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Flood risk analysis for the Iowa Statewide Floodplain Mapping Project

Benjamin Samuel Reith
University of Iowa

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FLOOD RISK ANALYSIS FOR THE IOWA STATEWIDE FLOODPLAIN MAPPING PROJECT

by

Benjamin Samuel Reith

A thesis submitted in partial fulfillment
of the requirements for the Master of
Science degree in Civil and Environmental Engineering
in the Graduate College of
The University of Iowa

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Thesis Supervisor: Professor Larry J. Weber

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

Benjamin Samuel Reith

has been approved by the Examining Committee
for the thesis requirement for the Master of Science
degree in Civil and Environmental Engineering at the December 2012
graduation.

Thesis Committee: ______________________________
Larry J. Weber, Thesis Supervisor

____
Nathan C. Young

____
Marian V.I. Muste

____
Witold F. Krajewski

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ABSTRACT

Flooding is a major hazard in the Midwest, accounting for more economic damage than any other hazard. Recent major flooding events in Iowa have created a greater need for the monitoring of floodplain areas. The objective of this paper is to evaluate flood risk through the synthesis of geospatial data with flood maps for thirteen Hydrologic Unit Codes (HUC 8s) in southwest Iowa. Using ArcGIS, exposure of ecosystem services, population, and environmental hazards can be located within the 10, 50, 100, 500 year floodplains. Additionally, the effectiveness of hydric soils as a floodplain proxy is evaluated using SSURGO soil data. An overview of FEMA HAZUS-MH 2.0 flood loss estimation software is provided and a model of the East Nishnabotna HUC 8 is evaluated. An alternative economic loss framework based on an NED land use raster and structure data is compared for the region. This study aims to provide beneficial floodplain information for development and regulation decisions.

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CHAPTER 1: INTRODUCTION

Flooding is the greatest natural hazard in the Midwest, accounting for billions of dollars in damages and loss of life. In 2008, 85 of Iowa's 99 counties were federally declared disaster areas as nine major rivers crested at record levels and twenty two levees were breached (Community Foundation Great River Bend, 2009). This resulted in an estimated $10 billion in damages and the evacuation of over 40,000 Iowans (Baldwin, 2008). The agriculture industry was particularly devastated by flooding events. An estimated 16 percent of Iowa's 25 million tillable acres were inundated, causing billions in loses for local farmers (Baldwin, 2008). The impact of the 2008 events still lingers as many communities continue rebuilding efforts.

In the spring of 2009, the state of Iowa appropriated $1.3 million for the creation of the Iowa Flood Center (IFC) a research unit within the University of Iowa's IIHR Hydroscience and Engineering (IIHR). In addition, the United States Department of Housing and Urban Developed (HUD) granted $15 million to the state of Iowa for floodplain mapping in the 85 counties declared disaster areas (Thomas, 2011). After a successful pilot study, the Iowa Department of Natural Resources (IDNR) awarded $10 million to the IFC to produce flood maps and an additional $5 million to create and submit FEMA approved maps (Thomas, 2011). The IDNR provided additional funding to the United State Army Corps of Engineers (USACE) for mapping of the remaining 14 counties. In 2009 the IFC began work on the Iowa Statewide Floodplain Mapping Project (FPM). Figure 1.1 shows the anticipated sequence for mapping over the next three years (IFC, 2011). Hydrologic Unit Codes or HUC 8s are watersheds that serve the unit of progression for floodplain mapping. Work began in southwest Iowa and as of July 2012, 13 of Iowa's 56 HUC 8s have complete hydraulics.

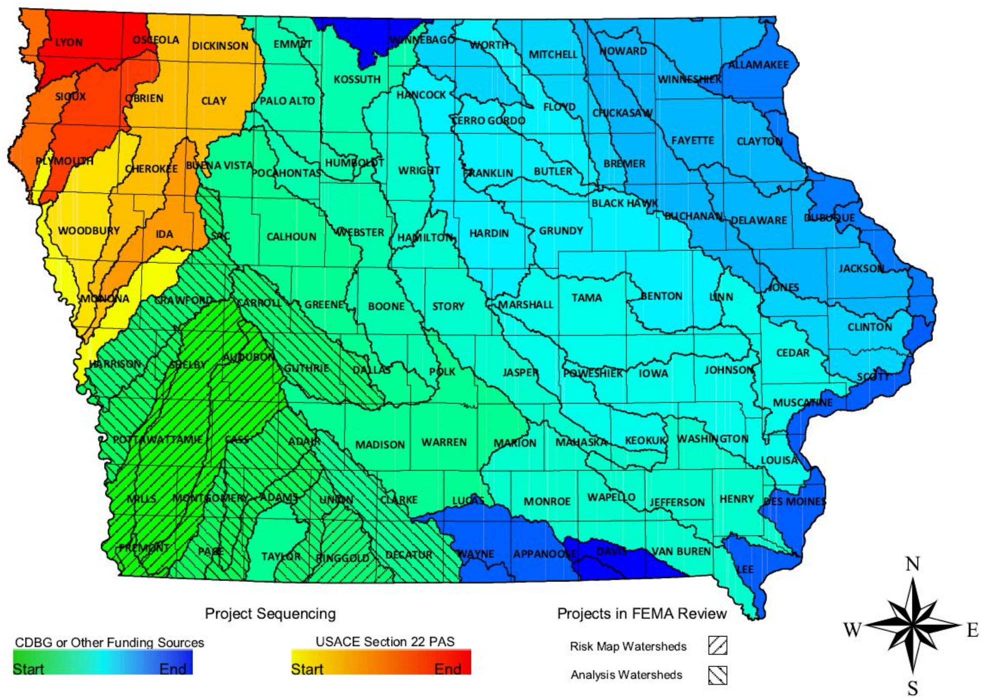

Figure 1.1 Sequence of completion for the statewide floodplain mapping project (IFC, 2011)

In 2011, record rains and rapid snow-melt resulted in the flooding of the Missouri River Basin. Despite record releases from USACE reservoirs, the Missouri River reached record-high levels. Six Iowa counties along the Missouri were declared presidential disaster areas and sustained an estimated $85 million in damages as well as five casualties. The flood also forced long term closings of Missouri River traffic bridges, making it impossible to cross for a stretch of more than 100 miles (National Weather Service, 2011). Despite heightened preparedness, the 2011 floods served as a reminder of the uncontrollability of this hazard.

CHAPTER 2: BACKGROUND INFORMATION

2.1 Floodplain Risk Assessment

Flooding is a natural occurrence. It is neither technically or financially feasible to prevent all properties from flooding. As a result, floodplain risk management strategies must be employed to optimize flood protection benefits and minimize harm. Two methods are employed to achieve this. These involve reducing the likelihood of flooding and reducing the impacts when flooding occurs. At the same time two major drivers of flooding, climate change and land use development, are increasing risk. Altered precipitation patterns and increased storm intensities are largely beyond human influence; however, intelligent land use and development can reduce exposure in potentially hazards areas. Flood risk assessment serves as the main tool for effective risk planning and management. Risk is defined as the possibility of loss or injury and can be expressed by the following equation (Su, Kang, Chang, & Chen, 2005):

$$R = H \cdot V \tag{2.1}$$

Where: R: Risk

H: Hazard, the probability of a destructive phenomenon (flooding)

V: Vulnerability, the degree of loss sustained

Flood hazard is evaluated through the creation of inundation maps. The development of these products typically requires the use of a hydraulic model. Maps used in this study are products of the Iowa Flood Center in conjunction with Iowa DNR. Using high resolution LiDAR data, stream centerlines are delineated and annual exceedance discharges are determined using United States Geological Survey (USGS) regression equations. Water surface elevations are generated in a one dimensional HEC-RAS model and are exported for mapping on a Digital Elevation Model (DEM) (Thomas, 2011). Water surfaces and extents examined in this analysis are for the 10, 50, 100, and 500 year floods, which correspond to annual probabilities of 10%, 2%, 1%, and 0.2% respectively.

Flood vulnerability is measured through use of flood loss functions. Often these relationships correlate damage to flood depth, but are functions of inundation timing for crops. Depth-damage functions vary for specific types of land use zoning, economic activity, and construction features. The two major sources of damage curves in the United States are the USACE and Federal Insurance Agency (FIA). The FIA constructs curves based on historic data using reports for over 300,000 claims (FEMA, 2012).

Exposure is another component of vulnerability and is defined as human activities affected by the hazardous event (Su, Kang, Chang, & Chen, 2005). This includes agriculture, infrastructure, and human life. Analysis of exposure is done by utilizing geospatial and demographic data. Every ten years, the United States Census acquires and records information from the population. Nearly every country has some form of regular data collection. The smallest geographic unit of aggregated data used by the census is known as a block. Until recently, census blocks have served as the highest resolution of data. Studies such as Herath (2003), Su and Kang (2005), and Sanyal and Lu (2005) have coupled hydraulic models with census data at this level to estimate flood losses. Recent developments in geographic information systems (GIS) have enabled higher data resolution. Land cover grids can categorize land up to a resolution of 1m square cells. Georeferencing can pinpoint and classify individual structures, roads, and other critical infrastructure. These improvements enable both more accurate flood map delineation and exposure estimation.

2.2 Indirect Losses

Apart from direct damage, flooding can also cause disruption through secondary effects. Indirect damage is induced by flooding, but occurs in a space or time outside the actual event. Evacuation measures and displacement affects surrounding regions helping the displaced. Road closures and transport detours create traffic disruptions. Disposal of flood-damaged building finishes and structural components can be a significant problem proceeding flood event. Costs for these factors and other indirect implications can be substantial. Government expenditures for emergency evacuation and debris cleanup for 2005's Hurricane Katrina total more than $5 billion, equaling 3.5% of the event's total economic loss (Thieken, Elmer, Kreibich, & Ackermann, 2008).

Business disruptions are a major source of indirect loss. All businesses are forward or backward-linked, relying on regional customers or suppliers. This makes them vulnerable to interruptions in their operations. Any shutdown or damage will cause a ripple effect throughout regional economies. The extent of indirect losses depends on factors such as the availability of market alternatives, length of interruption, and transferability of production. A similar backwards effect is also present. Closed businesses result in reduced demand for external suppliers who may be forced to reduce operations. Disruption of businesses also results in layoffs and lost wages. While these individuals often receive disaster assistance and unemployment compensation, spending throughout the recovery period typically decreases (FEMA, 2012).

Another major indirect loss is the interference of transportation systems. Many studies have examined the impact of floods on transportation infrastructure; however few have focused on the resulting traffic disruption. In a 2005 study, the impact of flooding on urban transportation is assessed for the Boston metro area. Using an Urban Transportation Modeling System (UTMS) and ArcGIS, traffic flows for the region were modeled for 3 scenarios: no flooding, 100-year flood, and 500-year flood. Trips with inundated origin locations or destinations were canceled. Road links with inundation were closed and trips normally using them were rerouted with the shortest possible detour. For the 500 year flooding event, 908,000 inundated road links resulted in an increase of 4,183,000 miles driven each day. The added congestion lowered average road traveling speeds by 2.0 miles per hour, and increased daily vehicle hours traveled by 4.4 million hours for the total metro area (Suarez, Anderson, Mahal, & Lakshmanan, 2005). These staggering totals show how substantial the amount of productivity can be lost from a major natural hazard. Increased vehicle travel hours also results in additional emissions from idling automobiles.

2.3 Flood Risk Analysis in Iowa

The United Nations Education, Scientific, and Cultural Organization's (UNESCO) Hydrology for the Environment, Life and Policy (HELP) program aims to improve the link between hydrology and society. HELP seeks to do this through five key policy issues: water and climate, water and food, water quality and human health, water and the environment, and water and conflict. In March 2009, the Iowa-Cedar Rivers Basin was added to the worldwide network of UNESCO HELP basins. Following the devastation of the 2008 floods, the Iowa-Cedar Rivers Basin has placed an emphasis on flood mitigation and risk management. To address these issues, a grass-roots organization, the Cedar River Watershed Coalition (CRWC) was formed in 2010 (Adkins & Hadish, Floodplain Assessment and Decision Support Tool Iowa in Iowa, 2009). The role of the CRWC and Iowa HELP basin is to build a collaborative group that bridges the gap between researchers, policy makers, and citizens.

In 2010, a resourceful web portal, the Floodplain Assessment and Decision Support Tool (FADST) was made available to the public. Developed in a joint effort by the effort by the USDA Natural Resources Conservation Service (NRCS) and the Iowa DNR, the chief goal of the FADST is to help prioritize floodplain for program use and detailed study. It operates by quantifying activities, infrastructure, and populations within floodplains. Geospatial data from the Iowa DNR, NRCS, Iowa DOT, US Census, and other entities are intersected with a polygon defined by floodplain soils and Hydrologic Unit Code (HUC) boundaries. The quantified values for the 27 layers are then normalized to values ranging from 0-100. They values can be then combined and weighted to analyze scenarios desired by the user. Results can be displayed via geographic information systems (GIS) in a color coded display at a resolution up to a HUC 12 (Adkins & Hadish, Floodplain Assessment and Decision Support Tool Iowa in Iowa, 2009).

2.4 Hazus Multi-Hazard

On a national level the Federal Emergency Management Agency (FEMA) has developed Hazus, a GIS-based software program that can quantify human, property, and financial impacts of natural hazards. It includes models for earthquakes, floods, and hurricanes. The first release of Hazus in 1997 exclusively applied to earthquakes. Development of flood and hurricane models began in 1999 and was included in the 2004 release of Hazus multi-hazard (MH). An enhanced version, Hazus-MH 2.0, was released in May 2011 (Schneider & Schauer, 2006) .

Hazus contains a nationwide database of inventory on critical facilities and lifeline system such as schools, hospitals, utilities, and transportation systems. Population and demographic information are available at the block level from the 2010 U.S. Census. Effects of inundation time, flow velocity, debris generation, and advance warning can also be considered in the model. Using these factors and depth-damage curves developed by the Federal Insurance Administration, damage can be estimated. A Hazus-MH flood model can be operated at three varying levels of accuracy depending on expertise and available data. A Level 1 analysis simply requires the input of a DEM which can be obtained from the USGS National Elevation Dataset (NED). The DEM coupled with stream discharges and other hydraulic data is used to calculate water surface elevations and flood extents. A Level 2 analysis utilizes a Flood Information Tool (FIT) which allows users to input cross-sections and site-specific inventory data. Level 3 involves the manipulation of additional parameters such as structure type and base flood elevation (Scawthorn, et al., 2006).

Figure 2.1 schematically depicts Hazus' flood loss estimation model. Parts (a) and (b) represent the progression from DEM to flood surface elevation. Part (c) shows census and property data overlaid in areas of flooding. In part (d), losses are calculated using appropriate depth-damage relationships for inundated crops and infrastructure. Finally, economic losses are determined in part (e) using an inventory of standard costs. At this step, secondary effects such as business interruptions are also estimated.

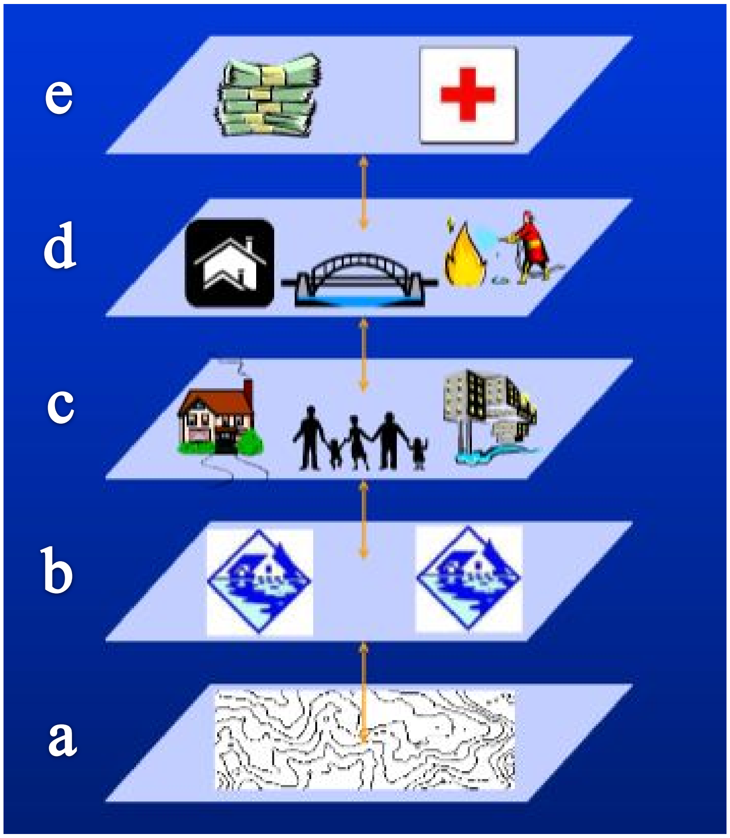

Figure 2.1: Hazus flood loss estimation methodology (Scawthorn, et al., 2006)

Since its release, Hazus flood models have been compared with existing methodologies and real-life hazard occurrences. In 2007, FEMA contracted with the

URS Group to perform a validation study to recreate flood losses for St. George, Utah. According to FEMA records, 28 homes were seriously damaged or destroyed and $230 million in total losses were incurred. The return period of the event was estimated to be the 100 year event and a Level 1 analysis was run at this frequency. A majority of the study region had overestimated floodplain boundaries by Hazus, however the study states "Hazus generally did a good job identifying which areas would likely flood". No quantitative results were included, but Hazus attributes the overestimation to inaccurate DEM resolution and ponded areas from debris blockage. For residential damages, Hazus estimated $4.1 million versus $3.0 million from the county assessor, however there was significant variation between census blocks. It also evaluated total infrastructure damages at $25 million against actual damage totals of $31 million, which represents a reasonable agreement (URS, 2007).

However, studies conducted by others have shown far less correlation. One investigation performed by Ding, White, Ullman, and Fashokun (2008) compared Hazus Level 1 and 2 analyses with results from a highly detailed hydraulics analysis by FEMA for the densely developed White Oak Bayou Watershed in Texas. For low frequency floods (1% and 0.2%), the Level 1 analysis underestimated the size of the floodplain by 60% and Level 2 by 30% when compared to the detailed study. For damage estimates, the Level 1 analysis drastically overestimated damage done for all return periods. For example, the 10 year flood had estimated total losses at $216 million versus $104 million for Level 2 and $41 million for the existing study. As flood frequency decreases these values converge, but still have major disparities. The authors suggest the use of differing damage curves, structure classifications, and building distribution assumptions are a likely cause of these discrepancies (Ding, White, Ullman, & Fashokun, 2008).

CHAPTER 3: GEOSPATIAL ANALYSIS

This study uses a method of overlaying geospatial data with ArcGIS to analyze the impacts of flooding. Exposure of ecosystem services, population, and environmental hazards are located within the 10, 50, 100, 500 year floodplains. Using a NED land use raster, a damage estimation model is created and evaluated. Additionally, the effectiveness of hydric soils as a floodplain proxy is evaluated using SSURGO soil data. This information can be beneficial for floodplain management and planning purposes.

3.1 Study Site

The study region encompasses the Digital Flood Insurance Maps (DRIMS) produced by the Iowa Flood Center. The two primary land units used in this analysis are counties and HUC 8s. Eight digit Hydrologic Unit Codes are watershed boundaries and are most suitable to hydrologic and environmental applications. The structure of local and regional governments makes counties more applicable to considerations such as infrastructure and economic loss. Figure 3.1 depicts the coverage of the study. As of July 2012, 13 of the 56 HUC 8s in Iowa have been mapped, all located in southwest Iowa. The completed region overlaps 27 of Iowa's 99 counties, with 9 falling entirely within mapped HUC 8s. 23 of 27 counties had federal disaster declarations from the 2008 floods (Shelby, Sac, Ida, and Buena Vista are the exceptions). Five counties (Fremont, Mills, Pottawattamie, Harrison, and Monona) were also declared disaster counties in 2011. It is important to note the Missouri River was not modeled as part of the statewide floodplain mapping project, rather it was completed by the USACE. The inclusion would increase flooding in the five disaster counties bordering the river.

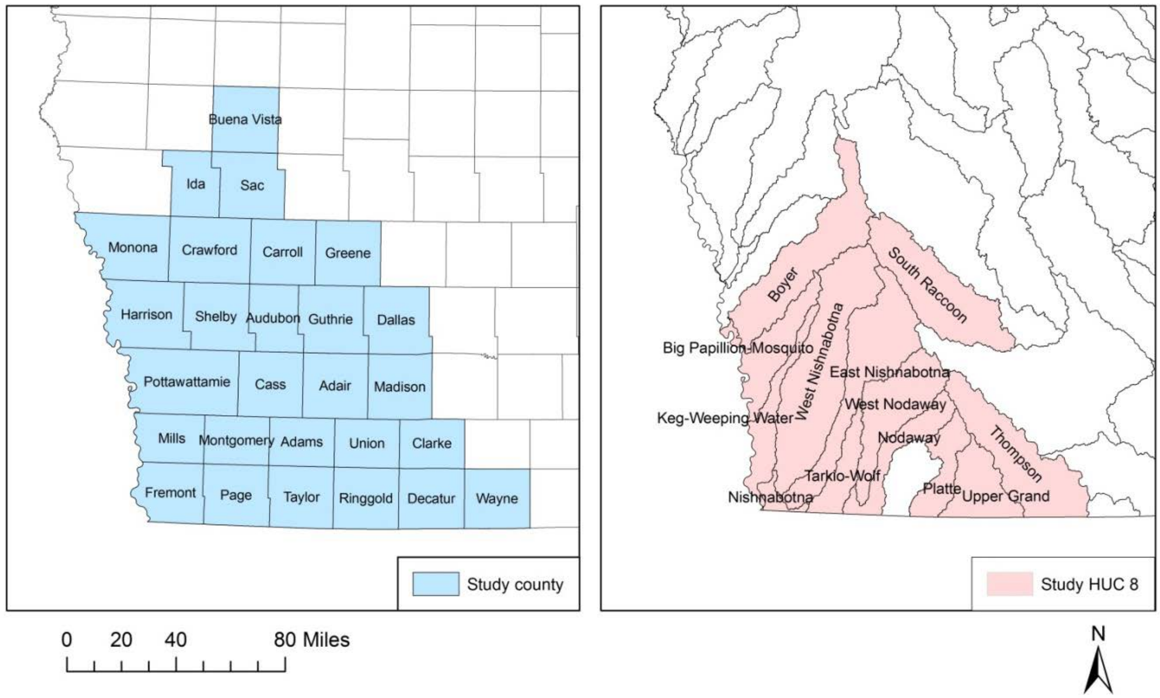

Figure 3.1: Study region by county and HUC 8

3.2 Source Data

Geospatial data was collected from multiple sources. The Iowa DNR Natural Resources Geographic Information Systems (NRGIS) repository provided the 2002 land cover grid, watershed boundaries, environmental and municipal facilities, and structure data for selected counties. The United States Census Bureau contributed county and state boundaries data, and census blocs and tracts from the 2010 Census. Soil data comes from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database. High resolution orthophotos for the study region were acquired from the Iowa Geographic Map Server. All geo-referenced data is projected in Universal Transverse Mercator (UTM), Zone 15, North American Datum 1983 (NAD83).

Digital Flood Insurance Rate Maps or DFIRMS are maps where floodplains of various return periods are mapped according to FEMA guidelines. The Iowa Flood Center produces the maps of southwest Iowa used in this study. Individual streams are modeled, combined, and edited in post-processing to create a finished product. The 10, 50, 100, and 500 year return periods are the inundation levels of interest.

The United States Department of Agriculture provides agricultural commodity prices for Iowa current as of May 31, 2012. The Flood Insurance Agency (FIA) supplies depth-damage curves for residential. Functions for commercial and industrial facilities are provided by The USACE – Galveston. Ecosystem service values for land cover classes are taken from results of a 2004 study performed by Earth Economics. 2010 census data for Iowa and selected counties are obtained using the online resource American FactFinder. Population, housing, and business and industry were the predominant census categories of data used.

3.3 GIS Techniques

The floodplain mapping products server supplies ArcGIS shapefiles of the flood extents for each HUC 8 and return period. These polygon files were combined using the merge feature to obtain a single file which was named 'Master_Flood_Map_XXX', with XXX denoting the return period. For many HUC 8s, these shapefiles had yet to undergo post-processing and quality control. Prior to the hydraulics post-processing in the FEMA submittal process, discrepancies exist in the shapefiles including duplicate polygons. Due to preliminary modeling errors on some reaches, flood boundaries for a lower return period may also extend further than a larger period. Additionally, disconnected ponded areas may be present at lower frequencies but not at higher. Due to these hydraulic inaccuracies, it was essential to modify the shapefiles before performing the overlaying analysis. A flowchart showing pre-analysis processing of the 500 year shapefile is displayed below in Figure 3.2.

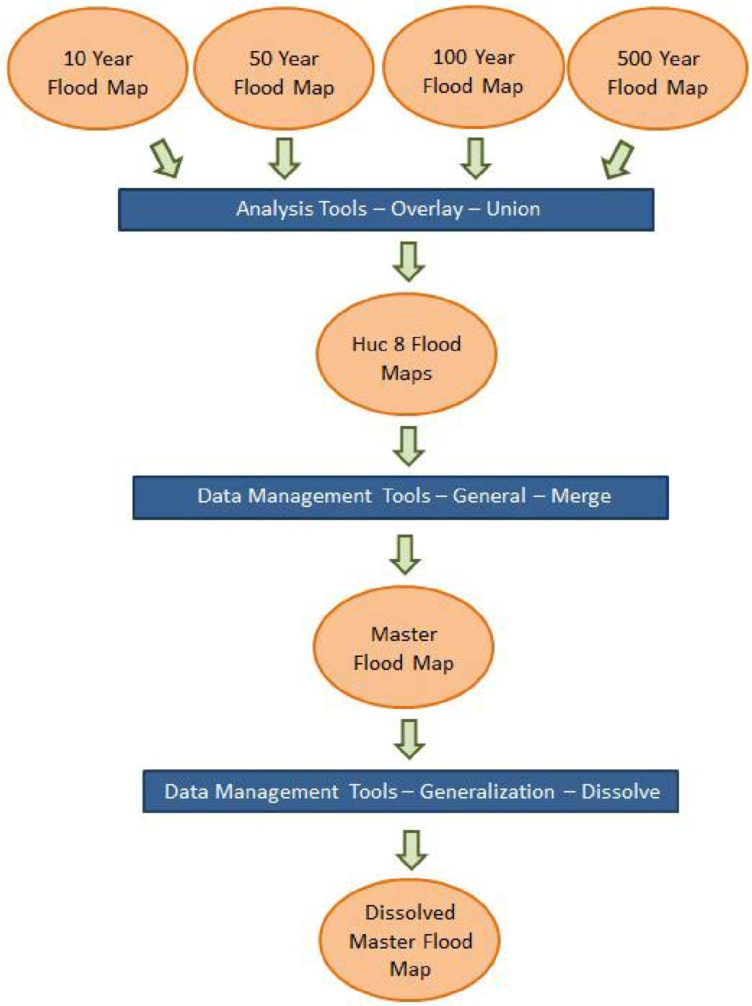

Figure 3.2: Pre-processing of flood shapefiles

The issue of inconsistent flood extents was addressed using the 'Union' feature in ArcGIS. The union function computes the geometric overlap of all input features. For each return period, the corresponding shapefile and each lower return period file were used. For example, the 500 year flood extent was the union of the 500, 100, 50 and 10 year files, while the 50 consisted of the 50 and 10 year union.

The 'Dissolve' tool is used to eliminate duplicate polygons. The dissolve function aggregates features based on a specified attributes. If unspecified, the shapefiles dissolves into a single feature. With these modifications executed, analysis can begin. It is important to note the accuracy of the files is not yet appropriate for DFIRM submittal, but is regarded appropriate for the study.

Discrete and continuous data are the two main types of geospatial data. These require two similar but different methodologies for processing and analysis. Discrete data represents individual features such roads, structures, or utilities. Figure 3.3 depicts the process of intersecting discrete data with the modified flood maps.

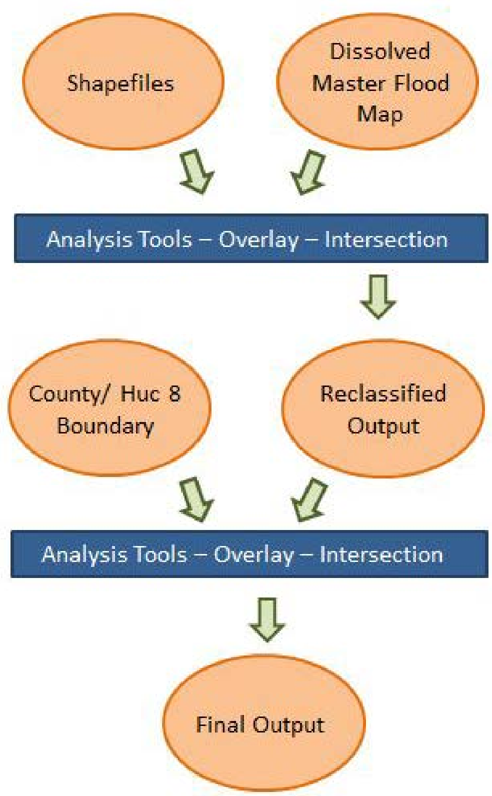

Figure 3.3: Geoprocessing procedure for discrete data

The 'Intersect' tool computes the geometric intersection of selected input features and creates an output feature class. The desired discrete shapefile is intersected with the dissolved flood map to determine features located in the floodplain. This layer can be intersected again with the region of interest to parcel the data by county or HUC 8 unit. The resulting data is exported to Excel for further analysis.

Continuous data contains a large range of numeric values that show change with spatial variability. DEMs and a land use grid are the two types of rasters used in this study. Figure 3.4 displays the methodology of intersecting a continuous raster with the flood maps.

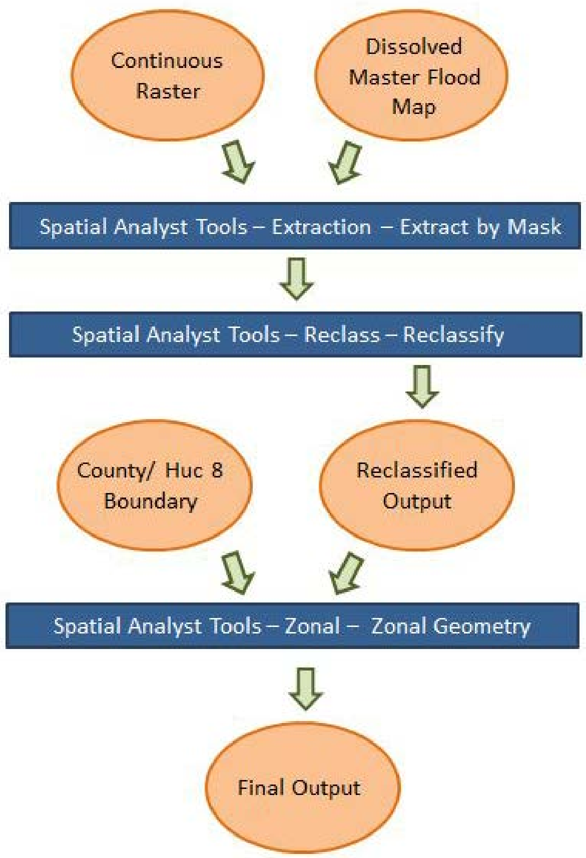

Figure 3.4: Geoprocessing procedure for continuous data

The 'Extract by Mask' tool extracts cells of a raster that correspond to a selected shapefile, which in this case is the flood inundation. For some applications presented in proceeding sections, the values of a raster are reclassified using the 'reclassify' feature. The user inputs the raster, specifies the desire field, and then assigns the values to be remapped. To parse and summarize the raster by county or HUC 8, the 'Zonal Statistics as Table' feature is employed. This tool summarizes the values of a raster within the zones of another polygon and reports the results in tabular form. These tables are again exported to Excel for further analysis.

The procedures above describes the optimal form of evaluation. The storage and processing required for 27 counties worth of data was too intensive for a standard computer. In particular, all raster data, flood maps, and SSURGO soil data provided difficulties. As a result, flood maps were split into units smaller than HUC 8s for more computationally demanding processes. The outputs were then combined to obtain complete results.

3.4 Land Cover

The 2002 NED land cover grid was developed by the Iowa Department of Natural Resources using satellite imagery collected in 2002 and 2003. It contains 17 unique classifications at a resolution of 15 meters. When intersected with flood inundation files, the landscape of flood prone areas can be characterized. This is depicted within ArcGIS in Figure 3.5. Figure 3.6 displays the composition of inundated land with respect to return period.

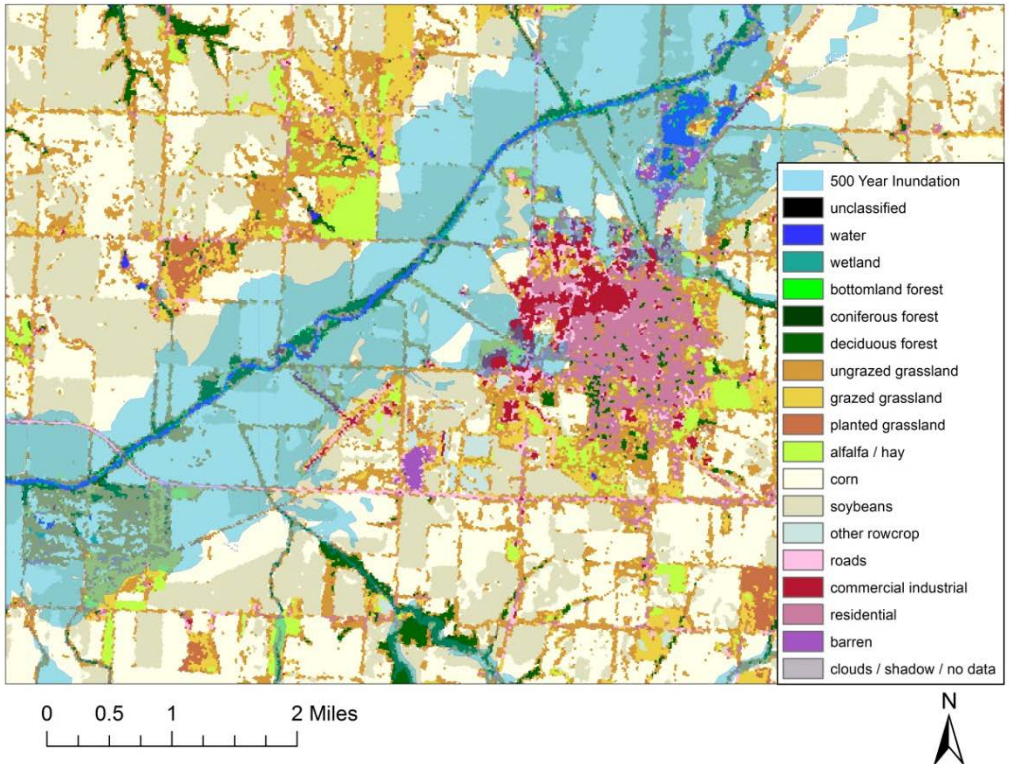

Figure 3.5: Inundated land use for the 500 year flood

Inundation extents range from 445,755 acres for the 10 year event up to 724,011 for the 500 year. A vast majority of flooded area is classified as agricultural land. The predominant land cover types are corn, soybeans, and ungrazed grassland which combine for an average of 77.3%. This reflects the topography of Iowa as a whole. Developed lands (residential, commercial/industrial, and roads) account for 2.1%, while forests comprise 9.1%. Detailed results by HUC 8 and county are shown in Appendices A and B, respectively.

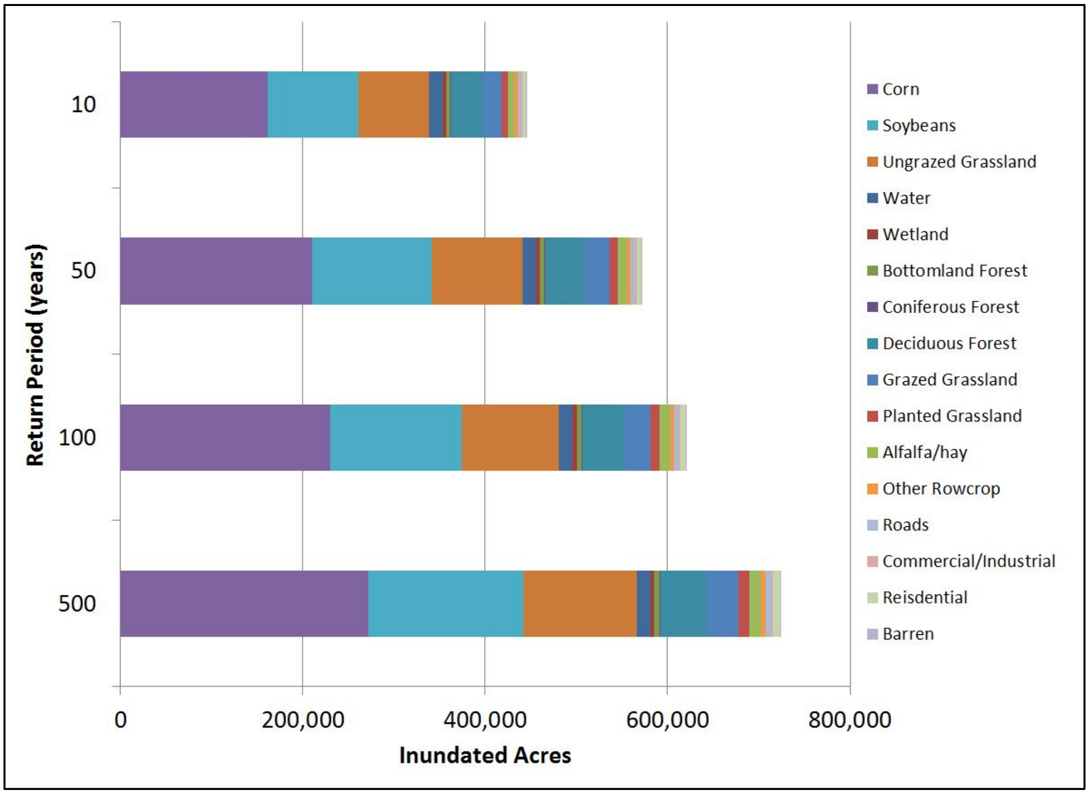

Figure 3.6: Floodplain land cover for southwest Iowa

Comparing the land cover compositions for each return period, shows how floodplains change with extent. Table 3.2 shows incremental changes in land cover for each category. The 50 year floodplain is 35.42% larger than the 10 year. When normalized to the change in frequency (factor of 5), this corresponds to a 7.08% increase. The 100 year event is 8.45% larger than the 50, but when adjusted (factor of 2) corresponds to a 4.23% incremental increase. For 500 years, these percentages are 16.35% and 3.27%. Floodplain extents expand more rapidly to incremental changes at lower return periods. For the same decrease in frequency, floodplain inundation increases at more than twice the rate for the 10 to 50 year interval in comparison to the 100 to 500 year timeframe.

