Missouri River Recovery Program

DRAFT

Missouri River Recovery Management Plan and Environmental Impact Statement

IRRIGATION ENVIRONMENTAL CONSEQUENCES ANALYSIS TECHNICAL REPORT

December 2016

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Missouri River Recovery Management Plan and Environmental Impact Statement

Irrigation
Environmental Consequences Analysis

Technical Report

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Acronyms and Abbreviations

BiOp	2003 Amended Biological Opinion
CSREES	Cooperative State Research, Education, and Extension Service
DSS	Data Storage System
EIS	Draft Environmental Impact Statement
EQ	Environmental Quality
ER	Engineering Regulation
ERS	USDA Economic Research Service
ESH	Emergent Sandbar Habitat
FRIS	USDA Farm and Ranch Irrigation Survey
H&H	Hydrologic and Hydraulic (H&H) modeling of the river and reservoir system
HC	Human Considerations
HEC	USACE, Institute for Water Resources, Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-ResSim	Reservoir System Simulation
MRRIC	Missouri River Recovery Implementation Committee
MRRP	Missouri River Recovery Program
MRRMP-EIS	Missouri River Recovery Management Plan and Environmental Impact Statement
NED	National Economic Development
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
OSE	Other Social Effects
P&G	Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
POR	Period of Record
RAS	River Analysis System
RED	Regional Economic Development
ResSim	Reservoir System Simulation
SWH	Shallow Water Habitat
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U. S. Fish and Wildlife Service

1.0 Introduction

The USACE in cooperation with the USFWS are developing a Missouri River Recovery Management Plan and Draft Environmental Impact Statement (MRRMP Draft EIS). The purpose of the MRRMP-EIS is to develop a management plan that includes a suite of actions that removes or precludes jeopardy status for the piping plover, the interior least tern, and the pallid sturgeon using USACE authorities.

The purpose of the Irrigation Technical Report is to provide additional information and results on the impact analysis relevant to irrigation that was completed for the MRRMP-EIS. Additional details on the National Economic Development (NED) and Regional Economic Development (RED) methodology and results are provided in this technical report. The Other Social Effects (OSE) are presented in the MRRMP-EIS, Chapter 3, Irrigation Environmental Consequences section. No Environmental Quality (EQ) analysis was undertaken for Irrigation.

1.1 Summary of Alternatives

The MRRMP Draft EIS evaluates the following Management Plan alternatives. Detailed description of the alternatives is provided in the Draft EIS, Chapter 2.

- **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 BiOp compliance. Management actions under No Action include creation of early life stage habitat for the pallid sturgeon and emergent sandbar habitat (ESH), as well as a spring plenary pulse. The construction of habitat will be focused in the Garrison and Gavins reaches for ESH (an average rate of 107 acres per year) and between Ponca to the mouth near St. Louis for 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 No Action 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 3,546 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 only create ESH through mechanical means at an average rate of 391 acres per year across the entire system. 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 additional 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.

- **Alternative 4** – **Spring ESH Creating Release.** The USACE would mechanically construct ESH annually at an average rate of 240 acres per year across the entire system. 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 (current operations), with the addition of a spring release designed to create ESH for the least tern and piping plover. An additional 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 309 acres per year across the entire system. This alternative is based on Alternative 1 (current operations), with the addition of a release in the fall designed to create sandbar habitat for the least tern and piping plover. An additional 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 303 acres per year across the entire system. 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 or would be terminated whenever flood targets are exceeded. An additional 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 were 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 Draft 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 MP-EIS. Further guidance that is specific to 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 national economic development (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 regional economic development (RED) account evaluates changes in the distribution of regional economic activity (i.e. jobs and income).
- The environmental quality (EQ) displays non-monetary effect of significant natural and cultural resources.

- The other social effects (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 that impacts are not double-counted. The human considerations objectives and metrics developed by the USACE and Missouri River Recovery Implementation Committee (MRRIC) are not only rooted in the economic, social, and cultural values associated with the natural resources of the Missouri River, but were designed with consideration of the four accounts

1.3 Approach for Evaluating Environmental Consequences to Irrigation Operations from the Missouri River Recovery Management Plan

The Missouri River Mainstem Reservoir System Master Water Control Manual reports that there are 1,026 intakes in 42 counties that use the Missouri River for irrigation purposes (USACE 2006). At the time of this analysis, 816 intakes along the Missouri River were permitted for irrigation use. Under favorable operating conditions, water intakes are sufficiently below surface elevations, enabling water from the reservoirs and river reaches to be pumped to agricultural fields within the floodplain. When river stages and reservoir elevations fall below operating thresholds, intakes lose access to water and shutdown. These shut downs adversely affect farm production, especially when water access is inhibited for consecutive days. The conceptual flow chart Figure 1 demonstrates, in a stepwise manner, how changes to the physical conditions of the Missouri River and its floodplain can affect irrigation and crop yields. This figure also shows the intermediate factors and criteria that were applied in assessing the NED, RED, and OSE consequences to irrigation.

The environmental consequences analysis included a NED, RED, and OSE assessment. The NED analysis estimated the change in net farm income under each of the MRRMP alternatives. The RED analysis used results from the NED analysis to estimate changes in sales, employment, and labor income resulting from each of the MRRMP alternatives.

The NED analysis followed a three-step process (Figure 2). The first step evaluated the changes in river conditions including changes in river stage, river flow and reservoir elevations at specified intervals along the river under each of the MRRMP-EIS alternatives. The results of this step were then integrated into the economic analysis, which calculated the change in yields due to changes in access to water from the Missouri River for irrigation. The calculations are performed over a modeled 82-year period of record (POR). Further details on the methodology are provided in the following sections. Figure 2 summarizes the overall NED analysis.

The one-time spawning cue test (Level 2) release that may be implemented under Alternatives 3, 4, and 5 was not included in the hydrologic modeling for these alternatives because of the uncertainty of the hydrologic conditions that would be present if implemented. Hydrologic modeling for Alternative 6 simulates reoccurring implementation (Level 3) of this spawning cue over the wide range of hydrologic conditions in the POR. Therefore, the impacts from the potential implementation of a one-time spawning cue test release would be bound by the range of impacts described for individual releases under Alternative 6.

CHANGES IN: Physical Components of Missouri River Watershed

- Reservoir elevations
- River flows and stages
- Sediment load
- Channel morphology (including erosion or ice-flow and buildup concerns)
- Water temperature

Leads To

CHANGES IN: Irrigation Conditions

- Access to water during irrigation season

Leads To

CHANGES IN: Irrigation Activity

- Irrigated acreage and yield

Leads To

CHANGES IN: Beneficial Effects and/or Costs

- NED – Net farm income, as measured by changes in irrigated acreage

Leads To

CHANGES IN: Beneficial and/or Adverse RED

- RED – Economic output/sales, income, employment by industry and region, and tax receipts to local governments

Leads To

CHANGES IN: OSE

- Individual and community well-being, traditional ways of life

Figure 1. Flow Chart of Inputs Considered in Objectives/Metrics Evaluation for Irrigation

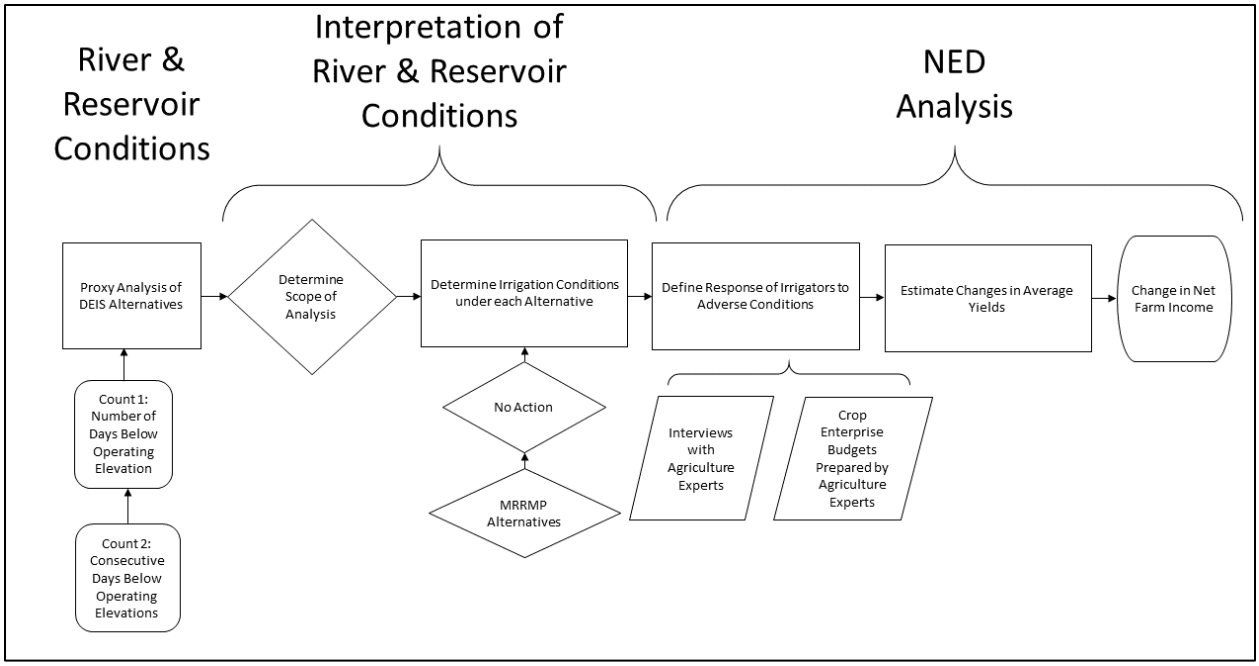

Figure 2. Approach for Evaluating Environmental Consequences to Irrigation Operations

1.4 Assumptions

The following discussion highlights the significant assumptions used the evaluation of impacts to irrigation operations from the MRRP-EIS alternatives:

- 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 POR under each of the MRRMP-EIS alternatives, as well as Alternative 1.
- It is assumed that if the river or reservoir level falls below a critical operating threshold the intake will lose access to water for a full day.
- Where available, detailed information on irrigation intake operating requirements were used in the analysis. When not available, the project team assumed that certain reported operating thresholds given for single intakes would apply to similar intakes located in the general vicinity.
- Based on interviews with irrigation intake owners and farm operators, it was assumed that impacts will increase as the number of consecutive days without access to water increases.
- Impacts to irrigation intakes are assumed to take the form of declining crop yields. As the number of days increases in which access to water is curtailed, the expected yield per acre is expected to decrease.
- Water used for irrigation is assumed to be constant for all irrigators and equal to the state average estimated in the 2013 Farm and Ranch Irrigation Survey (USDA 2013).
- Crop harvest patterns (i.e., the percentage of corn, alfalfa, and barley) for crops harvested using only Missouri River water are assumed to be equal to the harvest

patterns for crops irrigated with water from any source, as reported in the 2012 Census of Agriculture (USDA 2012)

- Permit requirements in South Dakota and North Dakota require irrigators to report actual irrigated acreage by source. Based on this data, it was assumed that the number of acres irrigated with Missouri River water equated to 37.6 percent of permitted acres. This same assumption was applied in Montana because permit holders are not required to report actual irrigated acreage and, thus, there was no current information available.
- Crop enterprise budgets were used for irrigation costs per acre and crop yields per acre (both irrigated and dryland). Every effort was made to use a budget that included the county under study. In the event that a suitable budget was not available, a budget prepared for a similar geography and rainfall pattern was used.
- The price received per unit of production is assumed to be equal to the state-level normalized price estimates for commodities prepared by the United States Department of Agriculture Economic Research Service (USDA 2015) for 2015.
- The irrigation season in Montana, North Dakota, and South Dakota, was assumed to last 153 days (May 1 to September 30). In Nebraska, the irrigation season is assumed to last from May 1 to October 31.

1.5 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 Management Plan 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 HEC-RAS models or carried through to the irrigation model described is this document. The project team has attempted to address risk and uncertainty in the Management Plan 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 irrigation intakes and agricultural production.

2.0 Analysis of River Conditions

The purpose of the river conditions analysis was to link the H&H model outputs of river/reservoir operations under each of the MRRMP-EIS alternatives with the economic analysis that was performed on irrigation intakes. This analysis was completed in Microsoft Excel® and provided an estimate of the number of days irrigation intakes would have access to water at various locations along the river. The output of this model was used in the economic model to evaluate potential NED and RED effects on changes in river flows, river stages, and reservoir elevations to irrigation operations accessing water from the Missouri River.

As river flows and reservoir elevations fall below minimum operating requirements, intakes become unavailable to provide water for crops. This in turn can drive changes in crop yields and operation and maintenance costs of the intakes. The analysis of river conditions was developed using outputs from H&H models developed by the USACE. District engineers used specialized software to simulate river and reservoir operations for planning studies and decision support developed by the Institute for Water Resources, Hydrologic Engineering Center (HEC) (USACE

2016a; USACE 2016b). Hydrologic Engineering Center River Analysis System (HEC-RAS) and Reservoir System Simulation (HEC-ResSim) data was used to provide a profile of river and reservoir behavior at locations that approximately corresponded to locations of irrigation intakes, in the form of HEC-DSS (Data Storage System) flat files. River and reservoir behavior for each location was analyzed over a period of 82 years, from 1930 to 2012.

The USACE developed the initial list of 1,027 irrigation intakes that are used for irrigation along the river from Montana to Nebraska. That list included access requirements at many of those intakes. These intakes were located in 42 counties between the Fort Peck Dam in Montana, and Rulo, Nebraska. This initial list of intakes did not include irrigators in Iowa, Missouri, and Kansas. Additional investigation with state Departments of Natural Resources confirmed that there are no intakes permitted for irrigation from the Missouri River in these states.

In order to reduce the processing time, individual intake locations were aggregated into 242 groups that were located in close proximity with each other and appeared to have similar access requirements. Groups did not cross county lines, shared a common required operating flow/elevation, were within ten river miles of each other, and did not cross tribal boundaries. Each group included approximately four intakes.

For the intakes identified to represent a group, an Excel®-based analysis was developed to identify whether or not the river and reservoir conditions fell within the access requirements of the irrigation intake. The results obtained were assumed to be consistent for all intakes in the group.

2.1 Metric Definitions

Three metrics were developed in order to approximate access to water for irrigation under the MRRMP-EIS alternatives. Table 1 identifies the metrics that were calculated in the river condition analysis.

Table 1. Irrigation Proxy Metrics

Proxy Metric	Description
Metric 1 – Total days below minimum access requirements	This metric is an estimate of the number of days river flows or reservoir elevations fall below minimum access requirements. The total number of days below minimum access requirements was estimated for each county for each alternative.
Metric 2 – Average number of consecutive days below minimum access requirements	This metric is an estimate of the average length of time, in days, for all occurrences of river flows or reservoir elevations falling below minimum access requirements during the annual irrigation season. This metric was estimated for each county for each alternative.
Metric 3 – Frequency below minimum access requirements for five or more consecutive days	This metric is an estimate of the frequency of river flows or reservoir elevations falling below minimum access requirements for more than five consecutive days of the annual irrigation season. This metric is calculated for each county and alternative.

