Missouri River Recovery Management Plan and Environmental Impact Statement

Interior Drainage Environmental Consequences Analysis

Technical Report

August 2018

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Acronyms and Abbreviations

AGDAM	Agricultural Flood Damage Analysis
BiOp	2003 Amended Biological Opinion
EIS	environmental impact statement
EQ	environmental quality
ER	Engineering Regulation
ESA	Endangered Species Act
ESH	emergent sandbar habitat
FEMA	Federal Emergency Management Agency
FRM	Flood Risk Management
FY	fiscal year
H&H	Hydrologic and Hydraulic (Model)
HC	human considerations
HEC-AGDAM	Hydrologic Engineering Center - Agricultural Flood Damage Analysis
HEC-DSS	Hydrologic Engineering Center - Data Storage System
HEC-FIA	Hydrologic Engineering Center - Flood Impact Analysis
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-IFH	Hydrologic Engineering Center - Interior Flood Hydrology
HEC-RAS	Hydrologic Engineering Center - River Analysis System
HMS	Hydrologic Modeling System
MRLS	Missouri River Levee System
MRRMP-EIS	Missouri River Recovery Management Plan and Environmental Impact Statement
MRRP	Missouri River Recovery Program
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
POR	period of record
RED	regional economic development
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service

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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 this Interior Drainage 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 interior drainage.

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 effects to HC 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 interior drainage 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 agriculture include reservoir elevations, river flows/stages, geomorphology, and flood risk management infrastructure (e.g., levees). Changes in these characteristics could result in changes in land use and agricultural conditions (beneficial or adverse), such as land use and management, land ownership, and present flooding hazards, including interior drainage to agricultural operations. Changes in land use and agricultural conditions could change agricultural operations, such as the number of harvested acres, farming expenses, cropping patterns, or crop yields, which could reduce income to farmers. Changes in agricultural production, net income to farmers, and employment could have implications for agricultural ways of life and community resiliency.

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 interior drainage. This figure also shows the intermediate factors and criteria that were applied in assessing the NED, RED, and OSE consequences to interior drainage.

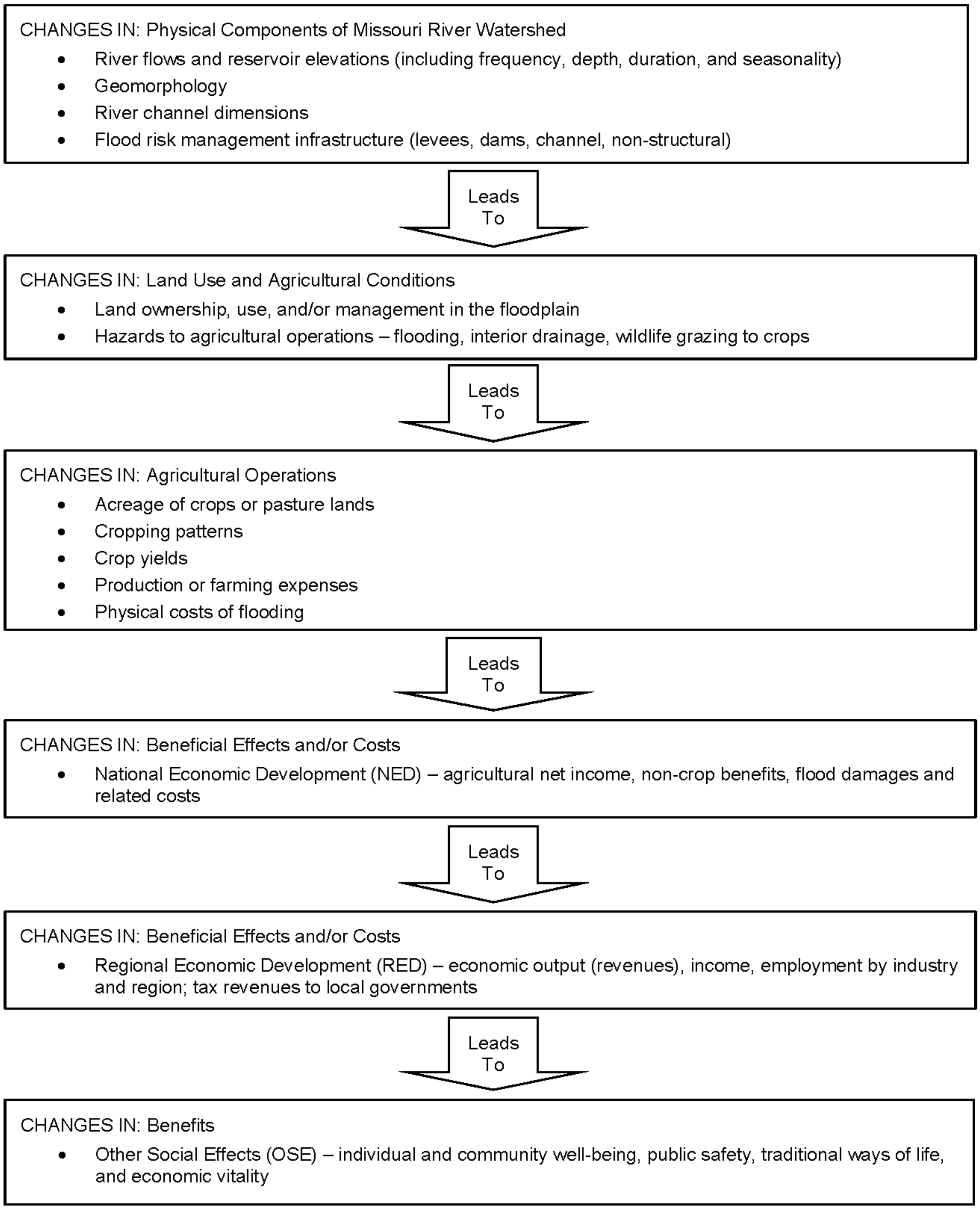

Figure 1. Flow Chart of Inputs Considered in Interior Drainage Evaluation

2.0 Methodology and Assumptions

The methodology includes a summary of assumptions and risk and uncertainty considerations. The initial step in the process, evaluating the relationship between river conditions and interior drainage, is then described, as well as the subsequent steps to assess the NED, RED, and OSE impacts.

The approach for evaluating environmental consequences to interior drainage 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 thresholds were reached during flood or high-water events under both without-project and with-project conditions based on hydrologic and hydraulic modeling. The results of this analysis were used to verify that further interior drainage analysis to estimate changes in NED, RED, and OSE impacts was warranted. This second step in the process estimated impacts associated with agricultural losses and damage to structures and associated contents. Figure 2 illustrates an overview of the approach for interior drainage.