Table 3.1: Incremental changes in flood plain land cover

Incremental Increase in Floodplain Landuse (%)									
Return Period	Water	Wetland	Bottomland Forest	Coniferous Forest	Deciduous Forest	Ungrazed Grassland	Grazed Grassland	Planted Grassland	Alfalfa/ hay
10	---	---	---	---	---	---	---	---	---
50	10.96	18.1	19.97	19.08	35.06	34.17	36.07	33.01	40.5
100	1.46	2.79	3.27	6.13	6.05	7.63	8.08	9.1	8.82
500	0.81	3.38	3.38	9.16	11.44	15.5	17.76	17.09	18.47
Corn	Corn	Soybeans	Other Rowcrop	Roads	Commercial/ Industrial	Reisdential	Barren	Total	Normalized
---	---	---	---	---	---	---	---	---	---
36.32	36.32	39.36	44.2	35.66	36.55	34.42	24.75	35.42	7.08
9.61	9.61	9.2	7.51	9.22	10.85	7.45	4.01	8.45	4.23
17.69	17.69	17.69	18.38	19.85	22.73	16.71	7.18	16.35	3.27

Figure 3.7 shows a breakdown for each land use type and the percentage falling within the four increments. In total, the 10 year floodplain is approximately 62% the size of the 500. Wetlands and bottomland forests are more prevalent in riparian areas near rivers as they each contain 86% of their total within the 10 year inundation. Coniferous and deciduous forests also have higher than average values for the return period. In contrast, infrastructure such as commercial/industrial land and roads are less prevalent within the smallest extent. In the 100 to 500 year increment however, 19% and 17% percent respectively of their totals are contained in comparison to the 14% overall average. For this same increment, only 3% of wetlands and bottomland forest land totals exist. Agricultural lands tend to represent the incremental averages, as they are the dominant land type in the region.

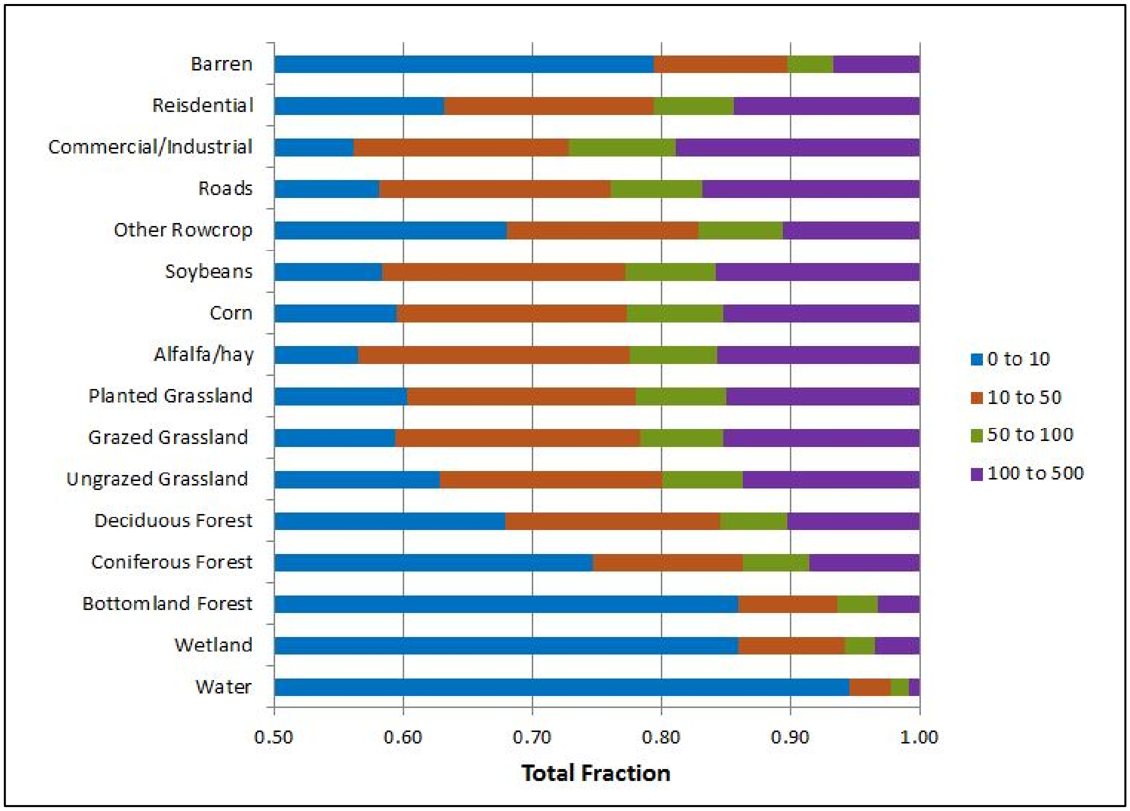

Figure 3.7: Incremental composition of floodplain landcover

3.5 Economic Damage Estimation

3.5.1 Agricultural Damage

Agriculture damage can be evaluated using results from the floodplain land use analysis. Agricultural commodity prices for Iowa were obtained from the United States Department of Agriculture and are current as of May 31, 2012. Average yields per acre were obtained the National Agriculture Statistical Service (NASS). Following the appropriate conversions, values for alfalfa/hay, corn, soybeans and oats were calculated per 15m cells. A summary of values and calculations are shown in Table 3.2. The generated shapefiles were reclassified using the Spatial Analysis Tools in ArcGIS. The 'Other Rowcrops' land use category was assumed to be oats, as they are the most abundant crop in Iowa not specified in the grid. The results were summed and parsed by both HUC 8 and county using the 'Zonal Statistics as Table' tool.

Table 3.2: Crop exposure calculations

Crop Type	Price/Unit	Yield/Acre	Cost Per Acre ($)	Cost per Cell ($)
Alfalfa/hay	$142/ ton	5.65	802.30	44.61
Corn	$6.1/BU	135.26	825.09	45.87
Soybeans	$13.6/BU	45.88	623.97	34.69
Other Rowcrops (oats)	$3.7/BU	69.52	257.22	14.30

Agricultural damage curves supplied by the USACE are shown below in Figure 3.8. Damage to crops is a function of inundation timing in contrast to buildings, which use depth. Corn has time a period of 64 days from July to September where 100% damage occurs upon inundation. This timeframe is 34 days in July-August for Soybeans, and a mere 3 days in late August for alfalfa/hay. The date of flooding was assumed to be Julian date 243 or August 29 which coincides with maximum damage for all crops.

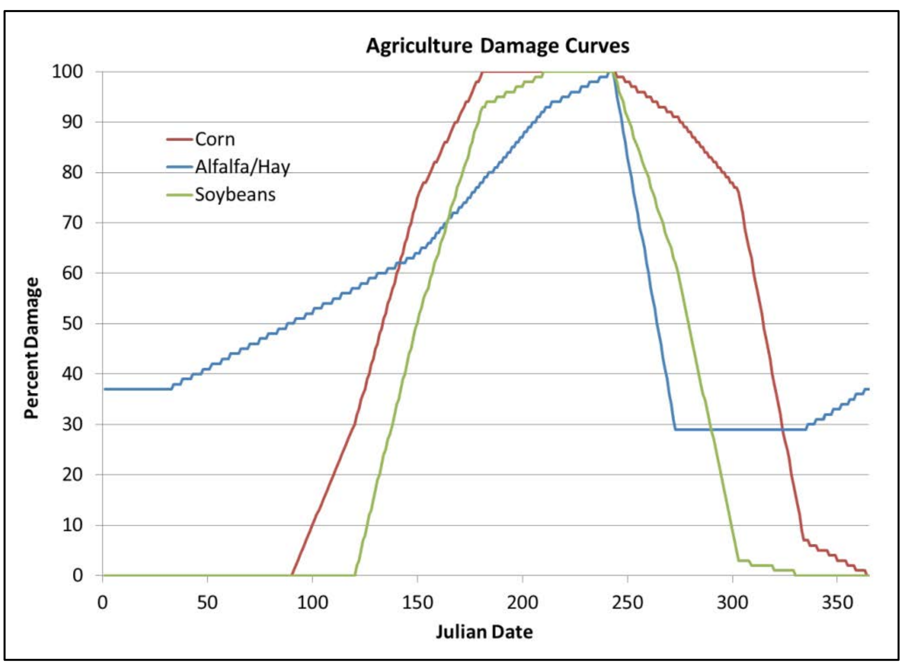

Figure 3.8: Agriculture losses by return period

Results of crop damage broken down by return period are shown in Figure 3.9. For the 500 year event, there is $340 million dollars in agricultural damage decreasing to $202 million for the 10 year occurrence. Corn is responsible for 65% of total damage as it comprises the largest amount of agricultural land and also yields the highest value per acre. Alfalfa and soybeans contribute 31% and 3% of totals respectively while oats comprise less than 1%.

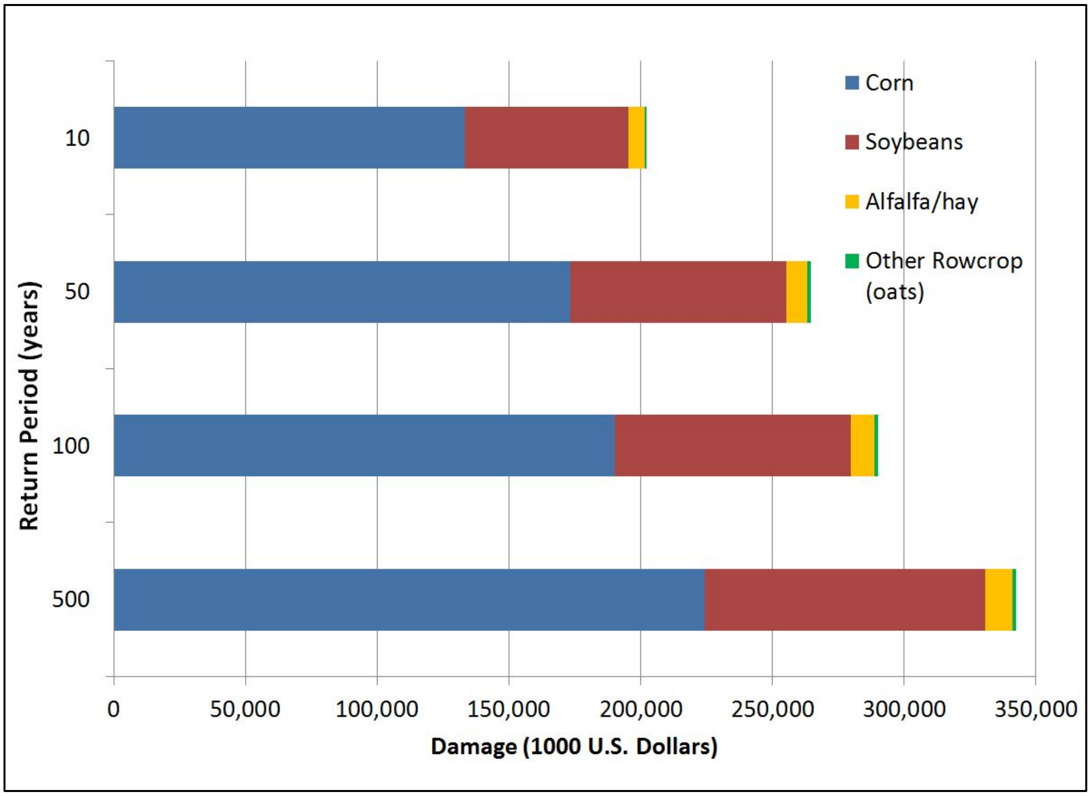

Figure 3.9: Agriculture losses by return period

Table 3.3 displays agricultural losses partitioned by HUC 8. More detailed results by HUC 8 and county are included in Appendices A and B. Crop damage was normalized by inundation area to obtain an average value per acre. Boyer watershed (HUC 10240002) suffers the greatest agricultural losses ranging from $33 to $62 million depending on flood frequency. Accounting for differences in inundation area, the Nishnabotna watershed (HUC 10240004) has the highest losses near $600 in crop damage per acre. For most regions, crop loss per acre decreases as return period decreases. This suggests that as inundation boundaries extend, crop lands are proportionally more likely to be inundated, than unaltered natural lands.

Table 3.3: Agriculture losses by HUC 8

	Inundation Area (sqm)				Agricultural Losses ($)				Loss Per Acre ($)			
HUC 8	500	100	50	10	500	100	50	10	500	100	50	10
7100007	106.41	89.16	82.77	63.50	29,893,200	24,287,589	22,278,026	16,153,130	439	426	421	397
10230006	88.10	78.29	72.42	57.08	27,030,652	23,718,613	21,970,603	17,047,139	479	473	474	467
10230007	150.08	133.06	123.66	99.37	51,505,529	45,498,886	42,172,366	33,431,206	536	534	533	526
10240001	111.71	106.53	104.48	97.07	38,915,149	37,209,427	36,506,144	34,272,060	544	546	546	552
10240002	189.48	154.93	141.51	107.16	62,413,512	50,057,558	45,204,706	33,118,844	515	505	499	483
10240003	130.43	106.79	97.52	73.27	40,609,880	32,560,981	29,336,096	21,130,237	487	476	470	451
10240004	32.07	34.80	30.33	32.18	12,013,179	13,327,195	11,425,046	12,466,023	585	598	589	605
10240005	17.99	11.97	10.64	7.43	4,709,617	2,806,797	2,469,934	1,560,552	409	366	363	328
10240009	78.62	58.87	50.55	33.60	24,166,233	17,099,051	14,077,409	8,471,000	480	454	435	394
10240010	41.60	36.14	32.87	22.39	11,353,834	9,631,450	8,543,700	5,174,699	426	416	406	361
10240012	41.19	37.07	34.00	20.01	10,018,452	8,943,423	8,057,304	4,243,524	380	377	370	331
10280101	38.70	29.82	26.70	19.08	8,488,795	6,107,319	5,407,848	3,731,242	343	320	316	306
10280102	104.89	93.06	86.17	64.36	21,282,020	18,665,972	16,985,804	11,531,068	317	313	308	280
Total	1,131	971	894	696	342,400,051	289,914,259	264,434,986	202,330,723	5,941	5,806	5,730	5,480

3.5.2 Road Damage Estimation

Flooding can damage roadways in multiple ways. Overtopping floodwaters can harm road surfaces, erosion can cause embankment slopes to fail, and culverts can be washed away. A study prepared for the USACE developed damage functions based on road type and flood water force. Relationships were established using 19 sites from Missouri, Nevada, and Texas. For a standard 2-3 meter asphalt lane, damage from submergence is 10% under low force flood conditions such as riverine flooding (BMA Engineering, 2004). The land use grid was used to calculate damage to roadways. The analysis makes the following assumptions:

- All roads are undivided 2 lane rural roads with 5’ paved shoulders
- Construction of this road type costs $2,388,000 per mile (Florida Department of Transportation)
- Upon inundation, roads lose 10% of their value
- Each 15m grid cell classified as ‘road’ represents a 15m length of road
- Completing the proper conversions, each inundated road cell represents $2,225 in damages

Road cells were reclassified and analyzed using the same procedure used for agriculture. Table 3.4 summarizes road mileage and damage for each HUC 8. Results at the county level are included in Appendix B. For the 500 year event, 1008 miles are inundated resulting in $112 million in damages. For the 10 year event, this decreases to 586 miles and $65 million. When comparing these values from real scenarios in the study, the calculated values seem high. This likely is due to the low 15m resolution of the land use grid. The DFIRMs produced by the statewide project are mapped using 1m DEMs, which in comparison have 225 times greater resolution. At 1m resolution, road embankments can be captured. Many segments of road avoid inundation due to these embankments; however areas within the 15m cell are inundated. This triggers a false positive as just a small portion of the cell is inundated. Through visual inspection of satellite imagery and the clipped land use grid, approximately half of road cells were falsely identified and are excluded from the results.

Table 3.4: Road damage by HUC 8

	Length of Inundated Road (miles)				Total Road Damage ($)			
HUC 8	500	100	50	10	500	100	50	10
7100007	25.55	19.18	16.96	11.12	6,101,674	4,579,360	4,050,535	2,655,512
10230006	82.40	69.63	64.24	51.37	19,676,244	16,628,512	15,341,116	12,267,512
10230007	78.44	66.31	60.50	45.61	18,732,430	15,833,721	14,448,012	10,891,116
10240001	70.94	64.58	63.50	57.95	16,941,047	15,420,802	15,163,116	13,837,430
10240002	33.74	27.48	23.55	14.44	8,056,570	6,563,233	5,623,558	3,448,233
10240003	42.80	31.06	27.45	18.37	10,221,547	7,415,977	6,554,953	4,386,872
10240004	19.81	19.48	18.14	16.80	4,731,488	4,650,767	4,330,988	4,012,244
10240005	3.79	2.32	1.96	1.33	905,523	553,663	467,767	317,709
10240009	13.33	9.30	8.10	5.50	3,183,302	2,219,826	1,934,198	1,313,267
10240010	6.47	5.43	4.85	3.20	1,544,047	1,297,744	1,159,070	763,744
10240012	12.32	10.69	9.88	6.88	2,942,174	2,553,058	2,358,500	1,643,395
10280101	20.19	15.71	13.87	9.33	4,820,488	3,752,488	3,311,628	2,227,070
10280102	59.17	48.90	43.58	30.76	14,130,302	11,676,593	10,406,791	7,345,605
Total	469	390	357	273	111,986,837	93,145,744	85,150,233	65,109,709

3.5.3 Georeferenced Structures

Individual structures were georeferenced off of 2010 NAIP aerial photography and classified into 16 building categories. The datasets are developed as part of the Iowa Geocoding project and as of July, 2012 exist for 17 of the 27 southwest Iowa counties located within the study site. All points are referenced to the center of the structure.

3.5.3.1 Data Reconstruction

For the ten unmapped counties, structure data was reconstructed off of the land use grid. The sixteen building categories were regrouped into three main groups: commercial/industrial, agriculture, and residential. These categories were selected to correspond to the three land use categories of similar classification. Results from section 3.4 were used to determine the number of inundated residential acres for each county. This was done for all four return periods. For the seventeen counties with completed structure data, the total amount of inundated residential structures (sum of multi-unit, single-unit, and mobile homes) was calculated and recorded. The number of flooded residential structures was then plotted against the area of inundated land classified as residential, shown in Figure 3.10 below. A regression was performed on the plotted data to obtain a representative equation for the relationship. An approximate number of residential structures was determined for the ten counties missing data using equations and inundated land uses. Proportions representative of the existing seventeen counties were then applied to the new data. Of all residential structures, 88% were single-unit, 8% were multi-unit, and 4% were mobile homes.

Commercial, industrial, and agricultural buildings followed a similar procedure. The sums of inundated commercial and industrial buildings were plotted against the inundated land use of the same category. Using the regression equations and proportions (89% commercial, 11% industrial), structure quantities were estimated for the ten counties. Inundated agriculture structures were plotted against the sum of all inundated crops (corn, soybeans, alfalfa/hay, and other rowcrops).

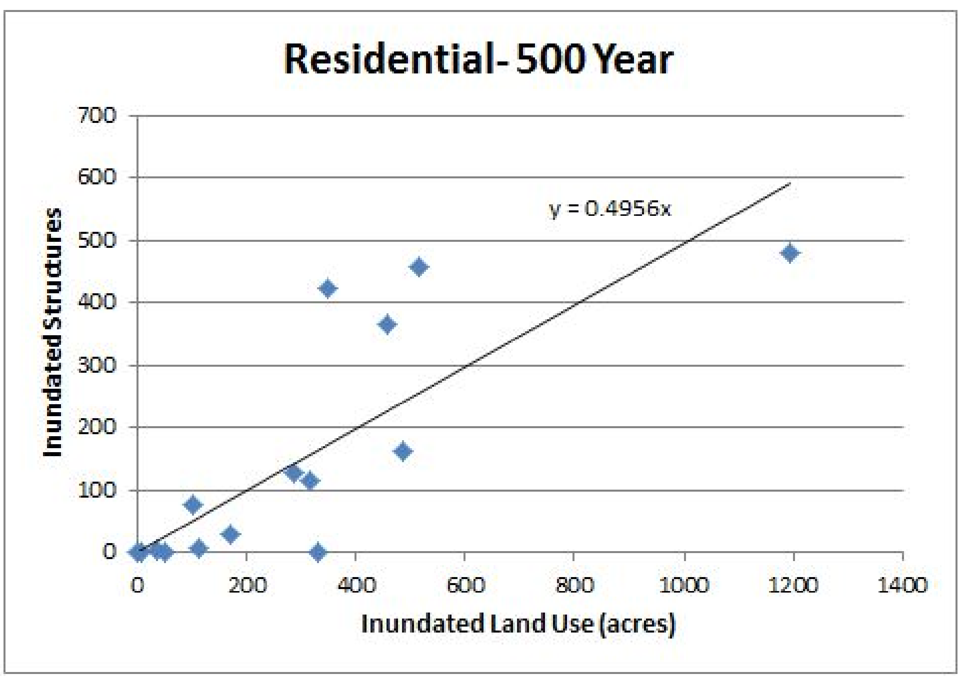

Figure 3.10: Regression for residential structure data reconstruction

Table 3.5 displays a summary of the inundated structures for southwest Iowa. More detailed results, breaking down each building classification per county are included in Appendix A. Reconstructed results by HUC 8 are included in Appendix B. Cells shaded in blue denote reconstructed data. The nine counties that have been fully mapped by the FPM project are denoted in bold lettering. 11,068 buildings fall within the 500 year floodplain. Of this 5,889 are classified as residential, 975 are related to business and industry, and 4,204 are agriculture structures such as barns. These numbers decrease to 3,147, 502, and 1,985 respectively for the 10 year event. Pottawattamie County has the greatest damage for residential, commercial, and industrial structures as it contains the largest city in the study region, Council Bluffs. Fremont County has the highest number of agricultural structure .

Table 3.5: Summary of georeferenced structure data.

Total Structures												
County	500			100			50			10		
	Residential	Commercial/ Industrial	Agriculture	Residential	Commercial/ Industrial	Agriculture	Residential	Commercial/ Industrial	Agriculture	Residential	Commercial/ Industrial	Agriculture
Adair	104	2	89	79	1	63	71	1	51	43	1	31
Adams	217	10	86	171	7	69	150	7	45	88	3	23
Audubon	**108**	**15**	**86**	**76**	**8**	**46**	**66**	**6**	**32**	**29**	**2**	**14**
Buena Vista	1	0	3	1	0	3	1	0	2	1	0	2
Carroll	128	36	208	55	14	139	47	8	102	35	4	63
Cass	**163**	**77**	**120**	**100**	**38**	**73**	**63**	**34**	**58**	**17**	**17**	**20**
Clarke	0	0	3	0	0	2	0	0	1	0	0	1
Crawford	31	17	199	9	6	71	6	3	53	0	0	16
Dallas	6	0	22	3	0	17	3	0	17	2	0	12
Decatur	0	1	11	0	1	4	0	0	1	0	0	1
Fremont	**480**	**162**	**779**	**436**	**145**	**655**	**431**	**144**	**651**	**379**	**130**	**612**
Greene	0	0	0	0	0	0	0	0	0	0	0	0
Guthrie	116	8	144	70	6	99	58	5	75	25	0	22
Harrison	423	126	675	366	114	559	342	96	476	288	68	268
Ida	0	0	1	0	0	0	0	0	0	0	0	0
Madison	10	1	7	9	1	6	9	1	5	7	1	4
Mills	**459**	**67**	**478**	**393**	**56**	**398**	**366**	**49**	**371**	**328**	**35**	**337**
Monona	0	0	1	0	0	0	0	0	0	0	0	0
Montgomery	**366**	**72**	**83**	**111**	**23**	**44**	**52**	**10**	**33**	**16**	**1**	**22**
Page	**381**	**20**	**170**	**303**	**12**	**123**	**271**	**10**	**107**	**191**	**7**	**75**
Pottawattamie	**2383**	**318**	**645**	**1783**	**263**	**465**	**1609**	**246**	**421**	**1491**	**215**	**334**
Ringgold	**181**	**15**	**132**	**142**	**11**	**91**	**128**	**11**	**73**	**73**	**9**	**37**
Sac	3	0	52	0	0	36	0	0	32	0	0	17
Shelby	**78**	**15**	**105**	**67**	**5**	**40**	**54**	**4**	**29**	**0**	**1**	**21**
Taylor	120	1	34	100	1	27	92	1	22	59	1	14
Union	122	11	65	105	9	55	99	9	48	73	7	38
Wayne	9	1	6	7	1	4	5	1	3	2	0	1
Total	5,889	975	4,204	4,386	722	3,089	3,923	646	2,708	3,147	502	1,985
	11,068			8,197			7,277			5,634		

Reconstructed data is denoted in blue. Fully mapped counties are denoted in bold lettering.

3.5.3.2 Infrastructure Damage

Total building damage was estimated using geospatial and structure data and depth-damage curves. Average structure values and square footages were obtained for Iowa from the 2010 Census and the 2012 National Construction Estimator. In order to apply damage curves, the total value of each structure must be known. Table 3.6 displays assumptions for estimating economic losses and their sources.

Average values for single-unit and modular homes were taken directly from the U.S. Census.   Average square footages for commercial and industrial buildings were taken from Hazus which assumes typical sizes. Value per square foot data was also obtained from Hazus. All agricultural structures were assumed to be barns of average size (1,200 square feet) and value ($35,550) for Iowa. These figures were obtained from National Construction Estimator guide for 2012.

Table 3.6: Structural damage assumptions

Structure Classification	Average Square Footage	Value/ Square feet ($)	Average Value ($)	Percent Damage	Loss Per Structure ($)	Source
Single Unit Residential			123,000	20	24,600	Census
Mulit-Unit Residential	5,000	50	250,000	20	50,000	Beacon
Modular Residential			20,400	20	4,080	Census
Commercial	5,000	82.63	413,150	10	41,315	Census/Hazus
Industrial	30,000	75.95	2,278,500	10	227,850	Census/Hazus
Agricultural			35,550	25	888	National Construction Estimator

Square footage and value data for multi-unit residential structures are absent in both census statistics and Hazus inventory. To acquire reasonable estimates for this category, Beacon, a web-based GIS property viewer is used. Beacon enables users to select and view parcels with information such as classification, owner, acreage, and value. Apartment and condominium units were located in southwest Iowa and their square footages were measured using a built-in tool. Values of these buildings were also noted. Upon examination of the values, typical values were assumed. Geospatial data featured in Beacon would be beneficial to this analysis, but source data is unavailable to the public.

Figure 3.11 presents the depth-damage relationships used in the study. Residential damage curves from the Federal Insurance Agency for RES1 Occupancy assume a one-story, no basement structure. Commercial, industrial, and agriculture damage curves for COM1, IND1, and AG1 occupancies were developed by the USACE-Galveston. Incorporation of depth grids and applying unique values in to damage curves for individual structures results in the greatest accuracy of loss estimation. However, this requires substantial time and geoprocessing, therefore was determined to be beyond the scope of this study. Upon inspection of depth grids, a flood depth of one foot was selected. This value underestimates for structures immediately adjacent to streams and may overestimate for small streams and structures on the floodplain fringe, but overall is most representative of a medium-large river floodplain. At this depth, interior finishings and inventory are damaged, but structural failure or damage is not imminent.

For one foot of inundation, residential units are expected to be damaged 20%, commercial and industrial 10%, and agricultural structures 25%. These percentages were multiplied the average structure value to obtain the loss per structure. Losses per structure were combined with infrastructure data from the previous section and summed for total economic losses.

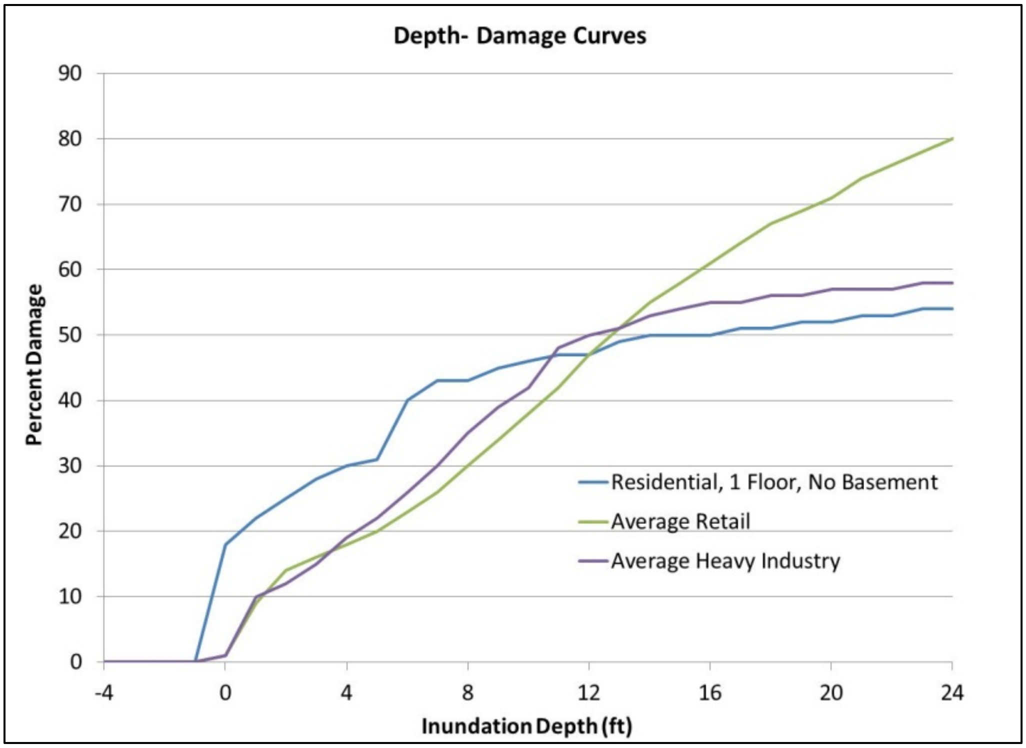

Figure 3.11: Depth-damage curves for selected occupancy classes

Table 3.7 displays a summary of the inundated structures for southwest Iowa. More detailed results, breaking down building classifications per county are included in Appendix A. Cells shaded in blue denote reconstructed data. The nine counties that have been fully mapped by the FPM project are denoted in bold lettering. For the 500 year event, there is $240 million in structure losses. For more frequent events, these totals are $178 million, $158 million, and $125 million. Of these totals, 54% is residential homes, 15% is commercial, 14% is agricultural, 10% is industrial, 6% is multi-unit homes, and 1% modular units. While agricultural structures are prevalent, their lower value ($35,550) results in an overall low contribution to damage totals. Conversely, industrial structures are less common and receive proportionally less damage; their high average value ($2.28 million) enables them to influence totals. Among fully completed counties, Pottawattamie suffers the greatest damages at $86 million for the 500 year flood decreasing to $55 million for the 10 year. Shelby County, located more upstream of major rivers receives the least damages, at a mere $2.3 million for the 500 year event decreasing down to $228,000.

Table 3.7: Summary of structural losses by county

Structure Losses								
County	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
Adair	195	3,553,138	143	2,635,468	123	2,332,018	75	1,409,788
Adams	313	6,949,330	247	5,507,538	202	4,747,358	114	2,588,878
Audubon	**209**	**4,560,440**	**130**	**2,886,320**	**104**	**2,407,865**	**45**	**955,615**
Buena Vista	4	51,263	4	51,263	3	42,375	3	42,375
Carroll	372	6,716,880	208	2,924,243	157	1,964,180	102	1,073,173
Cass	**360**	**9,739,075**	**211**	**5,429,778**	**155**	**4,216,125**	**54**	**1,671,375**
Clarke	3	26,663	2	17,775	1	8,888	1	8,888
Crawford	247	3,586,118	86	1,266,318	62	722,063	16	142,200
Dallas	28	343,125	20	224,888	20	224,888	14	155,850
Decatur	12	139,078	5	76,865	1	8,888	1	8,888
Fremont	**1,421**	**28,030,543**	**1,236**	**24,893,788**	**1,226**	**24,632,363**	**1,121**	**22,157,670**
Greene	0	0	0	0	0	0	0	0
Guthrie	268	4,609,415	175	2,995,248	138	2,445,433	47	769,485
Harrison	1,224	23,912,243	1,039	20,832,938	914	18,398,895	624	13,375,615
Ida	1	8,888	0	0	0	0	0	0
Madison	18	374,928	16	341,440	15	332,553	12	274,465
Mills	**1,004**	**17,621,035**	**847**	**14,933,715**	**786**	**13,544,053**	**700**	**11,603,693**
Monona	1	8,888	0	0	0	0	0	0
Montgomery	**521**	**14,010,783**	**178**	**4,466,340**	**95**	**1,966,973**	**39**	**548,360**
Page	**571**	**12,603,485**	**438**	**9,592,638**	**388**	**8,550,328**	**273**	**6,057,743**
Pottawattamie	**3,346**	**85,792,013**	**2,511**	**66,070,128**	**2,276**	**60,314,493**	**2,040**	**54,718,030**
Ringgold	**328**	**6,805,105**	**244**	**5,073,843**	**212**	**4,589,988**	**119**	**2,773,848**
Sac	55	535,950	36	319,950	32	284,400	17	151,088
Shelby	**198**	**2,305,783**	**112**	**1,042,490**	**87**	**663,838**	**22**	**227,953**
Taylor	155	3,446,890	128	2,862,398	115	2,595,760	74	1,703,100
Union	198	4,371,288	169	3,751,303	156	3,541,490	118	2,700,105
Wayne	16	341,440	12	274,465	9	190,978	3	58,088
Total	11068	240,443,780	8197	178,471,133	7277	158,726,185	5634	125,176,268

Reconstructed data is denoted in blue. Fully mapped counties are denoted in bold lettering.

3.5.4 Debris Estimation and Removal Costs

The cleanup and disposal of debris is a major effort following a flood event. The amount of generated debris and removal costs was estimated through structure data and resources from FEMA. Debris generation is based on three factors: water depth, occupancy type, and foundation type. FEMA's *Debris Management Guide* is used to estimate debris weight using these factors. A depth range of 0' - 4'is assumed. At this range, no structural or foundation damage occurs. All damage is attributed to finishes such as carpet, drywall, and insulation. All buildings are assumed to be without basements. Table 3.8 displays all values used in calculations. According to FEMA cost codes, it costs $20 per cubic yard for removal of debris from cradle to grave. It can also be approximated that a ton of debris equivalent to two cubic yards (FEMA, 1999).

Table 3.8: Debris generation and removal costs

Occupancy Type	Depth of Flooding	Debris Weight (tons/1,000 sq. ft.)	Square Footage	$ Per Structure
Residential	0' - 4'	4.1	1,800	295
Commercial	0' - 4'	1.8	5,000	360
Industrial	0'- 4'	0.5	30,000	600
Agricultural	0' - 4'	0.5	5,000	100

Estimated debris removal costs per structure were multiplied by the respective number of inundated structures per occupancy type. A summary of results is shown in Table 3.9. Cells shaded in blue denote reconstructed data. The nine counties that have been fully mapped by the FPM project are denoted in bold lettering. For the 500 year flood, 11,068 inundated buildings generate $2.23 million in debris removal costs, decreasing to $1.88 million, $1.59 million, and $1.26 million for higher frequency events.

While these are notable amounts, they only account for roughly 0.3% of total damage estimates.

Table 3.9: Debris removal costs by county

Debris Removal								
County	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
Adair	195	40,300	143	29,965	123	26,261	75	16,001
Adams	313	78,615	247	60,105	202	50,646	114	28,908
Audubon	209	42,960	130	30,140	104	24,350	45	10,387
Buena Vista	4	595	4	595	3	495	3	495
Carroll	372	60,960	208	35,645	157	26,177	102	17,489
Cass	360	64,885	211	51,440	155	33,265	54	11,455
Clarke	3	300	2	200	1	100	1	100
Crawford	247	30,245	86	12,155	62	7,718	16	1,600
Dallas	28	3,970	20	2,585	20	2,585	14	1,790
Decatur	12	1,100	5	760	1	100	1	100
Fremont	1,421	230,300	1,236	250,160	1,226	229,493	1,121	206,461
Greene	0	0	0	0	0	0	0	0
Guthrie	268	49,220	175	32,950	138	26,074	47	9,575
Harrison	1,224	200,685	1,039	208,030	914	173,450	624	129,136
Ida	1	100	0	0	0	0	0	0
Madison	18	3,650	16	3,615	15	3,371	12	2,681
Mills	1,004	187,405	847	177,335	786	157,574	700	139,556
Monona	1	100	0	0	0	0	0	0
Montgomery	521	121,070	178	46,145	95	21,184	39	7,136
Page	571	130,595	438	106,245	388	93,189	273	65,741
Pottawattamie	3,346	788,485	2,511	674,125	2,276	580,259	2,040	528,901
Ringgold	328	67,795	244	55,190	212	47,820	119	27,563
Sac	55	6,085	36	3,600	32	3,200	17	1,700
Shelby	198	34,710	112	25,805	87	19,694	22	2,316
Taylor	155	38,800	128	32,560	115	29,556	74	19,021
Union	198	43,090	169	39,955	156	36,333	118	27,231
Wayne	16	3,255	12	2,825	9	1,991	3	690
Total	11068	2,229,275	8197	1,882,130	7277	1,594,885	5634	1,256,033

Reconstructed data is denoted in blue. Fully mapped counties are denoted in bold lettering.