2.2 River Condition Analysis Results

The primary purpose of the river condition analysis was to better understand how each of the proposed alternatives might impact irrigation intakes. The tool presented results in three ways: by location for all years, for all locations and for all years, and for each location by year. The

river condition results were used in the economic analysis to estimate changes in yield, based on the length of time intakes would have access to water during the growing season. Both the total day and consecutive day results were used to define the scope of analysis (Section 3.0). To complete the economic analysis (Section 4.0), only the average number of consecutive days without access to water was used.

3.0 Defining Scope of Analysis

The results of the river conditions analysis were used in part to define the extent of the economic analysis for irrigation operations under each of the MRRMP-EIS alternatives. In particular, the river condition results were used to identify which counties should be subject to further evaluation in the MRRMP-EIS. The team evaluated the river conditions to determine potential impacts for irrigation intakes in each county under each of the MRRMP-EIS alternatives (Alternatives 2 through 6) compared to the no-action alternative (Alternative 1).

A county was selected for further analysis if the river conditions results indicated that the county would experience a notable increase in the number of days river flows or reservoir elevations fall below minimum operating thresholds under one or more of the MRRMP-EIS alternatives. These thresholds represent the water surface elevations in either the river or the reservoirs that would be needed for each intake to remain operational. Note that because all alternatives showed significant impacts during the drought years of the 1930s and early 1940s, the screening process largely focused on annual river conditions for years between 1942 and 2012. For more information on historic drought periods, refer to Section 3.2 in the MRRMP EIS.

Four screening criteria were developed to determine the scope of analysis for irrigation operations. Note that the river conditions results for irrigation intakes are aggregated to the county level, and screening criteria are also reported at a county level. The screening criteria are defined as follows.

Significant number of days with water levels below minimum operating requirements in a single year. Counties were selected for further analysis if there was an increase in the number of days with water levels below minimum operating elevations by at least 30 days in any single year under any of the MRRMP-EIS alternatives. This criterion was designed to represent an infrequent event that is likely to have long lasting effects. For example, the river conditions analysis showed that Richland County, Montana would experience an increase in the number of days below minimum operating requirements of 50 in 1973 under Alternative 2, which resulted in this county being selected for further analysis.

Measureable increases in water levels below minimum operating requirements over several years. This criterion evaluated which counties may experience a moderate increase in the number of days with water levels below minimum access requirements during a number of years under the MRRMP-EIS alternatives. This criterion was calculated in two steps. First, a moderate increase in the number of days below minimum operating requirements was defined as approximately 10 percent of the growing season or an increase of 15 days in a single year, relative to Alternative 1. Second, the annual frequency with which counties experienced this moderate increase under any alternative was calculated. Counties that experienced a moderate increase in the number of days below minimum operating requirements in six or more years (the 90th percentile of such occurrences) were selected for additional evaluation. For example, under Alternative 4, intakes in Mountrail County in North Dakota would experience seven years in which intakes would experience an increase by at least 15 days per year between 1956 and

1964 when water surface elevations would fall below minimum operating requirements and, thus, were selected for additional analysis.

Counties experiencing the greatest increase in the number of days water surface levels are below minimum operating requirements. This criterion identified counties that experienced the greatest increase in the total number of days when water surface elevations fall below minimum access requirements for years 1942 to 2012 for the MRRMP alternatives. Any county that realized an increase in the number of days within the 90th percentile for such occurrences during the period evaluated was selected for further analysis. For example, Dewey County in South Dakota would experience an increase of 323 days when water surface elevations would fall below minimum operating requirements from 1942 to 2012 under Alternative 6, which resulted in this county being selected for further analysis.

Increase in the number of consecutive days. This criterion measured the increase in the average number of consecutive days that intakes experience water surface elevations below minimum operating requirements from 1942 to 2012 for all alternatives. The sum of the average number of consecutive days over the total POR was analyzed, and counties that fell into the 90th percentile for such occurrences were selected for further analysis.

3.1 Initial Screening Results

Table 2 shows the results of the screening analysis described above and includes the counties that were identified for further analysis. Nineteen counties were identified as meeting the criteria described above. Only one county, Thurston, Nebraska, was selected on the basis of a single criterion. Seven counties, primarily in South Dakota, were identified on the basis of all four criteria.

Table 2. Counties Identified for Further Analysis in the Environmental Impact Statement

County	State	Single Year Impact	Moderate Impact for Several Years	Cumulative Impact	Cumulative Impact on Consecutive Days
McCone	MT	x			
Valley	MT	x			
Roosevelt	MT	x			
Richland	MT	x			
Williams	ND				x
McKenzie	ND				
Mountrail	ND	x	X	x	x
McLean	ND				
Mercer	ND	x		x	x
Oliver	ND				
Burleigh	ND				
Morton	ND				
Emmons	ND	x	x	x	x
Sioux	ND	x			x
Corson	SD				
Campbell	SD	x	x	x	x
Walworth	SD				

County	State	Single Year Impact	Moderate Impact for Several Years	Cumulative Impact	Cumulative Impact on Consecutive Days
Dewey	SD	x	x	x	x
Potter	SD	x	x	x	x
Sully	SD	x	x	x	x
Stanley	SD	x	x	x	x
Hughes	SD				
Buffalo	SD				
Hyde	SD				
Lyman	SD				
Brule	SD				
Charles Mix	SD				
Gregory	SD				
Boyd	NE				
Bon Homme	SD				
Knox	NE				
Cedar	NE				
Yankton	SD				
Clay	SD				
Dixon	NE				
Union	SD				
Thurston	NE			x	
Burt	NE				
Washington	NE				
Cass	NE	x	x	x	
Otoe	NE	x	x	x	
Nemaha	NE	x	x	x	

3.2 Irrigated Acreage Criterion

Upon further review of the initial screening results, it was determined that some of the 19 counties had very few acres irrigated using water from the Missouri River. Thus, an additional criterion was developed based on the number of irrigated acres within in each county. Counties that reported fewer than 1,000 acres irrigated in the most recent Census of Agriculture (USDA 2012) were eliminated from further study, including the following:

- Mountrail, North Dakota
- Sioux, North Dakota
- Dewey, North Dakota
- Potter, South Dakota
- Stanley, South Dakota

If fewer than 1,000 acres were permitted for agriculture irrigation using Missouri River water (as reported by the state governing body responsible for overseeing state water rights and

appropriations), they were also eliminated. Three counties were eliminated from further study on this basis, including:

- Thurston, Nebraska
- Cass, Nebraska
- Otoe, Nebraska

If fewer than 1,000 acres were actually irrigated according to usage statistics gathered by the South Dakota Department of Environment and Natural Resources or the North Dakota State Water Commission, they were also eliminated from further study. Note that neither the Nebraska Department of Natural Resources nor the Montana Department of Natural Resources and Conservation require surface water right owners to report actual irrigated acreage. Two counties were eliminated from further consideration based on reported irrigated acreage:

- Campbell, South Dakota
- Walworth, South Dakota

The team made every effort to validate data developed by state departments of natural resources and water commissions. Given the relatively low number of permitted acres in southeast Nebraska, the team made calls to water right owners in Nemaha, Nebraska, to verify that permitted acres were actually being irrigated. In this case, the listed owner of an appropriation with 873 permitted acres reported that the land and appropriation had been sold to the USACE several years ago and was no longer used for irrigation. The owner of another appropriation with 297 acres of permitted land also reported that the land had not been irrigated since 2010. Thus, Nemaha County was eliminated based on this information.

3.3 Scope of Analysis Results

The results of the screening analysis showed that eight counties in the upper basin would be evaluated for potential impacts of the MRRMP-EIS Alternatives on irrigation operations. These eight counties include approximately 138,500 permitted acres for irrigation using water from the Missouri River (more than half of all of the permitted acres for irrigation in the 42-county study area). The project team felt that these eight counties would encompass much of the impacts that would occur to irrigation operations along the river and are representative of the potential impacts that could occur. The eight identified counties for further analysis include the following:

- McCone, Montana
- Valley, Montana
- Roosevelt, Montana
- Richland, Montana
- Williams, North Dakota
- Mercer, North Dakota
- Emmons, North Dakota
- Sully, South Dakota

4.0 National Economic Development Analysis

An Excel®-based model was developed that builds upon the river condition analysis to evaluate the change in NED benefits for irrigation operations as a result of implementing the MRRMP-EIS alternatives. The NED analysis for the eight counties used data and information provided by the USACE, crop enterprise budgets developed by state agriculture extension agencies, state water permit data, crop data from the USDA, and weather information from the National Oceanic and Atmospheric Administration (NOAA). These data sources and the approach are described in more detail below.

4.1 Net Farm Income Approach

The NED analysis for irrigation was defined as changes in net farm income from irrigated acreage using Missouri River water. The proxy analysis showed that water surface elevations would fall below shutdown elevations for many of the irrigation intakes evaluated under MRRMP-EIS alternatives, as well as Alternative 1. For this analysis, the project team decided to focus on changes in crop yields and subsequent effects on net farm income from curtailed access to water under each of the MRRMP-EIS alternatives. Alternatively, the project team could have evaluated changes in costs to access water and its effect on net farm income. However, it was determined that this approach was not viable for this project because of the lack of data on costs associated with adapting to changing river conditions.

4.1.1 Estimated Cropping Patterns by County

For each county, production data (e.g., crop type, number of irrigated acres harvested) was taken from the 2012 Census of Agriculture. A crop profile for each county was developed based on the number of irrigated acres harvested. Hay and wheat are the most abundant crops grown using various irrigation methods in the eight counties (USDA 2012). The acres of field crops irrigated, using both surface water and groundwater sources, are included in Table 3. Crops for which no acreage is reported, or which were suppressed for privacy concerns, are not included.

Table 3. Irrigated Acres Harvested by County, 2012

County	Barley	Beans	Corn	Hay	Hay & Haylage	Lentils	Peas	Soybeans	Sugar beets	Wheat	Total
McCone, MT		7,012	380	6,589	3,423					4,228	**21,632**
Valley, MT	1,227		2,875	49,558	24,367		551			16,268	**94,846**
Roosevelt, MT	705	2,215	160	4,831	4,851				890	14,244	**27,896**
Richland, MT	11,498		7,818	19,643	10,446				16,695	29,714	**95,814**
Williams, ND	2,892	745	1,885	3,931	1,969	300	118	1,355		9,604	**22,799**
Mercer, ND			866	212	106						**1,184**
Emmons, ND			1,332					975			**2,307**
Sully, SD			13,341	640	320			8,796			**23,097**
Total	16,322	9,972	28,657	85,404	45,482	300	669	11,126	17,585	74,058	**289,575**

Source: USDA 2012

4.1.2 Estimated Harvested Acreage Irrigated by Missouri River

The acreage reported in Table 3 does not show the acres irrigated using water exclusively from the Missouri River. To determine amount of acreage irrigated with Missouri River water in each county being evaluated, the project team collected additional information from relevant state agencies. For instance, the North Dakota State Water Commission and South Dakota Department of Environment of Natural Resources require water permit irrigators to report annual water usage. For counties in North Dakota and South Dakota, the analysis utilized this data to estimate the number of acres irrigated with Missouri River water. The number of acres for each crop grown was estimated by applying the percentage of the irrigated harvested acres per crop type to the total irrigated acres using only Missouri River water.

Irrigators in Montana are not required to report actual water usage or irrigated acreage. Thus, the project team estimated the number of acres actually irrigated by applying the average percentage of actual acres irrigated in North Dakota and South Dakota to the number of total acres permitted in Montana. On average, 37.6 percent of permitted acres are actually irrigated in these two states and this percentage is assumed to be applicable for the four counties in Montana (Table 4). Note, that in Williams, Emmons, and Mercer counties in North Dakota, the number of actual acres irrigated exceeds the number of harvested acres reported. The team assumes that the percentage of each crop using water from the Missouri River would be equal to percentage of each crop using water from any water source in the county, as reported by United States Census of Agriculture. This assumption is carried forward even when that number exceeds the total number of acres irrigated as reported by the Census of Agriculture.

Table 4. Estimated Irrigated Cropland Using Missouri River Water

County	State	Irrigated Cropland Harvested[a]	Acres Permitted for Irrigation from Missouri River 2015[b]	Actual Acres Irrigated from Missouri[c] River
McCone	Montana	(suppressed)	16,209	(not reported)
Valley	Montana	38,873	4,978	(not reported)
Roosevelt	Montana	16,198	21,284	(not reported)
Richland	Montana	62,220	18,156	(not reported)
Williams	North Dakota	(suppressed)	39,966	12,423
Mercer	North Dakota	1,364	5,463	1,739
Emmons	North Dakota	3,872	9,508	6,450
Sully	South Dakota	24,556	22,950	7,744

Sources

a USDA 2012

b South Dakota Department of Environment and Natural Resources or North Dakota State Water Commission surface water right permit, 2015

c South Dakota Department of Environment and Natural Resources or North Dakota State Water Commission actual water use reports, 2012

4.1.3 Estimated Production per Acre

To estimate production per acre for crops in the eight counties evaluated, the team utilized crop enterprise budgets. Crop enterprise budgets are prepared by land grant universities that are part of the country's Cooperative State Research, Education, and Extension Service (CSREES). The CSREES supports technology transfer between research-based institutions and the agricultural community. As members of CSREES, North Dakota and South Dakota prepare crop enterprise budgets for the benefit of the farming communities in their respective states. These budgets include estimated costs for common inputs, such as fertilizer and pest control products, but also provide farmers with an estimated yield (NDSU 2016; SDSU 2014, 2016). Note that neither North Dakota nor South Dakota crop enterprise budgets include land costs, which are excluded from this analysis.

Montana State University has not prepared updated crop enterprise budgets in more than ten years and, according to conversations with researchers at the university, recommends that farmers use budgets prepared for western North Dakota until new crop budgets can be prepared (Haynes 2016). For the purposes of this project, the western North Dakota budgets were used to obtain an estimated per-acre cost for crops grown using surface irrigation methods and an estimated per-acre yield for farms in Montana.

In most cases, the crops reported by the Census of Agriculture matched the crop budgets prepared by the universities. The only exceptions are crops identified by the Census of Agriculture as hay, hay & haylage, beans, lentils, peas, and sugar beets. Hay and hay & haylage were assumed to be alfalfa in state budgets. Beans, lentils, and peas all use dry bean budgets. Beans were considered an appropriate choice because lentils are an edible pulse (i.e., the plant's seed or fruit) in the legume family, and field peas are an edible grain legume crop. No budget was available for sugar beets in Montana, North Dakota, or South Dakota. However, a budget was available for south central Idaho, where rainfall patterns are similar to the counties in eastern Montana where sugar beets are grown (University of Idaho 2013).

No budgets were available for dryland alfalfa in a northern state or for dryland sugar beets. A dryland budget was not available for alfalfa for Idaho, Montana, or North Dakota. However, the South Dakota 2016 projections prepared by South Dakota State University estimate a three-ton yield per acre for alfalfa grown under dryland conditions in the state. In Montana, one estimate suggests that dryland alfalfa production from 1984 through 2005 averaged 2.5 tons per acre. Based on this estimate, and the lower rainfall in Montana compared to South Dakota, an estimated yield of 2.5 tons per acre was assumed for dryland alfalfa production in Montana. All available information suggests that sugar beets cannot be grown in northern states without irrigation, and dryland production estimates for sugar beets are assumed to be zero tons per acre.

