Missouri River Recovery Management Plan and Environmental Impact Statement

Flood Risk Management Environmental Consequences Analysis

Technical Report

August 2018

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Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

BiOp	Biological Opinion (amended in 2003)
DEM	Digital Elevation Model
DSS	data storage system
EQ	environmental quality
ER	Engineering Regulation
ESA	Endangered Species Act
ESH	emergent sandbar habitat
H&H	hydrologic and hydraulic
HC	human considerations
HEC-FIA	Hydrologic Engineering Center - Flood Impact Analysis
HEC-RAS	Hydrologic Engineering Center - River Analysis System
MRRP	Missouri River Recovery Program
MRRMP-EIS	Missouri River Recovery Management Plan and Environmental Impact Statement
NASS	National Agricultural Statistics Service
NED	national economic development
NSI	National Structure Inventory
OSE	other social effects
P&G	1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
PAR	population at risk
RED	regional economic development
RM	river mile
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

1.0 Introduction

The Kansas City and Omaha Districts of the U.S. Army Corps of Engineers (USACE), in cooperation with the U.S. Fish and Wildlife Service (USFWS), have developed the Missouri River Recovery Management Plan and Environmental Impact Statement (MRRMP-EIS). The purpose of the MRRMP-EIS is to develop a suite of actions that meets Endangered Species Act (ESA) responsibilities for the piping plover, the interior least tern, and the pallid sturgeon.

The purpose of the Flood Risk Management Environmental Consequences Analysis Technical Report is to provide supplemental information on the flood risk management analysis and results in addition to the information presented in the MRRMP-EIS. Additional details on the national economic development (NED), regional economic development (RED), and other social effects (OSE) methodology and results are provided in this technical report. No environmental quality (EQ) analysis was undertaken for flood risk management.

1.1 Summary of Alternatives

The MRRMP-EIS evaluates the following alternatives. A detailed description of the alternatives is provided in Chapter 2 of the MRRMP-EIS.

- **Alternative 1 – No Action.** This is the No Action alternative, in which the Missouri River Recovery Program (MRRP) would continue to be implemented as it is currently, including a number of management actions associated with the MRRP and 2003 Amended Biological Opinion (BiOp) compliance. Management actions under Alternative 1 include creation of early life stage habitat for the pallid sturgeon and emergent sandbar habitat (ESH), as well as a spring pulse for pallid sturgeon. The construction of habitat would be focused in the Garrison and Gavins reaches for ESH (an average rate of 164 acres per year) and between Ponca to the mouth near St. Louis for pallid sturgeon early life stage habitat (3,999 additional acres constructed).
- **Alternative 2 – USFWS 2003 Biological Opinion Projected Actions**. This alternative represents the USFWS interpretation of the management actions that would be implemented as part of the 2003 Amended BiOp Reasonable and Prudent Alternative (USFWS 2003). Whereas Alternative 1 only includes the continuation of management actions USACE has implemented to date for BiOp compliance, Alternative 2 includes additional iterative actions and expected actions that the USFWS anticipates would ultimately be implemented through adaptive management and as impediments to implementation were removed. Considerably more early life stage habitat (10,758 additional acres constructed) and ESH (an average rate of 1,331 acres per year) would be constructed under Alternative 2 than under Alternative 1. In addition, a spring pallid sturgeon flow release would be implemented every year if specific conditions were met. Alternative 2 would also modify System operations to allow for summer flows that are sufficiently low to provide for early life stage habitat as rearing, refugia, and foraging areas for larval, juvenile, and adult pallid sturgeon.
- **Alternative 3 – Mechanical Construction**. The USACE would mechanically construct ESH at an average rate of 332 acres per year distributed between the Garrison, Fort Randall, and Gavins Point Reaches. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from System operations. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH. An estimated 3,380

acres of early life stage habitat for the pallid sturgeon would be constructed under Alternative 3. There would not be any reoccurring flow releases or pulses implemented under this alternative; however, should new information be learned through Level 1 and 2 studies over the next 9 years suggesting that spring discharges result in stronger aggregation of adult pallid sturgeon at spawning locations or increased reproductive success, a one-time spawning cue test could be implemented to provide additional information to support or refute this hypothesis. At the present time, it is assumed the test release would be similar to the timing, magnitude, duration, and pattern of the spawning cue included as a recurring release under Alternative 6.

- **Alternative 4 – Spring ESH Creating Release**. The USACE would mechanically construct ESH annually at an average rate of 195 acres per year distributed between the Garrison, Fort Randall, and Gavins Point Reaches. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from implementation of an ESH-creating reservoir release in the spring. Alternative 4 would be similar to Alternative 1 (the No Action alternative), with the addition of a spring release designed to create ESH for the least tern and piping plover. An estimated 3,380 acres of early life stage habitat for the pallid sturgeon would be constructed under Alternative 4.
- **Alternative 5 – Fall ESH Creating Release**. The USACE would mechanically construct ESH annually at an average rate of 253 acres per year distributed between the Garrison, Fort Randall, and Gavins Point Reaches. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from implementation of an ESH-creating reservoir release in the fall. Alternative 5 is similar to Alternative 1 (the No Action alternative), with the addition of a release in the fall designed to create sandbar habitat for the least tern and piping plover. An estimated 3,380 acres of early life stage habitat for the pallid sturgeon would be constructed under Alternative 5.
- **Alternative 6 – Pallid Sturgeon Spawning Cue**. The USACE would mechanically construct ESH annually at an average rate of 245 acres per year distributed between the Garrison, Fort Randall, and Gavins Point Reaches. In addition, the USACE would attempt a spawning cue pulse every three years in March and May. These spawning cue pulses would not be started and/or would be terminated whenever flood targets are exceeded. An estimated 3,380 acres of early life stage habitat for the pallid sturgeon would be constructed under Alternative 6.

1.2 USACE Planning Accounts

Alternative means of achieving species objectives will be evaluated including consideration for the effects of each action or alternative on a wide range of human considerations (HC). Human considerations to be evaluated in the MRRMP-EIS alternatives are rooted in the economic, social, and cultural values associated with the natural resources of the Missouri River. The HC effects evaluated in the MRRMP-EIS are required under the National Environmental Policy Act and its implementing regulations (40 CFR Parts 1500-1508). The 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) also served as the central guiding regulation for the economic and environmental analysis included within the MRRMP-EIS. Further guidance that is specific to the USACE is described in Engineering Regulation (ER) 1105-2-100, Planning Guidance Notebook, which provides the overall direction by which USACE Civil Works projects are formulated, evaluated, and selected for implementation. These guidance documents describe four accounts that were established to facilitate evaluation and display the effects of alternative plans:

- The NED account displays changes in the economic value of the national output of goods and services expressed in monetary units. Contributions to NED are the direct net benefits that accrue in the planning area and the rest of the Nation.
- The RED account registers changes in the distribution of regional economic activity (i.e., jobs and income).
- The EQ account displays non-monetary effect of significant natural and cultural resources.
- The OSE account registers plan effects from perspective that are relevant to the planning process, but are not reflected in the other three accounts. In a general sense, OSE refers to how the constituents of life that influence personal and group definitions of satisfaction, well-being, and happiness are affected by some condition or proposed intervention.

The accounts framework enables consideration of a range of both monetary and non-monetary values and interests that are expressed as important to stakeholders, while ensuring impacts are not double counted. The USACE planning accounts evaluated for flood risk management include NED, RED, and OSE.

1.3 Approach for Evaluating Environmental Consequences of the MRRMP-EIS

Physical characteristics of the Missouri River and its floodplain that are particularly important to flood risk include river flow and associated stages, water storage in System, river channel dimensions, and flow impedance. Changes in these characteristics can result in changes in the patterns of flooding (beneficially or adversely), such as the frequency of flooding, depths of inundation, and extent and duration of flooding. Changes in the patterns of flooding potentially increase or reduce the risks inherent in flooding to people in the floodplain, land, property (both urban and rural), and infrastructure. Ultimately, one metric for evaluating effects is in terms of monetary net changes (benefits or losses) to the nation's economy.

These changes in flood risk could result in changes in disruptions to transportation, businesses, and agriculture, as well as property damage. Change in regional economic effects such as jobs, income, and sales is also a consideration given changes in business and agriculture revenues from changes in probability of flood risk.

In addition to property and infrastructure damage, and changes in jobs and income, other flood risk-related concerns include public safety and health (including life loss), and cultural and social effects. For example, exposure to flooding could endanger people (i.e., direct exposure to contaminated flood waters, and mental health concerns such as trauma). Areas with vulnerable populations such as the elderly, the young, low income groups, and the ill are of particular concern during floods, and their exposure may be increased in some locations by changes in flooding patterns. Changes in flooding patterns, such as higher stages and more frequent flooding, could also affect sites considered sacred by Tribes within the Missouri River basin. Similar concerns could adversely affect long-established communities with a strong sense of tradition and cohesion

The conceptual flow chart shown in Figure 1 demonstrates, in a stepwise manner, how changes to the physical conditions of the Missouri River and its floodplain can impact flood risk management. This figure also shows the intermediate factors and criteria that were applied in assessing the NED, RED, and OSE consequences to flood risk management.

The approach for evaluating environmental consequences to flood risk management was initiated with an evaluation of thresholds which were developed to evaluate effects from changes in Missouri River flow and corresponding river stages, for any given event resulting from the alternatives. Effects on the built human environment were evaluated by the frequency and duration that certain damage thresholds were reached during flood or high-water events under both without-project and with-project conditions. The results of this analysis were used to verify that a full flood risk management analysis to estimate changes in NED, RED, and OSE impacts was warranted. This second step in the process estimated impacts associated with damage to structures and associated contents, agricultural losses, effects to critical infrastructure, and population at risk (PAR). Figure 2 illustrates an overview of the approach for flood risk management.

CHANGES IN: Physical Components of the Missouri River Watershed

- River flows and associated stages, including overbank stages
- Water storage in System
- Wetlands, chutes, backwaters, width expansion
- River channel dimensions
- Channel and floodplain roughness (flow impedance)
- Interior drainage (as related to agriculture)

Leads To

CHANGES IN: Patterns of Flooding

- Frequency of flooding
- Depths of inundation
- Extent of flooding
- Duration and seasonality of flooding

Leads To

CHANGES IN: Potential Flooding Consequences

- Physical costs of flooding
- Non-physical costs of flooding (clean-up, emergency costs, etc.)
- Interruptions in transportation, commercial, and agricultural activity

Leads To

CHANGES IN: Beneficial Effects and/or Costs

- National Economic Development (NED) – flood damages and related costs

Leads To

CHANGES IN: Beneficial Effects and/or Costs

- Regional Economic Development (RED) – economic output/sales, income, employment by industry and region

Leads To

CHANGES IN: Beneficial Effects and/or Costs

- Other Social Effects (OSE) – individual and community well-being, public safety, traditional ways of life, and economic vitality

Figure 1. Flow Chart of Inputs Considered in Flood Risk Management Evaluation

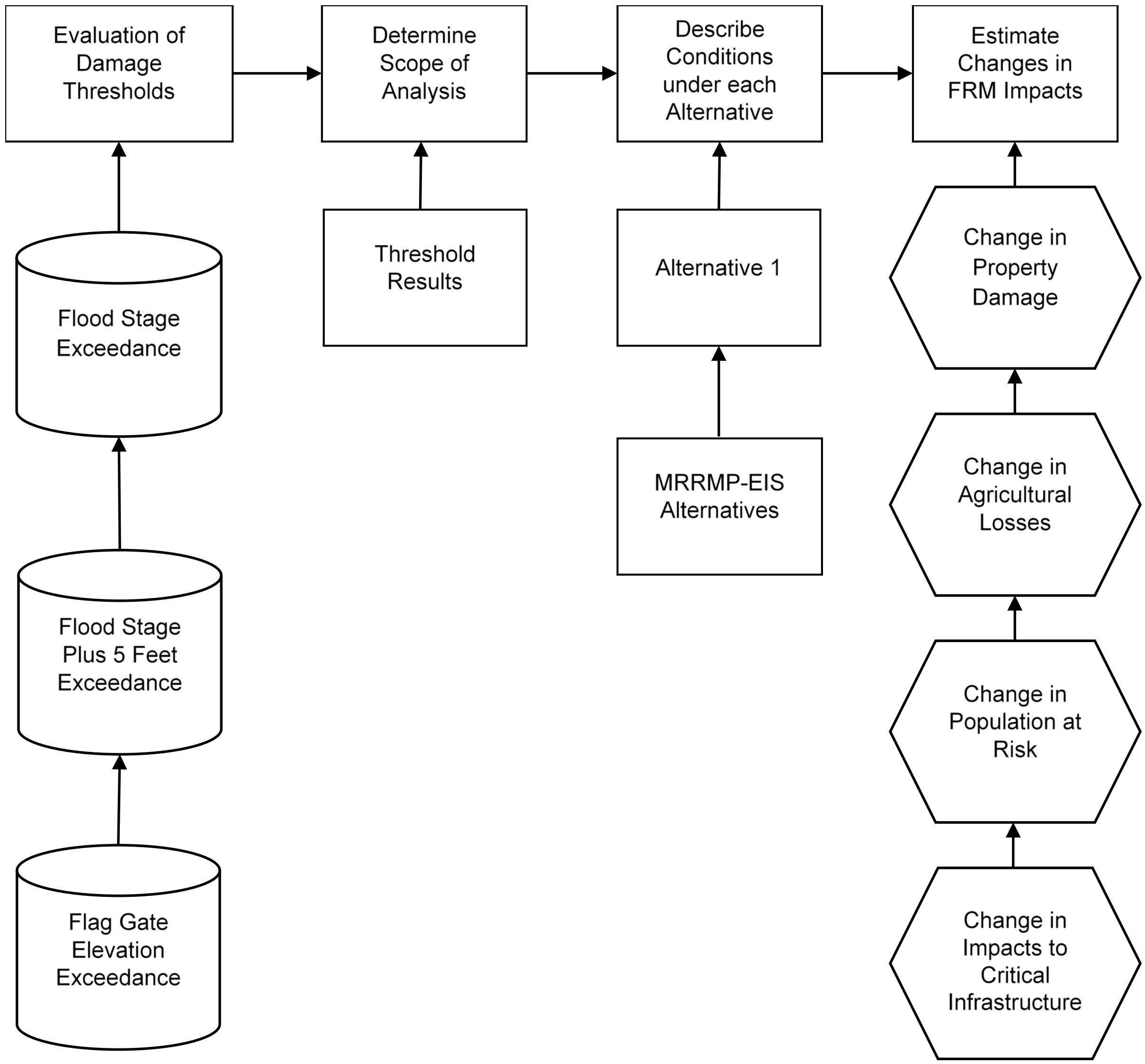

Figure 2. Approach for Evaluating Environmental Consequences to Flood Risk Management

2.0 Methodology and Assumptions

2.1 Assumptions

In modeling the environmental consequences to flood risk management from the MRRMP-EIS alternatives, the project team established a set of assumptions. The important assumptions used in the modeling effort are as follows.

- The economic analysis uses data from the hydrologic and hydraulic (H&H) modeling of the river and reservoir System. The analysis assumes that the H&H models reasonably estimate river flows and reservoir levels over the 82-period of record under each of the MRRMP-EIS alternatives as well as the Alternative 1.

- The impacts for Alternative 1 are presented for the purpose of providing a baseline and allowing for a comparison of the MRRMP-EIS alternatives.
- Aggradation and degradation is assumed to be occurring under all alternatives, including Alternative 1. This analysis does not attempt to evaluate flood risk management impacts as a result of aggradation and degradation, but focuses on incremental changes that may occur as a result of the MRRMP-EIS alternatives.
- The Missouri River floodplain land use would not change across alternatives or under different flood conditions.

2.2 Risk and Uncertainty

Risk and uncertainty are inherent with any model that is developed and used for water resource planning. Much of the risk and uncertainty with the overall MRRMP-EIS is associated with the operation of the Missouri River System and the extent to which flows and reservoir levels will mimic conditions that have occurred over the 82-year period of record. Unforeseen events such as climate change and weather patterns may cause river and reservoir conditions to change in the future and would not be captured by the Hydrologic Engineering Center - River Analysis System (HEC-RAS) models or carried through to the flood risk model described in this document. The project team has attempted to address risk and uncertainty in the MRRMP-EIS by defining and evaluating a reasonable range of plan alternatives that include an array of management actions within an adaptive management framework for the Missouri River. All of the alternatives were modeled to estimate impacts to flood risk management. The effects of climate change to flood risk management are discussed in further detail in the EIS, Section 3.12.5, Climate Change.

2.3 Economic Analysis and Modeling

A model was developed using the Hydrologic Engineering Center - Flood Impact Analysis (HEC-FIA) to evaluate the change in NED, RED, and OSE impacts associated with flood risk management as a result of the MRRMP-EIS alternatives. HEC-FIA evaluates impacts to a study area, with the damageable elements quantified through the addition of user defined agricultural inventories, structural inventories, critical infrastructure, and impact response curves. The HEC-FIA model estimates impacts associated with historical flood events through a set of geo-referenced hydrographs (stage or flow with accompanying rating curves) which represent a single event. Given the 82-year period of record, HEC-FIA estimated:

- Direct economic damages – Losses directly related to damages sustained by structures, contents, vehicles, etc. These losses are essentially all damage to property.
- Agricultural losses – Losses sustained to crops. Damages can be related to a loss of a crop in the ground, the inability to plant a crop due to flooding, or the loss related to planting a crop later in the season due to flooding at planting time. These losses relate to the timing of the flood, duration of flooding, season, and type of crop.
- Population at risk (PAR) – The number and location of people within the potentially inundated area during day and night conditions exposed to the flood hazard. PAR includes people permanently residing in the inundated area, as well as workers, customers of area businesses, and others temporarily in the area.
- Critical infrastructure – Critical infrastructure includes structures, such as public utilities, wastewater treatment plants, and bridges, in the floodplain that are critical to the nation

or region, but not part of a traditional structure inventory. The model will not calculate economic losses in terms of dollars, but instead report what critical infrastructure elements were inundated by a flood event.

2.4 National Economic Development Methodology

NED effects are defined as changes in the net value of the national output of goods and services. In the case of flood risk management, the conceptual basis for the NED impacts analysis is an increase or decrease in risk of physical and non-physical damage from flooding. The measurement of national economic effects was based on the estimated change in flood risk to structures and associated property and agriculture resulting from the MRRMP-EIS alternatives.

2.4.1 Property Damage Computation

In HEC-FIA, property damages are described by the magnitude of damages to buildings, their contents, and vehicles resulting from a flood event. Four inputs are required to compute the direct damages at locations throughout the study area: (i) Terrain Model, (ii) Structure Inventory, (iii) Inundation Data, and (iv) Depth-Percent Damage Relationships.

A terrain model in HEC-FIA is defined by importing a Digital Elevation Model (DEM) into the program. The DEM represents the ground elevation for the region being studied in a gridded format, which is used to provide elevation data for the structure inventory. The terrain is only used in the HEC-FIA computations when the input hydraulics data is defined using cross sectional data with hydrographs. For the Missouri River HEC-FIA model, a tiled image format (*.tif) terrain created by the HEC-RAS model was used.

Economic losses associated with direct damage to property are based on a structure inventory populated from the National Structure Inventory (NSI) that was developed by the HEC in coordination with FEMA's HAZUS database. The NSI converts Census block level data to a series of points, each representing a single structure. As part of the quality assurance and quality control process, these points were adjusted to ensure that they are located at their appropriate structure locations. HAZUS estimates building values by multiplying the total floor size of a building occupancy, which reflects the type of economic activity and is assumed to be uniform with the building replacement costs per square foot. Content values are estimated as a fixed percentage of the building asset value.

Computing consequences in an HEC-FIA project requires inundation data. Inundation data provides a pattern for HEC-FIA simulations, by defining the source and type of hydraulic information at any point in the study area. For the Missouri River HEC-FIA model, the inundation data was provided from the HEC-RAS model as a HEC-DSS (Data Storage System) file that contains stage hydrographs at cross sections and storage areas throughout the study area. The cross sections and storage areas define the geographic locations of the stage hydrographs. Time-series information is exchanged between HEC-DSS and HEC-FIA at each of the georeferenced cross section and storage area locations.

A depth-percent damage relationship (i.e., curve) defines the percent damage caused to a structure, a structure's contents, and any vehicles stored at a structure at incremental depths. As depth increases, percent damage also increases. Depth-percent damage relationships are defined in HEC-FIA within the Structure Occupancy Type. A structure occupancy type describes a class of structures (e.g., single family, no basement, one story). Data entered for a structure occupancy type is applied to all the structures assigned to that structure occupancy type. An example structure occupancy for a 1-story, no basement residence is provided in Figure 3.