3.5.5 Total Economic Losses

Total economic losses were calculated by summing damage results from agriculture, roads, structures, and debris removal. Results are shown in tabular form in Table 3.10 and in graphical form in Figure 3.12. Complete results are included in

Appendices A and B. Shaded rows denote counties fully covered by FPM maps. For the largest flooding event, nearly $700 million in economic losses occur for southwest Iowa. These values decrease to $565 million, $512 million, and $395 million for the 100, 50, and 10 year floods respectively. Across all return periods, 51% of losses occur in agriculture, 33% are from structures, and 16% from road damage. Debris removal costs are negligible. As return period increases, these percentages shift a few points from agriculture to infrastructure. The largest single contributor to the total is corn, accounting for 34% of total economic losses. Among the nine completed counties, Pottawattamie suffers the greatest total losses with $150 million for the 500 year event decreasing to $94 million for the 10 year. Audubon County undergoes the fewest damages at around $15 million decreasing to $3 million.

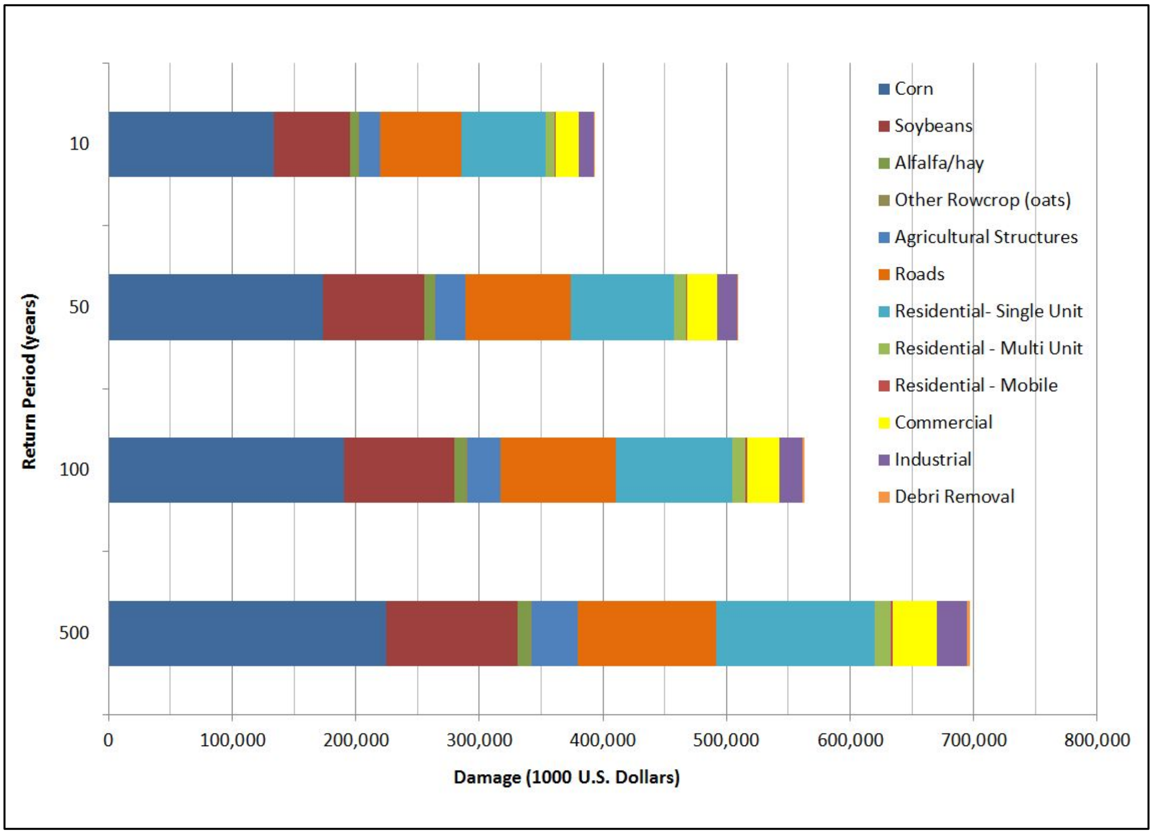

Figure 3.12: Total economic losses by return period

Table 3.10: Total economic losses by county

Damage Estimate ($1,000)				
County	500	100	50	10
Adair	13,809	10,709	9,414	5,825
Adams	17,367	13,438	11,418	6,162
Audubon	14,918	9,257	7,412	3,220
Buena Vista	462	394	360	295
Carroll	28,344	20,082	17,786	13,087
Cass	32,434	22,705	19,081	11,309
Clarke	1,479	1,287	1,166	684
Crawford	17,458	11,182	8,915	3,661
Dallas	4,999	4,171	3,797	2,740
Decatur	21,441	17,910	15,828	10,255
Fremont	95,473	89,749	85,961	80,439
Greene	1,300	831	763	598
Guthrie	17,084	13,268	11,722	6,700
Harrison	73,252	64,546	58,725	45,613
Ida	67	50	45	32
Madison	1,735	1,597	1,506	1,229
Mills	64,626	58,744	55,799	48,638
Monona	277	156	103	12
Montgomery	30,939	16,001	11,375	6,591
Page	32,316	25,449	23,231	16,579
Pottawattamie	150,343	121,169	111,111	94,404
Ringgold	25,076	19,308	17,083	9,885
Sac	9,083	8,014	7,639	6,581
Shelby	19,300	12,853	10,642	5,950
Taylor	8,161	6,971	6,322	4,069
Union	16,566	14,651	13,749	10,489
Wayne	1,322	1,051	823	287
Total	699,631	565,542	511,774	395,335

Reconstructed data is denoted in blue. Fully mapped counties are denoted in bold lettering.

A primary factor of total damage is the development density, a metric that can be represented by population. When normalized by this factor, new trends emerge. Figure 3.13 displays damage totals normalized by population for the nine completed counties. While Pottawattamie County has the greatest total damages, it also is the most populated (93,158) and contains Council Bluffs, the largest city in the study region. Calculating damage per capita reveals Pottawattamie County has the second lowest value for the three largest return periods. Eight of the nine counties have per capita damages that fall between $489 and $4,887. Fremont County stands alone as an outlier with all per capita damages exceeding $10,800.

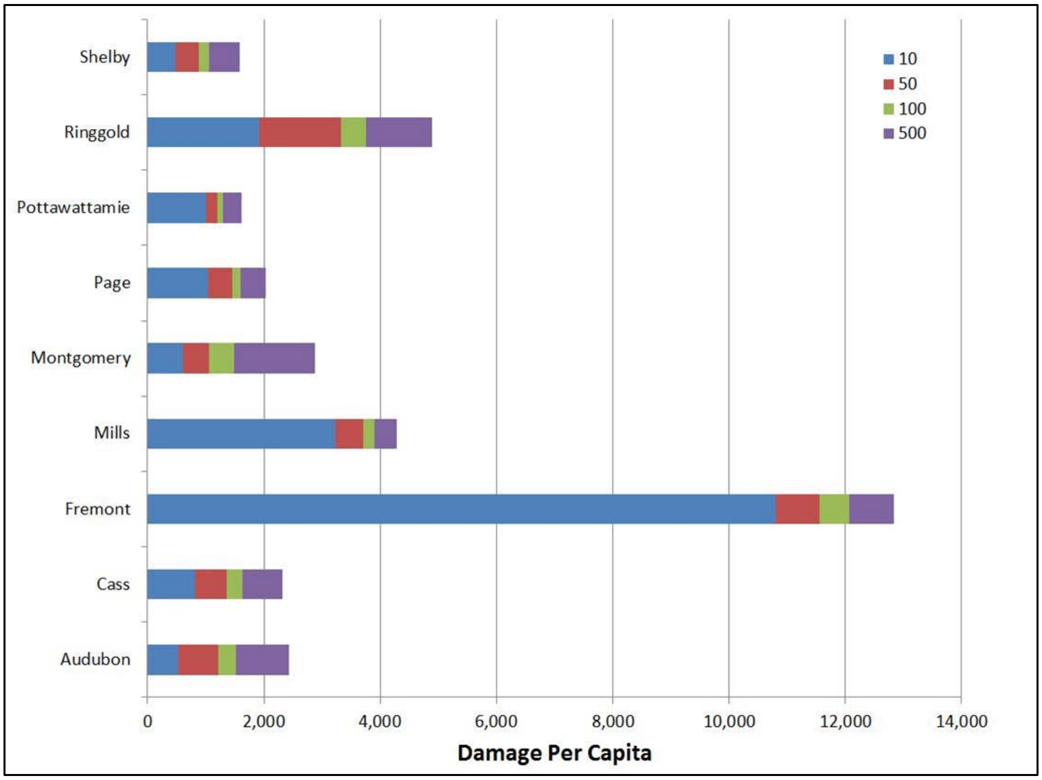

Figure 3.13: Normalized damages for fully mapped counties

Fremont County is situated in the southwest corner of Iowa, bordering Missouri and Nebraska. The majority of land in the study region drains to the Missouri River, with much of it via the East and West Nishabotna Rivers. The confluence of these two rivers is located in Fremont County, just outside the town of Hamburg. For the 500 year event, 28.83% of the county is inundation, as is a majority of Hamburg and other small towns along the Nishnabotna Rivers. As a result, Fremont County with only a population of 7,441 has damage totals that far exceed many counties that are more populous.

3.5.6 Displaced Population

The number of displaced individual in floodplains was estimated using Geo-referenced structures. For counties without this data, reconstructed values described in section 3.5.3.1 were used. The structure points falling within the flooding plain were classified as either single or multiple residential. The following assumptions were made based off of 2010 U.S. Census results for the state of Iowa:

- 2.54 people per single unit household
- 2.14 people per unit in a multi-unit structure
- 10.68 units per multi-unit structure

These figures were multiplied the appropriate building occupancy counts obtained earlier and summed to obtain final estimates. Table 3.11 shows results for each county and return period. Results by HUC 8 are listed in Appendix B Nearly 16,700 people within the region live in the 500 year floodplain. This quantity decreases to 8,700 for the 10 year event. Pottawattamie County is responsible for almost half of displaced individuals while five counties (Clarke, Decatur, Greene, Ida, Monona) have none. However, these five counties are not fully covered within the mapped HUC 8s.

Table 3.11: Displaced population by county and return period

Population within Floodplains				
County	Return Period			
	500	100	50	10
Adair	329	244	224	129
Adams	690	538	466	281
Audubon	**297**	**191**	**160**	**98**
Buena Vista	3	3	3	3
Carroll	340	132	119	86
Cass	319	148	99	15
Clarke	0	0	0	0
Crawford	79	23	15	0
Dallas	15	8	8	5
Decatur	0	0	0	0
Fremont	**1,311**	**1,184**	**1,054**	**1,003**
Greene	0	0	0	0
Guthrie	295	178	147	64
Harrison	1,140	987	909	764
Ida	0	0	0	0
Madison	36	31	28	23
Mills	**1,231**	**1,031**	**946**	**849**
Monona	0	0	0	0
Montgomery	**843**	**165**	**38**	**15**
Page	**1,162**	**891**	**794**	**546**
Pottawattamie	**7,021**	**5,340**	**4,877**	**4,136**
Ringgold	**563**	**432**	**394**	**224**
Sac	8	0	0	0
Shelby	**198**	**170**	**137**	**0**
Taylor	384	314	283	183
Union	391	329	309	227
Wayne	31	26	10	8
Total	16,684	12,364	11,021	8,659

Fully mapped counties are denoted in bold lettering.

The percent of the population lying within floodplains was determined by normalized values from Table 3.11 by population. Table 3.12 displays values for the nine fully mapped counties. 7.20% of citizens live within the 500 year floodplain. This percentages decrease to 5.32%, 4.73%, and 3.83% for the 100, 50, and 10 year events respectively. When normalized, Pottawattamie County's high number of displaced individuals is only slightly above the average region percentage. Fremont County has the highest percentage of population within floodplains with values for all return periods greater than 13%. Shelby and Cass counties have the lowest risk with values under 2.5%.

Table 3.12: Normalized population within floodplains

		Population within Floodplains				% of Population within Floodplains			
County	Pop. (2010)	500	100	50	10	500	100	50	10
Audubon	6,119	297	191	160	98	4.85	3.12	2.62	1.60
Cass	13,956	319	148	99	15	2.28	1.06	0.71	0.11
Fremont	7,441	1,311	1,184	1,054	1,003	17.62	15.91	14.16	13.48
Mills	15,059	1,231	1,031	946	849	8.17	6.84	6.28	5.64
Montgomery	10,740	843	165	38	15	7.85	1.53	0.35	0.14
Page	15,932	1,162	891	794	546	7.29	5.59	4.98	3.43
Pottawattamie	93,158	7,021	5,340	4,877	4,136	7.54	5.73	5.24	4.44
Ringgold	5,131	563	432	394	224	10.97	8.42	7.68	4.37
Shelby	12,167	198	170	137	0	1.63	1.40	1.13	0.00
Total	179,703	12,945	9,552	8,499	6,888	7.20	5.32	4.73	3.83

3.6 Environmental Impacts

3.6.1 Environmental Infrastructure

The inundation of hazardous or critical facilities poses environmental hazards. The Iowa Department of Natural Resources has compiled a record of sites including Animal Feeding Operations, spill incidents, manure applications, leaking underground storage tanks, and stormwater outlets. Using ArcGIS, these features were grouped into a feature class, intersected with flood inundation shapefiles, and partitioned by HUC 8. Figure 3.14 depicts this process within the ArcGIS environment.

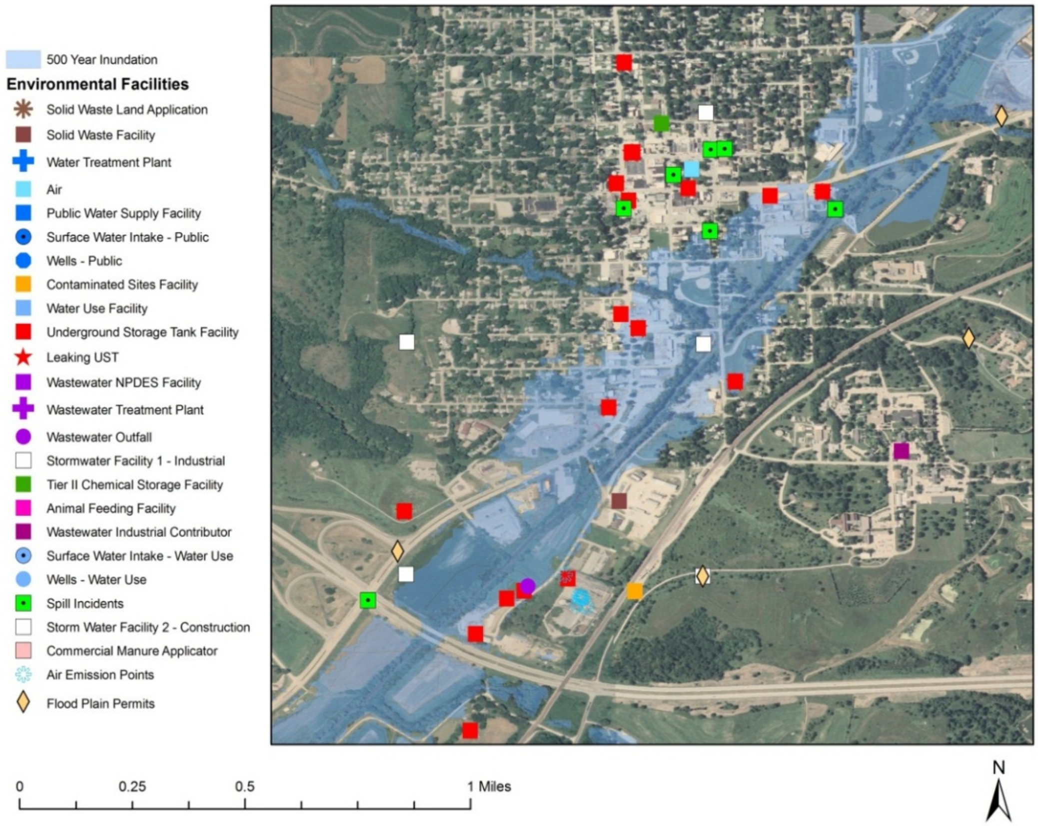

Figure 3.14: Environmental facilities within 500 year floodplain

Table 3.13 depicts results for the intersection of data. The feature class was categorized into two main groups. Full results for HUC 8 and county are included in Appendices A and B. ‘Direct Environmental Hazards’ contains risks which pose an immediate threat upon inundation. These features include applications of solid waste, historical spill sites, and wastewater discharges. Contact with animals and waste can introduce nitrogen, phosphorus, pathogens, antibiotics, pesticides and heavy metals into flood waters and streams. The second category consists primarily of water and wastewater infrastructure. It includes features such as wells, treatment plants, and supply facilities. Damage to these critical lifelines can result in environmental hazards such as a lack of potable water and the inability to treat waste and stormwater.

Table 3.13: Summary of environmental risks

Direct Environmental Hazard	500	100	50	10
Solid Waste Land Application	93	76	72	50
Solid Waste Facility	7	6	6	4
Contaminated Sites Facility	19	12	11	6
Leaking Underground Storage Tank	91	59	52	36
Wastewater NPDES Facility	19	16	12	10
Wastewater Outfall	108	95	91	69
Animal Feeding Facility	3	2	2	2
Wastewater Industrial Contributor	1	0	0	0
Spill Incidents	153	106	96	70
Commercial Manure Applicator	2	2	1	1
Total	496	374	343	248

Water Infrastructure	500	100	50	10
Water Treatment Plant	36	35	33	26
Public Water Supply Facility	61	57	53	45
Surface Water Intake - Public	8	4	4	4
Wells - Public	349	309	278	191
Water Use Facility	117	106	94	78
Underground Storage Tank Facility	209	144	131	85
Wastewater Treatment Plant	47	40	32	20
Stormwater Facility 1 - Industrial	175	149	55	23
Tier II Chemical Storage Facility	42	32	31	27
Surface Water Intake - Water Use	108	105	103	94
Wells - Water Use	394	353	322	241
Total	1546	1334	1136	834

There are nearly 500 environmentally hazardous sites located within the 500 year floodplain of the study site. Of these, 244 are spill or leak sites, 128 are wastewater facilities, and 124 relate to solid waste. Three confined animal feeding operations (CAFOs) are also inundated, which are considered especially hazardous due to their size and high density of waste and animals. As return period decreases, total sites decrease to 374, 343, and 248 with the 100, 50, and 10 year events respectively. For the 500 year event there are 1,542 water facilities located within the floodplain. Of these, 743 are wells, 251 are storage facilities, 112 are water intakes, and 83 are components of treatment plants. With increasing flood frequency, totals decrease to 1338, 1136, and 834 for the lower return periods.

3.6.2 Ecological Exposure

Natural ecosystems provide beneficial services that have economic value. Many of these functions are not fully understood and as a result are challenging to assess a dollar amount. Organizations such as Earth Economics have conducted studies and developed methodologies based on direct market valuation, indirect market valuation, and contingent valuation to estimate these values. These studies attempted to measure the magnitude of environmental processes and assign a comparable dollar value. Ecosystems services incorporated in a 2008 study were carbon sequestration, disturbance prevention, freshwater regulation, habitat provision, nutrient removal, waste assimilation, and aesthetics and cultural value (Ingraham & Foster, 2008). Five land cover classes were considered and prices were adjusted based on 11 distinct ecoregion groups. The values for Iowa's region are shown below in Table 3.16. All values are in terms of dollars per acre per year.

Table 3.14: Annual ecosystem service values (Ingraham & Foster, 2008)

Land Cover Class	Value ($/acre/year)
Wetland	7,426
Open Water	258
Shrubland	587
Grassland	71
Forest	846

Using these values, total floodplain ecological exposure for the study site was evaluated. The intersected shapefiles generated in the land use analysis were reclassified using the Spatial Analysis Tools in ArcGIS. Land cover values were converted from acre units to 15m cells and assigned to corresponding cells with the appropriated land classification. The results were summed and parsed by HUC 8 using the 'Zonal Statistics as Table' tool. Outputs are shown in graphical form in Figure 3.15. Full results by county and HUC 8 are included in Appendices A and B.

The annual economic value of natural floodplain services for the 500 year event is approximately $96 million decreasing to $72 million for the 10 year event. This small relatively small difference suggests that much of the high value ecological land is located immediated adjacent to streams and rivers in riparian areas. The two major contributors to ecologic value are wetlands and deciduous forests. Across all return periods, wetlands represent only 0.7% of inundated land in southwest Iowa, but contribute 35% of the ecologic value. Based on the study by Earth Economics, wetlands are nearly ten times as ecologically productive and beneficial than any other land type. Deciduous forests have moderate ecological value but contribute 43% to the total due to their abundance in floodplains.

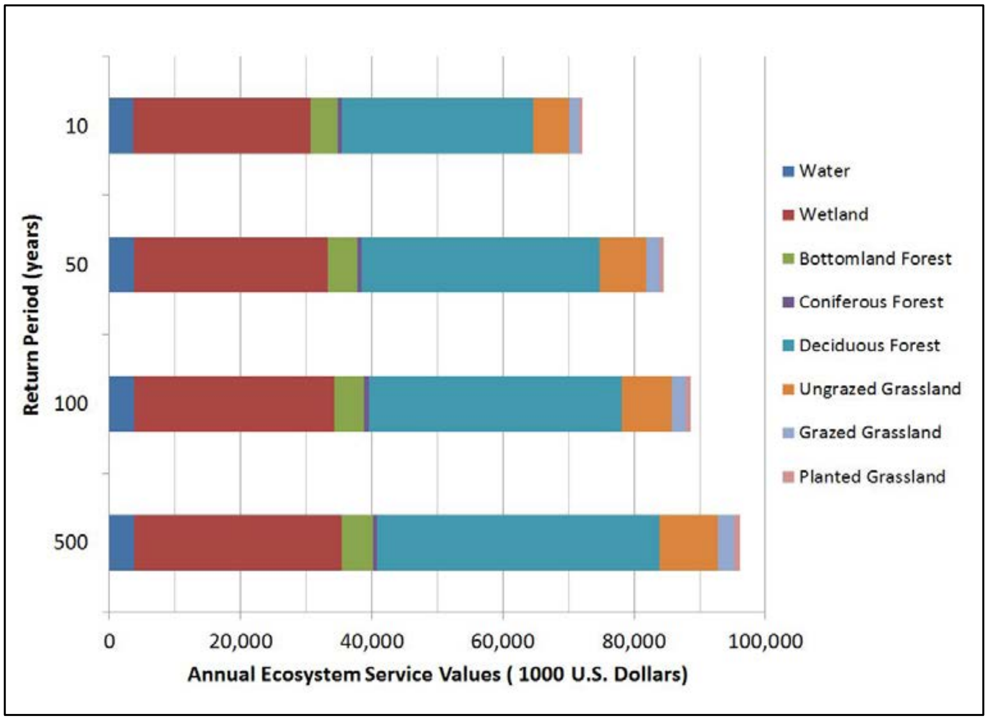

Figure 3.15: Breakdown of annual ecosystem services

Table 3.15 displays results broken down by HUC 8. Total ecological exposure values for each HUC 8 were normalized by inundation area to obtain an average value per acre. The Thompson watershed (HUC 10280102) has the most ecologically productive land with an average value of $262 per acre for the 500 year event and $318 for the 10 year. In contrast, the Nishnabotna watershed (HUC 10240004) had the lowest valued land at $46 per acre for the 500 year flood and $43 for the 10 year. The Nishnabotna was the smallest HUC 8 analyzed and is more developed than most other watersheds. These are likely factors which contribute to this result. Another notable trend is that value per acre tends to increase with decreasing return period. This again suggests the most ecologically beneficial lands lie adjacent to water sources. It is important to note agricultural lands likely provide ecological benefits that can be quantified, but were not included in the analysis. The methodology and criteria used in this study followed one performed by The Nature Conservancy in 2008 (Ingraham & Foster, 2008).

Table 3.15: Annual ecosystem services by HUC 8

	Inundation Area (sqm)				Ecological Exposure ($)				Ecologic Value Per Acre ($)			
HUC 8	500	100	50	10	500	100	50	10	500	100	50	10
7100007	106.41	89.16	82.77	63.50	11,616,796	10,747,860	10,350,579	9,211,093	171	188	195	227
10230006	88.10	78.29	72.42	57.08	7,969,492	7,748,003	7,293,870	6,113,833	141	155	157	167
10230007	150.08	133.06	123.66	99.37	10,933,500	10,284,516	9,910,481	8,976,036	114	121	125	141
10240001	111.71	106.53	104.48	97.07	4,449,201	4,273,265	4,184,883	3,773,865	62	63	63	61
10240002	189.48	154.93	141.51	107.16	14,086,858	12,879,725	12,417,951	11,057,658	116	130	137	161
10240003	130.43	106.79	97.52	73.27	9,829,302	9,014,312	8,594,584	7,458,250	118	132	138	159
10240004	32.07	34.80	30.33	32.18	947,289	949,419	907,512	888,746	46	43	47	43
10240005	17.99	11.97	10.64	7.43	1,194,519	951,614	808,587	705,111	104	124	119	148
10240009	78.62	58.87	50.55	33.60	5,405,225	4,668,322	4,336,710	3,396,110	107	124	134	158
10240010	41.60	36.14	32.87	22.39	4,064,237	3,737,880	3,562,710	2,831,422	153	162	169	198
10240012	41.19	37.07	34.00	20.01	3,944,665	3,662,818	3,461,715	2,165,927	150	154	159	169
10280101	38.70	29.82	26.70	19.08	4,058,312	3,456,309	3,155,727	2,465,180	164	181	185	202
10280102	104.89	93.06	86.17	64.36	17,577,323	16,211,147	15,471,694	13,096,211	262	272	281	318
Total	1,131	971	894	696	96,076,719	88,585,190	84,457,003	72,139,442	131	142	147	166

3.7 Floodplain Soil Evaluation

Historically, soil maps have been used as a simple and cost effective method to delineate river floodplains. Geologists have used soil maps based on the assumption that present soil characteristics are related to the presence or absent of past flooding (Cain & Beatty, 1968). Soil Survey Geographic (SSURGO) data was acquired from the NRCS. SSURGO data sets represent the most detailed level of soil geographic data developed and digitized by the National Cooperative Soil Survey (NCSS). The geospatial data is vast, containing 171 distinct categories of data. Three were used to help evaluate the use of soils as a proxy for flooding: flood frequency, hydrologic soil group, and hydric soil code. In the proceeding sections, data will be presented by both HUC 8 and county. While the HUC 8 is more appropriate for this criterion, data varies considerable from county to county because surveys are performed differently between them.

Polygon files for the 27 counties in the study were obtained from the NRGIS with data fields already spatially joined. The polygon features were combined to a single output using the ‘Merge’ tool in ArcGIS. This file was cropped to the inundation extents of each return period using the ‘Intersect’ tool. An additional field named ‘Area’ was created for the file and populated using the ‘Calculate Geometry’ feature, selecting acres for the unit. The acreage of each category was obtained using the ‘Summarize’ tool on the desired field in ArcGIS.

3.7.1 Flood Frequency

Flood frequency is a term used to describe the annual probability of a flood event. There are seven categories within the class (Miller, Fenton, Oneal, Tijffany, & Burras, 2010):

- None: Flooding is not probable
- Rare: Flooding is unlikely but possible under unusual weather conditions
- Occasional: Flooding occurs on an average of 50 times or less in 100 years

- Common: Flooding is likely under normal conditions
- Frequent: Flooding occurs on an average of more than 50 times in 100 year
- Ponded: Standing water on soils in closed depressions

Figure 3.16 displays the distribution of frequencies within the ArcGIS environment. Table 3.16 summarizes the results for each return period. Figure 3.17

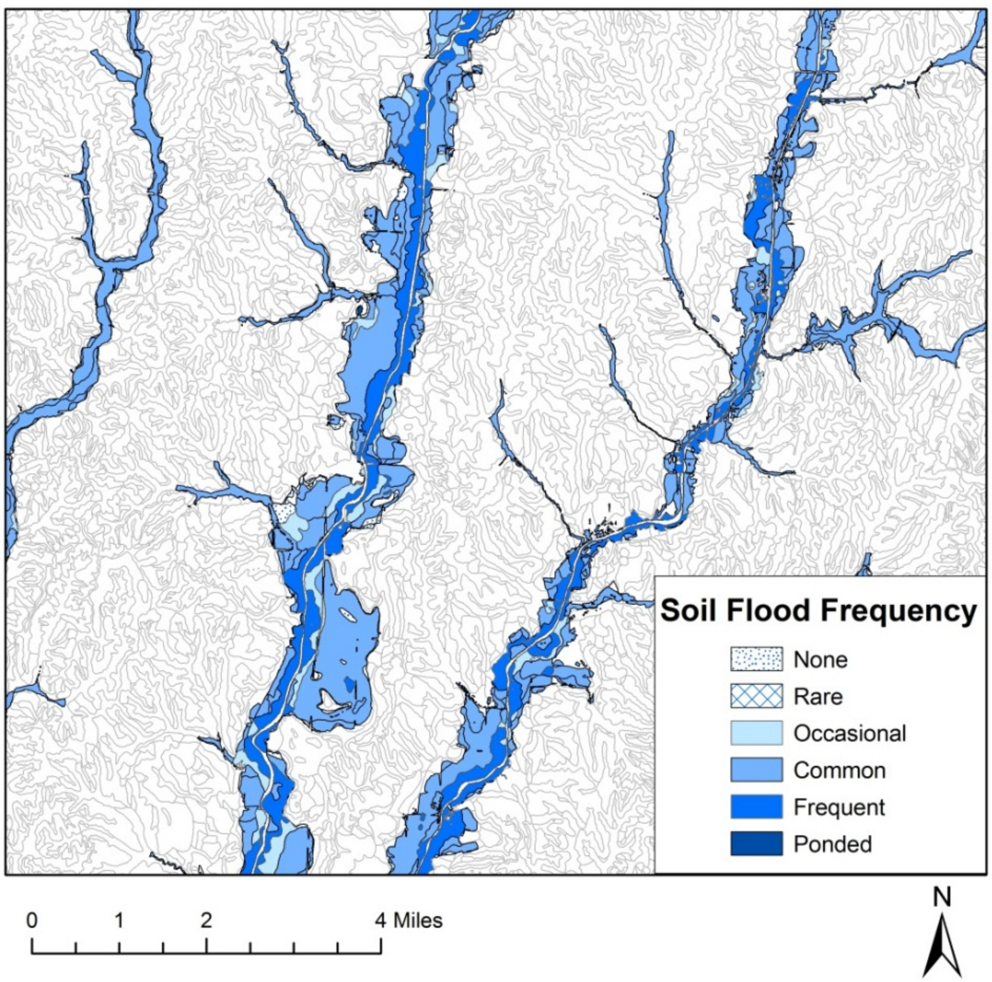

Figure 3.16: Flood frequency distribution within the 500 year floodplain

displays the data in graphical form. Complete results broken down by HUC 8 and county are included in Appendix A. Soils adjacent to streams are predominantly classified as 'Frequent'. Further from the channel, the 'Common' and 'Occasional' classification mostly border the 'Frequent' but with no clear pattern. The most common frequency was 'Occasional', accounting for roughly 46% of all floodplain soils. Percentages for this class stay effectively the same across the four return periods, ranging from 46.17 to 46.91%.

Table 3.16: Summary of flood frequency by return period

Flood Frequency (square miles)							
Return Period	None	Rare	Occasional	Common	Frequent	Ponded	No Data
10	42.54	78.10	192.34	72.73	26.16	4.72	28.56
50	59.53	88.20	253.29	101.00	35.76	4.96	31.40
100	66.71	92.11	276.38	110.14	38.80	5.03	32.22
500	88.23	102.72	325.93	131.38	44.21	5.35	33.51
Percentage							
10	10.21	18.75	46.17	17.46	6.28	1.13	---
50	10.97	16.25	46.67	18.61	6.59	0.91	---
100	11.32	15.63	46.91	18.69	6.59	0.85	---
500	12.64	14.72	46.71	18.83	6.33	0.77	---

As distance from a flooding source increases, the likelihood of it flooding decreases. This trend is supported is the change of the 'None' and 'Ponded' categories. As return period increases, the ponded areas decrease from 1.13% to 0.77% from the 10 to 500 year events. The opposite is true for the 'None' category which increases from 10.21% to 12.64% for the same scenario. However, this tendency is contradicted by the 'Frequent' (< 2 year flood) classification. As flood frequency increases there is no apparent pattern. With the 10 year flood as the minimum return period examined, the acreage of 'Frequent' soil was expected to be similar for all scenarios. Hence, the percentage was expected to decrease as floodplains extents increase. However, soils categorized as 'Frequent' were present in floodplains at the same proportion for all return periods. For this reason it is difficult to discern any conclusive trends in the data.

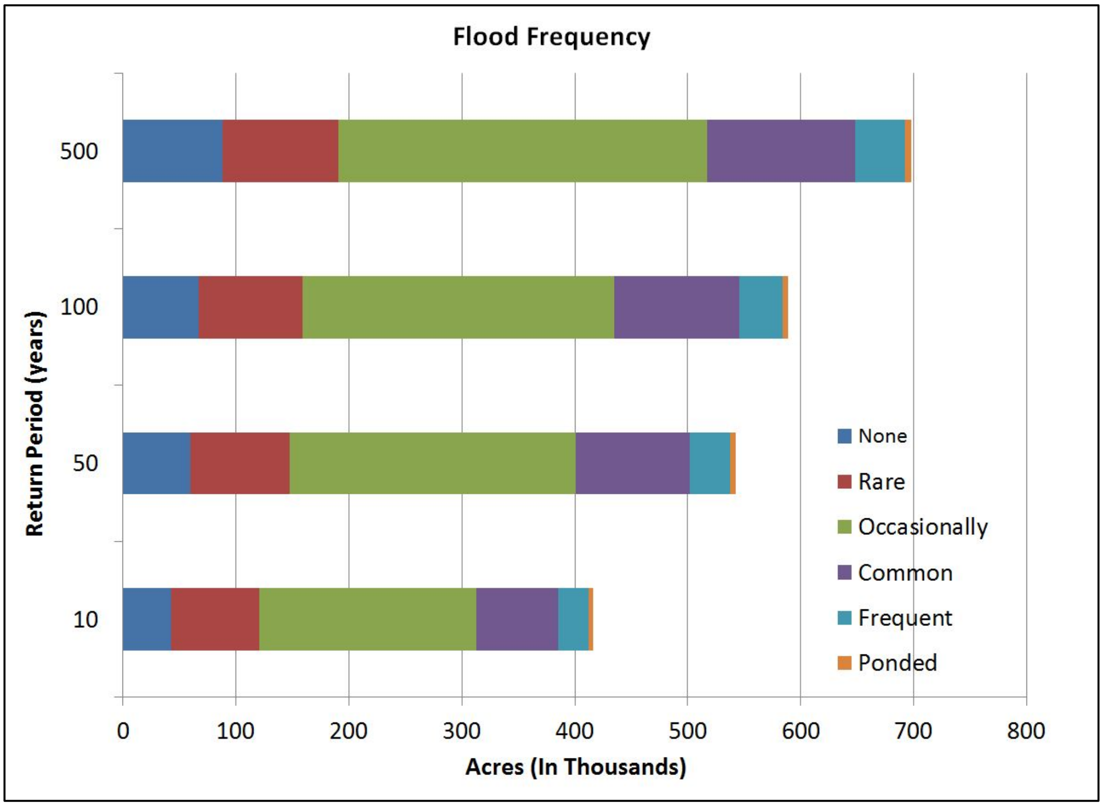

Figure 3.17: Distribution of flood frequency by return period

3.7.2 Hydrologic Soil Group

Hydrologic soil groups are used to estimate runoff from precipitation. Ratings are grouped according to their ability to intake water. Table 3.17 summarizes the four soil types examined in the analysis. Group A soils have high infiltration when wetted and are predominantly well drained gravely sands. Group B soils have moderate infiltration rates and are primarily moderately fine to moderately coarse well drained soils. Group C soils have slow infiltration rates, resulting in moderate runoff when wetted. Most soils in this group have a layer of fine or moderately fine texture that impedes infiltration. Group D soils have very low infiltration rates and produce the greatest amount of runoff when wet. Soils have considerable clay content which results in a high shrink-swell potential (Miller, Fenton, Oneal, Tijffany, & Burras, 2010).

Table 3.17: Hydrologic soil groups

Group	Type	Runoff Potential
A	Well drained sands and gravels	Low
B	Silt loam or loam	Low to Moderate
C	Sandy clay loam	Moderate
D	High clay content	High

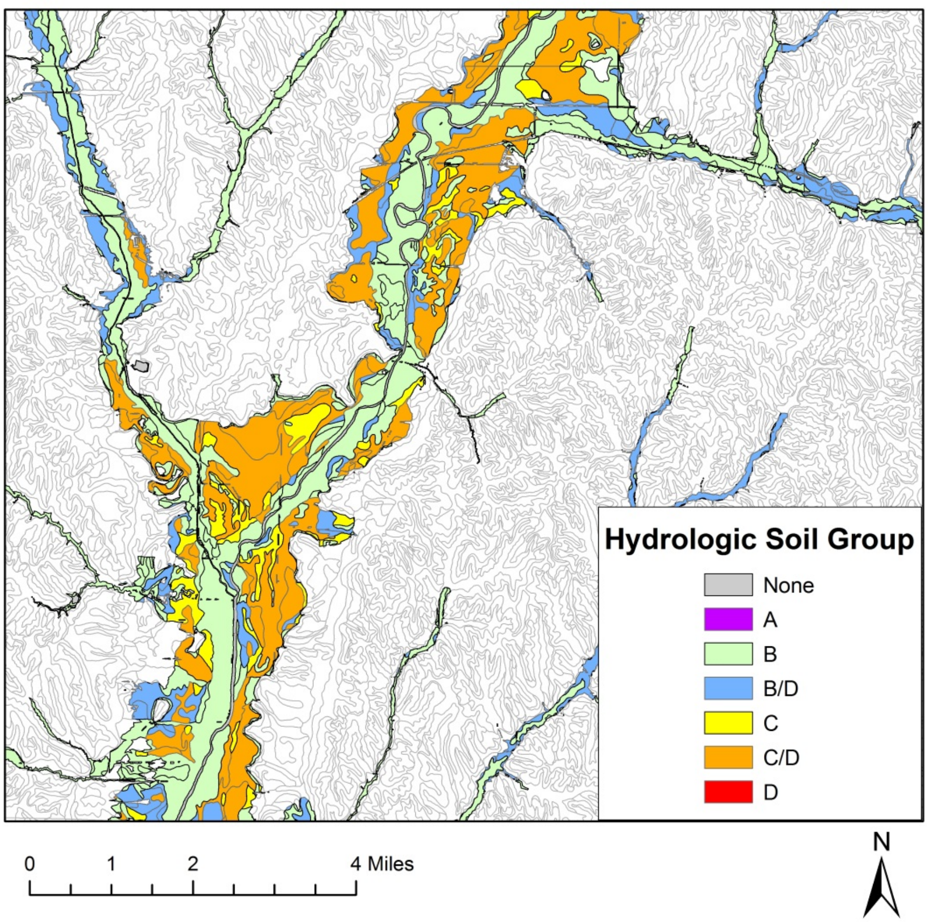

Figure 3.18: Hydrologic soil groups within the 500 year floodplain

Figure 3.18 displays the spatial distribution of hydrologic groups within the ArcGIS environment. Table 3.18 summarizes the results for each return period. Figure 3.19 displays the data in graphical form. From visual inspection, soils immediately adjacent to medium and large rivers are typically categorized as silty loams (group B). Advancing further out in the floodplain, soils transition to sandy clay loams (group C and C/D). For smaller streams, a majority of inundation occurs over group B/D soils. Very few sands (group A) and high clay content soils (group D) are found within the studied floodplains.