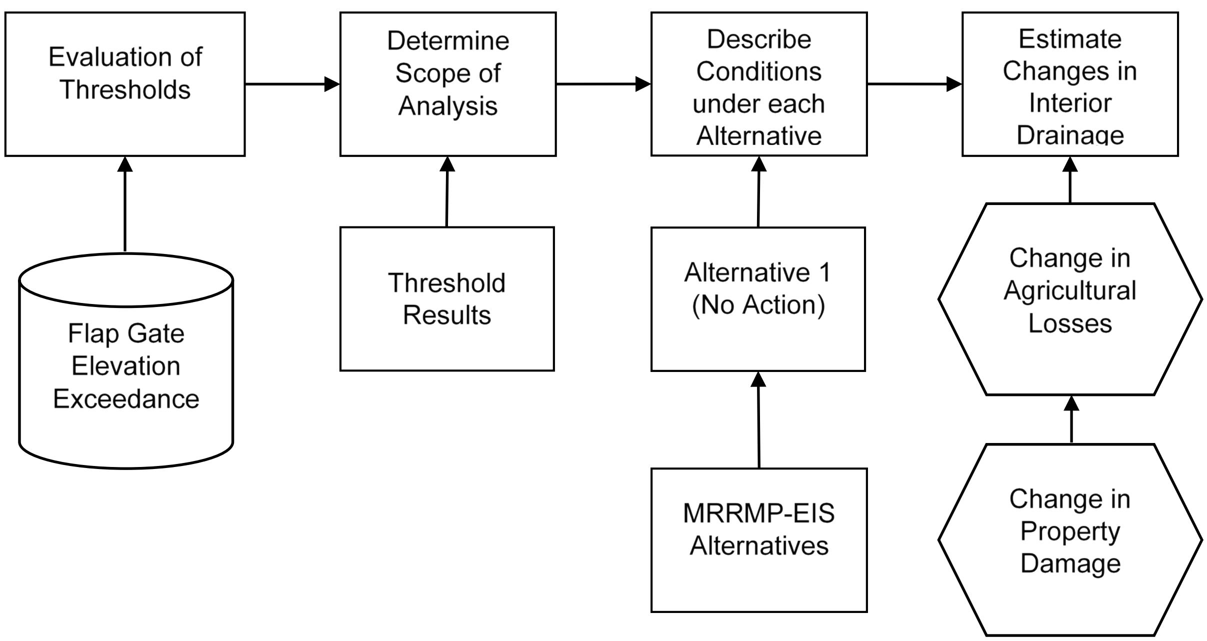

Figure 2. Process to Evaluate the Impacts to Interior Drainage

2.1 Assumptions

In modeling the environmental consequences to interior drainage 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 period of record (POR) under each of the MRRMP-EIS alternatives as well as Alternative 1.

- Because the models are quite complex and time consuming to develop, it was not feasible to model every levee on the Missouri River. Therefore, a sub-set of four sites, from the seven sites evaluated for the Master Manual (USACE 1998), were selected to be modeled in detail. These sites provide a reasonable representation of the magnitude of impacts to interior drainage that may occur under the MRRMP-EIS alternatives.
- Extrapolation from the four sites to other levee areas was not feasible since the hydraulics, hydrology, and drainage varies between sites. Translation of damage-duration relationships between sites would require additional evaluation to provide a reasonable methodology and verification of results.
- For each project alternative, the H&H model was run to determine the number of days per year that individual flap gate outlet elevations are exceeded at surveyed interior drainage sites. This information was used to determine changes in average number of days per year of interior drainage blockage.

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 POR. 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 interior drainage 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 interior drainage.

2.3 Economic Analysis and Modeling

An interior drainage analysis was completed to evaluate water surface elevations within federal levee areas along the Missouri River. Elevations within these leveed areas are affected by the ability to drain interior runoff into the Missouri River. Criteria for evaluation of interior areas of levee systems are specified in Engineer Manual (EM) 1110-2-1413 Hydrologic Analysis of Interior Areas and are applicable to the MRRMP-EIS to determine potential economic impacts of various habitat and or flow alternatives to existing leveed areas. Processes for interior drainage evaluation from EM 1110-2-1413 consist of generating continuous records (i.e., hydrologic POR) to a level of detail commensurate with the type of study. In this case, existing interior areas were analyzed against alternative river geometries and/or flow alternatives from the mainstem dams, both of which could influence exterior river stages.

During the Master Manual update process, an interior drainage study was conducted on seven representative sites as documented in *Volume 11: Interior Drainage Study, Master Water Control Manual, Northwest Division, August 1998*. The analysis was performed with a hydrologic model, HEC-IFH (Interior Flood Hydrology), which is no longer supported and is not compatible with current computer operating systems. Furthermore, it was not possible to update the former model or extrapolate model results to current conditions. However, the sites evaluated for the Master Manual were determined to be representative for the MRRMP-EIS. In addition, some of the calibration parameters were determined to be useful and repeating evaluation at those sites allowed for comparison to previous results.

Three programs HEC-RAS (River Analysis System), HEC-HMS (Hydrologic Modeling System), and HEC-FIA (Flood Impact Analysis)) were used to assemble models for evaluating interior drainage impacts to four sampled sites. The HEC-HMS model was used to model rainfall for the POR and determine runoff entering the levee interior area. Hydrologic parameters used in the previous HEC-IFH analysis were utilized where applicable in order to expedite modeling. The HEC-RAS model was based on the current modeling used for the alternatives analysis. The model utilized the runoff entering the levee cell, stage-storage for the area, Missouri River water levels, estimated seepage, and the hydraulic parameters of the drainage structures to perform computations of the drainage structures that convey runoff from the interior drainage area into the Missouri River. Model results determined daily ponding levels for the entire POR.

Crop damage as a result of levee overtopping was accounted for in the flood risk management environmental consequences assessment but damage to crops behind levees can be caused by other mechanisms. Once the four sites were refined in the HEC-RAS model, the daily ponding elevation information was used by the HEC-FIA model that was developed to compute agricultural losses from the inability to drain interior runoff occurring during two separate time windows:

1. Spring – This time window focused on the agricultural damages associated with the maximum 14-day duration for a spring stage event. This time window varied for each state based on typical planting dates obtained from the respective state’s agricultural extension service.
2. Summer-Fall – This time window focused on the agricultural damages associated with the maximum 1-day duration for a summer or fall stage event. This time window varied for each state based on typical harvesting dates obtained from the respective state’s agricultural extension service.

HEC-FIA evaluates impacts to a study area, with the damageable elements defined through the addition of user defined agricultural and structural inventories. The HEC-FIA model is able to estimate 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. For this specific analysis period, HEC-FIA estimated:

- 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.
- Direct Economic Losses – Losses directly related to damages sustained by structures, contents, equipment, vehicles, etc. These losses are essentially all damage to property.

For all of the selected sites, and under each alternative scenario, each individual year in the POR was run in HEC-FIA for both the spring and summer-fall time windows. The damages for each year were aggregated and averaged over the POR to estimate average annual damages for each site across all the alternatives.

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 interior drainage, 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 changes in agricultural losses and property damages from changes in interior drainage flooding resulting from the MRRMP-EIS alternatives.

2.4.1 Agricultural Damage Computation

When interior drainage sites lose the ability to drain runoff, damages can occur in agricultural areas 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 Data, (iii) Crop Planting Data, (iv) Crop Harvesting Data, and (v) Duration-Damage Relationships.