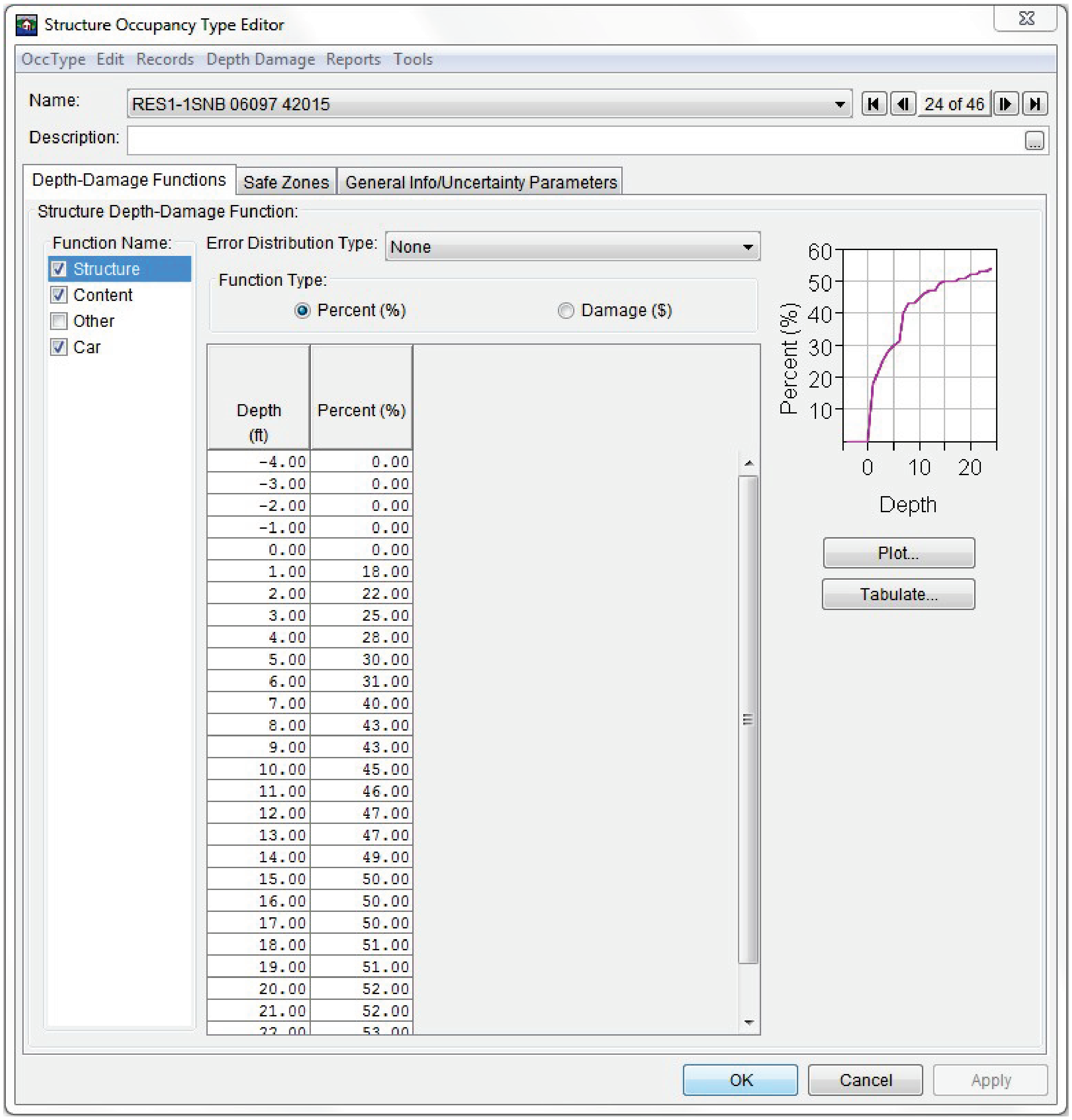

Figure 3. Structure Occupancy Type Example

Direct damages to a building, its contents, and its vehicles are calculated for a single structure as follows: $D_i = d_i * v_i$ where D_i is the direct damage, where the subscript i is used to represent buildings, contents, or vehicles; d_i is damage (in percent) as a function of depth and occupancy type, and v_i is value. To determine the percent direct damage to buildings, contents, and vehicles, both the depth at the structure and occupancy type of the structure need to be known. The occupancy type is specified as part of the structure inventory and is associated with individual depth-percent damage relationships for the building, contents, and vehicles.

Therefore, the depth at the structure can be used to determine the percentage that the building, contents, and vehicles are damaged. This percent damage can then be multiplied by the building, contents, and vehicles values (specified in the structure inventory) to determine the total direct damage that occurs at and within a structure.

For the MRRMP-EIS, HEC-FIA was run to compute the property and infrastructure damages associated with the maximum annual 1-day duration stage event for each year in the 82-year period of record.

2.4.2 Agricultural Damage Computation

When flooding occurs in agricultural areas, damages can occur to existing crops as well as interruptions to the planting, growing, and harvesting of crops. HEC-FIA can be used to compute the economic impacts of flooding these types of areas. Five inputs are required: (i) Duration of Inundation Data, (ii) National Agricultural Statistics Service (NASS) Data, (iii) Crop Planting Data, (iv) Crop Harvesting Data, and (v) Duration-Damage Relationships.

HEC-FIA uses the same inundation data mentioned in Section 2.4.1 Property Damage Computation, but in addition to comparing the stage hydrograph at each agricultural point from the NASS data it also looks at the duration of that stage to compute damages.

Agricultural losses were estimated using data downloaded from USDA's National Agricultural Statistics Service (NASS). The NASS Cropland Data Layer is a product that represents the type of crop and the geographic location of crops throughout the entire United States. The Cropland Data Layer is provided in the GeoTiff format, where each cell represents a crop type. HEC-FIA was used to import this data from the NASS API (Application Programming Interface) to streamline the collection of the type and distribution of crops in the study area.

Once the crops for the study area were identified, several variables in the model's "Crop Loss Editor" were inputted. The planting and harvesting dates for each crop were defined. The planting and harvesting dates were derived from the NASS Agricultural Handbook Number 628: "Field Crops: Usual Planting and Harvesting Dates." Another variable includes the cost to produce the crop. This includes the fixed costs and variable costs associated with planting and harvesting. These costs are defined on a monthly basis in the model. Additionally, the price received for crops and estimated yield information were populated. The crop budget data including the production costs and the estimated yields were obtained from the respective state's agricultural extension service. Evaluated crops by state are shown in Table 1. Further information and links to each state's crop budget data can be found in the references section of this document (North Dakota data was used for Montana since current crop data was not available for Montana). For data on the prices received for crops, the U.S. Department of Agriculture Economic Research Service (ERS) annually calculates "normalized prices," which smooths out the effects of short run seasonal or cyclical variation for key agricultural inputs and outputs. In accordance with USACE guidance, the state-level normalized prices for the report year 2016 (the latest available at the time of the modeling) were calculated by multiplying the national-level normalized prices by the average ratios of the state-level market prices to the national market prices for 2012-2014.

Table 1. Crops Evaluated by State

State	Crops
Montana	Barley, Corn, Dry Beans, Durum Wheat, Lentils, Spring Wheat, Winter Wheat
North Dakota	Barley, Corn, Dry Beans, Durum Wheat, Lentils, Oats, Soybeans, Spring Wheat, Sunflowers, Winter Wheat
South Dakota	Alfalfa, Corn, Oats, Soybeans, Spring Wheat, Sunflowers, Winter Wheat
Nebraska	Alfalfa, Corn, Soybeans, Winter Wheat
Iowa	Alfalfa, Corn, Soybeans, Winter Wheat
Kansas	Corn, Soybeans
Missouri	Alfalfa, Corn, Soybeans, Winter Wheat

A seasonal duration-damage curve from the HEC AGDAM (Agricultural Flood Damage Analysis) User's Manual was also used to define the percent of crop damage associated with the duration (in days) of inundation.

The computational procedures used by HEC-FIA to calculate agriculture flood damages at a single crop cell uses the inundation durations from the HEC-DSS stage hydrographs. Additionally, the procedures assume that crops are planted at the first available date after flooding and that crops will be planted immediately before an event (meaning that weather forecasting is not taken into account). Once the input data is defined, the model then follows these computational procedures:

1. Determine the crop type in each cell.
2. Determine the arrival of flooding for the crop cell.
3. Determine the duration of flooding for the crop cell.
4. Based on the arrival time and duration, determine if planting dates are impacted or if the crop is damaged before harvest.
5. If damaged during the growing season, determine if the duration is longer than the longest duration damage curve; if so, the model assumes all value placed in the field so far is lost. The loss is equivalent to the marketable value minus harvest costs, prorated by total value input to the field.
6. If the flooding caused planting later than the first day of the season for the primary crop, but the farmer was able to plant the primary crop later in the season, the damages are based on a reduction in full yield due to late planting.
7. After calculating the loss for each crop cell in the inundated area using the process described above, the output is displayed showing the crop type, location, duration, and total damage for each crop cell damaged.

2.4.3 Other Costs of Flooding

In conjunction with the tangible damages computed in the HEC-FIA model, there are other costs of flooding to the nation that could be impacted and were capture in the model, including emergency costs and disaster relief costs. Emergency costs can include emergency personnel costs, flood fighting costs (i.e., sandbagging), avoidance costs (raising or evacuation of property), temporary food and housing, debris cleanup, and damage to infrastructure items not otherwise included in the damage analysis such as sewer lines. Based on an analysis of approved USACE projects, it was assumed that these costs are equivalent to a maximum of nine percent of property damages (USACE 2014).

2.5 Regional Economic Development Methodology

The RED analysis evaluated the regional economic impacts associated with agricultural damages and structural damages, using information from the NED analysis from the period of record under each simulated alternative.

Agricultural Damage. The RED analysis used annual agricultural flood damages from the NED analysis to estimate the changes in regional economic conditions under the MRRMP-EIS alternatives. The NED evaluation included eight floodplain areas or river reach regions. Fort Peck Dam to Lake Sakakawea and Garrison Dam to Oahe Dam had less than $127,000 in annual agricultural damages in the worst-case years compared to Alternative 1. Because there would be negligible change in regional economic conditions in these reaches, no RED evaluation was undertaken. The RED impacts associated with agricultural damages, including employment, labor income and sales, were estimated for six of the eight regions using IMPLAN®, an input-output modeling software program. IMPLAN® uses inter-industry relationships to estimate the direct, indirect, and induced economic activity that can be expected in the study area as a result of generated demand for other goods and services associated with that industry—in this case, sales from agricultural products and employment of workers in agricultural industries.

A state or multi-state study area was identified for each region. The types of crops affected for each river reach were based on the types of crops damaged, as identified in the HEC-FIA evaluation. The types of crops were grouped based on the industry sectors for input into IMPLAN®. Table 2 describes the study areas and the types of crops affected for each of the river reaches.

Table 2. Study Areas and Crops Affected by River Reach

River Reach	State Study Area	Allocation of Crops Affected		
		Soybeans (Oilseed Farming)	Corn, Spring Wheat, Barley (Grain Farming)	Alfalfa, Hay (All Other Crop Farming)
Fort Randall to Gavins Point	South Dakota and Nebraska	42.2%	48.9%	8.8%
Gavins Point to Rulo	Iowa, Nebraska, and Missouri	46.4%	51.2%	2.4%
St. Joseph Reach	Nebraska, Kansas, and Missouri	51.2%	46.2%	2.6%
Kansas City Reach	Missouri	53.1%	43.9%	3.0%
Boonville Reach	Missouri	53.2%	43.8%	3.0%
Hermann Reach	Missouri	53.2%	43.8%	3.0%

For the purposes of evaluating regional economic impacts, it was assumed that agricultural damages are equal to a change in market value of crop production, which was used as the direct effect (i.e., final demand change) in IMPLAN® Pro. Agricultural damages, as estimated through the HEC-FIA model, include loss of crop value (less harvest costs) and the costs of agriculture inputs (if damage occurs prior to harvest). In HEC-FIA, harvest costs are often removed from the value of crops because the farmer would not incur these costs when crops are damaged. Because IMPLAN® Pro is a revenue-based input-output model, the inclusion of input costs would overstate economic impacts, while reducing harvest costs from the loss of crop value would decrease economic impacts. On balance, the project team felt that agricultural damages were a sufficient proxy for the market value of crops that would be affected from flood damages.

The regional economic impacts can be classified as direct, indirect, or induced sales and are measured through changes in employment, labor income and sales. Direct effects represent the impacts of the production values or industry sales specified as final demand changes. Indirect effects represent the impacts caused by the iteration of industries purchasing goods and services to support the directly affected industries. Induced effects represent the economic impacts from all affected workers spending their income in the study area economy.

Although the NED analysis included an 82-year period of record, there were five scenarios on which the RED analysis was focused for both of the evaluations: the best year (lowest agricultural loss year); the worst year (the highest agricultural loss year); the average annual over the 82-year period of record; the average of the eight worst years relative to Alternative 1; and the average of the eight best years relative to Alternative 1. These eight worst and best years relative to Alternative 1 allow an understanding of the skewness and magnitude of impacts in the largest difference years.

Structural Damage. The RED impacts of structural damages could include loss of business activity due to disruptions from transportation detours and delays and/or offices closures, resulting in loss of labor, income, and economic output. The HEC-FIA results from the NED analysis include structure and content damage, although the NED outputs do not include estimates of the potential loss in industry revenues. It is not appropriate to use property damage as a proxy for loss in industry sales because the estimates represent damages (or possible replacement costs) to structures and not disruptions or loss of industry sales, as needed for an economic impact analysis. As a result, the county-level average annual structural damage estimates from the NED evaluation were used to qualitatively describe the counties that would have the largest potential RED impacts under the MRRMP-EIS alternatives.

2.6 Other Social Effects Methodology

Changes in flood risk have a potential to cause other types of effects on individuals and communities in terms of individual and community well-being, as well as traditional ways of life. The HEC-FIA model was used to determine impacts to the OSE account. Any changes to these areas of concern, as defined in Section 3.22, Environmental Justice of the MRRMP-EIS, that would occur under MRRMP-EIS alternatives was examined to the extent possible. Inputs necessary for determining PAR and impacts to potential populations of concern were Census block level data and the outputs of the RED and NED flood risk management evaluation, which provide a sense of the magnitude of the impacts to the nation or to the regional area.

Beyond determining qualitative impacts to the population, PAR can be computed quantitatively in HEC-FIA. In order to do this, Census block data is imported into the model with populations evenly distributed to structures based on their occupancy type. The total PAR is computed by determining the number of people in structures that get inundated.

Flood risk impacts to critical infrastructure were also determined in the HEC-FIA model. The critical infrastructure inventory was imported from the Homeland Security Infrastructure Program Gold database developed by the National Geospatial-Intelligence Agency in partnership with the Department of Homeland Security. As it can be difficult to assign a value to these structures or facilities, the model does not calculate economic losses in terms of dollars (except to those structures in the National Structure Inventory and captured in the NED analysis), but rather reports what critical infrastructure elements were inundated by a flood event.

An environmental justice assessment was conducted to determine whether minority and low-income populations (i.e., "populations of concern") would be affected by a proposed federal action and whether they would experience disproportionate adverse impacts from the proposed action. Areas identified in the HEC-FIA model showing substantial flood damage or persons at risk, were analyzed for changes in incidences of flooding impacts on disproportionately minority or poor communities.

2.7 Environmental Quality Methodology

This account was not evaluated for flood risk management.

2.8 Geographic Areas

Flood risk management impacts are located all along the Missouri River. The impacts evaluated were organized into two groups depending on their location: "upper river" which includes Fort Peck Dam to Garrison Dam, Garrison Dam to Oahe Dam, and Fort Randall Dam to Gavins Point Dam and "lower river" which includes everything below Gavins Point Dam to the mouth of the Missouri River. The Oahe Dam to Big Bend Dam and Big Bend Dam to Fort Randall Dam were not modeled due to the lack of riverine conditions between these dams. The impacts were further broken down into eight separate reaches (three in the upper river and five in the lower river). Figures 4 and 5 map the upper river and lower river reaches, respectively.

Upper River

Fort Peck Dam to Garrison Dam: the reach extends from Fort Peck Dam in Montana to Garrison Dam in North Dakota. This reach includes part of the city of Williston, North Dakota.

Garrison Dam to Oahe Dam: the reach extends from Garrison Dam in central North Dakota to Lake Oahe Dam in South Dakota near Pierre. This reach includes part of the metropolitan area of Bismarck, North Dakota.

Fort Randall Dam to Gavins Point Dam: this reach in South Dakota extends from Fort Randall Dam to Gavins Point Dam near Yankton, South Dakota. Locations subject to flooding includes stretches from the mouth of the Niobrara River downstream to the outskirts of Springfield, South Dakota.

Figure 4. Upper River Reaches

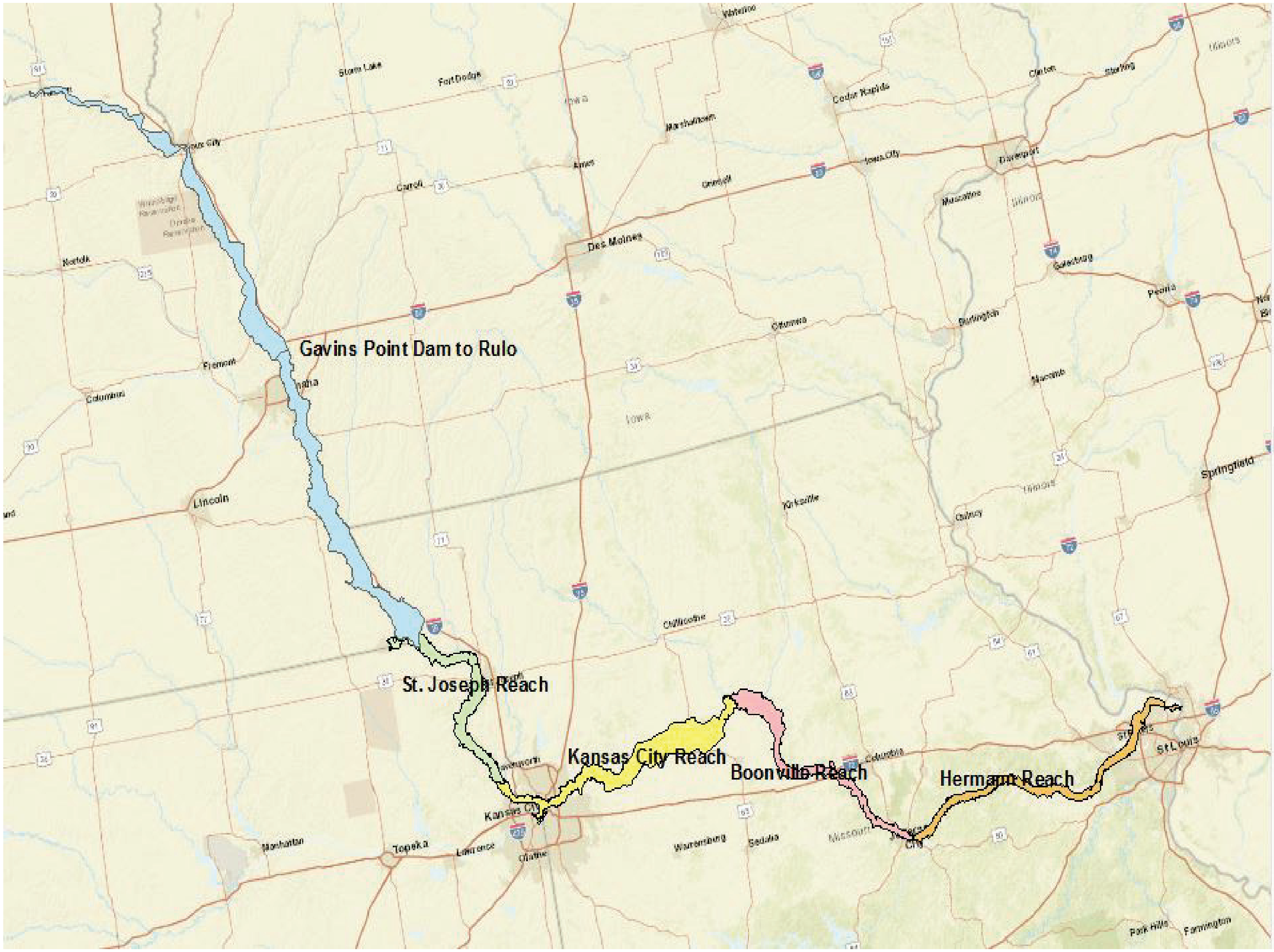

Figure 5. Lower River Reaches

Lower River

Gavins Point Dam to Rulo: the reach extends from Gavins Point Dam in South Dakota to approximately river mile (RM) 487 just south of Rulo, Nebraska. The reach includes the metropolitan areas of Sioux City and Council Bluffs, Iowa and Omaha, Nebraska.

Rulo to Platte River (Iowa and Missouri) (St. Joseph Reach): the reach extends from approximately RM 497 to RM 392. The reach includes part of the city of St. Joseph, Missouri.

Platte River (Iowa and Missouri) to Grand River (Kansas City Reach): the reach extends from approximately RM 392 to RM 252. The reach includes part of the metropolitan area of Kansas City, Missouri.

Grand River to Osage River (Boonville Reach): the reach extends from approximately RM 252 to RM 139. Locations that could be affected by flooding include the area near Boonville, Missouri.

Osage River to Mouth (Hermann Reach): the reach extends from approximately River Mile 139 to the mouth. The reach includes part of the metropolitan area of St. Louis, Missouri.

3.0 National Economic Development Evaluation Results

The NED analysis for flood risk management focused on the changes in property damages, agricultural losses, and other costs of flooding as a result of changing conditions in the Missouri River. The conceptual basis for the flood risk management NED impacts analysis is an increase or decrease in risk of physical and non-physical damage from flooding. A summary is provided below.

3.1 Summary of National Economic Development Results

Tables 3, 4, and 5 provide an overall summary of the NED analysis for each of the MRRMP-EIS alternatives. Table 3 summarizes the results for all of the average annual flood damages in the basin over the modeled 82-year period of record. Relative to Alternative 1, all of the alternatives showed a reduction in flood damages with Alternative 2 exhibiting the largest decrease with just over $1.7 million in average annual flood damage reduction.

Table 3. Estimated Annual National Economic Development Flood Damages of MRRMP-EIS Alternatives

All Locations	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Property Damages	$13,478,645	$12,351,595	$13,241,053	$13,018,154	$12,969,253	$13,063,132
Other Costs of Flooding	$1,213,078	$1,111,644	$1,191,695	$1,171,634	$1,167,233	$1,175,682
Agricultural Losses	$15,790,615	$15,313,896	$15,816,865	$15,604,506	$15,797,315	$15,960,672
Total Flood Damages	$30,482,337	$28,777,135	$30,249,612	$29,794,293	$29,933,801	$30,199,487
Change from Alternative 1	NA	-$1,705,203	-$232,725	-$688,044	-$548,536	-$282,851
Percentage Change from Alternative 1	NA	-5.6%	-0.8%	-2.3%	-1.8%	-0.9%

Notes: Average annual values at the Fiscal Year (FY) 2018 price level. Negative numbers indicate a decrease in damages relative to Alternative 1.