4.1.4 Estimate Irrigation Costs per Acre of Production

Numerous interviews with private irrigation intake maintenance providers, farmers, Farm Service Agency representatives, local agriculture extension service representatives, and academics failed to uncover data that could be used to build a consistent cost function for irrigation based on the number of days a water intake was operable. Because irrigation costs represent an average cost that likely capture a range of river and reservoir conditions that are representative of river conditions under the MRRMP-EIS alternatives, irrigation costs for each

crop were assumed to be constant and were taken from the crop enterprise budgets described above.

4.1.5 Estimate Change in Yield Due to Reduced Access to Water

The project team estimated changes in yields due to different levels of water access using information on yields for irrigated production of various crops in the states being evaluated. The team conservatively assumed that average yields would decline as soon as access to water became limited and would continue to decline to a level equivalent to yields that can be realized under dryland farming conditions.

Demand for Irrigation Water

To estimate average precipitation, or the amount of water that would be available for production under dryland farming conditions, the team used average annual recorded precipitation from 1985 to 2014 from NOAA. This value represents precipitation recorded at all weather stations in each county averaged for thirty years. This value was used as a baseline to estimate the number of acre-inches of water available under dryland farming practices and was used to estimate the lowest potential yields that can be expected under any year evaluated. In the eight counties evaluated the lowest recorded precipitation was in Richland County, North Dakota (Table 5). The average annual precipitation recorded at all weather stations in the county averaged just 13.2 inches over the 30-year period. The highest recorded precipitation was 20.4 inches, recorded in Sully County, South Dakota. In general, the upper reaches of the river had lower annual precipitation relative to lower reaches (NOAA 2014). Note that while this model does include precipitation in the analysis, evapotranspiration and crop soil properties are not considered.

Table 5. Average Recorded County Precipitation (1985–2014)

County	State	Inches
McCone	Montana	14.0
Valley	Montana	13.3
Roosevelt	Montana	15.0
Richland	Montana	13.2
Williams	North Dakota	16.9
Mercer	North Dakota	15.0
Emmons	North Dakota	17.8
Sully	South Dakota	20.4

Source: National Oceanic and Atmospheric Administration 2014.

To calculate the total number of acre-inches of water applied using irrigation, the average recorded precipitation was added to the average acre-inches of water applied per irrigated acre. The source for this second value was the 2013 Farm and Ranch Irrigation Survey (FRIS), which reports the average number of acre-feet of water applied for surface water operations (USDA 2013). Farmers using surface water on unenclosed (i.e., not protected by plastic greenhouse coverings) farms in Montana used the most water per irrigated acre, at 1.4 acre-feet, or 16.8 acre-inches. Farms in North Dakota applied the least per acre, at only 0.5 acre-feet of water or 6 acre-inches (Table 6).

Table 6. Estimated Quantity of Water Applied From On-Farm Surface Water, Only Source, Applied in the Open: 2013

State	Average Acre-Feet	Average Acre-Inches
Montana	1.4	16.8
Nebraska	1.1	13.2
North Dakota	0.5	6.0
South Dakota	0.7	8.4

Source: USDA 2013.

Note: 'In the open,' in this context, means that the farm is not covered by a plastic covering, such as used in a greenhouse.

The total amount of water used for irrigation operations in each state can vary wildly as a result of differences in the amount of annual precipitation and variations in irrigation practices. For instance, in Roosevelt County Montana, irrigated acres were assumed to receive 30.4 acre-inches of water per year. However, across the state line in Williams County North Dakota, irrigated acres were assumed to receive only 16.2 acres-inches of water per year.[1]

Supply of Irrigation Water

The number of acre-inches of water available for each calendar year is calculated according to the following formula.

$$W = \left(\frac{I_2 - I_1}{D_2}\right) * (D_2 - D_1) + I_1$$

Where:

W = acre-inches of water applied

I_2 = the maximum number of acre-inches that would be applied for an intake with full access

I_1 = the minimum number of acre-inches to be applied under zero access (i.e., rely only on rainfall)

D_2 = total possible days of irrigation in irrigation season

D_1 = number of consecutive days of access in the current year under each alternative

Production increases linearly as acre-inches of water increases (as calculated above). The minimum achievable yield for each crop is assumed to be equal to the yield achieved using dryland production techniques, as reported by crop enterprise budgets.

$$yield\ per\ acre = \frac{(Y_2 - Y_1)}{(I_2 - I_1)} * (W - I_2) + Y_1$$

1 Research suggests that, on the whole, irrigation systems in Montana are the least efficient included in the study area (ECONorthwest, 2008).

Where:

Y_1 = expected yield per acre under dryland conditions

Y_2 = expected yield under full irrigation conditions

W = acre-inches of water applied in the calendar year (see previous formula)

I_1 = the minimum number of acre-inches that would be applied under dryland conditions (i.e., average annual rainfall)

I_2 = the maximum number of acre-inches that would be applied under full operability

4.1.6 Estimate Production Value per Unit of Production by Commodity

The gross sales were calculated per crop per alternative for all acres included in the counties being evaluated. Gross sales were calculated by summing the total production for each crop, for each alternative, and multiplying by the normalized price per crop. That normalized prices were obtained from the U.S. Department of Agriculture Economic Research Service (ERS) (USDA 2015). Almost all crops as listed by the Census of Agriculture 2012, were included in the prices developed by the ERS, with the exception of lentils and peas, both of which are priced as dry beans. Commodity prices for 2015 that were used in the analysis are included in Table 7.

An important point on net farm income is that, for all crop producers, the price received from year to year will vary considerably. The NED analysis used normalized 2015 commodity prices[2] as published by USDA in accordance with USACE economic guidance (U.S. Water Resources Council 1983; ER 1105-2-100 Appendix E; USACE Economic Guidance Memorandum (EGM) 15-02). In 2015, the price received per ton of hay production was relatively low. Producers' costs, however, remained stable. The results of the NED analysis show that in areas where hay and other low-valued crops are grown, counties often show a negative net farm income.

Table 7. State-Level Normalized Commodities Price Estimates, 2015

State	Wheat, all types (bushel)	Corn for grain (bushel)	Oats (bushel)	Barley (bushel)	Hay, all types, baled (ton)	Dry beans (cwt.)	Sugar beets (ton)	Soybeans for beans (bushel)
Montana	$6.73	$5.37	$2.72	$5.32	$106.68	$30.45	$57.71	
Nebraska	$6.38	$5.22	$3.42		$132.29	$37.19	$56.66	$11.82
North Dakota	$6.80	$4.84	$2.68	$5.34	$83.03	$32.79	$57.62	$11.67
South Dakota	$6.67	$5.03	$3.15	$4.50	$131.73	$34.43		$11.85

Source: USDA, Economic Research Service 2015.

2 The USACE utilizes "normalized prices" developed by ERS which smooth out the effects of short-run seasonal and cyclical variations in prices for key agricultural crops. These prices are based on a five year lagged average of actual market prices. For 2015, ERS estimated normalized prices for crops based on an average of 2010-2014 market prices (USDA, 2016).

4.1.7 Calculation of Net Farm Income

The project team calculated net farm income that would be realized under different river conditions under each alternative. Net farm income was calculated as follows:

- Average yield per crop X normalized price per crop = Gross sales per acre irrigated
- Gross sales per acre – average production costs per acre = Net income per acre
- Net income per acre X number of acres irrigated = Total Net Farm income per county.

5.0 National Economic Development Results

The NED analysis focused on estimating change in net farm income (reported in 2016$) from irrigated agriculture using water from the Missouri River. For all counties, over the modeled POR, the alternative with the largest overall change in net farm income would be Alternative 4, with a decline of almost $17 M (Figure 3). Alternatives 2 and 6 are nearly tied for the next-worst adverse effects, with a decline of approximately $11 M. Under Alternative 3, net farm income would increase slightly for all counties.

Table 8 summarizes the change in total net farm income for the modeled POR for each of the counties evaluated and highlights several trends in how the counties are affected under each of the alternatives. Under Alternative 2, all counties would experience an overall decline in net farm income relative to Alternative 1. Under Alternative 3, the counties in Montana would experience a slight decline in net farm income relative to Alternative 1, but all of the remaining counties would experience an increase in net farm income ranging from less than one percent to four percent. Under Alternative 4, all counties would experience a decrease in net farm income relative to Alternative 1, ranging from a one percent decrease to a 54 percent decrease. Under Alternative 5, all counties in Montana and most in North Dakota would experience a slight decrease in net farm income relative to Alternative 1; Emmons County and Sully County would both experience a slight increase in net farm income relative to Alternative 1. Under Alternative 6, counties in Montana would experience a negligible impact in net farm income, where counties in North Dakota and South Dakota would experience a decrease in net farm income relative to Alternative 1.

An important point on net farm income is that, for all crop producers, the price received from year to year will vary considerably. The NED analysis used normalized 2015 commodity prices as published by USDA in accordance with USACE economic guidance (USACE 2000); results were normalized to 2016 dollars. The USDA's commodity prices are based on a 5-year moving average. When the 2015 price received for crops was used with annual production costs estimated from farm budgets, the results show negative net farm income for some crops analyzed (e.g., hay production). This could in part be due to the fact that the crops being grown in some of the counties are used as inputs for other agricultural production practices (e.g., livestock). In addition, using both average prices and costs may not accurately represent conditions currently being experienced by farmers and ranchers in this area. However, given that the purpose of the analysis is to compare changes in irrigation operations across the MRRMP alternatives, the project team feels that the analysis is a reasonable portrayal of the types of crops that are grown in these areas under the conditions likely to occur under each of the alternatives and allows for that comparison.

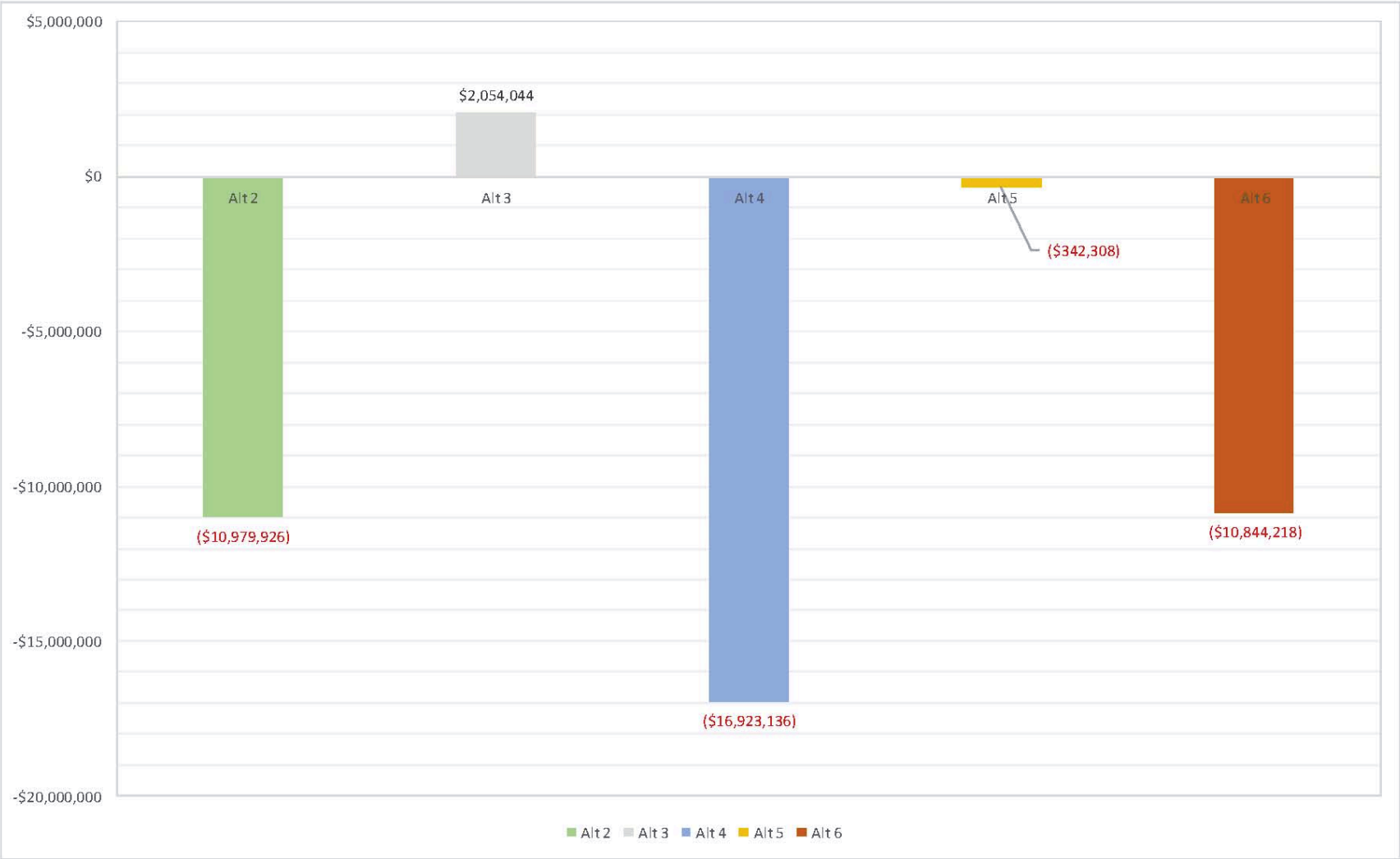

Figure 3. Change in Total Net Farm Income Relative to Alternative 1, All Counties (2016 Dollars)

Table 8. Total Net Farm Income by MRRMP-EIS Alternative, Thousands of 2016 Dollars

Type of Impact	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
McCone						
Total Net Farm Income	$52,134	$52,103	$52,053	$50,950	$52,109	$52,255
Percent Change in Net Farm Income Relative to Alt. 1	n/a	−0.1%	−0.2%	−2.3%	0.0%	0.2%
Change in Total Net Farm Income Relative to Alt. 1	n/a	−$30	−$81	−$1,184	−$25	$121
Valley						
Total Net Farm Income	$17,432	$17,414	$17,430	$16,971	$17,419	$17,451
Percent Change in Net Farm Income Relative to Alt. 1	n/a	−0.1%	0.0%	−2.6%	−0.1%	0.1%
Change in Total Net Farm Income Relative to Alt. 1	n/a	−$18	−$2	−$461	−$13	$19
Roosevelt						
Total Net Farm Income	$50,121	$49,991	$49,871	$48,867	$49,984	$50,071
Percent Change in Net Farm Income Relative to Alt. 1	n/a	−0.3%	−0.5%	−2.5%	−0.3%	−0.1%
Change in Total Net Farm Income Relative to Alt. 1	n/a	−$130	−$250	−$1,254	−$137	−$49
Richland						
Total Net Farm Income	$145,197	$145,106	$144,853	$143,749	$144,969	$145,029
Percent Change in Net Farm Income Relative to Alt. 1	n/a	−0.1%	−0.2%	−1.0%	−0.2%	−0.1%
Change in Total Net Farm Income Relative to Alt. 1	n/a	−$90	−$344	−$1,448	−$228	−$168
Williams						
Total Net Farm Income	−$8,810	−$10,160	−$8,458	−$13,555	−$9,924	−$11,006
Percent Change in Net Farm Income Relative to Alt. 1	n/a	−15.3%	4.0%	−53.9%	−12.6%	−24.9%
Change in Total Net Farm Income Relative to Alt. 1	n/a	−$1,350	$353	−$4,745	−$1,114	−$2,196
Mercer						
Total Net Farm Income	$5,268	$4,858	$5,341	$4,440	$5,116	$4,841
Percent Change in Net Farm Income Relative to Alt. 1	n/a	−7.8%	1.4%	−15.7%	−2.9%	−8.1%
Change in Total Net Farm Income Relative to Alt. 1	n/a	−$409	$73	−$827	−$152	−$426

Type of Impact	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Emmons						
Total Net Farm Income	$53,629	$50,188	$54,827	$50,907	$54,259	$49,999
Percent Change in Net Farm Income Relative to Alt. 1	n/a	−6.4%	2.2%	−5.1%	1.2%	−6.8%
Change in Total Net Farm Income Relative to Alt. 1	n/a	−$3,441	$1,197	−$2,722	$630	−$3,630
Sully						
Total Net Farm Income	$170,531	$164,847	$171,672	$165,982	$171,223	$165,845
Percent Change in Net Farm Income Relative to Alt. 1	n/a	−3.3%	0.7%	−2.7%	0.4%	−2.7%
Change in Total Net Farm Income Relative to Alt. 1	n/a	−$5,684	$1,141	−$4,550	$691	−$4,686

Estimated average annual net farm income is summarized in Table 9 and indicates a similar trend as total net farm income, with Sully County showing the highest annual average and Williams County showing the lowest annual average net farm income.