Computing consequences in an HEC-FIA project requires inundation data. Inundation data provides a pattern for HEC-FIA simulations, through defining the source and type of hydraulic information at any point in the study area. For the interior drainage 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 drainage areas. 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.

Agricultural losses were based on data downloaded from USDA's National Agricultural Statistics Service (NASS). The National Agricultural Statistics Service (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 imports 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 four interior drainage sites 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 Missouri and Iowa state agricultural extension services. Further information and links to each state's crop budget data can be found in the references section of this document. 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.

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.

2.4.2 Property Damage Computation

In HEC-FIA, property damages are described by the magnitude of damages to buildings, their contents, and vehicle values 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.

HEC-FIA uses the same inundation data mentioned in Section 2.4.1 Agricultural Damage Computation, but is only comparing the annual peak stage hydrograph at each structure point.

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.

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 Di is the direct damage, where the subscript i is used to represent buildings, contents, or vehicles; di is damage (in percent) as a function of depth and occupancy type, and vi 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.

2.5 Regional Economic Development Methodology

The NED results were further evaluated to determine if regional economic conditions would be affected under the MRRMP-EIS alternatives. For all action alternatives, the differences in damages on average compared to Alternative 1 would result in negligible NED impacts. The largest adverse difference in agricultural damages would occur under Alternative 2 with an increase in damages of $175,000 (Missouri River Levee System (MRLS)-488L), which would result in a loss of approximately 1 average annual job. Because all agricultural losses in any year would result in less than 1 job, a full RED analysis was not undertaken on the interior drainage impacts.

2.6 Other Social Effects Methodology

Since the interior drainage sites are primarily agricultural, the population at risk (PAR) totals are minimal for each of the sites. Under the largest modeled flood event (1993), the maximum PAR that could be affected by flooding would be 27 persons located at MRLS 246-L, 19 at MRLS 575-L, 7 at MRLS 536-L, and 0 at MRLS 488-L. Because the impacts to the population would be minimal in any year and the changes to Alternative 1 would be zero to negligible on average, a full OSE analysis was not undertaken on the interior drainage impacts modeling.

2.7 Geographic Areas

The four sites modeled for NED analysis were the Missouri River Levee System (MRLS) 575-L, MRLS 536-L, MRLS 488-L, and MRLS 246-L. Each site is a separable drainage area (described further below) as defined by the upstream and downstream tiebacks and the mainstem levee. Table 1 shows the land use for each of the modeled interior drainage sites.

MRLS 575-L

The MRLS 575-L levee is located in Fremont County, Iowa and is the largest interior drainage site modeled, comprising more than 93,000 acres with nearly 63.5 percent of the land use in corn and soybean production.

MRLS 536-L

The MRLS 536-L levee is located in Atchison County, Missouri and is comprised of approximately 14,400 acres, the majority of which are agricultural, including nearly 80 percent of land use in corn and soybean production.

MRLS 488-L

The MRLS 488-L levee is located in Holt County, Missouri and is comprised of approximately 9,500 acres, the majority of which are agricultural, with more than 81 percent of land use in corn and soybean production.

MRLS 246-L

The MRLS 246-L levee is located in Chariton County, Missouri and is comprised of approximately 32,000 acres, the majority of which are agricultural, with nearly 68 percent of the land use in corn and soybean production.

Table 1. Land Use of the Modeled Interior Drainage Sites

Interior Drainage Site	Total Floodplain Acres	Corn	Soybeans	Grass / Pasture	Deciduous Forest	Developed / Open Space	Other
MRLS 575-L	92,949	34.7%	28.8%	10.8%	9.5%	5.4%	10.8%
MRLS 536-L	14,005	45.2%	34.2%	1.8%	4.7%	6.1%	7.9%
MRLS 488-L	9,554	44.6%	36.5%	5.2%	7.7%	4.2%	1.8%
MRLS 246-L	31,936	25.6%	42.1%	11.7%	8.2%	2.8%	9.5%

Source: USDA NASS, Cropland Data Layer 2014

In addition to the modeling of the four selected interior drainage sites, the interior drainage analysis considered the effects of MRRMP-EIS alternatives on additional leveed floodplain areas. The analysis considered a larger number of drainage sites and compared the flap gate outlet elevations at each of the drainage sites with the river stages from the HEC-RAS modeled 82-year period of record to determine how often stages exceed the outlet elevations for each alternative. While the underlying hydrologic processes can be complex and dependent on multiple factors, this analysis provided an indicator of the potential risk for impacts at these interior drainage site locations. This analysis can be found in Chapter 3.12.4.2, Proxy Analysis, of the MRRMP-EIS.

3.0 National Economic Development Results Evaluation

3.1 Alternative 1 – Current System Operation and Current MRRP Implementation

Alternative 1 represents current System operations including a number of management actions associated with MRRP implementation. Management actions under Alternative 1 include construction of both SWH and ESH habitat and a spring plenary pulse or a bi-modal spring plenary pulse. The management actions included under Alternative 1 are focused on areas below Gavins Point Dam.

The impacts analysis for interior drainage under Alternative 1 is summarized in Table 2. Under Alternative 1, the modeled average annual interior drainage damages ranged from $116,459 (MRLS 536-L) to $398,562 (MRLS 246-L) for the four selected sites. Agricultural losses are the primary driver of the NED impact.

Table 2. Summary of Interior Drainage Impacts under Alternative 1

Interior Drainage Site	Average Annual Spring Agricultural Losses	Average Annual Summer-Fall Agricultural Losses	Average Annual Property Damages	Total Average Annual NED Damages
MRLS 575-L	$16,995	$211,987	$55	$229,037
MRLS 536-L	$4,803	$77,930	$33,726	$116,459
MRLS 488-L	$10,305	$224,055	$6	$234,366
MRLS 246-L	$7,017	$347,256	$44,289	$398,562

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

3.2 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 include:

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

The interior drainage NED analysis for Alternative 2 is summarized in Table 3. Across each of the interior drainage sites, the Alternative 2 modeling showed a small beneficial impact on NED relative to Alternative 1. The decrease in average annual damages ranged from 1.4 percent at MRLS 575-L to 4.7 percent at MRLS 488-L. The modeled site with the largest dollar impact was MRLS 246-L, which exhibited a decrease of $11,436 in average annual flood damages under Alternative 2.

Table 3. Summary of Interior Drainage NED Analysis for Alternative 2

Interior Drainage Site	Average Annual Spring Agricultural Losses	Average Annual Summer-Fall Agricultural Losses	Average Annual Property Damages	Total Average Annual NED Damages	Change in Total Average Annual NED Damages from Alternative 1	% Change from Alternative 1
MRLS 575-L	$17,175	$208,595	$54	$225,824	-$3,213	-1.4%
MRLS 536-L	$4,685	$77,125	$31,696	$113,506	-$2,953	-2.5%
MRLS 488-L	$9,651	$213,732	$0	$223,383	-$10,983	-4.7%
MRLS 246-L	$7,731	$339,465	$39,931	$387,127	-$11,436	-2.9%

Note: All totals are average annual values at the FY 2018 price level. Negative values indicate a decrease in damages relative to Alternative 1.