Table 4 summarizes the NED analysis for reaches in the upper river. Relative to Alternative 1, Alternative 3 modeling showed small adverse impacts with a $12,902, or 0.5 percent, average annual flood damage increase. Alternative 4 exhibited the largest beneficial impacts to flood risk management in the upper river, lowering damages relative to Alternative 1 by 6.7 percent, or $170,801, annually.

Table 4. Estimated Annual National Economic Development Flood Damages in the Upper River

Upper River	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Fort Peck to Garrison	$389,366	$390,737	$390,376	$390,555	$386,741	$388,483
Garrison to Oahe	$1,845,150	$1,804,569	$1,845,360	$1,663,570	$1,747,742	$1,816,809
Fort Randall to Gavins Point	$324,430	$292,137	$336,112	$334,019	$345,190	$343,760
Total Flood Damages	$2,558,946	$2,487,443	$2,571,848	$2,388,144	$2,479,673	$2,549,052
Change from Alternative 1	NA	-$71,503	$12,902	-$170,801	-$79,272	-$9,894
Percentage Change from Alternative 1	NA	-2.8%	0.5%	-6.7%	-3.1%	-0.4%

Notes: Average annual values at the FY 2018 price level. Negative numbers indicate a decrease in damages relative to Alternative 1.

Impacts of the MRRMP-EIS alternatives flood risk management modeling in the lower river varied slightly from those in the upper river as shown in Table 5 with all of the alternatives displaying beneficial impacts. Relative to Alternative 1, Alternative 2 had the greatest beneficial impact to flood risk management, lowering damages relative to Alternative 1 by $1,633,700, or 5.9 percent, on average annually.

Table 5. Estimated Annual National Economic Development Flood Damages in the Lower River

Lower River	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Gavins Point to Rulo	$12,338,778	$11,262,682	$12,351,651	$12,110,786	$12,168,351	$12,337,835
St. Joseph Reach	$2,150,668	$1,949,884	$2,192,779	$2,090,810	$2,174,023	$2,112,170
Kansas City Reach	$6,260,856	$6,084,431	$6,178,709	$6,150,432	$6,173,536	$6,192,308
Boonville Reach	$1,954,263	$1,859,547	$1,937,393	$1,937,659	$1,933,274	$1,957,328
Hermann Reach	$5,218,807	$5,133,148	$5,017,233	$5,116,463	$5,004,943	$5,050,794
Total Impacts	$27,923,391	$26,289,692	$27,677,764	$27,406,149	$27,454,128	$27,650,435
Change from Alternative 1*	NA	-$1,633,700	-$245,629	-$517,242	-$469,264	-$272,957
Percentage change from Alternative 1*	NA	-5.9%	-0.9%	-1.9%	-1.7%	-1.0%

Notes: Average annual values at the FY 2018 price level. Negative numbers indicate a decrease in damages relative to Alternative 1.

3.2 Alternative 1 – No Action (Current System Operation and Current MRRP Implementation)

Under Alternative 1, the MRRP would continue to be implemented as it is currently. This includes management actions that are in compliance with the BiOp. Management actions that may have impacts to flood risk management include ESH creation and spawning cue flow releases from Gavins Point Dam.

Modeling results under Alternative 1 indicate that the Missouri River floodplain would continue to experience flood damages when water surface elevations reach flood stages. The magnitude of these impacts would vary considerably from year to year depending on the natural hydrologic cycles of precipitation and snow pack and not on the management actions under Alternative 1.

The NED analysis for Alternative 1 is summarized in Table 6. The estimated flood damages to the Missouri River floodplain are $30.5 million under Alternative 1. Average annual flood damages totaled $27.9 million in the lower river and $2.6 million in the upper river. The Gavins Point to Rulo reach showed the largest average annual flood damages under Alternative 1 with an estimated $12.3 million, driven the significant impacts experienced in the reach under the 1993 and 2011 modeled events.

Table 6. Summary of National Economic Development Impacts for Alternative 1 by Reach

River Reach	Average Annual Property Damages	Average Annual Other Costs of Flooding	Average Annual Agricultural Losses	Average Annual Total Flood Damages
Missouri River	**$13,478,645**	**$1,213,078**	**$15,790,615**	**$30,482,337**
Upper River	**$1,894,217**	**$170,480**	**$494,249**	**$2,558,946**
Fort Peck to Garrison	$22,185	$1,997	$365,184	$389,366
Garrison to Oahe	$1,675,056	$150,755	$19,340	$1,845,150
Fort Randall to Gavins Point	$196,977	$17,728	$109,725	$324,430
Lower River	**$11,584,427**	**$1,042,598**	**$15,296,366**	**$27,923,391**
Gavins Point to Rulo	$4,919,021	$442,712	$6,977,045	$12,338,778
St. Joseph Reach	$817,600	$73,584	$1,259,503	$2,150,688
Kansas City Reach	$2,389,088	$215,018	$3,656,750	$6,260,856
Boonville Reach	$629,536	$56,658	$1,268,069	$1,954,263
Hermann Reach	$2,829,182	$254,626	$2,134,999	$5,218,807

Notes: Average annual values at the FY 2018 price level.

3.3 Alternative 2 – USFWS 2003 Biological Opinion Projected Actions

Alternative 2 represents the management actions that would be implemented as part of the 2003 Amended BiOp Reasonable and Prudent Alternative. Alternative 2 includes additional iterative actions that USFWS anticipates would be implemented under an adaptive management philosophy. Actions included under this alternative that may have impacts to flood risk management include:

- Creation of emergent sand bar habitat
- Reservoir unbalancing
- Spring reservoir release
- Low nesting season release
- Spawning cue flows
- Low summer flow

The NED analysis for Alternative 2 is summarized in Table 7. The Alternative 2 modeling indicates that flood risk management impacts along the Missouri River would average $1.7 million less per year relative to Alternative 1. This represents an overall decrease in flood damages of 5.6 percent which is the largest decrease among the MRRMP-EIS alternatives. These beneficial impacts, particularly in the lower river, would be due to lower peak releases, relative to Alternative 1, from Gavins Point Dam under extreme flood events. On average these impacts are relatively small in nature but there are some years when the flood damages were simulated to be of greater magnitude, especially in the lower river. The impacts are discussed in more detail below

Table 7. Summary of National Economic Development Analysis for Alternative 2

River Reach	Average Annual Property Damages	Average Annual Other Costs of Flooding	Average Annual Agricultural Losses	Average Annual Total Flood Damages	Average Annual Change from Alternative 1	% Change from Alternative 1
Missouri River	**$12,351,595**	**$1,111,644**	**$15,313,896**	**$28,777,135**	**-$1,705,203**	**-5.6%**
Upper River	**$1,842,530**	**$165,828**	**$479,085**	**$2,487,443**	**-$71,503**	**-2.8%**
Fort Peck to Garrison	$21,277	$1,915	$367,545	$390,737	$1,371	0.4%
Garrison to Oahe	$1,636,972	$147,327	$20,269	$1,804,569	-$40,582	-2.2%
Fort Randall to Gavins Point	$184,281	$16,585	$91,270	$292,137	-$32,293	-10.0%
Lower River	**$10,509,065**	**$945,816**	**$14,834,811**	**$26,289,692**	**-$1,633,700**	**-5.9%**
Gavins Point to Rulo	$4,117,942	$370,615	$6,774,125	$11,262,682	-$1,076,096	-8.7%
St. Joseph Reach	$685,501	$61,695	$1,202,687	$1,949,884	-$200,804	-9.3%
Kansas City Reach	$2,380,026	$214,202	$3,490,202	$6,084,431	-$176,426	-2.8%
Boonville Reach	$549,416	$49,447	$1,260,683	$1,859,547	-$94,716	-4.8%
Hermann Reach	$2,776,179	$249,856	$2,107,113	$5,133,148	-$85,659	-1.6%

Notes: All totals are average annual at the FY 2018 price level. Negative numbers indicate a decrease relative to Alternative 1.

When evaluating the impacts of each of the MRRMP-EIS alternatives, it is helpful to examine the annual impacts. Figure 6 shows the change in annual NED flood risk management impacts under Alternative 2 relative to Alternative 1 in the upper river. Some notable results include:

- In the 82-year period of record, 31 years showed an increase in damages relative to Alternative 1 although the impacts in the majority of the years were less than $10,000.
- The modeled range of impacts compared to Alternative 1 varied from a decrease in flood damages of $10,025,079 in the 2011 simulation to an increase in damages of $4,890,121 under the 1952 simulated event.
- The effect of Alternative 2 would decrease damages by $71,503 on average annually relative to Alternative 1 in the upper river as a whole, but the Fort Peck to Garrison reach would experience an average annual damage increase of $1,371 (0.4 percent).

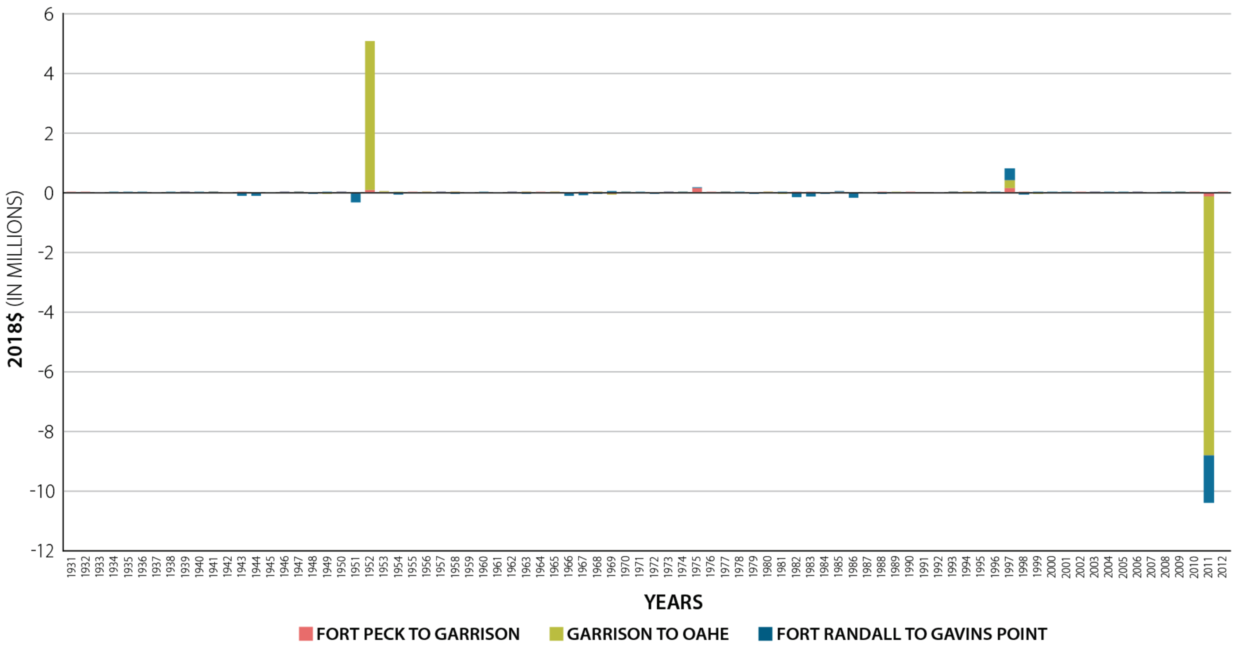

Figure 6. Alternative 2 Annual Flood Damage Difference from Alternative 1 in the Upper River

Figure 7 shows the change in annual NED flood risk management impacts under Alternative 2 relative to Alternative 1 in the lower river. Some notable results include:

- In the 82-year period of record, 70 years showed a decrease in flood damages relative to Alternative 1.
- Under the 2011 simulation, Alternative 2 experienced $64,066,520 less in damages relative to the Alternative 1 with the majority of that damage decrease ($58,034,512) occurring in the Gavins Point to Rulo reach.
- Five modeled years showed an increase in flood damages of greater than $5 million with the largest being an $8,853,731 increase under the 1983 simulation.
- All five reaches showed a decrease in damages on average over the modeled period of record relative to Alternative 1. The effect of Alternative 2 would decrease damages by $1,633,700 on average annually in the lower river relative to Alternative 1.

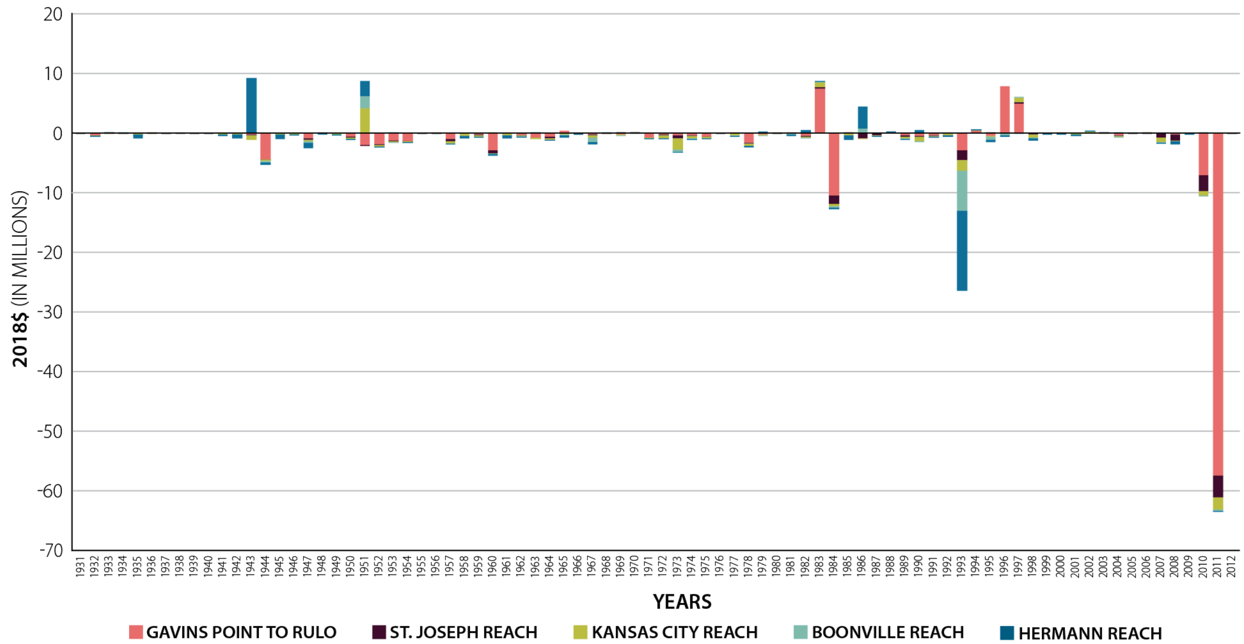

Figure 7. Alternative 2 Annual Flood Damage Difference from Alternative 1 in the Lower River

Additional results for the upper river are shown in Figure 8. Here the difference in NED impacts between Alternative 2 and Alternative 1 are plotted and color-coded based on the type of modeled release occurring each year. During the period of record, there were 3 years with a full release plus low summer flow action and 31 years with partial flow releases. Some notable results include:

- All three years with full release plus low summer flow events had a decrease in NED impacts under Alternative 2 relative to Alternative 1. The largest flood damage decrease for a full release plus low summer flow modeled event was $42,819 in the 1963 simulation.
- Partial flow release actions also appear to reduce damages in the upper river. Twenty-one of the 31 modeled years showed beneficial impacts and on average the annual difference would be a $25,750 decrease in damages below Alternative 1.

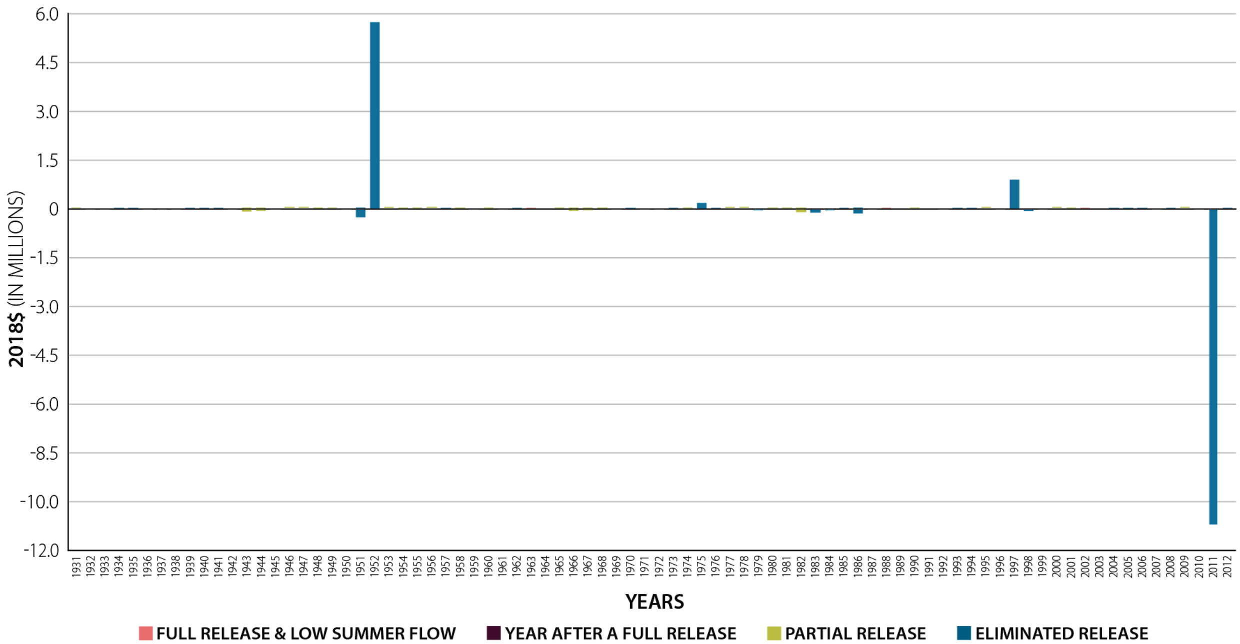

Figure 8. Alternative 2 Annual Flood Damage Difference from Alternative 1 in the Upper River by Release Type

Figure 9 shows the same data plot for impacts in the lower river under Alternative 2 release type. Some notable results include:

- Two of the full release plus low summer flow modeled years experienced an increase in flood damages for Alternative 2 relative to Alternative 1. However, on average, full release plus low summer flow event years showed a decrease in flood damages of $222,507 relative to Alternative 1.
- The largest modeled adverse impact year in the lower river was the partial flow release event year of 1943. That simulated event saw an increase in flood damages of $8,079,257 over Alternative 1. Overall, 29 of the 31 partial release years modeled showed beneficial impacts in the lower river under Alternative 2 with an average reduction in flood damages of $737,462.

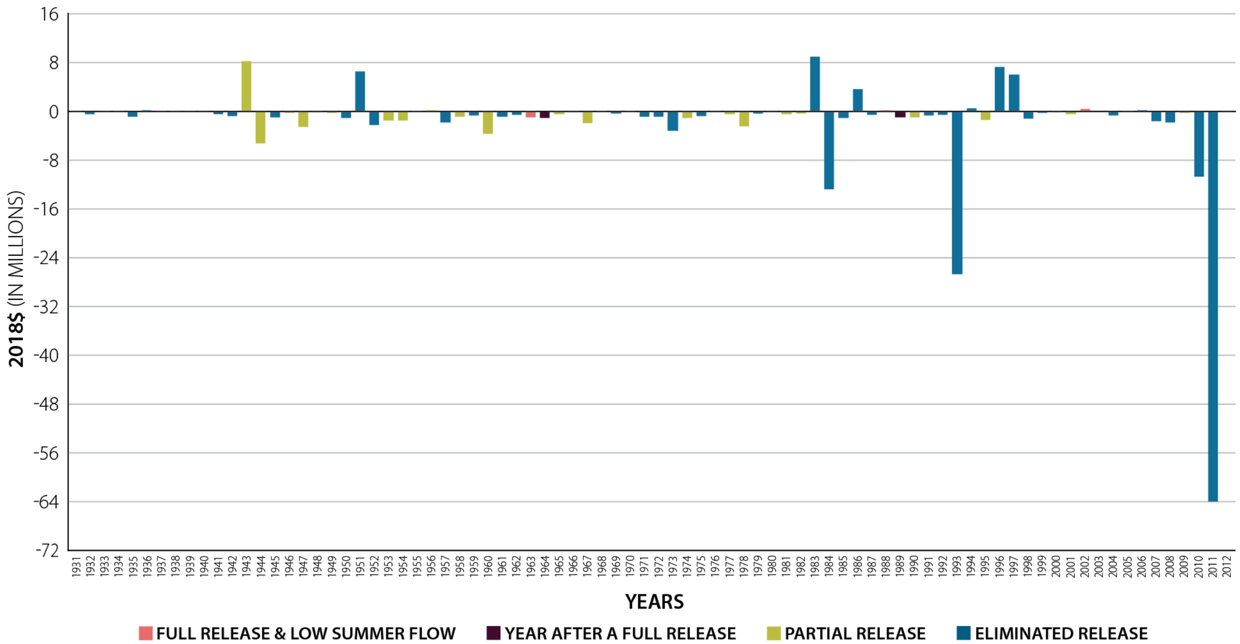

Figure 9. Alternative 2 Annual Flood Damage Difference from Alternative 1 in the Lower River by Release Type

3.4 Alternative 3 – Mechanical Construction Only

Management actions included under Alternative 3 would include those that focus on the creation of ESH through mechanical means. This alternative would have a small, beneficial impact on flood risk management. Overall, flood damages decreased by $232,725 annually (0.8 percent) across the 82-year modeled period of record relative to Alternative 1. All of the beneficial impacts under Alternative 3 would be realized in the lower river as the upper river showed a small uptick in damages (0.5 percent) relative to Alternative 1. The NED results for Alternative 3 are summarized in Table 8.

