used for corn and soybeans in future years. This allows more land to be used for irrigated corn production and thus should allocate more land for the production of soybeans. The results of this scenario are depicted in Tables 238 and 239 for Northwest Iowa and Buena Vista County, respectively.

Regional results As expected, more land is devoted to the production of soybeans but the deficit is still substantial, 31.1 and 23.4 million bushels in 2000 and 2020, respectively. There is also a deficit of 1.4 million bushels in 1980. An additional 100,000 acres needs to be terraced and soil erosion increases to 10.7 million tons

Table 238. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 5 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	1.4	31.1	23.4
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	865.0	1,231.2	1,130.5
Recreation needs met?	No	Yes	Yes	Yes
Soil erosion, million tons/yr	66.2	10.4	10.7	10.7
Terraces				
Class III, 1,000 acres	0	752.0	871.5	832.7
Class IV, 1,000 acres	0	54.0	68.6	66.9
Cost, million dollars	0	293.4	342.6	327.9
Reservoirs needed?	No	Yes	Yes	Yes
Land use, 1,000 acres				
Corn	1,664.0	1,306.1	1,539.7	1,396.1
Soybeans	880.5	1,327.1	1,281.1	1,397.3
Close grown crops	291.7	291.7	287.8	291.7
Rotation hay and pasture	395.4	395.4	363.5	369.1
Pasture	443.3	353.9	198.2	210.9

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

per year, an increase of 700,000 tons per year over CPS-4. Irrigation demands are slightly higher as would be expected. The land utilized for both close grown crops and rotation hay and pasture remains at about their 1967 levels. However, land devoted to permanent pasture decreases steadily throughout the period, from 440,000 acres in 1967 to

Table 239. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 5 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	0.1	3.3	2.7
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	99.4	123.0	112.6
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	1.1	1.1	1.1
Terraces				
Class III, 1,000 acres	0	27.1	27.1	27.1
Class IV, 1,000 acres	0	1.2	1.2	1.2
Cost, million dollars	0	10.3	10.3	10.3
Reservoirs needed?	No	Yes	Yes	Yes
Land use, 1,000 acres				
Corn	134.2	99.4	123.0	112.6
Soybeans	85.7	137.7	114.0	123.9
Close grown crops	17.6	17.6	17.6	17.6
Rotation hay and pasture	36.5	36.5	36.5	36.5
Pasture	24.8	7.6	7.6	7.6

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

only 210,000 acres in the year 2020. This scenario is not much of an improvement, if any, over the previous one.

County results The same results are true for Buena Vista County as shown in Table 239. The soybean deficit is still substantial, irrigation demands remain high, soil erosion and terracing increases slightly and the land devoted to permanent pasture decreases to about one-third of its 1967 value.

Crop planting scenario 6

CPS-6 allows corn and soybeans on all Class I through V lands which were planted to row and close grown crops, hay and pasture in 1967; uses full irrigation on Class I land for corn; and uses all Class I land before using Class II land, etc., growing corn first, then soybeans, then close grown crops, with all remaining land to be in hay and pasture. CPS-6 continues the trend begun in CPS-5 and allows all land used for row and close grown crops plus hay and pasture in 1967 to be utilized for row crops in some future year. This scenario is very similar to CPS-2 with the exception that irrigation was voluntary in CPS-2 while in CPS-6 irrigation of corn is mandatory on all Class I land. With mandatory irrigation, more land should be available for close grown crops, hay and pasture. Tables 240 and 241 show these results for Northwest Iowa and Buena Vista County, respectively.

Regional results In terms of soybean production, this scenario is a vast improvement over CPS-4 and CPS-5 since the deficit is almost eliminated. Irrigation demands are also somewhat less but terracing costs are $100 million dollars higher than in CPS-4 and the land devoted to close grown crops, hay and pasture decrease to only 30% of their 1967 value, from 1.1 million acres in 1967 to 0.3 million acres in the year 2000. This results in an increase in soil erosion to about 12 million tons per year.

County results The results for Buena Vista County, shown in

Table 240. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 6 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	2.0	0.1
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	572.7	1,122.6	721.8
Recreation needs met?	No	No	Yes	Yes
Soil erosion, million tons/yr	66.2	11.5	11.9	11.8
Terraces				
Class III, 1,000 acres	0	741.6	943.2	922.8
Class IV, 1,000 acres	0	32.2	77.8	63.0
Cost, million dollars	0	280.5	372.2	358.7
Reservoirs needed?	No	No	Yes	Yes
Land use, 1,000 acres				
Corn	1,664.0	1,415.1	1,553.3	1,491.1
Soybeans	880.5	1,324.3	1,785.0	1,685.2
Close grown crops	291.7	286.5	165.2	199.1
Rotation hay and pasture	395.4	307.8	84.4	155.5
Pasture	443.3	340.8	82.0	134.3

[a] Includes domestic, municipal, commercial and industrial.

[b] Includes domestic and livestock.

Table 241, also indicate this increase in soybean production. However, in the years 2000 and 2020 the results are the same as for the first three scenarios. Over 100,000 acres of corn are irrigated, 37,300 acres are terraced at a cost of $13.6 million, all agricultural land is used for row crop production except for about 6,300 acres of Class VI

Table 241. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 6 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.0	0.1
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	49.4	122.4	112.0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	1.2	1.2	1.2
Terraces				
Class III, 1,000 acres	0	27.6	33.6	33.6
Class IV, 1,000 acres	0	0.2	3.7	3.7
Cost, million dollars	0	10.0	13.6	13.6
Reservoirs needed?	No	No	Yes	Yes
Land use, 1,000 acres				
Corn	134.2	118.9	122.4	112.0
Soybeans	85.7	137.4	169.9	179.9
Close grown crops	17.6	17.6	0.0	0.0
Rotation hay and pasture	36.5	18.6	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

and VII land devoted to permanent pasture and soil erosion increases to 1.2 million tons per year.

Crop planting scenario 7

CPS-7 allows row crop acreage to expand onto land presently used for close grown crops, hay and pasture, other and conservation use only with each land capability class (LCC) claiming the same percentage of total production as it had in 1967, planting corn first and then soybeans on Class I through V land using no irrigation. CPS-7 is the "do nothing" alternative all over again, the same as CPS-1, but with the exception that two more land use categories, conservation use and other, are allowed to be converted to row crop purposes in an attempt to meet all corn and soybean demands without irrigation. This alternative leaves only urban and built-up areas, water areas and forested areas immune from conversion to row crops. The results of this alternative future are shown in Table 242 for Northwest Iowa and in Table 243 for Buena Vista County.

Regional results Even the inclusion of two more land use categories does not entirely eliminate the soybean deficit in the year 2000. However, this deficit could be eliminated by allowing some counties to produce more than their projected share of increased crop production. Under this scenario corn acreage increases to just over 2.1 million acres and land planted to soybeans increases to over 1.7 million acres. These 3.8 million acres devoted to row crops account for almost 83% of the total area of Northwest Iowa. At this same time, land devoted to conservation use only and other land use categories decreases from 618,000 acres in 1967 to only 16,400 acres in the year 2020. This may be an unacceptable solution, particularly to the environmental interest groups. One of the uses involved in the other land use category is feedlots. If these were converted to corn and soybean production, then cattle and hog demands could not be met.

By using conservation tillage methods and constructing terraces on

Table 242. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 7 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.5	Yes
Cattle	Yes	No	No	No
Hogs	Yes	No	No	No
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	No	No	No	No
Soil erosion, million tons/yr	66.2	11.0	12.6	11.9
Terraces				
Class III, 1,000 acres	0	979.7	1,148.0	1,071.8
Class IV, 1,000 acres	0	107.2	129.9	119.7
Cost, million dollars	0	397.7	467.8	436.1
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Other	141.6	76.9	8.2	30.1
Conservation use only	476.5	114.2	8.2	43.3
Corn	1,664.0	1,825.6	2,100.6	1,854.8
Soybeans	880.5	1,327.5	1,725.5	1,641.0
Close grown crops	291.7	290.9	199.0	273.3
Rotation hay and pasture	395.4	390.2	164.7	305.1
Pasture	443.3	267.3	84.7	141.1

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

about 1.3 million acres of Class III and IV land at a cost of $468 million, soil erosion can be held to 12.6 million tons per year. This is a great improvement over the 66.2 million tons which eroded in 1967, however, it is also the largest amount of any of the seven scenarios.

Table 243. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 7 with erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.2	Yes
Cattle	Yes	No	No	No
Hogs	Yes	No	No	No
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	1.2	1.3	1.3
Terraces				
Class III, 1,000 acres	0	35.3	41.8	41.8
Class IV, 1,000 acres	0	1.5	5.0	5.0
Cost, million dollars	0	13.3	17.1	17.1
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Other	9.3	0.0	0.0	0.0
Conservation use only	33.4	0.0	0.0	0.0
Corn	134.2	149.1	171.9	152.0
Soybeans	85.7	137.5	163.3	171.5
Close grown crops	17.6	17.6	0.0	11.4
Rotation hay and pasture	36.5	31.1	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

Since no irrigation is included in this scenario, no investment is required for the development of surface and/or ground water sources. This also means that there will be no benefits from recreation, flood control or low flow augmentation.

County results Most of the regional deficit in soybean production in the year 2000 occurs in Buena Vista County, 1.2 of the 1.5 million bushels. Land devoted to row crops increases from 219,900 acres in 1967 to 335,200 acres in the year 2000. As a percentage of the total area of the county, land devoted to row crops increases from 60% in 1967 to almost 92% in the year 2000. Land devoted to the conservation use only and other land use categories decreases from 42,700 acres in 1967 to zero beginning in 1980. This would also appear to be totally unacceptable for the reasons listed above.

Soil erosion is held to 1.3 million tons per year by using conservation tillage and constructing terraces on 46,800 acres of Class III and IV land at a cost of $17.1 million. Irrigation is not used but recreation demands are met because of the existence of Storm Lake.

Summary

The results for each of the seven crop planting scenarios with erosion control have been presented in the above paragraphs for the years 1967, 1980, 2000 and 2020. The critical year in each of these alternative futures is the year 2000. Table 244 depicts the results for this year in Northwest Iowa across all seven scenarios in order to give a composite view of the variation in results. This same view for a typical county, Buena Vista County, is shown in Table 245.

Regional results None of the scenarios is able to completely satisfy all crop and livestock demands in the year 2000. However, this is based on the assumption that all counties will produce the same percentage of total regional production as they did in 1967. This

Table 244. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenarios 1 through 7 with erosion control measures in the year 2000

Item	1	2	3	4	5	6	7
Population, 1,000 persons	265.8	265.8	265.8	265.8	265.8	265.8	265.8
Farm production met?							
Corn	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	12.5	2.1	2.0	34.9	31.1	2.0	1.5
Cattle	Yes	Yes	Yes	Yes	Yes	Yes	No
Hogs	Yes	Yes	Yes	Yes	Yes	Yes	No
Water supply met?							
Urban[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rural[b]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Irrigated corn							
Inches/acre/year	0.0	19.1	19.1	19.1	19.1	19.1	0.0
Acres, 1,000	0	1,073.6	1,023.1	1,209.0	1,231.2	1,122.6	0
Recreation needs met?	No	Yes	Yes	Yes	Yes	Yes	No
Soil erosion, million tons/yr	12.0	11.9	12.0	10.0	10.7	11.9	12.6
Terraces							
Class III, 1,000 acres	991.8	967.3	964.5	736.4	871.5	943.2	1,148.0
Class IV, 1,000 acres	116.9	81.8	113.6	58.6	68.6	77.8	129.9
Cost, million dollars	406.1	382.6	394.9	289.7	342.6	372.2	467.8
Reservoirs needed?	No	Yes	Yes	Yes	Yes	Yes	No
Land use, 1,000 acres							
Corn	2,097.1	1,620.8	1,609.4	1,555.2	1,539.7	1,553.3	2,100.6
Soybeans	1,473.9	1,758.0	1,803.4	977.3	1,281.1	1,785.0	1,725.5
Close grown crops	18.2	162.7	130.7	291.7	287.8	165.2	199.0
Rotation hay and pasture	0.1	77.9	44.9	395.4	363.5	84.4	164.7
Pasture	80.6	81.2	81.5	450.4	198.2	82.0	84.7

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

Table 245. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenarios 1 through 7 with erosion control measures in the year 2000

Item	1	2	3	4	5	6	7
Population, 1,000 persons	18.7	18.7	18.7	18.7	18.7	18.7	18.7
Farm production met?							
Corn	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	3.0	1.0	1.0	4.1	3.3	1.0	1.2
Cattle	Yes	Yes	Yes	Yes	Yes	Yes	No
Hogs	Yes	Yes	Yes	Yes	Yes	Yes	No
Water supply met?							
Urban[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rural[b]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Irrigated corn							
Inches/acre/year	0.0	19.1	19.1	19.1	19.1	19.1	0.0
Acres, 1,000	0	122.4	122.4	123.2	123.0	122.4	0
Recreation needs met?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	1.2	1.2	1.2	1.0	1.1	1.2	1.3
Terraces							
Class III, 1,000 acres	33.6	33.6	33.6	25.2	27.1	33.6	41.8
Class IV, 1,000 acres	3.7	3.7	3.7	1.0	1.2	3.7	5.0
Cost, million dollars	13.6	13.6	13.6	9.5	10.3	13.6	17.1
Reservoirs needed?	No	No	Yes	Yes	Yes	Yes	No
Land use, 1,000 acres							
Corn	171.9	122.4	122.4	123.2	123.0	122.4	171.9
Soybeans	120.4	169.9	169.9	96.1	114.0	169.9	163.3
Close grown crops	0.0	0.0	0.0	17.6	17.6	0.0	0.0
Rotation hay and pasture	0.0	0.0	0.0	36.5	36.5	0.0	0.0
Pasture	6.3	6.3	6.3	25.2	7.6	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

assumption allows some counties to devote more acreage to close grown crops, hay and pasture. By converting some of these acres to row crops, then all crop demands could be met, with the possible exceptions of scenarios 4 and 5. Also, livestock demands cannot be met in scenario 7 because the land needed for the raising of cattle and hogs is used for row crops.

Sufficient water is available to meet all urban and rural demands for water, excluding irrigation, from ground water sources. These demands are given priority over the use of water for irrigation and were listed in Tables 180 and 181. Average daily demands for urban and rural uses, including livestock, increased from 37.2 MG in 1980 to 42.6 MG in 2020. Peak daily demands increased from 69.4 MG in 1980 to 79.1 MG in 2020. These demands are based on the author's population and livestock projections and water use rates.

Demands for irrigation water can also be met, assuming a drought with a 50-yr recurrence interval lasting for two years. Both ground water sources and surface water reservoirs must be developed to meet the demand for 19.1 inches of water on 1.0 to 1.2 million acres of corn. The cost of this water as well as who should pay for its development are discussed in a later section. Assuming that the surface water reservoirs are constructed, then the future demands for water-based recreation will be met. There will also be some benefits from flood control and low flow augmentation.

Depending on the scenario, terraces are constructed on from 0.8 to 1.3 million acres at costs ranging from $290 to $468 million. With these expenditures, soil erosion is reduced from 66.2 million tons in

1967 to 10.0 to 12.6 million tons in the year 2000. The lowest erosion volumes and lowest costs are coupled with the highest deficits in soybean production. The reverse is also true.

The soybean deficit is also tied to land use. The greatest deficit occurs in scenario 4 which maintains land use as it was in 1967. The smallest deficit occurs in scenario 7 which allows row crops to be planted anywhere except in existing urban, forested and water areas. Any compromise solution which tends to decrease the soybean deficit to some low value, while still maintaining a large amount of land in close grown crops, hay and pasture, must include irrigating a million acres of corn. Which alternative future actually occurs will depend on decisions made in the social, financial and political arenas.

County results The results for Buena Vista County parallel those for the region as indicated in Table 245. Soybean deficits range from 1.0 to 4.1 million bushels in the year 2000. All urban and rural demands for water can be met. Irrigation demands vary over a very narrow range. Soil erosion also varies over a narrow range, from 1.0 to 1.3 million tons per year. However, the cost of obtaining this decrease in soil erosion, from the 3.4 million tons in 1967, varies from $9.5 to $17.1 million.

Land use in the county in the year 2000 does not present a very bright picture. With the exception of scenarios 4 and 5, which have the highest soybean deficits, only the absolute minimum amount of land is devoted to permanent pasture while none is used for either close grown crops or rotation hay and pasture.

Crop Planting Scenarios without Erosion Control

Another series of computer runs were made to determine what would occur if no erosion control measures were required in the future. This would continue the current trend of most people paying lip service to the need for erosion control but not doing much about it because of the costs involved. Tables 246 through 249 portray the regional results for scenarios 1, 2, 3 and 7, respectively. Tables 250 through 253 depict the same results for Buena Vista County. These four scenarios were chosen because they produced the greatest amounts of erosion.

Regional results

The obvious result, without the use of erosion control measures, is that soil erosion increases. However, the magnitude of the difference in soil erosion, with and without control measures, is startling. Rather than decreasing from 66.2 million tons in 1967 to 10 or 12 million tons per year, soil erosion increases to 86 to 97 million tons per year. This is an 8-fold difference. With 4.5 million acres in the region, soil erosion increases to an average of 21.6 tons per acre rather than decreasing to 2.8 tons per acre. The social, economic and environmental implications are obvious. Of course, since no money is spent to construct terraces, there is a cost reduction in crop production.

The other main effect of not constructing terraces is that more land is available for production of row crops. The difference is 10% on Class III land and 20% on Class IV land. Because of this, the soybean deficits are always lower than when erosion control measures are

Table 246. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 1 with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	2.9	1.7
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	No	No	No	No
Soil erosion, million tons/yr	66.2	79.4	94.8	86.9
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	1,664.0	1,758.8	2,023.8	1,787.0
Soybeans	880.5	1,283.9	1,508.5	1,529.7
Close grown crops	291.7	257.0	51.8	183.7
Rotation hay and pasture	395.4	251.9	5.1	83.8
Pasture	443.3	123.0	80.7	80.7

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

in effect. Rather than ranging from 1.5 to 12.5 million bushels in these four scenarios, they range from 1.0 to 2.9 million bushels in the year 2000.

One other result of this increase in usable land for row crop production is that the demand for irrigation water is less. The

Table 247. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 2 with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.5	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	135.6	899.1	303.4
Recreation needs met?	No	No	Yes	No
Soil erosion, million tons/yr	66.2	75.9	89.0	86.3
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	Yes	Yes
Land use, 1,000 acres				
Corn	1,664.0	1,693.8	1,706.5	1,682.4
Soybeans	880.5	1,285.8	1,701.9	1,601.1
Close grown crops	291.7	257.0	140.0	181.9
Rotation hay and pasture	395.4	252.1	38.9	74.7
Pasture	443.3	173.9	82.9	80.7

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

possibility exists that all irrigation demands could be met from ground water sources and no surface water reservoirs would have to be constructed. This would follow the preference expressed in the Iowa 2000 program to not build any more large-scale reservoirs. A final result

Table 248. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 3 with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.5	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	19.1	19.1
Acres, 1,000	0	0	771.3	302.4
Recreation needs met?	No	No	Yes	Yes
Soil erosion, million tons/yr	66.2	66.6	86.2	79.8
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	Yes	Yes
Land use, 1,000 acres				
Corn	1,664.0	1,691.9	1,674.1	1,624.9
Soybeans	880.5	1,314.0	1,733.2	1,641.9
Close grown crops	291.7	254.1	134.2	176.1
Rotation hay and pasture	395.4	262.5	45.5	97.3
Pasture	443.3	152.4	83.1	80.7

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

of this increase in usable land for row crop production is that somewhat more land can be used for close grown crops, hay and pasture.

County results

Most of the regional soybean deficit occurs in Buena Vista County. The county deficit for these four scenarios ranges from 0.9 to 2.9

Table 249. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 7 with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.8	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.0	Yes
Cattle	Yes	No	No	No
Hogs	Yes	No	No	No
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	No	No	No	No
Soil erosion, million tons/yr	66.2	80.4	97.3	88.4
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Other	141.6	90.7	14.8	40.2
Conservation use only	476.5	147.0	19.5	64.8
Corn	1,664.0	1,758.7	2,024.6	1,787.4
Soybeans	880.5	1,288.1	1,686.3	1,592.7
Close grown crops	291.7	291.8	214.6	284.5
Rotation hay and pasture	395.4	393.7	229.9	336.8
Pasture	443.3	322.8	100.9	181.7

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

million bushels while the regional deficit ranges from 1.0 to 2.9 million bushels. Also, soil erosion increases from 3.4 million tons in 1967 to a range in the future of 4.8 to 5.7 million tons per year, rather than decreasing to a range of 1.0 to 1.3 tons per year. With

Table 250. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 1 with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	2.9	1.7
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	4.7	4.8	4.8
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	134.2	147.1	169.6	149.9
Soybeans	85.7	136.7	122.8	142.0
Close grown crops	17.6	8.7	0.0	0.0
Rotation hay and pasture	36.5	0.0	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

no erosion control measures in the future, soil erosion could increase to an average of 15.6 tons per acre rather than decreasing to 3.6 tons per acre.

Without erosion control measures (terraces), some land is used for close grown crops in 1980 and 2020 in three of the four scenarios.

Table 251. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 2 with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	0.9	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	0	122.4	112.0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	4.7	4.8	4.8
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	Yes	No
Land use, 1,000 acres				
Corn	134.2	147.1	122.4	112.0
Soybeans	85.7	136.7	169.9	174.4
Close grown crops	17.6	8.7	0.0	5.5
Rotation hay and pasture	36.5	0.0	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

However, in the year 2000 the situation is the same with or without erosion control measures: no land is used for close grown crops or rotation hay and pasture and only Class VI and VII land is in permanent pasture.

Table 252. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 3 with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	0.9	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	19.1	19.1	19.1
Acres, 1,000	0	0	122.4	112.0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	4.3	4.8	4.5
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	Yes	Yes
Land use, 1,000 acres				
Corn	134.2	143.5	122.4	112.0
Soybeans	85.7	142.8	169.9	176.9
Close grown crops	17.6	6.2	0.0	3.0
Rotation hay and pasture	36.5	0.0	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

Table 253. Population (Rossmiller), OBERS crop (Rossmiller) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 7 with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.0	Yes
Cattle	Yes	No	No	No
Hogs	Yes	No	No	No
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	4.3	5.7	5.1
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Other	9.3	0.0	0.0	0.0
Conservation use only	33.4	0.0	0.0	0.0
Corn	134.2	147.1	169.6	149.9
Soybeans	85.7	136.1	165.6	169.2
Close grown crops	17.6	17.6	0.0	15.8
Rotation hay and pasture	36.5	34.5	0.0	0.0
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

Effect of Using Gibson's Increased Future Yields

Gibson (1976) also made projections of future land use in Iowa. He used future estimated crop yields based on a statistical analysis of historic crop yields. His and the author's estimates of future corn and soybean yields are compared in Table 254. Given OBERS future estimates of crop demands, using Gibson's yields should result in less land being required to meet these future crop demands. The results of using Gibson's crop yields with the author's population projections and no erosion control measures are summarized in the following paragraphs for scenarios 1, 2 and 3.

Table 254. Comparison of Gibson's and the author's future average state corn and soybean yields

Estimate	Year	Corn		Soybeans
		Nonirrigated	Irrigated	
Gibson[a]	1980	123	173	38
	2000	174	224	49
	2020	225	275	60
Rossmiller	1980	115	165	36
	2000	145	195	44
	2020	175	225	52

[a]Gibson (1976).

Crop planting scenario 1a

Regional results Table 255 portrays the results for Northwest Iowa. The effect of the higher yields is quite apparent in that only a small soybean deficit of 1.3 million bushels occurs in the year 2000. When the author's lower yields are used, deficits of 2.9 and 1.7 million

Table 255. Population (Rossmiller), OBERS crop (Gibson) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 1a with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.9	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	1.3	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	No	No	No	No
Soil erosion, million tons/yr	66.2	75.2	83.3	72.5
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	1,664.0	1,650.0	1,691.6	1,391.6
Soybeans	880.5	1,224.7	1,508.8	1,379.1
Close grown crops	291.7	280.7	211.8	287.7
Rotation hay and pasture	395.4	325.3	175.4	350.6
Pasture	443.3	194.2	82.7	256.9

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

bushels occur in the years 2000 and 2020, respectively.

Because of the higher yields, more land can be used for close grown crops, hay and pasture. This is true throughout the projection period. For example, in the year 2000 about 470,000 acres are devoted to these uses. However, when the lower yields are used, only 138,000 acres are devoted to these three land use categories. Soil erosion is also less, ranging from 72 to 83 million tons per year in the future rather than ranging from 79 to 95 million tons per year.

County results As shown in Table 256, Buena Vista County fares much better if future crop yields would be as estimated by Gibson. In both 1980 and 2020, all crop demands are met and there is still enough land to devote over 30,000 acres to close grown crops, hay and pasture. Only in the year 2000 does land use revert back to the familiar results of just 6,300 acres of Class VI and VII land being utilized for permanent pasture. Soil erosion is about the same, ranging from 4.0 to 4.8 million tons per year rather than ranging from 4.7 to 4.8 million tons per year.

Crop planting scenario 2a

Regional results The effect of the higher yields, coupled with irrigation where needed, results in all crop and livestock demands being met in all years as shown in Table 257. No irrigation is needed in 1980 or 2020. Only two counties, Buena Vista and Sac, require irrigation in the year 2000. Note that some reservoirs were a part of the final tableau.

Since no irrigation is required in either 1980 or 2020, land use in these two years is the same in CPS-2a as it was in CPS-1a. Soil erosion is also the same for these two scenarios in these two years. However, since some irrigation is used in the year 2000, the soil erosion is slightly less.

County results Table 258 also indicates the effects of the

Table 256. Population (Rossmiller), OBERS crop (Gibson) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 1a with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	0.8	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	0.0	0.0
Acres, 1,000	0	0	0	0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	4.1	4.8	4.0
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	134.2	137.7	141.5	116.7
Soybeans	85.7	129.7	150.8	146.0
Close grown crops	17.6	17.6	0.0	17.6
Rotation hay and pasture	36.5	7.5	0.0	11.6
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

higher yields used in combination with irrigation. All crop and livestock demands are met in all years. Soil erosion is less. Land devoted to close grown crops remains constant at 17,600 acres throughout the projection period. And even though the amount of land used for

Table 257. Population (Rossmiller), OBERS crop (Gibson) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 2a with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.9	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	Yes	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	19.1	0.0
Acres, 1,000	0	0	212.4	0
Recreation needs met?	No	No	No	No
Soil erosion, million tons/yr	66.2	75.2	81.7	72.5
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	Yes	No
Land use, 1,000 acres				
Corn	1,664.0	1,650.0	1,619.6	1,391.6
Soybeans	880.5	1,224.7	1,533.8	1,379.1
Close grown crops	291.7	280.7	242.9	287.7
Rotation hay and pasture	395.4	325.3	156.5	350.6
Pasture	443.3	194.2	82.7	256.9

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

hay and pasture is reduced from the 1967 level, some land is devoted to these uses in all years.

<u>Crop planting scenario 3a</u>

<u>Regional results</u> The regional results for CPS-3 are shown in Table 259. All crop and livestock demands are met in all years.

Table 258. Population (Rossmiller), OBERS crop (Gibson) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 2a with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	Yes	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	19.1	0.0
Acres, 1,000	0	0	105.7	0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	4.1	3.9	4.0
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	134.2	137.7	105.7	116.7
Soybeans	85.7	129.7	164.7	146.0
Close grown crops	17.6	17.6	17.6	17.6
Rotation hay and pasture	36.5	7.5	4.4	11.6
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

Irrigation is used only in the year 2000, the same as in CPS-2a. However, because the less sloping land is utilized for corn and soybean production, less acreage is needed in CPS-3a to meet the demand in any year. This allows more land to be devoted to close grown crops, hay and pasture, about 50,000 acres in this case. Because of this, soil

Table 259. Population (Rossmiller), OBERS crop (Gibson) and livestock production, land and water use, and soil erosion in Northwest Iowa using crop planting scenario No. 3a with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	291.9	276.9	265.8	261.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	Yes	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	19.1	0.0
Acres, 1,000	0	0	285.1	0
Recreation needs met?	No	No	No	No
Soil erosion, million tons/yr	66.2	58.5	72.3	56.1
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	Yes	No
Land use, 1,000 acres				
Corn	1,664.0	1,584.8	1,535.6	1,327.7
Soybeans	880.5	1,244.9	1,575.5	1,409.2
Close grown crops	291.7	281.0	251.7	289.0
Rotation hay and pasture	395.4	334.5	177.6	349.3
Pasture	443.3	229.5	85.8	290.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

erosion is also less.

County results The results for Buena Vista County are somewhat different as shown in Table 260. The difference is that slightly less land is available for close grown crops, hay and pasture in CPS-3a than

Table 260. Population (Rossmiller), OBERS crop (Gibson) and livestock production, land and water use, and soil erosion in Buena Vista County using crop planting scenario No. 3a with no erosion control measures during the period 1967 to 2020

Item	1967	1980	2000	2020
Population, 1,000 persons	20.8	19.8	18.7	18.4
Farm production met?				
Corn	Yes	Yes	Yes	Yes
Soybeans (million bushels deficit)	Yes	Yes	Yes	Yes
Cattle	Yes	Yes	Yes	Yes
Hogs	Yes	Yes	Yes	Yes
Water supply met?				
Urban[a]	Yes	Yes	Yes	Yes
Rural[b]	No	No	Yes	Yes
Irrigated corn				
Inches/acre/year	0.0	0.0	19.1	0.0
Acres, 1,000	0	0	105.7	0
Recreation needs met?	Yes	Yes	Yes	Yes
Soil erosion, million tons/yr	3.4	3.5	3.8	3.4
Terraces				
Class III, 1,000 acres	0	0	0	0
Class IV, 1,000 acres	0	0	0	0
Cost, million dollars	0	0	0	0
Reservoirs needed?	No	No	No	No
Land use, 1,000 acres				
Corn	134.2	134.2	105.7	113.2
Soybeans	85.7	135.2	169.0	151.3
Close grown crops	17.6	17.6	17.6	17.6
Rotation hay and pasture	36.5	5.5	0.1	9.8
Pasture	24.8	6.3	6.3	6.3

[a]Includes domestic, municipal, commercial and industrial.

[b]Includes domestic and livestock.

in CPS-2a. Otherwise the results are about the same: all crop and livestock demands are met and soil erosion is somewhat less.

Summary

The results shown in the foregoing tables bear out what intuition tells us should be the results of using higher yields. Crop and livestock demands are met. Less land is needed to meet the demand for row crops and soil erosion is less. Another effect of these increased yields is the decrease in the corn acreage which must be irrigated, a decrease of about 600,000 acres.

The corn and soybean yields which will occur in the future cannot be estimated accurately at this time. Any number which is used is a judgment decision. However, the results obtained through using the goal programming model indicate that higher yields have a beneficial effect on the land and water resources of the region. Thus, money spent on research to improve yields would be money well spent.

Using Gibson's higher yields has the same effect on future land use as would a reduction in future crop production demands. If the future demand for corn and soybeans, as presently projected by OBERS, is too high, then a reduction in future demand will have the same effect as an increase in crop yields — less land will be needed for corn and soybean production as compared to the author's estimates. Thus, actual future demands for agricultural production, and the role that Iowa is asked to play in meeting these demands, could be a major factor in determining the amount of land which will have to be devoted to row crop production in the future.

Sources of Water

Bishop, Hendriks and Milligan (1971) have suggested that the various sources of water be grouped under three headings: primary supply, secondary supply and supplementary supply. Surface water and ground water were included under primary supply. Municipal effluent, industrial waste and agricultural return flows represent the secondary supply, and imported water and desalination are the supplementary supply. Three sources, surface water, ground water and imported water, are used in this study of Northwest Iowa.

The other sources are not utilized for the following reasons. Municipal effluent and industrial wastes are returned to a watercourse after treatment. In many locations these effluents comprise a major portion of the flow in the streams and at times are the entire flow in an otherwise dry stream. The consequences of removing these flows from the streams and using them for some other purpose, such as land application for irrigation, have not been investigated, i.e., the consequences to the stream environment itself. However, the protected low flows established by the Iowa Natural Resources Council largely prevent appreciable reuse during drought periods. This reduces the need to investigate this alternative and tends to avoid any error introduced by neglecting it. Agricultural return flow is not a source of water in Northwest Iowa. Only supplemental irrigation is used and the application rates and volumes are such that this use is usually 100% consumptive. Many sources of water in Northwest Iowa contain high concentrations of total dissolved solids. Some are used for water supply, however, the problems detailed by Laverentz (1974) preclude their use on a larger scale than exists now.

Urban, rural residential and livestock demands

Regional water demands for urban, rural residential and livestock purposes during the period 1980-2020 for the author's and the state of Iowa's population projections are summarized in Table 261. The average daily demand in 1970 was 36.5 MG. The author's projections indicate a 12% increase in water demand in 1980 and a 33% increase from the 1970 demand by the year 2020. The projections done for the state of Iowa by Taylor (1976) indicate a 22% increase in 1980 and a 73% increase by 2020.

Table 261. Summary of regional average and peak water demands for urban, rural residential and livestock purposes using two population projections for the period 1980-2020

Year	Rossmiller		State of Iowa	
	Average use MGD	Peak use MGD	Average use MGD	Peak use MGD
1980	40.9	74.5	44.4	81.2
2000	44.7	80.2	54.6	99.6
2020	48.6	87.1	63.1	115.2

The increase in peak demands based on the author's projections range from 6.3 MGD in 1980 to 18.9 MGD in 2020. Assuming that all increased demands would be met from new wells in the sand and gravel aquifers of the region, a total of 15 new wells would be needed in 1980 and 44 new wells by 2020. This is a small increase and would pose no burden on the water resources of the region.

The increase in peak demands based on the projections by Taylor (1976) range from 13 MGD in 1980 to 47 MGD in the year 2020. Using the same assumption as above, a total of 31 new wells would be needed in 1980 and 110 new wells by 2020. Again, this number of new wells would pose no burden on the water resources of the region.

Thus, no matter which set of projections more accurately reflects the future urban, rural domestic and livestock water demands of the regions, the ground water resources of Northwest Iowa are adequate to meet this increased demand, providing the availability estimates used in this study are accurate.

Irrigation demands

The regional water demands for each of the seven crop planting scenarios using the author's yields and with erosion measures in place during the period 1980-2020 are summarized in Table 262. The demands are zero in scenarios 1 and 7 since no irrigation is allowed in these two scenarios. These demands are based on a drought with a 50-yr recurrence interval and future demands for corn and soybeans as projected by OBERS; therefore, they represent an upper limit (goal) for irrigation water demands. Some years in some scenarios indicate much lower demands than others. This is because only one, two or three counties require irrigation water. The higher demands are indicative of water for irrigation being used in all 12 counties.

Regional irrigation water demands for four crop planting scenarios using the author's yields and no erosion control measures for the period 1980-2020 are summarized in Table 263. Table 264 summarizes the regional irrigation demands for three crop planting scenarios

Table 262. Summary of regional irrigation water demands using the author's yields and with erosion control measures in place during the period 1980-2020

Scenario	Demand for irrigation water, MGD		
	1980	2000	2020
1	0	0	0
2	430	4640	1980
3	0	4420	1980
4	4260	5220	4880
5	3720	5320	4880
6	2470	4850	3120
7	0	0	0

Table 263. Summary of regional irrigation water demands using the author's yields and no erosion control measures during the period 1980-2020

Scenario	Demand for irrigation water, MGD		
	1980	2000	2020
1	0	0	0
2	590	3880	1310
3	0	3330	1310
7	0	0	0

Table 264. Summary of regional irrigation water demands using Gibson's yields and no erosion control measures during the period 1980-2020

Scenario	Demand for irrigation water, MGD		
	1980	2000	2020
1	0	0	0
2	0	920	0
3	0	1230	0

using the corn and soybean yields estimated by Gibson (1976) and no erosion control measures for the period 1980-2020.

The difference in demands, between irrigation and all other demands combined, ranges from 4 to 46 times greater for irrigation. Peak urban, rural domestic and livestock demands total 115 MGD in the year 2020 while irrigation demands range from 430 to 5,320 MGD. Irrigation demands are reduced by about 20% if no terraces are constructed. Demands for irrigation water are reduced by about 75% if no terraces are constructed and the higher crop yields of Gibson (1976) are used.

Are the water reservoirs of the region sufficient to meet these demands? The 24 reservoir sites will yield a total of about 870 MGD. Assuming erosion control measures are required, the volume set aside for sediment and storage could be reduced. This increase in usable volume for water supply will increase the yield of the reservoirs by an additional 300 MGD. The potential buried channel aquifers in Clay and Dickinson Counties will yield about 45 MGD on a long-term basis. Constructing 100 wells in each county along the interior rivers will yield about 520 MGD, again on a long-term basis. If 200 wells are constructed along the Big Sioux River in each of the three counties which border the river, an additional 260 MGD can be made available. A total of 600 wells in the Missouri River flood plain in Woodbury County will yield about 1,510 MGD. The grand total long-term yield of the above systems, from both surface and ground water sources, is just over 3,500 MGD.

The previous paragraph indicated that 100 wells would be constructed in the sand and gravel aquifers along the major rivers in each of the 12 counties which comprise the study region and that these 1,200 wells would yield a total of 520 MGD. Assuming that these wells were in operation 12 hours a day during a 120-day irrigation season, they would yield about 95,800 acre-feet a year. Recent estimates of the Iowa Geological Survey indicate that the alluvial sands and gravels of the interior streams in Northwest Iowa contain about 1,000,000 acre-feet of water in storage and have an average annual recharge of about 100,000 acre-feet (Iowa Natural Resources Council, 1978). Figure 32 shows the locations of the interior streams in Northwest Iowa. Assuming 25 miles of major streams in each county and a well on each side of the stream, well spacing would have to be one-half mile in order to construct 100 wells per county.

Another alternative source of water is to construct a surface intake on the Missouri River and pipe water to Northwest Iowa. The average flow in the river at Sioux City during 1977 was about 29,500 cfs (U.S. Geological Survey, 1978). If 10% of this average flow were diverted during the irrigation season, an additional 1,900 MGD could be made available. One other source of water could be made available, a surface intake on the Big Sioux River. The average flow in the river over the past 49 years is 820 cfs, however, the minimum flow on record is 4 cfs which occurred on January 17, 1977 (U.S. Geological Survey, 1978). Thus, the Big Sioux River would not be a reliable source of water unless a reservoir were constructed. Assuming a yield of one-half the average flow could be developed, an additional 265 MGD could be made available. The Corps of Engineers had investigated a reservoir site on the Big Sioux River but it was not included in this study because of its cost and social, physical and environmental impacts.

Based on the above, sufficient water could be developed to meet the irrigation demands on about 1.2 million acres of corn during a 50-yr drought _if_ some group or combination of groups were willing to invest about a billion dollars. If not, then some lesser amount of land could be irrigated for some less severe drought for some lesser amount of money.

In this case the question arises as to which source or combination of sources of water should be developed. Table 265 lists the six least expensive sources of water for irrigation in each county in Northwest Iowa. The annual costs include development, transmission, operation and maintenance costs. All ground water sources are included plus half of the reservoirs. These are the sources which kept appearing in the final tableau of the goal programming model. The ground water sources are generally cheaper but the cost of transmitting water from the Big Sioux and Missouri Rivers to distant interior counties is such that reservoirs located in these or nearby counties become a less expensive alternative.

The five potential reservoir sites which appear most often in Table 265 are Mill Creek in Cherokee County, Little Rock River in Lyon County, West Fork of the Little Sioux River in Woodbury County, Maple River in Ida County and Mud Creek in Woodbury County. These sites, and others if desired, can be subjected to further detailed study to determine their beneficial and adverse impacts if they were to be constructed in the future.

Table 265. Locations, annual costs and yields of the six least expensive sources of water for irrigation in each county in Northwest Iowa

County	1	2	3	4	5	6
Buena Vista	IR-81[a]	R2[b]-135	R16-324	MR-337	BS-342	R3-361
Cherokee	IR-81	R2-104	BS-222	MR-241	R8-243	R3-252
Clay	BC1-66	IR-81	BC2-82	R11-127	R2-225	R9-328
Dickinson	IR-81	BC413-89	R9-328	BS-342	R2-345	R6-518
Ida	IR-81	R8-159	R23-173	MR-241	R21-252	R24-255
Lyon	BS-74	IR-81	R9-114	MR-329	R2-375	R23-461
O'Brien	BC15-75	IR-81	R2-135	R11-155	R9-178	BS-222
Osceola	IR-81	R9-178	BS-222	R2-255	MR-433	R23-557
Plymouth	BS-74	IR-81	R2-105	MR-153	R21-161	R23-174
Sac	IR-81	R16-192	R2-210	R8-243	R23-283	MR-297
Sioux	BS-74	IR-81	R9-126	MR-249	R12-249	R2-254
Woodbury	MR-69	IR-81	R23-106	R21-161	R24-162	R22-435

[a]Annual cost in dollars per million gallons (MG).

[b]IR — aquifer of an interior river, 100 wells, 43 MGD; BS — aquifer of the Big Sioux River, 300 wells, 129 MGD; MR — aquifer of the Missouri River, 100 wells, 252 MGD; BC1 — buried channel aquifer at site 1, 4 wells, 6 MGD; BC2 — buried channel aquifer at site 2, 6 wells, 9 MGD; BC413 — buried channel aquifer at sites 4 through 13, 31 wells, 27 MGD; BC15 — buried channel aquifer at site 15, 4 wells, 3 MGD; R2 — reservoir on Mill Creek, 106 MGD; R3 — reservoir on Silver Creek, 12 MGD; R6 — reservoir on Stony Creek, 19 MGD; R8 — reservoir on the Maple River, 126 MGD; R9 — reservoir on the Little Rock River, 109 MGD; R11 — reservoir on Waterman Creek, 61 MGD; R12 — reservoir on Deep Creek, 16 MGD; R16 — reservoir on the Boyer River, 34 MGD; R21 — reservoir on Mud Creek, 15 MGD; R22 — reservoir on Reynolds Creek, 21 MGD; R23 — reservoir on the W. Fork of the Little Sioux River, 127 MGD; R24 — reservoir on Wolf Creek, 28 MGD.

Summary

Peak water demands for all urban, rural domestic and livestock purposes for both the low and high population projections can be met without stressing the water resources of Northwest Iowa. The same cannot be said for irrigation demands. One scenario requires over 5,000 MGD to be applied to over a million acres of corn. This volume of water could be made available if an investment of about one billion dollars is made. This includes the purchase of about 90,000 acres for reservoir sites and the laying of hundreds of miles of pipeline. The impacts of this and other decisions on the land and water resources and the people of Northwest Iowa and the trade-offs which could take place are discussed in the next section.

Impacts and Trade-Offs

Even though they were not identified as such, the previous sections contained several impacts and trade-offs concerning the population and the utilization of the land and water resources of Northwest Iowa. These impacts and trade-offs occur in many areas: social, political, economic, financial, legal, institutional, physical and technical. Most, if not all, of these impacts and trade-offs in all of these areas are interdependent to some extent. Thus, if a discussion of the impacts and trade-offs which occur, when certain decisions or events eventually take place in Northwest Iowa, is not clear-cut or orderly, wanders over a variety of topics, it is because this is the nature of the problem — it is complex and involves many aspects of people's lives and their use of resources.

Population

How many people will live in Northwest Iowa in the future? Two projections have been presented. Both foresee a continued decline in the number of farmers in the region. One projects a decline in the regional population while the other projects an increase in population.

Which is correct? What are the impacts of each?

Both project a decline in the farm population from 69,000 in 1970 to about 41,000 in the year 2020. This continues a trend which has existed for the past 50 years. The present trend of increasing farm size is also projected to continue. These two trends, coupled with increased demands for farm products, means that the trend towards increased mechanization of farming operations will also continue. This will require more farm machinery, more manufacturing plants, and more gasoline and oil products to run the machinery. The trend to larger equipment will probably also continue with its negative effects on soil erosion and the need to reconstruct terraces originally built for smaller equipment.

If the lower projection more accurately reflects the future population of Northwest Iowa, then there will be fewer people to be employed in the cities, to pay for local and county services, to maintain and improve the school systems, to maintain and improve the transportation systems, to maintain and improve the water supply and pollution control systems, to maintain and improve the recreational facilities, to pay for all the other services we have come to expect as essential services of government. Two counties would have fewer than 10,000 inhabitants and nine of the twelve counties would have populations of less than 20,000. And while there would be fewer people, they would still be as widely scattered as they are at present.

This diffusion of people throughout the region could be a problem but it could also be an opportunity. The state of Iowa contains about 100,000 miles of highways, about 1,000 miles per county. Most of this mileage is in the secondary road system which is maintained by the counties. The cost of maintaining this entire system places a large financial burden on the counties. If a portion of the system could be abandoned, maintenance costs would obviously decrease. Many social and political implications arise. Farmsteads could be moved to certain intersections or even to the edge of communities. The roads themselves could become field access lanes or could be reconverted to tillable land. Assuming that 20% of the system in each county could be abandoned and that the right-of-way width is 60 feet, then another 17,500 acres in the region could be used for farming. Relocating the farmstead locations could also have an effect on the length of pipeline required for the rural water systems. Land ownership changes or trades, if they could be achieved, would assist in such a relocation.

However, simply writing the words "abandoning the highways" and "relocating the farmsteads" does nothing to solve the social and political problems. The farmers are accustomed to having the county maintain the road systems; do they want to take over the maintenance themselves? Current Iowa law sets up the procedure for formally abandoning highways. The commission which decides if the right-of-way should or should not be abandoned is made up of local residents. The social and political pressures from their neighbors would be difficult to withstand. And requiring someone to move his home a quarter or half mile so that a roadway can be abandoned or a pipeline can be shortened is asking for a lot. Social and economic repercussions must then be addressed.

If the population does decrease in the future, the 73 cities projected to decrease in size may become less viable and 22 of the 41 cities projected to increase in size will still have 2020 populations of less than 1,000 inhabitants. With fewer persons constituting the labor force, industry will have less incentive to locate in the region. As a corollary impact, since new industries and businesses are not locating in the region, the excess labor force that does exist may migrate elsewhere to find work, thus continuing the downward trend in population.

Assuming that the trend to bigger farms and fewer farmers continues, the rural farm population in 2020 will be one-third of what it was in 1900 and just 60% of what it was in 1970, some 27,500 farmers and their families less. With 27,500 fewer customers in the future, many firms will go out of business and those remaining will most likely be concentrated in the larger cities. If new jobs are not created locally for these people, both the 27,500 farmers and their families and the employees of those firms which go out of business, they will have no other choice but to leave the region and seek employment elsewhere.

Some of those who are nearing retirement age may decide to remain in the region. However, a percentage of these retirees may not have sufficient funds to see them through their retirement years and they will impose further stress on county and state social service programs. Some with adequate funds may move to warmer winter climates, thus supporting the decline in population and in economic viability.

While these lower population numbers do have negative aspects, they also have positive connotations in terms of water resource utilization. The total volume of water demanded in the future will still be greater than it is today due to increased per capita use and expanded usage by some user groups. But in terms of water supply, pollution control, recreation and energy, lesser volumes of water will be needed in the future for the lower population projections than for the higher projections. In either case, the water resources of the region are adequate to handle the future demands. The assumption has been made that conservation of water will not become a way of life for the population of Northwest Iowa during the projection period.

The higher population projection envisions an increase in population in Northwest Iowa from 288,600 in 1970 to 323,700 in 2000 and to 341,200 in 2020. Since the number of farmers and their families are projected to decrease by about 26,000 during this 50-yr period, then the urban and suburban areas must attract 78,600 persons in order for this projection to be accurate. The only way that this will happen is for employment opportunities to increase.

Here then is an important implication of this study. Unless and until the state and federal governments take a more active role in rural development, the present trend of out-migration will continue. Their success to this point in time has not been overwhelming. Presently, federal regulations classify communities under 10,000 population as rural for certain types of support. This would include 112 of the 114 communities in the region since only Spencer and Sioux City have populations greater than 10,000. Thus the opportunity exists for future improvement if assistance is provided. However, the magnitude of assistance needed may be massive, and may well create adverse impacts elsewhere in the midwest or in the nation.

Land resources

Population levels impact not only the water resources of a region, but its land resources as well. Land must be used to house the increases in urban and rural population as well as to provide places for them to work and to supply their various needs. Using the author's lower projections, the demand for additional land for these intensive-use purposes is about 5,000 acres in the year 2000 and about 10,000 acres in the year 2020. Based on the projections by Taylor (1976) for the state of Iowa, the demands are 30,000 and 46,000 acres in these same two years, respectively. The assumption is made that these demands will be met because developers will pay prices for the land that farmers will accept. Most of this land will probably come from those land use categories which involve agricultural production and thus reduce the land available to support future crop production. The total area of Northwest Iowa is about 4.5 million acres.

The most important impacts on the land resources will come from the agricultural sector. In particular, the impacts will arise from trying to meet the future demands for corn and soybeans projected by OBERS. One scenario requires that over 3.3 million acres be devoted to these two crops with more than 1.1 million acres of corn being irrigated. The costs of irrigation would approach a billion dollars. This production could be accomplished and soil erosion reduced from 14 to less than 5 tons per acre by investing another $400 million and practicing conservation tillage methods.

One alternative would be to not irrigate and to not construct any terraces or practice any type of erosion control. The same future production could be maintained but 3.7 million acres would have to be devoted to corn and soybeans and soil erosion would increase to an average of 21 tons per acre. Water quality in the region would be degraded not only by the sediment but also by the increased amounts of fertilizers, herbicides and pesticides contained in the runoff.

Another alternative would be to not allow conversion of any more land to corn and soybean production. The irrigation demands are somewhat less and soil erosion is reduced to less than 3 tons per acre, but the trade-off is a reduction in potential income, about $250 million per year. This alternative ignores the OBERS projections and produces that volume of agricultural products based on a decision made at the local, state or federal level not to convert any more land to row crop production. If the demands for more production are accurate, then they would either not be met or the 35 million bushels of soybeans would have to be produced elsewhere.

At some point in time, some group of people at some level of the private sector and/or government is going to have to make some decisions concerning crop production levels, soil erosion, irrigation and financing all of the above.

Other impacts and trade-offs occur if certain decisions are made. If the decision is made to construct reservoirs to provide water for irrigation, then about 87,000 acres would probably be removed from agricultural production. These same 87,000 acres would become available for land- and water-based recreation. These 87,000 acres would also provide flood control benefits to both urban and rural areas. However, before any reservoirs were constructed, these benefits would have to be weighed against the costs of the projects, both economic and environmental.

Soil erosion affects both the quality of the surface water resources and the quality of the land resources themselves. Class I and II land can be protected by using contouring or minimum tillage. Class III and IV land require terraces. Terrace costs are about $360 per acre on Class III land and about $420 per acre on Class IV land. Current corn yields on Class III and IV land are about 80 and 60 bushels per acre, respectively. Current soybean yields on these two land capability classes are about 30 and 25 bushels per acre, respectively. Current production costs for these two crops are listed in Table 117.

A current federal program provides some cost sharing funds for the construction of terraces. These funds are allocated to the individual county committees who provide 50% to 75% of the funds needed to construct the terraces. Thus, the farmers must pay the remaining 25% to 50% of the cost. It is assumed in this study that they will share 50% of the cost and will finance their share by borrowing in the private market at a rate of 10% for 10 years. Table 266 lists the production costs plus the farmers' share of terrace construction costs in dollars per bushel of corn and soybeans on Class III and IV land.

Table 266. Production costs of corn and soybeans plus farmers' share of terrace construction costs on Class III and IV land, dollars per bushel

LCC	Corn	Soybeans
III	3.30	7.00
IV	4.50	8.60

With corn selling at $2.00 per bushel and soybeans at $7.00 per bushel, it is obvious that it is not profitable for farmers to construct terraces. Depending on the crop planting scenario used, terraces should be constructed on from 0.8 to 1.3 million acres of land at a cost ranging from $290 to $405 million. During 1978 in Iowa, terraces were constructed on a total of 1,470 farms. The federal government's share of the cost was $2,345,400 (Roy Fagan, ASCS, Des Moines, Iowa, personal communication, April 26, 1979). Based on this present rate of cost sharing, over 500 years will elapse before the 800,000 acres in Northwest Iowa have terraces constructed on them. The state and federal governments <u>must</u> give the reduction of soil erosion a higher priority in their budgets or Iowa will lose its capability to produce its share of agricultural products.

With these erosion control measures in place, soil erosion can be reduced from 66 million tons in 1967 to a range of 10 to 12 million tons per year depending on the crop planting scenario used. If the present trends are allowed to continue and with no erosion control measures in effect, soil erosion in the future could range up to 97 million tons per year. This is an average rate of 21 tons per acre per year over the entire Northwest Iowa region, including urban, forested and water areas. The average rate is 22 tons per acre per year if only the land used for agricultural purposes is included. As indicated in Appendix N, most of the erosion takes place on land devoted to the production of corn and soybeans.

Sometime soon, the people of Iowa and the nation must realize that our soil resources are not inexhaustable, but are being depleted rapidly. The technical means are at hand to slow the erosion process down to tolerable levels. The only ingredients lacking are the financial investment needed to protect the land and the social acceptance of "living" with terraced lands. Decisions will have to be made and soon if Iowa is to continue in its present role of being a major supplier of agricultural products to both the nation and the world.

Water resources

If the decision is made to drill wells along the Missouri or Big Sioux Rivers and to transport this water inland for irrigation purposes, questions may arise as to the legality of these transfers. Interstate legal problems could arise if a surface water intake was constructed on the bank of the Missouri River for this same purpose. Legal problems might also arise if water were transferred from one watershed to another within the Northwest Iowa region. Certain state and federal institutions could also become involved if certain decisions are needed.

A major decision that must be made is whether irrigation should be used on a large scale. If the decision is made in the affirmative, then another decision must be made as to who would pay for the construction of the facilities needed to provide irrigation water. If the farmers themselves finance the construction of these facilities, they would have to borrow the needed funds in the private market, currently at a rate of 10% for 10 years. Only Class I and IIe land used for corn is assumed to be irrigated. Using a yield of 170 bushels per acre for irrigated corn on Class I land and a total investment of a billion dollars to irrigate 1.1 million acres, the cost of irrigation alone is about $1.10 per bushel. Current production costs of corn without irrigation are about $235 per acre, thus total production costs including irrigation would be a minimum of $2.50 per bushel. Corn currently sells for about $2.00 per bushel, so farmers could not pay the total costs of providing water for irrigation. If the federal government wants Iowa farmers to produce row crops at the levels projected by OBERS, then some portion of the costs of irrigation must be borne by the state and/or federal governments. Future energy costs, either oil or electricity, to transmit and spread the water may rise to the point that even with some government subsidies, irrigation may not be profitable.

Providing sufficient water for irrigation to produce a full corn crop during a 50-yr drought which lasts for two years requires a huge commitment of money, material, labor and water. The decision could be made to provide only enough water for a 5- or 10-yr drought or some other recurrence interval. Decisions would then have to be made as to which source or combination of sources should be developed. Ground water could be favored over surface water in all cases so that no reservoirs would be constructed. In some counties this would impose a higher cost on the farmers since some reservoir sites will provide water for irrigation at a lesser cost than ground water.

A related decision that must be made is the importance of additional opportunities for water-based recreation and a reduction in urban and rural flood losses to the region.

<u>Other related social and political problems</u>

Some of the crop planting scenarios require that row crops be planted on the less sloping land and on land presently used for hay and pasture. In 1967 there were about 46,600 acres of Class I land used for rotation hay and pasture and about 23,700 acres of Class I land were utilized for permanent pasture. In 1967 about 171,100 acres of Class II land were used for rotation hay and pasture and about 145,800 acres were utilized for permanent pasture. This is a total of 387,200 acres of the best land in Northwest Iowa devoted to hay and pasture. This is the least erosion-prone land in the region and is capable of producing the highest yields of corn and soybeans.

A much more efficient use of this land would be to produce row crops — but how do you tell the owners of the land that they <u>must</u> produce corn <u>with irrigation</u> instead of raising hay and grass? What incentives are they to be given to make this change or what penalties should be assessed? At present this land could produce 66 million bushels of corn, one-fourth of the total demand projected for 1980. No erosion control measures are needed on Class I land to meet the 5 ton per acre per year standard. On Class II land either contouring or minimum tillage is sufficient to meet the standards. What incentives should be given or penalties assessed to have these farmers practice erosion control?

This question is even more important for those farmers who own Class III and IV land.

Assuming that the decision is made to irrigate on a large scale in Northwest Iowa, who will construct the various reservoirs, drill the thousands of wells and lay the hundreds of miles of pipeline? More importantly, who will operate and maintain the reservoirs, wells, pipelines and pumping stations? Will this task be given to an existing agency or will a new agency be created for this specific task? How will the costs of operating and maintaining this system be assessed and who will pay them? Numerous jobs would be created if the decision was made to go ahead with this alternative. The benefits and costs, both economic and environmental, of this alternative must be investigated thoroughly before proceeding.

The assumption is made in the model that all Class VI and VII land used for agricultural purposes in 1967 would be converted to permanent pasture. If livestock were allowed to graze on this land some type of erosion control would be needed to meet the standard. Some farmers may not want to raise cattle or may not be able to make a living raising grass and hay. There are about 80,000 acres in this category in Northwest Iowa. One alternative would be to buy this land and convert it to forest. Assuming a cost of $500 per acre, the total cost to buy the land would be $40 million. What would be the source of these funds?

Another assumption made in the model is that land demanded for all urban purposes and for rural residential purposes would be converted to these uses. This is the current trend in Iowa. The state legislature has been debating future land use policy for several years. A legislatively-appointed state land preservation committee has recently completed its study. Hopefully, the day is near at hand when the state will have a formal land use policy and a well-defined integrated program concerning the implementation of this policy.

A related problem, one which has been discussed before, is how the economic viability of the smaller communities is to be improved. One answer is to prevent out-migration by providing more employment opportunities, especially in sectors not related to agriculture. The answer is easy, but the specific solutions are much more difficult.

Based on the above results, the most feasible method of meeting both the NED and EQ objectives in Northwest Iowa is to relax the restriction that future agricultural production in each county cannot be more than its percentage of total 1967 regional production. The model could be changed to allow each county to produce whatever it can in each CPS. A total of about 150,000 acres of land used in 1967 for agricultural purposes on LCC II through V are not used for row crop production in the year 2000, the critical year, in Clay, Lyon, Plymouth and Sioux Counties. These 150,000 acres could produce about five million bushels of soybeans. This would eliminate the deficit in four of the seven crop planting scenarios as shown in Table 244.

More soybeans could be produced by lifting the restriction on the use of Class VI and VII land. These two classes would add another 80,000 acres to the total land area available for crop production and could yield an additional 1.5 million bushels of soybeans.

Additional land use categories could also be utilized for row crop production, as is done in CPS 7. Urban and built-up and water areas could not be converted to row crops. Much of the "other" land use category could not be converted because it includes land used for farmsteads and farm roads, rural nonfarm residences and ditch banks. Investment tracts and feedlots are also included in this category and could be converted to row crops. However, the conversion of feedlots would reduce the potential for cattle production. The other two categories are forests and conservation use only and conprise 86,000 and 476,000 acres, respectively. Much of the land included in the conservation land use category is composed of marsh land and wildlife habitat. Some of the marshes could be drained and a portion of the wildlife habitat could be eliminated if needed for crop production. If half of this land use category were converted to row crops, an additional ten million bushels of soybeans could be grown. If half of the forests were converted, another two million bushels of soybeans could be produced.

These increases in the NED objective must be weighed against the losses in the EQ objective. However, the problem of quantifying losses in the EQ account has not been addressed in this study. The number of acres of wildlife habitat lost is not a meaningful measure. What is the cost of eliminating 200,000 acres of wildlife habitat in terms of species diversity and ecological stability? What is the cost of losing 43,000 acres of forest?

In conclusion, there are many alternative methods of utilizing the human, land and water resources of Northwest Iowa in the future. Some of them will enhance both the economic and environmental health of the region. Hopefully, our future leaders, both in the public and private sectors, will have the fortitude and foresight to make the "correct" decisions. The value of goal programming models may be appreciable, in providing the information base upon which these decisions will be made.

IMPLICATIONS FOR GOAL PROGRAMMING

General Perspective

As discussed in previous sections, during the first half of this century most water resource development projects had a single purpose: power generation, flood control, navigation or water supply for irrigation, industrial or domestic uses. The single objective of all these projects was to improve national economic efficiency, which was expressed in a benefit-cost ratio. In the 1960's a new dimension was added to development projects and programs, that of environmental quality. This dimension had always been present but had not explicitly been taken into full account in the planning process.

In 1973 the U.S. Water Resources Council formalized this new procedure in its Principles and Standards. Both national economic development (NED) and environmental quality (EQ) were given equal status in the planning process. These two objectives were to be displayed in a system of four accounts: NED, EQ, regional development (RD) and social well-being (SWB). Alternative separate plans were to maximize NED and EQ, and other alternatives were to emphasize plans having results lying between these two extremes.

During the 1960's and 1970's several methodologies have been investigated which can include these dual objectives (NED and EQ) and multiple purposes (water quality, water supply, flood control, recreation, watershed management, navigation, irrigation, etc.). What is being sought is a methodology which can bring together into a single model, however large, all aspects of a problem and their interactions.

This study has concentrated on investigating the use of the methodology known as goal programming (GP) to determine if it meets these criteria.

Since the literature contained at most one study which did not use a hypothetical situation to test the goal programming methodology, the decision was made to use a real world situation as the case study. This has provided a better test for both the methodology and application by future users (decision makers such as politicians, administrators and agency personnel). The real world situation presents all the problems that normally show up in the planning process: lack of data in some areas, too much data in some areas, need for intermediate decisions along the way, conflicts between the various publics, planning constraints, insufficient financial resources. The case study area chosen for this investigation, the northwest region of Iowa, was selected because it provides a full complement of problems inherent in planning the development of land and water resources.

This study used goal programming in the context of a screening model to illustrate the trade-offs and impacts that would take place if decision makers were to implement certain policies and programs.

Methodology

Lee (1972) indicated that the goal programming approach is an appropriate, powerful, and flexible technique for analysis by the troubled modern decision maker, who is burdened with achieving multiple conflicting objectives under complex environmental constraints.

GP allows a simultaneous solution of a system of equations having complex multiple objectives and is capable of handling multiple goals with multiple subgoals. The GP approach uses an ordinal hierarchy among conflicting multiple goals so that the low-order goals are considered only after the higher-order goals are satisfied or have reached the desired limit. GP is an optimizing technique which minimizes the absolute difference between the goals which have been set and what can be achieved given the constraints which exist. These constraints can range from physical limits on resource availability to social and political interactions.

Some writers consider GP simply as an interesting modification of linear programming (LP). Other writers take the view that GP is a general formulation capable of solving real world problems and that LP is one special case of GP. After completing this study, the author subscribes to the latter view for the following reasons.

The case study of Northwest Iowa illustrates that the GP methodology reflects reality. In the land and water resource planning of Northwest Iowa, there are certain goals that we would like to attain. Some of these goals conflict with each other and there never seems to be enough resources available to meet all the goals. Thus, priorities were set for the case study, with some goals more important than others. There will be a willingness to make trade-offs if some goals can be met and others partially met or if there is some progress towards achieving all the goals.

The GP methodology in the case study of Northwest Iowa provided a logical, easily understood process. Other multiple objective methodologies might also provide a similar process, but this is particularly true of GP. This process enables the analyst to proceed from goal definition to goal achievement in an orderly manner. Much work is required to properly prepare the GP model, but in so doing the analyst is forced to understand the problem completely. This understanding aids in developing a better definition of interactions and this in turn produces more reliable results. "Proper preparation" involves the manner in which constraints are included. Constraints can be legal, institutional, social, economic, financial, physical, technical and political in nature.

The GP process as applied consisted of a series of six steps. First, the problem and its scope were defined. Existing and projected problems and demands were identified. The objectives, components of objectives and specific goals which would contribute to the achievement of the objectives also were identified. Second, the availability and capability of resources to meet the identified problems and demands, as well as the constraints on the utilization of the resources, were identified and evaluated. Third, each of the goals, constraints and resources were converted to an equation in the GP format. This conversion process is summarized below. These first three steps involve considerable thought and data collection, but they also force the analyst to understand fully the problem he is trying to solve.

Fourth, the appropriate deviation (or deviations) from each of the equations were placed into a commensurate, ordinal priority level. The decision as to which goals and constraints are placed in which priority levels was made by the author for the case study, the decision makers, the publics, or any combinations of these groups. In the real world, the manner in which priority levels are set and assignments to priority levels are made is important in order that the solution determined accurately reflects the desires of the affected population. These deviations may represent goals or constraints: corn production should be at a certain level, only so much land exists in a county, only so much water is available from a particular source, soil erosion should be reduced to a certain level, water from a particular source can only be used for a certain purpose or purposes.

Fifth, weights were assigned to the deviations within a given priority level. These weights are positive cardinal numbers which reflect the importance associated with the minimization of a deviation variable assigned to a given goal or constraint. These weights can be judgment values or they can reflect inherent features of the problem. The case study problem was then solved using a modified simplex method and the optimal solution determined.

Sixth, and last, in any GP model including that used in the case study, the goals, limits on constraints, priority rankings and weights can be changed to determine the effects these changes will have on the original solution. This will give the decision makers added insight into the sensitivity and importance of these changes towards meeting the objectives and goals of the original problem and the trade-offs involved in achieving these objectives and goals as closely as possible.

The process of converting the goals, constraints and resources into equations in the goal programming format repeated that developed previously. The basic form of the equation used in the case study is:

$$f(X) + n - p = b \tag{96}$$

where X is a decision variable

f(X) is the left-hand side of the linear or nonlinear goal equation

n is the negative deviation from the goal

p is the positive deviation from the goal

b is the right-hand side goal constant

In the above description, the word "constraint" or "resource" can be substituted for the word "goal."

In some instances, an exact goal may be set such as the number of bushels of corn projected as the future demand. In other instances, we may not be able to set an exact goal, but we may be able to define a desirable upper or lower limit. For instance, the lower limit for flood losses is zero. Our goal may be to minimize flood losses but we may not be able to agree on a definite value. While zero flood losses may be impossible to achieve, it is certainly a worthy goal.

Three possibilities exist for each equation: the left-hand side (f(X)) can be (1) less than or equal to, (2) greater than or equal to or (3) exactly equal to the right-hand side (b). How these are handled in a GP formulation were listed in Table 1. In type (1) equations, the positive deviation (p) is placed in the achievement function at some priority level and is minimized. Water from some source could be used for several purposes, but we cannot use more than is available. The negative deviation represents the unused water from the source. In type (2) equations, the negative deviation (n) is placed in the achievement function at some priority level and is minimized. One goal may be to provide a certain number of acres for recreational purposes. We do not mind if we overachieve this goal but we want to minimize its underachievement. The positive deviation represents the overachievement of the goal. In type (3) equations, both deviations are placed in the achievement function and both must be zero. An example of this would be that all land in a county must be used for some purpose, but no more nor less than exists.

The left-hand side (f(X)) takes whatever form is appropriate for the goal, constraint or resource involved in that particular equation. The right-hand side (b) is determined from the first three steps of the GP process.

Effectiveness of Methodology

This study has shown that, at least when applied as a screening model to determine the consequences of various policy and program level decisions, the GP methodology is effective in determining how resources should be utilized to meet specified goals and in determining the impacts and trade-offs that would occur if certain decisions are made. The previous section which analyzed the results for the Northwest Iowa study area are an indication of this.

This effectiveness is illustrated in two ways. First, as mentioned above, the printed output from the GP computer model explicitly lists the resources used and the impacts and trade-offs which occur when certain policy decisions are made and/or certain programs are implemented. Second, and maybe more importantly, because of the first three steps in the GP process, the analyst gains insights into the interrelationships which exist and the nature of the trade-offs which would have to take place. This allows him to construct a much more realistic model of the given problem.

An inherent difference between LP and GP is that the objective function of LP can do only one thing at a time; it can directly maximize profits or directly minimize costs, but only one thing at a time. The minimum cost of anything is zero, so the obvious way to minimize costs is not to do anything. No goods are produced and no services are provided. This will occur in a LP problem unless constraint equations are added to the formulation which require some level of performance. The maximum profit is boundless and is impossible to achieve. A more realistic approach is to select an upper limit on profits based on resource constraints and then come as close as possible to achieving this level of profits.

This is the type of approach used in goal programming. Rather than maximizing or minimizing the objective criterion directly, the absolute values of the deviations from preselected goals are placed in an achievement function and minimized. If the value of the achievement function is zero, then all goals have been reached. The constraints placed on our actions usually prevent us from reaching all of our goals, which may be in conflict with each other. GP is capable of handling all of these problems, allowing for a much more realistic representation of real world problems.

Another advantage of GP is that the achievement function can contain a variety of units. The objective function of LP must contain commensurate units. The unit is usually dollars but it could be acres, pounds or days. Whatever unit it is, each variable contained in the objective function must be expressed in that unit or in a commensurate unit. However, the achievement function of GP can contain many different units. The only requirement is that the units of the variables within any one priority level must be commensurate.

Effectiveness of the GP Model

Many studies have developed models which deal with the various aspects of land and water resource development. These include reservoir operation models for various purposes, recreation models, sedimentation models, water supply models, economic models and models for several aspects of water quality. The objective of this study was to use GP as a method of integrating these and other aspects of land and water resource planning into a single model while at the same time conforming to the spirit of the Principles and Standards of the U.S. Water Resources Council. This objective has been fulfilled. While the model developed in this study is by no means yet complete, it represents a good start towards a model which decision makers can use to provide the information base upon which decisions can be made for the future utilization of land and water resources.

Its effectiveness is shown in the amount of information it provides for decision making. Some of these items were discussed in the preceding paragraphs. Two others should also be mentioned. The model was developed as a static model, i.e., in a single run only the conditions at a single point in time can be determined. By running the model as an iterative process, the conditions at several points in time for various alternative futures can be determined. This gives the decision maker additional information on the future impacts and trade-offs that would occur if certain decisions were made now.

The other item is tied to the first. A portion of the printout indicates which sources of water were used for which purposes. By running the model at several points in time, information is provided on not only which sources are utilized but the point in time when they will be needed. Those sources which are selected most frequently in the various runs can then be subjected to more detailed study. Thus the model is effective in screening out those policies and programs which most nearly attain the desired goals but also screens out those particular sources of water which are most effective in achieving these goals.

The algorithm used in this study to minimize the achievement function needs to be improved so that it solves larger problems more efficiently. Problems with many complex interactions, are not solved efficiently. Both study time and computer budget ran out before the exact source of the problem could be determined. The model ran well when smaller problems were entered, problems which included 28 equations, 37 variables and 2 priority levels. However, no results were obtained within reasonable run costs when problems involving 71 equations, 172 variables and 3 priority levels were attempted. A solution methodology which will work has been devised but has not yet been added to the model. This methodology and other possibilities are discussed more fully in the next section.

The completed model has only been used on the study area in the 12-county, northwest region of Iowa. The author is confident that the same model, with some changes in input parameters, will work equally well on a much smaller area, such as a single city or township. This thought will be expressed in somewhat more detail in the next, and final, section.

CONCLUSIONS AND RECOMMENDATIONS

Scope of Water Resource Planning

Water resource planning to meet multiobjective goals is complex. Just as one can state that the universe is large, the foregoing statement provides little to give a starting point or a direct pathway to solve problems. What should be included in water resource planning? The comprehensive outlook requires that the answer be "everything." This is not a very satisfactory answer for someone needing immediate answers to a specific problem, but it does begin to give an idea of the full scope of the problem. What should be included in water resource planning? The research program support in this study was directed to multiple objective decision analysis using goal programming in water resource planning. This dissertation involves land and water resource planning using goal programming. One conclusion that was reached early in the study was that land resource planning and water resource planning must proceed concurrently. The two are so interrelated the planning profession considers that their utilization must be considered jointly.

What else should be included in water resource planning? Change the words "land resource planning" to "land use planning" and the connotation immediately includes all the emotional, social and political debate which has waxed and waned many times in Iowa in the last several years. Institutional impacts including politics are an obvious part of water resource planning. The recent conflict between President Carter and the western states concerning future federal water resource development projects in the arid west is an example of this.

Are transportation systems a part of water resource planning? A major portion of this study has evolved into the use of supplemental irrigation in Northwest Iowa to offset the lack of rainfall as a spur to increased crop production. Now the Milwaukee Road has announced plans to drop all rail service to Northwest Iowa. This is the primary east-west and north-south railroad existing in the region to transport these farm products to market. The Missouri River is navigable up to Sioux City but barge traffic on the Missouri River is not as highly developed as on the Mississippi. Thus, the lack of bulk carriers will mean higher transportation costs, resulting in lower profits to the region's farmers. Lower profits will mean less capital to invest in irrigation systems; systems which would help to smooth out the large fluctuations in annual income caused by varying weather conditions.

Is school district planning a part of water resource planning? Perry Creek in Sioux City is subject to flash floods which periodically cause considerable flood damage to homes and businesses in the western part of the city. The Corps of Engineers studied a large flood control reservoir at the request of local officials. This project is currently shelved because of objections received at the public hearing. The local rural school district indicated that because of the size of the reservoir, several county roads would be abandoned. The increased cost of busing children to school, caused by having to drive around the reservoir, would be the last straw in causing the financial collapse of the school district.

Another objection raised at the Corps' public hearing was that the reservoir would inundate too much farm land. Also, if land use planning in Sioux City was such that the flood plain of Perry Creek had not been allowed to be developed for urban purposes, the structural flood control solution would not have been required. These are other examples of the inseparability of land and water resources.

These examples add two more dimensions to water resource planning, economic and financial considerations.

Is health a part of water resource planning? The plight of rural residents with regards to the quantity and quality aspects of their water supplies has been thoroughly documented. Water quality is an obvious part of water resource planning. This leads us to include all aspects of the environmental quality of our land and water resources as a part of water resource planning. All sources of point and nonpoint source pollution automatically become a part of water resource planning.

What else should be included in water resource planning? The state water plan summary report for Iowa outlines major water management problems in seven functional water use categories and two support areas. These are:

1. water supply
2. flood plain management
3. fish and wildlife and water-oriented outdoor recreation
4. water quality
5. commercial and recreational navigation
6. energy
7. agriculture
8. water availability for multipurpose use

9. institutional relationships, law and government, and socio-economic impacts.

Water resource planning must include contributions from many disciplines. A recent environmental study of a proposed reservoir in central Iowa included the following 21 disciplines: agricultural engineering, agronomy, anthropology, biology, botany, civil engineering, economics, fish and wildlife, forestry, geography, geology, landscape architecture, law, outdoor recreation, political science, regional planning, sanitary engineering, sociology, urban planning, water resources engineering and zoology. Comprehensive planning indeed becomes complex. Goal programming was introduced as a step in the right direction, to assist in the analysis of complex problems.

The first step of the GP process is to define the problem and its scope, to identify existing and projected problems and demands, to identify objectives and to identify the components of the objectives and the specific goals which will contribute to the achievement of the objectives.

What should be included in water resource planning? This then was the dilemma posed in this study, as a model was sought which would include all pertinent aspects of water resource planning and which would fulfill the three objectives of the study:

1. to investigate and demonstrate the potential of goal programming as a planning tool in water resource allocation for competing uses while attempting to achieve the multiple objectives of the U.S. Water Resources Council,

2. to construct the model so that its input requirements,

flexibility of use, and output displays are such that it will become an integral part of the tools used by planners and decision makers at the state and regional levels to implement our desires for a better quantity and quality of life, and

3. to develop, as a secondary objective, a state water resource orientation with the proposed model, to illustrate for the benefit of the present emphasis on state water planning efforts now underway, the local-intrastate-state interactions and how these interface also with the river basin regional and national picture.

How well each of these objectives has been fulfilled will be discussed in turn, after detailing the decisions made as to what should be included in the GP model. Since Northwest Iowa was being used as the study area, an initial decision was made to include only those management categories which were most important in Northwest Iowa. This excluded three categories: energy, navigation and flood control. Energy was excluded because most energy sources are imported from outside the region. That portion of the electrical energy which is produced in the region uses water from the Missouri River for cooling purposes. Iowa law specifically exempts the use of water in the border streams from regulation. Flood control was excluded because it is not perceived as a major problem by the region's inhabitants. However, the manner in which flood control would be included in a GP model is discussed. Flood control storage opportunities were not neglected.

Past, present and future land use is included in the model as are historic and future uses of water for such purposes as domestic, municipal, commercial, industrial (other than energy), recreation, fish and wildlife and irrigation. The sources of water and their availability are included. Legal and institutional implications are also included, within the current Iowa agency organizational structure.

Another major decision that was made was the manner in which water quality was included in the model. Several parameters which describe water quality were considered as well as the data requirements and modeling effort, including run costs, which would be necessary to realistically include these parameters in the model. Soil erosion was chosen as the proxy for water quality since the region is an intensive crop area, and most of the data needed was required for other purposes also, the modeling effort and time requirements were small, and it could also be used as an indicator of the other parameters. Soil erosion also is an indicator of land quality and along with land use is an indicator of environmental quality.

The decision was also made to include time in the model by preparing the input data for estimating results at three points in the future. This not only allowed shifts in the various land and water parameters to be observed through time, but also gave an indication as to the time when certain sources of water should be developed for meeting beneficial use demands.

Fulfillment of Objectives

The first objective was to investigate and demonstrate the potential of goal programming. This objective has been fulfilled and the conclusion reached that GP is definitely a candidate methodology for use in land and water resource planning. The GP model as applied to the case study shows that it assists the planning process, particularly as this process is prescribed by the U.S. Water Resources Council. This is an obvious advantage since all water-related development programs and projects which receive federal funding must follow their principles and standards.

Because of the nature of water resource planning, the model becomes data intensive. As presently written, the GP model requires the following types of input: run identification information, land capability class identification, number of acres devoted to all land uses on all land capability classes in the base year, relative yield potentials for corn and soybeans on all land capability classes, corn and soybean yields on Class I land in the base year, average annual erosion rates for each land capability class on each land use with and without erosion control measures, land and water areas of potential reservoir sites, additions to urban land use and rural residential land use in future years, future increases in corn and soybean production demands, future irrigated and nonirrigated corn yields, future soybean yields, crop planting scenario number, are erosion control measures to be used?, sources and amounts of water available, future water demands for all uses and several items of cost data (development and transmission costs of both surface and ground water, and erosion control costs).

Some of these data are the results of calculations involving other inputs. For example, future water demands include water for people, livestock and crops. This requires estimates of future population, numbers of livestock, and water use rates of various types. Land use and identification of sources of water involves collecting information from several scattered sources.

As Iowans plan for their future, state agencies must bring together into a central location all the types of data which will be needed so that intelligent decisions on resource use and development can be made in the future. The IWARDS program initiated by the Iowa Geological Survey is a start in this direction.

Objective number three has also been fulfilled. This has been done in part by using Northwest Iowa as the study region. The region is similar to the state in that its economy is based to a large extent on agriculture. National demands for agricultural production and for industrial output as well as federal laws, regulations and institutions tend to dictate the manner in which Iowa utilizes its human, land and water resources. These demands plus local demands for land and water for recreation and domestic use place additional stress on these resources. These demands in Northwest Iowa may eventually require that water be transferred from the Missouri River. This will involve Iowa in discussions with other states in the region as to what Iowa's fair share of this water may be.

With some minor changes, the present model could also be used for a larger region, such as the state, or for a smaller region, such as a single county, township or community.

Objective number two has not been fulfilled completely. Here is where more attention and research is needed in the future. As mentioned before, two more items need to be added to the model: land and water demands for energy and the costs and benefits associated with flood control. Each of these could easily be the subject of additional research effort. Another research topic would be to improve the manner in which water quality is handled in the model. Other areas of land and water use such as recreation demands, industrial demands, urban demands and agricultural demands could also be improved and refined within the model.

The other major area that deserves attention is an improvement in the GP methodology itself. As mentioned before, results could not be obtained with reasonable run costs (less than $100.00) when large problems were input. Both time and computer funds were exhausted before this problem could be solved. The source listing of the present model is contained in Appendices L and M. A set of sample printout is included as Appendix N. A complete run using all data might require a thousand dollars or more to achieve final results.

Several items need to be investigated. The possibility exists that the present model is not correctly handling the larger problems. This could be checked in the following manner. Statements could be added to the program which would print out messages at certain stages of the iteration toward a solution. Then incrementally, larger and larger problems could be input to determine at what point the divergence or nonclosure occurs. The possibility exists that the algorithm being used is inefficient and simply requires a larger amount of time to solve the larger problems. This possibility has been discussed and a solution methodology devised which involves using the MPSX system of solving the simplex algorithm. However, merging the MPSX system with the present model is apparently not an easy task. It may require two or three computer runs to obtain a single set of output. A more efficient solution methodology coupled with a model that includes more of the aspects of water resource planning would be needed to completely fulfill the intent of objective number two. Unless a substantial allocation of computer time and budget is available, this testing of the GP model cannot be pursued.

Northwest Iowa

The purpose of this study was to explore the potential of goal programming as a methodology for land and water resource. As a corollary benefit, by using Northwest Iowa as a study region, several conclusions and recommendations can be made concerning the utilization of the region's land and water resources.

With regards to the water resources of the region, they are adequate to meet all demands including large-scale irrigation demands <u>if</u> some user group or groups are willing to invest approximately a billion dollars. The GP model results show that this would involve the construction of 24 reservoirs, thousands of wells, hundreds of miles of pipeline and several pumping stations. This system would be in addition to the wells, pumping stations, treatment plants and pipelines needed for the rural water systems in each county (presently estimated at $5 to $10 million per county).

The water resources will be adequate <u>if</u> the present estimates of availability and amounts of both surface water and ground water are accurate. This is especially true of ground water. The state of Iowa should authorize further study of the ground water resources of Northwest Iowa in order to improve current estimates of the location and availability of ground water in the region. This should include a search for buried channel aquifers. Only the alluvial sand and gravel aquifers were used in this study for new wells due to the action in 1978 of the Iowa Natural Resources Council, prohibiting the use of the Dakota Sandstone aquifer for irrigation purposes.

Supplemental irrigation would require huge volumes of water if consumptive irrigation were practiced on a large scale. This would increase the farmers' gross income in the region and would have a beneficial effect on the entire regional economy. It would also tend to smooth out the year-to-year fluctuations in the farmers' incomes.

The construction of reservoirs to provide water for irrigation would also provide water-based recreation areas and some flood control benefits. If some of these reservoirs were constructed in the counties bordering the Missouri and Big Sioux Rivers, another benefit would accrue. This would enhance social equity since these counties have the lowest per capita incomes in the region and thus are least able to travel to the eastern counties in the region which contain most of the existing water-based recreation facilities.

The GP model illustrates that the technical means exist to reduce soil erosion to the point where the long-term ability of the soil to support crop production is not reduced. This will require the construction of terraces on several hundred thousand acres of Class III and IV land at a cost of about $400 million plus the large-scale use of contouring and minimum tillage on Class I through IV land. If these measures are instituted, erosion in the region can be reduced from the 66 million tons which occurred in 1967 to just 10 million tons per year in the future. If these erosion control measures are not installed, erosion in the future could increase to almost 100 million tons per year.

Additional economic analysis indicates that it is not profitable for the farmers to pay for the construction of either erosion control measures (terraces) or the development of water for large-scale irrigation, even though a current federal program will pay half the cost of terraces. These calculations also indicate that it is better to grow soybeans on Class III and IV land rather than corn. New state and/or federal programs may be needed if these facilities are to become a reality. First, however, the decision must be made that either erosion or irrigation or both are going to receive a high priority in the future.

Based on the various crop planting scenarios used in this study, future crop and livestock production demands can be met if the resources are made available. This will have a beneficial effect on the regional economy. However, some groups may not be pleased with the amount of the land resources in the region which would have to be committed to these uses. These demands can be met with or without erosion control measures installed. However, the environmental costs of increased production without erosion control may not be worth the financial benefits.

The effects of using higher future yields (Gibson's rather than the author's) is such that money spent on research for this purpose would be money well spent. Both the state and federal governments are urged to increase their expenditures in this area, particularly in those aspects which do not increase environmental degradation.

One other aspect of crop production needs to be mentioned. The current model assumes that each county will produce the same share of total regional production in the future as it does now. The results indicate that some counties could produce more than their present share. If the model were changed to reflect this and future production were put on a regional basis rather than on a county basis, then the output from the model would indicate a different amount of land devoted to the various land use categories in each county than the present model.

Lastly, one point concerning the future population of the region needs to be mentioned again. If present trends continue, the regional population will decrease in the future. The present shift from rural to small urban areas may also continue but the overall effect will be a decrease in population. The effects of this have been discussed in some detail and is an area which also requires increased attention from the state and/or federal government.

Specific Recommendations

General

1. Both the state and federal governments need to define more clearly the "proper" scope of water resource planning.

2. The Iowa legislature must finally approach the problem and define by law how land use planning for the future will be implemented in Iowa.

3. The Iowa legislature must also provide guidance as to what order the various uses of water will be given priority during times of drought. This may require a series of public hearings on the subject before the final listing is provided for implementation by the state natural resource agencies.

4. Several areas of land and resource development will require funding from both the state and federal levels in the future. Some of these funding needs may be met under existing legislation. However, others may require new legislation which expands current authority. These areas include funding for irrigation, soil erosion and further studies to better define the occurrence and availability of ground water.

5. Because of the beneficial effects of increased crop yields, more research to improve crop yields is warranted.

6. More efficient use of land devoted to agriculture should be promoted as a means of increasing crop production. However, the means to achieve this and to persuade farmers that this is in their interest as well as the nation's interest is not clear. Discussion on this point is needed.

7. Data needs, as inputs to multiple objective models, are large and varied. Some state agency should be assigned the task of collecting these data into a central location and storing them in a form which can be used in future land and water resource planning efforts.

8. Discussions should begin with states which border both the Mississippi and Missouri Rivers to ensure that Iowa will be able to use its fair share of this water in the future.

<u>Goal programming</u>

1. The GP model as presently developed does not adequately handle larger problems. This area deserves further attention and sufficient funds should be allocated to solving this problem as indicated in the previous section.

2. Several other areas need attention and research in the future to improve the present form of the GP model.

   a. energy

   b. flood control

   c. water quality

   d. refinements in the manner in which land use is evaluated

   e. refinements in the manner in which water use is evaluated.

3. The present results should be strengthened by relaxing the present restrictions built into the model. These include the restriction that future agricultural production in each county cannot be more than its 1967 percentage of total regional production. This could be done by allowing each county to produce whatever amount of crops and livestock it can. Other restrictions which could be relaxed are those pertaining to the use of Class VI and VII land and to which land use categories can be used for crop production in the future.

4. Finally, the present model needs to be made more flexible so that it can handle changes in priorities more readily.

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Land and water resource planning

using goal programming

by

Ronald Leroy Rossmiller

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APPENDIX A.

POPULATION DATA

Table A-1. Historic population of Buena Vista County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Albert City[a]	0	261	567	563	759	736	722	683
Alta[a]	861	959	1,290	1,297	1,269	1,348	1,393	1,717
Lakeside[a]	0	0	0	0	103	219	306	353
Linn Grove[a]	0	0	433	360	402	320	330	240
Marathon[a]	659	532	520	573	597	565	516	447
Newell[a]	762	728	809	812	854	884	893	877
Rembrandt[a]	0	128	270	263	302	296	265	250
Sioux Rapids[a]	1,005	868	1,080	958	1,056	1,010	962	813
Storm Lake[a]	2,169	2,428	3,658	4,157	5,274	6,954	7,728	8,591
Truesdale[a]	0	0	113	116	135	158	153	132
Total urban[a]	5,456	5,904	8,740	9,099	10,751	12,490	13,268	14,103
Rural farm[b]	11,519	10,077	9,816	9,388	8,840	8,273	7,015	5,302
Rural nonfarm	0	0	0	180	247	350	906	1,288
Total rural	11,519	10,077	9,816	9,568	9,087	8,623	7,921	6,590
Total county[b]	16,975	15,981	18,556	18,667	19,838	21,113	21,189	20,693

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-2. Historic population of Cherokee County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Aurelia[a]	621	625	708	723	752	807	904	1,065
Cherokee[a]	3,865	4,884	5,824	6,443	7,469	7,705	7,724	7,272
Cleghorn[a]	0	186	232	238	236	246	228	274
Larrabee[a]	125	158	206	189	189	158	167	167
Marcus[a]	718	896	1,091	1,138	1,206	1,263	1,307	1,272
Meriden[a]	432	246	218	188	200	164	192	167
Quimby[a]	0	268	363	318	363	398	369	395
Washta[a]	431	410	508	448	442	403	310	319
Total urban[a]	6,192	7,673	9,150	9,685	10,857	11,144	11,201	10,931
Rural farm[b]	10,378	9,068	8,610	8,989	8,363	7,594	6,953	4,922
Rural nonfarm	0	0	0	63	38	314	444	1,416
Total rural	10,378	9,068	8,610	9,052	8,401	7,908	7,397	6,338
Total county[b]	16,570	16,741	17,760	18,737	19,258	19,052	18,598	17,269

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-3. Historic population of Clay County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Dickins[a]	0	255	337	333	378	311	241	240
Everly[a]	0	392	480	482	523	547	668	699
Fostoria[a]	0	0	119	142	136	147	167	219
Greenville[a]	0	0	167	168	169	173	173	117
Peterson[a]	521	480	580	598	603	589	565	469
Rossie[a]	0	0	0	85	95	112	102	91
Royal[a]	0	0	362	410	426	495	475	469
Spencer[a]	3,095	3,005	4,599	5,019	6,599	7,446	8,864	10,278
Webb[a]	0	150	219	240	254	235	236	234
Total urban[a]	3,616	4,282	6,863	7,477	9,183	10,055	11,491	12,816
Rural farm[b]	9,785	8,487	8,797	8,472	8,199	7,281	5,958	4,361
Rural nonfarm	0	0	0	158	380	767	1,056	1,287
Total rural	9,785	8,487	8,797	8,630	8,579	8,048	7,013	5,648
Total county[b]	13,401	12,766	15,660	16,107	17,762	18,103	18,504	18,464

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-4. Historic population of Dickinson County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Arnold's Park[a]	251	273	478	597	855	1,078	953	970
Lake Park[a]	541	552	789	708	828	924	952	918
Milford[a]	485	575	908	1,062	1,202	1,375	1,476	1,668
Okoboji[a]	0	0	0	176	271	336	330	361
Old Town[a]	0	0	0	0	0	40	27	24
Orleans[a]	92	105	123	126	244	317	280	396
Spirit Lake[a]	1,219	1,162	1,701	1,778	2,161	2,467	2,685	3,014
Superior[a]	187	154	200	168	230	240	190	139
Terrill[a]	217	253	440	416	452	425	382	397
Wahpeton[a]	0	0	0	0	73	127	117	149
West Okoboji[a]	0	0	0	112	117	158	171	210
Total urban[a]	2,992	3,074	4,639	5,143	6,433	7,487	7,563	8,246
Rural farm[b]	5,003	5,063	5,602	5,673	5,648	4,740	3,866	3,068
Rural nonfarm	0	0	0	166	104	529	1,145	1,251
Total rural	5,003	5,063	5,602	5,839	5,752	5,269	5,011	4,319
Total county[b]	7,995	8,137	10,241	10,982	12,185	12,756	12,574	12,565

[a] Johnson and Tait (1972).

[b] U.S. Department of Commerce, Bureau of the Census (1973).

Table A-5. Historic population of Ida County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Arthur[a]	162	215	290	249	254	243	265	273
Battle Creek[a]	542	527	785	804	827	873	786	837
Galva[a]	456	357	539	530	496	492	469	412
Holstein[a]	870	936	1,248	1,300	1,296	1,336	1,413	1,445
Ida Grove[a]	1,967	1,874	2,020	2,206	2,238	2,202	2,265	2,261
Total urban[a]	3,997	3,909	4,882	5,089	5,111	5,146	5,198	5,228
Rural farm[b]	8,330	7,387	6,807	6,844	5,936	5,495	4,963	3,669
Rural nonfarm	0	0	0	0	0	56	108	293
Total rural	8,330	7,387	6,807	6,844	5,936	5,551	5,071	3,962
Total county[b]	12,327	11,296	11,689	11,933	11,047	10,697	10,269	9,190

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-6. Historic population of Lyon County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Alvord[a]	249	283	359	313	306	263	238	204
Doon[a]	545	581	576	576	576	517	436	437
George[a]	394	606	788	907	1,107	1,210	1,200	1,194
Inwood[a]	477	595	746	670	634	644	638	644
Larchwood[a]	450	434	441	382	405	415	531	611
Lester[a]	225	244	250	231	286	217	239	238
Little Rock[a]	399	471	573	585	633	533	564	531
Rock Rapids[a]	1,766	2,005	2,172	2,221	2,556	2,640	2,780	2,632
Total urban[a]	4,505	5,219	5,905	5,885	6,503	6,439	6,626	6,491
Rural farm[a]	8,660	9,405	9,526	9,376	8,863	7,966	7,390	6,184
Rural nonfarm	0	0	0	32	8	292	452	665
Total rural	8,660	9,405	9,526	9,408	8,871	8,258	7,842	6,849
Total county[b]	13,165	14,624	15,431	15,293	15,374	14,697	14,468	13,340

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-7. Historic population of O'Brien County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Archer[a]	0	351	184	150	178	167	209	134
Calumet[a]	113	242	266	249	274	250	225	219
Hartley[a]	1,006	1,106	1,306	1,272	1,503	1,611	1,738	1,694
Moneta[a]	0	44	127	85	115	89	76	41
Paullina[a]	617	796	987	1,013	1,230	1,289	1,329	1,257
Primghar[a]	814	733	921	962	1,081	1,152	1,131	995
Sanborn[a]	1,247	1,174	1,497	1,213	1,344	1,337	1,323	1,465
Sheldon[a]	2,282	2,941	3,488	3,320	3,768	4,001	4,251	4,535
Sutherland[a]	722	664	876	802	875	835	883	875
Total urban[a]	6,801	8,051	9,652	9,066	10,368	10,731	11,165	11,215
Rural farm[b]	10,184	9,211	9,399	9,156	8,883	7,754	7,086	5,466
Rural nonfarm	0	0	0	187	42	485	589	841
Total rural	10,184	9,211	9,399	9,343	8,925	8,239	7,675	6,307
Total county[b]	16,985	17,262	19,051	18,409	19,293	18,970	18,840	17,522

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-8. Historic population of Osceola County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Ashton[a]	513	518	610	568	620	588	615	483
Harris[a]	217	239	359	328	309	319	258	195
Melvin[a]	0	195	282	301	328	325	364	325
Ocheyedan[a]	599	595	686	627	712	700	662	545
Sibley[a]	1,289	1,330	1,803	1,870	2,356	2,559	2,852	2,749
Total urban[a]	2,618	2,877	3,740	3,694	4,325	4,491	4,751	4,297
Rural farm[b]	6,107	6,079	6,483	6,436	6,167	5,387	4,999	3,687
Rural nonfarm	0	0	0	52	115	303	314	571
Total rural	6,107	6,079	6,483	6,488	6,282	5,690	5,313	4,258
Total county[b]	8,725	8,956	10,223	10,182	10,607	10,181	10,064	8,555

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-9. Historic population of Plymouth County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Akron[a]	1,029	1,130	1,324	1,304	1,314	1,251	1,351	1,324
Brunsville[a]	0	0	111	134	109	112	128	125
Craig[a]	0	0	156	155	165	142	117	98
Hinton[a]	0	329	263	289	340	345	403	488
Kingsley[a]	720	977	1,072	1,093	1,145	1,098	1,044	1,097
Le Mars[a]	4,146	4,157	4,683	4,788	5,353	5,844	6,767	8,159
Merrill[a]	389	520	633	605	547	605	645	790
Oyens[a]	0	94	100	106	104	95	114	145
Remsen[a]	835	1,076	1,144	1,181	1,196	1,280	1,338	1,367
Struble[a]	172	327	129	161	134	91	74	59
Westfield[a]	0	143	203	218	197	172	187	148
Total urban[a]	7,291	8,753	9,818	10,034	10,604	11,035	12,168	13,800
Rural farm[b]	14,918	14,376	13,766	13,857	12,681	11,335	10,115	8,664
Rural nonfarm	0	0	0	268	217	882	1,623	1,848
Total rural	14,918	14,376	13,766	14,125	12,898	12,217	11,738	10,512
Total county[b]	22,209	23,129	23,584	24,159	23,502	23,252	23,906	24,312

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-10. Historic population of Sac County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Auburn[a]	293	399	406	359	383	350	367	329
Early[a]	579	500	568	632	644	724	824	727
Grant City[a]	249	162	95	0	0	0	0	0
Lake View[a]	591	514	838	993	1,082	1,158	1,165	1,249
Lytton[a]	0	0	278	373	335	373	376	378
Nemaha[a]	0	0	166	146	169	184	151	117
Odebolt[a]	1,432	1,283	1,445	1,388	1,350	1,279	1,331	1,323
Sac City[a]	2,079	2,201	2,630	2,854	3,165	3,170	3,354	3,268
Schaller[a]	661	646	731	724	758	841	896	835
Wall Lake[a]	659	561	737	749	762	753	812	936
Total urban[a]	6,543	6,266	7,894	8,218	8,648	8,832	9,276	9,162
Rural farm[b]	11,096	10,289	9,606	9,038	8,790	8,215	6,738	5,410
Rural nonfarm	0	0	0	385	201	471	993	1,001
Total rural	11,096	10,289	9,606	9,423	8,991	8,686	7,731	6,411
Total county[b]	17,639	16,555	17,500	17,641	17,639	17,518	17,007	15,573

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-11. Historic population of Sioux County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Alton[a]	1,009	1,046	1,007	1,014	1,025	1,038	1,048	1,018
Boyden[a]	336	364	419	446	482	541	562	670
Chatsworth[a]	0	131	150	159	144	102	84	90
Granville[a]	351	400	358	390	361	350	381	383
Hawarden[a]	1,810	2,107	2,491	2,459	2,681	2,625	2,544	2,789
Hospers[a]	415	581	570	548	592	604	600	646
Hull[a]	626	658	791	905	1,072	1,127	1,289	1,523
Ireton[a]	545	631	730	612	653	573	510	582
Matlock[a]	94	118	94	103	112	104	103	89
Maurice[a]	280	290	329	274	272	256	237	266
Orange City[a]	1,457	1,374	1,632	1,727	1,920	2,166	2,707	3,572
Rock Valley[a]	1,054	1,198	1,347	1,204	1,507	1,581	1,693	2,205
Sioux Center[a]	810	1,064	1,389	1,497	1,680	1,860	2,275	3,450
Total urban[a]	8,787	9,962	11,307	11,338	12,501	12,927	14,033	17,283
Rural farm[b]	14,550	15,286	15,151	15,451	14,708	12,846	10,852	9,572
Rural nonfarm	0	0	0	17	0	608	1,490	1,141
Total rural	14,550	15,286	15,151	15,468	14,708	13,454	12,342	10,713
Total county[b]	23,337	25,248	26,458	26,806	27,209	26,381	26,375	27,996

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-12. Historic population of Woodbury County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Anthon[a]	437	635	783	826	881	770	681	711
Bronson[a]	0	0	0	0	0	0	0	193
Correctionville[a]	935	893	1,016	1,058	1,151	992	912	870
Cushing[a]	237	254	286	270	258	248	261	204
Danbury[a]	480	558	677	656	728	601	510	527
Hornick[a]	284	245	296	309	291	310	275	250
Lawton[a]	0	138	243	259	263	254	324	406
Moville[a]	507	552	878	911	973	964	1,156	1,198
Oto[a]	396	268	333	370	410	302	221	203
Pierson[a]	358	416	554	551	531	453	425	421
Salix[a]	387	390	396	374	392	337	394	387
Sergeant Bluff[a]	0	525	548	569	587	569	813	1,153
Sioux City[a]	33,111	47,828	71,227	79,183	82,364	83,991	89,159	85,925
Sloan[a]	643	547	608	636	628	654	704	799
Smithland[a]	435	334	321	389	389	373	349	293
Total urban[a]	38,210	53,583	78,166	86,361	89,846	90,818	96,184	93,540
Rural farm[b]	16,400	14,033	14,005	14,701	13,157	11,180	9,363	6,813
Rural nonfarm	0	0	0	607	624	1,919	2,302	2,699
Total rural	16,400	14,033	14,005	15,308	13,781	13,099	11,665	9,512
Total county[b]	54,610	67,616	92,171	101,669	103,627	103,917	107,849	103,052

[a]Johnson and Tait (1972).

[b]U.S. Department of Commerce, Bureau of the Census (1973).

Table A-13. Total annual resident births and deaths in Buena Vista, Cherokee and Clay Counties, 1940-1969[a]

Year	Buena Vista		Cherokee		Clay	
	Births	Deaths	Births	Deaths	Births	Deaths
1940	340	178	285	168	344	157
1941	318	198	331	145	350	149
1942	342	171	344	135	344	133
1943	337	169	328	154	304	149
1944	314	202	304	176	361	148
1945	332	199	329	146	290	126
1946	414	185	392	145	408	151
1947	505	167	403	190	462	154
1948	446	214	441	184	437	158
1949	525	166	461	163	430	174
Total	3,873	1,849	3,618	1,606	3,730	1,499
1950	511	204	464	169	471	153
1951	535	212	509	177	511	169
1952	512	199	447	174	466	141
1953	475	229	433	174	459	161
1954	540	220	426	169	451	155
1955	536	198	445	154	469	189
1956	527	167	402	175	441	156
1957	471	213	394	174	418	197
1958	458	231	375	178	398	165
1959	435	211	382	186	405	176
Total	5,000	2,084	4,277	1,730	4,489	1,662
1960	433	218	412	186	386	170
1961	424	219	415	190	377	172
1962	390	198	376	170	377	168
1963	415	247	304	181	354	172
1964	345	228	328	190	312	208
1965	329	229	273	176	274	192
1966	306	237	287	141	281	170
1967	269	230	267	191	253	177
1968	272	226	236	208	258	193
1969	286	255	280	173	279	195
Total	3,469	2,287	3,178	1,806	3,151	1,817

[a]Iowa Department of Health (1970).

Table A-14. Total annual resident births and deaths in Dickinson, Ida and Lyon Counties, 1940-1969[a]

Year	Dickinson		Ida		Lyon	
	Births	Deaths	Births	Deaths	Births	Deaths
1940	213	107	185	88	278	115
1941	220	108	179	108	281	124
1942	209	97	172	89	296	123
1943	202	102	179	101	250	115
1944	183	86	187	76	258	103
1945	175	79	204	100	314	127
1946	259	101	240	77	328	108
1947	304	113	252	105	355	107
1948	272	109	226	101	390	119
1949	281	131	247	100	348	101
Total	2,318	1,033	2,071	945	3,098	1,142
1950	316	126	228	108	370	119
1951	341	118	243	61	387	115
1952	291	102	267	88	397	119
1953	284	120	228	89	346	107
1954	276	104	238	93	397	120
1955	302	131	248	97	378	118
1956	307	136	243	120	360	109
1957	279	121	213	118	343	102
1958	238	123	220	96	353	119
1959	240	131	198	107	354	128
Total	2,874	1,212	2,326	977	3,685	1,156
1960	278	152	179	108	354	108
1961	233	126	196	116	328	136
1962	249	137	172	106	303	119
1963	219	147	153	111	268	131
1964	203	141	128	120	241	139
1965	190	132	144	112	262	156
1966	163	142	128	103	210	110
1967	152	137	124	118	215	139
1968	178	145	139	138	200	122
1969	172	154	136	120	230	133
Total	2,037	1,413	1,499	1,152	2,611	1,293

[a]Iowa Department of Health (1970).