Figure 3 shows the difference in damages between Alternative 2 and Alternative 1 for the years that were modeled for all sites. There is a noticeable increase in damages in the 1983 and 1997 simulations, particularly to MRLS 246-L and MRLS 488-L. Meanwhile in the 1993 modeled event, MRLS 246-L and MRLS 536-L experienced a relatively large decrease in interior drainage damages relative to Alternative 1.

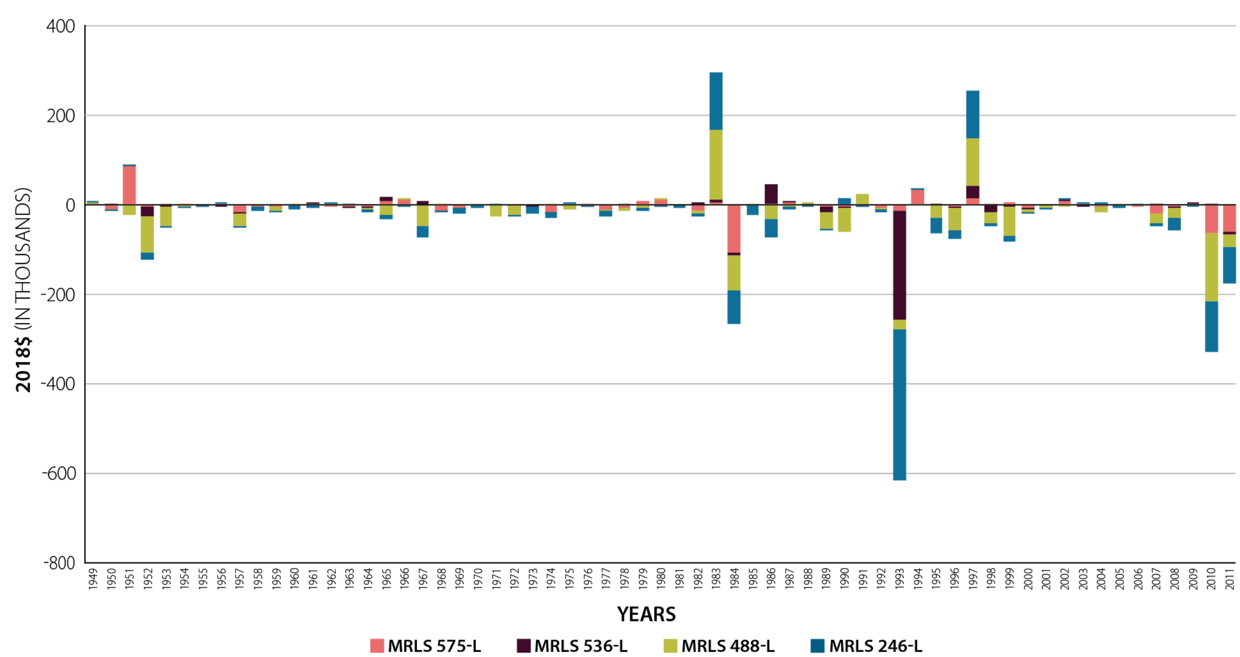

Figure 3. Alternative 2 Annual Flood Damage Difference from Alternative 1 for Interior Drainage Sites

In addition to the overall NED impacts, the interior drainage sites were analyzed to examine the difference in impacts during years when there is a release action and/or a low summer flow. These results are summarized and depicted in Figure 4. During the POR, there were 3 years with a modeled full flow release plus low summer flow action in addition to 25 modeled years with partial flow releases. In 20 of the 25 years with partial flow releases, the combined damages of the modeled interior drainage sites under Alternative 2 are less than the Alternative 1 damages. Each of the four modeled interior drainage sites exhibited a small decrease in NED damages on average relative to Alternative 1 under the partial release modeled events.

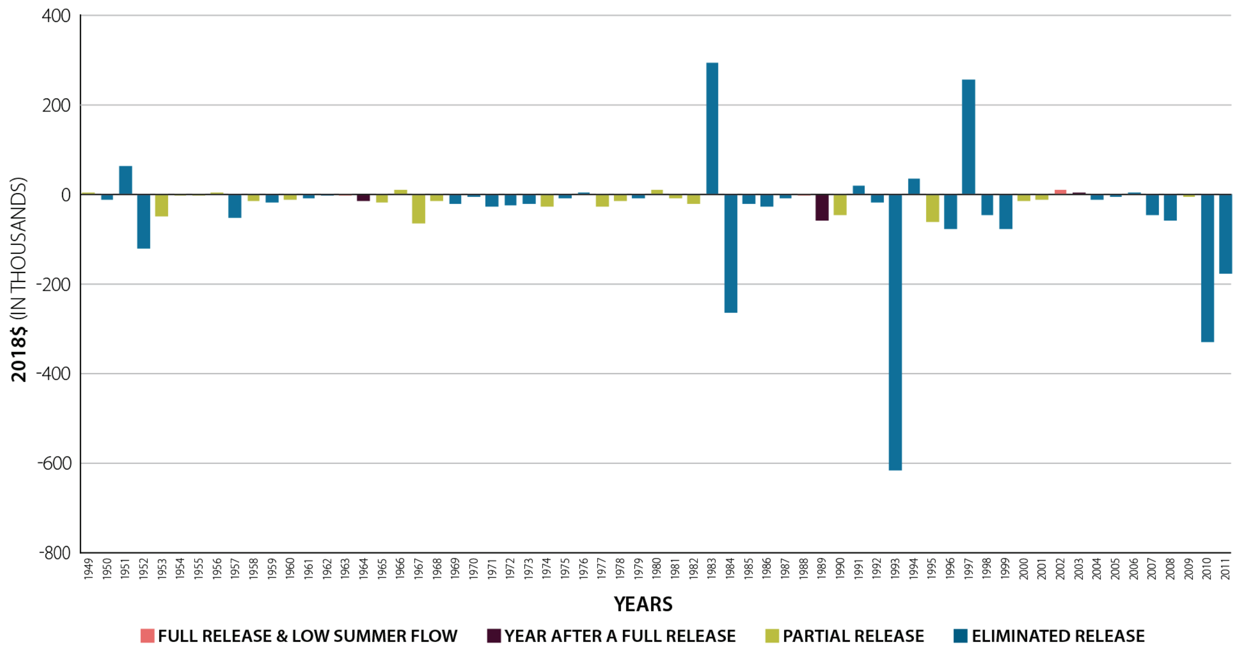

Figure 4. Alternative 2 Difference from Alternative 1 in Flood Damages by Release Type

3.3 Alternative 3 – Mechanical Construction Only

Management actions under Alternative 3 would include those that focus on the creation of ESH through mechanical means. Across each of the four modeled interior drainage sites, Alternative 3 would have a negligible to small impact on interior drainage relative to Alternative 1. The results of interior drainage NED analysis for Alternative 3 are summarized in Table 4. Interior drainage site MRLS 536-L showed the largest adverse impact under Alternative 3, with an estimated increase of $6,922, or 5.9 percent, in average annual damages over Alternative 1. MRLS 246-L was the only modeled site that showed beneficial impacts; however, these impacts were negligible with a decrease in average annual damages of less than 0.1 percent compared to Alternative 1.