Table 8. Summary of National Economic Development Analysis for Alternative 3

River Reach	Average Annual Property Damages	Average Annual Other Costs of Flooding	Average Annual Agricultural Losses	Average Annual Total Flood Damages	Average Annual Change from Alternative 1	% Change from Alternative 1
Missouri River	**$13,241,053**	**$1,191,695**	**$15,816,865**	**$30,249,612**	**-$232,725**	**-0.8%**
Upper River	**$1,904,044**	**$171,364**	**$496,440**	**$2,571,848**	**$12,902**	**0.5%**
Fort Peck to Garrison	$22,380	$2,014	$365,982	$390,376	$1,010	0.3%
Garrison to Oahe	$1,675,006	$150,751	$19,604	$1,845,360	$210	0.0%
Fort Randall to Gavins Point	$206,658	$18,599	$110,854	$336,112	$11,682	3.6%
Lower River	**$11,337,008**	**$1,020,331**	**$15,320,425**	**$27,677,764**	**-$245,628**	**-0.9%**

River Reach	Average Annual Property Damages	Average Annual Other Costs of Flooding	Average Annual Agricultural Losses	Average Annual Total Flood Damages	Average Annual Change from Alternative 1	% Change from Alternative 1
Gavins Point to Rulo	$4,860,172	$437,415	$7,054,064	$12,351,651	$12,873	0.1%
St. Joseph Reach	$824,299	$74,187	$1,294,292	$2,192,779	$42,091	2.0%
Kansas City Reach	$2,343,123	$210,881	$3,624,704	$6,178,709	-$82,148	-1.3%
Boonville Reach	$611,909	$55,072	$1,270,412	$1,937,393	-$16,870	-0.9%
Hermann Reach	$2,697,505	$242,775	$2,076,952	$5,017,233	-$201,574	-3.9%

Notes: All totals are average annual at the FY 2018 price level. Negative numbers indicate a decrease relative to Alternative 1.

Figure 10 shows the change in annual NED impacts to flood risk management in the upper river between Alternative 3 and Alternative 1. Some notable results include:

- There were 47 modeled years displaying adverse impacts in the upper river relative to Alternative 1. The differences over the period of record in the upper river ranged from $872,045 in increased damages for Alternative 3 in the 2011 simulated event to a $58,346 decrease in damages under the 1947 simulated event.
- Overall, the net annual effects of Alternative 3 in the upper river would be an increase in damages of $12,902 relative to Alternative 1.

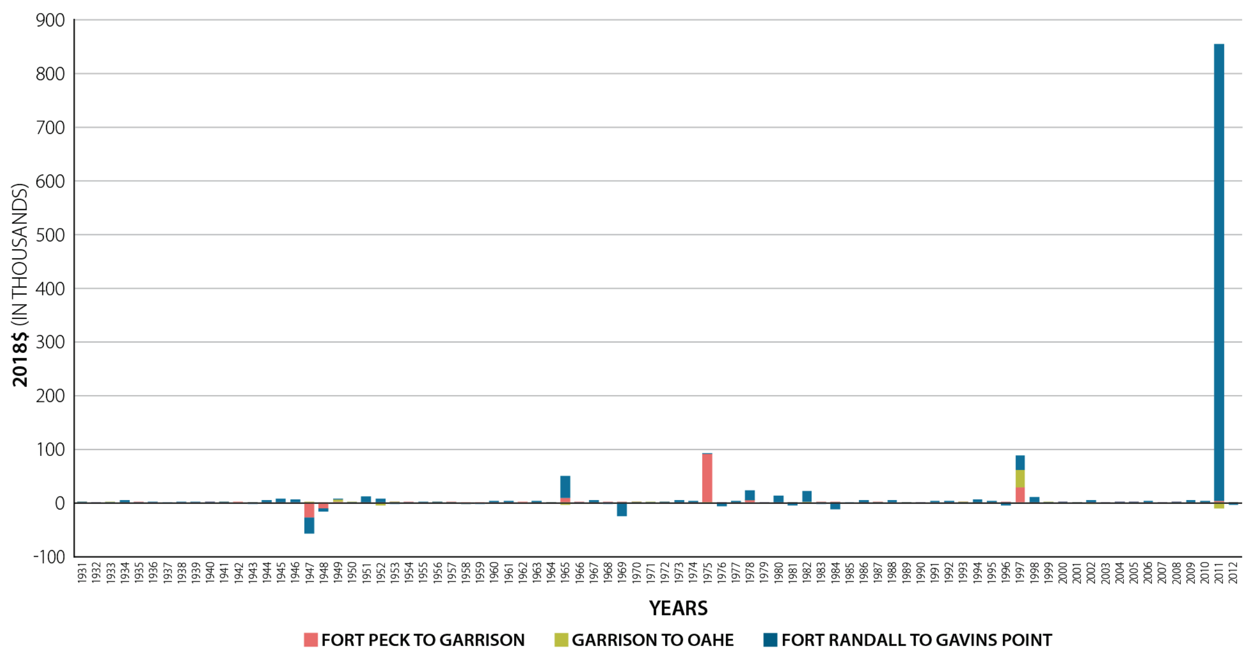

Figure 10. Alternative 3 Annual Flood Damage Difference from Alternative 1 in the Upper River

Figure 11 shows the change in annual NED impacts to flood risk management in the lower river. Some notable results include:

- In 39 of the 82 modeled years, flood damages increased over Alternative 1; however, in only 2 of those years did damages exceed $500,000 relative to Alternative 1. The same period of record showed a reduction in flood damages relative to Alternative 1 of greater than $500,000 in 8 years.
- The furthest upstream lower river reach (Gavins Point Dam to Rulo) experienced an increase in damages over Alternative 1 in 74 years out of the 82-year modeled period of record, however in most of these instances, there was only a small increase in damages. The furthest downstream lower river reach (Hermann Reach) only experienced adverse impacts in 2 modeled years.
- The NED impacts relative to Alternative 1 in the lower river ranged from an increase in flood damages of $646,383 under the 2010 simulated event to a decrease of flood damages of $7,224,221 in the 2011 simulation. In the lower river, Alternative 3 would decrease damages on average by $245,628 annually compared to Alternative 1.

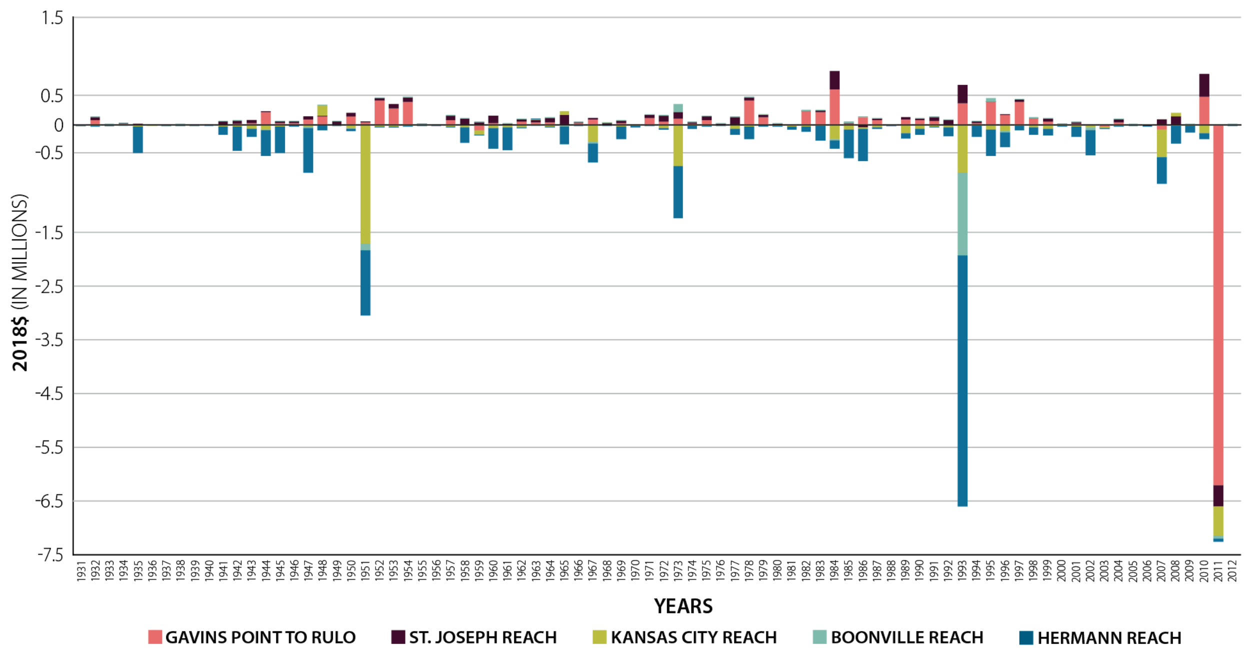

Figure 11. Alternative 3 Annual Flood Damage Difference from Alternative 1 in the Lower River

3.5 Alternative 4 – Spring ESH Creating Release

Alternative 4 focuses on developing ESH habitat through both mechanical and reservoir releases that would occur during the spring months. Both actions have the potential to affect flood risk management. Alternative 4 would have the second largest beneficial impact on flood risk management relative to Alternative 1 of any of the MRRMP-EIS alternatives. Across all locations flood damages would decrease by $688,044 annually, or 2.3 percent, relative to Alternative 1. In the upper river the average annual reduction in flood damages would be $170,801 (6.7 percent), while in the lower the river the flood damages would be reduced $517,242 annually. The NED results for Alternative 4 are summarized in Table 9.

Table 9. Summary of National Economic Development Analysis for Alternative 4

River Reach	Average Annual Property Damages	Average Annual Other Costs of Flooding	Average Annual Agricultural Losses	Average Annual Total Flood Damages	Average Annual Change from Alternative 1	% Change from Alternative 1
Missouri River	**$13,018,154**	**$1,171,634**	**$15,604,506**	**$29,794,293**	**-$688,044**	**-2.3%**
Upper River	**$1,741,697**	**$156,753**	**$489,694**	**$2,388,144**	**-$170,801**	**-6.7%**
Fort Peck to Garrison	$21,811	$1,963	$366,781	$390,555	$1,190	0.3%
Garrison to Oahe	$1,508,756	$135,788	$19,026	$1,663,570	-$181,580	-9.8%
Fort Randall to Gavins Point	$211,129	$19,002	$103,888	$334,019	$9,589	3.0%
Lower River	**$11,276,457**	**$1,014,881**	**$15,114,811**	**$27,406,149**	**-$517,242**	**-1.9%**
Gavins Point to Rulo	$4,797,127	$431,741	$6,881,918	$12,110,786	-$227,992	-1.8%
St. Joseph Reach	$765,527	$68,897	$1,256,385	$2,090,810	-$59,878	-2.8%
Kansas City Reach	$2,324,985	$209,249	$3,616,199	$6,150,432	-$110,424	-1.8%
Boonville Reach	$610,743	$54,967	$1,271,949	$1,937,659	-$16,605	-0.8%
Hermann Reach	$2,778,075	$250,027	$2,088,362	$5,116,463	-$102,344	-2.0%

Notes: All totals are average annual at the FY 2018 price level. Negative numbers indicate a decrease relative to Alternative 1.

Figure 12 shows the change in annual NED impacts to flood risk management in the upper river between Alternative 4 and Alternative 1:

- The decrease in impacts is driven almost entirely by the 2011 simulated event which resulted in a $15,022,990 decrease in damages over Alternative 1 in the upper river. Approximately 108 percent of this decrease is attributable to the Garrison Dam to Oahe Dam reach alone as the other two reaches in the upper river show adverse impacts in the 2011 simulation.
- Forty of the 82 modeled years in the upper river experienced an increase in damages relative to Alternative 1. The largest adverse year modeled was the 1950 simulation which showed a $1,357,972 increase in damages for Alternative 4 over Alternative 1.

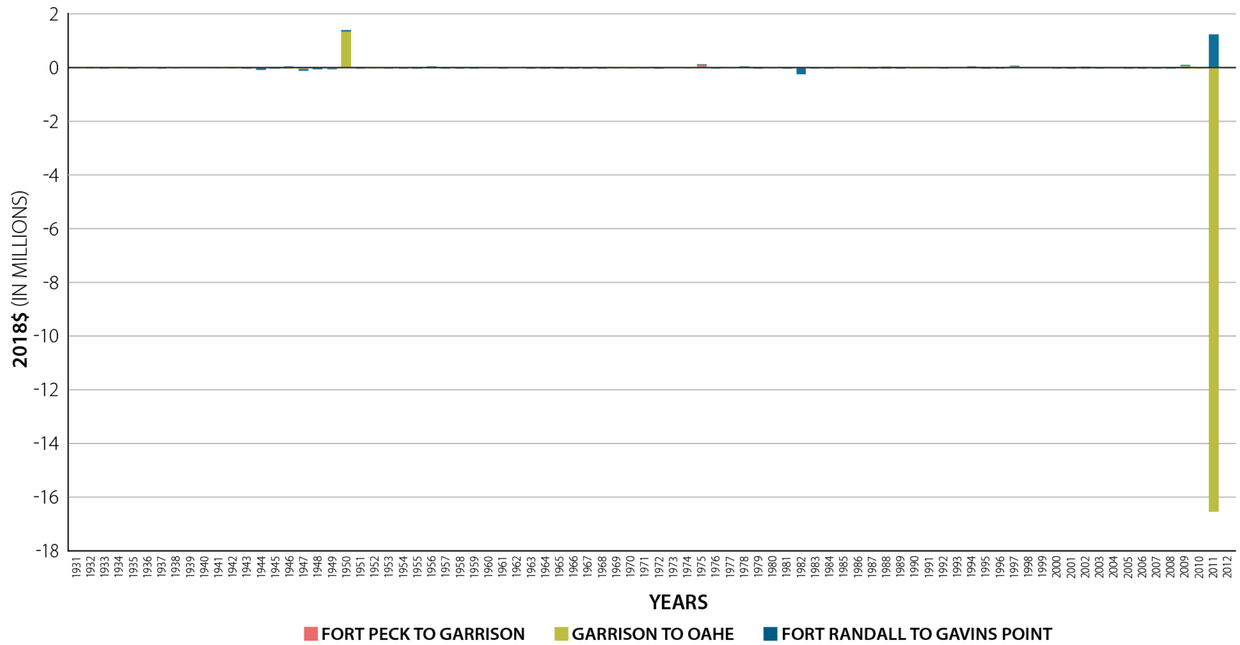

Figure 12. Alternative 4 Annual Flood Damage Difference from Alternative 1 in the Upper River

For the lower river under Alternative 4, the flood risk management NED impacts would also decrease on average relative to Alternative 1. Figure 13 shows the annual flood damage difference in the lower river. Some notable results include:

- Four years in the modeled period of record showed an increase in damages of greater than $1 million, while seven years experienced a decrease of the same amount or greater. Differences compared to Alternative 1 ranged from a reduction in flood damages of $23,060,984 in the 2010 simulation to an increase of flood damages of $2,950,212 under the 1945 simulated event.
- In 46 of the 82 years modeled under Alternative 4, flood damages decreased in relation to Alternative 1 with an average annual decrease of $517,242 across the entire modeled period of record in the lower river.

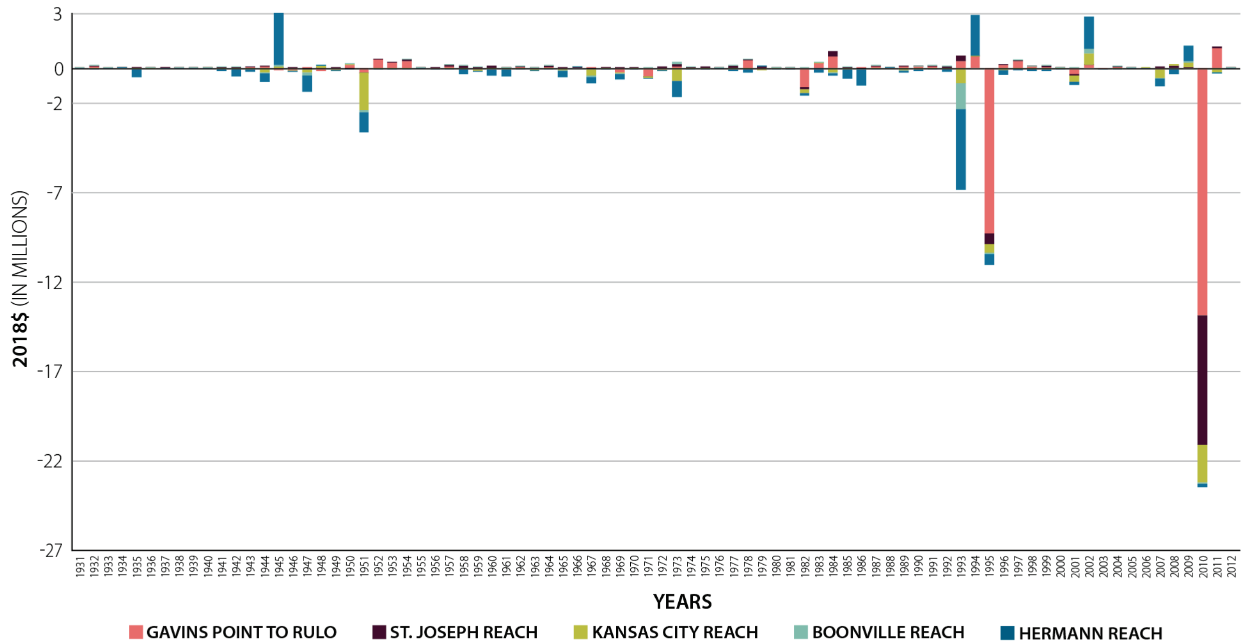

Figure 13. Alternative 4 Annual Flood Damage Difference from Alternative 1 in the Lower River

Figure 14 shows the difference in flood damages between Alternative 4 and Alternative 1 based on the type of release occurring each year for the upper river. Some notable results include:

- The largest beneficial impact under Alternative 4 compared to Alternative 1 in the upper river occurred in the modeled natural event of 2011. Whereas, the greatest adverse impacts were seen in the partial release event simulated year of 1950.
- There were nine full release events modeled under Alternative 4, with seven of those event years showing an increase in flood damages over Alternative 1. However, on average, the damages under Alternative 4 full release modeled years actually declined $16,268 due to the 1982 simulated event exhibiting a $220,066 decrease in damages.

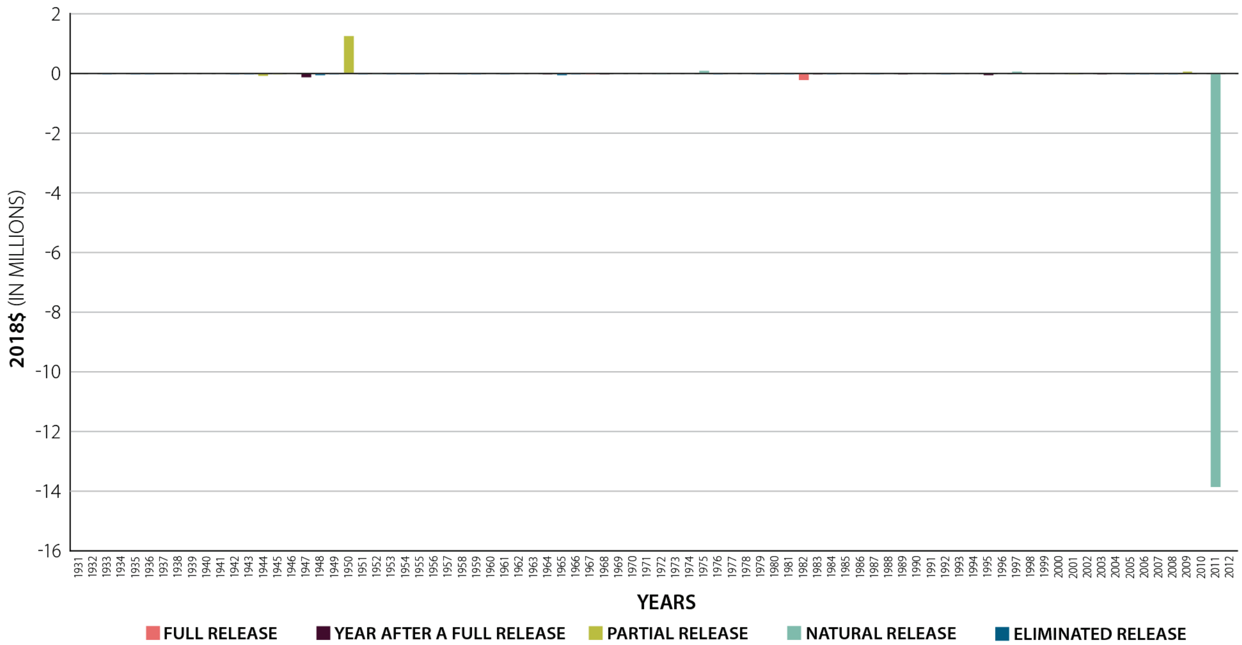

Figure 14. Alternative 4 Annual Flood Damage Difference from Alternative in the Upper River by Release Type

Figure 15 shows the same data plot for the change in flood impacts between Alternative 4 and Alternative 1 by release type in the lower river. Some notable results include:

- In the lower river, only two out of nine modeled full release action years resulted in an increase in flood damages relative to Alternative 1. However, both of those simulated years, 1994 and 2002, experienced an increase in damages over Alternative 1 of approximately $2.9 million. The Alternative 4 full release action years showed an average annual flood damage increase of $286,962.
- In addition to the full release events, there were seven partial events modeled. In the lower river, four of those seven partial events showed an increase in flood damages over Alternative 1 with an average annual increase of $352,259 under all partial event simulations.