Table 9. Average Annual Net Farm Income by MRRMP-EIS Alternative, Thousands of 2016 Dollars

County	Scenario	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
McCone	Average Annual Net Farm Income	$636	$635	$635	$621	$635	$637
	Change in Average Annual Net Income Relative to Alternative 1	n/a	−$0	−$1	−$14	−$0	$1
Valley	Average Annual Net Farm Income	$213	$212	$213	$207	$212	$213
	Change in Average Annual Net Income Relative to Alternative 1	n/a	−$0	−$0	−$6	−$0	$0
Roosevelt	Average Annual Net Farm Income	$611	$610	$608	$596	$610	$611
	Change in Average Annual Net Income Relative to Alternative 1	n/a	−$2	−$3	−$15	−$2	−$1
Richland	Average Annual Net Farm Income	$1,771	$1,770	$1,767	$1,753	$1,768	$1,769
	Change in Average Annual Net Income Relative to Alternative 1	n/a	−$1	−$4	−$18	−$3	−$2
Williams	Average Annual Net Farm Income	−$107	−$124	−$103	−$165	−$121	−$134
	Change in Average Annual Net Income Relative to Alternative 1	n/a	−$16	$4	−$58	−$14	−$27

County	Scenario	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Mercer	Average Annual Net Farm Income	$64	$59	$65	$54	$62	$59
	Change in Average Annual Net Income Relative to Alternative 1	n/a	−$5	$1	−$10	−$2	−$5
Emmons	Average Annual Net Farm Income	$654	$612	$669	$621	$662	$610
	Change in Average Annual Net Income Relative to Alternative 1	n/a	−$42	$15	−$33	$8	−$44
Sully	Average Annual Net Farm Income	$2,080	$2,010	$2,094	$2,024	$2,088	$2,023
	Change in Average Annual Net Income Relative to Alternative 1	n/a	−$69	$14	−$55	$8	−$57

However, several modeled years clearly show a greater beneficial or adverse impact under the MRRMP-EIS Alternatives (Figure 4). The most beneficial year modeled for all alternatives would be 1958, when Alternatives 2, 3, and 5 perform better than Alternative 1. The worst years, particularly for Alternatives 2, 4, and 6, occur between 1960 and 1967.

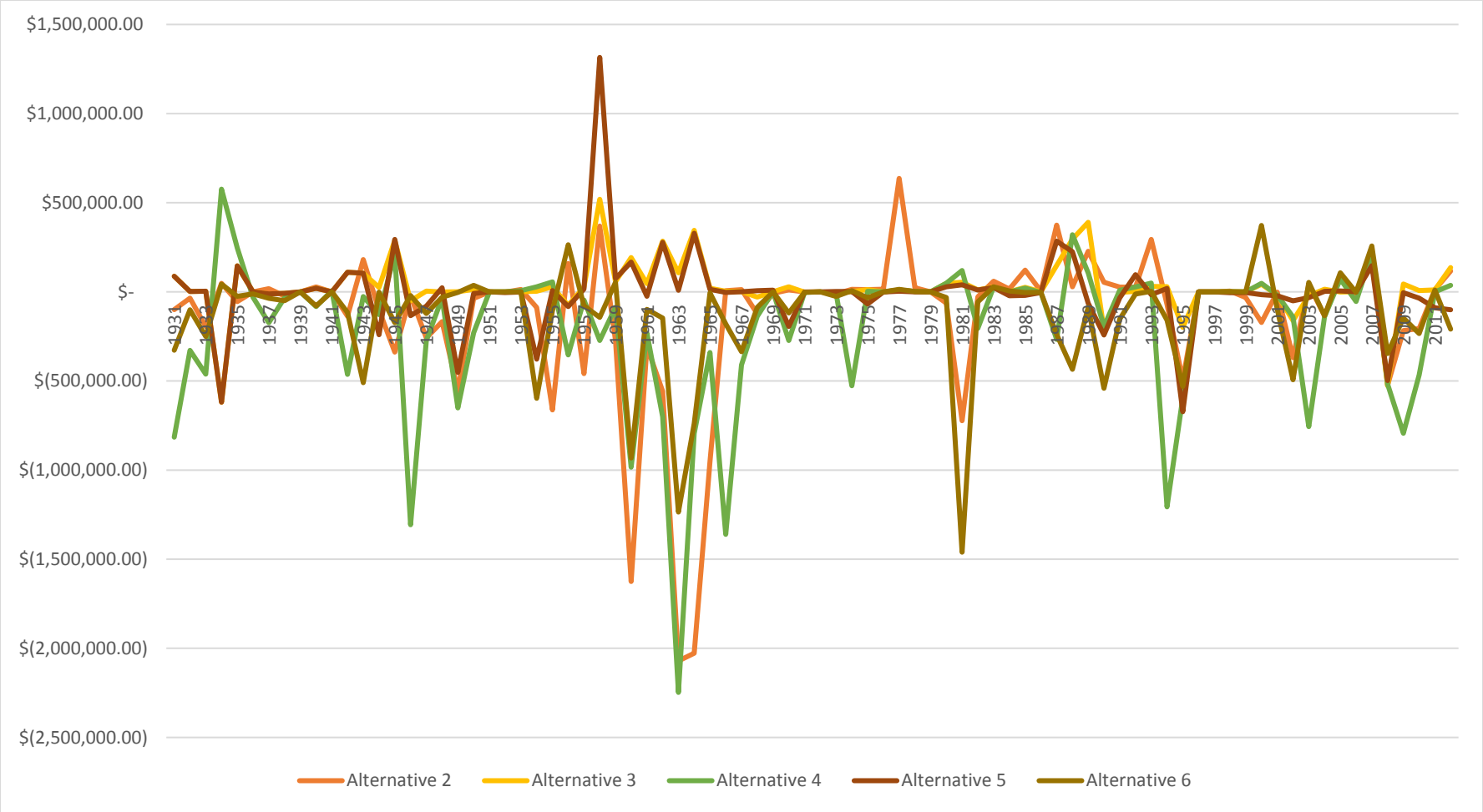

Figure 4. Change in Total Net Farm Income Relative to Alternative 1, All Counties (2016 Dollars)

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

Table 10 summarizes the NED analysis for Alternative 1. Overall, average annual net farm income for all counties would be over $5.9 million. Sully County would have the highest annual average net farm income of over $2 million. This would not be due to the high number of acres grown in the county but rather the relatively greater percentage of high valued crops (i.e., corn and soybeans) grown in that county compared to other counties evaluated. Conversely, the analysis showed that Williams County generates negative annual average net farm income of −$107,441. The results for Williams County are also likely driven by the crop mix grown in the county. Under Alternative 1, a negative net farm income does not imply a negative impact as a result of MRRMP implementation, but may reflect other factors such as relatively low pricing or the production of crops as an input for other industries such as livestock. (Akre 2016)

Table 10. Summary of National Economic Development Analysis for Alternative 1 (2016 Dollars)

	Benefit	Total Net Farm Income −POR	Average Annual Net Farm Income
Montana	McCone	$52,134,000	$636,000
	Valley	$17,432,000	$213,000
	Roosevelt	$50,121,000	$611,000
	Richland	$145,197,000	$1,771,000
North Dakota	Williams	−$8,810,000	−$107,000
	Mercer	$5,268,000	$64,000
	Emmons	$53,629,000	$654,000
South Dakota	Sully	$170,531,000	$2,080,000
	Total	$485,502,000	$5,921,000

Under Alternative 1, the highest variation in net farm income would be in Sully County, which would vary from $654,000 in drought years to $2.6 million during modeled years with greater access to water. The least amount of variation in net farm income would be in Valley County, which would vary from $58,000 during drought years to $239,000 during years of high water access. Based on the county location in the upper reaches of the river, it would not likely be as affected as much by changing conditions in the system as those counties further down river. For all eight counties, there would be lower net farm income during modeled years with drought conditions similar to those from 1930 to 1941, 1954 to 1961, 1987 to 1993, and 2000 to 2008.

5.2 Alternative 2 – USFWS 2003 Biological Opinion Projected Actions

Under Alternative 2, average annual net farm income would be approximately $5.8 million. Overall, the change in annual average net farm income relative to Alternative 1 would be fairly minimal, with a decrease of $136,000 under Alternative 2. Total net farm income over the POR would be $11 million lower for all eight counties relative to Alternative 1 (Table 11). This represents an overall decrease of 2.3 percent.

Table 11. Summary of National Economic Development Analysis for Alternative 2, 2016 Dollars

State	County	Total Net Farm Income	Change in Total Net Farm Income Relative to Alternative 1	Percent Change Relative to Alternative 1	Average Annual Net Farm Income	Change in Average Annual Net Farm Income Relative to Alternative 1
Montana	McCone	$52,103,000	−$30,000	−0.1%	$635,000	−$400
	Valley	$17,414,000	−$18,000	−0.1%	$212,000	−$200
	Roosevelt	$49,991,000	−$130,000	−0.3%	$610,000	−$2,000
	Richland	$145,106,000	−$90,000	−0.1%	$1,770,000	−$1,000
North Dakota	Williams	−$10,160,000	−$1,350,000	−15.3%	−$124,000	−$17,000
	Mercer	$4,858,000	−$409,000	−7.8%	$59,000	−$5,000
	Emmons	$50,188,000	−$3,441,000	−6.4%	$612,000	−$42,000
South Dakota	Sully	$164,847,000	−$5,684,000	−3.3%	$2,010,000	−$69,000
	Total*	$474,348,000	−$11,154,000	−2.3%	$5,785,000	−$136,000

* Note that 'total' here applies both to absolute figures (e.g., total net income over the POR) and relative figures (e.g., change in total net farm income relative to Alternative 1). For example, 'percent change relative to Alternative 1' is calculated by subtracting total net income under Alternative 2 from total net income under Alternative 1, and dividing the difference by the total net income under Alternative 1.

For all counties, the change in annual average net farm income relative to Alternative 1 would be negligible under Alternative 2. The change in average annual net income for all counties would be $136,000 with most of this decline occurring in Sully, Emmons, and Williams counties. Although Sully County would experience the largest overall decline in annual average net farm income relative to Alternative 1, the change amounts to only about three percent decline overall.

Figure 5 shows that for all counties the most adverse impacts would be experienced between 1955 and 1965, coinciding with a period of drought from 1954 to 1961. The figure also demonstrates that while several of those modeled years correspond to a partial release, there are multiple modeled years in the POR where a partial release would correspond to years of beneficial impact. The figure demonstrates that flow releases do not have a clear relationship to impacts on irrigation operations.

Under Alternative 2, most of the modeled years with the largest impacts to net farm income occur between 1960 and 1965. The largest decline in net farm income over Alternative 1 would occur in conditions similar to 1963, with a decline of $2.1 million. These impacts would be concentrated in the counties adjacent to Lake Oahe, and may be associated with a full pulse event similar to the one in 1958, which was followed by a moderate drought starting in 1959 and continuing until 1965. Under similar conditions, Lake Oahe would be five to eight feet lower under Alternative 2 than under Alternative 1, which would affect irrigation intakes ability to access water.

Another period of lower net farm income relative to Alternative 1 would occur between 1944 and 1950. A series of partial releases would begin in 1943 and repeat annually throughout this period. Emmons, Richland, Roosevelt, and Williams counties would all experience a decline in net farm income of $200,000 or greater during this period.

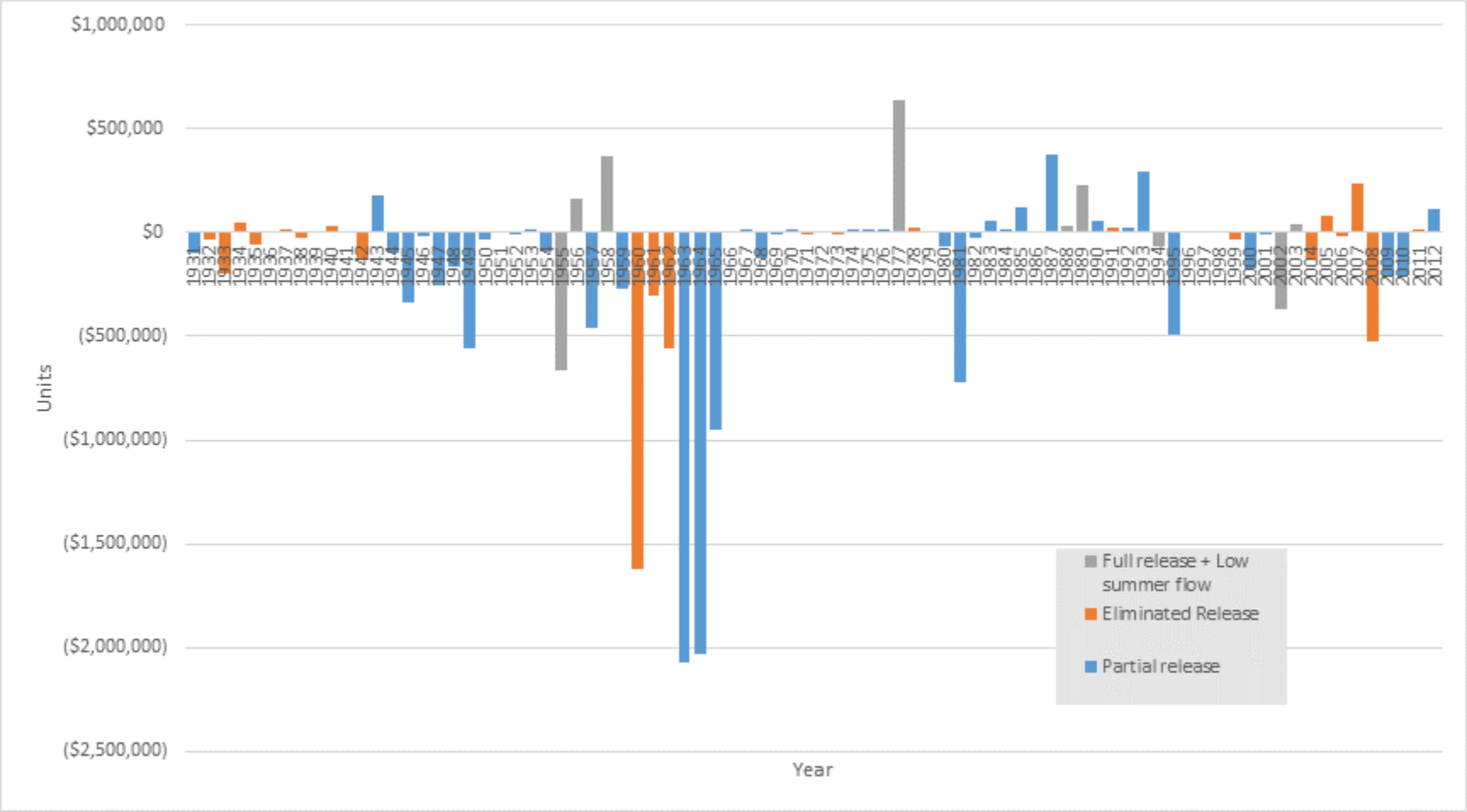

Figure 5. Annual Difference in Net Farm Income under Alternative 2 Relative to Alternative 1 (2016 Dollars)

5.3 Alternative 3 – Mechanical Construction Only

Under Alternative 3, average annual net farm income would be approximately $6.0 million. Overall, the change in annual average net farm income relative to Alternative 1 would be small, with an increase of $25,000. Total net farm income over the POR would be $2.1 million higher for all eight counties relative to Alternative 1 (Table 12); an increase of less than one percent. However, there would be modeled years when net farm income would decline under Alternative 3 relative to Alternative 1, although these losses would be small.