Table 4. Summary of Interior Drainage NED Analysis for Alternative 3

Interior Drainage Site	Average Annual Spring Agricultural Losses	Average Annual Summer-Fall Agricultural Losses	Average Annual Property Damages	Total Average Annual NED Damages	Change in Total Average Annual NED Damages from Alternative 1	% Change from Alternative 1
MRLS 575-L	$16,930	$212,701	$55	$229,687	$650	0.3%
MRLS 536-L	$5,192	$80,774	$37,415	$123,382	$6,922	5.9%
MRLS 488-L	$10,632	$226,519	$5	$237,156	$2,791	1.2%
MRLS 246-L	$7,021	$346,834	$44,686	$398,542	-$20	0.0%

Note: All totals are average annual values at the FY 2018 price level. Negative values indicate a decrease in damages relative to Alternative 1.

Figure 5 shows the difference of Alternative 3 from Alternative 1 for the years that were modeled for all sites. Over the total POR, the greatest one-year decreases in damages were -$35,519 (MRLS 246-L), -$24,641 (MRLS 488-L), -$19,450 (MRLS 536-L), and -$6,220 (MRLS 575-L). Across the same POR, the greatest one-year increases in damages were $407,051 (MRLS 536-L), $74,913 (MRLS 488-L), $33,582 (MRLS 246-L), and $20,757 (MRLS 575-L).

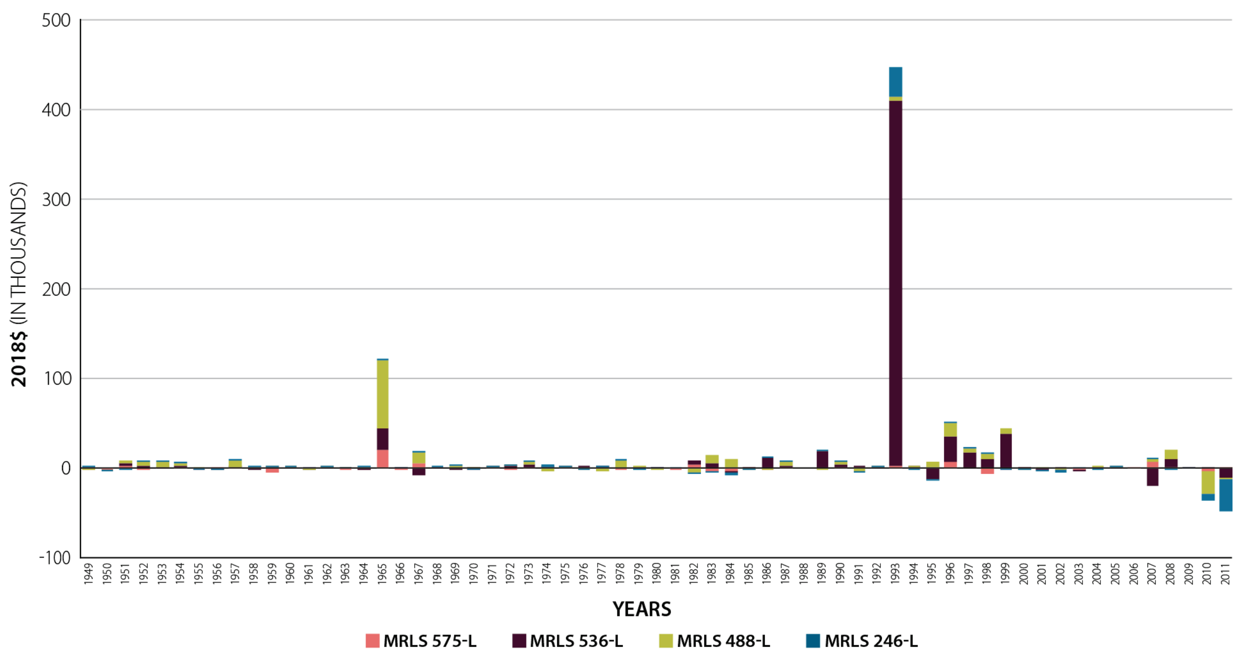

Figure 5. Alternative 3 Annual Flood Damage Difference from Alternative 1 for Interior Drainage Sites

3.4 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. The interior drainage NED results for Alternative 4 are summarized in Table 5. Alternative 4 would have small adverse impacts to MRLS 536-L and MRLS 246-L and small beneficial impacts to MRLS 575-L and MRLS 488-L.

The modeled site with the largest adverse impact was MRLS 536-L which showed an average annual increase in damages of $6,330, or 5.4 percent.

Table 5. Summary of Interior Drainage Analysis for Alternative 4

Interior Drainage Site	Average Annual Spring Agricultural Losses	Average Annual Summer-Fall Agricultural Losses	Average Annual Property Damages	Total Average Annual NED Damages	Change in Total Average Annual NED Damages from Alternative 1	% Change from Alternative 1
MRLS 575-L	$16,988	$211,310	$55	$228,353	-$684	−0.3%
MRLS 536-L	$5,301	$80,073	$37,415	$122,789	$6,330	5.6%
MRLS 488-L	$10,398	$221,140	$8	$231,546	-$2,819	−1.2%
MRLS 246-L	$7,586	$346,301	$44,679	$398,566	$4	0.0%

Note: All totals are average annual values at the FY 2018 price level. Negative values indicate a decrease in damages relative to Alternative 1.

Figure 6 shows the difference in damages between Alternative 4 and Alternative 1 for the years that were modeled for all sites. The most noticeable impacts are an increase in damages seen under the 1993 modeled event, particularly to MRLS 536-L and the decreases in impacts realized in the 1995 and 2010 simulations.