Table A-15. Total annual resident births and deaths in O'Brien, Osceola and Plymouth Counties, 1940-1969[a]

Year	O'Brien		Osceola		Plymouth	
	Births	Deaths	Births	Deaths	Births	Deaths
1940	323	198	197	76	441	223
1941	380	289	197	79	426	221
1942	373	152	234	103	461	212
1943	357	161	190	83	442	197
1944	325	156	191	55	423	173
1945	339	161	192	61	466	179
1946	455	159	238	65	522	218
1947	451	181	267	90	585	212
1948	488	180	247	62	608	200
1949	475	205	251	60	596	196
Total	3,966	1,842	2,205	734	4,970	2,031
1950	496	194	256	77	615	233
1951	531	172	278	57	651	206
1952	484	161	281	77	622	230
1953	437	163	277	78	592	226
1954	475	188	269	74	584	200
1955	486	162	281	68	624	237
1956	437	187	266	98	594	212
1957	454	197	262	93	563	204
1958	408	178	249	80	515	228
1959	418	220	232	86	545	203
Total	4,626	1,822	2,651	788	5,905	2,179
1960	431	166	232	104	571	242
1961	401	202	228	86	574	184
1962	384	182	222	79	507	224
1963	370	204	174	87	492	240
1964	322	202	189	71	460	216
1965	308	189	145	91	397	242
1966	272	172	161	91	406	246
1967	273	189	125	84	365	247
1968	259	219	130	74	365	245
1969	249	203	135	91	381	222
Total	3,269	1,928	1,741	858	4,518	2,308

[a]Iowa Department of Health (1970).

Table A-16. Total annual resident births and deaths in Sac, Sioux and Woodbury Counties and the State of Iowa, 1940-1969[a]

Year	Sac		Sioux		Woodbury		State	
	Births	Deaths	Births	Deaths	Births	Deaths	Births	Deaths
1940	332	130	559	212	1,788	952	45,433	26,362
1941	307	144	582	226	1,923	893	46,825	25,742
1942	346	139	586	162	2,002	939	49,235	25,146
1943	329	144	552	195	1,928	975	46,579	25,319
1944	346	152	531	205	2,068	1,018	45,263	25,068
1945	323	148	485	187	2,049	994	44,497	25,505
1946	376	130	619	207	2,372	1,051	55,743	25,408
1947	436	145	701	171	2,711	1,062	63,536	26,307
1948	376	156	715	206	2,632	1,093	60,396	25,935
1949	410	164	701	187	2,645	1,100	61,765	26,040
Total	3,581	1,452	6,031	1,958	22,118	10,077	519,272	256,832
1950	426	148	750	227	2,713	1,078	62,550	26,940
1951	446	166	728	214	2,987	1,087	66,123	26,287
1952	416	172	733	226	2,966	1,057	64,091	26,464
1953	421	161	767	212	2,860	1,107	62,521	26,715
1954	405	141	733	229	2,934	1,021	63,069	25,602
1955	429	165	713	209	2,805	1,027	63,624	26,672
1956	381	148	704	248	2,631	1,069	63,213	26,517
1957	391	158	691	223	2,710	1,133	63,497	27,917
1958	346	159	604	207	2,676	1,105	62,173	27,718
1959	359	163	689	252	2,609	1,200	64,473	28,317
Total	4,020	1,581	7,112	2,247	27,891	10,884	635,334	269,149
1960	376	190	624	229	2,662	1,137	64,050	28,741
1961	353	158	650	240	2,679	1,137	63,408	28,158
1962	326	177	604	236	2,554	1,151	61,003	28,632
1963	298	211	616	234	2,289	1,145	57,840	29,266
1964	258	189	577	263	2,162	1,156	55,443	29,157
1965	245	187	501	233	1,868	1,124	50,970	29,394
1966	224	200	462	262	1,852	1,144	48,641	29,611
1967	204	204	444	247	1,879	1,020	47,217	28,849
1968	207	180	440	275	1,814	1,150	46,737	29,852
1969	222	191	454	291	1,876	1,102	47,235	29,345
Total	2,713	1,887	5,372	2,510	21,635	11,266	542,544	291,005

[a]Iowa Department of Health (1970).

Table A-17. Farm population and density, number and size of farms in Buena Vista County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	7,570	1,973	361,009	183	3.8	13.4
1953	7,682	2,009	359,925	179	3.8	13.6
1954	7,679	1,990	359,573	181	3.8	13.7
1955	7,765	2,000	361,042	181	3.9	13.8
1956	7,571	1,969	359,766	183	3.8	13.5
1957	7,432	1,948	359,238	184	3.8	13.2
1958	7,342	1,935	360,237	186	3.8	13.0
1959	7,163	1,917	359,077	187	3.7	12.8
1960	6,999	1,866	359,792	193	3.7	12.4
1961	6,890	1,838	358,112	195	3.7	12.3
1962	6,942	1,801	358,276	199	3.8	12.4
1963	6,825	1,735	358,225	206	3.9	12.2
1964	6,479	1,675	357,583	213	3.9	11.6
1965	6,245	1,550	354,350	229	4.0	11.3
1966	6,031	1,498	352,382	235	4.0	11.0
1967	5,854	1,461	349,945	240	4.0	10.7
1968	—[b]	—	—	—	—	—
1969	5,566	1,388	348,844	251	4.0	10.2
1970	5,448	1,382	348,644	252	3.9	10.1
1971	—	1,374	350,762	255	—	—
1972	—	1,368	350,246	256	—	—
1973	—	1,352	350,018	259	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-18. Farm population and density, number and size of farms in Cherokee County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	6,922	1,768	363,003	205	3.9	12.2
1953	6,939	1,756	362,684	207	4.0	12.2
1954	7,049	1,780	363,734	204	4.0	12.4
1955	7,113	1,758	364,267	207	4.0	12.5
1956	6,857	1,749	363,645	208	3.9	12.1
1957	6,855	1,744	363,982	209	3.9	12.0
1958	6,898	1,734	364,768	210	4.0	12.1
1959	6,860	1,717	362,784	211	4.0	12.1
1960	6,758	1,671	362,089	217	4.0	11.9
1961	6,626	1,655	363,156	219	4.0	11.7
1962	6,625	1,631	362,944	223	4.1	11.7
1963	6,438	1,607	362,750	226	4.0	11.4
1964	6,286	1,543	362,011	235	4.1	11.1
1965	5,856	1,405	360,745	257	4.2	10.4
1966	5,707	1,352	358,172	265	4.2	10.2
1967	5,705	1,306	354,884	272	4.4	10.3
1968	—[b]	—	—	—	—	—
1969	5,390	1,237	352,766	285	4.4	9.8
1970	5,354	1,229	351,771	286	4.4	9.7
1971	—	1,223	351,424	287	—	—
1972	—	1,220	353,818	290	—	—
1973	—	1,213	353,999	292	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-19. Farm population and density, number and size of farms in Clay County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	6,898	1,792	354,868	198	3.8	12.4
1953	6,884	1,799	354,622	197	3.8	12.4
1954	6,920	1,793	354,330	198	3.8	12.5
1955	6,849	1,780	355,597	200	3.8	12.3
1956	6,617	1,754	355,276	203	3.8	11.9
1957	6,599	1,739	356,070	205	3.8	11.9
1958	6,536	1,722	355,385	206	3.8	11.8
1959	6,182	1,701	355,931	209	3.6	11.1
1960	6,012	1,646	356,560	217	3.6	10.8
1961	5,970	1,600	355,079	222	3.7	10.8
1962	5,701	1,553	355,735	229	3.7	10.2
1963	5,824	1,530	357,133	233	3.8	10.4
1964	5,757	1,505	357,207	237	3.8	10.3
1965	5,514	1,349	354,980	263	4.1	9.9
1966	5,355	1,302	353,325	271	4.1	9.7
1967	4,840	1,252	348,299	278	3.9	8.9
1968	—[b]	—	—	—	—	—
1969	4,473	1,146	345,409	301	3.9	8.3
1970	4,431	1,142	345,005	302	3.9	8.2
1971	—	1,135	347,382	306	—	—
1972	—	1,126	346,284	308	—	—
1973	—	1,120	345,429	308	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-20. Farm population and density, number and size of farms in Dickinson County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	4,340	1,156	233,333	202	3.8	11.9
1953	4,165	1,130	235,549	208	3.7	11.3
1954	4,109	1,092	233,705	214	3.8	11.2
1955	4,135	1,119	233,545	209	3.7	11.3
1956	4,075	1,114	230,664	207	3.6	11.3
1957	4,049	1,119	234,513	210	3.6	11.0
1958	3,893	1,100	232,376	211	3.5	10.7
1959	4,008	1,083	234,034	216	3.7	11.0
1960	3,777	1,051	233,860	223	3.6	10.3
1961	3,813	1,040	233,119	224	3.7	10.5
1962	3,653	977	229,507	235	3.7	10.2
1963	3,477	976	227,838	233	3.6	9.8
1964	3,418	943	230,671	245	3.6	9.5
1965	3,238	888	229,457	258	3.6	9.0
1966	3,119	858	227,124	265	3.6	8.8
1967	3,072	844	226,397	268	3.6	8.7
1968	—[b]	—	—	—	—	—
1969	2,803	765	225,584	295	3.7	8.0
1970	2,775	754	225,275	299	3.7	7.9
1971	—	747	225,475	302	—	—
1972	—	742	225,787	304	—	—
1973	—	728	225,808	310	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-21. Farm population and density, number and size of farms in Ida County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	5,133	1,344	273,035	203	3.8	12.0
1953	5,127	1,345	273,111	203	3.8	12.0
1954	5,222	1,342	273,530	204	3.9	12.2
1955	5,129	1,344	272,088	202	3.8	12.1
1956	4,888	1,323	271,912	206	3.7	11.5
1957	4,863	1,316	271,731	206	3.7	11.4
1958	4,874	1,310	272,479	208	3.7	11.4
1959	4,787	1,298	271,056	209	3.7	11.3
1960	4,732	1,272	271,064	213	3.7	11.2
1961	4,643	1,251	271,799	217	3.7	10.9
1962	4,594	1,234	269,461	218	3.7	10.9
1963	4,527	1,219	270,675	222	3.7	10.7
1964	4,370	1,215	270,641	233	3.6	10.3
1965	4,203	1,139	269,827	237	3.7	10.0
1966	4,116	1,096	269,327	246	3.8	9.8
1967	4,010	1,067	269,484	253	3.8	9.5
1968	—[b]	—	—	—	—	—
1969	3,732	998	270,745	271	3.7	8.8
1970	3,663	993	270,439	272	3.7	8.7
1971	—	987	270,399	274	—	—
1972	—	990	270,922	274	—	—
1973	—	973	270,193	278	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-22. Farm population and density, number and size of farms in Lyon County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	7,843	1,820	369,238	203	4.3	13.6
1953	7,858	1,839	369,392	201	4.3	13.6
1954	7,930	1,841	368,451	200	4.3	13.8
1955	7,719	1,855	367,362	198	4.2	13.4
1956	7,649	1,844	367,779	199	4.2	13.3
1957	7,709	1,844	368,021	200	4.2	13.4
1958	7,610	1,833	367,165	200	4.2	13.3
1959	7,678	1,828	368,353	202	4.2	13.3
1960	7,451	1,805	369,005	204	4.1	12.9
1961	7,291	1,769	368,045	208	4.1	12.7
1962	7,122	1,729	369,472	214	4.1	12.3
1963	7,175	1,725	368,367	214	4.2	12.5
1964	7,018	1,693	366,259	216	4.1	12.3
1965	6,494	1,658	364,637	220	3.9	11.4
1966	6,600	1,615	364,005	225	4.1	11.6
1967	6,452	1,578	363,655	230	4.1	11.4
1968	—[b]	—	—	—	—	—
1969	6,300	1,490	362,762	243	4.2	11.1
1970	6,212	1,473	363,800	247	4.2	10.9
1971	—	1,442	363,883	252	—	—
1972	—	1,432	363,581	254	—	—
1973	—	1,432	363,757	254	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-23. Farm population and density, number and size of farms in O'Brien County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	7,500	1,856	360,446	194	4.0	13.3
1953	7,557	1,869	360,608	193	4.0	13.4
1954	7,667	1,898	360,060	190	4.0	13.6
1955	7,553	1,913	359,951	188	3.9	13.4
1956	7,333	1,909	360,256	189	3.8	13.0
1957	7,312	1,895	359,132	190	3.8	13.0
1958	7,131	1,877	359,718	192	3.8	12.7
1959	7,092	1,858	358,468	193	3.8	12.7
1960	6,809	1,811	358,675	198	3.8	12.1
1961	6,813	1,793	359,311	200	3.8	12.1
1962	6,726	1,759	358,986	204	3.8	12.0
1963	6,682	1,734	358,585	207	3.8	11.9
1964	6,501	1,664	356,616	214	3.9	11.7
1965	6,213	1,586	354,469	223	3.9	11.2
1966	6,124	1,546	354,601	229	4.0	11.0
1967	5,936	1,484	354,005	239	4.0	10.7
1968	—[b]	—	—	—	—	—
1969	5,661	1,396	353,759	253	4.0	10.2
1970	5,627	1,383	353,134	255	4.0	10.2
1971	—	1,378	352,750	256	—	—
1972	—	1,371	352,360	257	—	—
1973	—	1,352	352,114	260	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-24. Farm population and density, number and size of farms in Osceola County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	5,285	1,274	251,859	198	4.1	13.4
1953	5,225	1,289	251,585	195	4.0	13.3
1954	5,301	1,286	251,802	196	4.1	13.5
1955	5,218	1,272	251,863	198	4.1	13.3
1956	5,166	1,273	251,226	197	4.0	13.2
1957	5,099	1,264	250,373	198	4.0	13.0
1958	4,955	1,251	248,188	198	4.0	12.8
1959	4,961	1,241	250,032	201	4.0	12.7
1960	4,732	1,221	249,810	205	3.9	12.1
1961	4,766	1,204	249,993	208	4.0	12.2
1962	4,672	1,172	248,025	212	4.0	12.0
1963	4,562	1,146	247,484	216	4.0	11.8
1964	4,432	1,113	248,438	223	4.0	11.4
1965	4,194	1,052	246,894	235	4.0	10.9
1966	4,166	1,025	245,800	240	4.1	10.8
1967	4,127	1,016	245,361	241	4.1	10.8
1968	—[b]	—	—	—	—	—
1969	3,787	955	245,297	257	4.0	9.9
1970	3,696	935	244,816	262	4.0	9.7
1971	—	910	245,519	270	—	—
1972	—	906	245,445	271	—	—
1973	—	905	245,874	272	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-25. Farm population and density, number and size of farms in Plymouth County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	10,980	2,727	543,312	199	4.0	12.9
1953	10,975	2,745	543,520	198	4.0	12.9
1954	11,129	2,730	541,911	199	4.1	13.1
1955	11,092	2,713	542,782	199	4.1	13.1
1956	10,878	2,696	540,504	200	4.0	12.9
1957	10,758	2,671	541,102	203	4.0	12.7
1958	10,689	2,646	541,967	205	4.0	12.6
1959	10,574	2,618	543,648	208	4.0	12.4
1960	10,267	2,572	542,012	211	4.0	12.1
1961	10,292	2,541	543,473	214	4.0	12.1
1962	10,145	2,483	541,993	218	4.1	12.0
1963	9,995	2,451	541,179	221	4.1	11.8
1964	9,707	2,400	541,926	226	4.0	11.5
1965	9,154	2,255	538,925	239	4.0	10.9
1966	8,911	2,204	537,492	244	4.0	10.6
1967	8,793	2,170	536,369	247	4.0	10.5
1968	—[b]	—	—	—	—	—
1969	8,432	2,079	534,499	257	4.0	10.1
1970	8,413	2,072	535,924	259	4.1	10.0
1971	—	2,065	536,424	260	—	—
1972	—	2,055	536,235	261	—	—
1973	—	2,016	534,821	265	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-26. Farm population and density, number and size of farms in Sac County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	7,823	1,934	360,076	186	4.0	13.9
1953	7,681	1,940	361,368	186	4.0	13.6
1954	7,676	1,918	361,025	188	4.0	13.6
1955	7,627	1,874	360,328	192	4.1	13.5
1956	7,481	1,871	358,844	192	4.0	13.3
1957	7,350	1,844	359,793	195	4.0	13.1
1958	7,363	1,826	360,996	198	4.0	13.0
1959	7,288	1,804	361,359	200	4.0	12.9
1960	7,095	1,758	362,868	206	4.0	12.5
1961	7,211	1,730	362,647	210	4.2	12.7
1962	7,018	1,699	363,273	214	4.1	12.4
1963	6,761	1,660	362,112	218	4.1	11.9
1964	6,695	1,637	361,516	221	4.1	11.8
1965	6,271	1,503	360,143	240	4.2	11.1
1966	6,103	1,454	363,607	250	4.2	10.7
1967	6,009	1,430	363,895	254	4.2	10.6
1968	—[b]	—	—	—	—	—
1969	5,532	1,321	363,626	275	4.2	9.7
1970	5,531	1,318	363,836	276	4.2	9.7
1971	—	1,306	363,961	279	—	—
1972	—	1,295	363,503	281	—	—
1973	—	1,280	363,528	284	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-27. Farm population and density, number and size of farms in Sioux County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	12,156	2,812	480,194	171	4.3	16.2
1953	12,259	2,833	480,294	170	4.3	16.3
1954	12,143	2,818	481,463	171	4.3	16.1
1955	12,076	2,819	480,628	170	4.3	16.1
1956	12,097	2,823	482,198	171	4.3	16.0
1957	12,004	2,798	482,310	172	4.3	15.9
1958	11,982	2,776	481,870	174	4.3	15.9
1959	11,887	2,763	481,967	174	4.3	15.8
1960	11,451	2,720	481,217	177	4.2	15.2
1961	11,410	2,670	483,079	181	4.3	15.1
1962	11,288	2,602	481,170	185	4.3	15.0
1963	10,997	2,514	481,563	192	4.4	14.6
1964	10,688	2,433	480,232	197	4.4	14.2
1965	10,367	2,363	478,322	202	4.4	13.9
1966	9,889	2,315	477,434	206	4.3	13.3
1967	9,725	2,274	477,348	210	4.3	13.0
1968	—[b]	—	—	—	—	—
1969	9,403	2,137	478,063	224	4.4	12.6
1970	9,375	2,132	478,020	224	4.4	12.6
1971	—	2,124	478,005	225	—	—
1972	—	2,115	477,988	226	—	—
1973	—	2,103	479,187	228	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-28. Farm population and density, number and size of farms in Woodbury County, 1952-1973[a]

Year	Population living on farms	Number of farms	Total land in farms acres	Average farm size acres	Persons per farm	Rural farm pop. density persons/sq. mi.
1952	11,080	2,865	528,796	185	3.9	13.4
1953	11,067	2,869	529,808	185	3.8	13.4
1954	11,141	2,864	529,713	185	3.9	13.5
1955	11,026	2,834	529,239	187	3.9	13.3
1956	10,779	2,809	527,861	188	3.8	13.1
1957	10,423	2,779	530,676	191	3.8	12.6
1958	10,483	2,753	530,441	193	3.8	12.6
1959	10,458	2,729	530,076	194	3.8	12.6
1960	10,180	2,682	530,745	198	3.8	12.3
1961	10,164	2,637	527,050	200	3.8	12.3
1962	10,226	2,611	527,684	202	3.9	12.4
1963	9,978	2,565	530,113	207	3.9	12.0
1964	9,426	2,536	530,115	209	3.7	11.4
1965	8,776	2,317	528,140	228	3.8	10.6
1966	8,712	2,251	518,077	230	3.9	10.8
1967	8,443	2,168	512,310	236	3.9	10.5
1968	—[b]	—	—	—	—	—
1969	8,013	2,028	506,504	250	3.9	10.1
1970	7,913	1,992	510,367	256	4.0	9.9
1971	—	1,931	510,172	264	—	—
1972	—	1,930	509,616	264	—	—
1973	—	1,927	510,697	265	—	—

[a]Iowa Department of Agriculture (1952-1973).

[b]Data not available.

Table A-29. Historic population percentages in Buena Vista County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Albert City[a]	0.00	4.42	6.49	6.19	7.06	5.89	5.44	4.84
Alta[a]	15.78	16.24	14.76	14.25	11.80	10.79	10.50	12.18
Lakeside[a]	0.00	0.00	0.00	0.00	0.96	1.75	2.31	2.50
Lynn Grove[a]	0.00	0.00	4.95	3.96	3.74	2.56	2.49	1.70
Marathon[a]	12.08	9.01	5.95	6.30	5.55	4.52	3.89	3.17
Newell[a]	13.97	12.33	9.26	8.92	7.94	7.08	6.73	6.22
Rembrandt[a]	0.00	2.18	3.09	2.89	2.81	2.38	2.00	1.77
Sioux Rapids[a]	18.42	14.70	12.36	10.53	9.82	8.09	7.25	5.76
Storm Lake[a]	39.75	41.12	41.85	45.69	49.06	55.68	58.24	60.92
Truesdale[a]	0.00	0.00	1.29	1.27	1.26	1.26	1.15	0.94
Total urban[b]	32.14	36.94	47.10	48.74	54.19	59.16	62.62	68.16
Rural farm[b]	67.86	63.06	52.90	50.29	44.56	39.18	33.10	25.62
Rural nonfarm[b]	0.00	0.00	0.00	0.97	1.25	1.66	4.28	6.22
Total rural[b]	67.86	63.06	52.90	51.26	45.81	40.84	37.38	31.84
Total county[c]	7.58	6.71	6.67	6.42	6.67	7.12	7.07	7.17

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-30. Historic population percentages in Cherokee County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Aurelia[a]	10.03	8.15	7.74	7.47	6.93	7.24	8.07	9.74
Cherokee[a]	62.41	63.65	63.65	66.53	68.79	69.14	68.96	66.53
Cleghorn[a]	0.00	2.42	2.54	2.46	2.18	2.21	2.04	2.51
Larrabee[a]	2.02	2.06	2.25	1.95	1.74	1.42	1.49	1.53
Marcus[a]	11.60	11.68	11.92	11.75	11.11	11.33	11.67	11.64
Meriden[a]	6.98	3.21	2.38	1.94	1.84	1.47	1.71	1.53
Quimby[a]	0.00	3.49	3.97	3.28	3.34	3.57	3.29	3.60
Washta[a]	6.96	5.34	5.55	4.62	4.07	3.62	2.77	2.92
Total urban[b]	37.37	45.83	51.52	51.69	56.38	58.49	60.23	63.30
Rural farm[b]	62.63	54.17	48.48	47.97	43.42	39.86	37.38	28.50
Rural nonfarm[b]	0.00	0.00	0.00	0.34	0.20	1.65	2.39	8.20
Total rural[b]	62.63	54.17	48.48	48.31	43.62	41.51	39.77	36.70
Total county[c]	7.40	7.03	6.38	6.45	6.48	6.42	6.21	5.99

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-31. Historic population percentages in Clay County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Dickins[a]	0.00	5.96	4.92	4.45	4.12	3.09	2.10	1.88
Everly[a]	0.00	9.15	7.00	6.45	5.70	5.44	5.81	5.45
Fostoria[a]	0.00	0.00	1.73	1.90	1.48	1.46	1.45	1.71
Greenville[a]	0.00	0.00	2.43	2.25	1.84	1.72	1.51	0.91
Peterson[a]	14.41	11.21	8.45	8.00	6.57	5.86	4.92	3.66
Rossie[a]	0.00	0.00	0.00	1.14	1.03	1.12	0.89	0.71
Royal[a]	0.00	0.00	5.27	5.48	4.64	4.92	4.13	3.66
Spencer[a]	85.59	70.18	67.01	67.12	71.86	74.05	77.14	80.20
Webb[a]	0.00	3.50	3.19	3.21	2.76	2.34	2.05	1.82
Total urban[b]	26.98	33.54	43.83	46.42	51.70	55.54	62.10	69.41
Rural farm[b]	73.02	66.48	56.17	52.60	46.16	40.22	32.20	23.62
Rural nonfarm[b]	0.00	0.00	0.00	0.98	2.14	4.24	5.70	6.97
Total rural[b]	73.02	66.48	56.17	53.58	48.30	44.46	37.90	30.59
Total county[c]	5.98	5.36	5.63	5.54	5.97	6.10	6.17	6.40

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-32. Historic population percentages in Dickinson County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Arnold's Park[a]	8.39	8.88	10.30	11.60	13.29	14.40	12.60	11.76
Lake Park[a]	18.08	17.96	17.02	13.77	12.87	12.34	12.59	11.13
Milford[a]	16.21	18.70	19.57	20.65	18.68	18.36	19.50	20.23
Okoboji[a]	0.00	0.00	0.00	3.42	4.22	4.49	4.36	4.38
Old Town[a]	0.00	0.00	0.00	0.00	0.00	0.53	0.36	0.29
Orleans[a]	3.08	3.42	2.65	2.45	3.79	4.23	3.70	4.80
Spirit Lake[a]	40.74	37.80	36.67	34.57	33.59	32.95	35.50	36.55
Superior[a]	6.25	5.01	4.31	3.27	3.58	3.21	2.52	1.69
Terrill[a]	7.25	8.23	9.48	8.09	7.03	5.68	5.05	4.81
Wahpeton[a]	0.00	0.00	0.00	0.00	1.13	1.70	1.56	1.81
West Okoboji[a]	0.00	0.00	0.00	2.18	1.82	2.11	2.26	2.55
Total urban[b]	37.42	37.78	45.30	46.83	52.80	58.69	60.15	65.63
Rural farm[b]	62.58	62.22	54.70	51.66	46.35	37.16	30.74	24.41
Rural nonfarm[b]	0.00	0.00	0.00	1.51	0.85	4.15	9.11	9.96
Total rural[b]	62.58	62.22	54.70	53.17	47.20	41.31	39.85	34.37
Total county[c]	3.57	3.41	3.68	3.78	4.10	4.30	4.19	4.35

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-33. Historic population percentages in Ida County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Arthur[a]	4.05	5.51	5.94	4.89	4.97	4.73	5.11	5.22
Battle Creek[a]	13.54	13.48	16.08	15.80	16.18	16.96	15.12	16.01
Galva[a]	11.42	9.13	11.04	10.42	9.70	9.56	9.02	7.88
Holstein[a]	21.77	23.94	25.56	25.54	25.36	25.96	27.18	27.64
Ida Grove[a]	49.22	47.94	41.38	43.35	43.79	42.79	43.57	43.25
Total urban[b]	32.42	34.61	41.77	42.65	46.27	48.11	50.62	56.89
Rural farm[b]	67.58	65.39	58.23	57.35	53.73	51.37	48.33	39.92
Rural nonfarm[b]	0.00	0.00	0.00	0.00	0.00	0.52	1.05	3.19
Total rural[b]	67.58	65.39	58.23	57.35	53.73	51.89	49.38	43.11
Total county[c]	5.50	4.74	4.20	4.11	3.72	3.61	3.43	3.19

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-34. Historic population percentages in Lyon County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Alvord[a]	5.53	5.42	6.08	5.32	4.71	4.08	3.59	3.14
Doon[a]	12.10	11.13	9.76	9.79	8.86	8.03	6.58	6.73
George[a]	8.74	11.61	13.35	15.41	17.02	18.79	18.11	18.40
Inwood[a]	10.59	11.40	12.63	11.38	9.75	10.00	9.63	9.92
Larchwood[a]	9.99	8.32	7.47	6.49	6.23	6.45	8.01	9.41
Lester[a]	4.99	4.68	4.23	3.93	4.40	3.37	3.61	3.67
Little Rock[a]	8.86	9.02	9.70	9.94	9.73	8.28	8.51	8.18
Rock Rapids[a]	39.20	38.42	36.78	37.74	39.30	41.00	41.96	40.55
Total urban[b]	34.22	35.69	38.27	38.48	42.30	43.81	45.80	48.66
Rural farm[b]	65.78	64.31	61.73	61.31	57.65	54.20	51.08	46.36
Rural nonfarm[b]	0.00	0.00	0.00	0.21	0.05	1.99	3.12	4.98
Total rural[b]	65.78	64.31	61.73	61.52	57.70	56.19	54.20	51.34
Total county[c]	5.88	6.14	5.55	5.26	5.17	4.95	4.83	4.62

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-35. Historic population percentages in O'Brien County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Archer[a]	0.00	4.36	1.91	1.65	1.72	1.56	1.87	1.19
Calumet[a]	1.66	3.00	2.76	2.75	2.64	2.33	2.02	1.96
Hartley[a]	14.79	13.74	13.53	14.03	14.50	15.01	15.57	15.10
Moneta[a]	0.00	0.55	1.32	0.94	1.11	0.83	0.68	0.37
Paullina[a]	9.07	9.89	10.22	11.17	11.86	12.01	11.90	11.21
Primghar[a]	11.97	9.10	9.54	10.61	10.43	10.74	10.13	8.87
Sanborn[a]	18.34	14.58	15.50	13.38	12.96	12.46	11.85	13.06
Sheldon[a]	33.55	36.53	36.14	36.62	36.34	37.28	38.07	40.44
Sutherland[a]	10.62	8.25	9.08	8.85	8.44	7.78	7.91	7.80
Total urban[b]	40.04	46.64	50.66	49.25	53.74	56.57	59.26	64.01
Rural farm[b]	59.96	53.36	49.34	49.73	46.04	40.87	37.61	31.19
Rural nonfarm[b]	0.00	0.00	0.00	1.02	0.22	2.56	3.13	4.80
Total rural[b]	59.96	53.36	49.34	50.75	46.26	43.43	40.74	35.99
Total county[c]	7.58	7.24	6.84	6.34	6.49	6.40	6.29	6.07

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-36. Historic population percentages in Osceola County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Ashton[a]	19.60	18.00	16.31	15.38	14.34	13.09	12.94	11.24
Harris[a]	8.29	8.31	9.60	8.88	7.14	7.10	5.44	4.54
Melvin[a]	0.00	6.78	7.54	8.15	7.58	7.24	7.66	7.56
Ocheyedan[a]	22.88	20.68	18.34	16.97	16.46	15.59	13.93	12.68
Sibley[a]	49.23	46.23	48.21	50.62	54.48	56.98	60.03	63.98
Total urban[b]	30.01	32.12	36.58	36.28	40.78	44.11	47.21	50.23
Rural farm[b]	69.99	67.88	63.42	63.21	58.14	52.91	49.67	43.10
Rural nonfarm[b]	0.00	0.00	0.00	0.51	1.08	2.98	3.12	6.67
Total rural[b]	69.99	67.88	63.42	63.72	59.22	55.89	52.79	49.77
Total county[c]	3.90	3.76	3.67	3.50	3.57	3.43	3.36	2.96

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-37. Historic population percentages in Plymouth County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Akron[a]	14.11	12.91	13.48	13.00	12.39	11.34	11.10	9.59
Brunsville[a]	0.00	0.00	1.13	1.34	1.03	1.01	1.05	0.91
Craig[a]	0.00	0.00	1.59	1.54	1.56	1.29	0.96	0.71
Hinton[a]	0.00	3.76	2.68	2.88	3.20	3.13	3.31	3.54
Kingsley[a]	9.88	11.16	10.92	10.89	10.80	9.95	8.58	7.95
Le Mars[a]	56.86	47.49	47.70	47.72	50.48	52.96	55.61	59.12
Merrill[a]	5.34	5.94	6.45	6.03	5.16	5.48	5.30	5.72
Oyens[a]	0.00	1.08	1.02	1.06	0.98	0.86	0.94	1.05
Remsen[a]	11.45	12.29	11.65	11.77	11.28	11.60	11.00	9.91
Struble[a]	2.36	3.74	1.31	1.60	1.26	0.82	0.61	0.43
Westfield[a]	0.00	1.63	2.07	2.17	1.86	1.56	1.54	1.07
Total urban[b]	32.83	37.84	41.63	41.53	45.12	47.46	50.90	56.74
Rural farm[b]	67.17	62.16	58.37	57.36	53.96	48.75	42.31	35.64
Rural nonfarm[b]	0.00	0.00	0.00	1.11	0.92	3.79	6.79	7.60
Total rural[b]	67.17	62.16	58.37	58.47	54.88	52.54	49.10	43.24
Total county[c]	9.92	9.70	8.47	8.31	7.90	7.84	7.98	8.43

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-38. Historic population percentages in Sac County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Auburn[a]	4.48	6.37	5.14	4.37	4.43	3.96	3.96	3.59
Early[a]	8.85	7.98	7.20	7.69	7.45	8.20	8.88	7.93
Grant City[a]	3.81	2.58	1.20	0.00	0.00	0.00	0.00	0.00
Lake View[a]	9.03	8.20	10.62	12.08	12.51	13.12	12.56	13.63
Lytton[a]	0.00	0.00	3.52	4.54	3.87	4.22	4.05	4.13
Nemaha[a]	0.00	0.00	2.10	1.78	1.95	2.08	1.63	1.28
Odebolt[a]	21.89	20.48	18.30	16.89	15.61	14.48	14.35	14.44
Sac City[a]	31.77	35.13	33.32	34.73	36.60	35.89	36.16	35.67
Schaller[a]	10.10	10.31	9.26	8.81	8.77	9.52	9.66	9.11
Wall Lake[a]	10.07	8.95	9.34	9.11	8.81	8.53	8.75	10.22
Total urban[b]	37.09	37.85	45.11	46.58	49.03	50.42	54.54	58.83
Rural farm[b]	62.91	62.15	54.89	51.23	49.83	46.89	39.62	34.74
Rural nonfarm[b]	0.00	0.00	0.00	2.18	1.14	2.69	5.84	6.43
Total rural[b]	62.91	62.15	54.89	53.42	50.97	49.59	45.46	41.17
Total county[c]	7.88	6.95	6.29	6.07	5.93	5.90	5.68	5.40

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-39. Historic population percentages in Sioux County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Alton[a]	11.48	10.50	8.91	8.94	8.20	8.03	7.47	5.89
Boydon[a]	3.82	3.65	3.70	3.93	3.85	4.18	4.00	3.88
Chatsworth[a]	0.00	1.32	1.33	1.40	1.15	0.79	0.60	0.52
Granville[a]	4.00	4.02	3.17	3.44	2.89	2.71	2.72	2.22
Hawarden[a]	20.60	21.15	22.03	21.69	21.45	20.31	18.13	16.14
Hospers[a]	4.72	5.83	5.04	4.83	4.73	4.67	4.28	3.74
Hull[a]	7.12	6.61	7.00	7.98	8.58	8.72	9.19	8.80
Ireton[a]	6.20	6.33	6.46	5.40	5.22	4.43	3.63	3.37
Matlock[a]	1.07	1.18	0.83	0.92	0.90	0.80	0.73	0.51
Maurice[a]	3.19	2.91	2.91	2.42	2.18	1.98	1.69	1.54
Orange City[a]	16.58	13.79	14.43	15.23	15.35	16.76	19.29	20.67
Rock Valley[a]	12.00	12.03	11.91	10.62	12.06	12.23	12.06	12.76
Sioux Center[a]	9.22	10.68	12.28	13.20	13.44	14.39	16.21	19.96
Total urban[b]	37.65	39.46	42.74	42.30	45.94	49.00	53.21	61.73
Rural farm[b]	62.35	60.54	57.26	57.64	54.06	48.70	41.14	34.19
Rural nonfarm[b]	0.00	0.00	0.00	0.06	0.00	2.30	5.65	4.08
Total rural[b]	62.35	60.54	57.26	57.70	54.06	51.00	46.79	38.27
Total county[c]	10.42	10.59	9.51	9.22	9.15	8.89	8.80	9.70

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-40. Historic population percentages in Woodbury County, 1900-1970

City	1900	1910	1920	1930	1940	1950	1960	1970
Anthon[a]	1.14	1.18	1.00	0.96	0.98	0.85	0.71	0.76
Bronson[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
Correctionville[a]	2.45	1.67	1.30	1.22	1.28	1.09	0.95	0.93
Cushing[a]	0.62	0.47	0.37	0.31	0.29	0.27	0.27	0.22
Danbury[a]	1.26	1.04	0.86	0.76	0.81	0.66	0.53	0.56
Hornick[a]	0.74	0.46	0.38	0.36	0.32	0.34	0.29	0.27
Lawton[a]	0.00	0.26	0.31	0.30	0.29	0.28	0.34	0.43
Moville[a]	1.33	1.03	1.12	1.05	1.08	1.06	1.20	1.28
Oto[a]	1.04	0.50	0.43	0.43	0.46	0.33	0.23	0.22
Pierson[a]	0.94	0.78	0.71	0.64	0.59	0.50	0.44	0.45
Salix[a]	1.00	0.73	0.51	0.43	0.44	0.38	0.41	0.41
Sergeant Bluff[a]	0.00	0.98	0.70	0.66	0.65	0.63	0.85	1.23
Sioux City[a]	86.66	89.26	91.12	91.69	91.68	92.48	92.69	91.86
Sloan[a]	1.68	1.02	0.78	0.74	0.70	0.72	0.73	0.85
Smithland[a]	1.14	0.62	0.41	0.45	0.43	0.41	0.36	0.32
Total urban[b]	69.97	79.25	84.81	84.94	86.70	87.40	89.18	90.77
Rural farm[b]	30.03	20.75	15.19	14.46	12.70	10.75	8.68	6.61
Rural nonfarm[b]	0.00	0.00	0.00	0.60	0.60	1.85	2.14	2.62
Total rural[b]	30.03	20.75	15.19	15.06	13.30	12.60	10.82	9.23
Total county[c]	24.39	28.37	33.11	34.99	34.85	35.03	35.99	35.72

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-41. Projected population percentages in Buena Vista County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Albert City[a]	4.84	4.53	4.23	3.92	3.61	3.30
Alta[a]	12.18	12.48	12.77	13.05	13.33	13.60
Lakeside[a]	2.50	2.79	3.07	3.35	3.63	3.90
Linn Grove[a]	1.70	1.49	1.28	1.07	0.86	0.66
Marathon[a]	3.17	2.96	2.75	2.55	2.35	2.15
Newell[a]	6.22	5.90	5.58	5.26	4.95	4.64
Rembrandt[a]	1.77	1.55	1.33	1.11	0.88	0.66
Sioux Rapids[a]	5.76	5.38	4.99	4.60	4.21	3.82
Storm Lake[a]	60.92	62.10	63.30	64.50	65.70	66.90
Truesdale[a]	0.94	0.82	0.70	0.59	0.48	0.37
Total urban[b]	68.16	69.30	70.45	71.60	72.75	73.90
Rural farm[b]	25.62	24.10	22.55	21.00	19.45	17.95
Rural nonfarm[b]	6.22	6.60	7.00	7.40	7.80	8.15
Total rural[b]	31.84	30.70	29.55	28.40	27.25	26.10
Total county[c]	7.17	7.12	7.08	7.05	7.02	7.00

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-42. Projected population percentages in Cherokee County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Aurelia[a]	9.74	10.40	11.05	11.70	12.35	13.00
Cherokee[a]	66.53	66.12	65.73	65.34	64.95	64.60
Cleghorn[a]	2.51	2.44	2.37	2.30	2.23	2.15
Larrabee[a]	1.53	1.47	1.41	1.35	1.31	1.25
Marcus[a]	11.64	11.66	11.69	11.71	11.72	11.74
Meriden[a]	1.53	1.45	1.36	1.28	1.19	1.10
Quimby[a]	3.60	3.61	3.61	3.61	3.61	3.60
Washta[a]	2.92	2.85	2.78	2.71	2.64	2.56
Total urban[b]	63.30	63.80	64.30	64.80	65.30	65.70
Rural farm[b]	28.50	27.25	26.00	24.75	23.50	22.30
Rural nonfarm[b]	8.20	8.95	9.70	10.45	11.20	12.00
Total rural[b]	36.70	36.20	35.70	35.20	34.70	34.30
Total county[c]	5.99	5.89	5.79	5.72	5.68	5.65

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-43. Projected population percentages in Clay County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Dickins[a]	1.88	1.65	1.43	1.22	1.01	0.85
Everly[a]	5.45	5.50	5.54	5.58	5.62	5.65
Fostoria[a]	1.71	1.80	1.90	2.00	2.10	2.20
Greenville[a]	0.91	0.81	0.70	0.59	0.48	0.35
Peterson[a]	3.66	3.43	3.21	2.99	2.77	2.54
Rossie[a]	0.71	0.63	0.55	0.48	0.42	0.35
Royal[a]	3.66	3.51	3.36	3.21	3.06	2.90
Spencer[a]	80.20	80.93	81.66	82.36	83.05	83.76
Webb[a]	1.82	1.74	1.65	1.57	1.49	1.40
Total urban[b]	69.41	70.10	70.85	71.65	72.45	73.30
Rural farm[b]	23.62	22.30	21.00	19.70	18.40	17.10
Rural nonfarm[b]	6.97	7.60	8.15	8.65	9.15	9.60
Total rural[b]	30.59	29.90	29.15	28.35	27.55	26.70
Total county[c]	6.40	6.60	6.80	7.00	7.20	7.40

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-44. Projected population percentages in Dickinson County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Arnold's Park[a]	11.76	11.67	11.58	11.49	11.40	11.30
Lake Park[a]	11.13	10.97	10.80	10.63	10.46	10.30
Milford[a]	20.23	20.39	20.55	20.70	20.85	21.00
Okoboji[a]	4.38	4.59	4.80	5.00	5.20	5.40
Old Town[a]	0.29	0.34	0.39	0.44	0.49	0.54
Orleans[a]	4.80	4.57	4.34	4.11	3.89	3.67
Spirit Lake[a]	36.55	36.84	37.13	37.42	37.71	38.00
Superior[a]	1.69	1.46	1.23	1.00	0.77	0.54
Terrill[a]	4.81	4.50	4.20	3.90	3.60	3.30
Wahpeton[a]	1.81	1.98	2.16	2.34	2.52	2.70
West Okoboji[a]	2.55	2.69	2.82	2.97	3.11	3.25
Total urban[b]	65.63	66.50	67.35	68.20	69.10	70.00
Rural farm[b]	24.41	22.70	21.00	19.30	17.60	15.90
Rural nonfarm[b]	9.96	10.80	11.65	12.50	13.30	14.10
Total rural[b]	34.37	33.50	32.65	31.80	30.90	30.00
Total county[c]	4.35	4.52	4.67	4.80	4.94	5.05

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-45. Projected population percentages in Ida County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Arthur[a]	5.22	4.70	4.20	3.70	3.20	2.70
Battle Creek[a]	16.01	16.04	16.08	16.12	16.16	16.20
Galva[a]	7.88	7.40	6.90	6.40	5.90	5.40
Holstein[a]	27.64	28.02	28.39	28.76	29.13	29.50
Ida Grove[a]	43.25	43.84	44.43	45.02	45.61	46.20
Total urban[b]	56.89	56.94	56.98	57.02	57.06	57.10
Rural farm[b]	39.92	39.30	38.70	38.10	37.50	36.90
Rural nonfarm[b]	3.19	3.76	4.32	4.88	5.44	6.00
Total rural[b]	43.11	43.06	43.02	42.98	42.94	42.90
Total county[c]	3.19	3.05	2.91	2.75	2.63	2.50

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-46. Projected population percentages in Lyon County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Alvord[a]	3.14	2.90	2.65	2.40	2.15	1.90
Doon[a]	6.73	6.88	7.03	7.17	7.31	7.45
George[a]	18.40	18.00	17.60	17.20	16.80	16.40
Inwood[a]	9.92	9.73	9.54	9.36	9.18	9.00
Larchwood[a]	9.41	9.90	10.40	10.90	11.40	11.90
Lester[a]	3.67	3.53	3.40	3.26	3.13	3.00
Little Rock[a]	8.18	8.24	8.30	8.35	8.40	8.45
Rock Rapids[a]	40.55	40.82	41.08	41.36	41.63	41.90
Total urban[b]	48.66	51.20	53.70	56.20	58.60	61.00
Rural farm[b]	46.36	43.20	40.10	37.00	34.00	31.00
Rural nonfarm[b]	4.98	5.60	6.20	6.80	7.40	8.00
Total rural[b]	51.34	48.80	46.30	43.80	41.40	39.00
Total county[c]	4.62	4.52	4.42	4.33	4.27	4.20

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-47. Projected population percentages in O'Brien County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Archer[a]	1.19	1.06	0.92	0.78	0.64	0.50
Calumet[a]	1.96	1.76	1.57	1.38	1.19	1.00
Hartley[a]	15.10	14.92	14.74	14.56	14.38	14.20
Moneta[a]	0.37	0.31	0.23	0.15	0.08	0.00
Paullina[a]	11.21	11.07	10.94	10.82	10.68	10.55
Primghar[a]	8.87	8.70	8.53	8.37	8.21	8.05
Sanborn[a]	13.06	12.94	12.83	12.72	12.61	12.50
Sheldon[a]	40.44	41.80	43.16	44.50	45.85	47.20
Sutherland[a]	7.80	7.44	7.08	6.72	6.36	6.00
Total urban[b]	64.01	65.00	66.00	67.00	68.00	69.00
Rural farm[b]	31.19	29.55	27.90	26.25	24.60	22.90
Rural nonfarm[b]	4.80	5.45	6.10	6.75	7.40	8.10
Total rural[b]	35.99	35.00	34.00	33.00	32.00	31.00
Total county[c]	6.07	5.94	5.80	5.68	5.60	5.50

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-48. Projected population percentages in Osceola County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Ashton[a]	11.24	11.02	10.80	10.58	10.36	10.14
Harris[a]	4.54	4.10	3.66	3.22	2.77	2.32
Melvin[a]	7.56	7.20	6.85	6.50	6.15	5.80
Ocheyedan[a]	12.68	11.94	11.20	10.46	9.73	9.00
Sibley[a]	63.98	65.74	67.49	69.24	70.99	72.74
Total urban[b]	50.23	50.80	51.35	51.90	52.50	53.10
Rural farm[b]	43.10	41.40	39.70	38.00	36.30	34.60
Rural nonfarm[b]	6.67	7.80	8.95	10.10	11.20	12.30
Total rural[b]	49.77	49.20	48.65	48.10	47.50	46.90
Total county[c]	2.96	2.85	2.76	2.66	2.57	2.50

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-49. Projected population percentages in Plymouth County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Akron[a]	9.59	9.17	8.75	8.33	7.91	7.50
Brunsville[a]	0.91	0.88	0.86	0.84	0.82	0.80
Craig[a]	0.71	0.63	0.55	0.47	0.39	0.31
Hinton[a]	3.54	3.63	3.72	3.82	3.90	4.00
Kingsley[a]	7.95	7.66	7.37	7.08	6.79	6.50
Le Mars[a]	59.12	60.09	61.05	62.00	62.95	63.90
Merrill[a]	5.72	5.77	5.82	5.86	5.90	5.94
Oyens[a]	1.05	1.10	1.14	1.18	1.22	1.25
Remsen[a]	9.91	9.78	9.66	9.54	9.42	9.30
Struble[a]	0.43	0.34	0.25	0.16	0.08	0.00
Westfield[a]	1.07	0.95	0.83	0.72	0.62	0.50
Total urban[b]	56.76	58.90	61.20	63.50	65.80	68.10
Rural farm[b]	35.64	32.90	30.10	27.30	24.50	21.70
Rural nonfarm[b]	7.60	8.20	8.70	9.20	9.70	10.20
Total rural[b]	43.24	41.10	38.80	36.50	34.20	31.90
Total county[c]	8.43	8.53	8.64	8.76	8.87	9.00

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-50. Projected population percentages in Sac County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Auburn[a]	3.59	3.40	3.20	3.02	2.83	2.64
Early[a]	7.93	7.54	7.15	6.76	6.38	6.00
Grant City[a]	0.00	0.00	0.00	0.00	0.00	0.00
Lake View[a]	13.63	13.67	13.71	13.74	13.77	13.80
Lytton[a]	4.13	4.10	4.07	4.04	4.02	4.00
Nemaha[a]	1.28	1.15	1.02	0.90	0.78	0.66
Odebolt[a]	14.44	14.20	13.98	13.75	13.52	13.30
Sac City[a]	35.67	36.35	37.02	37.68	38.34	39.00
Schaller[a]	9.11	9.15	9.19	9.23	9.27	9.30
Wall Lake[a]	10.22	10.44	10.66	10.88	11.09	11.30
Total urban[b]	58.83	59.60	60.30	61.00	61.85	62.70
Rural farm[b]	34.74	33.30	31.90	30.50	29.00	27.50
Rural nonfarm[b]	6.43	7.10	7.80	8.50	9.15	9.80
Total rural[b]	41.17	40.40	39.70	39.00	38.15	37.30
Total county[c]	5.40	5.23	5.05	4.89	4.75	4.60

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-51. Projected population percentages in Sioux County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Alton[a]	5.89	5.81	5.73	5.65	5.58	5.50
Boydon[a]	3.88	3.82	3.76	3.71	3.66	3.60
Chatsworth[a]	0.52	0.46	0.41	0.35	0.30	0.25
Granville[a]	2.22	2.17	2.12	2.08	2.04	2.00
Hawarden[a]	16.14	15.82	15.48	15.16	14.82	14.50
Hospers[a]	3.74	3.72	3.68	3.66	3.62	3.60
Hull[a]	8.80	9.04	9.28	9.52	9.76	10.00
Ireton[a]	3.37	3.32	3.26	3.21	3.16	3.10
Matlock[a]	0.51	0.45	0.40	0.35	0.30	0.25
Maurice[a]	1.54	1.47	1.41	1.33	1.26	1.20
Orange City[a]	20.67	20.76	20.86	20.94	21.02	21.10
Rock Valley[a]	12.76	12.79	12.83	12.85	12.88	12.90
Sioux Center[a]	19.96	20.37	20.78	21.19	21.60	22.00
Total urban[b]	61.73	64.80	67.85	70.90	73.95	77.00
Rural farm[b]	34.19	30.80	27.40	24.00	20.65	17.30
Rural nonfarm[b]	4.08	4.40	4.75	5.10	5.40	5.70
Total rural[b]	38.27	35.20	32.15	29.10	26.05	23.00
Total county[c]	9.70	9.75	9.80	9.85	9.90	9.95

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-52. Projected population percentages in Woodbury County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Anthon[a]	0.76	0.72	0.68	0.64	0.60	0.57
Bronson[a]	0.21	0.27	0.33	0.39	0.44	0.49
Correctionville[a]	0.93	0.88	0.83	0.78	0.73	0.69
Cushing[a]	0.22	0.20	0.18	0.16	0.14	0.12
Danbury[a]	0.56	0.54	0.52	0.50	0.48	0.46
Hornick[a]	0.27	0.25	0.23	0.21	0.19	0.17
Lawton[a]	0.43	0.49	0.54	0.59	0.64	0.69
Moville[a]	1.28	1.35	1.42	1.49	1.56	1.61
Oto[a]	0.22	0.20	0.18	0.16	0.14	0.12
Pierson[a]	0.45	0.42	0.40	0.38	0.36	0.34
Salix[a]	0.41	0.41	0.41	0.40	0.40	0.40
Sergeant Bluff[a]	1.23	1.29	1.34	1.39	1.44	1.49
Sioux City[a]	91.86	91.81	91.76	91.72	91.68	91.64
Sloan[a]	0.85	0.87	0.90	0.93	0.96	0.98
Smithland[a]	0.32	0.30	0.28	0.26	0.24	0.23
Total urban[b]	90.77	90.82	90.87	90.92	90.96	91.00
Rural farm[b]	6.61	6.35	6.09	5.83	5.59	5.35
Rural nonfarm[b]	2.62	2.83	3.04	3.25	3.45	3.65
Total rural[b]	9.23	9.18	9.13	9.08	9.04	9.00
Total county[c]	35.72	36.00	36.28	36.51	36.57	36.65

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-53. Projected population of Buena Vista County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Albert City	683	620	570	520	490	450
Alta	1,717	1,710	1,720	1,750	1,800	1,850
Lakeside	353	380	410	450	490	530
Linn Grove	240	200	170	140	120	90
Marathon	447	410	370	340	320	290
Newell	877	810	750	700	670	630
Rembrandt	250	210	180	150	120	90
Sioux Rapids	813	740	680	620	570	520
Storm Lake	8,591	8,530	8,520	8,640	8,890	9,100
Truesdale	132	110	90	80	60	50
Total urban	14,103	13,720	13,460	13,390	13,530	13,600
Rural farm	5,302	4,770	4,300	3,930	3,620	3,300
Rural nonfarm	1,288	1,310	1,340	1,380	1,450	1,500
Total rural	6,590	6,080	5,640	5,310	5,070	4,800
Total county	20,693	19,800	19,100	18,700	18,600	18,400

Table A-54. Projected population of Cherokee County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Aurelia	1,065	1,080	1,110	1.150	1,210	1,260
Cherokee	7,272	6,880	6,590	6,430	6,360	6,280
Cleghorn	274	250	240	230	220	210
Larrabee	167	150	140	130	130	120
Marcus	1,272	1,210	1,170	1,150	1,150	1,140
Meriden	167	150	140	130	120	110
Quimby	395	380	360	360	350	350
Washta	319	300	280	270	260	250
Total urban	10,931	10,400	10,030	9,850	9,800	9,720
Rural farm	4,922	4,440	4,060	3,760	3,520	3,300
Rural nonfarm	1,416	1,460	1,510	1,590	1,680	1,780
Total rural	6,338	5,900	5,570	5,350	5,200	5,080
Total county	17,269	16,300	15,600	15,200	15,000	14,800

Table A-55. Projected population of Clay County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Dickins	240	210	180	160	140	120
Everly	699	710	720	740	770	800
Fostoria	219	230	250	270	290	310
Greenville	117	100	90	80	70	50
Peterson	469	440	420	400	380	360
Rossie	91	80	70	60	60	50
Royal	469	460	440	430	420	410
Spencer	10,278	10,380	10,590	10,980	11,440	11,850
Webb	234	220	210	210	200	200
Total urban	12,816	12,830	12,970	13,330	13,770	14,150
Rural farm	4,361	4,080	3,840	3,660	3,500	3,300
Rural nonfarm	1,287	1,390	1,490	1,610	1,730	1,850
Total rural	5,648	5,470	5,330	5,270	5,230	5,150
Total county	18,464	18,300	18,300	18,600	19,000	19,300

Table A-56. Projected population of Dickinson County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Arnold's Park	970	970	980	1,000	1,020	1,050
Lake Park	918	920	920	930	940	950
Milford	1,668	1,690	1,730	1,800	1,870	1,940
Okoboji	361	380	410	440	470	500
Old Town	24	30	30	40	40	50
Orleans	396	380	370	360	350	340
Spirit Lake	3,014	3,060	3,160	3,270	3,390	3,510
Superior	139	120	110	90	70	50
Terrill	397	380	360	340	320	300
Wahpeton	149	160	180	200	230	250
West Okoboji	210	220	240	260	280	300
Total urban	8,246	8,310	8,490	8,730	8,980	9,240
Rural farm	3,068	2,840	2,640	2,470	2,290	2,100
Rural nonfarm	1,251	1,350	1,470	1,600	1,730	1,860
Total rural	4,319	4,190	4,110	4,070	4,020	3,960
Total county	12,565	12,500	12,600	12,800	13,000	13,200

Table A-57. Projected population of Ida County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Arthur	273	220	190	150	130	100
Battle Creek	837	770	710	670	640	600
Galva	412	350	310	270	230	200
Holstein	1,445	1,340	1,260	1,200	1,140	1,090
Ida Grove	2,261	2,100	1,970	1,870	1,800	1,720
Total urban	5,228	4,780	4,440	4,160	3,940	3,710
Rural farm	3,669	3,300	3,020	2,780	2,590	2,400
Rural nonfarm	293	320	340	360	370	390
Total rural	3,962	3,620	3,360	3,140	2,960	2,790
Total county	9,190	8,400	7,800	7,300	6,900	6,500

Table A-58. Projected population of Lyon County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Alvord	204	190	170	160	140	130
Doon	437	440	450	460	480	500
George	1,194	1,150	1,120	1,110	1,110	1,100
Inwood	644	620	620	610	610	600
Larchwood	611	630	660	700	750	800
Lester	238	230	220	210	210	200
Little Rock	531	530	530	540	560	570
Rock Rapids	2,632	2,610	2,620	2,670	2,760	2,810
Total urban	6,491	6,400	6,390	6,460	6,620	6,710
Rural farm	6,184	5,400	4,770	4,260	3,840	3,410
Rural nonfarm	665	700	740	780	840	880
Total rural	6,849	6,100	5,510	5,040	4,680	4,290
Total county	13,340	12,500	11,900	11,500	11,300	11,000

Table A-59. Projected population of O'Brien County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Archer	134	110	90	80	60	50
Calumet	219	190	160	140	120	100
Hartley	1,694	1,590	1,520	1,470	1,450	1,410
Moneta	41	30	20	20	10	0
Paullina	1,257	1,180	1,130	1,090	1,070	1,050
Primghar	995	930	880	850	830	800
Sanborn	1,465	1,380	1,320	1,290	1,270	1,240
Sheldon	4,535	4,460	4,450	4,500	4,610	4,690
Sutherland	875	790	730	680	640	600
Total urban	11,215	10,660	10,300	10,120	10,060	9,940
Rural farm	5,466	4,850	4,350	3,960	3,640	3,300
Rural nonfarm	841	890	950	1,020	1,100	1,160
Total rural	6,307	5,740	5,300	4,980	4,740	4,460
Total county	17,522	16,400	15,600	15,100	14,800	14,400

Table A-60. Projected population of Osceola County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Ashton	483	440	410	390	370	350
Harris	195	160	140	120	100	80
Melvin	325	290	260	240	220	200
Ocheyedan	545	480	430	380	350	310
Sibley	2,749	2,640	2,560	2,550	2,530	2,510
Total urban	4,297	4,010	3,800	3,680	3,570	3,450
Rural farm	3,687	3,270	2,940	2,700	2,470	2,250
Rural nonfarm	571	620	660	720	760	800
Total rural	4,258	3,890	3,600	3,420	3,230	3,050
Total county	8,555	7,900	7,400	7,100	6,800	6,500

Table A-61. Projected population of Plymouth County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Akron	1,324	1,270	1,250	1,230	1,220	1,200
Brunsville	125	120	120	120	130	130
Craig	98	90	80	70	60	50
Hinton	488	500	530	560	600	640
Kingsley	1,097	1,070	1,050	1,050	1,050	1,040
Le Mars	8,159	8,350	8,700	9,180	9,690	10,220
Merrill	790	800	830	870	900	950
Oyens	145	150	160	170	190	200
Remsen	1,367	1,370	1,380	1,410	1,450	1,490
Struble	59	50	40	20	10	0
Westfield	148	130	120	110	100	80
Total urban	13,800	13,900	14,260	14,800	15,400	16,000
Rural farm	8,664	7,760	7,010	6,360	5,730	5,100
Rural nonfarm	1,848	1,940	2,030	2,140	2,270	2,400
Total rural	10,512	9,700	9,040	8,500	8,000	7,500
Total county	24,312	23,600	23,300	23,300	23,400	23,500

Table A-62. Projected population of Sac County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Auburn	329	290	260	240	220	200
Early	727	660	590	540	490	450
Grant City	0	0	0	0	0	0
Lake View	1,249	1,180	1,120	1,090	1,060	1,040
Lytton	378	350	330	320	310	300
Nemaha	117	100	80	70	60	50
Odebolt	1,323	1,230	1,160	1,090	1,050	1,000
Sac City	3,268	3,140	3,040	2,990	2,960	2,930
Schaller	835	790	750	730	720	700
Wall Lake	936	900	870	860	860	850
Total urban	9,162	8,640	8,200	7,930	7,730	7,520
Rural farm	5,410	4,830	4,340	3,970	3,630	3,300
Rural nonfarm	1,001	1,030	1,060	1,100	1,140	1,180
Total rural	6,411	5,860	5,400	5,070	4,770	4,480
Total county	15,573	14,500	13,600	13,000	12,500	12,000

Table A-63. Projected population of Sioux County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Alton	1,018	1,020	1,030	1,050	1,080	1,100
Boyden	670	670	670	690	700	720
Chatsworth	90	80	70	60	60	50
Granville	383	380	380	390	390	400
Hawarden	2,789	2,770	2,770	2,820	2,860	2,900
Hospers	646	650	660	680	700	720
Hull	1,523	1,580	1,660	1,770	1,880	2,000
Ireton	582	580	580	600	610	620
Matlock	89	80	70	60	60	50
Maurice	266	260	250	250	240	240
Orange City	3,572	3,630	3,750	3,890	4,060	4,240
Rock Valley	2,205	2,240	2,300	2,380	2,490	2,580
Sioux Center	3,450	3,560	3,720	3,930	4,170	4,400
Total urban	17,283	17,500	17,910	18,570	19,300	20,020
Rural farm	9,572	8,310	7,230	6,290	5,390	4,500
Rural nonfarm	1,141	1,190	1,260	1,340	1,410	1,480
Total rural	10,713	9,500	8,490	7,630	6,800	5,980
Total county	27,996	27,000	26,400	26,200	26,100	26,000

Table A-64. Projected population of Woodbury County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Anthon	711	650	600	560	530	500
Bronson	193	240	290	340	390	440
Correctionville	870	800	740	690	640	600
Cushing	204	180	160	140	120	100
Danbury	527	490	460	440	420	400
Hornick	250	230	210	190	170	150
Lawton	406	440	480	520	560	600
Moville	1,198	1,220	1,260	1,310	1,370	1,400
Oto	203	180	160	140	120	100
Pierson	421	380	360	340	320	300
Salix	387	370	360	350	350	350
Sergeant Bluff	1,153	1,170	1,190	1,230	1,260	1,300
Sioux City	85,925	83,050	81,460	80,890	80,480	79,890
Sloan	799	790	800	820	840	850
Smithland	293	270	250	230	210	200
Total urban	93,540	90,460	88,780	88,190	87,780	87,180
Rural farm	6,813	6,320	5,950	5,560	5,390	5,120
Rural nonfarm	2,699	2,820	2,970	3,150	3,330	3,500
Total rural	9,512	9,140	8,920	8,810	8,720	8,620
Total county	103,052	99,600	97,700	97,000	96,500	95,800

Table A-65. State of Iowa projected population percentages in Buena Vista County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Albert City[a]	4.84	4.53	4.23	3.92	3.61	3.30
Alta[a]	12.18	12.48	12.77	13.05	13.33	13.60
Lakeside[a]	2.50	2.79	3.07	3.35	3.63	3.90
Linn Grove[a]	1.70	1.49	1.28	1.07	0.86	0.66
Marathon[a]	3.17	2.96	2.75	2.55	2.35	2.15
Newell[a]	6.22	5.90	5.58	5.26	4.95	4.64
Rembrandt[a]	1.77	1.55	1.33	1.11	0.88	0.66
Sioux Rapids[a]	5.76	5.38	4.99	4.60	4.21	3.82
Storm Lake[a]	60.92	62.10	63.30	64.50	65.70	66.90
Truesdale[a]	0.94	0.82	0.70	0.59	0.48	0.37
Total urban[b]	68.16	70.85	73.22	74.58	75.59	76.50
Rural farm[b]	25.62	22.39	19.66	17.74	16.36	15.05
Rural nonfarm[b]	6.22	6.76	7.12	7.68	8.05	8.45
Total rural[b]	31.84	29.15	26.78	25.42	24.41	23.50
Total county[c]	7.17	7.15	7.04	6.84	6.65	6.42

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-66. State of Iowa projected population percentages in Cherokee County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Aurelia[a]	9.74	10.40	11.05	11.70	12.35	13.00
Cherokee[a]	66.53	66.12	65.73	65.34	64.95	64.60
Cleghorn[a]	2.51	2.44	2.37	2.30	2.23	2.15
Larrabee[a]	1.53	1.47	1.41	1.35	1.31	1.25
Marcus[a]	11.64	11.66	11.69	11.71	11.72	11.74
Meriden[a]	1.53	1.45	1.36	1.28	1.19	1.10
Quimby[a]	3.60	3.61	3.61	3.61	3.61	3.60
Washta[a]	2.92	2.85	2.78	2.71	2.64	2.56
Total urban[b]	63.30	63.88	65.37	66.86	68.00	68.77
Rural farm[b]	28.50	27.14	24.66	22.33	20.34	18.60
Rural nonfarm[b]	8.20	8.98	9.97	10.81	11.66	12.63
Total rural[b]	36.70	36.12	34.63	33.14	32.00	31.23
Total county[c]	5.99	5.49	5.26	5.21	5.21	5.20

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-67. State of Iowa projected population percentages in Clay County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Dickins[a]	1.88	1.65	1.43	1.22	1.01	0.85
Everly[a]	5.45	5.50	5.54	5.58	5.62	5.65
Fostoria[a]	1.71	1.80	1.90	2.00	2.10	2.20
Greenville[a]	0.91	0.81	0.70	0.59	0.48	0.35
Peterson[a]	3.66	3.43	3.21	2.99	2.77	2.54
Rossie[a]	0.71	0.63	0.55	0.48	0.42	0.35
Royal[a]	3.66	3.51	3.36	3.21	3.06	2.90
Spencer[a]	80.20	80.93	81.66	82.36	83.05	83.76
Webb[a]	1.82	1.74	1.65	1.57	1.49	1.40
Total urban[b]	69.41	71.10	72.79	73.37	73.74	74.32
Rural farm[b]	23.62	21.20	18.96	17.78	16.92	15.99
Rural nonfarm[b]	6.97	7.70	8.25	8.85	9.34	8.69
Total rural[b]	30.59	28.90	27.21	26.63	26.26	25.68
Total county[c]	6.40	6.46	6.47	6.36	6.22	6.05

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-68. State of Iowa projected population percentages in Dickinson County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Arnold's Park[a]	11.76	11.67	11.58	11.49	11.40	11.30
Lake Park[a]	11.13	10.97	10.80	10.63	10.46	10.30
Milford[a]	20.23	20.39	20.55	20.70	20.85	21.00
Okoboji[a]	4.38	4.59	4.80	5.00	5.20	5.40
Old Town[a]	0.29	0.34	0.39	0.44	0.49	0.54
Orleans[a]	4.80	4.57	4.34	4.11	3.89	3.67
Spirit Lake[a]	36.55	36.84	37.13	37.42	37.71	38.00
Superior[a]	1.69	1.46	1.23	1.00	0.77	0.54
Terrill[a]	4.81	4.50	4.20	3.90	3.60	3.30
Wahpeton[a]	1.81	1.98	2.16	2.34	2.52	2.70
West Okoboji[a]	2.55	2.69	2.82	2.97	3.11	3.25
Total urban[b]	65.63	69.48	72.08	72.58	73.01	73.55
Rural farm[b]	24.41	19.22	15.75	14.14	12.82	11.62
Rural nonfarm[b]	9.96	11.30	12.17	13.28	14.17	14.83
Total rural[b]	34.37	30.52	27.92	27.42	26.99	26.45
Total county[c]	4.35	4.96	5.35	5.25	5.37	5.30

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-69. State of Iowa projected population percentages in Ida County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Arthur[a]	5.22	4.70	4.20	3.70	3.20	2.70
Battle Creek[a]	16.01	16.04	16.08	16.12	16.16	16.20
Galva[a]	7.88	7.40	6.90	6.40	5.90	5.40
Holstein[a]	27.64	28.02	28.39	28.76	29.13	29.50
Ida Grove[a]	43.25	43.84	44.43	45.02	45.61	46.20
Total urban[b]	56.89	58.30	60.64	62.60	64.19	65.95
Rural farm[b]	39.92	37.80	34.75	31.99	29.63	27.15
Rural nonfarm[b]	3.19	3.90	4.61	5.41	6.18	6.90
Total rural[b]	43.11	41.70	39.36	37.40	35.81	34.05
Total county[c]	3.19	2.93	2.78	2.68	2.63	2.59

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-70. State of Iowa projected population percentages in Lyon County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Alvord[a]	3.14	2.90	2.65	2.40	2.15	1.90
Doon[a]	6.73	6.88	7.03	7.17	7.31	7.45
George[a]	18.40	18.00	17.60	17.20	16.80	16.40
Inwood[a]	9.92	9.73	9.54	9.36	9.18	9.00
Larchwood[a]	9.41	9.90	10.40	10.90	11.40	11.90
Lester[a]	3.67	3.53	3.40	3.26	3.13	3.00
Little Rock[a]	8.18	8.24	8.30	8.35	8.40	8.45
Rock Rapids[a]	40.55	40.82	41.08	41.36	41.63	41.90
Total urban[b]	48.66	52.76	58.09	62.58	66.43	70.25
Rural farm[b]	46.36	41.47	35.25	29.85	25.13	20.58
Rural nonfarm[b]	4.98	5.77	6.66	7.57	8.44	9.17
Total rural[b]	51.34	47.24	41.91	37.42	33.57	29.75
Total county[c]	4.62	4.37	4.32	4.41	4.60	4.86

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-71. State of Iowa projected population percentages in O'Brien County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Archer[a]	1.19	1.06	0.92	0.78	0.64	0.50
Calumet[a]	1.96	1.76	1.57	1.38	1.19	1.00
Hartley[a]	15.10	14.92	14.74	14.56	14.38	14.20
Moneta[a]	0.37	0.31	0.23	0.15	0.08	0.00
Paullina[a]	11.21	11.07	10.94	10.82	10.68	10.55
Primghar[a]	8.87	8.70	8.53	8.37	8.21	8.05
Sanborn[a]	13.06	12.94	12.83	12.72	12.61	12.50
Sheldon[a]	40.44	41.80	43.16	44.50	45.85	47.20
Sutherland[a]	7.80	7.44	7.08	6.72	6.36	6.00
Total urban[b]	64.01	67.44	70.54	72.20	73.42	74.76
Rural farm[b]	31.19	26.94	23.00	20.50	18.53	16.52
Rural nonfarm[b]	4.80	5.62	6.46	7.30	8.05	8.72
Total rural[b]	35.99	32.56	29.46	27.80	26.58	25.24
Total county[c]	6.07	6.04	6.04	5.97	5.91	5.85

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-72. State of Iowa projected population percentages in Osceola County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Ashton[a]	11.24	11.02	10.80	10.58	10.36	10.14
Harris[a]	4.54	4.10	3.66	3.22	2.77	2.32
Melvin[a]	7.56	7.20	6.85	6.50	6.15	5.80
Ocheyedan[a]	12.68	11.94	11.20	10.46	9.73	9.00
Sibley[a]	63.98	65.74	67.49	69.24	70.99	72.74
Total urban[b]	50.23	54.13	58.34	60.53	62.81	64.92
Rural farm[b]	43.10	37.50	31.65	27.61	23.61	19.98
Rural nonfarm[b]	6.67	8.37	9.99	11.86	13.58	15.10
Total rural[b]	49.77	45.87	41.64	39.47	37.19	35.08
Total county[c]	2.96	2.93	2.97	3.02	3.15	3.30

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-73. State of Iowa projected population percentages in Plymouth County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Akron[a]	9.59	9.17	8.75	8.33	7.91	7.50
Brunsville[a]	0.91	0.88	0.86	0.84	0.82	0.80
Craig[a]	0.71	0.63	0.55	0.47	0.39	0.31
Hinton[a]	3.54	3.63	3.72	3.82	3.90	4.00
Kingsley[a]	7.95	7.66	7.37	7.08	6.79	6.50
Le Mars[a]	59.12	60.09	61.05	62.00	62.95	63.90
Merrill[a]	5.72	5.77	5.82	5.86	5.90	5.94
Oyens[a]	1.05	1.10	1.14	1.18	1.22	1.25
Remsen[a]	9.91	9.78	9.66	9.54	9.42	9.30
Struble[a]	0.43	0.34	0.25	0.16	0.08	0.00
Westfield[a]	1.07	0.95	0.83	0.72	0.62	0.50
Total urban[b]	56.76	59.33	62.64	65.35	67.84	70.18
Rural farm[b]	35.64	32.40	28.59	25.19	22.12	19.27
Rural nonfarm[b]	7.60	8.27	8.77	9.46	10.04	10.55
Total rural[b]	43.24	40.67	37.36	34.65	32.16	29.82
Total county[c]	8.43	8.04	7.83	7.80	7.79	7.75

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-74. State of Iowa projected population percentages in Sac County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Auburn[a]	3.59	3.40	3.20	3.02	2.83	2.64
Early[a]	7.93	7.54	7.15	6.76	6.38	6.00
Grant City[a]	0.00	0.00	0.00	0.00	0.00	0.00
Lake View[a]	13.63	13.67	13.71	13.74	13.77	13.80
Lytton[a]	4.13	4.10	4.07	4.04	4.02	4.00
Nemaha[a]	1.28	1.15	1.02	0.90	0.78	0.66
Odebolt[a]	14.44	14.20	13.98	13.75	13.52	13.30
Sac City[a]	35.67	36.35	37.02	37.68	38.34	39.00
Schaller[a]	9.11	9.15	9.19	9.23	9.27	9.30
Wall Lake[a]	10.22	10.44	10.66	10.88	11.09	11.30
Total urban[b]	58.83	60.82	63.57	65.24	67.00	68.73
Rural farm[b]	34.74	31.96	28.38	25.75	23.08	20.47
Rural nonfarm[b]	6.43	7.22	8.05	9.01	9.92	10.80
Total rural[b]	41.17	39.18	36.43	34.76	33.00	31.27
Total county[c]	5.40	5.07	4.88	4.76	4.73	4.72

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-75. State of Iowa projected population percentages in Sioux County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Alton[a]	5.89	5.81	5.73	5.65	5.58	5.50
Boydon[a]	3.88	3.82	3.76	3.71	3.66	3.60
Chatsworth[a]	0.52	0.46	0.41	0.35	0.30	0.25
Granville[a]	2.22	2.17	2.12	2.08	2.04	2.00
Hawarden[a]	16.14	15.82	15.48	15.16	14.82	14.50
Hospers[a]	3.74	3.72	3.68	3.66	3.62	3.60
Hull[a]	8.80	9.04	9.28	9.52	9.76	10.00
Ireton[a]	3.37	3.32	3.26	3.21	3.16	3.10
Matlock[a]	0.51	0.45	0.40	0.35	0.30	0.25
Maurice[a]	1.54	1.47	1.41	1.33	1.26	1.20
Orange City[a]	20.67	20.76	20.86	20.94	21.02	21.10
Rock Valley[a]	12.76	12.79	12.83	12.85	12.88	12.90
Sioux Center[a]	19.96	20.37	20.78	21.19	21.60	22.00
Total urban[b]	61.73	67.80	72.74	75.89	78.58	81.27
Rural farm[b]	34.19	27.59	22.32	18.63	15.56	12.71
Rural nonfarm[b]	4.08	4.61	4.94	5.48	5.86	6.02
Total rural[b]	38.27	32.20	27.26	24.11	21.42	18.73
Total county[c]	9.70	10.11	10.35	10.43	10.42	10.37

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-76. State of Iowa projected population percentages in Woodbury County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Anthon[a]	0.76	0.72	0.68	0.64	0.60	0.57
Bronson[a]	0.21	0.27	0.33	0.39	0.44	0.49
Correctionville[a]	0.93	0.88	0.83	0.78	0.73	0.69
Cushing[a]	0.22	0.20	0.18	0.16	0.14	0.12
Danbury[a]	0.56	0.54	0.52	0.50	0.48	0.46
Hornick[a]	0.27	0.25	0.23	0.21	0.19	0.17
Lawton[a]	0.43	0.49	0.54	0.59	0.64	0.69
Moville[a]	1.28	1.35	1.42	1.49	1.56	1.61
Oto[a]	0.22	0.20	0.18	0.16	0.14	0.12
Pierson[a]	0.45	0.42	0.40	0.38	0.36	0.34
Salix[a]	0.41	0.41	0.41	0.40	0.40	0.40
Sergeant Bluff[a]	1.23	1.29	1.34	1.39	1.44	1.49
Sioux City[a]	91.86	91.81	91.76	91.72	91.68	91.64
Sloan[a]	0.85	0.87	0.90	0.93	0.96	0.98
Smithland[a]	0.32	0.30	0.28	0.26	0.24	0.23
Total urban[b]	90.77	91.34	91.76	92.08	92.19	92.30
Rural farm[b]	6.61	5.82	5.18	4.63	4.32	3.99
Rural nonfarm[b]	2.62	2.84	3.06	3.29	3.49	3.71
Total rural[b]	9.23	8.66	8.24	7.92	7.81	7.70
Total county[c]	35.72	36.45	36.72	37.12	37.54	37.58

[a]As percent of total urban.

[b]As percent of total county.

[c]As percent of region.

Table A-77. State of Iowa projected population in Buena Vista County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Albert City	683	680	680	650	600	550
Alta	1,717	1,880	2,060	2,160	2,230	2,280
Lakeside	353	420	500	550	610	650
Linn Grove	240	220	210	180	140	110
Marathon	447	450	440	420	390	360
Newell	877	890	900	870	830	780
Rembrandt	250	230	210	180	150	110
Sioux Rapids	813	810	800	760	700	640
Storm Lake	8,591	9,390	10,220	10,650	10,990	11,230
Truesdale	132	120	110	100	80	60
Total urban	14,103	15,090	16,130	16,520	16,720	16,770
Rural farm	5,302	4,770	4,330	3,930	3,620	3,300
Rural nonfarm	1,288	1,440	1,570	1,700	1,780	1,850
Total rural	6,590	6,210	5,900	5,630	5,400	5,150
Total county	20,693	21,300	22,030	22,150	22,120	21,920

Table A-78. State of Iowa projected population in Cherokee County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Aurelia	1,065	1,010	1,190	1,320	1,450	1,590
Cherokee	7,272	6,900	7,060	7,340	7,650	7,880
Cleghorn	274	270	260	260	260	260
Larrabee	167	160	150	150	150	150
Marcus	1,272	1,260	1,260	1,320	1,380	1,430
Meriden	167	160	150	150	140	140
Quimby	395	380	390	410	430	440
Washta	319	310	300	310	310	310
Total urban	10,931	10,450	10,760	11,260	11,770	12,200
Rural farm	4,922	4,440	4,060	3,760	3,520	3,300
Rural nonfarm	1,416	1,470	1,640	1,820	2,020	2,240
Total rural	6,338	5,910	5,700	5,580	5,540	5,540
Total county	17,269	16,360	16,460	16,840	17,310	17,740

Table A-79. State of Iowa projected population in Clay County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Dickins	240	230	210	180	150	130
Everly	699	750	820	840	860	870
Fostoria	219	250	280	300	320	340
Greenville	117	110	100	90	70	50
Peterson	469	470	470	450	420	390
Rossie	91	90	80	70	60	50
Royal	469	480	500	480	470	440
Spencer	10,278	11,060	12,040	12,450	12,670	12,860
Webb	234	240	240	240	230	210
Total urban	12,816	13,680	14,740	15,100	15,250	15,340
Rural farm	4,361	4,080	3,840	3,660	3,500	3,300
Rural nonfarm	1,287	1,480	1,670	1,820	1,930	2,000
Total rural	5,648	5,560	5,510	5,480	5,430	5,300
Total county	18,464	19,240	20,250	20,580	20,680	20,640

Table A-80. State of Iowa projected population in Dickinson County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Arnold's Park	970	1,200	1,400	1,460	1,490	1,500
Lake Park	918	1,130	1,300	1,350	1,360	1,370
Milford	1,668	2,090	2,490	2,620	2,720	2,790
Okoboji	361	470	580	630	680	720
Old Town	24	30	40	50	60	70
Orleans	396	470	520	520	510	490
Spirit Lake	3,014	3,790	4,490	4,750	4,920	5,050
Superior	139	150	150	130	100	70
Terrill	397	460	510	490	470	440
Wahpeton	149	200	260	300	330	360
West Okoboji	210	280	340	380	400	430
Total urban	8,246	10,270	12,080	12,680	13,040	13,290
Rural farm	3,068	2,840	2,640	2,470	2,290	2,100
Rural nonfarm	1,251	1,670	2,040	2,320	2,530	2,680
Total rural	4,319	4,510	4,680	4,790	4,820	4,780
Total county	12,565	14,780	16,760	17,470	17,860	18,070

Table A-81. State of Iowa projected population in Ida County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Arthur	273	240	220	200	180	160
Battle Creek	837	820	850	880	910	940
Galva	412	380	360	350	330	310
Holstein	1,445	1,430	1,500	1,560	1,630	1,730
Ida Grove	2,261	2,220	2,340	2,450	2,560	2,690
Total urban	5,228	5,090	5,270	5,440	5,610	5,830
Rural farm	3,669	3,300	3,020	2,780	2,590	2,400
Rural nonfarm	293	340	400	470	540	610
Total rural	3,962	3,640	3,420	3,250	3,130	3,010
Total county	9,190	8,730	8,690	8,690	8,740	8,840

Table A-82. State of Iowa projected population in Lyon County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Alvord	204	200	210	210	220	220
Doon	437	470	550	640	740	870
George	1,194	1,240	1,380	1,550	1,700	1,910
Inwood	644	670	750	840	930	1,050
Larchwood	611	680	820	970	1,160	1,380
Lester	238	240	270	390	320	350
Little Rock	531	570	650	740	850	980
Rock Rapids	2,632	2,800	3,230	3,690	4,230	4,880
Total urban	6,491	6,870	7,860	8,930	10,150	11,640
Rural farm	6,184	5,400	4,770	4,260	3,840	3,410
Rural nonfarm	665	750	900	1,080	1,290	1,520
Total rural	6,849	6,150	5,670	5,340	5,130	4,930
Total county	13,340	13,020	13,530	14,270	15,280	16,570

Table A-83. State of Iowa projected population in O'Brien County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Archer	134	130	120	110	90	70
Calumet	219	210	210	190	170	150
Hartley	1,694	1,810	1,970	2,030	2,070	2,120
Moneta	41	40	30	20	10	0
Paullina	1,257	1,340	1,460	1,510	1,540	1,580
Primghar	995	1,060	1,140	1,170	1,180	1,200
Sanborn	1,465	1,570	1,710	1,770	1,820	1,870
Sheldon	4,535	5,080	5,760	6,210	6,620	7,040
Sutherland	875	900	940	940	920	900
Total urban	11,215	12,140	13,340	13,950	14,420	14,930
Rural farm	5,466	4,850	4,350	3,960	3,640	3,300
Rural nonfarm	841	1,010	1,220	1,410	1,580	1,740
Total rural	6,307	5,860	5,570	5,370	5,220	5,040
Total county	17,522	18,000	18,910	19,320	19,640	19,970

Table A-84. State of Iowa projected population in Osceola County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Ashton	483	520	580	630	680	740
Harris	195	190	200	190	180	170
Melvin	325	340	370	380	400	420
Ocheyedan	545	560	610	620	640	660
Sibley	2,749	3,110	3,660	4,100	4,670	5,320
Total urban	4,297	4,720	5,420	5,920	6,570	7,310
Rural farm	3,687	3,270	2,940	2,700	2,470	2,250
Rural nonfarm	571	730	930	1,160	1,420	1,700
Total rural	4,258	4,000	3,870	3,860	3,890	3,950
Total county	8,555	8,720	9,290	9,780	10,460	11,260

Table A-85. State of Iowa projected population in Plymouth County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Akron	1,324	1,300	1,340	1,370	1,390	1,390
Brunsville	125	130	130	140	140	150
Craig	98	90	80	80	70	60
Hinton	488	520	570	630	680	740
Kingsley	1,097	1,090	1,130	1,170	1,190	1,210
Le Mars	8,159	8,530	9,390	10,230	11,070	11,870
Merrill	790	820	890	970	1,040	1,100
Oyens	145	160	180	190	210	230
Remsen	1,367	1,380	1,480	1,570	1,660	1,730
Struble	59	50	40	30	10	0
Westfield	148	140	130	120	110	90
Total urban	13,800	14,210	15,360	16,500	17,570	18,570
Rural farm	8,664	7,760	7,010	6,360	5,730	5,100
Rural nonfarm	1,848	1,980	2,150	2,390	2,600	2,790
Total rural	10,512	9,740	9,160	8,750	8,330	7,890
Total county	24,312	23,950	24,520	25,250	25,900	26,460

Table A-86. State of Iowa projected population in Sac County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Auburn	329	320	310	300	300	290
Early	729	690	690	680	670	660
Grant City	0	0	0	0	0	0
Lake View	1,249	1,250	1,330	1,390	1,450	1,530
Lytton	378	390	400	410	420	440
Nemaha	117	110	100	90	80	70
Odebolt	1,323	1,300	1,360	1,390	1,420	1,470
Sac City	3,268	3,330	3,600	3,790	4,050	4,340
Schaller	835	840	890	920	980	1,030
Wall Lake	936	960	1,040	1,090	1,170	1,250
Total urban	9,162	9,190	9,720	10,060	10,540	11,080
Rural farm	5,410	4,830	4,340	3,970	3,630	3,300
Rural nonfarm	1,001	1,090	1,230	1,390	1,560	1,740
Total rural	6,411	5,920	5,570	5,360	5,190	5,040
Total county	15,573	15,110	15,290	15,420	15,730	16,120

Table A-87. State of Iowa projected population in Sioux County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Alton	1,018	1,190	1,350	1,450	1,520	1,580
Boyden	670	780	880	950	1,000	1,040
Chatsworth	90	90	100	90	80	70
Granville	383	440	500	530	560	580
Hawarden	2,789	3,230	3,650	3,880	4,030	4,170
Hospers	646	760	870	940	980	1,040
Hull	1,523	1,840	2,190	2,440	2,660	2,880
Ireton	582	680	770	820	860	890
Matlock	89	90	90	90	80	70
Maurice	266	300	330	340	340	340
Orange City	3,572	4,250	4,910	5,370	5,730	6,070
Rock Valley	2,205	2,610	3,020	3,290	3,500	3,710
Sioux Center	3,450	4,160	4,900	5,430	5,880	6,330
Total urban	17,283	20,420	23,560	25,620	27,220	28,770
Rural farm	9,572	8,310	7,230	6,290	5,390	4,500
Rural nonfarm	1,141	1,390	1,600	1,850	2,030	2,130
Total rural	10,713	9,700	8,830	8,140	7,420	6,630
Total county	27,996	30,120	32,390	33,760	34,640	35,400

Table A-88. State of Iowa projected population in Woodbury County, 1970-2020

City	1970	1980	1990	2000	2010	2020
Anthon	711	710	720	710	690	670
Bronson	193	270	350	430	510	580
Correctionville	870	870	880	860	840	820
Cushing	204	200	190	180	160	140
Danbury	527	540	550	550	550	540
Hornick	250	250	240	230	220	200
Lawton	406	490	570	650	740	820
Moville	1,198	1,340	1,500	1,650	1,790	1,900
Oto	203	200	190	180	160	140
Pierson	421	420	420	420	410	400
Salix	387	410	430	440	460	470
Sergeant Bluff	1,153	1,280	1,410	1,540	1,660	1,760
Sioux City	85,925	91,050	96,780	101,470	105,480	108,510
Sloan	799	860	950	1,030	1,100	1,160
Smithland	293	300	300	290	280	270
Total urban	93,540	99,190	105,480	110,630	115,050	118,380
Rural farm	6,813	6,320	5,950	5,560	5,390	5,120
Rural nonfarm	2,699	3,090	3,520	3,950	4,360	4,750
Total rural	9,512	9,410	9,470	9,510	9,750	9,870
Total county	103,052	108,600	114,950	120,140	124,800	128,250

APPENDIX B.

PERSONAL INCOME, 1970-1975

Table B-1. Personal income in Buena Vista County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	15.9	15.4	22.8	48.6	38.3	38.3
Nonfarm	36.2	38.5	38.7	43.5	49.3	45.1
Government	6.2	6.7	7.4	7.4	8.2	9.1
Total	58.3	60.8	68.9	99.5	95.8	92.5
Nonfarm						
Manufacturing	11.5	12.2	13.0	14.2	16.3	9.1
Mining	—	—	—	0.1	0.2	0.2
Contract const.	2.6	2.7	2.2	2.6	3.2	3.5
Wsle. and retail trade	10.5	10.9	10.6	12.3	14.0	15.3
Fin., ins., real estate	2.0	2.1	2.4	2.5	2.9	3.2
Transp., comm., pub. util.	2.8	3.0	3.0	3.4	3.5	3.7
Services	6.8	7.0	7.0	7.8	8.6	9.5
Other industries	—	—	—	0.5	0.6	0.6
Government						
Federal, civilian	1.1	1.2	1.4	1.1	1.5	1.6
Federal, military	0.2	0.2	0.2	0.3	0.3	0.3
State and local	4.9	5.2	5.7	6.0	6.4	7.2

Table B-2. Personal income in Cherokee County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	10.4	10.6	17.3	36.0	19.8	28.0
Nonfarm	30.8	32.6	31.8	34.6	38.5	40.4
Government	9.3	10.0	10.9	11.8	12.5	14.2
Total	50.5	53.2	60.0	82.4	70.8	82.6
Nonfarm						
Manufacturing	10.6	10.5	11.1	12.0	12.2	13.6
Mining	—	—	—	—	—	—
Contract const.	2.9	3.5	3.7	3.4	3.9	4.3
Wsle. and retail trade	8.0	8.5	7.2	8.7	11.1	10.2
Fin., ins., real estate	1.0	1.2	1.3	1.4	1.6	1.7
Transp., comm., pub. util.	2.4	2.8	2.6	2.8	2.9	2.9
Services	5.5	5.7	5.6	5.9	6.4	7.2
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	0.8	0.8	1.0	1.0	1.1	1.2
Federal, military	0.2	0.2	0.2	0.2	0.2	0.2
State and local	8.4	9.0	9.7	10.6	11.3	12.8

Table B-3. Personal income in Clay County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	13.5	11.7	18.0	37.8	22.6	29.1
Nonfarm	33.6	38.3	36.4	41.9	51.2	58.1
Government	7.0	7.7	8.3	9.0	9.7	11.1
Total	54.1	57.7	62.7	88.7	83.5	98.3
Nonfarm						
Manufacturing	7.5	9.8	9.0	9.8	12.9	15.9
Mining	—	—	—	—	—	—
Contract const.	3.7	4.7	2.8	3.2	5.0	5.4
Wsle. and retail trade	11.0	12.2	12.7	14.9	17.2	19.3
Fin., ins., real estate	—	2.7	2.1	2.4	2.9	3.0
Transp., comm., pub. util.	4.0	3.9	3.7	4.5	5.2	5.7
Services	4.5	4.6	5.8	6.4	7.4	8.2
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	1.1	1.2	1.3	1.4	1.6	1.8
Federal, military	0.2	0.2	0.2	0.2	0.2	0.3
State and local	5.7	6.2	6.8	7.4	7.9	9.0

Table B-4. Personal income in Dickinson County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	10.3	7.5	11.0	23.9	11.6	17.6
Nonfarm	17.5	18.5	21.3	26.9	33.0	33.5
Government	4.0	4.3	4.6	5.1	5.5	6.3
Total	31.8	30.3	36.9	55.9	50.1	57.4
Nonfarm						
Manufacturing	5.2	5.1	6.7	8.9	11.9	10.6
Mining	—	—	—	—	—	—
Contract const.	1.2	1.7	1.9	2.4	3.1	2.7
Wsle. and retail trade	6.0	6.3	6.9	8.7	10.1	11.3
Fin., ins., real estate	0.8	0.8	0.8	0.9	1.1	1.2
Transp., comm., pub. util.	1.0	1.1	1.2	1.5	1.6	1.6
Services	3.0	3.1	3.5	4.1	4.7	5.5
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	0.4	0.4	0.4	0.5	0.5	0.6
Federal, military	0.2	0.3	0.3	0.3	0.4	0.4
State and local	3.2	3.6	3.9	4.3	4.6	5.3

Table B-5. Personal income in Ida County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	10.8	9.4	15.6	25.1	16.3	21.5
Nonfarm	12.2	12.8	11.5	13.4	15.0	16.9
Government	2.6	2.9	3.1	3.3	3.5	4.0
Total	25.6	25.1	30.2	41.8	34.8	42.4
Nonfarm						
Manufacturing	1.7	2.0	2.2	2.7	2.8	3.2
Mining	0.0	0.0	0.0	0.0	0.0	0.0
Contract const.	2.4	2.6	1.7	2.0	2.5	3.0
Wsle. and retail trade	4.0	4.0	3.6	4.4	4.8	5.1
Fin., ins., real estate	—	0.7	—	0.8	0.9	1.0
Transp., comm., pub. util.	1.0	1.2	0.8	0.8	1.0	1.2
Services	2.3	2.1	2.3	2.4	2.7	3.1
Other industries	—	0.2	—	0.2	0.2	0.2
Government						
Federal, civilian	0.5	0.6	0.6	0.6	0.7	0.8
Federal, military	0.2	0.2	0.3	0.3	0.3	0.3
State and local	1.9	2.1	2.2	2.4	2.6	2.9

Table B-6. Personal income in Lyon County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	13.3	10.4	18.9	31.7	8.6	20.7
Nonfarm	11.4	12.2	12.1	14.5	17.0	17.6
Government	3.2	3.4	3.6	4.0	4.4	4.9
Total	27.9	26.0	34.6	50.2	30.0	43.2
Nonfarm						
Manufacturing	1.0	1.0	1.3	1.8	2.7	3.0
Mining	—	—	—	—	—	—
Contract const.	1.0	1.2	1.0	1.3	1.8	1.5
Wsle. and retail trade	4.6	4.6	4.3	5.1	5.8	6.2
Fin., ins., real estate	0.8	0.9	0.8	0.9	1.0	1.0
Transp., comm., pub. util.	0.6	0.7	1.0	1.1	1.1	—
Services	—	—	—	3.8	4.1	4.3
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	0.4	0.5	0.4	0.5	0.6	0.7
Federal, military	0.1	0.1	0.2	0.2	0.2	0.2
State and local	2.7	2.9	3.0	3.3	3.6	4.1

Table B-7. Personal income in O'Brien County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	16.5	12.2	20.9	40.0	22.3	33.0
Nonfarm	21.3	25.8	24.0	28.2	32.0	34.0
Government	4.9	5.4	5.9	6.4	6.9	7.7
Total	42.7	43.4	50.8	74.6	61.2	74.7
Nonfarm						
Manufacturing	1.6	3.3	3.6	4.6	5.1	4.9
Mining	—	—	—	—	—	—
Contract const.	1.4	1.8	1.7	2.1	2.8	2.7
Wsle. and retail trade	9.1	10.7	8.5	10.6	12.1	13.4
Fin., ins., real estate	1.1	1.2	1.8	1.8	2.1	2.2
Transp., comm., pub. util.	2.3	2.7	3.0	3.2	3.4	3.6
Services	5.0	5.1	4.8	5.2	5.8	6.4
Other industries	0.9	1.0	—	—	—	—
Government						
Federal, civilian	0.7	0.8	0.9	1.0	1.1	1.2
Federal, military	0.2	0.2	0.3	0.3	0.3	0.3
State and local	4.0	4.3	4.7	5.0	5.4	6.2

Table B-8. Personal income in Osceola County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	13.4	8.6	14.7	26.1	9.4	18.5
Nonfarm	10.4	11.3	10.7	12.1	13.4	14.4
Government	2.3	2.6	2.9	3.1	3.4	3.9
Total	26.1	22.5	28.3	41.3	26.2	36.8
Nonfarm						
Manufacturing	2.3	2.4	2.4	2.3	2.5	2.8
Mining	—	—	—	—	—	—
Contract const.	1.4	1.7	1.3	1.5	1.8	1.8
Wsle. and retail trade	3.6	3.9	3.9	4.9	5.3	5.7
Fin., ins., real estate	0.5	0.5	0.6	0.7	0.8	0.9
Transp., comm., pub. util.	1.0	1.1	0.6	0.7	0.8	0.9
Services	1.4	1.4	1.6	1.8	1.9	2.0
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	0.5	0.6	0.6	0.6	0.8	0.9
Federal, military	0.1	0.1	0.1	0.2	0.2	0.2
State and local	1.7	1.9	2.1	2.3	2.5	2.8

Table B-9. Personal income in Plymouth County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	17.3	14.4	27.0	47.8	21.4	26.4
Nonfarm	27.2	29.9	30.0	34.2	38.6	42.7
Government	6.4	7.0	7.7	8.2	8.9	10.0
Total	50.9	51.3	64.7	90.2	68.9	79.1
Nonfarm						
Manufacturing	4.6	4.8	4.3	4.8	5.4	6.5
Mining	—	—	—	—	—	—
Contract const.	1.9	1.7	2.4	2.2	2.8	2.6
Wsle. and retail trade	9.8	10.7	10.4	12.8	14.0	15.5
Fin., ins., real estate	1.6	1.8	2.1	2.3	2.5	2.8
Transp., comm., pub. util.	3.1	3.6	3.3	3.9	4.5	5.0
Services	5.7	6.7	6.8	7.4	8.2	9.3
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	1.1	1.2	1.2	1.3	1.5	1.7
Federal, military	0.4	0.4	0.4	0.5	0.5	0.5
State and local	4.9	5.4	6.0	6.4	6.9	7.8

Table B-10. Personal income in Sac County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	17.0	10.7	20.5	41.0	33.9	32.9
Nonfarm	19.4	19.6	21.8	24.8	28.7	31.9
Government	4.0	4.4	4.7	5.0	5.3	6.0
Total	40.4	34.7	47.0	70.8	67.9	70.8
Nonfarm						
Manufacturing	3.5	3.9	4.4	5.7	7.2	8.1
Mining	—	—	—	—	—	—
Contract const.	3.2	2.4	2.7	3.4	3.7	3.7
Wsle. and retail trade	6.9	7.3	7.0	7.8	8.5	9.8
Fin., ins., real estate	1.0	1.1	1.7	1.4	1.6	1.7
Transp., comm., pub. util.	1.1	1.1	1.6	1.5	2.4	2.4
Services	3.2	3.2	3.7	4.3	4.5	5.6
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	0.5	0.7	0.7	0.7	0.8	0.8
Federal, military	0.2	0.2	0.2	0.3	0.3	0.3
State and local	3.3	3.5	3.8	4.0	4.3	4.8

Table B-11. Personal income in Sioux County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	29.0	16.3	31.2	52.9	24.7	34.1
Nonfarm	34.6	39.8	40.0	47.3	53.1	58.6
Government	6.3	6.8	7.4	8.1	8.7	9.8
Total	69.9	62.9	78.6	108.3	86.5	102.5
Nonfarm						
Manufacturing	9.0	11.3	12.8	14.7	15.5	16.5
Mining	—	—	—	—	—	—
Contract const.	3.3	4.0	3.3	4.0	4.6	5.1
Wsle. and retail trade	10.6	11.9	11.2	13.9	16.1	18.8
Fin., ins., real estate	1.6	1.8	1.9	2.1	2.3	2.5
Transp., comm., pub. util.	1.4	1.5	1.5	2.1	2.6	2.7
Services	7.6	8.2	8.4	9.3	10.2	11.4
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	0.9	0.9	1.0	1.2	1.3	1.4
Federal, military	0.3	0.3	0.3	0.4	0.4	0.4
State and local	5.1	5.6	6.0	6.6	7.0	8.0

Table B-12. Personal income in Woodbury County by major sources during the 1970-1975 period, millions of dollars

Industry	1970	1971	1972	1973	1974	1975
Farm	15.8	13.8	25.4	48.1	23.2	37.0
Nonfarm	251.8	263.1	287.3	334.1	376.8	398.9
Government	34.9	37.9	40.9	43.0	46.3	52.0
Total	302.5	314.8	353.6	425.2	446.3	487.9
Nonfarm						
Manufacturing	67.8	68.3	77.2	93.7	101.8	97.4
Mining	—	—	—	—	—	—
Contract const.	19.6	23.1	24.9	29.6	35.2	35.4
Wsle. and retail trade	68.4	69.9	72.9	83.2	92.9	98.2
Fin., ins., real estate	15.7	17.1	18.3	19.3	21.2	24.7
Transp., comm., pub. util.	28.1	31.6	37.6	45.2	54.6	63.4
Services	51.5	52.5	55.6	62.1	69.3	77.7
Other industries	—	—	—	—	—	—
Government						
Federal, civilian	9.4	10.1	10.6	10.6	11.8	13.1
Federal, military	1.7	1.9	2.1	2.2	2.3	2.3
State and local	23.8	25.9	28.2	30.2	32.2	36.5

APPENDIX C.

MANUFACTURERS LOCATED IN NORTHWEST IOWA

Table C-1. Manufacturers located in Buena Vista County in 1977[a]

Location	Code[b]	Name	Products
Albert City	A	Appeal & Marathon Republic	Newspaper, commercial printing
	A	Albert City Mfg. Co.	Turkey range shelters & waterers
	A	Safe-Well Mfg. Co.	Well chlorinators & pellets
	A	Sohigro Service Co.	Dry & liquid blended fertilizer
	A	Tomann-Wagg Mfg. Co.	Steel fence posts & fasteners, electric water heaters, electric drive-over gates & fence controllers
Alta	A	Alta Advertizer	Newspaper, commercial printing
	A	Becker Mfg. Co., Inc.	Custom exec. office furniture, wood banking counters & accessories
Linn Grove	A	Wall Lake Processing Co.	Meat & bone meal, grease, hides
Newell	A	Paulson Publishing Co.	Newspaper, job printing
Sioux Rapids	A	Bulletin-Press	Newspaper, commercial printing
	A	Grau Enterprises, Inc.	Bean weeding vehicle, control switches, grain supplement & silage meters
Storm Lake	C	Aalfs Mfg. Co.	Jeans
	A	Arlite Electronics	Fluorescent & mercury vapor light fixtures
	B	B.V. Stationery & Printing	Advertising guide, job printing
	B	DeKalb Ag Research	Hybrid seed corn
	E	Hygrade Food Products Corp.	Hog slaughter, pork cuts & products, lard, inedible oil, animal feed
	A	Iowa Pellets, Inc.	Livestock & poultry feeds
	B	Merrill Mfg. Co., Inc.	Yard hydrants, pitless adapters, pipe fittings & valves, air volume controls

A	NW Concrete Products Co.	Patio blocks, precast steps, septic tanks, hot huts, well pits, stepping stones
A	Olsen Welding & Machine	Confinement cleaning system, snow blower, snow scoop
A	Port-A-Hut, Inc.	Farrowing house & pig shelter
	Storm Lake Newspapers, Inc.	Newspaper, commercial printing
A	Storm Lake Ready Mix	Ready mixed concrete
A	Storm Lake Tank & Silo	Wooden tanks
A	Superior Ready Mix Conc.	Ready mixed concrete
E	Thompson Industries, Ltd.	Frozen eviscerated turkeys & parts
A	Thompson Industries, Ltd.	Livestock & poultry feed
A	Transagra Corp.	Livestock & poultry feed & additives
A	Twin-Hydro Industries	Gas tanks, running gears, wagon boxes, feeders, horse & livestock trailers
B	Vista Products Co.	Canned peas, corn & cut green beans
A	Walton Sign Co.	Plastic, metal, wood, glass & neon signs

[a] Iowa Development Commission (1978a).