Table 12. Summary of National Economic Development Analysis for Alternative 3, 2016 Dollars

State	County	Total Net Farm Income	Change in Total Net Farm Income Relative to Alternative 1	Percent Change Relative to Alternative 1	Average Annual Net Farm Income	Change in Average Annual Net Farm Income Relative to Alternative 1
Montana	McCone	$52,053,000	−$81,000	−0.2%	$635,000	−$1,000
	Valley	$17,430,000	−$2,000	0.0%	$213,000	$0
	Roosevelt	$49,871,000	−$250,000	−0.5%	$608,000	−$3,000
	Richland	$144,853,000	−$344,000	−0.2%	$1,767,000	−$4,000
North Dakota	Williams	−$8,458,000	$353,000	4.0%	−$103,000	$4,000
	Mercer	$5,341,000	$73,000	1.4%	$65,000	$900
	Emmons	$54,827,000	$1,197,000	2.2%	$669,000	$15,000
South Dakota	Sully	$171,672,000	$1,141,000	0.7%	$2,094,000	$14,000
	Total*	$487,588,000	$2,087,000	0.4%	$5,946,000	$25,000

* Note that 'total' here applies both to absolute figures (e.g., total net income over the POR) and relative figures (e.g., change in total net farm income relative to Alternative 1). For example, 'percent change relative to Alternative 1' is calculated by subtracting total net income under Alternative 3 from total net income under Alternative 1, and dividing the difference by the total net income under Alternative 1.

The increase in net farm income for the eight counties evaluated would be driven by increases in North Dakota and South Dakota. In Montana, all counties would experience a very small decrease in net farm income, amounting to less than a one percent change in all cases.

Under Alternative 3, the most adverse impact would occur during drought conditions. However, overall, average annual net farm income would improve, relative to Alternative 1 (Table 12) under Alternative 3. The longest period of relative improvement would occur during drought conditions that, in other alternatives, coincide with flow events. In years when net farm income would be worse than Alternative 1, the impacts would not be expected to last longer than three years.

The increase in net farm income for the eight counties evaluated would be greatest in North Dakota and South Dakota. Williams County would experience the largest improvement in net farm income, relative to Alternative 1, with an increase of $4,300 in average annual net farm income. In Montana, all counties would experience a very small decrease in net farm income relative to Alternative 1, amounting to less than a one percent change in all cases. Roosevelt County would experience the largest decline in net farm income under Alternative 3, with a very small decrease of −$3,000 in average annual net farm income relative to Alternative 1.

Figure 6 shows the annual NED impacts to irrigation intakes for all counties over the entire POR. The figure shows a relatively large, positive difference for intakes between 1955 and 1965 relative to Alternative 1. During these conditions, net farm income would increase by as much as $519,000 relative to Alternative 1. Net farm income in Sully and Emmons Counties would be particularly beneficially impacted relative to Alternative 1 in this period. This is likely because there are no flow actions under Alternative 3, where under Alternative 1, flow actions begin in 1954 and last until 1970. Net farm income would similarly improve relative to Alternative 1 under conditions similar to those from 1942 and 1945, and from 1987 to 1989. The longest periods of relative improvement would occur during drought conditions that, in under other alternatives, coincide with flow events.

When net farm income would be worse under Alternative 3 relative to Alternative 1, the impacts would not last longer than three years. Under conditions similar to those between 2002 and 2004, net farm income would drop by $200,000 compared to Alternative 1, possibly due to elevated water levels in support of spawning cues that would occur under Alternative 1 and would ensure that farm irrigators would have access to water throughout the irrigation season.

Under Alternative 3, the most adverse impact would occur during conditions similar to those in 1934, when net farm income would be $619,000 lower than Alternative 1. The highest-single year decline in annual net farm income of $477,000 would be in Richland County. Roosevelt County, which is adjacent to Richland County, would also be adversely affected, with a decline in net farm income of $185,000 relative to Alternative 1. Flows between Fort Peck and Lake Sakakawea would decline sharply relative to Alternative 1 during conditions similar to those in July of 1934 and would remain low for the remainder of the growing season, which would result in lower net farm income in these counties.

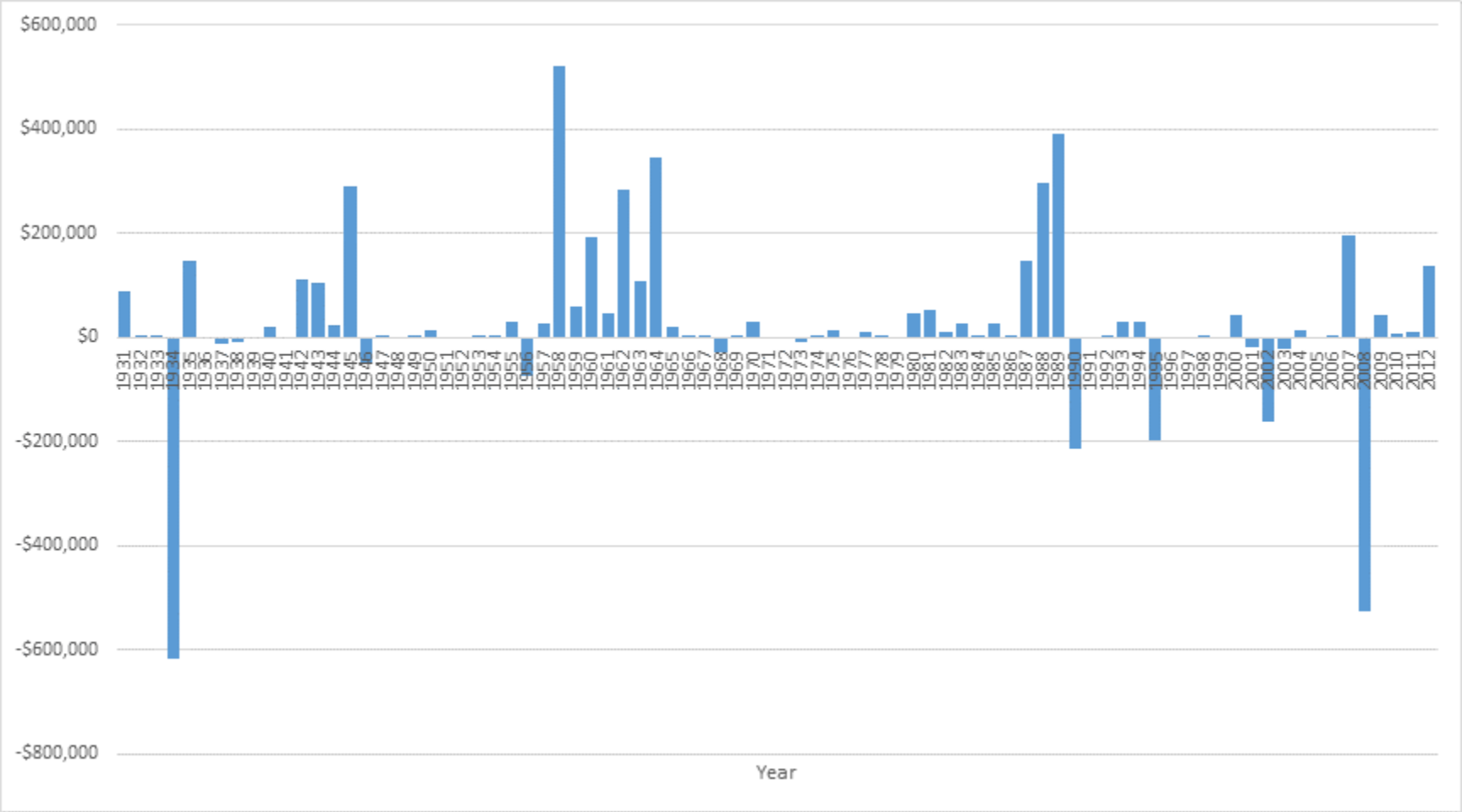

Figure 6. Annual Difference in Net Farm Income under Alternative 3 Relative to Alternative 1 (2016 Dollars)

5.4 Alternative 4 – Spring ESH Creating Release

Under Alternative 4, average annual net farm income for all counties would be approximately $5.7 million. For all counties, total net farm income would decline by $17.2 million relative to Alternative 1 over the entire POR, a decline of 3.5 percent. Average annual net farm income would decline by more than $209,000 for all counties evaluated. The NED results for Alternative 4 are summarized in Table 13. Every county along the river would experience a decline in total net farm income of at least $461,000 under this alternative. The largest decline would be in Williams County, ND, which would decline by $5 million (54 percent) relative to Alternative 1.

Table 13. Summary of National Economic Development Analysis for Alternative 4, 2016 Dollars

State	County	Total Net Farm Income	Change in Total Net Farm Income Relative to Alternative 1	Percent Change Relative to Alternative 1	Average Annual Net Farm Income	Change in Average Annual Net Farm Income Relative to Alternative 1
Montana	McCone	$50,950,000	−$1,184,000	−2.3%	$621,000	−$14,400
	Valley	$16,971,000	−$461,000	−2.6%	$207,000	−$6,000
	Roosevelt	$48,867,000	−$1,254,000	−2.5%	$596,000	−$15,000
	Richland	$143,749,000	−$1,448,000	−1.0%	$1,753,000	−$18,000
North Dakota	Williams	−$13,555,000	−$4,745,000	−53.9%	−$165,000	−$58,000
	Mercer	$4,440,000	−$827,000	−15.7%	$54,000	−$10,000
	Emmons	$50,907,000	−$2,722,000	−5.1%	$621,000	−$33,000
South Dakota	Sully	$165,982,000	−$4,550,000	−2.7%	$2,024,000	−$56,000
	Total*	$468,311,000	−$17,191,000	−3.5%	$5,711,000	−$210,000

* Note that 'total' here applies both to absolute figures (e.g., total net income over the POR and relative figures (e.g., change in total net farm income relative to Alternative 1). For example, 'percent change relative to Alternative 1' is calculated by subtracting total net income under Alternative 4 from total net income under Alternative 1, and dividing the difference by the total net income under Alternative 1.

Figure 7 shows the annual NED impacts to irrigation intakes for all counties. The graphic shows several periods of adverse impacts relative to Alternative 1. The largest declines in net farm income would occur in years with conditions similar to those from 1957 to 1963. Modeled results show that a full duration event tied to ESH creation in 1961, which was followed by prolonged drought conditions, would likely result in a decline in net farm income. In the years following the release, water levels would remain low, especially in Lake Oahe, while the system rebalances. The largest single-year decline in net income would occur in 1963 when total net farm income would be more than $2.3 million lower than would be the case under Alternative 1. This loss would be concentrated in Sully County where net farm income would be $1.2 million lower than the same year modeled under Alternative 1.

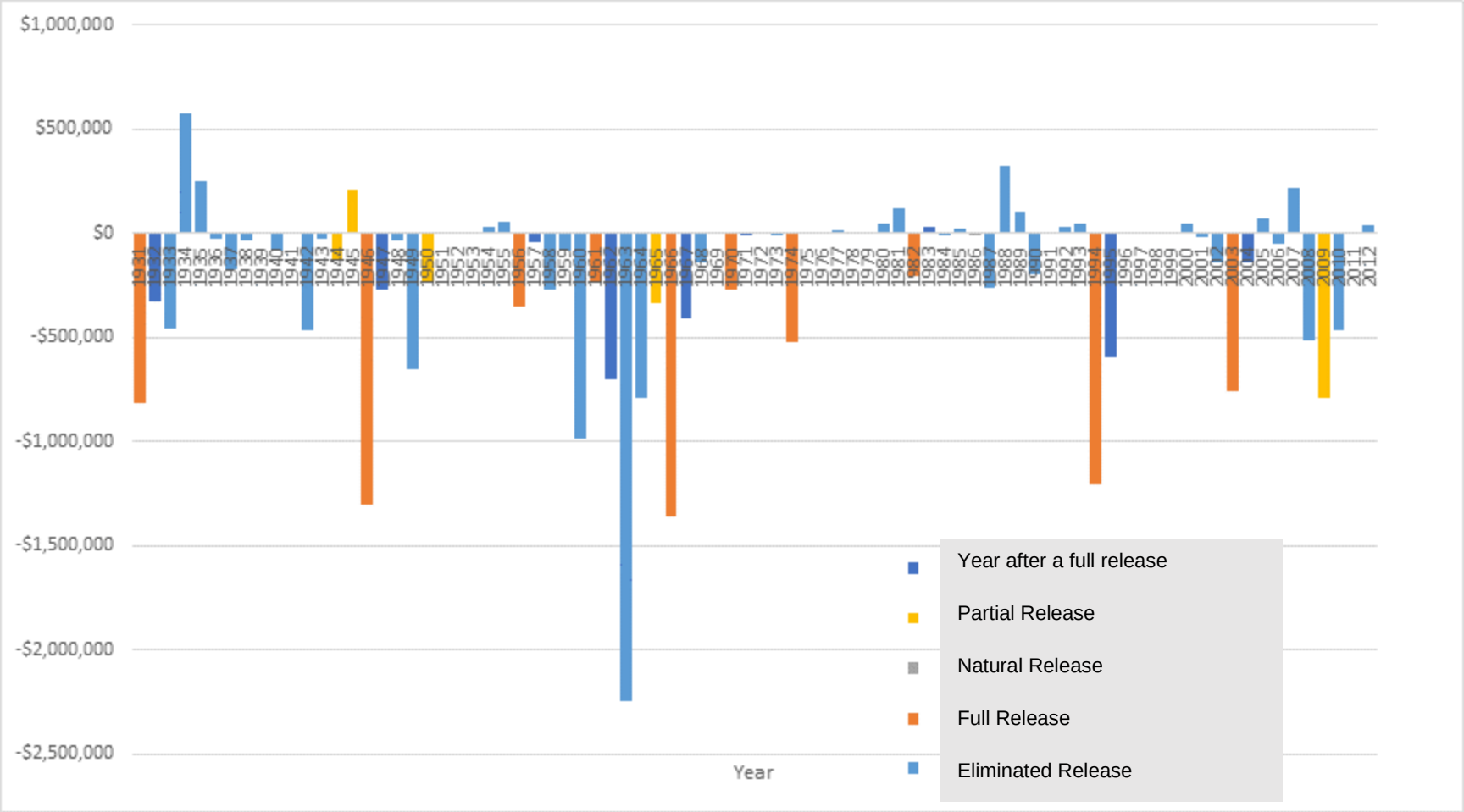

Figure 7. Annual Difference in Net Farm Income under Alternative 4 Relative to Alternative 1 (2016 Dollars)

There would also be a negative impact on net farm income during conditions similar to those between 1946 and 1950. Under these conditions, flows at Garrison Dam would spike during the spring release then fall for the remainder of the growing season. Downstream at Bismarck, North Dakota, flow levels would fall by nearly 10,000 cfs under conditions similar to those in 1946 relative to levels under Alternative 1. Flow levels would remain low for a number of modeled years before falling under conditions similar to those in 1950. Aside from Mercer and Valley counties, all counties would experience a decline in net farm income of at least $200,000 during this period.