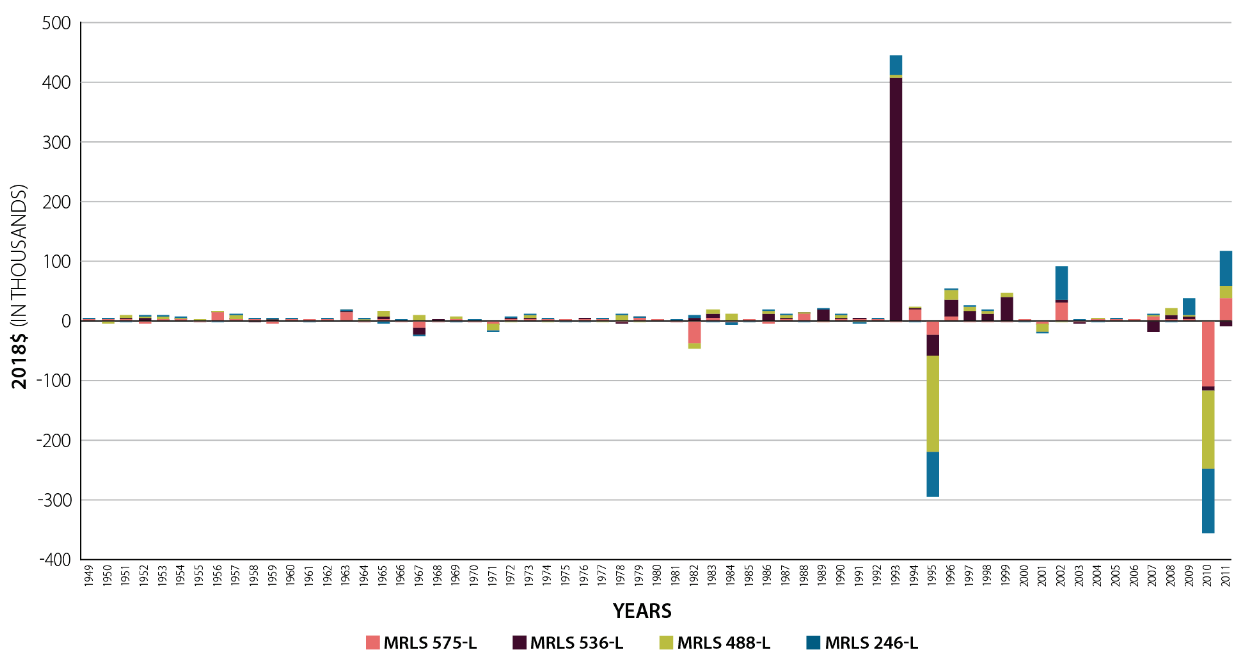

Figure 6. Alternative 4 Annual Flood Damage Difference from Alternative 1 for Interior Drainage Sites

Figure 7 shows the difference in annual NED interior drainage damages during years when there was a full or partial flow release. Under Alternative 4, there were 8 years with a modeled full flow release and 5 modeled years with a partial release. The combined damages at the four interior drainage sites are adverse under 5 of the 8 full flow release years. On average, the combined damages are $10,549 greater annually under Alternative 4 full flow release years relative to Alternative 1. Three of the five Alternative 4 partial release years also show adverse impacts relative to Alternative 1. Combined, the four sites averaged an additional $6,564 in damages under Alternative 4 partial release simulations.

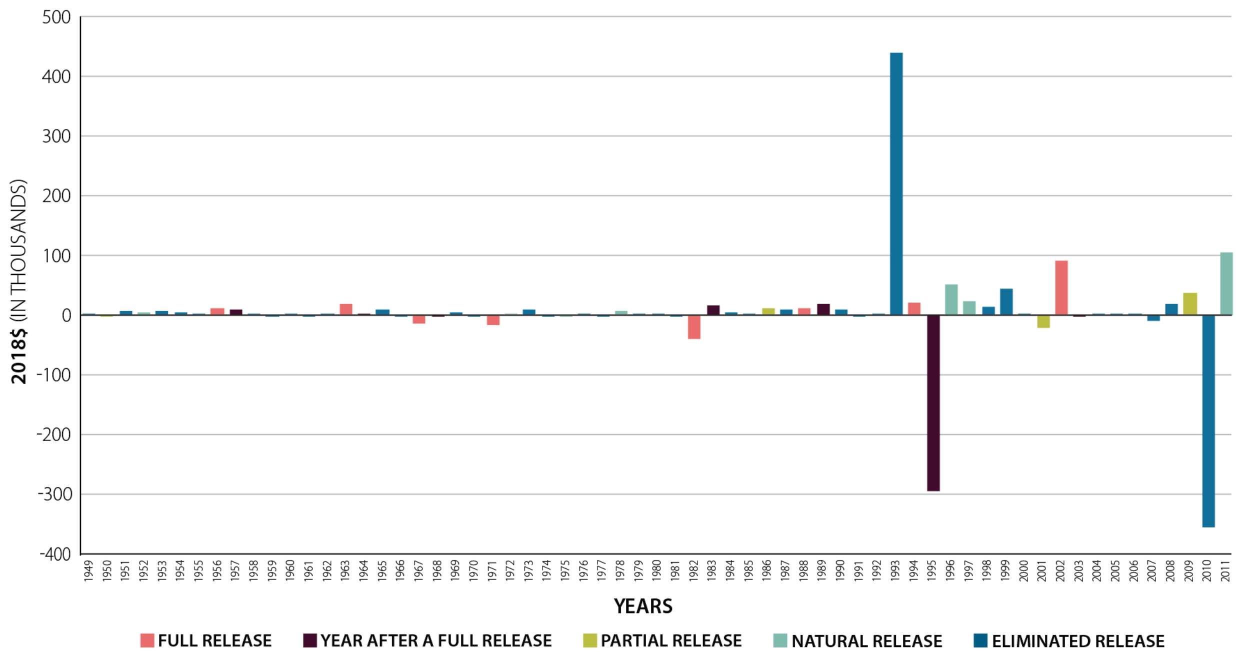

Figure 7. Alternative 4 Difference from Alternative 1 in Flood Damages by Release Type

3.5 Alternative 5 – Fall ESH Creating Release

Alternative 5 focuses on developing ESH habitat through both mechanical and reservoir releases that would occur during the fall months. The interior drainage NED analysis is summarized in Table 6. Alternative 5 had a small adverse impact relative to Alternative 1 at three of the modeled interior drainage sites: MRLS 575-L, MRLS 536-L, and MRLS 488-L. At MRLS 246-L, the modeled results showed a relatively negligible decrease in average annual damages compared to Alternative 1. The site with the largest impact was MRLS 536-L, which experienced an increase of 6.1 percent in average annual damages over Alternative 1.

Table 6. Summary of Interior Drainage NED Analysis for Alternative 5

Interior Drainage Site	Average Annual Spring Agricultural Losses	Average Annual Summer-Fall Agricultural Losses	Average Annual Property Damages	Total Average Annual NED Damages	Change in Total Average Annual NED Damages from Alternative 1	% Change from Alternative 1
MRLS 575-L	$16,821	$214,979	$55	$231,855	$2,819	1.2%
MRLS 536-L	$5,149	$81,014	$37,413	$123,576	$7,116	6.1%
MRLS 488-L	$10,246	$224,745	$5	$234,997	$631	0.3%
MRLS 246-L	$6,957	$345,956	$44,677	$397,591	-$972	-0.2%

Note: All totals are average annual values at the FY 2018 price level. Negative values indicate a decrease in damages relative to Alternative 1.

Figure 8 shows the difference in damages of Alternative 5 from Alternative 1 for the years that were modeled for all sites. The most noticeable impacts are the relatively large increase in damages in the 1993 simulated event, particularly to MRLS 536-L, and the relatively large decrease in damages noticed under the 1995 simulation.