Silt loam soils (group B) are most prevalent in floodplains, comprising 46%. Sands and gravels are least represented at just 0.4%. Percentages for the entire 27 counties of SSURGO data are listed at the bottom of Table 3.18. In comparison with surrounding soil, floodplain regions have fewer silty and sandy clay loams. Only 53% of this land is categorized as hydrologic groups B or C while this value is around 80% for the entire southwest Iowa region. Riverine regions tend to have higher composition of clays (containing group D), with 43% of soils containing clay properties in contrast to just 20%.

Table 3.18: Summary of hydrologic soil group by return period

Hydrologic Soil Group (square miles)							
Return Period	A	B	B/D	C	C/D	D	No Data
10	1.73	202.59	70.58	34.20	41.56	65.91	28.58
50	2.11	264.23	93.15	43.86	60.55	78.80	31.42
100	2.26	287.32	101.36	46.89	67.97	83.35	32.24
500	3.05	341.54	123.96	53.48	85.01	90.75	33.54
Percentage							
10	0.42	45.69	18.88	7.69	9.05	14.05	---
50	0.39	46.19	18.94	7.49	10.24	13.56	---
100	0.38	46.41	18.98	7.37	10.64	13.42	---
500	0.44	46.90	19.73	7.08	11.32	12.66	---
Full Region	0.34	64.19	10.43	15.47	3.56	6.00	---

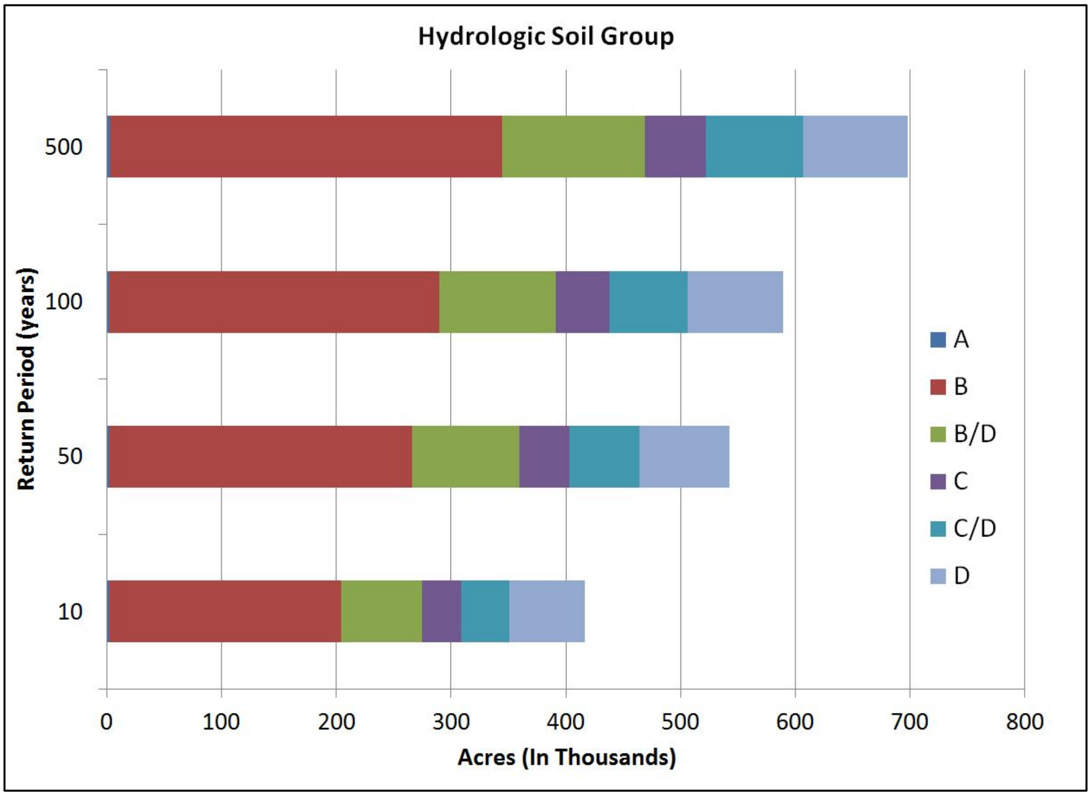

Figure 3.19: Distribution of hydrologic soil groups by return period

3.7.3 Hydric Soil Code

Hydric soils are formed under conditions of saturation, ponding, or flooding during the growing season. The soil develops anaerobic conditions in its upper layers which can be used as a field indicator (Soil Survey Staff, 1999). In the past, hydric soil maps have been used to cost-effectively and quickly approximate floodplains. SSURGO soil data includes a hydric soil code, a yes/no field identifying whether or not a soil meets specific criteria for hydric soils.

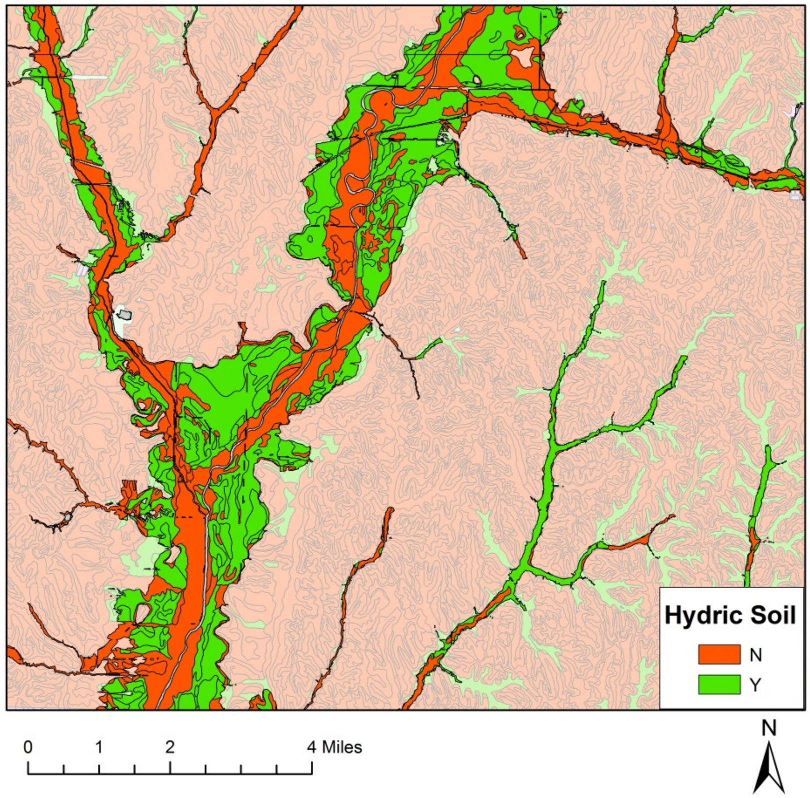

Figure 3.20: Hydric soils within the 500 year floodplain

Table 3.19 summarizes the results for each return period. Figure 3.21 displays the data in graphical form. Complete results broken down by HUC 8 and county are included in Appendix A. Within the study region, 25% of all soils are classified as hydric. Figure 3.20 displays the distribution of hydric soils within the ArcGIS environment. Hydric soils closely follow stream networks. Floodplains of Southwest Iowa are comprised of approximately 45% hydric soils. Soils immediately adjacent to streams tend to be non-hydric while hydric soils lie further away in the floodplains. Much of the hydric soils falling outside of study floodplains cover streams too small to be mapped. If a higher drainage density were used, this percentage would increase.

Table 3.19: Summary of hydric soils by return period

Hydric Soil Code					
	Area (sq miles)			Percentage	
Return Period	Yes	No	No Data	Yes	No
10	184.72	225.82	17.87	44.99	55.01
50	243.55	290.13	26.96	45.64	54.36
100	265.03	313.68	27.66	45.80	54.20
500	307.97	375.45	28.92	45.06	54.94
		Full Region Average		25.03	74.97

No trend is apparent when comparing between return periods. The distribution of hydric soils across the four return periods remains effectively the same, ranging between 44.99% and 45.80%. It was expected that the percentages of hydric soils decrease as return period increases as extents of frequencies examined would not spend enough time inundated to develop hydric conditions. In other words, the further away from the floodplain a soil lies, the less inundation time it has, and hence is less likely to be hydric. While it can provide a high level view of stream networks, the poor accuracy of SSURGO hydric data makes it unsuitable for the accurate delineation of floodplains.

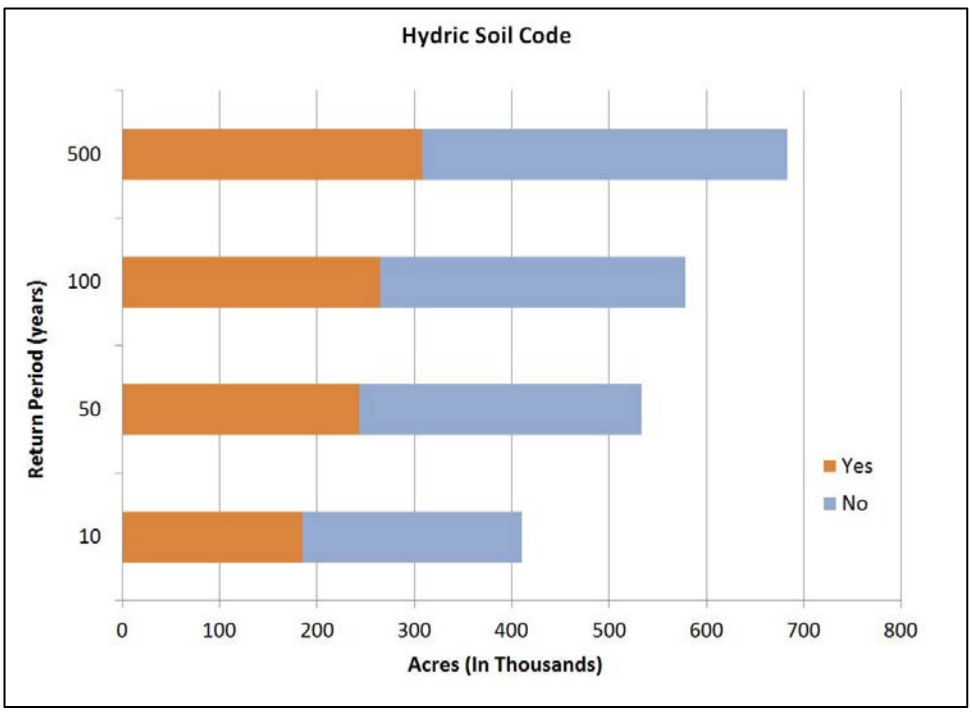

Figure 3.21: Distribution of hydric soils by return period

CHAPTER 4: HAZUS-MH

Without historical hazard data or complementing model, it is difficult to judge the accuracy and significance of the results. In order to better evaluate the geospatial analysis, a Level 1 Hazus model was run on a watershed within the region. A side by side comparison of methodologies, assumptions, and results can reveal the strengths and weaknesses of both. There are two main components with each model: hydrology/hydraulics and loss estimation. Both packages were evaluated as a whole. It is possible to evaluate FPM outputs with Hazus' inventory and likewise Hazus hydraulic output with processes described above, but these scenarios were left for further study

4.1 Hydrologic Analysis

With a supplied DEM, the first process Hazus performs is identifying stream reaches. Each DEM cell is compared to its 8 neighbors to identify a slope and flow direction. An accumulation grid is created by determining the number of cells which flow to a particular cell. Multiplying the accumulation of a cell with its area provides an associated drainage area. The collection of cells that exceed a user specified threshold is considered a stream network. Endpoints of cells are classified as nodes of which there are three types: sources, junctions, and outlets. Sources are the 'highest' points of a stream. Junctions are where two reaches join. Outlets are the 'lowest' points of a stream (FEMA, 2012). Figure 4.1 displays an example stream network.

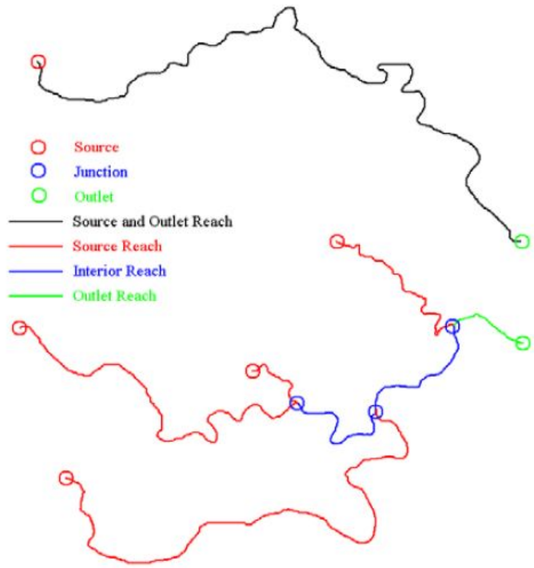

Figure 4.1: Stream network nomenclature (FEMA, 2012)

From the stream network, watersheds can be delineated by taking upstream areas of the sources. After a study region is defined, watersheds that cover the region are identified and selected. The user can then select which reaches within the watershed to be considered for hydrologic analysis. Streams of the West Nishnabotna watershed with a drainage threshold of 2 square miles are shown below in Figure 4.2.

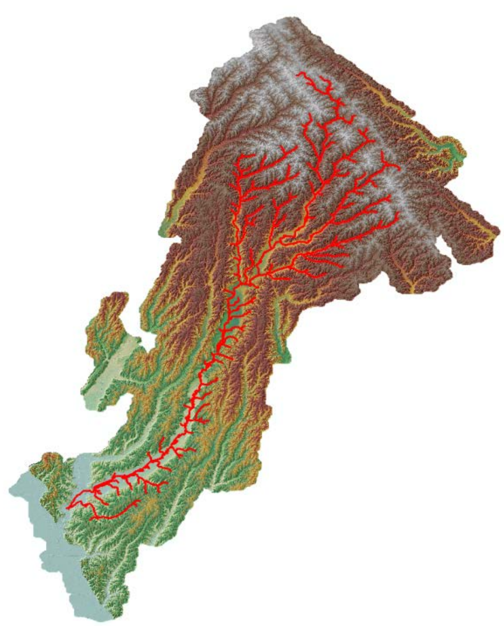

Figure 4.2: Delineated streams in the East Nishnabotna watershed

Hydrological analyses are performed at each node using USGS regression equations. In order to perform the analysis, the following are calculated from the DEM at each node (FEMA, 2012):

- The record number of the reach
- A value denoting if the node is at the upstream or downstream end of the reach
- The drainage area for the node
- The average elevation of the basin
- The average slope of the basin
- The straight line distance between the source and outlet of the basin
- The channel length of the longest drainage path
- The elevation of a point 10 percent along the channel length upstream from the outlet
- The elevation of a point 85 percent along the channel length upstream from the outlet

Using this data, the appropriate regional regression equation can be applied. Each state is divided into unique hydrologic regions with equations typically following the form (Scawthorn, et al., 2006):

$$Q_T = Cf_i(P_1)f_2(P_2)\ldots f_n(P_n) \qquad (4.1)$$

Where: Q_T is the discharge value with return period T; C is a constant; and $f_i(P_i)$ denotes a function of the i^{th} parameter of the equation.

Results of the regression equations are adjusted using stream gauge data when the drainage area at the gauge is between 50 and 150% the drainage area of the node. Discharge values are calculated by interpolating from the from the gauge default values in the flood frequency database (FEMA, 2012).

4.2 Hydraulic Analysis

With discharge values determined for each frequency assigned to every reach, hydraulic analysis can begin. The default Level 1 analysis estimates a floodplain extent and defines cross sections which are then used to obtain a flood elevation. Initially, stream reaches are buffered two times the cell size of the DEM. Cross sections are placed along the centerline at intervals equal or less than 1,000 feet apart, progressing from upstream to downstream. Cross sections are drawn perpendicularly to the buffered region and extended by a distance that is ten times the square root of the corresponding discharge value.

A sample Hazus cross section is shown below in Figure 4.3. Flood elevations are computed at each cross section using Manning's equation (FEMA, 2012):

$$Q = \frac{1.486}{n} A R^{\frac{2}{3}} \sqrt{S_f} \tag{4.2}$$

Where: Q is discharge, n is Manning's n value, A is cross sectional area, R is hydraulic radius, and S_f is friction slope

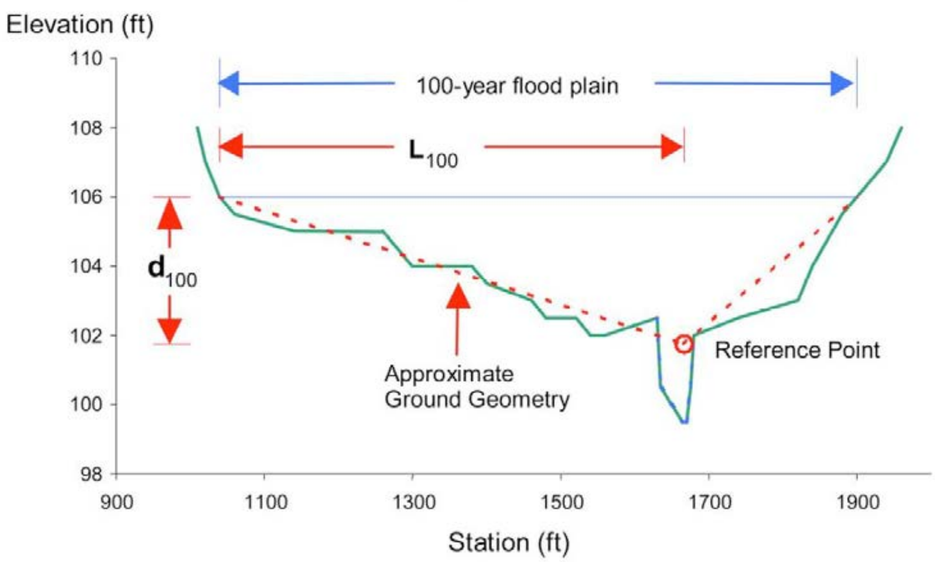

Figure 4.3: Sample Hazus cross section (Scawthorn, et al., 2006)

Hazus uses a series of approximations to solve Manning's Equation. A default value of 0.08 is used for Manning's n. Slope is calculated on the streamline between cross sections of the reach. In regions where cross section geometry is unable to be extracted from the DEM, it is approximated by a triangle to simplify area and hydraulic radius calculations. Rearranging variables and accounting for this modification, Manning's equation can be written as follows (FEMA, 2012) :

$$d \approx \left(\frac{1.07nQS_s}{\sqrt{S_f}}\right)^{\frac{3}{8}} \tag{4.3}$$

Where: d is flood depth, and S_s is side-slope which equals twice the depth of the triangle divided by the top width

Flood surface elevations are created by interpolating between cross sections. Depth grid are generated by subtracting the ground elevation of the DEM grid from the flood surface elevation. This concept is displayed in Figure 4.4. For backwater and nonconveyance areas lying outside the flow regions, a 'sink filling' process is used. Using the technique described above in the hydrology section, cells are identified as sinks and then 'filled' to the proper water surface elevation (FEMA, 2012).

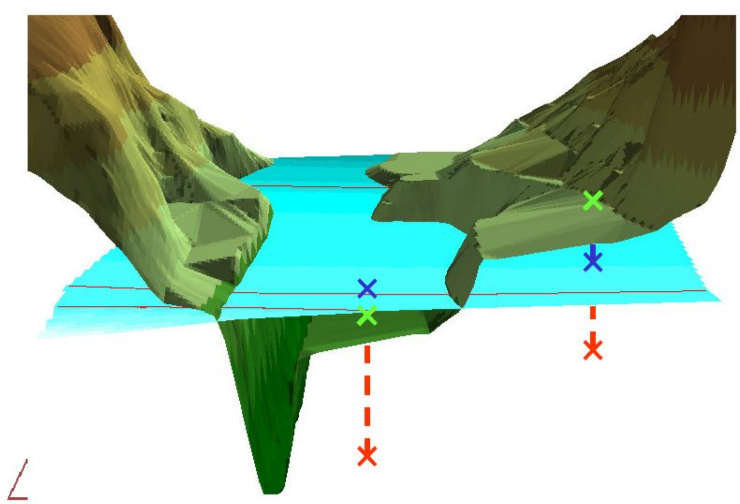

Figure 4.4: Determination of flood depth grid (FEMA, 2012)

4.3 Damage and Loss Assessment

Hazus contains a nationwide inventory of buildings, facilities, transportation systems, utilities, agriculture, and hazardous material facilities. Using this database, the program estimates flood losses through use of an array of damage curves from the Federal Insurance Administration (FIA) and the USACE. An additional tool allows users to import customized building data, however stock data was used for this study (Scawthorn, et al., 2006).

The 2010 US Census was used as the source of residential data and is aggregated at the census block level. Figure 4.5 depicts this concept within ArcGIS. The census provides data on housing counts but not home values, square footages, number of stories, or features such as basements. To account for this, income relationships were established for these categories for regions across the country. Similar regressions were used to approximate multiple unit and manufactured housing. A 2006 study by Dun and Bradstreet serves as the primary source for business and industrial data (Schneider & Schauer, 2006). Critical facilities including hospitals, schools, police stations, transportation systems, and utilities are assigned default parameters for valuation and depth functionality.

Building counts for each census block are assumed to be evenly distributed throughout the block. Flood depths calculated in the hydraulic analysis are also assumed to be uniform across each block for a Level 1 analysis. In urban regions (Figure 4.5a), this is a reasonable approximation. However, in less densely populated areas with much larger blocks (Figure 4.5b), this method is much less accurate. The appropriate depth-damage curves are applied based on building classification and summed for each type of building in the block. The output is an area-weighted estimate of damage for each census block (FEMA, 2012).

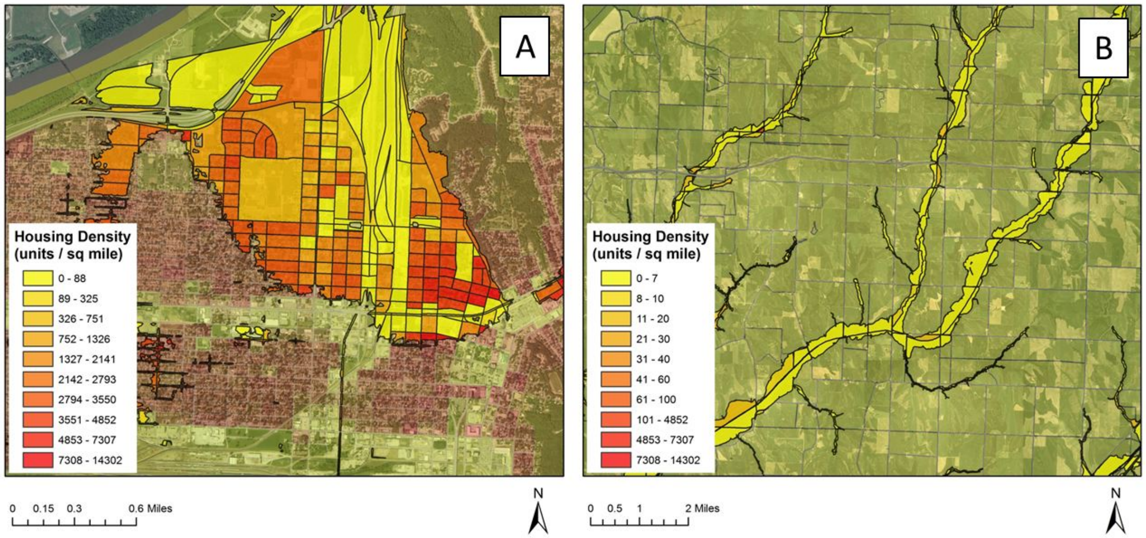

Figure 4.5: Housing density by census block

The loss estimation model for agriculture is based on the USACE Agriculture Flood Damage Analysis (AGDAM) methodology and program. This method combines datasets from the National Resources Inventory (NRI) and National Agriculture Statistics Service (NASS) to create a general distribution of crops by type, average yield, and unit price. Polygons for each county with weighed crop acreages was developed from a 1992 NRI dataset. 2010 agricultural data compiled by NASS is combined with the shapefiles to provide a spatial representation of the data. Similar to the method of direct building loss estimation, an even distribution of crop types and water depth is assumed for each census block. However, damage to crops depends on the timing and duration of flooding rather than depth. Damage curves developed by the USACE are a function of Julian calendar date which is provided by the user (FEMA, 2012).

4.4 East Nishnabotna Model

4.4.1 Study Region

The selected watershed, East Nishnabotna, is located in southwest Iowa and is shown below in Figure 4.6. The geographical area of the HUC 8 is 1,323 mi^2 (3,427 km^2) and contains portions of Adair, Audubon, Carroll, Cass, Fremont, Guthrie, Montgomery, Page, Pottawattamie, and Shelby counties. The primary river of the watershed is the East Nishnabotna which flows through communities including Atlantic, Red Oak, and Shenandoah. There are 3,638 census blocks and a total population of 38,828 people (2010 Census Bureau data) in the watershed. Hazus estimates there are 21,251 buildings in the region with an aggregate value of $2.85 billion (2006 dollars). The East Nishnabotna watershed was chosen because it contains a desired balance of communities and agriculture, has no major levees, and is completely contained within Iowa.

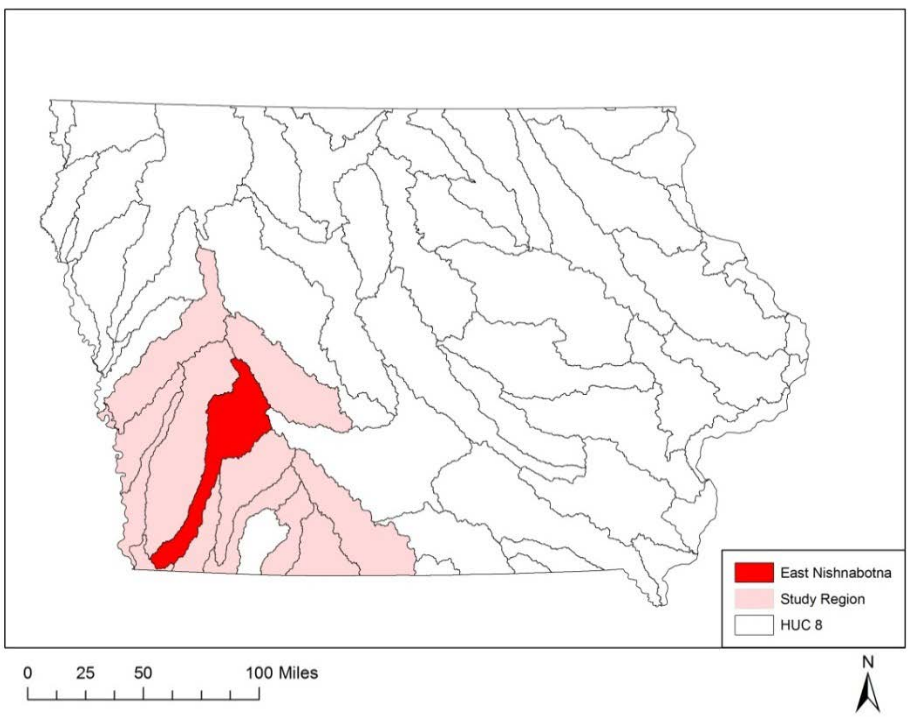

Figure 4.6: East Nishnabotna watershed

4.4.2 Flood Model Inputs and Parameters

Upon input of the watershed, Hazus aggregates census blocks and data within the boundary. The type of flood was selected as ‘riverine’ to deactivate coastal flooding components of the flood model. Topology was defined by inputting a USGS National Elevation Dataset (NED) 1 arc second (30m) DEM. Hazus determined the extent of the DEM and cropped it appropriately. In order to generate a stream network, a stream density of 2.0 square miles was selected. Optimally, a drainage density of 1.0 square miles would be used to match streams modeled in the statewide mapping project; however computing limitations would not allow for processing at the HUC 8 scale. Manning’s n for Manning’s equation was left at the default value of 0.08. The desired flood extents and elevations were determined for the 10, 50, 100, and 500 year return periods. For agriculture, the date of flooding was set to August 29 to coincide with maximum crop losses.

4.4.3 Hydraulics Outputs and Comparison

Prior to comparing loss estimations, it is important to evaluate differences in the hydraulic outputs between the models. Table 4.1 summarizes hydraulics properties for each within the East Nishnabotna watershed. As part of the FPM project, 263 streams were modeled in the East Nishnabotna with a total stream length 1,191 miles. Hazus partitions stream networks into reaches for analysis. 318 reaches were modeled, but fewer full streams and only 629 miles were mapped. This is a result of a higher drainage threshold for modeling. Table 4.2 shows important differences between the FPM and Hazus hydraulic models. In addition, stream resolution and sinuosity are also responsible for the additional stream mileage in the FPM. The higher resolution 1 meter LiDAR DEM delineates streams with greater detail, capturing more meandering in the network.

Table 4.1. Comparison of Hazus and FPM flood maps

	Hazus	FPM
Stream Miles	629	1191
Reaches	318	263

	Return Period			
	500	100	50	10
HAZUS Inundation (square miles)	111	85	76	54
FPM Inundation (square miles)	130	107	98	73
% Difference	17	26	29	35
	Incremental Change			
HAZUS Inundation (square miles)	26	9	22	54
FPM Inundation (square miles)	24	9	24	73
% Difference	-9	3	10	36

Inundation extents are also underestimated by the Hazus flood model. Figure 4.7 shows the overlay of FPM and Hazus inundation shapefiles for the East Nishnabotna River and adjacent tributaries. For the 500 year event, Hazus estimates 111 square miles of inundation while the FPM estimates 130 square miles for the East Nishnabotna watershed, a difference of 17%. As return period decreases this difference increases to 26%, 29%, and 35% for the 100, 50, and 10 year floods respectively. This trend can be explored further by analyzing the incremental change in floodplains between return periods. Comparing the 10 year floodplains, the statewide project produces a boundary 19 square miles and 36% larger the Hazus flood model. For the 50, 100, and 500 year return periods, differences in incremental changes do not exceed 2 square miles or 10% of the area. For the 500 year floodplain, Hazus has a greater incremental change from the 100 year.

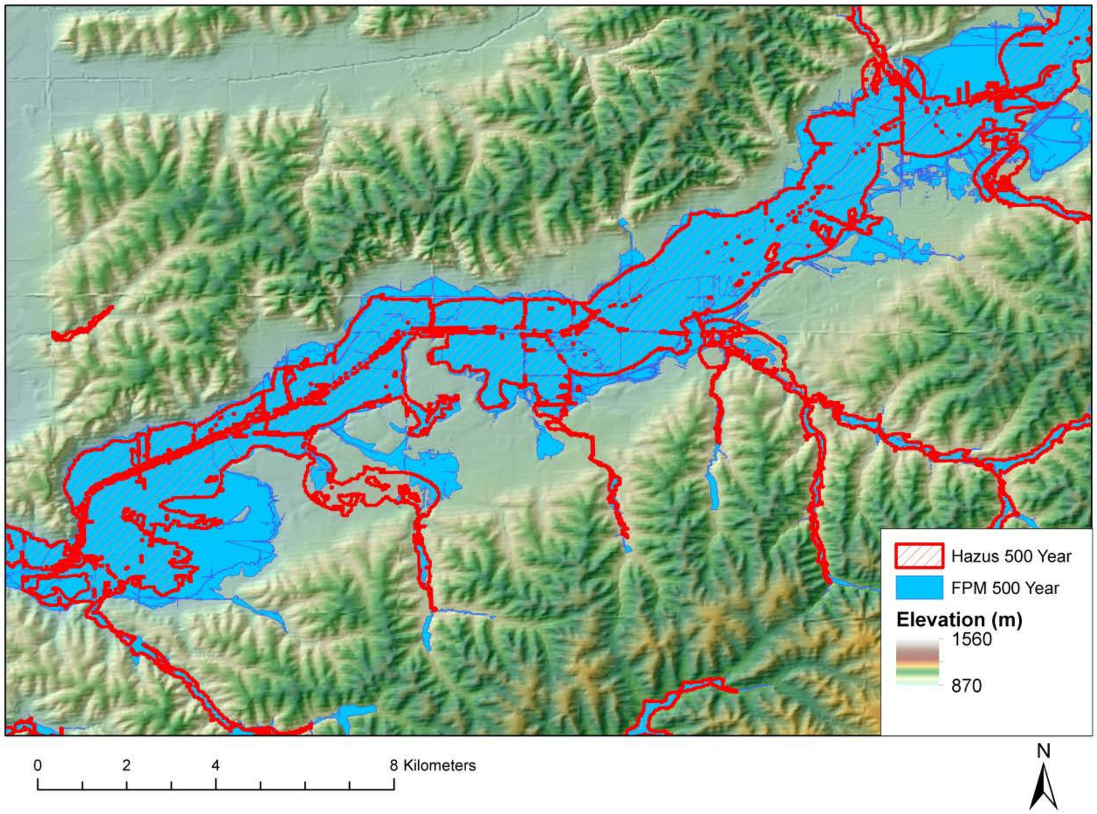

Figure 4.7: Comparison of Hazus and FPM flood extents for the 500 year event

A portion of this discrepancy can be attributed to fewer streams being modeled. Streams excluded from Hazus drain between 1 and 2 square miles. The inundation from these small streams however, contributes a very small portion to the total. From inspection of the flood maps (see Figure 4.7), a vast majority of the difference occurs in rivers with the largest drainage areas. Hazus also assumes a constant Manning's n when solving for water surfaces elevations, in contrast to a spatially varied value for the FPM. Additionally, Hazus places arbitrary cross sections throughout the model in comparison to a detailed modeling process.

A likely explanation for this result is the application of USGS regression equations. Hazus uses the 1987 equations developed by Lara for all reaches. In 2001, another set of equations was developed by Eash. In comparison, the 1987 equations tend to underestimate discharges for larger streams as they do not include data from major flooding events in 1993 (Thomas, 2011). The statewide project uses a combination of the 1987 and 2001 equations. Annual exceedance discharges for sites draining between 1 and 20 square miles are determined by use of the 1987 equations. For sites draining between 20 and 50 square miles, annual exceedance discharges are calculated as the arithmetic mean of values from the 1987 and 2001 equations. For sites greater than 50 square miles, the 2001 equations are solely used (Thomas, 2011). Twelve streams in the watershed drain more than 20 square miles, of which five drain over 50 square miles.

Other differences and assumptions in the models also contribute to the varying results. Differing DEM resolutions and sources can influence flood extents. This was examined in a 2011 study by Charrier and Li which utilized 1, 3, 5, 10, 15, and 30 meter DEMs from LiDAR (used by the statewide project) and the USGS (used as the default for Hazus). It was determined that stream length increases with DEM resolution and USGS DEMs produce smaller floodplains than LiDAR. These findings are consistent when comparing FPM and Hazus outputs. However, the study also found that higher resolution DEMs produce smaller floodplains. This is inconsistent with the results. When comparing the two DEMs used, (30m USGS and 1m LiDAR) the 1m LiDAR produced a larger floodplain (Charrier & Li , 2011).

Table 4.2: Comparison of hydraulic model parameters

State Floodplain Mapping Project	Hazus Hydraulic Model
1 meter LiDAR DEM	1 arc-second (30 meter) DEM
1 square mile stream density	2 square mile stream density
Spatially varied Manning's n	Constant Manning's n (0.08)
1987 and 2001 USGS regression equations	1987 USGS regression equations
Inputted cross-sections	Automated cross-sections

4.4.4 Loss Estimation Results and Comparison

Upon completion of the hydraulics model, Hazus uses its inventory of census and supplementary data to estimate damage and direct economic losses. Results for the analysis are paired with totals from the FPM and methodologies previously described are shown in Table 4.3 for the East Nishnabotna watershed. For the 500 year event, Hazus estimates total losses of $128 million. For the same return period, the geospatial analysis estimates $83 million, a decrease of 43%. It is important to note that this value excludes damage to roads and agricultural structures, data which is not present in the Hazus model. Hazus estimates higher agricultural and commercial/industrial losses for all return periods. For residential property, Hazus totals lower damages for the three largest return periods. Differences in total economic losses between the two methodologies remain essentially constant, ranging from 43 to 45%. Additionally, Hazus consistently determines a greater number of inundated buildings.

Table 4.3: Damage summary comparison of study results and Hazus flood model

Floodplain Mapping	Return Period							
HAZUS-MH Flood Model	500		100		50		10	
Residential Property Losses (million $)	21.0	17.6	11.0	8.4	7.4	6.8	3.1	3.8
Commercial/Industrial Losses (million $)	12.4	39.3	5.5	18.0	4.0	15.2	1.6	6.7
Agricultural Losses (million $)	40.0	71.0	32.0	58.0	29.3	52.0	21.1	36.0
Road Damage (million $)	10.0	---	7.4	---	6.6	---	4.4	---
Inundated Households	734	856	349	367	238	290	93	138
Damaged Schools	4	2	1	1	1	1	0	0
Total Losses (million $)	73.4	128	48.5	84.4	40.7	74.1	25.8	46.5
% Difference	-43		-43		-45		-44	

Two categories, agricultural and commercial/commercial losses, have notable disparities between methodologies. Agricultural results vary up to 45% while commercial/industrial losses can differ up to 76%. There are multiple differences between the two loss estimation methods that heavily influence the results. Both the presented model and the Hazus flood model make assumptions about flood depth. In this regard, Hazus provides greater accuracy of data. Hazus calculates an average depth per census block prior to applying depth-damage relationships. The geospatial analysis assumes a constant depth of one foot throughout floodplains. Depth grids are available are available as outputs from both hydraulic analysis but are not utilized in each case. With added geoprocessing work, depth grids can be incorporated but was considered beyond the scope of this study.