Another long period of relative decline in net farm income compared to Alternative 1 would occur during drought conditions between 2001 and 2004. A full duration ESH release would cause reservoir elevations at Lake Sakakawea and Lake Oahe to sharply decline relative to Alternative 1. Starting in 2003, reservoir elevations would be ten feet lower than would be the case under Alternative 1. By about 2010, water levels would again reach the levels of Alternative 1 as the system rebalances. During this period, net farm income would decline by more than $1.0 million for all counties (Figure 7).

5.5 Alternative 5 – Fall ESH Creating Release

The NED results for Alternative 5 are summarized in Table 14. Average annual net farm income for all counties would be approximately $5.9 million. For all eight counties evaluated, annual average net farm income would decline by $4,000 relative to Alternative 1. Total net farm income would decrease by approximately $348,000 relative to Alternative 1 over the POR, or less than one percent. For Emmons and Sully, net farm income would increase by at least $630,000. Overall, the difference between net farm income under Alternative 5 and Alternative 1 would be negligible. Negative effects would be temporary, and would not last longer than two years.

Under Alternative 5, most of the counties evaluated would experience a decline in total net farm income relative to Alternative 1. The exception is Emmons and Sully counties which would experience a very slight increase in total net farm income relative to Alternative 1. Williams County would be the most adversely impacted under Alternative 5, with annual average net income falling by less than $14,000 relative to Alternative 1. The other counties would experience negligible impacts, with average annual net farm income declining by no more than three percent relative to Alternative 1.

The longest period of decline in net farm income relative to Alternative 1 would last for five years, similar to conditions between 1998 and 2003. However, this decline would be relatively small and would not exceed $51,000 for all counties relative to Alternative 1. Modeling results show that reservoir elevations at Lake Sakakawea would be lower than under Alternative 1 starting in conditions similar to 1997, which may be cause of these impacts. Under Alternative 5, there would be full duration flow events due to normal operations under conditions similar to 1996 and 1997 that are not present under Alternative 1.

Table 14. Summary of National Economic Development Analysis for Alternative 4, 2016 Dollars

State	County	Total Net Farm Income	Change in Total Net Farm Income Relative to Alternative 1	Percent Change Relative to Alternative 1	Average Annual Net Farm Income	Change in Average Annual Net Farm Income Relative to Alternative 1
Montana	McCone	$50,950,000	−$1,184,000	−2.3%	$621,000	−$14,400
	Valley	$16,971,000	−$461,000	−2.6%	$207,000	−$6,000
	Roosevelt	$48,867,000	−$1,254,000	−2.5%	$596,000	−$15,000
	Richland	$143,749,000	−$1,448,000	−1.0%	$1,753,000	−$18,000
North Dakota	Williams	−$13,555,000	−$4,745,000	−53.9%	−$165,000	−$58,000
	Mercer	$4,440,000	−$827,000	−15.7%	$54,000	−$10,000
	Emmons	$50,907,000	−$2,722,000	−5.1%	$621,000	−$33,000
South Dakota	Sully	$165,982,000	−$4,550,000	−2.7%	$2,024,000	−$56,000
	Total*	$468,311,000	−$17,191,000	−3.5%	$5,711,000	−$210,000

* Note that 'total' here applies both to absolute figures (e.g., total net income over the POR and relative figures (e.g., change in total net farm income relative to Alternative 1). For example, 'percent change relative to Alternative 1' is calculated by subtracting total net income under Alternative 4 from total net income under Alternative 1, and dividing the difference by the total net income under Alternative 1.

Under conditions similar to 1995, net farm income would decline the most, relative to Alternative 1, when net farm income for all eight counties would decline by $673,000. Reservoir levels at Lake Sakakawea would be very low during this period, but would return to Alternative 1 levels in the following year. This is likely the result of system rebalancing following a full duration flow event similar to what was modeled in 1994.

Figure 8 shows the annual NED impacts to irrigation intakes. The graph shows that irrigation intakes experience isolated years of negative impact, but only two instances in which adverse impacts last for longer than a single year. From 1957 to 1964, including a period of drought, all counties would experience beneficial impacts relative to Alternative 1. This is likely because there would be no flow actions under Alternative 5 during similar conditions to Alternative 1. The figure also demonstrates that full and partial releases are not having a direct adverse impact on intakes.

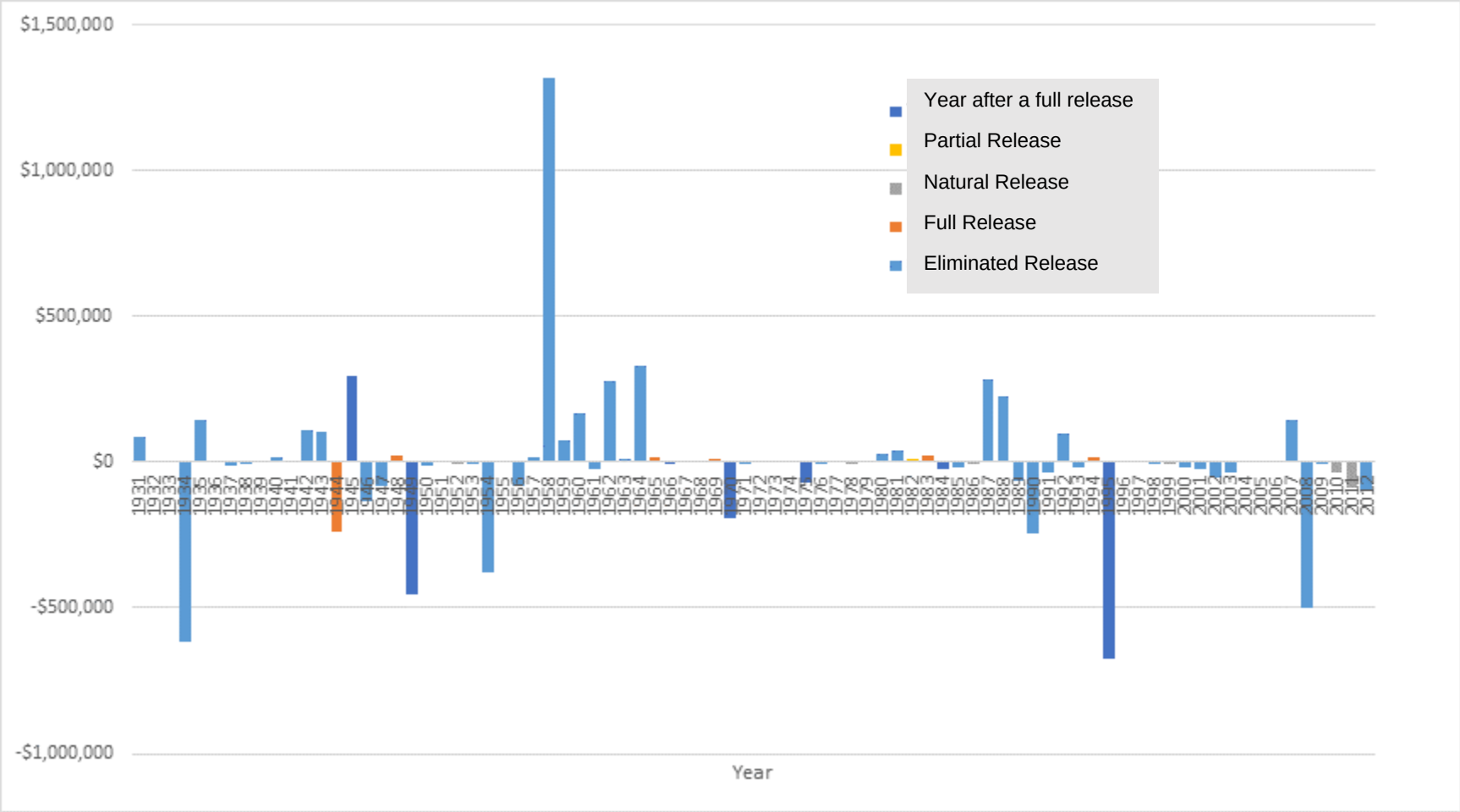

Figure 8. Annual Difference in Net Farm Income under Alternative 5 Relative to Alternative 1 (2016 Dollars)

5.6 Alternative 6 – Pallid Sturgeon Spawning Cue

The NED results for Alternative 6 are summarized in Table 15. Average annual net farm income for all counties would be $5.8 million, and would decline by $134,000 relative to Alternative 1. Under Alternative 6, total net farm income over the POR would be $11.0 million lower for all eight counties evaluated relative to Alternative 1, a decrease of 2.3 percent. Counties in South Dakota and North Dakota would experience the most adverse impacts under this alternative. Sully County would have the highest overall change in dollar value, relative to Alternative 1, with a decrease of $4.7 million in total net farm income. McCone and Valley would experience slight benefits over Alternative 1, though the increase in net income would amount to less than half a percent in both cases.

Table 15. Summary of National Economic Development Analysis for Alternative 5, 2016 Dollars

State	County	Total Net Farm Income	Change in Total Net Farm Income Relative to Alternative 1	Percent Change Relative to Alternative 1	Average Annual Net Farm Income	Change in Average Annual Net Farm Income Relative to Alternative 1
Montana	McCone	$52,109,000	−$25,000	0.0%	$635,000	−$300
	Valley	$17,419,000	−$13,000	−0.1%	$212,000	−$200
	Roosevelt	$49,984,000	−$137,000	−0.3%	$610,000	−$2,000
	Richland	$144,969,000	−$228,000	−0.2%	$1,768,000	−$3,000
North Dakota	Williams	−$9,924,000	−$1,114,000	−12.6%	−$121,000	−$14,000
	Mercer	$5,116,000	−$152,000	−2.9%	$62,000	−$2,000
	Emmons	$54,259,000	$630,000	1.2%	$662,000	$8,000
South Dakota	Sully	$171,223,000	$691,000	0.4%	$2,088,000	$8,000
	Total*	$485,154,000	−$348,000	−0.1%	$5,917,000	−$4,000

* Note that 'total' here applies both to absolute figures (e.g., total net income over the POR) and relative figures (e.g., change in total net farm income relative to Alternative 1). For example, 'percent change relative to Alternative 1' is calculated by subtracting total net income under Alternative 5 from total net income under Alternative 1, and dividing the difference by the total net income under Alternative 1.

Figure 9 shows the annual NED impacts to irrigation intakes. The graph shows several periods of decline in net farm income, relative to Alternative 1. In general, periods of decline in net farm income relative to Alternative 1 coincide with partial release events. However, in several of the modeled years when a release would be occurring, intakes realize an increase in total net farm income. The largest single decline in net farm income would occur in 1981, during a partial flow release.

Sully County would experience the largest single-year decline in net farm income of any county under Alternative 6 with a decline of $1.1 million under conditions similar to those in 1981. However, Sully County would be adversely impacted for only one year. This would be the largest single decline in net farm income for all counties, declining by $1.5 million relative to Alternative 1. Under Alternative 6, this impact would occur during a full duration release event similar to the one in 1981, which would result in water levels at Lake Oahe and downstream to be much lower than would be the case under Alternative 1, causing impacts to intakes in this county.

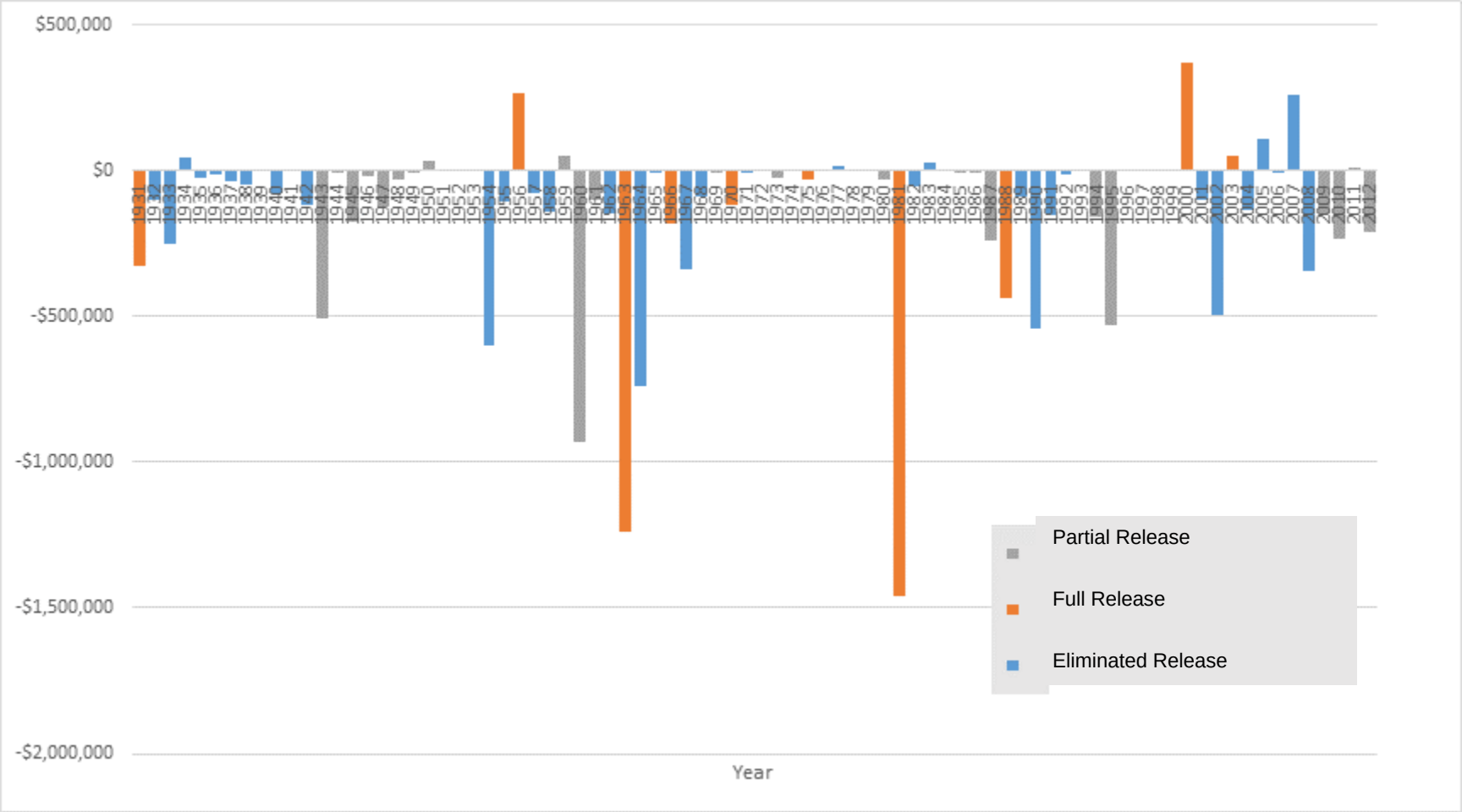

Figure 9. Annual Difference in Net Farm Income under Alternative 6 Relative to Alternative 1 (2016 Dollars)

The four counties in Montana—McCone, Richland, Roosevelt, and Valley—would be beneficially impacted under conditions similar to those between 2000 and 2007. Over the entire period, net farm income in these four counties would be $1.1 million higher than Alternative 1. The most beneficial impact would occur in Richland County in 2000 when net farm income would improve by $364,000 over Alternative 1. Partial duration events similar to those in 1997 to 1999 may have the effect of increasing water levels in conditions similar to 2000. Although March and May spawning cues would occur under conditions similar to 2000 under Alternative 6, net farm income would be higher in that year than under Alternative 1.