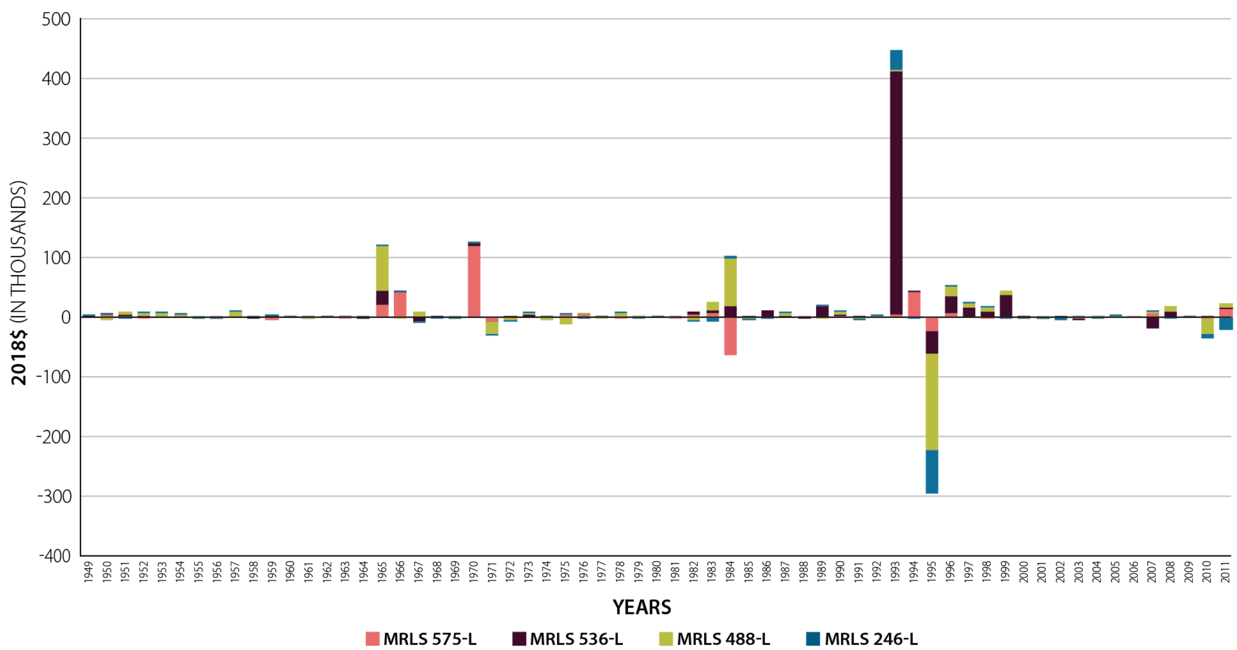

Figure 8. Alternative 5 Annual Flood Damage Difference from Alternative 1 for Interior Drainage Sites

Figure 9 shows the difference in annual NED damages during years when there was a modeled full or partial flow release. Under Alternative 5, there were six modeled years with a full flow release and two additional years with a simulated partial flow release. The combined damages at the modeled interior drainage sites are adverse under 5 of the 6 full flow action years. On average, the combined damages are $39,413 greater annually under Alternative 5 full flow release years relative to Alternative 1. In addition to full flow release actions, there were two years modeled with a partial flow release. The two furthest upstream sites, MRLS 575-L and MRLS 536-L, showed small increases in damages over Alternative 1 under the partial release simulated events while the two furthest downstream sites, MRLS 488-L and MRLS 246-L, showed small beneficial impacts under the same Alternative 5 modeled conditions.

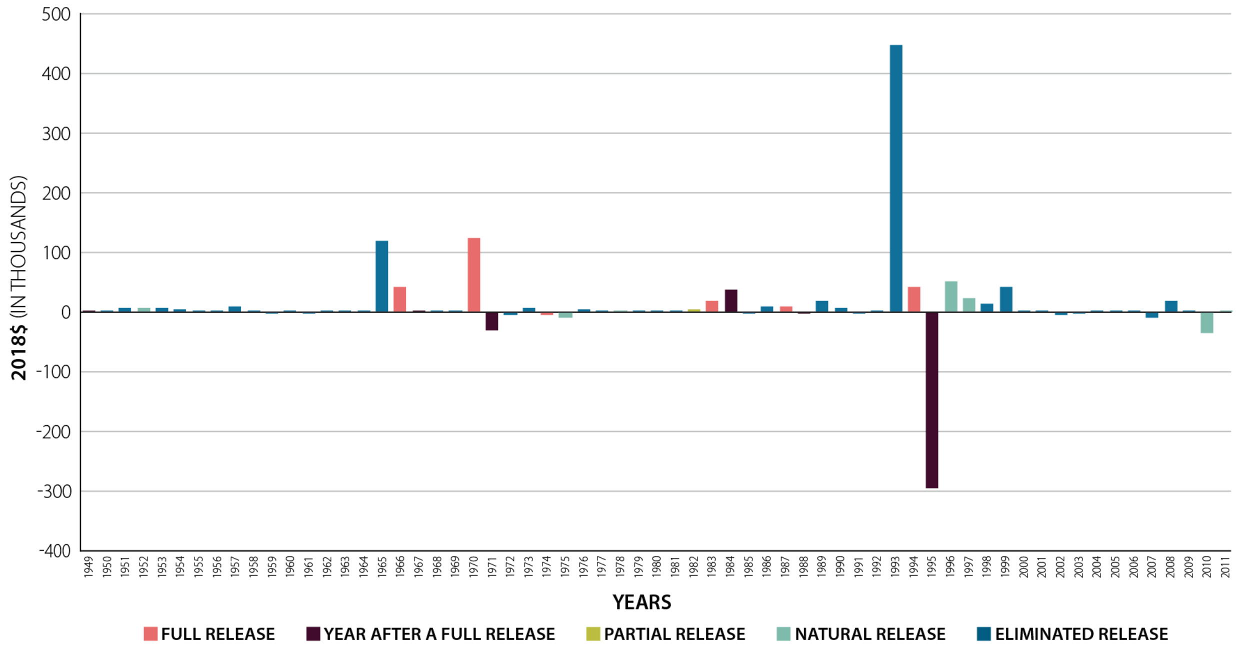

Figure 9. Alternative 5 Difference from Alternative 1 in Flood Damages by Release Type

3.6 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. The results of the interior drainage NED analysis for Alternative 6 are summarized in Table 7. Alternative 6 would have a small, adverse impact on interior drainage relative to Alternative 1 at the three modeled sites furthest upstream: MRLS 575-L, MRLS 536-L, and MRLS 488-L. The site with the largest adverse impact is MRLS 536-L, which exhibited an increase of $7,468, or 6.4 percent, in average annual damages over Alternative 1. The furthest downstream site, MRLS 246-L, experienced a small decrease in average annual damages of $1,228 or -0.3 percent.

Table 7. Summary of Interior Drainage NED Analysis for Alternative 6

Interior Drainage Site	Average Annual Spring Agricultural Losses	Average Annual Summer-Fall Agricultural Losses	Average Annual Property Damages	Total Average Annual NED Damages	Change in Total Average Annual NED Damages from Alternative 1	% Change from Alternative 1
MRLS 575-L	$16,778	$213,414	$55	$230,247	$1,210	0.5%
MRLS 536-L	$5,160	$81,360	$37,408	$123,927	$7,468	6.4%
MRLS 488-L	$10,706	$225,781	$6	$236,493	$2,127	0.9%
MRLS 246-L	$7,080	$345,572	$44,683	$397,334	-$1,228	-0.3%

Note: All totals are average annual values at the FY 2018 price level. Negative values indicate a decrease in damages relative to Alternative 1.