[b] Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-2. Manufacturers located in Cherokee County in 1977[a]

Location	Code[b]	Name	Products
Aurelia	A	Sentinel Publishing Co.	Newspaper, commercial printing
Cherokee	B	Ament Co.	Wood trusses, wall panels
	C	Caswell Mfg. Co.	Steel fence, weighing crate, sow feeding stall tanks
	A	Cher. Conc. Prod. Co., Inc.	Conc. blocks, well curbing, drain tile, septic tanks
	A	Christensen Bros., Inc.	Ready mixed concrete
	A	France Grain & Feed	Pig & dairy feed, cattle feeds
	A	Jesse's Fine Meats, Inc.	Beef steaks, roasts & patties, ground beef
	C	Lundell Mfg. Co., Inc.	Balers, subsoilers, shredders, snow blowers
	A	Rapid American Press	Commercial & job printing
	A	Ross Feed Service	Complete animal feeds, blended fertilizer
	A	Thomas Mfg. Co., Inc.	Picnic table frames, park benches, sod cutter, rock-lift, steel park grills
	B	Times Publishing Co., Inc.	Newspaper, job printing
	B	Walnut Grove Products Div.	Hog, cattle, dairy & poultry feeds
	A	Wayne Printing	Commercial printing
	F	Wilson Foods Corp.	Pork & beef, lard, grease & tallow
	A	Wittkamp Welding & Mfg.	Bicycle stand
Cleghorn	A	Shafer Formula Co., Inc.	Livestock feed additives
	A	Wetherell Mfg. Co.	Weed sprayers, cultivators, deep till machines, chisel plows, V plows
Larrabee	A	Farmers Co-op. Elev. Co.	Livestock feed
Marcus	A	Farmers Co-op. Elev. Co.	Feed, liquid & dry fertilizer
	A	Marcus News	Newspaper, commercial printing
	A	Marcus Ready Mix	Ready mixed concrete

Quimby	B	Simonson Mfg. Co.	Fertilizer spreaders, bulk feed bodies
	B	Simonson Mill, Inc.	Livestock & poultry feed, meat scrap, soap, grease, mixed fertilizer

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-3. Manufacturers located in Clay County in 1977[a]

Location	Code[b]	Name	Products
Dickins	A	Nolin Milling, Inc.	Dog food cake, fish bait, soybean oil & meal
Everly	A	The Everly News	Newspaper, offset printing
	B	Farmers Co-op. Elev. Co.	Livestock feed, fertilizer
	A	Honeybee Co., Inc.	Chem. eductor, farm tanks, oxidation wheels, tractor loader, fertilizer mixer
	A	Topsoil-Schoenewe, Inc.	Mixed liquid & dry fertilizer
Fostoria	A	Fostoria Welding	Aluminum castings & signs, job welding
	A	Wonder Whip Co., Inc.	Crops; stockyard, buggy & racing whips
Peterson	A	The Peterson Patriot	Newspaper, commercial printing
	A	Topsoil Fertilizer Co.	Fertilizer
Royal	A	Anderson Mfg. Co.	Shotgun shell case trimmer
	A	Cargill, Inc.	Feed
Spencer	C	Aalfs Mfg. Co.	Jeans
	A	C-D Farm Service Co.	Blended fertilizer
	A	Carroll's Bakery, Inc.	Doughnuts, cakes, breads, rolls, cookies
	A	Christians Corp.	Ridge type ventilator
	A	Clay Co. Conc.	Ready mixed concrete
	D	Eaton Corp.-Fluid Power	Light & heavy duty hydrostatic transmissions
	A	F & W Precasting, Inc.	Conc. feed bunks, bunker silos, partitions
	A	Gen. Machine Works Co.	Nuts, spindles, shafting, castings
	C	Iowa Veneers, Inc.	Single ply hardwood veneer
	A	Jabirch Corp.	Fiberglass canes, tubing, arrows, fishing rods
	A	Lakes Conc. Industries	Concrete & haydite block
	A	Lumbermens Millwork Supply	Pre-hung door units
	C	Morton Buildings, Inc.	Farm & industrial buildings

A	Mugge Feed Co.	Livestock & poultry feed
C	National-Spencer, Inc.	Gear boxes, pumps, grease guns & fillers
A	Nylrem Enterprises	Hair rollers
C	PCP Mfg., Inc.	Hog & calf facilities, plastic slats
A	P & H Fixture Co.	Revolving office files, bank furniture
B	Pixler Electric Co.	Flagpoles, switch panels, motors, coils
A	The Shopper	Shopping guide
B	Daily Reporter & Times	Newspapers, shopping guide
E	Spencer Foods, Inc.	Dressed beef carcasses, beef by-products
B	Spencer Ready Mix	Ready mix conc., bagged conc. & mortar mix
A	Spencer Rendering Co.	Meat & bone meal, inedible tallow, hides
A	Standard Printing, Inc.	Commercial printing
E	Superior Inc.	Grease guns, pumps, suction guns, fittings
B	Van Ladder, Inc.	Aerial ladder, man-lift, pickup covers
A	Wheeler Mfg. Co.	Railings & columns, ornamental metal work

[a] Iowa Development Commission (1978a).

[b] Number of employees: A = 1-20, B = 21-50, C = 51-100, D= 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-4. Manufacturers located in Dickinson County in 1977[a]

Location	Code[b]	Name	Products
Arnold's Park	A	Orr Machine Works	Fiberglass fishing rod blanks
Lake Park	A	Arco Dehydrating Co.	Alfalfa pellets, reground pellet meal
	A	Lake Park News	Newspaper, commercial printing
Milford	A	Danbom Industries	Fiberglass tops for boat stands, dock ladders
	A	Milford Mail Publishing	Newspaper publishing
	A	Northern Iowa Die Casting	Zinc die castings, fixtures, dies, jigs
	C	Style-Craft, Inc.	Upholstered furniture
Spirit Lake	F	Berkley & Co., Inc.	Rope, twisted wire, fishing line, leaders, rods, reels, macrame products
	B	Coca-Cola Bottling Co.	Soft drinks
	D	Consumers, Inc.	Roof & floor trusses, prefab walls
	A	Distinctive Packaging	Folding cartons, corrugated paper box
	A	Ferguson Mfg. Co.	Screw machine parts, zinc plating
	A	Lakes Printing Co.	Commercial printing
	E	McQuay-Perfex Inc.	Ice machines, air cond. units, heat pump air duct, water purifier
	B	Beacon Publishing Co.	Newspaper, job printing
	A	Ready Mix Co.	Conc. feed bunks, curbs, ready mix conc.
	B	Stoller Fisheries, Inc.	Fish meal & oil, carp pituitary hormone
Terrill	B	Terminal Co-op. Co.	Livestock & poultry feed

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-5. Manufacturers located in Ida County in 1977[a]

Location	Code[b]	Name	Products
Battle Creek	A	Battle Creek Times	Newspaper
Holstein	B	Bye & Bye, Inc.	Commercial printing, brochures, office forms, bound books, four color printing
	A	Holstein Ready Mix	Ready mixed concrete
	C	V-T Industries, Inc.	Plastic covered millwork, doors, bathroom vanities, formica products, cabinets
Ida Grove	A	Farmland Indus. Inc.	Poultry, swine, dairy, beef & sheep feeds
	C	Gomaco Corp.	Slope paving equip., slip form pavers, conc. finishing machines, curb & gutter machines
	A	Ida Co. Courier-Reminder	Newspaper, job printing
	A	Ida Co. Pioneer Record	Newspaper, commercial printing, books
	A	Lemco Plastics, Inc.	Light fixtures, wheel guards, trailer parts
	D	Midwest Industries, Inc.	Docks & dock equip., lift & planter harrow, boat trailers & hoists, hyd. wagon hoist
	A	United Builders, Inc.	Ready mixed concrete

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-6. Manufacturers located in Lyon County in 1977[a]

Location	Code[b]	Name	Products
Doon	A	Aardema Well Tile Co.	Conc. well curbing & covers, hog troughs
	A	Doon Press	Newspaper publishing
	A	Northwest Mfg. Co.	Farm gates, cow stalls, haystack feeders
George	A	George Conc. Products	Ready mixed concrete
	A	Lyon County News	Newspaper, job printing, booklets
	A	Siebring Mfg. Co.	Space heaters, air tanks, hog fans, furnaces
	C	Sudenga Industries, Inc.	RR car unloading hoppers, bulk feed bodies, augers & fertilizer equipment
Inwood	A	Farmers Co-op. Assn.	Feed
	A	Herald Printing Co.	Newspaper, commercial printing
	A	Little John's Camper Co.	Custom built campers
Larchwood	A	Farmers Co-op Assn.	Feed
	A	Miller Loaders, Inc.	Hyd. front end farm loaders, livestock pens
Rock Rapids	A	Bakers Print Shop	Booklets, church pub., catalogs, directories
	A	Barrows Enterprises, Inc.	Fiberglass & aluminum pickup covers
	A	Cayel-Craft, Inc.	Elec. fence posts, ambulances & fire trucks
	D	K-Products, Inc.	Men's premium caps
	A	Lyon Co. Reporter	Newspaper, commercial printing
	A	Pettengill's Conc. & Gravel	Septic tanks, feed bunks, pump its, ready mixed concrete

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-7. Manufacturers located in O'Brien County in 1977[a]

Location	Code[b]	Name	Products
Calumet	A	Burt's Farm Service	Blended fertilizer
Hartley	A	Brinkert Feed Co.	Livestock & poultry feed
	A	Brown Mfg., Inc.	Polyp clamp, finger splints
	A	C-D Farm Service Co.	Dry blended fertilizers
	A	Hartley Ready Mix	Ready mixed concrete
	A	Hartley Sentinel, Inc.	Newspaper, commercial printing
	A	Hopers	Boat hoists
	A	Huntting Elevator Co.	Livestock & poultry feeds
	C	Spencer Foods, Inc.	Ground beef, primal cuts, retail portions
	A	Van Olst	Rolls, cakes, doughnuts, cookies, bread
Paullina	A	Farmers Co-op. Co.	Feed
	A	Lenz Mfg. Co.	Chisel plows, rotary hoe, tiller-seeder
	A	Cement Tile Factory	Conc. block & well curbing, culvert & tile drain
	A	Paullina Grain Co.	Feed concentrates
	A	Paullina Ready Mix	Ready mixed concrete
	A	Paullina Times	Newspaper, commercial printing
Primghar	A	O'Brien County Bell	Newspaper, commercial printing
	A	Topsoil-Schoenewe, Inc.	Blended fertilizer
	A	Triple R, Inc.	Chisel plows, rotary hoe carrier, custom farm mach.
Sanborn	C	Assoc. Milk Producers, Inc.	Cheese
	A	Co-op. Grain Co.	Feed, dry fertilizer
	A	Sanborn Publishing, Inc.	Newspaper, commercial printing
Sheldon	D	Aalfs Mfg. Co.	Jeans
	A	Atlas Concrete Co.	Ready mixed concrete
	C	Big 4, Div. of Land O'Lakes	Animal feeds, soybean meal, crude soybean oil

	A	Farmers Co-op. Elev. Assn.	Livestock & poultry feed, dry blended fertilizer
	A	Oelwein Chemical Co., Inc.	Animal & poultry feeds
	A	Sheldon De-Hy Co.	Alfalfa products
	A	Sheldon Publishing Co.	Newspaper, commercial printing
	A	Siouxland Ophthalmic Lab.	Ophthalmic products
	A	United Marble, Inc.	Sills, hearths, vanity tops, wall paneling
Sutherland	A	Sutherland Courier	Newspaper
	A	Farmers Co-op. Co.	Feed concentrates, bulk blend fertilizers

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-8. Manufacturers located in Osceola County in 1977[a]

Location	Code[b]	Name	Products
Ashton	A	Ashton Tile Co.	Farm drain tile
	A	Farmers Co-op. Elev. Co.	Livestock & poultry feed
Ocheyedan	A	The Press, Inc.	Newspaper, commercial printing
	A	Rehms-Stewart, Inc.	Ready mixed concrete
Sibley	C	Assoc. Milk Producers, Inc.	Butter, milk powder, ice cream mix, milk
	D	Chase Bag Co.	Paper bags, multiwall packages
	A	Hopcaid Fertilizer Div.	Liquid fertilizer
	B	Merrick Co., Inc.	Christmas, greeting, religious, thank you cards
	B	Sibley Conc. Products Co.	Culvert & storm sewer pipe, manholes, drain & well tile, ready mixed concrete
	C	Sibley Egg & Poultry Co.	Dressed poultry
	A	Sibley Publishing Co.	Newspaper, commercial printing
	A	Topsoil-Schoenewe, Inc.	Blended fertilizer

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-9. Manufacturers located in Plymouth County in 1977[a]

Location	Code[b]	Name	Products
Akron	A	Akron Register-Tribune	Newspaper, commercial printing
Hinton	B	Farmers Co-op. Co.	Feed
	A	The Hinton Progress	Newspaper
Kingsley	A	Kingsley News-Times	Newspaper, job printing
	A	Page & Son, Inc.	Cement crib staves & stave silos
	A	Swains Wrecker Mfg.	Towing equip., wrecker cranes, telescoping stands
Le Mars	C	Aalfs Mfg. Co.	Jeans
	D	Dubuque Packing Co.	Carcass beef, beef offal
	C	Harker's Wholesale Meats	Portioned meat products
	A	Jo-Nee Mfg. Co.	Jeans, jackets, shorts, peddle pushers
	B	LeMars Daily Sentinel	Newspaper, commercial printing
	A	Moorman Mfg. Co.	Livestock feed
	A	North Sioux Industries	Fiberglass bathtubs, shower stalls
	B	Pech Mfg. Co., Inc.	Earth boring machines
	A	Rapid American Press	Commercial printing
	A	Russell Ready Mix, Inc.	Ready mixed concrete
	A	Service Hydraulics	Hydraulic cylinders
	B	Sioux Tools, Inc.	Abrasives
	B	Supersweet Feeds	Hog, dairy, beef & poultry feed
	B	Wells Blue Bunny Co.	Ice cream mix & bars, ice cream, sherbet
	B	Wells Blue Bunny Co.	Fluid milk prod., sour cream, dips, cheese
Merrill	A	Digz-All, Inc.	Trenchers
	A	Terra Western Corp.	Dry blend fertilizer
Remsen	A	Bell-Enterprise	Newspaper, commercial printing
	A	Bituminous Mat'l. & Supply Co.	Asphalt emulsions

A	Farmers Co-op. Co.	Swine, cattle & poultry supplements
A	Remsen Roller Mill	Livestock feed, fertilizer, mixing & blending
A	Russell Ready Mix, Inc.	Ready mixed concrete

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-10. Manufacturers located in Sac County in 1977[a]

Location	Code[b]	Name	Products
Auburn	A	Auburn Enterprise	Newspaper, commercial printing
	A	Brincks Enterprises, Inc.	Feed, fertilizer
Lake View	A	Egyptian Conc. Vault Co.	Burial vaults, hog troughs, benches, urns, baths
	B	Hanson Silo Co.	Concrete silo staves
	A	Jacobsen Hybrid Corn Co.	Hybrid seed corn
	B	Lake View Conc. Products Co.	Conc. & haydite block, drain & well tile, culverts
	B	Lake View Lumber & Ready Mix	Ready mixed concrete
	A	Lake View Resort Newspaper	Newspaper, commercial printing
	B	Quinn Popcorn Co.	Popcorn
	A	Stock Popcorn Co.	Popcorn
Lytton	B	Assoc. Milk Producers, Inc.	Powdered milk
Odebolt	A	Odebolt Chronicle	Newspaper, commercial printing
	A	Odebolt Co-op. Elevator	Mixed feed
Sac City	A	Da Le, Inc.	Uniform lettering, awards, patches, emblems
	A	Dixon Homes	Trusses, wall panels, gable ends
	A	E-Z Products	Rat & mouse killer
	A	Hosteng Conc. & Gravel	Ready mixed concrete
	E	Royal Industries	Cultivators, drawbars, harrows, dump wagons, subsoilers, chisel plows, mulchers
	A	Sac Sun Co., Inc.	Newspaper
	A	Simplot Soilbuilders	Dry blended fertilizers
	A	Trojan Seed Corn Co.	Hybrid seed corn
Schaller	A	American Popcorn Co.	Popcorn
	B	Consolidated Popcorn, Inc.	Popcorn

	A	Jacques Seed Co.	Seed corn
	B	Woodke Enterprises, Inc.	Tractor cabs, truck feed bodies, trailers
Wall Lake	A	Boyer Valley Fertilizer Co.	Dry & liquid fertilizer
	A	Cookies Food Products	Barbeque sauce, chef's & French dressing
	B	National Oats Co., Inc.	Popcorn
	A	Reiter Feed Co., Inc.	Livestock & poultry feed
	A	Wall Lake Blade	Newspaper, commercial printing
	A	Wall Lake Processing Co.	Dry rendered tankage, animal feeding fat

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-11. Manufacturers located in Sioux County in 1977[a]

Location	Code[b]	Name	Products
Alton	A	Alton Premium Feed Co.	Livestock & poultry feeds & supplements
	A	Alton Rendering Works	Meat meal, inedible tallow
	A	Alton Well & Conc. Co., Inc.	Conc. blocks, drain & well tile
	A	Bitucote Products Co.	Asphalt emulsions
	A	Homeponents, Inc.	Wood roof trusses, prefab. house components
Boyden	C	Dethmers Mfg. Co.	Storage tanks, applicators, sprayers
	A	Farmers Co-op. Assn.	Hot, cattle, sheet & poultry feed, fertilizer
	A	Farmers Feed & Supply	Feed minerals
	C	Smit & Son Packing Co.	Dressed beef, beef portion cuts
Granville	A	Farmers Co-op. Co.	Feeds
Hawarden	A	Cenex Soil Service	Fertilizer
	D	Coilcraft, Inc.-Otis Div.	Radio & TV coils
	A	Hawarden-Akron Ready Mix	Ready mixed concrete
	A	Cement Block & Silo Co.	Conc. block, silo staves & well tile
	C	Hawarden of Iowa, Inc.	Carcass beef, beef variety meats
	A	Hawarden Machine Inc.	Cattle head gates, chutes, hog holding equip.
	A	The Independent	Newspaper, commercial printing
	A	Jim's Farm Supply	Livestock feeds
	C	K-Products, Inc.	Men's premium caps
	A	Sioux Fertilizer, Inc.	Liquid feed, fertilizer
Hospers	B	Banner Industries, Inc.	Beef by-products, dressed beef
	A	H & S Mfg., Inc.	Brackets, stalls, slatted floors, boat winches
	A	Silak Co., Inc.	Animal health products
	A	VW Dock Co.	Boat docks, marine accessories
	A	Woudstra Packing Co.	Wieners, bologna, pressed ham, ground beef

Hull	A	Graham Welding	Machine shop
	A	Groeneweg Mfg.	Fuel tanks, auger & drag feeders, V-belt drives
	A	Hull Bakery	Bread, rolls, cakes, pastries, cookies
	A	Hull Industries Co.	Alum. & zinc castings, lawn mower parts
	A	Index Publishing Co.	Newspaper, commercial printing
	A	Index Reporter	Newspaper, commercial printing
	B	K & O Mfg. Co., Inc.	Bale elev., hog farrowing crates, gates, racks
	B	Koyker Mfg. Co.	Tool boxes, loaders, stackers, gates, grease guns
Ireton	A	Farmers Co-op. Society	Feed
	A	Ireton Booster	Newspaper
Orange City	A	Farmers Mutual Coop	Feed, liquid & dry fertilizer
	C	Harker's Wholesale Meat	Portioned meat products
	E	K-Products, Inc.	Jackets, caps, emblems
	B	Mid-West Pre-Casting	Conc. silos, bunk feeders & slats, support
	A	Russell Ready Mix, Inc.	Stepping stones, ready mixed concrete
	B	S & W Ammunition Co.	Bullets, arrowheads
	A	Silent Drive, Inc.	Snow plows, V-belt drive, suspensions
	A	Sioux County Capital	Newspaper, commercial printing
	B	Siouxland Harvestores	Silos
	A	Tolman Welding & Mfg.	Tanks, elbows, valves, bins, hoppers, augers
	C	Vogel Paint & Wax Co., Inc.	Enamels, traffic & wall paints
	A	Wooden Shoe Factory	Wooden shoes
Rock Valley	A	Farmers Elevator Co.	Rolled oats, feed, pellets, fertilizer
	D	Hayes-Albion Corp.	Automotive & misc. screw machine
	C	Hope Haven Train. Center	Pallets, stakes, pipe, hitch pins, oil filters
	B	K-Products, Inc.	Men's jackets & caps

[a]Iowa Development Commission (1978a).

[b]Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-11. Continued

Location	Code[b]	Name	Products
Rock Valley	A	Kats Machine & Mfg.	Farrowing pens, hitches, tractor dual wheels
	A	Pollema Mfg., Inc.	Silo chutes, drag feeders, hitches, running gears
	A	Rock Valley Bee	Newspaper, commercial printing
	B	Cement Block & Tile, Inc.	Cement block, feed bunk, ready mixed conc.
	B	Roorda Machine Shop	Manure spreaders, feeder wagons
Sioux Center	B	Assoc. Milk Producers	Butter, dry milk, dried buttermilk
	A	Custom Casemakers	Custom made cases, sample cases
	B	Farmers Co-op. Society	Dog food, livestock & poultry feed
	A	Gerritsma Sawmill	Planks, lumber, pallets, truck body parts
	A	Joe's Ready Mix Co.	Ready mixed concrete
	C	K-Products, Inc.	Men's jackets & premium caps
	A	Kosters Mfg. Co., Inc.	Well cover, harrow, drag feeder, feed pans
	A	Olivier Ready Built Homes	Pre-built homes
	B	Sioux Automation Center	Latches, clamps, carts, chutes, gates
	A	Sioux Center News	Newspaper, job printing
	A	Sioux Center Shopper	Job printing
	C	Sioux Preme Packing Co.	Carcass hogs, lard, grease, bone meal
	A	Siouxland Mat Co.	Rubber stripping, mats, pads
	A	Soo Ready Mix Co.	Ready mixed concrete
	D	UM Div. of Dyna Technology	Electric universal motor mfg.

Table C-12. Manufacturers located in Woodbury County in 1977[a]

Location	Code[b]	Name	Products
Anthon	A	Terra Western Corp.	Dry blend fertilizer
Correctionville	A	Correctionville News	Newspaper, commercial printing
Danbury	A	Agfood & Chemicals, Inc.	Liquid feeds & fertilizers
	A	Brenner & Son Vault Co.	Concrete burial vaults
	A	Welte Vault Co.	Conc. burial vaults, hog troughs, boxes
Hornick	A	Farmers Co-op. Elev. Co.	Livestock feed, liquid fertilizer
Lawton	A	Stockmens, Inc.	Lariets, boat tie downs, bridles, whips, halters
Moville	A	Moville Feed & Grain	Rolled oats, oat hulls
	A	Moville Record	Newspaper, job printing
	A	NW Iowa Farm Bur. Service	Blended fertilizer
Pierson	A	Farmers Co-op. Elev. Co.	Cattle & hog feed, starter & supplement
	A	Malcolm H. Grieve	Hybrid seed corn
Salix	A	Mook's Repair	Ornamental metal work
Sergeant Bluff	A	Ballou Brick Co.	Brick & structural tile
	A	Beermann Bros. Dehy	Dehy. alfalfa pellets, alfalfa & corn cubes
	A	Bud's Dairy, Inc.	Ice cream, fluid milk
	B	FMC Corp.-Ag. Chem. Div.	Agricultural insecticides
	C	Farmland Industries, Inc.	Soybean meal & hulls, soybean oil
	A	Haviland Bros. Packing Co.	Fresh & smoked sausage, ham & bacon
	C	Kind & Knox Gelatin	Grease, skin residue, gelatin
	A	Wilbert Vault Co.	Concrete burial vaults

	D	Terra Chem. Inter., Inc.	Ammonia, urea, fertilizer solutions
	A	Walker Products Co.	Pet & mink food raw materials
Sioux City	A	ABC Sign Co.	Labels, emblems, decals & signs
	E	Aalfs Mfg. Co.	Jeans
	C	Advance Industries	Microwave towers, antennas, rotators
	B	All Power, Inc.	Shackles, hooks, conveyors, sprockets, trolleys
	C	American Equip. Co.	Farm mach., farm, construction, & indus. equip.
	A	Amer. Letter & Advis. Co.	Offset printing
	C	Amer. Popcorn Co.	Popcorn
	A	Avery Bros. Sign Co.	Commercial & highway signs
	A	Bohans Mattress Co.	Pillows, furniture, mattresses, box springs
	A	Bolstein Printers Co.	Trade journal, catalogs, offset printing
	B	Boyers Provisions Co.	Wieners, sausage, luncheon meats
	B	Braunger Insti. Foods	Beef, pork & lamb products, corned beef
	A	Brothers Paper Box Co.	Paper, cardboard, displays, boxes
	A	Cardis Mfg. Co., Inc.	Ornamental iron
	C	Cargill, Inc.	Protein feeds, soybean oil & meal
	B	Cargill Nutrena Feed Div.	Animal feed
	B	Central Soya Co., Inc.	Cattle, hog & poultry feed
	D	Chesterman Co.	Soft drinks
	A	Coe Adver. Service	Commercial & highway signs
	D	Conc. Pipe Machinery Co.	Conc. pipe machines & attachments
	A	Concrete Products Co.	Concrete blocks
	C	Container Corp. of Amer.	Corrugated shipping containers
	A	Daily Reporter	Newspaper, commercial printing
	A	Davidson Lumber Co., Inc.	Corn cribs, wood slat snow fence
	B	Digz-All, Inc.	Trenchers, backhoes, vibrator plows
	A	Fabricators, Inc.	Tables, bin gates, augers, feed mill equip.

[a] Iowa Development Commission (1978a).

[b] Number of employees: A = 1-20, B = 21-50, C = 51-100, D = 101-250, E = 251-500, F = 501-1,000, G = over 1,000.

Table C-12. Continued

Location	Code[b]	Name	Products
Sioux City	B	Fimco, Inc.	Lubricating oils & greases
	A	Friend-Pike Sheet Metal	Water wheel humidifiers
	A	Gatens Printing Co.	Printing, lithographing
	A	Gates Rubber Co.	Rubber covered parts, chute lining mat'l.
	C	Gerkin Co.	Alum. doors & windows, patio doors
	B	Great Plains Processing	Processed hides, tankage, grease
	A	Gunderson's Indus. Equip.	Spec. machines & equip., shop welding
	B	Haakinson & Beaty Co.	Structural steel, ornamental iron
	A	Harrington-Wallman Prntng.	Commercial printing
	B	Hart Beverage Co., Inc.	Soft drinks
	D	Hoerner Waldorf Corp.	Corrugaged packaging material
	A	Hollar Stamp Co.	Stamps, stencils, rubber stamps
	B	Hovland Mfg. Co.	Pedal pushers, shorts, slacks
	D	ITT Continental Baking	Bread
	A	Industrial Diversified	Polyurethane products
	B	Interstate Air Cond. Corp.	Ductwork, louvers, dampers, hoods
	A	Iowa Broom Works	Brooms & brushes
	A	Jarvis Candy Co.	Candies
	B	Kay-Dee Feed Co.	Animal feeds
	B	Kent Feeds, Inc.	Livestock & poultry feeds
	A	Kern Advertising Co.	Electric signs
	A	Lanes Bottling Co.	Soft drinks
	A	Lewis Bedding CMT Inc.	Mattresses & box springs
	A	Lunar Communications	Towers, pre-assembled buildings
	A	Medco Labs, Inc.	Lotions and creams (dermatology)
	D	Metz Baking Co.	Bakery products
	B	Meyer Beef, Inc.	Beef slaughtering, dressed beef, hides, offal
	A	Milligan & Son	Cattle & hog feed & supplement
	C	Missouri Valley Steel Co.	Structural steel, machine shop

A	Modern Engineering Co.	Sheet metal, dust control sys., grain elev. equip.
C	Multech Corp.	Semi-trailers, lowboy gooseneck trailers
A	Murphy Products Co., Inc.	Animal, poultry & mineral feed
B	National Optical	Eyeglasses
A	Larsen's Printing	Booklets, forms, commercial printing
A	National Wood Works	Molding trim, cabinets, doors, screens, sash
A	Norfolk Feed Mills	Livestock feed
D	North Amer. Mfg. Co.	Farm equip., wagons, fork lift trucks
C	Nutra-Flow Chem. Co.	Liquid fertilizer, fert. & feed equip.
A	Otte Mfg. Co.	Power lawn mower
B	Palmer Candy Co.	Candy bars
D	Prince Mfg. Co.	Hydraulic valves & pumps, cylinders
B	Ralston Purina Co.	Livestock & poultry feed
C	Raskin Packing Co.	Dressed beef carcass, offal products
A	Record Printing Co.	Newspaper, commercial printing
C	Roberts Dairy Co.	Ice cream mix, fluid milk & cream, fruit drinks
D	Rocklin Mfg. Co.	Ag. tractor attach., machine tools, meat hooks, food ind. machinery, tool & die equip., controls
A	Royal Ornamental Iron	Flood gates, ladders, gates, anchor bolts
A	St. Regis Paper Co.	Corrugated culvert pipe
B	Sioux City Bakery	Bread, rolls, cakes, doughnuts, pies
C	Sioux City Brick & Tile	Clay brick & tile, clay products
D	Sioux City Foundry	Castings, steel tanks, metal parts
D	Sioux City Newspapers	Newspaper, computer typesetting
B	Sioux City Tent & Awning	Canvas awnings, aluminum awnings
C	Sioux Honey Ass'n.	Liquid & creamed honey
E	Sioux Quality Packers	Pork cuts, offal, lard, grease, meat, bone meal
E	Sioux Tools, Inc.	Portable electric & air tools
A	Snider Shade & Drapery	Draperies, blinds, shades, awnings
A	Solar/Rotonics, Inc.	Agricultural spray tanks
B	Soo Tractor Co., Inc.	Tractor blades, loaders, hoists, job shop
A	Sooland Burial Vault Co.	Concrete burial boxes & vaults

Table C-12. Continued

Location	Code[b]	Name	Products
Sioux City	C	Standard Ready Mix Co.	Ready mixed concrete
	B	State Steel Supply Co.	Custom fabrication
	A	Steele's Ice Service	Ice
	A	Steffe's Ceramic Studio	Greenware
	B	Steffen, Inc.	Truck bodies
	A	Sunkist Cake & Pie Co.	Cakes, bread, doughnuts, rolls
	B	Sunstar Foods, Inc.	Vanilla, cane & maple syrup
	D	Swift Dairy & Poultry Co.	Dressed turkeys
	D	Swift Fresh Meat Co.	Pork
	A	Tennis Plating Co.	Plating, metal polishing, galvanizing
	A	Tri-State Tallow Co.	Feed, tallow
	A	22nd Street Press	Commercial printing
	E	United Packing of Iowa	Meat products
	B	Verstegen, Inc.	Boxes, trade journals, commercial printing
	A	Verzani Printing & Litho.	Commercial printing & lithographing
	D	Wall Street Mission	Pallets, slope & hub stakes
	A	Weber Optical, Inc.	Eyeglasses
	C	Weller Co.	Plastic moldings, containers, lids, pipe fittings
	A	Wertz Feed Products	Bird, livestock & poultry feed, grains
	B	Western States Mfg. Co.	Felt battery washers, tire & tube repairs
	E	Wilson Trailer	Livestock, grain & flatbed semitrailers
	E	Winco Div., Dyna Tech. Inc.	Generators
	G	Zenith Elec. Corp.	Radio chassis & TV components
Sloan	A	Diamond Printing Co.	Job printing, business forms, booklets

APPENDIX D.

1967 LAND USE IN NORTHWEST IOWA

Table D-1. 1967 land use in Buena Vista County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conservation use only	Water areas
I	3,998	0	608	2,962	3,540
IIe	3,000	456	6,078	11,915	0
IIIe	3,000	152	810	6,285	0
IVe	2,000	912	405	857	0
VIe	0	456	0	0	0
VIIe	0	2,735	0	0	0
IIw	2,000	0	1,013	9,428	0
IIIw	2,000	0	0	1,142	0
IVw	0	0	0	0	0
Vw	0	304	0	286	0
VIIw	0	0	0	0	0
IIs	0	0	405	571	0
IIIs	0	0	0	0	0
IVs	0	0	0	0	0
VIs	0	0	0	0	0
VIIs	0	0	0	0	0
Total	15,998	5,015	9,319	33,446	3,540

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
25,362	16,215	2,676	4,900	218	60,479
51,237	32,758	7,070	14,724	2,173	129,411
9,882	6,318	1,911	3,917	3,477	35,752
359	229	193	992	1,738	7,685
242	154	0	203	1,087	2,142
0	—	0	0	4,563	7,298
40,067	25,617	5,733	8,601	3,259	95,718
4,273	2,634	0	976	0	11,025
0	0	0	0	0	0
248	158	0	406	8,256	9,658
0	0	0	0	0	0
2,314	1,480	0	1,756	0	6,526
118	75	0	0	0	193
118	75	0	0	0	193
0	0	0	0	0	0
0	0	0	0	0	0
134,220	85,713	17,583	36,475	24,771	366,080

Table D-2. 1967 land use in Cherokee County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	3,400	0	618	3,248	310
IIe	2,148	0	6,595	8,742	0
IIIe	2,100	1,310	2,267	15,237	0
IVe	1,700	1,047	0	0	0
VIe	0	0	206	250	0
VIIe	0	7,072	0	250	0
IIw	2,100	1,047	1,031	2,997	0
IIIw	2,100	524	0	1,250	0
IVw	0	0	0	0	0
Vw	0	0	206	2,249	0
VIIw	0	0	0	0	0
IIs	0	0	0	0	0
IIIs	0	0	0	0	0
IVs	0	0	0	0	0
VIs	0	0	0	0	0
VIIs	0	0	0	0	0
Total	13,548	11,000	10,923	34,223	310

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
18,283	9,716	1,755	2,045	3,168	42,543
57,800	30,715	9,582	13,469	4,356	133,407
27,715	14,727	7,153	11,054	10,692	92,255
404	214	405	511	1,980	6,261
135	71	270	206	5,742	6,880
0	0	0	0	8,514	15,836
13,178	6,957	1,484	1,705	7,722	38,221
1,750	930	270	0	0	6,824
0	0	0	0	0	0
3,333	1,771	540	0	14,454	22,553
0	0	0	0	198	198
165	88	0	511	198	962
0	0	0	0	0	0
0	0	0	0	198	198
269	143	0	0	0	412
0	0	0	170	0	170
123,032	65,332	21,459	29,671	57,222	366,720

Table D-3. 1967 land use in Clay County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	3,400	278	3,827	4,479	4,930
IIe	1,700	765	1,722	8,462	0
IIIe	1,000	904	1,148	2,821	0
IVe	295	417	0	352	0
VIe	0	209	0	0	0
VIIe	0	347	0	0	0
IIw	6,900	3,132	2,693	14,309	0
IIIw	500	139	2,296	705	0
IVw	0	0	0	0	0
Vw	0	974	0	0	0
VIIw	0	0	0	0	0
IIs	0	765	2,118	5,818	0
IIIs	0	70	396	705	0
IVs	0	0	0	0	0
VIs	0	0	0	0	0
VIIs	0	0	191	0	0
Total	13,795	8,000	14,391	37,651	4,930

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
46,858	30,238	205	9,227	820	104,262
17,357	11,144	0	5,126	2,255	48,531
7,742	4,971	0	2,255	2,666	23,507
250	160	0	410	1,230	3,114
125	80	0	0	615	1,029
0	0	0	0	1,025	1,372
55,693	35,756	820	7,177	9,227	135,707
3,746	2,405	205	0	410	10,406
0	0	0	0	0	0
0	0	0	0	2,871	3,845
0	0	0	0	0	0
9,240	5,933	820	2,666	2,255	29,615
1,124	721	0	0	205	3,221
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	191
142,135	91,408	2,050	26,861	23,579	364,800

Table D-4. 1967 land use in Dickinson County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser- vation use only	Water areas
I	2,500	187	1,159	0	4,636
IIe	2,128	643	3,284	320	4,895
IIIe	2,000	938	3,284	6,953	0
IVe	500	322	773	773	0
VIe	0	241	0	0	0
VIIe	0	133	0	0	0
IIw	2,000	484	772	0	6,319
IIIw	1,000	375	0	386	0
IVw	0	0	0	0	0
Vw	0	536	0	0	0
VIIw	0	81	0	0	0
IIs	0	81	193	2,318	0
IIIs	0	0	0	0	0
IVs	0	0	0	193	0
VIs	0	26	0	0	0
VIIs	0	0	0	0	0
Total	10,128	4,047	9,465	10,943	15,850

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
19,933	13,288	3,283	4,442	1,164	50,592
22,032	14,666	2,704	6,953	3,993	61,618
14,023	9,348	1,738	7,726	5,822	51,832
927	618	0	579	1,996	6,488
116	77	193	579	1,497	2,703
0	0	0	0	832	965
17,847	11,898	1,159	4,056	2,994	47,529
2,434	1,622	1,159	1,545	2,329	10,850
0	0	0	0	0	0
232	154	0	0	3,327	4,249
464	309	0	0	499	1,353
811	541	0	0	499	4,443
0	0	0	0	0	0
0	0	0	0	0	193
0	0	0	0	166	192
116	66	0	0	0	193
78,935	52,598	10,236	25,880	25,118	243,200

Table D-5. 1967 land use in Ida County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	1,000	0	0	1,003	364
IIe	2,350	201	2,407	7,021	0
IIIe	4,711	803	3,210	20,662	0
IVe	0	0	401	4,414	0
VIe	0	0	0	0	0
VIIe	0	0	201	0	0
IIw	1,200	201	602	1,204	0
IIIw	0	0	0	0	0
IVw	0	0	0	0	0
Vw	0	0	201	1,404	0
VIIw	0	0	0	0	0
IIs	0	0	0	0	0
IIIs	0	0	0	0	0
IVs	0	0	0	0	0
VIs	0	0	0	401	0
VIIs	0	0	0	0	0
Total	9,261	1,205	7,022	36,109	364

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
2,187	1,024	201	201	0	5,980
26,094	12,223	4,814	8,626	5,016	68,752
50,452	23,572	11,836	17,653	10,031	142,930
7,104	3,328	201	2,006	802	18,256
411	192	401	0	1,805	2,809
0	0	0	0	602	803
5,465	2,560	1,205	1,807	6,218	20,462
0	0	0	0	0	0
0	0	0	0	0	0
4,918	2,303	0	401	5,015	14,242
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	201	602
479	324	0	201	0	1,004
97,110	45,526	18,658	30,895	29,690	275,840

Table D-6. 1967 land use in Lyon County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	1,900	679	2,063	5,421	425
IIe	6,091	1,762	5,571	19,359	0
IIIe	2,000	722	1,650	9,034	0
IVe	0	48	413	258	0
VIe	0	15	206	257	0
VIIe	0	90	0	0	0
IIw	1,500	471	413	2,323	0
IIIw	0	29	206	0	0
IVw	0	0	0	0	0
Vw	0	71	0	774	0
VIIw	0	0	0	0	0
IIs	0	47	0	258	0
IIIs	0	22	206	258	0
IVs	0	9	0	517	0
VIs	0	15	0	258	0
VIIs	0	20	0	0	0
Total	11,491	4,000	10,728	38,717	425

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
29,345	13,810	4,282	3,508	3,252	64,685
67,994	31,851	15,255	15,177	7,806	170,866
24,802	11,671	6,691	7,122	5,692	69,384
409	192	803	725	1,301	4,149
140	66	0	0	650	1,334
0	0	535	206	6,017	6,848
10,647	5,010	1,070	5,604	13,497	40,535
140	66	267	0	1,627	2,335
0	0	0	0	0	0
842	396	0	619	3,090	5,792
0	0	0	0	0	0
1,917	902	534	0	488	4,146
678	319	0	413	162	2,058
0	0	0	0	326	852
421	198	267	206	163	1,528
409	193	536	0	650	1,808
137,744	64,674	30,240	33,580	44,721	376,320

Table D-7. 1967 land use in O'Brien County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	4,400	0	3,684	6,658	400
IIe	6,600	1,451	6,755	13,412	0
IIIe	1,000	0	205	1,235	0
IVe	0	0	0	0	0
VIe	0	731	205	0	0
VIIe	0	1,452	0	0	0
IIw	2,093	0	616	4,941	0
IIIw	0	0	0	0	0
IVw	0	0	0	0	0
Vw	0	366	0	353	0
VIIw	0	0	0	0	0
IIs	0	0	0	352	0
IIIs	0	0	0	0	0
IVs	0	0	0	0	0
VIs	0	0	0	0	0
VIIs	0	0	0	0	0
Total	14,093	4,000	11,465	26,951	400

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
41,764	28,193	7,242	10,634	4,298	107,273
69,585	46,825	10,672	13,714	2,252	171,266
4,289	2,895	763	2,866	4,503	17,756
117	79	0	0	614	810
0	0	0	0	614	1,550
241	163	0	0	2,866	4,722
21,718	14,661	762	2,740	3,889	31,420
117	79	0	0	0	196
0	0	0	0	0	0
2,122	1,433	0	409	7,369	12,052
0	0	0	0	0	0
0	0	0	0	0	352
0	0	0	0	0	0
117	79	0	0	407	603
0	0	0	0	0	0
0	0	0	0	0	0
140,070	94,407	19,439	30,363	26,812	368,000

Table D-8. 1967 land use in Osceola County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	2,670	800	2,769	5,680	430
IIe	3,840	950	4,998	11,958	0
IIIe	900	250	741	3,438	0
IVe	0	0	0	149	0
VIe	0	0	0	149	0
VIIe	0	0	0	0	0
IIw	1,220	0	198	4,335	0
IIIw	0	0	0	149	0
IVw	0	0	0	0	0
Vw	0	0	198	1,046	0
VIIw	0	0	0	0	0
IIs	0	0	0	0	0
IIIs	0	0	0	0	0
IVs	0	0	0	0	0
VIs	0	0	0	0	0
VIIs	0	0	0	0	0
Total	8,630	2,000	8,904	26,904	430

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
33,242	19,607	2,776	2,776	1,983	72,733
43,085	25,473	4,362	7,138	2,181	103,985
7,781	4,589	2,379	3,569	2,181	25,828
396	234	0	198	595	1,572
0	0	0	0	1,388	1,537
0	0	0	396	198	594
13,715	8,089	1,785	2,182	3,371	34,895
263	155	0	0	0	567
0	0	0	0	0	0
2,904	1,713	198	397	5,353	11,809
0	0	0	0	0	0
0	0	0	397	0	397
131	77	0	595	0	803
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
101,517	59,937	11,500	17,648	17,250	254,720

Table D-9. 1967 land use in Plymouth County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	700	0	1,683	236	1,050
IIe	4,500	462	6,029	13,424	0
IIIe	8,697	0	5,312	33,845	0
IVe	1,300	6,461	605	5,417	0
VIe	0	0	202	0	0
VIIe	0	5,077	403	0	0
IIw	1,800	0	1,050	4,710	0
IIIw	0	0	0	0	0
IVw	0	0	0	0	0
Vw	0	0	272	1,413	0
VIIw	0	0	0	0	0
IIs	0	0	0	0	0
IIIs	0	0	0	0	0
IVs	0	0	0	0	0
VIs	0	0	0	0	0
VIIs	0	0	0	0	0
Total	16,997	12,000	15,556	59,045	1,050

[a] Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
10,895	3,749	605	2,218	389	21,525
55,391	19,108	11,492	13,509	10,892	134,807
98,786	33,991	25,605	33,872	20,422	260,530
5,994	2,062	1,411	5,645	9,530	38,425
0	0	0	605	2,917	3,724
0	0	0	0	10,697	16,177
21,215	7,300	2,823	5,645	11,669	56,212
1,482	510	0	403	0	2,395
0	0	0	0	0	0
4,362	1,508	605	1,612	8,558	18,330
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	195	195
0	0	0	0	0	0
198,125	68,228	42,541	63,509	75,269	552,320

Table D-10. 1967 land use in Sac County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	2,400	0	309	2,676	1,020
IIe	7,690	1,154	6,877	14,233	0
IIIe	3,600	231	2,727	9,093	0
IVe	0	0	202	532	0
VIe	0	0	0	0	0
VIIe	0	1,615	202	0	0
IIw	3,900	0	2,632	10,208	0
IIIw	0	0	0	1,647	0
IVw	0	0	0	0	0
Vw	0	3,000	605	0	0
VIIw	0		0	0	0
IIs	0	0	0	1,647	0
IIIs	0	0	0	0	0
IVs	0	0	0	0	0
VIs	0	0	0	0	0
VIIs	0	0	0	0	0
Total	17,590	6,000	13,554	40,036	1,020

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
19,235	11,200	5,644	1,578	1,612	45,674
55,983	32,703	15,318	7,891	6,047	147,896
21,146	12,313	8,667	5,749	4,636	68,162
637	371	202	789	806	3,539
255	149	202	113	1,008	1,727
0	0	403	113	403	2,736
29,298	17,060	4,031	2,480	5,039	74,648
2,802	1,632	605	113	403	7,202
0	0	0	0	0	0
1,528	890	0	225	5,039	11,287
0	0	0	0	0	0
1,273	742	1,612	113	0	5,387
0	0	0	0	403	403
255	149	202	451	0	1,057
0	0	202	0	0	202
0	0	0	0	0	0
132,412	77,209	37,088	19,615	25,396	369,920

Table D-11. 1967 land use in Sioux County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conservation use only	Water areas
I	2,600	412	2,087	3,636	810
IIe	8,202	1,313	5,535	17,150	0
IIIe	5,400	821	3,619	19,051	0
IVe	0	17	0	0	0
VIe	0	3	0	636	0
VIIe	0	35	5,322	0	0
IIw	1,700	272	426	1,907	0
IIIw	0	2	0	0	0
IVw	0	0	0	0	0
Vw	0	32	639	0	0
VIIw	0	0	0	0	0
IIs	0	34	0	636	0
IIIs	0	10	0	0	0
IVs	0	13	0	0	0
VIs	0	5	0	0	0
VIIs	0	31	213	0	0
Total	17,902	3,000	17,841	43,016	810

[a] Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
31,333	15,926	4,258	2,752	3,126	66,940
94,697	48,355	24,268	8,505	5,473	213,498
51,657	26,257	18,946	6,004	6,058	137,813
1,412	717	0	83	391	2,620
141	72	0	0	0	852
0	0	0	0	0	5,357
15,525	7,892	4,258	1,334	9,772	43,086
0	0	0	0	196	198
0	0	0	0	0	0
988	502	0	83	2,736	4,980
0	0	0	0	0	0
3,105	1,579	0	0	196	5,550
282	144	0	0	1,172	1,608
1,412	717	0	0	0	2,142
424	215	213	0	0	857
0	0	0	0	4,495	4,739
200,976	102,376	51,943	18,761	33,615	490,240

Table D-12. 1967 land use in Woodbury County by use and capability class, acres[a]

Capability class	Urban & built-up	Forest	Other	Conser-vation use only	Water areas
I	3,600	3,337	2,843	9,096	1,470
IIe	3,400	1,668	710	3,216	0
IIIe	11,917	13,330	3,553	25,435	0
IVe	3,400	6,665	1,066	8,186	0
VIe	0	0	356	4,971	0
VIIe	0	0	0	0	0
IIw	1,300	0	2,843	3,350	0
IIIw	3,600	0	710	33,635	0
IVw	0	0	0	584	0
Vw	0	0	0	0	0
VIIw	0	0	0	214	0
IIs	0	0	0	293	0
IIIs	0	0	356	507	0
IVs	0	0	0	0	0
VIs	0	0	0	0	0
VIIs	0	0	0	0	0
Total	27,217	25,000	12,437	89,487	1,470

[a]Iowa Conservation Needs Committee (1970).

Corn	Soybeans	Close grown crops	Rotation hay and pasture	Pasture	Total
30,941	12,700	922	2,351	3,634	70,894
25,064	10,287	2,459	7,267	11,968	66,039
68,538	28,252	18,856	38,468	24,364	232,713
15,580	6,395	4,304	8,335	14,105	68,036
125	51	205	2,351	3,847	11,906
0	0	0	854	428	1,282
11,478	4,711	717	214	1,068	25,681
21,581	8,858	1,229	1,923	428	71,964
625	256	0	214	0	1,679
250	102	0	0	0	352
0	0	103	0	0	317
1,124	461	205	0	0	2,083
2,423	994	0	214	0	4,494
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
177,729	73,067	29,000	62,191	59,842	557,440

APPENDIX E.

LOW-FLOW PARTIAL-RECORD STREAM GAGING STATIONS

Table E-1. Average discharge and low-flow data for low-flow partial-record stream gaging stations in Northwest Iowa[a]

Stream	Number	Location
Big Sioux River		
Rock River	6-4831.00	Near Rock Rapids
Kanaranzi Creek	6-4832.60	Near Rock Rapids
Tom Creek	6-4832.80	At Rock Rapids
Rock River	6-4833.00	Below Rock Rapids
Mud Creek	6-4833.20	At Lester
Mud Creek	6-4833.30	Near Doon
Rock River	6-4833.40	Near Doon
Little Rock River	6-4833.60	Near Little Rock
Little Rock River	6-4833.80	At Little Rock
Little Rock River	6-4834.00	Near George
Otter Creek	6-4834.60	Near Ashton
Otter Creek	6-4834.70	Near Matlock
Otter Creek	6-4834.80	Near George
Little Rock River	6-4834.90	Near Doon
Sixmile Creek	6-4841.00	Near Hawarden
Sixmile Creek	6-4841.50	Near Chatsworth
Indian Creek	6-4842.00	Near Chatsworth
Broken Kettle Creek	6-4858.00	Near Adaville
Broken Kettle Creek	6-4859.00	Near Sioux City
Floyd River		
Floyd River	6-6000.20	Near Sheldon
Little Floyd River	6-6000.40	Near Sheldon
Floyd River	6-6000.60	Below Sheldon
Deep Creek	6-6001.20	Near Oyens
Willow Creek	6-6001.40	Near Oyens
Deep Creek	6-6001.60	At LeMars
Floyd River	6-6001.80	At LeMars
Floyd River	6-6002.00	Near Merrill
W. Br. Floyd River	6-6002.50	Near Middleburg
W. Br. Floyd River	6-6004.00	Near Merrill

[a]Heinitz (1970).

[b]7-day 2-year low flow.

[c]7-day 10-year low flow.

[d]Not determined.

Record length years	D.A. sq. mi.	Computed average Q cfs	Lowest Q measured cfs	Computed low-flow Q_2[b] cfs	Computed low-flow Q_{10}[c] cfs
8	558	122	2.29	3.8	–[d]
8	203	50	0.14	0.7	<0.1
8	61.9	16	0.00	0.0	0.0
8	859	194	0.46	2.5	–
8	63.7	14	0.00	<0.1	–
8	138	29	0.07	0.4	<0.1
8	1,050	247	1.00	6.6	–
8	92.0	23	0.00	0.0	0.0
8	134	33	0.10	0.2	<0.1
8	199	53	1.10	1.1	–
8	88.0	25	0.60	0.4	<0.1
8	129	38	0.23	0.5	<0.1
8	208	60	0.00	1.3	–
8	474	135	0.48	3.2	–
8	68.8	15	0.26	0.4	–
8	104	22	0.25	0.6	–
9	62.2	14	0.06	0.1	–
9	60.7	14	1.38	1.4	–
9	97.4	22	1.72	1.8	–
8	64.0	19	0.32	0.5	–
8	59.3	17	0.00	<0.1	–
8	165	50	0.00	0.2	<0.1
9	82.7	23	0.01	0.7	–
9	65.2	16	0.00	0.0	0.0
9	156	42	0.00	0.4	<0.1
8	478	133	1.57	2.5	–
9	489	130	2.07	4.5	–
8	59.7	14	0.00	0.0	0.0
9	232	54	0.92	2.2	–

Table E-1. Continued

Stream	Number	Location
Monona-Harrison Ditch		
Big Whiskey Slough	6-6015.00	Near Kingsley
W. Fk. Little Sioux River	6-6016.00	Near Fielding
W. Fk. Little Sioux River	6-6017.00	Near Kingsley
Mud Creek	6-6018.00	At Moville
W. Fk. Little Sioux River	6-6019.00	At Moville
Elliot Creek	6-6022.00	Near Bronson
Big Whiskey Creek	6-6022.50	Near Bronson
Wolf Creek	6-6023.00	Near Holly Springs
Little Sioux River		
Little Sioux River	6-6036.00	Near Montgomery
W. Fk. Little Sioux River	6-6037.00	Near Lake Park
W. Fk. Little Sioux River	6-6038.00	Near Montgomery
Little Sioux River	6-6039.00	Near Milford
Okoboji Lake Outlet	6-6044.00	Near Milford
Ocheyedan River	6-6045.00	Near Bigelow
Little Ocheyedan River	6-6046.00	Near May City
Ocheyedan River	6-6047.00	Near May City
Stoney Creek	6-6048.00	Near Fostoria
Stoney Creek	6-6049.00	Near Everly
Ocheyedan River	6-6050.00	Near Spencer
Little Sioux River	6-6051.00	At Spencer
Muddy Creek	6-6052.00	Near Langdon
Muddy Creek	6-6053.00	Near Spencer
Pickerel Run	6-6054.00	Near Spencer
Lost Island Outlet	6-6055.00	Near Dickens
Willow Creek	6-6057.00	Near Rossi
Willow Creek	6-6058.00	Near Greenville
Waterman Creek	6-6059.00	Near Hartley
Waterman Creek	6-6060.00	Near Sutherland
Little Sioux River	6-6061.00	Near Sutherland
Mill Creek	6-6062.00	Near Pualina
Mill Creek	6-6063.00	Near Cherokee
Little Sioux River	6-6064.00	At Cherokee
Pierson Creek	6-6065.00	Near Correctionville
Maple River	6-6068.00	Near Aurelia
Maple River	6-6069.00	Near Ida Grove
Odebolt Creek	6-6071.00	At Ida Grove
Maple River	6-6074.00	Near Turin
Soldier River		
Soldier River	6-6083.00	Near Rickets

Record length years	D.A. sq. mi.	Computed average Q cfs	Lowest Q measured cfs	Computed low-flow Q_2[b] cfs	Computed low-flow Q_{10}[c] cfs
9	55.3	15	0.42	0.6	–
9	135	38	2.00	2.5	–
9	219	60	2.12	5.4	–
9	68.7	16	0.00	<0.1	–
9	344	94	3.25	6.0	–
9	58.6	13	0.39	0.4	–
9	62.4	14	0.06	0.3	
9	99.2	22	1.11	1.5	
8	118	31	0.00	0.1	–
8	116	29	0.00	0.0	0.0
8	173	45	0.00	<0.1	–
8	333	90	0.00	<0.1	–
8	151	44	0.79	1.0	–
8	68.7	17	0.00	<0.1	–
8	54.2	15	0.00	<0.1	–
8	226	66	2.63	3.7	–
8	65.4	18	0.71	1.1	–
8	81.6	23	0.02	1.2	–
8	426	125	2.95	4.5	–
9	990	278	7.44	14.0	–
9	59.7	18	0.30	0.6	–
9	102	31	0.36	1.1	–
9	75.7	23	0.00	0.0	0.0
9	151	47	1.09	1.5	–
9	62.6	20	0.00	0.0	0.0
9	90.3	29	0.00	<0.1	–
8	58.4	18	0.01	<0.1	–
8	139	45	0.15	0.4	<0.1
8	1,803	566	1.83	25.0	–
8	61.6	19	0.00	<0.1	–
8	292	93	0.89	28.0	–
8	2,173	679	3.63	33.0	–
9	55.1	13	0.01	0.2	<0.1
8	85.2	27	0.03	<0.1	–
9	364	108	5.22	9.4	–
9	61.1	17	2.10	2.1	–
9	741	214	16.20	25.0	6.4
9	90.5	25	1.89	3.2	–

Table E-1. Continued

Stream	Number	Location
Soldier River	6-6083.50	Near Ute
East Soldier River	6-6084.00	Near Ute
Boyer River		
Boyer River	6-6092.60	Near Early
East Boyer River	6-6093.00	At Vail
East Boyer River	6-6093.50	At Denison
Boyer River	6-6094.00	Near Denison
North Raccoon River		
North Raccoon River	5-4821.00	Near Rembrandt
North Raccoon River	5-4821.20	Near Truesdale
Little Cedar Creek	5-4821.80	Near Fonda
Big Cedar Creek	5-4822.00	At Fonda
Big Cedar Creek	5-4822.20	At Sac City
Indian Creek	5-4823.20	Near Lake View
Camp Creek	5-4823.60	Near Lytton
Camp Creek	5-4823.80	Near Lake City
North Raccoon River	5-4824.00	Near Lake City

Record length years	D.A. sq. mi.	Computed average Q cfs	Lowest Q measured cfs	Computed low-flow Q_2[b] cfs	Computed low-flow Q_{10}[c] cfs
9	155	42	3.73	5.4	–
9	97.8	28	3.05	3.4	–
9	67.8	20	0.37	0.8	–
9	65.4	20	1.07	3.3	–
9	130	41	3.05	5.2	–
9	517	164	7.79	15.0	–
	77.4	27	0.63	0.5	–
	164	55	0.90	0.7	–
	83.5	28	0.20	0.2	<0.1
	196	68	0.24	0.4	<0.1
	342	115	2.35	2.5	–
	90.2	29	1.16	1.0	–
	62.0	23	0.05	0.5	<0.1
	147	56	0.18	0.8	–
	1,003	343	10.10	13.0	–

APPENDIX F.

PRECIPITATION DATA

Table F-1. PRECIPITATION DATA IN INCHES AT AKRON, IOWA.

PERIOD OF RECORD IS 1928 TO 1977. N = 50

YEAR	JUNE	JULY	AUGUST	ANNUAL
1928	3.25	4.66	4.64	26.18
1929	3.50	2.11	3.79	22.88
1930	3.73	0.01	2.89	20.80
1931	2.32	0.95	1.75	18.20
1932	4.69	1.52	2.47	24.60
1933	0.67	4.39	3.89	21.73
1934	9.13	4.17	2.23	26.91
1935	4.50	5.30	2.20	27.36
1936	1.72	0.42	1.91	16.02
1937	2.20	2.56	8.87	28.66
1938	3.55	5.93	2.55	32.27
1939	6.11	1.08	2.46	15.13
1940	6.98	3.81	5.18	28.69
1941	8.08	1.87	1.27	26.85
1942	4.86	3.81	1.36	21.80
1943	5.57	3.39	0.75	18.57
1944	9.02	5.16	6.16	36.19
1945	4.40	4.43	3.80	26.91
1946	3.41	0.39	4.49	28.17
1947	5.22	0.45	1.70	26.34
1948	5.98	3.71	2.90	26.03
1949	3.82	4.08	5.83	32.19
1950	5.23	3.91	3.46	26.41
1951	8.52	3.84	7.86	42.95
1952	3.57	6.08	4.41	24.72
1953	6.20	3.62	4.27	30.20
1954	8.58	2.77	2.16	28.74
1955	3.83	4.15	1.09	19.90
1956	2.32	2.15	2.26	14.42
1957	4.54	4.91	3.16	26.51
1958	1.94	4.37	0.74	16.52
1959	2.83	1.65	3.64	28.89
1960	2.78	0.85	7.35	30.45
1961	2.68	4.09	4.58	27.74
1962	6.21	4.44	4.89	31.10
1963	4.03	3.03	5.51	21.57
1964	4.35	5.44	2.77	29.26
1965	4.97	2.58	3.07	34.16
1966	4.48	7.02	6.91	29.39
1967	7.96	1.12	4.84	21.08

Table F-1. PRECIPITATION DATA IN INCHES AT AKRON, IOWA.
Continued PERIOD OF RECORD IS 1928 TO 1977. N = 50

YEAR	JUNE	JULY	AUGUST	ANNUAL
1968	4.46	4.51	3.30	31.75
1969	7.86	2.76	4.47	29.38
1970	3.65	0.94	1.30	27.75
1971	10.49	2.15	0.30	27.10
1972	0.92	6.05	2.91	28.24
1973	2.56	3.56	0.84	23.64
1974	3.57	1.29	2.05	17.40
1975	5.35	1.10	4.41	23.16
1976	0.60	1.91	1.53	12.75
1977	4.20	3.57	1.49	28.16

Table F-2. PRECIPITATION DATA IN INCHES AT ALTON, IOWA.

PERIOD OF RECORD IS 1906 TO 1977. N = 72

YEAR	JUNE	JULY	AUGUST	ANNUAL
1906	4.42	1.80	5.31	33.89
1907	4.56	5.36	2.83	27.14
1908	4.35	4.19	3.95	32.52
1909	5.96	6.61	0.99	36.48
1910	1.26	3.84	4.43	17.42
1911	1.71	1.89	4.11	23.65
1912	1.77	3.24	2.61	21.32
1913	2.09	3.66	3.25	21.88
1914	5.33	1.94	1.85	23.76
1915	4.40	5.69	2.27	29.58
1916	2.81	3.18	1.60	25.47
1917	4.47	1.69	2.01	22.52
1918	4.70	3.28	5.15	31.40
1919	4.89	4.45	2.40	28.40
1920	3.39	4.29	3.20	29.34
1921	0.56	3.24	2.50	24.24
1922	1.67	4.13	4.31	24.23
1923	4.38	2.07	4.47	30.30
1924	4.08	0.89	5.22	20.62
1925	3.24	2.48	0.31	14.42
1926	2.50	2.88	3.86	24.40
1927	2.02	1.94	2.13	24.28
1928	3.97	5.02	5.12	25.72
1929	3.85	1.69	3.47	22.14
1930	5.10	0.39	1.67	21.40
1931	3.69	2.07	5.22	24.47
1932	5.66	2.51	4.55	28.54
1933	1.03	5.09	2.31	20.80
1934	6.81	3.73	3.79	23.08
1935	4.84	2.99	2.41	22.21
1936	1.67	1.34	2.78	17.80
1937	2.29	1.37	4.81	25.75
1938	1.78	3.36	2.61	28.69
1939	3.87	3.63	3.50	18.58
1940	6.63	2.26	4.45	29.50
1941	7.39	1.46	0.82	29.16
1942	7.96	4.19	4.34	32.63
1943	6.61	3.82	2.44	23.06
1944	5.23	7.09	7.60	38.25
1945	6.71	4.13	3.35	30.32

Table F-2. PRECIPITATION DATA IN INCHES AT ALTON, IOWA.
Continued PERIOD OF RECORD IS 1906 TO 1977. N = 72

YEAR	JUNE	JULY	AUGUST	ANNUAL
1946	4.85	1.74	2.79	29.74
1947	7.70	0.59	2.23	30.36
1948	5.53	5.22	5.58	28.74
1949	2.86	1.91	2.07	25.44
1950	4.23	4.84	1.88	28.75
1951	4.43	5.08	6.77	31.79
1952	3.52	4.39	3.48	20.41
1953	7.29	4.18	4.06	31.15
1954	7.64	2.00	6.05	30.02
1955	2.22	2.99	2.76	17.62
1956	2.62	5.18	3.01	18.61
1957	5.09	4.26	3.92	28.21
1958	1.99	2.83	0.72	13.29
1959	3.22	0.55	7.18	30.45
1960	2.65	1.81	8.95	31.06
1961	5.01	2.79	6.55	29.24
1962	4.50	5.81	5.16	30.76
1963	3.54	4.23	1.99	20.04
1964	3.34	5.79	2.95	28.08
1965	3.24	5.10	3.42	33.39
1966	4.10	2.09	2.42	20.93
1967	8.30	1.01	1.45	17.49
1968	2.87	4.85	0.79	29.65
1969	3.67	4.03	3.98	26.82
1970	2.95	2.00	0.90	29.72
1971	5.12	2.90	0.55	22.98
1972	2.36	6.41	1.78	28.59
1973	3.13	5.85	1.56	28.08
1974	5.00	1.17	6.27	22.49
1975	5.10	1.13	2.89	25.04
1976	1.27	1.68	0.62	14.66
1977	1.53	5.48	1.81	30.32

Table F-3. PRECIPITATION DATA IN INCHES AT CHEROKEE, IOWA,

PERIOD OF RECORD IS 1922 TO 1977. N = 56

YEAR	JUNE	JULY	AUGUST	ANNUAL
1922	2.21	4.81	3.03	23.88
1923	5.02	1.36	5.43	31.16
1924	5.95	1.61	6.12	23.70
1925	5.35	2.47	0.94	19.56
1926	4.74	3.50	2.53	33.23
1927	2.82	2.63	1.60	24.85
1928	2.31	2.41	2.75	21.35
1929	3.65	2.82	2.46	23.04
1930	3.44	1.12	1.10	20.32
1931	2.25	6.16	2.37	28.67
1932	3.48	2.12	5.47	26.87
1933	0.90	5.62	2.44	22.89
1934	6.80	5.45	5.01	26.70
1935	2.63	1.93	1.85	21.02
1936	2.48	0.20	2.17	22.20
1937	2.99	3.93	7.55	30.68
1938	4.11	9.33	2.85	42.86
1939	3.00	2.63	4.11	19.32
1940	6.28	3.64	5.37	30.91
1941	6.31	2.07	2.03	32.55
1942	4.96	5.24	1.58	26.85
1943	8.59	5.18	1.01	25.44
1944	8.15	8.16	4.08	37.49
1945	5.64	4.50	6.38	37.68
1946	3.21	0.72	2.36	29.27
1947	8.60	0.82	1.18	29.56
1948	4.41	3.90	5.43	25.72
1949	4.19	2.13	1.00	25.34
1950	4.13	7.54	1.13	24.86
1951	5.91	3.89	7.84	38.87
1952	3.46	6.28	4.43	25.28
1953	11.52	4.94	4.93	37.31
1954	8.63	0.77	5.33	29.86
1955	1.64	4.44	0.11	16.64
1956	1.13	2.23	2.31	15.84
1957	7.88	6.04	3.39	34.72
1958	2.54	2.09	1.11	12.11
1959	4.94	1.49	7.02	38.91
1960	1.92	2.92	6.31	28.76
1961	5.83	4.57	3.98	30.93

Table F-3. PRECIPITATION DATA IN INCHES AT CHEROKEE, IOWA.
Continued PERIOD OF RECORD IS 1922 TO 1977. N = 56

YEAR	JUNE	JULY	AUGUST	ANNUAL
1962	5.18	7.54	5.17	30.94
1963	2.51	4.18	2.83	20.72
1964	2.62	5.30	2.33	31.10
1965	2.02	1.40	2.52	30.62
1966	3.20	2.67	4.07	21.38
1967	9.64	1.34	2.63	23.05
1968	5.93	5.49	4.15	34.51
1969	8.19	3.22	4.44	28.78
1970	2.37	4.70	1.41	28.55
1971	7.21	2.96	0.66	24.17
1972	1.37	4.47	2.94	27.62
1973	1.76	5.05	1.76	28.01
1974	4.68	1.67	5.40	20.50
1975	5.38	0.41	4.56	29.06
1976	1.51	0.77	0.41	15.15
1977	4.55	4.55	3.62	34.30

Table F-4. PRECIPITATION DATA IN INCHES AT HAWARDEN, IOWA.

PERIOD OF RECORD IS 1927 TO 1977. N = 51

YEAR	JUNE	JULY	AUGUST	ANNUAL
1927	2.49	1.37	1.79	25.09
1928	3.92	3.25	6.63	28.75
1929	3.42	4.59	1.70	26.24
1930	4.97	0.12	2.96	24.15
1931	2.98	1.21	2.05	20.50
1932	2.65	2.88	3.82	23.60
1933	1.08	5.05	5.03	24.33
1934	7.36	3.47	3.44	24.16
1935	5.08	2.57	2.08	24.75
1936	1.94	0.40	3.13	21.73
1937	3.20	0.86	4.86	24.86
1938	2.74	3.03	1.69	28.75
1939	4.34	2.00	2.10	14.56
1940	5.53	3.05	2.40	24.47
1941	7.59	1.19	0.62	25.91
1942	6.65	3.20	2.36	25.08
1943	3.75	5.90	1.94	20.27
1944	7.47	6.30	6.27	34.94
1945	4.88	5.25	4.24	28.65
1946	3.37	1.09	2.49	26.69
1947	5.20	1.29	3.65	26.53
1948	4.75	2.77	5.13	25.07
1949	2.94	2.05	3.07	25.86
1950	5.64	5.49	0.89	25.83
1951	5.41	4.32	8.28	39.34
1952	2.22	6.26	5.60	23.12
1953	9.25	5.34	4.34	35.44
1954	8.31	2.19	1.93	26.64
1955	5.15	2.25	0.72	16.44
1956	1.85	3.34	2.37	16.10
1957	5.55	5.75	2.87	28.78
1958	1.33	3.83	1.36	14.64
1959	2.72	0.79	4.60	29.36
1960	2.27	1.29	6.57	29.45
1961	2.66	1.96	4.61	23.96
1962	7.29	5.90	5.62	34.30
1963	2.51	3.40	2.96	17.43
1964	3.97	3.11	2.65	25.37
1965	8.88	2.55	2.50	37.11
1966	3.16	5.34	6.11	25.03

Table F-4. PRECIPITATION DATA IN INCHES AT HAWARDEN, IOWA.
Continued PERIOD OF RECORD IS 1927 TO 1977. N = 51

YEAR	JUNE	JULY	AUGUST	ANNUAL
1967	7.24	2.12	2.82	19.21
1968	2.90	4.19	1.26	27.43
1969	5.80	4.35	6.28	30.28
1970	2.52	2.28	0.83	28.71
1971	6.81	1.78	1.23	23.33
1972	3.81	7.26	1.26	31.58
1973	2.57	4.08	0.83	23.93
1974	5.69	1.12	3.97	19.52
1975	4.61	0.75	6.40	25.41
1976	0.97	1.67	1.21	13.97
1977	1.66	2.86	1.94	27.34

Table F-5. PRECIPITATION DATA IN INCHES AT HOLSTEIN, IOWA.
PERIOD OF RECORD IS 1934 TO 1977. N = 44

YEAR	JUNE	JULY	AUGUST	ANNUAL
1934	7.47	5.40	1.97	26.89
1935	2.03	5.58	1.81	23.57
1936	1.29	0.20	2.04	16.51
1937	3.17	1.40	8.57	28.67
1938	4.32	3.36	0.95	31.37
1939	3.38	2.59	4.06	18.53
1940	6.07	5.32	6.18	32.85
1941	5.45	3.56	1.81	36.30
1942	6.25	3.64	1.24	25.24
1943	6.83	3.94	3.29	24.21
1944	7.21	8.81	5.50	39.24
1945	4.58	3.57	4.78	31.91
1946	2.55	0.50	2.32	25.90
1947	7.68	0.92	0.62	26.59
1948	4.18	3.85	3.93	26.42
1949	3.75	4.33	1.85	27.78
1950	5.42	6.80	1.63	29.47
1951	6.45	2.67	13.03	43.10
1952	5.09	5.64	2.71	27.69
1953	3.83	1.94	2.71	23.25
1954	10.21	1.80	2.53	33.90
1955	2.19	7.23	1.26	21.10
1956	2.01	2.53	3.65	18.67
1957	7.04	4.68	2.43	33.59
1958	4.41	5.09	1.22	18.63
1959	3.01	1.20	2.65	34.17
1960	2.58	2.09	6.28	27.30
1961	6.61	4.15	5.16	33.82
1962	4.10	4.66	6.46	30.52
1963	9.05	3.27	3.50	30.01
1964	2.76	4.22	2.67	26.53
1965	2.08	1.72	3.60	35.07
1966	3.22	2.99	6.45	21.19
1967	13.42	1.37	2.43	28.65
1968	4.56	5.50	3.29	35.41
1969	6.13	2.61	1.20	24.23
1970	2.16	3.98	1.36	28.77
1971	5.63	4.43	1.17	30.80
1972	3.77	6.16	3.98	33.99
1973	3.57	5.46	1.03	35.19

Table F-5. PRECIPITATION DATA IN INCHES AT HOLSTEIN, IOWA,
Continued PERIOD OF RECORD IS 1934 TO 1977. N = 44

YEAR	JUNE	JULY	AUGUST	ANNUAL
1974	3.42	1.49	4.93	22.78
1975	7.14	0.78	7.07	37.19
1976	2.07	0.97	0.15	15.54
1977	3.76	6.18	4.96	36.74

Table F-6. PRECIPITATION DATA IN INCHES AT IDA GROVE, IOWA.

PERIOD OF RECORD IS 1945 TO 1977. N = 33

YEAR	JUNE	JULY	AUGUST	ANNUAL
1945	2.72	6.45	2.44	31.72
1946	4.27	1.20	3.25	31.11
1947	6.57	1.04	0.74	25.95
1948	4.18	4.52	2.86	31.47
1949	1.75	4.28	3.91	26.27
1950	6.71	6.08	2.05	26.78
1951	9.12	5.06	14.85	51.62
1952	5.21	5.75	2.74	29.68
1953	4.34	2.46	3.71	26.34
1954	8.24	2.02	3.23	36.78
1955	2.30	5.81	1.12	18.41
1956	2.54	1.34	3.75	17.04
1957	6.37	3.94	3.10	28.76
1958	4.25	5.42	2.53	20.29
1959	4.89	0.57	3.09	34.02
1960	3.18	2.93	3.16	25.39
1961	6.12	2.55	2.56	27.12
1962	3.66	7.77	13.50	43.42
1963	5.06	3.67	4.31	27.06
1964	4.89	5.31	3.93	34.97
1965	2.25	2.33	3.97	35.25
1966	5.85	2.79	5.48	22.51
1967	14.05	4.02	2.07	29.40
1968	4.69	2.81	6.28	36.51
1969	6.73	1.62	2.14	28.26
1970	1.42	4.02	1.84	27.75
1971	3.06	4.01	1.31	27.60
1972	6.31	4.69	4.03	34.60
1973	3.04	3.71	0.70	31.06
1974	2.72	1.37	4.76	22.65
1975	5.45	1.60	6.48	35.81
1976	2.56	0.85	0.51	16.02
1977	4.45	3.40	4.53	34.60

Table F-7. PRECIPITATION DATA IN INCHES AT INWOOD, IOWA.

PERIOD OF RECORD IS 1904 TO 1972. N = 69

YEAR	JUNE	JULY	AUGUST	ANNUAL
1904	4.08	3.78	1.99	21.08
1905	9.92	1.29	2.76	23.67
1906	7.94	1.29	7.21	35.73
1907	4.98	5.65	1.45	21.87
1908	6.69	3.20	1.94	32.76
1909	8.53	4.37	2.70	37.08
1910	1.33	3.53	4.46	18.52
1911	3.12	2.34	3.73	22.03
1912	1.13	3.22	1.63	15.25
1913	3.76	2.85	0.91	25.84
1914	7.43	2.60	2.44	28.61
1915	5.41	6.09	2.55	31.52
1916	3.68	2.22	2.44	22.55
1917	4.90	2.80	1.55	21.89
1918	6.44	3.46	3.02	29.97
1919	8.48	4.83	0.99	29.61
1920	4.92	2.75	2.20	29.75
1921	3.09	4.36	2.82	24.97
1922	1.71	4.63	3.42	21.83
1923	3.26	2.59	4.39	24.03
1924	4.33	1.04	2.71	19.41
1925	4.70	3.47	1.13	17.95
1926	4.76	2.74	2.89	24.60
1927	1.58	1.73	0.82	21.89
1928	6.31	1.75	7.08	30.64
1929	3.03	4.02	2.46	23.57
1930	5.43	0.18	0.87	21.01
1931	2.85	1.27	1.88	18.81
1932	3.54	1.61	5.80	22.78
1933	0.78	4.60	6.33	26.63
1934	5.59	4.35	2.09	21.29
1935	3.51	2.62	2.86	20.79
1936	1.46	0.36	4.50	20.56
1937	2.17	1.75	4.05	25.83
1938	2.51	4.39	0.90	27.73
1939	5.50	6.31	4.52	24.59
1940	6.77	2.22	2.36	26.10
1941	5.47	1.93	0.61	24.00
1942	6.82	2.86	4.11	29.38
1943	8.91	3.36	3.93	27.68

Table F-7. PRECIPITATION DATA IN INCHES AT INWOOD, IOWA.
Continued PERIOD OF RECORD IS 1904 TO 1972, N = 69

YEAR	JUNE	JULY	AUGUST	ANNUAL
1944	6.62	4.17	7.14	37.61
1945	3.97	4.37	2.04	26.81
1946	4.14	1.27	2.28	29.31
1947	5.45	0.72	1.36	22.00
1948	3.38	4.30	1.47	23.24
1949	1.92	5.08	4.24	26.26
1950	4.63	3.82	1.30	20.38
1951	5.25	3.19	4.73	32.73
1952	4.56	2.14	4.94	19.70
1953	5.04	2.53	4.69	28.12
1954	8.90	1.28	4.76	28.67
1955	3.47	2.30	0.43	13.29
1956	2.92	4.38	3.66	19.46
1957	4.06	3.83	0.39	25.48
1958	1.69	2.84	0.39	12.65
1959	3.17	0.34	7.12	29.64
1960	3.01	1.27	7.33	30.41
1961	3.22	1.96	4.60	24.57
1962	7.60	4.02	4.60	30.69
1963	3.33	6.01	1.42	19.72
1964	3.59	3.02	3.26	28.33
1965	4.10	3.90	1.81	29.21
1966	2.18	2.95	3.81	19.07
1967	7.55	0.31	3.63	19.60
1968	3.96	4.49	1.00	30.40
1969	4.22	4.83	1.74	23.54
1970	2.11	2.24	0.10	21.25
1971	6.58	2.71	1.06	20.78
1972	3.75	4.77	2.98	31.91

Table F-8. PRECIPITATION DATA IN INCHES AT LAKE PARK, IOWA, PERIOD OF RECORD IS 1927 TO 1977, N = 51

YEAR	JUNE	JULY	AUGUST	ANNUAL
1927	1.74	1.45	1.39	23.75
1928	5.80	1.16	8.59	28.08
1929	1.89	3.86	2.57	25.80
1930	4.73	0.33	1.35	25.37
1931	2.24	2.62	2.19	21.82
1932	4.34	3.80	3.52	26.26
1933	1.04	4.51	4.04	22.13
1934	6.12	3.66	4.36	24.64
1935	4.88	3.48	5.83	27.06
1936	2.23	0.58	3.14	22.87
1937	4.60	2.34	7.10	31.54
1938	5.75	5.02	2.04	35.91
1939	3.74	5.32	3.67	20.42
1940	5.57	0.52	4.00	23.02
1941	5.13	1.81	1.62	27.06
1942	4.68	6.65	4.42	30.89
1943	10.18	4.80	4.12	34.70
1944	4.50	5.46	6.98	30.12
1945	5.48	3.98	2.31	25.06
1946	4.11	1.45	1.28	29.30
1947	5.75	2.90	2.48	26.78
1948	4.18	4.72	0.01	21.64
1949	2.55	4.56	3.10	25.17
1950	3.02	6.04	1.08	21.04
1951	6.05	4.91	4.60	33.50
1952	7.35	3.72	2.34	21.14
1953	10.52	4.03	5.01	33.67
1954	9.50	3.87	5.63	32.72
1955	2.60	1.93	2.64	16.26
1956	2.73	4.24	6.13	25.56
1957	6.86	5.81	4.22	32.41
1958	4.05	2.86	1.23	13.43
1959	2.25	0.56	3.11	29.70
1960	2.22	2.84	4.50	31.23
1961	2.32	2.42	2.35	23.35
1962	5.46	8.17	4.09	29.96
1963	3.81	9.31	1.54	23.61
1964	2.80	3.69	5.47	31.90
1965	5.60	0.81	2.54	35.16
1966	4.30	3.17	3.12	21.43

Table F-8. PRECIPITATION DATA IN INCHES AT LAKE PARK, IOWA.
Continued PERIOD OF RECORD IS 1927 TO 1977. N = 51

YEAR	JUNE	JULY	AUGUST	ANNUAL
1967	7.57	0.62	2.91	19.99
1968	4.41	3.29	2.56	34.33
1969	5.91	7.02	2.16	30.85
1970	1.91	4.30	3.52	29.42
1971	5.70	2.95	1.23	22.22
1972	1.81	6.21	1.79	26.94
1973	2.79	2.77	1.29	28.11
1974	3.87	0.81	4.61	19.98
1975	8.66	0.30	6.55	34.17
1976	2.82	1.56	0.38	14.99
1977	4.06	2.31	3.55	33.13

Table F-9. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA,
PERIOD OF RECORD IS 1897 TO 1977. N = 81

YEAR	JUNE	JULY	AUGUST	ANNUAL
1897	3.11	2.09	2.60	26.25
1898	4.72	3.34	2.31	21.59
1899	6.26	3.22	5.51	27.90
1900	3.42	12.00	2.85	35.32
1901	3.26	2.10	1.09	24.32
1902	4.68	7.08	3.65	29.99
1903	3.80	5.46	5.79	38.22
1904	2.73	3.27	1.92	21.04
1905	4.31	2.86	3.88	39.97
1906	5.45	1.20	3.46	35.31
1907	4.04	6.50	1.09	23.12
1908	4.14	3.63	2.35	30.37
1909	7.22	6.82	1.43	39.01
1910	1.76	5.18	3.63	18.19
1911	4.79	1.27	3.46	24.41
1912	3.26	5.05	2.75	27.34
1913	1.18	1.80	1.65	20.44
1914	3.46	2.75	1.25	25.06
1915	5.45	5.84	2.82	31.62
1916	3.52	4.01	1.11	24.62
1917	3.73	3.71	2.11	20.78
1918	4.80	1.96	2.41	25.86
1919	5.12	7.38	1.75	31.12
1920	3.41	2.84	4.52	31.42
1921	1.70	2.88	5.14	21.18
1922	2.37	3.20	3.28	26.27
1923	5.89	2.09	5.62	32.76
1924	5.34	2.69	6.02	26.37
1925	5.89	2.96	0.50	17.68
1926	3.58	3.79	4.14	27.22
1927	3.78	1.79	1.80	28.38
1928	2.65	4.57	2.98	25.90
1929	3.51	1.88	2.01	21.20
1930	3.03	0.36	2.45	22.39
1931	3.01	1.32	1.92	21.51
1932	3.59	3.91	3.29	29.63
1933	2.18	5.22	2.62	21.83
1934	7.96	4.67	2.31	26.58
1935	4.04	3.57	1.64	25.55
1936	2.14	0.52	3.16	19.09

Table F-9. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA.
Continued PERIOD OF RECORD IS 1897 TO 1977. N = 81

YEAR	JUNE	JULY	AUGUST	ANNUAL
1937	1.99	0.73	3.47	22.01
1938	3.79	4.95	1.35	32.59
1939	3.58	2.88	3.30	20.54
1940	6.49	3.14	6.36	32.17
1941	5.37	2.05	1.96	31.69
1942	4.69	3.39	2.49	23.07
1943	6.11	5.30	0.74	21.67
1944	3.84	4.23	4.86	29.73
1945	7.31	5.92	5.39	35.63
1946	4.07	1.11	4.06	30.86
1947	4.63	0.67	1.25	24.06
1948	6.43	3.66	3.81	26.50
1949	3.92	4.97	2.04	33.02
1950	9.65	5.90	2.12	28.35
1951	5.07	3.55	9.08	42.35
1952	4.22	5.97	4.11	26.42
1953	5.91	4.44	3.51	32.05
1954	6.51	1.36	2.90	26.42
1955	2.08	2.89	1.08	16.33
1956	0.94	1.87	2.79	13.93
1957	5.36	4.25	4.22	30.76
1958	1.58	2.96	0.46	14.86
1959	2.46	1.47	5.40	29.72
1960	2.87	0.75	7.60	28.37
1961	5.52	2.56	3.38	24.26
1962	5.42	5.22	2.81	29.09
1963	4.04	3.04	3.60	17.93
1964	2.22	3.61	3.56	25.86
1965	3.37	2.63	1.52	29.57
1966	4.41	2.83	4.09	20.76
1967	8.56	1.00	3.17	20.36
1968	2.71	3.69	4.21	30.66
1969	6.13	3.41	4.38	31.57
1970	0.93	1.89	0.63	20.21
1971	9.21	2.32	0.69	26.81
1972	3.71	6.25	1.95	30.30
1973	2.23	6.70	0.77	27.55
1974	5.88	0.93	5.30	23.20
1975	5.16	1.01	4.98	27.31
1976	0.96	1.37	1.06	13.02

Table F-9. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA.
Continued PERIOD OF RECORD IS 1897 TO 1977. N = 81

YEAR	JUNE	JULY	AUGUST	ANNUAL
1977	3.82	2.98	1.75	31.65

Table F-10. PRECIPITATION DATA IN INCHES AT MAPLETON, IOWA, PERIOD OF RECORD IS 1938 TO 1977. N = 40

YEAR	JUNE	JULY	AUGUST	ANNUAL
1938	4.10	4.43	1.48	32.48
1939	2.65	4.53	3.12	17.55
1940	6.08	7.40	4.43	31.45
1941	6.07	1.02	2.42	25.09
1942	9.08	3.24	1.48	27.29
1943	4.30	5.32	1.08	20.48
1944	8.51	2.56	8.47	35.45
1945	3.01	4.02	2.28	28.97
1946	4.71	1.05	5.94	31.73
1947	6.81	0.85	0.46	24.41
1948	3.11	4.01	4.01	24.84
1949	2.60	1.90	2.44	18.31
1950	7.46	6.81	5.16	32.87
1951	8.09	3.73	8.32	40.73
1952	7.87	7.21	3.29	33.64
1953	5.48	1.59	2.20	23.75
1954	4.88	1.03	4.07	32.81
1955	4.25	2.05	1.75	15.90
1956	3.61	3.00	2.56	18.64
1957	4.97	4.04	2.90	27.17
1958	2.80	6.14	1.40	18.93
1959	4.93	0.89	3.60	34.90
1960	3.81	2.41	5.52	29.69
1961	3.38	3.63	2.73	27.87
1962	4.09	7.72	9.86	37.75
1963	6.69	1.86	4.05	24.75
1964	4.11	3.60	3.79	30.52
1965	2.43	3.35	2.02	30.38
1966	6.72	2.75	5.68	23.43
1967	12.71	0.73	1.58	24.88
1968	6.93	2.34	4.15	33.42
1969	4.49	3.87	3.47	25.32
1970	1.57	2.31	1.59	27.07
1971	3.04	2.98	1.16	24.22
1972	3.08	7.01	3.41	34.24
1973	3.98	5.23	1.55	33.18
1974	2.61	1.21	4.96	23.86
1975	4.46	1.04	3.20	27.15
1976	1.10	1.45	1.02	17.45
1977	3.57	6.11	4.04	32.87

Table F-11. PRECIPITATION DATA IN INCHES AT MERRILL, IOWA.

PERIOD OF RECORD IS 1946 TO 1977. N = 32

YEAR	JUNE	JULY	AUGUST	ANNUAL
1946	2.78	0.65	2.55	24.83
1947	4.24	1.40	0.40	21.63
1948	6.62	4.95	2.34	24.80
1949	4.47	4.01	3.63	32.97
1950	4.09	8.07	3.38	25.79
1951	5.29	3.72	7.79	38.84
1952	5.00	6.54	4.61	27.55
1953	6.51	3.63	3.38	31.76
1954	4.73	1.54	3.56	24.40
1955	2.80	2.96	1.37	18.70
1956	1.46	2.59	2.13	13.14
1957	5.15	4.09	4.86	29.73
1958	1.79	3.80	1.43	18.85
1959	2.73	0.93	3.42	27.59
1960	2.30	1.10	6.66	26.14
1961	3.74	3.03	3.42	23.19
1962	4.53	4.90	4.15	27.08
1963	3.83	2.65	3.04	18.52
1964	2.66	4.05	5.59	27.15
1965	2.89	4.08	1.67	30.06
1966	6.43	4.84	4.80	26.08
1967	8.30	2.16	5.05	23.80
1968	3.90	3.83	3.20	31.97
1969	5.31	3.61	4.34	27.05
1970	2.99	2.33	1.38	29.75
1971	8.98	1.18	0.61	24.91
1972	2.53	5.31	2.15	29.60
1973	1.82	6.46	0.61	26.90
1974	4.43	1.78	3.12	19.84
1975	2.91	0.99	3.35	19.76
1976	0.51	2.19	2.22	15.73
1977	5.26	3.92	1.25	32.19

Table F-12. PRECIPITATION DATA IN INCHES AT MILFORD, IOWA, PERIOD OF RECORD IS 1939 TO 1977. N = 39

YEAR	JUNE	JULY	AUGUST	ANNUAL
1939	3.67	3.38	3.74	25.63
1940	3.83	0.57	3.72	19.20
1941	6.10	2.77	2.56	29.61
1942	3.21	4.64	5.58	28.29
1943	8.80	4.88	5.50	29.58
1944	5.18	5.84	5.78	28.94
1945	8.58	4.36	0.88	29.01
1946	4.56	0.99	1.98	29.86
1947	5.40	1.95	0.94	25.70
1948	4.08	2.08	0.98	21.60
1949	5.99	2.24	1.77	24.35
1950	3.36	5.62	1.41	21.14
1951	7.20	4.63	4.73	37.21
1952	6.23	3.89	4.73	22.14
1953	8.55	3.44	3.72	29.68
1954	8.40	3.31	6.01	32.56
1955	3.09	2.33	2.77	19.50
1956	2.80	3.83	4.74	21.82
1957	5.93	5.28	3.34	29.26
1958	2.51	3.15	1.17	12.70
1959	2.07	0.12	3.15	28.54
1960	3.38	2.95	5.89	34.59
1961	3.22	2.71	1.84	26.84
1962	5.67	9.89	6.41	33.28
1963	3.09	6.69	0.49	19.97
1964	1.46	7.50	2.90	34.48
1965	2.64	0.92	2.34	28.29
1966	4.07	4.79	3.42	23.76
1967	7.26	0.50	2.40	20.04
1968	4.79	3.69	2.49	32.29
1969	5.76	6.20	3.72	32.44
1970	1.35	3.53	2.81	29.14
1971	4.93	3.99	1.24	27.02
1972	2.41	7.55	2.13	31.25
1973	2.91	2.92	2.43	30.74
1974	3.31	0.88	3.98	18.68
1975	8.15	0.21	6.81	33.12
1976	3.22	1.20	0.41	15.33
1977	3.98	1.77	4.77	36.31

Table F-13. PRECIPITATION DATA IN INCHES AT PRIMGHAR, IOWA.
PERIOD OF RECORD IS 1937 TO 1977. N = 41

YEAR	JUNE	JULY	AUGUST	ANNUAL
1937	2.38	3.92	6.19	30.09
1938	2.54	5.71	1.27	32.57
1939	2.76	2.16	5.30	18.30
1940	5.97	3.00	4.24	29.27
1941	5.60	1.50	0.89	25.80
1942	5.50	2.41	4.40	27.68
1943	7.58	4.51	4.60	30.32
1944	6.11	6.12	8.11	37.97
1945	5.83	3.67	2.44	27.88
1946	4.25	1.38	2.06	29.38
1947	7.12	0.16	0.53	30.48
1948	5.51	3.01	2.15	22.09
1949	2.57	2.12	1.77	22.12
1950	3.87	9.11	0.73	26.94
1951	4.83	6.97	6.97	43.54
1952	5.01	3.42	5.82	24.51
1953	7.86	2.26	4.92	32.47
1954	6.67	2.37	5.44	30.01
1955	3.08	2.88	1.11	19.29
1956	2.10	4.26	3.58	22.51
1957	5.96	4.59	5.82	31.19
1958	4.55	1.98	0.86	14.96
1959	3.51	0.07	6.06	30.62
1960	2.44	1.72	6.21	29.64
1961	2.87	4.32	2.31	25.91
1962	4.14	7.07	5.14	29.45
1963	3.44	4.42	2.91	19.20
1964	3.20	3.16	3.48	27.13
1965	4.14	1.08	1.91	31.48
1966	4.03	1.56	2.53	20.92
1967	6.75	0.45	1.88	17.86
1968	4.00	2.10	2.29	32.07
1969	3.58	6.57	3.53	29.49
1970	2.14	1.86	0.73	26.43
1971	8.76	3.61	0.81	29.37
1972	2.00	5.16	4.25	29.95
1973	2.73	5.50	8.96	35.08
1974	8.13	2.91	10.33	31.41
1975	6.40	0.19	12.26	37.99
1976	4.01	2.40	0.84	19.66

Table F-13. PRECIPITATION DATA IN INCHES AT PRIMGHAR, IOWA.
Continued PERIOD OF RECORD IS 1937 TO 1977. N = 41

YEAR	JUNE	JULY	AUGUST	ANNUAL
1977	2.97	7.25	3.60	37.80

Table F-14. PRECIPITATION DATA IN INCHES AT ROCK RAPIDS, IOWA.

PERIOD OF RECORD IS 1904 TO 1977. N = 74

YEAR	JUNE	JULY	AUGUST	ANNUAL
1904	2.30	3.95	2.40	16.20
1905	9.17	2.63	6.00	36.63
1906	5.65	0.92	3.65	26.12
1907	6.57	6.04	1.05	22.23
1908	5.72	3.36	1.35	27.37
1909	7.57	4.63	0.75	30.64
1910	1.90	3.12	1.48	15.08
1911	1.95	3.81	4.17	23.80
1912	0.78	4.15	1.90	16.27
1913	2.98	2.41	1.21	19.59
1914	7.82	2.41	3.57	30.91
1915	4.01	7.02	4.95	33.27
1916	3.39	2.19	1.24	21.10
1917	4.60	1.86	0.87	21.67
1918	5.50	6.04	3.51	32.90
1919	7.12	4.32	1.44	32.18
1920	5.23	4.60	3.38	34.25
1921	1.66	2.10	4.06	22.38
1922	1.55	5.04	1.95	23.57
1923	3.88	4.19	5.38	28.80
1924	4.81	1.68	2.59	21.30
1925	4.75	1.92	1.83	18.55
1926	2.97	2.80	3.69	24.45
1927	1.99	2.45	0.73	30.32
1928	7.10	1.44	7.25	29.88
1929	2.42	3.11	3.15	30.00
1930	4.85	0.80	0.95	23.16
1931	2.05	1.69	3.60	21.07
1932	2.12	4.04	6.66	28.53
1933	1.50	2.40	6.71	27.24
1934	7.30	4.89	2.52	23.38
1935	3.84	2.64	5.40	25.00
1936	2.25	0.79	3.56	21.88
1937	3.18	1.41	4.55	22.18
1938	2.92	3.36	0.70	31.31
1939	5.20	3.81	3.57	22.11
1940	4.45	1.80	3.11	22.92
1941	5.18	2.60	0.88	25.03
1942	5.24	2.81	4.26	32.17
1943	10.17	3.90	5.75	32.12

Table F-14. PRECIPITATION DATA IN INCHES AT ROCK RAPIDS, IOWA.
Continued PERIOD OF RECORD IS 1904 TO 1977. N = 74

YEAR	JUNE	JULY	AUGUST	ANNUAL
1944	7.40	8.27	6.99	41.69
1945	6.70	2.76	2.68	29.46
1946	6.07	1.88	2.04	31.04
1947	6.74	0.15	0.77	24.67
1948	5.01	5.07	1.95	25.58
1949	2.67	4.91	2.86	27.68
1950	5.07	5.94	0.99	24.29
1951	6.07	3.55	4.56	38.18
1952	4.98	3.10	5.39	22.27
1953	5.62	2.48	4.54	26.89
1954	6.95	2.76	3.07	26.46
1955	3.32	5.10	0.76	18.47
1956	3.27	4.33	3.74	20.98
1957	6.97	4.36	6.45	32.27
1958	3.64	3.14	0.65	15.78
1959	1.65	0.21	8.16	29.18
1960	2.42	1.60	3.80	27.76
1961	3.17	1.37	5.35	26.46
1962	4.63	4.05	3.53	25.59
1963	4.01	4.51	1.61	18.36
1964	2.52	6.27	5.10	30.48
1965	3.09	2.01	1.94	29.21
1966	2.95	2.06	3.06	20.35
1967	8.13	1.40	3.26	21.08
1968	5.39	3.71	1.51	32.61
1969	6.44	4.76	1.51	24.99
1970	2.35	1.36	0.30	21.38
1971	6.11	4.27	1.44	24.45
1972	4.01	5.43	2.13	30.46
1973	1.62	4.17	1.53	25.86
1974	1.96	0.72	6.66	17.01
1975	6.32	0.80	8.09	29.87
1976	1.93	1.82	0.95	13.58
1977	3.11	4.69	5.50	36.29

Table F-15. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.
PERIOD OF RECORD IS 1893 TO 1977. N = 85

YEAR	JUNE	JULY	AUGUST	ANNUAL
1893	5.20	2.12	2.05	22.11
1894	6.20	2.76	3.60	29.81
1895	6.75	1.95	7.89	31.74
1896	4.95	6.74	1.85	39.12
1897	2.25	3.40	1.45	22.57
1898	3.83	1.55	4.20	27.54
1899	4.31	1.27	2.79	26.83
1900	6.49	5.63	6.46	34.21
1901	2.05	0.35	1.21	24.35
1902	5.63	12.61	8.03	42.77
1903	4.20	7.26	6.16	36.24
1904	4.77	3.15	5.48	25.73
1905	2.07	8.65	3.46	35.47
1906	2.68	0.99	1.69	23.63
1907	5.45	7.56	3.11	30.56
1908	4.63	4.91	6.73	32.73
1909	4.24	4.59	0.29	31.85
1910	1.39	1.07	3.54	14.75
1911	5.95	1.53	3.93	33.92
1912	3.57	2.64	4.58	30.33
1913	1.30	2.10	2.22	27.39
1914	3.60	3.61	2.01	30.13
1915	2.60	7.38	1.22	41.27
1916	2.45	0.48	2.92	22.66
1917	5.07	0.93	1.90	19.22
1918	3.57	2.90	1.83	27.94
1919	10.86	2.47	2.28	34.64
1920	4.49	2.72	4.63	28.48
1921	1.13	4.80	3.54	23.34
1922	1.34	4.19	3.17	30.02
1923	5.19	1.55	7.10	29.37
1924	6.04	2.51	5.16	24.92
1925	4.81	2.52	3.38	21.75
1926	5.67	2.33	3.06	30.59
1927	1.53	1.19	2.59	22.19
1928	3.95	3.45	4.29	26.93
1929	2.81	3.49	1.99	21.02
1930	5.33	0.83	3.08	25.56
1931	7.88	1.69	4.44	39.69
1932	4.20	3.51	5.02	28.74

Table F-15. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.
Continued PERIOD OF RECORD IS 1893 TO 1977, N = 85

YEAR	JUNE	JULY	AUGUST	ANNUAL
1933	0.56	4.43	3.25	22.64
1934	2.11	5.19	4.06	24.97
1935	5.51	1.51	2.08	27.54
1936	2.16	0.95	2.09	18.13
1937	3.64	1.80	8.13	28.64
1938	2.03	12.02	3.08	39.94
1939	4.00	3.03	4.11	19.66
1940	3.91	5.66	7.09	29.80
1941	8.00	1.17	2.52	28.67
1942	4.34	6.37	1.80	29.16
1943	7.92	4.65	5.72	33.56
1944	6.83	4.27	5.83	32.17
1945	4.29	4.19	4.00	38.91
1946	4.45	0.86	1.27	28.84
1947	7.64	1.23	0.42	28.12
1948	3.76	3.21	3.80	26.71
1949	2.44	2.21	2.54	23.16
1950	5.97	4.30	1.67	24.85
1951	5.46	4.13	10.66	43.41
1952	5.50	4.89	2.10	27.49
1953	4.36	1.03	1.98	20.76
1954	8.68	2.14	6.82	36.81
1955	1.74	3.92	1.46	16.95
1956	2.62	1.91	4.42	21.11
1957	7.86	4.87	2.75	34.71
1958	4.76	4.66	0.64	17.44
1959	2.72	0.64	2.43	31.21
1960	2.24	2.25	5.68	22.98
1961	3.59	4.35	2.03	28.50
1962	4.48	5.19	9.51	32.50
1963	2.99	3.97	2.83	23.64
1964	2.26	4.85	3.32	24.54
1965	2.34	1.76	2.62	37.56
1966	5.70	2.28	3.21	20.92
1967	13.30	2.38	3.24	29.74
1968	4.40	3.47	5.08	36.53
1969	5.54	2.65	1.25	23.92
1970	2.25	5.47	2.26	29.38
1971	2.56	3.57	1.46	26.90
1972	5.92	7.36	3.99	38.74

Table F-15. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.
Continued PERIOD OF RECORD IS 1893 TO 1977. N = 85

YEAR	JUNE	JULY	AUGUST	ANNUAL
1973	4.58	6.78	1.78	44.51
1974	2.70	1.93	5.76	23.90
1975	5.28	1.81	3.29	34.19
1976	1.41	2.57	0.40	18.73
1977	4.18	2.38	6.12	33.49

Table F-16. PRECIPITATION DATA IN INCHES AT SANBORN, IOWA.
PERIOD OF RECORD IS 1915 TO 1977. N = 63

YEAR	JUNE	JULY	AUGUST	ANNUAL
1915	3.69	5.03	4.71	29.45
1916	4.12	2.14	2.51	26.57
1917	5.41	3.50	2.26	31.20
1918	4.86	4.87	4.94	35.32
1919	6.83	4.13	3.05	34.99
1920	3.48	4.28	1.80	31.56
1921	3.76	1.28	3.13	24.10
1922	1.89	3.59	3.41	26.73
1923	4.93	1.90	4.70	28.25
1924	4.00	2.51	3.90	22.04
1925	3.09	0.80	0.61	13.77
1926	1.62	4.01	4.05	32.64
1927	1.92	3.40	1.08	27.32
1928	4.58	1.74	8.72	25.87
1929	4.29	3.04	3.20	28.50
1930	4.99	0.77	1.01	24.06
1931	2.62	4.14	2.91	26.38
1932	4.11	1.31	7.58	28.57
1933	0.87	3.87	3.74	24.36
1934	6.89	5.01	2.75	26.24
1935	4.91	6.73	2.75	32.04
1936	2.38	1.15	3.43	23.92
1937	3.94	5.58	6.15	36.13
1938	4.24	5.30	1.45	37.51
1939	4.52	4.22	5.46	22.94
1940	6.15	2.68	4.00	28.28
1941	4.88	1.95	2.01	27.40
1942	4.90	2.77	5.95	30.58
1943	7.25	7.29	4.67	32.19
1944	6.17	6.15	5.96	36.46
1945	6.68	4.40	1.61	29.52
1946	4.40	1.97	3.33	32.77
1947	5.50	0.54	1.24	30.54
1948	3.60	3.58	2.21	23.13
1949	3.20	2.56	1.61	25.51
1950	5.62	7.70	1.54	29.14
1951	6.79	5.63	8.08	46.02
1952	4.08	5.20	6.42	24.21
1953	9.23	2.41	4.57	32.01
1954	8.02	2.38	3.67	31.17

Table F-16. PRECIPITATION DATA IN INCHES AT SANBORN, IOWA.
Continued PERIOD OF RECORD IS 1915 TO 1977. N = 63

YEAR	JUNE	JULY	AUGUST	ANNUAL
1955	3.19	3.89	1.29	20.47
1956	2.40	3.42	4.62	21.53
1957	6.18	2.98	3.58	27.01
1958	4.13	3.08	0.98	16.17
1959	2.82	0.35	4.40	29.91
1960	2.09	1.89	6.29	31.75
1961	2.44	3.03	2.21	26.32
1962	3.17	5.38	4.90	27.06
1963	3.33	5.87	2.21	20.97
1964	4.14	4.33	3.57	32.20
1965	3.85	1.41	2.40	35.89
1966	3.23	2.56	3.73	21.25
1967	5.87	0.51	3.11	17.57
1968	4.63	3.73	3.08	33.61
1969	2.75	5.83	4.86	25.78
1970	1.93	1.11	0.85	24.34
1971	8.93	2.91	1.43	27.03
1972	1.79	5.82	2.40	27.37
1973	2.61	3.40	6.05	29.30
1974	2.69	0.63	10.34	23.03
1975	7.25	0.41	8.40	32.08
1976	2.93	1.83	0.94	17.88
1977	2.61	6.78	4.64	33.70

Table F-17. PRECIPITATION DATA IN INCHES AT SHELDON, IOWA.
PERIOD OF RECORD IS 1926 TO 1977. N = 52

YEAR	JUNE	JULY	AUGUST	ANNUAL
1926	2.03	3.09	3.31	26.99
1927	2.18	1.73	0.84	25.59
1928	4.84	3.29	8.08	29.14
1929	4.01	3.15	3.84	27.56
1930	5.17	0.28	1.25	23.97
1931	2.45	2.71	3.75	23.82
1932	3.76	1.39	7.35	28.55
1933	0.96	4.83	3.03	22.89
1934	5.98	5.51	3.25	24.65
1935	3.87	4.03	3.15	25.74
1936	1.53	1.46	3.75	21.78
1937	4.04	2.93	5.64	29.89
1938	2.87	4.39	0.66	30.63
1939	3.22	3.58	3.52	18.28
1940	6.75	2.09	3.66	25.02
1941	6.20	1.83	1.22	26.19
1942	6.16	3.61	5.39	33.24
1943	7.95	5.22	4.50	28.40
1944	7.11	6.03	7.46	39.34
1945	4.90	3.12	2.18	26.18
1946	5.63	2.22	3.39	31.89
1947	5.71	0.99	3.01	28.49
1948	4.11	3.90	1.17	22.43
1949	2.02	1.77	2.44	21.98
1950	5.32	5.29	0.73	23.67
1951	9.09	6.89	5.42	46.02
1952	4.03	4.62	4.85	22.92
1953	10.49	2.12	4.74	34.27
1954	7.04	2.83	2.90	27.10
1955	2.55	2.59	0.62	15.84
1956	3.40	4.51	3.69	21.76
1957	6.66	3.07	3.92	28.80
1958	3.43	3.05	0.90	15.41
1959	4.41	0.34	4.60	31.02
1960	2.48	1.59	7.71	32.51
1961	2.85	2.51	3.15	23.12
1962	3.80	5.25	5.22	27.37
1963	2.19	4.51	2.37	18.64
1964	2.74	6.39	3.91	29.60
1965	3.52	1.30	1.86	31.73

Table F-17. PRECIPITATION DATA IN INCHES AT SHELDON, IOWA,
Continued PERIOD OF RECORD IS 1926 TO 1977. N = 52

YEAR	JUNE	JULY	AUGUST	ANNUAL
1966	3.62	1.74	3.38	20.90
1967	7.27	0.57	3.89	20.54
1968	2.21	2.88	1.47	28.14
1969	3.31	6.38	3.57	27.09
1970	1.48	2.25	0.62	24.72
1971	9.05	2.56	1.01	26.73
1972	2.67	6.70	2.96	29.98
1973	3.10	5.33	7.39	32.13
1974	4.55	1.31	7.47	22.89
1975	8.29	0.27	6.80	31.25
1976	2.96	2.52	0.82	18.36
1977	2.05	6.19	4.13	33.23

Table F-18. PRECIPITATION DATA IN INCHES AT SIBLEY, IOWA.