The longest period of decline under Alternative 6 would occur under conditions similar to those between 1954 and 1971, when net farm income would be adversely impacted relative to Alternative 1. Under similar conditions, the worst year modeled in that period would be 1963, when net income for the eight counties evaluated would be $1.2 million lower than is expected under Alternative 1. The lower net income would be expected under conditions similar to a March spawning cue release in 1956 and corresponding lower reservoir elevations at Lake Oahe.

Net farm income would also be adversely affected for eight years between 1943 and 1950 and eight years between 1986 and 1993. Other periods of lower income generally last between three and four years and the effects are generally small. Under Alternative 6, annual net farm income would be lower than Alternative 1 in 67 percent of the modeled years in the POR. However, in most years these differences are small.

In general, flow releases and partial flow releases modeled under Alternative 6 correspond somewhat to the year of greatest change (positive or negative) in net farm income. A full duration event that would occur in 1981 would also be the year of greatest decline in net farm income, relative to Alternative 1 (Figure 9). The year modeled of highest beneficial impact would occur in 2000 and corresponds to spawning cues scheduled for March and May. The same spawning cues are scheduled under Alternative 1. March spawning cues scheduled between 1996 and 1999 under Alternative 6 may account for the difference.

6.0 Regional Economic Development Analysis

The RED analysis focuses on changes in the distribution of economic activity at a local and regional scale. For irrigation, the RED analysis focused on the change in employment, income, and sales that would occur at the regional level for each of the MRRMP-EIS Alternatives. The RED impacts were estimated by examining changes in gross sales of crops grown using water from the Missouri River for irrigation purposes. The methodology and results are discussed in detail under this section.

6.1 Regional Economic Development Approach

The RED methodology built on the NED evaluation and focused on the change in gross sales of irrigated crops grown in the eight counties evaluated. The change in gross sales under each MRRMP-EIS alternatives relative to Alternative 1 were used to estimate change in regional economic activity measured by changes in employment, income, and sales. The analysis used the IMPLAN® Input-Output modeling system to describe the flow of dollars from purchasers to producers. For example, agriculture production requires support from farm equipment manufacturing and fertilizer producers. Every sale of a bushel of corn must also be accompanied by sales in these other industries. Furthermore, the labor required to produce a

bushel of corn also must be accompanied with those laborer's purchases of household items. A social accounting matrix (SAM) is used in IMPLAN® to model these inter-industry transactions, industry-institution (institutions include households), and inter-institution transactions. This essentially provides a picture of the study area economy and the response of the economy to an impact. The RED analysis developed a separate study area for each of the eight counties evaluated.

An external shock to a region can have a direct, indirect, and induced effect on the economy. Effects can be described as direct, indirect, and induced which are defined as follows:

- The direct effect includes the initial expenditures and production revenues made by the industry experiencing the economic change, much of which will be felt locally.
- Purchases made within the study area for goods and services required for production represents indirect effects.
- Induced effects include the local spending by employees, both in the directly affected and indirectly affected industries.

Economic impacts estimated with IMPLAN are reported on an annual basis. Because of the overwhelming number of calculations that would need to be run to estimate the RED impacts for eight counties over the POR, seven scenarios were developed that describe the range of RED impacts that can occur under each of the MRRMP-EIS Alternatives. Each of the scenarios was based on actual net sales calculated for each county under each alternative and are summarized in Table 16.

Table 16. Scenarios Considered in the Regional Economic Development Analysis

Scenario	Description
Average Annual Production Value	The average annual production value for each county for all years included in the POR by alternative.
Lowest Annual Production Value	The lowest annual production value achieved in each county in the POR by alternative.
Highest Annual Production Value	The highest annual production values achieved in each county during the POR for each alternative.
10th percentile	Annual production value equal to the 10th percentile of all annual production values observed for each county in the POR by alternative.
90th percentile	Annual production values equal to the 90th percentile of all annual production values observed during the POR by county by alternative.
Average Production Value for Eight Best Years	The average production value observed in the eight best years in the POR relative to Alternative 1.
Average Production Value for Eight Worst Years	The average production value observed in the eight worst years in the POR relative to the Alternative 1.

7.0 Regional Economic Development Results

The results in this section focus on changes in sales, labor income, and employment in each county associated with the MRRMP-EIS alternatives.

7.1 Summary of Regional Economic Development Results

The RED analysis for each alternative is summarized in Table 17. The table shows the total average annual employment, labor income, and sales for all eight counties. Across all alternatives, employment varies only by 2.3 jobs. Tables 18, 19, and 20 summarize these results for each of the eight counties included in the NED analysis. For all alternatives, the change in RED impacts relative to Alternative 1 are extremely small.

Table 17. Regional Economic Development Results by Alternative Based on Average Annual Production Values

Alternative	RED Results		
	Employment	Labor Income (1,000$)	Sales (1,000$)
Alternative 1	343.4	$10,489	$43,084
Alternative 2	341.3	$10,367	$42,912
Alternative 3	343.6	$10,503	$43,117
Alternative 4	341.3	$10,407	$42,807
Alternative 5	343.3	$10,487	$43,075
Alternative 6	342.3	$10,428	$42,910

Note: All dollar values are in 2016 dollars.

Table 18. Employment Results by Alternative

County	Type of Impact	Alt 1	Relative to Alternative 1				
			Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
McCone	Average Annual Value of Ag Production	29.1	0.0	0.0	−0.1	0.0	0.0
	Worst Year Production Value	27.8	0.0	−0.8	0.1	0.1	0.0
	Best Year Production Value	29.7	0.0	0.0	0.0	0.0	0.0
	Average Production Value for Eight Best Years	n/a	29.1	29.1	29.1	29.1	29.1
	Average Production Value for Eight Worst Years	n/a	28.5	28.5	28.5	28.5	28.5
Valley	Average Annual Value of Ag Production	9.7	0.0	0.0	−0.1	0.0	0.0
	Worst Year Production Value	8.3	−0.1	0.0	0.1	0.0	−0.1
	Best Year Production Value	9.9	0.0	0.0	0.0	0.0	0.0
	Average Production Value for Eight Best Years	n/a	9.7	9.7	9.7	9.7	9.7
	Average Production Value for Eight Worst Years	n/a	9.3	9.3	9.3	9.3	9.3

County	Type of Impact	Alt 1	Relative to Alternative 1				
			Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Roosevelt	Average Annual Value of Ag Production	67.4	0.0	0.0	−0.2	0.0	0.0
	Worst Year Production Value	58.8	0.5	−2.7	2.7	−2.7	0.5
	Best Year Production Value	69.2	0.0	0.0	0.0	0.0	0.0
	Average Production Value for Eight Best Years	n/a	67.0	67.0	67.0	67.0	67.0
	Average Production Value for Eight Worst Years	n/a	66.0	66.0	66.0	66.0	66.0
Richland	Average Annual Value of Ag Production	72.1	0.0	−0.1	−0.2	0.0	0.0
	Worst Year Production Value	59.0	−0.9	−6.0	3.7	−6.0	−0.8
	Best Year Production Value	74.6	0.0	0.0	0.0	0.0	0.0
	Average Production Value for Eight Best Years	n/a	73.1	73.1	73.1	73.1	73.1
	Average Production Value for Eight Worst Years	n/a	68.5	68.5	68.5	68.5	68.5
Williams	Average Annual Value of Ag Production	79.0	−0.2	0.1	−0.7	−0.2	−0.3
	Worst Year Production Value	69.6	−0.5	−0.6	−0.5	−0.6	−0.5
	Best Year Production Value	86.6	0.0	0.0	0.0	0.0	0.0
	Average Production Value for Eight Best Years	n/a	85.2	85.2	85.2	85.2	85.2
	Average Production Value for Eight Worst Years	n/a	77.4	77.4	77.4	77.4	77.4
Mercer	Average Annual Value of Ag Production	20.0	−0.1	0.0	−0.2	0.0	−0.1
	Worst Year Production Value	15.9	0.0	0.0	0.0	0.0	0.0
	Best Year Production Value	21.6	0.0	0.0	0.0	0.0	0.0
	Average Production Value for Eight Best Years	n/a	20.6	20.6	20.6	20.6	20.6
	Average Production Value for Eight Worst Years	n/a	18.6	18.6	18.6	18.6	18.6
Emmons	Average Annual Value of Ag Production	49.5	−0.5	0.2	−0.4	0.1	−0.5
	Worst Year Production Value	39.0	0.0	0.0	0.0	0.0	0.0
	Best Year Production Value	56.9	0.0	0.0	0.0	0.0	0.0
	Average Production Value for Eight Best Years	n/a	48.2	48.2	48.2	48.2	48.2
	Average Production Value for Eight Worst Years	n/a	44.6	44.6	44.6	44.6	44.6
Sully	Average Annual Value of Ag Production	22.0	−0.3	0.1	−0.2	0.0	−0.2
	Worst Year Production Value	16.2	0.0	0.0	0.0	0.0	0.0
	Best Year Production Value	24.4	0.0	0.0	0.0	0.0	0.0
	Average Production Value for Eight Best Years	n/a	19.4	19.4	19.4	19.4	19.4
	Average Production Value for Eight Worst Years	n/a	19.5	19.5	19.5	19.5	19.5

Table 19. Labor Income Results by Alternative, 2016 Dollars

County	Type of Impact	Alt 1	Relative to Alternative 1				
			Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
McCone	Average Annual Value of Ag Production	$399,735	−$45	−$119	−$1,730	−$36	$177
	Worst Year Production Value	$381,820	−$188	−$10,514	$767	$1,506	$502
	Best Year Production Value	$407,909	−$2	−$6	−$84	−$2	$9
	Average Production Value for Eight Best Years	n/a	$399,510	$399,510	$399,510	$399,510	$399,510
	Average Production Value for Eight Worst Years	n/a	$391,474	$391,474	$391,474	$391,474	$391,474
Valley	Average Annual Value of Ag Production	$205,618	−$42	−$6	−$1,081	−$30	$45
	Worst Year Production Value	$176,105	−$2,499	$421	$2,455	−$402	−$1,969
	Best Year Production Value	$211,412	$0	$0	−$1	$0	$0
	Average Production Value for Eight Best Years	n/a	$206,901	$206,901	$206,901	$206,901	$206,901
	Average Production Value for Eight Worst Years	n/a	$198,468	$198,468	$198,468	$198,468	$198,468
Roosevelt	Average Annual Value of Ag Production	$634,849	−$224	−$429	−$2,158	−$235	−$85
	Worst Year Production Value	$553,889	$4,249	−$25,494	$25,890	−$25,488	$4,544
	Best Year Production Value	$651,761	−$9	−$17	−$85	−$9	−$3
	Average Production Value for Eight Best Years	n/a	$631,097	$631,097	$631,097	$631,097	$631,097
	Average Production Value for Eight Worst Years	n/a	$621,560	$621,560	$621,560	$621,560	$621,560
Richland	Average Annual Value of Ag Production	$1,077,171	−$214	−$812	−$3,422	−$539	−$397
	Worst Year Production Value	$881,680	−$13,149	−$89,751	$55,281	−$89,742	−$12,055
	Best Year Production Value	$1,114,472	−$10	−$38	−$159	−$25	−$18
	Average Production Value for Eight Best Years	n/a	$1,091,904	$1,091,904	$1,091,904	$1,091,904	$1,091,904
	Average Production Value for Eight Worst Years	n/a	$1,023,521	$1,023,521	$1,023,521	$1,023,521	$1,023,521

County	Type of Impact	Alt 1	Relative to Alternative 1				
			Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Williams	Average Annual Value of Ag Production	$3,364,630	−$8,275	$2,161	−$29,084	−$6,828	−$13,461
	Worst Year Production Value	$2,964,678	−$19,739	−$26,017	−$21,008	−$26,038	−$19,751
	Best Year Production Value	$3,688,624	−$24	$6	−$86	−$20	−$39
	Average Production Value for Eight Best Years	n/a	$3,628,856	$3,628,856	$3,628,856	$3,628,856	$3,628,856
	Average Production Value for Eight Worst Years	n/a	$3,296,155	$3,296,155	$3,296,155	$3,296,155	$3,296,155
Mercer	Average Annual Value of Ag Production	$480,346	−$2,134	$380	−$4,312	−$792	−$2,222
	Worst Year Production Value	$382,157	−$10	$2	−$20	−$4	−$10
	Best Year Production Value	$517,653	−$13	$2	−$27	−$5	−$14
	Average Production Value for Eight Best Years	n/a	$494,693	$494,693	$494,693	$494,693	$494,693
	Average Production Value for Eight Worst Years	n/a	$445,592	$445,592	$445,592	$445,592	$445,592
Emmons	Average Annual Value of Ag Production	$1,815,820	−$17,308	$6,022	−$13,691	$3,166	−$18,259
	Worst Year Production Value	$1,428,349	$117	$21	$487	$11	$471
	Best Year Production Value	$2,084,027	−$89	$31	−$70	$16	−$94
	Average Production Value for Eight Best Years	n/a	$1,766,717	$1,766,717	$1,766,717	$1,766,717	$1,766,717
	Average Production Value for Eight Worst Years	n/a	$1,633,235	$1,633,235	$1,633,235	$1,633,235	$1,633,235
Sully	Average Annual Value of Ag Production	$2,510,582	−$32,715	$6,565	−$26,186	$3,979	−$26,971
	Worst Year Production Value	$1,846,625	−$148	$29	−$118	$18	−$122
	Best Year Production Value	$2,780,039	−$223	$44	−$178	$27	−$184
	Average Production Value for Eight Best Years	n/a	$2,209,980	$2,209,980	$2,209,980	$2,209,980	$2,209,980
	Average Production Value for Eight Worst Years	n/a	$2,226,296	$2,226,296	$2,226,296	$2,226,296	$2,226,296