Figure 10 shows the difference in damages of Alternative 6 from Alternative 1 for the years that were modeled for all sites. The most noticeable impacts are the increases in damages relative to Alternative 1 exhibited under the 1967 and 1993 modeled events, and the decrease in damages depicted in the 2010 simulation under Alternative 6.

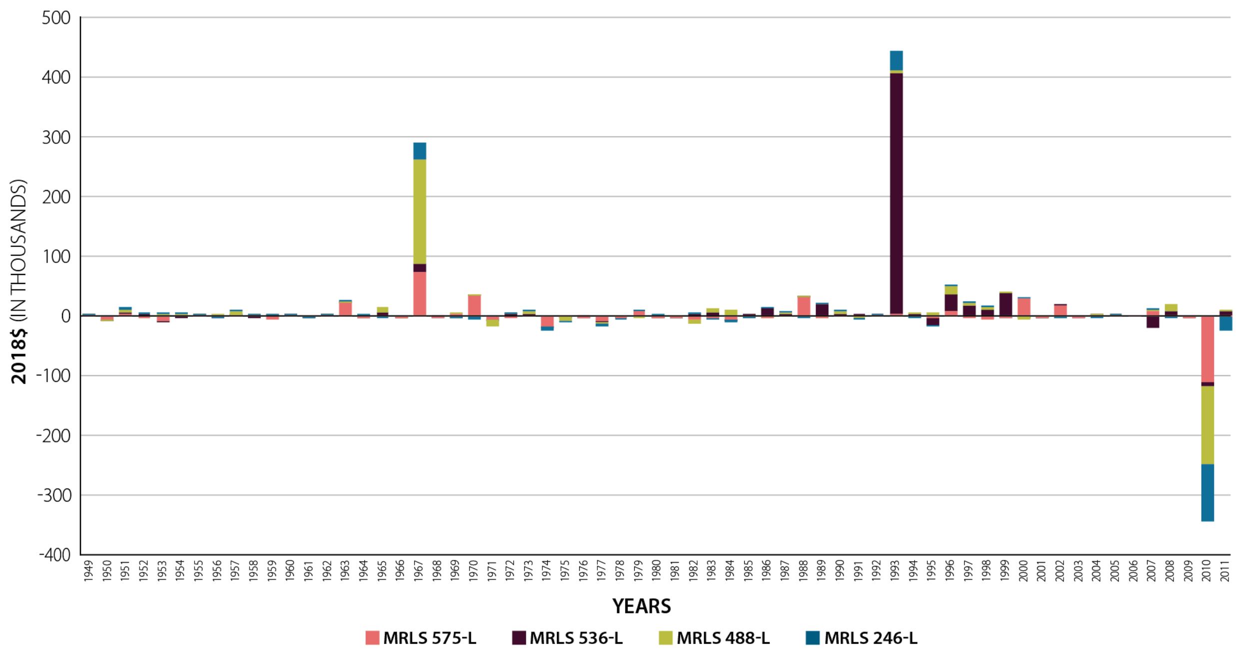

Figure 10. Alternative 6 Annual Flood Damage Difference from Alternative 1 for Interior Drainage Sites

The interior drainage impacts during years when there was a modeled release event are depicted in Figure 11. During the POR, there were 5 years modeled with a full flow release and 23 years with a modeled partial flow release. The combined damages at the four interior drainage sites are adverse under all 5 full flow action years. On average, the combined damages are $79,441 greater annually under Alternative 6 full flow release years relative to Alternative 1. Of the 23 partial release years under Alternative 6, 10 show combined adverse impacts relative to Alternative 1, with the four sites combining for $2,612 more in average annual damages under all Alternative 6 partial release years.

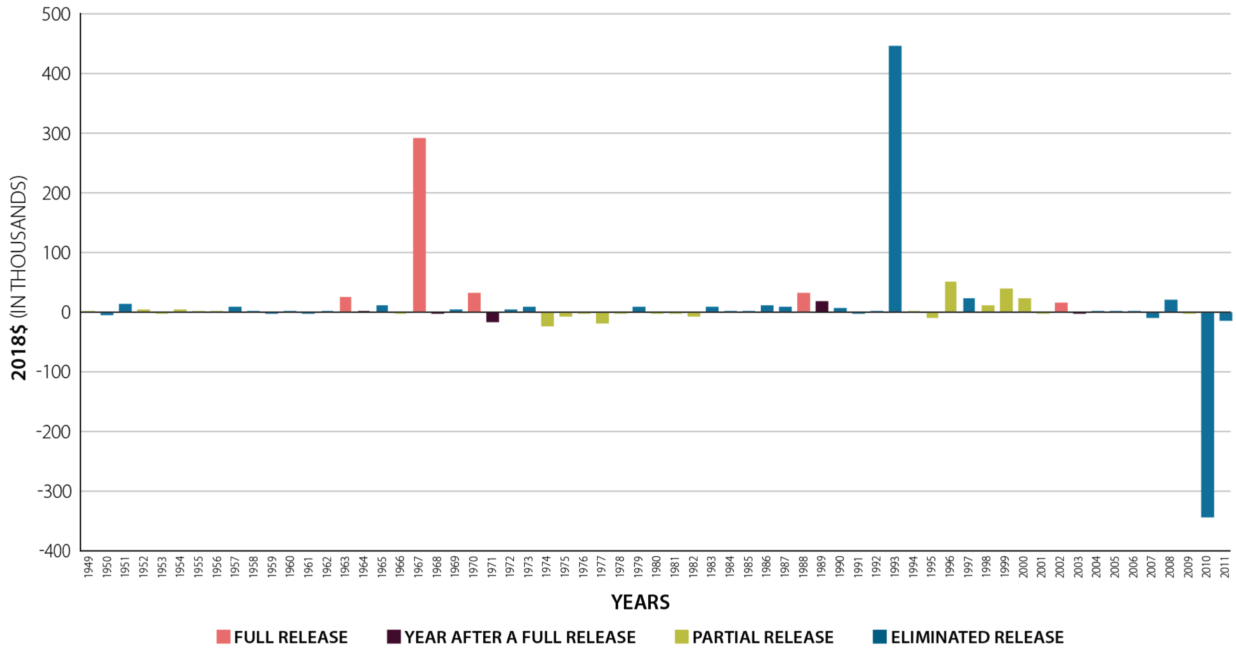

Figure 11. Alternative 6 Difference from Alternative 1 in Flood Damages by Release Type

4.0 Conclusion

The interior drainage models provide a powerful tool to assess the complicated interaction between reservoir releases hundreds of miles upstream of a levee unit on interior ponding resulting from rainfall and/or seepage. However, limited conclusions can be extrapolated to the entire river. With such slight differences compared to Alternative 1, it is difficult to separate the impact of flow changes from the reservoirs from the impact of added habitat to make global conclusions. Changes are highly localized, depending upon factors such as how low the culvert outlet is and the interior area available for ponding before damages occur. While the magnitude of impacts would vary considerably from year to year as a result of the natural hydrologic cycles of precipitation and runoff, the interior drainage effects would be negligible to small on average annually for each of the alternatives.

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