PERIOD OF RECORD IS 1936 TO 1977, N = 42

YEAR	JUNE	JULY	AUGUST	ANNUAL
1936	1.96	0.79	2.81	20.84
1937	4.35	3.80	5.26	29.81
1938	4.64	5.39	1.02	37.60
1939	4.54	3.46	2.96	17.70
1940	5.13	1.34	3.04	21.36
1941	5.24	3.08	1.13	26.77
1942	4.15	3.22	5.37	31.59
1943	8.93	5.04	4.01	28.53
1944	7.46	5.51	6.54	35.97
1945	5.71	4.14	1.89	24.97
1946	4.43	2.02	1.19	26.96
1947	8.66	0.08	3.99	29.70
1948	4.92	4.29	1.11	23.31
1949	2.62	6.49	4.18	28.51
1950	2.28	8.68	0.68	23.29
1951	5.28	5.24	3.91	35.33
1952	6.00	3.02	4.37	22.95
1953	10.42	4.46	5.26	36.72
1954	10.60	3.64	2.73	31.06
1955	2.43	3.03	0.60	16.38
1956	3.23	6.75	6.33	28.57
1957	6.45	5.62	6.19	35.59
1958	3.94	3.14	1.44	17.76
1959	3.13	0.11	5.91	30.20
1960	3.00	2.39	4.58	31.72
1961	3.79	2.33	2.68	25.95
1962	3.79	5.60	4.56	29.31
1963	5.94	5.53	2.01	25.06
1964	3.10	5.34	3.55	32.71
1965	3.85	1.69	2.47	35.02
1966	3.49	2.35	6.04	25.55
1967	7.34	1.62	4.48	22.90
1968	3.77	2.62	3.05	32.99
1969	5.04	4.97	3.73	28.12
1970	2.94	5.42	0.59	27.14
1971	6.07	2.99	1.83	24.46
1972	3.44	6.24	2.11	28.70
1973	3.57	3.45	1.93	25.93
1974	2.67	0.88	9.72	24.04
1975	6.31	0.13	11.32	31.33

Table F-18. PRECIPITATION DATA IN INCHES AT SIBLEY, IOWA.
Continued PERIOD OF RECORD IS 1936 TO 1977. N = 42

YEAR	JUNE	JULY	AUGUST	ANNUAL
1976	2.90	2.27	0.64	17.28
1977	3.42	4.95	4.82	35.38

Table F-19. PRECIPITATION DATA IN INCHES AT SIOUX CENTER, IOWA.

PERIOD OF RECORD IS 1900 TO 1977. N = 78

YEAR	JUNE	JULY	AUGUST	ANNUAL
1900	4.42	12.31	3.20	38.98
1901	5.40	3.29	4.46	31.68
1902	1.63	5.64	5.05	29.08
1903	2.99	2.70	4.33	28.81
1904	4.57	7.75	1.47	26.79
1905	8.87	0.73	2.76	33.56
1906	5.17	2.04	5.77	36.58
1907	3.77	4.30	1.88	21.38
1908	4.81	3.95	3.11	34.16
1909	4.48	7.74	1.07	34.30
1910	1.74	4.06	2.83	15.55
1911	1.45	1.64	3.28	22.94
1912	1.48	3.78	3.61	20.62
1913	2.80	2.64	1.09	23.58
1914	6.18	1.48	1.34	24.71
1915	4.09	4.56	2.49	29.26
1916	2.44	1.80	2.56	27.19
1917	3.54	1.10	1.56	21.63
1918	5.01	3.18	3.97	34.93
1919	4.59	5.43	0.97	30.35
1920	3.40	2.31	2.42	29.51
1921	2.40	3.02	3.00	27.55
1922	1.72	5.18	3.29	26.61
1923	4.54	3.05	4.20	26.93
1924	5.43	1.85	7.36	27.56
1925	4.65	4.24	0.49	18.79
1926	3.51	3.79	3.43	36.19
1927	2.11	1.06	1.28	29.49
1928	4.85	3.80	9.96	32.46
1929	2.90	3.10	1.48	20.57
1930	4.51	0.69	1.56	23.74
1931	3.34	1.30	1.09	20.15
1932	4.08	0.95	6.34	25.11
1933	0.15	5.92	4.05	27.55
1934	7.09	3.96	3.32	24.60
1935	5.47	2.93	3.48	25.93
1936	1.83	1.67	3.23	22.98
1937	4.43	1.95	4.94	28.19
1938	2.48	3.69	1.41	32.26
1939	3.94	1.53	2.28	14.83

Table F-19. PRECIPITATION DATA IN INCHES AT SIOUX CENTER, IOWA.
Continued PERIOD OF RECORD IS 1900 TO 1977. N = 78

YEAR	JUNE	JULY	AUGUST	ANNUAL
1940	6.25	3.41	3.80	26.57
1941	6.16	1.66	0.83	25.20
1942	8.22	5.05	7.00	34.78
1943	5.71	5.71	2.90	24.19
1944	10.94	4.13	6.54	39.48
1945	4.34	2.75	2.46	24.90
1946	3.98	0.25	4.26	27.38
1947	5.53	0.83	1.80	26.43
1948	4.94	4.01	3.07	25.54
1949	2.07	3.76	2.75	28.97
1950	5.22	4.87	1.14	26.13
1951	5.86	5.46	5.92	41.14
1952	2.40	6.90	6.57	25.49
1953	8.54	3.57	4.61	33.76
1954	8.85	1.94	2.54	26.06
1955	3.67	5.57	1.86	16.53
1956	3.85	4.82	3.46	22.56
1957	5.80	5.31	3.02	31.31
1958	2.83	2.86	0.86	15.79
1959	3.43	0.69	7.89	32.05
1960	3.07	2.52	6.53	32.80
1961	4.93	3.10	5.76	28.47
1962	5.35	4.40	4.35	27.20
1963	3.47	4.23	1.77	17.83
1964	3.86	4.37	3.99	24.94
1965	5.51	3.93	2.35	34.70
1966	2.99	1.82	3.55	20.12
1967	6.79	0.70	1.58	16.29
1968	3.53	4.96	0.90	29.48
1969	4.69	4.17	3.06	24.78
1970	1.93	1.87	0.48	27.15
1971	11.84	2.35	0.94	28.54
1972	4.11	6.42	1.62	29.48
1973	3.23	5.09	2.43	27.44
1974	6.43	2.43	5.90	24.04
1975	8.05	0.82	4.56	28.22
1976	1.59	2.07	0.59	17.88
1977	1.23	4.94	1.54	29.55

Table F-20. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA.
PERIOD OF RECORD IS 1891 TO 1977. N = 87

YEAR	JUNE	JULY	AUGUST	ANNUAL
1891	7.62	5.77	3.54	33.29
1892	1.50	2.63	4.14	26.38
1893	1.63	2.29	5.85	23.05
1894	2.74	1.81	1.68	17.84
1895	4.95	2.63	1.54	20.29
1896	2.94	5.54	0.86	30.77
1897	2.13	2.26	2.51	20.38
1898	6.61	2.78	3.10	22.91
1899	4.76	1.00	4.91	22.67
1900	4.32	8.72	3.56	33.22
1901	4.70	1.24	1.75	26.59
1902	2.02	5.03	2.19	20.14
1903	5.65	5.57	5.67	41.10
1904	3.46	5.49	2.68	21.46
1905	2.55	1.41	1.84	31.66
1906	4.02	2.37	2.74	31.41
1907	4.21	5.78	1.53	19.93
1908	4.67	2.73	4.28	26.44
1909	5.20	4.09	3.02	29.64
1910	1.41	3.69	2.76	16.85
1911	2.12	1.56	2.86	24.02
1912	3.49	3.68	7.03	30.54
1913	0.75	1.92	1.88	20.31
1914	3.91	1.16	1.74	24.77
1915	5.65	7.45	1.79	33.46
1916	2.32	3.89	2.33	24.51
1917	3.91	0.85	2.66	21.32
1918	4.27	2.08	2.64	25.41
1919	6.06	4.16	1.91	29.16
1920	3.06	3.89	4.30	31.96
1921	2.10	2.06	3.17	21.61
1922	2.03	5.97	2.92	25.94
1923	5.14	2.93	7.60	34.56
1924	5.42	2.87	4.24	22.82
1925	5.36	1.43	0.71	18.01
1926	1.92	1.99	3.54	24.26
1927	3.52	1.81	1.90	27.63
1928	3.07	3.83	2.67	24.67
1929	8.47	3.27	1.55	26.81
1930	5.67	0.72	0.89	23.55

Table F-20. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA.
Continued PERIOD OF RECORD IS 1891 TO 1977. N = 87

YEAR	JUNE	JULY	AUGUST	ANNUAL
1931	2.90	1.74	3.90	24.00
1932	4.95	2.61	2.94	22.88
1933	1.90	3.20	1.74	20.29
1934	6.27	4.93	1.12	22.81
1935	2.16	2.02	2.00	21.96
1936	2.04	0.18	1.66	17.28
1937	5.11	1.61	7.09	28.88
1938	2.59	6.70	0.59	31.79
1939	4.31	2.14	1.97	16.96
1940	7.40	3.55	4.18	32.34
1941	6.42	2.31	1.26	30.96
1942	4.83	1.66	1.56	19.28
1943	4.91	4.66	1.44	22.95
1944	4.32	4.18	4.17	27.12
1945	6.50	3.89	1.47	28.52
1946	4.04	1.45	2.19	28.85
1947	5.84	0.41	0.63	22.73
1948	4.71	3.19	3.53	25.28
1949	3.08	5.59	3.62	31.13
1950	4.90	4.13	4.31	21.70
1951	4.00	2.99	7.75	34.85
1952	2.11	5.17	3.27	23.73
1953	5.90	0.53	1.79	23.92
1954	6.81	1.37	1.54	24.68
1955	2.91	3.50	0.61	14.72
1956	3.30	5.36	1.54	17.76
1957	8.67	4.27	2.10	32.03
1958	1.87	4.52	1.64	18.30
1959	3.02	2.85	2.31	30.33
1960	2.27	2.60	5.78	25.36
1961	3.39	4.36	7.00	31.49
1962	7.63	6.12	2.64	32.86
1963	5.74	2.39	4.35	23.04
1964	2.71	6.00	5.35	27.30
1965	2.01	2.16	1.85	28.39
1966	5.09	2.93	4.88	21.45
1967	8.78	2.02	1.35	22.43
1968	3.85	1.68	1.52	24.22
1969	5.71	4.92	5.91	28.37
1970	2.63	1.89	1.01	28.81

Table F-20. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA.
Continued PERIOD OF RECORD IS 1891 TO 1977. N = 87

YEAR	JUNE	JULY	AUGUST	ANNUAL
1971	3.65	1.57	0.12	19.63
1972	3.79	10.33	2.09	33.72
1973	3.54	4.90	1.05	27.89
1974	3.28	1.29	3.27	17.96
1975	5.34	1.61	4.56	26.31
1976	0.75	1.50	0.30	14.33
1977	3.84	3.90	2.54	28.66

Table F-21. PRECIPITATION DATA IN INCHES AT SIOUX RAPIDS, IOWA.
PERIOD OF RECORD IS 1942 TO 1977. N = 36

YEAR	JUNE	JULY	AUGUST	ANNUAL
1942	6.26	2.88	2.24	25.52
1943	7.68	4.72	2.52	27.55
1944	7.44	6.47	7.19	35.71
1945	4.49	3.00	6.59	34.02
1946	4.23	1.42	1.62	30.56
1947	6.77	4.00	1.27	31.83
1948	5.66	4.41	4.26	27.37
1949	3.47	2.59	2.86	24.81
1950	5.87	6.64	0.85	28.29
1951	6.03	5.47	6.58	39.11
1952	2.68	5.54	3.86	21.47
1953	7.32	2.22	5.24	28.14
1954	11.01	2.58	7.56	37.43
1955	2.59	2.27	0.65	15.18
1956	1.42	2.80	4.13	19.35
1957	5.35	4.12	5.58	32.88
1958	2.88	1.98	0.89	14.17
1959	6.37	1.25	5.86	38.70
1960	4.50	2.21	5.35	27.52
1961	4.16	5.25	2.05	31.22
1962	3.22	8.58	6.29	30.85
1963	4.95	4.88	1.90	20.68
1964	4.65	5.01	3.43	31.84
1965	2.12	1.09	2.09	30.18
1966	3.76	3.58	3.14	18.00
1967	8.38	0.53	0.84	20.38
1968	4.48	3.36	2.20	31.82
1969	7.63	5.18	5.11	32.93
1970	1.94	1.55	1.86	28.01
1971	7.23	3.20	0.99	27.88
1972	2.04	5.18	6.62	32.89
1973	1.67	5.62	6.83	36.96
1974	1.27	0.54	4.46	16.24
1975	5.28	0.64	11.72	36.37
1976	2.63	1.22	0.56	17.52
1977	4.76	5.68	3.43	38.18

Table F-22. PRECIPITATION DATA IN INCHES AT SPENCER, IOWA.

PERIOD OF RECORD IS 1912 TO 1977. N = 66

YEAR	JUNE	JULY	AUGUST	ANNUAL
1912	1.97	3.16	3.40	24.69
1913	1.60	2.76	5.71	29.86
1914	4.42	1.45	3.20	29.55
1915	2.57	3.68	1.94	26.46
1916	3.26	1.84	2.35	26.13
1917	4.19	2.13	2.84	25.59
1918	4.42	5.25	4.16	34.52
1919	6.36	4.17	2.06	33.98
1920	2.01	5.55	4.83	33.29
1921	2.02	0.75	3.50	22.86
1922	1.32	4.95	5.55	26.89
1923	4.66	0.57	5.20	25.55
1924	4.75	0.69	5.49	23.86
1925	4.65	4.24	0.49	18.79
1926	3.53	6.45	2.56	32.65
1927	1.84	0.47	2.09	27.23
1928	5.45	1.48	6.04	27.15
1929	2.19	2.30	2.03	23.71
1930	2.48	0.32	2.77	21.61
1931	3.38	2.00	4.38	30.23
1932	2.53	2.43	4.30	25.04
1933	0.59	5.04	4.06	23.33
1934	7.80	5.47	2.83	27.66
1935	6.28	3.88	3.12	28.47
1936	3.21	0.60	4.41	23.26
1937	5.16	1.05	7.28	33.75
1938	5.39	4.84	1.31	38.25
1939	4.52	2.74	6.94	23.26
1940	7.53	1.55	3.36	26.49
1941	7.49	2.75	1.71	34.21
1942	5.78	4.13	4.04	30.92
1943	8.92	5.31	4.08	31.60
1944	5.97	5.69	8.71	33.71
1945	6.29	3.61	1.66	26.35
1946	3.56	1.05	2.40	26.98
1947	5.12	1.83	0.45	28.14
1948	5.61	3.35	3.03	24.96
1949	4.43	2.97	2.35	25.81
1950	3.81	6.42	0.69	27.82
1951	6.82	6.77	6.52	44.15

Table F-22. PRECIPITATION DATA IN INCHES AT SPENCER, IOWA.
Continued PERIOD OF RECORD IS 1912 TO 1977. N = 66

YEAR	JUNE	JULY	AUGUST	ANNUAL
1952	4.24	3.90	4.44	21.97
1953	7.75	2.27	3.39	27.65
1954	7.85	3.16	6.65	34.78
1955	3.26	4.68	0.60	18.98
1956	2.67	4.22	5.62	23.48
1957	4.47	2.18	3.45	26.92
1958	3.77	2.17	1.13	14.41
1959	3.24	0.17	3.65	32.12
1960	2.22	2.80	3.43	27.07
1961	1.51	6.26	1.93	28.28
1962	6.10	6.87	5.59	31.02
1963	2.92	4.93	2.31	20.97
1964	3.73	6.00	4.62	35.18
1965	2.10	1.54	4.15	31.25
1966	2.39	2.00	2.71	16.99
1967	7.92	0.45	0.89	19.86
1968	3.06	5.90	2.35	30.39
1969	7.73	7.54	6.03	38.03
1970	2.67	1.48	1.30	27.93
1971	5.46	6.31	1.06	28.26
1972	2.49	6.18	2.39	28.31
1973	2.01	3.11	4.03	35.34
1974	2.64	0.84	4.07	16.73
1975	6.54	0.22	12.13	38.36
1976	2.72	1.22	0.56	16.70
1977	2.21	2.61	5.18	33.43

Table F-23. PRECIPITATION DATA IN INCHES AT STORM LAKE, IOWA.

PERIOD OF RECORD IS 1899 TO 1977. N = 79

YEAR	JUNE	JULY	AUGUST	ANNUAL
1899	7.98	0.62	2.01	26.03
1900	6.97	9.16	4.58	36.94
1901	2.87	1.67	2.15	22.99
1902	5.37	10.49	5.52	38.63
1903	4.85	5.83	7.65	36.80
1904	3.66	2.56	5.16	24.19
1905	5.20	1.30	2.67	33.13
1906	4.37	2.83	5.44	34.36
1907	4.15	7.88	5.37	28.15
1908	9.63	5.26	5.69	40.20
1909	3.48	5.87	2.66	33.54
1910	2.00	2.61	2.66	14.30
1911	3.56	2.82	2.11	27.55
1912	3.75	3.90	5.33	32.14
1913	1.15	1.81	1.52	27.09
1914	4.86	3.82	0.82	31.13
1915	3.84	5.45	3.97	39.02
1916	2.37	1.43	2.06	25.66
1917	4.34	2.66	2.75	26.02
1918	4.43	3.60	2.91	27.77
1919	11.97	2.40	1.74	31.72
1920	4.16	5.92	1.94	33.99
1921	1.08	2.65	4.30	20.44
1922	3.06	5.08	2.79	26.00
1923	7.30	1.93	4.48	32.10
1924	5.55	1.13	5.67	25.46
1925	5.34	1.12	1.59	16.57
1926	3.26	2.07	3.47	29.04
1927	5.08	1.20	1.51	29.36
1928	3.26	2.60	4.46	27.38
1929	2.96	4.19	2.95	25.53
1930	6.69	1.22	6.71	27.75
1931	2.57	2.70	2.35	30.37
1932	6.29	2.40	6.51	32.68
1933	0.33	5.58	1.82	21.63
1934	5.10	7.56	4.94	30.41
1935	2.84	1.46	2.38	22.92
1936	2.51	0.51	2.25	19.96
1937	3.75	1.00	5.04	27.02
1938	3.95	6.22	1.33	36.36

Table F-23. PRECIPITATION DATA IN INCHES AT STORM LAKE, IOWA.
Continued PERIOD OF RECORD IS 1899 TO 1977. N = 79

YEAR	JUNE	JULY	AUGUST	ANNUAL
1939	3.38	1.36	4.43	19.81
1940	5.01	4.29	3.64	27.83
1941	6.29	1.53	2.62	29.24
1942	6.71	5.45	1.70	27.82
1943	7.31	6.12	1.93	30.68
1944	5.75	6.97	5.39	34.39
1945	3.31	5.98	4.87	32.89
1946	6.46	0.66	2.25	33.67
1947	5.08	1.62	0.81	27.55
1948	4.97	3.06	5.30	29.79
1949	2.86	3.27	1.32	22.48
1950	3.74	4.63	1.71	22.71
1951	8.88	5.13	8.91	45.94
1952	3.73	6.78	3.93	25.90
1953	5.02	5.20	3.27	28.72
1954	8.41	1.70	5.84	36.94
1955	1.93	2.70	0.62	15.76
1956	1.57	2.46	2.83	16.92
1957	4.08	5.41	3.67	29.40
1958	5.33	5.06	1.27	17.90
1959	2.93	1.13	3.75	31.42
1960	3.95	3.90	5.19	26.78
1961	3.62	3.60	3.52	28.50
1962	3.35	6.65	9.20	31.27
1963	6.33	3.83	3.35	24.43
1964	3.79	4.38	3.43	26.60
1965	2.04	1.33	2.46	32.85
1966	2.21	1.92	3.66	17.05
1967	10.81	2.61	3.01	28.22
1968	4.30	3.51	4.60	33.66
1969	9.24	6.09	2.81	34.27
1970	1.86	3.10	1.46	23.90
1971	7.01	5.12	1.03	29.23
1972	4.15	5.72	4.70	34.29
1973	1.65	5.06	4.57	34.24
1974	3.86	1.84	5.44	22.35
1975	6.54	0.56	4.51	34.31
1976	2.95	0.63	0.25	13.90
1977	3.29	5.18	5.20	38.39

Table F-24. PRECIPITATION DATA IN INCHES AT AKRON, IOWA.

PERIOD OF RECORD IS 1928 TO 1977, N = 50

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
10.49	1971	7.02	1966	8.87	1937	42.95	1951
9.13	1934	6.08	1952	7.86	1951	36.19	1944
9.02	1944	6.05	1972	7.35	1960	34.16	1965
8.58	1954	5.93	1938	6.91	1966	32.27	1938
8.52	1951	5.44	1964	6.16	1944	32.19	1949
8.08	1941	5.30	1935	5.83	1949	31.75	1968
7.96	1967	5.16	1944	5.51	1963	31.10	1962
7.86	1969	4.91	1957	5.18	1940	30.45	1960
6.98	1940	4.66	1928	4.89	1962	30.20	1953
6.21	1962	4.51	1968	4.84	1967	29.39	1966
6.20	1953	4.44	1962	4.64	1928	29.38	1969
6.11	1939	4.43	1945	4.58	1961	29.26	1964
5.98	1948	4.39	1933	4.49	1946	28.89	1959
5.57	1943	4.37	1958	4.47	1969	28.74	1954
5.35	1975	4.17	1934	4.41	1952	28.69	1940
5.23	1950	4.15	1955	4.41	1975	28.66	1937
5.22	1947	4.09	1961	4.27	1953	28.24	1972
4.97	1965	4.08	1949	3.89	1933	28.17	1946
4.86	1942	3.91	1950	3.80	1945	28.16	1977
4.69	1932	3.84	1951	3.79	1929	27.75	1970
4.54	1957	3.81	1940	3.64	1959	27.74	1961
4.50	1935	3.81	1942	3.46	1950	27.36	1935
4.48	1966	3.71	1948	3.30	1968	27.10	1971
4.46	1968	3.62	1953	3.16	1957	26.91	1934
4.40	1945	3.57	1977	3.07	1965	26.91	1945
4.35	1964	3.56	1973	2.91	1972	26.85	1941
4.20	1977	3.39	1943	2.90	1948	26.51	1957
4.03	1963	3.03	1963	2.89	1930	26.41	1950
3.83	1955	2.77	1954	2.77	1964	26.34	1947
3.82	1949	2.76	1969	2.55	1938	26.18	1928
3.73	1930	2.58	1965	2.47	1932	26.03	1948
3.65	1970	2.56	1937	2.46	1939	24.72	1952
3.57	1952	2.15	1956	2.26	1956	24.60	1932
3.57	1974	2.15	1971	2.23	1934	23.64	1973
3.55	1938	2.11	1929	2.20	1935	23.16	1975
3.50	1929	1.91	1976	2.16	1954	22.88	1929
3.41	1946	1.87	1941	2.05	1974	21.80	1942
3.25	1928	1.65	1959	1.91	1936	21.73	1933

Table F-24. PRECIPITATION DATA IN INCHES AT AKRON, IOWA.

Continued PERIOD OF RECORD IS 1928 TO 1977. N = 50

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.83	1959	1.52	1932	1.75	1931	21.57	1963
2.78	1960	1.29	1974	1.70	1947	21.08	1967
2.68	1961	1.12	1967	1.53	1976	20.80	1930
2.56	1973	1.10	1975	1.49	1977	19.90	1955
2.32	1931	1.08	1939	1.36	1942	18.57	1943
2.32	1956	0.95	1931	1.30	1970	18.20	1931
2.20	1937	0.94	1970	1.27	1941	17.40	1974
1.94	1958	0.85	1960	1.09	1955	16.52	1958
1.72	1936	0.45	1947	0.84	1973	16.02	1936
0.92	1972	0.42	1936	0.75	1943	15.13	1939
0.67	1933	0.39	1946	0.74	1958	14.42	1956
0.60	1976	0.01	1930	0.30	1971	12.75	1976

Table F-25. PRECIPITATION DATA IN INCHES AT ALTON, IOWA,
PERIOD OF RECORD IS 1906 TO 1977, N = 72

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
8.30	1967	7.09	1944	8.95	1960	38.25	1944
7.96	1942	6.61	1909	7.60	1944	36.48	1909
7.70	1947	6.41	1972	7.18	1959	33.89	1906
7.64	1954	5.85	1973	6.77	1951	33.39	1965
7.39	1941	5.81	1962	6.55	1961	32.63	1942
7.29	1953	5.79	1964	6.27	1974	32.52	1908
6.81	1934	5.69	1915	6.05	1954	31.79	1951
6.71	1945	5.48	1977	5.58	1948	31.40	1918
6.63	1940	5.36	1907	5.31	1906	31.15	1953
6.61	1943	5.22	1948	5.22	1924	31.06	1960
5.96	1909	5.18	1956	5.22	1931	30.76	1962
5.66	1932	5.10	1965	5.16	1962	30.45	1959
5.53	1948	5.09	1933	5.15	1918	30.36	1947
5.33	1914	5.08	1951	5.12	1928	30.32	1945
5.23	1944	5.02	1928	4.81	1937	30.32	1977
5.12	1971	4.85	1968	4.55	1932	30.30	1923
5.10	1930	4.84	1950	4.47	1923	30.02	1954
5.10	1975	4.45	1919	4.45	1940	29.74	1946
5.09	1957	4.39	1952	4.43	1910	29.72	1970
5.01	1961	4.29	1920	4.34	1942	29.65	1968
5.00	1974	4.26	1957	4.31	1922	29.58	1915
4.89	1919	4.23	1963	4.11	1911	29.50	1940
4.85	1946	4.19	1908	4.06	1953	29.34	1920
4.84	1935	4.19	1942	3.98	1969	29.24	1961
4.70	1918	4.18	1953	3.95	1908	29.16	1941
4.56	1907	4.13	1922	3.92	1957	28.75	1950
4.50	1962	4.13	1945	3.86	1926	28.74	1948
4.47	1917	4.03	1969	3.79	1934	28.69	1938
4.43	1951	3.84	1910	3.50	1939	28.59	1972
4.42	1906	3.82	1943	3.48	1952	28.54	1932
4.40	1915	3.73	1934	3.47	1929	28.40	1919
4.38	1923	3.66	1913	3.42	1965	28.21	1957
4.35	1908	3.63	1939	3.35	1945	28.08	1964
4.23	1950	3.36	1938	3.25	1913	28.08	1973
4.10	1966	3.28	1918	3.20	1920	27.14	1907
4.08	1924	3.24	1912	3.01	1956	26.82	1969
3.97	1928	3.24	1921	2.95	1964	25.75	1937
3.87	1939	3.18	1916	2.89	1975	25.72	1928

Table F-25. PRECIPITATION DATA IN INCHES AT ALTON, IOWA.
Continued PERIOD OF RECORD IS 1906 TO 1977. N = 72

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
3.85	1929	2.99	1935	2.83	1907	25.47	1916
3.69	1931	2.99	1955	2.79	1946	25.44	1949
3.67	1969	2.90	1971	2.78	1936	25.04	1975
3.54	1963	2.88	1926	2.76	1955	24.47	1931
3.52	1952	2.83	1958	2.61	1912	24.40	1926
3.39	1920	2.79	1961	2.61	1938	24.28	1927
3.34	1964	2.51	1932	2.50	1921	24.24	1921
3.24	1925	2.48	1925	2.44	1943	24.23	1922
3.24	1965	2.26	1940	2.42	1966	23.76	1914
3.22	1959	2.09	1966	2.41	1935	23.65	1911
3.13	1973	2.07	1923	2.40	1919	23.08	1934
2.95	1970	2.07	1931	2.31	1933	23.06	1943
2.87	1968	2.00	1954	2.27	1915	22.98	1971
2.86	1949	2.00	1970	2.23	1947	22.52	1917
2.81	1916	1.94	1914	2.13	1927	22.49	1974
2.65	1960	1.94	1927	2.07	1949	22.21	1935
2.62	1956	1.91	1949	2.01	1917	22.14	1929
2.50	1926	1.89	1911	1.99	1963	21.88	1913
2.36	1972	1.81	1960	1.88	1950	21.40	1930
2.29	1937	1.80	1906	1.85	1914	21.32	1912
2.22	1955	1.74	1946	1.81	1977	20.93	1966
2.09	1913	1.69	1917	1.78	1972	20.80	1933
2.02	1927	1.69	1929	1.67	1930	20.62	1924
1.99	1958	1.68	1976	1.60	1916	20.41	1952
1.78	1938	1.46	1941	1.56	1973	20.04	1963
1.77	1912	1.37	1937	1.45	1967	18.61	1956
1.71	1911	1.34	1936	0.99	1909	18.58	1939
1.67	1922	1.17	1974	0.90	1970	17.80	1936
1.67	1936	1.13	1975	0.82	1941	17.62	1955
1.53	1977	1.01	1967	0.79	1968	17.49	1967
1.27	1976	0.89	1924	0.72	1958	17.42	1910
1.26	1910	0.59	1947	0.62	1976	14.66	1976
1.03	1933	0.55	1959	0.55	1971	14.42	1925
0.56	1921	0.39	1930	0.31	1925	13.29	1958

Table F-26. PRECIPITATION DATA IN INCHES AT CHEROKEE, IOWA.
PERIOD OF RECORD IS 1922 TO 1977. N = 56

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
11.52	1953	9.33	1938	7.84	1951	42.86	1938
9.64	1967	8.16	1944	7.55	1937	38.91	1959
8.63	1954	7.54	1950	7.02	1959	38.87	1951
8.60	1947	7.54	1962	6.38	1945	37.68	1945
8.59	1943	6.28	1952	6.31	1960	37.49	1944
8.19	1969	6.16	1931	6.12	1924	37.31	1953
8.15	1944	6.04	1957	5.47	1932	34.72	1957
7.88	1957	5.62	1933	5.43	1923	34.51	1968
7.21	1971	5.49	1968	5.43	1948	34.30	1977
6.80	1934	5.45	1934	5.40	1974	33.23	1926
6.31	1941	5.30	1964	5.37	1940	32.55	1941
6.28	1940	5.24	1942	5.33	1954	31.16	1923
5.95	1924	5.18	1943	5.17	1962	31.10	1964
5.93	1968	5.05	1973	5.01	1934	30.94	1962
5.91	1951	4.94	1953	4.93	1953	30.93	1961
5.83	1961	4.81	1922	4.56	1975	30.91	1940
5.64	1945	4.70	1970	4.44	1969	30.68	1937
5.38	1975	4.57	1961	4.43	1952	30.62	1965
5.35	1925	4.55	1977	4.15	1968	29.86	1954
5.18	1962	4.50	1945	4.11	1939	29.56	1947
5.02	1923	4.47	1972	4.08	1944	29.27	1946
4.96	1942	4.44	1955	4.07	1966	29.06	1975
4.94	1959	4.18	1963	3.98	1961	28.78	1969
4.74	1926	3.93	1937	3.62	1977	28.76	1960
4.68	1974	3.90	1948	3.39	1957	28.67	1931
4.55	1977	3.89	1951	3.03	1922	28.55	1970
4.41	1948	3.64	1940	2.94	1972	28.01	1973
4.19	1949	3.50	1926	2.85	1938	27.62	1972
4.13	1950	3.22	1969	2.83	1963	26.87	1932
4.11	1938	2.96	1971	2.75	1928	26.85	1942
3.65	1929	2.92	1960	2.63	1967	26.70	1934
3.48	1932	2.82	1929	2.53	1926	25.72	1948
3.46	1952	2.67	1966	2.52	1965	25.44	1943
3.44	1930	2.63	1927	2.46	1929	25.34	1949
3.21	1946	2.63	1939	2.44	1933	25.28	1952
3.20	1966	2.47	1925	2.37	1931	24.86	1950
3.00	1939	2.41	1928	2.36	1946	24.85	1927
2.99	1937	2.23	1956	2.33	1964	24.17	1971

Table F-26. PRECIPITATION DATA IN INCHES AT CHEROKEE, IOWA.
Continued PERIOD OF RECORD IS 1922 TO 1977. N = 56

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.82	1927	2.13	1949	2.31	1956	23.88	1922
2.63	1935	2.12	1932	2.17	1936	23.70	1924
2.62	1964	2.09	1958	2.03	1941	23.05	1967
2.54	1958	2.07	1941	1.85	1935	23.04	1929
2.51	1963	1.93	1935	1.76	1973	22.89	1933
2.48	1936	1.67	1974	1.60	1927	22.20	1936
2.37	1970	1.61	1924	1.58	1942	21.38	1966
2.31	1928	1.49	1959	1.41	1970	21.35	1928
2.25	1931	1.40	1965	1.18	1947	21.02	1935
2.21	1922	1.36	1923	1.13	1950	20.72	1963
2.02	1965	1.34	1967	1.11	1958	20.50	1974
1.92	1960	1.12	1930	1.10	1930	20.32	1930
1.76	1973	0.82	1947	1.01	1943	19.56	1925
1.64	1955	0.77	1954	1.00	1949	19.32	1939
1.51	1976	0.77	1976	0.94	1925	16.64	1955
1.37	1972	0.72	1946	0.66	1971	15.84	1956
1.13	1956	0.41	1975	0.41	1976	15.15	1976
0.90	1933	0.20	1936	0.11	1955	12.11	1958

Table F-27. PRECIPITATION DATA IN INCHES AT HAWARDEN, IOWA.

PERIOD OF RECORD IS 1927 TO 1977. N = 51

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
9.25	1953	7.26	1972	8.28	1951	39.34	1951
8.88	1965	6.30	1944	6.63	1928	37.11	1965
8.31	1954	6.26	1952	6.57	1960	35.44	1953
7.59	1941	5.90	1943	6.40	1975	34.94	1944
7.47	1944	5.90	1962	6.28	1969	34.30	1962
7.36	1934	5.75	1957	6.27	1944	31.58	1972
7.29	1962	5.49	1950	6.11	1966	30.28	1969
7.24	1967	5.34	1953	5.62	1962	29.45	1960
6.81	1971	5.34	1966	5.60	1952	29.36	1959
6.65	1942	5.25	1945	5.13	1948	28.78	1957
5.80	1969	5.05	1933	5.03	1933	28.75	1928
5.69	1974	4.59	1929	4.86	1937	28.75	1938
5.64	1950	4.35	1969	4.61	1961	28.71	1970
5.55	1957	4.32	1951	4.60	1959	28.65	1945
5.53	1940	4.19	1968	4.34	1953	27.43	1968
5.41	1951	4.08	1973	4.24	1945	27.34	1977
5.20	1947	3.83	1958	3.97	1974	26.69	1946
5.15	1955	3.47	1934	3.82	1932	26.64	1954
5.08	1935	3.40	1963	3.65	1947	26.53	1947
4.97	1930	3.34	1956	3.44	1934	26.24	1929
4.88	1945	3.25	1928	3.13	1936	25.91	1941
4.75	1948	3.20	1942	3.07	1949	25.86	1949
4.61	1975	3.11	1964	2.96	1930	25.83	1950
4.34	1939	3.05	1940	2.96	1963	25.41	1975
3.97	1964	3.03	1938	2.87	1957	25.37	1964
3.92	1928	2.88	1932	2.82	1967	25.09	1927
3.81	1972	2.86	1977	2.65	1964	25.08	1942
3.75	1943	2.77	1948	2.50	1965	25.07	1948
3.42	1929	2.57	1935	2.49	1946	25.03	1966
3.37	1946	2.55	1965	2.40	1940	24.86	1937
3.20	1937	2.28	1970	2.37	1956	24.75	1935
3.16	1966	2.25	1955	2.36	1942	24.47	1940
2.98	1931	2.19	1954	2.10	1939	24.33	1933
2.94	1949	2.12	1967	2.08	1935	24.16	1934
2.90	1968	2.05	1949	2.05	1931	24.15	1930
2.74	1938	2.00	1939	1.94	1943	23.96	1961
2.72	1959	1.96	1961	1.94	1977	23.93	1973
2.66	1961	1.78	1971	1.93	1954	23.60	1932

Table F-27. PRECIPITATION DATA IN INCHES AT HAWARDEN, IOWA.

Continued PERIOD OF RECORD IS 1927 TO 1977. N = 51

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.65	1932	1.67	1976	1.79	1927	23.33	1971
2.57	1973	1.37	1927	1.70	1929	23.12	1952
2.52	1970	1.29	1947	1.69	1938	21.73	1936
2.51	1963	1.29	1960	1.36	1958	20.50	1931
2.49	1927	1.21	1931	1.26	1968	20.27	1943
2.27	1960	1.19	1941	1.26	1972	19.52	1974
2.22	1952	1.12	1974	1.23	1971	19.21	1967
1.94	1936	1.09	1946	1.21	1976	17.43	1963
1.85	1956	0.86	1937	0.89	1950	16.44	1955
1.66	1977	0.79	1959	0.83	1970	16.10	1956
1.33	1958	0.75	1975	0.83	1973	14.64	1958
1.08	1933	0.40	1936	0.72	1955	14.56	1939
0.97	1976	0.12	1930	0.62	1941	13.97	1976

Table F-28. PRECIPITATION DATA IN INCHES AT HOLSTEIN, IOWA.
PERIOD OF RECORD IS 1934 TO 1977. N = 44

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
13.42	1967	8.81	1944	13.03	1951	43.10	1951
10.21	1954	7.23	1955	8.57	1937	39.24	1944
9.05	1963	6.80	1950	7.07	1975	37.19	1975
7.68	1947	6.18	1977	6.46	1962	36.74	1977
7.47	1934	6.16	1972	6.45	1966	36.30	1941
7.21	1944	5.64	1952	6.28	1960	35.41	1968
7.14	1975	5.58	1935	6.18	1940	35.19	1973
7.04	1957	5.50	1968	5.50	1944	35.07	1965
6.83	1943	5.46	1973	5.16	1961	34.17	1959
6.61	1961	5.40	1934	4.96	1977	33.99	1972
6.45	1951	5.32	1940	4.93	1974	33.90	1954
6.25	1942	5.09	1958	4.78	1945	33.82	1961
6.13	1969	4.68	1957	4.06	1939	33.59	1957
6.07	1940	4.66	1962	3.98	1972	32.85	1940
5.63	1971	4.43	1971	3.93	1948	31.91	1945
5.45	1941	4.33	1949	3.65	1956	31.37	1938
5.42	1950	4.22	1964	3.60	1965	30.80	1971
5.09	1952	4.15	1961	3.50	1963	30.52	1962
4.58	1945	3.98	1970	3.29	1943	30.01	1963
4.56	1968	3.94	1943	3.29	1968	29.47	1950
4.41	1958	3.85	1948	2.71	1952	28.77	1970
4.32	1938	3.64	1942	2.71	1953	28.67	1937
4.18	1948	3.57	1945	2.67	1964	28.65	1967
4.10	1962	3.56	1941	2.65	1959	27.78	1949
3.83	1953	3.36	1938	2.53	1954	27.69	1952
3.77	1972	3.27	1963	2.43	1957	27.30	1960
3.76	1977	2.99	1966	2.43	1967	26.89	1934
3.75	1949	2.67	1951	2.32	1946	26.59	1947
3.57	1973	2.61	1969	2.04	1936	26.53	1964
3.42	1974	2.59	1939	1.97	1934	26.42	1948
3.38	1939	2.53	1956	1.85	1949	25.90	1946
3.22	1966	2.09	1960	1.81	1935	25.24	1942
3.17	1937	1.94	1953	1.81	1941	24.23	1969
3.01	1959	1.80	1954	1.63	1950	24.21	1943
2.76	1964	1.72	1965	1.36	1970	23.57	1935
2.58	1960	1.49	1974	1.26	1955	23.25	1953
2.55	1946	1.40	1937	1.24	1942	22.78	1974
2.19	1955	1.37	1967	1.22	1958	21.19	1966

Table F-28. PRECIPITATION DATA IN INCHES AT HOLSTEIN, IOWA.
Continued PERIOD OF RECORD IS 1934 TO 1977. N = 44

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.16	1970	1.20	1959	1.20	1969	21.10	1955
2.08	1965	0.97	1976	1.17	1971	18.67	1956
2.07	1976	0.92	1947	1.03	1973	18.63	1958
2.03	1935	0.78	1975	0.95	1938	18.53	1939
2.01	1956	0.50	1946	0.62	1947	16.51	1936
1.29	1936	0.20	1936	0.15	1976	15.54	1976

Table F-29. PRECIPITATION DATA IN INCHES AT IDA GROVE, IOWA.

PERIOD OF RECORD IS 1945 TO 1977. N = 33

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
14.05	1967	7.77	1962	14.85	1951	51.62	1951
9.12	1951	6.45	1945	13.50	1962	43.42	1962
8.24	1954	6.08	1950	6.48	1975	36.78	1954
6.73	1969	5.81	1955	6.28	1968	36.51	1968
6.71	1950	5.75	1952	5.48	1966	35.81	1975
6.57	1947	5.42	1958	4.76	1974	35.25	1965
6.37	1957	5.31	1964	4.53	1977	34.97	1964
6.31	1972	5.06	1951	4.31	1963	34.60	1972
6.12	1961	4.69	1972	4.03	1972	34.60	1977
5.85	1966	4.52	1948	3.97	1965	34.02	1959
5.45	1975	4.28	1949	3.93	1964	31.72	1945
5.21	1952	4.02	1967	3.91	1949	31.47	1948
5.06	1963	4.02	1970	3.75	1956	31.11	1946
4.89	1959	4.01	1971	3.71	1953	31.06	1973
4.89	1964	3.94	1957	3.25	1946	29.68	1952
4.69	1968	3.71	1973	3.23	1954	29.40	1967
4.45	1977	3.67	1963	3.16	1960	28.76	1957
4.34	1953	3.40	1977	3.10	1957	28.26	1969
4.27	1946	2.93	1960	3.09	1959	27.75	1970
4.25	1958	2.81	1968	2.86	1948	27.60	1971
4.18	1948	2.79	1966	2.74	1952	27.12	1961
3.66	1962	2.55	1961	2.56	1961	27.06	1963
3.18	1960	2.46	1953	2.53	1958	26.78	1950
3.06	1971	2.33	1965	2.44	1945	26.34	1953
3.04	1973	2.02	1954	2.14	1969	26.27	1949
2.72	1945	1.62	1969	2.07	1967	25.95	1947
2.72	1974	1.60	1975	2.05	1950	25.39	1960
2.56	1976	1.37	1974	1.84	1970	22.65	1974
2.54	1956	1.34	1956	1.31	1971	22.51	1966
2.30	1955	1.20	1946	1.12	1955	20.29	1958
2.25	1965	1.04	1947	0.74	1947	18.41	1955
1.75	1949	0.85	1976	0.70	1973	17.04	1956
1.42	1970	0.57	1959	0.51	1976	16.02	1976

Table F-30. PRECIPITATION DATA IN INCHES AT INWOOD, IOWA.

PERIOD OF RECORD IS 1904 TO 1972. N = 69

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
9.92	1905	6.31	1939	7.33	1960	37.61	1944
8.91	1943	6.09	1915	7.21	1906	37.08	1909
8.90	1954	6.01	1963	7.14	1944	35.73	1906
8.53	1909	5.65	1907	7.12	1959	32.76	1908
8.48	1919	5.08	1949	7.08	1928	32.73	1951
7.94	1906	4.83	1919	6.33	1933	31.91	1972
7.60	1962	4.83	1969	5.80	1932	31.52	1915
7.55	1967	4.77	1972	4.94	1952	30.69	1962
7.43	1914	4.63	1922	4.76	1954	30.64	1928
6.82	1942	4.60	1933	4.73	1951	30.41	1960
6.77	1940	4.49	1968	4.69	1953	30.40	1968
6.69	1908	4.39	1938	4.60	1961	29.97	1918
6.62	1944	4.38	1956	4.60	1962	29.75	1920
6.58	1971	4.37	1909	4.52	1939	29.64	1959
6.44	1918	4.37	1945	4.50	1936	29.61	1919
6.31	1928	4.36	1921	4.46	1910	29.38	1942
5.59	1934	4.35	1934	4.39	1923	29.31	1946
5.50	1939	4.30	1948	4.24	1949	29.21	1965
5.47	1941	4.17	1944	4.11	1942	28.67	1954
5.45	1947	4.02	1929	4.05	1937	28.61	1914
5.43	1930	4.02	1962	3.93	1943	28.33	1964
5.41	1915	3.90	1965	3.81	1966	28.12	1953
5.25	1951	3.83	1957	3.73	1911	27.73	1938
5.04	1953	3.82	1950	3.66	1956	27.68	1943
4.98	1907	3.78	1904	3.63	1967	26.84	1913
4.92	1920	3.53	1910	3.42	1922	26.81	1945
4.90	1917	3.47	1925	3.26	1964	26.63	1933
4.76	1926	3.46	1918	3.02	1918	26.26	1949
4.70	1925	3.36	1943	2.98	1972	26.10	1940
4.63	1950	3.22	1912	2.89	1926	25.83	1937
4.56	1952	3.20	1908	2.86	1935	25.48	1957
4.33	1924	3.19	1951	2.82	1921	24.97	1921
4.22	1969	3.02	1964	2.76	1905	24.60	1926
4.14	1946	2.95	1966	2.71	1924	24.59	1939
4.10	1965	2.86	1942	2.70	1909	24.57	1961
4.08	1904	2.85	1913	2.55	1915	24.03	1923
4.06	1957	2.84	1958	2.46	1929	24.00	1941
3.97	1945	2.80	1917	2.44	1914	23.67	1905

Table F-30. PRECIPITATION DATA IN INCHES AT INWOOD, IOWA.
Continued PERIOD OF RECORD IS 1904 TO 1972. N = 69

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
3.96	1968	2.75	1920	2.44	1916	23.57	1929
3.76	1913	2.74	1926	2.36	1940	23.54	1969
3.75	1972	2.71	1971	2.28	1946	23.24	1948
3.68	1916	2.62	1935	2.20	1920	22.78	1932
3.59	1964	2.60	1914	2.09	1934	22.55	1916
3.54	1932	2.59	1923	2.04	1945	22.03	1911
3.51	1935	2.53	1953	1.99	1904	22.00	1947
3.47	1955	2.34	1911	1.94	1908	21.89	1917
3.38	1948	2.30	1955	1.88	1931	21.89	1927
3.33	1963	2.24	1970	1.81	1965	21.87	1907
3.26	1923	2.22	1916	1.74	1969	21.83	1922
3.22	1961	2.22	1940	1.63	1912	21.29	1934
3.17	1959	2.14	1952	1.55	1917	21.25	1970
3.12	1911	1.96	1961	1.47	1948	21.08	1904
3.09	1921	1.93	1941	1.45	1907	21.01	1930
3.03	1929	1.75	1928	1.42	1963	20.79	1935
3.01	1960	1.75	1937	1.36	1947	20.78	1971
2.92	1956	1.73	1927	1.30	1950	20.56	1936
2.85	1931	1.61	1932	1.13	1925	20.38	1950
2.51	1938	1.29	1905	1.06	1971	19.72	1963
2.18	1966	1.29	1906	1.00	1968	19.70	1952
2.17	1937	1.28	1954	0.99	1919	19.60	1967
2.11	1970	1.27	1931	0.91	1913	19.46	1956
1.92	1949	1.27	1946	0.90	1938	19.41	1924
1.71	1922	1.27	1960	0.87	1930	19.07	1966
1.69	1958	1.04	1924	0.82	1927	18.81	1931
1.58	1927	0.72	1947	0.61	1941	18.52	1910
1.46	1936	0.36	1936	0.43	1955	17.95	1925
1.33	1910	0.34	1959	0.39	1957	15.25	1912
1.13	1912	0.31	1967	0.39	1958	13.29	1955
0.78	1933	0.18	1930	0.10	1970	12.65	1958

Table F-31. PRECIPITATION DATA IN INCHES AT LAKE PARK, IOWA, PERIOD OF RECORD IS 1927 TO 1977. N = 51

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
10.52	1953	9.31	1963	8.59	1928	35.91	1938
10.18	1943	8.17	1962	7.10	1937	35.16	1965
9.50	1954	7.02	1969	6.98	1944	34.70	1943
8.66	1975	6.65	1942	6.55	1975	34.33	1968
7.57	1967	6.21	1972	6.13	1956	34.17	1975
7.35	1952	6.04	1950	5.83	1935	33.67	1953
6.86	1957	5.81	1957	5.63	1954	33.50	1951
6.12	1934	5.46	1944	5.47	1964	33.13	1977
6.05	1951	5.32	1939	5.01	1953	32.72	1954
5.91	1969	5.02	1938	4.61	1974	32.41	1957
5.80	1928	4.91	1951	4.60	1951	31.90	1964
5.75	1938	4.80	1943	4.50	1960	31.54	1937
5.75	1947	4.72	1948	4.42	1942	31.23	1960
5.70	1971	4.56	1949	4.36	1934	30.89	1942
5.60	1965	4.51	1933	4.22	1957	30.85	1969
5.57	1940	4.30	1970	4.12	1943	30.12	1944
5.48	1945	4.24	1956	4.09	1962	29.96	1962
5.46	1962	4.03	1953	4.04	1933	29.70	1959
5.13	1941	3.98	1945	4.00	1940	29.42	1970
4.88	1935	3.87	1954	3.67	1939	29.30	1946
4.73	1930	3.86	1929	3.55	1977	28.11	1973
4.68	1942	3.80	1932	3.52	1932	28.08	1928
4.60	1937	3.72	1952	3.52	1970	27.06	1935
4.50	1944	3.69	1964	3.14	1936	27.06	1941
4.41	1968	3.66	1934	3.12	1966	26.94	1972
4.34	1932	3.48	1935	3.11	1959	26.78	1947
4.30	1966	3.29	1968	3.10	1949	26.26	1932
4.18	1948	3.17	1966	2.91	1967	25.80	1929
4.11	1946	2.95	1971	2.64	1955	25.56	1956
4.06	1977	2.90	1947	2.57	1929	25.37	1930
4.05	1958	2.86	1958	2.56	1968	25.17	1949
3.87	1974	2.84	1960	2.54	1965	25.06	1945
3.81	1963	2.77	1973	2.48	1947	24.64	1934
3.74	1939	2.62	1931	2.35	1961	23.75	1927
3.02	1950	2.42	1961	2.34	1952	23.61	1963
2.82	1976	2.34	1937	2.31	1945	23.35	1961
2.80	1964	2.31	1977	2.19	1931	23.02	1940
2.79	1973	1.93	1955	2.16	1969	22.87	1936

Table F-31. PRECIPITATION DATA IN INCHES AT LAKE PARK, IOWA.
Continued PERIOD OF RECORD IS 1927 TO 1977. N = 51

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.73	1956	1.81	1941	2.04	1938	22.22	1971
2.60	1955	1.56	1976	1.79	1972	22.13	1933
2.55	1949	1.45	1927	1.62	1941	21.82	1931
2.32	1961	1.45	1946	1.54	1963	21.64	1948
2.25	1959	1.16	1928	1.39	1927	21.43	1966
2.24	1931	0.81	1965	1.35	1930	21.14	1952
2.23	1936	0.81	1974	1.29	1973	21.04	1950
2.22	1960	0.62	1967	1.28	1946	20.42	1939
1.91	1970	0.58	1936	1.23	1958	19.99	1967
1.89	1929	0.56	1959	1.23	1971	19.98	1974
1.81	1972	0.52	1940	1.08	1950	16.26	1955
1.74	1927	0.33	1930	0.38	1976	14.99	1976
1.04	1933	0.30	1975	0.01	1948	13.43	1958

Table F-32. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA.
PERIOD OF RECORD IS 1897 TO 1977. N = 81

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
9.65	1950	12.00	1900	9.08	1951	42.35	1951
9.21	1971	7.38	1919	7.60	1960	39.97	1905
8.56	1967	7.08	1902	6.36	1940	39.01	1909
7.96	1934	6.82	1909	6.02	1924	38.22	1903
7.31	1945	6.70	1973	5.79	1903	35.63	1945
7.22	1909	6.50	1907	5.62	1923	35.32	1900
6.51	1954	6.25	1972	5.51	1899	35.31	1906
6.49	1940	5.97	1952	5.40	1959	33.02	1949
6.43	1948	5.92	1945	5.39	1945	32.76	1923
6.26	1899	5.90	1950	5.30	1974	32.59	1938
6.13	1969	5.84	1915	5.14	1921	32.17	1940
6.11	1943	5.46	1903	4.98	1975	32.05	1953
5.91	1953	5.30	1943	4.86	1944	31.69	1941
5.89	1923	5.22	1933	4.52	1920	31.65	1977
5.89	1925	5.22	1962	4.38	1969	31.62	1915
5.88	1974	5.18	1910	4.22	1957	31.57	1969
5.52	1961	5.05	1912	4.21	1968	31.42	1920
5.45	1906	4.97	1949	4.14	1926	31.12	1919
5.45	1915	4.95	1938	4.11	1952	30.86	1946
5.42	1962	4.67	1934	4.09	1966	30.76	1957
5.37	1941	4.57	1928	4.06	1946	30.66	1968
5.36	1957	4.44	1953	3.88	1905	30.37	1908
5.34	1924	4.25	1957	3.81	1948	30.30	1972
5.16	1975	4.23	1944	3.65	1902	29.99	1902
5.12	1919	4.01	1916	3.63	1910	29.73	1944
5.07	1951	3.91	1932	3.60	1963	29.72	1959
4.80	1918	3.79	1926	3.56	1964	29.63	1932
4.79	1911	3.71	1917	3.51	1953	29.57	1965
4.72	1898	3.69	1968	3.47	1937	29.09	1962
4.69	1942	3.66	1948	3.46	1906	28.38	1927
4.68	1902	3.63	1908	3.46	1911	28.37	1960
4.63	1947	3.61	1964	3.38	1961	28.35	1950
4.41	1966	3.57	1935	3.30	1939	27.90	1899
4.31	1905	3.55	1951	3.29	1932	27.55	1973
4.22	1952	3.41	1969	3.28	1922	27.34	1912
4.14	1908	3.39	1942	3.17	1967	27.31	1975
4.07	1946	3.34	1898	3.16	1936	27.22	1926
4.04	1907	3.27	1904	2.98	1928	26.81	1971

Table F-32. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA.

Continued PERIOD OF RECORD IS 1897 TO 1977. N = 81

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.04	1935	3.22	1899	2.90	1954	26.58	1934
4.04	1963	3.20	1922	2.85	1900	26.50	1948
3.92	1949	3.14	1940	2.82	1915	26.42	1952
3.84	1944	3.04	1963	2.81	1962	26.42	1954
3.82	1977	2.98	1977	2.79	1956	26.37	1924
3.80	1903	2.96	1925	2.75	1912	26.27	1922
3.79	1938	2.96	1958	2.62	1933	26.25	1897
3.78	1927	2.89	1955	2.60	1897	25.90	1928
3.73	1917	2.88	1921	2.49	1942	25.86	1918
3.71	1972	2.88	1939	2.45	1930	25.86	1964
3.59	1932	2.86	1905	2.41	1918	25.55	1935
3.58	1926	2.84	1920	2.35	1908	25.06	1914
3.58	1939	2.83	1966	2.31	1898	24.62	1916
3.52	1916	2.75	1914	2.31	1934	24.41	1911
3.51	1929	2.69	1924	2.12	1950	24.32	1901
3.46	1914	2.63	1965	2.11	1917	24.26	1961
3.42	1900	2.56	1961	2.04	1949	24.06	1947
3.41	1920	2.32	1971	2.01	1929	23.20	1974
3.37	1965	2.10	1901	1.96	1941	23.12	1907
3.26	1901	2.09	1897	1.95	1972	23.07	1942
3.26	1912	2.09	1923	1.92	1904	22.39	1930
3.11	1897	2.05	1941	1.92	1931	22.01	1937
3.03	1930	1.96	1918	1.80	1927	21.83	1933
3.01	1931	1.89	1970	1.75	1919	21.67	1943
2.87	1960	1.88	1929	1.75	1977	21.59	1898
2.73	1904	1.87	1956	1.65	1913	21.51	1931
2.71	1968	1.80	1913	1.64	1935	21.20	1929
2.65	1928	1.79	1927	1.52	1965	21.18	1921
2.46	1959	1.47	1959	1.43	1909	21.04	1904
2.37	1922	1.37	1976	1.35	1938	20.78	1917
2.23	1973	1.36	1954	1.25	1914	20.76	1966
2.22	1964	1.32	1931	1.25	1947	20.54	1939
2.18	1933	1.27	1911	1.11	1916	20.44	1913
2.14	1936	1.20	1906	1.09	1901	20.36	1967
2.08	1955	1.11	1946	1.09	1907	20.21	1970
1.99	1937	1.01	1975	1.08	1955	19.09	1936
1.76	1910	1.00	1967	1.06	1976	18.19	1910
1.70	1921	0.93	1974	0.77	1973	17.93	1963

Table F-32. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA.
Continued PERIOD OF RECORD IS 1897 TO 1977. N = 81

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
1.58	1958	0.75	1960	0.74	1943	17.68	1925
1.18	1913	0.73	1937	0.69	1971	16.33	1955
0.96	1976	0.67	1947	0.63	1970	14.86	1958
0.94	1956	0.52	1936	0.50	1925	13.93	1956
0.93	1970	0.36	1930	0.46	1958	13.02	1976

Table F-33. PRECIPITATION DATA IN INCHES AT MAPLETON, IOWA.

PERIOD OF RECORD IS 1938 TO 1977. N = 40

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
12.71	1967	7.72	1962	9.86	1962	40.73	1951
9.08	1942	7.40	1940	8.47	1944	37.75	1962
8.51	1944	7.21	1952	8.32	1951	35.45	1944
8.09	1951	7.01	1972	5.94	1946	34.90	1959
7.87	1952	6.81	1950	5.68	1966	34.24	1972
7.46	1950	6.14	1958	5.52	1960	33.64	1952
6.93	1968	6.11	1977	5.16	1950	33.42	1968
6.81	1947	5.32	1943	4.96	1974	33.18	1973
6.72	1966	5.23	1973	4.43	1940	32.87	1950
6.69	1963	4.53	1939	4.15	1968	32.87	1977
6.08	1940	4.43	1938	4.07	1954	32.81	1954
6.07	1941	4.04	1957	4.05	1963	32.48	1938
5.48	1953	4.02	1945	4.04	1977	31.73	1946
4.97	1957	4.01	1948	4.01	1948	31.45	1940
4.93	1959	3.87	1969	3.79	1964	30.52	1964
4.88	1954	3.73	1951	3.60	1959	30.38	1965
4.71	1946	3.63	1961	3.47	1969	29.69	1960
4.49	1969	3.60	1964	3.41	1972	28.97	1945
4.46	1975	3.35	1965	3.29	1952	27.87	1961
4.30	1943	3.24	1942	3.20	1975	27.29	1942
4.25	1955	3.00	1956	3.12	1939	27.17	1957
4.11	1964	2.98	1971	2.90	1957	27.15	1975
4.10	1938	2.75	1966	2.73	1961	27.07	1970
4.09	1962	2.56	1944	2.56	1956	25.32	1969
3.98	1973	2.41	1960	2.44	1949	25.09	1941
3.81	1960	2.34	1968	2.42	1941	24.88	1967
3.61	1956	2.31	1970	2.28	1945	24.84	1948
3.57	1977	2.05	1955	2.20	1953	24.75	1963
3.38	1961	1.90	1949	2.02	1965	24.41	1947
3.11	1948	1.86	1963	1.75	1955	24.22	1971
3.08	1972	1.59	1953	1.59	1970	23.86	1974
3.04	1971	1.45	1976	1.58	1967	23.75	1953
3.01	1945	1.21	1974	1.55	1973	23.43	1966
2.80	1958	1.05	1946	1.48	1938	20.48	1943
2.65	1939	1.04	1975	1.48	1942	18.93	1958
2.61	1974	1.03	1954	1.40	1958	18.64	1956
2.60	1949	1.02	1941	1.16	1971	18.31	1949
2.43	1965	0.89	1959	1.08	1943	17.55	1939

Table F-33. PRECIPITATION DATA IN INCHES AT MAPLETON, IOWA.

Continued PERIOD OF RECORD IS 1938 TO 1977. N = 40

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
1.57	1970	0.85	1947	1.02	1976	17.45	1976
1.10	1976	0.73	1967	0.46	1947	15.90	1955

Table F-34. PRECIPITATION DATA IN INCHES AT MERRILL, IOWA.

PERIOD OF RECORD IS 1946 TO 1977. N = 32

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
8.98	1971	8.07	1950	7.79	1951	38.84	1951
8.30	1967	6.54	1952	6.66	1960	32.97	1949
6.62	1948	6.46	1973	5.59	1964	32.19	1977
6.51	1953	5.31	1972	5.05	1967	31.97	1968
6.43	1966	4.95	1948	4.86	1957	31.76	1953
5.31	1969	4.90	1962	4.80	1966	30.06	1965
5.29	1951	4.84	1966	4.61	1952	29.75	1970
5.26	1977	4.09	1957	4.34	1969	29.73	1957
5.15	1957	4.08	1965	4.15	1962	29.60	1972
5.00	1952	4.05	1964	3.63	1949	27.59	1959
4.73	1954	4.01	1949	3.56	1954	27.55	1952
4.53	1962	3.92	1977	3.42	1959	27.15	1964
4.47	1949	3.83	1968	3.42	1961	27.08	1962
4.43	1974	3.80	1958	3.38	1950	27.05	1969
4.24	1947	3.72	1951	3.38	1953	26.90	1973
4.09	1950	3.63	1953	3.35	1975	26.14	1960
3.90	1968	3.61	1969	3.20	1968	26.08	1966
3.83	1963	3.03	1961	3.12	1974	25.79	1950
3.74	1961	2.96	1955	3.04	1963	24.91	1971
2.99	1970	2.65	1963	2.55	1946	24.83	1946
2.91	1975	2.59	1956	2.34	1948	24.80	1948
2.89	1965	2.33	1970	2.22	1976	24.40	1954
2.80	1955	2.19	1976	2.15	1972	23.80	1967
2.78	1946	2.16	1967	2.13	1956	23.19	1961
2.73	1959	1.78	1974	1.67	1965	21.63	1947
2.66	1964	1.54	1954	1.43	1958	19.84	1974
2.53	1972	1.40	1947	1.38	1970	19.76	1975
2.30	1960	1.18	1971	1.37	1955	18.85	1958
1.82	1973	1.10	1960	1.25	1977	18.70	1955
1.79	1958	0.99	1975	0.61	1971	18.52	1963
1.46	1956	0.93	1959	0.61	1973	15.73	1976
0.51	1976	0.65	1946	0.40	1947	13.14	1956

Table F-35. PRECIPITATION DATA IN INCHES AT MILFORD, IOWA.

PERIOD OF RECORD IS 1939 TO 1977. N = 39

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
8.80	1943	9.89	1962	6.81	1975	37.21	1951
8.58	1945	7.55	1972	6.41	1962	36.31	1977
8.55	1953	7.50	1964	6.01	1954	34.59	1960
8.40	1954	6.69	1963	5.89	1960	34.48	1964
8.15	1975	6.20	1969	5.78	1944	33.28	1962
7.26	1967	5.84	1944	5.58	1942	33.12	1975
7.20	1951	5.62	1950	5.50	1943	32.56	1954
6.23	1952	5.28	1957	4.77	1977	32.44	1969
6.10	1941	4.88	1943	4.74	1956	32.29	1968
5.99	1949	4.79	1966	4.73	1951	31.25	1972
5.93	1957	4.64	1942	4.73	1952	30.74	1973
5.76	1969	4.63	1951	3.98	1974	29.86	1946
5.67	1962	4.36	1945	3.74	1939	29.68	1953
5.40	1947	3.99	1971	3.72	1940	29.61	1941
5.18	1944	3.89	1952	3.72	1953	29.58	1943
4.93	1971	3.83	1956	3.72	1969	29.26	1957
4.79	1968	3.69	1968	3.42	1966	29.14	1970
4.56	1946	3.53	1970	3.34	1957	29.01	1945
4.08	1948	3.44	1953	3.15	1959	28.94	1944
4.07	1966	3.38	1939	2.90	1964	28.54	1959
3.98	1977	3.31	1954	2.81	1970	28.29	1942
3.83	1940	3.15	1958	2.77	1955	28.29	1965
3.67	1939	2.95	1960	2.56	1941	27.02	1971
3.38	1960	2.92	1973	2.49	1968	26.84	1961
3.36	1950	2.77	1941	2.43	1973	25.70	1947
3.31	1974	2.71	1961	2.40	1967	25.63	1939
3.22	1961	2.33	1955	2.34	1965	24.35	1949
3.22	1976	2.24	1949	2.13	1972	23.76	1966
3.21	1942	2.08	1948	1.98	1946	22.14	1952
3.09	1955	1.95	1947	1.84	1961	21.82	1956
3.09	1963	1.77	1977	1.77	1949	21.60	1948
2.91	1973	1.20	1976	1.41	1950	21.14	1950
2.80	1956	0.99	1946	1.24	1971	20.04	1967
2.64	1965	0.92	1965	1.17	1958	19.97	1963
2.51	1958	0.88	1974	0.98	1948	19.50	1955
2.41	1972	0.57	1940	0.94	1947	19.20	1940
2.07	1959	0.50	1967	0.88	1945	18.68	1974
1.46	1964	0.21	1975	0.49	1963	15.33	1976

Table F-35. Continued

PRECIPITATION DATA IN INCHES AT MILFORD, IOWA.
PERIOD OF RECORD IS 1939 TO 1977. N = 39

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
1.35	1970	0.12	1959	0.41	1976	12.70	1958

Table F-36. PRECIPITATION DATA IN INCHES AT PRIMGHAR, IOWA.
PERIOD OF RECORD IS 1937 TO 1977. N = 41

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
8.76	1971	9.11	1950	12.26	1975	43.54	1951
8.13	1974	7.25	1977	10.33	1974	37.99	1975
7.86	1953	7.07	1962	8.96	1973	37.97	1944
7.58	1943	6.97	1951	8.11	1944	37.80	1977
7.12	1947	6.57	1969	6.97	1951	35.08	1973
6.75	1967	6.12	1944	6.21	1960	32.57	1938
6.67	1954	5.71	1938	6.19	1937	32.47	1953
6.40	1975	5.50	1973	6.06	1959	32.07	1968
6.11	1944	5.16	1972	5.82	1952	31.48	1965
5.97	1940	4.59	1957	5.82	1957	31.41	1974
5.96	1957	4.51	1943	5.44	1954	31.19	1957
5.83	1945	4.42	1963	5.30	1939	30.62	1959
5.60	1941	4.32	1961	5.14	1962	30.48	1947
5.51	1948	4.26	1956	4.92	1953	30.32	1943
5.50	1942	3.92	1937	4.60	1943	30.09	1937
5.01	1952	3.67	1945	4.40	1942	30.01	1954
4.83	1951	3.61	1971	4.25	1972	29.95	1972
4.55	1958	3.42	1952	4.24	1940	29.64	1960
4.25	1946	3.16	1964	3.60	1977	29.49	1969
4.14	1962	3.01	1948	3.58	1956	29.45	1962
4.14	1965	3.00	1940	3.53	1969	29.38	1946
4.03	1966	2.91	1974	3.48	1964	29.37	1971
4.01	1976	2.88	1955	2.91	1963	29.27	1940
4.00	1968	2.41	1942	2.53	1966	27.88	1945
3.87	1950	2.40	1976	2.44	1945	27.68	1942
3.58	1969	2.37	1954	2.31	1961	27.13	1964
3.51	1959	2.26	1953	2.29	1968	26.94	1950
3.44	1963	2.16	1939	2.15	1948	26.43	1970
3.20	1964	2.12	1949	2.06	1946	25.91	1961
3.08	1955	2.10	1968	1.91	1965	25.80	1941
2.97	1977	1.98	1958	1.88	1967	24.51	1952
2.87	1961	1.86	1970	1.77	1949	22.51	1956
2.76	1939	1.72	1960	1.27	1938	22.12	1949
2.73	1973	1.56	1966	1.11	1955	22.09	1948
2.57	1949	1.50	1941	0.89	1941	20.92	1966
2.54	1938	1.38	1946	0.86	1958	19.66	1976
2.44	1960	1.08	1965	0.84	1976	19.29	1955
2.38	1937	0.45	1967	0.81	1971	19.20	1963

Table F-36. PRECIPITATION DATA IN INCHES AT PRIMGHAR, IOWA.
Continued PERIOD OF RECORD IS 1937 TO 1977. N = 41

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.14	1970	0.19	1975	0.73	1950	18.30	1939
2.10	1956	0.16	1947	0.73	1970	17.86	1967
2.00	1972	0.07	1959	0.53	1947	14.96	1958

Table F-37. PRECIPITATION DATA IN INCHES AT ROCK RAPIDS, IOWA.
PERIOD OF RECORD IS 1904 TO 1977. N = 74

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
10.17	1943	8.27	1944	8.16	1959	41.69	1944
9.17	1905	7.02	1915	8.09	1975	38.18	1951
8.13	1967	6.27	1964	7.25	1928	36.63	1905
7.82	1914	6.04	1907	6.99	1944	36.29	1977
7.57	1909	6.04	1918	6.71	1933	34.25	1920
7.40	1944	5.94	1950	6.66	1932	33.27	1915
7.30	1934	5.43	1972	6.66	1974	32.90	1918
7.12	1919	5.10	1955	6.45	1957	32.61	1968
7.10	1928	5.07	1948	6.00	1905	32.27	1957
6.97	1957	5.04	1922	5.75	1943	32.18	1919
6.95	1954	4.91	1949	5.50	1977	32.17	1942
6.74	1947	4.89	1934	5.40	1935	32.12	1943
6.70	1945	4.76	1969	5.39	1952	31.31	1938
6.57	1907	4.69	1977	5.38	1923	31.04	1946
6.44	1969	4.63	1909	5.35	1961	30.91	1914
6.32	1975	4.60	1920	5.10	1964	30.64	1909
6.11	1971	4.51	1963	4.95	1915	30.48	1964
6.07	1946	4.36	1957	4.56	1951	30.46	1972
6.07	1951	4.33	1956	4.55	1937	30.32	1927
5.72	1908	4.32	1919	4.54	1953	30.00	1929
5.65	1906	4.27	1971	4.26	1942	29.88	1928
5.62	1953	4.19	1923	4.17	1911	29.87	1975
5.50	1918	4.17	1973	4.06	1921	29.46	1945
5.39	1968	4.15	1912	3.80	1960	29.21	1965
5.24	1942	4.05	1962	3.74	1956	29.18	1959
5.23	1920	4.04	1932	3.69	1926	28.80	1923
5.20	1939	3.95	1904	3.65	1906	28.53	1932
5.18	1941	3.90	1943	3.60	1931	27.76	1960
5.07	1950	3.81	1911	3.57	1914	27.68	1949
5.01	1948	3.81	1939	3.57	1939	27.37	1908
4.98	1952	3.71	1968	3.56	1936	27.24	1933
4.85	1930	3.55	1951	3.53	1962	26.89	1953
4.81	1924	3.36	1908	3.51	1918	26.46	1954
4.75	1925	3.36	1938	3.38	1920	26.46	1961
4.63	1962	3.14	1958	3.26	1967	26.12	1906
4.60	1917	3.12	1910	3.15	1929	25.86	1973
4.45	1940	3.11	1929	3.11	1940	25.59	1962
4.01	1915	3.10	1952	3.07	1954	25.58	1948

Table F-37. PRECIPITATION DATA IN INCHES AT ROCK RAPIDS, IOWA.
Continued PERIOD OF RECORD IS 1904 TO 1977. N = 74

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.01	1963	2.81	1942	3.06	1966	25.03	1941
4.01	1972	2.80	1926	2.86	1949	25.00	1935
3.88	1923	2.76	1945	2.68	1945	24.99	1969
3.84	1935	2.76	1954	2.59	1924	24.67	1947
3.64	1958	2.64	1935	2.52	1934	24.45	1926
3.39	1916	2.63	1905	2.40	1904	24.45	1971
3.32	1955	2.60	1941	2.13	1972	24.29	1950
3.27	1956	2.48	1953	2.04	1946	23.80	1911
3.18	1937	2.45	1927	1.95	1922	23.57	1922
3.17	1961	2.41	1913	1.95	1948	23.38	1934
3.11	1977	2.41	1914	1.94	1965	23.16	1930
3.09	1965	2.40	1933	1.90	1912	22.92	1940
2.98	1913	2.19	1916	1.83	1925	22.38	1921
2.97	1926	2.10	1921	1.61	1963	22.27	1952
2.95	1966	2.06	1966	1.53	1973	22.23	1907
2.92	1938	2.01	1965	1.51	1968	22.18	1937
2.67	1949	1.92	1925	1.51	1969	22.11	1939
2.52	1964	1.88	1946	1.48	1910	21.88	1936
2.42	1929	1.86	1917	1.44	1919	21.67	1917
2.42	1960	1.82	1976	1.44	1971	21.38	1970
2.35	1970	1.80	1940	1.35	1908	21.30	1924
2.30	1904	1.69	1931	1.24	1916	21.10	1916
2.25	1936	1.68	1924	1.21	1913	21.08	1967
2.12	1932	1.60	1960	1.05	1907	21.07	1931
2.05	1931	1.44	1928	0.99	1950	20.98	1956
1.99	1927	1.41	1937	0.95	1930	20.35	1966
1.96	1974	1.40	1967	0.95	1976	19.59	1913
1.95	1911	1.37	1961	0.88	1941	18.55	1925
1.93	1976	1.36	1970	0.87	1917	18.47	1955
1.90	1910	0.92	1906	0.77	1947	18.36	1963
1.66	1921	0.80	1930	0.76	1955	17.01	1974
1.65	1959	0.80	1975	0.75	1909	16.27	1912
1.62	1973	0.79	1936	0.73	1927	16.20	1904
1.55	1922	0.72	1974	0.70	1938	15.78	1958
1.50	1933	0.21	1959	0.65	1958	15.08	1910
0.78	1912	0.15	1947	0.30	1970	13.58	1976

Table F-38. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.

PERIOD OF RECORD IS 1893 TO 1977. N = 85

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
13.30	1967	12.61	1902	10.66	1951	44.51	1973
10.86	1919	12.02	1938	9.51	1962	43.41	1951
8.68	1954	8.65	1905	8.13	1937	42.77	1902
8.00	1941	7.56	1907	8.03	1902	41.27	1915
7.92	1943	7.38	1915	7.89	1895	39.94	1938
7.88	1931	7.36	1972	7.10	1923	39.69	1931
7.86	1957	7.26	1903	7.09	1940	39.12	1896
7.64	1947	6.78	1973	6.82	1954	38.91	1945
6.83	1944	6.74	1896	6.73	1908	38.74	1972
6.75	1895	6.37	1942	6.46	1900	37.56	1965
6.49	1900	5.66	1940	6.16	1903	36.81	1954
6.20	1894	5.63	1900	6.12	1977	36.53	1968
6.04	1924	5.47	1970	5.83	1944	36.24	1903
5.97	1950	5.19	1934	5.76	1974	35.47	1905
5.95	1911	5.19	1962	5.72	1943	34.71	1957
5.92	1972	4.91	1908	5.68	1960	34.64	1919
5.70	1966	4.89	1952	5.48	1904	34.21	1900
5.67	1926	4.87	1957	5.16	1924	34.19	1975
5.63	1902	4.85	1964	5.08	1968	33.92	1911
5.54	1969	4.80	1921	5.02	1932	33.56	1943
5.51	1935	4.66	1958	4.63	1920	33.49	1977
5.50	1952	4.65	1943	4.58	1912	32.73	1908
5.46	1951	4.59	1909	4.44	1931	32.50	1962
5.45	1907	4.43	1933	4.42	1956	32.17	1944
5.33	1930	4.35	1961	4.29	1928	31.85	1909
5.28	1975	4.30	1950	4.20	1898	31.74	1895
5.20	1893	4.27	1944	4.11	1939	31.21	1959
5.19	1923	4.19	1922	4.06	1934	30.59	1926
5.07	1917	4.19	1945	4.00	1945	30.56	1907
4.95	1896	4.13	1951	3.99	1972	30.33	1912
4.81	1925	3.97	1963	3.93	1911	30.13	1914
4.77	1904	3.92	1955	3.80	1948	30.02	1922
4.76	1958	3.61	1914	3.60	1894	29.81	1894
4.63	1908	3.57	1971	3.54	1910	29.80	1940
4.58	1973	3.51	1932	3.54	1921	29.74	1967
4.49	1920	3.49	1929	3.46	1905	29.38	1970
4.48	1962	3.47	1968	3.38	1925	29.37	1923
4.45	1946	3.45	1928	3.32	1964	29.16	1942

Table F-38. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.
Continued PERIOD OF RECORD IS 1893 TO 1977. N = 85

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.40	1968	3.40	1897	3.29	1975	28.84	1946
4.36	1953	3.21	1948	3.25	1933	28.74	1932
4.34	1942	3.15	1904	3.24	1967	28.67	1941
4.31	1899	3.03	1939	3.21	1966	28.64	1937
4.29	1945	2.90	1918	3.17	1922	28.50	1961
4.24	1909	2.76	1894	3.11	1907	28.48	1920
4.20	1903	2.72	1920	3.08	1930	28.12	1947
4.20	1932	2.65	1969	3.08	1938	27.94	1918
4.18	1977	2.64	1912	3.06	1926	27.54	1898
4.00	1939	2.57	1976	2.92	1916	27.54	1935
3.95	1928	2.52	1925	2.83	1963	27.49	1952
3.91	1940	2.51	1924	2.79	1899	27.39	1913
3.83	1898	2.47	1919	2.75	1957	26.93	1928
3.76	1948	2.38	1967	2.62	1965	26.90	1971
3.64	1937	2.38	1977	2.59	1927	26.83	1899
3.60	1914	2.33	1926	2.54	1949	26.71	1948
3.59	1961	2.28	1966	2.52	1941	25.73	1904
3.57	1912	2.25	1960	2.43	1959	25.56	1930
3.57	1918	2.21	1949	2.28	1919	24.97	1934
2.99	1963	2.14	1954	2.26	1970	24.92	1924
2.81	1929	2.12	1893	2.22	1913	24.85	1950
2.72	1959	2.10	1913	2.10	1952	24.54	1964
2.70	1974	1.95	1895	2.09	1936	24.35	1901
2.68	1906	1.93	1974	2.08	1935	23.92	1969
2.62	1956	1.91	1956	2.05	1893	23.90	1974
2.60	1915	1.81	1975	2.03	1961	23.64	1963
2.56	1971	1.80	1937	2.01	1914	23.63	1906
2.45	1916	1.76	1965	1.99	1929	23.34	1921
2.44	1949	1.69	1931	1.98	1953	23.16	1949
2.34	1965	1.55	1898	1.90	1917	22.98	1960
2.26	1964	1.55	1923	1.85	1896	22.66	1916
2.25	1897	1.53	1911	1.83	1918	22.64	1933
2.25	1970	1.51	1935	1.80	1942	22.57	1897
2.24	1960	1.27	1899	1.78	1973	22.19	1927
2.16	1936	1.23	1947	1.69	1906	22.11	1893
2.11	1934	1.19	1927	1.67	1950	21.75	1925
2.07	1905	1.17	1941	1.46	1955	21.11	1956
2.05	1901	1.07	1910	1.46	1971	21.02	1929

Table F-38. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.
Continued PERIOD OF RECORD IS 1893 TO 1977. N = 85

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.03	1938	1.03	1953	1.45	1897	20.92	1966
1.74	1955	0.99	1906	1.27	1946	20.76	1953
1.53	1927	0.95	1936	1.25	1969	19.66	1939
1.41	1976	0.93	1917	1.22	1915	19.22	1917
1.39	1910	0.86	1946	1.21	1901	18.73	1976
1.34	1922	0.83	1930	0.64	1958	18.13	1936
1.30	1913	0.64	1959	0.42	1947	17.44	1958
1.13	1921	0.48	1916	0.40	1976	16.95	1955
0.56	1933	0.35	1901	0.29	1909	14.75	1910

Table F-39. PRECIPITATION DATA IN INCHES AT SANBORN, IOWA.
PERIOD OF RECORD IS 1915 TO 1977. N = 63

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
9.23	1953	7.70	1950	10.34	1974	46.02	1951
8.93	1971	7.29	1943	8.72	1928	37.51	1938
8.02	1954	6.78	1977	8.40	1975	36.46	1944
7.25	1943	6.73	1935	8.08	1951	36.13	1937
7.25	1975	6.15	1944	7.58	1932	35.89	1965
6.89	1934	5.87	1963	6.42	1952	35.32	1918
6.83	1919	5.83	1969	6.29	1960	34.99	1919
6.79	1951	5.82	1972	6.15	1937	33.70	1977
6.68	1945	5.63	1951	6.05	1973	33.61	1968
6.18	1957	5.58	1937	5.96	1944	32.77	1946
6.17	1944	5.38	1962	5.95	1942	32.64	1926
6.15	1940	5.30	1938	5.46	1939	32.20	1964
5.87	1967	5.20	1952	4.94	1918	32.19	1943
5.62	1950	5.03	1915	4.90	1962	32.08	1975
5.50	1947	5.01	1934	4.86	1969	32.04	1935
5.41	1917	4.87	1918	4.71	1915	32.01	1953
4.99	1930	4.40	1945	4.70	1923	31.75	1960
4.93	1923	4.33	1964	4.67	1943	31.56	1920
4.91	1935	4.28	1920	4.64	1977	31.20	1917
4.90	1942	4.22	1939	4.62	1956	31.17	1954
4.88	1941	4.14	1931	4.57	1953	30.58	1942
4.86	1918	4.13	1919	4.40	1959	30.54	1947
4.63	1968	4.01	1926	4.05	1926	29.91	1959
4.58	1928	3.89	1955	4.00	1940	29.52	1945
4.52	1939	3.87	1933	3.90	1924	29.45	1915
4.40	1946	3.73	1968	3.74	1933	29.30	1973
4.29	1929	3.59	1922	3.73	1966	29.14	1950
4.24	1938	3.58	1948	3.67	1954	28.57	1932
4.14	1964	3.50	1917	3.58	1957	28.50	1929
4.13	1958	3.42	1956	3.57	1964	28.28	1940
4.12	1916	3.40	1927	3.43	1936	28.25	1923
4.11	1932	3.40	1973	3.41	1922	27.40	1941
4.08	1952	3.08	1958	3.33	1946	27.37	1972
4.00	1924	3.04	1929	3.20	1929	27.32	1927
3.94	1937	3.03	1961	3.13	1921	27.06	1962
3.85	1965	2.98	1957	3.11	1967	27.03	1971
3.76	1921	2.91	1971	3.08	1968	27.01	1957
3.69	1915	2.77	1942	3.05	1919	26.73	1922

Table F-39. PRECIPITATION DATA IN INCHES AT SANBORN, IOWA.

Continued PERIOD OF RECORD IS 1915 TO 1977. N = 63

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
3.60	1948	2.68	1940	2.91	1931	26.57	1916
3.48	1920	2.56	1949	2.75	1934	26.38	1931
3.33	1963	2.56	1966	2.75	1935	26.32	1961
3.23	1966	2.51	1924	2.51	1916	26.24	1934
3.20	1949	2.41	1953	2.40	1965	25.87	1928
3.19	1955	2.38	1954	2.40	1972	25.78	1969
3.17	1962	2.14	1916	2.26	1917	25.51	1949
3.09	1925	1.97	1946	2.21	1948	24.36	1933
2.93	1976	1.95	1941	2.21	1961	24.34	1970
2.82	1959	1.90	1923	2.21	1963	24.21	1952
2.75	1969	1.89	1960	2.01	1941	24.10	1921
2.69	1974	1.83	1976	1.80	1920	24.06	1930
2.62	1931	1.74	1928	1.61	1945	23.92	1936
2.61	1973	1.41	1965	1.61	1949	23.13	1948
2.61	1977	1.31	1932	1.54	1950	23.03	1974
2.44	1961	1.28	1921	1.45	1938	22.94	1939
2.40	1956	1.15	1936	1.43	1971	22.04	1924
2.38	1936	1.11	1970	1.29	1955	21.53	1956
2.09	1960	0.80	1925	1.24	1947	21.25	1966
1.93	1970	0.77	1930	1.08	1927	20.97	1963
1.92	1927	0.63	1974	1.01	1930	20.47	1955
1.89	1922	0.54	1947	0.98	1958	17.88	1976
1.79	1972	0.51	1967	0.94	1976	17.57	1967
1.62	1926	0.41	1975	0.85	1970	16.17	1958
0.87	1933	0.35	1959	0.61	1925	13.77	1925

Table F-40. PRECIPITATION DATA IN INCHES AT SHELDON, IOWA.

PERIOD OF RECORD IS 1926 TO 1977. N = 52

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
10.49	1953	6.89	1951	8.08	1928	46.02	1951
9.09	1951	6.70	1972	7.71	1960	39.34	1944
9.05	1971	6.39	1964	7.47	1974	34.27	1953
8.29	1975	6.38	1969	7.46	1944	33.24	1942
7.95	1943	6.19	1977	7.39	1973	33.23	1977
7.27	1967	6.03	1944	7.35	1932	32.51	1960
7.11	1944	5.51	1934	6.80	1975	32.13	1973
7.04	1954	5.33	1973	5.64	1937	31.89	1946
6.75	1940	5.29	1950	5.42	1951	31.73	1965
6.66	1957	5.25	1962	5.39	1942	31.25	1975
6.20	1941	5.22	1943	5.22	1962	31.02	1959
6.16	1942	4.83	1933	4.85	1952	30.63	1938
5.98	1934	4.62	1952	4.74	1953	29.98	1972
5.71	1947	4.51	1956	4.60	1959	29.89	1937
5.63	1946	4.51	1963	4.50	1943	29.60	1964
5.32	1950	4.39	1938	4.13	1977	29.14	1928
5.17	1930	4.03	1935	3.92	1957	28.80	1957
4.90	1945	3.90	1948	3.91	1964	28.55	1932
4.84	1928	3.61	1942	3.89	1967	28.49	1947
4.55	1974	3.58	1939	3.84	1929	28.40	1943
4.41	1959	3.29	1928	3.75	1931	28.14	1968
4.11	1948	3.15	1929	3.75	1936	27.56	1929
4.04	1937	3.12	1945	3.69	1956	27.37	1962
4.03	1952	3.09	1926	3.66	1940	27.10	1954
4.01	1929	3.07	1957	3.57	1969	27.09	1969
3.87	1935	3.05	1958	3.52	1939	26.99	1926
3.80	1962	2.93	1937	3.39	1946	26.73	1971
3.76	1932	2.88	1968	3.38	1966	26.19	1941
3.62	1966	2.83	1954	3.31	1926	26.18	1945
3.52	1965	2.71	1931	3.25	1934	25.74	1935
3.43	1958	2.59	1955	3.15	1935	25.59	1927
3.40	1956	2.56	1971	3.15	1961	25.02	1940
3.31	1969	2.52	1976	3.03	1933	24.72	1970
3.22	1939	2.51	1961	3.01	1947	24.65	1934
3.10	1973	2.25	1970	2.96	1972	23.97	1930
2.96	1976	2.22	1946	2.90	1954	23.82	1931
2.87	1938	2.12	1953	2.44	1949	23.67	1950
2.85	1961	2.09	1940	2.37	1963	23.12	1961

Table F-40. PRECIPITATION DATA IN INCHES AT SHELDON, IOWA.
Continued PERIOD OF RECORD IS 1926 TO 1977. N = 52

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.74	1964	1.83	1941	2.18	1945	22.92	1952
2.67	1972	1.77	1949	1.86	1965	22.89	1933
2.55	1955	1.74	1966	1.47	1968	22.89	1974
2.48	1960	1.73	1927	1.25	1930	22.43	1948
2.45	1931	1.59	1960	1.22	1941	21.98	1949
2.21	1968	1.46	1936	1.17	1948	21.78	1936
2.19	1963	1.39	1932	1.01	1971	21.76	1956
2.18	1927	1.31	1974	0.90	1958	20.90	1966
2.05	1977	1.30	1965	0.84	1927	20.54	1967
2.03	1926	0.99	1947	0.82	1976	18.64	1963
2.02	1949	0.57	1967	0.73	1950	18.36	1976
1.53	1936	0.34	1959	0.66	1938	18.28	1939
1.48	1970	0.28	1930	0.62	1955	15.84	1955
0.96	1933	0.27	1975	0.62	1970	15.41	1958

Table F-41. PRECIPITATION DATA IN INCHES AT SIBLEY, IOWA.

PERIOD OF RECORD IS 1936 TO 1977. N = 42

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
10.60	1954	8.68	1950	11.32	1975	37.60	1938
10.42	1953	6.75	1956	9.72	1974	36.72	1953
8.93	1943	6.49	1949	6.54	1944	35.97	1944
8.66	1947	6.24	1972	6.33	1956	35.59	1957
7.46	1944	5.62	1957	6.19	1957	35.38	1977
7.34	1967	5.60	1962	6.04	1966	35.33	1951
6.45	1957	5.53	1963	5.91	1959	35.02	1965
6.31	1975	5.51	1944	5.37	1942	32.99	1968
6.07	1971	5.42	1970	5.26	1937	32.71	1964
6.00	1952	5.39	1938	5.26	1953	31.72	1960
5.94	1963	5.34	1964	4.82	1977	31.59	1942
5.71	1945	5.24	1951	4.58	1960	31.33	1975
5.28	1951	5.04	1943	4.56	1962	31.06	1954
5.24	1941	4.97	1969	4.48	1967	30.20	1959
5.13	1940	4.95	1977	4.37	1952	29.81	1937
5.04	1969	4.46	1953	4.18	1949	29.70	1947
4.92	1948	4.29	1948	4.01	1943	29.31	1962
4.64	1938	4.14	1945	3.99	1947	28.70	1972
4.54	1939	3.80	1937	3.91	1951	28.57	1956
4.43	1946	3.64	1954	3.73	1969	28.53	1943
4.35	1937	3.46	1939	3.55	1964	28.51	1949
4.15	1942	3.45	1973	3.05	1968	28.12	1969
3.94	1958	3.22	1942	3.04	1940	27.14	1970
3.85	1965	3.14	1958	2.96	1939	26.96	1946
3.79	1961	3.08	1941	2.81	1936	26.77	1941
3.79	1962	3.03	1955	2.73	1954	25.95	1961
3.77	1968	3.02	1952	2.68	1961	25.93	1973
3.57	1973	2.99	1971	2.47	1965	25.55	1966
3.49	1966	2.62	1968	2.11	1972	25.06	1963
3.44	1972	2.39	1960	2.01	1963	24.97	1945
3.42	1977	2.35	1966	1.93	1973	24.46	1971
3.23	1956	2.33	1961	1.89	1945	24.04	1974
3.13	1959	2.27	1976	1.83	1971	23.31	1948
3.10	1964	2.02	1946	1.44	1958	23.29	1950
3.00	1960	1.69	1965	1.19	1946	22.95	1952
2.94	1970	1.62	1967	1.13	1941	22.90	1967
2.90	1976	1.34	1940	1.11	1948	21.36	1940
2.67	1974	0.88	1974	1.02	1938	20.84	1936

Table F-41. **PRECIPITATION DATA IN INCHES AT SIBLEY, IOWA.**

Continued **PERIOD OF RECORD IS 1936 TO 1977. N = 42**

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.62	1949	0.79	1936	0.68	1950	17.76	1958
2.43	1955	0.13	1975	0.64	1976	17.70	1939
2.28	1950	0.11	1959	0.60	1955	17.28	1976
1.96	1936	0.08	1947	0.59	1970	16.38	1955

Table F-42. PRECIPITATION DATA IN INCHES AT SIOUX CENTER, IOWA.
PERIOD OF RECORD IS 1900 TO 1977. N = 78

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
11.84	1971	12.31	1900	9.96	1928	41.14	1951
10.94	1944	7.75	1904	7.89	1959	39.48	1944
8.87	1905	7.74	1909	7.36	1924	38.98	1900
8.85	1954	6.90	1952	7.00	1942	36.58	1906
8.54	1953	6.42	1972	6.57	1952	36.19	1926
8.22	1942	5.92	1933	6.54	1944	34.93	1918
8.05	1975	5.71	1943	6.53	1960	34.78	1942
7.09	1934	5.64	1902	6.34	1932	34.70	1965
6.79	1967	5.57	1955	5.92	1951	34.30	1909
6.43	1974	5.46	1951	5.90	1974	34.16	1908
6.25	1940	5.43	1919	5.77	1906	33.76	1953
6.18	1914	5.31	1957	5.76	1961	33.56	1905
6.16	1941	5.18	1922	5.05	1902	32.80	1960
5.86	1951	5.09	1973	4.94	1937	32.46	1928
5.80	1957	5.05	1942	4.61	1953	32.26	1938
5.71	1943	4.96	1968	4.56	1975	32.05	1959
5.53	1947	4.94	1977	4.46	1901	31.68	1901
5.51	1965	4.87	1950	4.35	1962	31.31	1957
5.47	1935	4.82	1956	4.33	1903	30.35	1919
5.43	1924	4.56	1915	4.26	1946	29.55	1977
5.40	1901	4.40	1962	4.20	1923	29.51	1920
5.35	1962	4.37	1964	4.05	1933	29.49	1927
5.22	1950	4.30	1907	3.99	1964	29.48	1968
5.17	1906	4.24	1925	3.97	1918	29.48	1972
5.01	1918	4.23	1963	3.80	1940	29.26	1915
4.94	1948	4.17	1969	3.61	1912	29.08	1902
4.93	1961	4.13	1944	3.55	1966	28.97	1949
4.85	1928	4.06	1910	3.48	1935	28.81	1903
4.81	1908	4.01	1948	3.46	1956	28.54	1971
4.69	1969	3.96	1934	3.43	1926	28.47	1961
4.65	1925	3.95	1908	3.32	1934	28.22	1975
4.59	1919	3.93	1965	3.29	1922	28.19	1937
4.57	1904	3.80	1928	3.28	1911	27.56	1924
4.54	1923	3.79	1926	3.23	1936	27.55	1921
4.51	1930	3.78	1912	3.20	1900	27.55	1933
4.48	1909	3.76	1949	3.11	1908	27.44	1973
4.43	1937	3.69	1938	3.07	1948	27.38	1946
4.42	1900	3.57	1953	3.06	1969	27.20	1962

Table F-42. PRECIPITATION DATA IN INCHES AT SIOUX CENTER, IOWA.
Continued PERIOD OF RECORD IS 1900 TO 1977. N = 78

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.34	1945	3.41	1940	3.02	1957	27.19	1916
4.11	1972	3.29	1901	3.00	1921	27.15	1970
4.09	1915	3.18	1918	2.90	1943	26.93	1923
4.08	1932	3.10	1929	2.83	1910	26.79	1904
3.98	1946	3.10	1961	2.76	1905	26.61	1922
3.94	1939	3.05	1923	2.75	1949	26.57	1940
3.86	1964	3.02	1921	2.56	1916	26.43	1947
3.85	1956	2.93	1935	2.54	1954	26.13	1950
3.77	1907	2.86	1958	2.49	1915	26.06	1954
3.67	1955	2.75	1945	2.46	1945	25.93	1935
3.54	1917	2.70	1903	2.43	1973	25.54	1948
3.53	1968	2.64	1913	2.42	1920	25.49	1952
3.51	1926	2.52	1960	2.35	1965	25.20	1941
3.47	1963	2.43	1974	2.28	1939	25.11	1932
3.43	1959	2.35	1971	1.88	1907	24.94	1964
3.40	1920	2.31	1920	1.86	1955	24.90	1945
3.34	1931	2.07	1976	1.80	1947	24.78	1969
3.23	1973	2.04	1906	1.77	1963	24.71	1914
3.07	1960	1.95	1937	1.62	1972	24.60	1934
2.99	1903	1.94	1954	1.58	1967	24.19	1943
2.99	1966	1.87	1970	1.56	1917	24.04	1974
2.90	1929	1.85	1924	1.56	1930	23.74	1930
2.83	1958	1.82	1966	1.54	1977	23.58	1913
2.80	1913	1.80	1916	1.48	1929	22.98	1936
2.48	1938	1.67	1936	1.47	1904	22.94	1911
2.44	1916	1.66	1941	1.41	1938	22.56	1956
2.40	1921	1.64	1911	1.34	1914	21.63	1917
2.40	1952	1.53	1939	1.28	1927	21.38	1907
2.11	1927	1.48	1914	1.14	1950	20.62	1912
2.07	1949	1.30	1931	1.09	1913	20.57	1929
1.93	1970	1.10	1917	1.09	1931	20.15	1931
1.83	1936	1.06	1927	1.07	1909	20.12	1966
1.74	1910	0.95	1932	0.97	1919	18.79	1925
1.72	1922	0.83	1947	0.94	1971	17.88	1976
1.63	1902	0.82	1975	0.90	1968	17.83	1963
1.59	1976	0.73	1905	0.86	1958	16.53	1955
1.48	1912	0.70	1967	0.83	1941	16.29	1967
1.45	1911	0.69	1930	0.59	1976	15.79	1958

Table F-42. PRECIPITATION DATA IN INCHES AT SIOUX CENTER, IOWA.
Continued PERIOD OF RECORD IS 1900 TO 1977. N = 78

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
1.23	1977	0.69	1959	0.49	1925	15.55	1910
0.15	1933	0.25	1946	0.48	1970	14.83	1939

Table F-43. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA.
PERIOD OF RECORD IS 1891 TO 1977. N = 87

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
8.78	1967	10.33	1972	7.75	1951	41.10	1903
8.67	1957	8.72	1900	7.60	1923	34.85	1951
8.47	1929	7.45	1915	7.09	1937	34.56	1923
7.63	1962	6.70	1938	7.03	1912	33.72	1972
7.62	1891	6.12	1962	7.00	1961	33.46	1915
7.40	1940	6.00	1964	5.91	1969	33.29	1891
6.81	1954	5.97	1922	5.85	1893	33.22	1900
6.61	1898	5.78	1907	5.78	1960	32.86	1962
6.50	1945	5.77	1891	5.67	1903	32.34	1940
6.42	1941	5.59	1949	5.35	1964	32.03	1957
6.27	1934	5.57	1903	4.91	1899	31.96	1920
6.06	1919	5.54	1896	4.88	1966	31.79	1938
5.90	1953	5.49	1904	4.56	1975	31.66	1905
5.84	1947	5.36	1956	4.35	1963	31.49	1961
5.74	1963	5.17	1952	4.31	1950	31.41	1906
5.71	1969	5.03	1902	4.30	1920	31.13	1949
5.67	1930	4.93	1934	4.28	1908	30.96	1941
5.65	1903	4.92	1969	4.24	1924	30.77	1896
5.65	1915	4.90	1973	4.18	1940	30.54	1912
5.42	1924	4.66	1943	4.17	1944	30.33	1959
5.36	1925	4.52	1958	4.14	1892	29.64	1909
5.34	1975	4.36	1961	3.90	1931	29.16	1919
5.20	1909	4.27	1957	3.62	1949	28.88	1937
5.14	1923	4.18	1944	3.56	1900	28.85	1946
5.11	1937	4.16	1919	3.54	1891	28.81	1970
5.09	1966	4.13	1950	3.54	1926	28.66	1977
4.95	1895	4.09	1909	3.53	1948	28.52	1945
4.95	1932	3.90	1977	3.27	1952	28.39	1965
4.91	1943	3.89	1916	3.27	1974	28.37	1969
4.90	1950	3.89	1920	3.17	1921	27.89	1973
4.83	1942	3.89	1945	3.10	1898	27.63	1927
4.76	1899	3.83	1928	3.02	1909	27.30	1964
4.71	1948	3.69	1910	2.94	1932	27.12	1944
4.70	1901	3.68	1912	2.92	1922	26.81	1929
4.67	1908	3.55	1940	2.86	1911	26.59	1901
4.32	1900	3.50	1955	2.76	1910	26.44	1908
4.32	1944	3.27	1929	2.74	1906	26.38	1892
4.31	1939	3.20	1933	2.68	1904	26.31	1975

Table F-43. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA.
Continued PERIOD OF RECORD IS 1891 TO 1977. N = 87

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.27	1918	3.19	1948	2.67	1928	25.94	1922
4.21	1907	2.99	1951	2.66	1917	25.41	1918
4.04	1946	2.93	1923	2.64	1918	25.36	1960
4.02	1906	2.93	1966	2.64	1962	25.28	1948
4.00	1951	2.87	1924	2.54	1977	24.77	1914
3.91	1914	2.85	1959	2.51	1897	24.68	1954
3.91	1917	2.78	1898	2.33	1916	24.67	1928
3.85	1968	2.73	1908	2.31	1959	24.51	1916
3.84	1977	2.63	1892	2.19	1902	24.26	1926
3.79	1972	2.63	1895	2.19	1946	24.22	1968
3.65	1971	2.61	1932	2.10	1957	24.02	1911
3.54	1973	2.60	1960	2.09	1972	24.00	1931
3.52	1927	2.39	1963	2.00	1935	23.92	1953
3.49	1912	2.37	1906	1.97	1939	23.73	1952
3.46	1904	2.31	1941	1.91	1919	23.55	1930
3.39	1961	2.29	1893	1.90	1927	23.05	1893
3.30	1956	2.26	1897	1.88	1913	23.04	1963
3.28	1974	2.16	1965	1.85	1965	22.95	1943
3.08	1949	2.14	1939	1.84	1905	22.91	1898
3.07	1928	2.08	1918	1.79	1915	22.88	1932
3.06	1920	2.06	1921	1.79	1953	22.82	1924
3.02	1959	2.02	1935	1.75	1901	22.81	1934
2.94	1896	2.02	1967	1.74	1914	22.73	1947
2.91	1955	1.99	1926	1.74	1933	22.67	1899
2.90	1931	1.92	1913	1.68	1894	22.43	1967
2.74	1894	1.89	1970	1.66	1936	21.96	1935
2.71	1964	1.81	1894	1.64	1958	21.70	1950
2.63	1970	1.81	1927	1.56	1942	21.61	1921
2.59	1938	1.74	1931	1.55	1929	21.46	1904
2.55	1905	1.68	1968	1.54	1895	21.45	1966
2.32	1916	1.66	1942	1.54	1954	21.32	1917
2.27	1960	1.61	1937	1.54	1956	20.38	1897
2.16	1935	1.61	1975	1.53	1907	20.31	1913
2.13	1897	1.57	1971	1.52	1968	20.29	1895
2.12	1911	1.56	1911	1.47	1945	20.29	1933
2.11	1952	1.50	1976	1.44	1943	20.14	1902
2.10	1921	1.45	1946	1.35	1967	19.93	1907
2.04	1936	1.43	1925	1.26	1941	19.63	1971

Table F-43. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA.
Continued PERIOD OF RECORD IS 1891 TO 1977. N = 87

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.03	1922	1.41	1905	1.12	1934	19.28	1942
2.02	1902	1.37	1954	1.05	1973	18.30	1958
2.01	1965	1.29	1974	1.01	1970	18.01	1925
1.92	1926	1.24	1901	0.89	1930	17.96	1974
1.90	1933	1.16	1914	0.86	1896	17.84	1894
1.87	1958	1.00	1899	0.71	1925	17.76	1956
1.63	1893	0.85	1917	0.63	1947	17.28	1936
1.50	1892	0.72	1930	0.61	1955	16.96	1939
1.41	1910	0.53	1953	0.59	1938	16.85	1910
0.75	1913	0.41	1947	0.30	1976	14.72	1955
0.75	1976	0.18	1936	0.12	1971	14.33	1976

Table F-44. PRECIPITATION DATA IN INCHES AT SIOUX RAPIDS, IOWA,
PERIOD OF RECORD IS 1942 TO 1977. N = 36

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
11.01	1954	8.58	1962	11.72	1975	39.11	1951
8.38	1967	6.64	1950	7.56	1954	38.70	1959
7.68	1943	6.47	1944	7.19	1944	38.18	1977
7.63	1969	5.68	1977	6.83	1973	37.43	1954
7.44	1944	5.62	1973	6.62	1972	36.96	1973
7.32	1953	5.54	1952	6.59	1945	36.37	1975
7.23	1971	5.47	1951	6.58	1951	35.71	1944
6.77	1947	5.25	1961	6.29	1962	34.02	1945
6.37	1959	5.18	1969	5.86	1959	32.93	1969
6.26	1942	5.18	1972	5.58	1957	32.89	1972
6.03	1951	5.01	1964	5.35	1960	32.88	1957
5.87	1950	4.88	1963	5.24	1953	31.84	1964
5.66	1948	4.72	1943	5.11	1969	31.83	1947
5.35	1957	4.41	1948	4.46	1974	31.82	1968
5.28	1975	4.12	1957	4.26	1948	31.22	1961
4.95	1963	4.00	1947	4.13	1956	30.85	1962
4.76	1977	3.58	1966	3.86	1952	30.56	1946
4.65	1964	3.36	1968	3.43	1964	30.18	1965
4.50	1960	3.20	1971	3.43	1977	28.29	1950
4.49	1945	3.00	1945	3.14	1966	28.14	1953
4.48	1968	2.88	1942	2.86	1949	28.01	1970
4.23	1946	2.80	1956	2.52	1943	27.88	1971
4.16	1961	2.59	1949	2.24	1942	27.55	1943
3.76	1966	2.58	1954	2.20	1968	27.52	1960
3.47	1949	2.27	1955	2.09	1965	27.37	1948
3.22	1962	2.22	1953	2.05	1961	25.52	1942
2.88	1958	2.21	1960	1.90	1963	24.81	1949
2.68	1952	1.98	1958	1.86	1970	21.47	1952
2.63	1976	1.55	1970	1.62	1946	20.68	1963
2.59	1955	1.42	1946	1.27	1947	20.38	1967
2.12	1965	1.25	1959	0.99	1971	19.35	1956
2.04	1972	1.22	1976	0.89	1958	18.00	1966
1.94	1970	1.09	1965	0.85	1950	17.52	1976
1.67	1973	0.64	1975	0.84	1967	16.24	1974
1.42	1956	0.54	1974	0.65	1955	15.18	1955
1.27	1974	0.53	1967	0.56	1976	14.17	1958

Table F-45. PRECIPITATION DATA IN INCHES AT SPENCER, IOWA.