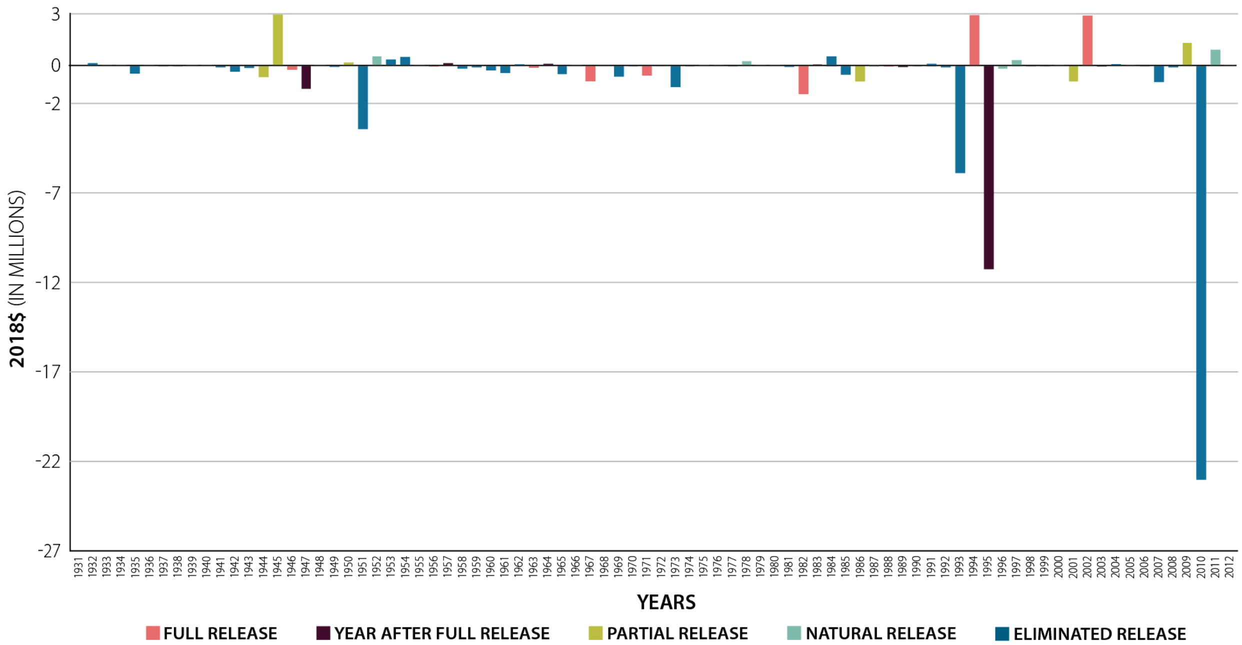

Figure 15. Alternative 4 Annual Flood Damage Difference from Alternative 1 in the Lower River by Release Type

3.6 Alternative 5 – Fall ESH Creating Release

Alternative 5 would focus on developing ESH habitat through both mechanical and reservoir releases that would occur during the fall months. Both actions have the potential to affect flood risk management. Alternative 5 is expected to have a beneficial impact on flood risk management. Across all locations the modeled damages decreased by $548,536 annually or 1.8 percent less than Alternative 1. The NED results for Alternative 5 are summarized in Table 10.

Table 10. Summary of National Economic Development Analysis for Alternative 5

River Reach	Average Annual Property Damages	Average Annual Other Costs of Flooding	Average Annual Agricultural Losses	Average Annual Total Flood Damages	Average Annual Change from Alternative 1	% Change from Alternative 1
Missouri River	**$12,969,253**	**$1,167,233**	**$15,797,315**	**$29,933,801**	**-$548,536**	**-1.8%**
Upper River	**$1,783,391**	**$160,505**	**$535,777**	**$2,479,673**	**-$79,272**	**-3.1%**
Fort Peck to Garrison	$21,280	$1,915	$363,545	$386,741	-$2,625	-0.7%
Garrison to Oahe	$1,584,983	$142,648	$20,111	$1,747,742	-$97,408	-5.3%
Fort Randall to Gavins Point	$177,128	$15,942	$152,121	$345,190	$20,761	6.4%
Lower River	**$11,185,862**	**$1,006,728**	**$15,261,538**	**$27,454,128**	**-$469,264**	**-1.7%**
Gavins Point to Rulo	$4,735,114	$426,160	$7,007,077	$12,168,351	-$170,427	-1.4%
St. Joseph Reach	$812,992	$73,169	$1,287,861	$2,174,023	$23,335	1.1%
Kansas City Reach	$2,337,880	$210,409	$3,625,247	$6,173,536	-$87,320	-1.4%
Boonville Reach	$610,690	$54,962	$1,267,622	$1,933,274	-$20,989	-1.1%
Hermann Reach	$2,689,186	$242,027	$2,073,731	$5,004,943	-$213,863	-4.1%

Notes: All totals are average annual at the FY 2018 price level. Negative numbers indicate a decrease relative to Alternative 1.

Figure 16 shows the annual NED impacts to flood risk management in the upper river under Alternative 5 compared to Alternative 1. Some notable results include:

- There were 6 modeled years where the increase in flood damages over Alternative 1 exceeded $400,000 in the upper river. The majority of the flood damages in these years were driven by the increases occurring in the Fort Randall to Gavins Point reach.
- The overall reduction in flood damages for the upper river under Alternative 5 is almost entirely driven by the decrease experienced in the 2011 modeled event. In the Garrison to Oahe reach alone, the 2011 simulation reduced damages compared to Alternative 1 by $7,986,179.

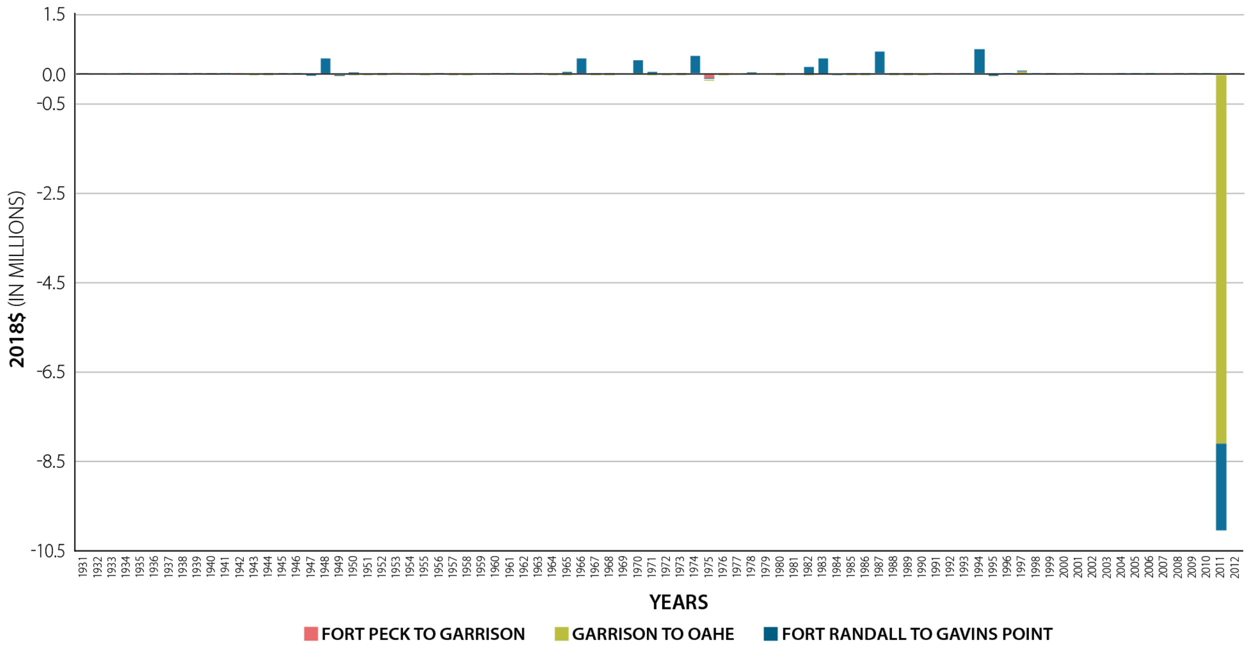

Figure 16. Alternative 5 Annual Flood Damage Difference from Alternative 1 in the Upper River

Figure 17 shows the change annual NED impacts to flood risk management in the lower river under Alternative 5 compared to Alternative 1. Some notable results include:

- The Alternative 5 modeled impacts relative to Alternative 1 in the lower river ranged from a decrease of $18,808,756 in the 2011 simulated event to an increase of $1,717,411 under the 1984 simulation. The Hermann Reach experienced the greatest beneficial impact with a decrease of $213,863 in average annual flood damages modeled under Alternative 5 compared to Alternative 1.
- There were seven modeled events under Alternative 4 that experienced a decrease in flood damages of greater than $1 million compared to Alternative 1. Inversely, there were four modeled events that showed an increase of $1 million or greater in flood damages relative to Alternative 1.

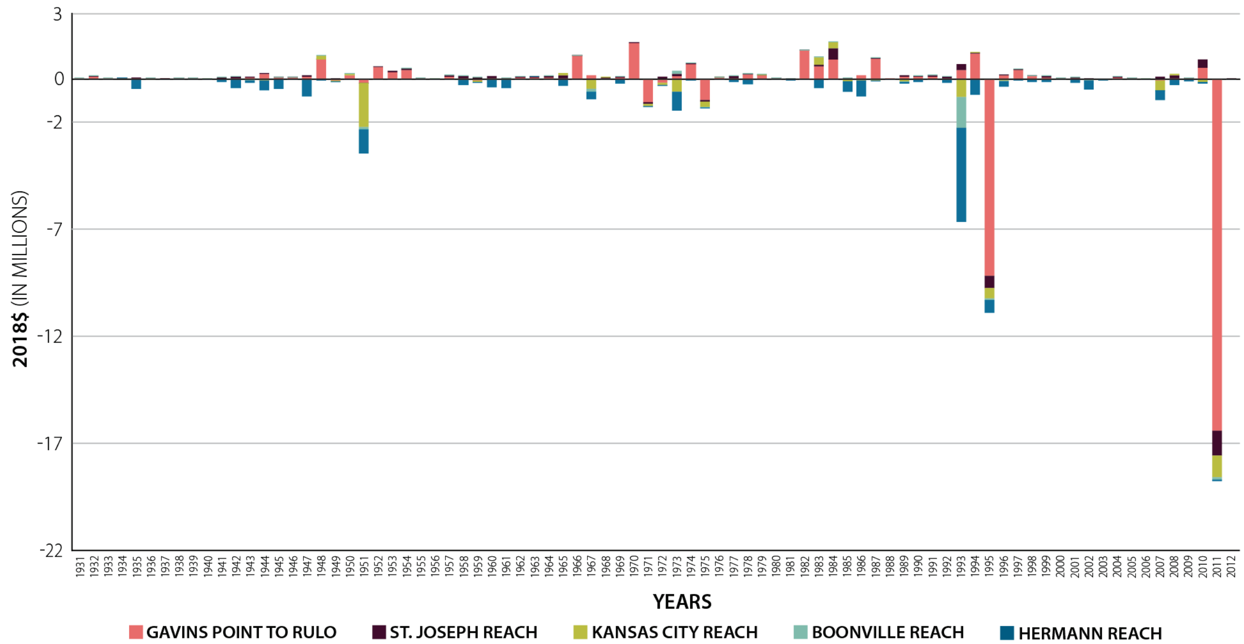

Figure 17. Alternative 5 Annual Flood Damage Difference from Alternative 1 in the Lower River

Figure 18 shows the difference in NED flood risk management impacts between Alternative 5 and Alternative 1 by the type of release occurring each year in the upper river. Some notable results include:

- All seven modeled years with full release action events exhibited increased impacts relative to Alternative 1 in the upper river. On average, a full flow release action under Alternative 5 displayed an increase in flood damages relative to Alternative 1 in the upper river of $480,095 with the largest increase being $664,862 under the 1994 simulation.
- A natural release event year, 2011, experienced the largest beneficial impacts relative to Alternative 1, with a $9,887,823 reduction in flood damages modeled.

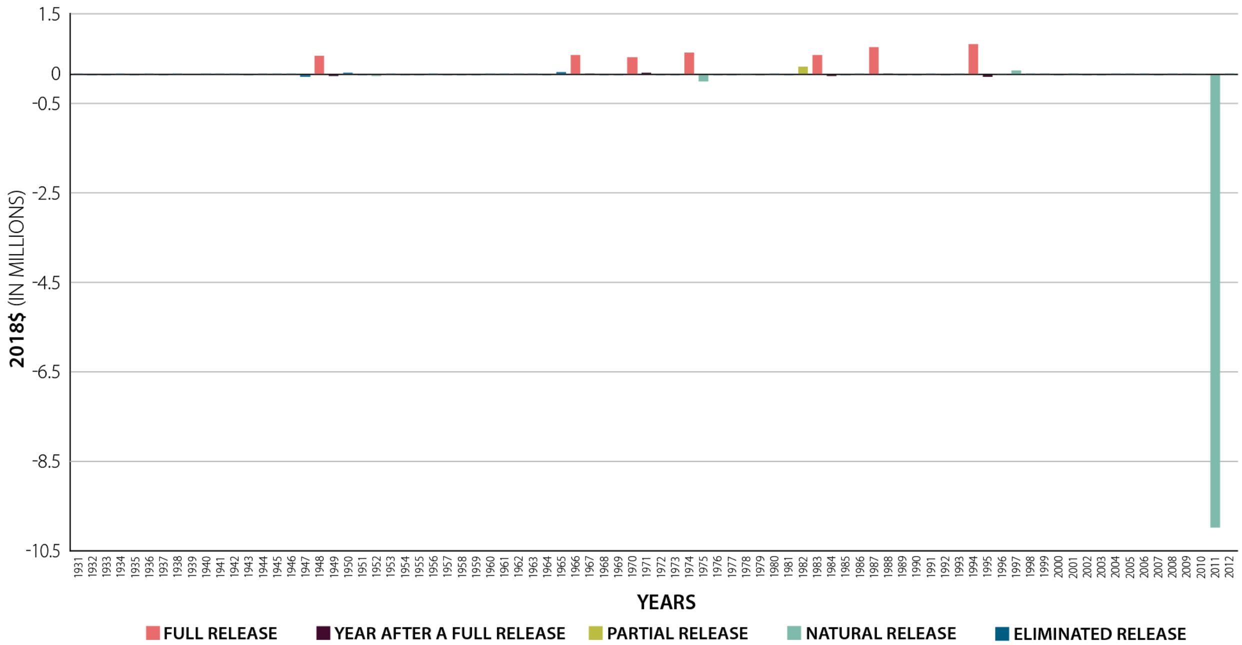

Figure 18. Alternative 5 Annual Flood Damage Difference from Alternative 1 in the Upper River by Release Type

Figure 19 shows the same data plot for flood impacts by release type in the lower river for Alternative 5.

- All seven modeled years with full release action events exhibited increased impacts relative to Alternative 1 in the lower river. On average, a modeled full flow release action under Alternative 5 had an increase in flood damages relative to Alternative 1 in the lower river of $904,108 with the largest increase being $1,679,452 in the 1970 simulated event.
- There were only 2 partial release modeled events under Alternative 5; however, those simulated event years, 1982 and 2010, showed an average increase in flood damages over Alternative 1 of $962,606 in the lower river.

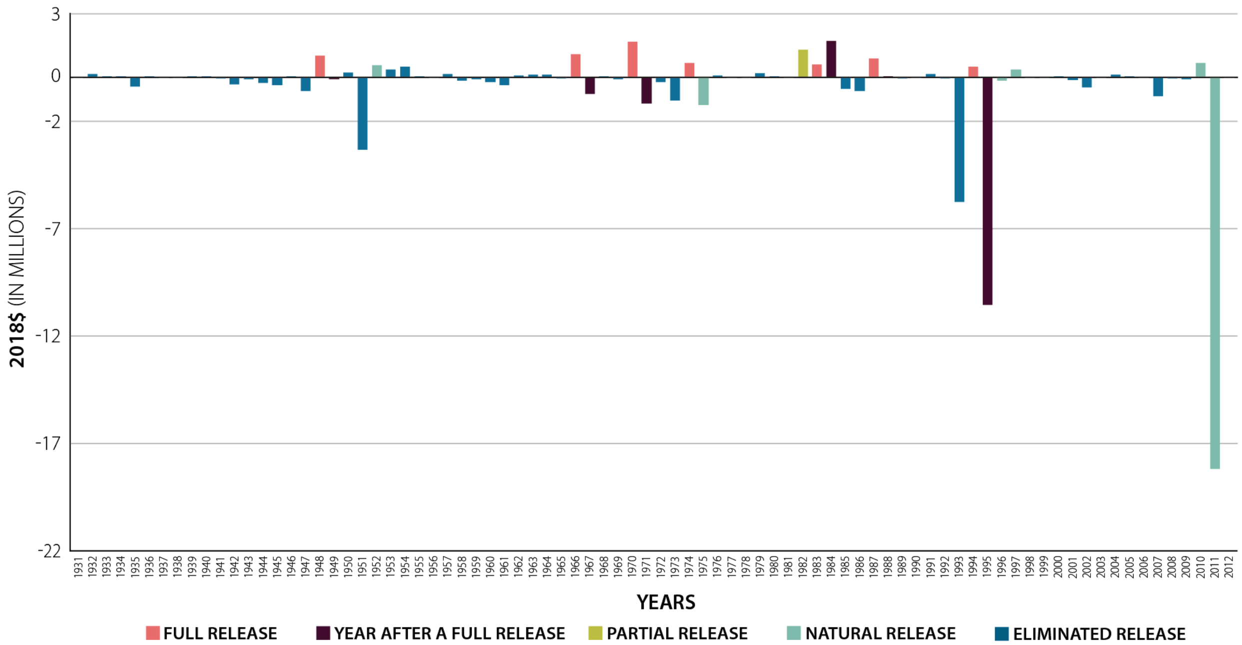

Figure 19. Alternative 5 Annual Flood Damage Difference from Alternative 1 in the Lower River by Release Type

3.7 Alternative 6 – Pallid Sturgeon Spawning Cue

Alternative 6 includes actions that would develop ESH habitat through mechanical means and a spawning cue flow that would be mimicked through bi-modal pulses that would occur in March and May. Both of these management actions have the potential to impact flood risk management. Alternative 6 would have a small, beneficial impact on flood risk management. Overall, NED damages would decrease by $282,851 annually or a decrease of 0.9 percent relative to Alternative 1. Both the upper and lower river would experience decreases in flood damages under Alternative 6. The NED results for Alternative 6 are summarized in Table 11.

Table 11. Summary of National Economic Development Analysis for Alternative 6

River Reach	Average Annual Property Damages	Average Annual Other Costs of Flooding	Average Annual Agricultural Losses	Average Annual Total Flood Damages	Average Annual Change from Alternative 1	% Change from Alternative 1
Missouri River	**$13,063,132**	**$1,175,682**	**$15,960,672**	**$30,199,487**	**-$282,851**	**-0.9%**
Upper River	**$1,886,653**	**$169,799**	**$492,600**	**$2,549,052**	**-$9,894**	**-0.4%**
Fort Peck to Garrison	$22,256	$2,003	$364,223	$388,483	-$883	-0.2%
Garrison to Oahe	$1,649,125	$148,421	$19,263	$1,816,809	-$28,341	-1.5%
Fort Randall to Gavins Point	$215,272	$19,375	$109,113	$343,760	$19,330	6.0%
Lower River	**$11,176,479**	**$1,005,883**	**$15,468,072**	**$27,650,435**	**-$272,957**	**-1.0%**
Gavins Point to Rulo	$4,721,689	$424,952	$7,191,194	$12,337,835	-$943	0.0%
St. Joseph Reach	$768,439	$69,160	$1,274,571	$2,112,170	-$38,518	-1.8%
Kansas City Reach	$2,347,832	$211,305	$3,633,171	$6,192,308	-$68,548	-1.1%
Boonville Reach	$617,741	$55,597	$1,283,991	$1,957,328	$3,065	0.2%
Hermann Reach	$2,720,779	$244,870	$2,085,145	$5,050,794	-$168,012	-3.2%

Notes: All totals are average annual at the FY18 price level. Negative numbers indicate a decrease relative to Alternative 1.

Figure 20 shows the annual NED impacts to flood risk management in the upper river under Alternative 6 relative to Alternative 1. Some notable results include:

- There was only one modeled year that differed by greater or less than $200,000 in flood damages in the upper river. That year, 2011, showed a decrease in flood damages in the Garrison to Oahe reach of $2,285,571 compared to Alternative 1. However, that same simulated event showed an increase in flood damages in the Fort Randall to Gavins Point reach of $1,614,637 under Alternative 6.
- The range of simulated upper river impacts varied from a $652,205 reduction in flood damages relative to Alternative 1 in the 2011 simulation to a $143,982 increase in damages in the 2000 modeled event. On average, annual damages would decrease compared to Alternative 1 by $9,894 in the upper river.