Another important disparity in methodologies is that Hazus does not utilize spatially referenced structure or land use data. Instead it takes building counts and creates an even distribution throughout each census block. Residential building counts for each block are taken from the U.S. Census. Commercial and industrial structure data comes from an independent study conducted by Dun & Bradstreet (Schneider & Schauer, 2006). Typical percent distributions for square footage, occupancy class, foundation type, number of stories, first floor elevation, and construction material are applied to provide a more representative variation of infrastructure. These approximations exist because Hazus is intended for use nationwide. Geospatial data with the features and accuracy used in this study is unavailable in many regions of the country. As a result, block level is the highest level of accuracy for a national inventory.

The distribution of square footages likely accounts for the variation in commercial/industrial losses. Over all return periods, residential losses differ around 15% between methods. There is relatively little variation in home square footages; a typical Iowa home is 1,800 square feet. Depending on classification, industrial and commercial square footages can vary greatly. Assumed building square footages in Hazus range from 4,100 to 145,000 square feet for commercial, and 30,000 to 45,000 square feet for industrial. In the proposed procedure, commercial structures were assumed to be COM8 (5,000 square feet) and industrial to be IND1 (30,000 square feet). These decisions were made from examining satellite imagery and data within BEACON.

Both values fall on the low end of Hazus' distribution, and thus result in lower damage totals.

Agricultural lands account for the greatest loss disparity when comparing methods. Identical crop yields and prices from 2012 were used in the models, so varying coverage is likely responsible for the discrepancy. Similar to the building distribution, Hazus uses a procedure to approximate the distribution of agricultural lands. Crop data is gathered from the National Resource Inventory (NRI) dataset for each county. Proportions for each crop in the county are then assigned over the polygon. The NRI polygon clipped by Hazus classifies 97.6% of the area in the East Nishnabotna watershed as agricultural land. When overlaid and inspected with the landuse raster, it becomes apparent that all but residential and commercial lands fall within the polygon. This includes lands classified as wetlands, forests, ungrazed grasslands, roads, and barren, all categories that were excluded from the presented damage analysis. When broken down, only 66.6% of lands were classified as agriculture (corn, alfalfa, soybeans, other rowcrops) for the geospatial analysis. This estimate neglects damage to grazing and grasslands, a factor which is challenging to quantify, but overall seems to be a more accurate representation of the landscape.

Results from the East Nishnabotna watershed comparison are consistent with the findings from Ding, White, Ullman, and Fashokun (2008). The Level 1 hydraulic analysis consistently underestimates floodplain size across all return periods when matched with FPM products. Loss estimates for Hazus also substantially overestimate in comparison to detailed studies, with a large portion of the discrepancy coming from commercial and industrial structures. Results for a Level 2 analysis show closer estimates (Ding, White, Ullman, & Fashokun, 2008). A more detailed Hazus study for East Nishnabotna would be beneficial for further comparison.

CHAPTER 5: SUMMARY

5.1 Summary

This study presents a methodology to evaluate flood risk through the synthesis of geospatial data with flood maps for thirteen HUC 8s in southwest Iowa. Using ArcGIS, exposure of infrastructure, environmental hazards, are located within the 10, 50, 100, and 500 year floodplains. An economic loss framework based on an NED landuse raster and structure data is presented for the region and compared with results from FEMA Hazus-HM flood loss scenario.

The largest component of the study is development of a loss estimation methodology using geospatial data and an inventory of statistics. Agricultural losses were calculated using a reclassified NED landuse grid, USACE damage curves, and commodity prices. Road damages were evaluated using a similar methodology and established depth-damage relationships from a 2004 study. Individual structures geoferenced off of 2010 NAIP aerial photography were used to estimate infrastructure damage. This data was reconstructed for 10 of the 27 study counties using classified industrial, commercial, and residential lands. Losses from structures were determined using 2010 Census data, and appropriate damage curves. Debris estimation and removal costs were assessed using structure data and FEMA guidelines. Total economics losses for southwest Iowa range from $395 million for the 10 year event up to $700 million for the 500 year.

The composition of floodplain soils was also explored using SSURGO soil data. County datasets were merged and cropped to inundation extents for each return period. Flood frequency of floodplain soils was analyzed to evaluate the accuracy of SSURGO classifications. Hydrologic soil group percentages were calculated and trends were observed. Finally, the prevalence of hydric soils in floodplains was assessed to evaluate the effectiveness of this trait as a proxy. The accuracy of SSURGO data was deemed too low for the analysis to draw any conclusive trends.

A Hazus flood model was created for the East Nishnabotna watershed. Flood extents and depth grids were generated from a simplified hydraulics procedure. Coupling these outputs with Hazus' nationwide inventory of buildings, facilities, crops, and other census demographics, damage for the region is estimated. Hydraulics and loss estimation capabilities for both Hazus and the presented model were compared and assessed. Between models, the Hazus generated floodplains are consistently smaller across all return periods. The geospatial analysis consistently estimate lower damage totals for agriculture, commercial, and industrial losses. Overall damage totals are 44% higher for Hazus. These discrepancies are likely attributed to the assumption and distribution of infrastructure within Hazus.

5.2 Future Work

To achieve greater accuracy, a customized Hazus flood model could be used. This study uses a Level 1 Hazus analysis which utilizes many default parameters. Inputs from the statewide floodplain mapping project could be used as they are generated with a more hydraulically representative model. Using identical hydraulic inputs, the Hazus loss estimation methodology can be isolated for more detailed analysis. One major assumption made to simplified damage estimation was a constant flood depth. Incorporation of depth grid would allow to apply depth-damage relationships to individual structures.

Recent developments in geographic information systems (GIS) have enabled higher data resolution. The Iowa DNR is producing a 1 meter land use grid as part of the Iowa Geocoding project, and also intends to complete work on the georeferenced structure dataset. This represents an increase of 225 times in resolution from the 15 meter grid. At this detail, outlines of all structures, roadways, and water bodies can be discerned. This would greatly improve the accuracy of damage estimation for such features. Additionally, within the new grid there are more detailed land use categories. This would refine estimates for ecosystem services within the floodplains.

Finally, the study region for this study can be expanded. Currently, thirteen of Iowa's fifty six HUC 8s have been mapped. There are no major urban areas within southwest Iowa, and damage totals are heavily weighted toward agriculture. Incorporation of metro areas like Des Moines and Cedar Rapids, would provide a new setting to perform analysis and compare between models, where discrepancies in infrastructure damage would be more pronounced. Inundation from the Missouri River would also be valuable to incorporate. It is not modeled as part of the Statewide Floodplain Mapping Project and was completed by the USACE. The inclusion of its inundation would wash out smaller inundations and increase losses in the five bordering counties in the study.

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APPENDIX A: DETAILED RESULTS OF GEOSPATIAL ANALYSIS BY HUC 8

Table A.1: Land cover distribution by HUC 8 for 10 year floodplain

10 Year Land Cover (acres)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Water	2,634	1,046	1,521	616	1,523	1,574	208	0	691	853	738	146	2,868	14,417
Wetland	398	511	738	221	569	327	60	6	71	70	57	63	587	3,678
Bottomland Forest	1,128	147	371	98	1,430	594	7	117	409	379	49	0	161	4,891
Coniferous Forest	59	98	116	70	80	48	15	3	31	20	33	6	61	640
Deciduous Forest	4,690	1,518	2,220	1,189	4,921	3,938	159	497	2,233	1,758	1,395	1,930	8,305	34,755
Ungrazed Grassland	6,725	6,904	9,819	9,508	12,442	8,759	2,815	1,434	4,555	2,635	2,956	2,338	7,345	78,235
Grazed Grassland	2,100	929	1,675	1,599	1,967	1,773	357	406	1,373	1,230	1,284	1,976	4,244	20,913
Planted Grassland	714	652	856	769	678	764	213	147	438	251	282	391	920	7,075
Alfalfa/hay	612	224	493	237	717	552	35	153	291	282	648	1,093	2,118	7,456
Corn	12,911	13,661	26,043	28,989	26,234	18,276	13,108	1,257	6,998	4,259	2,618	1,786	6,656	162,797
Soybeans	8,186	9,042	18,781	16,189	17,787	9,000	2,525	654	4,019	2,328	2,530	2,238	6,993	100,272
Other Rowcrop	66	291	258	1,187	136	554	530	11	62	73	58	42	225	3,494
Roads	144	664	589	749	187	237	217	17	71	41	89	120	397	3,523
Commercial/Industrial	42	400	145	373	45	99	152	3	13	9	8	13	56	1,360
Reisdential	472	629	339	653	343	621	314	81	356	207	154	96	381	4,646
Barren	45	68	79	114	6	108	26	0	44	35	0	56	161	742
Total	40,927	36,785	64,043	62,561	69,066	47,225	20,741	4,787	21,655	14,430	12,899	12,296	41,478	448,893

Table A.2: Land cover distribution by HUC 8 for 50 year floodplain

50 Year Land Cover (acres)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Water	2,653	1,245	1,571	635	1,566	1,604	208	1	729	870	754	154	2,904	14,895
Wetland	414	601	786	227	599	352	61	5	83	82	76	74	649	4,008
Bottomland Forest	1,169	183	391	125	1,530	641	7	96	469	434	103	0	173	5,323
Coniferous Forest	56	118	122	91	91	54	16	4	41	25	43	8	71	740
Deciduous Forest	5,615	1,841	2,631	1,474	5,767	4,723	169	589	2,958	2,327	2,492	2,488	10,209	43,281
Ungrazed Grassland	8,704	8,574	12,185	10,407	16,236	11,281	2,825	1,939	6,293	3,698	4,695	3,205	9,623	99,664
Grazed Grassland	2,787	1,184	1,978	1,780	2,621	2,433	385	572	1,948	1,578	1,838	2,829	5,645	27,577
Planted Grassland	933	790	955	829	828	1,001	233	225	622	359	436	607	1,332	9,150
Alfalfa/hay	815	299	689	278	922	722	39	199	417	374	949	1,575	2,938	10,215
Corn	17,678	17,696	32,651	30,859	36,281	25,508	11,963	1,998	11,939	7,269	5,267	2,584	9,672	211,364
Soybeans	11,485	11,529	23,877	17,218	23,732	12,411	2,339	1,082	6,358	3,642	4,782	3,264	10,708	132,428
Other Rowcrop	121	359	315	1,314	169	678	564	16	98	133	93	52	339	4,253
Roads	219	830	782	820	304	355	234	25	105	63	128	179	563	4,607
Commercial/Industrial	74	503	243	407	72	166	158	4	18	17	10	17	73	1,763
Reisdential	571	815	438	749	482	808	323	104	458	280	247	113	449	5,838
Barren	48	107	85	119	7	116	26	0	46	36	0	62	185	838
Total	53,343	46,674	79,699	67,335	91,207	62,855	19,550	6,858	32,581	21,187	21,914	17,210	55,534	575,946

Table A.3: Land cover distribution by HUC 8 for 100 year floodplain

100 Year Land Cover (acres)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Water	2,669	1,352	1,612	638	1,580	1,621	209	1	733	873	757	161	2,911	15,117
Wetland	421	630	804	229	613	363	62	7	87	84	79	84	668	4,129
Bottomland Forest	1,194	203	410	129	1,552	656	7	129	493	446	106	0	176	5,503
Coniferous Forest	60	120	137	94	97	58	16	4	43	26	46	9	74	785
Deciduous Forest	5,920	1,991	2,780	1,534	6,020	5,002	175	682	3,208	2,461	2,652	2,697	10,799	45,921
Ungrazed Grassland	9,339	9,267	13,058	10,627	17,639	12,172	3,115	2,146	7,006	4,031	5,060	3,591	10,385	107,436
Grazed Grassland	3,008	1,284	2,136	1,817	2,858	2,635	415	612	2,154	1,687	1,989	3,110	6,127	29,832
Planted Grassland	1,017	888	1,009	841	894	1,087	249	239	691	397	485	703	1,470	9,972
Alfalfa/hay	883	332	748	286	1,024	773	40	208	471	402	1,023	1,718	3,214	11,121
Corn	19,231	19,115	35,185	31,432	40,301	28,331	13,872	2,311	14,579	8,268	5,876	2,954	10,673	232,128
Soybeans	12,576	12,422	25,794	17,573	26,113	13,804	2,867	1,199	7,663	4,034	5,310	3,713	11,726	144,792
Other Rowcrop	148	382	378	1,342	182	714	606	18	127	152	96	69	376	4,590
Roads	248	900	857	834	355	401	252	30	120	70	138	203	632	5,039
Commercial/Industrial	87	562	283	414	86	198	172	5	21	19	12	18	86	1,963
Reisdential	610	889	481	750	536	893	345	122	503	305	260	123	472	6,291
Barren	52	121	88	120	6	119	26	0	47	37	0	66	190	872
Total	57,462	50,459	85,761	68,661	99,856	68,828	22,428	7,714	37,944	23,293	23,890	19,218	59,978	625,492

Table A.4: Land cover distribution by HUC 8 for 500 year floodplain

500 Year Land Cover (acres)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Water	2,701	1,257	1,639	648	1,632	1,653	209	5	738	882	760	188	2,932	15,243
Wetland	433	632	839	233	638	373	62	7	93	87	80	104	698	4,278
Bottomland Forest	1,235	209	420	131	1,604	675	8	127	520	466	110	0	181	5,687
Coniferous Forest	72	134	144	93	117	61	16	5	46	30	48	10	81	858
Deciduous Forest	6,570	2,144	3,051	1,645	6,762	5,573	187	881	3,783	2,724	2,891	3,066	11,912	51,187
Ungrazed Grassland	11,085	10,256	14,789	11,187	21,360	14,496	3,021	2,932	8,754	4,579	5,619	4,642	11,760	124,479
Grazed Grassland	3,600	1,498	2,392	1,924	3,540	3,301	417	823	2,710	1,901	2,250	3,703	7,113	35,174
Planted Grassland	1,229	930	1,073	874	1,074	1,325	258	337	906	479	566	934	1,741	11,727
Alfalfa/hay	1,093	405	865	312	1,307	936	43	256	613	452	1,140	2,042	3,714	13,178
Corn	23,707	21,849	39,648	32,825	50,488	35,033	12,520	3,982	20,618	9,776	6,611	4,330	12,209	273,597
Soybeans	15,416	14,035	29,419	18,425	32,207	17,671	2,535	1,994	10,887	4,733	5,920	5,305	13,254	171,802
Other Rowcrop	191	442	421	1,405	213	839	591	29	160	205	103	105	427	5,132
Roads	330	1,065	1,013	917	436	553	256	49	172	84	159	261	764	6,059
Commercial/Industrial	130	689	352	450	107	317	175	6	28	26	13	23	105	2,421
Reisdential	727	1,100	571	804	630	1,127	342	162	598	348	278	155	507	7,350
Barren	65	135	91	124	7	125	26	0	48	38	0	75	201	934
Total	68,585	56,779	96,725	71,999	122,121	84,060	20,667	11,597	50,674	26,809	26,548	24,944	67,599	729,107

Table A.5: Agricultural losses by HUC 8 for the 10 year flood

10 Year Agricultural Damage ($)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Alfalfa/hay	490,715	179,863	395,572	190,239	575,121	443,143	28,075	122,948	233,723	226,086	520,003	876,809	1,699,623	5,981,920
Corn	10,652,564	11,271,647	21,488,113	23,918,619	21,645,552	15,079,002	10,815,038	1,037,441	5,773,952	3,514,328	2,160,347	1,473,308	5,492,151	134,322,061
Soybeans	5,107,690	5,642,002	11,718,854	10,101,593	11,098,739	5,615,940	1,575,268	408,368	2,507,677	1,452,363	1,578,342	1,396,640	4,363,237	62,566,712
Other Rowcrop	17,008	74,875	66,421	305,432	34,953	142,448	136,399	2,880	15,885	18,708	14,935	10,888	57,809	898,640
Total	16,267,977	17,168,387	33,668,960	34,515,883	33,354,364	21,280,533	12,554,780	1,571,638	8,531,237	5,211,485	4,273,626	3,757,644	11,612,820	203,769,333

Table A.6: Agricultural losses by HUC 8 for the 50 year flood

50 Year Agricultural Damage ($)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Alfalfa/hay	601,227	221,059	508,365	205,024	680,451	532,830	28,516	147,125	307,556	276,313	700,329	1,162,697	2,168,475	7,539,967
Corn	13,048,127	13,061,683	24,100,403	22,777,522	26,779,268	18,828,220	8,830,158	1,474,510	8,812,222	5,365,169	3,887,394	1,907,618	7,139,135	156,011,429
Soybeans	8,477,183	8,509,377	17,623,783	12,708,832	17,517,324	9,161,023	1,726,564	798,812	4,693,066	2,688,411	3,529,666	2,409,040	7,903,935	97,747,016
Other Rowcrop	89,143	265,072	232,837	970,154	124,767	500,719	416,660	11,572	72,694	97,821	68,851	38,517	250,277	3,139,084
Total	22,215,680	22,057,190	42,465,388	36,661,532	45,101,810	29,022,793	11,001,898	2,432,018	13,885,539	8,427,715	8,186,240	5,517,872	17,461,822	264,437,495

Table A.7: Agricultural losses by HUC 8 for the 100 year flood

100 Year Agricultural Damage ($)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Alfalfa/hay	651,481	245,194	551,841	210,851	755,666	570,438	29,549	153,406	347,313	296,398	755,294	1,268,329	2,372,631	8,208,392
Corn	14,194,665	14,109,118	25,970,703	23,200,753	29,746,720	20,911,644	10,238,917	1,705,901	10,761,085	6,102,527	4,336,991	2,180,543	7,877,981	171,337,548
Soybeans	9,282,277	9,168,834	19,038,699	12,971,011	19,274,098	10,188,704	2,115,948	885,351	5,655,946	2,977,660	3,919,464	2,740,608	8,654,972	106,873,572
Other Rowcrop	109,228	281,934	279,123	990,859	134,520	527,334	447,201	13,349	94,061	111,872	70,504	50,667	277,181	3,387,832
Total	24,237,650	23,805,079	45,840,366	37,373,474	49,911,005	32,198,120	12,831,615	2,758,006	16,858,405	9,488,458	9,082,253	6,240,146	19,182,766	289,807,343

Table A.8: Agricultural losses by HUC 8 for the 500 year flood

500 Year Agricultural Damage ($)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Alfalfa/hay	806,747	298,671	638,215	230,564	964,864	690,907	31,739	189,278	452,573	333,510	841,420	1,507,489	2,741,228	9,727,204
Corn	17,498,355	16,126,956	29,264,763	24,228,517	37,266,271	25,858,458	9,241,404	2,939,102	15,218,751	7,216,004	4,879,616	3,196,156	9,011,832	201,946,186
Soybeans	11,379,090	10,359,385	21,714,837	13,599,555	23,772,844	13,043,540	1,871,168	1,472,154	8,035,644	3,493,257	4,369,599	3,916,033	9,782,748	126,809,855
Other Rowcrop	141,297	326,195	310,615	1,037,393	156,919	619,576	436,373	21,366	118,237	151,340	76,125	77,860	314,830	3,788,126
Total	29,825,489	27,111,207	51,928,429	39,096,029	62,160,899	40,212,481	11,580,684	4,621,901	23,825,206	11,194,110	10,166,760	8,697,539	21,850,637	342,271,372

Table A.9: Existing structure data by HUC 8

Existing Structure Data												
HUC 8	500			100			50			10		
	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture
7100007	258	41	358	127	14	232	108	8	182	62	1	87
10230006	2251	303	460	1760	250	335	1602	240	320	1498	211	255
10230007	493	150	968	391	127	701	365	105	627	301	74	362
10240001	545	75	721	472	57	651	466	51	659	413	34	615
10240002	188	29	394	118	21	190	73	14	121	5	7	81
10240003	587	174	238	231	74	146	134	54	124	36	18	65
10240004	313	125	351	293	126	329	282	126	278	265	126	273
10240005	0	1	6	0	1	6	0	1	4	0	0	3
10240009	1	0	15	1	0	6	1	0	3	1	0	3
10240010	0	0	0	0	0	0	0	0	0	0	0	0
10240012	0	0	0	0	0	0	0	0	0	0	0	0
10280101	0	0	0	0	0	0	0	0	0	0	0	0
10280102	0	1	14	0	1	6	0	0	2	0	0	2
Total	4,636	899	3,525	3,393	671	2,602	3,031	599	2,320	2,581	471	1,746
	9,060			6,666			5,950			4,798		

Table A.10: Reconstructed structure data by HUC 8

Reconstructed Structure Data												
HUC 8	500			100			50			10		
	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture
7100007	6	0	2	4	0	1	3	0	1	2	0	0
10230006	0	0	0	0	0	0	0	0	0	0	0	0
10230007	1	0	5	1	0	4	1	0	3	1	0	2
10240001	0	0	0	0	0	0	0	0	0	0	0	0
10240002	9	0	14	5	0	6	4	0	4	3	0	2
10240003	167	28	117	121	14	78	105	12	60	63	6	33
10240004	0	0	0	0	0	0	0	0	0	0	0	0
10240005	74	2	25	52	2	11	42	1	9	28	1	5
10240009	280	6	140	223	4	98	203	3	77	137	2	48
10240010	263	11	112	212	7	87	189	7	69	117	4	42
10240012	210	5	102	181	5	83	167	4	67	87	3	35
10280101	112	8	84	81	6	55	72	5	43	51	4	30
10280102	131	16	78	113	14	65	106	14	55	76	10	42
Total	1,253	76	679	993	52	488	892	46	388	565	30	239
	2,008			1,533			1,326			834		

Table A.11: Total structures by HUC 8

Total Structures												
HUC 8	500			100			50			10		
	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture	Residential	Commercial /Industrial	Agriculture
7100007	264	41	360	131	14	233	111	8	183	64	1	87
10230006	2251	303	460	1760	250	335	1602	240	320	1498	211	255
10230007	494	150	973	392	127	705	366	105	630	302	74	364
10240001	545	75	721	472	57	651	466	51	659	413	34	615
10240002	197	29	408	123	21	196	77	14	125	8	7	83
10240003	754	202	355	352	88	224	239	66	184	99	24	98
10240004	313	125	351	293	126	329	282	126	278	265	126	273
10240005	74	3	31	52	3	17	42	2	13	28	1	8
10240009	281	6	155	224	4	104	204	3	80	138	2	51
10240010	263	11	112	212	7	87	189	7	69	117	4	42
10240012	210	5	102	181	5	83	167	4	67	87	3	35
10280101	112	8	84	81	6	55	72	5	43	51	4	30
10280102	131	17	92	113	15	71	106	14	57	76	10	44
Total	5,889	975	4,204	4,386	723	3,090	3,923	645	2,708	3,146	501	1,985
	11,068			8,199			7,276			5,632		

Table A.12: Agricultural structure losses by HUC 8

Agricultural Structures								
HUC 8	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
7100007	360	3,199,680	233	2,070,904	183	1,626,504	87	773,256
10230006	460	4,088,480	335	2,977,480	320	2,844,160	255	2,266,440
10230007	973	8,648,024	705	6,266,040	630	5,599,440	364	3,235,232
10240001	721	6,408,248	651	5,786,088	659	5,857,192	615	5,466,120
10240002	408	3,626,304	196	1,742,048	125	1,111,000	83	737,704
10240003	355	3,155,240	224	1,990,912	184	1,635,392	98	871,024
10240004	351	3,119,688	329	2,924,152	278	2,470,864	273	2,426,424
10240005	31	275,528	17	151,096	13	115,544	8	71,104
10240009	155	1,377,640	104	924,352	80	711,040	51	453,288
10240010	112	995,456	87	773,256	69	613,272	42	373,296
10240012	102	906,576	83	737,704	67	595,496	35	311,080
10280101	84	746,592	55	488,840	43	382,184	30	266,640
10280102	92	817,696	71	631,048	57	506,616	44	391,072
Total	4,204	37,365,152	3,090	27,463,920	2,708	24,068,704	1,985	17,642,680

Table A.13: Commercial structure losses by HUC 8

Commercial Structures								
HUC 8	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
7100007	36	1,487,340	12	495,780	7	289,205	1	41,315
10230006	270	11,155,050	223	9,213,245	214	8,841,410	188	7,767,220
10230007	134	5,536,210	113	4,668,595	93	3,842,295	66	2,726,790
10240001	67	2,768,105	51	2,107,065	45	1,859,175	30	1,239,450
10240002	26	1,074,190	19	784,985	12	495,780	6	247,890
10240003	180	7,436,700	78	3,222,570	59	2,437,585	21	867,615
10240004	111	4,585,965	112	4,627,280	112	4,627,280	112	4,627,280
10240005	3	123,945	3	123,945	2	82,630	1	41,315
10240009	5	206,575	4	165,260	3	123,945	2	82,630
10240010	10	413,150	6	247,890	6	247,890	4	165,260
10240012	4	165,260	4	165,260	4	165,260	3	123,945
10280101	7	289,205	5	206,575	4	165,260	4	165,260
10280102	15	619,725	13	537,095	12	495,780	9	371,835
Total	868	35,861,420	643	26,565,545	573	23,673,495	447	18,467,805

Table A.14: Industrial structure losses by HUC 8

Industrial Structures								
HUC 8	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
7100007	5	1,139,250	2	455,700	1	227,850	0	0
10230006	33	7,519,050	27	6,151,950	26	5,924,100	23	5,240,550
10230007	16	3,645,600	14	3,189,900	12	2,734,200	8	1,822,800
10240001	8	1,822,800	6	1,367,100	6	1,367,100	4	911,400
10240002	3	683,550	2	455,700	2	455,700	1	227,850
10240003	22	5,012,700	10	2,278,500	7	1,594,950	3	683,550
10240004	14	3,189,900	14	3,189,900	14	3,189,900	14	3,189,900
10240005	0	0	0	0	0	0	0	0
10240009	1	227,850	0	0	0	0	0	0
10240010	1	227,850	1	227,850	1	227,850	0	0
10240012	1	227,850	1	227,850	0	0	0	0
10280101	1	227,850	1	227,850	1	227,850	0	0
10280102	2	455,700	2	455,700	2	455,700	1	227,850
Total	107	24,379,950	80	18,228,000	72	16,405,200	54	12,303,900

Table A.15: Mobile residential structure losses by HUC 8

Residential - Mobile								
HUC 8	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
7100007	32	130,560	32	130,560	32	130,560	27	110,160
10230006	81	330,480	61	248,880	54	220,320	49	199,920
10230007	26	106,080	24	97,920	21	85,680	16	65,280
10240001	101	412,080	94	383,520	96	391,680	92	375,360
10240002	99	403,920	71	289,680	58	236,640	0	0
10240003	32	130,560	19	77,520	15	61,200	7	28,560
10240004	11	44,880	11	44,880	10	40,800	10	40,800
10240005	3	12,240	2	8,160	2	8,160	1	4,080
10240009	11	44,880	9	36,720	8	32,640	5	20,400
10240010	11	44,880	8	32,640	8	32,640	5	20,400
10240012	8	32,640	7	28,560	7	28,560	3	12,240
10280101	4	16,320	3	12,240	3	12,240	2	8,160
10280102	5	20,400	5	20,400	4	16,320	3	12,240
Total	424	1,729,920	346	1,411,680	318	1,297,440	220	897,600

Table A.16: Multi-unit structure losses by HUC 8

Residential - Multi Unit								
HUC 8	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
7100007	4	200,000	0	0	0	0	0	0
10230006	119	5,950,000	104	5,200,000	98	4,900,000	90	4,500,000
10230007	8	400,000	7	350,000	5	250,000	4	200,000
10240001	8	400,000	4	200,000	2	100,000	2	100,000
10240002	1	50,000	0	0	0	0	0	0
10240003	25	1,250,000	15	750,000	8	400,000	5	250,000
10240004	10	500,000	10	500,000	10	500,000	10	500,000
10240005	6	300,000	4	200,000	3	150,000	2	100,000
10240009	22	1,100,000	18	900,000	16	800,000	11	550,000
10240010	21	1,050,000	17	850,000	15	750,000	9	450,000
10240012	17	850,000	14	700,000	13	650,000	7	350,000
10280101	9	450,000	6	300,000	6	300,000	4	200,000
10280102	10	500,000	9	450,000	8	400,000	6	300,000
Total	260	13,000,000	208	10,400,000	184	9,200,000	150	7,500,000

Table A.17: Single-unit residential structure losses by HUC 8

Residential - Single Unit								
HUC 8	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
7100007	218	5,362,800	99	2,423,592	70	1,722,000	36	885,600
10230006	1,964	48,314,400	1,591	39,138,600	1,431	35,202,600	1,321	32,496,600
10230007	441	10,845,648	361	8,877,648	330	8,118,000	282	6,934,248
10240001	415	10,209,000	374	9,200,400	363	8,929,800	305	7,503,000
10240002	92	2,263,200	51	1,264,440	19	455,592	6	147,600
10240003	677	16,654,200	315	7,749,000	215	5,298,840	81	1,992,600
10240004	282	6,937,200	267	6,568,200	252	6,199,200	241	5,928,600
10240005	65	1,601,952	43	1,057,800	33	811,800	25	606,144
10240009	249	6,125,400	187	4,600,200	175	4,305,000	112	2,755,200
10240010	233	5,731,800	177	4,354,200	161	3,960,600	101	2,484,600
10240012	189	4,649,400	159	3,918,288	142	3,493,200	73	1,795,800
10280101	99	2,424,576	71	1,753,488	63	1,558,656	43	1,057,800
10280102	116	2,853,600	96	2,361,600	91	2,238,600	64	1,574,400
Total	5,040	123,973,176	3,791	93,267,456	3,345	82,293,888	2,690	66,162,192

Table A.18: Total structure losses by HUC 8

Structure Losses								
HUC 8	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
7100007	655	11,765,630	378	5,588,344	293	4,217,519	151	1,834,931
10230006	2,927	79,497,660	2,341	63,028,555	2,143	58,399,990	1,926	53,405,530
10230007	1,598	29,651,914	1,224	23,453,055	1,091	20,875,615	740	14,987,302
10240001	1,320	22,536,833	1,180	19,044,173	1,171	18,627,947	1,048	15,939,730
10240002	629	8,224,164	339	4,551,613	216	2,766,520	96	1,410,244
10240003	1,291	34,131,400	661	16,142,302	488	11,442,727	215	4,840,949
10240004	779	18,623,633	743	17,977,412	676	17,274,044	660	16,811,404
10240005	108	2,310,713	69	1,614,801	53	1,266,534	37	831,499
10240009	443	9,057,745	322	6,872,532	282	6,095,625	181	4,107,518
10240010	388	8,413,936	296	6,731,836	260	5,955,252	161	3,542,756
10240012	321	6,733,326	268	5,795,374	233	5,055,516	121	2,691,465
10280101	204	4,165,367	141	3,006,705	120	2,637,334	83	1,747,060
10280102	240	5,267,121	196	4,529,643	174	4,186,816	127	2,951,197
Total	10,903	240,379,442	8,158	178,336,345	7,200	158,801,439	5,546	125,101,585

Table A.19: Debris removal costs by HUC 8

Debris Removal								
HUC 8	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
7100007	665	126,890	378	67,323	302	51,510	152	27,645
10230006	3,014	801,380	2,345	648,000	2,162	591,625	1,964	537,680
10230007	1,617	295,230	1,224	235,185	1,101	208,700	740	154,015
10240001	1,341	255,600	1,180	226,300	1,176	221,695	1,062	192,405
10240002	634	108,600	340	63,748	216	40,593	98	12,830
10240003	1,311	330,030	664	159,435	489	114,168	221	46,595
10240004	789	172,845	748	166,580	686	156,760	664	153,015
10240005	108	26,045	72	17,235	57	13,230	37	9,314
10240009	442	101,090	332	74,970	287	67,785	191	43,580
10240010	386	93,575	306	71,050	265	63,940	163	39,565
10240012	317	75,370	269	63,523	238	55,930	125	29,065
10280101	204	44,430	142	31,583	120	27,686	85	18,895
10280102	240	54,445	199	45,430	177	41,605	130	29,775
Total	11,068	2,485,530	8,199	1,870,361	7,276	1,655,228	5,632	1,294,378

Table A.20: Total economic losses by HUC 8

Damage Estimate ($1,000)				
HUC 8	500	100	50	10
7100007	47,820	34,473	30,535	20,786
10230006	127,086	104,110	96,390	83,379
10230007	100,608	85,362	77,998	59,701
10240001	78,830	72,065	70,674	64,485
10240002	78,550	61,090	53,532	38,226
10240003	84,895	55,916	47,135	30,555
10240004	35,109	35,626	32,764	33,531
10240005	7,864	4,944	4,180	2,730
10240009	36,167	26,026	21,983	13,996
10240010	21,246	17,589	15,606	9,558
10240012	19,918	17,494	15,656	8,638
10280101	17,728	13,031	11,495	7,751
10280102	41,303	35,434	32,097	21,939
Total	697,123	563,160	510,044	395,275

Table A.21: Displaced population by HUC 8

HUC 8	Return Period			
	500	100	50	10
7100007	678	332	259	160
10230006	6,465	5,307	4,819	4,441
10230007	1,271	1,052	945	799
10240001	1,396	1,231	1,187	1,030
10240002	496	311	194	15
10240003	2,068	1,009	671	277
10240004	851	813	772	744
10240005	237	157	121	86
10240009	895	690	636	415
10240010	844	651	589	365
10240012	682	572	517	268
10280101	357	253	233	157
10280102	414	353	327	234
Total	16,654	12,730	11,270	8,992

Table A.22: Total number of environmental facilities by HUC 8

Total Environmental Factors														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	**Total**
Solid Waste Land Application	12	134	75	17	21	5	10	0	2	0	4	0	12	**292**
Solid Waste Facility	2	11	7	1	9	8	0	1	3	0	2	0	4	**48**
Water Treatment Plant	30	19	38	17	41	32	1	3	18	8	5	3	12	**227**
Air Facility	36	22	31	8	37	34	3	1	21	11	11	9	14	**238**
Public Water Supply Facility	56	62	54	46	50	57	3	7	28	11	12	23	58	**467**
Surface Water Intake - Public	1	3	0	0	2	0	0	8	38	4	7	5	6	**74**
Wells - Public	141	112	132	73	230	182	9	1	64	18	11	29	56	**1058**
Contaminated Sites Facility	10	29	10	6	9	19	2	0	5	2	5	1	2	**100**
Water Use Facility	24	76	109	36	23	47	22	3	13	7	4	40	34	**438**
Underground Storage Tank Facility	239	354	255	91	318	324	22	23	78	48	63	48	97	**1960**
Leaking Underground Storage Tank	99	191	95	30	88	142	8	4	35	16	33	18	42	**801**
Wastewater NPDES Facility	23	19	16	4	14	13	0	1	5	4	4	9	19	**131**
Wastewater Treatment Plant	34	29	27	10	36	25	2	2	9	8	5	9	24	**220**
Wastewater Outfall	40	33	30	8	36	39	3	3	14	9	9	10	28	**262**
Stormwater Facility	20	37	32	4	17	46	1	3	9	6	10	3	9	**197**
Tier II Chemical Storage Facility	64	44	39	9	42	50	2	2	20	9	14	17	20	**332**
Animal Feeding Facility	9	1	2	1	7	6	0	0	2	0	1	0	1	**30**
Wastewater Industrial Contributor	2	0	3	1	0	5	0	0	1	0	1	0	1	**14**
Surface Water Intake - Water Use	24	20	37	18	36	61	4	5	20	14	7	111	49	**406**
Wells - Water Use	59	145	161	56	172	116	32	2	31	4	0	0	13	**791**
Spill Incidents	201	285	216	49	125	179	7	9	37	29	46	31	65	**1279**
Commercial Manure Applicator	10	2	15	1	5	3	0	0	4	0	3	6	2	**51**
Flood Plain Permits	274	188	379	117	280	461	25	57	170	107	69	186	231	**2544**
Total	**1410**	**1816**	**1763**	**603**	**1598**	**1854**	**156**	**135**	**627**	**315**	**326**	**558**	**799**	**11960**

Table A.23: Environmental facilities by HUC 8 located within the 10 year floodplain

10 Year Environmental Factors														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Solid Waste Land Application	0	24	12	5	0	0	6	0	2	0	0	0	1	**50**
Solid Waste Facility	0	2	2	0	0	0	0	0	0	0	0	0	0	**4**
Water Treatment Plant	0	1	13	9	0	2	1	0	0	0	0	0	0	**26**
Air Facility	0	1	1	1	1	3	3	0	0	0	0	0	1	**11**
Public Water Supply Facility	0	3	21	15	3	2	1	0	0	0	0	0	0	**45**
Surface Water Intake - Public	1	0	0	0	0	0	0	0	1	0	2	0	0	**4**
Wells - Public	13	12	35	20	79	13	3	0	9	3	0	2	2	**191**
Contaminated Sites Facility	0	3	0	1	1	0	1	0	0	0	0	0	0	**6**
Water Use Facility	2	13	25	17	5	7	7	0	1	0	0	0	1	**78**
Underground Storage Tank Facility	3	27	9	15	5	8	11	0	2	2	0	1	2	**85**
Leaking Underground Storage Tank	1	13	9	4	1	2	5	0	0	1	0	0	0	**36**
Wastewater NPDES Facility	1	2	3	1	1	1	0	0	0	1	0	0	0	**10**
Wastewater Treatment Plant	2	2	4	1	3	3	2	0	0	3	0	0	0	**20**
Wastewater Outfall	13	9	9	1	14	9	3	1	4	2	0	0	4	**69**
Stormwater Facility	1	4	3	2	1	11	1	0	0	0	0	0	0	**23**
Tier II Chemical Storage Facility	2	7	3	3	1	8	2	0	0	0	0	0	1	**27**
Animal Feeding Facility	1	0	1	0	0	0	0	0	0	0	0	0	0	**2**
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Surface Water Intake - Water Use	6	8	9	4	19	26	3	0	4	3	1	3	8	**94**
Wells - Water Use	5	31	59	43	61	17	13	0	6	0	0	0	6	**241**
Spill Incidents	5	15	17	18	4	4	2	0	0	0	1	0	4	**70**
Commercial Manure Applicator	0	0	1	0	0	0	0	0	0	0	0	0	0	**1**
Flood Plain Permits	52	29	52	20	76	88	4	7	18	17	4	8	23	**398**
Total	**108**	**206**	**288**	**180**	**275**	**204**	**68**	**8**	**47**	**32**	**8**	**14**	**53**	**1491**