PERIOD OF RECORD IS 1912 TO 1977. N = 66

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
8.92	1943	7.54	1969	12.13	1975	44.15	1951
7.92	1967	6.87	1962	8.71	1944	38.36	1975
7.85	1954	6.77	1951	7.28	1937	38.25	1938
7.80	1934	6.45	1926	6.94	1939	38.03	1969
7.75	1953	6.42	1950	6.65	1954	35.34	1973
7.73	1969	6.31	1971	6.52	1951	35.18	1964
7.53	1940	6.26	1961	6.04	1928	34.78	1954
7.49	1941	6.18	1972	6.03	1969	34.52	1918
6.82	1951	6.00	1964	5.71	1913	34.21	1941
6.54	1975	5.90	1968	5.62	1956	33.98	1919
6.36	1919	5.69	1944	5.59	1962	33.75	1937
6.29	1945	5.55	1920	5.55	1922	33.71	1944
6.28	1935	5.47	1934	5.49	1924	33.43	1977
6.10	1962	5.31	1943	5.20	1923	33.29	1920
5.97	1944	5.25	1918	5.18	1977	32.65	1926
5.78	1942	5.04	1933	4.83	1920	32.12	1959
5.61	1948	4.95	1922	4.62	1964	31.60	1943
5.46	1971	4.93	1963	4.44	1952	31.25	1965
5.45	1928	4.84	1938	4.41	1936	31.02	1962
5.39	1938	4.68	1955	4.38	1931	30.92	1942
5.16	1937	4.24	1925	4.30	1932	30.39	1968
5.12	1947	4.22	1956	4.16	1918	30.23	1931
4.75	1924	4.17	1919	4.15	1965	29.86	1913
4.66	1923	4.13	1942	4.08	1943	29.55	1914
4.65	1925	3.90	1952	4.07	1974	28.47	1935
4.52	1939	3.88	1935	4.06	1933	28.31	1972
4.47	1957	3.68	1915	4.04	1942	28.28	1961
4.43	1949	3.61	1945	4.03	1973	28.26	1971
4.42	1914	3.35	1948	3.65	1959	28.14	1947
4.42	1918	3.16	1912	3.50	1921	27.93	1970
4.24	1952	3.16	1954	3.45	1957	27.82	1950
4.19	1917	3.11	1973	3.43	1960	27.66	1934
3.81	1950	2.97	1949	3.40	1912	27.65	1953
3.77	1958	2.80	1960	3.39	1953	27.23	1927
3.73	1964	2.76	1913	3.36	1940	27.15	1928
3.56	1946	2.75	1941	3.20	1914	27.07	1960
3.53	1926	2.74	1939	3.12	1935	26.98	1946
3.38	1931	2.61	1977	3.03	1948	26.92	1957

Table F-45. PRECIPITATION DATA IN INCHES AT SPENCER, IOWA.

Continued PERIOD OF RECORD IS 1912 TO 1977, N = 66

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
3.26	1916	2.43	1932	2.84	1917	26.89	1922
3.26	1955	2.30	1929	2.83	1934	26.49	1940
3.24	1959	2.27	1953	2.77	1930	26.46	1915
3.21	1936	2.18	1957	2.71	1966	26.35	1945
3.06	1968	2.17	1958	2.56	1926	26.13	1916
2.92	1963	2.13	1917	2.40	1946	25.81	1949
2.72	1976	2.00	1931	2.39	1972	25.59	1917
2.67	1956	2.00	1966	2.35	1916	25.55	1923
2.67	1970	1.84	1916	2.35	1949	25.04	1932
2.64	1974	1.83	1947	2.35	1968	24.96	1948
2.57	1915	1.55	1940	2.31	1963	24.69	1912
2.53	1932	1.54	1965	2.09	1927	23.86	1924
2.49	1972	1.48	1928	2.06	1919	23.71	1929
2.48	1930	1.48	1970	2.03	1929	23.48	1956
2.39	1966	1.45	1914	1.94	1915	23.33	1933
2.22	1960	1.22	1976	1.93	1961	23.26	1936
2.21	1977	1.05	1937	1.71	1941	23.26	1939
2.19	1929	1.05	1946	1.66	1945	22.86	1921
2.10	1965	0.84	1974	1.31	1938	21.97	1952
2.02	1921	0.75	1921	1.30	1970	21.61	1930
2.01	1920	0.69	1924	1.13	1958	20.97	1963
2.01	1973	0.60	1936	1.06	1971	19.86	1967
1.97	1912	0.57	1923	0.89	1967	18.98	1955
1.84	1927	0.47	1927	0.69	1950	18.79	1925
1.60	1913	0.45	1967	0.60	1955	16.99	1966
1.51	1961	0.32	1930	0.56	1976	16.73	1974
1.32	1922	0.22	1975	0.49	1925	16.70	1976
0.59	1933	0.17	1959	0.45	1947	14.41	1958

Table F-46. PRECIPITATION DATA IN INCHES AT STORM LAKE, IOWA.

PERIOD OF RECORD IS 1899 TO 1977. N = 79

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
11.97	1919	10.49	1902	9.20	1962	45.94	1951
10.81	1967	9.16	1900	8.91	1951	40.20	1908
9.63	1908	7.88	1907	7.65	1903	39.02	1915
9.24	1969	7.56	1934	6.71	1930	38.63	1902
8.88	1951	6.97	1944	6.51	1932	38.39	1977
8.41	1954	6.78	1952	5.84	1954	36.94	1900
7.98	1899	6.65	1962	5.69	1908	36.94	1954
7.31	1943	6.22	1938	5.67	1924	36.80	1903
7.30	1923	6.12	1943	5.52	1902	36.36	1938
7.01	1971	6.09	1969	5.44	1906	34.39	1944
6.97	1900	5.98	1945	5.44	1974	34.36	1906
6.71	1942	5.92	1920	5.39	1944	34.31	1975
6.69	1930	5.87	1909	5.37	1907	34.29	1972
6.54	1975	5.83	1903	5.33	1912	34.27	1969
6.46	1946	5.72	1972	5.30	1948	34.24	1973
6.33	1963	5.58	1933	5.20	1977	33.99	1920
6.29	1932	5.45	1915	5.19	1960	33.67	1946
6.29	1941	5.45	1942	5.16	1904	33.66	1968
5.75	1944	5.41	1957	5.04	1937	33.54	1909
5.55	1924	5.26	1908	4.94	1934	33.13	1905
5.37	1902	5.20	1953	4.87	1945	32.89	1945
5.34	1925	5.18	1977	4.70	1972	32.85	1965
5.33	1958	5.13	1951	4.60	1968	32.68	1932
5.20	1905	5.12	1971	4.58	1900	32.14	1912
5.10	1934	5.08	1922	4.57	1973	32.10	1923
5.08	1927	5.06	1958	4.51	1975	31.72	1919
5.08	1947	5.06	1973	4.48	1923	31.42	1959
5.02	1953	4.63	1950	4.46	1928	31.27	1962
5.01	1940	4.38	1964	4.43	1939	31.13	1914
4.97	1948	4.29	1940	4.30	1921	30.68	1943
4.86	1914	4.19	1929	3.97	1915	30.41	1934
4.85	1903	3.90	1912	3.93	1952	30.37	1931
4.43	1918	3.90	1960	3.75	1959	29.79	1948
4.37	1906	3.83	1963	3.67	1957	29.40	1957
4.34	1917	3.82	1914	3.66	1966	29.36	1927
4.30	1968	3.60	1918	3.64	1940	29.24	1941
4.16	1920	3.60	1961	3.52	1961	29.23	1971
4.15	1907	3.51	1968	3.47	1926	29.04	1926

Table F-46. PRECIPITATION DATA IN INCHES AT STORM LAKE, IOWA.

Continued PERIOD OF RECORD IS 1899 TO 1977. N = 79

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.15	1972	3.27	1949	3.43	1964	28.72	1953
4.08	1957	3.10	1970	3.35	1963	28.50	1961
3.95	1938	3.06	1948	3.27	1953	28.22	1967
3.95	1960	2.83	1906	3.01	1967	28.15	1907
3.86	1974	2.82	1911	2.95	1929	27.83	1940
3.84	1915	2.70	1931	2.91	1918	27.82	1942
3.79	1964	2.70	1955	2.83	1956	27.77	1918
3.75	1912	2.66	1917	2.81	1969	27.75	1930
3.75	1937	2.65	1921	2.79	1922	27.55	1911
3.74	1950	2.61	1910	2.75	1917	27.55	1947
3.73	1952	2.61	1967	2.67	1905	27.38	1928
3.66	1904	2.60	1928	2.66	1909	27.09	1913
3.62	1961	2.56	1904	2.66	1910	27.02	1937
3.56	1911	2.46	1956	2.62	1941	26.78	1960
3.48	1909	2.40	1919	2.46	1965	26.60	1964
3.38	1939	2.40	1932	2.38	1935	26.03	1899
3.35	1962	2.07	1926	2.35	1931	26.02	1917
3.31	1945	1.93	1923	2.25	1936	26.00	1922
3.29	1977	1.92	1966	2.25	1946	25.90	1952
3.26	1926	1.84	1974	2.15	1901	25.66	1916
3.26	1928	1.81	1913	2.11	1911	25.53	1929
3.06	1922	1.70	1954	2.06	1916	25.46	1924
2.96	1929	1.67	1901	2.01	1899	24.43	1963
2.95	1976	1.62	1947	1.94	1920	24.19	1904
2.93	1959	1.53	1941	1.93	1943	23.90	1970
2.87	1901	1.46	1935	1.82	1933	22.99	1901
2.86	1949	1.43	1916	1.74	1919	22.92	1935
2.84	1935	1.36	1939	1.71	1950	22.71	1950
2.57	1931	1.33	1965	1.70	1942	22.48	1949
2.51	1936	1.30	1905	1.59	1925	22.35	1974
2.37	1916	1.22	1930	1.52	1913	21.63	1933
2.21	1966	1.20	1927	1.51	1927	20.44	1921
2.04	1965	1.13	1924	1.46	1970	19.96	1936
2.00	1910	1.13	1959	1.33	1938	19.81	1939
1.93	1955	1.12	1925	1.32	1949	17.90	1958
1.86	1970	1.00	1937	1.27	1958	17.05	1966
1.65	1973	0.66	1946	1.03	1971	16.92	1956
1.57	1956	0.63	1976	0.82	1914	16.57	1925

Table F-46. PRECIPITATION DATA IN INCHES AT STORM LAKE, IOWA.
Continued PERIOD OF RECORD IS 1899 TO 1977. N = 79

JUNE		JULY		AUGUST		ANNUAL	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
1.15	1913	0.62	1899	0.81	1947	15.76	1955
1.08	1921	0.56	1975	0.62	1955	14.30	1910
0.33	1933	0.51	1936	0.25	1976	13.90	1976

Table F-47. PRECIPITATION DATA IN INCHES AT AKRON, IOWA.

PERIOD OF RECORD IS 1928 TO 1977. N = 50

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
14.18	1944	13.93	1966	20.34	1944
13.30	1934	11.70	1951	20.22	1951
12.64	1971	11.43	1937	18.41	1966
12.36	1951	11.32	1944	15.97	1940
11.50	1966	10.49	1952	15.54	1962
11.35	1954	9.91	1949	15.53	1934
10.79	1940	9.33	1962	15.09	1969
10.65	1962	9.30	1928	14.09	1953
10.62	1969	8.99	1940	14.06	1952
9.95	1941	8.96	1972	13.92	1967
9.82	1953	8.67	1961	13.73	1949
9.80	1935	8.54	1963	13.63	1937
9.79	1964	8.48	1938	13.51	1954
9.69	1948	8.28	1933	12.94	1971
9.65	1952	8.23	1945	12.63	1945
9.48	1938	8.21	1964	12.61	1957
9.45	1957	8.20	1960	12.60	1950
9.14	1950	8.07	1957	12.59	1948
9.08	1967	7.89	1953	12.57	1963
8.97	1968	7.81	1968	12.56	1964
8.96	1943	7.50	1935	12.55	1928
8.83	1945	7.37	1950	12.27	1968
8.67	1942	7.23	1969	12.03	1938
7.98	1955	6.61	1948	12.00	1935
7.91	1928	6.40	1934	11.35	1961
7.90	1949	5.96	1967	11.22	1941
7.77	1977	5.90	1929	10.98	1960
7.55	1965	5.65	1965	10.86	1975
7.19	1939	5.51	1975	10.62	1965
7.06	1963	5.29	1959	10.03	1942
6.97	1972	5.24	1955	9.88	1972
6.77	1961	5.17	1942	9.71	1943
6.45	1975	5.11	1958	9.65	1939
6.31	1958	5.06	1977	9.40	1929
6.21	1932	4.93	1954	9.26	1977
6.12	1973	4.88	1946	9.07	1955
5.67	1947	4.41	1956	8.95	1933
5.61	1929	4.40	1973	8.68	1932

Table F-47. PRECIPITATION DATA IN INCHES AT AKRON, IOWA.
Continued PERIOD OF RECORD IS 1928 TO 1977. N = 50

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
5.06	1933	4.14	1943	8.29	1946
4.86	1974	3.99	1932	8.12	1959
4.76	1937	3.54	1939	7.37	1947
4.59	1970	3.44	1976	7.05	1958
4.48	1959	3.34	1974	6.96	1973
4.47	1956	3.14	1941	6.91	1974
3.80	1946	2.90	1930	6.73	1956
3.74	1930	2.70	1931	6.63	1930
3.63	1960	2.45	1971	5.89	1970
3.27	1931	2.33	1936	5.02	1931
2.51	1976	2.24	1970	4.05	1936
2.14	1936	2.15	1947	4.04	1976

Table F-48. PRECIPITATION DATA IN INCHES AT ALTON, IOWA.
PERIOD OF RECORD IS 1906 TO 1977. N = 72

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
12.57	1909	14.69	1944	19.92	1944
12.32	1944	11.85	1951	16.49	1942
12.15	1942	10.97	1962	16.33	1948
11.47	1953	10.80	1948	16.28	1951
10.84	1945	10.76	1960	15.69	1954
10.75	1948	10.14	1928	15.53	1953
10.54	1934	9.34	1961	15.47	1962
10.43	1943	8.74	1964	14.35	1961
10.31	1962	8.53	1942	14.33	1934
10.09	1915	8.52	1965	14.19	1945
9.92	1907	8.44	1922	14.11	1928
9.64	1954	8.43	1918	13.56	1909
9.51	1951	8.27	1910	13.41	1960
9.35	1957	8.24	1953	13.34	1940
9.34	1919	8.19	1956	13.27	1957
9.31	1967	8.19	1907	13.13	1918
9.13	1964	8.19	1972	12.87	1943
9.07	1950	8.18	1957	12.75	1907
8.99	1928	8.14	1908	12.72	1932
8.98	1973	8.05	1954	12.49	1908
8.89	1940	8.01	1969	12.44	1974
8.85	1941	7.96	1915	12.36	1915
8.77	1972	7.87	1952	12.08	1964
8.54	1908	7.73	1959	11.76	1965
8.34	1965	7.60	1909	11.74	1919
8.29	1947	7.52	1934	11.68	1969
8.17	1932	7.49	1920	11.53	1906
8.02	1971	7.48	1945	11.39	1952
7.98	1918	7.44	1974	11.00	1939
7.91	1952	7.41	1973	10.98	1931
7.83	1935	7.40	1933	10.95	1950
7.80	1956	7.29	1931	10.95	1959
7.80	1961	7.29	1977	10.92	1923
7.77	1963	7.13	1939	10.88	1920
7.72	1968	7.11	1906	10.81	1956
7.70	1969	7.06	1932	10.76	1967
7.68	1920	6.91	1913	10.55	1972
7.50	1939	6.85	1919	10.54	1973

Table F-48. PRECIPITATION DATA IN INCHES AT ALTON, IOWA.
Continued PERIOD OF RECORD IS 1906 TO 1977. N = 72

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
7.27	1914	6.74	1926	10.52	1947
7.01	1977	6.72	1950	10.24	1935
6.59	1946	6.71	1940	10.19	1924
6.45	1923	6.54	1923	10.11	1922
6.23	1975	6.26	1943	9.76	1963
6.22	1906	6.22	1963	9.67	1941
6.19	1966	6.18	1937	9.53	1910
6.17	1974	6.11	1924	9.38	1946
6.16	1917	6.00	1911	9.24	1926
6.12	1933	5.97	1938	9.12	1975
5.99	1916	5.85	1912	9.12	1914
5.80	1922	5.75	1955	9.01	1929
5.76	1931	5.74	1921	9.00	1913
5.75	1913	5.64	1968	8.82	1977
5.72	1925	5.40	1935	8.61	1966
5.54	1929	5.16	1929	8.57	1971
5.49	1930	4.78	1916	8.51	1968
5.38	1926	4.53	1946	8.47	1937
5.21	1955	4.51	1966	8.43	1933
5.14	1938	4.12	1936	8.17	1917
5.10	1910	4.07	1927	7.97	1955
5.01	1912	4.02	1975	7.75	1938
4.97	1924	3.98	1949	7.71	1911
4.95	1970	3.79	1914	7.62	1912
4.82	1958	3.70	1917	7.59	1916
4.77	1949	3.55	1958	7.16	1930
4.46	1960	3.45	1971	6.84	1949
3.96	1927	2.90	1970	6.30	1921
3.80	1921	2.82	1947	6.09	1927
3.77	1959	2.79	1925	6.03	1925
3.66	1937	2.46	1967	5.85	1970
3.60	1911	2.30	1976	5.79	1936
3.01	1936	2.28	1941	5.54	1958
2.95	1976	2.06	1930	3.57	1976

Table F-49. PRECIPITATION DATA IN INCHES AT CHEROKEE, IOWA,
PERIOD OF RECORD IS 1922 TO 1977. N = 56

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
16.46	1953	12.71	1962	21.39	1953
16.31	1944	12.24	1944	20.39	1944
13.92	1957	12.18	1938	17.89	1962
13.77	1943	11.73	1951	17.64	1951
13.44	1938	11.48	1937	17.31	1957
12.72	1962	10.88	1945	17.26	1934
12.25	1934	10.71	1952	16.52	1945
11.67	1950	10.46	1934	16.29	1938
11.42	1968	9.87	1953	15.85	1969
11.41	1969	9.64	1968	15.57	1968
10.98	1967	9.43	1957	15.29	1940
10.40	1961	9.33	1948	14.78	1943
10.20	1942	9.23	1960	14.73	1954
10.17	1971	9.01	1940	14.47	1937
10.14	1945	8.67	1950	14.38	1961
9.92	1940	8.55	1961	14.17	1952
9.80	1951	8.53	1931	13.74	1948
9.74	1952	8.51	1959	13.68	1924
9.42	1947	8.17	1977	13.61	1967
9.40	1954	8.06	1933	13.45	1959
9.10	1977	7.84	1922	12.80	1950
8.41	1931	7.73	1924	12.72	1977
8.38	1941	7.66	1969	11.81	1923
8.31	1948	7.63	1964	11.78	1942
8.24	1926	7.59	1932	11.75	1974
7.92	1964	7.41	1972	11.15	1960
7.82	1925	7.07	1974	11.07	1932
7.56	1924	7.01	1963	10.83	1971
7.07	1970	6.82	1942	10.78	1931
7.02	1922	6.81	1973	10.77	1926
6.92	1937	6.79	1923	10.60	1947
6.81	1973	6.74	1939	10.41	1941
6.69	1963	6.74	1966	10.35	1975
6.52	1933	6.19	1943	10.25	1964
6.47	1929	6.11	1970	10.05	1922
6.43	1959	6.10	1954	9.94	1966
6.38	1923	6.03	1926	9.74	1939
6.35	1974	5.28	1929	9.52	1963

Table F-49. PRECIPITATION DATA IN INCHES AT CHEROKEE, IOWA.
Continued PERIOD OF RECORD IS 1922 TO 1977. N = 56

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
6.32	1949	5.16	1928	8.96	1933
6.08	1955	4.97	1975	8.93	1929
5.87	1966	4.55	1955	8.78	1972
5.84	1972	4.54	1956	8.76	1925
5.79	1975	4.23	1927	8.57	1973
5.63	1939	4.10	1941	8.48	1970
5.60	1932	3.97	1967	7.47	1928
5.45	1927	3.92	1965	7.32	1949
4.84	1960	3.78	1935	7.05	1927
4.72	1928	3.62	1971	6.41	1935
4.63	1958	3.41	1925	6.29	1946
4.56	1935	3.20	1958	6.19	1955
4.56	1930	3.13	1949	5.94	1965
3.93	1946	3.08	1946	5.74	1958
3.42	1965	2.37	1936	5.67	1956
3.36	1956	2.22	1930	5.66	1930
2.68	1936	2.00	1947	4.85	1936
2.28	1976	1.18	1976	2.69	1976

Table F-50. PRECIPITATION DATA IN INCHES AT HAWARDEN, IOWA.

PERIOD OF RECORD IS 1927 TO 1977. N = 51

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
14.59	1953	12.60	1951	20.04	1944
13.77	1944	12.57	1944	18.93	1953
13.19	1962	11.86	1952	18.81	1962
11.43	1965	11.52	1962	18.01	1951
11.30	1957	11.45	1966	16.43	1969
11.13	1950	10.63	1969	14.61	1966
11.07	1972	10.08	1933	14.37	1945
10.83	1934	9.88	1928	14.27	1934
10.50	1954	9.68	1953	14.17	1957
10.15	1969	9.49	1945	14.08	1952
10.13	1945	8.62	1957	13.93	1965
9.85	1942	8.52	1972	13.80	1928
9.73	1951	7.90	1948	12.65	1948
9.65	1943	7.86	1960	12.43	1954
9.36	1967	7.84	1943	12.33	1972
8.78	1941	7.15	1975	12.21	1942
8.59	1971	6.91	1934	12.18	1967
8.58	1940	6.70	1932	12.02	1950
8.50	1966	6.57	1961	11.76	1975
8.48	1952	6.38	1950	11.59	1943
8.01	1929	6.36	1963	11.16	1933
7.65	1935	6.29	1929	10.98	1940
7.52	1948	5.76	1964	10.78	1974
7.40	1955	5.72	1937	10.14	1947
7.17	1928	5.71	1956	10.13	1960
7.09	1968	5.56	1942	9.82	1971
7.08	1964	5.45	1940	9.73	1935
6.81	1974	5.45	1968	9.73	1964
6.65	1973	5.39	1959	9.71	1929
6.49	1947	5.19	1958	9.40	1941
6.34	1939	5.12	1949	9.35	1932
6.13	1933	5.09	1974	9.23	1961
5.91	1963	5.05	1965	8.92	1937
5.77	1938	4.94	1947	8.87	1963
5.53	1932	4.94	1967	8.44	1939
5.36	1975	4.91	1973	8.35	1968
5.19	1956	4.80	1977	8.12	1955
5.16	1958	4.72	1938	8.11	1959

Table F-50. PRECIPITATION DATA IN INCHES AT HAWARDEN, IOWA.
Continued PERIOD OF RECORD IS 1927 TO 1977. N = 51

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
5.09	1930	4.65	1935	8.06	1949
4.99	1949	4.12	1954	8.05	1930
4.80	1970	4.10	1939	7.56	1956
4.62	1961	3.58	1946	7.48	1973
4.52	1977	3.53	1936	7.46	1938
4.46	1946	3.26	1931	6.95	1946
4.19	1931	3.16	1927	6.52	1958
4.06	1937	3.11	1970	6.46	1977
3.86	1927	3.08	1930	6.24	1931
3.56	1960	3.01	1971	5.65	1927
3.51	1959	2.97	1955	5.63	1970
2.64	1976	2.88	1976	5.47	1936
2.34	1936	1.81	1941	3.85	1976

Table F-51. PRECIPITATION DATA IN INCHES AT HOLSTEIN, IOWA.

PERIOD OF RECORD IS 1934 TO 1977. N = 44

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
16.02	1944	15.70	1951	22.15	1951
14.79	1967	14.31	1944	21.52	1944
12.87	1934	11.50	1940	17.57	1940
12.32	1963	11.14	1977	17.22	1967
12.22	1950	11.12	1962	15.92	1961
12.01	1954	10.14	1972	15.82	1963
11.72	1957	9.97	1937	15.22	1962
11.39	1940	9.44	1966	14.99	1975
10.77	1943	9.31	1961	14.90	1977
10.76	1961	8.79	1968	14.84	1934
10.73	1952	8.49	1955	14.54	1954
10.06	1968	8.43	1950	14.15	1957
10.06	1971	8.37	1960	14.06	1943
9.94	1977	8.35	1952	13.91	1972
9.93	1972	8.35	1945	13.85	1950
9.89	1942	7.85	1975	13.44	1952
9.50	1958	7.78	1948	13.35	1968
9.42	1955	7.39	1935	13.14	1937
9.12	1951	7.37	1934	12.93	1945
9.03	1973	7.23	1943	12.66	1966
9.01	1941	7.11	1957	11.96	1948
8.76	1962	6.89	1964	11.23	1971
8.74	1969	6.77	1963	11.13	1942
8.60	1947	6.65	1939	10.95	1960
8.15	1945	6.49	1973	10.82	1941
8.08	1949	6.42	1974	10.72	1958
8.03	1948	6.31	1958	10.68	1955
7.92	1975	6.18	1949	10.06	1973
7.68	1938	6.18	1956	10.03	1939
7.61	1935	5.60	1971	9.94	1969
6.98	1964	5.37	1941	9.93	1949
6.21	1966	5.34	1970	9.84	1974
6.14	1970	5.32	1965	9.65	1964
5.97	1939	4.88	1942	9.42	1935
5.77	1953	4.65	1953	9.22	1947
4.91	1974	4.33	1954	8.63	1938
4.67	1960	4.31	1938	8.46	1953
4.57	1937	3.85	1959	8.19	1956

Table F-51. PRECIPITATION DATA IN INCHES AT HOLSTEIN, IOWA.
Continued PERIOD OF RECORD IS 1934 TO 1977. N = 44

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.54	1956	3.81	1969	7.50	1970
4.21	1959	3.80	1967	7.40	1965
3.80	1965	2.82	1946	6.86	1959
3.05	1946	2.24	1936	5.37	1946
3.04	1976	1.54	1947	3.53	1936
1.49	1936	1.12	1976	3.19	1976

Table F-52. PRECIPITATION DATA AT IDA GROVE, IOWA,

PERIOD OF RECORD IS 1945 TO 1977, N = 33

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
18.07	1967	21.27	1962	29.03	1951
14.18	1951	19.91	1951	24.93	1962
12.79	1950	9.24	1964	20.14	1967
11.43	1962	9.09	1968	15.03	1972
11.00	1972	8.89	1945	14.84	1950
10.96	1952	8.72	1972	14.13	1964
10.31	1957	8.49	1952	14.12	1966
10.26	1954	8.27	1966	13.78	1968
10.20	1964	8.19	1949	13.70	1952
9.67	1958	8.13	1950	13.53	1975
9.17	1945	8.08	1975	13.49	1954
8.73	1963	7.98	1963	13.41	1957
8.70	1948	7.95	1958	13.04	1963
8.67	1961	7.93	1977	12.38	1977
8.64	1966	7.38	1948	12.20	1958
8.35	1969	7.04	1957	11.61	1945
8.11	1955	6.93	1955	11.56	1948
7.85	1977	6.30	1965	11.23	1961
7.61	1947	6.17	1953	10.51	1953
7.50	1968	6.13	1974	10.49	1969
7.07	1971	6.09	1960	9.94	1949
7.05	1975	6.09	1967	9.27	1960
6.80	1953	5.86	1970	9.23	1955
6.75	1973	5.32	1971	8.85	1974
6.11	1960	5.25	1954	8.72	1946
6.03	1949	5.11	1961	8.55	1959
5.47	1946	5.09	1956	8.55	1965
5.46	1959	4.45	1946	8.38	1971
5.44	1970	4.41	1973	8.35	1947
4.58	1965	3.76	1969	7.63	1956
4.09	1974	3.66	1959	7.45	1973
3.88	1956	1.78	1947	7.28	1970
3.41	1976	1.36	1976	3.92	1976

Table F-53. PRECIPITATION DATA IN INCHES AT INWOOD, IOWA.
PERIOD OF RECORD IS 1904 TO 1972. N = 69

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
13.31	1919	11.31	1944	17.93	1944
12.90	1909	10.93	1933	16.44	1906
12.27	1943	10.83	1939	16.33	1939
11.81	1939	9.32	1949	16.22	1962
11.62	1962	8.83	1928	16.20	1943
11.50	1915	8.64	1915	15.60	1909
11.21	1905	8.62	1962	15.14	1928
10.79	1944	8.60	1960	14.94	1954
10.63	1907	8.50	1906	14.30	1919
10.18	1954	8.05	1922	14.05	1915
10.03	1914	8.04	1956	13.97	1905
9.94	1934	7.99	1910	13.79	1942
9.90	1918	7.92	1951	13.17	1951
9.89	1908	7.75	1972	12.92	1918
9.68	1942	7.46	1959	12.47	1914
9.34	1963	7.43	1963	12.26	1953
9.29	1971	7.41	1932	12.08	1907
9.23	1906	7.29	1943	12.03	1934
9.05	1969	7.22	1953	11.83	1908
8.99	1940	7.18	1921	11.71	1933
8.52	1972	7.10	1907	11.64	1952
8.45	1950	7.08	1952	11.61	1960
8.45	1968	7.07	1909	11.50	1972
8.44	1951	6.98	1923	11.49	1967
8.34	1945	6.97	1942	11.35	1940
8.17	1925	6.76	1966	11.24	1949
8.06	1928	6.57	1969	10.96	1956
8.00	1965	6.56	1961	10.95	1932
7.89	1957	6.48	1918	10.79	1969
7.86	1904	6.48	1929	10.76	1963
7.86	1967	6.44	1934	10.63	1959
7.70	1917	6.41	1945	10.39	1926
7.68	1948	6.28	1964	10.38	1945
7.67	1920	6.07	1911	10.35	1971
7.57	1953	6.04	1954	10.27	1921
7.50	1926	5.82	1919	10.24	1923
7.45	1921	5.80	1937	9.87	1964
7.40	1941	5.77	1948	9.87	1920

Table F-53. PRECIPITATION DATA IN INCHES AT INWOOD, IOWA.
Continued PERIOD OF RECORD IS 1904 TO 1972. N = 69

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
7.30	1956	5.77	1904	9.85	1904
7.05	1929	5.71	1965	9.81	1965
7.00	1949	5.63	1926	9.78	1961
6.90	1938	5.49	1968	9.76	1922
6.70	1952	5.48	1935	9.75	1950
6.61	1913	5.29	1938	9.51	1929
6.61	1964	5.14	1908	9.45	1968
6.34	1922	5.12	1950	9.32	1910
6.17	1947	5.04	1914	9.30	1925
6.13	1935	4.95	1920	9.25	1917
5.90	1916	4.86	1936	9.19	1911
5.85	1923	4.85	1912	9.15	1948
5.77	1955	4.66	1916	8.99	1935
5.61	1930	4.60	1925	8.94	1966
5.46	1911	4.58	1940	8.34	1916
5.41	1946	4.35	1917	8.28	1957
5.38	1933	4.22	1957	8.08	1924
5.37	1924	4.05	1905	8.01	1941
5.18	1961	3.94	1967	7.97	1937
5.15	1932	3.77	1971	7.80	1938
5.13	1966	3.76	1913	7.69	1946
4.86	1910	3.75	1924	7.53	1947
4.53	1958	3.55	1946	7.52	1913
4.35	1912	3.23	1958	6.48	1930
4.35	1970	3.15	1931	6.32	1936
4.28	1960	2.73	1955	6.20	1955
4.12	1931	2.55	1927	6.00	1931
3.92	1937	2.54	1941	5.98	1912
3.51	1959	2.34	1970	4.92	1958
3.31	1927	2.08	1947	4.45	1970
1.82	1936	1.05	1930	4.13	1927

Table F-54. PRECIPITATION DATA IN INCHES AT LAKE PARK, IOWA.

PERIOD OF RECORD IS 1927 TO 1977. N = 51

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
14.98	1943	12.44	1944	19.56	1953
14.55	1953	12.26	1962	19.10	1943
13.63	1962	11.07	1942	19.00	1954
13.37	1954	10.85	1963	17.72	1962
13.12	1963	10.37	1956	16.94	1944
12.93	1969	10.03	1957	16.89	1957
12.67	1957	9.75	1928	15.75	1942
11.33	1942	9.51	1951	15.56	1951
11.07	1952	9.50	1954	15.55	1928
10.96	1951	9.44	1937	15.51	1975
10.77	1938	9.31	1935	15.09	1969
9.96	1944	9.18	1969	14.66	1963
9.78	1934	9.16	1964	14.19	1935
9.46	1945	9.04	1953	14.14	1934
9.06	1950	8.99	1939	14.04	1937
9.06	1939	8.92	1943	13.41	1952
8.96	1975	8.55	1933	13.10	1956
8.90	1948	8.02	1934	12.81	1938
8.65	1947	8.00	1972	12.73	1939
8.65	1971	7.82	1970	11.96	1964
8.36	1935	7.66	1949	11.77	1945
8.19	1967	7.34	1960	11.66	1932
8.14	1932	7.32	1932	11.13	1947
8.02	1972	7.12	1950	11.10	1967
7.70	1968	7.06	1938	10.59	1966
7.47	1966	6.85	1975	10.26	1968
7.11	1949	6.43	1929	10.21	1949
6.97	1956	6.29	1945	10.14	1950
6.96	1928	6.29	1966	10.09	1940
5.94	1937	6.06	1952	9.92	1977
6.94	1941	5.86	1977	9.88	1971
6.91	1958	5.85	1968	9.81	1972
6.49	1964	5.42	1974	9.73	1970
6.41	1965	5.38	1947	9.59	1933
6.37	1977	4.81	1931	9.56	1960
6.21	1970	4.77	1961	9.29	1974
6.09	1940	4.73	1948	8.95	1965
5.75	1929	4.57	1955	8.91	1948

Table F-54. PRECIPITATION DATA IN INCHES AT LAKE PARK, IOWA.
Continued PERIOD OF RECORD IS 1927 TO 1977. N = 51

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
5.56	1973	4.52	1940	8.56	1941
5.56	1946	4.18	1971	8.32	1929
5.55	1933	4.09	1958	8.14	1958
5.06	1960	4.06	1973	7.17	1955
5.06	1930	3.72	1936	7.09	1961
4.86	1931	3.67	1959	7.05	1931
4.74	1961	3.53	1967	6.85	1973
4.68	1974	3.43	1941	6.84	1946
4.53	1955	3.35	1965	6.41	1930
4.38	1976	2.84	1927	5.95	1936
3.19	1927	2.73	1946	5.92	1959
2.81	1936	1.94	1976	4.76	1976
2.81	1959	1.68	1930	4.58	1927

Table F-55. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA.

PERIOD OF RECORD IS 1897 TO 1977. N = 81

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
15.55	1950	14.85	1900	18.62	1945
15.42	1900	12.63	1951	18.27	1900
14.04	1909	11.31	1945	17.70	1951
13.23	1945	11.25	1903	17.67	1950
12.63	1934	10.73	1902	15.99	1940
12.50	1919	10.08	1952	15.47	1909
11.76	1902	9.50	1940	15.41	1902
11.53	1971	9.13	1919	15.05	1903
11.41	1943	9.09	1944	14.99	1899
11.29	1915	8.81	1910	14.94	1934
10.64	1962	8.73	1899	14.30	1952
10.54	1907	8.71	1924	14.25	1919
10.35	1953	8.66	1915	14.11	1915
10.19	1952	8.47	1957	14.05	1924
10.09	1948	8.35	1960	13.92	1969
9.96	1972	8.25	1909	13.90	1948
9.63	1940	8.20	1972	13.86	1953
9.61	1957	8.03	1962	13.83	1957
9.56	1967	8.02	1921	13.60	1923
9.54	1969	8.02	1950	13.45	1962
9.48	1899	7.95	1953	12.93	1944
9.26	1903	7.93	1926	12.73	1967
8.93	1973	7.90	1968	12.22	1971
8.89	1949	7.84	1933	12.15	1943
8.85	1925	7.80	1912	12.11	1974
8.74	1938	7.79	1969	11.91	1972
8.62	1951	7.71	1923	11.63	1907
8.31	1912	7.59	1907	11.51	1926
8.08	1961	7.55	1928	11.46	1961
8.08	1942	7.47	1948	11.33	1966
8.07	1944	7.47	1973	11.22	1960
8.06	1898	7.36	1920	11.15	1975
8.03	1924	7.20	1932	11.06	1912
7.98	1923	7.17	1964	11.05	1905
7.87	1954	7.01	1949	10.93	1949
7.77	1908	6.98	1934	10.79	1932
7.61	1935	6.92	1966	10.77	1920
7.53	1916	6.87	1959	10.77	1954

Table F-55. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA.
Continued PERIOD OF RECORD IS 1897 TO 1977. N = 81

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
7.50	1932	6.74	1905	10.68	1963
7.44	1917	6.64	1963	10.61	1968
7.42	1941	6.48	1922	10.57	1910
7.40	1933	6.30	1938	10.57	1942
7.37	1926	6.23	1974	10.37	1898
7.24	1966	6.18	1939	10.20	1928
7.22	1928	6.04	1943	10.12	1908
7.17	1905	5.99	1975	10.11	1906
7.08	1963	5.98	1908	10.09	1938
6.94	1910	5.94	1961	10.02	1933
6.81	1974	5.88	1942	9.76	1939
6.80	1977	5.82	1917	9.72	1921
6.76	1918	5.65	1898	9.70	1973
6.65	1906	5.21	1935	9.55	1917
6.46	1939	5.19	1904	9.52	1911
6.40	1968	5.17	1946	9.39	1964
6.25	1920	5.12	1916	9.38	1941
6.21	1914	4.73	1911	9.35	1925
6.17	1975	4.73	1977	9.33	1959
6.06	1911	4.69	1897	9.25	1935
6.00	1904	4.66	1906	9.24	1946
6.00	1965	4.66	1956	9.17	1918
5.83	1964	4.37	1918	8.85	1922
5.57	1922	4.26	1954	8.64	1916
5.57	1927	4.20	1937	8.55	1977
5.39	1929	4.17	1967	7.92	1904
5.36	1901	4.15	1965	7.80	1897
5.30	1947	4.01	1941	7.52	1965
5.20	1897	4.00	1914	7.46	1914
5.18	1946	3.97	1955	7.40	1929
4.97	1955	3.89	1929	7.37	1927
4.58	1921	3.68	1936	6.55	1947
4.54	1958	3.59	1927	6.45	1901
4.33	1931	3.46	1925	6.25	1931
3.93	1959	3.45	1913	6.19	1937
3.62	1960	3.42	1958	6.05	1955
3.39	1930	3.24	1931	5.84	1930
2.98	1913	3.19	1901	5.82	1936

Table F-55. PRECIPITATION DATA IN INCHES AT LE MARS, IOWA.
Continued PERIOD OF RECORD IS 1897 TO 1977, N = 81

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.82	1970	3.01	1971	5.60	1956
2.81	1956	2.81	1930	5.00	1958
2.72	1937	2.52	1970	4.63	1913
2.66	1936	2.43	1976	3.45	1970
2.33	1976	1.92	1947	3.39	1976

Table F-56. PRECIPITATION DATA IN INCHES AT MAPLETON, IOWA.

PERIOD OF RECORD IS 1938 TO 1977. N = 40

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
15.08	1952	17.58	1962	21.67	1962
14.27	1950	12.05	1951	20.14	1951
13.48	1940	11.97	1950	19.54	1944
13.44	1967	11.83	1940	19.43	1950
12.32	1942	11.03	1944	18.37	1952
11.82	1951	10.50	1952	17.91	1940
11.81	1962	10.42	1972	15.15	1966
11.07	1944	10.15	1977	15.02	1967
10.09	1972	8.43	1966	13.80	1942
9.68	1977	8.02	1948	13.72	1977
9.62	1943	7.93	1960	13.50	1972
9.47	1966	7.65	1939	13.42	1968
9.27	1968	7.54	1958	12.60	1963
9.21	1973	7.39	1964	11.91	1957
9.01	1957	7.34	1969	11.83	1969
8.94	1958	6.99	1946	11.74	1960
8.55	1963	6.94	1957	11.70	1946
8.53	1938	6.78	1973	11.50	1964
8.36	1969	6.49	1968	11.13	1948
7.71	1964	6.40	1943	10.76	1973
7.66	1947	6.36	1961	10.70	1943
7.18	1939	6.30	1945	10.34	1958
7.12	1948	6.17	1974	10.30	1939
7.09	1941	5.91	1938	10.01	1938
7.07	1953	5.91	1963	9.98	1954
7.03	1945	5.56	1956	9.74	1961
7.01	1961	5.37	1965	9.51	1941
6.61	1956	5.10	1954	9.42	1959
6.30	1955	4.72	1942	9.31	1945
6.22	1960	4.49	1959	9.27	1953
6.02	1971	4.34	1949	9.17	1956
5.91	1954	4.24	1975	8.78	1974
5.82	1959	4.14	1971	8.70	1975
5.78	1965	3.90	1970	8.12	1947
5.76	1946	3.80	1955	8.05	1955
5.50	1975	3.79	1953	7.80	1965
4.50	1949	3.44	1941	7.18	1971
3.88	1970	2.47	1976	6.94	1949

Table F-56. PRECIPITATION DATA IN INCHES AT MAPLETON, IOWA,
Continued PERIOD OF RECORD IS 1938 TO 1977. N = 40

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
3.82	1974	2.31	1967	5.47	1970
2.55	1976	1.31	1947	3.57	1976

Table F-57. PRECIPITATION DATA IN INCHES AT MERRILL, IOWA.

PERIOD OF RECORD IS 1946 TO 1977. N = 32

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
12.16	1950	11.51	1951	16.80	1951
11.57	1948	11.45	1950	16.15	1952
11.54	1952	11.15	1952	16.07	1966
11.27	1966	9.64	1964	15.54	1950
10.46	1967	9.64	1966	15.51	1967
10.16	1971	9.05	1962	14.10	1957
10.14	1953	8.95	1957	13.91	1948
9.43	1962	7.95	1969	13.58	1962
9.24	1957	7.76	1960	13.52	1953
9.18	1977	7.64	1949	13.26	1969
9.01	1951	7.46	1972	12.30	1964
8.92	1969	7.29	1948	12.11	1949
8.48	1949	7.21	1967	10.93	1968
8.28	1973	7.07	1973	10.77	1971
7.84	1972	7.03	1968	10.43	1977
7.73	1968	7.01	1953	10.19	1961
6.97	1965	6.45	1961	10.06	1960
6.77	1961	5.75	1965	9.99	1972
6.71	1964	5.69	1963	9.83	1954
6.48	1963	5.23	1958	9.52	1963
6.27	1954	5.17	1977	9.33	1974
6.21	1974	5.10	1954	8.89	1973
5.76	1955	4.90	1974	8.64	1965
5.64	1947	4.72	1956	7.25	1975
5.59	1958	4.41	1976	7.13	1955
5.32	1970	4.35	1959	7.08	1959
4.05	1956	4.34	1975	7.02	1958
3.90	1975	4.33	1955	6.70	1970
3.66	1959	3.71	1970	6.18	1956
3.43	1946	3.20	1946	6.04	1947
3.40	1960	1.80	1947	5.98	1946
2.70	1976	1.79	1971	4.92	1976

Table F-58. PRECIPITATION DATA IN INCHES AT MILFORD, IOWA.
PERIOD OF RECORD IS 1939 TO 1977. N = 39

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
15.56	1962	16.30	1962	21.97	1962
13.68	1943	11.62	1944	19.18	1943
12.94	1945	10.40	1964	17.72	1954
11.99	1953	10.38	1943	16.80	1944
11.96	1969	10.22	1942	16.56	1951
11.83	1951	9.92	1969	15.71	1953
11.71	1954	9.68	1972	15.68	1969
11.21	1957	9.36	1951	15.17	1975
11.02	1944	9.32	1954	14.85	1952
10.12	1952	8.84	1960	14.55	1957
9.96	1972	8.62	1952	13.82	1945
9.78	1963	8.62	1957	13.43	1942
8.98	1950	8.57	1956	12.28	1966
8.96	1964	8.21	1966	12.22	1960
8.92	1971	7.18	1963	12.09	1972
8.87	1941	7.16	1953	11.86	1964
8.86	1966	7.12	1939	11.43	1941
8.48	1968	7.03	1950	11.37	1956
8.36	1975	7.02	1975	10.97	1968
8.23	1949	6.54	1977	10.79	1939
7.85	1942	6.34	1970	10.52	1977
7.76	1967	6.18	1968	10.39	1950
7.35	1947	5.35	1973	10.27	1963
7.05	1939	5.33	1941	10.16	1967
6.63	1956	5.24	1945	10.16	1971
6.33	1960	5.23	1971	10.00	1949
6.16	1948	5.10	1955	8.29	1947
5.93	1961	4.86	1974	8.26	1973
5.83	1973	4.55	1961	8.19	1955
5.75	1977	4.32	1958	8.17	1974
5.66	1958	4.29	1940	8.12	1940
5.55	1946	4.01	1949	7.77	1961
5.42	1955	3.27	1959	7.69	1970
4.88	1970	3.26	1965	7.53	1946
4.42	1976	3.06	1948	7.14	1948
4.40	1940	2.97	1946	6.83	1958
4.19	1974	2.90	1967	5.90	1965
3.56	1965	2.89	1947	5.34	1959

Table F-58. PRECIPITATION DATA IN INCHES AT MILFORD, IOWA.
Continued PERIOD OF RECORD IS 1939 TO 1977. N = 39

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
2.19	1959	1.61	1976	4.83	1976

Table F-59. PRECIPITATION DATA IN INCHES AT PRIMGHAR, IOWA.

PERIOD OF RECORD IS 1937 TO 1977. N = 41

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
12.98	1950	14.46	1973	21.37	1974
12.37	1971	14.23	1944	20.34	1944
12.23	1944	13.94	1951	18.85	1975
12.09	1943	13.24	1974	18.77	1951
11.80	1951	12.45	1975	17.19	1973
11.21	1962	12.21	1962	16.69	1943
11.04	1974	10.85	1977	16.37	1957
10.55	1957	10.41	1957	16.35	1962
10.22	1977	10.11	1937	15.04	1953
10.15	1969	10.10	1969	14.48	1954
10.12	1953	9.84	1950	14.25	1952
9.50	1945	9.41	1972	13.82	1977
9.04	1954	9.24	1952	13.71	1950
8.97	1940	9.11	1943	13.68	1969
8.52	1948	7.93	1960	13.21	1940
8.43	1952	7.84	1956	13.18	1971
8.25	1938	7.81	1954	12.49	1937
8.23	1973	7.46	1939	12.31	1942
7.91	1942	7.33	1963	11.94	1945
7.86	1963	7.24	1940	11.41	1972
7.28	1947	7.18	1953	10.77	1963
7.20	1967	6.98	1938	10.67	1948
7.19	1961	6.81	1942	10.37	1960
7.16	1972	6.64	1964	10.22	1939
7.10	1941	6.63	1961	9.94	1956
6.59	1975	6.13	1959	9.84	1964
6.53	1958	6.11	1945	9.64	1959
6.41	1976	5.16	1948	9.52	1938
6.36	1956	4.42	1971	9.50	1961
6.36	1964	4.39	1968	9.08	1967
6.30	1937	4.09	1966	8.39	1968
6.10	1963	3.99	1955	8.12	1966
5.96	1955	3.89	1949	7.99	1941
5.63	1946	3.44	1946	7.81	1947
5.59	1966	3.24	1976	7.69	1946
5.22	1965	2.99	1965	7.39	1958
4.92	1939	2.84	1958	7.25	1976
4.69	1949	2.59	1970	7.13	1965

Table F-59. Continued

PRECIPITATION DATA IN INCHES AT PRIMGHAR, IOWA.
PERIOD OF RECORD IS 1937 TO 1977. N = 41

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.16	1960	2.39	1941	7.07	1955
4.00	1970	2.33	1967	6.46	1949
3.58	1959	0.69	1947	4.73	1970

Table F-60. PRECIPITATION DATA IN INCHES AT ROCK RAPIDS, IOWA.

PERIOD OF RECORD IS 1904 TO 1977. N = 74

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
15.67	1944	15.26	1944	22.66	1944
14.07	1943	11.97	1915	19.82	1943
12.61	1907	11.37	1964	17.80	1905
12.20	1909	10.81	1957	17.78	1957
12.19	1934	10.70	1932	15.98	1915
11.80	1905	10.19	1977	15.79	1928
11.54	1918	9.65	1943	15.21	1975
11.44	1919	9.57	1923	15.05	1918
11.33	1957	9.55	1918	14.71	1934
11.20	1969	9.11	1933	14.18	1951
11.03	1915	8.89	1975	13.89	1964
11.01	1950	8.69	1928	13.80	1914
10.38	1971	8.63	1905	13.66	1907
10.23	1914	8.49	1952	13.47	1952
10.08	1948	8.37	1959	13.45	1923
9.83	1920	8.11	1951	13.30	1977
9.71	1954	8.07	1956	13.21	1920
9.62	1951	8.04	1935	12.95	1909
9.53	1967	7.98	1911	12.88	1919
9.46	1945	7.98	1920	12.82	1932
9.44	1972	7.77	1949	12.79	1967
9.10	1968	7.58	1962	12.78	1954
9.08	1908	7.56	1972	12.71	1969
9.01	1939	7.41	1934	12.64	1953
8.79	1964	7.38	1939	12.58	1939
8.68	1962	7.38	1974	12.31	1942
8.54	1928	7.09	1907	12.21	1962
8.52	1963	7.07	1942	12.14	1945
8.42	1955	7.02	1948	12.03	1948
8.10	1953	7.02	1953	12.00	1950
8.08	1952	6.99	1922	11.88	1935
8.07	1923	6.93	1950	11.82	1971
8.05	1942	6.72	1961	11.57	1972
7.95	1946	6.49	1926	11.34	1956
7.80	1977	6.35	1904	10.61	1968
7.78	1941	6.27	1969	10.61	1933
7.60	1956	6.26	1929	10.44	1949
7.58	1949	6.16	1921	10.43	1908

Table F-60. PRECIPITATION DATA IN INCHES AT ROCK RAPIDS, IOWA.
Continued PERIOD OF RECORD IS 1904 TO 1977. N = 74

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
7.12	1975	6.12	1963	10.22	1906
6.89	1947	6.05	1912	10.13	1963
6.78	1958	5.98	1914	10.02	1959
6.67	1925	5.96	1937	9.99	1946
6.59	1922	5.86	1955	9.93	1911
6.57	1906	5.83	1954	9.89	1961
6.49	1924	5.76	1919	9.46	1926
6.48	1935	5.71	1971	9.36	1940
6.46	1917	5.70	1973	9.34	1974
6.28	1938	5.44	1945	9.18	1955
6.25	1904	5.40	1960	9.14	1937
6.25	1940	5.38	1909	9.08	1924
6.16	1932	5.29	1931	8.68	1929
5.79	1973	5.22	1968	8.66	1941
5.77	1926	5.12	1966	8.65	1904
5.76	1911	4.91	1940	8.54	1922
5.65	1930	4.71	1908	8.50	1925
5.58	1916	4.66	1967	8.07	1966
5.53	1929	4.60	1910	7.82	1921
5.39	1913	4.57	1906	7.82	1960
5.10	1965	4.35	1936	7.66	1947
5.02	1910	4.27	1924	7.43	1958
5.01	1966	4.06	1938	7.34	1931
4.93	1912	3.95	1965	7.33	1917
4.59	1937	3.92	1946	7.32	1973
4.54	1961	3.79	1958	7.04	1965
4.44	1927	3.75	1925	6.98	1938
4.02	1960	3.62	1913	6.83	1912
3.90	1933	3.48	1941	6.82	1916
3.76	1921	3.43	1916	6.60	1936
3.75	1976	3.18	1927	6.60	1913
3.74	1931	2.77	1976	6.60	1930
3.71	1970	2.73	1917	6.50	1910
3.04	1936	1.75	1930	5.17	1927
2.68	1974	1.66	1970	4.70	1976
1.86	1959	0.92	1947	4.01	1970

Table F-61. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.

PERIOD OF RECORD IS 1893 TO 1977, N = 85

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
18.24	1902	20.64	1902	26.27	1902
15.68	1967	15.10	1938	20.25	1951
14.05	1938	14.79	1951	19.18	1962
13.33	1919	14.70	1962	18.92	1967
13.28	1972	13.42	1903	18.58	1900
13.01	1907	12.75	1940	18.29	1943
12.73	1957	12.11	1905	17.64	1954
12.57	1943	12.09	1900	17.62	1903
12.12	1900	11.64	1908	17.27	1972
11.69	1896	11.35	1972	17.13	1938
11.46	1903	10.67	1907	16.93	1944
11.36	1973	10.37	1943	16.66	1940
11.10	1944	10.10	1944	16.59	1895
10.82	1954	9.93	1937	16.27	1908
10.72	1905	9.84	1895	16.12	1907
10.71	1942	9.25	1934	15.61	1919
10.39	1952	8.96	1954	15.48	1957
10.27	1950	8.65	1923	14.18	1905
9.98	1915	8.63	1904	14.01	1931
9.67	1962	8.60	1915	13.84	1923
9.59	1951	8.59	1896	13.71	1924
9.57	1931	8.56	1973	13.57	1937
9.57	1940	8.55	1968	13.54	1896
9.54	1908	8.53	1932	13.40	1904
9.42	1958	8.50	1977	13.14	1973
9.17	1941	8.34	1921	12.95	1968
8.96	1894	8.19	1945	12.73	1932
8.87	1947	8.17	1942	12.68	1977
8.83	1909	8.17	1964	12.56	1894
8.70	1895	7.93	1960	12.51	1942
8.55	1924	7.74	1928	12.49	1952
8.48	1945	7.73	1970	12.48	1945
8.19	1969	7.69	1974	11.94	1950
8.00	1926	7.68	1933	11.84	1920
7.98	1966	7.67	1924	11.69	1941
7.94	1961	7.62	1957	11.69	1928
7.92	1904	7.36	1922	11.41	1911
7.87	1968	7.35	1920	11.36	1934

Table F-61. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.
Continued PERIOD OF RECORD IS 1893 TO 1977. N = 85

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
7.72	1970	7.22	1912	11.20	1915
7.71	1932	7.14	1939	11.19	1966
7.48	1911	7.01	1948	11.14	1939
7.40	1928	6.99	1952	11.06	1926
7.33	1925	6.80	1963	10.79	1912
7.32	1893	6.38	1961	10.77	1948
7.30	1934	6.36	1894	10.71	1925
7.21	1914	6.33	1956	10.43	1964
7.21	1920	6.13	1931	10.39	1974
7.11	1964	5.97	1950	10.38	1975
7.09	1975	5.90	1925	10.17	1960
7.03	1939	5.75	1898	10.06	1958
7.02	1935	5.62	1914	9.98	1970
6.97	1948	5.62	1967	9.97	1961
6.96	1963	5.49	1966	9.79	1963
6.74	1923	5.48	1929	9.58	1898
6.56	1977	5.46	1911	9.47	1921
6.47	1918	5.39	1926	9.44	1969
6.30	1929	5.38	1955	9.37	1893
6.21	1912	5.30	1958	9.29	1947
6.16	1930	5.10	1975	9.24	1930
6.13	1971	5.03	1971	9.22	1914
6.00	1917	4.88	1909	9.12	1909
5.93	1921	4.85	1897	9.10	1935
5.66	1955	4.75	1919	8.95	1956
5.65	1897	4.75	1949	8.70	1922
5.58	1899	4.73	1918	8.37	1899
5.53	1922	4.61	1910	8.30	1918
5.44	1937	4.38	1965	8.29	1929
5.39	1953	4.32	1913	8.24	1933
5.38	1898	4.17	1893	7.90	1917
5.31	1946	4.06	1899	7.59	1971
4.99	1933	3.91	1930	7.37	1953
4.65	1949	3.90	1969	7.19	1949
4.63	1974	3.78	1927	7.12	1955
4.53	1956	3.69	1941	7.10	1897
4.49	1960	3.59	1935	6.72	1965
4.10	1965	3.40	1916	6.58	1946

Table F-61. PRECIPITATION DATA IN INCHES AT SAC CITY, IOWA.
Continued PERIOD OF RECORD IS 1893 TO 1977. N = 85

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
3.98	1976	3.07	1959	6.00	1910
3.67	1906	3.04	1936	5.85	1916
3.40	1913	3.01	1953	5.79	1959
3.36	1959	2.97	1976	5.62	1913
3.11	1936	2.83	1917	5.36	1906
2.93	1916	2.68	1906	5.31	1927
2.72	1927	2.13	1946	5.20	1936
2.46	1910	1.65	1947	4.38	1976
2.40	1901	1.56	1901	3.61	1901

Table F-62. PRECIPITATION DATA IN INCHES AT SANBORN, IOWA.
PERIOD OF RECORD IS 1915 TO 1977. N = 63

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
14.54	1943	13.71	1951	20.50	1951
13.32	1950	12.11	1944	19.21	1943
12.42	1951	11.96	1943	18.28	1944
12.32	1944	11.73	1937	16.21	1953
11.90	1934	11.62	1952	16.06	1975
11.84	1971	11.42	1977	15.70	1952
11.64	1935	10.97	1974	15.67	1937
11.64	1953	10.69	1969	15.04	1928
11.08	1945	10.46	1928	14.86	1950
10.96	1919	10.28	1962	14.67	1918
10.40	1954	9.81	1918	14.65	1934
9.73	1918	9.74	1915	14.39	1935
9.54	1938	9.68	1939	14.20	1939
9.52	1937	9.48	1935	14.07	1954
9.39	1977	9.45	1973	14.03	1977
9.28	1952	9.24	1950	14.01	1919
9.20	1963	8.89	1932	13.66	1974
9.16	1957	8.81	1975	13.62	1942
8.91	1917	8.72	1942	13.45	1962
8.83	1940	8.22	1972	13.44	1969
8.74	1939	8.18	1960	13.43	1915
8.72	1915	8.08	1963	13.27	1971
8.58	1969	8.06	1926	13.00	1932
8.55	1962	8.04	1956	12.83	1940
8.47	1964	7.90	1964	12.74	1957
8.36	1968	7.76	1934	12.69	1945
7.76	1920	7.61	1933	12.06	1973
7.67	1942	7.18	1919	12.04	1964
7.66	1975	7.05	1931	11.53	1923
7.61	1972	7.00	1922	11.44	1968
7.33	1929	6.98	1953	11.41	1963
7.21	1958	6.81	1968	11.17	1917
7.18	1948	6.75	1938	10.99	1938
7.08	1955	6.68	1940	10.53	1929
6.83	1923	6.60	1923	10.44	1956
6.83	1941	6.56	1957	10.41	1924
6.76	1931	6.41	1924	10.27	1960
6.51	1924	6.29	1966	10.01	1972

Table F-62. PRECIPITATION DATA IN INCHES AT SANBORN, IOWA.
Continued PERIOD OF RECORD IS 1915 TO 1977. N = 63

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
6.38	1967	6.24	1929	9.70	1946
6.37	1946	6.08	1920	9.68	1926
6.32	1928	6.05	1954	9.67	1931
6.26	1916	6.01	1945	9.56	1920
6.04	1947	5.79	1948	9.52	1966
6.01	1973	5.76	1917	9.49	1967
5.82	1956	5.30	1946	9.39	1948
5.79	1966	5.24	1961	8.89	1922
5.76	1949	5.18	1955	8.84	1941
5.76	1930	4.75	1959	8.77	1916
5.63	1926	4.65	1916	8.48	1933
5.48	1922	4.58	1936	8.37	1955
5.47	1961	4.48	1927	8.19	1958
5.42	1932	4.41	1921	8.17	1921
5.32	1927	4.34	1971	7.68	1961
5.26	1965	4.17	1949	7.66	1965
5.04	1921	4.06	1958	7.57	1959
4.76	1976	3.96	1941	7.37	1949
4.74	1933	3.81	1965	7.28	1947
3.98	1960	3.62	1967	6.96	1936
3.89	1925	2.77	1976	6.77	1930
3.53	1936	1.96	1970	6.40	1927
3.32	1974	1.78	1930	5.70	1976
3.17	1959	1.78	1947	4.50	1925
3.04	1970	1.41	1925	3.89	1970

Table F-63. PRECIPITATION DATA IN INCHES AT SHELDON, IOWA. PERIOD OF RECORD IS 1926 TO 1977. N = 52

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
15.98	1951	13.49	1944	21.40	1951
13.17	1943	12.72	1973	20.60	1944
13.14	1944	12.31	1951	17.67	1943
12.61	1953	11.37	1928	17.35	1953
11.61	1971	10.47	1962	16.21	1928
11.49	1934	10.32	1977	15.82	1973
10.61	1950	10.30	1964	15.36	1975
9.87	1954	9.95	1969	15.16	1942
9.77	1942	9.72	1943	14.74	1934
9.73	1957	9.66	1972	14.27	1962
9.69	1969	9.47	1952	13.65	1957
9.37	1972	9.30	1960	13.50	1952
9.13	1964	9.00	1942	13.33	1974
9.05	1962	8.78	1974	13.26	1969
8.84	1940	8.76	1934	13.04	1964
8.65	1952	8.74	1932	12.77	1954
8.56	1975	8.57	1937	12.62	1971
8.43	1973	8.20	1956	12.61	1937
8.24	1977	7.86	1933	12.50	1932
8.13	1928	7.18	1935	12.50	1940
8.03	1941	7.10	1939	12.37	1977
8.02	1945	7.07	1975	12.33	1972
8.01	1948	6.99	1929	11.78	1960
7.91	1956	6.99	1957	11.73	1967
7.90	1935	6.88	1963	11.60	1956
7.85	1946	6.86	1953	11.34	1950
7.84	1967	6.46	1931	11.24	1946
7.26	1938	6.40	1926	11.05	1935
7.16	1929	6.02	1950	11.00	1929
6.97	1937	5.75	1940	10.32	1939
6.80	1939	5.73	1954	10.20	1945
6.70	1947	5.66	1961	9.71	1947
6.70	1963	5.61	1946	9.35	1959
6.48	1958	5.30	1945	9.25	1941
5.86	1974	5.21	1936	9.18	1948
5.79	1933	5.12	1966	9.07	1963
5.48	1976	5.07	1948	8.91	1931
5.45	1930	5.05	1938	8.82	1933

Table F-63. PRECIPITATION DATA IN INCHES AT SHELDON, IOWA.
Continued PERIOD OF RECORD IS 1926 TO 1977. N = 52

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
5.36	1961	4.94	1959	8.74	1966
5.36	1966	4.46	1967	8.51	1961
5.16	1931	4.35	1968	8.43	1926
5.15	1932	4.21	1949	7.92	1938
5.14	1955	4.00	1947	7.38	1958
5.12	1926	3.95	1958	6.74	1936
5.09	1968	3.57	1971	6.70	1930
4.82	1965	3.34	1976	6.68	1965
4.75	1959	3.21	1955	6.56	1968
4.07	1960	3.16	1965	6.30	1976
3.91	1927	3.05	1941	6.23	1949
3.79	1949	2.87	1970	5.76	1955
3.73	1970	2.57	1927	4.75	1927
2.99	1936	1.53	1930	4.35	1970

Table F-64. PRECIPITATION DATA IN INCHES AT SIBLEY, IOWA.

PERIOD OF RECORD IS 1936 TO 1977. N = 42

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
14.88	1953	13.08	1956	20.14	1953
14.24	1954	12.05	1944	19.51	1944
13.97	1943	11.81	1957	18.26	1957
12.97	1944	11.45	1975	17.98	1943
12.07	1957	10.67	1949	17.76	1975
11.47	1963	10.60	1974	16.97	1954
10.96	1950	10.16	1962	16.31	1956
10.52	1951	9.77	1977	14.43	1951
10.03	1938	9.72	1953	13.95	1962
10.01	1969	9.36	1950	13.74	1969
9.98	1956	9.15	1951	13.48	1963
9.85	1945	9.06	1937	13.44	1967
9.68	1972	9.05	1943	13.41	1937
9.39	1962	8.89	1964	13.39	1952
9.21	1948	8.70	1969	13.29	1949
9.11	1949	8.59	1942	13.27	1974
9.06	1971	8.39	1966	13.19	1977
9.02	1952	8.35	1972	12.74	1942
8.96	1967	7.54	1963	12.73	1947
8.74	1947	7.39	1952	11.99	1964
8.44	1964	6.97	1960	11.88	1966
8.37	1977	6.42	1939	11.79	1972
8.36	1970	6.41	1938	11.74	1945
8.32	1941	6.37	1954	11.64	1950
8.15	1937	6.10	1967	11.05	1938
8.00	1939	6.03	1945	10.96	1939
7.37	1942	6.02	1959	10.89	1971
7.08	1958	6.01	1970	10.32	1948
7.02	1973	5.67	1968	9.97	1960
6.47	1940	5.40	1948	9.51	1940
6.45	1946	5.38	1973	9.45	1941
6.44	1975	5.01	1961	9.44	1968
6.39	1968	4.82	1971	9.15	1959
6.12	1961	4.58	1958	8.95	1973
5.84	1966	4.38	1940	8.95	1970
5.54	1965	4.21	1941	8.80	1961
5.46	1955	4.16	1965	8.52	1958
5.39	1960	4.07	1947	8.01	1965

Table F-64. PRECIPITATION DATA IN INCHES AT SIBLEY, IOWA.
Continued PERIOD OF RECORD IS 1936 TO 1977. N = 42

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
5.17	1976	3.63	1955	7.64	1946
3.55	1974	3.60	1936	6.06	1955
3.24	1959	3.21	1946	5.81	1976
2.75	1936	2.91	1976	5.56	1936

Table F-65. PRECIPITATION DATA IN INCHES AT SIOUX CENTER, IOWA.

PERIOD OF RECORD IS 1900 TO 1977. N = 78

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
16.73	1900	15.51	1900	21.61	1944
15.07	1944	13.76	1928	20.27	1942
14.19	1971	13.47	1952	19.93	1900
13.27	1942	12.05	1942	18.61	1928
12.32	1904	11.38	1951	17.24	1951
12.22	1909	10.69	1902	16.72	1953
12.11	1953	10.67	1944	15.87	1952
11.42	1943	9.97	1933	15.13	1971
11.32	1951	9.22	1904	14.76	1974
11.11	1957	9.21	1924	14.64	1924
11.05	1934	9.05	1960	14.37	1934
10.79	1954	8.86	1961	14.32	1943
10.53	1972	8.81	1909	14.13	1957
10.09	1950	8.75	1962	14.10	1962
10.02	1919	8.61	1943	13.79	1961
9.75	1962	8.58	1959	13.79	1904
9.66	1940	8.47	1922	13.46	1940
9.60	1905	8.36	1964	13.43	1975
9.44	1965	8.33	1957	13.33	1954
9.30	1952	8.33	1974	13.29	1909
9.24	1955	8.28	1956	13.15	1901
8.95	1948	8.18	1953	12.98	1906
8.89	1925	8.04	1972	12.36	1905
8.87	1975	7.81	1906	12.32	1902
8.86	1974	7.75	1901	12.22	1964
8.86	1969	7.52	1973	12.16	1918
8.76	1908	7.43	1955	12.15	1972
8.69	1901	7.39	1912	12.13	1956
8.67	1956	7.29	1932	12.12	1960
8.65	1915	7.28	1934	12.02	1948
8.65	1928	7.25	1923	12.01	1959
8.49	1968	7.23	1969	11.92	1969
8.40	1935	7.22	1926	11.88	1935
8.32	1973	7.21	1940	11.87	1908
8.23	1964	7.15	1918	11.79	1965
8.19	1918	7.08	1948	11.79	1923
8.07	1907	7.06	1908	11.37	1932
8.03	1961	7.05	1915	11.32	1937

Table F-65. PRECIPITATION DATA IN INCHES AT SIOUX CENTER, IOWA.
Continued PERIOD OF RECORD IS 1900 TO 1977. N = 78

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
7.82	1941	7.03	1903	11.23	1950
7.70	1963	6.89	1910	11.14	1915
7.66	1914	6.89	1937	11.10	1955
7.59	1923	6.51	1949	10.99	1919
7.49	1967	6.48	1977	10.75	1973
7.30	1926	6.41	1935	10.73	1926
7.28	1924	6.40	1919	10.19	1922
7.27	1902	6.28	1965	10.12	1933
7.21	1906	6.18	1907	10.02	1903
7.09	1945	6.02	1921	9.95	1907
6.90	1922	6.01	1950	9.55	1945
6.38	1937	6.00	1963	9.47	1963
6.36	1947	5.86	1968	9.39	1968
6.17	1938	5.38	1975	9.38	1925
6.17	1977	5.37	1966	9.07	1967
6.07	1933	5.21	1945	9.00	1914
6.00	1929	5.10	1938	8.87	1912
5.83	1949	4.92	1911	8.65	1941
5.80	1910	4.90	1936	8.63	1910
5.71	1920	4.73	1920	8.58	1949
5.69	1903	4.73	1925	8.49	1946
5.69	1958	4.58	1929	8.42	1921
5.59	1960	4.51	1946	8.36	1966
5.47	1939	4.48	1954	8.16	1947
5.44	1913	4.36	1916	8.13	1920
5.42	1921	3.81	1939	7.75	1939
5.26	1912	3.73	1913	7.71	1977
5.20	1930	3.72	1958	7.58	1938
5.03	1932	3.49	1905	7.48	1929
4.81	1966	3.29	1971	6.80	1916
4.64	1917	2.82	1914	6.76	1930
4.64	1931	2.66	1917	6.73	1936
4.24	1916	2.66	1976	6.55	1958
4.23	1946	2.63	1947	6.53	1913
4.12	1959	2.49	1941	6.37	1911
3.80	1970	2.39	1931	6.20	1917
3.66	1976	2.35	1970	5.73	1931
3.50	1936	2.34	1927	4.45	1927

Table F-65. PRECIPITATION DATA IN INCHES AT SIOUX CENTER, IOWA.
Continued PERIOD OF RECORD IS 1900 TO 1977. N = 78

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
3.17	1927	2.28	1967	4.28	1970
3.09	1911	2.25	1930	4.25	1976

Table F-66. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA, PERIOD OF RECORD IS 1891 TO 1977. N = 87

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
14.12	1972	12.42	1972	16.93	1891
13.75	1962	12.28	1900	16.89	1903
13.39	1891	11.36	1961	16.60	1900
13.10	1915	11.35	1964	16.54	1969
13.04	1900	11.24	1903	16.39	1962
12.94	1957	10.83	1969	16.21	1972
11.74	1929	10.74	1951	15.67	1923
11.22	1903	10.71	1912	15.13	1940
11.20	1934	10.53	1923	15.04	1957
10.95	1940	9.31	1891	14.89	1915
10.80	1967	9.24	1915	14.75	1961
10.63	1969	9.21	1949	14.74	1951
10.39	1945	8.89	1922	14.20	1912
10.22	1919	8.76	1962	14.06	1964
9.99	1907	8.70	1937	13.81	1937
9.57	1943	8.44	1950	13.34	1950
9.39	1898	8.44	1952	13.29	1929
9.29	1909	8.38	1960	12.90	1966
9.29	1938	8.35	1944	12.67	1944
9.03	1950	8.19	1920	12.53	1924
8.95	1904	8.17	1904	12.49	1898
8.73	1941	8.14	1893	12.48	1963
8.71	1964	7.81	1966	12.32	1934
8.67	1949	7.73	1940	12.31	1909
8.66	1956	7.31	1907	12.29	1949
8.50	1944	7.29	1938	12.15	1967
8.48	1896	7.22	1902	12.13	1919
8.44	1973	7.11	1909	11.86	1945
8.29	1924	7.11	1924	11.68	1908
8.18	1954	7.01	1908	11.63	1904
8.13	1963	6.90	1956	11.52	1907
8.07	1923	6.77	1892	11.51	1975
8.02	1966	6.74	1963	11.43	1948
8.00	1922	6.72	1948	11.25	1920
7.90	1948	6.50	1928	11.01	1943
7.75	1961	6.45	1910	10.92	1922
7.74	1977	6.44	1977	10.67	1899
7.58	1895	6.40	1896	10.65	1960

Table F-66. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA.
Continued PERIOD OF RECORD IS 1891 TO 1977, N = 87

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
7.56	1932	6.37	1957	10.55	1952
7.40	1908	6.22	1916	10.50	1932
7.28	1952	6.17	1975	10.28	1977
7.17	1912	6.16	1958	10.20	1956
7.05	1902	6.10	1943	9.99	1941
6.99	1951	6.07	1919	9.88	1938
6.95	1920	6.05	1934	9.77	1893
6.95	1975	5.95	1973	9.72	1954
6.90	1928	5.91	1899	9.57	1928
6.79	1925	5.88	1898	9.49	1973
6.72	1937	5.64	1931	9.34	1896
6.49	1942	5.55	1932	9.24	1902
6.45	1939	5.53	1926	9.13	1906
6.43	1953	5.36	1945	9.12	1895
6.41	1955	5.23	1921	8.99	1918
6.39	1906	5.16	1959	8.54	1916
6.39	1958	5.11	1906	8.54	1931
6.39	1930	4.94	1933	8.42	1939
6.35	1918	4.82	1929	8.27	1892
6.25	1947	4.77	1897	8.22	1953
6.21	1916	4.72	1918	8.18	1959
5.94	1901	4.56	1974	8.05	1942
5.87	1959	4.42	1911	8.03	1958
5.76	1899	4.17	1895	7.86	1910
5.53	1968	4.11	1939	7.84	1974
5.49	1946	4.11	1955	7.69	1901
5.33	1927	4.02	1935	7.68	1946
5.22	1971	4.01	1965	7.50	1925
5.10	1910	3.80	1913	7.45	1926
5.10	1933	3.71	1927	7.42	1917
5.07	1914	3.64	1946	7.33	1921
4.87	1960	3.57	1941	7.28	1930
4.76	1917	3.51	1917	7.23	1927
4.64	1931	3.49	1894	7.05	1968
4.57	1974	3.37	1967	7.02	1955
4.55	1894	3.25	1905	6.90	1897
4.52	1970	3.22	1942	6.88	1947
4.39	1897	3.20	1968	6.84	1933

Table F-66. PRECIPITATION DATA IN INCHES AT SIOUX CITY, IOWA.
Continued PERIOD OF RECORD IS 1891 TO 1977. N = 87

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
4.18	1935	2.99	1901	6.81	1914
4.17	1965	2.91	1954	6.54	1911
4.16	1921	2.90	1970	6.23	1894
4.13	1892	2.90	1914	6.18	1935
3.96	1905	2.32	1953	6.02	1965
3.92	1893	2.14	1925	5.80	1905
3.91	1926	1.84	1936	5.53	1970
3.68	1911	1.80	1976	5.34	1971
2.67	1913	1.69	1971	4.55	1913
2.25	1976	1.61	1930	3.88	1936
2.22	1936	1.04	1947	2.55	1976

Table F-67. PRECIPITATION DATA IN INCHES AT SIOUX RAPIDS, IOWA.
PERIOD OF RECORD IS 1942 TO 1977. N = 36

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
13.91	1944	14.87	1962	21.15	1954
13.59	1954	13.66	1944	21.10	1944
12.81	1969	12.45	1973	18.09	1962
12.51	1950	12.36	1975	18.08	1951
12.40	1943	12.05	1951	17.92	1969
11.80	1962	11.80	1972	17.64	1975
11.50	1951	10.29	1969	15.05	1957
10.77	1947	10.14	1954	14.92	1943
10.44	1977	9.70	1957	14.78	1953
10.43	1971	9.59	1945	14.33	1948
10.07	1948	9.40	1952	14.12	1973
9.83	1963	9.11	1977	14.08	1945
9.66	1964	8.67	1948	13.87	1977
9.54	1953	8.44	1964	13.84	1972
9.47	1957	7.56	1960	13.48	1959
9.41	1961	7.49	1950	13.36	1950
9.14	1942	7.46	1953	13.09	1964
8.91	1967	7.30	1961	12.08	1952
8.22	1952	7.24	1943	12.06	1960
7.84	1968	7.11	1959	12.04	1947
7.62	1959	6.93	1956	11.73	1963
7.49	1945	6.78	1963	11.46	1961
7.34	1966	6.72	1966	11.42	1971
7.29	1973	5.56	1968	11.38	1942
7.22	1972	5.45	1949	10.48	1966
6.71	1960	5.27	1947	10.04	1968
6.06	1949	5.12	1942	9.75	1967
5.92	1975	5.00	1974	8.92	1949
5.65	1946	4.19	1971	8.35	1956
4.86	1955	3.41	1970	7.27	1946
4.86	1958	3.18	1965	6.27	1974
4.22	1956	3.04	1946	5.75	1958
3.85	1976	2.92	1955	5.51	1955
3.49	1970	2.87	1958	5.35	1970
3.21	1965	1.78	1976	5.30	1965
1.81	1974	1.37	1967	4.41	1976

Table F-68. PRECIPITATION DATA IN INCHES AT SPENCER, IOWA.

PERIOD OF RECORD IS 1912 TO 1977. N = 66

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
15.27	1969	14.40	1944	21.30	1969
14.23	1943	13.57	1969	20.37	1944
13.59	1951	13.29	1951	20.11	1951
13.27	1934	12.46	1962	18.89	1975
12.97	1962	12.35	1975	18.56	1962
11.77	1971	10.62	1964	18.31	1943
11.66	1944	10.50	1922	17.66	1954
11.01	1954	10.38	1920	16.10	1934
10.53	1919	9.84	1956	14.35	1964
10.24	1941	9.81	1954	14.20	1939
10.23	1938	9.68	1939	13.95	1942
10.23	1950	9.41	1918	13.83	1918
10.16	1935	9.39	1943	13.49	1937
10.02	1953	9.10	1933	13.41	1953
9.98	1926	9.01	1926	13.28	1935
9.91	1942	8.57	1972	12.97	1928
9.90	1945	8.47	1913	12.83	1971
9.73	1964	8.34	1952	12.59	1919
9.67	1918	8.33	1937	12.58	1952
9.08	1940	8.30	1934	12.54	1926
8.96	1948	8.25	1968	12.51	1956
8.96	1968	8.19	1961	12.44	1940
8.89	1925	8.17	1942	12.39	1920
8.67	1972	7.79	1977	11.99	1948
8.37	1967	7.52	1928	11.95	1941
8.14	1952	7.37	1971	11.82	1922
7.94	1955	7.24	1963	11.56	1945
7.85	1963	7.14	1973	11.54	1938
7.77	1961	7.11	1950	11.31	1968
7.56	1920	7.00	1935	11.06	1972
7.40	1949	6.73	1932	10.93	1924
7.26	1939	6.56	1912	10.92	1950
6.95	1947	6.38	1931	10.43	1923
6.93	1928	6.38	1948	10.16	1963
6.89	1956	6.23	1919	10.10	1957
6.76	1975	6.23	1960	10.07	1913
6.65	1957	6.18	1924	10.00	1977
6.32	1917	6.15	1938	9.76	1931

Table F-68. PRECIPITATION DATA IN INCHES AT SPENCER, IOWA.
Continued PERIOD OF RECORD IS 1912 TO 1977. N = 66

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
6.27	1922	5.77	1923	9.75	1949
6.25	1915	5.69	1965	9.70	1961
6.21	1937	5.66	1953	9.69	1933
5.94	1958	5.63	1957	9.38	1925
5.87	1914	5.62	1915	9.26	1932
5.63	1933	5.32	1949	9.26	1967
5.44	1924	5.28	1955	9.16	1917
5.38	1931	5.27	1945	9.15	1973
5.23	1923	5.01	1936	9.07	1914
5.13	1912	4.97	1917	8.54	1955
5.12	1973	4.91	1940	8.53	1912
5.10	1916	4.91	1974	8.45	1960
5.02	1960	4.73	1925	8.22	1936
4.96	1932	4.71	1966	8.19	1915
4.82	1977	4.65	1914	7.79	1965
4.61	1946	4.46	1941	7.55	1974
4.49	1929	4.33	1929	7.45	1916
4.39	1966	4.25	1921	7.40	1947
4.36	1913	4.19	1916	7.10	1966
4.15	1970	3.82	1959	7.07	1958
3.94	1976	3.45	1946	7.06	1959
3.81	1936	3.30	1958	7.01	1946
3.64	1965	3.09	1930	6.52	1929
3.48	1974	2.78	1970	6.27	1921
3.41	1959	2.56	1927	5.57	1930
2.80	1930	2.28	1947	5.45	1970
2.77	1921	1.78	1976	4.50	1976
2.31	1927	1.34	1967	4.40	1927

Table F-69. PRECIPITATION DATA IN INCHES AT STORM LAKE, IOWA.
PERIOD OF RECORD IS 1899 TO 1977. N = 79

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
16.13	1900	16.01	1902	22.92	1951
15.86	1902	15.85	1962	21.38	1902
15.33	1969	14.04	1951	20.71	1900
14.89	1908	13.74	1900	20.58	1908
14.37	1919	13.48	1903	19.20	1962
14.01	1951	13.25	1907	18.33	1903
13.43	1943	12.50	1934	18.14	1969
13.42	1967	12.36	1944	18.11	1944
12.72	1944	10.95	1908	17.60	1934
12.66	1934	10.85	1945	17.40	1907
12.16	1942	10.71	1952	16.43	1967
12.13	1971	10.42	1972	16.11	1919
12.03	1907	10.38	1977	15.95	1954
10.68	1903	9.63	1973	15.36	1943
10.51	1952	9.42	1915	15.20	1932
10.39	1958	9.23	1912	14.62	1930
10.22	1953	9.09	1960	14.57	1972
10.17	1938	9.08	1957	14.44	1952
10.16	1963	8.91	1932	14.16	1945
10.11	1954	8.90	1969	13.86	1942
10.08	1920	8.53	1909	13.71	1923
10.00	1962	8.47	1953	13.67	1977
9.87	1972	8.36	1948	13.51	1963
9.49	1957	8.27	1906	13.49	1953
9.35	1909	8.11	1968	13.33	1948
9.30	1940	8.05	1943	13.26	1915
9.29	1915	7.93	1930	13.16	1957
9.29	1945	7.93	1940	13.16	1971
9.23	1923	7.87	1922	13.04	1960
8.69	1932	7.86	1920	12.98	1912
8.68	1914	7.81	1964	12.94	1940
8.60	1899	7.72	1904	12.64	1906
8.47	1977	7.55	1938	12.41	1968
8.37	1950	7.54	1954	12.35	1924
8.17	1964	7.40	1933	12.02	1920
8.14	1922	7.28	1974	12.01	1909
8.03	1918	7.18	1963	11.66	1958
8.03	1948	7.15	1942	11.61	1975

Table F-69. PRECIPITATION DATA IN INCHES AT STORM LAKE, IOWA.
Continued PERIOD OF RECORD IS 1899 TO 1977. N = 79

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
7.91	1930	7.14	1929	11.60	1964
7.85	1960	7.12	1961	11.50	1938
7.82	1941	7.06	1928	11.38	1904
7.81	1968	6.95	1921	11.28	1973
7.65	1912	6.80	1924	11.14	1974
7.22	1961	6.51	1918	10.94	1918
7.20	1906	6.41	1923	10.93	1922
7.15	1929	6.34	1950	10.74	1961
7.12	1946	6.33	1958	10.61	1899
7.10	1975	6.15	1971	10.44	1941
7.00	1917	6.04	1937	10.32	1928
6.71	1973	5.79	1939	10.10	1929
6.70	1947	5.62	1967	10.08	1950
6.68	1924	5.58	1966	9.79	1937
6.50	1905	5.54	1926	9.75	1917
6.46	1925	5.41	1917	9.50	1914
6.38	1911	5.29	1956	9.37	1946
6.28	1927	5.27	1910	9.17	1905
6.22	1904	5.07	1975	9.17	1939
6.13	1949	5.05	1931	8.80	1926
5.91	1933	4.93	1911	8.49	1911
5.86	1928	4.88	1959	8.05	1925
5.70	1974	4.64	1914	8.03	1921
5.33	1926	4.59	1949	7.81	1959
5.27	1931	4.56	1970	7.79	1927
4.96	1970	4.15	1941	7.79	1966
4.75	1937	4.14	1919	7.73	1933
4.74	1939	3.97	1905	7.62	1931
4.63	1955	3.84	1935	7.51	1947
4.61	1910	3.82	1901	7.45	1949
4.54	1901	3.79	1965	7.27	1910
4.30	1935	3.49	1916	6.86	1956
4.13	1966	3.33	1913	6.69	1901
4.06	1959	3.32	1955	6.68	1935
4.03	1956	2.91	1946	6.42	1970
3.80	1916	2.76	1936	5.86	1916
3.73	1921	2.71	1925	5.83	1965
3.58	1976	2.71	1927	5.27	1936

Table F-69. PRECIPITATION DATA IN INCHES AT STORM LAKE, IOWA,
Continued PERIOD OF RECORD IS 1899 TO 1977. N = 79

JUNE - JULY		JULY - AUGUST		JUNE - AUGUST	
AMOUNT	YEAR	AMOUNT	YEAR	AMOUNT	YEAR
3.37	1965	2.63	1899	5.25	1955
3.02	1936	2.43	1947	4.48	1913
2.96	1913	0.88	1976	3.83	1976

Table F-70. Statistical parameters of June precipitation in Northwest Iowa, inches

Location	N years	Mean	Standard deviation	Skew	Coeff. of variation
Akron	49	4.64	2.32	0.570	0.50
Alton	71	4.07	1.82	0.370	0.45
Cherokee	55	4.50	2.44	0.750	0.54
Hawarden	50	4.39	2.11	0.508	0.48
Holstein	43	4.84	2.48	1.194	0.51
Ida Grove	32	4.83	2.53	1.637	0.52
Inwood	69	4.51	2.11	0.532	0.47
Lake Park	50	4.56	2.22	0.837	0.49
Le Mars	80	4.22	1.86	0.595	0.44
Mapleton	39	4.89	2.34	1.130	0.48
Merrill	31	4.06	1.94	0.688	0.48
Milford	38	4.66	2.11	0.542	0.45
Primghar	40	4.60	1.86	0.486	0.40
Rock Rapids	73	4.42	2.11	0.413	0.48
Sac City	84	4.35	2.21	1.124	0.51
Sanborn	62	4.30	1.83	0.644	0.42
Sheldon	51	4.43	2.20	0.818	0.50
Sibley	41	4.82	2.12	1.168	0.44
Sioux Center	77	4.44	2.15	1.017	0.48
Sioux City	86	4.11	1.84	0.486	0.45
Sioux Rapids	35	4.78	2.30	0.475	0.48
Spencer	65	4.24	2.01	0.466	0.47
Storm Lake	78	4.57	2.24	0.959	0.49

Table F-71. Statistical parameters of July precipitation in Northwest Iowa, inches

Location	N years	Mean	Standard deviation	Skew	Coeff. of variation
Akron	49	3.15	1.76	0.037	0.56
Alton	71	3.29	1.64	0.248	0.50
Cherokee	55	3.54	2.11	0.571	0.60
Hawarden	50	3.11	1.81	0.410	0.58
Holstein	43	3.54	1.98	0.371	0.56
Ida Grove	32	3.50	1.86	0.283	0.53
Inwood	69	3.04	1.47	0.073	0.48
Lake Park	50	3.46	2.09	0.507	0.60
Le Mars	80	3.42	2.00	1.173	0.58
Mapleton	39	3.34	2.04	0.688	0.61
Merrill	31	3.33	1.82	0.604	0.55
Milford	38	3.56	2.24	0.620	0.63
Primghar	40	3.29	2.08	0.705	0.63
Rock Rapids	73	3.20	1.68	0.484	0.52
Sac City	84	3.49	2.35	1.504	0.67
Sanborn	62	3.32	1.83	0.301	0.55
Sheldon	51	3.19	1.76	0.379	0.55
Sibley	41	3.61	2.00	0.152	0.55
Sioux Center	77	3.44	2.02	1.239	0.59
Sioux City	86	3.25	1.91	1.035	0.59
Sioux Rapids	35	3.49	1.98	0.414	0.57
Spencer	65	3.26	2.04	0.270	0.62
Storm Lake	78	3.60	2.20	0.692	0.61

Table F-72. Statistical parameters of August precipitation in Northwest Iowa, inches

Location	N years	mean	Standard deviation	Skew	Coeff. of variation
Akron	49	3.41	1.95	0.762	0.57
Alton	71	3.36	1.82	0.677	0.54
Cherokee	55	3.33	1.96	0.442	0.59
Hawarden	50	3.27	1.92	0.641	0.59
Holstein	43	3.38	2.48	1.707	0.73
Ida Grove	32	3.76	3.10	2.504	0.82
Inwood	69	2.97	1.86	0.708	0.63
Lake Park	50	3.33	1.87	0.665	0.56
Le Mars	80	3.06	1.70	0.874	0.56
Mapleton	39	3.40	2.13	1.290	0.63
Merrill	31	3.23	1.73	0.556	0.54
Milford	38	3.18	1.77	0.377	0.56
Primghar	40	3.89	2.81	1.028	0.72
Rock Rapids	73	3.19	2.03	0.642	0.64
Sac City	84	3.56	2.11	1.070	0.59
Sanborn	62	3.67	2.15	0.935	0.58
Sheldon	51	3.56	2.10	0.504	0.59
Sibley	41	3.59	2.38	1.170	0.66
Sioux Center	77	3.23	1.97	0.942	0.61
Sioux City	86	2.85	1.76	0.994	0.62
Sioux Rapids	35	3.86	2.59	0.812	0.67
Spencer	65	3.57	2.14	1.201	0.60
Storm Lake	78	3.52	1.87	0.703	0.53

Table F-73. Statistical parameters of June plus July precipitation in Northwest Iowa, inches

Location	N years	Mean	Standard deviation	Skew	Coeff. of variation
Akron	49	7.79	2.93	0.032	0.38
Alton	71	7.36	2.37	0.163	0.32
Cherokee	55	8.04	3.31	0.619	0.41
Hawarden	50	7.50	2.93	0.406	0.39
Holstein	43	8.38	3.23	0.017	0.38
Ida Grove	32	8.33	3.15	0.953	0.38
Inwood	69	7.55	2.48	0.202	0.33
Lake Park	50	8.03	3.09	0.499	0.38
Le Mars	80	7.64	2.91	0.473	0.38
Mapleton	39	8.23	2.98	0.531	0.36
Merrill	31	7.39	2.71	0.032	0.37
Milford	38	8.23	3.06	0.278	0.37
Primghar	40	7.89	2.52	0.383	0.32
Rock Rapids	73	7.62	2.87	0.370	0.38
Sac City	84	7.84	3.14	0.644	0.40
Sanborn	62	7.62	2.68	0.486	0.35
Sheldon	51	7.62	2.76	0.753	0.36
Sibley	41	8.43	2.86	0.255	0.34
Sioux Center	77	7.88	2.82	0.647	0.36
Sioux City	86	7.36	2.72	0.527	0.37
Sioux Rapids	35	8.27	3.14	-0.097	0.38
Spencer	65	7.50	3.04	0.483	0.40
Storm Lake	78	8.17	3.28	0.574	0.40

Table F-74. Statistical parameters of July plus August precipitation in Northwest Iowa, inches

Location	N years	Mean	Standard deviation	Skew	Coeff. of variation
Akron	49	6.56	2.85	0.330	0.43
Alton	71	6.65	2.44	0.303	0.37
Cherokee	55	6.88	2.92	0.090	0.42
Hawarden	50	6.38	2.81	0.689	0.44
Holstein	43	6.93	3.02	0.613	0.44
Ida Grove	32	7.26	4.04	2.219	0.56
Inwood	69	6.00	2.14	0.131	0.36
Lake Park	50	6.80	2.77	0.070	0.41
Le Mars	80	6.48	2.48	0.567	0.38
Mapleton	39	6.74	3.22	1.149	0.48
Merrill	31	6.57	2.60	0.178	0.40
Milford	38	6.75	3.08	0.712	0.46
Primghar	40	7.18	3.64	0.367	0.51
Rock Rapids	73	6.39	2.53	0.590	0.40
Sac City	84	7.05	3.41	1.162	0.48
Sanborn	62	6.99	2.80	0.126	0.40
Sheldon	51	6.75	2.83	0.410	0.42
Sibley	41	7.20	2.70	0.332	0.38
Sioux Center	77	6.67	2.81	0.574	0.42
Sioux City	86	6.10	2.71	0.362	0.44
Sioux Rapids	35	7.35	3.49	0.263	0.47
Spencer	65	6.84	2.91	0.535	0.42
Storm Lake	78	7.12	3.21	0.725	0.45

Table F-75. Statistical parameters of June through August precipitation in Northwest Iowa, inches

Location	N years	Mean	Standard deviation	Skew	Coeff. of variation
Akron	49	11.20	3.75	0.264	0.33
Alton	71	10.72	3.10	0.301	0.29
Cherokee	55	11.38	4.17	0.258	0.37
Hawarden	50	10.77	3.70	0.634	0.34
Holstein	43	11.77	4.03	0.308	0.34
Ida Grove	32	12.09	5.04	1.725	0.42
Inwood	69	10.51	3.02	0.268	0.29
Lake Park	50	11.36	3.91	0.330	0.34
Le Mars	80	10.70	3.38	0.130	0.32
Mapleton	39	11.63	4.17	0.781	0.36
Merrill	31	10.62	3.51	0.195	0.33
Milford	38	11.41	4.04	0.572	0.35
Primghar	40	11.78	4.13	0.586	0.35
Rock Rapids	73	10.81	3.53	0.708	0.33
Sac City	84	11.40	4.21	0.715	0.37
Sanborn	62	11.30	3.51	0.276	0.31
Sheldon	51	11.18	3.83	0.503	0.34
Sibley	41	12.02	3.63	0.408	0.30
Sioux Center	77	11.12	3.61	0.521	0.32
Sioux City	86	10.21	3.34	0.225	0.33
Sioux Rapids	35	12.13	4.45	0.094	0.37
Spencer	65	11.07	3.87	0.767	0.35
Storm Lake	78	11.69	4.21	0.505	0.36

Table F-76. June precipitation in inches for several recurrence intervals at various locations in Northwest Iowa

Location	Recurrence interval, years					
	2	5	10	25	50	100
Akron	4.42	2.65	1.84	1.07	0.61	0.23
Alton	3.96	2.52	1.82	1.13	0.70	0.34
Cherokee	4.20	2.41	1.64	0.92	0.51	0.18
Hawarden	4.21	2.58	1.82	1.08	0.64	0.26
Holstein	4.36	2.75	2.15	1.66	1.42	1.25
Ida Grove	4.17	2.77	2.34	2.04	1.92	1.85
Inwood	4.32	2.70	1.95	1.23	0.80	0.44
Lake Park	4.25	2.66	1.99	1.38	1.04	0.77
Le Mars	4.04	2.62	1.99	1.38	1.02	0.72
Mapleton	4.46	2.91	2.31	1.82	1.57	1.39
Merrill	3.84	2.40	1.76	1.16	0.82	0.54
Milford	4.47	2.85	2.11	1.39	0.96	0.60
Primghar	4.45	3.01	2.33	1.68	1.28	0.94
Rock Rapids	4.28	2.62	1.83	1.04	0.57	0.16
Sac City	3.94	2.48	1.91	1.45	1.21	1.03
Sanborn	4.10	2.73	2.12	1.50	1.20	0.92
Sheldon	4.13	2.55	1.87	1.26	0.92	0.65
Sibley	4.42	3.03	2.50	2.07	1.86	1.70
Sioux Center	4.08	2.61	2.02	1.52	1.25	1.05
Sioux City	3.96	2.53	1.87	1.22	0.82	0.49
Sioux Rapids	4.60	2.81	1.97	1.15	0.66	0.24
Spencer	4.08	2.52	1.78	1.06	0.63	0.26
Storm Lake	4.22	2.66	2.02	1.47	1.18	0.94
Region	4.22	2.67	2.00	1.38	1.02	0.74

Table F-77. July precipitation in inches for several recurrence intervals at various locations in Northwest Iowa

Location	Recurrence interval, years					
	2	5	10	25	50	100
Akron	3.14	1.67	0.90	0.09	0.00	0.00
Alton	3.22	1.89	1.24	0.56	0.14	0.00
Cherokee	3.34	1.73	1.00	0.29	0.00	0.00
Hawarden	2.99	1.56	0.88	0.21	0.00	0.00
Holstein	3.42	1.85	1.09	0.34	0.00	0.00
Ida Grove	3.41	1.91	1.18	0.43	0.00	0.00
Inwood	3.02	1.80	1.17	0.50	0.08	0.00
Lake Park	3.29	1.67	0.92	0.18	0.00	0.00
Le Mars	3.04	1.73	1.24	0.84	0.63	0.49
Mapleton	3.11	1.59	0.92	0.29	0.00	0.00
Merrill	3.15	1.77	1.15	0.55	0.20	0.00
Milford	3.33	1.64	0.88	0.16	0.00	0.00
Primghar	3.05	1.51	0.83	0.19	0.00	0.00
Rock Rapids	3.06	1.76	1.15	0.56	0.20	0.00
Sac City	2.93	1.55	0.94	0.77	0.63	0.54
Sanborn	3.23	1.76	1.04	0.31	0.00	0.00
Sheldon	3.08	1.68	1.02	0.35	0.00	0.00
Sibley	3.56	1.92	1.08	0.21	0.00	0.00
Sioux Center	3.03	1.74	1.26	0.88	0.70	0.56
Sioux City	2.93	1.62	1.11	0.67	0.44	0.26
Sioux Rapids	3.39	1.80	1.03	0.25	0.00	0.00
Spencer	3.17	1.52	0.71	0.00	0.00	0.00
Storm Lake	3.34	1.71	1.00	0.33	0.00	0.00
Region	3.18	1.71	0.99	0.39	0.13	0.08

Table F-78. August precipitation in inches for several recurrence intervals at various locations in Northwest Iowa

Location	Recurrence interval, years					
	2	5	10	25	50	100
Akron	3.16	1.74	1.13	0.56	0.24	0.00
Alton	3.16	1.80	1.20	0.63	0.30	0.04
Cherokee	3.19	1.65	0.93	0.21	0.00	0.00
Hawarden	3.07	1.62	0.98	0.37	0.01	0.00
Holstein	2.72	1.38	0.97	0.71	0.61	0.55
Ida Grove	2.64	1.56	1.37	1.30	1.29	1.28
Inwood	2.75	1.38	0.77	0.21	0.00	0.00
Lake Park	3.12	1.73	1.11	0.52	0.18	0.00
Le Mars	2.82	1.61	1.10	0.65	0.40	0.21
Mapleton	2.96	1.61	1.13	0.75	0.57	0.44
Merrill	3.07	1.75	1.14	0.59	0.21	0.09
Milford	3.07	1.67	0.99	0.32	0.00	0.00
Primghar	3.42	1.50	0.73	0.08	0.00	0.00
Rock Rapids	2.97	1.45	0.77	0.12	0.00	0.00
Sac City	3.21	1.76	1.18	0.69	0.42	0.22
Sanborn	3.34	1.84	1.22	0.68	0.38	0.15
Sheldon	3.39	1.76	1.01	0.27	0.00	0.00
Sibley	3.14	1.58	0.99	0.51	0.27	0.09
Sioux Center	2.93	1.55	0.98	0.49	0.22	0.02
Sioux City	2.56	1.35	0.86	0.44	0.22	0.05
Sioux Rapids	3.51	1.64	0.84	0.12	0.00	0.00
Spencer	3.15	1.76	1.24	0.83	0.62	0.47
Storm Lake	3.30	1.92	1.31	0.74	0.41	0.14
Region	3.07	1.63	1.04	0.51	0.28	0.16

Table F-79. June plus July precipitation in inches for several recurrence intervals at various locations in Northwest Iowa

Location	Recurrence interval, years					
	2	5	10	25	50	100
Akron	7.77	5.32	4.04	2.70	1.83	1.05
Alton	7.30	5.35	4.37	3.35	2.71	2.14
Cherokee	7.70	5.20	4.08	3.01	2.38	1.87
Hawarden	7.31	4.99	3.89	2.79	2.13	1.56
Holstein	8.37	5.66	4.25	2.75	1.79	0.92
Ida Grove	7.84	5.64	4.75	3.97	3.56	3.23
Inwood	7.47	5.44	4.43	3.38	2.73	2.15
Lake Park	7.77	5.38	4.27	3.19	2.54	1.99
Le Mars	7.42	5.15	4.09	3.04	2.41	1.88
Mapleton	7.97	5.68	4.62	3.60	2.99	2.48
Merrill	7.37	5.10	3.93	2.68	1.88	1.16
Milford	8.09	5.62	4.41	3.18	2.42	1.76
Primghar	7.73	5.74	4.78	3.82	3.24	2.74
Rock Rapids	7.44	5.17	4.08	2.98	2.31	1.73
Sac City	7.51	6.05	4.09	3.09	2.51	2.03
Sanborn	7.40	5.32	4.36	3.40	2.83	2.35
Sheldon	7.28	5.26	4.38	3.57	3.11	2.73
Sibley	8.31	6.00	4.85	3.68	2.94	2.31
Sioux Center	7.58	5.46	4.52	3.62	3.09	2.66
Sioux City	7.12	5.03	4.07	3.13	2.58	2.11
Sioux Rapids	8.32	5.64	4.21	2.66	1.65	0.73
Spencer	7.26	4.90	3.80	2.72	2.07	1.52
Storm Lake	7.86	5.36	4.22	3.12	2.48	1.94
Region	7.66	5.41	4.28	3.19	2.53	1.96

Table F-80. July plus August precipitation in inches for several recurrence intervals at various locations in Northwest Iowa

Location	Recurrence interval, years					
	2	5	10	25	50	100
Akron	6.40	4.13	3.02	1.90	1.22	0.63
Alton	6.53	4.57	3.61	2.64	2.04	1.52
Cherokee	6.84	4.41	3.17	1.86	1.02	0.28
Hawarden	6.06	3.97	3.05	2.18	1.69	1.28
Holstein	6.63	4.34	3.31	2.33	1.75	1.27
Ida Grove	5.92	4.23	3.87	3.70	3.65	3.64
Inwood	5.95	4.18	3.29	2.35	1.76	1.23
Lake Park	6.76	4.46	3.27	2.02	1.22	0.51
Le Mars	6.25	4.35	3.49	2.66	2.17	1.76
Mapleton	5.97	4.08	3.46	3.01	2.82	2.70
Merrill	6.49	4.36	3.29	2.18	1.48	0.86
Milford	6.44	4.11	3.06	2.06	1.47	0.98
Primghar	6.96	4.07	2.68	1.29	0.44	0.00
Rock Rapids	6.14	4.22	3.35	2.51	2.02	1.61
Sac City	6.40	4.17	3.32	2.62	2.29	2.03
Sanborn	6.93	4.62	3.44	2.21	1.43	0.74
Sheldon	6.56	4.33	3.27	2.22	1.58	1.04
Sibley	7.05	4.89	3.85	2.80	2.16	1.60
Sioux Center	6.40	4.26	3.29	2.35	1.79	1.33
Sioux City	5.93	3.78	2.75	1.72	1.08	0.54
Sioux Rapids	7.19	4.38	2.99	1.58	0.70	0.00
Spencer	6.58	4.35	3.32	2.32	1.72	1.22
Storm Lake	6.73	4.37	3.34	2.38	1.83	1.38
Region	6.48	4.33	3.42	2.20	1.71	1.22

Table F-81. June through August precipitation in inches for several recurrence intervals at various locations in Northwest Iowa

Location	Recurrence interval, years					
	2	5	10	25	50	100
Akron	11.03	8.00	6.52	5.00	4.05	3.23
Alton	10.56	8.08	6.86	5.63	4.86	4.20
Cherokee	11.20	7.83	6.16	4.47	3.41	2.48
Hawarden	10.38	7.60	6.35	5.16	4.48	3.91
Holstein	11.56	8.33	6.76	5.16	4.17	3.32
Ida Grove	10.75	8.03	7.23	6.72	6.51	6.42
Inwood	10.37	7.94	6.74	5.51	4.75	4.09
Lake Park	11.14	8.02	6.51	4.98	4.04	3.22
Le Mars	10.62	7.83	6.42	4.94	4.00	3.17
Mapleton	11.09	8.06	6.76	5.56	4.89	4.34
Merrill	10.50	7.64	6.20	4.72	3.79	2.98
Milford	11.03	7.95	6.54	5.19	4.39	3.72
Primghar	11.38	8.24	6.82	5.44	4.64	3.97
Rock Rapids	10.40	7.78	6.64	5.57	4.96	4.46
Sac City	10.97	7.79	6.36	4.98	4.18	3.52
Sanborn	11.14	8.31	6.92	5.49	4.61	3.84
Sheldon	10.86	7.90	6.52	5.18	4.37	3.69
Sibley	11.77	8.92	7.56	6.20	5.38	4.68
Sioux Center	10.81	8.03	6.74	5.49	4.77	4.12
Sioux City	10.09	7.37	6.02	4.63	3.76	3.00
Sioux Rapids	12.06	8.36	6.47	4.49	3.22	2.09
Spencer	10.58	7.76	6.54	5.42	4.78	4.27
Storm Lake	11.34	8.09	6.57	5.10	4.22	3.48
Region	10.94	7.99	6.62	5.26	4.44	3.75

APPENDIX G.