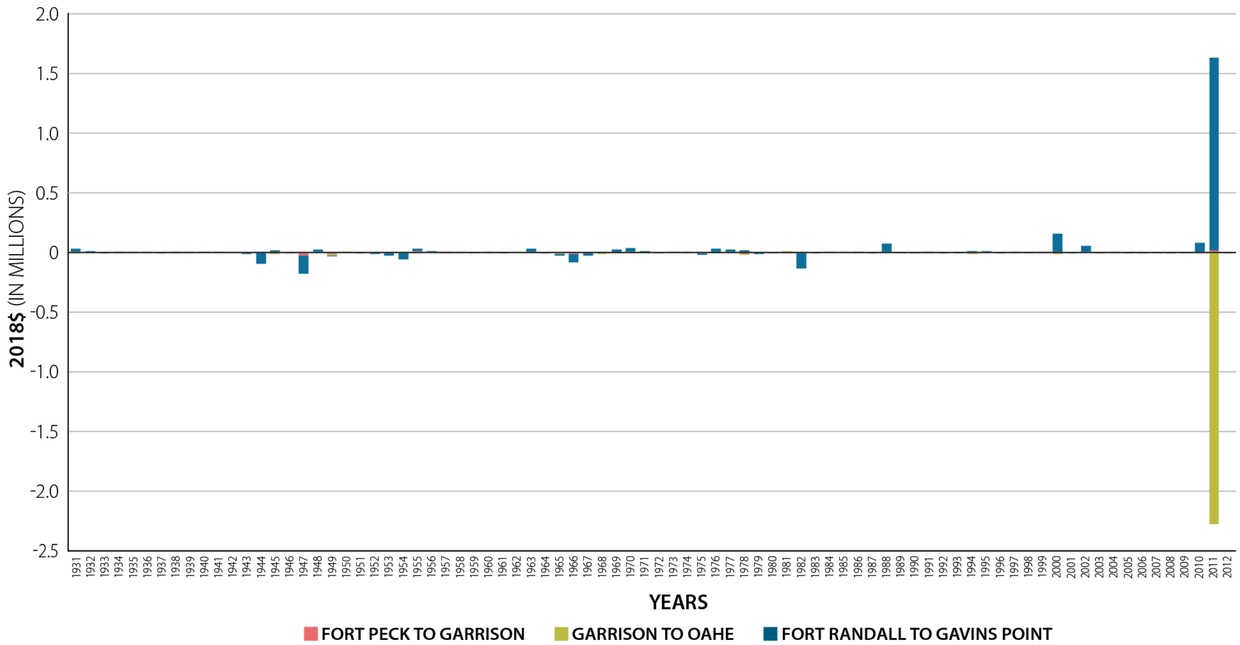

Figure 20. Alternative 6 Annual Flood Damage Difference from Alternative 1 in the Upper River

Figure 21 shows the change to annual flood risk management NED impacts in the lower river. Some notable results include:

- In the lower river, there were 37 modeled years in the 82-year period of record that showed an increase in flood damages over Alternative 1. However, within the reaches themselves, the St. Joseph Reach had 70 modeled increase years over Alternative 1 compared to only 12 such years in the Hermann Reach.
- There were six modeled events that exceeded $1 million in additional flood damages over Alternative 1 as well as six modeled events that decreased by more than $1 million in flood damages under Alternative 6.
- The modeled range of lower river annual flood damages compared to Alternative 1 varied from a $13,558,327 decrease in flood damages in the 2010 simulated event to a $6,571,826 increase in flood damages in the 1967 simulation.

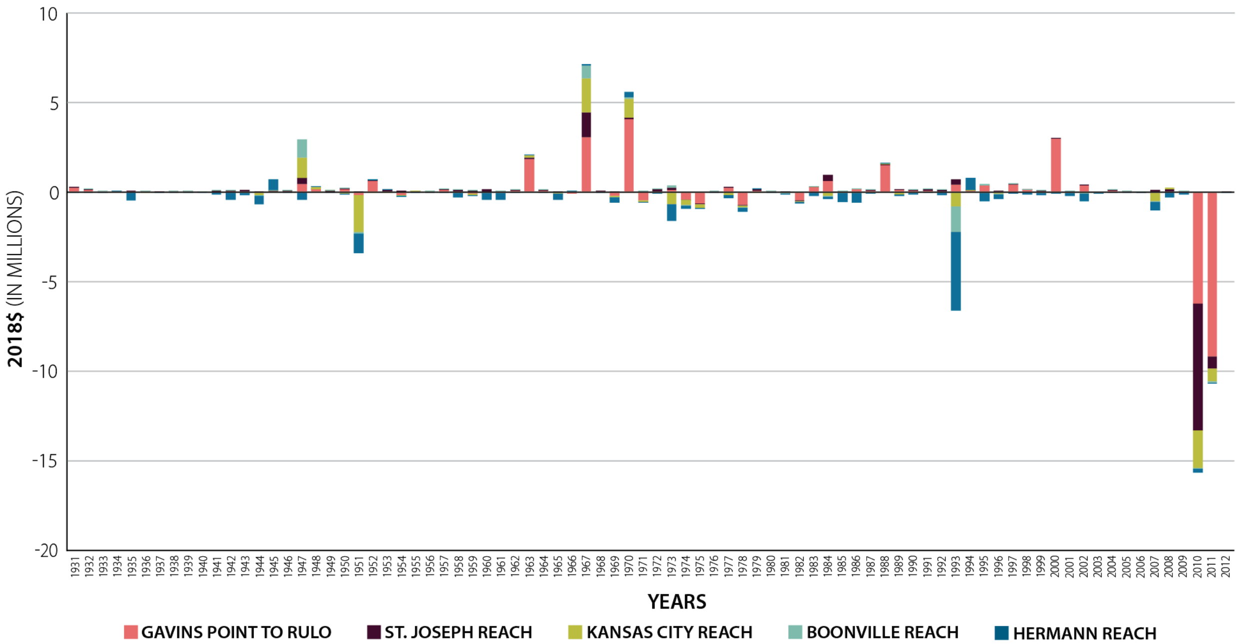

Figure 21. Alternative 6 Annual Flood Damage Difference from Alternative 1 in the Lower River

Figure 22 shows the difference in flood damages between Alternative 6 and Alternative 1 by the type of release occurring each year in the upper river. Some notable results include:

- All but one of the six modeled full release years had increasing flood damages relative to Alternative 1, while over half of the 29 partial event years showed a decrease in flood damages.
- The six full release action years produced an average annual increase in flood damages over Alternative 1 of $32,106. The modeled year with the largest adverse impact, 2000, was a partial release event that displayed an additional $143,982 in flood damages under Alternative 6.

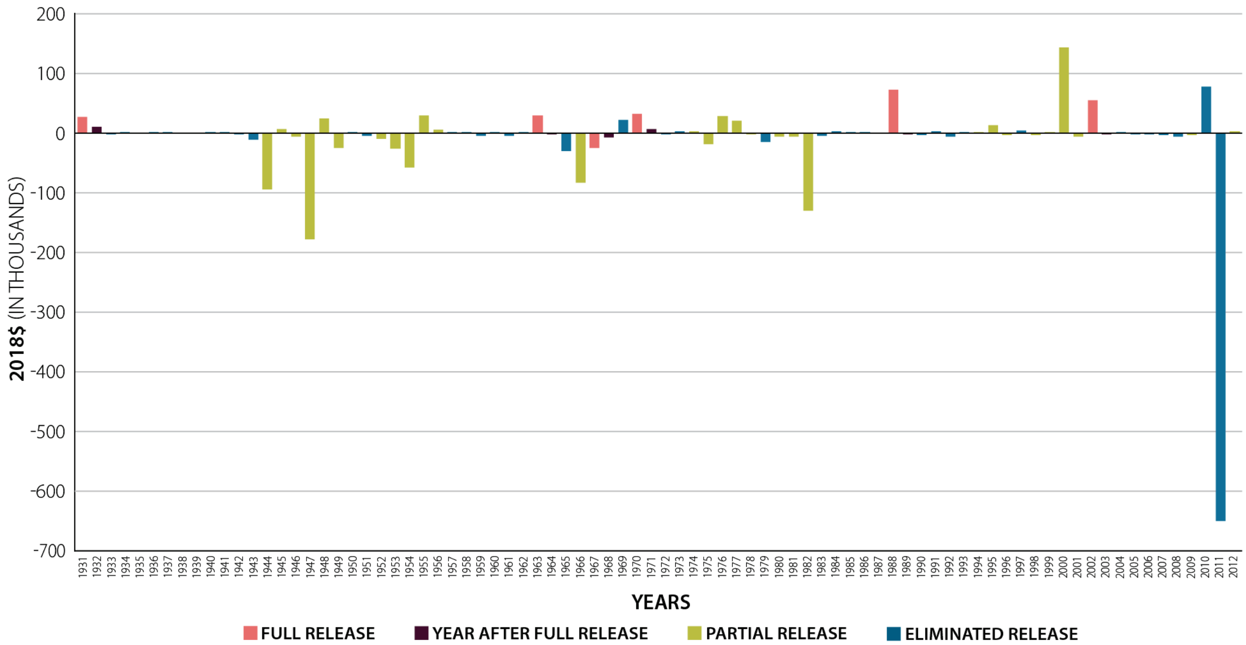

Figure 22. Alternative 6 Annual Flood Damage Difference from Alternative 1 in the Upper River by Release Type

Figure 23 shows the impacts of the Alternative 6 release actions compared to Alternative 1 in the lower river. Some notable results include:

- Again, five out of the six years when a full release was simulated, impacts in the lower river increased relative to Alternative 1. The top nine adverse impact years in the lower river were either full or partial release years under Alternative 6.
- Overall, the lower river experienced an annual decrease in flood damages of $260,760 compared to the Alternative 1; however, under the Alternative 6 full release event years the flood damages increased by an average of $2,735,524.

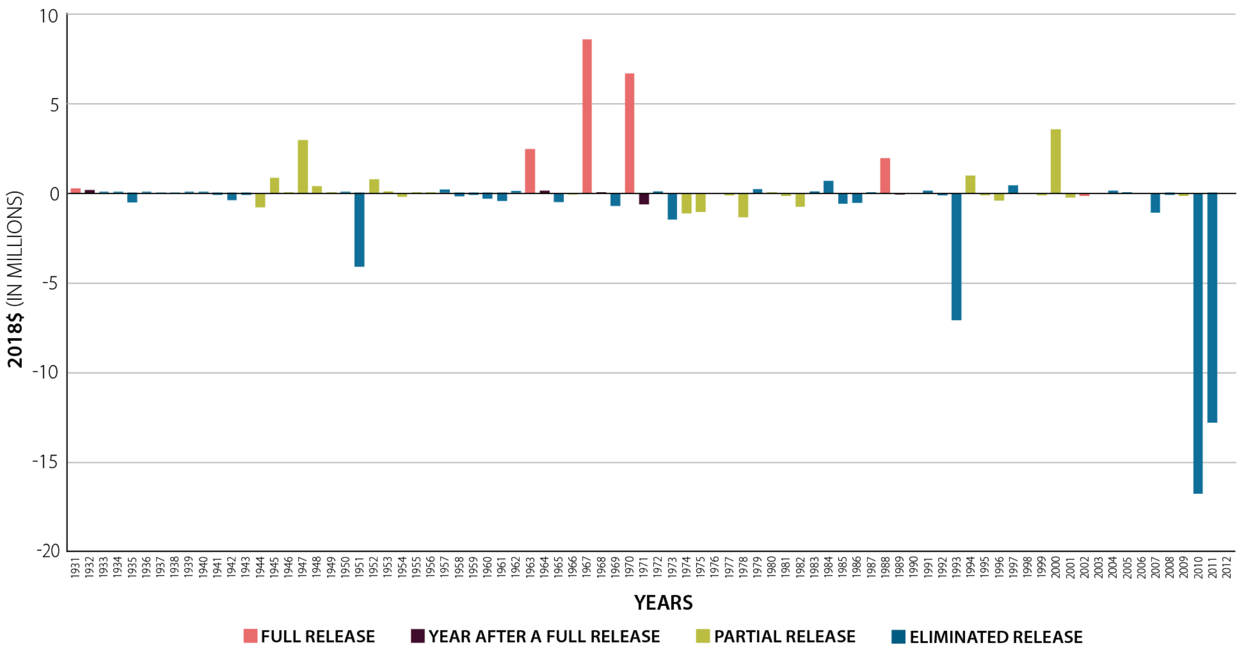

Figure 23. Alternative 6 Annual Flood Damage Difference from Alternative 1 in the Lower River by Release Type

4.0 Regional Economic Development Evaluation Results

The RED analysis focused on whether changes in flood risk management impacts due to the MRRMP-EIS alternatives would have a measurable impact on local economies. The results are summarized below.

4.1 Summary of Regional Economic Development Results

A summary of the RED effects associated with agricultural damages for each alternative is provided in Tables 12, 13, and 14 for employment, labor income, and sales, respectively. On average, there is very little change in RED effects from agricultural damages relative to Alternative 1. The Gavins Point Dam to Rulo and Kansas City reaches on average would experience very small changes (less than 2 jobs) in RED effects under Alternatives 2 and 4 compared to Alternative 1. All other reaches and action alternatives would experience a change of one job or less compared to Alternative 1.

Table 12. Employment Regional Economic Development Effects Associated with Agricultural Damage for All MRRMP-EIS Alternatives

River Reach	Alternatives					
	1	2	3	4	5	6
Average Annual Direct, Indirect, and Induced Jobs						
Fort Randall Dam to Gavins Point Dam	0.5	0.5	0.5	0.5	0.8	0.5
Gavins Point Dam to Rulo	40.1	38.9	40.5	39.5	40.3	41.3
St. Joseph Reach	7.7	7.3	7.9	7.7	7.9	7.8
Kansas City Reach	34.4	32.8	34.1	34.0	34.1	34.1
Boonville Reach	11.9	11.9	11.9	12.0	11.9	12.1
Hermann Reach	20.1	19.8	19.5	19.6	19.5	19.6
Change in Average Annual Direct, Indirect, and Induced Jobs						
Fort Randall Dam to Gavins Point Dam	0.0	0.1	0.0	0.0	-0.2	-0.0
Gavins Point Dam to Rulo	0.0	1.2	-0.4	0.5	-0.2	-1.2
St. Joseph Reach	0.0	0.3	-0.2	0.0	-0.2	-0.1
Kansas City Reach	0.0	1.6	0.3	0.4	0.3	0.2
Boonville Reach	0.0	0.1	0.0	0.0	0.0	-0.1
Hermann Reach	0.0	0.3	0.5	0.4	0.6	0.5
Average of 8 Worst Years Relative to Alternative 1 -- Direct, Indirect, and Induced Jobs						
Fort Randall Dam to Gavins Point Dam	0.0	-0.1	-0.1	-0.1	-2.1	-0.3
Gavins Point to Rulo	0.0	-12.7	-2.1	-2.2	-7.0	-13.1
St. Joseph Reach	0.0	-0.5	-0.9	-0.7	-1.1	-1.2
Kansas City Reach	0.0	-2.7	-0.4	-1.4	-1.5	-2.9
Boonville Reach	0.0	-2.8	-0.4	-0.7	-0.3	-1.8
Hermann Reach	0.0	-3.6	0.0	-1.2	-0.1	-0.5
Average of 8 Best Years Relative to Alternative 1 -- Direct, Indirect, and Induced Jobs						
Fort Randall Dam to Gavins Point Dam	0.0	0.7	0.1	0.3	0.1	0.4
Gavins Point Dam to Rulo	0.0	13.6	0.4	9.1	8.9	2.8
St. Joseph Reach	0.0	2.1	0.1	2.0	0.6	1.5
Kansas City Reach	0.0	6.7	1.6	2.8	2.4	2.4
Boonville Reach	0.0	2.1	0.3	0.5	0.4	0.4
Hermann Reach	0.0	3.4	3.0	3.3	3.1	2.8

Note: Negative values indicate adverse impact to RED effects compared to Alternative 1, while positive values indicate beneficial impacts to RED effects compared to Alternative 1.

Table 13. Labor Income Regional Economic Development Effects Associated with Agricultural Damage for All MRRMP-EIS Alternatives

River Reach	Alternatives 1	2	3	4	5	6
Average Annual Direct, Indirect, and Induced Labor Income						
Fort Randall Dam to Gavins Point Dam	$46,020	$38,280	$46,493	$43,572	$63,801	$45,763
Gavins Point Dam to Rulo	$2,638,284	$2,561,552	$2,667,408	$2,602,313	$2,649,640	$2,719,262
St. Joseph Reach	$525,302	$501,606	$539,812	$524,001	$537,129	$531,587
Kansas City Reach	$1,463,262	$1,396,617	$1,450,438	$1,447,035	$1,450,656	$1,453,826
Boonville Reach	$507,616	$504,659	$508,554	$509,169	$507,437	$513,990
Hermann Reach	$854,653	$843,491	$831,417	$835,984	$830,128	$834,697
Change in Average Annual Direct, Indirect, and Induced Labor Income						
Fort Randall Dam to Gavins Point Dam	$0	$7,740	-$473	$2,448	-$17,781	$257
Gavins Point Dam to Rulo	$0	$76,732	-$29,124	$35,971	-$11,356	-$80,978
St. Joseph Reach	$0	$23,696	-$14,509	$1,301	-$11,827	-$6,284
Kansas City Reach	$0	$66,645	$12,823	$16,227	$12,606	$9,435
Boonville Reach	$0	$2,957	-$938	-$1,553	$179	-$6,373
Hermann Reach	$0	$11,163	$23,236	$18,669	$24,526	$19,957
Average of 8 Worst Years Relative to Alternative 1 -- Direct, Indirect, and Induced Labor Income						
Fort Randall Dam to Gavins Point Dam	$0	-$6,916	-$7,093	-$8,883	-$181,165	-$23,443
Gavins Point Dam to Rulo	$0	-$839,008	-$136,942	-$147,794	-$458,788	-$862,537
St. Joseph Reach	$0	-$36,787	-$58,728	-$48,313	-$73,246	-$83,544
Kansas City Reach	$0	-$115,442	-$15,121	-$60,228	-$63,539	-$122,348
Boonville Reach	$0	-$118,595	-$18,479	-$31,345	-$13,316	-$77,871
Hermann Reach	$0	-$153,097	-$91	-$49,833	-$5,290	-$23,376
Average of 8 Best Years Relative to Alternative 1 -- Direct, Indirect, and Induced Labor Income						
Fort Randall Dam to Gavins Point Dam	$0	$57,553	$4,938	$29,387	$10,232	$30,568
Gavins Point Dam to Rulo	$0	$895,382	$24,134	$596,457	$587,072	$181,102
St. Joseph Reach	$0	$142,136	$7,082	$135,524	$43,087	$103,562
Kansas City Reach	$0	$286,939	$68,708	$120,020	$103,610	$102,541
Boonville Reach	$0	$87,669	$12,400	$21,446	$18,566	$16,103
Hermann Reach	$0	$144,367	$126,422	$139,060	$132,399	$120,342

Note: All values are at the FY 2018 price level. Negative values indicate adverse impact to RED effects compared to Alternative 1, while positive values indicate beneficial impacts to RED effects compared to Alternative 1.

Table 14. Sales Regional Economic Development Effects Associated with Agricultural Damage for All MRRMP-EIS Alternatives

River Reach	Alternatives					
	1	2	3	4	5	6
Average Annual Direct, Indirect, and Induced Sales						
Fort Randall Dam to Gavins Point Dam	$172,297	$143,318	$174,069	$163,131	$238,868	$171,335
Gavins Point Dam to Rulo	$11,462,775	$11,129,393	$11,589,312	$11,306,488	$11,512,116	$11,814,607
St. Joseph Reach	$2,129,665	$2,033,596	$2,188,489	$2,124,392	$2,177,614	$2,155,143
Kansas City Reach	$5,989,231	$5,716,449	$5,936,744	$5,922,814	$5,937,634	$5,950,612
Boonville Reach	$2,076,408	$2,064,314	$2,080,244	$2,082,761	$2,075,675	$2,102,479
Hermann Reach	$3,495,967	$3,450,305	$3,400,918	$3,419,601	$3,395,644	$3,414,334
Change in Average Annual Direct, Indirect, and Induced Sales						
Fort Randall Dam to Gavins Point Dam	$0	$28,979	-$1,773	$9,166	-$66,571	$962
Gavins Point Dam to Rulo	$0	$333,382	-$126,537	$156,287	-$49,341	-$351,832
St. Joseph Reach	$0	$96,069	-$58,824	$5,273	-$47,949	-$25,478
Kansas City Reach	$0	$272,782	$52,487	$66,418	$51,597	$38,619
Boonville Reach	$0	$12,094	-$3,837	-$6,353	$732	-$26,071
Hermann Reach	$0	$45,661	$95,048	$76,366	$100,323	$81,633
Average of 8 Worst Years Relative to Alternative 1 -- Direct, Indirect, and Induced Sales						
Fort Randall Dam to Gavins Point Dam	$0	-$25,895	-$26,557	-$33,257	-$678,275	-$87,768
Gavins Point Dam to Rulo	$0	-$3,645,310	-$594,984	-$642,134	-$1,993,336	-$3,747,536
St. Joseph Reach	$0	-$149,140	-$238,092	-$195,867	-$296,951	-$338,703
Kansas City Reach	$0	-$472,513	-$61,893	-$246,517	-$260,070	-$500,778
Boonville Reach	$0	-$485,114	-$75,590	-$128,218	-$54,470	-$318,533
Hermann Reach	$0	-$626,246	-$371	-$203,842	-$21,638	-$95,621
Average of 8 Best Years Relative to Alternative 1 -- Direct, Indirect, and Induced Sales						
Fort Randall Dam to Gavins Point Dam	$0	$215,475	$18,489	$110,024	$38,309	$114,444
Gavins Point Dam to Rulo	$0	$3,890,244	$104,855	$2,591,476	$2,550,701	$786,851
St. Joseph Reach	$0	$576,245	$28,711	$549,438	$174,682	$419,857
Kansas City Reach	$0	$1,174,459	$281,226	$491,248	$424,081	$419,709
Boonville Reach	$0	$358,612	$50,722	$87,724	$75,944	$65,871
Hermann Reach	$0	$590,533	$517,131	$568,827	$541,581	$492,262

Note: All values are at the FY 2018 price level. Negative values indicate adverse impact to RED effects compared to Alternative 1, while positive values indicate beneficial impacts to RED effects compared to Alternative 1.

Table 15 summarizes the change in average annual structural damages by county for the action alternatives compared to Alternative 1. The largest increases in structural damages relative to Alternative 1 occur in Carroll and St. Louis counties in Missouri under Alternative 2; in Knox County, Nebraska under Alternatives 3, 4, and 6; and in Union County South Dakota under Alternative 4. The largest decreases in structural damages occur in Holt county in Missouri under Alternatives 2, 4, and 6 and Osage county in Missouri under Alternatives 2, 3, 5 and 6; in Cass County, Nebraska under Alternative 2; in Union County, South Dakota under Alternatives 2 and 5; and in Burleigh County under Alternatives 4 and 5.