Table A.24: Environmental facilities by HUC 8 located within the 50 year floodplain

50 Year Environmental Factors														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	**Total**
Solid Waste Land Application	1	35	20	6	1	0	6	0	2	0	0	0	1	**72**
Solid Waste Facility	0	2	2	0	1	1	0	0	0	0	0	0	0	**6**
Water Treatment Plant	3	1	16	9	0	2	1	0	1	0	0	0	0	**33**
Air Facility	1	2	2	1	4	4	3	0	0	0	0	0	1	**18**
Public Water Supply Facility	4	5	22	15	3	2	1	0	0	0	0	0	1	**53**
Surface Water Intake - Public	1	0	0	0	0	0	0	0	1	0	2	0	0	**4**
Wells - Public	26	14	53	21	113	26	3	0	12	4	0	4	2	**278**
Contaminated Sites Facility	0	3	4	1	1	0	1	0	0	1	0	0	0	**11**
Water Use Facility	4	16	36	16	6	7	7	0	1	0	0	0	1	**94**
Underground Storage Tank Facility	5	40	18	18	10	19	12	0	2	4	0	1	2	**131**
Leaking Underground Storage Tank	2	22	10	6	1	3	6	0	0	2	0	0	0	**52**
Wastewater NPDES Facility	1	2	3	1	3	1	0	0	0	1	0	0	0	**12**
Wastewater Treatment Plant	4	3	5	1	7	4	2	0	1	4	0	0	1	**32**
Wastewater Outfall	15	12	14	2	18	13	3	1	4	4	0	0	5	**91**
Stormwater Facility	1	4	5	25	1	17	1	0	0	0	1	0	0	**55**
Tier II Chemical Storage Facility	5	7	4	3	1	8	2	0	0	0	0	0	1	**31**
Animal Feeding Facility	1	0	1	0	0	0	0	0	0	0	0	0	0	**2**
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Surface Water Intake - Water Use	6	9	10	4	22	29	3	0	5	3	1	3	8	**103**
Wells - Water Use	9	39	85	40	92	27	13	0	8	0	0	0	9	**322**
Spill Incidents	5	23	27	19	5	8	2	0	0	1	1	0	5	**96**
Commercial Manure Applicator	1	0	1	0	0	9	0	0	0	0	0	0	0	**11**
Flood Plain Permits	65	40	68	25	96	111	4	10	33	28	11	15	30	**536**
Total	**160**	**279**	**406**	**213**	**385**	**291**	**70**	**11**	**70**	**52**	**16**	**23**	**67**	**2043**

Table A.25: Environmental facilities by HUC 8 located within the 100 year floodplain

100 Year Environmental Factors														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	**Total**
Solid Waste Land Application	1	37	22	6	1	0	6	0	2	0	0	0	1	**76**
Solid Waste Facility	0	2	2	0	1	1	0	0	0	0	0	0	0	**6**
Water Treatment Plant	3	1	16	9	2	2	1	0	1	0	0	0	0	**35**
Air Facility	1	2	5	1	5	4	3	0	1	0	0	0	1	**23**
Public Water Supply Facility	4	5	22	16	4	3	1	0	0	0	1	0	1	**57**
Surface Water Intake - Public	1	0	0	0	0	4	0	0	1	0	2	0	0	**8**
Wells - Public	27	15	59	21	126	35	3	0	12	4	1	4	2	**309**
Contaminated Sites Facility	0	3	4	1	2	0	1	0	0	1	0	0	0	**12**
Water Use Facility	5	17	43	16	6	8	9	0	1	0	0	0	1	**106**
Underground Storage Tank Facility	6	43	19	18	13	23	12	0	2	5	0	1	2	**144**
Leaking Underground Storage Tank	2	26	10	6	3	4	6	0	0	2	0	0	0	**59**
Wastewater NPDES Facility	1	2	4	1	4	3	0	0	0	1	0	0	0	**16**
Wastewater Treatment Plant	4	4	8	2	8	6	2	0	1	4	0	0	1	**40**
Wastewater Outfall	15	12	16	2	18	13	3	1	5	5	0	0	5	**95**
Stormwater Facility	14	6	32	27	21	18	5	1	0	4	8	4	9	**149**
Tier II Chemical Storage Facility	3	8	5	3	2	8	2	0	0	0	0	0	1	**32**
Animal Feeding Facility	1	0	1	0	0	0	0	0	0	0	0	0	0	**2**
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Surface Water Intake - Water Use	6	9	12	4	20	29	3	0	5	3	1	5	8	**105**
Wells - Water Use	10	40	95	40	101	33	16	0	8	0	0	0	10	**353**
Spill Incidents	7	27	27	20	5	9	4	0	0	1	1	0	5	**106**
Commercial Manure Applicator	1	0	1	0	0	0	0	0	0	0	0	0	0	**2**
Flood Plain Permits	70	43	72	25	104	124	6	13	43	31	12	15	33	**591**
Total	**182**	**302**	**475**	**218**	**446**	**327**	**83**	**15**	**82**	**61**	**26**	**29**	**80**	**2326**

Table A.26: Environmental facilities by HUC 8 located within the 500 year floodplain

500 Year Environmental Factors														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	**Total**
Solid Waste Land Application	1	49	25	7	1	0	6	0	2	0	0	0	2	**93**
Solid Waste Facility	0	3	2	0	1	1	0	0	0	0	0	0	0	**7**
Water Treatment Plant	3	1	17	9	2	2	1	0	1	0	0	0	0	**36**
Air Facility	1	4	5	1	6	6	3	0	1	1	0	0	1	**29**
Public Water Supply Facility	5	5	22	15	6	5	1	0	0	0	1	0	1	**61**
Surface Water Intake - Public	1	0	0	0	0	0	0	0	1	0	2	0	0	**4**
Wells - Public	30	16	66	22	134	49	3	0	16	4	1	5	3	**349**
Contaminated Sites Facility	0	3	4	1	4	5	1	0	0	1	0	0	0	**19**
Water Use Facility	5	21	46	17	7	10	9	0	1	0	0	0	1	**117**
Underground Storage Tank Facility	11	55	33	20	19	48	13	0	2	5	0	1	2	**209**
Leaking Underground Storage Tank	6	34	13	8	5	15	7	0	0	3	0	0	0	**91**
Wastewater NPDES Facility	1	2	4	2	5	4	0	0	0	1	0	0	0	**19**
Wastewater Treatment Plant	4	4	9	4	9	8	2	1	1	4	0	0	1	**47**
Wastewater Outfall	16	13	17	3	21	16	3	2	6	6	0	0	5	**108**
Stormwater Facility	18	7	37	27	28	23	5	1	0	6	8	5	10	**175**
Tier II Chemical Storage Facility	4	10	9	3	2	11	2	0	0	0	0	0	1	**42**
Animal Feeding Facility	1	0	1	0	1	0	0	0	0	0	0	0	0	**3**
Wastewater Industrial Contributor	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Surface Water Intake - Water Use	7	9	11	4	21	31	3	0	5	3	1	5	8	**108**
Wells - Water Use	13	50	107	40	107	40	16	0	11	0	0	0	10	**394**
Spill Incidents	12	38	52	20	6	12	6	0	0	1	1	0	5	**153**
Commercial Manure Applicator	1	0	1	0	0	0	0	0	0	0	0	0	0	**2**
Flood Plain Permits	86	47	82	25	125	146	6	18	68	33	12	18	36	**702**
Total	**226**	**371**	**563**	**228**	**511**	**432**	**87**	**22**	**115**	**68**	**26**	**34**	**86**	**2769**

Table A.27: Annual value of ecosystem services within the 10 year floodplain by HUC 8

10 Year Ecolologic Exposure ($)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Grassland	681,508	606,216	882,296	848,372	1,077,904	806,960	241,832	141,948	454,816	294,008	323,112	336,136	893,632	7,588,740
Open Water	658,588	261,534	380,240	154,084	380,842	393,568	51,898	28	172,732	213,276	184,408	36,540	717,122	3,604,860
Forest	4,934,154	1,479,936	2,272,638	1,139,233	5,398,702	3,844,976	152,280	517,705	2,243,639	1,811,192	1,239,625	1,625,401	7,157,630	33,817,111
Wetland	2,936,843	3,766,147	5,440,862	1,632,176	4,200,210	2,412,746	442,736	45,430	524,923	512,946	418,782	467,103	4,327,827	27,128,731
Total	9,211,093	6,113,833	8,976,036	3,773,865	11,057,658	7,458,250	888,746	705,111	3,396,110	2,831,422	2,165,927	2,465,180	13,096,211	72,139,442

Table A.28: Annual value of ecosystem services within the 50 year floodplain by HUC 8

50 Year Ecolologic Exposure ($)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Grassland	887,624	753,580	1,080,032	929,916	1,406,348	1,051,236	245,920	195,468	633,216	402,540	497,880	474,400	1,185,868	9,744,028
Open Water	663,432	311,416	392,728	158,844	391,454	401,142	52,052	196	182,182	217,560	188,566	38,570	726,180	3,724,322
Forest	5,742,084	1,797,797	2,639,614	1,418,930	6,201,462	4,548,566	161,022	577,818	2,910,898	2,338,391	2,214,828	2,095,119	8,775,041	41,421,570
Wetland	3,057,439	4,431,077	5,798,107	1,677,193	4,418,687	2,593,640	448,518	35,105	610,414	604,219	560,441	547,638	4,784,605	29,567,083
Total	10,350,579	7,293,870	9,910,481	4,184,883	12,417,951	8,594,584	907,512	808,587	4,336,710	3,562,710	3,461,715	3,155,727	15,471,694	84,457,003

Table A.29: Annual value of ecosystem services within the 100 year floodplain by HUC 8

100 Year Ecolologic Exposure ($)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Grassland	954,712	817,200	1,157,612	949,120	1,528,224	1,135,532	270,024	214,056	703,736	436,912	538,320	528,968	1,284,644	10,519,060
Open Water	667,380	338,044	403,004	159,628	394,996	405,314	52,248	364	183,302	218,386	189,224	40,152	727,972	3,780,014
Forest	6,022,486	1,942,792	2,793,633	1,474,108	6,437,872	4,798,465	166,239	684,743	3,142,373	2,463,082	2,354,183	2,270,993	9,274,745	43,825,714
Wetland	3,103,282	4,649,967	5,930,267	1,690,409	4,518,633	2,675,001	460,908	52,451	638,911	619,500	581,091	616,196	4,923,786	30,460,402
Total	10,747,860	7,748,003	10,284,516	4,273,265	12,879,725	9,014,312	949,419	951,614	4,668,322	3,737,880	3,662,818	3,456,309	16,211,147	88,585,190

Table A.30: Annual value of ecosystem services within the 500 year floodplain by HUC 8

500 Year Ecolologic Exposure ($)														
HUC 8	7100007	10230006	10230007	10240001	10240002	10240003	10240004	10240005	10240009	10240010	10240012	10280101	10280102	Total
Grassland	1,136,928	906,156	1,304,060	999,164	1,855,576	1,366,084	264,072	292,400	883,780	497,164	602,612	662,920	1,472,700	12,243,616
Open Water	675,304	314,300	409,864	162,120	407,988	413,364	52,234	1,372	184,408	220,528	189,966	46,956	733,124	3,811,528
Forest	6,612,900	2,087,505	3,033,662	1,569,424	7,120,876	5,296,383	177,096	849,948	3,650,631	2,702,265	2,559,432	2,582,321	10,220,150	48,462,593
Wetland	3,191,664	4,661,531	6,185,914	1,718,493	4,702,418	2,753,471	453,887	50,799	686,406	644,280	592,655	766,115	5,151,349	31,558,982
Total	11,616,796	7,969,492	10,933,500	4,449,201	14,086,858	9,829,302	947,289	1,194,519	5,405,225	4,064,237	3,944,665	4,058,312	17,577,323	96,076,719

Table A.31: Flood frequency of 10 year floodplain soils by HUC 8

10 Year Soil Flood Frequency (acres)							
HUC 8	None	Rare	Occassional	Common	Frequent	Ponded	No Data
7100007	9,043	66	17,938	329	5,152	1,283	6,497
10230006	1,608	9,752	21,041	978	5	0	2,879
10230007	3,929	6,519	37,239	11,404	867	1,071	2,143
10240001	4,872	38,434	13,313	2,860	98	436	2,013
10240002	3,117	4,128	34,832	18,941	3,284	707	3,091
10240003	4,296	2,971	30,474	4,471	2,138	1,033	3,697
10240004	1,874	13,763	4,447	0	0	186	290
10240005	254	0	1,900	2,364	0	0	138
10240009	2,919	301	5,896	9,933	696	0	1,516
10240010	1,921	157	5,062	5,087	730	0	1,233
10240012	1,940	124	7,409	1,921	526	0	778
10280101	1,002	220	9,180	443	860	0	310
10280102	5,763	1,661	3,606	14,003	11,801	0	3,978
Total	**42,537**	**78,096**	**192,337**	**72,733**	**26,158**	**4,717**	**28,562**

Table A.32: Flood frequency of 50 year floodplain soils by HUC 8

50 Year Soil Flood Frequency (acres)							
HUC 8	None	Rare	Occassional	Common	Frequent	Ponded	No Data
7100007	12,598	167	24,362	389	6,560	1,475	7,150
10230006	2,439	11,058	27,956	1,342	8	0	3,326
10230007	5,760	8,315	43,473	16,145	1,700	1,079	2,327
10240001	5,680	40,180	14,707	3,523	123	448	2,061
10240002	4,926	5,214	44,120	27,114	4,803	714	3,282
10240003	6,164	4,283	40,166	5,968	2,786	1,050	4,120
10240004	2,130	14,543	4,591	0	0	193	311
10240005	417	0	2,764	3,398	0	0	145
10240009	4,432	655	10,008	14,232	1,023	1	1,813
10240010	2,716	257	8,173	7,308	790	0	1,694
10240012	2,752	341	14,227	2,596	960	0	802
10280101	1,416	401	13,009	753	1,027	0	326
10280102	8,101	2,788	5,730	18,234	15,978	0	4,038
Total	**59,531**	**88,202**	**253,286**	**101,001**	**35,759**	**4,960**	**31,396**

Table A.33: Flood frequency of 100 year floodplain soils by HUC 8

100 Year Soil Flood Frequency (acres)							
HUC 8	None	Rare	Occassional	Common	Frequent	Ponded	No Data
7100007	14,156	205	26,257	418	6,982	1,527	7,297
10230006	2,793	11,815	30,240	1,497	9	0	3,529
10230007	6,586	9,214	45,905	17,750	1,940	1,083	2,396
10240001	6,014	40,706	15,148	3,682	126	450	2,078
10240002	5,791	5,579	47,854	30,167	5,382	716	3,323
10240003	6,952	4,558	44,311	6,400	3,022	1,054	4,219
10240004	2,249	14,821	4,642	0	0	196	316
10240005	481	0	3,020	3,926	0	0	149
10240009	5,018	878	13,054	15,545	1,103	1	1,914
10240010	3,022	312	9,192	7,921	798	0	1,789
10240012	3,054	381	15,770	2,666	971	0	810
10280101	1,598	473	14,626	816	1,088	0	333
10280102	9,000	3,165	6,361	19,349	17,376	0	4,062
Total	**66,714**	**92,107**	**276,380**	**110,137**	**38,797**	**5,028**	**32,215**

Table A.34: Flood frequency of 500 year floodplain soils by HUC 8

500 Year Soil Flood Frequency (acres)							
HUC 8	None	Rare	Occassional	Common	Frequent	Ponded	No Data
7100007	19,645	292	30,314	496	7,757	1,811	7,605
10230006	4,164	17,496	34,895	2,146	11	0	3,730
10230007	8,632	10,827	49,761	20,483	2,534	1,091	2,468
10240001	6,654	41,819	16,264	4,042	137	456	2,109
10240002	8,737	6,294	57,595	37,711	6,452	725	3,413
10240003	9,809	5,260	53,921	7,714	3,470	1,066	4,393
10240004	1,850	13,813	4,392	0	0	196	314
10240005	744	5	3,927	6,684	0	0	159
10240009	7,505	1,480	19,718	18,420	1,200	2	2,061
10240010	3,752	422	10,575	9,077	817	0	1,962
10240012	3,647	472	17,650	2,783	988	0	818
10280101	2,063	694	19,548	933	1,175	0	368
10280102	11,029	3,849	7,366	20,893	19,666	0	4,109
Total	**88,231**	**102,725**	**325,925**	**131,383**	**44,206**	**5,348**	**33,508**

Table A.35: Hydrologic groups of 10 year floodplain soils by HUC 8

10 Year Soil Hydrologic Group (acres)							
HUC 8	A	B	B/D	C	C/D	D	No Data
7100007	69	9,719	21,323	682	2,018	1	6,497
10230006	812	17,249	604	2,863	37	11,820	2,879
10230007	131	26,388	10,718	1,406	2,764	19,624	2,143
10240001	708	37,833	1,267	4,120	133	15,937	2,028
10240002	0	31,119	13,789	5,063	14,877	160	3,091
10240003	1	25,623	6,342	3,126	8,970	1,322	3,697
10240004	6	10,663	394	853	51	8,303	290
10240005	0	1,024	3,223	8	253	9	138
10240009	1	11,925	4,099	374	1,209	2,137	1,516
10240010	1	5,806	4,250	289	287	2,324	1,233
10240012	0	6,000	2,457	419	1,288	1,756	778
10280101	0	7,212	84	375	3,254	780	310
10280102	0	12,025	2,026	14,623	6,417	1,742	3,978
Total	**1,729**	**202,585**	**70,576**	**34,201**	**41,556**	**65,915**	**28,577**

Table A.36: Hydrologic groups of 50 year floodplain soils by HUC 8

50 Year Soil Hydrologic Group (acres)							
HUC 8	A	B	B/D	C	C/D	D	No Data
7100007	100	13,931	26,988	1,178	3,352	1	7,150
10230006	1,028	23,678	900	3,281	61	13,853	3,326
10230007	139	36,555	12,358	1,600	3,276	22,544	2,327
10240001	833	41,333	1,500	4,243	162	16,562	2,090
10240002	0	42,375	18,825	5,847	19,670	175	3,282
10240003	1	33,034	8,821	3,895	12,570	2,096	4,120
10240004	7	11,672	415	890	51	8,421	311
10240005	0	1,521	4,676	21	344	17	145
10240009	2	17,410	6,654	723	2,342	3,221	1,813
10240010	3	8,286	5,899	437	443	4,175	1,694
10240012	0	9,496	3,305	742	3,715	3,618	802
10280101	0	9,928	131	473	4,903	1,171	326
10280102	0	15,015	2,682	20,528	9,661	2,945	4,038
Total	**2,114**	**264,234**	**93,155**	**43,858**	**60,551**	**78,801**	**31,425**

Table A.37: Hydrologic groups of 100 year floodplain soils by HUC 8

100 Year Soil Hydrologic Group (acres)							
HUC 8	A	B	B/D	C	C/D	D	No Data
7100007	113	15,395	28,946	1,364	3,723	2	7,297
10230006	1,115	25,830	992	3,452	64	14,901	3,529
10230007	146	40,473	12,887	1,654	3,469	23,850	2,396
10240001	871	42,458	1,575	4,297	169	16,730	2,106
10240002	1	47,141	20,733	6,011	21,423	179	3,323
10240003	2	35,872	9,941	4,048	14,057	2,378	4,219
10240004	7	12,050	422	899	51	8,479	316
10240005	0	1,774	5,226	28	378	22	149
10240009	1	19,951	7,856	902	3,233	3,655	1,914
10240010	4	9,094	6,408	479	483	4,776	1,789
10240012	0	10,318	3,394	797	4,498	3,835	810
10280101	0	10,957	147	506	5,594	1,398	333
10280102	0	16,003	2,831	22,449	10,823	3,145	4,062
Total	**2,260**	**287,317**	**101,358**	**46,885**	**67,966**	**83,348**	**32,243**

Table A.38: Hydrologic groups of 500 year floodplain soils by HUC 8

500 Year Soil Hydrologic Group (acres)							
HUC 8	A	B	B/D	C	C/D	D	No Data
7100007	153	19,641	34,558	1,697	4,265	4	7,605
10230006	1,764	33,901	1,373	4,561	70	17,042	3,730
10230007	162	48,057	13,823	1,733	3,896	25,656	2,468
10240001	950	44,874	1,805	4,420	183	17,110	2,141
10240002	2	58,209	26,602	6,327	26,111	263	3,413
10240003	2	42,968	13,163	4,406	17,713	2,989	4,393
10240004	7	11,207	427	938	51	7,622	314
10240005	0	3,217	7,332	61	711	38	159
10240009	2	26,068	10,672	1,496	5,475	4,613	2,061
10240010	6	10,577	7,381	607	559	5,513	1,962
10240012	0	11,640	3,589	965	5,247	4,100	818
10280101	0	13,467	177	588	7,830	2,349	368
10280102	0	17,718	3,058	25,678	12,900	3,449	4,109
Total	**3,049**	**341,544**	**123,961**	**53,475**	**85,010**	**90,748**	**33,539**

Table A.39: Hydric composition of 10 year floodplain soils by HUC 8

10 Year Hydric Soil Code (acres)					
HUC 8	Yes	No	Yes (%)	No (%)	No Data
7100007	24,286	9,526	72	28	0
10230006	8,627	24,088	26	74	3,549
10230007	32,243	27,774	54	46	3,156
10240001	13,328	44,455	23	77	4,244
10240002	30,620	33,527	48	52	3,952
10240003	18,894	25,892	42	58	4,295
10240004	8,309	11,325	42	58	926
10240005	3,555	963	79	21	138
10240009	10,250	9,495	52	48	1,516
10240010	8,436	4,521	65	35	1,233
10240012	7,569	4,351	64	36	778
10280101	4,481	7,223	38	62	310
10280102	14,122	22,681	38	62	4,007
Total	**184,719**	**225,820**	**45**	**55**	**28,103**

Table A.40: Hydric composition of 50 year floodplain soils by HUC 8

50 Year Hydric Soil Code (acres)					
HUC 8	Yes	No	Yes (%)	No (%)	No Data
7100007	31,691	13,860	70	30	7,150
10230006	10,493	31,338	25	75	4,298
10230007	36,712	37,898	49	51	4,188
10240001	13,939	48,051	22	78	4,732
10240002	40,371	44,494	48	52	5,310
10240003	26,625	33,089	45	55	4,825
10240004	8,444	12,229	41	59	1,094
10240005	5,114	1,464	78	22	146
10240009	16,453	13,898	54	46	1,813
10240010	12,685	6,559	66	34	1,694
10240012	13,509	7,368	65	35	802
10280101	6,704	9,902	40	60	326
10280102	20,814	29,980	41	59	4,076
Total	**243,552**	**290,131**	**46**	**54**	**40,454**

Table A.41: Hydric composition of 100 year floodplain soils by HUC 8

100 Year Hydric Soil Code (acres)					
HUC 8	Yes	No	Yes (%)	No (%)	No Data
7100007	34,192	15,353	69	31	7,297
10230006	11,370	33,884	25	75	4,628
10230007	38,471	41,703	48	52	4,701
10240001	14,113	49,185	22	78	4,907
10240002	43,921	49,006	47	53	5,884
10240003	29,737	35,791	45	55	4,989
10240004	8,506	12,547	40	60	1,171
10240005	5,704	1,722	77	23	150
10240009	19,496	16,102	55	45	1,914
10240010	14,041	7,204	66	34	1,789
10240012	14,907	7,935	65	35	810
10280101	7,687	10,915	41	59	333
10280102	22,880	32,332	41	59	4,100
Total	**265,026**	**313,678**	**46**	**54**	**42,673**

Table A.42: Hydric composition of 500 year floodplain soils by HUC 8

500 Year Hydric Soil Code (acres)					
HUC 8	Yes	No	Yes (%)	No (%)	No Data
7100007	40,812	19,504	68	32	7,605
10230006	12,672	44,111	22	78	5,659
10230007	41,173	48,808	46	54	5,814
10240001	14,550	51,705	22	78	5,228
10240002	53,692	59,778	47	53	7,457
10240003	38,013	42,271	47	53	5,350
10240004	7,686	11,618	40	60	1,261
10240005	8,170	3,185	72	28	164
10240009	20,770	27,555	43	57	2,061
10240010	16,308	8,336	66	34	1,962
10240012	16,750	8,790	66	34	818
10280101	11,012	13,401	45	55	368
10280102	26,365	36,392	42	58	4,154
Total	**307,972**	**375,453**	**45**	**55**	**47,901**

APPENDIX B: DETAILED RESULTS OF GEOSPATIAL ANALYSIS BY COUNTY

Table B.1: Land cover distribution by county for 10 year floodplain

10 Year Land Cover (acres)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Water	355	9	295	95	45	0	151	798	83	1,429	1,781	479	867	495
Wetland	101	1	8	11	6	2	11	566	35	616	155	139	450	83
Bottomland Forest	422	0	26	72	68	0	160	139	90	627	746	171	466	281
Coniferous Forest	23	1	0	6	11	1	6	67	17	124	47	40	75	33
Deciduous Forest	1,130	6	43	269	588	487	408	1,215	847	3,129	2,750	790	2,260	1,525
Ungrazed Grassland	2,933	200	457	1,589	1,990	90	3,037	5,185	1,490	9,661	2,990	2,390	7,430	3,713
Grazed Grassland	342	47	252	271	879	206	538	552	406	1,379	769	469	1,565	1,372
Planted Grassland	175	9	17	163	127	20	118	526	211	745	264	177	707	436
Alfalfa/hay	235	3	45	45	391	114	239	155	147	440	258	146	204	341
Corn	3,747	182	347	1,505	2,862	14	8,744	18,297	1,254	22,384	4,062	2,164	18,860	7,100
Soybeans	2,690	147	364	838	2,014	75	5,716	13,796	1,064	12,954	2,651	1,376	13,963	2,714
Other Rowcrop	10	1	0	21	3	3	22	259	53	124	34	8	1,013	450
Roads	43	0	3	24	26	4	58	447	28	644	39	42	662	94
Commercial/Industrial	4	0	0	6	1	1	13	109	3	415	14	15	222	47
Reisdential	51	1	43	69	75	5	162	232	102	705	208	63	362	262
Barren	2	1	0	0	0	0	2	52	0	88	0	0	45	21
Total	12,261	610	1,899	4,986	9,086	1,022	19,385	42,395	5,831	55,464	16,769	8,469	49,152	18,967
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Water	21	0	2,102	625	1,162	131	410	840	702	0	0	455	1,090	14,423
Wetland	6	0	197	100	312	50	224	39	110	3	0	98	375	3,699
Bottomland Forest	0	0	53	349	187	62	196	299	349	0	1	9	118	4,891
Coniferous Forest	1	0	36	9	51	7	6	21	15	3	1	8	32	640
Deciduous Forest	390	0	2,485	2,075	1,845	256	1,489	1,504	1,985	323	54	2,241	4,663	34,758
Ungrazed Grassland	235	15	3,118	2,817	12,547	2,470	1,109	2,165	3,633	429	85	2,724	3,747	78,249
Grazed Grassland	328	5	1,955	462	1,648	741	684	1,211	759	175	1	1,786	2,113	20,914
Planted Grassland	51	0	387	151	766	210	373	223	329	32	0	384	472	7,075
Alfalfa/hay	174	3	969	233	395	188	141	230	188	109	3	946	1,114	7,456
Corn	87	10	2,678	4,001	43,163	4,174	1,296	2,218	7,557	313	6	2,425	3,550	163,000
Soybeans	217	33	2,568	2,539	18,449	3,271	538	1,497	3,883	334	3	2,804	3,935	100,432
Other Rowcrop	28	0	57	13	1,051	9	13	63	78	0	0	43	139	3,494
Roads	18	0	171	54	569	45	58	31	88	22	0	139	215	3,523
Commercial/Industrial	0	0	17	21	362	14	16	9	17	2	0	21	34	1,362
Reisdential	4	0	126	202	994	24	86	159	329	11	0	125	246	4,646
Barren	17	0	49	31	101	25	42	25	87	1	0	56	94	742
Total	1,577	65	16,970	13,682	83,602	11,678	6,680	10,532	20,108	1,756	155	14,264	21,938	449,304

Table B.2: Land cover distribution by county for 50 year floodplain

50 Year Land Cover (acres)														
	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Water	359	9	301	97	46	0	156	814	85	1,641	1,794	517	894	502
Wetland	108	1	8	14	7	3	14	625	43	680	163	158	462	88
Bottomland Forest	463	0	27	82	82	0	167	145	108	677	779	186	507	305
Coniferous Forest	23	1	0	6	18	2	7	71	24	150	44	45	93	37
Deciduous Forest	1,368	7	44	406	795	748	451	1,407	1,163	3,623	3,420	1,016	2,675	1,941
Ungrazed Grassland	4,040	224	519	2,420	2,740	201	3,850	6,346	2,115	11,969	4,020	3,608	8,692	5,064
Grazed Grassland	495	49	298	415	1,207	358	734	611	598	1,836	1,061	676	1,821	1,870
Planted Grassland	222	10	23	227	197	56	156	577	303	900	366	230	766	598
Alfalfa/hay	295	4	51	72	505	232	326	189	217	567	341	269	258	454
Corn	6,665	226	462	3,479	4,797	114	11,104	22,764	2,164	28,553	6,340	4,928	21,691	10,899
Soybeans	4,770	186	420	2,075	3,223	251	7,611	17,081	1,577	16,337	4,142	3,327	15,777	4,162
Other Rowcrop	18	1	0	52	12	9	30	305	58	177	76	21	1,126	528
Roads	69	1	5	41	38	10	91	570	39	847	64	101	753	151
Commercial/Industrial	10	0	1	14	3	3	31	161	3	532	25	54	254	82
Reisdential	76	1	45	97	104	8	207	284	137	931	256	105	457	360
Barren	2	1	1	0	0	0	3	58	0	126	1	1	45	23
Total	18,983	721	2,203	9,498	13,773	1,994	24,937	52,007	8,636	69,545	22,890	15,241	56,272	27,064
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Water	22	0	2,118	647	1,177	132	405	847	747	0	0	473	1,115	14,900
Wetland	7	0	204	108	337	53	230	45	121	3	0	123	428	4,030
Bottomland Forest	0	0	71	388	214	63	195	350	351	0	1	30	130	5,324
Coniferous Forest	1	0	40	10	57	7	5	27	17	3	1	12	39	740
Deciduous Forest	600	0	2,997	2,462	2,177	272	1,697	2,241	2,360	351	61	3,272	5,731	43,286
Ungrazed Grassland	373	22	3,879	3,822	13,638	2,835	1,363	3,166	4,651	492	139	4,304	5,191	99,681
Grazed Grassland	507	7	2,476	639	1,854	813	862	1,564	1,125	220	1	2,654	2,828	27,579
Planted Grassland	88	0	491	200	883	229	451	332	462	44	1	622	717	9,150
Alfalfa/hay	252	6	1,265	301	465	231	185	338	250	124	5	1,452	1,561	10,215
Corn	160	16	3,479	6,382	44,462	4,735	1,757	4,409	11,006	385	86	4,898	5,675	211,634
Soybeans	461	41	3,297	3,775	19,570	3,789	729	2,791	4,906	413	39	5,311	6,578	132,640
Other Rowcrop	40	0	67	24	1,145	10	19	101	126	0	0	81	227	4,253
Roads	29	0	228	84	632	51	82	51	119	27	0	212	313	4,608
Commercial/Industrial	0	0	21	35	387	17	20	16	26	2	0	27	43	1,765
Reisdential	7	0	147	280	1,086	31	99	222	401	13	0	191	292	5,838
Barren	20	0	51	32	107	26	43	28	95	1	0	62	114	838
Total	2,566	93	20,833	19,189	88,191	13,294	8,142	16,526	26,764	2,080	334	23,723	30,981	576,482

Table B.3: Land cover distribution by county for 100 year floodplain

100 Year Land Cover (acres)	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Water	364	9	302	102	46	0	157	876	85	1,701	1,803	538	899	508
Wetland	112	1	8	15	7	4	15	654	44	692	166	165	464	90
Bottomland Forest	471	0	28	84	86	0	172	159	112	692	796	197	517	317
Coniferous Forest	26	1	0	6	18	2	8	80	25	156	47	50	96	40
Deciduous Forest	1,432	7	45	470	850	821	469	1,520	1,253	3,778	3,635	1,090	2,790	2,094
Ungrazed Grassland	4,425	229	544	2,746	2,960	240	4,107	6,984	2,272	12,759	4,315	4,060	9,063	5,577
Grazed Grassland	542	51	311	463	1,315	406	796	658	666	2,015	1,151	772	1,881	2,038
Planted Grassland	242	10	26	255	222	70	170	660	335	955	400	253	782	659
Alfalfa/hay	312	4	54	85	537	269	354	206	237	625	366	308	278	488
Corn	7,954	246	515	4,462	5,476	166	11,888	24,626	2,417	30,730	7,009	5,999	22,554	12,727
Soybeans	5,618	203	448	2,604	3,690	298	8,244	18,492	1,711	17,500	4,588	4,006	16,424	4,929
Other Rowcrop	22	1	0	67	13	11	33	356	60	194	97	36	1,151	564
Roads	82	1	5	52	44	13	106	619	43	933	71	121	774	171
Commercial/Industrial	14	0	1	19	4	3	40	183	4	596	29	71	261	92
Reisdential	87	1	46	109	114	10	224	308	144	1,020	275	124	475	402
Barren	2	1	1	0	0	0	4	60	0	140	2	1	46	23
Total	21,703	764	2,334	11,542	15,381	2,312	26,784	56,442	9,407	74,486	24,749	17,792	58,454	30,720

	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Water	22	1	2,122	652	1,184	132	410	851	748	0	0	482	1,119	15,114
Wetland	7	0	205	112	352	53	232	47	124	3	0	134	444	4,151
Bottomland Forest	0	0	71	408	219	64	197	364	384	0	1	31	132	5,503
Coniferous Forest	1	0	42	11	58	8	6	29	18	3	1	13	41	785
Deciduous Forest	641	0	3,093	2,622	2,274	275	1,764	2,385	2,529	360	68	3,560	6,104	45,929
Ungrazed Grassland	401	23	4,055	4,302	14,258	2,947	1,458	3,482	5,025	509	158	4,833	5,731	107,464
Grazed Grassland	555	8	2,626	706	1,944	834	922	1,660	1,225	236	2	2,956	3,095	29,834
Planted Grassland	100	0	526	221	923	239	488	368	496	48	0	732	791	9,972
Alfalfa/hay	269	7	1,343	329	504	238	201	367	267	129	5	1,604	1,736	11,121
Corn	173	17	3,659	7,932	47,186	4,930	1,929	5,370	11,865	403	127	5,652	6,417	232,431
Soybeans	505	46	3,472	4,576	20,576	3,964	808	3,276	5,188	430	67	6,084	7,326	145,074
Other Rowcrop	41	0	69	27	1,205	11	22	112	143	0	0	99	258	4,591
Roads	32	0	248	100	664	54	92	57	133	30	0	239	356	5,041
Commercial/Industrial	0	0	23	49	407	18	21	17	30	2	0	29	53	1,965
Reisdential	8	0	152	326	1,123	32	105	244	435	13	0	206	309	6,291
Barren	21	0	52	32	107	25	43	29	97	1	0	66	117	872
Total	2,776	102	21,760	22,405	92,983	13,826	8,699	18,658	28,708	2,167	432	26,719	34,030	626,138

Table B.4: Land cover distribution by county for 500 year floodplain

500 Year Land Cover (acres)	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Water	388	9	312	106	46	0	162	833	86	1,692	1,812	563	914	523
Wetland	121	1	10	16	7	4	16	678	44	704	169	171	471	93
Bottomland Forest	494	0	30	90	90	0	180	154	115	711	823	206	526	329
Coniferous Forest	28	1	1	7	19	2	9	81	26	178	56	56	103	41
Deciduous Forest	1,600	7	54	581	943	955	518	1,634	1,423	4,116	4,104	1,231	3,094	2,383
Ungrazed Grassland	5,697	244	705	3,651	3,453	306	5,000	7,759	2,574	14,582	4,959	5,062	9,783	6,778
Grazed Grassland	676	52	368	634	1,569	499	1,013	681	790	2,480	1,391	992	2,010	2,505
Planted Grassland	297	11	43	332	284	103	214	642	395	1,082	492	302	812	820
Alfalfa/hay	366	4	77	141	612	318	467	235	263	792	427	388	321	569
Corn	11,767	298	911	7,195	6,932	224	14,606	27,898	2,804	35,706	8,442	8,025	24,288	16,430
Soybeans	7,939	239	594	4,433	4,736	362	10,152	20,780	1,946	20,249	5,518	5,485	17,619	6,559
Other Rowcrop	38	1	3	136	17	13	42	385	62	235	119	59	1,202	613
Roads	112	1	7	81	58	17	155	700	49	1,111	90	190	826	240
Commercial/Industrial	22	0	1	36	5	3	72	202	4	729	37	115	280	122
Reisdential	102	1	51	142	138	12	289	351	157	1,252	316	170	517	490
Barren	2	1	2	0	0	0	15	62	0	153	3	2	47	26
Total	29,648	870	3,165	17,581	18,911	2,819	32,909	63,075	10,739	85,769	28,758	23,016	62,814	38,521