OUTDOOR RECREATION AREAS IN NORTHWEST IOWA

Table G-1. Existing natural and artificial water areas in Northwest Iowa[a]

County	No.	Name	Location[b]
Buena Vista	1	Pickeral Lake	93-35-01
	2	Storm Lake	90-37-10
	3	Storm Lake Shooting Area	90-37-05
	4	Linn Grove Park	93-37-08
Cherokee	5	Barnes Access	92-39-16
	6	Larson Lake	92-39-36
	7	Stieneke Access	90-41-16
	8	Soo Access	93-39-09
	9	Spring Lake	92-40-28
Clay	10	Barringer Slough	96-35-14
	11	Brugeman Park	97-38-30
	12	Dan Green Slough	97-35-09
	13	Deweys Pasture	97-35-25
	14	Elk Lake	97-35-36
	15	Kindlespire Park	94-36-20
	16	Lost Island Lake	96-35-01
	17	Mud Lake	94-35-25
	18	Ocheyedan Area	96-37-07
	19	Round Lake	97-35-34
	20	Scharnberg Park	96-38-11
	21	Smith Slough	97-35-26
	22	Trumbull Lake	97-35-27
Dickinson	23	Arnold's Pond	100-38-31
	24	Center Lake	99-36-12

[a]Planning and Coordination Section (1972).

[b]Tier-Range-Section.

[c]FP = farm pond, GP = gravel pit, M = marsh, NL = natural lake, OL = oxbow lake, OSI = off-stream impoundment, P = pond.

[d]I = high density recreation areas, II = general outdoor recreation areas, III = natural environment areas, IV = unique-natural areas.

[e]Water plus adjacent land area.

Ownership	Type of water[c]	Classification[d]	Acreage Water	Total[e]
State	NL	Sovereign lake	176	176
State	NL	Sovereign lake	3,097	3,097
State	M	Wildlife area	264	276
County	P	II	2	18
			3,539	3,567
County	M	River access	4	9
County	P	Fishing access	4	11
County	M	River access	1	16
State	M	River access	1	17
City	P	I	18	18
			28	71
State	NL	Wildlife area	778	1,071
County	GP	II	8	8
State	NL	Sovereign lake	311	311
State	M	Wildlife area	161	401
State	NL	Sovereign lake	261	261
County	P	II	5	160
State	NL	Sovereign lake	1,260	1,332
State	NL	Sovereign lake	252	252
State	M	Wildlife area	25	100
State	NL	Sovereign lake	438	438
County	GP	II	10	36
State	NL	Wildlife area	236	292
State	NL	Sovereign lake	1,185	1,224
			4,930	5,886
Private	P	II	14	14
State	NL	Sovereign lake	329	342

Table G-1. Continued

County	No.	Name	Location[b]
Dickinson	25	Cory Marsh	100-38-13
	26	Christopherson Slough	100-35-13
	27	Diamond Lake	100-37-15
	28	East Okoboji Lake	99-36-29
	29	Garlock Slough	99-37-35
	30	Hales Slough	100-36-23
	31	Hottes Lake	100-36-18
	32	Jemmerson Slough	100-36-31
	33	Lake Park Pond	100-38-32
	34	Lily Lake	99-35-18
	35	Little Spirit Lake	100-36-08
	36	Lower Gar Lake	99-36-32
	37	Marble Lake	100-36-29
	38	Minnewashta Lake	99-36-30
	39	Pleasant Lake	99-35-07
	40	Prairie Lake	99-36-23
	41	Sandbar Slough	100-36-14
	42	Silver Lake	100-38-33
	43	Spirit Lake	100-36-23
	44	Spring Run	99-36-23
	45	Sunken Lake	100-36-17
	46	Swan Lake	100-35-26
	47	Upper Gar Lake	99-36-29
	48	Welsh Lake	100-37-24
	49	West Okoboji Lake	99-36-22
Ida	50	Moorhead Park	86-40-11
	51	School Pond	87-41-26
	52	Town and Country	89-39-35
Lyon	53	Githie Manitou Monument	100-49-11
O'Brien	54	Bruegman Area	97-39-14
	55	Dauma Park	96-41-05
	56	Dog Creek Park	94-39-24
	57	Mill Creek	95-41-03
	58	Van Nyhuis #1	97-42-21
	59	Van Nyhuis #2	97-42-11

Ownership	Type of water[c]	Classification[d]	Acreage Water	Acreage Total[e]
State	NL	Wildlife area	30	38
State	NL	Wildlife area	171	535
State	NL	Wildlife area	166	563
State	NL	Sovereign lake	1,873	1,873
State	NL	Wildlife area	100	222
State	NL	Wildlife area	59	85
State	NL	Sovereign lake	378	378
State	NL	Wildlife area	88	343
State	NL	II	5	5
State	NL	Sovereign lake	60	60
State	NL	Sovereign lake	214	214
State	NL	Sovereign lake	252	273
State	NL	Sovereign lake	183	183
State	NL	Sovereign lake	122	122
State	NL	Sovereign lake	77	84
State	NL	Sovereign lake	100	109
State	NL	Wildlife area	30	30
State	NL	Sovereign lake	1,058	1,141
State	NL	Sovereign lake	5,684	5,685
State	NL	Wildlife area	370	769
State	NL	Wildlife area	62	62
State	NL	Sovereign lake	371	380
State	NL	Sovereign lake	43	43
State	NL	Sovereign lake	75	75
State	NL	Sovereign lake	3,939	3,939
			15,853	17,567
County	OSI	III	12	260
State	FP	III	3	3
Private	OSI	III	12	12
			27	275
State	P	IV	1	91
			1	91
County	P	II	10	20
County	GP	II	10	21
County	OSI	II	35	110
State	OSI	II	25	158
Private	GP	II	315	315
Private	GP	II	4	4
			399	628

Table G-1. Continued

County	No.	Name	Location[b]
Osceola	60	Ashton Pits	98-42-11
	61	Iowa Lake	100-39-09
	62	May City Pit Area	98-39-06
	63	Ocheyedan Pit Area	99-40-23
	64	Peters Pit Area	100-42-19
	65	Rush Lake	100-39-36
	66	Sibley Pit	99-42-13
Plymouth	67	LeMars Pit	94-45-25
Sac	68	Black Hawk Marsh	86-36-04
	69	Black Hawk Lake	87-36-34
	70	Grant Park	86-35-14
	71	Sac City Access	88-36-25
Sioux	72	Alton Wayside	95-44-35
	73	County Hiway Pond	97-46-21
	74	Floyd Park Pit	94-44-11
	75	Haywarden Pit	94-48-03
	76	Oak Grove	95-47-05
	77	Rock Valley Access	97-46-15
	78	Sioux Center Pit	95-45-08
	79	Van Zee Pit	97-46-19
Woodbury	80	Browns Lake	87-46-28
	81	Little Sioux Park	88-43-12
	82	Midway Park	89-44-10
	83	Park Pits	89-42-12
	84	Synder Bend	86-47-16
	85	Winnebago Bend	86-47-28

Ownership	Type of water[c]	Classification[d]	Acreage Water	Acreage Total[e]
State	GP	Wildlife area	11	33
State	NL	Sovereign lake	114	114
County	GP	Fishing access	1	6
County	GP	Fishing access	2	18
County	GP	Fishing access	3	19
State	NL	Sovereign lake	314	336
Private	GP	Fishing access	2	2
			447	528
County	GP	III	3	3
			3	3
State	M	Wildlife area	56	206
State	NL	Sovereign lake	957	957
County	P	II	5	98
State	M	River access	2	23
			1,020	1,284
State	P	Rest area	2	11
State	GP	II	15	15
County	GP	II	2	2
Private	GP	II	?	?
State	GP	II	5	102
County	M	River access	4	52
County	GP	II	5	5
County	GP	II	7	7
			40	194
State	OL	Wildlife area	325	784
County	GP	II	3	448
State	OL	Wildlife area	2	2
County	OSI	II	14	14
State	OL	River access, II	375	409
State	OL	River access	555	584
			1,274	2,241

Table G-2. Existing outdoor recreation areas in Northwest Iowa without bodies of water[a]

County	No.	Name	Location[b]	Ownership	Classification[c]	Area acres
Buena Vista	1	Bel Air Access	90-37-03	State	Lake access	4
	2	Buena Vista Co. Park	93-38-10	County	II	292
	3	Caseno Bay	90-37-08	State	VII	14
	4	Storm Lake Reserve	90-37-11	State	VII	12
						322
Cherokee	5	Martin Access	92-40-01	County	River access	164
	6	Meriden Wayside	92-41-11	State	Rest area	16
	7	Nelson Access	93-39-16	County	River access	9
	8	Pearse Access	91-40-31	County	River access	14
	9	Ranney Knob Area	90-41-31	County	River access	73
	10	Ritts Access	90-41-30	County	River access	9
						285
Clay	11	Grandview Park	97-35-36	County	VII	1
	12	Little Sioux Wildlife Area	95-36-13	State	Wildlife area	160
	13	Oneota Park	96-36-16	County	VII	8
	14	Wanata Reserve	94-38-33	State	III	160
	15	Wapiti Marsh	96-35-27	State	Wildlife area	80
	16	Weterell Area	94-38-32	County	VII	3
						412
Dickinson	17	Abbie Gardner Sharp Cabin	99-36-29	State	VI	1
	18	Arnold's Park Station	99-36-29	State	Lake access	1
	19	Camp Winakawin	99-36-29	Private	II	8
	20	Caylor Prairie	99-37-06	State	IV	160
	21	Cen La Campground	100-36-33	Private	II	12
	22	Crandalls Beach	100-36-17	State	Lake access	6
	23	Crows Nest	100-36-33	Private	II	20

	24	East Okoboji Area	99-36-03	State	River access	24
	25	Four Mile Lake	99-35-13	State	Wildlife area	5
	26	Gerks Resort	100-36-29	Private	II	4
	27	Gull Point Area	99-37-25	State	II	65
	28	Hogsback Area	100-36-19	State	Wildlife area	262
	29	Lazy Lagoon	99-37-09	State	Lake access	1
	30	Marble Beach	100-36-17	State	Lake access	64
	31	Mini-Waukon State Area	100-36-09	State	Lake access	20
	32	Narrows Access	99-36-15	State	Lake access	1
	33	Nordstroms Beach	100-36-33	Private	II	40
	34	Orleans Beach	100-36-27	State	II	2
	35	Pikes Point	99-36-19	State	II	15
	36	Pillsbury Point	99-36-30	State	II	6
	37	Trappers Bay	100-38-28	State	Lake access	65
	38	White Oaks	98-37-12	Private	II	4
	39	Yager Slough	100-38-36	State	Wildlife area	56
						842
Ida	40	Galva Wayside	89-39-35	State	Rest area	4
	41	Heiber Access	87-41-26	County	River access	5
	42	Sherman Park	89-40-18	County	II	4
	43	Washta Access	89-41-07	State	River access	52
						65
Lyon	44	Big Sioux Wildlife Area	98-48-10	State	Wildlife area	435
	45	Hwy. 9 Wayside #1	100-45-31	City	Rest area	10

[a]Planning and Coordination Section (1972).

[b]Tier-Range-Section.

[c]II = general outdoor recreation areas, III = natural environment areas, VI = historic and cultural sites, VII = reserved open spaces and undeveloped lands.

Table G-2. Continued

County	No.	Name	Location[b]	Ownership	Classification[c]	Area acres
Lyon	46	Hwy. 9 Wayside #2	100-45-35	State	Rest area	1
	47	Hwy. 75 Wayside	99-45-33	County	VII	5
						451
O'Brien	48	Covey Church Park	95-39-05	County	II	1
	49	Litka Park	95-39-28	County	III	4
	50	Peterson Wayside	97-40-30	State	Rest area	1
	51	Porter Wildlife Area	96-39-33	County	VII	1
	52	Wall Park	95-40-28	County	II	1
	53	Wittrock Indian Village	94-39-11	State	VII	5
						13
Osceola	54	Hwy. 60 Wayside	99-42-12	State	Rest area	1
	55	Jct. 9 & 237 Wayside	99-40-02	State	Rest area	1
	56	Johnson Wilderness Area	99-41-12	County	Wildlife area	6
						8
Plymouth	57	Big Sioux Park	93-48-31	County	VII	33
	58	Millsite Access	92-49-28	State	River access	16
	59	SE Wildwood Park	90-44-13	County	VII	36
						85
Sac	60	Black Hawk Lake State Park	86-36-04	State	II	267
	61	Hagge Park	87-36-36	County	II	85
	62	Kiowa Marsh	89-35-30	State	Wildlife area	40
	63	Lake View Hatchery & Pits	86-36-03	State	Fish hatchery	156
	64	Luback Forest	87-36-25	County	VII	28
	65	Reiff Park	88-37-16	County	III	80

	66	Tomahawk Marsh	87-36-09	State	Wildlife area	39
						695
Sioux	67	Big Sioux Park	95-48-12	County	II	57
	68	Rock-Sioux Access	97-48-24	State	River access	30
	69	Winterfield Access	97-46-16	County	River access	22
						109
Woodbury	70	Bigelow Park	87-47-33	State	Fishing access	17
	71	Hwy. 20 Wayside #1	89-46-32	State	Rest area	1
	72	Hwy. 20 Wayside #2	89-43-36	State	Rest area	6
	73	Smithland Forest	86-44-27	County	III	50
	74	Snyder Bend	87-47-30	County	River access	34
	75	Stone Park	89-48-01	State	III	865
	76	War Eagle Park	89-47-30	County	II	24
	77	Winnebago Bend	86-47-32	State	River access	29
						1,026

Table G-3. Acreage desirable for recreation in Buena Vista County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicing	DL	0.03480	99
	Swimming beach	DL	0.00412	12
	Boating access	DL	0.00563	16
	Parking	DL	0.00833	24
	Sanitation	DL	0.00938	27
	Camping	DL	0.01333	38
	Roads and trails	POP	0.00240	50
	Administration	POP	0.00050	10
	Subtotal			276
Water	Fishing	POP	0.00500	104
	Boating	POP	0.00500	104
	Water skiing	POP	0.00500	104
	Swimming	DL	0.00126	4
	Subtotal			316
Total				592

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-4. Acreage desirable for recreation in Cherokee County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	82
	Swimming beach	DL	0.00412	10
	Boating access	DL	0.00563	13
	Parking	DL	0.00833	20
	Sanitation	DL	0.00938	22
	Camping	DL	0.01333	32
	Roads and trails	POP	0.00240	42
	Administration	POP	0.00050	9
	Subtotal			230
Water	Fishing	POP	0.00500	87
	Boating	POP	0.00500	87
	Water skiing	POP	0.00500	87
	Swimming	DL	0.00126	3
	Subtotal			264
Total				494

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-5. Acreage desirable for recreation in Clay County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	92
	Swimming beach	DL	0.00412	11
	Boating access	DL	0.00563	15
	Parking	DL	0.00833	22
	Sanitation	DL	0.00938	25
	Camping	DL	0.01333	35
	Roads and trails	POP	0.00240	46
	Administration	POP	0.00050	10
	Subtotal			256
Water	Fishing	POP	0.00500	97
	Boating	POP	0.00500	97
	Water skiing	POP	0.00500	97
	Swimming	DL	0.00126	3
	Subtotal			294
Total				550

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-6. Acreage desirable for recreation in Dickinson County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	63
	Swimming beach	DL	0.00412	7
	Boat access	DL	0.00563	10
	Parking	DL	0.00833	15
	Sanitation	DL	0.00938	17
	Camping	DL	0.01333	24
	Roads and trails	POP	0.00240	32
	Administration	POP	0.00050	7
	Subtotal			175
Water	Fishing	POP	0.00500	66
	Boating	POP	0.00500	66
	Water skiing	POP	0.00500	66
	Swimming	DL	0.00126	2
	Subtotal			200
Total				375

[a] DL = design load; POP = population.

[b] U.S. Department of the Interior (1967).

[c] Acres = unit x factor.

Table G-7. Acreage desirable for recreation in Ida County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	44
	Swimming beach	DL	0.00412	5
	Boating access	DL	0.00563	7
	Parking	DL	0.00833	10
	Sanitation	DL	0.00938	12
	Camping	DL	0.01333	17
	Roads and trails	POP	0.00240	22
	Administration	POP	0.00050	5
	Subtotal			122
Water	Fishing	POP	0.00500	46
	Boating	POP	0.00500	46
	Water skiing	POP	0.00500	46
	Swimming	DL	0.00126	2
	Subtotal			140
Total				262

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-8. Acreage desirable for recreation in Lyon County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	63
	Swimming beach	DL	0.00412	7
	Boating access	DL	0.00563	10
	Parking	DL	0.00833	15
	Sanitation	DL	0.00938	17
	Camping	DL	0.01333	24
	Roads and trails	POP	0.00240	32
	Administration	POP	0.00050	7
	Subtotal			175
Water	Fishing	POP	0.00500	67
	Boating	POP	0.00500	67
	Water skiing	POP	0.00500	67
	Swimming	DL	0.00126	2
	Subtotal			203
Total				378

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-9. Acreage desirable for recreation in O'Brien County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	84
	Swimming beach	DL	0.00412	9
	Boating access	DL	0.00563	14
	Parking	DL	0.00833	20
	Sanitation	DL	0.00938	23
	Camping	DL	0.01333	32
	Roads and trails	POP	0.00240	42
	Administration	POP	0.00050	9
	Subtotal			233
Water	Fishing	POP	0.00500	88
	Boating	POP	0.00500	88
	Water skiing	POP	0.00500	88
	Swimming	DL	0.00126	3
	Subtotal			267
Total				500

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-10. Acreage desirable for recreation in Osceola County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	40
	Swimming beach	DL	0.00412	5
	Boating access	DL	0.00562	7
	Parking	DL	0.00833	10
	Sanitation	DL	0.00938	11
	Camping	DL	0.01333	15
	Roads and trails	POP	0.00240	20
	Administration	POP	0.00050	5
	Subtotal			113
Water	Fishing	POP	0.00500	43
	Boating	POP	0.00500	43
	Water skiing	POP	0.00500	43
	Swimming	DL	0.00126	2
	Subtotal			131
Total				244

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-11. Acreage desirable for recreation in Plymouth County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	116
	Swimming beach	DL	0.00412	14
	Boating access	DL	0.00563	19
	Parking	DL	0.00833	28
	Sanitation	DL	0.00938	31
	Camping	DL	0.01333	44
	Roads and trails	POP	0.00240	58
	Administration	POP	0.00050	12
	Subtotal			322
Water	Fishing	POP	0.00500	122
	Boating	POP	0.00500	122
	Water skiing	POP	0.00500	122
	Swimming	DL	0.00126	4
	Subtotal			370
Total				692

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-12. Acreage desirable for recreation in Sac County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	74
	Swimming beach	DL	0.00412	9
	Boating access	DL	0.00563	12
	Parking	DL	0.00833	18
	Sanitation	DL	0.00938	20
	Camping	DL	0.01333	29
	Roads and trails	POP	0.00240	37
	Administration	POP	0.00050	8
	Subtotal			207
Water	Fishing	POP	0.00500	78
	Boating	POP	0.00500	78
	Water skiing	POP	0.00500	78
	Swimming	DL	0.00126	3
	Subtotal			237
Total				444

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-13. Acreage desirable for recreation in Sioux County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	134
	Swimming beach	DL	0.00412	16
	Boating access	DL	0.00563	22
	Parking	DL	0.00833	32
	Sanitation	DL	0.00938	36
	Camping	DL	0.01333	51
	Roads and trails	POP	0.00240	67
	Administration	POP	0.00050	14
	Subtotal			372
Water	Fishing	POP	0.00500	140
	Boating	POP	0.00500	140
	Water skiing	POP	0.00500	140
	Swimming	DL	0.00126	5
	Subtotal			425
Total				797

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

Table G-14. Acreage desirable for recreation in Woodbury County through 2020

Location	Use	Unit[a]	Factor[b]	Acres[c]
Land	Picnicking	DL	0.03480	491
	Swimming beach	DL	0.00412	58
	Boating access	DL	0.00563	79
	Parking	DL	0.00833	118
	Sanitation	DL	0.00938	132
	Camping	DL	0.01333	188
	Roads and trails	POP	0.00240	247
	Administration	POP	0.00050	52
	Subtotal			1,365
Water	Fishing	POP	0.00500	515
	Boating	POP	0.00500	515
	Water skiing	POP	0.00500	515
	Swimming	DL	0.00126	18
	Subtotal			1,563
Total				2,928

[a]DL = design load; POP = population.

[b]U.S. Department of the Interior (1967).

[c]Acres = unit x factor.

APPENDIX H.

CROP AND LIVESTOCK DATA

Table H-1. Total corn acreage from 1952 through 1976 in Buena Vista, Cherokee, Clay, Dickinson, Ida and Lyon Counties

Year	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
1952	135,710	119,993	127,709	80,989	93,125	132,340
1953	138,694	127,320	132,841	87,049	96,451	141,660
1954	124,506	114,695	118,203	75,960	89,617	130,519
1955	132,968	124,087	125,396	80,538	92,461	135,752
1956	112,754	78,231	126,151	76,424	40,921	137,468
1957	124,537	111,946	123,629	80,559	83,051	139,485
1958	123,609	123,628	123,389	79,623	89,870	140,605
1959	161,286	152,630	154,870	102,408	109,982	165,683
1960	156,415	145,096	148,039	100,826	107,904	157,740
1961	123,875	116,635	115,368	74,273	85,985	131,577
1962	123,100	119,761	114,745	73,522	87,871	132,486
1963	137,285	129,056	125,907	80,360	96,826	138,406
1964	120,734	105,732	114,342	75,208	83,554	124,478
1965	119,472	104,933	111,690	70,314	84,529	128,572
1966	124,497	111,423	115,983	74,171	85,971	130,688
1967	134,220	117,936	121,817	76,587	97,110	137,744
1968	123,985	106,918	107,989	69,704	81,495	113,967
1969	124,783	113,551	104,903	69,045	87,995	126,764
1970	136,090	115,303	113,658	71,576	91,250	121,618
1971	151,298	131,853	132,712	87,098	113,074	149,938
1972	139,919	129,676	123,449	77,329	107,748	139,857
1973	145,811	137,005	129,366	85,906	114,645	152,181
1974	163,143	151,923	138,206	88,433	123,168	144,003
1975	157,735	141,598	136,291	92,402	122,444	146,824
1976	161,314	132,273	138,655	88,609	119,797	132,731

Table H-2. Total corn acreage from 1952 through 1976 in O'Brien, Osceola, Plymouth, Sac, Sioux and Woodbury Counties

Year	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
1952	128,510	91,214	200,340	129,457	185,085	183,910
1953	136,685	96,338	208,223	133,713	195,468	195,237
1954	121,042	88,806	191,661	123,117	182,070	177,470
1955	126,678	93,309	199,929	129,360	188,830	185,719
1956	121,576	91,278	85,449	70,524	184,684	104,983
1957	121,292	96,236	163,926	116,075	189,181	132,517
1958	127,743	94,819	197,474	122,066	201,630	163,327
1959	160,913	115,968	239,173	152,738	238,343	209,099
1960	152,932	109,357	222,235	149,291	230,869	212,849
1961	128,740	88,180	194,687	122,049	195,763	167,890
1962	129,634	87,852	198,075	120,911	199,604	165,639
1963	136,958	94,172	207,691	133,964	200,787	178,535
1964	122,062	87,751	169,147	117,531	179,542	146,153
1965	123,861	85,373	175,948	115,330	189,824	144,195
1966	128,238	87,169	188,367	123,135	198,131	156,099
1967	132,660	91,111	207,518	132,379	200,976	177,729
1968	118,563	81,079	176,772	122,822	173,089	142,959
1969	129,120	83,931	187,882	122,497	193,921	151,548
1970	132,320	86,458	195,288	128,898	178,149	154,355
1971	146,022	101,166	226,869	146,968	218,335	204,655
1972	138,220	92,595	219,493	135,548	205,632	187,601
1973	141,927	98,340	235,685	149,530	227,956	215,363
1974	154,345	99,830	238,957	159,368	233,989	236,792
1975	150,571	100,198	228,296	157,736	217,461	229,449
1976	149,281	101,188	215,308	150,416	187,680	223,007

Table H-3. Average corn yield in bushels per acre from 1952 through 1977 in Buena Vista, Cherokee, Clay, Dickinson, Ida and Lyon Counties

Year	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
1952	66.5	66.5	65.0	57.2	66.6	51.7
1953	60.0	61.5	56.1	54.3	55.7	52.4
1954	61.9	62.2	61.9	60.3	56.7	56.1
1955	45.7	52.8	44.5	46.5	32.3	43.4
1956	33.4	23.6	53.3	55.6	20.6	43.7
1957	59.1	65.3	55.7	57.5	59.9	57.7
1958	63.7	56.7	50.4	50.7	65.6	42.4
1959	69.1	62.9	60.9	40.3	63.8	48.0
1960	73.3	70.9	64.7	61.3	73.9	59.5
1961	83.0	81.2	76.1	64.7	81.8	64.6
1962	77.9	81.6	75.4	63.2	83.7	68.1
1963	82.7	72.6	80.2	80.1	80.0	64.3
1964	84.3	77.1	80.3	76.6	82.9	68.4
1965	64.2	67.9	68.8	57.6	76.7	72.3
1966	84.8	85.0	86.6	90.5	90.6	71.8
1967	93.5	88.0	75.2	72.5	92.4	75.6
1968	102.0	89.4	93.3	84.7	78.9	68.3
1969	101.7	104.4	106.9	102.5	103.1	103.6
1970	83.8	70.1	81.7	90.2	65.3	51.4
1971	103.0	99.0	101.0	94.0	99.0	84.0
1972	114.0	112.0	113.0	105.0	112.0	106.0
1973	109.5	109.7	105.2	103.9	104.8	101.7
1974	90.8	84.5	70.3	59.3	80.9	47.1
1975	97.6	91.1	93.7	85.8	94.0	71.8
1976	74.0	69.4	85.3	66.9	62.4	57.1
1977	118.5	110.1	115.9	100.9	108.0	89.8

Table H-4. Average corn yield in bushels per acre from 1952 through 1977 in O'Brien, Osceola, Plymouth, Sac, Sioux and Woodbury Counties

Year	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
1952	65.1	57.4	55.6	66.6	61.8	53.7
1953	61.7	48.0	51.4	54.9	57.1	46.7
1954	61.6	57.9	50.3	58.9	59.8	44.0
1955	54.2	50.1	36.9	52.5	46.9	31.0
1956	46.5	56.7	19.1	26.5	39.2	24.5
1957	62.8	60.8	55.2	58.8	57.5	56.7
1958	55.1	55.5	50.4	70.5	48.1	59.3
1959	60.5	52.0	55.7	65.6	55.0	57.9
1960	70.6	62.9	50.8	76.9	68.9	59.6
1961	77.7	67.6	70.4	81.4	70.4	70.0
1962	77.8	70.3	74.4	80.1	79.5	68.3
1963	73.4	77.7	58.2	82.1	56.4	66.2
1964	73.9	71.1	63.9	85.6	66.6	69.6
1965	73.6	69.1	75.8	69.3	84.0	74.9
1966	85.0	79.8	87.5	86.6	78.5	87.5
1967	73.0	80.0	82.8	90.9	73.3	76.6
1968	75.1	72.4	68.7	97.7	67.6	59.0
1969	116.9	111.3	89.4	98.9	101.2	93.8
1970	73.1	82.2	56.8	67.3	52.4	52.8
1971	100.0	94.0	83.0	87.0	87.0	86.0
1972	117.0	114.0	107.0	110.0	105.0	107.0
1973	120.1	102.3	95.3	107.6	104.3	97.9
1974	77.4	52.5	61.5	85.2	69.5	63.4
1975	95.1	89.2	65.3	86.7	72.0	80.9
1976	91.7	75.9	52.8	55.1	61.5	61.1
1977	118.0	111.4	91.0	88.2	92.7	101.5

Table H-5. Total soybean acreage from 1952 through 1976 in Buena Vista, Cherokee, Clay, Dickinson, Ida and Lyon Counties

Year	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
1952	25,748	22,218	27,243	11,495	5,213	15,216
1953	26,254	22,732	28,282	10,401	5,454	14,825
1954	35,495	30,482	38,825	19,816	7,894	23,578
1955	35,149	27,095	40,709	23,762	7,330	26,448
1956	41,808	32,649	45,349	26,849	7,764	23,633
1957	42,964	34,364	46,613	30,062	12,935	24,439
1958	53,078	38,110	54,489	34,591	13,374	32,626
1959	37,688	28,925	41,072	25,288	9,443	23,944
1960	43,667	29,588	46,232	24,346	9,107	23,095
1961	60,863	43,471	59,324	35,850	17,464	31,774
1962	61,768	41,880	60,906	34,351	16,787	33,121
1963	65,056	42,724	64,849	37,151	18,890	36,890
1964	80,274	56,591	76,193	43,812	28,818	46,559
1965	87,008	56,244	81,639	50,649	36,081	52,685
1966	87,969	58,402	83,844	51,985	35,573	55,707
1967	93,562	65,332	91,408	52,598	40,278	57,266
1968	94,858	65,530	89,574	52,993	39,451	57,675
1969	92,242	58,496	83,052	51,874	36,830	47,047
1970	94,854	60,342	92,377	55,082	39,795	52,174
1971	86,927	53,606	87,053	54,394	34,564	45,140
1972	92,720	60,906	92,278	55,253	37,214	50,300
1973	121,469	80,434	116,875	72,093	52,052	72,383
1974	111,979	78,451	107,188	68,292	47,871	68,613
1975	115,351	75,825	110,387	70,475	48,912	73,345
1976	107,946	66,474	100,768	67,535	41,545	66,679

Table H-6. Total soybean acreage from 1952 through 1976 in O'Brien, Osceola, Plymouth, Sac, Sioux and Woodbury Counties

Year	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
1952	35,090	20,658	19,768	22,513	24,757	22,613
1953	35,506	20,882	18,881	21,437	24,877	25,770
1954	50,055	32,790	27,195	26,501	35,540	33,370
1955	49,873	36,226	24,542	25,784	34,171	33,006
1956	54,896	36,893	20,119	28,624	34,467	26,831
1957	56,244	37,217	30,816	32,834	34,665	35,127
1958	63,870	45,306	32,212	37,250	38,959	44,684
1959	51,419	36,035	19,292	27,994	28,955	38,706
1960	53,457	35,007	16,470	29,268	27,075	30,678
1961	67,378	44,023	29,253	42,790	37,605	38,686
1962	66,119	42,271	27,865	43,018	36,793	32,928
1963	69,570	44,264	35,037	44,550	39,802	42,423
1964	79,665	50,827	52,097	56,164	53,036	55,486
1965	86,524	53,632	58,685	64,371	58,997	60,391
1966	87,688	57,024	61,703	69,867	62,464	62,047
1967	94,407	59,937	68,228	77,209	68,781	57,761
1968	95,451	61,382	70,192	78,179	65,031	61,931
1969	88,325	55,058	59,077	72,726	54,906	55,032
1970	95,187	60,820	62,788	76,077	56,754	57,821
1971	87,495	57,430	52,821	66,804	49,645	45,936
1972	90,758	63,107	53,920	69,923	50,511	49,255
1973	118,946	83,302	84,369	90,630	73,419	67,472
1974	114,938	75,926	74,618	83,996	69,469	63,383
1975	116,164	79,056	81,623	89,886	69,508	66,942
1976	102,236	73,307	75,016	80,748	63,012	55,683

Table H-7. Average soybean yield in bushels per acre from 1952 through 1976 in Buena Vista, Cherokee, Clay, Dickinson, Ida and Lyon Counties

Year	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
1952	27.1	28.1	25.4	18.9	28.2	20.3
1953	23.7	27.9	24.0	20.1	23.9	22.3
1954	28.1	30.2	27.8	25.2	27.8	25.6
1955	17.7	21.0	18.3	18.4	18.8	17.3
1956	13.7	9.6	20.1	18.8	8.1	16.6
1957	27.1	29.3	25.1	23.1	26.8	25.8
1958	23.2	23.4	19.8	19.3	26.9	17.7
1959	30.3	29.0	27.4	19.9	26.9	22.4
1960	28.5	29.9	25.7	22.9	28.7	26.4
1961	31.1	31.3	28.1	23.3	31.5	27.6
1962	28.1	30.3	28.1	23.8	29.9	26.1
1963	32.2	32.7	30.5	28.2	33.0	27.2
1964	31.0	30.5	28.4	25.5	31.7	26.5
1965	23.1	24.5	22.5	19.2	25.6	22.8
1966	30.6	32.7	30.4	28.8	32.5	26.5
1967	30.1	30.5	22.2	19.4	29.4	24.4
1968	33.2	28.3	27.2	21.7	26.1	18.9
1969	30.0	35.9	34.8	31.3	34.2	33.4
1970	28.1	26.3	28.9	29.2	26.6	20.7
1971	32.0	32.0	33.0	30.0	31.0	30.0
1972	35.0	37.0	38.0	37.0	37.0	39.0
1973	36.5	39.6	35.0	34.9	35.5	35.6
1974	32.2	31.0	27.3	26.0	29.7	26.6
1975	37.4	38.1	34.6	31.1	37.2	36.2
1976	27.5	30.8	29.8	26.2	28.2	28.0

Table H-8. Average soybean yields in bushels per acre from 1952 through 1976 in O'Brien, Osceola, Plymouth, Sac, Sioux and Woodbury Counties

Year	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
1952	23.6	20.0	24.3	27.4	22.8	21.7
1953	25.4	16.6	24.2	24.7	25.3	16.1
1954	29.1	25.6	26.4	29.7	28.5	20.3
1955	20.7	18.9	15.8	19.7	19.6	12.2
1956	18.5	19.5	7.3	10.0	16.7	10.1
1957	28.6	25.5	26.7	27.5	26.9	26.8
1958	22.4	20.9	19.9	26.3	20.1	24.4
1959	28.2	22.8	25.4	27.7	25.8	19.5
1960	28.4	24.7	25.8	29.2	28.2	23.9
1961	30.0	25.7	29.8	33.0	28.9	24.4
1962	29.0	25.1	29.7	29.8	29.7	21.1
1963	31.0	28.7	29.5	32.8	27.6	26.9
1964	29.3	24.9	28.6	32.5	28.5	26.8
1965	23.9	22.2	26.0	25.4	27.3	23.0
1966	31.3	27.6	31.7	32.1	29.2	28.7
1967	23.4	24.5	30.3	31.1	25.4	23.4
1968	22.2	19.2	22.5	33.1	20.3	20.1
1969	37.5	33.4	30.9	30.9	34.3	31.2
1970	28.0	28.2	23.1	26.7	23.1	21.5
1971	35.0	31.0	27.0	29.0	30.0	27.0
1972	42.0	40.0	38.0	34.0	39.0	34.0
1973	40.1	34.7	35.2	34.0	38.5	31.2
1974	28.2	23.6	32.5	31.2	32.4	27.7
1975	37.0	35.4	35.4	34.1	36.5	33.5
1976	33.9	29.0	26.8	25.7	30.9	24.8

Table H-9. Total hay acreage from 1952 through 1976 in Buena Vista, Cherokee, Clay, Dickinson, Ida and Lyon Counties

Year	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
1952	29,143	36,124	30,401	22,311	32,809	26,734
1953	32,736	36,902	31,661	23,225	34,025	25,756
1954	35,276	37,307	34,174	21,321	35,194	26,751
1955	36,601	40,070	34,785	23,663	37,540	29,224
1956	29,694	36,380	31,135	23,072	28,631	35,861
1957	34,015	33,896	35,852	25,596	29,019	33,798
1958	33,270	33,755	31,130	23,005	31,122	28,521
1959	28,555	28,942	26,263	20,977	27,804	27,273
1960	27,702	31,140	26,942	21,825	30,821	27,506
1961	25,130	29,776	26,332	19,940	27,573	28,108
1962	26,180	30,815	27,816	21,402	28,712	29,493
1963	24,311	28,596	26,982	20,527	26,581	29,997
1964	22,609	27,602	25,140	19,580	25,035	28,380
1965	20,228	25,496	22,154	17,599	23,525	28,195
1966	18,961	25,018	23,610	16,581	23,164	28,238
1967	16,007	23,532	19,204	16,245	21,406	28,018
1968	13,577	19,598	16,267	13,128	19,933	28,603
1969	12,772	20,092	16,246	13,351	20,279	28,869
1970	10,824	18,589	14,074	12,094	19,144	26,014
1971	9,230	15,903	12,869	11,860	15,343	24,162
1972	7,649	14,108	12,733	11,139	14,622	22,836
1973	9,149	14,862	13,836	11,764	16,631	23,349
1974	8,479	16,218	13,232	12,062	15,662	23,248
1975	8,810	15,733	14,603	11,394	15,325	24,371
1976	7,636	12,293	11,535	10,882	14,257	22,739

Table H-10. Total hay acreage from 1952 through 1976 in O'Brien, Osceola, Plymouth, Sac, Sioux and Woodbury Counties

Year	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
1952	28,544	17,623	39,591	36,395	33,234	38,422
1953	28,974	17,870	40,476	39,358	32,896	40,386
1954	28,716	17,396	40,813	40,563	32,433	43,052
1955	31,302	19,888	48,055	43,952	38,598	50,626
1956	30,085	21,212	56,746	36,987	61,153	57,680
1957	32,328	22,757	49,349	36,694	46,677	50,008
1958	26,730	19,128	43,953	40,121	39,359	43,503
1959	24,568	19,063	40,349	35,077	37,251	37,574
1960	25,708	19,333	42,260	36,689	38,968	38,890
1961	24,858	19,277	39,760	33,673	38,189	34,776
1962	24,807	19,904	41,941	38,018	40,266	37,177
1963	23,656	19,580	39,236	34,360	41,603	35,851
1964	22,665	18,709	38,540	32,556	38,829	33,001
1965	19,276	16,811	37,165	29,359	36,992	32,335
1966	19,824	17,139	35,161	30,166	35,730	32,783
1967	19,759	16,247	34,167	27,756	39,334	31,408
1968	19,010	14,971	33,076	23,448	45,614	28,905
1969	18,104	14,194	33,401	24,360	39,814	28,450
1970	15,211	13,368	29,583	23,175	37,051	26,563
1971	13,031	11,589	26,662	18,916	33,041	21,443
1972	11,901	10,457	25,931	16,255	30,866	19,421
1973	12,434	11,464	26,427	18,812	29,520	21,071
1974	11,921	11,162	27,002	16,479	32,019	21,834
1975	12,020	10,706	28,204	16,514	33,420	21,081
1976	10,322	9,065	26,360	15,913	28,539	18,195

Table H-11. Total pasture acreage from 1952 through 1974 in Buena Vista, Cherokee, Clay, Dickinson, Ida and Lyon Counties

Year	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
1952	53,579	79,935	57,568	41,273	57,698	61,603
1953	51,387	77,517	54,177	42,719	54,901	59,648
1954	51,465	79,662	56,934	43,414	56,348	60,605
1955	50,972	79,144	55,664	40,285	56,439	60,578
1956	47,622	79,722	54,353	39,573	55,998	62,130
1957	43,685	75,350	51,364	36,588	53,620	55,531
1958	42,163	72,153	49,826	32,652	52,488	54,393
1959	39,488	70,686	46,324	31,660	50,952	52,057
1960	38,516	68,891	43,539	30,253	47,904	51,779
1961	39,135	66,180	45,681	33,122	49,304	50,596
1962	39,296	66,813	44,611	31,295	48,224	51,815
1963	38,620	68,009	44,365	31,467	47,835	51,651
1964	38,367	65,601	44,089	30,671	46,293	49,579
1965	35,211	65,909	44,299	29,912	45,521	46,988
1966	34,023	64,918	43,378	28,219	45,697	44,721
1967	33,259	63,717	42,990	27,933	45,002	44,275
1968	32,800	65,122	44,241	26,412	44,659	44,709
1969	30,915	64,271	46,303	24,105	42,430	44,371
1970	28,179	61,476	38,120	23,832	41,953	44,248
1971	28,385	60,112	37,991	22,046	38,056	41,805
1972	25,090	57,085	37,423	23,726	35,598	42,077
1973	24,158	57,244	37,569	21,488	34,531	41,914
1974	25,684	57,906	36,349	24,006	37,762	41,921

Table H-12. Total pasture acreage from 1952 through 1974 in O'Brien, Osceola, Plymouth, Sac, Sioux and Woodbury Counties

Year	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
1952	57,003	32,729	106,417	62,059	71,843	115,811
1953	54,973	30,963	106,144	58,484	68,870	115,736
1954	56,692	31,952	110,511	59,216	70,378	117,634
1955	56,477	31,554	108,410	57,826	68,253	115,022
1956	54,793	30,347	109,883	58,338	66,300	116,655
1957	50,253	27,661	99,962	56,169	61,307	100,224
1958	47,824	25,890	94,562	54,224	59,801	95,936
1959	44,374	24,241	91,501	52,685	52,839	96,453
1960	42,701	22,757	87,816	50,566	48,630	94,753
1961	42,841	23,461	88,774	50,809	48,821	94,365
1962	41,435	23,128	90,342	50,614	42,613	95,421
1963	40,725	22,453	89,268	48,971	47,140	98,749
1964	40,254	22,753	91,258	47,522	46,244	101,941
1965	38,555	21,848	90,839	44,483	42,370	100,342
1966	37,214	21,281	87,963	43,978	39,282	95,769
1967	36,939	20,762	87,208	42,670	39,405	96,113
1968	37,099	20,727	89,715	46,982	41,875	94,601
1969	30,262	22,026	87,660	47,827	40,869	92,883
1970	29,387	17,096	84,130	45,961	37,441	92,360
1971	29,129	16,277	83,974	40,128	34,647	90,269
1972	28,978	15,861	75,322	40,052	34,257	88,977
1973	28,834	13,566	76,468	38,198	27,025	92,418
1974	28,214	15,102	76,421	37,513	31,264	94,128

Table H-13. Total number of cattle marketed from 1952 through 1976 in Buena Vista, Cherokee, Clay, Dickinson, Ida and Lyon Counties

Year	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
1952	26,757	41,562	19,135	7,674	31,987	26,152
1953	34,000	50,517	24,771	10,814	38,040	33,895
1954	36,565	53,036	25,609	9,547	37,470	38,190
1955	41,011	60,142	29,245	11,210	42,155	42,488
1956	34,797	56,224	25,966	12,478	35,144	40,197
1957	34,375	58,107	30,666	14,275	30,148	44,261
1958	41,556	78,142	36,651	16,755	43,665	52,856
1959	48,724	89,650	38,872	12,190	49,077	52,745
1960	46,940	87,714	38,306	16,630	49,984	52,392
1961	51,308	86,975	43,411	19,347	56,204	58,269
1962	51,164	91,742	46,799	21,927	60,311	62,029
1963	52,829	99,553	52,106	23,757	66,177	66,463
1964	46,988	97,407	51,521	23,211	66,102	68,120
1965	50,577	99,951	56,422	27,537	69,727	78,324
1966	53,111	108,429	54,108	25,104	76,394	84,908
1967	55,763	105,696	61,956	29,385	82,719	95,266
1968	61,659	114,098	62,676	27,040	87,483	99,203
1969	59,681	107,160	62,578	27,953	83,252	93,626
1970	56,213	100,887	62,180	31,241	83,494	98,741
1971	50,088	89,267	55,318	28,445	73,457	98,697
1972	49,586	98,091	56,101	29,265	74,444	98,812
1973	43,446	119,053	53,381	32,090	76,338	114,144
1974	40,545	118,835	48,144	31,589	77,670	106,774
1975	31,900	79,946	42,369	29,710	69,347	90,203
1976	36,909	93,368	51,717	36,428	71,588	92,368

Table H-14. Total number of cattle marketed from 1952 through 1976 in O'Brien, Osceola, Plymouth, Sac, Sioux and Woodbury Counties

Year	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
1952	28,947	12,653	57,140	32,128	56,581	46,707
1953	36,465	15,620	64,644	39,306	68,092	56,273
1954	40,425	17,894	65,736	38,417	76,697	52,668
1955	45,247	20,374	69,950	45,240	82,629	53,660
1956	41,668	21,185	58,347	38,551	76,806	46,730
1957	39,822	22,108	54,267	37,051	81,150	37,022
1958	49,516	27,696	86,536	49,396	107,642	55,397
1959	53,223	30,163	96,148	61,306	108,364	67,138
1960	51,057	28,740	95,572	67,542	98,114	73,211
1961	56,178	30,102	102,420	75,509	109,702	69,810
1962	61,948	32,736	111,216	77,309	120,304	77,136
1963	66,778	35,027	111,808	85,118	130,062	81,458
1964	61,548	37,190	103,021	79,836	131,394	76,787
1965	66,972	37,685	110,746	87,102	141,537	82,796
1966	75,396	40,699	121,898	98,722	167,560	90,234
1967	82,444	45,692	139,529	105,039	188,432	93,033
1968	91,772	45,177	155,658	120,170	206,328	102,186
1969	91,875	42,121	133,236	133,091	196,847	91,747
1970	97,598	50,176	132,471	136,308	217,467	90,045
1971	72,829	47,409	115,900	119,832	226,139	76,436
1972	92,789	50,072	114,176	108,276	235,587	99,904
1973	91,390	61,257	134,711	123,262	267,042	121,469
1974	101,360	62,645	137,227	85,169	270,742	86,732
1975	96,110	51,292	129,722	70,401	242,980	71,782
1976	108,987	49,524	122,099	86,674	312,675	86,320

Table H-15. Total number of hogs marketed from 1967 through 1976 in Buena Vista, Cherokee, Clay, Dickinson, Ida and Lyon Counties

Year	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
1967	215,557	217,773	133,564	75,442	186,750	194,392
1968	233,202	223,933	129,479	82,713	175,230	194,036
1969	214,163	200,487	117,141	79,441	173,525	182,684
1970	242,684	222,670	131,026	85,493	186,218	198,373
1971	242,044	206,178	128,466	77,647	182,610	209,283
1972	262,437	216,341	125,542	79,302	173,262	220,513
1973	257,228	218,948	139,402	77,413	171,972	218,346
1974	263,122	224,357	127,932	79,421	173,412	231,826
1975	231,383	200,787	119,508	76,496	133,899	193,305
1976	251,480	205,877	142,068	87,384	148,628	229,000

Table H-16. Total number of hogs marketed from 1967 through 1976 in O'Brien, Osceola, Plymouth, Sac, Sioux and Woodbury Counties

Year	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
1967	220,782	109,198	382,321	239,663	361,642	214,185
1968	232,754	110,187	404,799	239,910	372,874	235,664
1969	212,281	103,178	368,787	227,166	353,394	222,007
1970	229,850	113,744	380,299	237,518	368,420	241,429
1971	230,708	111,001	400,175	226,609	375,491	232,230
1972	235,504	111,754	419,317	237,450	387,777	226,544
1973	241,078	121,104	408,135	230,938	400,262	233,830
1974	236,586	122,452	431,254	239,781	415,951	242,549
1975	205,587	112,588	369,550	204,673	414,626	204,918
1976	236,156	104,630	400,300	226,190	447,510	210,313

APPENDIX I.

FUTURE TOTAL RURAL DOMESTIC AND URBAN WATER USE IN NORTHWEST IOWA

Table I-1. Estimated average and peak rural domestic and urban water demands for Buena Vista County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Albert City	0.15	0.14	0.13	0.28	0.26	0.24
Alta	0.41	0.46	0.52	0.76	0.85	0.96
Lake Side	0.09	0.12	0.15	0.17	0.22	0.28
Linn Grove	0.05	0.04	0.03	0.09	0.07	0.06
Marathon	0.10	0.09	0.08	0.18	0.17	0.15
Newell	0.19	0.18	0.18	0.35	0.33	0.33
Rembrandt	0.05	0.04	0.03	0.09	0.07	0.06
Sioux Rapids	0.18	0.16	0.15	0.33	0.30	0.28
Storm Lake	2.39	2.59	2.91	4.42	4.79	5.38
Truesdale	0.03	0.02	0.01	0.06	0.04	0.02
Total urban[b]	3.64	3.84	4.19	6.73	7.10	7.76
Rural farm	0.24	0.24	0.23	0.44	0.44	0.43
Rural nonfarm	0.09	0.11	0.14	0.17	0.20	0.26
Total rural	0.33	0.35	0.37	0.61	0.64	0.69
Total county	3.97	4.19	4.56	7.34	7.74	8.45

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-2. Estimated average and peak rural domestic and urban water demands for Cherokee County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Aurelia	0.26	0.30	0.35	0.48	0.56	0.65
Cherokee	1.93	1.93	2.01	3.57	3.57	3.72
Cleghorn	0.06	0.06	0.06	0.11	0.11	0.11
Larrabee	0.04	0.03	0.03	0.07	0.06	0.06
Marcus	0.29	0.30	0.32	0.54	0.56	0.59
Meriden	0.04	0.03	0.03	0.07	0.06	0.06
Quimby	0.09	0.09	0.10	0.17	0.17	0.19
Washta	0.07	0.07	0.07	0.13	0.13	0.13
Total urban[b]	2.78	2.81	2.97	5.14	5.22	5.51
Rural farm	0.22	0.23	0.23	0.41	0.43	0.43
Rural nonfarm	0.10	0.13	0.16	0.19	0.24	0.30
Total rural	0.32	0.36	0.39	0.60	0.67	0.73
Total county	3.10	3.17	3.36	5.74	5.89	6.24

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-3. Estimated average and peak rural domestic and urban water demands for Clay County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Dickins	0.03	0.02	0.02	0.06	0.04	0.04
Everly	0.09	0.10	0.11	0.17	0.19	0.20
Fostoria	0.03	0.04	0.04	0.06	0.07	0.07
Greenville	0.01	0.01	0.01	0.02	0.02	0.02
Peterson	0.05	0.05	0.05	0.09	0.09	0.09
Rossie	0.01	0.01	0.01	0.02	0.02	0.02
Royal	0.06	0.06	0.06	0.11	0.11	0.11
Spencer	1.56	1.76	2.01	2.89	3.26	3.72
Webb	0.03	0.03	0.03	0.06	0.06	0.06
Total urban[b]	1.87	2.08	2.34	3.48	3.86	4.33
Rural farm	0.20	0.22	0.23	0.37	0.41	0.43
Rural nonfarm	0.10	0.13	0.17	0.19	0.24	0.31
Total rural	0.30	0.35	0.40	0.56	0.65	0.74
Total county	2.17	2.45	2.74	4.04	4.51	5.07

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-4. Estimated average and peak rural domestic and urban water demands for Dickinson County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Arnold's Park	0.23	0.26	0.29	0.43	0.48	0.54
Lake Park	0.22	0.24	0.27	0.41	0.44	0.50
Milford	0.41	0.47	0.54	0.76	0.87	1.00
Okoboji	0.09	0.11	0.14	0.17	0.20	0.26
Old Town	0.01	0.01	0.01	0.02	0.02	0.02
Orleans	0.09	0.09	0.10	0.17	0.17	0.19
Spirit Lake	0.86	0.98	1.12	1.59	1.81	2.07
Superior	0.03	0.02	0.01	0.06	0.04	0.02
Terrill	0.09	0.09	0.08	0.17	0.17	0.15
Wahpeton	0.04	0.05	0.07	0.07	0.09	0.13
West Okoboji	0.05	0.07	0.08	0.09	0.13	0.15
Total urban[b]	2.12	2.39	2.71	3.94	4.42	5.03
Rural farm	0.14	0.15	0.15	0.26	0.28	0.28
Rural nonfarm	0.09	0.13	0.17	0.17	0.24	0.31
Total rural	0.23	0.28	0.32	0.43	0.52	0.59
Total county	2.35	2.67	3.03	4.37	4.94	5.62

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-5. Estimated average and peak rural domestic and urban water demands for Ida County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Arthur	0.03	0.02	0.01	0.06	0.04	0.02
Battle Creek	0.09	0.09	0.08	0.17	0.17	0.15
Galva	0.04	0.04	0.03	0.07	0.07	0.06
Holstein	0.16	0.16	0.15	0.30	0.30	0.28
Ida Grove	0.25	0.24	0.24	0.46	0.44	0.44
Total urban[b]	0.57	0.55	0.51	1.06	1.02	0.95
Rural farm	0.17	0.17	0.17	0.31	0.31	0.31
Rural nonfarm	0.02	0.03	0.04	0.04	0.06	0.07
Total rural	0.19	0.20	0.21	0.35	0.37	0.38
Total county	0.76	0.75	0.72	1.41	1.39	1.33

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-6. Estimated average and peak rural domestic and urban water demands for Lyon County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Alvord	0.02	0.02	0.02	0.04	0.04	0.04
Doon	0.05	0.06	0.07	0.09	0.11	0.13
George	0.14	0.14	0.15	0.26	0.26	0.28
Inwood	0.07	0.08	0.08	0.13	0.15	0.15
Larchwood	0.08	0.09	0.11	0.15	0.17	0.20
Lester	0.03	0.03	0.03	0.06	0.06	0.06
Little Rock	0.06	0.07	0.08	0.11	0.13	0.15
Rock Rapids	0.37	0.40	0.45	0.68	0.74	0.83
Total urban[b]	0.82	0.89	0.99	1.52	1.66	1.84
Rural farm	0.27	0.26	0.24	0.50	0.48	0.44
Rural nonfarm	0.05	0.06	0.08	0.09	0.11	0.15
Total rural	0.32	0.32	0.32	0.59	0.59	0.59
Total county	1.14	1.21	1.31	2.11	2.25	2.43

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-7. Estimated average and peak rural domestic and urban water demands for O'Brien County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Archer	0.01	0.01	0.01	0.02	0.02	0.02
Calumet	0.02	0.02	0.02	0.04	0.04	0.04
Hartley	0.19	0.19	0.20	0.35	0.35	0.37
Moneta	0.01	0.01	0.00	0.02	0.02	0.00
Paullina	0.14	0.14	0.15	0.26	0.26	0.28
Primghar	0.11	0.11	0.11	0.20	0.20	0.20
Sanborn	0.17	0.17	0.17	0.31	0.31	0.31
Sheldon	0.62	0.68	0.75	1.15	1.26	1.39
Sutherland	0.09	0.09	0.09	0.17	0.17	0.17
Total urban[b]	1.36	1.42	1.50	2.52	2.63	2.78
Rural farm	0.24	0.24	0.23	0.44	0.44	0.43
Rural nonfarm	0.06	0.08	0.11	0.11	0.15	0.20
Total rural	0.30	0.32	0.34	0.55	0.59	0.63
Total county	1.66	1.74	1.84	3.07	3.22	3.41

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-8. Estimated average and peak rural domestic and urban water demands for Osceola County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Ashton	0.05	0.05	0.05	0.09	0.09	0.09
Harris	0.02	0.02	0.01	0.04	0.04	0.02
Melvin	0.03	0.03	0.03	0.06	0.06	0.06
Ocheyedan	0.06	0.05	0.04	0.11	0.09	0.07
Sibley	0.37	0.38	0.40	0.68	0.70	0.74
Total urban[b]	0.53	0.53	0.53	0.98	0.98	0.98
Rural farm	0.16	0.16	0.16	0.30	0.30	0.30
Rural nonfarm	0.04	0.06	0.07	0.07	0.11	0.13
Total rural	0.20	0.22	0.23	0.37	0.41	0.43
Total county	0.73	0.75	0.76	1.35	1.39	1.41

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-9. Estimated average and peak rural domestic and urban water demands for Plymouth County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Akron	0.15	0.16	0.17	0.28	0.30	0.31
Brunsville	0.01	0.02	0.02	0.02	0.04	0.04
Craig	0.01	0.01	0.01	0.02	0.02	0.02
Hinton	0.06	0.07	0.09	0.11	0.13	0.17
Kingsley	0.13	0.14	0.15	0.24	0.26	0.28
Le Mars	1.17	1.38	1.74	2.16	2.55	3.22
Merrill	0.10	0.11	0.13	0.19	0.20	0.24
Oyens	0.02	0.02	0.03	0.04	0.04	0.06
Remsen	0.16	0.18	0.21	0.30	0.33	0.39
Struble	0.01	0.01	0.00	0.02	0.02	0.00
Westfield	0.02	0.01	0.01	0.04	0.02	0.02
Total urban[b]	1.84	2.11	2.56	3.42	3.91	4.75
Rural farm	0.39	0.38	0.36	0.72	0.70	0.67
Rural nonfarm	0.14	0.17	0.22	0.26	0.31	0.41
Total rural	0.53	0.55	0.58	0.98	1.01	1.08
Total county	2.37	2.66	3.14	4.40	4.92	5.83

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-10. Estimated average and peak rural domestic and urban water demands for Sac County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Auburn	0.07	0.06	0.06	0.13	0.11	0.11
Early	0.16	0.14	0.13	0.30	0.26	0.24
Grant City	0.00	0.00	0.00	0.00	0.00	0.00
Lake View	0.28	0.28	0.29	0.52	0.52	0.54
Lytton	0.08	0.08	0.08	0.15	0.15	0.15
Nemaha	0.02	0.02	0.01	0.04	0.04	0.02
Odebolt	0.30	0.28	0.28	0.56	0.52	0.52
Sac City	0.88	0.90	0.94	1.63	1.66	1.74
Schaller	0.19	0.19	0.20	0.35	0.35	0.37
Wall Lake	0.22	0.22	0.24	0.41	0.41	0.44
Total urban[b]	2.20	2.17	2.23	4.09	4.02	4.13
Rural farm	0.24	0.24	0.23	0.44	0.44	0.43
Rural nonfarm	0.07	0.09	0.11	0.13	0.17	0.20
Total rural	0.31	0.33	0.34	0.57	0.61	0.63
Total county	2.51	2.50	2.57	4.66	4.63	4.76

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-11. Estimated average and peak rural domestic and urban water demands for Sioux County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Alton	0.12	0.14	0.15	0.22	0.26	0.28
Boyden	0.08	0.09	0.10	0.15	0.17	0.19
Chatsworth	0.01	0.01	0.01	0.02	0.02	0.02
Granville	0.05	0.05	0.06	0.09	0.09	0.11
Hawarden	0.39	0.42	0.46	0.72	0.78	0.85
Hospers	0.08	0.09	0.10	0.15	0.17	0.19
Hull	0.19	0.23	0.28	0.35	0.43	0.52
Ireton	0.07	0.08	0.09	0.13	0.15	0.17
Matlock	0.01	0.01	0.01	0.02	0.02	0.02
Maurice	0.03	0.03	0.03	0.06	0.06	0.06
Orange City	0.51	0.58	0.68	0.94	1.07	1.26
Rock Valley	0.27	0.31	0.41	0.50	0.57	0.76
Sioux Center	0.50	0.59	0.70	0.93	1.09	1.30
Total urban[b]	2.31	2.63	3.08	4.28	4.88	5.73
Rural farm	0.42	0.38	0.32	0.78	0.70	0.59
Rural nonfarm	0.08	0.11	0.13	0.15	0.20	0.24
Total rural	0.50	0.49	0.45	0.93	0.90	0.83
Total county	2.81	3.12	3.53	5.21	5.78	6.56

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-12. Estimated average and peak rural domestic and urban water demands for Woodbury County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Anthon	0.08	0.07	0.07	0.15	0.13	0.13
Bronson	0.03	0.04	0.06	0.06	0.07	0.11
Correctionville	0.10	0.09	0.08	0.19	0.17	0.15
Cushing	0.02	0.02	0.01	0.04	0.04	0.02
Danbury	0.06	0.06	0.06	0.11	0.11	0.11
Hornick	0.03	0.03	0.02	0.06	0.06	0.04
Lawton	0.05	0.07	0.08	0.09	0.13	0.15
Moville	0.15	0.17	0.20	0.28	0.31	0.37
Oto	0.02	0.02	0.01	0.04	0.04	0.02
Pierson	0.05	0.04	0.04	0.09	0.07	0.07
Salix	0.04	0.05	0.05	0.07	0.09	0.09
Sergeant Bluff	0.14	0.16	0.18	0.26	0.30	0.33
Sioux City	12.46	12.94	13.58	23.05	23.94	25.12
Sloan	0.10	0.11	0.12	0.19	0.20	0.22
Smithland	0.03	0.03	0.03	0.06	0.06	0.06
Total urban[b]	13.36	13.90	14.59	24.74	25.72	26.99
Rural farm	0.32	0.33	0.36	0.59	0.61	0.67
Rural nonfarm	0.20	0.25	0.32	0.37	0.46	0.59
Total rural	0.52	0.58	0.68	0.96	1.07	1.26
Total county	13.88	14.48	15.27	25.70	26.79	28.25

[a]Based on Rossmiller's population projections and per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-13. State of Iowa estimated average and peak rural domestic and urban water demands for Buena Vista County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Albert City	0.16	0.17	0.15	0.30	0.31	0.28
Alta	0.45	0.56	0.64	0.83	1.04	1.18
Lake Side	0.10	0.14	0.18	0.18	0.26	0.33
Linn Grove	0.05	0.05	0.03	0.09	0.09	0.06
Marathon	0.11	0.11	0.10	0.20	0.20	0.18
Newell	0.21	0.23	0.22	0.39	0.42	0.41
Rembrandt	0.06	0.05	0.03	0.11	0.09	0.06
Sioux Rapids	0.19	0.20	0.18	0.35	0.37	0.33
Storm Lake	2.63	3.20	3.82	4.86	5.92	7.07
Truesdale	0.03	0.03	0.02	0.06	0.06	0.04
Total urban[b]	3.99	4.74	5.37	7.37	8.76	9.94
Rural farm	0.24	0.24	0.23	0.44	0.44	0.42
Rural nonfarm	0.10	0.14	0.17	0.18	0.26	0.31
Total rural	0.34	0.38	0.40	0.62	0.70	0.73
Total county	4.33	5.12	5.77	7.99	9.46	10.67

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-14. State of Iowa estimated average and peak rural domestic and urban water demands for Cherokee County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Aurelia	0.24	0.34	0.44	0.44	0.63	0.81
Cherokee	1.93	2.20	2.52	3.57	4.07	4.66
Cleghorn	0.06	0.07	0.07	0.11	0.13	0.13
Larrabee	0.04	0.04	0.04	0.07	0.07	0.07
Marcus	0.30	0.34	0.40	0.56	0.63	0.74
Meriden	0.04	0.04	0.04	0.07	0.07	0.07
Quimby	0.09	0.11	0.12	0.17	0.20	0.22
Washta	0.07	0.08	0.09	0.13	0.15	0.17
Total urban[b]	2.77	3.22	3.72	5.12	5.95	6.87
Rural farm	0.22	0.22	0.23	0.41	0.41	0.42
Rural nonfarm	0.10	0.14	0.20	0.18	0.26	0.37
Total rural	0.32	0.36	0.43	0.59	0.67	0.79
Total county	3.09	3.58	4.15	5.71	6.62	7.66

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-15. State of Iowa estimated average and peak rural domestic and urban water demands for Clay County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Dickins	0.03	0.02	0.02	0.06	0.04	0.04
Everly	0.09	0.11	0.12	0.17	0.20	0.22
Fostoria	0.03	0.04	0.05	0.06	0.07	0.09
Greenville	0.01	0.01	0.01	0.02	0.02	0.02
Peterson	0.06	0.06	0.06	0.11	0.11	0.11
Rossie	0.01	0.01	0.01	0.02	0.02	0.02
Royal	0.06	0.06	0.06	0.11	0.11	0.11
Spencer	1.66	1.99	2.19	3.07	3.68	4.05
Webb	0.03	0.03	0.03	0.06	0.06	0.06
Total urban[b]	1.98	2.33	2.55	3.68	4.31	4.72
Rural farm	0.20	0.22	0.23	0.41	0.41	0.42
Rural nonfarm	0.10	0.14	0.18	0.18	0.26	0.33
Total rural	0.30	0.36	0.41	0.59	0.67	0.75
Total county	2.28	2.69	2.96	4.27	4.98	5.47

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-16. State of Iowa estimated average and peak rural domestic and urban water demands for Dickinson County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Arnold's Park	0.29	0.38	0.42	0.54	0.70	0.78
Lake Park	0.27	0.35	0.38	0.50	0.65	0.70
Milford	0.50	0.79	0.89	0.92	1.46	1.65
Okoboji	0.11	0.16	0.20	0.20	0.30	0.37
Old Town	0.01	0.01	0.02	0.02	0.02	0.04
Orleans	0.11	0.14	0.14	0.20	0.26	0.26
Spirit Lake	1.06	1.42	1.62	1.96	2.63	3.00
Superior	0.04	0.03	0.02	0.07	0.06	0.04
Terrill	0.11	0.13	0.12	0.20	0.24	0.22
Wahpeton	0.05	0.08	0.10	0.09	0.15	0.18
West Okoboji	0.07	0.10	0.12	0.13	0.18	0.22
Total urban[b]	2.62	3.59	4.03	4.83	6.65	7.46
Rural farm	0.14	0.15	0.15	0.26	0.28	0.28
Rural nonfarm	0.12	0.18	0.24	0.22	0.33	0.44
Total rural	0.26	0.33	0.39	0.48	0.61	0.72
Total county	2.88	3.92	4.42	5.31	7.26	8.18

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-17. State of Iowa estimated average and peak rural domestic and urban water demands for Ida County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Arthur	0.03	0.03	0.02	0.06	0.06	0.04
Battle Creek	0.10	0.11	0.13	0.18	0.22	0.26
Galva	0.04	0.04	0.04	0.07	0.07	0.07
Holstein	0.17	0.20	0.24	0.31	0.37	0.44
Ida Grove	0.27	0.32	0.43	0.50	0.59	0.80
Total urban[b]	0.61	0.70	0.86	1.12	1.31	1.61
Rural farm	0.16	0.17	0.17	0.30	0.31	0.31
Rural nonfarm	0.02	0.04	0.05	0.04	0.07	0.09
Total rural	0.18	0.21	0.22	0.34	0.38	0.40
Total county	0.79	0.91	1.08	1.46	1.69	2.01

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-18. State of Iowa estimated average and peak rural domestic and urban water demands for Lyon County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Alvord	0.02	0.03	0.03	0.04	0.06	0.06
Doon	0.06	0.08	0.12	0.11	0.15	0.22
George	0.15	0.20	0.28	0.28	0.37	0.52
Inwood	0.08	0.11	0.15	0.15	0.20	0.28
Larchwood	0.08	0.13	0.19	0.15	0.24	0.35
Lester	0.03	0.04	0.05	0.06	0.07	0.09
Little Rock	0.07	0.10	0.14	0.13	0.18	0.26
Rock Rapids	0.39	0.55	0.78	0.72	1.02	1.44
Total urban[b]	0.88	1.24	1.74	1.64	2.29	3.22
Rural farm	0.27	0.26	0.24	0.50	0.48	0.44
Rural nonfarm	0.05	0.09	0.14	0.09	0.17	0.26
Total rural	0.32	0.35	0.38	0.59	0.65	0.70
Total county	1.20	1.59	2.12	2.23	2.94	3.92

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-19. State of Iowa estimated average and peak rural domestic and urban water demands for O'Brien County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Archer	0.02	0.01	0.01	0.04	0.02	0.02
Calumet	0.02	0.02	0.02	0.04	0.04	0.04
Hartley	0.22	0.26	0.30	0.41	0.48	0.56
Moneta	0.00	0.00	0.00	0.00	0.00	0.00
Paullina	0.16	0.20	0.22	0.30	0.37	0.41
Primghar	0.13	0.15	0.17	0.24	0.28	0.31
Sanborn	0.19	0.23	0.26	0.35	0.42	0.48
Sheldon	0.71	0.93	1.13	1.31	1.72	2.09
Sutherland	0.11	0.12	0.13	0.20	0.22	0.24
Total urban[b]	1.56	1.92	2.24	2.89	3.55	4.15
Rural farm	0.24	0.24	0.23	0.44	0.44	0.42
Rural nonfarm	0.07	0.11	0.16	0.13	0.20	0.30
Total rural	0.31	0.35	0.39	0.57	0.64	0.72
Total county	1.87	2.27	2.63	3.46	4.19	4.87

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-20. State of Iowa estimated average and peak rural domestic and urban water demands for Osceola County in 1980, 2000 and 2020, MGD[a]

Location	Average 1980	Average 2000	Average 2020	Peak 1980	Peak 2000	Peak 2020
Ashton	0.06	0.08	0.10	0.11	0.15	0.18
Harris	0.02	0.02	0.02	0.04	0.04	0.04
Melvin	0.04	0.05	0.06	0.07	0.09	0.11
Ocheyedan	0.07	0.08	0.09	0.13	0.15	0.17
Sibley	0.44	0.62	0.85	0.81	1.15	1.57
Total urban[b]	0.63	0.85	1.12	1.16	1.58	2.07
Rural farm	0.16	0.16	0.16	0.30	0.30	0.30
Rural nonfarm	0.05	0.09	0.15	0.09	0.17	0.28
Total rural	0.21	0.25	0.31	0.39	0.47	0.58
Total county	0.84	1.10	1.43	1.55	2.05	2.65

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-21. State of Iowa estimated average and peak rural domestic and urban water demands for Plymouth County in 1980, 2000 and 2020, MGD[a]

Location	Average 1980	Average 2000	Average 2020	Peak 1980	Peak 2000	Peak 2020
Akron	0.16	0.18	0.19	0.30	0.33	0.35
Brunsville	0.02	0.02	0.02	0.04	0.04	0.04
Craig	0.01	0.01	0.01	0.02	0.02	0.02
Hinton	0.06	0.08	0.10	0.11	0.15	0.18
Kingsley	0.13	0.15	0.17	0.24	0.28	0.31
Le Mars	1.19	1.64	2.02	2.20	3.03	3.74
Merrill	0.10	0.13	0.15	0.18	0.24	0.28
Oyens	0.02	0.02	0.03	0.04	0.04	0.06
Remsen	0.16	0.20	0.24	0.30	0.37	0.44
Struble	0.01	0.00	0.00	0.02	0.00	0.00
Westfield	0.02	0.02	0.01	0.04	0.04	0.02
Total urban[b]	1.88	2.45	2.94	3.49	4.54	5.44
Rural farm	0.39	0.38	0.36	0.74	0.70	0.67
Rural nonfarm	0.14	0.19	0.25	0.26	0.35	0.46
Total rural	0.53	0.57	0.61	1.00	1.05	1.13
Total county	2.41	3.02	3.55	4.49	5.59	6.57

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-22. State of Iowa estimated average and peak rural domestic and urban water demands for Sac County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Auburn	0,08	0.08	0.08	0.15	0.15	0.15
Early	0.16	0.18	0.18	0.30	0.33	0.33
Grant City	0.00	0.00	0.00	0.00	0.00	0.00
Lake View	0.30	0.36	0.43	0.56	0.67	0.80
Lytton	0.09	0.11	0.12	0.17	0.20	0.22
Nemaha	0.03	0.02	0.02	0.06	0.04	0.04
Odebolt	0.31	0.36	0.41	0.57	0.67	0.76
Sac City	0.93	1.14	1.39	1.72	2.11	2.57
Schaller	0.20	0.24	0.29	0.37	0.44	0.54
Wall Lake	0.23	0.28	0.35	0.42	0.52	0.65
Total urban[b]	2.33	2.77	3.27	4.32	5.13	6.06
Rural farm	0.24	0.24	0.23	0.44	0.44	0.42
Rural nonfarm	0.08	0.11	0.16	0.15	0.20	0.30
Total rural	0.32	0.35	0.39	0.59	0.64	0.72
Total county	2.65	3.12	3.66	4.91	5.77	6.78

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-23. State of Iowa estimated average and peak rural domestic and urban water demands for Sioux County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Alton	0.14	0.19	0.22	0.26	0.35	0.41
Boyden	0.09	0.12	0.14	0.17	0.22	0.26
Chatsworth	0.01	0.01	0.01	0.02	0.02	0.02
Granville	0.05	0.07	0.08	0.09	0.13	0.15
Hawarden	0.45	0.58	0.67	0.83	1.07	1.24
Hospers	0.09	0.12	0.14	0.17	0.22	0.26
Hull	0.22	0.32	0.48	0.41	0.59	0.89
Ireton	0.08	0.11	0.12	0.15	0.20	0.22
Matlock	0.01	0.01	0.01	0.02	0.02	0.02
Maurice	0.04	0.04	0.05	0.07	0.07	0.09
Orange City	0.60	0.80	0.97	1.11	1.48	1.79
Rock Valley	0.36	0.49	0.59	0.67	0.91	1.09
Sioux Center	0.58	0.81	1.01	1.07	1.50	1.87
Total urban[b]	2.72	3.67	4.49	5.04	6.78	8.31
Rural farm	0.42	0.38	0.32	0.78	0.70	0.59
Rural nonfarm	0.10	0.15	0.19	0.18	0.28	0.35
Total rural	0.52	0.53	0.51	0.96	0.98	0.94
Total county	3.24	4.20	5.00	6.00	7.76	9.25

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

Table I-24. State of Iowa estimated average and peak rural domestic and urban water demands for Woodbury County in 1980, 2000 and 2020, MGD[a]

Location	Average			Peak		
	1980	2000	2020	1980	2000	2020
Anthon	0.08	0.09	0.09	0.15	0.17	0.17
Bronson	0.03	0.06	0.08	0.06	0.11	0.15
Correctionville	0.10	0.11	0.11	0.18	0.20	0.20
Cushing	0.02	0.02	0.02	0.04	0.04	0.04
Danbury	0.06	0.07	0.08	0.11	0.13	0.15
Hornick	0.03	0.03	0.03	0.06	0.06	0.06
Lawton	0.06	0.08	0.11	0.11	0.15	0.20
Moville	0.16	0.21	0.27	0.30	0.39	0.50
Oto	0.02	0.02	0.02	0.04	0.04	0.04
Pierson	0.05	0.05	0.06	0.09	0.09	0.11
Salix	0.05	0.06	0.06	0.09	0.11	0.11
Sergeant Bluff	0.15	0.20	0.25	0.28	0.37	0.46
Sioux City	13.66	16.24	18.45	25.27	30.04	34.13
Sloan	0.10	0.13	0.16	0.18	0.24	0.30
Smithland	0.04	0.04	0.04	0.07	0.07	0.07
Total urban[b]	14.61	17.41	19.83	27.03	32.21	36.69
Rural farm	0.32	0.33	0.36	0.59	0.61	0.67
Rural nonfarm	0.22	0.32	0.43	0.41	0.59	0.80
Total rural	0.54	0.65	0.79	1.00	1.20	1.47
Total county	15.15	18.06	20.62	28.03	33.41	38.16

[a]Based on per capita use rates listed in Table 179.

[b]Urban includes domestic, public, commercial and municipally-supplied industrial uses.

APPENDIX J.

EXISTING SOURCES FOR MUNICIPAL WATER SUPPLIES

Table J-1. Definitions for abbreviations used in the tables for existing municipal water supply sources[a]

Abbreviation	Meaning
Mun.	Municipally owned
Pri.	Privately owned
G	Gravel
S	Sand
S-G	Sand and gravel
S.W.	Surface water
Pleis.	Pleistocene
Dol.	Dolomite
Ls	Limestone
Ss	Sandstone
C.V.	Cedar Valley
Dak.	Dakota
Ga.	Galena
Jor.	Jordan
Ma.	Maquoketa
Miss.	Mississippian
P.C.	Prairie Du Chien
St.L.	St. Lawrence
St.P.	St. Peter
Wap.	Wapsipinicon

[a]Iowa Department of Health (1964).

Table J-2. Existing sources of water supply for incorporated communities in Buena Vista County[a]

City	1970 pop.	Ownership	Well		Chief aquifer	Remarks
			Date installed	Depth feet		
Albert City	683	Mun.	1937	189	Pleis. S-G	
			1949	189	Pleis. S-G	
Alta	1,717	Mun.	1928	419	Dak. Ss	
			1950	507	Dak. Ss	
Lakeside	353					Water bought from Storm Lake
Linn Grove	240	Mun.	?	30	Recent S-G	
Marathon	447	Mun.	1939	185	Pleis. S-G	
			1959	185	Pleis. S-G	
Newell	877	Mun.	1939	300	Pleis. S-G	
			1957	300	Pleis. S-G	
Rembrandt	250	Mun.	1935	400	Dak. Ss	
Sioux Rapids	813	Mun.	1890	28	Recent S-G	
Storm Lake	8,591	Mun.	1935	110	Pleis. S-G	
			1939	110	Pleis. S-G	
			1952	110	Pleis. S-G	
			?	117	Pleis. S-G	
			1959	1,690	P.C. & St.L. Dol. and Jor. Ss	
Truesdale	132	Mun.	1955	442	Dak. Ss	

[a]Iowa Department of Health (1964).

Table J-3. Existing sources of water supply for incorporated communities in Cherokee County[a]

City	1970 pop.	Ownership	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Aurelia	1,065	Mun.	1923	303	Dak. Ss	
			1937	305	Dak. Ss	
Cherokee	7,272	Mun.	1951	203	Dak. Ss	
			1954	210	Dak. Ss	
			1958	254	Dak. Ss	
Cleghorn	274	Mun.	1935	398	Pleis. S-G	
Larrabee	167	Mun.	1938	375	Pleis. S-G, Dak. Ss	
Marcus	1,272	Mun.	1915	1,300	St.P. Ss, Jor. Ss	
			1948	884	Wap. Dol., Ma. & Ga. Dol.	
Meriden	167	Mun.	1956	380	Dak. Ss	
Quimby	395	Mun.	1930	170	Pleis. S-G	
Washta	319	Mun.	1919	28	Recent S-G	
			1957	36	Recent S-G	

[a] Iowa Department of Health (1964).

Table J-4. Existing sources of water supply for incorporated communities in Clay County[a]

City	1970 pop.	Owner-ship	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Dickins	240					No data given in reference
Everly	699	Mun.	1921	25	Pleis. S-G	
Fostoria	219	Mun.	1957	50	Pleis. S-G	
Greenville	117					No data given in reference
Peterson	469	Mun.	1935	108	Pleis. S-G	
			1955	110	Pleis. S-G	
Rossie	91					No data given in reference
Royal	469	Mun.	1933	341	Pleis. S-G	
Spencer	10,278	Mun.	1956	45	Recent S-G	
			1956	45	Recent S-G	
			1956	45	Recent S-G	
			1956	45	Recent S-G	
			1958	956	Jor. Ss, St.L. Dol.	
Webb	234	Mun.	1914	115	Pleis. S-G	
			1956	600	?	

[a]Iowa Department of Health (1964).

Table J-5. Existing sources of water supply for incorporated communities in Dickinson County[a]

City	1970 pop.	Ownership	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Arnold's Park	970	Mun.				S.W. — West Okoboji Lake
Lake Park	918	Mun.				S.W. — Silver Lake
Milford	1,668	Mun.				S.W. — West Okoboji Lake
Okoboji	361	Mun.				S.W. — West Okoboji Lake
Old Town	24					No data given in reference
Orleans	396	Mun.				Water bought from Spirit Lake
Spirit Lake	3,014	Mun.				S.W. — Spirit Lake
Superior	139	Mun.	1913	90	Pleis. S-G	
Terrill	397	Mun.	1947	128	Pleis. S-G	
Wahpeton	149					No data given in reference
West Okoboji	210					Water bought from Milford

[a]Iowa Department of Health (1964).

Table J-6. Existing sources of water supply for incorporated communities in Ida County[a]

City	1970 pop.	Owner-ship	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Arthur	273	Mun.	1923	24	Recent S-G	
			1924	20	Recent S-G	
			1956	22	Recent S-G	
Battle Creek	837	Mun.	1929	42	Recent S-G	
			1950	42	Recent S-G	
Galva	412	Mun.	1934	48	Recent S-G	
			1957	48	Recent S-G	
Holstein	1,445	Mun.	1937	644	Dak. Ss, Miss. Ls	
			1952	440	Dak. Ss	
Ida Grove	2,261	Mun.	1945	68	Pleis. S-G	
			1948	68	Pleis. S-G	
			1956	320	Dak. Ss	

[a]Iowa Department of Health (1964).

Table J-7. Existing sources of water supply for incorporated communities in Lyon County[a]

City	1970 pop.	Ownership	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Alvord		Mun.	1895	38	Pleis. S-G	
			?	38	Pleis. S-G	
Doon		Mun.	1923	32	Pleis. S-G	
			1957	40	Pleis. S-G	
George		Mun.	1910	30	Recent S-G	
			1936	30	Recent S-G	
			1955	32	Recent S-G	
Inwood		Mun.	1941	511	Dak. Ss	
			1955	530	Dak. Ss	
Larchwood		Mun.	1936	562	Dak. Ss	
			1957	540	Dak. Ss	
Lester		Mun.	1930	25	Pleis. S-G	
Little Rock		Mun.	1908	28	Recent S-G	
Rock Rapids		Mun.	?	35	Recent S-G	
			?	38	Recent S-G	
			1951	32	Recent S-G	
			1956	31	Recent S-G	
			1956	31	Recent S-G	

[a]Iowa Department of Health (1964).

Table J-8. Existing sources of water supply for incorporated communities in O'Brien County[a]

City	1970 pop.	Owner-ship	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Archer	134					No data given in reference
Calumet	219	Mun.	1949	64	Pleis. S-G	
			1951	48	Pleis. S-G	
			1953	120	Pleis. S-G	
			1956	525	Dak. Ss	
Hartley	1,694	Mun.	1938	640	Dak. Ss	
			1938	640	Dak. Ss	
			1960	?	?	
Moneta	41					No data given in reference
Paullina	1,257	Mun.	1920	20	Recent S-G	
			1948	38	Recent S-G	
			1951	38	Recent S-G	
			1955	38	Recent S-G	
			1955	38	Recent S-G	
Primghar	995	Mun.	1915	25	Recent S-G	
			1931	428	Pleis. S-G	
			1932	428	Pleis. S-G	
			1957	625	Dak. Ss	
			1957	625	Dak. Ss	
Sanborn	1,465	Mun.	1919	80	Pleis. S-G	
			1934	80	Pleis. S-G	
Sheldon	4,535	Mun.	?	25	Recent S-G	
			?	25	Recent S-G	
			1918	27	Recent S-G	
			1921	27	Recent S-G	
			1949	25	Recent S-G	
			1956	25	Recent S-G	

			1956	25	Recent S-G
			1959	?	Recent S-G
Sutherland	875	Mun.	1902	212	Pleis. S-G
			1930	593	Dak. Ss
			1953	450	Dak. Ss

[a]Iowa Department of Health (1964).

Table J-9. Existing sources of water supply for incorporated communities in Osceola County[a]

City	1970 pop.	Owner-ship	Well		Chief aquifer	Remarks
			Date installed	Depth feet		
Ashton	483	Mun.	1900	68	Pleis. G	
			1900	68	Pleis. G	
Harris	195	Mun.	1936	65	Pleis. S	
Melvin	325	Mun.	1957	470	Pleis. S-G	
Ocheyedan	545	Mun.	?	28	Pleis. S-G	
			1955	50	Pleis. S-G	
			1958	32	Pleis. S-G	
Sibley	2,749	Mun.	1934	688	Dak. Ss	
			1946	749	Dak. Ss	
			1960	739	Dak. Ss	

[a]Iowa Department of Health (1964).

Table J-10. Existing sources of water supply for incorporated communities in Plymouth County[a]

City	1970 pop.	Owner-ship	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Akron	1,324	Mun.	1940	56	Recent S-G	
			1959	47	Recent S-G	
Brunsville	125					No data given in reference
Craig	98	Mun.	1926	208	Pleis. S-G	
Hinton	488	Mun.	?	53	Recent S-G	
Kingsley	1,097	Mun.	?	32	Recent S-G	
			1956	37	Recent S-G	
Le Mars	8,159	Pri.	1939	109	Pleis. S-G	
			1950	313	Dak. Ss	
			1955	103	Pleis. S-G	
Merrill	790	Mun.	1960	43	?	
Oyens	145	Mun.	1953	215	Pleis. S-G or Dak. Ss	
Remsen	1,367	Mun.	1912	34	Recent S-G	
			1937	428	Dak. Ss	
			1940	37	Recent S-G	
			1957	36	Recent S-G	
			1958	36	Recent S-G	
Struble	59					No data given in reference
Westfield	148					No data given in reference

[a]Iowa Department of Health (1964).

Table J-11. Existing sources of water supply for incorporated communities in Sac County[a]

City	1970 pop.	Owner-ship	Well		Chief aquifer	Remarks
			Date installed	Depth feet		
Auburn	329	Mun.	1943	246	Dak. Ss	
			1952	242	Dak. Ss	
Early	727	Mun.	1914	10	S-G	
			1957	33	Pleis. S-G	
Lake View	1,249	Mun.	1945	39	Pleis. S-G	
			1956	48	Pleis. S-G	
Lytton	378	Mun.	1954	1,550	C.V., Ga., St.P.	
			1956	1,855	C.V., Ga., St.P., P.C., Jor.	
Nemaha	117					No data given in reference
Odebolt	1,323	Mun.	1910	28	Pleis. S-G	
			1930	32	Pleis. S-G	
			1933	30	Pleis. S-G	
			1934	20	Pleis. S-G	
			1952	2,200	St.P. Ss, P.C. Dol., Jor. Ss	
Sac City	3,268	Mun.	1935	62	Pleis. S-G	
			1940	248	Pleis. S-G	
			1961	145	Pleis. S-G	
Schaller	835	Mun.	1940	354	Dak. Ss	
			1957	460	Dak. Ss	
Wall Lake	936	Mun.	?	26	Recent S-G	
			?	26	Recent S-G	

[a]Iowa Department of Health (1964).

Table J-12. Existing sources of water supply for incorporated communities in Sioux County[a]

City	1970 pop.	Owner-ship	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Alton	1,018	Mun.	1897	28	Recent S-G	
			1900	24	Recent S-G	
			1939	26	Recent S-G	
			1945	26	Recent S-G	
Boyden	670	Mun.	?	30	Recent S-G	
			1939	500	Dak. Ss	
			1952	15	Recent S-G	
			?	30	Recent S-G	
Chatsworth	90					No data given in reference
Granville	383	Mun.	1931	489	Pleis. S-G or Dak. Ss	
Hawarden	2,789	Mun.	1924	36	Pleis. S-G	
			1931	36	Pleis. S-G	
			1950	33	Pleis. S-G	
			1957	33	Pleis. S-G	
			1957	32	Pleis. S-G	
			1960	35	Pleis. S-G	
Hospers	646	Mun.	1908	32	Recent S-G	
			1949	37	Recent S-G	
Hull	1,523	Mun.	1940	650	Dak. Ss	
			1959	650	Dak. Ss	
Ireton	582	Mun.	1946	543	Dak. Ss	
Matlock	89	Mun.	1939	34	Pleis. S-G	
			1959	20	Pleis. S-G	
Maurice	266	Mun.	1923	30	Pleis. S-G	
			1939	231	Dak. Ss	
Orange City	3,572	Mun.	1935	521	Dak. Ss	
			1946	30	Pleis. S-G	
			1946	30	Pleis. S-G	

			1955	30	Pleis. S-G
Rock Valley	2,205	Mun.	1922	29	Pleis. S-G
			1956	64	Pleis. S-G
			1960	51	Pleis. S-G
Sioux Center	3,450	Mun.	1934	39	S-G
			1953	38	S-G
			1956	39	S-G
			1960	39	S-G

[a] Iowa Department of Health (1964).

Table J-13. Existing sources of water supply for incorporated communities in Woodbury County[a]

City	1970 pop.	Ownership	Well: Date installed	Well: Depth feet	Chief aquifer	Remarks
Anthon	711	Mun.	1927	142	Pleis. S-G	
			1941	143	Pleis. S-G	
Bronson	193					No data given in reference
Correctionville	870	Mun.	1925	136	Pleis. S-G	
			1927	26	Recent S-G	
			1957	187	Pleis. S-G, Dak. Ss	
Cushing	204	Mun.	1950	36	Recent S-G	
			1959	36	Recent S-G	
Danbury	527	Mun.	1939	62	Recent S-G	
			1955	68	Recent S-G	
Hornick	250	Mun.	?	127	Pleis. S-G	
			1951	127	Pleis. S-G	
Lawton	406	Mun.	1935	100	Pleis. S-G	
			1935	84	Pleis. S-G	
Moville	1,198	Mun.	1920	48	Recent S-G	
			1934	49	Recent S-G	
Oto	203	Mun.	1956	65	Recent S-G	
Pierson	421	Mun.	1920	26	Recent S-G	
			1956	32	Recent S-G	
Salix	387	Mun.	1950	170	Pleis. S-G or Dak. Ss	
Sergeant Bluff	1,153	Mun.	1940	234	Dak. Ss	
			1953	450	Miss. Ls & Dol.	
Sioux City	85,925	Mun.	1911	396	Dak. Ss	
			1918	302	Dak. Ss	
			1919	338	Dak. Ss	
			1923	349	Dak. Ss	
			1926	290	Dak. Ss	
			1937	340	Dak. Ss	

			1941	361	Dak. Ss
			1943	278	Dak. Ss
			1944	286	Dak. Ss
			1947	330	Dak. Ss
			1949	327	Dak. Ss
			1949	261	Dak. Ss
			1957	450	Dak. Ss
Sloan	799	Mun.	1949	85	Pleis. S-G
			?	97	Pleis. S-G
Smithland	293	Mun.	1954	65	Pleis. S-G

[a]Iowa Department of Health (1964).

APPENDIX K.

COST DATA

Table K-1. Determination of total annual costs for potential reservoir sites 1 through 6 in Northwest Iowa

Item	Potential reservoir site 1	2	3	4	5	6
Total supply, MGD[a]	16.0	105.9	12.5	18.2	22.0	18.7
Const. cost, $\$ \times 10^6$	8.2	25.6	7.9	11.8	12.3	14.5
Annual cost, $\$ \times 10^3$	475.6	1,489.6	458.7	687.7	716.8	843.9
Reservoir ORM, $\$/yr \times 10^3$	134.9	395.9	130.6	189.5	197.0	229.7
Subtotal annual cost, $/MG	318	148	393	402	346	478
Buena Vista	82[b]	120	165	—	—	—
	400	135	361	—	—	—
Cherokee	—	30	55	—	—	—
	—	104	252	—	—	—
Clay	—	210	—	40	37	—
	—	225	—	442	383	—
Dickinson	—	330	—	—	—	40
	—	345	—	—	—	518
Ida	—	—	—	—	—	—
Lyon	—	360	—	—	—	—
	—	375	—	—	—	—
O'Brien	—	120	—	—	—	—
	—	135	—	—	—	—
Osceola	—	240	—	—	—	—
	—	255	—	—	—	—
Plymouth	—	90	—	—	—	—
	—	105	—	—	—	—

[a]MGD = acre-feet/120/3.07.

[b]Upper number = annual transmission cost, $/MG; lower number = total annual cost, $/MG.

Table K-1. Continued

Item	Potential reservoir site					
	1	2	3	4	5	6
Sac	—	210	—	—	—	—
	—	224	—	—	—	—
Sioux	—	240	—	—	—	—
	—	254	—	—	—	—
Woodbury	—	—	—	—	—	—

Table K-2. Determination of total annual costs for potential reservoir sites 7 through 12 in Northwest Iowa

Item	Potential reservoir site 7	8	9	10	11	12
Total supply, MGD[a]	15.2	126.0	109.1	18.4	61.1	16.0
Const. cost, $ x 10^6	11.3	42.8	29.8	15.5	17.1	11.6
Annual cost, $ x 10^3	658.6	2,494.4	1,736.7	903.3	996.6	676.0
Reservoir ORM, $/yr x 10^3	182.0	654.5	459.5	245.0	269.0	186.5
Subtotal annual cost, $/MG	461	208	168	520	173	449
Buena Vista	—	440[b]	—	—	—	—
	—	463	—	—	—	—
Cherokee	—	220	—	—	—	—
	—	243	—	—	—	—
Clay	—	660	300	—	41	—
	—	683	328	—	127	—
Dickinson	—	935	300	—	—	—
	—	958	328	—	—	—
Ida	43	55	—	—	—	—
	274	159	—	—	—	—
Lyon	—	935	30	—	—	—
	—	958	114	—	—	—
O'Brien	—	440	150	50	68	200
	—	463	178	310	155	350
Osceola	—	715	150	—	—	—
	—	738	178	—	—	—
Plymouth	—	—	—	—	—	50
	—	—	—	—	—	200

[a]MGD = acre-feet/120/3.07.

[b]Upper number = annual transmission cost, $/MG; lower number = total annual cost, $/MG.

Table K-2. Continued

Item	Potential reservoir site					
	7	8	9	10	11	12
Sac	215	220	—	—	—	—
	445	243	—	—	—	—
Sioux	—	—	42	100	—	100
	—	—	126	360	—	249
Woodbury	—	—	—	—	—	—

Table K-3. Determination of total annual costs for potential reservoir sites 13 through 18 in Northwest Iowa

Item	Potential reservoir site					
	13	14	15	16	17	18
Total supply, MGD[a]	7.9	10.6	18.4	33.9	11.7	31.5
Const. cost, $\$ \times 10^6$	8.2	8.9	12.4	13.8	9.1	21.0
Annual cost, $\$ \times 10^3$	477.9	518.7	722.7	804.3	530.3	1,223.9
Reservoir ORM, $\$/yr \times 10^3$	135.5	146.0	198.5	219.5	149.0	327.5
Subtotal annual cost, $/MG	647	523	417	252	484	410
Buena Vista	—	—	—	198[b]	—	—
	—	—	—	324	—	—
Cherokee	—	—	—	—	—	—
Clay	—	—	—	—	—	—
Dickinson	—	—	—	—	—	—
Ida	—	—	—	—	—	—
Lyon	—	—	—	—	—	—
O'Brien	—	—	250	—	—	—
	—	—	389	—	—	—
Osceola	—	—	—	—	—	—
Plymouth	50	46	50	—	—	—
	697	569	189	—	—	—
Sac	—	—	—	66	46	—
	—	—	—	192	530	—
Sioux	—	—	120	—	—	70
	—	—	259	—	—	480
Woodbury	—	—	—	—	—	—

[a]MGD = acre-feet/120/3.07.

[b]Upper number = annual transmission cost, $/MG; lower number = total annual cost, $/MG.

Table K-4. Determination of total annual costs for potential reservoir sites 19 through 24 in Northwest Iowa

Item	Potential reservoir site					
	19	20	21	22	23	24
Total supply, MGD[a]	16.3	15.2	20.9	5.4	127.0	27.7
Const. cost, $\$ \times 10^6$	11.1	11.4	11.6	6.2	30.3	15.0
Annual cost, $\$ \times 10^3$	646.9	664.4	676.0	361.3	1,765.9	874.2
Reservoir ORM, $\$/yr \times 10^3$	179.0	183.5	186.5	105.5	467.0	237.5
Subtotal annual cost, $/MG	422	465	344	720	147	334
Buena Vista	—	—	—	—	416[b]	—
	—	—	—	—	429	—
Cherokee	—	—	—	—	256	—
	—	—	—	—	269	—
Clay	—	—	—	—	576	—
	—	—	—	—	579	—
Dickinson	—	—	—	—	—	—
Ida	—	—	184	150	160	200
	—	—	252	510	173	255
Lyon	—	—	—	—	448	—
	—	—	—	—	461	—
O'Brien	—	—	—	—	384	—
	—	—	—	—	397	—
Osceola	—	—	—	—	544	—
	—	—	—	—	557	—
Plymouth	—	—	92	—	160	200
	—	—	161	—	174	256

[a]MGD = acre-feet/120/3.07.

[b]Upper number = annual transmission cost, $/MG; lower number = total annual cost, $/MG.

Table K-4. Continued

Item	Potential reservoir site					
	19	20	21	22	23	24
Sac	—	—	368	—	269	400
	—	—	437	—	283	455
Sioux	—	—	322	—	320	480
	—	—	391	—	334	536
Woodbury	42	42	92	75	32	50
	464	507	161	435	106	162

Table K-5. Determination of total annual costs for the future development of the alluvial aquifers at six communities in Northwest Iowa

Item	Storm Lake	Cherokee	Spencer	Great Lakes	Rock Rapids	Sheldon
Total supply, MGD	0.86	0.43	0.43	1.29	0.43	0.43
Number of wells	2	1	1	3	1	1
Well & pump cost, $\$ \times 10^3$	34.0	17.0	17.0	51.0	17.0	17.0
Annual cost, $\$ \times 10^3$[a]	3.75	1.87	1.87	5.62	1.87	1.87
Well & pump ORM, $\$/yr \times 10^3$	12.39	6.20	6.20	18.58	6.20	6.20
Treatment plant cost, $\$ \times 10^6$	0.26	0.17	0.17	0.33	0.17	0.17
Annual cost, $\$ \times 10^3$[a]	28.64	18.73	18.73	36.36	18.73	18.73
Plant ORM, $\$/yr \times 10^3$	30.46	19.68	19.68	39.33	19.68	19.68
Subtotal annual cost, $/MG	240	296	296	212	296	296
Pipeline length, miles	1	1	1	1	1	2
Transmission cost, $/MG	17	21	21	15	21	42
Total annual cost, $/MG	257	317	317	227	317	338

[a] 10% per year for 25 years.

Table K-6. Determination of total annual costs for the future development of the alluvial aquifers at six communities in Northwest Iowa

Item	Sibley	Le Mars	Sac City	Orange City	Sioux Center	Sioux City
Total supply, MGD	0.43	0.86	0.43	0.43	0.43	5.04
Number of wells	1	2	1	1	1	2
Well & pump cost, $\$ \times 10^3$	17.0	34.0	17.0	17.0	17.0	68.4
Annual cost, $\$ \times 10^3$[a]	1.87	3.75	1.87	1.87	1.87	7.54
Well & pump ORM, $\$/yr \times 10^3$	6.20	12.39	6.20	6.20	6.20	46.26
Treatment plant cost, $\$ \times 10^6$	0.17	0.26	0.17	0.17	0.17	0.79
Annual cost, $\$ \times 10^3$[a]	18.73	28.64	18.73	18.73	18.73	87.03
Plant ORM, $\$/yr \times 10^3$	19.68	30.46	19.68	19.68	19.68	92.80
Subtotal annual cost, \$/MG	296	240	296	296	296	127
Pipeline length, miles	1	1	1	3	3	2
Transmission cost, \$/MG	21	17	21	63	63	20
Total annual cost, \$/MG	317	257	317	359	359	147

[a]10% per year for 25 years.

Table K-7. Determination of total annual costs for the development of supplies for six county rural water districts in Northwest Iowa in 1980

Item	Buena Vista	Cherokee	Clay	Dickinson	Ida	Lyon
Total supply, MGD	3.44	3.01	2.16	2.16	2.15	2.15
Number of wells	8	7	3	3	5	5
Well & pump cost, $\$ \times 10^3$	136.0	119.0	65.0	79.6	85.0	85.0
Annual cost, $\$ \times 10^3$[a]	7.93	6.94	3.79	4.64	4.95	4.95
Well & pump ORM, $\$/yr \times 10^3$	52.96	46.34	35.97	44.64	33.10	33.10
Treatment plant cost, $\$ \times 10^6$	0.62	0.57	0.46	0.46	0.46	0.46
Annual cost, $\$ \times 10^3$[a]	36.13	33.22	26.81	26.81	26.81	26.81
Plant ORM, $\$/yr \times 10^3$	72.96	67.07	54.42	54.42	54.26	54.26
Subtotal annual cost, $/MG	135	140	153	166	152	152
Pipeline length, miles	5	4	6	8	4	4
Transmission cost, $/MG	52	42	72	96	48	48
Total annual cost, $/MG	187	182	225	262	200	200

[a] 5% per year for 40 years.