Table 15. Change in Average Annual Structural Damages Relative to Alternative 1 by County

	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Montana					
McCone	-$21	$0	-$7	-$7	$0
Richland	-$79	-$1	-$12	-$12	-$1
Roosevelt	-$509	$67	-$266	-$333	-$1
Valley	-$15	$0	-$3	-$3	$0
North Dakota					
Burleigh	-$34,161	-$29	-$130,149	-$74,670	-$20,761
McKenzie	$117	$15	$10	-$77	-$9
McLean	-$946	$0	-$949	-$13	-$285
Mercer	-$903	$31	-$289	-$254	$89
Morton	-$2,702	-$21	-$35,001	-$15,387	-$4,805
Oliver	-$78	$0	-$87	-$2	-$31
Williams	$306	$83	$80	-$220	-$56
South Dakota					
Charles Mix	-$68	$190	$262	-$443	$345
Clay	-$110	-$38	-$6	-$47	-$47
Union	-$197,243	-$26,679	$10,540	-$81,534	-$40,932
Yankton	-$63	-$38	-$6	-$31	-$31
Nebraska					
Boyd	-$3,770	$2,659	$3,679	-$5,666	$4,776
Burt	-$8,488	-$1,360	$101	-$3,587	-$1,948
Cass	-$141,351	-$1,368	-$11,626	-$7,579	-$7,480
Cedar	-$26	-$9	-$1	-$10	-$10
Dakota	-$27,050	-$873	$1,787	-$5,641	-$2,050
Dixon	-$3,348	-$201	$665	-$765	-$619
Douglas	-$7,702	-$1,746	-$994	-$4,089	-$638
Knox	-$8,857	$6,833	$10,211	-$13,739	$13,174
Nemaha	-$240	$35	$35	$36	$35
Otoe	-$866	$93	-$1,153	$18	-$308
Richardson	-$1,625	$931	$140	$761	$349
Sarpy	-$1,039	-$113	-$139	-$327	-$261

	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Thurston	-$392	-$60	-$11	-$151	-$84
Washington	-$38,298	-$4,969	-$1,216	-$12,115	-$6,448
Iowa					
Fremont	$818	-$8	-$162	-$230	$300
Harrison	-$75,400	-$9,536	-$598	-$27,515	-$12,680
Monona	-$9,899	$124	$1,250	-$1,708	-$306
Pottawattamie	-$66,036	-$8,521	-$9,520	-$18,929	-$6,934
Woodbury	-$97,941	-$2,216	$5,760	-$15,131	-$5,529
Kansas					
Atchison	$29	-$35	-$82	-$47	-$96
Doniphan	-$2,079	$184	-$161	$46	-$225
Leavenworth	-$275	$658	-$539	-$1,238	$1,454
Wyandotte	$99	$201	$195	$192	$198
Missouri					
Andrew	-$19,605	-$1,659	-$5,334	-$2,634	-$5,242
Atchison	-$50,530	$1,372	$799	$1,217	$976
Boone	-$15,090	-$2,684	-$3,158	-$3,104	-$82
Buchanan	-$86,979	-$670	-$37,983	-$6,372	-$35,115
Callaway	-$17,241	-$20,298	-$18,648	-$20,624	-$17,879
Carroll	$20,575	-$12,195	-$12,222	-$12,274	-$12,208
Chariton	-$29,821	-$3,101	-$3,469	-$3,687	-$1,390
Clay	-$767	-$3,894	-$3,905	-$3,913	-$3,900
Cole	-$15,095	-$9,521	-$9,538	-$9,533	-$9,446
Cooper	-$2,491	$359	$356	$355	$359
Franklin	-$18,586	-$19,021	-$18,823	-$19,137	-$18,927
Gasconade	$4,200	-$8,266	-$2,984	-$8,655	-$6,169
Holt	-$77,455	-$3,745	-$118,052	-$6,901	-$113,429
Howard	-$7,406	$3,081	$2,943	$3,002	$3,539
Jackson	-$8,508	-$19,471	-$19,023	-$22,465	-$15,472
Lafayette	-$1,726	-$1,395	-$1,389	-$1,546	-$1,311
Moniteau	-$6,911	-$561	-$590	-$576	-$425
Montgomery	$5,801	-$3,126	-$3,135	-$3,142	-$3,088
Osage	-$55,634	-$73,117	-$12,577	-$78,373	-$58,234
Platte	-$22,850	$9,307	-$24,995	$5,066	-$7,583
Ray	-$12,758	-$11,564	-$11,567	-$11,619	-$11,518
St. Charles	$3,816	-$8,840	-$864	-$10,854	-$6,239
St. Louis	$26,592	$2,459	$4,160	$2,319	$3,056
Saline	-$3,902	$856	$856	$854	$856
Warren	-$4,465	-$6,183	-$3,089	-$6,345	-$4,787

Note: All values are at the FY 2018 price level.

4.2 Alternative 1 – No Action (Current System Operation and Current MRRP Implementation)

The RED analysis for flood risk management focuses on the locality of flood damages and the types of property being damaged. The changes to the local economy can be measured in terms of economic output, income, and employment. Table 16 summarizes the economic impacts for each of the regions associated with changes in agricultural damages from flooding. Under Alternative 1, agricultural damages would result in an annual average reduction of between 1 and 40 jobs, and between $46,000 and $2.6 million in labor income depending on the region impacted. On average, three regions tend to experience the greatest RED impacts associated with agricultural damages under Alternative 1: Gavins Point Dam to Rulo, Kansas City Reach, and Hermann Reach.

Relatively high water or flooding years, such as those that occurred with conditions similar to 1951, 1984, 1986, 1993, and 2011, would account for the largest economic impacts from agricultural damages. These flooding effects are a result of the natural hydrologic cycles of precipitation and snow pack and not from the management actions under Alternative 1. In years when flooding would occur, there would be large adverse impacts to regional economic conditions from agricultural damages and loss in the market value of crop production in most of the regions.

Under Alternative 1, the structural damages associated with flooding would have the largest impacts to the following counties with over $1 million in average annual damages:

- Burleigh County, North Dakota (Garrison Dam to Oahe Dam)
- Holt County, Missouri (Gavins Point Dam to Rulo)
- Osage County, Missouri (Hermann Reach)

Residences, businesses, farming structures, and transportation facilities would be most affected in the above-mentioned counties, with large RED effects occurring during flooding events.

4.3 Alternative 2 – USFWS 2003 Biological Opinion Projected Actions

Under Alternative 2, agricultural flood damages would result in an increase of less than 2 average annual jobs across all locations, while average labor income would range from an increase of $3,000 in the Boonville reach to $76,000 in the Gavins Point Dam to Rulo reach relative to Alternative 1. Under the eight worst years relative to Alternative 1, Gavins Point Dam to Rulo tends to experience the largest impacts, with on average 13 fewer jobs and $839,000 less in labor income compared to Alternative 1. The impacts during the eight worst years relative to Alternative 1 would result in negligible to small adverse impacts to regional economic conditions and would be more than offset with years that would have increases in regional economic benefits from decreased agricultural damages. Table 17 summarizes the differences in economic impacts for each of the flood risk management regions under Alternative 2 relative to Alternative 1.

Table 16. Regional Economic Development Effects Associated with Agricultural Damage – Alternative 1

River Reach	Jobs			Labor Income			Sales		
	Average Annual	Max Ag Damage Year	Min Ag Damage Year	Average Annual	Max Ag Damage Year	Min Ag Damage Year	Average Annual	Max Ag Damage Year	Min Ag Damage Year
Missouri River	**-115**	**-1,585**	**-1**	**-$6,035,000**	**-$79,176,000**	**-$82,000**	**-$25,326,000**	**-$330,732,000**	**-$351,000**
Upper River	**-1**	**-5**	**-**	**-$46,000**	**-$421,000**	**-$7,000**	**-$172,000**	**-$1,578,000**	**-$28,000**
Fort Randall Dam to Gavins Point Dam	-1	-5	-	-$46,000	-$421,000	-$7,000	-$172,000	-$1,578,000	-$28,000
Lower River	**-114**	**-1,580**	**-1**	**-$5,989,000**	**-$78,755,000**	**-$75,000**	**-$25,154,000**	**-$329,154,000**	**-$323,000**
Gavins Point Dam to Rulo	-40	-424	-1	-$2,638,000	-$27,917,000	-$67,000	-$11,463,000	-$121,293,000	-$293,000
St. Joseph Reach	-8	-64	-	-$525,000	-$4,360,000	-$1,000	-$2,130,000	-$17,677,000	-$3,000
Kansas City Reach	-34	-568	-	-$1,463,000	-$24,201,000	-$3,000	-$5,989,000	-$99,058,000	-$13,000
Boonville Reach	-12	-298	-	-$508,000	-$12,707,000	-$1,000	-$2,076,000	-$51,978,000	-$4,000
Hermann Reach	-20	-225	-	-$855,000	-$9,570,000	-$3,000	-$3,496,000	-$39,148,000	-$10,000

Note: All values are at the FY 2018 price level. Negative values indicate adverse impact to RED effects.

Table 17. Regional Economic Development Impacts Associated with Agricultural Damage under Alternative 2 Compared to Alternative 1

River Reach	Change in Jobs			Change in Labor Income			Change in Sales		
	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years
Missouri River	**4**	**-22**	**29**	**$188,000**	**-$1,270,000**	**$1,614,000**	**$790,000**	**-$5,404,000**	**$6,805,000**
Upper River	**0**	**0**	**1**	**$8,000**	**-$7,000**	**$58,000**	**$29,000**	**-$26,000**	**$215,000**
Fort Randall Dam to Gavins Point Dam	0	0	1	$8,000	-$7,000	$58,000	$29,000	-$26,000	$215,000
Lower River	**3**	**-22**	**28**	**$180,000**	**-$1,263,000**	**$1,556,000**	**$761,000**	**-$5,378,000**	**$6,590,000**
Gavins Point Dam to Rulo	1	-13	14	$76,000	-$839,000	$895,000	$334,000	-$3,645,000	$3,890,000
St. Joseph Reach	0	-1	2	$23,000	-$37,000	$142,000	$96,000	-$149,000	$576,000
Kansas City Reach	2	-3	7	$66,000	-$115,000	$287,000	$273,000	-$473,**000**	$1,174,000
Boonville Reach	0	-3	2	$3,000	-$119,000	$88,000	$12,000	-$485,000	$359,000
Hermann Reach	0	-4	3	$12,000	-$153,000	$144,000	$46,000	-$626,000	$591,000

Note: All values are at the FY 2018 price level. Negative values indicate adverse impact to RED effects compared to Alternative 1, while positive values indicate beneficial impacts to RED effects compared to Alternative 1.

The counties that would have the largest increase in structural damages on average under Alternative 2 compared to Alternative 1 are the following:

- Carroll County, Missouri (Kansas City reach) (increase in structural damages of $20,575)
- St. Louis County, Missouri (Hermann reach) (increase in structural damages of $26,592)
- Montgomery County, Missouri (Hermann reach) (increase in structural damages of $5,801)

Residences, businesses, farming structures, and transportation facilities would be most affected in the above mentioned counties, with potentially small RED effects occurring during flooding events relative to Alternative 1.

The counties that would have the largest average decrease in structural damages under Alternative 2 compared to Alternative 1 are the following:

- Union County, South Dakota (Gavins Point Dam to Rulo reach) (decrease in structural damages of $197,243)
- Cass County, Nebraska (Gavins Point Dam to Rulo reach) (decrease in structural damages of $141,351)
- Woodbury County, Iowa (Gavins Point Dam to Rulo reach) (decrease in structural damages of $97,941)

4.4 Alternative 3 – Mechanical Construction Only

Under Alternative 3, agricultural damages would result in a change of less than one average annual job in the Hermann Reach, while average labor income would range from a decrease of $24,000 in the Hermann Reach to an increase of $29,000 in the Gavins Pont Dam to Rulo reach relative to Alternative 1. Under the eight worst years relative to Alternative 1, two regions tend to experience the largest impacts: St. Joseph reach and Boonville reach. On average, in these regions, there would be a reduction of $18,000 to $59,000 in labor income compared to Alternative 1. The impacts during the eight worst years relative to Alternative 1 would result in negligible adverse impacts to regional economic conditions. Table 18 summarizes the average annual impacts from agricultural damages and the differences in economic impacts for each of the flood risk management regions under Alternative 3 relative to Alternative 1.

The counties that would have the largest increase in average annual structural damages under Alternative 3 compared to Alternative 1, are the following:

- Knox County, Nebraska (Randall Dam to Gavins reach) (increase in structural damages of $6,833)
- Howard County, Missouri (Boonville reach) (increase in structural damages of $3,081)
- Boyd County, Nebraska (Randall to Gavins reach) (increase in structural damages of $2,659)

Residences, businesses, farming structures, and transportation facilities would be most affected in the above-mentioned counties, with potentially small RED effects occurring during flooding events relative to Alternative 1.

Table 18. Regional Economic Development Impacts Associated with Agricultural Damage under Alternative 3 Compared to Alternative 1

River Reach	Change in Jobs			Change in Labor Income			Change in Sales		
	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years
All Regions	**0**	**-4**	**5**	**-$8,000**	**-$236,000**	**$243,000**	**-$43,000**	**-$998,000**	**$1,001,000**
Upper River	**0**	**0**	**0**	**$0**	**-$7,000**	**$5,000**	**-$2,000**	**-$27,000**	**$18,000**
Fort Randall Dam to Gavins Point Dam	0	0	0	$0	-$7,000	$5,000	-$2,000	-$27,000	$18,000
Lower River	**0**	**-4**	**5**	**-$8,000**	**-$229,000**	**$238,000**	**-$41,000**	**-$971,000**	**$983,000**
Gavins Point Dam to Rulo	0	-2	0	-$29,000	$137,000	$24,000	-$126,000	-$595,000	$105,000
St. Joseph Reach	0	-1	0	-$15,000	-$59,000	$7,000	-$58,000	-$238,000	$29,000
Kansas City Reach	0	0	2	$13,000	-$15,000	$69,000	$52,000	-$62,000	$281,000
Boonville Reach	0	0	0	-$1,000	-$18,000	$12,000	-$4,000	-$76,000	$51,000
Hermann Reach	1	0	3	$24,000	$0	$126,000	$95,000	$0	$517,000

Note: All values are at the FY 2018 price level. Negative values indicate adverse impact to RED effects compared to Alternative 1, while positive values indicate beneficial impacts to RED effects compared to Alternative 1.

The counties that would have the largest decrease in average annual structural damages under Alternative 3 compared to Alternative 1, are the following:

- Osage County, Missouri (Hermann reach) (decrease in structural damages of $73,117)
- Union County, South Dakota (Gavins Point Dam to Rulo reach) (decrease in structural damages of $26,675)
- Callaway County, Missouri (Boonville reach) (decrease in structural damages of $20,298)

4.5 Alternative 4 – Spring ESH Creating Release

Under Alternative 4, agricultural damages from flooding would result in a change of one average annual job across the upper and lower river, while average labor income would range from an increase of $36,000 in the Gavins Point Dam to Rulo Reach to a decrease of $1,000 in the Boonville Reach relative to Alternative 1. Under the eight worst years relative to Alternative 1, Gavins Point Dam to Rulo Reach would experience the largest adverse impacts, with two fewer jobs and a reduction in $148,000 in labor income compared to Alternative 1 on average in these years. The impacts during the eight worst years relative to Alternative 1 would result in adverse impacts to regional economic conditions that would be negligible even in small rural farming economies. Table 19 summarizes the average annual impacts from agricultural damages and differences in economic impacts for each of the reaches under Alternative 4 relative to Alternative 1.

The counties that would have the largest increase in average annual structural damages under Alternative 4 compared to Alternative 1 are the following:

- Union County, South Dakota (Gavins Point Dam to Rulo reach) (increase in structural damages of $10,540)
- Knox County, Nebraska (Randall Dam to Gavins reach) (increase in structural damages of $10,211)
- Woodbury County, Iowa (Gavins Point Dam to Rulo reach) (increase in structural damages of $5,760)

Residences, businesses, farming structures, and transportation facilities would be most affected in the above mentioned counties, with potentially small RED effects occurring during flooding events relative to Alternative 1.

The counties that would have the largest decrease in structural damages under Alternative 4 compared to Alternative 1, on average per county, are the following

- Burleigh County, North Dakota (Garrison to Oahe reach) (decrease in structural damages of $130,149)
- Holt County, Missouri (Gavins Point Dam to Rulo and St. Joseph reaches) (decrease in structural damages of $118,052)
- Morton County, North Dakota (Garrison to Oahe reach) (decrease in structural damages of $35,001)

Table 19. Regional Economic Development Impacts Associated with Agricultural Damage under Alternative 4 Compared to Alternative 1

River Reach	Change in Jobs			Change in Labor Income			Change in Sales		
	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years
Missouri River	**1**	**-6**	**18**	**$73,000**	**-$346,000**	**$1,041,000**	**$307,000**	**-$1,450,000**	**$4,398,000**
Upper River	**0**	**0**	**0**	**$2,000**	**-$9,000**	**$29,000**	**$9,000**	**-$33,000**	**$110,000**
Fort Randall Dam to Gavins Point Dam	0	0	0	$2,000	-$9,000	$29,000	$9,000	-$33,000	$110,000
Lower River	**1**	**-6**	**18**	**$71,000**	**-$337,000**	**$1,012,000**	**$298,000**	**-$1,417,000**	**$4,288,000**
Gavins Point Dam to Rulo	1	-2	9	$36,000	-$148,000	$596,000	$157,000	-$642,000	$2,591,000
St. Joseph Reach	0	-1	2	$1,000	-$48,000	$136,000	$6,000	-$196,000	$549,000
Kansas City Reach	0	-1	3	$16,000	-$60,000	$120,000	$66,000	-$247,000	$491,000
Boonville Reach	0	-1	1	-$1,000	-$31,000	$21,000	-$7,000	-$128,000	$88,000
Hermann Reach	0	-1	3	$19,000	-$50,000	$139,000	$76,000	-$204,000	$569,000

Note: All values are at the FY 2018 price level. Negative values indicate adverse impact to RED effects compared to Alternative 1, while positive values indicate beneficial impacts to RED effects compared to Alternative 1.

4.6 Alternative 5 – Fall ESH Creating Release

Under Alternative 5, a decrease in agricultural damages would result in an increase of one average annual job in the Hermann Reach, while average labor income would range from an increase of $25,000 in the Hermann Reach to a reduction of $18,000 in the Fort Randall Dam to Gavins Point Dam Reach relative to Alternative 1. Under the eight worst years relative to Alternative 1, the Gavins Point Dam to Rulo Reach would experience that largest adverse impacts, with seven fewer jobs and a reduction of $459,000 in labor income compared to Alternative 1. The impacts during the eight worst years relative to Alternative 1 would result in adverse impacts to regional economic conditions that would be negligible even in small rural farming economies. Table 20 summarizes the average annual impacts from agricultural damages and differences in economic impacts for each of the flood risk management regions under Alternative 5 relative to Alternative 1.

The counties that would have the largest increase in annual average structural damages under Alternative 5 compared to Alternative 1 are the following:

- St. Louis County, Missouri (Hermann reach) (increase in structural damages of $2,319)
- Howard County, Missouri (Boonville reach) (increase in structural damages of $3,002)
- Atchison County, Missouri (Gavins Point Dam to Rulo reach) (increase in structural damages of $1,217)

Residences, businesses, farming structures, and transportation facilities would be most affected in the above mentioned counties, with potentially small RED effects occurring during flooding events relative to Alternative 1.

The counties that would have the largest decrease in structural damages under Alternative 5 compared to Alternative 1, on average per county, are the following

- Union County, South Dakota (Gavins Point Dam to Rulo reach) (decrease in structural damages of $81,534)
- Burleigh County, North Dakota (Garrison to Oahe reach) (decrease in structural damages of $74,670)
- Osage County, Missouri (Hermann reach) (decrease in structural damages of $73,373)

4.7 Alternative 6 – Pallid Sturgeon Spawning Cue

Under Alternative 6, agricultural damages from flooding would result in a decrease of one average annual jobs in the lower river, while average labor income would range from an increase of $20,000 in the Hermann Reach to a decrease of $81,000 in the Gavins Point Dam to Rulo Reach relative to Alternative 1. Under the eight worst years relative to Alternative 1, Gavins Point Dam to Rulo would experience 13 fewer jobs and $863,000 less in labor income compared to Alternative 1. Table 21 summarizes the average annual impacts from agricultural damages and differences in economic impacts for each of the regions under Alternative 6 relative to Alternative 1.

Table 20. Regional Economic Development Impacts Associated with Agricultural Damage under Alternative 5 Compared to Alternative 1

River Reach	Change in Jobs			Change in Labor Income			Change in Sales		
	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years
Missouri River	**1**	**-12**	**16**	**-$4,000**	**-$795,000**	**$895,000**	**-$13,000**	**-$3,304,000**	**$3,806,000**
Upper River	**0**	**-2**	**0**	**-$18,000**	**-$181,000**	**$10,000**	**-$67,000**	**-$678,000**	**$38,000**
Fort Randall Dam to Gavins Point Dam	0	-2	0	-$18,000	-$181,000	$10,000	-$67,000	-$678,000	$38,000
Lower River	**1**	**-10**	**16**	**$14,000**	**-$614,000**	**$885,000**	**$54,000**	**-$2,626,000**	**$3,768,000**
Gavins Point Dam to Rulo	0	-7	9	-$12,000	-$459,000	$587,000	-$49,000	-$1,993,000	$2,551,000
St. Joseph Reach	0	-1	1	-$12,000	-$73,000	$43,000	-$48,000	-$297,000	$175,000
Kansas City Reach	0	-1	2	$12,000	-$64,000	$104,000	$51,000	-$260,000	$424,000
Boonville Reach	0	0	0	$1,000	-$13,000	$19,000	$0	-$54,000	$76,000
Hermann Reach	1	0	3	$25,000	-$5,000	$132,000	$100,000	-$22,000	$542,000

Note: All values are at the FY 2018 price level. Negative values indicate adverse impact to RED effects compared to Alternative 1, while positive values indicate beneficial impacts to RED effects compared to Alternative 1.