	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Water	22	2	2,131	666	1,179	135	418	859	750	0	0	511	1,131	15,249
Wetland	8	0	212	118	362	55	237	51	125	3	0	156	468	4,300
Bottomland Forest	0	0	73	435	227	65	202	383	385	0	2	32	136	5,687
Coniferous Forest	1	0	44	13	58	8	7	33	20	3	1	15	46	858
Deciduous Forest	710	0	3,266	2,978	2,511	283	1,883	2,715	2,918	373	71	4,018	6,826	51,192
Ungrazed Grassland	453	25	4,380	5,483	15,026	3,206	1,624	4,151	6,147	545	190	6,029	6,695	124,506
Grazed Grassland	647	9	2,910	946	2,139	893	1,021	1,890	1,564	261	3	3,568	3,664	35,176
Planted Grassland	124	0	602	309	996	251	554	472	636	53	1	961	936	11,727
Alfalfa/hay	303	8	1,474	412	589	266	229	445	322	141	5	1,937	2,069	13,178
Corn	196	23	4,007	11,571	47,700	5,445	2,244	7,085	14,645	434	200	7,344	7,517	273,935
Soybeans	563	52	3,786	6,673	21,511	4,439	979	4,268	6,252	462	148	7,924	8,422	172,089
Other Rowcrop	43	0	74	40	1,232	14	33	132	200	0	0	140	300	5,133
Roads	37	0	286	148	747	60	109	77	177	32	0	305	444	6,061
Commercial/Industrial	1	0	26	88	458	20	25	24	50	3	0	35	67	2,423
Reisdential	9	0	160	461	1,203	36	113	287	505	14	1	241	332	7,350
Barren	23	0	54	32	112	26	43	30	101	2	0	75	123	934
Total	3,139	119	23,486	30,373	96,048	15,202	9,721	22,903	34,799	2,326	622	33,290	39,177	729,799

Table B.5: Agricultural losses by county for the 10 year flood

10 Year Agricultural Damage ($)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Alfalfa/hay	193,907	2,820	36,748	37,441	322,686	94,065	197,467	127,577	121,290	363,085	212,813	120,828	168,392	281,409
Corn	3,181,000	154,779	294,869	1,277,876	2,429,780	11,979	7,423,394	15,534,404	1,064,770	19,004,521	3,449,058	1,837,428	16,012,431	130,480
Soybeans	1,726,857	94,403	233,670	537,980	1,293,381	48,388	3,670,057	8,858,249	683,035	8,317,357	1,702,232	883,237	8,965,054	49,876
Other Rowcrop	2,771	213	0	5,439	711	904	5,824	68,525	13,960	32,751	9,084	2,015	268,216	8,263
Total	5,104,535	252,214	565,287	1,858,736	4,046,559	155,336	11,296,742	24,588,755	1,883,056	27,717,714	5,373,187	2,843,508	25,414,094	470,027
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Alfalfa/hay	143,755	2,496	800,267	192,105	326,338	154,987	116,483	189,886	155,357	89,674	2,866	781,315	919,385	6,155,442
Corn	73,872	8,271	2,273,813	3,397,006	36,646,075	3,543,798	1,100,470	1,882,730	6,415,811	265,729	5,277	2,058,711	3,014,004	132,492,336
Soybeans	139,195	20,994	1,649,063	1,630,046	11,845,702	2,100,082	345,472	961,103	2,492,935	214,257	1,726	1,800,517	2,526,619	62,791,486
Other Rowcrop	7,350	0	15,205	3,423	278,056	2,341	3,527	16,568	20,732	0	0	11,292	36,826	813,999
Total	364,173	31,762	4,738,348	5,222,579	49,096,171	5,801,209	1,565,952	3,050,287	9,084,835	569,660	9,868	4,651,835	6,496,835	202,253,263

Table B.6: Agricultural losses by county for the 50 year flood

50 Year Agricultural Damage ($)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Alfalfa/hay	233,936	2,840	40,254	57,386	400,368	184,095	258,390	149,833	171,713	449,187	270,240	213,121	204,866	360,025
Corn	5,432,909	184,624	376,504	2,836,403	3,910,141	92,700	9,051,624	18,556,568	1,764,217	23,276,406	5,168,092	4,017,310	17,681,922	8,884,527
Soybeans	2,940,387	114,423	259,083	1,279,056	1,986,617	154,877	4,692,048	10,529,917	972,271	10,071,257	2,553,660	2,051,060	9,726,468	2,566,017
Other Rowcrop	4,496	213	28	13,204	2,945	2,405	7,684	77,590	14,812	44,949	19,195	5,364	286,243	134,122
Total	8,611,729	302,101	675,871	4,186,049	6,300,071	434,077	14,009,745	29,313,908	2,923,013	33,841,799	8,011,187	6,286,855	27,899,499	11,944,690
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Alfalfa/hay	200,117	5,060	1,002,361	238,818	368,368	182,941	146,726	267,577	198,298	98,483	3,950	1,151,084	1,237,229	8,097,269
Corn	130,218	12,962	2,836,357	5,202,872	36,244,697	3,859,524	1,431,894	3,594,159	8,972,251	313,746	70,152	3,992,982	4,625,906	172,521,667
Soybeans	284,108	25,473	2,032,628	2,327,091	12,064,846	2,335,962	449,582	1,720,423	3,024,711	254,769	24,300	3,274,096	4,055,212	81,770,342
Other Rowcrop	10,145	0	17,018	6,090	291,010	2,647	4,852	25,669	31,915	14	0	20,603	57,641	1,080,858
Total	624,588	43,495	5,888,365	7,774,871	48,968,922	6,381,074	2,033,054	5,607,828	12,227,176	667,012	98,402	8,438,766	9,975,988	263,470,136

Table B.7: Agricultural losses by county for the 100 year flood

100 Year Agricultural Damage ($)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Alfalfa/hay	247,117	3,018	42,562	67,727	425,621	213,565	280,626	163,458	187,957	495,078	289,946	244,233	220,089	386,920
Corn	6,484,100	200,370	419,773	3,637,428	4,517,907	136,789	9,808,317	20,318,872	1,994,593	25,354,969	5,782,868	4,949,663	18,608,806	10,500,576
Soybeans	3,463,144	125,089	276,273	1,605,620	2,302,393	185,650	5,143,814	11,538,304	1,067,647	10,919,167	2,862,697	2,499,432	10,248,359	3,075,738
Other Rowcrop	5,535	213	43	17,132	3,429	2,832	8,509	90,396	15,125	49,261	24,588	9,135	292,447	143,257
Total	10,199,897	328,691	738,651	5,327,906	7,249,350	538,835	15,241,266	32,111,031	3,265,321	36,818,475	8,960,099	7,702,462	29,369,701	14,106,491
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Alfalfa/hay	213,032	5,326	1,064,363	261,053	399,169	188,356	159,464	291,233	211,479	102,078	4,172	1,271,803	1,375,878	8,815,321
Corn	141,081	13,693	2,983,098	6,466,391	38,465,841	4,019,181	1,572,884	4,377,428	9,672,406	328,854	103,700	4,607,740	5,231,261	190,698,588
Soybeans	311,238	28,200	2,140,631	2,821,165	12,684,596	2,443,724	498,389	2,019,788	3,198,469	265,193	41,524	3,750,532	4,516,599	90,033,375
Other Rowcrop	32,576	0	54,545	21,348	955,006	8,876	17,353	88,408	113,440	89	0	78,378	204,644	2,236,565
Total	697,928	47,219	6,242,637	9,569,957	52,504,612	6,660,137	2,248,089	6,776,857	13,195,794	696,213	149,395	9,708,453	11,328,382	291,783,849

Table B.8: Agricultural losses by county for the 500 year flood

500 Year Agricultural Damage ($)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Alfalfa/hay	290,212	2,974	61,202	111,398	484,915	251,733	370,454	185,915	208,860	627,469	338,588	307,343	254,174	451,096
Corn	9,592,715	243,228	742,420	5,865,508	5,650,989	182,341	11,906,877	22,742,298	2,285,545	29,106,815	6,881,828	6,541,564	19,799,229	13,393,679
Soybeans	4,894,040	147,180	365,948	2,732,630	2,919,918	223,151	6,258,319	12,810,721	1,199,737	12,483,259	3,401,946	3,381,616	10,861,692	4,043,476
Other Rowcrop	9,761	213	740	34,633	4,311	3,344	10,558	97,895	15,766	59,619	30,165	15,054	305,495	155,750
Total	14,786,728	393,595	1,170,310	8,744,169	9,060,133	660,570	18,546,208	35,836,829	3,709,907	42,277,163	10,652,528	10,245,577	31,220,590	18,044,001
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Alfalfa/hay	240,061	5,947	1,168,038	326,516	466,496	211,213	181,654	352,879	255,239	111,398	4,305	1,535,785	1,640,349	10,446,216
Corn	159,475	18,896	3,266,309	9,432,145	38,884,336	4,438,680	1,828,938	5,775,502	11,938,690	353,774	163,263	5,986,415	6,127,496	223,308,955
Soybeans	347,205	31,963	2,334,167	4,113,649	13,261,200	2,736,392	603,285	2,630,943	3,853,979	284,971	91,401	4,884,824	5,191,990	106,089,601
Other Rowcrop	33,996	0	59,028	31,600	976,309	10,918	26,363	104,386	158,532	133	0	110,954	238,019	2,493,543
Total	780,737	56,806	6,827,542	13,903,910	53,588,342	7,397,203	2,640,240	8,863,710	16,206,439	750,277	258,969	12,517,979	13,197,853	342,338,315

Table B.9: Road damage by county

County	Length of Inundated Road (miles)				Total Road Damage ($)			
	500	100	50	10	500	100	50	10
Shelby	8.65	6.32	5.38	3.31	2,066,160	1,509,528	1,283,978	791,494
Buena Vista	0.06	0.05	0.06	0.03	14,485	11,381	13,450	8,277
Greene	0.52	0.37	0.35	0.22	124,156	88,978	83,805	52,766
Audubon	6.23	4.01	3.14	1.88	1,488,836	958,069	749,074	450,065
Adair	4.48	3.39	2.92	2.00	1,069,810	810,117	698,377	478,000
Wayne	1.30	0.98	0.80	0.32	310,390	233,827	191,407	77,597
Carroll	12.02	8.18	7.08	4.51	2,870,070	1,953,385	1,690,589	1,078,087
Harrison	54.18	47.90	44.10	34.59	12,937,040	11,437,858	10,530,486	8,259,468
Taylor	3.80	3.34	3.05	2.14	908,407	798,736	729,416	511,108
Pottawattamie	85.94	72.23	65.55	49.86	20,521,928	17,249,387	15,652,949	11,906,547
Guthrie	7.00	5.48	4.92	3.04	1,670,931	1,307,775	1,174,307	726,312
Crawford	14.73	9.39	7.79	3.23	3,516,715	2,242,048	1,859,234	771,836
Mills	63.91	59.89	58.23	51.24	15,260,824	14,300,685	13,906,490	12,236,594
Cass	18.59	13.27	11.72	7.26	4,439,606	3,168,044	2,797,645	1,733,009
Clarke	2.89	2.47	2.21	1.36	690,100	589,740	528,697	323,840
Ida	0.00	0.01	0.00	0.00	1,035	2,069	1,035	1,035
Union	22.14	19.20	17.66	13.24	5,288,005	4,585,490	4,218,195	3,162,870
Montgomery	11.49	7.73	6.50	4.14	2,742,810	1,844,749	1,552,983	989,108
Fremont	57.84	51.40	48.88	44.00	13,811,304	12,274,876	11,672,720	10,507,724
Sac	4.64	4.19	3.92	3.47	1,108,091	999,455	935,307	828,740
Dallas	8.43	7.09	6.38	4.48	2,012,359	1,693,693	1,524,013	1,069,810
Adams	5.98	4.45	3.91	2.40	1,428,827	1,061,533	934,273	572,152
Page	13.71	10.31	9.24	6.80	3,274,611	2,462,424	2,206,870	1,624,372
Madison	2.51	2.30	2.08	1.67	599,052	548,355	496,623	399,368
Monona	0.03	0.03	0.02	0.01	7,242	6,208	4,139	2,069
Ringgold	23.59	18.52	16.40	10.75	5,632,537	4,423,052	3,917,117	2,567,957
Decatur	34.33	27.58	24.26	16.65	8,198,425	6,586,468	5,792,905	3,977,126
Total	469	390	357	273	111,993,755	93,147,931	85,146,086	65,107,331

Table B.10: Structure data reconstruction for the 10 year flood

10 Year Structure Reconstruction									
County	Com/Ind Acreage	Point Data	Reconstructed	Res. Acreage	Point Data	Reconstructed	Agr. Acreage	Point Data	Reconstructed
Adair	1.45	---	1	74.06	---	43	5,233	---	31
Adams	8.51	---	3	158.35	---	88	3,979	---	23
Audubon	6.45	---	2	68.55	---	29	2,392	---	14
Buena Vista	0.00	---	0	1.00	---	1	331	---	2
Carroll	12.68	4	---	160.96	35	---	14,618	63	---
Cass	46.54	17	---	260.15	17	---	10,530	20	---
Clarke	0.06	0	---	4.23	0	---	502	1	---
Crawford	14.46	0	---	62.83	0	---	3,668	16	---
Dallas	15.46	0	---	85.01	2	---	1,975	12	---
Decatur	33.30	0	---	244.75	0	---	8,677	1	---
Fremont	359.45	130	---	987.43	379	---	62,617	612	---
Greene	0.28	0	---	42.31	0	---	750	0	---
Guthrie	13.57	0	---	206.66	25	---	6,957	22	---
Harrison	108.08	68	---	230.35	288	---	32,280	268	---
Ida	0.00	---	0	0.11	---	0	45	---	0
Madison	1.72	---	1	10.73	---	7	750	---	4
Mills	220.45	35	---	359.61	328	---	33,802	337	---
Monona	0.17	0	---	0.11	0	---	12	0	---
Montgomery	20.91	1	---	200.82	16	---	6,738	22	---
Page	17.24	---	7	327.03	---	191	11,624	---	75
Pottawattamie	412.04	215	---	699.82	1,491	---	35,651	334	---
Ringgold	20.74	---	9	123.76	---	73	6,175	---	37
Sac	14.34	0	---	24.02	0	---	7,588	17	---
Shelby	3.95	1	---	50.15	0	---	6,635	21	---
Taylor	3.22	---	1	101.02	---	59	2,500	---	14
Union	16.40	---	7	125.32	---	73	6,230	---	38
Wayne	1.06	---	0	4.73	---	2	205	---	1
Total	1352.49	471	31	4613.86	2,581	566	272464.32	1,746	239

Table B.11: Structure data reconstruction for the 50 year flood

50 Year Structure Reconstruction									
County	Com/Ind Acreage	Point Data	Reconstructed	Res. Acreage	Point Data	Reconstructed	Agr. Acreage	Point Data	Reconstructed
Adair	3.11	---	1	103.58	---	71	8,476	---	51
Adams	15.62	---	7	220.78	---	150	7,585	---	45
Audubon	13.57	---	6	96.41	---	66	5,639	---	32
Buena Vista	0.00	---	0	1.17	---	1	414	---	2
Carroll	30.30	8	---	205.27	47	---	18,938	102	---
Cass	81.51	34	---	357.05	63	---	15,931	58	---
Clarke	0.22	0	---	7.01	0	---	907	1	---
Crawford	53.26	3	---	104.14	6	---	8,485	53	---
Dallas	19.40	0	---	98.74	3	---	2,671	17	---
Decatur	43.14	0	---	290.39	0	---	13,942	1	---
Fremont	384.24	144	---	1078.56	431	---	65,183	651	---
Greene	0.50	0	---	44.87	0	---	926	0	---
Guthrie	24.85	5	---	253.92	58	---	10,822	75	---
Harrison	159.79	96	---	281.94	342	---	40,057	476	---
Ida	0.00	---	0	0.17	---	0	63	---	0
Madison	2.17	---	1	12.90	---	9	916	---	5
Mills	252.20	49	---	453.85	366	---	38,581	371	---
Monona	0.11	0	---	0.22	0	---	130	0	---
Montgomery	34.58	10	---	277.55	52	---	10,409	33	---
Page	25.63	---	10	398.59	---	271	16,175	---	107
Pottawattamie	528.13	246	---	924.50	1,609	---	45,315	421	---
Ringgold	26.35	---	11	189.31	---	128	11,660	---	73
Sac	17.29	0	---	30.63	0	---	8,704	32	---
Shelby	10.29	4	---	75.56	54	---	11,665	29	---
Taylor	3.34	---	1	136.27	---	92	3,988	---	22
Union	20.68	---	9	146.34	---	99	8,051	---	48
Wayne	2.67	---	1	7.95	---	5	602	---	3
Total	1752.97	599	47	5797.67	3,031	892	356235.34	2,320	388

Table B.12: Structure data reconstruction for the 100 year flood

100 Year Structure Reconstruction									
County	Com/Ind Acreage	Point Data	Reconstructed	Res. Acreage	Point Data	Reconstructed	Agr. Acreage	Point Data	Reconstructed
Adair	3.73	---	1	112.87	---	79	9,648	---	89
Adams	17.24	---	7	242.69	---	171	9,061	---	69
Audubon	18.74	---	8	108.47	---	76	7,169	---	46
Buena Vista	0.11	---	0	1.22	---	1	450	---	3
Carroll	39.48	14	---	221.95	55	---	20,375	139	---
Cass	91.24	38	---	399.48	100	---	18,577	73	---
Clarke	0.39	0	---	7.62	0	---	981	2	---
Crawford	70.22	6	---	122.98	9	---	10,276	71	---
Dallas	21.07	0	---	104.19	3	---	2,940	17	---
Decatur	53.10	1	---	306.35	0	---	15,628	4	---
Fremont	403.81	145	---	1115.03	436	---	68,985	655	---
Greene	0.50	0	---	45.70	0	---	1,010	0	---
Guthrie	28.69	6	---	272.71	71	---	11,975	99	---
Harrison	181.36	114	---	306.07	366	---	43,375	559	---
Ida	0.00	---	0	0.17	---	0	69	---	0
Madison	2.39	---	1	13.29	---	9	956	---	6
Mills	259.15	56	---	471.25	393	---	40,124	398	---
Monona	0.17	0	---	0.44	0	---	198	0	---
Montgomery	48.76	23	---	323.25	111	---	12,775	44	---
Page	29.41	---	12	431.78	---	303	17,341	---	123
Pottawattamie	591.51	263	---	1013.34	1,783	---	48,705	465	---
Ringgold	28.69	---	11	204.49	---	181	13,346	---	91
Sac	18.13	0	---	32.08	0	---	9,079	36	---
Shelby	14.01	5	---	86.07	67	---	13,808	40	---
Taylor	3.61	---	1	142.72	---	100	4,394	---	27
Union	22.96	---	9	151.06	---	105	8,484	---	55
Wayne	3.00	---	1	10.17	---	7	739	---	4
Total	1951.46	671	51	6247.46	3,394	1,032	390468.24	2,602	513

Table B.13: Structure data reconstruction for the 500 year flood

500 Year Structure Reconstruction									
County	Com/Ind Acreage	Point Data	Reconstructed	Res. Acreage	Point Data	Reconstructed	Agr. Acreage	Point Data	Reconstructed
Adair	5.28	---	2	137.38	---	104	12,211	---	89
Adams	23.74	---	10	284.78	---	217	11,846	---	86
Audubon	35.36	---	15	140.61	---	108	11,822	---	86
Buena Vista	0.33	---	0	1.22	---	1	538	---	3
Carroll	71.67	36	---	286.94	128	---	25,090	208	---
Cass	120.76	77	---	486.43	163	---	24,002	120	---
Clarke	0.72	0	---	8.45	0	---	1,097	3	---
Crawford	114.03	17	---	168.58	31	---	13,859	199	---
Dallas	24.35	0	---	112.70	6	---	3,460	22	---
Decatur	66.89	1	---	330.03	0	---	18,180	11	---
Fremont	454.35	162	---	1194.65	480	---	70,535	779	---
Greene	0.72	0	---	50.21	0	---	1,573	0	---
Guthrie	36.36	8	---	313.69	116	---	14,405	144	---
Harrison	200.10	126	---	348.27	423	---	48,954	675	---
Ida	0.00	---	0	0.22	---	0	82	---	1
Madison	2.61	---	1	13.90	---	10	1,030	---	7
Mills	277.99	67	---	513.79	459	---	43,126	478	---
Monona	0.11	0	---	0.67	0	---	351	1	---
Montgomery	87.35	72	---	458.08	366	---	18,564	83	---
Page	49.87	---	20	501.83	---	381	21,269	---	170
Pottawattamie	724.06	318	---	1243.19	2,383	---	56,583	645	---
Ringgold	35.19	---	15	239.57	---	181	17,224	---	132
Sac	19.79	0	---	35.47	3	---	10,093	52	---
Shelby	21.35	15	---	101.41	78	---	19,970	105	---
Taylor	3.78	---	1	155.62	---	120	5,040	---	34
Union	26.13	---	11	158.96	---	122	9,276	---	65
Wayne	3.45	---	1	12.06	---	9	910	---	6
Total	2406.37	899	76	7298.72	4,636	1,253	461090.17	3,525	679

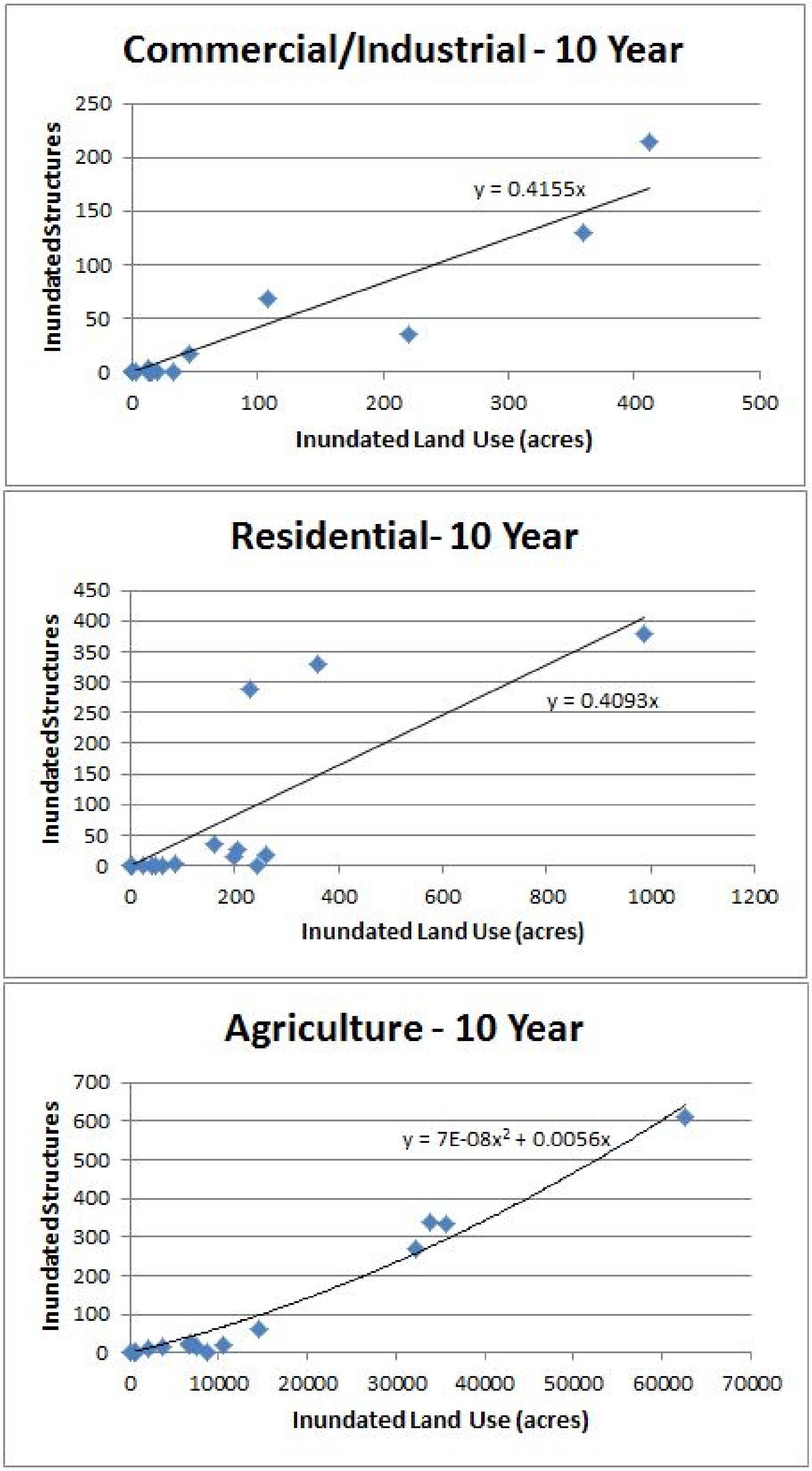

Figure B.1: Regressions for data reconstruction – 10 year event

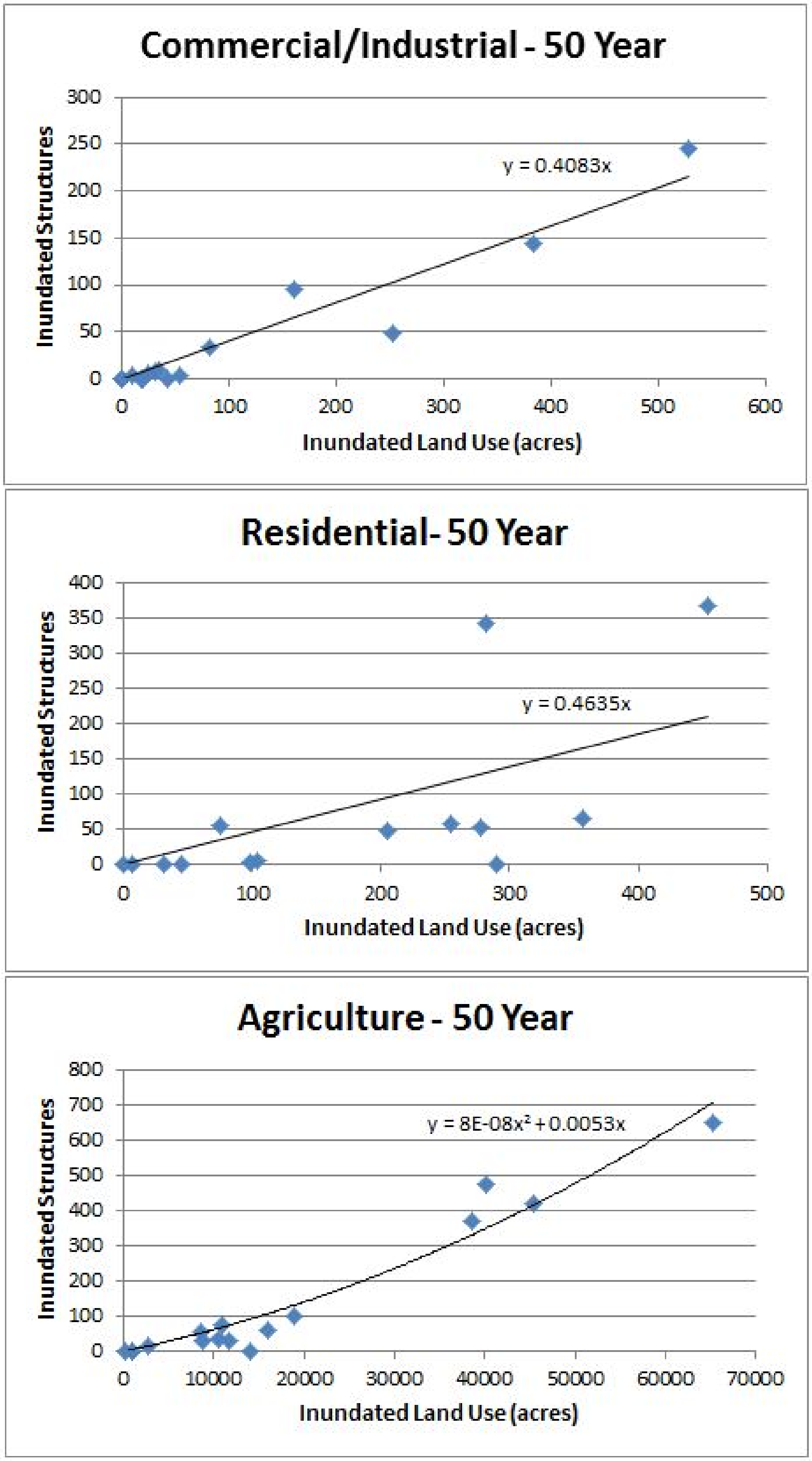

Figure B.2: Regressions for data reconstruction – 50 year event

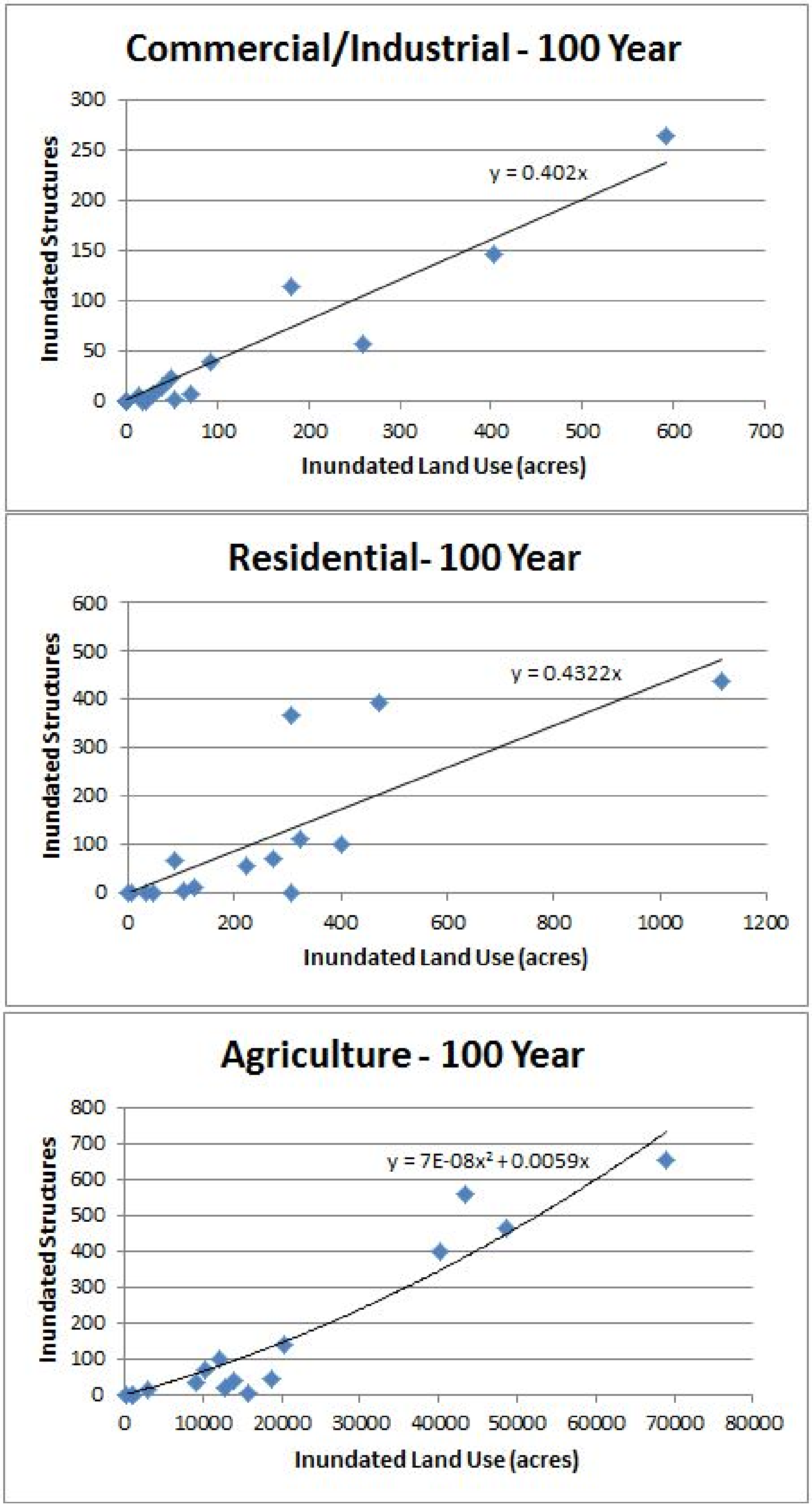

Figure B.3: Regressions for data reconstruction – 100 year event

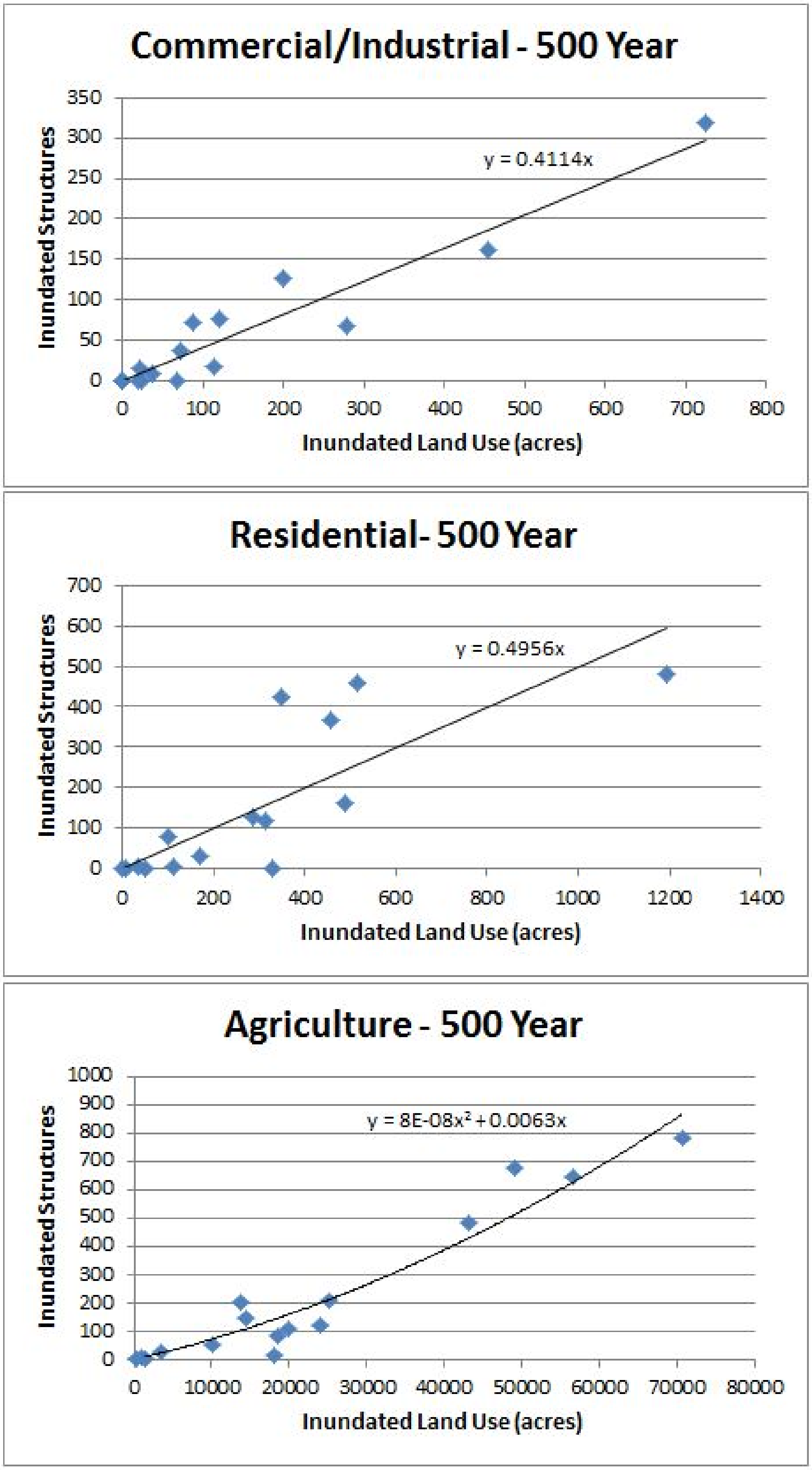

Figure B.4: Regressions for data reconstruction – 500 year event

Table B.14: Agricultural structure losses by county. Reconstructed data is denoted in blue. Fully mapped counties are listed in bold.

Agricultural Structures								
County	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
Adair	89	790,988	63	559,913	51	453,263	31	275,513
Adams	86	764,325	69	613,238	45	399,938	23	204,413
Audubon	**86**	**764,325**	**46**	**408,825**	**32**	**284,400**	**14**	**124,425**
Buena Vista	3	26,663	3	26,663	2	17,775	2	17,775
Carroll	208	1,848,600	139	1,235,363	102	906,525	63	559,913
Cass	**120**	**1,066,500**	**73**	**648,788**	**58**	**515,475**	**20**	**177,750**
Clarke	3	26,663	2	17,775	1	8,888	1	8,888
Crawford	199	1,768,613	71	631,013	53	471,038	16	142,200
Dallas	22	195,525	17	151,088	17	151,088	12	106,650
Decatur	11	97,763	4	35,550	1	8,888	1	8,888
Fremont	**779**	**6,923,363**	**655**	**5,821,313**	**651**	**5,785,763**	**612**	**5,439,150**
Greene	0	0	0	0	0	0	0	0
Guthrie	144	1,279,800	99	879,863	75	666,563	22	195,525
Harrison	675	5,999,063	559	4,968,113	476	4,230,450	268	2,381,850
Ida	1	8,888	0	0	0	0	0	0
Madison	7	62,213	6	53,325	5	44,438	4	35,550
Mills	**478**	**4,248,225**	**398**	**3,537,225**	**371**	**3,297,263**	**337**	**2,995,088**
Monona	1	8,888	0	0	0	0	0	0
Montgomery	**83**	**737,663**	**44**	**391,050**	**33**	**293,288**	**22**	**195,525**
Page	**170**	**1,510,875**	**123**	**1,093,163**	**107**	**950,963**	**75**	**666,563**
Pottawattamie	**645**	**5,732,438**	**465**	**4,132,688**	**421**	**3,741,638**	**334**	**2,968,425**
Ringgold	**132**	**1,173,150**	**91**	**808,763**	**73**	**648,788**	**37**	**328,838**
Sac	52	462,150	36	319,950	32	284,400	17	151,088
Shelby	**105**	**933,188**	**40**	**355,500**	**29**	**257,738**	**21**	**186,638**
Taylor	34	302,175	27	239,963	22	195,525	14	124,425
Union	65	577,688	55	488,813	48	426,600	38	337,725
Wayne	6	53,325	4	35,550	3	26,663	1	8,888
Total	4204	37,363,050	3089	27,453,488	2708	24,067,350	1985	17,641,688

Table B.15: Commercial structure losses by county. Reconstructed data is denoted in blue. Fully mapped counties are listed in bold.