Table K-8. Determination of total annual costs for the development of supplies for six county rural water districts in Northwest Iowa in 1980

Item	O'Brien	Osceola	Plymouth	Sac	Sioux	Woodbury
Total supply, MGD	3.60	1.44	3.01	3.87	4.73	3.44
Number of wells	5	2	7	9	11	8
Well & pump cost, $\$ \times 10^{3}$	132.5	46.6	119.0	153.0	187.0	136.0
Annual cost, $\$ \times 10^{3}$[a]	7.72	2.72	6.94	8.92	10.90	7.93
Well & pump ORM, $\$/yr \times 10^{3}$	74.40	24.78	46.34	59.58	72.82	52.96
Treatment plant cost, $\$ \times 10^{6}$	0.64	0.36	0.57	0.67	0.76	0.62
Annual cost, $\$ \times 10^{3}$[a]	37.30	20.90	33.22	39.05	44.29	36.13
Plant ORM, $\$/yr \times 10^{3}$	75.08	42.15	67.07	78.58	89.17	72.96
Subtotal annual cost, $/MG	148	172	140	132	126	135
Pipeline length, miles	9	8	5	7	4	8
Transmission cost, $/MG	90	120	53	70	38	80
Total annual cost, $/MG	238	292	193	202	164	215

[a] 5% per year for 40 years.

Table K-9. Determination of total annual costs for the development of water for irrigation from six buried channel aquifers in Northwest Iowa

Item	Buried channel aquifer site 1	2	4	5	6	8
Total supply, MGD	5.8	8.6	10.1	2.9	2.2	2.9
Number of wells	4	6	7	4	3	4
Well & pump cost, $\$ \times 10^3$	92.5	166.6	194.3	106.1	79.6	106.1
Annual cost, $\$ \times 10^{3}$[a]	5.39	9.71	11.32	6.18	4.64	6.18
Well & pump ORM, $\$/yr \times 10^3$	27.80	49.86	58.17	19.64	14.74	19.64
Subtotal annual cost, $/MG	48	58	57	74	73	74
Pipeline length, miles	2	3	4	1	1	1
Transmission cost, $/MG	18	24	30	11	12	11
Clay	66[b]	82	—	—	—	—
Dickinson	—	—	87	85	85	85

[a] 5% per year for 40 years.

[b] Total annual cost, $/MG.

Table K-10. Determination of total annual costs for the development of water for irrigation from six buried channel aquifers in Northwest Iowa

Item	Buried channel aquifer site					
	9	10	11	12	13	15
Total supply, MGD	2.2	1.4	2.9	1.4	1.4	2.9
Number of wells	3	2	4	2	2	4
Well & pump cost, $\$ \times 10^3$	79.6	53.0	106.1	53.0	53.0	93.3
Annual cost, $\$ \times 10^3$[a]	4.64	3.09	6.18	3.09	3.09	5.44
Well & pump ORM, $\$/yr \times 10^3$	14.73	9.82	19.64	9.82	9.82	16.92
Subtotal annual cost, $/MG	73	77	74	77	77	64
Pipeline length, miles	1	1	1	1	1	1
Transmission cost, $/MG	12	15	11	15	15	11
Dickinson	85[b]	92	85	92	92	—
O'Brien	—	—	—	—	—	75

[a]5% per year for 40 years.

[b]Total annual cost, $/MG.

Table K-11. Determination of total annual costs for the development of water for irrigation from the border and interior rivers of Northwest Iowa for use at the point of origin

Item	Missouri River	Big Sioux River	Interior Rivers
Total supply, MGD/site	2.52	0.86	0.86
Number of wells	1	2	2
Well & pump cost, $\$ \times 10^3$	34.2	34.0	34.0
Annual cost, $\$ \times 10^{3}$[a]	3.77	3.74	3.74
Well & pump ORM, $\$/yr \times 10^3$	15.38	4.38	4.38
Subtotal annual cost, $/MG	63	79	79
Pipeline length, miles	0.8	0.1	0.1
Transmission cost, $/MG	9	2	2
Buena Vista	—	—	81[b]
Cherokee	—	—	81
Clay	—	—	81
Dickinson	—	—	81
Ida	—	—	81
Lyon	—	81	81
O'Brien	—	—	81
Osceola	—	—	81
Plymouth	—	81	81
Sac	—	—	81

[a]10% per year for 25 years.

[b]Total annual cost, $/MG/site.

Table K-11. Continued

Item	Missouri River	Big Sioux River	Interior Rivers
Sioux	—	81	81
Woodbury	72	—	81

Table K-12. Determination of total annual costs for the development of water for irrigation from the border rivers of Northwest Iowa for use in the same or another county

Item	Missouri River			Big Sioux River		
	1	2	3	1	2	3
Total supply, MGD	63.0	126.0	252.0	43.0	86.0	129.0
Number of wells	25	50	100	100	200	300
Well & pump cost, $\$ \times 10^6$	0.86	1.71	3.42	1.70	3.40	5.10
Annual cost, $\$ \times 10^3$[a]	50.12	99.66	199.32	99.08	198.15	297.23
Well & pump ORM, $\$/yr \times 10^3$	384.50	769.00	1,538.00	219.00	438.00	657.00
Subtotal annual cost, $/MG	57	57	57	62	62	62
Buena Vista	—	70–315[b]	70–280	—	70–394	70–280
	—	372	337	—	356	342
Cherokee	—	—	46–184	40–200	40–168	40–160
	—	—	241	262	230	222
Clay	—	94–423	94–376	—	70–294	70–280
	—	480	433	—	356	342
Dickinson	—	—	118–472	—	70–294	70–280
	—	—	529	—	356	342
Ida	46–207	46–207	46–184	—	—	—
	264	264	241	—	—	—

Lyon	— —	68–306 363	68–272 329	2–10 72	3–13 75	3–12 74
O'Brien	— —	— —	70–280 337	40–200 262	40–168 230	40–160 222
Osceola	— —	— —	94–376 433	40–200 262	40–168 230	40–160 222
Plymouth	24–108 165	24–108 165	24–96 153	2–10 72	3–13 75	3–12 74
Sac	60–270 327	60–270 327	60–240 297	— —	— —	— —
Sioux	48–214 271	48–216 273	48–192 249	2–10 72	3–13 75	3–12 74
Woodbury	2–9 66	2–9 66	3–12 69	— —	— —	— —

[a] 5% per year for 40 years.

[b] Upper numbers: pipeline length, mi. - transmission cost, \$/MG; lower number: total annual cost, \$/MG.

APPENDIX L.

SOURCE LISTING FOR THE GOAL PROGRAMMING MODEL

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C
C
C     ROSSMILLER'S  GOAL  PROGRAMMING  MODEL
C
C
C           YR(N) = YEARS UNDER CONSIDERATION
C          CO(I,M) = COUNTY NAME
C    LUTCC(I,J,K) = ACRES OF J-TH LAND USE ON K-TH
C                   CAPABILITY CLASS IN I-TH COUNTY IN 1967
C   LUTCCY(I,J,K) = ACRES OF J-TH LAND USE ON K-TH
C                   CAPABILITY CLASS IN I-TH COUNTY
C                   IN SOME FUTURE YEAR
C        LUT(I,J) = TOTAL ACRES OF J-TH LAND USE
C                   IN I-TH COUNTY IN 1967
C       LUTY(I,J) = TOTAL ACRES OF J-TH LAND USE
C                   IN I-TH COUNTY IN SOME FUTURE YEAR
C       LUCC(I,K) = TOTAL ACRES OF K-TH CAPABILITY CLASS
C                   IN I-TH COUNTY
C         LUCA(I) = TOTAL ACRES IN I-TH COUNTY
C         LCCI(K) = LAND CAPABILITY CLASS IDENTIFICATION
C       CCCRYP(K) = CORN CAPABILITY CLASS RELATIVE YIELD
C                   POTENTIAL    RATIO OF LCC(K) TO LCC I
C       SCCRYP(K) = SOYBEAN CAPABILITY CLASS RELATIVE YIELD
C                   POTENTIAL    RATIO OF LCC(K) TO LCC I
C       RCYCC1(I) = RELATIVE CORN YIELD ON LCC I,
C                   BUSHELS PER ACRE, IN 1967
C         ICY1(I) = RELATIVE CORN YIELD ON LCC I,
C                   BUSHELS PER ACRE, IN SOME FUTURE YEAR
C        IICY1(I) = RELATIVE IRRIGATED CORN YIELD ON LCC I,
C                   BUSHELS PER ACRE, IN SOME FUTURE YEAR
C       RSYCC1(I) = RELATIVE SOYBEAN YIELD ON LCC I,
C                   BUSHELS PER ACRE , IN 1967
C         FSY1(I) = RELATIVE SOYBEAN YIELD ON LCC I,
C                   BUSHELS PER ACRE, IN SOME FUTURE YEAR
C       KCCP(I,K) = TOTAL CORN PRODUCTION IN BUSHELS ON
C                   K-TH CAPABILITY CLASS IN I-TH COUNTY
C                   IN 1967
C      KCCPY(I,K) = TOTAL CORN PRODUCTION IN BUSHELS ON
C                   K-TH CAPABILITY CLASS IN I-TH COUNTY
C                   IN SOME FUTURE YEAR
C       KCSP(I,K) = TOTAL SOYBEAN PRODUCTION IN BUSHELS ON
C                   K-TH CAPABILITY CLASS IN I-TH COUNTY
C                   IN 1967
C      KCSPY(I,K) = TOTAL SOYBEAN PRODUCTION IN BUSHELS ON
C                   K-TH CAPABILITY CLASS IN I-TH COUNTY
C                   IN SOME FUTURE YEAR
C         KTCP(I) = TOTAL CORN PRODUCTION IN BUSHELS
C                   IN I-TH COUNTY IN 1967
C        KTCPY(I) = TOTAL CORN PRODUCTION IN BUSHELS
C                   IN I-TH COUNTY IN SOME FUTURE YEAR
C         KTSP(I) = TOTAL SOYBEAN PRODUCTION IN BUSHELS
C                   IN I-TH COUNTY IN 1967
C        KTSPY(I) = TOTAL SOYBEAN PRODUCTION IN BUSHELS
C                   IN I-TH COUNTY IN SOME FUTURE YEAR
C      AETCC(J,K) = AVERAGE ANNUAL EROSION RATES IN TONS PER
C                   ACRE ON EACH LAND USE AND CAPABILITY CLASS
C                   WITHOUT EROSION CONTROL MEASURES
C      RETCC(J,K) = AVERAGE ANNUAL EROSION RATES IN TONS PER
C                   ACRE ON EACH LAND USE AND CAPABILITY CLASS
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C                  WITH EROSION CONTROL MEASURES
C          RFEC =  REDUCTION FACTOR FOR EROSION CONTROL
C                  MEASURES  -  THERE IS LESS LAND
C                  AVAILABLE FOR CROP PRODUCTION
C    KCE(I,J,K) =  TOTAL EROSION IN TONS PER YEAR FROM THE
C                  K-TH CAPABILITY CLASS ON THE J-TH LAND
C                  USE IN THE I-TH COUNTY
C     KCTE(I,K) =  TOTAL EROSION IN TONS PER YEAR FROM THE
C                  K-TH CAPABILITY CLASS IN THE I-TH COUNTY
C     LUTE(I,J) =  TOTAL EROSION IN TONS PER YEAR FROM THE
C                  J-TH LAND USE IN THE I-TH COUNTY
C        KTE(I) =  TOTAL EROSION IN TONS PER YEAR FROM THE
C                  I-TH COUNTY
C       LUUR(I) =  FUTURE ADDITIONS TO URBAN LAND USE, ACRES
C      LURUR(I) =  FUTURE ADDITIONS TO RURAL RESIDENTIAL
C                  LAND USE, ACRES
C                  RESIDENTIAL LAND USES, ACRES
C        OBERSC =  OBERS FUTURE INCREASES IN CORN
C                  PRODUCTION AS A PERCENTAGE OF
C                  1967 PRODUCTION
C        OBERSS =  OBERS FUTURE INCREASES IN SOYBEAN
C                  PRODUCTION AS A PERCENTAGE OF
C                  1967 PRODUCTION
C     KC1TAC(I) =  RELATIVE TOTAL ACRES OF CORN ON LCC I
C                  IN SOME FUTURE YEAR
C     KC1TAS(I) =  RELATIVE TOTAL ACRES OF SOYBEANS ON LCC I
C                  IN SOME FUTURE YEAR
C      LU68(I,K) = TOTAL ACRES OF LAND USES 6,7 AND 8 ON
C                  K-TH CAPABILITY CLASS IN I-TH COUNTY
C                  IN 1967
C    LU610(I,K) =  TOTAL ACRES OF LAND USES 6,7,8,9 AND 10
C                  ON K-TH CAPABILITY CLASS IN I-TH COUNTY
C                  IN 1967
C     LUICY1(I) =  ACRES OF IRRIGATED CORN ON LCC I LAND
C                  IN I-TH COUNTY IN SOME FUTURE YEAR
C     LUICY2(I) =  ACRES OF IRRIGATED CORN ON LCC IIE LAND
C                  IN I-TH COUNTY IN SOME FUTURE YEAR
C     LUICYT(I) =  TOTAL ACRES OF IRRIGATED CORN
C                  IN I-TH COUNTY IN SOME FUTURE YEAR
C             I =  COUNTY, 1 TO 12
C               =   1    BUENA VISTA
C               =   2    CHEROKEE
C               =   3    CLAY
C               =   4    DICKINSON
C               =   5    IDA
C               =   6    LYON
C               =   7    O'BRIEN
C               =   8    OSCEOLA
C               =   9    PLYMOUTH
C               =  10    SAC
C               =  11    SIOUX
C               =  12    WOODBURY
C             J =  LAND USE TYPE, 1 TO 10
C               =   1    URBAN AND BUILT-UP
C               =   2    FOREST
C               =   3    OTHER
C               =   4    CONSERVATION USE ONLY
C               =   5    WATER AREAS
C               =   6    CORN
C               =   7    SOYBEANS
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C                    =  8   CLOSE GROWN CROPS
C                    =  9   ROTATION HAY AND PASTURE
C                    = 10   PASTURE
C                  K = LAND CAPABILITY CLASS, 1 TO 16
C                    =  1 = 1
C                    =  2 = 2E, 3 = 2W, 4 = 2S, 5 = 3E, 6 = 3W
C                    =  7 = 3S, 8 = 4E, 9 = 4W, 10 = 4S, 11 = 5W
C                    = 12 = 6E, 13 = 6S, 14 = 7E, 15 = 7W
C                    = 16 = 7S
C
C             0.94 = 150.4/160
C                    THAT PORTION OF A QUARTER SECTION OF LAND
C                    WHICH CAN BE IRRIGATED USING A CENTER
C                    PIVOT SYSTEM WITH CORNER ATTACHMENTS
C
      DIMENSION LUTCC(12,10,16),LUT(12,10),LUCC(12,16)
      DIMENSION CO(12,3),LUCA(12),LCCI(16),CCCRYP(16)
      DIMENSION SCCRYP(16),RCYCC1(12),RSYCC1(12),IYR(2)
      DIMENSION KCCP(12,16),KCSP(12,16),KTCP(12),KTSP(12)
      DIMENSION AETCC(10,16),KCE(12,10,16),KCTE(12,16)
      DIMENSION LUTE(12,10),KTE(12),LURUR(12),LUUR(12)
      DIMENSION LUTCCY(12,10,16),LUTY(12,10),FSY1(12)
      DIMENSION ICY1(12),IICY1(12),KCCPY(12,16),KTCPY(12)
      DIMENSION KCSPY(12,16),KTSPY(12),LUC67(12),LUS67(12)
      DIMENSION KC1TAC(12),KC1TAS(12),LU68(12,16),LU610(12,16)
      DIMENSION LUC671(12),LUICY1(12),LNFC(12),LU610Y(12,16)
      DIMENSION LUCC18(12,16),LUCC90(12,16),LU68Y(12,16)
      DIMENSION LUCY(12),RATIOC(12),RATIOS(12),LUCC17(12,16)
      DIMENSION LUCC80(12,16),LUICY2(12),LUICYT(12)
      DIMENSION LU67(12,16),NCPR(12),NSPR(12),LUCC16(12,16)
      DIMENSION LU67Y(12,16),ID1(17),ID2(17),ID3(17),ID4(17)
      DIMENSION ID5(17),MRES(25,4),NO(25),RETCC(10,16)
      DIMENSION RIWAFY(12),RIWMGD(12),LURESL(12),LURESW(12)
      DIMENSION LU310(12,16),LU310Y(12,16)
C
C        READ IN IDENTIFICATION INFORMATION
C
      READ (5,787) (ID1(J),J=1,17)
      READ (5,787) (ID2(J),J=1,17)
      READ (5,787) (ID3(J),J=1,17)
      READ (5,787) (ID4(J),J=1,17)
      READ (5,787) (ID5(J),J=1,17)
  787 FORMAT (5X,17A4)
C
C        READ IN BASE YEAR AND SOME FUTURE YEAR
C
      READ (5,1) IYR(1),IYR(2)
    1 FORMAT (4X,I4,4X,I4)
C
C        READ IN LAND CAPABILITY CLASS IDENTIFICATION
C
      READ (5,5) (LCCI(K),K=1,16)
    5 FORMAT (16A4)
C
C        READ IN COUNTY NAME
C
      DO 10 I=1,12
        READ (5,15) (CO(I,M),M=1,3)
   15   FORMAT (3A4)
C
```

```
C         READ IN NUMBER OF ACRES IN THE I-TH COUNTY DEVOTED
C         TO ALL LAND USES (J) ON ALL LAND CAPABILITY CLASSES
C         (LCC) (K) IN THE BASE YEAR
C
        DO 20 K=1,16
          READ (5,30) (LUTCC(I,J,K),J=1,10)
   30     FORMAT (10I8)
   20   CONTINUE
   10 CONTINUE
C
C         READ IN THE RELATIVE YIELD POTENTIAL
C         FOR CORN ON EACH LCC
C
      READ (5,250) (CCCRYP(K),K=1,16)
  250 FORMAT (16F4.1)
C
C         READ IN THE RELATIVE YIELD POTENTIAL
C         FOR SOYBEANS ON EACH LCC
C
      READ (5,260) (SCCRYP(K),K=1,16)
  260 FORMAT (16F4.2)
C
C         READ IN THE RELATIVE CORN YIELD
C         ON LCC 1 IN THE BASE YEAR
C
      READ (5,270) (RCYCC1(I),I=1,12)
  270 FORMAT (12F6.1)
C
C         READ IN THE RELATIVE SOYBEAN YIELD
C         ON LCC 1 IN THE BASE YEAR
C
      READ (5,270) (RSYCC1(I),I=1,12)
C
C         READ IN THE AVERAGE ANNUAL EROSION RATES IN TONS
C         PER ACRE FOR EACH LCC ON EACH LAND USE  -  ASSUMES
C         NO EROSION CONTROL MEASURES ARE IN PLACE
C
      DO 590 K=1,16
        READ (5,595) (AETCC(J,K),J=1,10)
  595   FORMAT (10F8.1)
  590 CONTINUE
C
C         READ IN NUMBER OF POSSIBLE RESERVOIR SITES
C
      READ (5,775) MM
  775 FORMAT (I5)
      IF (MM.EQ.0) GO TO 7000
C
C         READ IN LAND AND WATER AREAS OF M-TH RESERVOIR
C         AND COUNTY IN WHICH IT IS LOCATED
C
C         MRES(M,1) = LAND AREA, ACRES
C         MRES(M,2) = WATER AREA, ACRES
C         MRES(M,3) = TOTAL RESERVOIR AREA, ACRES
C         MRES(M,4) = COUNTY IN WHICH RESERVOIR IS LOCATED
C                     I = 1 TO 12
C
      DO 776 M=1,MM
        READ (5,777) MRES(M,1),MRES(M,2),MRES(M,4)
  777   FORMAT (3I10)
```

```
         MRES(M,3)=MRES(M,1)+MRES(M,2)
         NO(M)=0
  776 CONTINUE
C
C           READ IN ADDITIONS TO URBAN AND RURAL RESIDENTIAL
C           LAND USE IN FUTURE YEARS
C
 7000 READ (5,771) (LUUR(I),I=1,12)
  771 FORMAT (12I6)
      READ (5,771) (LURUR(I),I=1,12)
C
C           READ IN OBERS FUTURE INCREASES IN
C           CORN AND SOYBEAN PRODUCTION USING
C           1967 PRODUCTION AS THE BASE
C
      READ (5,772) OBERSC,OBERSS
  772 FORMAT (2F8.3)
C
C           READ IN RELATIVE NON-IRRIGATED CORN YIELDS
C           ON LCC I LAND, BUSHELS PER ACRE,
C           IN SOME FUTURE YEAR
C
      READ (5,773) (ICY1(I),I=1,12)
  773 FORMAT (12I6)
C
C           READ IN RELATIVE IRRIGATED CORN YIELDS
C           ON LCC I LAND, BUSHELS PER ACRE,
C           IN SOME FUTURE YEAR
C
      READ (5,773) (IICY1(I),I=1,12)
C
C           READ IN RELATIVE SOYBEAN YIELDS
C           ON LCC I LAND, BUSHELS PER ACRE,
C           IN SOME FUTURE YEAR
C
      READ (5,774) (FSY1(I),I=1,12)
  774 FORMAT (12F6.1)
C
C           READ IN CROP PLANTING SCENARIO NUMBER, L
C           READ IN STRUCTURAL EROSION CONTROL (?)
C                 IEC = 0 = NO
C                 IEC = 1 = YES
C           READ IN ANNUAL GROSS IRRIGATION WATER REQUIRED
C           FOR SOME RECURRENCE INTERVAL, INCHES OF WATER,
C           AIWRI
C
      READ (5,786) L,IEC,AIWRI
  786 FORMAT (2I5,F10.1)
      IF (IEC.EQ.0) GO TO 810
C
C           READ IN THE AVERAGE ANNUAL EROSION RATES IN TONS
C           PER ACRE FOR EACH LCC ON EACH LAND USE  -  ASSUMES
C           STRUCTURAL AND CULTURAL EROSION CONTROL MEASURES
C           ARE IN PLACE
C
      DO 801 K=1,16
        READ (5,595) (RETCC(J,K),J=1,10)
  801 CONTINUE
  810 LUV=0
C
```

```
C         PRINT INPUT DATA
C
      OBC=100.*OBERSC
      OBS=100.*OBERSS
      WRITE (6,788) (ID1(J),J=1,17)
  788 FORMAT ('1',//////22X,17A4)
      WRITE (6,789) (ID2(J),J=1,17)
      WRITE (6,789) (ID3(J),J=1,17)
      WRITE (6,789) (ID4(J),J=1,17)
      WRITE (6,789) (ID5(J),J=1,17)
  789 FORMAT ('0',21X,17A4)
      WRITE (6,780) IYR(2)
  780 FORMAT ('1',//////45X,'DATA USED FOR ',I4,' ',
     1 'PROJECTIONS',///22X,'COUNTY',10X,'LAND USED FOR',7X,
     2 'INCREASED',6X,'IRRIGATED',6X,'INCREASED',/61X,'CORN',
     3 11X,'CORN',9X,'SOYBEAN',/37X,'URBAN      RURAL',8X,
     4 'YIELD',10X,'YIELD',10X,'YIELD',///37X,'ACRES      ',
     5 'ACRES',8X,'BU/AC',10X,'BU/AC',10X,'BU/AC',/)
      DO 781 I=1,12
         WRITE (6,782) (CO(I,M),M=1,3),LUUR(I),LURUR(I),
     1 ICY1(I),IICY1(I),FSY1(I)
  782    FORMAT ('0',18X,3A4,2I10,I13,I15,F15.1)
  781 CONTINUE
      WRITE (6,783) OBC,OBS,AIWRI
  783 FORMAT ('0',//30X,'OBERS PROJECTIONS  -  AS A ',
     1 'PERCENTAGE OF 1967 PRODUCTION',//44X,'CORN   =   ',
     2 F5.1,//40X,'SOYBEANS   =   ',F5.1,///30X,'ANNUAL ',
     3 'GROSS IRRIGATION WATER REQUIRED = ',F4.1,' INCHES')
      WRITE (6,3100)
 3100 FORMAT ('1',//////37X,'POTENTIAL RESERVOIR SITES',
     1 ///22X,'NO.',7X,'COUNTY',15X,'LAND',15X,'WATER',
     2 //52X,'ACRES',15X,'ACRES'/)
      IF (MM.EQ.0) GO TO 7010
      DO 3110 M=1,MM
         I=MRES(M,4)
         WRITE (6,3120) M,(CO(I,N),N=1,3),MRES(M,1),
     1                  MRES(M,2)
 3120    FORMAT ('0',21X,I2,4X,3A4,I17,I20)
 3110 CONTINUE
C
C         CALCULATE TOTAL NUMBER OF ACRES DEVOTED TO EACH
C         LAND USE IN THE BASE YEAR AND TOTAL NUMBER OF ACRES
C         WHICH EXIST IN EACH LCC IN EACH COUNTY
C
 7010 DO 40 I=1,12
         LUCA(I)=0
         DO 50 J=1,10
            LUT(I,J)=0
   50    CONTINUE
         DO 60 K=1,16
            LUCC(I,K)=0
   60    CONTINUE
   40 CONTINUE
      DO 70 I=1,12
         DO 80 J=1,10
            DO 90 K=1,16
               LUT(I,J)=LUT(I,J)+LUTCC(I,J,K)
   90       CONTINUE
            LUCA(I)=LUCA(I)+LUT(I,J)
   80    CONTINUE
```

```
   70 CONTINUE
      DO 100 I=1,12
        DO 110 K=1,16
          DO 120 J=1,10
            LUCC(I,K)=LUCC(I,K)+LUTCC(I,J,K)
  120     CONTINUE
  110   CONTINUE
  100 CONTINUE
      LL=0
C
C          PRINT OUT NUMBER OF ACRES DEVOTED TO EACH LAND USE
C          ON EACH LCC AND TOTAL ACREAGE DEVOTED TO EACH LAND
C          USE AND EACH LCC IN EACH COUNTY IN THE BASE YEAR
C
      CALL PLU(CO,IYR(1),LL,LCCI,LUTCC,LUCC,LUT,LUCA)
C
C          CALCULATE THE BUSHELS OF CORN AND SOYBEANS GROWN
C          ON EACH LCC AND THE TOTAL BUSHELS OF CORN AND
C          SOYBEANS GROWN IN EACH COUNTY IN THE BASE YEAR
C
      DO 280 I=1,12
        KTCP(I)=0
        KTSP(I)=0
        DO 290 K=1,16
          KCCP(I,K)=0
          KCSP(I,K)=0
  290   CONTINUE
  280 CONTINUE
      DO 300 I=1,12
        DO 310 K=1,16
          KCCP(I,K)=LUTCC(I,6,K)*RCYCC1(I)*CCCRYP(K)
          KCSP(I,K)=LUTCC(I,7,K)*RSYCC1(I)*SCCRYP(K)
          KTCP(I)=KTCP(I)+KCCP(I,K)
          KTSP(I)=KTSP(I)+KCSP(I,K)
  310   CONTINUE
  300 CONTINUE
C
C          PRINT OUT THE BUSHELS OF CORN AND SOYBEANS GROWN
C          ON EACH LCC AND THE TOTAL BUSHELS OF CORN AND
C          SOYBEANS GROWN IN EACH COUNTY IN THE BASE YEAR
C
      CALL PCSP(IYR(1),LL,LCCI,KCCP,KTCP,KCSP,KTSP)
C
C          CALCULATE THE EROSION IN TONS PER YEAR FROM EACH
C          LAND USE AND LCC IN EACH COUNTY IN THE BASE YEAR
C
      DO 600 I=1,12
        KTE(I)=0
        DO 610 J=1,10
          LUTE(I,J)=0
          DO 620 K=1,16
            KCTE(I,K)=0
            KCE(I,J,K)=0
  620     CONTINUE
  610   CONTINUE
  600 CONTINUE
      DO 630 I=1,12
        DO 640 J=1,10
          DO 650 K=1,16
            KCE(I,J,K)=LUTCC(I,J,K)*AETCC(J,K)/100
```

```
        LUTE(I,J)=LUTE(I,J)+KCE(I,J,K)
650     CONTINUE
        KTE(I)=KTE(I)+LUTE(I,J)
640   CONTINUE
630 CONTINUE
    DO 660 I=1,12
      DO 670 K=1,16
        DO 680 J=1,10
          KCTE(I,K)=KCTE(I,K)+KCE(I,J,K)
680     CONTINUE
670   CONTINUE
660 CONTINUE
C
C        PRINT OUT THE EROSION IN TONS PER YEAR FROM EACH
C        LAND USE AND LCC IN EACH COUNTY IN THE BASE YEAR
C
    CALL PSE(CO,IYR(I),LL,LCCI,KCE,KCTE,LUTE,KTE)
    DO 785 I=1,12
      LUICY1(I)=0
      LUICY2(I)=0
      LUICYT(I)=0
785 CONTINUE
C
C        SET ACREAGE IN EACH LAND USE IN FUTURE YEARS
C        EQUAL INITIALLY TO LAND USE ACREAGES IN 1967
C
    DO 790 I=1,12
      DO 795 J=1,10
        DO 800 K=1,16
          LUTCCY(I,J,K)=LUTCC(I,J,K)
800     CONTINUE
795   CONTINUE
790 CONTINUE
C
C        ADDITIONS TO URBAN AND RURAL RESIDENTIAL
C        LAND USE IN SOME FUTURE YEAR, ACRES
C
    DO 820 I=1,12
      DO 830 K=1,5
        IF (K.EQ.4) GO TO 830
        LUTCCY(I,1,K)=LUTCCY(I,1,K)+LUUR(I)/4
        LUTCCY(I,3,K)=LUTCCY(I,3,K)+LURUR(I)/4
830   CONTINUE
820 CONTINUE
C
C        ALL CLASS VI AND VII LANDS USED FOR CROPS
C        IN 1967 ARE CONVERTED TO PERMANENT PASTURE
C        IN FUTURE YEARS
C
    DO 840 I=1,12
      DO 850 J=6,9
        DO 860 K=12,16
          LUTCCY(I,10,K)=LUTCCY(I,10,K)+LUTCCY(I,J,K)
          LUTCCY(I,J,K)=0
860     CONTINUE
850   CONTINUE
840 CONTINUE
C
C
C        CROP PLANTING SCENARIO 3
```

```
C
C
C        UTILIZE ALL LAND USED FOR ROW AND CLOSE GROWN CROPS,
C        HAY AND PASTURE IN 1967 WITH THE SAME PERCENTAGE
C        OF LAND UTILIZED IN 1967 FOR ROW AND CLOSE GROWN
C        CROPS USED FIRST FOR CORN AND THEN FOR SOYBEANS ON
C        CLASS I THROUGH V LAND USING IRRIGATION AS NEEDED
C
C
C        CALCULATE TOTAL ACREAGE IN LAND USES 6 THROUGH 8
C        AND LAND USES 6 THROUGH 10 ON LLC I THROUGH V LAND
C        IN EACH COUNTY IN 1967
C
      DO 980 I=1,12
        DO 985 K=1,11
          LU68(I,K)=0
          DO 990 J=6,8
            LU68(I,K)=LU68(I,K)+LUTCC(I,J,K)
  990     CONTINUE
            LU68(I,K)=LU68(I,K)+LUTCC(I,1,K)-LUTCCY(I,1,K)+
     1        LUTCC(I,3,K)-LUTCCY(I,3,K)
            LU610(I,K)=LU68(I,K)
          DO 1000 J=9,10
            LU610(I,K)=LU610(I,K)+LUTCC(I,J,K)
 1000     CONTINUE
          LU610Y(I,K)=LU610(I,K)
  985   CONTINUE
  980 CONTINUE
C
C        ACRES USED FOR CORN PRODUCTION IN SOME FUTURE YEAR
C
 4000 DO 1002 I=1,12
        KK=0
        LOVE=0
        LUICY1(I)=0
        LUICY2(I)=0
        DO 1004 K=1,16
          LUTCCY(I,6,K)=0
          KCCPY(I,K)=0
 1004   CONTINUE
C
C        CALCULATE CORN PRODUCTION ON LCC I THROUGH V LAND
C
        KTCPY(I)=KTCP(I)*OBERSC
 1005   CONTINUE
        IF (LOVE.EQ.0) KI=1
        IF (LOVE.GT.0) KI=3
        DO 1009 K=KI,11
          IF (LU68(I,K).EQ.0) GO TO 1009
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7055
          IF (K-5) 7050,7051,7052
 7050     RFEC=1.0
          GO TO 7055
 7051     RFEC=0.9
          GO TO 7055
 7052     IF (K-8) 7051,7053,7054
 7053     RFEC=0.8
          GO TO 7055
 7054     IF (K-11) 7053,7050,7055
```

```
7055      RAT=LU610(I,K)
          TIO=LU68(I,K)
          RATIOC(I)=RAT/TIO
          LUTCCY(I,6,K)=LUTCC(I,6,K)*RATIOC(I)/CCCRYP(K)/RFEC
          IF (LUTCCY(I,6,K).LT.LU610(I,K)) GO TO 1010
          LUTCCY(I,6,K)=LU610(I,K)
1010      CONTINUE
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          KTCPY(I)=KTCPY(I)-KCCPY(I,K)
          IF (KTCPY(I).GT.0) GO TO 1009
          KK=K+1
          KTCPY(I)=KTCPY(I)+KCCPY(I,K)
          LUTCCY(I,6,K)=KTCPY(I)/ICY1(I)/CCCRYP(K)/RFEC
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          GO TO 1011
1009    CONTINUE
1011    CONTINUE
        IF (LOVE.GT.0) GO TO 1021
        KTCPY(I)=0
        DO 1014 K=1,11
          KTCPY(I)=KTCPY(I)+KCCPY(I,K)
1014    CONTINUE
C
C        CHECK FOR ADDITIONAL CORN PRODUCTION
C        NEEDED ON LCC I THROUGH V LAND
C
C           KPRA = ADDITIONAL CORN PRODUCTION REQUIRED,
C                  BUSHELS
C          LNFCA = ADDITIONAL LAND NEEDED FOR CORN, ACRES
C            LLO = LAND LEFT OVER, ACRES
C           ICPR = IRRIGATED CORN PRODUCTION REQUIRED,
C                  BUSHELS
C
       IF (LOVE.GT.0) GO TO 1024
       DO 1015 K=1,11
        LUCC16(I,K)=0
        DO 1016 J=1,6
          LUCC16(I,K)=LUCC16(I,K)+LUTCCY(I,J,K)
1016    CONTINUE
1015    CONTINUE
        DO 1017 K=1,11
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7065
          IF (K-5) 7060,7061,7062
7060      RFEC=1.0
          GO TO 7065
7061      RFEC=0.9
          GO TO 7065
7062      IF (K-8) 7061,7063,7064
7063      RFEC=0.8
          GO TO 7065
7064      IF (K-11) 7063,7060,7065
7065      LLO=LUCC(I,K)-LUCC16(I,K)
          IF (LLO.EQ.0) GO TO 1017
          KPRA=KTCP(I)*OBERSC-KTCPY(I)
          LNFCA=KPRA/ICY1(I)/CCCRYP(K)/RFEC
          ITEST4=LNFCA-LLO
        IF (ITEST4.GT.0) GO TO 1018
          LUTCCY(I,6,K)=LUTCCY(I,6,K)+LNFCA
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
```

```
      GO TO 1021
1018    LUTCCY(I,6,K)=LUTCCY(I,6,K)+LLO
        KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
        KTCPY(I)=KTCPY(I)+LLO*ICY1(I)*CCCRYP(K)*RFEC
1017  CONTINUE
      IF (LOVE.GT.0) GO TO 1021
      ICPR=KTCP(I)*OBERSC-KTCPY(I)
      LUICY1(I)=ICPR/(IICY1(I)-ICY1(I))/.94
      ITEST5=LUICY1(I)-LUTCCY(I,6,1)
      IF (ITEST5.GT.0) GO TO 1019
      KCCPY(I,1)=LUTCCY(I,6,1)*ICY1(I)+LUICY1(I)*(IICY1(I)
     1-ICY1(I))*.94
      GO TO 1021
1019  LUICY1(I)=LUTCCY(I,6,1)
      KCCPY(I,1)=LUTCCY(I,6,1)*IICY1(I)*.94+
     1   LUTCCY(I,6,1)*ICY1(I)*.06
      KCCPY(I,2)=ICPR-KCCPY(I,1)
      LUICY2(I)=KCCPY(I,2)/CCCRYP(2)/(IICY1(I)-ICY1(I))/.94
      ITEST6=LUICY2(I)-LUTCCY(I,6,2)
      IF (ITEST6.GT.0) GO TO 1020
      KCCPY(I,2)=LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)+
     1LUICY2(I)*(IICY1(I)-ICY1(I))*CCCRYP(2)*.94
      GO TO 1021
1020  LUICY2(I)=LUTCCY(I,6,2)
      KCCPY(I,2)=LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)+
     1LUICY2(I)*(IICY1(I)-ICY1(I))*CCCRYP(2)*.94
1021  CONTINUE
      KTCPY(I)=0
      DO 1023 K=1,11
        KTCPY(I)=KTCPY(I)+KCCPY(I,K)
1023  CONTINUE
      LUICYT(I)=LUICY1(I)+LUICY2(I)
      NCPR(I)=KTCP(I)*OBERSC-KTCPY(I)
C
C      ACRES USED FOR SOYBEAN PRODUCTION
C      IN SOME FUTURE YEAR
C
1024  CONTINUE
      KK=0
      DO 1025 K=1,16
        LUTCCY(1,7,K)=0
        KCSPY(I,K)=0
1025  CONTINUE
C
C      CALCULATE SOYBEAN PRODUCTION
C      ON LCC I THROUGH V LAND
C
      KTSPY(1)=KTSP(I)*OBERSS
      DO 1026 K=1,11
        IF (LU68(I,K).EQ.0) GO TO 1026
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7075
        IF (K-5) 7070,7071,7072
7070    RFEC=1.0
        GO TO 7075
7071    RFEC=0.9
        GO TO 7075
7072    IF (K-8) 7071,7073,7074
7073    RFEC=0.8
        GO TO 7075
```

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7074      IF (K-11) 7073,7070,7075
7075      RAT=LU610(I,K)
          TIO=LU68(I,K)
          RATIOS(I)=RAT/TIO
          LUTCCY(I,7,K)=LUTCC(I,7,K)*RATIOS(I)/SCCRYP(K)/RFEC
          IF (LUTCCY(I,7,K).LT.(LU610(I,K)-
   1         LUTCCY(I,6,K))) GO TO 1029
          LUTCCY(I,7,K)=LU610(I,K)-LUTCCY(I,6,K)
1029      CONTINUE
          KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
          KTSPY(I)=KTSPY(I)-KCSPY(I,K)
          IF (KTSPY(I).GT.0) GO TO 1026
          KK=K+1
          KTSPY(I)=KTSPY(I)+KCSPY(I,K)
          LUTCCY(I,7,K)=KTSPY(I)/FSY1(I)/SCCRYP(K)/RFEC
          KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
          GO TO 1031
1026    CONTINUE
1031    CONTINUE
        KTSPY(I)=0
        DO 1032 K=1,11
          KTSPY(I)=KTSPY(I)+KCSPY(I,K)
1032    CONTINUE
C
C         CHECK FOR ADDITIONAL SOYBEAN PRODUCTION
C         NEEDED ON LCC II THROUGH V LAND
C
C             NSPN = NET SOYBEAN PRODUCTION NEEDED, BUSHELS
C             LNFS = LAND NEEDED FOR SOYBEANS, ACRES
C              LLO = LAND LEFT OVER, ACRES
C
        DO 1033 K=1,11
          LUCC17(I,K)=0
          DO 1034 J=1,7
            LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
1034      CONTINUE
1033    CONTINUE
        DO 1035 K=1,11
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7085
          IF (K-5) 7080,7081,7082
7080      RFEC=1.0
          GO TO 7085
7081      RFEC=0.9
          GO TO 7085
7082      IF (K-8) 7081,7083,7084
7083      RFEC=0.8
          GO TO 7085
7084      IF (K-11) 7083,7080,7085
7085    LLO=LUCC(I,K)-LUCC17(I,K)
        IF (LLO.EQ.0) GO TO 1035
        NSPN=KTSP(I)*OBERSS-KTSPY(I)
        LNFS=NSPN/FSY1(I)/SCCRYP(K)/RFEC
        ITEST1=LNFS-LLO
        IF (ITEST1.GT.0) GO TO 1036
        LUTCCY(I,7,K)=LUTCCY(I,7,K)+LNFS
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        GO TO 1037
1036    LUTCCY(I,7,K)=LUTCCY(I,7,K)+LLO
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
```

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      KTSPY(I)=KTSPY(I)+LLO*FSY1(I)*SCCRYP(K)*RFEC
 1035 CONTINUE
 1037  CONTINUE
       KTSPY(I)=0
       DO 1028 K=1,11
         KTSPY(I)=KTSPY(I)+KCSPY(I,K)
 1028  CONTINUE
       NSPR(I)=KTSP(I)*OBERSS-KTSPY(I)
C
C       USE IRRIGATION OF CORN ON LCC I AND IIE LAND TO
C       OBTAIN ADDITIONAL LAND FOR PRODUCTION OF SOYBEANS
C
       LOVE=LOVE+1
       RNSP=NSPR(I)
       IF (LOVE.EQ.2) GO TO 1049
       IF (FSY1(I).GT.RNSP) GO TO 1049
       IF (LUICY2(I).EQ.LUTCCY(I,6,2)) GO TO 1049
       LUTCCY(I,6,1)=LU610(I,1)
       LU610Y(I,1)=0
       LUICY1(I)=LUTCCY(I,6,1)
       KCCPY(I,1)=LUTCCY(I,6,1)*IICY1(I)*.94+
     1    LUTCCY(I,6,1)*ICY1(I)*.06
       KTCPY(I)=KTCP(I)*OBERSC-KCCPY(I,1)
       KCCPY(I,2)=LU610(I,2)*IICY1(I)*CCCRYP(2)*.94+
     1    LU610(I,2)*ICY1(I)*CCCRYP(2)*.06
       ITEST5=KTCPY(I)-KCCPY(I,2)
       IF (ITEST5.LE.0) GO TO 1040
       LUTCCY(I,6,2)=LU610(I,2)
       KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1    LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
       KTCPY(I)=KTCPY(I)-KCCPY(I,2)
       LUICY2(I)=LUTCCY(I,6,2)
       LUTCCY(I,7,2)=0
       DO 1039 K=3,11
         LU610Y(I,K)=LU610(I,K)
 1039  CONTINUE
       GO TO 1005
 1040  LUTCCY(I,6,2)=KTCPY(I)/CCCRYP(2)/(.94*IICY1(I)+
     1    .06*ICY1(I))
       KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1    LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
       KTCPY(I)=KCCPY(I,1)+KCCPY(I,2)
       LU610Y(I,2)=LU610(I,2)-LUTCCY(I,6,2)
       LUICY2(I)=LUTCCY(I,6,2)
       LUICYT(I)=LUICY1(I)+LUICY2(I)
       DO 1042 K=3,11
         LU610Y(I,K)=LU610(I,K)
 1042  CONTINUE
       DO 1045 K=3,16
         LUTCCY(I,6,K)=0
         KCCPY(I,K)=0
 1045  CONTINUE
       GO TO 1024
 1049  CONTINUE
C
C       CALCULATE ACRE-FEET OF WATER NEEDED TO IRRIGATE
C       LUICYT(I) IN EACH COUNTY AND THEN CONVERT THESE
C       VOLUMES TO MGD FOR EACH COUNTY ASSUMING A 120 DAY
C       IRRIGATION SEASON
C
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C                AIWRI = ANNUAL GROSS IRRIGATION WATER REQUIRED
C                        FOR SOME RECURRENCE INTERVAL. INCHES
C            RIWAFY(I) = VOLUME OF IRRIGATION WATER REQUIRED
C                        IN EACH COUNTY. ACRE-FEET PER YEAR
C            RIWMGD(I) = DAILY VOLUME OF IRRIGATION WATER
C                        REQUIRED IN EACH COUNTY. MILLION
C                        GALLONS PER DAY
C
      RIWAFY(I)=LUICYT(I)*AIWRI/12.
      RIWMGD(I)=RIWAFY(I)/368.4
C
C      CALCULATE LAND USED FOR CLOSE GROWN CROPS
C      IN SOME FUTURE YEAR
C
      LUTY(I,8)=0
      DO 1050 K=1,11
        LUCC17(I,K)=0
        DO 1055 J=1,7
          LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
 1055   CONTINUE
        LUCC80(I,K)=LUCC(I,K)-LUCC17(I,K)
        ITEST6=LUTCCY(I,8,K)-LUCC80(I,K)
        IF (ITEST6.LT.0) GO TO 1058
        LUTCCY(I,8,K)=LUCC80(I,K)
        LUTCCY(I,9,K)=0
        LUTCCY(I,10,K)=0
 1058   CONTINUE
        LUTY(I,8)=LUTY(I,8)+LUTCCY(I,8,K)
 1050 CONTINUE
      DO 1060 K=1,11
        LU8N=LUT(I,8)-LUTY(I,8)
        LU90=LUCC80(I,K)-LUTCCY(I,8,K)
        IF (LU90.EQ.0) GO TO 1060
        ITEST7=LU8N-LU90
        IF (ITEST7.GT.0) GO TO 1062
        LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU8N
        GO TO 1064
 1062   LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU90
        LUTY(I,8)=LUTY(I,8)+LU90
        LUTCCY(I,9,K)=0
        LUTCCY(I,10,K)=0
 1060 CONTINUE
 1064 CONTINUE
C
C      CALCULATE LAND USED FOR HAY AND PASTURE
C      IN SOME FUTURE YEAR
C
      LUTY(I,9)=0
      DO 1070 K=1,11
        LUCC18(I,K)=LUCC17(I,K)+LUTCCY(I,8,K)
        LUCC90(I,K)=LUCC(I,K)-LUCC18(I,K)
        ITEST8=LUTCCY(I,9,K)-LUCC90(I,K)
        IF (ITEST8.LT.0) GO TO 1072
        LUTCCY(I,9,K)=LUCC90(I,K)
        LUTCCY(I,10,K)=0
        GO TO 1074
 1072   LUTCCY(I,10,K)=LUCC90(I,K)-LUTCCY(I,9,K)
 1074   CONTINUE
        LUTY(I,9)=LUTY(I,9)+LUTCCY(I,9,K)
 1070 CONTINUE
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      DO 1075 K=1,11
         LU9N=LUT(I,9)-LUTY(I,9)
         IF (LU9N.LE.0) GO TO 1079
         IF (LUTCCY(I,10,K).EQ.0) GO TO 1075
         ITEST9=LU9N-LUTCCY(I,10,K)
         IF (ITEST9.GT.0) GO TO 1077
         LUTCCY(I,9,K)=LUTCCY(I,9,K)+LU9N
         LUTCCY(I,10,K)=LUTCCY(I,10,K)-LU9N
         GO TO 1079
 1077    LUTCCY(I,9,K)=LUTCCY(I,9,K)+LUTCCY(I,10,K)
         LUTY(I,9)=LUTY(I,9)+LUTCCY(I,10,K)
         LUTCCY(I,10,K)=0
 1075 CONTINUE
 1079 CONTINUE
 1002 CONTINUE
      IF (LUV.EQ.1) GO TO 1795
      LUVE=0
      DO 2990 I=1,12
         IF (LUICYT(I).NE.0) GO TO 2995
         LUVE=1
 2990 CONTINUE
      IF (LUVE.EQ.1) GO TO 1795
 2995 CALL GP(RIWMGD,NO)
      DO 3000 I=1,12
         LURESL(I)=0
         LURESW(I)=0
         DO 3005 M=1,MM
            IF (I.NE.MRES(M,4)) GO TO 3005
            LURESL(I)=LURESL(I)+MRES(M,1)*NO(M)
            LURESW(I)=LURESW(I)+MRES(M,2)*NO(M)
 3005    CONTINUE
 3000 CONTINUE
C
C        ADDITIONS TO CONSERVATION USE ONLY AND WATER
C        AREAS LAND USE IN SOME FUTURE YEAR, ACRES
C
      DO 3820 I=1,12
         IF (I.EQ.5) GO TO 3840
         DO 3830 K=1,5
            IF (K.EQ.4) GO TO 3830
            LUTCCY(I,4,K)=LUTCCY(I,4,K)+LURESL(I)/4
            LUTCCY(I,5,K)=LUTCCY(I,5,K)+LURESW(I)/4
 3830    CONTINUE
         GO TO 3820
 3840    DO 3850 K=2,5
            IF (K.EQ.4) GO TO 3850
            LUTCCY(I,4,K)=LUTCCY(I,4,K)+LURESL(I)/3
            LUTCCY(I,5,K)=LUTCCY(I,5,K)+LURESW(I)/3
 3850    CONTINUE
 3820 CONTINUE
      DO 3870 I=1,12
         DO 3880 K=1,11
            LU68(I,K)=0
            DO 3890 J=6,8
               LU68(I,K)=LU68(I,K)+LUTCC(I,J,K)
 3890       CONTINUE
               LU68(I,K)=LU68(I,K)+LUTCC(I,1,K)-LUTCCY(I,1,K)+
     1            LUTCC(I,3,K)-LUTCCY(I,3,K)+LUTCC(I,4,K)-
     2            LUTCCY(I,4,K)+LUTCC(I,5,K)-LUTCCY(I,5,K)
            LU610(I,K)=LU68(I,K)
```

```
          DO 3900 J=9,10
            LU610(I,K)=LU610(I,K)+LUTCC(I,J,K)
 3900     CONTINUE
          LU610Y(I,K)=LU610(I,K)
 3880   CONTINUE
 3870 CONTINUE
      LUV=1
      GO TO 4000
 1795 DO 1790 I=1,12
        LUCY(I)=0
        DO 1800 J=1,10
          LUTY(I,J)=0
          DO 1810 K=1,16
            LUTY(I,J)=LUTY(I,J)+LUTCCY(I,J,K)
 1810     CONTINUE
          LUCY(I)=LUCY(I)+LUTY(I,J)
 1800   CONTINUE
 1790 CONTINUE
      CALL PLU(CO,IYR(2),L,LCCI,LUTCCY,LUCC,LUTY,LUCY)
      WRITE (6,1812) IYR(2),L
 1812 FORMAT ('1',//////20X,'LAND USED FOR IRRIGATED CORN',
     1 ' IN ',I4,5X,'ACRES     CPS-',I1)
      WRITE (6,1814)
 1814 FORMAT ('0',//22X,'COUNTY',17X,'I',8X,'IIE',6X,'TOTAL')
      WRITE (6,160)
  160   FORMAT (' ')
      DO 1816 I=1,12
        WRITE (6,1818) (CO(I,M),M=1,3),LUICY1(I),LUICY2(I),
     1    LUICYT(I)
 1818 FORMAT ('0',/17X,3A4,I19,2I10)
 1816 CONTINUE
      WRITE (6,1813) IYR(2),L
 1813 FORMAT ('1',//////20X,'NET CORN AND SOYBEAN ',
     1 'PRODUCTION NEEDED IN ',I4,5X,'BUSHELS     CPS-',I1)
      WRITE (6,1815)
 1815 FORMAT ('0',///32X,'COUNTY',15X,'CORN',14X,'SOYBEANS')
      WRITE (6,160)
      DO 1817 I=1,12
        WRITE (6,1819) (CO(I,M),M=1,3),NCPR(I),NSPR(I)
 1819 FORMAT ('0',/27X,3A4,2I20)
 1817 CONTINUE
      CALL PCSP(IYR(2),L,LCCI,KCCPY,KTCPY,KCSPY,KTSPY)
C
C         CALCULATE THE EROSION IN TONS PER YEAR
C         FROM EACH LAND USE AND LCC IN EACH COUNTY
C         IN SOME FUTURE YEAR
C
      DO 2600 I=1,12
        KTE(I)=0
        DO 2610 J=1,10
          LUTE(I,J)=0
          DO 2620 K=1,16
            KCTE(I,K)=0
            KCE(I,J,K)=0
 2620     CONTINUE
 2610   CONTINUE
 2600 CONTINUE
      DO 2630 I=1,12
        DO 2640 J=1,10
          DO 2650 K=1,16
```

```
            IF (IEC.EQ.1) AETCC(J.K)=RETCC(J.K)
            KCE(I.J.K)=LUTCCY(I.J.K)*AETCC(J.K)/100
            LUTE(I.J)=LUTE(I.J)+KCE(I.J.K)
 2650     CONTINUE
          KTE(I)=KTE(I)+LUTE(I.J)
 2640   CONTINUE
 2630 CONTINUE
      DO 2660 I=1.12
        DO 2670 K=1.16
          DO 2680 J=1.10
            KCTE(I.K)=KCTE(I.K)+KCE(I.J.K)
 2680     CONTINUE
 2670   CONTINUE
 2660 CONTINUE
C
C         PRINT OUT THE EROSION IN TONS PER YEAR
C         FROM EACH LAND USE AND LCC IN EACH COUNTY
C         IN SOME FUTURE YEAR
C
      CALL PSE(CO.IYR(2).L.LCCI.KCE.KCTE.LUTE.KTE)
      WRITE (6.240)
  240 FORMAT ('1',10X,'END OF JOB',//////)
      STOP
      END
C
C
C         PLU  -  PRINT LAND USE
C
C
      SUBROUTINE PLU(CO.MM.L.LCCI.LUTCCY.LUCC.LUTY.LUCY)
C
C         PRINTS OUT NUMBER OF ACRES DEVOTED TO EACH LAND USE
C         ON EACH LCC AND TOTAL ACREAGE DEVOTED TO EACH LAND
C         USE AND EACH LCC IN EACH COUNTY IN THE BASE YEAR
C         OR SOME FUTURE YEAR
C
      DIMENSION LUTCCY(12.10.16).LUTY(12.10).LUCC(12.16)
      DIMENSION CO(12.3).LUCY(12).LCCI(16)
      DO 1820 I=1.12
        WRITE (6.145) (CO(I.M).M=1.3).MM.L
  145   FORMAT ('1',//////20X.3A4.' COUNTY'.11X.I4.
     1  ' LAND USE'.10X.'ACRES'.10X.'CPS-'.I1)
        WRITE (6.150)
  150   FORMAT (' '//16X.'CAPY.  URBAN  FOREST OTHER  '.
     1  'CONSER  WATER   CORN     SOY  CLOSE ROTATION PASTURE'.
     2  '  TOTAL'./16X.'CLASS BUILTUP'.15X.'VATION  AREAS'.
     3  9X.'BEANS GROWN  HAY AND'./43X.'USE ONLY'.21X.
     4  'CROPS  PASTURE')
        WRITE (6.160)
  160   FORMAT (' ')
        WRITE (6.170) LCCI(1).(LUTCCY(I.J.1).J=1.10).
     1  LUCC(I.1)
  170   FORMAT ('0'.14X.A4.I9.3I7.I8.2I7.I6.3I8)
        WRITE (6.160)
        DO 1830 K=2.4
          WRITE (6.170) LCCI(K).(LUTCCY(I.J.K).J=1.10).
     1    LUCC(I.K)
 1830   CONTINUE
        WRITE (6.160)
```

```
      DO 1840 K=5,7
        WRITE (6,170) LCCI(K),(LUTCCY(I,J,K),J=1,10),
     1    LUCC(I,K)
 1840 CONTINUE
      WRITE (6,160)
      DO 1850 K=8,10
        WRITE (6,170) LCCI(K),(LUTCCY(I,J,K),J=1,10),
     1    LUCC(I,K)
 1850 CONTINUE
      WRITE (6,160)
      WRITE (6,170) LCCI(11),(LUTCCY(I,J,11),J=1,10),
     1 LUCC(I,11)
      WRITE (6,160)
      DO 1860 K=12,13
        WRITE (6,170) LCCI(K),(LUTCCY(I,J,K),J=1,10),
     1    LUCC(I,K)
 1860 CONTINUE
      WRITE (6,160)
      DO 1870 K=14,16
        WRITE (6,170) LCCI(K),(LUTCCY(I,J,K),J=1,10),
     1    LUCC(I,K)
 1870 CONTINUE
      WRITE (6,160)
      WRITE (6,230) (LUTY(I,J),J=1,10),LUCY(I)
  230 FORMAT ('0',15X,'TOTAL',4I7,I8,2I7,I6,3I8)
 1820 CONTINUE
      RETURN
      END
C
C
C        PCSP  -  PRINT CORN AND SOYBEAN PRODUCTION
C
C

      SUBROUTINE PCSP(MM,L,LCCI,KCCPY,KTCPY,KCSPY,KTSPY)
C
C        PRINTS OUT THE BUSHELS OF CORN AND SOYBEANS GROWN
C        ON EACH LCC AND THE TOTAL BUSHELS OF CORN AND
C        SOYBEANS GROWN IN EACH COUNTY IN THE BASE YEAR
C
      DIMENSION KCCPY(12,16),KCSPY(12,16),KTCPY(12)
      DIMENSION KTSPY(12),LCCI(16)
      WRITE (6,325) MM,L
  325 FORMAT ('1',//////16X,I4,' CORN PRODUCTION',10X,
     1 'BUSHELS',10X,'CPS-',I1)
      WRITE (6,330)
  330 FORMAT ('0',//16X,'CAPY.   BUENA  CHEROKEE   CLAY',
     1 '    DICKINSON     IDA      LYON',/16X,'CLASS    VISTA')
      WRITE (6,160)
  160 FORMAT (' ')
      WRITE (6,340) LCCI(1),(KCCPY(I,1),I=1,6)
  340 FORMAT ('0',14X,A4,I11,2I9,I10,2I9)
      WRITE (6,160)
      DO 1880 K=2,4
      WRITE (6,340) LCCI(K),(KCCPY(I,K),I=1,6)
 1880 CONTINUE
      WRITE (6,160)
      DO 1890 K=5,7
      WRITE (6,340) LCCI(K),(KCCPY(I,K),I=1,6)
 1890 CONTINUE
```

```
      WRITE (6,160)
      DO 1900 K=8,10
      WRITE (6,340) LCCI(K),(KCCPY(I,K),I=1,6)
 1900 CONTINUE
      WRITE (6,160)
      WRITE (6,340) LCCI(11),(KCCPY(I,11),I=1,6)
      WRITE (6,160)
      DO 1910 K=12,13
      WRITE (6,340) LCCI(K),(KCCPY(I,K),I=1,6)
 1910 CONTINUE
      WRITE (6,160)
      DO 1920 K=14,16
      WRITE (6,340) LCCI(K),(KCCPY(I,K),I=1,6)
 1920 CONTINUE
      WRITE (6,160)
      WRITE (6,400) (KTCPY(I),I=1,6)
  400 FORMAT ('0',15X,'TOTAL',3I9,I10,2I9)
      WRITE (6,325) MM,L
      WRITE (6,410)
  410 FORMAT ('0',//16X,'CAPY.  O BRIEN  OSCEOLA PLYMOUTH',
     1 '     SAC     SIOUX  WOODBURY',/16X,'CLASS')
      WRITE (6,160)
      WRITE (6,420) LCCI(1),(KCCPY(I,1),I=7,12)
  420 FORMAT ('0',14X,A4,I11,5I9)
      WRITE (6,160)
      DO 1930 K=2,4
      WRITE (6,420) LCCI(K),(KCCPY(I,K),I=7,12)
 1930 CONTINUE
      WRITE (6,160)
      DO 1940 K=5,7
      WRITE (6,420) LCCI(K),(KCCPY(I,K),I=7,12)
 1940 CONTINUE
      WRITE (6,160)
      DO 1950 K=8,10
      WRITE (6,420) LCCI(K),(KCCPY(I,K),I=7,12)
 1950 CONTINUE
      WRITE (6,160)
      WRITE (6,420) LCCI(11),(KCCPY(I,11),I=7,12)
      WRITE (6,160)
      DO 1960 K=12,13
      WRITE (6,420) LCCI(K),(KCCPY(I,K),I=7,12)
 1960 CONTINUE
      WRITE (6,160)
      DO 1970 K=14,16
      WRITE (6,420) LCCI(K),(KCCPY(I,K),I=7,12)
 1970 CONTINUE
      WRITE (6,160)
      WRITE (6,475) (KTCPY(I),I=7,12)
  475 FORMAT ('0',15X,'TOTAL',6I9)
      WRITE (6,485) MM,L
  485 FORMAT ('1',//////16X,I4,' SOYBEAN PRODUCTION',10X,
     1 'BUSHELS',10X,'CPS-',I1)
      WRITE (6,330)
      WRITE (6,160)
      WRITE (6,340) LCCI(1),(KCSPY(I,1),I=1,6)
      WRITE (6,160)
      DO 1980 K=2,4
      WRITE (6,340) LCCI(K),(KCSPY(I,K),I=1,6)
 1980 CONTINUE
      WRITE (6,160)
```

```
      DO 1990 K=5,7
         WRITE (6,340) LCCI(K),(KCSPY(I,K),I=1,6)
 1990 CONTINUE
         WRITE (6,160)
      DO 2000 K=8,10
         WRITE (6,340) LCCI(K),(KCSPY(I,K),I=1,6)
 2000 CONTINUE
         WRITE (6,160)
      WRITE (6,340) LCCI(11),(KCSPY(I,11),I=1,6)
         WRITE (6,160)
      DO 2010 K=12,13
         WRITE (6,340) LCCI(K),(KCSPY(I,K),I=1,6)
 2010 CONTINUE
         WRITE (6,160)
      DO 2020 K=14,16
         WRITE (6,340) LCCI(K),(KCSPY(I,K),I=1,6)
 2020 CONTINUE
         WRITE (6,160)
      WRITE (6,400) (KTSPY(I),I=1,6)
      WRITE (6,485) MM,L
      WRITE (6,410)
         WRITE (6,160)
      WRITE (6,420) LCCI(1),(KCSPY(I,1),I=7,12)
         WRITE (6,160)
      DO 2030 K=2,4
         WRITE (6,420) LCCI(K),(KCSPY(I,K),I=7,12)
 2030 CONTINUE
         WRITE (6,160)
      DO 2040 K=5,7
         WRITE (6,420) LCCI(K),(KCSPY(I,K),I=7,12)
 2040 CONTINUE
         WRITE (6,160)
      DO 2050 K=8,10
         WRITE (6,420) LCCI(K),(KCSPY(I,K),I=7,12)
 2050 CONTINUE
         WRITE (6,160)
      WRITE (6,420) LCCI(11),(KCSPY(I,11),I=7,12)
         WRITE (6,160)
      DO 2060 K=12,13
         WRITE (6,420) LCCI(K),(KCSPY(I,K),I=7,12)
 2060 CONTINUE
         WRITE (6,160)
      DO 2070 K=14,16
         WRITE (6,420) LCCI(K),(KCSPY(I,K),I=7,12)
 2070 CONTINUE
         WRITE (6,160)
      WRITE (6,475) (KTSPY(I),I=7,12)
 2090 CONTINUE
      RETURN
      END
C
C
C         PSE  -  PRINT SOIL EROSION
C
C

      SUBROUTINE PSE(CO,MM,L,LCCI,KCE,KCTE,LUTE,KTE)
C
C         PRINTS OUT THE EROSION IN TONS PER YEAR FROM EACH
C         LAND USE AND LCC IN EACH COUNTY IN THE BASE YEAR
```

```
C         OR SOME FUTURE YEAR
C
      DIMENSION LCCI(16),KCE(12,10,16),KCTE(12,16),KTE(12)
      DIMENSION LUTE(12,10),CO(12,3)
      DO 690 I=1,12
        WRITE (6,700) (CO(I,M),M=1,3),MM,L
  700   FORMAT ('1',//////20X,3A4,' COUNTY',6X,I4,
     1  ' SOIL EROSION',6X,'100 TONS/YEAR',6X,'CPS-',I1)
        WRITE (6,150)
  150   FORMAT (' '//16X,'CAPY.  URBAN  FOREST OTHER  ',
     1  'CONSER  WATER   CORN     SOY  CLOSE ROTATION PASTURE',
     2  '  TOTAL',/16X,'CLASS BUILTUP',15X,'VATION   AREAS',
     3  9X,'BEANS GROWN   HAY AND',/43X,'USE ONLY',21X,
     4  'CROPS  PASTURE')
        WRITE (6,160)
  160   FORMAT (' ')
        WRITE (6,710) LCCI(1),(KCE(I,J,1),J=1,10),KCTE(I,1)
  710   FORMAT ('0',14X,A4,I9,3I7,I8,I7,2I6,3I8)
        WRITE (6,160)
        DO 720 K=2,4
          WRITE (6,710) LCCI(K),(KCE(I,J,K),J=1,10),KCTE(I,K)
  720   CONTINUE
        WRITE (6,160)
        DO 730 K=5,7
          WRITE (6,710) LCCI(K),(KCE(I,J,K),J=1,10),KCTE(I,K)
  730   CONTINUE
        WRITE (6,160)
        DO 740 K=8,10
          WRITE (6,710) LCCI(K),(KCE(I,J,K),J=1,10),KCTE(I,K)
  740   CONTINUE
        WRITE (6,160)
        WRITE (6,710) LCCI(11),(KCE(I,J,11),J=1,10),
     1  KCTE(I,11)
        WRITE (6,160)
        DO 750 K=12,13
          WRITE (6,710) LCCI(K),(KCE(I,J,K),J=1,10),KCTE(I,K)
  750   CONTINUE
        WRITE (6,160)
        DO 760 K=14,16
          WRITE (6,710) LCCI(K),(KCE(I,J,K),J=1,10),KCTE(I,K)
  760   CONTINUE
        WRITE (6,160)
        WRITE (6,770) (LUTE(I,J),J=1,10),KTE(I)
  770   FORMAT ('0',15X,'TOTAL',4I7,I8,I7,2I6,3I8)
  690 CONTINUE
      RETURN
      END
C
C
C         GOAL PROGRAMMING - LEE
C
C

      SUBROUTINE GP(RIWMGD,NO)
      DIMENSION X(200),Y(60),AMT(60),DOD(60),DUD(200)
      DIMENSION KEPT(60),PRDT(60),RHS1(60),ZVAL(10)
      DIMENSION C(60,200),D(60,200),RVLX(10,200),NEGSLK(60)
      DIMENSION VALX(10,200),VALY(60,10),NO(25),RIWMGD(12)
      REAL NEGSLK
    5 CALL START(N,M,L,C,VALX,VALY,PRDT,RHS1,KPCK,KEPT,
```

```
     1             TEST,IRS,ISR,RIWMGD)
      DO 20 J=1,M
        X(J)=J
   20 CONTINUE
      DO 21 I=1,N
        Y(I)=I
   21 CONTINUE
      DO 26 K=1,L
        DO 25 I=1,N
          VALY(I,K)=VALX(K,I)
   25   CONTINUE
   26 CONTINUE
      ITAB=0
C
C         BRING IN NEW VARIABLES
C
      ITER=0
C
C         CALCULATE NET CONTRIBUTION
C         OF EACH VARIABLE (RVLX(K,J))
C
   31 L1=0
   32 K3=L-L1
   33 IF (K3-1) 800,40,40
   40 DO 65 K=1,K3
        DO 60 J=1,M
          SUMP=0.
          DO 50 I=1,N
            P=VALY(I,K)*C(I,J)
            SUMP=SUMP+P
   50     CONTINUE
          RVLX(K,J)=SUMP-VALX(K,J)
   60   CONTINUE
   65 CONTINUE
      ITER=ITER+1
C
C         BRING IN X(K2)
C
      ZMAX=0.
      DO 90 J=1,M
        IF (K3-L) 91,70,70
   91   K4=K3+1
        DO 92 K=K4,L
          IF (RVLX(K,J)) 90,92,92
   92   CONTINUE
   70   IF (RVLX(K3,J)-ZMAX) 90,90,80
   80   ZMAX=RVLX(K3,J)
        K2=J
   90 CONTINUE
   95 IF (ZMAX) 790,790,100
C
C         WHICH VARIABLE IS REMOVED FROM THE BASIS?
C
C         CALCULATE LIMITING AMOUNT FOR EACH BASIS VARIABLE
C
  100 DO 150 I=1,N
        IF (PROT(I)) 110,120,120
  110   WRITE(6,115) PROT(I)
  115   FORMAT (10X,8F10.0)
        GO TO 830
```

```
  120    IF (C(I,K2)) 130,130,140
  130    AMT(I)=-1.
         GO TO 150
  140    AMT(I)=PRDT(I)/C(I,K2)
  150 CONTINUE
C
C          SELECT SMALLEST POSITIVE LIMITING AMOUNT
C
      I=1
  160 IF (AMT(I)) 170,210,210
  170 I=I+1
      IF (I-N) 160,160,180
  180 WRITE (6,115) AMT(N)
      GO TO 830
  210 ZMIN=AMT(I)
      K1=I
  220 I=I+1
      IF (I-N) 230,230,300
  230 IF (AMT(I)) 220,240,240
  240 IF (ZMIN-AMT(I)) 220,220,210
C
C          REMOVE Y(K1)
C
  300 Y(K1)=X(K2)
      DO 310 K=1,L
        VALY(K1,K)=VALX(K,K2)
  310 CONTINUE
C
C          CALCULATE NEW RIGHT-HAND SIDES
C
      DO 400 I=1,N
        PRDT(I)=PRDT(I)-ZMIN*C(I,K2)
  400 CONTINUE
      PRDT(K1)=ZMIN
C
C          CALCULATE NEW SUBSTITUTION RATES
C
      DO 505 J=1,M
        DO 500 I=1,N
  501     D(I,J)=C(I,J)-C(K1,J)*(C(I,K2)/C(K1,K2))
  500   CONTINUE
  505 CONTINUE
      DO 510 J=1,M
        D(K1,J)=C(K1,J)/C(K1,K2)
  510 CONTINUE
      DO 530 J=1,M
        DO 520 I=1,N
          C(I,J)=D(I,J)
  520   CONTINUE
  530 CONTINUE
C
C          WRITE ALL TABLES OR JUST OPTIMAL TABLE
C
      IF (ITAB) 40,40,600
C
C          WRITE EACH TABLE
C
  600 DO 610 I=1,N
        WRITE (6,115) Y(I),PRDT(I)
  610 CONTINUE
```

```
      DO 620 I=1,N
         WRITE (6,615) (C(I,J),J=1,M)
  615    FORMAT ('0',10X,10F10.3)
  620 CONTINUE
      GO TO 40
C
C          MOVE TO NEXT LOWER PRIORITY LEVEL
C
  790 L1=L1+1
      GO TO 32
C
C          WRITE FINAL RESULTS
C
  800 WRITE (6,1014) ITER
 1014 FORMAT ('0',9X,'ITERATIONS.............',I4)
      WRITE (6,1015)
 1015 FORMAT (' ')
      WRITE (6,5000)
 5000 FORMAT ('1',////55X,'THE SIMPLEX SOLUTION',25X,'PAGE 05')
      WRITE (6,5001)
 5001 FORMAT ('0',/5X,'THE RIGHT HAND SIDE')
  801 DO 810 I=1,N
         WRITE (6,802) Y(I),PRDT(I)
  802    FORMAT ('0',10X,F10.0,F10.1)
  810 CONTINUE
      WRITE (6,5002)
 5002 FORMAT ('0',/5X,'THE SUBSTITUTION RATES')
  811 DO 812 I=1,N
         WRITE (6,615) (C(I,J),J=1,M)
  812 CONTINUE
      WRITE (6,5003)
 5003 FORMAT ('0',/5X,'THE ZJ-CJ MATRIX')
  813 DO 814 K=1,L
         WRITE (6,615) (RVLX(K,J),J=1,M)
  814 CONTINUE
C
C          EVALUATE OBJECTIVE FUNCTION
C
      DO 825 K=1,L
         ZVAL(K)=0.
         DO 820 I=1,N
            ZVAL(K)=ZVAL(K)+PRDT(I)*VALY(I,K)
  820    CONTINUE
  825 CONTINUE
      WRITE (6,5004)
 5004 FORMAT ('0',///5X,'AN EVALUATION OF THE OBJECTIVE
      DO 828 K=1,L                                          FUNCTION')
         KK=L-K
         IF (TEST.EQ.1.0) GO TO 89
         KK=KK+1
   89    WRITE (6,829) KK,ZVAL(K)
  829    FORMAT ('0',I21,F15.2)
  828 CONTINUE
      CALL FINISH(RHS1,PRDT,VALY,L,KPCK,Y,N,KEPT,TEST,
     1                IRS,ISR,NEGSLK)
C
C          DETERMINE WHICH RESERVOIR SITES, IF ANY,
C          HAVE BEEN USED
C
      DO 900 M=IRS,ISR
```

```
        IF (RHS1(M)-NEGSLK(M).LE.1.) GO TO 900
        N=M-IRS+1
        NO(N)=1
  900 CONTINUE
  830 RETURN
      END
C
C
      SUBROUTINE START(NROWS,NVAR,NPRT,C,VALX,VALY,RHS,RHS1,
     1 KPCK,KEPT,TEST,IRS,ISR,RIWMGD)
C
C        THE START SUBROUTINE IS DESIGNED TO TAKE INFORMATION
C        IN A SPECIFIED FORMAT AND TRANSFORM IT INTO A
C        SERIES OF USABLE MATRICES
C
      DIMENSION RHS(60),KEPT(60),RHS1(60),EQUALS(60)
      DIMENSION C(60,200),RVLX(10,200),VALX(10,200)
      DIMENSION VALY(60,10),RIWMGD(12)
      REAL L,NEG
      DATA POS,NEG/'POS ','NEG '/
      DATA DATA/'DATA'/
      DATA OBJ/'OBJ '/
      DATA PROB/'PROB'/
      DATA B/'B'/
      DATA E,G,L/'E','G','L'/
      DATA RGHT/'RGHT'/
      NR=60
      NV=200
      TEST=0.0
C
C        READ THE PROBLEM CARD FOR THE NUMBER
C        OF ROWS AND VARIABLES
C
   10 READ (5,1) ANAME,NROWS,NVAR,NPRT
    1 FORMAT (A4,3I3)
      LISP=NPRT+1
      IF (NVAR.LE.0) GO TO 1020
      IF (NPRT.LE.0) GO TO 1020
      IF (NROWS.LE.0) GO TO 1020
      IF (ANAME.NE.PROB) GO TO 901
C
C        READ THE SIGN CARD
C        IT WILL CONTAIN ONE OF THE FOLLOWING
C        LETTERS FOR EACH ROW
C
C               FOR EQUALS                              E
C               FOR LESS THAN OR EQUAL TO               L
C               FOR GREATER THAN OR EQUAL TO            G
C               FOR BOTH DEVIATIONS                     B
C
      READ (5,11) (EQUALS(I),I=1,NROWS)
   11 FORMAT (80A1)
C
C        COUNT THE NUMBER OF POSITIVE SLACK VARIABLES
C
      NART=0
      NFLDS=0
      DO 12 I=1,NROWS
        IF (EQUALS(I).EQ.B) NFLDS=NFLDS+1
```

```
      IF (EQUALS(I).EQ.G) NFLDS=NFLDS+1
   12 CONTINUE
C
C        TEST FOR SIZE
C
      NSIZE=NFLDS+NROWS+NVAR
      IF (NROWS.GT.NR) GO TO 911
      IF (NSIZE.GT.NV) GO TO 911
C
C        CLEAR ALL MATRICES
C
      KDUD=NPRT+1
      DO 34 J=1,NSIZE
        DO 33 I=1,NROWS
          KEPT(I)=0
          IF (I.GT.KDUD) GO TO 32
          K=I
          RVLX(K,J)=0.0
          VALX(K,J)=0.0
   32     IF (I.EQ.J) C(I,J)=1.0
          VALY(I,K)=0.0
          IF (I.NE.J) C(I,J)=0.0
   33   CONTINUE
   34 CONTINUE
      KPCK=0
      K=KDUD
C
C        ADJUST THE SLACK VARIABLES AND OBJECTIVE FUNCTION
C        TO MEET THE REQUIREMENTS OF THE SIGN
C
      DO 13 I=1,NROWS
        IF (EQUALS(I).EQ.E) GO TO 14
        IF (EQUALS(I).EQ.G) GO TO 15
        IF (EQUALS(I).EQ.L) GO TO 13
        IF (EQUALS(I).EQ.B) GO TO 16
        GO TO 910
   14   J=I
        VALX(K,J)=1.0
        NART=NART+1
        TEST=1.0
        GO TO 13
   15   KPCK=KPCK+1
        J=NROWS+KPCK
        C(I,J)=-1.0
        KEPT(I)=J
        J=I
        VALX(K,J)=1.0
        NART=NART+1
        TEST=1.0
        GO TO 13
   16   KPCK=KPCK+1
        J=KPCK+NROWS
        C(I,J)=-1.0
        KEPT(I)=J
   13 CONTINUE
C
C        READ THE OBJECTIVE FUNCTION
C
      READ (5,21) ANAME
   21 FORMAT (A4,2I5,F16.0)
```

```
   19 I=0
      IF (ANAME.NE.OBJ) GO TO 920
      IF (ANAME.EQ.OBJ) GO TO 20
   20 READ (5,21) ANAME,I,M,TEMP
      IF (ANAME.EQ.DATA) GO TO 30
      IF (M.LE.0) GO TO 1022
      K=LISP-M
      IF (J.LE.0) GO TO 1022
      IF (K.GT.NPRT) GO TO 1024
      IF (ANAME.EQ.POS) GO TO 25
      IF (ANAME.EQ.NEG) GO TO 26
      GO TO 27
   25 J=KEPT(I)
      IF (KEPT(I).EQ.0) GO TO 1026
      VALX(K,J)=TEMP
      GO TO 20
   26 J=I
      VALX(K,J)=TEMP
      GO TO 20
   27 IF (TEMP) 926,20,926
C
C        READ THE DATA MATRIX IN
C
   30 READ (5,21) ANAME,I,J,TEMP
      IF (ANAME.EQ.RGHT) GO TO 40
      IF (I.LE.0) GO TO 1090
      IF (J.EQ.0) GO TO 1090
      J=KPCK+NROWS+J
      C(I,J)=TEMP
      GO TO 30
C
C        READ THE RIGHT HAND SIDE
C
   40 READ (5,44) (RHS(I),I=1,NROWS)
   44 FORMAT (8F10.2)
C
C        READ IN VARIOUS ROW NUMBERS
C
C        IRR = NUMBER OF FIRST ROW WHICH DEALS WITH THE
C              TOTAL DEMAND OF SOME WATER USE DESTINATION
C        IRS = NUMBER OF FIRST ROW WHICH DEALS WITH A
C              WATER SOURCE THAT IS A RESERVOIR
C        ISR = NUMBER OF LAST ROW WHICH DEALS WITH A
C              WATER SOURCE THAT IS A RESERVOIR
C
      READ (5,90) IRR,IRS,ISR
   90 FORMAT (3I5)
C
C        CHANGE THE RIGHT HAND SIDES OF THOSE ROWS WHICH
C        DEAL WITH THE TOTAL DEMAND OF SOME WATER USE
C        DESTINATION
C
      DO 100 M=1,12
        IF (RIWMGD(M).EQ.0.) GO TO 100
        RHS(IRR)=RHS(IRR)*RIWMGD(M)
        IRR=IRR+1
  100 CONTINUE
C
C        WRITE THE ABOVE RESULTS
C
```

```
      WRITE (6,5015)
5015 FORMAT ('1',////55X,'THE RIGHT HAND SIDE - INPUT',33X,
    1 'PAGE 01',/)
      DO 41 I=1,NROWS
        IF (RHS(I)) 941,42,43
  42    RHS(I)=.00001
  43    RHS1(I)=RHS(I)
        WRITE (6,1111) I,RHS(I)
1111    FORMAT (10X,I3,2X,F15.5)
  41 CONTINUE
      WRITE (6,620)
 620 FORMAT ('1',////)
      WRITE (6,5016)
5016 FORMAT (55X,'THE SUBSTITUTION RATES - INPUT',18X,
    1 'PAGE 02',/)
      DO 1112 I=1,NROWS
        WRITE (6,2519) I
2519    FORMAT (' ',3X,'ROW',I4)
        WRITE (6,1113) (C(I,J),J=1,NSIZE)
1113 FORMAT (' ',10X,10F10.3)
1112 CONTINUE
      WRITE (6,620)
      WRITE (6,5017)
5017 FORMAT (55X,'THE OBJECTIVE FUNCTION - INPUT',19X,
    1 'PAGE 03',/)
      DO 1114 K=1,NPRT
        M=LISP-K
        WRITE (6,2150) M
2150 FORMAT (' ',2X,'PRIORITY',I5)
        WRITE (6,1113) (VALX(K,J),J=1,NSIZE)
1114 CONTINUE
      WRITE (6,620)
      WRITE (6,5018)
5018 FORMAT (55X,'SUMMARY OF INPUT INFORMATION ',19X,
    1 'PAGE 04',//)
      NVAR=NSIZE
      WRITE (6,2017) NROWS,NVAR,NPRT,NART
2017 FORMAT (10X,'NUMBER OF ROWS..........',I4,//10X,
    1 'NUMBER OF VARIABLES.....',I4,//10X,'NUMBER OF',
    2 ' PRIORITIES....',I4,//10X,'ADDED PRIORITIES........',I4)
      IF (NART.GT.0) NPRT=NPRT+1
      RETURN
 901 WRITE (6,902)
 902 FORMAT ('  PROBLEM CARD MISSING OR MISPUNCHED.')
      GO TO 999
 910 WRITE (6,914)
 914 FORMAT ('PROGRAM CONTAINS AN ERROR EITHER IN THE ',
    1 'NUMBER OF ROWS PUNCHED OR IN THE SIGN CARD.  THE ',
    2 'VALUE IS SOMETHING OTHER THAN "E", "G" OR "L".')
      GO TO 999
 911 WRITE (6,912)
 912 FORMAT ('  THE NUMBER OF VARIABLES NEEDED TO COMPUTE',
    1 /,'  THIS PROGRAM IS TOO GREAT UNDER PRESENT DIMENSIONS.',
    2 /,'  SEE YOUR PROGRAMMER FOR ALTERING THIS RESTRICTION',
    3 /,'  TO MEET YOUR NEEDS.')
      GO TO 999
 920 WRITE (6,921)
 921 FORMAT ('  AN OBJECTIVE CARD WITH THE VALUE',F16.3,
    1 /,'  IS FOUND BUT INSTRUCTIONS AS TO WHICH DEVIATION',
    2 /,'  HAS BEEN NEGLECTED.  EXAMINE YOR DATA.')
```

```
      GO TO 999
  926 WRITE (6,927)
  927 FORMAT (' A CARD IN THE OBJECTIVE SECTION DEFINED',
     1 /,'  SOME VALUE FOR THE OBJECTIVE FUNCTION BUT FAILED',
     2 /,'  TO DEFINE WHETHER THIS WAS TO APPLY TO THE ',
     3 /,'  POSITIVE OR NEGATIVE DEVIATION.')
      GO TO 999
  941 WRITE (6,942)
  942 FORMAT ('  NEGATIVE VALUES ARE NOT ALLOWED ON THE ',
     1 /,'  RIGHT HAND SIDE.  CORRECT THE PROBLEM BY ',
     2 /,'  MULTIPLYING ENTIRE CONSTRAINT THROUGH BY ',
     3 /,'  MINUS ONE.')
      GO TO 999
 1020 WRITE (6,1021)
 1021 FORMAT ('  NUMBER OF ROWS, VARIABLES OR PRIORITIES',
     1 /,'  CANNOT BE EQUAL TO ZERO UNDER ANY CIRCUMSTANCES.')
      GO TO 999
 1022 WRITE (6,1023)
 1023 FORMAT ('  COLUMN VALUE OR PRIORITY VALUE IS EQUAL ',
     1 /,'  TO OR LESS THAN ZERO.')
      GO TO 999
 1024 WRITE (6,1025)
 1025 FORMAT ('  OBJECTIVE FUNCTION PRIORITY EXCEEDS',
     1 /,'  STATED NUMBER OF PRIORITIES.')
      GO TO 999
 1026 WRITE (6,1027)
 1027 FORMAT ('  ATTEMPT IS MADE TO MINIMIZE NON-EXISTANT',
     1 /,'  POSITIVE DEVIATION.')
      GO TO 999
 1090 WRITE (6,1091)
 1091 FORMAT ('IMPROPER DATA COLUMN OR ROW DEFINITION.')
  999 STOP
      END
C
C
      SUBROUTINE FINISH(RHS1,RHS,VALY,NPRT,KPCK,Y,NROWS,
     1 KEPT,TEST,IRS,ISR,NEGSLK)
      DIMENSION Y(60),RHS(60),KEPT(60),RHS1(60)
      DIMENSION VALY(60,10),ZVAL(10),NEGSLK(60)
      REAL NEGSLK
C
C         RHS1 IS THE RESERVED VECTOR OF RHS VALUES FROM
C         THE BEGINNING.  THE ENDING RHS VALUES ARE SUBTRACTED
C         FROM THE BEGINNING ONES AND THE RESULT IS PLACED
C         INTO THE APPROPRIATE SLACK COLUMN.  THE REMAINDER
C         OF THE VALUES ARE PRINTED ON PAGE TWO OF THE RESULTS.
C
C         SLACK ANALYSIS
C
      WRITE (6,21)
   21 FORMAT ('1',////120X,'PAGE 06',//50X,'SLACK ANALYSIS')
      WRITE (6,8)
    8 FORMAT ('0',//13X,'ROW',4X,'AVAILABLE',13X,'POS-SLK',13X,
     1 'NEG-SLK',/)
      DO 19 I=1,NROWS
        NEGSLK(I)=0.0
        POSSLK=0.0
        DO 11 J=1,NROWS
          M=Y(J)
```

```
            IF (I-M) 9,10,9
  9         IF (M-KEPT(I)) 11,12,11
 11       CONTINUE
          GO TO 13
 10       NEGSLK(I)=RHS(J)
          GO TO 13
 12       POSSLK=RHS(J)
 13 WRITE (6,14) I,RHS1(I),POSSLK,NEGSLK(I)
 14       FORMAT ('0',12X,I3,F14.1,2F20.1)
 19 CONTINUE
C
C          VARIABLE AMOUNTS
C
    WRITE (6,44)
 44 FORMAT ('1',////120X,'PAGE 07',//50X,'VARIABLE ANALYSIS')
    WRITE (6,45)
 45 FORMAT (////,11X,'VARIABLE',13X,'AMOUNT',//)
    DO 41 I=1,NROWS
       NCHCK=Y(I)-KPCK-NROWS
       IF (NCHCK) 41,41,42
 42    WRITE (6,43) NCHCK,RHS(I)
 43    FORMAT ('0',12X,I3,F21.1)
 41 CONTINUE
    WRITE (6,72)
 72 FORMAT ('1',//)
    WRITE (6,50)
 50 FORMAT (//55X,'ANALYSIS OF THE OBJECTIVE',23X,'PAGE 08',
   1  ////21X,'PRIORITY',8X,'UNDER-ACHIEVEMENT',/)
    DO 52 K=1,NPRT
       ZVAL(K)=0.0
       DO 51 I=1,NROWS
          ZVAL(K)=ZVAL(K)+VALY(I,K)*RHS(I)
 51    CONTINUE
       LISP=NPRT+1
       KK=LISP-K
       IF (TEST.EQ.0.0) GO TO 53
       KK=NPRT-K
       IF (KK.GT.0) GO TO 53
       WRITE (6,78) ZVAL(K)
 78    FORMAT (////45X,'ARTIFICIAL',5X,F19.1)
       GO TO 77
 53    WRITE (6,54) KK,ZVAL(K)
 54    FORMAT ('0',23X,I2,4X,F20.1)
 52 CONTINUE
 77 CONTINUE
    RETURN
    END
```

APPENDIX M.

SOURCE LISTING FOR THE CROP PLANTING SCENARIOS

```
C
C
C         CROP PLANTING SCENARIO 1
C
C
C         ALLOW ROW CROP ACREAGE TO EXPAND ONTO LAND
C         PRESENTLY USED FOR CLOSE GROWN CROPS, HAY AND
C         PASTURE WITH EACH LAND CAPABILITY CLASS (LCC)
C         CLAIMING THE SAME PERCENTAGE OF TOTAL PRODUCTION
C         AS IT HAD IN 1967, PLANTING CORN FIRST AND THEN
C         SOYBEANS ON CLASS I THROUGH V LAND USING
C         NO IRRIGATION
C
C
C         CALCULATE TOTAL ACREAGE IN LAND USES 6 THROUGH 8
C         AND LAND USES 6 THROUGH 10 ON LCC I THROUGH V LAND
C         IN EACH COUNTY IN 1967
C
      DO 870 I=1,12
        DO 880 K=1,11
          LU68(I,K)=0
          DO 890 J=6,8
            LU68(I,K)=LU68(I,K)+LUTCC(I,J,K)
  890     CONTINUE
            LU68(I,K)=LU68(I,K)+LUTCC(I,1,K)-LUTCCY(I,1,K)+
     1        LUTCC(I,3,K)-LUTCCY(I,3,K)
          LU610(I,K)=LU68(I,K)
          DO 900 J=9,10
            LU610(I,K)=LU610(I,K)+LUTCC(I,J,K)
  900     CONTINUE
          LU610Y(I,K)=LU610(I,K)
  880   CONTINUE
  870 CONTINUE
C
C         ACRES USED FOR CORN PRODUCTION IN SOME FUTURE YEAR
C
 4000 DO 902 I=1,12
        KK=0
        LUICY1(I)=0
        LUICY2(I)=0
        LUC67(I)=0
        DO 903 K=1,16
          LUC67(I)=LUC67(I)+LUTCC(I,6,K)
          LUTCCY(I,6,K)=0
          KCCPY(I,K)=0
  903   CONTINUE
C
C         CALCULATE CORN PRODUCTION ON LCC I THROUGH V LAND
C
        KTCPY(I)=KTCP(I)*OBERSC
        KCITAC(I)=KTCP(I)*OBERSC/ICY1(I)
        RAT=KCITAC(I)
        TIO=LUC67(I)
        RATIOC(I)=RAT/TIO
```

```
      DO 909 K=1,11
        IF (LU68(I,K).EQ.0) GO TO 909
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7055
        IF (K-5) 7050,7051,7052
 7050   RFEC=1.0
        GO TO 7055
 7051   RFEC=0.9
        GO TO 7055
 7052   IF (K-8) 7051,7053,7054
 7053   RFEC=0.8
        GO TO 7055
 7054   IF (K-11) 7053,7050,7055
 7055   LUTCCY(I,6,K)=LUTCC(I,6,K)*RATIOC(I)/CCCRYP(K)/RFEC
        IF (LUTCCY(I,6,K).LT.LU610(I,K)) GO TO 910
        LUTCCY(I,6,K)=LU610(I,K)
  910   CONTINUE
        KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
        KTCPY(I)=KTCPY(I)-KCCPY(I,K)
        IF (KTCPY(I).GT.0) GO TO 909
        KK=K+1
        KTCPY(I)=KTCPY(I)+KCCPY(I,K)
        LUTCCY(I,6,K)=KTCPY(I)/ICY1(I)/CCCRYP(K)/RFEC
        KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
        GO TO 911
  909 CONTINUE
  911 CONTINUE
      KTCPY(I)=0
      DO 914 K=1,11
        KTCPY(I)=KTCPY(I)+KCCPY(I,K)
  914 CONTINUE
C
C       CHECK FOR ADDITIONAL CORN PRODUCTION
C       NEEDED ON LCC I THROUGH V LAND
C
C       KPRA = ADDITIONAL CORN PRODUCTION REQUIRED, BUSHELS
C      LNFCA = ADDITIONAL LAND NEEDED FOR CORN, ACRES
C        LLO = LAND LEFT OVER, ACRES
C
     DO 915 K=1,11
      LUCC16(I,K)=0
      DO 916 J=1,6
        LUCC16(I,K)=LUCC16(I,K)+LUTCCY(I,J,K)
  916 CONTINUE
  915 CONTINUE
      DO 917 K=1,11
        LLO=LUCC(I,K)-LUCC16(I,K)
        IF (LLO.EQ.0) GO TO 917
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7065
        IF (K-5) 7060,7061,7062
 7060   RFEC=1.0
        GO TO 7065
 7061   RFEC=0.9
        GO TO 7065
 7062   IF (K-8) 7061,7063,7064
 7063   RFEC=0.8
        GO TO 7065
 7064   IF (K-11) 7063,7060,7065
 7065   KPRA=KTCP(I)*OBERSC-KTCPY(I)
```

```
      LNFCA=KPRA/ICY1(I)/CCCRYP(K)/RFEC
       ITEST4=LNFCA-LLO
    IF (ITEST4.GT.0) GO TO 918
      LUTCCY(I,6,K)=LUTCCY(I,6,K)+LNFCA
      KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
      GO TO 921
 918  LUTCCY(I,6,K)=LUTCCY(I,6,K)+LLO
      KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
      KTCPY(I)=KTCPY(I)+LLO*ICY1(I)*CCCRYP(K)*RFEC
 917  CONTINUE
 921  CONTINUE
      KTCPY(I)=0
      DO 923 K=1,11
        KTCPY(I)=KTCPY(I)+KCCPY(I,K)
 923  CONTINUE
     NCPR(I)=KTCP(I)*OBERSC-KTCPY(I)
C
C       ACRES USED FOR SOYBEAN PRODUCTION
C       IN SOME FUTURE YEAR
C
 924  CONTINUE
      KK=0
      LUS67(I)=0
      DO 925 K=1,16
        LUS67(I)=LUS67(I)+LUTCC(I,7,K)
        LUTCCY(I,7,K)=0
        KCSPY(I,K)=0
 925  CONTINUE
C
C       CALCULATE SOYBEAN PRODUCTION ON
C       LCC I THROUGH V LAND
C
      KTSPY(I)=KTSP(I)*OBERSS
      KC1TAS(I)=KTSP(I)*OBERSS/FSY1(I)
      RAT=KC1TAS(I)
      TIO=LUS67(I)
      RATIOS(I)=RAT/TIO
      DO 926 K=1,11
        IF (LU68(I,K).EQ.0) GO TO 926
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7075
        IF (K-5) 7070,7071,7072
 7070   RFEC=1.0
        GO TO 7075
 7071   RFEC=0.9
        GO TO 7075
 7072   IF (K-8) 7071,7073,7074
 7073   RFEC=0.8
        GO TO 7075
 7074   IF (K-11) 7073,7070,7075
 7075   LUTCCY(I,7,K)=LUTCC(I,7,K)*RATIOS(I)/SCCRYP(K)/RFEC
        IF (LUTCCY(I,7,K).LT.(LU610(I,K)-
     1     LUTCCY(I,6,K))) GO TO 929
        LUTCCY(I,7,K)=LU610(I,K)-LUTCCY(I,6,K)
 929    CONTINUE
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        KTSPY(I)=KTSPY(I)-KCSPY(I,K)
        IF (KTSPY(I).GT.0) GO TO 926
        KK=K+1
        KTSPY(I)=KTSPY(I)+KCSPY(I,K)
```

```
          LUTCCY(I,7,K)=KTSPY(I)/FSY1(I)/SCCRYP(K)/RFEC
          KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
          GO TO 931
  926   CONTINUE
  931   CONTINUE
        KTSPY(I)=0
        DO 932 K=1,11
          KTSPY(I)=KTSPY(I)+KCSPY(I,K)
  932   CONTINUE
C
C         CHECK FOR ADDITIONAL SOYBEAN PRODUCTION
C         NEEDED ON LCC I THROUGH V LAND
C
C            NSPN = NET SOYBEAN PRODUCTION NEEDED, BUSHELS
C            LNFS = LAND NEEDED FOR SOYBEANS, ACRES
C             LLO = LAND LEFT OVER, ACRES
C
        DO 933 K=1,11
          LUCC17(I,K)=0
          DO 934 J=1,7
            LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
  934     CONTINUE
  933   CONTINUE
        DO 935 K=1,11
        LLO=LUCC(I,K)-LUCC17(I,K)
        IF (LLO.EQ.0) GO TO 935
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7085
          IF (K-5) 7080,7081,7082
 7080     RFEC=1.0
          GO TO 7085
 7081     RFEC=0.9
          GO TO 7085
 7082     IF (K-8) 7081,7083,7084
 7083     RFEC=0.8
          GO TO 7085
 7084     IF (K-11) 7083,7080,7085
 7085   NSPN=KTSP(I)*OBERSS-KTSPY(I)
        LNFS=NSPN/FSY1(I)/SCCRYP(K)/RFEC
        ITEST1=LNFS-LLO
        IF (ITEST1.GT.0) GO TO 936
        LUTCCY(I,7,K)=LUTCCY(I,7,K)+LNFS
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        GO TO 937
  936   LUTCCY(I,7,K)=LUTCCY(I,7,K)+LLO
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        KTSPY(I)=KTSPY(I)+LLO*FSY1(I)*SCCRYP(K)*RFEC
  935  CONTINUE
  937   CONTINUE
        KTSPY(I)=0
        DO 928 K=1,11
          KTSPY(I)=KTSPY(I)+KCSPY(I,K)
  928   CONTINUE
        NSPR(I)=KTSP(I)*OBERSS-KTSPY(I)
C
C         CALCULATE LAND USED FOR CLOSE GROWN CROPS
C         IN SOME FUTURE YEAR
C
  949   CONTINUE
        LUTY(I,8)=0
```

```
      DO 950 K=1,11
        LUCC17(I,K)=0
        DO 954 J=1,7
          LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
954     CONTINUE
        LUCC80(I,K)=LUCC(I,K)-LUCC17(I,K)
        ITEST3=LUTCCY(I,8,K)-LUCC80(I,K)
        IF (ITEST3.LT.0) GO TO 958
        LUTCCY(I,8,K)=LUCC80(I,K)
        LUTCCY(I,9,K)=0
        LUTCCY(I,10,K)=0
958     CONTINUE
        LUTY(I,8)=LUTY(I,8)+LUTCCY(I,8,K)
950   CONTINUE
      DO 960 K=1,11
        LU8N=LUT(I,8)-LUTY(I,8)
        LU90=LUCC80(I,K)-LUTCCY(I,8,K)
        IF (LU90.EQ.0) GO TO 960
        ITEST4=LU8N-LU90
        IF (ITEST4.GT.0) GO TO 962
        LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU8N
        GO TO 964
962     LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU90
        LUTY(I,8)=LUTY(I,8)+LU90
        LUTCCY(I,9,K)=0
        LUTCCY(I,10,K)=0
960   CONTINUE
964   CONTINUE
C
C        CALCULATE LAND USED FOR HAY AND PASTURE
C        IN SOME FUTURE YEAR
C
      LUTY(I,9)=0
      DO 970 K=1,11
        LUCC18(I,K)=LUCC17(I,K)+LUTCCY(I,8,K)
        LUCC90(I,K)=LUCC(I,K)-LUCC18(I,K)
        ITEST5=LUTCCY(I,9,K)-LUCC90(I,K)
        IF (ITEST5.LT.0) GO TO 972
        LUTCCY(I,9,K)=LUCC90(I,K)
        LUTCCY(I,10,K)=0
        GO TO 974
972     LUTCCY(I,10,K)=LUCC90(I,K)-LUTCCY(I,9,K)
974     CONTINUE
        LUTY(I,9)=LUTY(I,9)+LUTCCY(I,9,K)
970   CONTINUE
      DO 975 K=1,11
        LU9N=LUT(I,9)-LUTY(I,9)
        IF (LU9N.LE.0) GO TO 979
        IF (LUTCCY(I,10,K).EQ.0) GO TO 975
        ITEST6=LU9N-LUTCCY(I,10,K)
        IF (ITEST6.GT.0) GO TO 977
        LUTCCY(I,9,K)=LUTCCY(I,9,K)+LU9N
        LUTCCY(I,10,K)=LUTCCY(I,10,K)-LU9N
        GO TO 979
977     LUTCCY(I,9,K)=LUTCCY(I,9,K)+LUTCCY(I,10,K)
        LUTY(I,9)=LUTY(I,9)+LUTCCY(I,10,K)
        LUTCCY(I,10,K)=0
975   CONTINUE
979   CONTINUE
902 CONTINUE
```

```
C
C
C         CROP PLANTING SCENARIO 2
C
C
C         ALLOW ROW CROP ACREAGE TO EXPAND ONTO LAND
C         PRESENTLY USED FOR CLOSE GROWN CROPS, HAY AND
C         PASTURE WITH EACH LAND CAPABILITY CLASS (LCC)
C         CLAIMING THE SAME PERCENTAGE OF TOTAL PRODUCTION
C         AS IT HAD IN 1967, PLANTING CORN FIRST AND THEN
C         SOYBEANS ON CLASS I THROUGH V LAND USING
C         IRRIGATION AS NEEDED
C
C
C         CALCULATE TOTAL ACREAGE IN LAND USES 6 THROUGH 8
C         AND LAND USES 6 THROUGH 10 ON LLC I THROUGH V LAND
C         IN EACH COUNTY IN 1967
C
      DO 870 I=1,12
        DO 880 K=1,11
          LU68(I,K)=0
          DO 890 J=6,8
            LU68(I,K)=LU68(I,K)+LUTCC(I,J,K)
  890     CONTINUE
            LU68(I,K)=LU68(I,K)+LUTCC(I,1,K)-LUTCCY(I,1,K)+
     1        LUTCC(I,3,K)-LUTCCY(I,3,K)
          LU610(I,K)=LU68(I,K)
          DO 900 J=9,10
            LU610(I,K)=LU610(I,K)+LUTCC(I,J,K)
  900     CONTINUE
          LU610Y(I,K)=LU610(I,K)
  880   CONTINUE
  870 CONTINUE
C
C         ACRES USED FOR CORN PRODUCTION IN SOME FUTURE YEAR
C
 4000 DO 902 I=1,12
        KK=0
        LOVE=0
        LUICY1(I)=0
        LUICY2(I)=0
        LUC67(I)=0
        DO 903 K=1,16
          LUC67(I)=LUC67(I)+LUTCC(I,6,K)
          LUTCCY(I,6,K)=0
          KCCPY(I,K)=0
  903   CONTINUE
C
C         CALCULATE CORN PRODUCTION ON LCC I THROUGH V LAND
C
        KTCPY(I)=KTCP(I)*OBERSC
  905   CONTINUE
        KC1TAC(I)=KTCP(I)*OBERSC/ICY1(I)
        RAT=KC1TAC(I)
        TIO=LUC67(I)
        RATIOC(I)=RAT/TIO
        IF (LOVE.EQ.0) KI=1
        IF (LOVE.GT.0) KI=3
        DO 909 K=KI,11
          IF (LU68(I,K).EQ.0) GO TO 909
```

```
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7055
          IF (K-5) 7050,7051,7052
 7050     RFEC=1.0
          GO TO 7055
 7051     RFEC=0.9
          GO TO 7055
 7052     IF (K-8) 7051,7053,7054
 7053     RFEC=0.8
          GO TO 7055
 7054     IF (K-11) 7053,7050,7055
 7055     LUTCCY(I,6,K)=LUTCC(I,6,K)*RATIOC(I)/CCCRYP(K)/RFEC
          IF (LUTCCY(I,6,K).LT.LU610(I,K)) GO TO 910
          LUTCCY(I,6,K)=LU610(I,K)
  910     CONTINUE
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          KTCPY(I)=KTCPY(I)-KCCPY(I,K)
          IF (KTCPY(I).GT.0) GO TO 909
          KK=K+1
          KTCPY(I)=KTCPY(I)+KCCPY(I,K)
          LUTCCY(I,6,K)=KTCPY(I)/ICY1(I)/CCCRYP(K)/RFEC
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          GO TO 911
  909   CONTINUE
  911   CONTINUE
        IF (LOVE.GT.0) GO TO 921
        KTCPY(I)=0
        DO 914 K=1,11
          KTCPY(I)=KTCPY(I)+KCCPY(I,K)
  914   CONTINUE
C
C         CHECK FOR ADDITIONAL CORN PRODUCTION
C         NEEDED ON LCC I THROUGH V LAND
C
C         KPRA = ADDITIONAL CORN PRODUCTION REQUIRED, BUSHELS
C           LNFCA = ADDITIONAL LAND NEEDED FOR CORN, ACRES
C          LLO = LAND LEFT OVER, ACRES
C         ICPR = IRRIGATED CORN PRODUCTION REQUIRED, BUSHELS
C
       IF (LOVE.GT.0) GO TO 924
       DO 915 K=1,11
        LUCC16(I,K)=0
        DO 916 J=1,6
          LUCC16(I,K)=LUCC16(I,K)+LUTCCY(I,J,K)
  916   CONTINUE
  915   CONTINUE
        DO 917 K=1,11
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7065
          IF (K-5) 7060,7061,7062
 7060     RFEC=1.0
          GO TO 7065
 7061     RFEC=0.9
          GO TO 7065
 7062     IF (K-8) 7061,7063,7064
 7063     RFEC=0.8
          GO TO 7065
 7064     IF (K-11) 7063,7060,7065
 7065     LLO=LUCC(I,K)-LUCC16(I,K)
          IF (LLO.EQ.0) GO TO 917
```