Table 21. Regional Economic Development Impacts Associated with Agricultural Damage under Alternative 6 Compared to Alternative 1

River Reach	Change in Jobs			Change in Labor Income			Change in Sales		
	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years	Average Annual	8 Worst Years	8 Best Years
Missouri River	**-1**	**-20**	**10**	**-$65,000**	**-$1,193,000**	**$555,000**	**-$282,000**	**-$5,091,000**	**$2,299,000**
Upper River	**0**	**0**	**0**	**$0**	**-$23,000**	**$31,000**	**$1,000**	**-$88,000**	**$114,000**
Fort Randall Dam to Gavins Point Dam	0	0	0	$0	-$23,000	$31,000	$1,000	-$88,000	$114,000
Lower River	**-1**	**-20**	**10**	**-$65,000**	**-$1,170,000**	**$524,000**	**-$283,000**	**-$5,003,000**	**$2,185,000**
Gavins Point Dam to Rulo	-1	-13	3	-$81,000	-$863,000	$181,000	-$352,000	-$3,748,000	$787,000
St. Joseph Reach	0	-1	2	-$7,000	-$84,000	$104,000	-$25,000	-$339,000	$420,000
Kansas City Reach	0	-3	2	$9,000	-$122,000	$103,000	$38,000	-$501,000	$420,000
Boonville Reach	0	-2	0	-$6,000	-$78,000	$16,000	-$26,000	-$319,000	$66,000
Hermann Reach	0	-1	3	$20,000	-$23,000	$120,000	$82,000	-$96,000	$492,000

Note: All values are at the FY 2018 price level. Negative values indicate adverse impact to RED effects compared to Alternative 1, while positive values indicate beneficial impacts to RED effects compared to Alternative 1.

The counties that would have the largest increase in structural damages under Alternative 6 compared to Alternative 1, on average per county, are the following:

- Knox County, Nebraska (Randall Dam to Gavins reach) (increase in structural damages of $13,174)
- Boyd County, Nebraska (Randall to Gavins reach) (increase in structural damages of $4,776)
- Howard County, Missouri (Boonville reach) (increase in structural damages of $3,539)

Residences, businesses, farming structures, and transportation facilities would be most affected in the above mentioned counties, with potentially small RED effects occurring during flooding events relative to Alternative 1.

The counties that would have the largest decrease in average annual structural damages under Alternative 6 compared to Alternative 1 are the following

- Holt County, Missouri (Gavins Point Dam to Rulo and St. Joseph reaches) (decrease in structural damages of $113,429)
- Osage County, Missouri (Hermann reach) (decrease in structural damages of $58,234)
- Union County, South Dakota (Gavins Point Dam to Rulo reach) (decrease in structural damages of $40,932)

5.0 Other Social Effects Results

The OSE analysis for flood risk management relied on the results of the FIA modeling to determine the scale of impacts that could occur to individual and community well-being, economic vitality, and critical infrastructure. In addition to looking at the PAR and critical infrastructure facilities that could be inundated, an environmental justice assessment was conducted to determine whether minority and low-income populations (i.e., “populations of concern”) would be affected by a proposed federal action and whether they would experience disproportionate adverse impacts from the proposed action. Areas identified in the HEC-FIA model showing substantial flood damage or persons at risk, were analyzed for changes in incidences of flooding impacts on disproportionately minority or poor communities.

5.1 Summary of Other Social Effects Impacts

A summary of the PAR, critical infrastructure facilities impacted, and impacts to environmental justice populations of concern for each alternative are summarized in Table 22.

Table 22. Environmental Consequences Relative to Flood Risk Management: Other Social Effects

Alternative	OSE Impacts
Alternative 1	Average Annual PAR: 592, Maximum PAR: 14,936. Critical infrastructure at risk: 830.
Alternative 2	Average Annual PAR: 566, Maximum PAR: 13,704. Critical infrastructure at risk: 821. Census blocks with populations of concern showing adverse impacts relative to Alternative 1: 3.
Alternative 3	Average Annual PAR: 588, Maximum PAR: 14,886. Critical infrastructure at risk: 830. Census blocks with populations of concern showing adverse impacts relative to Alternative: 1.
Alternative 4	Average Annual PAR: 587, Maximum PAR: 14,058. Critical infrastructure at risk: 828. Census blocks with populations of concern showing adverse impacts relative to Alternative: 3.
Alternative 5	Average Annual PAR: 578, Maximum PAR: 14,321. Critical infrastructure at risk: 830. Census blocks with populations of concern showing adverse impacts relative to Alternative: 1.
Alternative 6	Average Annual PAR: 587, Maximum PAR: 14,726. Critical infrastructure at risk: 830. Census blocks with populations of concern showing adverse impacts relative to Alternative: 2.

5.2 Alternative 1 – No Action (Current System Operation and Current MRRP Implementation)

Beyond determining economic damages, the population impacted can be computed quantitatively in HEC-FIA. Table 23 shows the PAR under Alternative 1. The largest modeled flood events indicated that more than 14,900 people could be affected by Missouri River flooding. For the upper river the largest modeled flood event was 2011, whereas in the lower river the largest modeled flood event was 1993.

Table 23. Population at Risk under Alternative 1

River Reach	Largest Flood Event in Period of Record	Average Annual
Missouri River	**14,936**	**592**
Upper River	**9,412**	**212**
Fort Peck Dam to Garrison Dam	81	2
Garrison Dam to Oahe Dam	9,258	207
Fort Randall Dam to Gavins Point Dam	73	3
Lower River	**5,646**	**385**
Gavins Point Dam to Rulo	4,896	217
St. Joseph Reach	958	46
Kansas City Reach	1,746	41
Boonville Reach	825	55
Hermann Reach	940	67

Six hundred census block groups intersect the Missouri River floodplain, of which 186 contain potential environmental justice populations of concern. The largest impacts to populations of concern under Alternative 1 would occur to poverty block groups in Carroll and Chariton counties in Missouri and minority race block groups in Platte and Cole counties in Missouri.

Another aspect of OSE is potential impacts to critical infrastructure under large flood events. Homeland Security Infrastructure Program Gold is a database of critical facilities that was imported into the HEC-FIA model. HEC-FIA then reports what facilities are impacted during individual events. The largest modeled lower and upper river flood events were selected for comparison across the MRRMP-EIS alternatives. As noted above, the largest modeled flood events are 2011 for the upper river and 1993 for the lower river. The quantity and type of facilities impacted for Alternative 1 is shown by upper and lower river in Table 24.

Table 24. Critical Infrastructure Impacted in Largest Flood Event in Period of Record under Alternative 1

Critical Infrastructure	Upper River	Lower River
Agricultural Facilities	3	4
Chemical Industries	4	11
Communication Towers	0	4
Educational Schools	2	0
Emergency – EMS	0	4
Emergency – Fire Stations	0	6
Emergency – National Shelters	2	2
Energy – Plants	0	5
Energy – Propane Locations	4	7
Energy – Substations	8	12
Law Enforcement	2	2
Mail - USPS	2	10
Manufacturing Plants	2	10
Public – Campgrounds	0	2
Public – Libraries	0	2
Public – Parks	0	26
Public – Worship	1	1
Transportation – Airports	0	20
Transportation – Bridges	21	528
Transportation – Ports	0	121
Wastewater Treatment Plants	0	2

5.3 Alternative 2 – USFWS 2003 Biological Opinion Projected Actions

For Alternative 2, the greatest changes PAR relative to Alternative 1 across the entire period of record would range from an 839 person decrease to a 174 person increase in the lower river. For the upper river, the population impacted differential relative to Alternative 1 would range from a 393 person decrease to a 271 person increase. Table 25 shows the PAR under Alternative 2.

Table 25. Population at Risk under Alternative 2

River Reach	Largest Flood Event in Period of Record	Average Annual	Largest Increase Relative to Alternative 1	Largest Decrease Relative to Alternative 1
Missouri River	**13,704**	**566**	**185**	**-1,232**
Upper River	**9,019**	**212**	**271**	**-393**
Fort Peck to Garrison	80	2	9	-6
Garrison to Oahe	8,866	207	271	-392
Fort Randall to Gavins Point	73	3	17	-9
Lower River	**5,077**	**355**	**174**	**-839**
Gavins Point to Rulo	4,205	198	146	-753
St. Joseph Reach	948	45	3	-47
Kansas City Reach	1,677	38	28	-131
Boonville Reach	797	52	16	-225
Hermann Reach	787	66	116	-258

In addition to PAR, impacts to census block groups with potential populations of concern were evaluated for Alternative 2. The census block groups 291892114011 (St. Louis County, MO) and 291833104002 (St. Charles County, MO) with minority race populations and census block 290339603004 (Chariton County, MO) with a high poverty population were identified as showing adverse average annual adverse impacts under Alternative 2 compared to Alternative 1. However, while in some years the modeled damages were large in nature, on average the impacts were small and deemed not disproportionate in relation to the general population.

Table 26 lists the type and quantity of critical infrastructure that were impacted under the largest modeled flood event for both the upper and lower river during the period of record for Alternative 2. While the impacts on average would be less, the table provides an indication of the potential infrastructure impacted under the worst-case scenario.

Table 26. Critical Infrastructure Impacted in Largest Flood Event in Period of Record under Alternative 2

Critical Infrastructure	Upper River	Change from Alternative 1	Lower River	Change from Alternative 1
Agricultural Facilities	3	0	4	0
Chemical Industries	4	0	11	0
Communication Towers	0	0	3	1
Educational Schools	2	0	0	0
Emergency – EMS	0	0	3	1
Emergency – Fire Stations	0	0	4	2
Emergency – National Shelters	2	0	2	0
Energy – Plants	0	0	5	0
Energy – Propane Locations	4	0	5	2
Energy – Substations	8	0	11	1
Law Enforcement	2	0	2	0

Critical Infrastructure	Upper River	Change from Alternative 1	Lower River	Change from Alternative 1
Mail – USPS	2	0	10	0
Manufacturing Plants	2	0	10	0
Public – Campgrounds	0	0	2	0
Public – Libraries	0	0	2	0
Public – Parks	0	0	26	0
Public – Worship	1	0	1	0
Transportation – Airports	0	0	20	0
Transportation – Bridges	21	0	526	2
Transportation – Ports	0	0	121	0
Wastewater Treatment Plants	0	0	2	0

5.4 Alternative 3 – Mechanical Construction Only

For Alternative 3 the greatest changes in PAR relative to Alternative 1 across the entire period of record would range from a 224 person decrease to a 41 person increase in the lower river. For the upper river, the changes in population impacted would range from a 3 person decrease to a 20 person increase. Table 27 shows the PAR under Alternative 3.

Table 27. Population at Risk under Alternative 3

River Reach	Largest Flood Event in Period of Record	Average Annual	Largest Increase Relative to Alternative 1	Largest Decrease Relative to Alternative 1
Missouri River	**14,886**	**588**	**41**	**-226**
Upper River	**9,412**	**212**	**20**	**-3**
Fort Peck to Garrison	81	2	6	0
Garrison to Oahe	9,258	207	20	-9
Fort Randall to Gavins Point	**73**	**3**	**3**	**-3**
Lower River	**5,564**	**377**	**41**	**-224**
Gavins Point to Rulo	4,821	217	46	-75
St. Joseph Reach	958	46	3	-5
Kansas City Reach	1,730	39	1	-43
Boonville Reach	817	49	2	-220
Hermann Reach	895	64	5	-118

In addition to PAR, impacts to census block groups with potential populations of concern were evaluated for Alternative 3. The census block group 291892114011 (St. Louis County, MO) was identified as showing adverse average annual adverse impacts under Alternative 3 compared to Alternative 1. However, while in some years the modeled damages were large in nature, on average the impacts were small and deemed not disproportionate in relation to the general population.

Table 28 lists the type and quantity of critical infrastructure that would be impacted during the largest modeled flood event in the period of record for both the lower and upper river under Alternative 3. While the impacts on average would be less, the table provides an indication of the infrastructure that would be impacted under the worst-case scenario.

Table 28. Critical Infrastructure Impacted in Largest Flood Event in Period of Record under Alternative 3

Critical Infrastructure	Upper River	Change from Alternative 1	Lower River	Change from Alternative 1
Agricultural Facilities	3	0	4	0
Chemical Industries	4	0	11	0
Communication Towers	0	0	4	0
Educational Schools	2	0	0	0
Emergency – EMS	0	0	4	0
Emergency – Fire Stations	0	0	6	0
Emergency – National Shelters	2	0	2	0
Energy – Plants	0	0	5	0
Energy – Propane Locations	4	0	7	0
Energy – Substations	8	0	11	0
Law Enforcement	2	0	2	0
Mail - USPS	2	0	9	1
Manufacturing Plants	2	0	10	0
Public – Campgrounds	0	0	2	0
Public – Libraries	0	0	2	0
Public – Parks	0	0	26	0
Public – Worship	1	0	1	0
Transportation – Airports	0	0	20	0
Transportation – Bridges	21	0	530	-2
Transportation – Ports	0	0	121	0
Wastewater Treatment Plants	0	0	2	0

5.5 Alternative 4 – Spring ESH Creating Release

For Alternative 4, the greatest changes in population impacted relative to Alternative 1 across the period of record would range from a 429 person decrease to a 177 person increase in the lower river. For the upper river, the range differential relative to Alternative 1 would be a 919 person decrease to a 754 person increase. Table 29 shows the PAR under Alternative 4.

In addition to PAR, impacts to census block groups with potential populations of concern were evaluated for Alternative 4. The census block groups 291892114011 (St. Louis County, MO), 291833104002 (St. Charles County, MO), and 291892109272 (St. Louis County, MO) with minority race populations were identified as showing adverse average annual adverse impacts under Alternative 4 compared to Alternative 1. However, while in some years the modeled damages were large in nature, on average the impacts were small and deemed not disproportionate in relation to the general population.

Table 29. Population at Risk under Alternative 4

River Reach	Largest Flood Event in Period of Record	Average Annual	Largest Increase Relative to Alternative 1	Largest Decrease Relative to Alternative 1
Missouri River	**14,058**	**587**	**788**	**-878**
Upper River	**8,493**	**212**	**754**	**-919**
Fort Peck to Garrison	81	2	1	0
Garrison to Oahe	8,339	207	754	-919
Fort Randall to Gavins Point	73	4	9	-3
Lower River	**5,679**	**375**	**177**	**-429**
Gavins Point to Rulo	4,934	217	166	-335
St. Joseph Reach	958	45	4	-162
Kansas City Reach	1,730	39	6	-45
Boonville Reach	817	49	7	-221
Hermann Reach	895	66	76	-118

Table 30 lists the type and quantity of critical infrastructure that would be impacted under the largest modeled flood event in the period of record for Alternative 4 for both the upper and lower river. While the impacts on average would be less, the table provides an indication of the potential infrastructure impacted under the worst-case scenario.

Table 30. Critical Infrastructure Impacted in the Largest Flood Event in Period of Record under Alternative 4

Critical Infrastructure	Upper River	Change from Alternative 1	Lower River	Change from Alternative 1
Agricultural Facilities	3	0	4	0
Chemical Industries	4	0	11	0
Communication Towers	0	0	4	0
Educational Schools	2	0	0	0
Emergency – EMS	0	0	4	0
Emergency – Fire Stations	0	0	6	0
Emergency – National Shelters	2	0	2	0
Energy – Plants	0	0	5	0
Energy – Propane Locations	4	0	7	0
Energy – Substations	8	0	11	1
Law Enforcement	0	2	2	0
Mail - USPS	2	0	9	1
Manufacturing Plants	2	0	10	0
Public – Campgrounds	0	0	2	0
Public – Libraries	0	0	2	0
Public – Parks	0	0	26	0

Critical Infrastructure	Upper River	Change from Alternative 1	Lower River	Change from Alternative 1
Public – Worship	1	0	1	0
Transportation – Airports	0	0	20	0
Transportation – Bridges	21	0	530	-2
Transportation – Ports	0	0	121	0
Wastewater Treatment Plants	0	0	2	0

5.6 Alternative 5 – Fall ESH Creating Release

For Alternative 5, the greatest changes in population impacted relative to Alternative 1 would range from a 239 person decrease to a 41 person increase in the lower river. For the upper river, the population impacted differential relative to Alternative 1 would range from a 403 person decrease to a 20 person increase. Table 31 shows the population at risk under Alternative 5.

Table 31. Population at Risk under Alternative 5

River Reach	Largest Flood Event in Period of Record	Average Annual	Largest Increase Relative to Alternative 1	Largest Decrease Relative to Alternative 1
Missouri River	**14,321**	**578**	**41**	**-615**
Upper River	**9,009**	**208**	**20**	**-403**
Fort Peck to Garrison	81	2	6	-1
Garrison to Oahe	8,855	202	20	-403
Fort Randall to Gavins Point	73	3	9	-3
Lower River	**5,407**	**373**	**41**	**-239**
Gavins Point to Rulo	4,674	213	46	-222
St. Joseph Reach	958	46	3	-11
Kansas City Reach	1,730	39	0	-45
Boonville Reach	817	49	2	-220
Hermann Reach	895	64	5	-118

In addition to PAR, impacts to census block groups with potential populations of concern were evaluated for Alternative 5. The census block group 291892114011 (St. Louis County, MO) was identified as showing adverse average annual adverse impacts under Alternative 5 compared to Alternative 1. However, while in some years the modeled damages were large in nature, on average the impacts were small and deemed not disproportionate in relation to the general population.

Table 32 lists the type and quantity of critical infrastructure that would be impacted during the largest flood event for both the upper and lower river during the modeled period of record for Alternative 5. While the impacts on average would be less, the table provides an indication of the infrastructure that would be impacted under the worst-case scenario.

Table 32. Critical Infrastructure Impacted in the Largest Flood Event in Period of Record under Alternative 5

Critical Infrastructure	Upper River	Change from Alternative 1	Lower River	Change from Alternative 1
Agricultural Facilities	3	0	4	0
Chemical Industries	4	0	11	0
Communication Towers	0	0	4	0
Educational Schools	2	0	0	0
Emergency – EMS	0	0	4	0
Emergency – Fire Stations	0	0	6	0
Emergency – National Shelters	2	0	2	0
Energy – Plants	0	0	5	0
Energy – Propane Locations	4	0	7	0
Energy – Substations	8	0	11	1
Law Enforcement	2	0	2	0
Mail - USPS	2	0	9	1
Manufacturing Plants	2	0	10	0
Public – Campgrounds	0	0	2	0
Public – Libraries	0	0	2	0
Public – Parks	0	0	26	0
Public – Worship	1	0	1	0
Transportation – Airports	0	0	20	0
Transportation – Bridges	21	0	530	-2
Transportation – Ports	0	0	121	0
Wastewater Treatment Plants	0	0	2	0

5.7 Alternative 6 – Pallid Sturgeon Spawning Cue

For Alternative 6, the greatest changes in PAR relative Alternative 1 across the entire period of record would range from a decrease of 230 people to a 244 person increase in the lower river and a 123 person decrease to 13 person increase in the upper river. Table 33 shows the PAR under Alternative 6.

In addition to PAR, impacts to census block groups with potential populations of concern were evaluated for Alternative 6. The census block groups 291892114011 (St. Louis County, MO and 291892109272 (St. Louis County, MO) with minority race populations were identified as showing adverse average annual adverse impacts under Alternative 6 compared to Alternative 1. However, while in some years the modeled damages were large in nature, on average the impacts were small and deemed not disproportionate in relation to the general population.

Table 33. Population at Risk under Alternative 6

River Reach	Largest Flood Event in Period of Record	Average Annual	Largest Increase Relative to Alternative 1	Largest Decrease Relative to Alternative 1
Missouri River	**14,726**	**587**	**249**	**-230**
Upper River	**9,289**	**211**	**13**	**-123**
Fort Peck to Garrison	81	2	0	0
Garrison Dam to Oahe	9,135	205	3	-123
Fort Randall to Gavins Point	73	4	13	-4
Lower River	**5,527**	**382**	**244**	**-230**
Gavins Point to Rulo	4,787	218	166	-109
St. Joseph Reach	958	48	240	-162
Kansas City Reach	1,730	39	4	-45
Boonville Reach	817	52	19	-220
Hermann Reach	895	64	9	-118

Table 34 lists the type and quantity of critical infrastructure that would be impacted during the largest modeled flood event in both the upper and lower river during the period of record for Alternative 6. While the impacts on average would be less, the table provides an indication of the potential infrastructure impacted under the worst-case scenario.

Table 34. Critical Infrastructure Impacted in the Largest Flood Event in Period of Record under Alternative 6

Critical Infrastructure	Upper River	Upper River	Lower River	Lower River
Agricultural Facilities	3	0	4	0
Chemical Industries	4	0	11	0
Communication Towers	0	0	4	0
Educational Schools	2	0	0	0
Emergency – EMS	0	0	4	0
Emergency – Fire Stations	0	0	6	0
Emergency – National Shelters	2	0	2	0
Energy – Plants	0	0	5	0
Energy – Propane Locations	4	0	7	0
Energy – Substations	8	0	11	1
Law Enforcement	2	0	2	0
Mail - USPS	2	0	9	1
Manufacturing Plants	2	0	10	0
Public – Campgrounds	0	0	2	0
Public – Libraries	0	0	2	0
Public – Parks	0	0	26	0
Public – Worship	1	0	1	0
Transportation – Airports	0	0	20	0
Transportation – Bridges	21	0	530	-2
Transportation – Ports	0	0	121	0
Wastewater Treatment Plants	0	0	2	0

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