Commercial Structures								
County	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
Adair	2	82,630	1	41,315	1	41,315	1	41,315
Adams	9	371,835	6	247,890	6	247,890	3	123,945
Audubon	**13**	**537,095**	**7**	**289,205**	**5**	**206,575**	**2**	**82,630**
Buena Vista	0	0	0	0	0	0	0	0
Carroll	32	1,322,080	12	495,780	7	289,205	4	165,260
Cass	**69**	**2,850,735**	**34**	**1,404,710**	**30**	**1,239,450**	**15**	**619,725**
Clarke	0	0	0	0	0	0	0	0
Crawford	15	619,725	5	206,575	3	123,945	0	0
Dallas	0	0	0	0	0	0	0	0
Decatur	1	41,315	1	41,315	0	0	0	0
Fremont	**144**	**5,949,360**	**129**	**5,329,635**	**128**	**5,288,320**	**116**	**4,792,540**
Greene	0	0	0	0	0	0	0	0
Guthrie	7	289,205	5	206,575	4	165,260	0	0
Harrison	112	4,627,280	101	4,172,815	85	3,511,775	61	2,520,215
Ida	0	0	0	0	0	0	0	0
Madison	1	41,315	1	41,315	1	41,315	1	41,315
Mills	**60**	**2,478,900**	**50**	**2,065,750**	**44**	**1,817,860**	**31**	**1,280,765**
Monona	0	0	0	0	0	0	0	0
Montgomery	**64**	**2,644,160**	**20**	**826,300**	**9**	**371,835**	**1**	**41,315**
Page	**18**	**743,670**	**11**	**454,465**	**9**	**371,835**	**6**	**247,890**
Pottawattamie	**283**	**11,692,145**	**234**	**9,667,710**	**219**	**9,047,985**	**191**	**7,891,165**
Ringgold	**13**	**537,095**	**10**	**413,150**	**10**	**413,150**	**8**	**330,520**
Sac	0	0	0	0	0	0	0	0
Shelby	**13**	**537,095**	**4**	**165,260**	**4**	**165,260**	**1**	**41,315**
Taylor	1	41,315	1	41,315	1	41,315	1	41,315
Union	10	413,150	8	330,520	8	330,520	6	247,890
Wayne	1	41,315	1	41,315	1	41,315	0	0
Total	868	35,861,420	641	26,482,915	575	23,756,125	448	18,509,120

Table B.16: Industrial structure losses by county. Reconstructed data is denoted in blue. Fully mapped counties are listed in bold.

Industrial Structures								
County	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
Adair	0	0	0	0	0	0	0	0
Adams	1	227,850	1	227,850	1	227,850	0	0
Audubon	**2**	**455,700**	**1**	**227,850**	**1**	**227,850**	**0**	**0**
Buena Vista	0	0	0	0	0	0	0	0
Carroll	4	911,400	2	455,700	1	227,850	0	0
Cass	**8**	**1,822,800**	**4**	**911,400**	**4**	**911,400**	**2**	**455,700**
Clarke	0	0	0	0	0	0	0	0
Crawford	2	455,700	1	227,850	0	0	0	0
Dallas	0	0	0	0	0	0	0	0
Decatur	0	0	0	0	0	0	0	0
Fremont	**18**	**4,101,300**	**16**	**3,645,600**	**16**	**3,645,600**	**14**	**3,189,900**
Greene	0	0	0	0	0	0	0	0
Guthrie	1	227,850	1	227,850	1	227,850	0	0
Harrison	14	3,189,900	13	2,962,050	11	2,506,350	7	1,594,950
Ida	0	0	0	0	0	0	0	0
Madison	0	0	0	0	0	0	0	0
Mills	**7**	**1,594,950**	**6**	**1,367,100**	**5**	**1,139,250**	**4**	**911,400**
Monona	0	0	0	0	0	0	0	0
Montgomery	**8**	**1,822,800**	**3**	**683,550**	**1**	**227,850**	**0**	**0**
Page	**2**	**455,700**	**1**	**227,850**	**1**	**227,850**	**1**	**227,850**
Pottawattamie	**35**	**7,974,750**	**29**	**6,607,650**	**27**	**6,151,950**	**24**	**5,468,400**
Ringgold	**2**	**455,700**	**1**	**227,850**	**1**	**227,850**	**1**	**227,850**
Sac	0	0	0	0	0	0	0	0
Shelby	**2**	**455,700**	**1**	**227,850**	**0**	**0**	**0**	**0**
Taylor	0	0	0	0	0	0	0	0
Union	1	227,850	1	227,850	1	227,850	1	227,850
Wayne	0	0	0	0	0	0	0	0
Total	107	24,379,950	81	18,455,850	71	16,177,350	54	12,303,900

Table B.17: Mobile residential losses by county. Reconstructed data is denoted in blue. Fully mapped counties are listed in bold.

Residential - Mobile								
County	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
Adair	4	16,320	3	12,240	3	12,240	2	8,160
Adams	9	36,720	7	28,560	6	24,480	4	16,320
Audubon	**4**	**16,320**	**3**	**12,240**	**3**	**12,240**	**2**	**8,160**
Buena Vista	0	0	0	0	0	0	0	0
Carroll	30	122,400	30	122,400	30	122,400	25	102,000
Cass	**3**	**12,240**	**1**	**4,080**	**0**	**0**	**0**	**0**
Clarke	0	0	0	0	0	0	0	0
Crawford	1	4,080	1	4,080	1	4,080	0	0
Dallas	0	0	0	0	0	0	0	0
Decatur	0	0	0	0	0	0	0	0
Fremont	**49**	**199,920**	**43**	**175,440**	**46**	**187,680**	**41**	**167,280**
Greene	0	0	0	0	0	0	0	0
Guthrie	2	8,160	2	8,160	2	8,160	2	8,160
Harrison	25	102,000	22	89,760	19	77,520	15	61,200
Ida	0	0	0	0	0	0	0	0
Madison	0	0	0	0	0	0	0	0
Mills	**107**	**436,560**	**88**	**359,040**	**86**	**350,880**	**83**	**338,640**
Monona	0	0	0	0	0	0	0	0
Montgomery	**22**	**89,760**	**13**	**53,040**	**10**	**40,800**	**4**	**16,320**
Page	**13**	**53,040**	**12**	**48,960**	**11**	**44,880**	**8**	**32,640**
Pottawattamie	**61**	**248,880**	**41**	**167,280**	**34**	**138,720**	**28**	**114,240**
Ringgold	**7**	**28,560**	**6**	**24,480**	**5**	**20,400**	**3**	**12,240**
Sac	0	0	0	0	0	0	0	0
Shelby	**75**	**306,000**	**66**	**269,280**	**53**	**216,240**	**0**	**0**
Taylor	5	20,400	4	16,320	4	16,320	2	8,160
Union	5	20,400	4	16,320	4	16,320	3	12,240
Wayne	0	0	0	0	0	0	0	0
Total	422	1,721,760	346	1,411,680	317	1,293,360	222	905,760

Table B.18: Multi-unit residential losses by county. Reconstructed data is denoted in blue. Fully mapped counties are listed in bold.

Residential - Multi Unit								
County	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
Adair	8	400,000	6	300,000	6	300,000	3	150,000
Adams	17	850,000	14	700,000	12	600,000	7	350,000
Audubon	**9**	**450,000**	**6**	**300,000**	**5**	**250,000**	**3**	**150,000**
Buena Vista	0	0	0	0	0	0	0	0
Carroll	4	200,000	0	0	0	0	0	0
Cass	**2**	**100,000**	**1**	**50,000**	**0**	**0**	**0**	**0**
Clarke	0	0	0	0	0	0	0	0
Crawford	0	0	0	0	0	0	0	0
Dallas	0	0	0	0	0	0	0	0
Decatur	0	0	0	0	0	0	0	0
Fremont	**10**	**500,000**	**10**	**500,000**	**10**	**500,000**	**10**	**500,000**
Greene	0	0	0	0	0	0	0	0
Guthrie	0	0	0	0	0	0	0	0
Harrison	8	400,000	7	350,000	5	250,000	4	200,000
Ida	0	0	0	0	0	0	0	0
Madison	1	50,000	1	50,000	1	50,000	1	50,000
Mills	**8**	**400,000**	**4**	**200,000**	**2**	**100,000**	**2**	**100,000**
Monona	0	0	0	0	0	0	0	0
Montgomery	**10**	**500,000**	**4**	**200,000**	**0**	**0**	**0**	**0**
Page	**31**	**1,550,000**	**24**	**1,200,000**	**22**	**1,100,000**	**15**	**750,000**
Pottawattamie	**119**	**5,950,000**	**104**	**5,200,000**	**98**	**4,900,000**	**90**	**4,500,000**
Ringgold	**13**	**650,000**	**10**	**500,000**	**10**	**500,000**	**6**	**300,000**
Sac	0	0	0	0	0	0	0	0
Shelby	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Taylor	10	500,000	8	400,000	7	350,000	5	250,000
Union	10	500,000	8	400,000	8	400,000	6	300,000
Wayne	1	50,000	1	50,000	0	0	0	0
Total	261	13,050,000	208	10,400,000	186	9,300,000	152	7,600,000

Table B.19: Single-unit residential losses by county. Reconstructed data is denoted in blue. Fully mapped counties are listed in bold.

Residential - Single Unit								
County	500		100		50		10	
	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)	Structures	Damage ($)
Adair	92	2,263,200	68	1,672,800	60	1,476,000	36	885,600
Adams	191	4,698,600	146	3,591,600	127	3,124,200	77	1,894,200
Audubon	**75**	**1,845,000**	**47**	**1,156,200**	**39**	**959,400**	**24**	**590,400**
Buena Vista	1	24,600	1	24,600	1	24,600	1	24,600
Carroll	87	2,140,200	22	541,200	17	418,200	9	221,400
Cass	**114**	**2,804,400**	**53**	**1,303,800**	**39**	**959,400**	**6**	**147,600**
Clarke	0	0	0	0	0	0	0	0
Crawford	30	738,000	8	196,800	5	123,000	0	0
Dallas	6	147,600	3	73,800	3	73,800	2	49,200
Decatur	0	0	0	0	0	0	0	0
Fremont	**425**	**10,455,000**	**310**	**7,626,000**	**378**	**9,298,800**	**332**	**8,167,200**
Greene	0	0	0	0	0	0	0	0
Guthrie	114	2,804,400	68	1,672,800	56	1,377,600	23	565,800
Harrison	390	9,594,000	337	8,290,200	318	7,822,800	269	6,617,400
Ida	0	0	0	0	0	0	0	0
Madison	10	246,000	8	196,800	7	172,200	5	123,000
Mills	**344**	**8,462,400**	**301**	**7,404,600**	**278**	**6,838,800**	**243**	**5,977,800**
Monona	0	0	0	0	0	0	0	0
Montgomery	**268**	**6,592,800**	**35**	**861,000**	**5**	**123,000**	**2**	**49,200**
Page	**314**	**7,724,400**	**238**	**5,854,800**	**209**	**5,141,400**	**144**	**3,542,400**
Pottawattamie	**2203**	**54,193,800**	**1624**	**39,950,400**	**1474**	**36,260,400**	**1222**	**30,061,200**
Ringgold	**160**	**3,936,000**	**122**	**3,001,200**	**108**	**2,656,800**	**60**	**1,476,000**
Sac	3	73,800	0	0	0	0	0	0
Shelby	**3**	**73,800**	**1**	**24,600**	**1**	**24,600**	**0**	**0**
Taylor	104	2,558,400	86	2,115,600	78	1,918,800	49	1,205,400
Union	107	2,632,200	92	2,263,200	84	2,066,400	61	1,500,600
Wayne	8	196,800	6	147,600	4	98,400	3	73,800
Total	5049	124,205,400	3576	87,969,600	3291	80,958,600	2568	63,172,800

Table B.20: Environmental facilities by county located within the 10 year floodplain

10 Year Environmental Factors														
County	Adair	Adams	Audubon	Buena Vista	Carroll	Cass	Clarke	Crawford	Dallas	Decatur	Fremont	Greene	Guthrie	Harrison
Solid Waste Land Application	0	0	0	3	1	0	0	0	0	1	6	0	0	14
Solid Waste Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Treatment Plant	0	0	0	0	1	0	0	1	0	0	3	0	0	3
Air Facility	0	0	0	0	0	2	0	0	0	0	4	0	0	2
Public Water Supply Facility	0	0	0	0	0	2	0	0	0	0	6	0	0	7
Surface Water Intake - Public	0	0	0	0	0	0	0	0	0	0		0	1	0
Wells - Public	3	0	1	0	15	3	0	8	5	0	13	0	2	7
Contaminated Sites Facility	0	0	0	0	1	0	0	0	0	0	1	0	0	1
Water Use Facility	0	0	0	1	1	1	0	2	0	0	25	0	2	16
Underground Storage Tank Facility	0	0	0	1	2	4	0	0	0	2	11	0	0	4
Leaking Underground Storage Tank	0	0	0	0	0	0	0	0	0	0	6	0	1	6
Wastewater NPDES Facility	0	1	0	0	2	0	0	0	0	0	1	0	0	2
Wastewater Treatment Plant	0	1	0	0	0	0	0	1	0	0	3	0	1	1
Wastewater Outfall	1	0	2	0	4	4	0	4	2	3	7	0	6	6
Stormwater Facility	0	0	0	0	2	0	0	1	0	0	2	0	0	1
Tier II Chemical Storage Facility	0	0	0	0	1	5	0	0	0	1	3	0	1	3
Animal Feeding Facility	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water Intake - Water Use	1	3	0	2	0	8	0	2	0	3	24	0	5	7
Wells - Water Use	3	0	0	0	12	8	0	4	2	6	52	0	2	51
Spill Incidents	0	0	1	0	3	1	0	1	1	0	5	0	2	6
Commercial Manure Applicator	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Flood Plain Permits	2	12	1	0	15	31	0	14	9	10	32	3	26	27
Total	**10**	**17**	**5**	**7**	**61**	**69**	**0**	**38**	**19**	**26**	**204**	**3**	**50**	**164**

Table B.20: Environmental facilities by county located within the 10 year floodplain (continued)

10 Year Environmental Factors														
County	Ida	Madison	Mills	Monona	Montgomery	Page	Pottawattamie	Ringgold	Sac	Shelby	Taylor	Union	Wayne	**Total**
Solid Waste Land Application	0	0	1	0	2	0	26	0	0	0	0	0	0	**54**
Solid Waste Facility	0	0	0	0	0	0	5	0	0	0	0	0	0	**5**
Water Treatment Plant	0	0	1	0	2	0	0	0	0	0	0	0	0	**11**
Air Facility	0	0	1	0	0	0	1	0	0	0	0	0	0	**10**
Public Water Supply Facility	0	0	4	0	0	0	3	0	0	0	0	0	0	**22**
Surface Water Intake - Public	0	0	0	0	0	1	0	1	0	0	0	2	0	**5**
Wells - Public	0	0	7	0	0	5	29	2	0	25	0	2	0	**127**
Contaminated Sites Facility	0	0	1	0	0	0	3	0	0	0	0	0	0	**7**
Water Use Facility	0	0	6	0	0	2	13	0	0	1	0	1	0	**71**
Underground Storage Tank Facility	0	0	5	0	0	4	15	0	1	0	0	0	0	**49**
Leaking Underground Storage Tank	0	0	5	0	1	0	16	0	0	0	0	0	0	**35**
Wastewater NPDES Facility	0	0	1	0	0	0	3	0	2	0	0	0	0	**12**
Wastewater Treatment Plant	0	0	1	0	0	1	2	0	1	0	0	0	0	**12**
Wastewater Outfall	0	0	3	0	3	2	12	0	3	5	0	2	0	**69**
Stormwater Facility	0	0	3	0	0	0	9	0	0	2	0	1	0	**21**
Tier II Chemical Storage Facility	0	0	3	0	0	1	6	0	0	0	0	0	0	**24**
Animal Feeding Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Surface Water Intake - Water Use	0	0	4	0	4	6	11	3	0	4	0	6	0	**93**
Wells - Water Use	0	0	16	0	0	2	29	0	1	47	0	0	0	**235**
Spill Incidents	0	0	11	0	1	0	15	0	1	3	0	2	0	**53**
Commercial Manure Applicator	0	0	0	0	0	0	1	0	0	0	0	0	0	**2**
Flood Plain Permits	0	0	32	1	31	22	57	9	7	14	4	17	0	**376**
Total	**0**	**0**	**105**	**1**	**44**	**46**	**256**	**15**	**16**	**101**	**4**	**33**	**0**	**1,294**

Table B.21: Environmental facilities by county located within the 50 year floodplain

50 Year Environmental Factors														
County	Adair	Adams	Audubon	Buena Vista	Carroll	Cass	Clarke	Crawford	Dallas	Decatur	Fremont	Greene	Guthrie	Harrison
Solid Waste Land Application	0	0	0	3	1	0	0	1	0	1	6	0	0	22
Solid Waste Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Treatment Plant	0	0	0	0	1	0	0	1	0	0	3	0	0	3
Air Facility	0	0	0	0	2	2	0	0	0	0	4	0	0	2
Public Water Supply Facility	0	0	1	0	0	2	0	0	0	0	6	0	2	7
Surface Water Intake - Public	0	0	0	0	0	0	0	0	0	0		0	1	0
Wells - Public	6	1	6	0	19	6	0	22	5	0	14	0	5	9
Contaminated Sites Facility	0	1	1	0	1	0	0	0	0	0	1	0		3
Water Use Facility	0	0	0	1	1	1	0	2	0	0	27	0	3	30
Underground Storage Tank Facility	0	0	0	1	6	8	0	2	0	2	11	0	1	6
Leaking Underground Storage Tank	0	2	0	0	0	1	0	0	0	0	9	0	2	7
Wastewater NPDES Facility	0	1	0	0	2	0	0	0	0	0	1	0		2
Wastewater Treatment Plant	0	3	0	0	0	0	0	3	0	0	4	0	2	1
Wastewater Outfall	1	2	2	0	5	6	0	8	2	5	7	0	9	6
Stormwater Facility	0	0	1	0	2	3	0	1	1	1	4	0		5
Tier II Chemical Storage Facility	0	0	0	0	1	7	0	0	0	1	3	0	1	4
Animal Feeding Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water Intake - Water Use	1	3	0	2	0	8	0	2	1	3	24	0	5	7
Wells - Water Use	3	0	5	0	17	11	0	10	2	6	58	0	3	68
Spill Incidents	0	0	2	1	3	2	0	4	1	0	6	0	3	11
Commercial Manure Applicator	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Flood Plain Permits	4	24	6	0	18	45	1	27	10	12	38	3	34	33
Total	**15**	**37**	**24**	**8**	**79**	**102**	**1**	**83**	**22**	**31**	**226**	**3**	**72**	**226**

Table B.21: Environmental facilities by county located within the 50 year floodplain (continued)

50 Year Environmental Factors														
County	Ida	Madison	Mills	Monona	Montgomery	Page	Pottawattamie	Ringgold	Sac	Shelby	Taylor	Union	Wayne	**Total**
Solid Waste Land Application	0	0	1	0	2	0	32	0	0	0	0	0	0	**69**
Solid Waste Facility	0	0	0	0	1	0	5	0	0	0	0	0	0	**6**
Water Treatment Plant	0	0	1	0	2	1	1	0	0	0	0	0	0	**13**
Air Facility	0	0	3	0	0	0	2	0	0	0	0	0	0	**15**
Public Water Supply Facility	0	0	5	0	0	0	4	0	0	0	0	1	0	**28**
Surface Water Intake - Public	0	0	0	0	0	1	0	1	0	0	0	2	0	**5**
Wells - Public	0	0	12	0	0	6	32	3	0	42	0	2	0	**190**
Contaminated Sites Facility	0	0	1	0	0	0	3	0	0	0	0	0	0	**11**
Water Use Facility	0	0	6	0	0	3	13	0	0	1	0	1	0	**89**
Underground Storage Tank Facility	0	0	6	0	6	4	24	0	1	0	0	0	0	**78**
Leaking Underground Storage Tank	0	0	5	0	1	0	26	0	0	0	0	0	0	**53**
Wastewater NPDES Facility	0	0	2	0	0	0	6	0	2	0	0	0	0	**16**
Wastewater Treatment Plant	0	0	2	0	0	3	4	0	1	0	0	0	0	**23**
Wastewater Outfall	0	0	6	0	3	2	18	0	4	5	0	2	0	**93**
Stormwater Facility	0	0	3	0	0	2	11	0	1	2	0	2	0	**39**
Tier II Chemical Storage Facility	0	0	3	0	0	1	6	0	1	0	0	0	0	**28**
Animal Feeding Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Surface Water Intake - Water Use	0	0	4	0	4	6	11	3	0	4	0	8	0	**96**
Wells - Water Use	0	0	17	0	0	4	29	0	1	70	0	4	0	**308**
Spill Incidents	0	0	11	0	2	0	22	0	1	4	0	3	0	**76**
Commercial Manure Applicator	0	0	0	0	0	0	1	0	0	0	0	0	0	**2**
Flood Plain Permits	0	0	40	2	50	26	65	16	7	22	4	17	0	**504**
Total	**0**	**0**	**128**	**2**	**71**	**59**	**315**	**23**	**19**	**150**	**4**	**42**	**0**	**1,742**

Table B.22: Environmental facilities by county located within the 100 year floodplain

100 Year Environmental Factors														
County	Adair	Adams	Audubon	Buena Vista	Carroll	Cass	Clarke	Crawford	Dallas	Decatur	Fremont	Greene	Guthrie	Harrison
Solid Waste Land Application	0	0	0	3	1	0	0	1	0	1	6	0	0	27
Solid Waste Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Treatment Plant	0	0	0	0	1	0	0	3	0	0	3	0	0	3
Air Facility	0	0	0	0	2	3	0	0	0	0	4	0	0	3
Public Water Supply Facility	0	0	2	0	0	2	0	0	0	0	7	0	2	7
Surface Water Intake - Public	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Wells - Public	8	1	11	0	19	6	0	23	5	0	17	0	5	11
Contaminated Sites Facility	0	1	1	0	1	1	0	0	0	0	1	0	0	3
Water Use Facility	0	0	0	1	1	2	0	2	0	0	30	0	4	36
Underground Storage Tank Facility	0	1	1	1	6	10	0	2	0	2	11	0	1	8
Leaking Underground Storage Tank	0	2	1	0	2	1	0	0	0	0	9	0	2	7
Wastewater NPDES Facility	0	1	1	0	3	0	0	0	0	0	1	0	0	2
Wastewater Treatment Plant	0	3	0	0	0	0	0	5	0	0	4	0	2	2
Wastewater Outfall	1	3	5	0	15	6	0	11	2	6	11	0	15	8
Stormwater Facility	0	1	1	0	2	3	0	3	1	4	7	0	0	7
Tier II Chemical Storage Facility	0	0	0	0	2	7	0	0	0	1	3	0	1	5
Animal Feeding Facility	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water Intake - Water Use	1	5	0	2	0	8	0	2	1	3	25	0	5	7
Wells - Water Use	3	0	8	0	20	13	0	11	3	6	65	0	4	71
Spill Incidents	0	0	2	1	6	4	0	4	1	0	8	0	3	11
Commercial Manure Applicator	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Flood Plain Permits	8	27	6	0	22	49	1	29	10	14	40	4	37	33
Total	**21**	**46**	**39**	**8**	**106**	**115**	**1**	**96**	**23**	**37**	**252**	**4**	**83**	**251**

Table B.22: Environmental facilities by county located within the 100 year floodplain (continued)

100 Year Environmental Factors														
County	Ida	Madison	Mills	Monona	Montgomery	Page	Pottawattamie	Ringgold	Sac	Shelby	Taylor	Union	Wayne	**Total**
Solid Waste Land Application	2	0	2	0	34	0	0	0	0	0	0	0	0	**77**
Solid Waste Facility	0	0	1	0	5	0	0	0	0	0	0	0	0	**6**
Water Treatment Plant	1	0	2	1	1	0	0	0	0	0	0	0	0	**15**
Air Facility	4	0	0	0	3	0	0	0	0	0	0	0	0	**19**
Public Water Supply Facility	5	0	0	0	4	0	0	1	0	1	0	1	0	**32**
Surface Water Intake - Public	0	0	0	1	0	1	0	0	0	2	0	2	0	**8**
Wells - Public	12	0	0	6	38	4	0	43	0	2	0	2	0	**213**
Contaminated Sites Facility	1	0	0	0	3	0	0	0	0	0	0	0	0	**12**
Water Use Facility	6	0	0	3	16	0	0	1	0	1	0	1	0	**104**
Underground Storage Tank Facility	9	0	7	5	26	0	1	0	0	0	0	0	0	**91**
Leaking Underground Storage Tank	5	0	1	0	27	0	0	0	0	0	0	0	0	**57**
Wastewater NPDES Facility	2	0	0	0	6	0	2	0	0	0	0	0	0	**18**
Wastewater Treatment Plant	2	0	0	3	4	0	1	0	0	0	0	0	0	**26**
Wastewater Outfall	9	0	3	2	37	0	4	5	0	2	0	2	0	**147**
Stormwater Facility	2	0	1	5	13	0	1	4	0	3	0	2	0	**60**
Tier II Chemical Storage Facility	3	0	0	1	7	0	1	0	0	0	0	0	0	**31**
Animal Feeding Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Surface Water Intake - Water Use	4	0	4	7	11	4	0	4	0	8	0	8	0	**109**
Wells - Water Use	19	0	1	4	39	0	1	75	0	4	0	4	0	**351**
Spill Incidents	11	0	3	0	28	0	1	5	0	3	1	3	0	**95**
Commercial Manure Applicator	0	0	0	0	1	0	0	0	0	0	0	0	0	**2**
Flood Plain Permits	40	2	55	31	76	18	7	25	4	19	0	17	0	**574**
Total	**137**	**2**	**80**	**69**	**379**	**27**	**19**	**163**	**4**	**45**	**1**	**42**	**0**	**2,050**

Table B.23: Environmental facilities by county located within the 500 year floodplain

500 Year Environmental Factors														
County	Adair	Adams	Audubon	Buena Vista	Carroll	Cass	Clarke	Crawford	Dallas	Decatur	Fremont	Greene	Guthrie	Harrison
Solid Waste Land Application	0	0	0	4	1	0	0	3	0	2	6	0	0	34
Solid Waste Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water Treatment Plant	0	0	0	0	1	0	0	4	0	0	3	0	0	3
Air Facility	0	1	0	0	2	4	0	2	0	0	4	0	0	3
Public Water Supply Facility	0	0	3	0	1	2	0	0	0	0	7	0	2	7
Surface Water Intake - Public	0	1	0	0	0	0	0	0	0	1	0	0	1	0
Wells - Public	9	2	16	0	22	15	0	26	5	0	18	0	5	11
Contaminated Sites Facility	0	1	1	0	1	1	0	0	0	0	1	0	0	3
Water Use Facility	0	0	0	1	1	2	0	2	0	0	30	0	5	41
Underground Storage Tank Facility	0	2	3	1	7	12	0	11	0	3	14	0	1	10
Leaking Underground Storage Tank	0	3	1	0	5	4	0	3	0	0	12	0	2	7
Wastewater NPDES Facility	0	1	1	0	3	1	0	0	0	0	1	0	0	2
Wastewater Treatment Plant	0	3	0	0	0	0	0	5	0	0	5	0	2	2
Wastewater Outfall	1	3	5	0	15	6	0	11	2	6	11	0	15	8
Stormwater Facility	0	0	2	0	3	3	0	3	0	1	3	0	0	4
Tier II Chemical Storage Facility	0	0	1	0	3	8	0	2	0	1	3	0	2	5
Animal Feeding Facility	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surface Water Intake - Water Use	1	5	0	2	0	8	0	2	1	3	26	0	5	7
Wells - Water Use	3	0	13	0	22	16	0	13	3	6	65	1	4	88
Spill Incidents	0	1	3	1	8	4	0	13	2	0	9	0	4	14
Commercial Manure Applicator	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Flood Plain Permits	13	29	10	0	24	64	1	38	12	15	44	4	42	37
Total	**27**	**52**	**59**	**9**	**122**	**150**	**1**	**138**	**25**	**38**	**262**	**5**	**91**	**286**

Table B.23: Environmental facilities by county located within the 500 year floodplain (continued)

500 Year Environmental Factors														
County	Ida	Madison	Mills	Monona	Montgomery	Page	Pottawattamie	Ringgold	Sac	Shelby	Taylor	Union	Wayne	Total
Solid Waste Land Application	2	0	2	0	39	0	0	0	0	1	0	0	0	**94**
Solid Waste Facility	0	0	1	0	6	0	0	0	0	0	0	0	0	**7**
Water Treatment Plant	1	0	2	1	1	0	0	1	0	0	0	0	0	**17**
Air Facility	4	0	0	2	3	0	0	0	0	0	0	0	0	**25**
Public Water Supply Facility	5	0	0	0	5	0	0	1	0	1	0	1	0	**35**
Surface Water Intake - Public	0	0	0	1	0	1	0	0	0	2	0	2	0	**9**
Wells - Public	12	0	0	6	47	6	0	47	0	2	0	2	0	**251**
Contaminated Sites Facility	2	0	1	2	4	0	0	1	0	0	0	0	0	**18**
Water Use Facility	7	0	0	3	16	0	0	1	0	1	0	1	0	**111**
Underground Storage Tank Facility	11	0	9	7	33	0	1	1	0	0	0	0	0	**126**
Leaking Underground Storage Tank	7	0	6	0	43	0	0	0	0	0	0	0	0	**93**
Wastewater NPDES Facility	2	0	0	0	6	0	2	1	0	0	0	0	0	**20**
Wastewater Treatment Plant	3	0	2	3	4	0	1	0	0	0	0	0	0	**30**
Wastewater Outfall	9	0	3	2	37	0	4	7	0	3	0	2	0	**150**
Stormwater Facility	2	0	1	2	9	0	0	0	0	2	0	2	0	**37**
Tier II Chemical Storage Facility	3	0	0	1	10	0	1	0	0	0	0	0	0	**40**
Animal Feeding Facility	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Wastewater Industrial Contributor	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Surface Water Intake - Water Use	4	0	4	7	12	5	0	4	0	8	0	8	0	**112**
Wells - Water Use	21	0	2	4	45	0	2	79	0	4	0	4	0	**395**
Spill Incidents	11	0	3	0	35	0	2	6	0	3	1	3	0	**123**
Commercial Manure Applicator	0	0	0	0	1	0	0	0	0	0	0	0	0	**2**
Flood Plain Permits	46	2	75	37	83	21	7	33	4	19	0	17	0	**677**
Total	**152**	**2**	**111**	**78**	**439**	**33**	**20**	**182**	**4**	**46**	**1**	**42**	**0**	**2,375**

Table B.24: Annual value of ecosystem services within the 10 year floodplain by county

10 Year Ecolologic Exposure ($)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Water	246,432	18,292	51,880	144,536	214,040	22,508	263,816	447,480	150,564	841,908	287,432	216,908	693,144	394,496
Wetland	88,760	2,324	73,668	23,688	11,354	0	37,772	199,556	20,832	357,350	445,312	119,742	216,902	123,788
Bottomland Forest	1,321,687	5,593	57,904	291,494	559,770	409,793	482,314	1,193,142	801,632	3,256,536	2,974,113	840,313	2,350,940	1,543,856
Coniferous Forest	745,878	10,325	55,755	84,252	45,017	13,216	84,665	4,173,365	261,016	4,545,478	1,143,597	1,026,718	3,320,933	610,001
Total	2,402,757	36,534	239,207	543,970	830,181	445,517	868,567	6,013,543	1,234,044	9,001,272	4,850,454	2,203,681	6,581,919	2,672,141
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Water	43,912	1,380	390,084	245,040	1,068,808	244,436	154,720	257,152	337,248	45,424	6,160	349,648	452,372	7,589,820
Wetland	5,362	0	525,672	156,338	290,570	32,718	102,494	209,930	175,490	112	56	113,876	272,622	3,606,288
Bottomland Forest	327,825	47	2,160,872	2,042,996	1,748,588	272,647	1,419,259	1,530,696	1,971,509	273,681	46,671	1,895,463	4,040,449	33,819,790
Coniferous Forest	42,539	0	1,452,934	734,727	2,299,997	372,113	1,653,239	286,209	810,306	19,824	0	722,750	2,767,513	27,282,367
Total	419,638	1,427	4,529,562	3,179,101	5,407,963	921,914	3,329,712	2,283,987	3,294,553	339,041	52,887	3,081,737	7,532,956	72,298,265

Table B.25: Annual value of ecosystem services within the 50 year floodplain by county

50 Year Ecolologic Exposure ($)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Water	339,812	20,244	59,924	218,804	296,092	43,896	338,600	538,240	215,540	1,050,488	389,136	322,480	805,772	538,088
Wetland	89,796	2,268	75,250	24,262	11,438	0	39,004	203,588	21,322	410,284	448,616	129,206	223,622	125,538
Bottomland Forest	1,556,029	6,157	60,019	415,198	751,248	628,813	525,131	1,362,248	1,086,969	3,735,654	3,561,707	1,047,160	2,749,547	1,916,754
Coniferous Forest	798,329	8,673	59,059	102,011	50,799	22,715	104,489	4,609,493	315,945	5,015,472	1,201,830	1,163,834	3,407,250	650,888
Total	2,783,966	37,342	254,252	760,275	1,109,577	695,424	1,007,224	6,713,569	1,639,776	10,211,898	5,601,289	2,662,680	7,186,191	3,231,268
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Water	69,148	2,040	489,088	332,944	1,169,868	277,012	191,212	361,640	445,688	54,004	10,008	541,520	624,072	9,745,360
Wetland	5,404	98	529,690	161,700	294,378	32,942	101,290	211,862	186,704	98	56	118,328	278,852	3,725,596
Bottomland Forest	504,451	94	2,609,534	2,401,559	2,054,981	287,640	1,592,501	2,197,297	2,290,169	297,557	53,016	2,782,165	4,952,155	41,425,753
Coniferous Forest	49,147	0	1,504,559	797,503	2,484,195	387,807	1,692,887	328,335	891,667	21,063	0	904,057	3,155,320	29,727,327
Total	628,150	2,232	5,132,871	3,693,706	6,003,422	985,401	3,577,890	3,099,134	3,814,228	372,722	63,080	4,346,070	9,010,399	84,624,036

Table B.26: Annual value of ecosystem services within the 100 year floodplain by county

100 Year Ecolologic Exposure ($)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Water	372,136	20,704	62,936	247,504	321,224	51,168	362,416	593,108	233,812	1,123,692	419,132	363,340	837,716	591,136
Wetland	90,986	2,324	75,432	25,424	11,466	0	39,200	219,128	21,364	425,222	450,800	134,638	224,756	127,022
Bottomland Forest	1,619,103	6,063	61,617	471,175	801,303	690,618	544,025	1,477,210	1,166,634	3,884,127	3,758,731	1,122,313	2,856,331	2,057,237
Coniferous Forest	823,935	10,325	60,711	111,510	51,625	27,671	107,793	4,824,666	321,314	5,102,615	1,224,132	1,219,176	3,425,835	666,582
Total	2,906,160	39,416	260,696	855,613	1,185,618	769,457	1,053,434	7,114,112	1,743,124	10,535,656	5,852,795	2,839,467	7,344,638	3,441,977
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Water	75,424	2,268	514,936	373,568	1,223,480	287,188	204,868	393,656	481,996	56,576	11,476	608,692	687,044	10,521,196
Wetland	5,418	168	530,488	163,142	295,932	33,096	102,606	212,898	187,068	112	70	120,470	279,902	3,779,132
Bottomland Forest	539,278	94	2,691,878	2,552,335	2,141,038	291,212	1,651,110	2,331,341	2,460,309	304,607	59,032	3,025,296	5,269,311	43,833,328
Coniferous Forest	52,864	0	1,515,710	824,348	2,594,466	392,350	1,711,472	343,616	916,447	21,063	0	989,135	3,276,329	30,615,690
Total	672,984	2,530	5,253,012	3,913,393	6,254,916	1,003,846	3,670,056	3,281,511	4,045,820	382,358	70,578	4,743,593	9,512,586	88,749,346

Table B.27: Annual value of ecosystem services within the 500 year floodplain by county

500 Year Ecolologic Exposure ($)														
County	Shelby	Buena Vista	Greene	Audubon	Adair	Wayne	Carroll	Harrison	Taylor	Pottawattamie	Guthrie	Crawford	Mills	Cass
Water	476,516	21,924	79,680	329,860	379,108	64,852	444,808	648,828	268,592	1,296,184	488,856	454,016	900,600	721,772
Wetland	96,950	2,282	77,966	26,460	11,508	28	40,418	208,250	21,420	422,982	453,124	140,840	228,536	130,802
Bottomland Forest	1,780,877	6,204	70,218	569,734	883,647	803,982	592,905	1,569,001	1,313,368	4,200,813	4,182,530	1,252,738	3,125,359	2,310,990
Coniferous Forest	892,493	8,673	73,927	118,531	53,277	30,975	120,183	5,002,256	322,966	5,190,171	1,246,847	1,261,715	3,474,156	688,058
Total	3,246,836	39,083	301,791	1,044,585	1,327,540	899,837	1,198,314	7,428,335	1,926,346	11,110,150	6,371,357	3,109,309	7,728,651	3,851,622
	Clarke	Ida	Union	Montgomery	Fremont	Sac	Dallas	Adams	Page	Madison	Monona	Ringgold	Decatur	Total
Water	87,452	2,456	563,892	481,372	1,297,412	310,828	228,572	465,348	596,376	61,372	13,792	754,284	806,956	12,245,708
Wetland	5,446	392	532,826	166,488	294,742	33,712	104,496	214,816	187,642	112	70	127,792	282,814	3,812,914
Bottomland Forest	596,853	94	2,839,693	2,875,648	2,346,804	299,155	1,756,108	2,628,616	2,789,591	315,887	61,476	3,411,871	5,882,614	48,466,776
Coniferous Forest	56,581	826	1,560,727	871,843	2,670,458	402,675	1,750,707	375,830	923,881	21,476	0	1,148,966	3,451,028	31,719,226
Total	746,332	3,768	5,497,138	4,395,351	6,609,416	1,046,370	3,839,883	3,684,610	4,497,490	398,847	75,338	5,442,913	10,423,412	96,244,624