```
        KPRA=KTCP(I)*OBERSC-KTCPY(I)
        LNFCA=KPRA/ICY1(I)/CCCRYP(K)/RFEC
        ITEST4=LNFCA-LLO
      IF (ITEST4.GT.0) GO TO 918
        LUTCCY(I,6,K)=LUTCCY(I,6,K)+LNFCA
        KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
      GO TO 921
918     LUTCCY(I,6,K)=LUTCCY(I,6,K)+LLO
        KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
        KTCPY(I)=KTCPY(I)+LLO*ICY1(I)*CCCRYP(K)*RFEC
917   CONTINUE
      IF (LOVE.GT.0) GO TO 921
      ICPR=KTCP(I)*OBERSC-KTCPY(I)
      LUICY1(I)=ICPR/(IICY1(I)-ICY1(I))/.94
      ITEST5=LUICY1(I)-LUTCCY(I,6,1)
      IF (ITEST5.GT.0) GO TO 919
      KCCPY(I,1)=LUTCCY(I,6,1)*ICY1(I)+LUICY1(I)*(IICY1(I)
     1 -ICY1(I))*.94
      GO TO 921
919   LUICY1(I)=LUTCCY(I,6,1)
      KCCPY(I,1)=LUTCCY(I,6,1)*IICY1(I)*.94+
     1   LUTCCY(I,6,1)*ICY1(I)*.06
      KCCPY(I,2)=ICPR-KCCPY(I,1)
      LUICY2(I)=KCCPY(I,2)/CCCRYP(2)/(IICY1(I)-ICY1(I))/.94
      ITEST6=LUICY2(I)-LUTCCY(I,6,2)
      IF (ITEST6.GT.0) GO TO 920
      KCCPY(I,2)=LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)+
     1 LUICY2(I)*(IICY1(I)-ICY1(I))*CCCRYP(2)*.94
      GO TO 921
920   LUICY2(I)=LUTCCY(I,6,2)
      KCCPY(I,2)=LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)+
     1 LUICY2(I)*(IICY1(I)-ICY1(I))*CCCRYP(2)*.94
921   CONTINUE
      KTCPY(I)=0
      DO 923 K=1,11
        KTCPY(I)=KTCPY(I)+KCCPY(I,K)
923   CONTINUE
      LUICYT(I)=LUICY1(I)+LUICY2(I)
      NCPR(I)=KTCP(I)*OBERSC-KTCPY(I)
C
C       ACRES USED FOR SOYBEAN PRODUCTION
C       IN SOME FUTURE YEAR
C
924   CONTINUE
      KK=0
      LUS67(I)=0
      DO 925 K=1,16
        LUS67(I)=LUS67(I)+LUTCC(I,7,K)
        LUTCCY(I,7,K)=0
        KCSPY(I,K)=0
925   CONTINUE
C
C       CALCULATE SOYBEAN PRODUCTION ON
C       LCC I THROUGH V LAND
C
      KTSPY(I)=KTSP(I)*OBERSS
      KC1TAS(I)=KTSP(I)*OBERSS/FSY1(I)
      RAT=KC1TAS(I)
      TIO=LUS67(I)
      RATIOS(I)=RAT/TIO
```

```
      DO 926 K=1,11
        IF (LU68(I,K).EQ.0) GO TO 926
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7075
        IF (K-5) 7070,7071,7072
 7070   RFEC=1.0
        GO TO 7075
 7071   RFEC=0.9
        GO TO 7075
 7072   IF (K-8) 7071,7073,7074
 7073   RFEC=0.8
        GO TO 7075
 7074   IF (K-11) 7073,7070,7075
 7075   LUTCCY(I,7,K)=LUTCC(I,7,K)*RATIOS(I)/SCCRYP(K)/RFEC
        IF (LUTCCY(I,7,K).LT.(LU610(I,K)-
     1     LUTCCY(I,6,K))) GO TO 929
        LUTCCY(I,7,K)=LU610(I,K)-LUTCCY(I,6,K)
  929   CONTINUE
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        KTSPY(I)=KTSPY(I)-KCSPY(I,K)
        IF (KTSPY(I).GT.0) GO TO 926
        KK=K+1
        KTSPY(I)=KTSPY(I)+KCSPY(I,K)
        LUTCCY(I,7,K)=KTSPY(I)/FSY1(I)/SCCRYP(K)/RFEC
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        GO TO 931
  926 CONTINUE
  931 CONTINUE
      KTSPY(I)=0
      DO 932 K=1,11
        KTSPY(I)=KTSPY(I)+KCSPY(I,K)
  932 CONTINUE
C
C      CHECK FOR ADDITIONAL SOYBEAN PRODUCTION
C      NEEDED ON LCC II THROUGH V LAND
C
C         NSPN = NET SOYBEAN PRODUCTION NEEDED, BUSHELS
C         LNFS = LAND NEEDED FOR SOYBEANS, ACRES
C          LLO = LAND LEFT OVER, ACRES
C
      DO 933 K=1,11
        LUCC17(I,K)=0
        DO 934 J=1,7
          LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
  934   CONTINUE
  933 CONTINUE
      DO 935 K=1,11
      LLO=LUCC(I,K)-LUCC17(I,K)
       IF (LLO.EQ.0) GO TO 935
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7085
        IF (K-5) 7080,7081,7082
 7080   RFEC=1.0
        GO TO 7085
 7081   RFEC=0.9
        GO TO 7085
 7082   IF (K-8) 7081,7083,7084
 7083   RFEC=0.8
        GO TO 7085
 7084   IF (K-11) 7083,7080,7085
```

```
 7085   NSPN=KTSP(I)*OBERSS-KTSPY(I)
        LNFS=NSPN/FSY1(I)/SCCRYP(K)/RFEC
        ITEST1=LNFS-LLO
        IF (ITEST1.GT.0) GO TO 936
        LUTCCY(I,7,K)=LUTCCY(I,7,K)+LNFS
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        GO TO 937
  936   LUTCCY(I,7,K)=LUTCCY(I,7,K)+LLO
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        KTSPY(I)=KTSPY(I)+LLO*FSY1(I)*SCCRYP(K)*RFEC
  935  CONTINUE
  937   CONTINUE
        KTSPY(I)=0
        DO 928 K=1,11
          KTSPY(I)=KTSPY(I)+KCSPY(I,K)
  928   CONTINUE
        NSPR(I)=KTSP(I)*OBERSS-KTSPY(I)
C
C        USE IRRIGATION OF CORN ON LCC I AND IIE LAND TO
C        OBTAIN ADDITIONAL LAND FOR PRODUCTION OF SOYBEANS
C
        LOVE=LOVE+1
        RNSP=NSPR(I)
        IF (LOVE.EQ.2) GO TO 949
        IF (FSY1(I).GT.RNSP) GO TO 949
        IF (LUICY2(I).EQ.LUTCCY(I,6,2)) GO TO 949
        LUTCCY(I,6,1)=LU610(I,1)
        LU610Y(I,1)=0
        LUICY1(I)=LUTCCY(I,6,1)
        KCCPY(I,1)=LUTCCY(I,6,1)*IICY1(I)*.94+
     1     LUTCCY(I,6,1)*ICY1(I)*.06
        KTCPY(I)=KTCP(I)*OBERSC-KCCPY(I,1)
        KCCPY(I,2)=LU610(I,2)*IICY1(I)*CCCRYP(2)*.94+
     1     LU610(I,2)*ICY1(I)*CCCRYP(2)*.06
        ITEST5=KTCPY(I)-KCCPY(I,2)
        IF (ITEST5.LE.0) GO TO 940
        LUTCCY(I,6,2)=LU610(I,2)
        KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1     LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
        KTCPY(I)=KTCPY(I)-KCCPY(I,2)
        LUICY2(I)=LUTCCY(I,6,2)
        LUTCCY(I,7,2)=0
        DO 939 K=3,11
          LU610Y(I,K)=LU610(I,K)
  939   CONTINUE
        GO TO 905
  940   LUTCCY(I,6,2)=KTCPY(I)/CCCRYP(2)/(.94*IICY1(I)+
     1     .06*ICY1(I))
        KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1     LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
        KTCPY(I)=KCCPY(I,1)+KCCPY(I,2)
        LU610Y(I,2)=LU610(I,2)-LUTCCY(I,6,2)
        LUICY2(I)=LUTCCY(I,6,2)
        LUICYT(I)=LUICY1(I)+LUICY2(I)
        DO 942 K=3,11
          LU610Y(I,K)=LU610(I,K)
  942   CONTINUE
        DO 945 K=3,16
          LUTCCY(I,6,K)=0
          KCCPY(I,K)=0
```

```
  945     CONTINUE
          GO TO 924
  949     CONTINUE
C
C          CALCULATE ACRE-FEET OF WATER NEEDED TO IRRIGATE
C          LUICYT(I) IN EACH COUNTY AND THEN CONVERT THESE
C          VOLUMES TO MGD FOR EACH COUNTY ASSUMING A 120 DAY
C          IRRIGATION SEASON
C
C               AIWRI = ANNUAL GROSS IRRIGATION WATER REQUIRED
C                       FOR SOME RECURRENCE INTERVAL, INCHES
C          RIWAFY(I) = VOLUME OF IRRIGATION WATER REQUIRED
C                       IN EACH COUNTY, ACRE-FEET PER YEAR
C          RIWMGD(I) = DAILY VOLUME OF IRRIGATION WATER
C                       REQUIRED IN EACH COUNTY, MILLION
C                       GALLONS PER DAY
C
          RIWAFY(I)=LUICYT(I)*AIWRI/12.
          RIWMGD(I)=RIWAFY(I)/368.4
C
C          CALCULATE LAND USED FOR CLOSE GROWN CROPS
C          IN SOME FUTURE YEAR
C
          LUTY(I,8)=0
          DO 950 K=1,11
            LUCC17(I,K)=0
            DO 954 J=1,7
              LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
  954       CONTINUE
            LUCC80(I,K)=LUCC(I,K)-LUCC17(I,K)
            ITEST3=LUTCCY(I,8,K)-LUCC80(I,K)
            IF (ITEST3.LT.0) GO TO 958
            LUTCCY(I,8,K)=LUCC80(I,K)
            LUTCCY(I,9,K)=0
            LUTCCY(I,10,K)=0
  958       CONTINUE
            LUTY(I,8)=LUTY(I,8)+LUTCCY(I,8,K)
  950     CONTINUE
          DO 960 K=1,11
            LU8N=LUT(I,8)-LUTY(I,8)
            LU90=LUCC80(I,K)-LUTCCY(I,8,K)
            IF (LU90.EQ.0) GO TO 960
            ITEST4=LU8N-LU90
            IF (ITEST4.GT.0) GO TO 962
            LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU8N
            GO TO 964
  962       LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU90
            LUTY(I,8)=LUTY(I,8)+LU90
            LUTCCY(I,9,K)=0
            LUTCCY(I,10,K)=0
  960     CONTINUE
  964     CONTINUE
C
C          CALCULATE LAND USED FOR HAY AND PASTURE
C          IN SOME FUTURE YEAR
C
          LUTY(I,9)=0
          DO 970 K=1,11
            LUCC18(I,K)=LUCC17(I,K)+LUTCCY(I,8,K)
            LUCC90(I,K)=LUCC(I,K)-LUCC18(I,K)
```

```
          ITEST5=LUTCCY(I,9,K)-LUCC90(I,K)
          IF (ITEST5.LT.0) GO TO 972
          LUTCCY(I,9,K)=LUCC90(I,K)
          LUTCCY(I,10,K)=0
          GO TO 974
  972     LUTCCY(I,10,K)=LUCC90(I,K)-LUTCCY(I,9,K)
  974     CONTINUE
          LUTY(I,9)=LUTY(I,9)+LUTCCY(I,9,K)
  970   CONTINUE
        DO 975 K=1,11
          LU9N=LUT(I,9)-LUTY(I,9)
          IF (LU9N.LE.0) GO TO 979
          IF (LUTCCY(I,10,K).EQ.0) GO TO 975
          ITEST6=LU9N-LUTCCY(I,10,K)
          IF (ITEST6.GT.0) GO TO 977
          LUTCCY(I,9,K)=LUTCCY(I,9,K)+LU9N
          LUTCCY(I,10,K)=LUTCCY(I,10,K)-LU9N
          GO TO 979
  977     LUTCCY(I,9,K)=LUTCCY(I,9,K)+LUTCCY(I,10,K)
          LUTY(I,9)=LUTY(I,9)+LUTCCY(I,10,K)
          LUTCCY(I,10,K)=0
  975   CONTINUE
  979   CONTINUE
  902 CONTINUE
C
C
C          CROP PLANTING SCENARIO 4
C
C
C          ONLY ALLOW CORN AND SOYBEANS ON THOSE
C          CLASS I THROUGH V LANDS WHICH WERE
C          PLANTED TO ROW CROPS IN 1967;  USE FULL
C          IRRIGATION ON CLASS I LAND FOR CORN;  USE ALL
C          CLASS I LAND BEFORE USING CLASS II LAND, ETC.,
C          GROWING CORN FIRST, THEN SOYBEANS, THEN CLOSE
C          GROWN CROPS, WITH ALL REMAINING LAND TO BE IN
C          HAY AND PASTURE
C
C
C          CALCULATE TOTAL ACREAGE IN LAND USES 6 AND 7 ON
C          LCC I THROUGH V LAND IN EACH COUNTY IN 1967
C
      DO 1100 I=1,12
        DO 1110 K=1,11
          LU67(I,K)=0
          DO 1120 J=6,7
            LU67(I,K)=LU67(I,K)+LUTCC(I,J,K)
 1120     CONTINUE
          LU67(I,K)=LU67(I,K)+LUTCC(I,1,K)-LUTCCY(I,1,K)+
     1          LUTCC(I,3,K)-LUTCCY(I,3,K)
          LU67Y(I,K)=LU67(I,K)
 1110   CONTINUE
 1100 CONTINUE
C
C          ACRES USED FOR CORN PRODUCTION IN SOME FUTURE YEAR
C
 4000 DO 1150 I=1,12
        KK=0
        LOVE=0
        LUICY1(I)=0
```

```
      LUICY2(I)=0
      DO 1155 K=1,11
        KCCPY(I,K)=0
        LU67Y(I,K)=LU67(I,K)
 1155 CONTINUE
C
C      CALCULATE CORN PRODUCTION UN LCC I LAND
C
      KTCPY(I)=KTCP(I)*OBERSC
      KCCPY(I,1)=LU67Y(I,1)*IICY1(I)*.94+
     1   LU67Y(I,1)*ICY1(I)*.06
      ITEST1=KTCPY(I)-KCCPY(I,1)
      IF (ITEST1) 1160,1170,1180
 1160 LUTCCY(I,6,1)=KTCPY(I)/(.94*IICY1(I)+.06*ICYI(I))
      LUICY1(I)=LUTCCY(I,6,1)
      LU67Y(I,1)=LU67Y(I,1)-LUTCCY(I,6,1)
      KCCPY(I,1)=LUTCCY(I,6,1)*IICY1(I)*.94+
     1   LUTCCY(I,6,1)*ICY1(I)*.06
      KTCPY(I)=KCCPY(I,1)
      GO TO 1172
 1170 LUTCCY(I,6,1)=LU67Y(I,1)
      LUICY1(I)=LUTCCY(I,6.1)
      LU67Y(I,1)=0
 1172 KK=2
      GO TO 1190
 1180 LUTCCY(I,6,1)=LU67Y(I,1)
      LUICY1(I)=LUTCCY(I,6,1)
      LU67Y(I,1)=0
      KTCPY(I)=ITEST1
C
C      CALCULATE CORN PRODUCTION ON LCC II THROUGH V LAND
C
 1181 CONTINUE
      IF (LOVE.EQ.0) KI=2
      IF (LOVE.EQ.1) KI=3
      DO 1182 K=KI,11
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7055
        IF (K-5) 7050,7051,7052
 7050   RFEC=1.0
        GO TO 7055
 7051   RFEC=0.9
        GO TO 7055
 7052   IF (K-8) 7051,7053,7054
 7053   RFEC=0.8
        GO TO 7055
 7054   IF (K-11) 7053,7050,7055
 7055   KCCPY(I,K)=LU67Y(I,K)*ICY1(I)*CCCRYP(K)*RFEC
        ITEST2=KTCPY(I)-KCCPY(I,K)
        IF (ITEST2) 1184,1186,1188
 1184   LUTCCY(I,6,K)=KTCPY(I)/ICY1(I)/CCCRYP(K)/RFEC
        KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
        LU67Y(I,K)=LU67Y(I,K)-LUTCCY(I,6,K)
        KK=K+1
        GO TO 1190
 1186   LUTCCY(I,6,K)=LU67Y(I,K)
        LU67Y(I,K)=0
        KK=K+1
        GO TO 1190
 1188   LUTCCY(I,6,K)=LU67Y(I,K)
```

```
           LU67Y(I,K)=0
           KTCPY(I)=ITEST2
 1182     CONTINUE
C
C          CALCULATE IRRIGATED CORN PRODUCTION
C          NEEDED ON LCC IIE LAND
C
C             ICPR = IRRIGATED CORN PRODUCTION REQUIRED, BUSHELS
C
          IF (LOVE.EQ.1) GO TO 1190
          KTCPY(I)=0
          DO 1191 K=1,11
           KTCPY(I)=KTCPY(I)+KCCPY(I,K)
 1191     CONTINUE
          ICPR=KTCP(I)*OBERSC-KTCPY(I)
          LUICY2(I)=ICPR/CCCRYP(2)/(IICY1(I)-ICY1(I))/.94
          ITEST3=LUICY2(I)-LUTCCY(I,6,2)
          IF (ITEST3.LE.0) GO TO 1192
          LUICY2(I)=LUTCCY(I,6,2)
 1192     KCCPY(I,2)=LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)+
     1    LUICY2(I)*(IICY1(I)-ICY1(I))*CCCRYP(2)*.94
 1190     IF (KK.EQ.0) KK=12
          KTCPY(I)=0
          DO 1194 K=KK,16
           LUTCCY(I,6,K)=0
           KCCPY(I,K)=0
 1194     CONTINUE
          DO 1196 K=1,11
           KTCPY(I)=KTCPY(I)+KCCPY(I,K)
 1196     CONTINUE
          LUICYT(I)=LUICY1(I)+LUICY2(I)
          NCPR(I)=KTCP(I)*OBERSC-KTCPY(I)
C
C          ACRES USED FOR SOYBEAN PRODUCTION
C          IN SOME FUTURE YEAR
C
          KK=0
          DO 1198 K=1,16
           KCSPY(I,K)=0
 1198     CONTINUE
C
C          CALCULATE SOYBEAN PRODUCTION ON LCC I LAND
C
          KTSPY(I)=KTSP(I)*OBERSS
          IF (LU67Y(I,1)) 1201,1200,1201
 1200     LUTCCY(I,7,1)=0
          GO TO 1212
 1201     KCSPY(I,1)=LU67Y(I,1)*FSY1(I)
          ITEST3=KTSPY(I)-KCSPY(I,1)
          IF (ITEST3) 1202,1205,1210
 1202     LUTCCY(I,7,1)=KTSPY(I)/FSY1(I)
          LU67Y(I,1)=LU67Y(I,1)-LUTCCY(I,7,1)
          KCSPY(I,1)=LUTCCY(I,7,1)*FSY1(I)
          KTSPY(I)=KCSPY(I,1)
          GO TO 1207
 1205     LUTCCY(I,7,1)=LU67Y(I,1)
          LU67Y(I,1)=0
 1207     KK=2
          GO TO 1228
 1210     LUTCCY(I,7,1)=LU67Y(I,1)
```

```
      LU67Y(I,1)=0
      KTSPY(I)=ITEST3
C
C       CALCULATE SOYBEAN PRODUCTION
C       ON LCC II THROUGH V LAND
C
 1212 CONTINUE
      DO 1220 K=2,11
        IF (LU67Y(I,K)) 1218,1215,1218
 1215   LUTCCY(I,7,K)=0
        GO TO 1220
 1218   RFEC=1.0
        IF (IEC.EQ.0) GO TO 7065
        IF (K-5) 7060,7061,7062
 7060   RFEC=1.0
        GO TO 7065
 7061   RFEC=0.9
        GO TO 7065
 7062   IF (K-8) 7061,7063,7064
 7063   RFEC=0.8
        GO TO 7065
 7064   IF (K-11) 7063,7060,7065
 7065   KCSPY(I,K)=LU67Y(I,K)*FSY1(I)*SCCRYP(K)*RFEC
        ITEST4=KTSPY(I)-KCSPY(I,K)
        IF (ITEST4) 1222,1224,1226
 1222   LUTCCY(I,7,K)=KTSPY(I)/FSY1(I)/SCCRYP(K)/RFEC
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        LU67Y(I,K)=LU67Y(I,K)-LUTCCY(I,7,K)
        KK=K+1
        GO TO 1228
 1224   LUTCCY(I,7,K)=LU67Y(I,K)
        LU67Y(I,K)=0
        KK=K+1
        GO TO 1228
 1226   LUTCCY(I,7,K)=LU67Y(I,K)
        LU67Y(I,K)=0
        KTSPY(I)=ITEST4
 1220 CONTINUE
 1228   IF (KK.EQ.0) KK=12
        DO 1230 KI=KK,16
          LUTCCY(I,7,KI)=0
          KCSPY(I,KI)=0
 1230   CONTINUE
      KTSPY(I)=0
      DO 1235 K=1,11
        KTSPY(I)=KTSPY(I)+KCSPY(I,K)
 1235 CONTINUE
C
      NSPR(I)=KTSP(I)*OBERSS-KTSPY(I)
C
C       USE IRRIGATION OF CORN ON LCC IIE LAND TO OBTAIN
C       ADDITIONAL LAND FOR PRODUCTION OF SOYBEANS
C
      LOVE=LOVE+1
      RNSP=NSPR(I)
      IF (LOVE.EQ.2) GO TO 1249
      IF (FSY1(I).GT.RNSP) GO TO 1249
      IF (LUICY2(I).EQ.LUTCCY(I,6,2)) GO TO 1249
      KTCPY(I)=KTCP(I)*OBERSC-KCCPY(I,1)
      KCCPY(I,2)=LU67(I,2)*IICY1(I)*CCCRYP(2)*.94+
```

```
     1       LU67(I,2)*ICY1(I)*CCCRYP(2)*.06
        ITESTS=KTCPY(I)-KCCPY(I,2)
        IF (ITESTS.LE.0) GO TO 1240
        LUTCCY(I,6,2)=LU67(I,2)
        KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1       LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
        KTCPY(I)=KTCPY(I)-KCCPY(I,2)
        LUICY2(I)=LUTCCY(I,6,2)
        LUTCCY(I,7,2)=0
        DO 1238 K=3,11
          LU67Y(I,K)=LU67(I,K)
 1238   CONTINUE
        GO TO 1181
 1240   LUTCCY(I,6,2)=KTCPY(I)/CCCRYP(2)/(.94*IICY1(I)+
     1       .06*ICY1(I))
        KCCPY(I,2)=LUTCCY(I,6,2,*IICY1(I)*CCCRYP(2)*.94+
     1       LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
        KTCPY(I)=KCCPY(I,1)+KCCPY(I,2)
        LU67Y(I,2)=LU67(I,2)-LUTCCY(I,6,2)
        LUICY2(I)=LUTCCY(I,6,2)
        LUICYT(I)=LUICY1(I)+LUICY2(I)
        DO 1242 K=3,11
          LU67Y(I,K)=LU67(I,K)
 1242   CONTINUE
        DO 1245 K=3,16
          LUTCCY(I,6,K)=0
          KCCPY(I,K)=0
 1245   CONTINUE
      KTSPY(I)=KTSP(I)*OBERSS-LUTCCY(I,7,1)*FSY1(I)
        GO TO 1212
 1249   CONTINUE
C
C         CALCULATE ACRE-FEET OF WATER NEEDED TO IRRIGATE
C         LUICYT(I) IN EACH COUNTY AND THEN CONVERT THESE
C         VOLUMES TO MGD FOR EACH COUNTY ASSUMING A 120 DAY
C         IRRIGATION SEASON
C
C             AIWRI = ANNUAL GROSS IRRIGATION WATER REQUIRED
C                     FOR SOME RECURRENCE INTERVAL, INCHES
C         RIWAFY(I) = VOLUME OF IRRIGATION WATER REQUIRED
C                     IN EACH COUNTY, ACRE-FEET PER YEAR
C         RIWMGD(I) = DAILY VOLUME OF IRRIGATION WATER
C                     REQUIRED IN EACH COUNTY, MILLION
C                     GALLONS PER DAY
C
        RIWAFY(I)=LUICYT(I)*AIWRI/12.
        RIWMGD(I)=RIWAFY(I)/368.4
C
C         CALCULATE LAND USED FOR CLOSE GROWN CROPS
C         IN SOME FUTURE YEAR
C
        LUTY(I,8)=0
        DO 1250 K=1,11
          LUCC17(I,K)=0
          DO 1255 J=1,7
            LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
 1255     CONTINUE
          LUCC80(I,K)=LUCC(I,K)-LUCC17(I,K)
          ITEST6=LUTCCY(I,8,K)-LUCC80(I,K)
          IF (ITEST6.LT.0) GO TO 1258
```

```
          LUTCCY(I,8,K)=LUCC80(I,K)
          LUTCCY(I,9,K)=0
          LUTCCY(I,10,K)=0
 1258     CONTINUE
          LUTY(I,8)=LUTY(I,8)+LUTCCY(I,8,K)
 1250   CONTINUE
        DO 1260 K=1,11
          LU8N=LUT(I,8)-LUTY(I,8)
          LU90=LUCC80(I,K)-LUTCCY(I,8,K)
          IF (LU90.EQ.0) GO TO 1260
          ITEST7=LU8N-LU90
          IF (ITEST7.GT.0) GO TO 1262
          LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU8N
          GO TO 1264
 1262     LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU90
          LUTY(I,8)=LUTY(I,8)+LU90
          LUTCCY(I,9,K)=0
          LUTCCY(I,10,K)=0
 1260   CONTINUE
 1264   CONTINUE
C
C         CALCULATE LAND USED FOR HAY AND PASTURE
C         IN SOME FUTURE YEAR
C
        LUTY(I,9)=0
        DO 1270 K=1,11
          LUCC18(I,K)=LUCC17(I,K)+LUTCCY(I,8,K)
          LUCC90(I,K)=LUCC(I,K)-LUCC18(I,K)
          ITEST8=LUTCCY(I,9,K)-LUCC90(I,K)
          IF (ITEST8.LT.0) GO TO 1272
          LUTCCY(I,9,K)=LUCC90(I,K)
          LUTCCY(I,10,K)=0
          GO TO 1274
 1272     LUTCCY(I,10,K)=LUCC90(I,K)-LUTCCY(I,9,K)
 1274     CONTINUE
          LUTY(I,9)=LUTY(I,9)+LUTCCY(I,9,K)
 1270   CONTINUE
        DO 1275 K=1,11
          LU9N=LUT(I,9)-LUTY(I,9)
          IF (LU9N.LE.0) GO TO 1279
          IF (LUTCCY(I,10,K).EQ.0) GO TO 1275
          ITEST9=LU9N-LUTCCY(I,10,K)
          IF (ITEST9.GT.0) GO TO 1277
          LUTCCY(I,9,K)=LUTCCY(I,9,K)+LU9N
          LUTCCY(I,10,K)=LUTCCY(I,10,K)-LU9N
          GO TO 1279
 1277     LUTCCY(I,9,K)=LUTCCY(I,9,K)+LUTCCY(I,10,K)
          LUTY(I,9)=LUTY(I,9)+LUTCCY(I,10,K)
          LUTCCY(I,10,K)=0
 1275   CONTINUE
 1279   CONTINUE
 1150 CONTINUE
C
C
C         CROP PLANTING SCENARIO 5
C
C
C         ONLY ALLOW CORN AND SOYBEANS ON THOSE CLASS I
C         THROUGH V LANDS WHICH WERE PLANTED TO
C         ROW AND CLOSE GROWN CROPS IN 1967;  USE FULL
```

```
C         IRRIGATION ON CLASS I LAND FOR CORN;  USE ALL
C         CLASS I LAND BEFORE USING CLASS II LAND, ETC.,
C         GROWING CORN FIRST, THEN SOYBEANS, THEN CLOSE
C         GROWN CROPS, WITH ALL REMAINING LAND TO BE IN
C         HAY AND PASTURE
C
C
C         CALCULATE TOTAL ACREAGE IN LAND USES 6 THROUGH 8
C         ON LCC I THROUGH V LAND IN EACH COUNTY IN 1967
C
      DO 1280 I=1,12
        DO 1290 K=1,11
          LU68(I,K)=0
          DO 1300 J=6,8
            LU68(I,K)=LU68(I,K)+LUTCC(I,J,K)
 1300     CONTINUE
          LU68(I,K)=LU68(I,K)+LUTCC(I,1,K)-LUTCCY(I,1,K)+
     1        LUTCC(I,3,K)-LUTCCY(I,3,K)
          LU68Y(I,K)=LU68(I,K)
 1290   CONTINUE
 1280 CONTINUE
C
C         ACRES USED FOR CORN PRODUCTION IN SOME FUTURE YEAR
C
 4000 DO 1350 I=1,12
        KK=0
        LOVE=0
        LUICY1(I)=0
        LUICY2(I)=0
        DO 1355 K=1,11
          KCCPY(I,K)=0
          LU68Y(I,K)=LU68(I,K)
 1355   CONTINUE
C
C         CALCULATE CORN PRODUCTION ON LCC I LAND
C
        KTCPY(I)=KTCP(I)*OBERSC
        KCCPY(I,1)=LU68Y(I,1)*IICY1(I)*.94+
     1     LU68Y(I,1)*ICY1(I)*.06
        ITEST1=KTCPY(I)-KCCPY(I,1)
        IF (ITEST1) 1360,1370,1380
 1360   LUTCCY(I,6,1)=KTCPY(I)/(.94*IICY1(I)+.06*ICY1(I))
        LUICY1(I)=LUTCCY(I,6,1)
        LU68Y(I,1)=LU68Y(I,1)-LUTCCY(I,6,1)
        KCCPY(I,1)=LUTCCY(I,6,1)*IICY1(I)*.94+
     1     LUTCCY(I,6,1)*ICY1(I)*.06
        KTCPY(I)=KCCPY(I,1)
        GO TO 1372
 1370   LUTCCY(I,6,1)=LU68Y(I,1)
        LUICY1(I)=LUTCCY(I,6,1)
        LU68Y(I,1)=0
 1372   KK=2
        GO TO 1390
 1380   LUTCCY(I,6,1)=LU68Y(I,1)
        LUICY1(I)=LUTCCY(I,6,1)
        LU68Y(I,1)=0
        KTCPY(I)=ITEST1
C
C         CALCULATE CORN PRODUCTION ON LCC II THROUGH V LAND
C
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```
 1381   CONTINUE
        IF (LOVE.EQ.0) KI=2
        IF (LOVE.EQ.1) KI=3
        DO 1382 K=KI,11
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7055
          IF (K-5) 7050,7051,7052
 7050     RFEC=1.0
          GO TO 7055
 7051     RFEC=0.9
          GO TO 7055
 7052     IF (K-8) 7051,7053,7054
 7053     RFEC=0.8
          GO TO 7055
 7054     IF (K-11) 7053,7050,7055
 7055     KCCPY(I,K)=LU68Y(I,K)*ICY1(I)*CCCRYP(K)*RFEC
          ITEST2=KTCPY(I)-KCCPY(I,K)
          IF (ITEST2) 1384,1386,1388
 1384     LUTCCY(I,6,K)=KTCPY(I)/ICY1(I)/CCCRYP(K)/RFEC
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          LU68Y(I,K)=LU68Y(I,K)-LUTCCY(I,6,K)
          KK=K+1
          GO TO 1390
 1386     LUTCCY(I,6,K)=LU68Y(I,K)
          LU68Y(I,K)=0
          KK=K+1
          GO TO 1390
 1388     LUTCCY(I,6,K)=LU68Y(I,K)
          LU68Y(I,K)=0
          KTCPY(I)=ITEST2
 1382   CONTINUE
C
C        CALCULATE IRRIGATED CORN PRODUCTION
C        NEEDED ON LCC IIE LAND
C
C           ICPR = IRRIGATED CORN PRODUCTION REQUIRED, BUSHELS
C
        IF (LOVE.EQ.1) GO TO 1390
        KTCPY(I)=0
        DO 1391 K=1,11
          KTCPY(I)=KTCPY(I)+KCCPY(I,K)
 1391   CONTINUE
        ICPR=KTCP(I)*OBERSC-KTCPY(I)
        LUICY2(I)=ICPR/CCCRYP(2)/(IICY1(I)-ICY1(I))/.94
        ITEST3=LUICY2(I)-LUTCCY(I,6,2)
        IF (ITEST3.LE.0) GO TO 1392
        LUICY2(I)=LUTCCY(I,6,2)
 1392   KCCPY(I,2)=LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)+
      1 LUICY2(I)*(IICY1(I)-ICY1(I))*CCCRYP(2)*.94
 1390   IF (KK.EQ.0) KK=12
        KTCPY(I)=0
        DO 1394 K=KK,16
          LUTCCY(I,6,K)=0
          KCCPY(I,K)=0
 1394   CONTINUE
        DO 1396 K=1,11
          KTCPY(I)=KTCPY(I)+KCCPY(I,K)
 1396   CONTINUE
        LUICYT(I)=LUICY1(I)+LUICY2(I)
        NCPR(I)=KTCP(I)*OBERSC-KTCPY(I)
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```
C
C          ACRES USED FOR SOYBEAN PRODUCTION
C          IN SOME FUTURE YEAR
C
       KK=0
       DO 1398 K=1,16
         KCSPY(I,K)=0
 1398  CONTINUE
C
C          CALCULATE SOYBEAN PRODUCTION ON LCC I LAND
C
       KTSPY(I)=KTSP(I)*OBERSS
       IF (LU68Y(I,1)) 1401,1400,1401
 1400  LUTCCY(I,7,1)=0
       GO TO 1412
 1401  KCSPY(I,1)=LU68Y(I,1)*FSY1(I)
       ITEST3=KTSPY(I)-KCSPY(I,1)
       IF (ITEST3) 1402,1405,1410
 1402  LUTCCY(I,7,1)=KTSPY(I)/FSY1(I)
       LU68Y(I,1)=LU68Y(I,1)-LUTCCY(I,7,1)
       KCSPY(I,1)=LUTCCY(I,7,1)*FSY1(I)
       KTSPY(I)=KCSPY(I,1)
       GO TO 1407
 1405  LUTCCY(I,7,1)=LU68Y(I,1)
       LU68Y(I,1)=0
 1407  KK=2
       GO TO 1428
 1410  LUTCCY(I,7,1)=LU68Y(I,1)
       LU68Y(I,1)=0
       KTSPY(I)=ITEST3
C
C          CALCULATE SOYBEAN PRODUCTION
C          ON LCC II THROUGH V LAND
C
 1412  CONTINUE
       DO 1420 K=2,11
         IF (LU68Y(I,K)) 1418,1415,1418
 1415    LUTCCY(I,7,K)=0
         GO TO 1420
 1418    RFEC=1.0
         IF (IEC.EQ.0) GO TO 7065
         IF (K-5) 7060,7061,7062
 7060    RFEC=1.0
         GO TO 7065
 7061    RFEC=0.9
         GO TO 7065
 7062    IF (K-8) 7061,7063,7064
 7063    RFEC=0.8
         GO TO 7065
 7064    IF (K-11) 7063,7060,7065
 7065    KCSPY(I,K)=LU68Y(I,K)*FSY1(I)*SCCRYP(K)*RFEC
         ITEST4=KTSPY(I)-KCSPY(I,K)
         IF (ITEST4) 1422,1424,1426
 1422    LUTCCY(I,7,K)=KTSPY(I)/FSY1(I)/SCCRYP(K)/RFEC
         KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
         LU68Y(I,K)=LU68Y(I,K)-LUTCCY(I,7,K)
         KK=K+1
         GO TO 1428
 1424    LUTCCY(I,7,K)=LU68Y(I,K)
         LU68Y(I,K)=0
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```
          KK=K+1
          GO TO 1428
 1426     LUTCCY(I,7,K)=LU68Y(I,K)
          LU68Y(I,K)=0
          KTSPY(I)=ITEST4
 1420   CONTINUE
 1428     IF (KK.EQ.0) KK=12
          DO 1430 KI=KK,16
            LUTCCY(I,7,KI)=0
            KCSPY(I,KI)=0
 1430     CONTINUE
        KTSPY(I)=0
        DO 1435 K=1,11
          KTSPY(I)=KTSPY(I)+KCSPY(I,K)
 1435   CONTINUE
        NSPR(I)=KTSP(I)*OBERSS-KTSPY(I)
C
C         USE IRRIGATION OF CORN ON LCC IIE LAND TO OBTAIN
C         ADDITIONAL LAND FOR PRODUCTION OF SOYBEANS
C
        LOVE=LOVE+1
        RNSP=NSPR(I)
        IF (LOVE.EQ.2) GO TO 1449
        IF (FSY1(I).GT.RNSP) GO TO 1449
        IF (LUICY2(I).EQ.LUTCCY(I,6,2)) GO TO 1449
        KTCPY(I)=KTCP(I)*OBERSC-KCCPY(I,1)
        KCCPY(I,2)=LU68(I,2)*IICY1(I)*CCCRYP(2)*.94+
     1     LU68(I,2)*ICY1(I)*CCCRYP(2)*.06
        ITEST5=KTCPY(I)-KCCPY(I,2)
        IF (ITEST5.LE.0) GO TO 1440
        LUTCCY(I,6,2)=LU68(I,2)
        KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1     LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
        KTCPY(I)=KTCPY(I)-KCCPY(I,2)
        LUICY2(I)=LUTCCY(I,6,2)
        LUTCCY(I,7,2)=0
        DO 1438 K=3,11
          LU68Y(I,K)=LU68(I,K)
 1438   CONTINUE
        GO TO 1381
 1440   LUTCCY(I,6,2)=KTCPY(I)/CCCRYP(2)/(.94*IICY1(I)+
     1     .06*ICY1(I))
        KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1     LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
        KTCPY(I)=KCCPY(I,1)+KCCPY(I,2)
        LU68Y(I,2)=LU68(I,2)-LUTCCY(I,6,2)
        LUICY2(I)=LUTCCY(I,6,2)
        LUICYT(I)=LUICY1(I)+LUICY2(I)
        DO 1442 K=3,11
          LU68Y(I,K)=LU68(I,K)
 1442   CONTINUE
        DO 1445 K=3,16
          LUTCCY(I,6,K)=0
          KCCPY(I,K)=0
 1445   CONTINUE
      KTSPY(I)=KTSP(I)*OBERSS-LUTCCY(I,7,1)*FSY1(I)
        GO TO 1412
 1449   CONTINUE
C
C         CALCULATE ACRE-FEET OF WATER NEEDED TO IRRIGATE
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```
C         LUICYT(I) IN EACH COUNTY AND THEN CONVERT THESE
C         VOLUMES TO MGD FOR EACH COUNTY ASSUMING A 120 DAY
C         IRRIGATION SEASON
C
C             AIWRI = ANNUAL GROSS IRRIGATION WATER REQUIRED
C                     FOR SOME RECURRENCE INTERVAL, INCHES
C         RIWAFY(I) = VOLUME OF IRRIGATION WATER REQUIRED
C                     IN EACH COUNTY, ACRE-FEET PER YEAR
C         RIWMGD(I) = DAILY VOLUME OF IRRIGATION WATER
C                     REQUIRED IN EACH COUNTY, MILLION
C                     GALLONS PER DAY
C
      RIWAFY(I)=LUICYT(I)*AIWRI/12.
      RIWMGD(I)=RIWAFY(I)/368.4
C
C         CALCULATE LAND USED FOR CLOSE GROWN CROPS
C         IN SOME FUTURE YEAR
C
      LUTY(I,8)=0
      DO 1450 K=1,11
        LUCC17(I,K)=0
        DO 1455 J=1,7
          LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
 1455   CONTINUE
        LUCC80(I,K)=LUCC(I,K)-LUCC17(I,K)
        ITEST6=LUTCCY(I,8,K)-LUCC80(I,K)
        IF (ITEST6.LT.0) GO TO 1458
        LUTCCY(I,8,K)=LUCC80(I,K)
        LUTCCY(I,9,K)=0
        LUTCCY(I,10,K)=0
 1458   CONTINUE
        LUTY(I,8)=LUTY(I,8)+LUTCCY(I,8,K)
 1450 CONTINUE
      DO 1460 K=1,11
        LU8N=LUT(I,8)-LUTY(I,8)
        LU90=LUCC80(I,K)-LUTCCY(1,8,K)
        IF (LU90.EQ.0) GO TO 1460
        ITEST7=LU8N-LU90
        IF (ITEST7.GT.0) GO TO 1462
        LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU8N
        GO TO 1464
 1462   LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU90
        LUTY(I,8)=LUTY(I,8)+LU90
        LUTCCY(I,9,K)=0
        LUTCCY(I,10,K)=0
 1460 CONTINUE
 1464 CONTINUE
C
C         CALCULATE LAND USED FOR HAY AND PASTURE
C         IN SOME FUTURE YEAR
C
      LUTY(I,9)=0
      DO 1470 K=1,11
        LUCC18(I,K)=LUCC17(I,K)+LUTCCY(I,8,K)
        LUCC90(I,K)=LUCC(I,K)-LUCC18(I,K)
        ITEST8=LUTCCY(I,9,K)-LUCC90(I,K)
        IF (ITEST8.LT.0) GO TO 1472
        LUTCCY(I,9,K)=LUCC90(I,K)
        LUTCCY(I,10,K)=0
        GO TO 1474
```

```
1472      LUTCCY(I,10,K)=LUCC90(I,K)-LUTCCY(I,9,K)
1474      CONTINUE
          LUTY(I,9)=LUTY(I,9)+LUTCCY(I,9,K)
1470    CONTINUE
        DO 1475 K=1,11
          LU9N=LUT(I,9)-LUTY(I,9)
          IF (LU9N.LE.0) GO TO 1479
          IF (LUTCCY(I,10,K).EQ.0) GO TO 1475
          ITEST9=LU9N-LUTCCY(I,10,K)
          IF (ITEST9.GT.0) GO TO 1477
          LUTCCY(I,9,K)=LUTCCY(I,9,K)+LU9N
          LUTCCY(I,10,K)=LUTCCY(I,10,K)-LU9N
          GO TO 1479
1477      LUTCCY(I,9,K)=LUTCCY(I,9,K)+LUTCCY(I,10,K)
          LUTY(I,9)=LUTY(I,9)+LUTCCY(I,10,K)
          LUTCCY(I,10,K)=0
1475    CONTINUE
1479    CONTINUE
1350  CONTINUE
C
C
C           CROP PLANTING SCENARIO 6
C
C
C           ALLOW CORN AND SOYBEANS ON ALL CLASS I THROUGH V
C           LANDS WHICH WERE PLANTED TO ROW AND
C           CLOSE GROWN CROPS, HAY AND PASTURE IN 1967;  USE
C           FULL IRRIGATION ON CLASS I LAND FOR CORN;  USE ALL
C           CLASS I LAND BEFORE USING CLASS II LAND, ETC.,
C           GROWING CORN FIRST, THEN SOYBEANS, THEN CLOSE
C           GROWN CROPS, WITH ALL REMAINING LAND TO BE IN
C           HAY AND PASTURE
C
C
C           CALCULATE TOTAL ACREAGE IN LAND USES 6 THROUGH 10
C           ON LCC I THROUGH V LAND IN EACH COUNTY IN 1967
C
      DO 1530 I=1,12
        DO 1535 K=1,11
          LU610(I,K)=0
          DO 1540 J=6,10
            LU610(I,K)=LU610(I,K)+LUTCC(I,J,K)
1540      CONTINUE
          LU610(I,K)=LU610(I,K)+LUTCC(I,1,K)-LUTCCY(I,1,K)+
     1        LUTCC(I,3,K)-LUTCCY(I,3,K)
          LU610Y(I,K)=LU610(I,K)
1535    CONTINUE
1530  CONTINUE
C
C           ACRES USED FOR CORN PRODUCTION IN SOME FUTURE YEAR
C
      DO 1550 I=1,12
        KK=0
        LOVE=0
        LUICY1(I)=0
        LUICY2(I)=0
        DO 1555 K=1,11
          KCCPY(I,K)=0
          LU610Y(I,K)=LU610(I,K)
1555    CONTINUE
```

```
C
C        CALCULATE CORN PRODUCTION ON LCC I LAND
C
      KTCPY(I)=KTCP(I)*OBERSC
      KCCPY(I,1)=LU610Y(I,1)*IICY1(I)*.94+
     1    LU610Y(I,1)*ICY1(I)*.06
      ITEST1=KTCPY(I)-KCCPY(I,1)
      IF (ITEST1) 1560,1570,1580
 1560 LUTCCY(I,6,1)=KTCPY(I)/(.94*IICY1(I)+.06*ICY1(I))
      LUICY1(I)=LUTCCY(I,6,1)
      LU610Y(I,1)=LU610Y(I,1)-LUTCCY(I,6,1)
      KCCPY(I,1)=LUTCCY(I,6,1)*IICY1(I)*.94+
     1    LUTCCY(I,6,1)*ICY1(I)*.06
      KTCPY(I)=KCCPY(I,1)
      GO TO 1572
 1570 LUTCCY(I,6,1)=LU610Y(I,1)
      LUICY1(I)=LUTCCY(I,6,1)
      LU610Y(I,1)=0
      LUTCCY(I,7,1)=0
 1572 KK=2
      GO TO 1590
 1580 LUTCCY(I,6,1)=LU610Y(I,1)
      LUICY1(I)=LUTCCY(I,6,1)
      LU610Y(I,1)=0
      LUTCCY(I,7,1)=0
      KTCPY(I)=ITEST1
C
C        CALCULATE CORN PRODUCTION ON LCC II THROUGH V LAND
C
 1581 CONTINUE
      IF (LOVE.EQ.0) KI=2
      IF (LOVE.EQ.1) KI=3
      DO 1582 K=KI,11
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7055
        IF (K-5) 7050,7051,7052
 7050   RFEC=1.0
        GO TO 7055
 7051   RFEC=0.9
        GO TO 7055
 7052   IF (K-8) 7051,7053,7054
 7053   RFEC=0.8
        GO TO 7055
 7054   IF (K-11) 7053,7050,7055
 7055   KCCPY(I,K)=LU610Y(I,K)*ICY1(I)*CCCRYP(K)*RFEC
        ITEST2=KTCPY(I)-KCCPY(I,K)
        IF (ITEST2) 1584,1586,1588
 1584   LUTCCY(I,6,K)=KTCPY(I)/ICY1(I)/CCCRYP(K)/RFEC
        KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
        LU610Y(I,K)=LU610Y(I,K)-LUTCCY(I,6,K)
        KK=K+1
        GO TO 1590
 1586   LUTCCY(I,6,K)=LU610Y(I,K)
        LU610Y(I,K)=0
        KK=K+1
        GO TO 1590
 1588   LUTCCY(I,6,K)=LU610Y(I,K)
        LU610Y(I,K)=0
        KTCPY(I)=ITEST2
 1582 CONTINUE
```

```
C
C         CALCULATE IRRIGATED CORN PRODUCTION
C         NEEDED ON LCC IIE LAND
C
C            ICPR = IRRIGATED CORN PRODUCTION REQUIRED
C
      IF (LOVE.EQ.1) GO TO 1590
      KTCPY(I)=0
      DO 1591 K=1,11
        KTCPY(I)=KTCPY(I)+KCCPY(I,K)
 1591 CONTINUE
      ICPR=KTCP(I)*OBERSC-KTCPY(I)
      LUICY2(I)=ICPR/CCCRYP(2)/(IICY1(I)-ICY1(I))/.94
      ITEST3=LUICY2(I)-LUTCCY(I,6,2)
      IF (ITEST3.LE.0) GO TO 1592
      LUICY2(I)=LUTCCY(I,6,2)
 1592 KCCPY(I,2)=LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)+
     1 LUICY2(I)*(IICY1(I)-ICY1(I))*CCCRYP(2)*.94
 1590 IF (KK.EQ.0) KK=12
      DO 1594 K=KK,16
        LUTCCY(I,6,K)=0
        KCCPY(I,K)=0
 1594 CONTINUE
      KTCPY(I)=0
      DO 1596 K=1,11
        KTCPY(I)=KTCPY(I)+KCCPY(I,K)
 1596 CONTINUE
      LUICYT(I)=LUICY1(I)+LUICY2(I)
      NCPR(I)=KTCP(I)*OBERSC-KTCPY(I)
C
C         ACRES USED FOR SOYBEAN PRODUCTION
C         IN SOME FUTURE YEAR
C
      KK=0
      DO 1598 K=1,16
        KCSPY(I,K)=0
 1598 CONTINUE
C
C         CALCULATE SOYBEAN PRODUCTION ON LCC I LAND
C
      KTSPY(I)=KTSP(I)*OBERSS
      IF (LU610Y(I,1)) 1601,1600,1601
 1600 LUTCCY(I,7,1)=0
      GO TO 1612
 1601 KCSPY(I,1)=LU610Y(I,1)*FSY1(I)
      ITEST3=KTSPY(I)-KCSPY(I,1)
      IF (ITEST3) 1602,1605,1610
 1602 LUTCCY(I,7,1)=KTSPY(I)/FSY1(I)
      LU610Y(I,1)=LU610Y(I,1)-LUTCCY(I,7,1)
      KCSPY(I,1)=LUTCCY(I,7,1)*FSY1(I)
      KTSPY(I)=KCSPY(I,1)
      GO TO 1607
 1605 LUTCCY(I,7,1)=LU610Y(I,1)
      LU610Y(I,1)=0
 1607 KK=2
      GO TO 1628
 1610 LUTCCY(I,7,1)=LU610Y(I,1)
      LU610Y(I,1)=0
      KTSPY(I)=ITEST3
C
```

```
C         CALCULATE SOYBEAN PRODUCTION
C         ON LCC II THROUGH V LAND
C
 1612   CONTINUE
        DO 1620 K=2,11
          IF (LU610Y(I,K)) 1618,1615,1618
 1615     LUTCCY(I,7,K)=0
          GO TO 1620
 1618     RFEC=1.0
          IF (IEC.EQ.0) GO TO 7065
          IF (K-5) 7060,7061,7062
 7060     RFEC=1.0
          GO TO 7065
 7061     RFEC=0.9
          GO TO 7065
 7062     IF (K-8) 7061,7063,7064
 7063     RFEC=0.8
          GO TO 7065
 7064     IF (K-11) 7063,7060,7065
 7065     KCSPY(I,K)=LU610Y(I,K)*FSY1(I)*SCCRYP(K)*RFEC
          ITEST4=KTSPY(I)-KCSPY(I,K)
          IF (ITEST4) 1622,1624,1626
 1622     LUTCCY(I,7,K)=KTSPY(I)/FSY1(I)/SCCRYP(K)/RFEC
          KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
          LU610Y(I,K)=LU610Y(I,K)-LUTCCY(I,7,K)
          KK=K+1
          GO TO 1628
 1624     LUTCCY(I,7,K)=LU610Y(I,K)
          LU610Y(I,K)=0
          KK=K+1
          GO TO 1628
 1626     LUTCCY(I,7,K)=LU610Y(I,K)
          LU610Y(I,K)=0
          KTSPY(I)=ITEST4
 1620   CONTINUE
 1628     IF (KK.EQ.0) KK=12
          DO 1630 KI=KK,16
            LUTCCY(I,7,KI)=0
            KCSPY(I,KI)=0
 1630     CONTINUE
        KTSPY(I)=0
        DO 1635 K=1,11
          KTSPY(I)=KTSPY(I)+KCSPY(I,K)
 1635   CONTINUE
        NSPR(I)=KTSP(I)*OBERSS-KTSPY(I)
C
C         USE IRRIGATION OF CORN ON LCC IIE LAND TO OBTAIN
C         ADDITIONAL LAND FOR PRODUCTION OF SOYBEANS
C
        LOVE=LOVE+1
        RNSP=NSPR(I)
        IF (LOVE.EQ.2) GO TO 1649
        IF (FSY1(I).GT.RNSP) GO TO 1649
        IF (LUICY2(I).EQ.LUTCCY(I,6,2)) GO TO 1649
        KTCPY(I)=KTCP(I)*OBERSC-KCCPY(I,1)
        KCCPY(I,2)=LU610(I,2)*IICY1(I)*CCCRYP(2)*.94+
     1    LU610(I,2)*ICY1(I)*CCCRYP(2)*.06
        ITEST5=KTCPY(I)-KCCPY(I,2)
        IF (ITEST5.LE.0) GO TO 1640
        LUTCCY(I,6,2)=LU610(I,2)
```

```
      KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1   LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
      KTCPY(I)=KTCPY(I)-KCCPY(I,2)
      LUICY2(I)=LUTCCY(I,6,2)
      LUTCCY(I,7,2)=0
      DO 1638 K=3,11
        LU610Y(I,K)=LU610(I,K)
 1638 CONTINUE
      GO TO 1581
 1640 LUTCCY(I,6,2)=KTCPY(I)/CCCRYP(2)/(.94*IICY1(I)+
     1   .06*ICY1(I))
      KCCPY(I,2)=LUTCCY(I,6,2)*IICY1(I)*CCCRYP(2)*.94+
     1   LUTCCY(I,6,2)*ICY1(I)*CCCRYP(2)*.06
      KTCPY(I)=KCCPY(I,1)+KCCPY(I,2)
      LU610Y(I,2)=LU610(I,2)-LUTCCY(I,6,2)
      LUICY2(I)=LUTCCY(I,6,2)
      LUICYT(I)=LUICY1(I)+LUICY2(I)
      DO 1642 K=3,11
        LU610Y(I,K)=LU610(I,K)
 1642 CONTINUE
      DO 1645 K=3,16
        LUTCCY(I,6,K)=0
        KCCPY(I,K)=0
 1645 CONTINUE
    KTSPY(I)=KTSP(I)*OBERSS-LUTCCY(I,7,1)*FSY1(I)
      GO TO 1612
 1649 CONTINUE
C
C      CALCULATE ACRE-FEET OF WATER NEEDED TO IRRIGATE
C      LUICYT(I) IN EACH COUNTY AND THEN CONVERT THESE
C      VOLUMES TO MGD FOR EACH COUNTY ASSUMING A 120 DAY
C      IRRIGATION SEASON
C
C          AIWRI = ANNUAL GROSS IRRIGATION WATER REQUIRED
C                  FOR SOME RECURRENCE INTERVAL, INCHES
C      RIWAFY(I) = VOLUME OF IRRIGATION WATER REQUIRED
C                  IN EACH COUNTY, ACRE-FEET PER YEAR
C      RIWMGD(I) = DAILY VOLUME OF IRRIGATION WATER
C                  REQUIRED IN EACH COUNTY, MILLION
C                  GALLONS PER DAY
C
      RIWAFY(I)=LUICYT(I)*AIWRI/12.
      RIWMGD(I)=RIWAFY(I)/368.4
C
C      CALCULATE LAND USED FOR CLOSE GROWN CROPS
C      IN SOME FUTURE YEAR
C
      LUTY(I,8)=0
      DO 1650 K=1,11
        LUCC17(I,K)=0
        DO 1655 J=1,7
          LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
 1655   CONTINUE
        LUCC80(I,K)=LUCC(I,K)-LUCC17(I,K)
        ITEST6=LUTCCY(I,8,K)-LUCC80(I,K)
        IF (ITEST6.LT.0) GO TO 1658
        LUTCCY(I,8,K)=LUCC80(I,K)
        LUTCCY(I,9,K)=0
        LUTCCY(I,10,K)=0
 1658   CONTINUE
```

```
         LUTY(I,8)=LUTY(I,8)+LUTCCY(I,8,K)
 1650    CONTINUE
         DO 1660 K=1,11
           LU8N=LUT(I,8)-LUTY(I,8)
           LU90=LUCC80(I,K)-LUTCCY(I,8,K)
           IF (LU90.EQ.0) GO TO 1660
           ITEST7=LU8N-LU90
           IF (ITEST7.GT.0) GO TO 1662
           LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU8N
           GO TO 1664
 1662      LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU90
           LUTY(I,8)=LUTY(I,8)+LU90
           LUTCCY(I,9,K)=0
           LUTCCY(I,10,K)=0
 1660    CONTINUE
 1664    CONTINUE
C
C         CALCULATE LAND USED FOR HAY AND PASTURE
C         IN SOME FUTURE YEAR
C
         LUTY(I,9)=0
         DO 1670 K=1,11
           LUCC18(I,K)=LUCC17(I,K)+LUTCCY(I,8,K)
           LUCC90(I,K)=LUCC(I,K)-LUCC18(I,K)
           ITEST8=LUTCCY(I,9,K)-LUCC90(I,K)
           IF (ITEST8.LT.0) GO TO 1672
           LUTCCY(I,9,K)=LUCC90(I,K)
           LUTCCY(I,10,K)=0
           GO TO 1674
 1672      LUTCCY(I,10,K)=LUCC90(I,K)-LUTCCY(I,9,K)
 1674      CONTINUE
           LUTY(I,9)=LUTY(I,9)+LUTCCY(I,9,K)
 1670    CONTINUE
         DO 1675 K=1,11
           LU9N=LUT(I,9)-LUTY(I,9)
           IF (LU9N.LE.0) GO TO 1679
           IF (LUTCCY(I,10,K).EQ.0) GO TO 1675
           ITEST9=LU9N-LUTCCY(I,10,K)
           IF (ITEST9.GT.0) GO TO 1677
           LUTCCY(I,9,K)=LUTCCY(I,9,K)+LU9N
           LUTCCY(I,10,K)=LUTCCY(I,10,K)-LU9N
           GO TO 1679
 1677      LUTCCY(I,9,K)=LUTCCY(I,9,K)+LUTCCY(I,10,K)
           LUTY(I,9)=LUTY(I,9)+LUTCCY(I,10,K)
           LUTCCY(I,10,K)=0
 1675    CONTINUE
 1679    CONTINUE
 1550 CONTINUE
C
C
C         CROP PLANTING SCENARIO 7
C
C
C         ALLOW ROW CROP ACREAGE TO EXPAND ONTO LAND
C         PRESENTLY USED FOR CLOSE GROWN CROPS, HAY AND
C         PASTURE, OTHER AND CONSERVATION USE ONLY WITH EACH
C         LAND CAPABILITY CLASS (LCC) CLAIMING THE SAME
C         PERCENTAGE OF TOTAL PRODUCTION AS IT HAD IN 1967,
C         PLANTING CORN FIRST AND THEN SOYBEANS ON CLASS I
C         THROUGH V LAND USING NO IRRIGATION
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C
C
C         CALCULATE TOTAL ACREAGE IN LAND USES 3 THROUGH 10
C         LAND, OMITTING USE 5 (WATER), ON LCC I THROUGH V
C         LAND IN EACH COUNTY IN 1967
C
      DO 870 I=1,12
        DO 880 K=1,11
          LU68(I,K)=0
          DO 890 J=6,8
            LU68(I,K)=LU68(I,K)+LUTCC(I,J,K)
  890     CONTINUE
            LU68(I,K)=LU68(I,K)+LUTCC(I,1,K)-LUTCCY(I,1,K)+
     1        LUTCC(I,3,K)-LUTCCY(I,3,K)
          LU610(I,K)=LU68(I,K)
          DO 895 J=9,10
            LU610(I,K)=LU610(I,K)+LUTCC(I,J,K)
  895     CONTINUE
          LU310(I,K)=LU610(I,K)
          DO 900 J=3,4
            LU310(I,K)=LU310(I,K)+LUTCC(I,J,K)
  900     CONTINUE
          LU610Y(I,K)=LU610(I,K)
          LU310Y(I,K)=LU310(I,K)
  880   CONTINUE
  870 CONTINUE
C
C         ACRES USED FOR CORN PRODUCTION IN SOME FUTURE YEAR
C
 4000 DO 902 I=1,12
        KK=0
        LUICY1(I)=0
        LUICY2(I)=0
        LUC67(I)=0
        DO 903 K=1,16
          LUC67(I)=LUC67(I)+LUTCC(I,6,K)
          LUTCCY(I,6,K)=0
          KCCPY(I,K)=0
  903   CONTINUE
C
C         CALCULATE CORN PRODUCTION ON LCC I THROUGH V LAND
C
        KTCPY(I)=KTCP(I)*OBERSC
        KC1TAC(I)=KTCP(I)*OBERSC/ICY1(I)
        RAT=KC1TAC(I)
        TIO=LUC67(I)
        RATIOC(I)=RAT/TIO
        DO 909 K=1,11
          IF (LU68(I,K).EQ.0) GO TO 909
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7055
          IF (K-5) 7050,7051,7052
 7050     RFEC=1.0
          GO TO 7055
 7051     RFEC=0.9
          GO TO 7055
 7052     IF (K-8) 7051,7053,7054
 7053     RFEC=0.8
          GO TO 7055
 7054     IF (K-11) 7053,7050,7055
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```
 7055     LUTCCY(I,6,K)=LUTCC(I,6,K)*RATIOC(I)/CCCRYP(K)/RFEC
          IF (LUTCCY(I,6,K).LT.LU310(I,K)) GO TO 910
          LUTCCY(I,6,K)=LU310(I,K)
  910     CONTINUE
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          KTCPY(I)=KTCPY(I)-KCCPY(I,K)
          IF (KTCPY(I).GT.0) GO TO 909
          KK=K+1
          KTCPY(I)=KTCPY(I)+KCCPY(I,K)
          LUTCCY(I,6,K)=KTCPY(I)/ICY1(I)/CCCRYP(K)/RFEC
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          GO TO 911
  909   CONTINUE
  911   CONTINUE
        KTCPY(I)=0
        DO 914 K=1,11
          KTCPY(I)=KTCPY(I)+KCCPY(I,K)
  914   CONTINUE
C
C          CHECK FOR ADDITIONAL CORN PRODUCTION
C          NEEDED ON LCC I THROUGH V LAND
C
C          KPRA = ADDITIONAL CORN PRODUCTION REQUIRED, BUSHELS
C         LNFCA = ADDITIONAL LAND NEEDED FOR CORN, ACRES
C           LLO = LAND LEFT OVER, ACRES
C
       DO 915 K=1,11
        LUCC16(I,K)=0
        DO 916 J=1,6
          IF (J.EQ.3.OR.J.EQ.4) GO TO 916
          LUCC16(I,K)=LUCC16(I,K)+LUTCCY(I,J,K)
  916   CONTINUE
  915   CONTINUE
        DO 917 K=1,11
          LLO=LUCC(I,K)-LUCC16(I,K)
          IF (LLO.EQ.0) GO TO 917
          RFEC=1.0
          IF (IEC.EQ.0) GO TO 7065
          IF (K-5) 7060,7061,7062
 7060     RFEC=1.0
          GO TO 7065
 7061     RFEC=0.9
          GO TO 7065
 7062     IF (K-8) 7061,7063,7064
 7063     RFEC=0.8
          GO TO 7065
 7064     IF (K-11) 7063,7060,7065
 7065     KPRA=KTCP(I)*OBERSC-KTCPY(I)
          LNFCA=KPRA/ICY1(I)/CCCRYP(K)/RFEC
          ITEST4=LNFCA-LLO
        IF (ITEST4.GT.0) GO TO 918
          LUTCCY(I,6,K)=LUTCCY(I,6,K)+LNFCA
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          GO TO 921
  918     LUTCCY(I,6,K)=LUTCCY(I,6,K)+LLO
          KCCPY(I,K)=LUTCCY(I,6,K)*ICY1(I)*CCCRYP(K)*RFEC
          KTCPY(I)=KTCPY(I)+LLO*ICY1(I)*CCCRYP(K)*RFEC
  917   CONTINUE
  921   CONTINUE
        KTCPY(I)=0
```

```
      DO 923 K=1,11
        KTCPY(I)=KTCPY(I)+KCCPY(I,K)
923   CONTINUE
    NCPR(I)=KTCP(I)*OBERSC-KTCPY(I)
C
C        ACRES USED FOR SOYBEAN PRODUCTION
C        IN SOME FUTURE YEAR
C
924   CONTINUE
      KK=0
      LUS67(I)=0
      DO 925 K=1,16
        LUS67(I)=LUS67(I)+LUTCC(I,7,K)
        LUTCCY(I,7,K)=0
        KCSPY(I,K)=0
925   CONTINUE
C
C        CALCULATE SOYBEAN PRODUCTION ON
C        LCC I THROUGH V LAND
C
      KTSPY(I)=KTSP(I)*OBERSS
      KC1TAS(I)=KTSP(I)*OBERSS/FSY1(I)
      RAT=KC1TAS(I)
      TIO=LUS67(I)
      RATIOS(I)=RAT/TIO
      DO 926 K=1,11
        IF (LU68(I,K).EQ.0) GO TO 926
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7075
        IF (K-5) 7070,7071,7072
7070    RFEC=1.0
        GO TO 7075
7071    RFEC=0.9
        GO TO 7075
7072    IF (K-8) 7071,7073,7074
7073    RFEC=0.8
        GO TO 7075
7074    IF (K-11) 7073,7070,7075
7075    LUTCCY(I,7,K)=LUTCC(I,7,K)*RATIOS(I)/SCCRYP(K)/RFEC
        IF (LUTCCY(I,7,K).LT.(LU310(I,K)-
     1     LUTCCY(I,6,K))) GO TO 929
        LUTCCY(I,7,K)=LU310(I,K)-LUTCCY(I,6,K)
929     CONTINUE
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        KTSPY(I)=KTSPY(I)-KCSPY(I,K)
        IF (KTSPY(I).GT.0) GO TO 926
        KK=K+1
        KTSPY(I)=KTSPY(I)+KCSPY(I,K)
        LUTCCY(I,7,K)=KTSPY(I)/FSY1(I)/SCCRYP(K)/RFEC
        KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
        GO TO 931
926   CONTINUE
931   CONTINUE
      KTSPY(I)=0
      DO 932 K=1,11
        KTSPY(I)=KTSPY(I)+KCSPY(I,K)
932   CONTINUE
C
C        CHECK FOR ADDITIONAL SOYBEAN PRODUCTION
C        NEEDED ON LCC I THROUGH V LAND
```

```
C
C           NSPN = NET SOYBEAN PRODUCTION NEEDED, BUSHELS
C           LNFS = LAND NEEDED FOR SOYBEANS, ACRES
C            LLO = LAND LEFT OVER, ACRES
C
      DO 933 K=1,11
        LUCC17(I,K)=0
        DO 934 J=1,7
          IF (J.EQ.3.OR.J.EQ.4) GO TO 934
          LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
  934   CONTINUE
  933 CONTINUE
      DO 935 K=1,11
      LLO=LUCC(I,K)-LUCC17(I,K)
      IF (LLO.EQ.0) GO TO 935
        RFEC=1.0
        IF (IEC.EQ.0) GO TO 7085
        IF (K-5) 7080,7081,7082
 7080   RFEC=1.0
        GO TO 7085
 7081   RFEC=0.9
        GO TO 7085
 7082   IF (K-8) 7081,7083,7084
 7083   RFEC=0.8
        GO TO 7085
 7084   IF (K-11) 7083,7080,7085
 7085 NSPN=KTSP(I)*OBERSS-KTSPY(I)
      LNFS=NSPN/FSY1(I)/SCCRYP(K)/RFEC
      ITEST1=LNFS-LLO
      IF (ITEST1.GT.0) GO TO 936
      LUTCCY(I,7,K)=LUTCCY(I,7,K)+LNFS
      KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
      GO TO 937
  936 LUTCCY(I,7,K)=LUTCCY(I,7,K)+LLO
      KCSPY(I,K)=LUTCCY(I,7,K)*FSY1(I)*SCCRYP(K)*RFEC
      KTSPY(I)=KTSPY(I)+LLO*FSY1(I)*SCCRYP(K)*RFEC
  935 CONTINUE
  937 CONTINUE
      KTSPY(I)=0
      DO 928 K=1,11
        KTSPY(I)=KTSPY(I)+KCSPY(I,K)
  928 CONTINUE
      NSPR(I)=KTSP(I)*OBERSS-KTSPY(I)
C
C        CALCULATE LAND USED FOR CLOSE GROWN CROPS
C        IN SOME FUTURE YEAR
C
  949 CONTINUE
      LUTY(I,8)=0
      DO 950 K=1,11
        LUCC17(I,K)=0
        DO 954 J=1,7
          IF (J.EQ.3.OR.J.EQ.4) GO TO 954
          LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
  954   CONTINUE
        LUCC80(I,K)=LUCC(I,K)-LUCC17(I,K)
        ITEST3=LUTCCY(I,8,K)-LUCC80(I,K)
        IF (ITEST3.LT.0) GO TO 958
        LUTCCY(I,8,K)=LUCC80(I,K)
        LUTCCY(I,9,K)=0
```

```
          LUTCCY(I,10,K)=0
  958     CONTINUE
          LUTY(I,8)=LUTY(I,8)+LUTCCY(I,8,K)
  950   CONTINUE
        DO 960 K=1,11
          LU8N=LUT(I,8)-LUTY(I,8)
          LU90=LUCC80(I,K)-LUTCCY(I,8,K)
          IF (LU90.EQ.0) GO TO 960
          ITEST4=LU8N-LU90
          IF (ITEST4.GT.0) GO TO 962
          LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU8N
          GO TO 964
  962     LUTCCY(I,8,K)=LUTCCY(I,8,K)+LU90
          LUTY(I,8)=LUTY(I,8)+LU90
          LUTCCY(I,9,K)=0
          LUTCCY(I,10,K)=0
  960   CONTINUE
  964   CONTINUE
C
C         CALCULATE LAND USED FOR HAY AND PASTURE
C         IN SOME FUTURE YEAR
C
        LUTY(I,9)=0
        DO 970 K=1,11
          LUCC18(I,K)=LUCC17(I,K)+LUTCCY(I,8,K)
          LUCC90(I,K)=LUCC(I,K)-LUCC18(I,K)
          ITEST5=LUTCCY(I,9,K)-LUCC90(I,K)
          IF (ITEST5.LT.0) GO TO 972
          LUTCCY(I,9,K)=LUCC90(I,K)
          LUTCCY(I,10,K)=0
          GO TO 974
  972     LUTCCY(I,10,K)=LUCC90(I,K)-LUTCCY(I,9,K)
  974     CONTINUE
          LUTY(I,9)=LUTY(I,9)+LUTCCY(I,9,K)
  970   CONTINUE
        DO 975 K=1,11
          LU9N=LUT(I,9)-LUTY(I,9)
          IF (LU9N.LE.0) GO TO 979
          IF (LUTCCY(I,10,K).EQ.0) GO TO 975
          ITEST6=LU9N-LUTCCY(I,10,K)
          IF (ITEST6.GT.0) GO TO 977
          LUTCCY(I,9,K)=LUTCCY(I,9,K)+LU9N
          LUTCCY(I,10,K)=LUTCCY(I,10,K)-LU9N
          GO TO 979
  977     LUTCCY(I,9,K)=LUTCCY(I,9,K)+LUTCCY(I,10,K)
          LUTY(I,9)=LUTY(I,9)+LUTCCY(I,10,K)
          LUTCCY(I,10,K)=0
  975   CONTINUE
  979   CONTINUE
C
C         CALCULATE LAND USED FOR PASTURE, OTHER AND
C         CONSERVATION USE ONLY IN SOME FUTURE YEAR
C
        DO 940 K=1,11
          LUCC17(I,K)=0
          DO 941 J=1,9
            IF (J.EQ.3.OR.J.EQ.4) GO TO 941
            LUCC17(I,K)=LUCC17(I,K)+LUTCCY(I,J,K)
  941     CONTINUE
          LUCC80(I,K)=LUCC(I,K)-LUCC17(I,K)
```

```
         LUTCCY(I,3,K)=LUCC80(I,K)/3
         IF (LUTCCY(I,3,K).GT.LUTCC(I,3,K)) LUTCCY(I,3,K)=
    1      LUTCC(I,3,K)
         LUTCCY(I,4,K)=LUCC80(I,K)/3
         IF (LUTCCY(I,4,K).GT.LUTCC(I,4,K)) LUTCCY(I,4,K)=
    1      LUTCC(I,4,K)
         LUTCCY(I,10,K)=LUCC80(I,K)-LUTCCY(I,3,K)-
    1      LUTCCY(I,4,K)
940    CONTINUE
902 CONTINUE
```

APPENDIX N.

SAMPLE PROGRAM OUTPUT

1967 BASE CONDITIONS AND 2020 FUTURE CONDITIONS

ROSSMILLER'S POPULATION PROJECTIONS

ROSSMILLER'S CORN AND SOYBEAN YIELDS

NO EROSION CONTROL MEASURES

CROP PLANTING SCENARIO NO. 3

DATA USED FOR 2020 PROJECTIONS

COUNTY	LAND USED FOR URBAN	LAND USED FOR RURAL	INCREASED CORN YIELD	IRRIGATED CORN YIELD	INCREASED SOYBEAN YIELD
	ACRES	ACRES	BU/AC	BU/AC	BU/AC
BUENA VISTA	412	212	200	258	57.3
CHEROKEE	100	360	192	248	60.6
CLAY	880	560	194	250	54.8
DICKINSON	620	612	179	231	48.4
IDA	0	100	201	258	62.1
LYON	240	212	164	210	51.8
O'BRIEN	80	320	191	245	57.3
OSCEOLA	0	232	181	233	51.8
PLYMOUTH	1272	552	166	214	56.5
SAC	0	180	192	248	57.8
SIOUX	1420	340	173	223	56.2
WOODBURY	420	800	176	226	51.2

OBERS PROJECTIONS - AS A PERCENTAGE OF 1967 PRODUCTION

CORN = 214.4

SOYBEANS = 354.9

ANNUAL GROSS IRRIGATION WATER REQUIRED = 19.1 INCHES

POTENTIAL RESERVOIR SITES

NO.	COUNTY	LAND ACRES	WATER ACRES
1	CHEROKEE	2400	3400
2	IDA	6100	9500
3	LYON	4700	4800
4	SAC	1420	1580
5	WOODBURY	4100	6200

BUENA VISTA COUNTY 1967 LAND USE ACRES CPS-0

CAPY. CLASS	URBAN BUILTUP	FOREST	OTHER	CONSERVATION USE ONLY	WATER AREAS	CORN	SOY BEANS	CLOSE GROWN CROPS	ROTATION HAY AND PASTURE	PASTURE	TOTAL
1	3998	0	608	2962	3540	25362	16215	2676	4900	218	60479
2E	3000	456	6078	11915	0	51237	32758	7070	14724	2173	129411
2W	2000	0	1013	9428	0	40067	25617	5733	8601	3259	95718
2S	0	0	405	571	0	2314	1480	0	1756	0	6526
3E	3000	152	810	6285	0	9882	6318	1911	3917	3477	35752
3W	2000	0	0	1142	0	4273	2634	0	976	0	11025
3S	0	0	0	0	0	118	75	0	0	0	193
4E	2000	912	405	857	0	359	229	193	992	1738	7685
4W	0	0	0	0	0	0	0	0	0	0	0
4S	0	0	0	0	0	118	75	0	0	0	193
5W	0	304	0	286	0	248	158	0	406	8256	9658
6E	0	456	0	0	0	242	154	0	203	1087	2142
6S	0	0	0	0	0	0	0	0	0	0	0
7E	0	2735	0	0	0	0	0	0	0	4563	7298
7W	0	0	0	0	0	0	0	0	0	0	0
7S	0	0	0	0	0	0	0	0	0	0	0
TOTAL	15998	5015	9319	33446	3540	134220	85713	17583	36475	24771	366080

WOODBURY COUNTY 1967 LAND USE ACRES CPS-0

CAPY. CLASS	URBAN BUILTUP	FOREST	OTHER	CONSER VATION USE ONLY	WATER AREAS	CORN	SOY BEANS	CLOSE GROWN CROPS	ROTATION HAY AND PASTURE	PASTURE	TOTAL
1	3600	3337	2843	9096	1470	30941	12700	922	2351	3634	70894
2E	3400	1668	710	3216	0	25064	10287	2459	7267	11968	66039
2W	1300	0	2843	3350	0	11478	4711	717	214	1068	25681
2S	0	0	0	293	0	1124	461	205	0	0	2083
3E	11917	13330	3553	25435	0	68538	28252	18856	38468	24364	232713
3W	3600	0	710	33635	0	21581	8858	1229	1923	428	71964
3S	0	0	356	507	0	2423	994	0	214	0	4494
4E	3400	6665	1066	8186	0	15580	6395	4304	8335	14105	68036
4W	0	0	0	584	0	625	256	0	214	0	1679
4S	0	0	0	0	0	0	0	0	0	0	0
5W	0	0	0	0	0	250	102	0	0	0	352
6E	0	0	356	4971	0	125	51	205	2351	3847	11906
6S	0	0	0	0	0	0	0	0	0	0	0
7E	0	0	0	0	0	0	0	0	854	428	1282
7W	0	0	0	214	0	0	0	103	0	0	317
7S	0	0	0	0	0	0	0	0	0	0	0
TOTAL	27217	25000	12437	89487	1470	177729	73067	29000	62191	59842	557440

1967 CORN PRODUCTION BUSHELS CPS-0

CAPY. CLASS	BUENA VISTA	CHEROKEE	CLAY	DICKINSON	IDA	LYON
1	2622430	1789905	3898585	1592646	235758	2441503
2E	4768114	5092756	1299691	1584320	2531639	5091389
2W	3728634	1161113	4170291	1283377	530214	797247
2S	143560	9692	461260	38879	0	95696
3E	919618	2441968	579720	1008393	4894852	1857173
3W	309279	119927	218167	136133	0	8153
3S	6100	0	46758	0	0	28204
4E	22272	23730	12479	44440	459486	20417
4W	0	0	0	0	0	0
4S	4880	0	0	0	0	0
5W	12821	163150	0	9268	265080	35027
6E	15013	7929	6239	5561	26583	6988
6S	0	15801	0	0	0	21016
7E	0	0	0	0	0	0
7W	0	0	0	18536	0	0
7S	0	0	0	4634	25818	17014
TOTAL	12552721	10825971	10693190	5726187	8969430	10419827

1967 CORN PRODUCTION BUSHELS CPS-0

CAPY. CLASS	O BRIEN	OSCEOLA	PLYMOUTH	SAC	SIOUX	WOODBURY
1	3307708	2895378	1017592	1942735	2547372	2763031
2E	4960017	3377432	4656166	5088854	6928979	2014393
2W	1548058	1075118	1783331	2663188	1135963	922486
2S	0	0	0	77143	151461	60223
3E	305719	609952	8303949	1922171	3779742	5508398
3W	6486	16035	96893	198101	0	1349028
3S	0	5705	0	0	11463	108186
4E	5559	20694	335903	38602	68877	834776
4W	0	0	0	0	0	33487
4S	3706	0	0	10301	45918	0
5W	84031	126469	203705	77164	40162	11162
6E	0	0	0	15453	6877	6697
6S	0	0	0	0	20682	0
7E	9543	0	0	0	0	0
7W	0	0	0	0	0	0
7S	0	0	0	0	0	0
TOTAL	10230827	8126783	16397539	12033712	14737496	13611867

1967 SOYBEAN PRODUCTION BUSHELS CPS-0

CAPY. CLASS	BUENA VISTA	CHEROKEE	CLAY	DICKINSON	IDA	LYON
1	515637	321599	701521	276390	34918	359060
2E	989619	965833	245613	289800	395964	786719
2W	773889	218762	788062	235104	82931	123746
2S	44710	2767	130763	10690	0	22279
3E	174793	424093	100334	169161	699310	263998
3W	67008	24626	44636	26990	0	1372
3S	1908	0	13381	0	0	6635
4E	5461	5312	2783	9640	85113	3744
4W	0	0	0	0	0	0
4S	1478	0	0	0	0	0
5W	2009	23448	0	1281	31412	4118
6E	1958	940	742	640	2618	686
6S	0	1893	0	0	0	2059
7E	0	0	0	0	0	0
7W	0	0	0	2570	0	0
7S	0	0	0	640	4419	2007
TOTAL	2578470	1989273	2027835	1022906	1336685	1576423

1967 SOYBEAN PRODUCTION BUSHELS CPS-0

CAPY. CLASS	O BRIEN	OSCEOLA	PLYMOUTH	SAC	SIOUX	WOODBURY
1	693547	509782	127091	374079	434779	335279
2E	1094300	629183	615373	1037665	1254086	257997
2W	342627	199798	235096	541313	204678	118151
2S	0	0	0	23543	40951	11561
3E	61958	103803	1002495	357791	623630	648891
3W	1554	3224	13831	43607	0	187080
3S	0	1601	0	0	3144	20993
4E	1457	4563	52426	9293	14680	126620
4W	0	0	0	0	0	4190
4S	1204	0	0	3085	12135	0
5W	14100	17815	20448	11890	5481	1077
6E	0	0	0	1990	786	538
6S	0	0	0	0	2347	0
7E	1603	0	0	0	0	0
7W	0	0	0	0	0	0
7S	0	0	0	0	0	0
TOTAL	2212350	1469769	2066760	2404256	2596697	1712377

BUENA VISTA COUNTY 1967 SOIL EROSION 100 TONS/YEAR CPS-0

CAPY. CLASS	URBAN BUILTUP	FOREST	OTHER	CONSER VATION USE ONLY	WATER AREAS	CORN	SOY BEANS	CLOSE GROWN CROPS	ROTATION HAY AND PASTURE	PASTURE	TOTAL
1	3	0	0	2	0	887	567	16	4	0	1479
2E	5	0	12	23	0	5021	3210	113	29	4	8417
2W	3	0	2	18	0	3926	2510	91	17	6	6573
2S	0	0	0	1	0	226	145	0	3	0	375
3E	41	0	11	87	0	6067	3879	193	54	20	10352
3W	27	0	0	15	0	2623	1617	0	13	0	4295
3S	0	0	0	0	0	72	46	0	0	0	118
4E	93	9	19	40	0	482	307	42	46	34	1072
4W	0	0	0	0	0	0	0	0	0	0	0
4S	0	0	0	0	0	158	100	0	0	0	258
5W	0	0	0	0	0	8	5	0	0	8	21
6E	0	7	0	0	0	538	342	0	15	35	937
6S	0	0	0	0	0	0	0	0	0	0	0
7E	0	54	0	0	0	0	0	0	0	415	469
7W	0	0	0	0	0	0	0	0	0	0	0
7S	0	0	0	0	0	0	0	0	0	0	0
TOTAL	172	70	44	186	0	20008	12728	455	181	522	34366

WOODBURY COUNTY 1967 SOIL EROSION 100 TONS/YEAR CPS-0

CAPY. CLASS	URBAN BUILTUP	FOREST	OTHER	CONSERVATION USE ONLY	WATER AREAS	CORN	SOY BEANS	CLOSE GROWN CROPS	ROTATION HAY AND PASTURE	PASTURE	TOTAL
1	3	3	2	9	0	1082	444	5	2	3	1553
2E	6	3	1	6	0	2456	1008	39	14	23	3556
2W	2	0	5	6	0	1124	461	11	0	2	1611
2S	0	0	0	0	0	110	45	3	0	0	158
3E	166	79	49	356	0	42082	17346	1904	538	146	62666
3W	50	0	9	470	0	13250	5438	124	26	2	19369
3S	0	0	4	7	0	1487	610	0	2	0	2110
4E	159	66	50	384	0	20939	8594	955	391	282	31820
4W	0	0	0	27	0	839	344	0	10	0	1220
4S	0	0	0	0	0	0	0	0	0	0	0
5W	0	0	0	0	0	8	3	0	0	0	11
6E	0	0	27	387	0	278	113	75	183	126	1189
6S	0	0	0	0	0	0	0	0	0	0	0
7E	0	0	0	0	0	0	0	0	179	38	217
7W	0	0	0	44	0	0	0	62	0	0	106
7S	0	0	0	0	0	0	0	0	0	0	0
TOTAL	386	151	147	1696	0	83655	34406	3178	1345	622	125586

THE RIGHT HAND SIDE - INPUT

1	86.00000
2	86.00000
3	86.00000
4	252.00000
5	252.00000
6	129.00000
7	105.89990
8	126.00000
9	109.10000
10	33.89999
11	127.00000
12	483.98070
13	334.89790
14	487.44140
15	0.00001
16	0.00001
17	0.00001

THE SUBSTITUTION RATES - INPUT

ROW 1										
	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				
ROW 2										
	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				
ROW 3										
	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				
ROW 4										
	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				
ROW 5										
	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				
ROW 6										
	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				
ROW 7										
	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	1.000	1.000	1.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				
ROW 8										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000
	0.000	0.000	0.000	0.000	0.000	0.000				
ROW 9										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	1.000	0.000	0.000	0.000	0.000	0.000				
ROW 10										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	1.000	1.000	0.000	0.000	0.000				
ROW 11										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	1.000	1.000	1.000				
ROW 12										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	1.000	0.000	0.000	0.000	0.000	0.000	-1.000	0.000	0.000
	0.000	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	1.000
	0.000	0.000	1.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000
	0.000	1.000	0.000	1.000	0.000	0.000				
ROW 13										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	-1.000	0.000
	0.000	0.000	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000
	1.000	0.000	0.000	1.000	0.000	1.000	0.000	0.000	1.000	0.000
	1.000	0.000	0.000	0.000	1.000	0.000				
ROW 14										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	-1.000
	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	1.000	0.000
	0.000	1.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	1.000
	0.000	0.000	1.000	0.000	0.000	1.000				
ROW 15										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
	-1.000	0.000	0.000	81.000	0.000	0.000	337.000	0.000	0.000	337.000
	0.000	0.000	342.000	0.000	135.000	0.000	0.000	463.000	0.000	0.000
	0.000	324.000	0.000	429.000	0.000	0.000				
ROW 16										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
	0.000	-1.000	0.000	0.000	81.000	0.000	0.000	433.000	0.000	0.000
	433.000	0.000	0.000	222.000	0.000	255.000	0.000	0.000	738.000	0.000
	178.000	0.000	0.000	0.000	557.000	0.000				
ROW 17										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
	0.000	0.000	-1.000	0.000	0.000	81.000	0.000	0.000	297.000	0.000
	0.000	297.000	0.000	0.000	0.000	0.000	210.000	0.000	0.000	243.000
	0.000	0.000	192.000	0.000	0.000	283.000				

THE OBJECTIVE FUNCTION - INPUT

PRIORITY 2										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				
PRIORITY 1										
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	1.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000				

SUMMARY OF INPUT INFORMATION

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THE RIGHT HAND SIDE

21.	119693.1
22.	59699.0
23.	114052.1
27.	50.9
29.	114.5
40.	126.0
46.	127.0
31.	10.8
35.	105.9
43.	33.9
4.	86.6
30.	241.2
34.	129.0
41.	109.1
24.	86.0
25.	86.0
26.	86.0

THE SUBSTITUTION RATES

-255.999	-0.000	0.000	-0.000	-0.000	-0.000	-201.999	0.000	-0.001	-0.000
0.000	336.999	0.000	-0.000	-1.000	-0.000	-0.000	-336.999	-0.000	0.000
1.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
-0.000	-0.000	-5.000	-0.000	-0.000	-201.999	-201.999	-126.000	0.000	-0.000
-0.000	13.000	-0.000	-92.000	0.000	-0.000				
-0.000	-352.000	-0.000	-0.000	-0.000	-211.000	0.000	-0.000	-255.000	-0.000
-0.000	0.000	433.000	0.000	-0.000	-1.000	-0.000	-0.000	-433.000	-0.000

-0.000	1.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.001	-0.000	-0.000
-0.000	0.000	-211.000	-0.000	-0.000	178.000	0.000	-0.000	-305.000	-0.000
-0.000	-0.000	-0.000	-0.000	-124.000	-0.000				
-0.000	0.000	-216.000	-0.000	-0.000	0.000	-0.000	-54.000	0.000	-105.000
-14.000	0.000	-0.000	296.999	-0.000	-0.000	-1.000	-0.000	0.000	-296.999
-0.000	-0.000	1.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
-0.000	0.000	-0.000	-0.000	-0.000	-0.000	87.000	-54.000	-54.000	-0.000
-0.000	-105.000	-0.000	-14.000	-14.000	-0.000				
-1.000	-1.000	-0.000	-0.000	-1.000	-1.000	-1.000	-0.000	-1.000	-0.000
-0.000	1.000	1.000	0.000	-0.000	-0.000	-0.000	-1.000	-1.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	1.000	1.000	-0.000	-0.000
-0.000	-1.000	0.000	-0.000	-0.000	0.000	-1.000	1.000	1.000	-0.000
-0.000	1.000	-0.000	1.000	1.000	-0.000				
-0.000	-0.000	-1.000	-0.000	-0.000	-0.000	-0.000	-1.000	-0.000	-1.000
-1.000	0.000	0.000	1.000	-0.000	-0.000	-0.000	-0.000	-0.000	-1.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	1.000	-0.000
-0.000	1.000	-0.000	-0.000	-0.000	0.000	1.000	-1.000	-1.000	-0.000
-0.000	-1.000	-0.000	-1.000	-1.000	-0.000				
0.000	0.000	0.000	-0.000	-0.000	0.000	0.000	1.000	-0.000	0.000
0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
-0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	1.000	1.000	1.000
-0.000	-0.000	-0.000	-0.000	0.000	-0.000				
0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	0.000	0.000
1.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000
-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.000
-0.000	0.000	-0.000	1.000	1.000	1.000				
-0.000	-1.000	-0.000	-0.000	-0.000	-1.000	0.000	-0.000	-1.000	-0.000
-0.000	0.000	1.000	0.000	-0.000	-0.000	-0.000	-0.000	-1.000	-0.000

-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	1.000	-0.000	-0.000
1.000	0.000	-1.000	-0.000	-0.000	1.000	0.000	-0.000	1.000	-0.000
-0.000	-0.000	-0.000	-0.000	1.000	-0.000				
0.000	-0.000	-0.000	-0.000	0.000	-0.000	1.000	-0.000	-0.000	-0.000
-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
-0.000	0.000	-0.000	-0.000	1.000	1.000	1.000	-0.000	0.000	-0.000
-0.000	-0.000	-0.000	-0.000	0.000	-0.000				
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	1.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	1.000	1.000	-0.000	-0.000	-0.000				
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	-1.000	-1.000	-1.000	0.000	0.000	0.000	1.000	1.000	1.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000
0.000	-0.000	0.000	-0.000	-0.000	0.000				
0.000	1.000	0.000	-0.000	1.000	1.000	-0.000	0.000	1.000	0.000
0.000	-0.000	-1.000	-0.000	-0.000	-0.000	-0.000	0.000	1.000	0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-1.000	-0.000	1.000
-0.000	1.000	1.000	-0.000	-0.000	-1.000	-0.000	0.000	-1.000	-0.000
-0.000	0.000	-0.000	0.000	-1.000	-0.000				
0.000	-0.000	0.000	-0.000	-0.000	1.000	0.000	0.000	0.000	0.000
0.000	-0.000	0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.000	-0.000	0.000
-0.000	-0.000	1.000	1.000	-0.000	0.000	0.000	0.000	0.000	-0.000
-0.000	0.000	-0.000	0.000	0.000	-0.000				
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	1.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000

-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
1.000	-0.000	-0.000	-0.000	-0.000	-0.000				
1.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	1.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000				
-0.000	1.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	1.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000				
-0.000	0.000	1.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000	-0.000
-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000	-0.000	0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	1.000	-0.000	0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	0.000	0.000	-0.000	-0.000	-0.000
-0.000	-0.000	-0.000	-0.000	-0.000	-0.000				

THE ZJ-CJ MATRIX

-255.999	-351.999	-216.000	0.000	-0.000	-211.000	-201.999	-54.000	-255.000	-105.000
-14.000	336.999	432.999	296.999	-1.000	-1.000	-1.000	-336.999	-432.999	-296.999
0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.000	0.000	-0.000
0.000	-0.000	-216.000	0.000	0.000	-24.000	-115.000	-180.000	-358.999	0.000
0.000	-92.000	0.000	-106.000	-138.000	0.000				
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	-1.000	-1.000	-1.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000				
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

0.000	0.000	0.000	0.000	-1.000	-1.000	-1.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000				

AN EVALUATION OF THE OBJECTIVE FUNCTION

2	293444.10
1	0.00
0	0.00

SLACK ANALYSIS

ROW	AVAILABLE	POS-SLK	NEG-SLK
1	86.0	0.0	0.0
2	86.0	0.0	0.0
3	86.0	0.0	0.0
4	252.0	0.0	86.6
5	252.0	0.0	0.0
6	129.0	0.0	0.0
7	105.9	0.0	0.0
8	126.0	0.0	0.0
9	109.1	0.0	0.0
10	33.9	0.0	0.0
11	127.0	0.0	0.0
12	484.0	0.0	0.0
13	334.9	0.0	0.0
14	487.4	0.0	0.0
15	0.0	119693.1	0.0
16	0.0	59699.0	0.0
17	0.0	114052.1	0.0

VARIABLE ANALYSIS

VARIABLE	AMOUNT
4	50.9
6	114.5
17	126.0
23	127.0
8	10.8
12	105.9
20	33.9
7	241.2
11	129.0
18	109.1
1	86.0
2	86.0
3	86.0

ANALYSIS OF THE OBJECTIVE

PRIORITY	UNDER-ACHIEVEMENT
2	293444.2
1	0.0

ARTIFICIAL 0.0

BUENA VISTA COUNTY 2020 LAND USE ACRES CPS-3

CAPY. CLASS	URBAN BUILTUP	FOREST	OTHER	CONSER VATION USE ONLY	WATER AREAS	CORN	SOY BEANS	CLOSE GROWN CROPS	ROTATION HAY AND PASTURE	PASTURE	TOTAL
1	4101	0	661	2962	3540	49215	0	0	0	0	60479
2E	3103	456	6131	11915	0	62805	45001	0	0	0	129411
2W	2103	0	1066	9428	0	0	83121	0	0	0	95718
2S	0	0	405	571	0	0	5550	0	0	0	6526
3E	3103	152	863	6285	0	0	25349	0	0	0	35752
3W	2000	0	0	1142	0	0	7443	440	0	0	11025
3S	0	0	0	0	0	0	93	100	0	0	193
4E	2000	912	405	857	0	0	1372	2139	0	0	7685
4W	0	0	0	0	0	0	0	0	0	0	0
4S	0	0	0	0	0	0	120	73	0	0	193
5W	0	304	0	286	0	0	8822	246	0	0	9658
6E	0	456	0	0	0	0	0	0	0	1686	2142
6S	0	0	0	0	0	0	0	0	0	0	0
7E	0	2735	0	0	0	0	0	0	0	4563	7298
7W	0	0	0	0	0	0	0	0	0	0	0
7S	0	0	0	0	0	0	0	0	0	0	0
TOTAL	16410	5015	9531	33446	3540	112020	176871	2998	0	6249	366080

WOODBURY COUNTY 2020 LAND USE ACRES CPS-3

CAPY. CLASS	URBAN BUILTUP	FOREST	OTHER	CONSERVATION USE ONLY	WATER AREAS	CORN	SOY BEANS	CLOSE GROWN CROPS	ROTATION HAY AND PASTURE	PASTURE	TOTAL
1	3705	3337	3043	10121	3020	35383	12285	0	0	0	70894
2E	3505	1668	910	4241	1550	43184	10981	0	0	0	66039
2W	1405	0	3043	4375	1550	13919	1389	0	0	0	25681
2S	0	0	0	293	0	1790	0	0	0	0	2083
3E	12022	13330	3753	26460	1550	86630	82543	6425	0	0	232713
3W	3600	0	710	33635	0	0	11894	18271	3854	0	71964
3S	0	0	356	507	0	0	1320	0	2311	0	4494
4E	3400	6665	1066	8186	0	0	15807	4304	28608	0	68036
4W	0	0	0	584	0	0	513	0	582	0	1679
4S	0	0	0	0	0	0	0	0	0	0	0
5W	0	0	0	0	0	0	255	0	97	0	352
6E	0	0	356	4971	0	0	0	0	0	6579	11906
6S	0	0	0	0	0	0	0	0	0	0	0
7E	0	0	0	0	0	0	0	0	0	1282	1282
7W	0	0	0	214	0	0	0	0	0	103	317
7S	0	0	0	0	0	0	0	0	0	0	0
TOTAL	27637	25000	13237	93587	7670	180906	136987	29000	35452	7964	557440

LAND USED FOR IRRIGATED CORN IN 2020 ACRES CPS-3

COUNTY	I	IIE	TOTAL
BUENA VISTA	49215	62805	112020
CHEROKEE	0	0	0
CLAY	0	0	0
DICKINSON	0	0	0
IDA	0	0	0
LYON	0	0	0
O'BRIEN	0	0	0
OSCEOLA	60326	17188	77514
PLYMOUTH	0	0	0
SAC	38474	74431	112905
SIOUX	0	0	0
WOODBURY	0	0	0

NET CORN AND SOYBEAN PRODUCTION NEEDED IN 2020   BUSHELS   CPS-3

COUNTY	CORN	SOYBEANS
BUENA VISTA	160	9
CHEROKEE	144	0
CLAY	128	36
DICKINSON	16	29
IDA	192	2
LYON	112	18
O'BRIEN	80	26
OSCEOLA	48	6
PLYMOUTH	128	7
SAC	128	35
SIOUX	0	37
WOODBURY	112	26

2020 CORN PRODUCTION BUSHELS CPS-3

CAPY. CLASS	BUENA VISTA	CHEROKEE	CLAY	DICKINSON	IDA	LYON
I	12526200	4159488	10277344	4120759	465516	5536476
2E	14386613	13146796	4250287	5047907	7132344	13426728
2W	0	3719519	8398434	3108263	2176407	3376792
2S	0	110822	0	0	0	0
3E	0	2074118	0	0	9456004	0
3W	0	0	0	0	0	0
3S	0	0	0	0	0	0
4E	0	0	0	0	0	0
4W	0	0	0	0	0	0
4S	0	0	0	0	0	0
5W	0	0	0	0	0	0
6E	0	0	0	0	0	0
6S	0	0	0	0	0	0
7E	0	0	0	0	0	0
7W	0	0	0	0	0	0
7S	0	0	0	0	0	0
TOTAL	26912813	23210743	22926065	12276929	19230271	22339996

2020 CORN PRODUCTION BUSHELS CPS-3

CAPY. CLASS	O BRIEN	OSCEOLA	PLYMOUTH	SAC	SIOUX	WOODBURY
1	9521732	13867740	2127456	9412278	6044447	6227408
2E	12413070	3556058	11817838	16387911	17754768	6840345
2W	0	0	5495977	0	3781018	2204769
2S	0	0	0	0	506544	189024
3E	0	0	15714935	0	3510412	13722191
3W	0	0	0	0	0	0
3S	0	0	0	0	0	0
4E	0	0	0	0	0	0
4W	0	0	0	0	0	0
4S	0	0	0	0	0	0
5W	0	0	0	0	0	0
6E	0	0	0	0	0	0
6S	0	0	0	0	0	0
7E	0	0	0	0	0	0
7W	0	0	0	0	0	0
7S	0	0	0	0	0	0
TOTAL	21934802	17423798	35156206	25800189	31597189	29183737

2020 SOYBEAN PRODUCTION BUSHELS CPS-3

CAPY. CLASS	BUENA VISTA	CHEROKEE	CLAY	DICKINSON	IDA	LYON
1	0	711322	1863857	909000	78991	929810
2E	2449629	2203548	581978	860101	715137	2196143
2W	4524691	458026	3134636	837525	0	514835
2S	302114	0	1007412	35818	0	189015
3E	1263672	3045908	380883	699582	3028105	1617463
3W	341187	143016	140288	136797	0	15167
3S	4263	0	43883	0	0	26024
4E	58961	115942	43812	79751	626014	24281
4W	0	0	0	0	0	0
4S	4263	0	0	0	0	0
5W	202200	382167	0	71690	295645	81968
6E	0	0	0	0	0	0
6S	0	0	0	0	0	0
7E	0	0	0	0	0	0
7W	0	0	0	0	0	0
7S	0	0	0	0	0	0
TOTAL	9150980	7059929	7196749	3630264	4743892	5594706

2020 SOYBEAN PRODUCTION BUSHELS CPS-3

CAPY. CLASS	O BRIEN	OSCEOLA	PLYMOUTH	SAC	SIOUX	WOODBURY
1	2416856	0	258996	0	1237299	628991
2E	3825855	3198305	1655014	2345534	3567838	534115
2W	990390	1431223	612378	3136074	750503	67560
2S	0	10530	0	205363	0	0
3E	321638	330739	4251661	2513645	3458564	3676794
3W	4492	7997	34623	103947	0	487178
3S	0	15374	0	0	30347	54067
4E	18694	27350	303235	49679	49231	606988
4W	0	0	0	0	0	16284
4S	13926	0	0	15015	40279	0
5W	259752	194685	219016	163412	81579	5222
6E	0	0	0	0	0	0
6S	0	0	0	0	0	0
7E	0	0	0	0	0	0
7W	0	0	0	0	0	0
7S	0	0	0	0	0	0
TOTAL	7851603	5216203	7334923	8532669	9215640	6077199

BUENA VISTA COUNTY   2020 SOIL EROSION   100 TONS/YEAR   CPS-3

CAPY. CLASS	URBAN BUILTUP	FOREST	OTHER	CONSER VATION USE ONLY	WATER AREAS	CORN	SOY BEANS	CLOSE GROWN CROPS	ROTATION HAY AND PASTURE	PASTURE	TOTAL
1	4	0	0	2	0	1722	0	0	0	0	1728
2E	6	0	12	23	0	6154	4410	0	0	0	10605
2W	4	0	2	18	0	0	8145	0	0	0	8169
2S	0	0	0	1	0	0	543	0	0	0	544
3E	43	0	12	87	0	0	15564	0	0	0	15706
3W	27	0	0	15	0	0	4570	44	0	0	4656
3S	0	0	0	0	0	0	57	10	0	0	67
4E	93	9	19	40	0	0	1843	474	0	0	2478
4W	0	0	0	0	0	0	0	0	0	0	0
4S	0	0	0	0	0	0	161	16	0	0	177
5W	0	0	0	0	0	0	308	1	0	0	309
6E	0	7	0	0	0	0	0	0	0	55	62
6S	0	0	0	0	0	0	0	0	0	0	0
7E	0	54	0	0	0	0	0	0	0	415	469
7W	0	0	0	0	0	0	0	0	0	0	0
7S	0	0	0	0	0	0	0	0	0	0	0
TOTAL	177	70	45	186	0	7876	35601	545	0	470	44970

WOODBURY COUNTY 2020 SOIL EROSION 100 TONS/YEAR CPS-3

CAPY. CLASS	URBAN BUILTUP	FOREST	OTHER	CONSERVATION USE ONLY	WATER AREAS	CORN	SOY BEANS	CLOSE GROWN CROPS	ROTATION HAY AND PASTURE	PASTURE	TOTAL
1	3	3	3	10	0	1238	429	0	0	0	1686
2E	7	3	1	8	0	4232	1076	0	0	0	5327
2W	2	0	6	8	0	1364	136	0	0	0	1516
2S	0	0	0	0	0	175	0	0	0	0	175
3E	168	79	52	370	0	53190	50681	648	0	0	105188
3W	50	0	9	470	0	0	7302	1845	53	0	9729
3S	0	0	4	7	0	0	810	0	32	0	853
4E	159	66	50	384	0	0	21244	955	1344	0	24202
4W	0	0	0	27	0	0	689	0	27	0	743
4S	0	0	0	0	0	0	0	0	0	0	0
5W	0	0	0	0	0	0	8	0	0	0	8
6E	0	0	27	387	0	0	0	0	0	217	631
6S	0	0	0	0	0	0	0	0	0	0	0
7E	0	0	0	0	0	0	0	0	0	116	116
7W	0	0	0	44	0	0	0	0	0	9	53
7S	0	0	0	0	0	0	0	0	0	0	0
TOTAL	389	151	152	1715	0	60199	82375	3448	1456	342	150227