Table 20. Sales Results by Alternative, 2016 Dollars Alternative 1

County	Type of Impact	Alt 1	Relative to Alternative 1				
			Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
McCone	Average Annual Value of Ag Production	$4,166,849	−$445	−$1,186	−$17,257	−$360	$1,766
	Worst Year Production Value	$3,980,102	−$1,942	−$109,546	$8,742	$15,711	$5,153
	Best Year Production Value	$4,252,053	−$2	−$5	−$77	−$2	$8
	Average Production Value for Eight Best Years	n/a	$4,164,522	$4,164,522	$4,164,522	$4,164,522	$4,164,522
	Average Production Value for Eight Worst Years	n/a	$4,080,756	$4,080,756	$4,080,756	$4,080,756	$4,080,756
Valley	Average Annual Value of Ag Production	$1,470,617	−$300	−$41	−$7,726	−$217	$323
	Worst Year Production Value	$1,259,534	−$17,871	$3,009	$17,562	−$2,872	−$14,081
	Best Year Production Value	$1,512,058	$0	$0	$0	$0	$0
	Average Production Value for Eight Best Years	n/a	$1,479,793	$1,479,793	$1,479,793	$1,479,793	$1,479,793
	Average Production Value for Eight Worst Years	n/a	$1,419,479	$1,419,479	$1,419,479	$1,419,479	$1,419,479
Roosevelt	Average Annual Value of Ag Production	$5,937,219	−$2,020	−$3,879	−$19,489	−$2,127	−$769
	Worst Year Production Value	$5,180,065	$39,805	−$238,313	$242,761	−$238,307	$42,519
	Best Year Production Value	$6,095,381	−$9	−$18	−$88	−$10	−$3
	Average Production Value for Eight Best Years	n/a	$5,902,193	$5,902,193	$5,902,193	$5,902,193	$5,902,193
	Average Production Value for Eight Worst Years	n/a	$5,813,004	$5,813,004	$5,813,004	$5,813,004	$5,813,004
Richland	Average Annual Value of Ag Production	$7,800,139	−$1,482	−$5,627	−$23,720	−$3,738	−$2,751
	Worst Year Production Value	$6,384,525	−$95,164	−$649,734	$401,226	−$649,731	−$87,198
	Best Year Production Value	$8,070,247	−$3	−$13	−$56	−$9	−$6
	Average Production Value for Eight Best Years	n/a	$7,906,891	$7,906,891	$7,906,891	$7,906,891	$7,906,891

County	Type of Impact	Alt 1	Relative to Alternative 1				
			Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
	Average Production Value for Eight Worst Years	n/a	$7,411,701	$7,411,701	$7,411,701	$7,411,701	$7,411,701
Williams	Average Annual Value of Ag Production	$10,011,949	−$24,588	$6,420	−$86,419	−$20,290	−$39,997
	Worst Year Production Value	$8,821,833	−$58,706	−$77,426	−$62,404	−$77,455	−$58,723
	Best Year Production Value	$10,976,040	−$33	$9	−$118	−$28	−$54
	Average Production Value for Eight Best Years	n/a	$10,798,229	$10,798,229	$10,798,229	$10,798,229	$10,798,229
	Average Production Value for Eight Worst Years	n/a	$9,808,226	$9,808,226	$9,808,226	$9,808,226	$9,808,226
Mercer	Average Annual Value of Ag Production	$1,629,992	−$7,202	$1,283	−$14,554	−$2,673	−$7,501
	Worst Year Production Value	$1,296,799	−$3	$1	−$6	−$1	−$3
	Best Year Production Value	$1,756,586	−$4	$1	−$8	−$1	−$4
	Average Production Value for Eight Best Years	n/a	$1,678,716	$1,678,716	$1,678,716	$1,678,716	$1,678,716
	Average Production Value for Eight Worst Years	n/a	$1,512,092	$1,512,092	$1,512,092	$1,512,092	$1,512,092
Emmons	Average Annual Value of Ag Production	$5,877,867	−$55,768	$19,403	−$44,115	$10,203	−$58,832
	Worst Year Production Value	$4,623,613	$585	−$3	$1,738	−$1	$1,740
	Best Year Production Value	$6,746,062	$11	−$4	$9	−$2	$11
	Average Production Value for Eight Best Years	n/a	$5,719,174	$5,719,174	$5,719,174	$5,719,174	$5,719,174
	Average Production Value for Eight Worst Years	n/a	$5,287,067	$5,287,067	$5,287,067	$5,287,067	$5,287,067
Sully	Average Annual Value of Ag Production	$6,189,425	−$80,196	$16,094	−$64,192	$9,753	−$66,116
	Worst Year Production Value	$4,552,550	−$26	$5	−$21	$3	−$21
	Best Year Production Value	$6,853,728	−$39	$8	−$31	$5	−$32
	Average Production Value for Eight Best Years	n/a	$5,448,746	$5,448,746	$5,448,746	$5,448,746	$5,448,746

County	Type of Impact	Alt 1	Relative to Alternative 1				
			Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
	Average Production Value for Eight Worst Years	n/a	$5,488,975	$5,488,975	$5,488,975	$5,488,975	$5,488,975

7.2 Alternative 1 – No Action (Current System Operation and MRRP Management Actions

The RED analysis for Alternative 1 was focused on employment, labor income, and sales generated from irrigated agriculture in the eight counties being evaluated. Table 21 summarizes the economic impacts for all counties. Under Alternative 1, irrigated agriculture would provide 343 jobs per year on average for all counties, $10 million in labor income, and $43 million in sales. The number of jobs supported on average annually would be highest in Williams County, with 77.7 jobs (Table 18). Average annual labor income would be highest in Williams County at $3.4 million.[3] Average annual sales would also be highest in Williams County at $9.9 million per year. Average annual labor income and sales would be lowest in Valley County at $205,000 and $1.5 million, respectively. Total employment would vary from 77 jobs from the worst year to the best year.

Table 21. Regional Economic Development Effects for Irrigated Agriculture Using Missouri River Water: Alternative 1

Economic Impact	Scenario	Results
Employment	Average Annual	343.4
	Best Year	367.0
	Worst Year	290.0
Labor Income	Average Annual	$10,489,000
	Best Year	$11,277,000
	Worst Year	$8,481,000
Total Sales	Average Annual	$43,084,000
	Best Year	$45,541,000
	Worst Year	$35,536,000

Note: All dollar values are reported in 2016 dollars.

7.3 Alternative 2 – USFWS 2003 Biological Opinion Projected Actions

Relative to Alternative 1, RED impacts to employment, labor income, and sales would be negligible under Alternative 2 (Table 22). For all eight counties evaluated employment would change on average by 1.1 jobs per year. Under the eight worst years when the value of production would decline, total job losses across all eight counties would be 14 and labor income would decline by $613,000.

Sully County and Emmons County would account for much of the change in sales, employment, and labor income. For instance, of the approximately $61,000 loss in average annual labor income, Sully County would account for over half of this loss, while Emmons would account for another 27 percent of the decline. The least affected county would be Valley County, with

[3] In considering this labor income impact, it is worth noting that labor income is calculated based on sales, which do not account for the cost of production.

virtually no change in jobs, employment, or sales relative to Alternative 1 (Tables 18, 19, and 20).

Table 22. Regional Economic Development Impacts of Alternative 2 Relative to Alternative 1

Economic Impact	Scenario	Results
Change in Jobs from Alternative 1	Average Annual Value of Production	342.4
	Change in Average Annual Value of Production from Alternative 1	−1.1
	Average of eight largest increase years relative Alternative 1	7.1
	Average of eight largest decrease years relative Alternative 1	−14.0
Change in Labor Income from Alternative 1	Average Annual Value of Production	$10,265,000
	Change in Average Annual Value of Production from Alternative 1	−$224,000
	Average of eight largest increase years relative Alternative 1	$193,000
	Average of eight largest decrease years relative Alternative 1	−$613,000
Change in Sales from Alternative 1	Average Annual Value of Production	$42,243,000
	Change in Average Annual Value of Production from Alternative 1	−$841,000
	Average of eight largest increase years relative Alternative 1	$864,000
	Average of eight largest decrease years relative Alternative 1	−$2,038,000

Note: All dollar values are reported in 2016 dollars.

7.4 Alternative 3 – Mechanical Construction Only

Alternative 3 would have negligible RED impacts relative to Alternative 1. Half of the counties in this analysis experience small, beneficial impacts in economic activity, while the other half experience small, adverse impacts. During the worst eight years modeled, relative to Alternative 1, the total number of jobs for all eight counties would decrease by almost four, and labor income would decline by $70,000 (Table 23). The most adversely impacted county would be Richland, where average annual labor income would be $775 lower when compared to Alternative 1 (Table 19). For the other counties, there would be a change of less than $3,000 dollars in labor income, on average. None of the counties would experience a change in average annual employment of more than one job (Table 18).

Table 23. Regional Economic Development Impacts of Alternative 3 Relative to Alternative 1

Economic Impact	Scenario	Results
Change in Jobs from Alternative 1	Average Annual Value of Production	343.6
	Change in Average Annual Value of Production from Alternative 1	0.2
	Average of eight largest increase years over Alternative 1	4.8
	Average of eight largest decrease years over Alternative 1	−3.8
Change in Labor Income from Alternative 1	Average Annual Value of Production	$10,339,000
	Change in Average Annual Value of Production from Alternative 1	$14,000
	Average of eight largest increase years over Alternative 1	$169,000
	Average of eight largest decrease years over Alternative 1	−$70,000
Change in Sales from Alternative 1	Average Annual Value of Production	$42,445,000
	Change in Average Annual Value of Production from Alternative 1	$32,000

	Average of eight largest increase years over Alternative 1	$640,000
	Average of eight largest decrease years over Alternative 1	−$428,000

Note: All dollar values are reported in 2016 dollars.

7.5 Alternative 4 – Spring ESH Creating Release

All eight counties experience small, temporary, and adverse RED impacts under Alternative 4. On average the change in economic activity would lead to a decline in annual employment of two jobs and a reduction in labor income of $81,000 across all eight counties (Table 24). During the worst eight years, labor income would be $646,000 lower than Alternative 1, and the number of jobs would decline by more than 17. Williams County would experience the largest total decline in jobs, labor income, and sales relative to Alternative 1 (Tables 18, 19, and 20). In Williams County, average annual employment would decline by nearly one job, average annual labor income would decline by $29,000, and average annual sales would decline by $86,000.

Table 24. Regional Economic Development Impacts of Alternative 4 Relative to Alternative 1

Economic Impact	Scenario	Results
Change in Jobs from Alternative 1	Average Annual Value of Production	341.3
	Change in Average Annual Value of Production from Alternative 1	−2.0
	Average of eight largest increase years over Alternative 1	5.2
	Average of eight largest decrease years over Alternative 1	−17.3
Change in Labor Income from Alternative 1	Average Annual Value of Production	$10,245,000
	Change in Average Annual Value of Production from Alternative 1	−$81,000
	Average of eight largest increase years over Alternative 1	$111,000
	Average of eight largest decrease years over Alternative 1	−$646,000
Change in Sales from Alternative 1	Average Annual Value of Production	$42,139,000
	Change in Average Annual Value of Production from Alternative 1	−$277,000
	Average of eight largest increase years over Alternative 1	$602,000
	Average of eight largest decrease years over Alternative 1	−$2,321,000

Note: All dollar values are reported in 2016 dollars.

7.6 Alternative 5 – Fall ESH Creating Release

RED impacts under Alternative 5 are negligible in all counties (Table 25). On average, employment would decline by less than one job for all counties. Economic activity in some counties would improve under Alternative 5, though these changes would be small relative to Alternative 1. During the worst eight years modeled relative to Alternative 1, labor income would decline by $172,000 with a decline of nearly seven jobs. Sully County would experience the most substantial benefit relative to Alternative 1, with an increase in average annual labor income of $4,000 relative to Alternative 1 (Table 19). Williams County would experience the most adverse impacts in terms of total RED impact, with a decline in average annual employment of less than one job relative to Alternative 1, a decline in average annual labor income of $6,800, and a decline in sales of approximately $20,000 (Tables 18, 19, and 20). No other county would experience a decline of more than $1,000 in average annual labor income or a decline in average annual sales of more than $4,000.

Table 25. Regional Economic Development Impacts of Alternative 5 Relative to Alternative 1

Economic Impact	Scenario	Results
Change in Jobs from Alternative 1	Average Annual Value of Production	343.3
	Change in Average Annual Value of Production from Alternative 1	−0.1
	Average of eight largest increase years over Alternative 1	5.9
	Average of eight largest decrease years over Alternative 1	−6.8
Change in Labor Income from Alternative 1	Average Annual Value of Production	$10,324,000
	Change in Average Annual Value of Production from Alternative 1	−$1,000
	Average of eight largest increase years over Alternative 1	$166,000
	Average of eight largest decrease years over Alternative 1	−$172,000
Change in Sales from Alternative 1	Average Annual Value of Production	$42,403,000
	Change in Average Annual Value of Production from Alternative 1	−$9,000
	Average of eight largest increase years over Alternative 1	$742,000
	Average of eight largest decrease years over Alternative 1	−$800,000

Note: All dollar values are reported in 2016 dollars.

7.7 Alternative 6 – Pallid Sturgeon Spawning Cue

RED impacts under Alternative 6 are negligible for all counties relative to the Alternative 1. On average, employment would be reduced by 1.1 jobs for all counties under Alternative 6 relative to Alternative 1 (Table 26). During the worst eight years modeled relative to Alternative 1, employment would decrease by 12 jobs across all eight counties and labor income by $500,000. The largest impacts would occur in Sully, Emmons, and Williams counties, which would experience a decline of at least $13,000 in labor income (Table 19). However, average annual employment would decline by less than one job in these counties (Table 18). Sully County would be the most adversely affected, in terms of total RED impact, with a decline of $27,000 in labor income and a loss of less than one job. McCone and Valley Counties would experience slight beneficial impacts under this alternative, with average annual labor income increasing by a few hundred dollars relative to Alternative 1.

Table 26. Regional Economic Development Impacts of Alternative 6 Relative to Alternative 1

Economic Impact	Scenario	Results
Change in Jobs from Alternative 1	Average Annual Value of Production	342.3
	Change in Average Annual Value of Production from Alternative 1	−1.1
	Average of eight largest increase years over Alternative 1	4.2
	Average of eight largest decrease years over Alternative 1	−12.0
Change in Labor Income from Alternative 1	Average Annual Value of Production	$10,265,000
	Change in Average Annual Value of Production from Alternative 1	−$61,000
	Average of eight largest increase years over Alternative 1	$67,000
	Average of eight largest decrease years over Alternative 1	−$500,000

Economic Impact	Scenario	Results
Change in Sales from Alternative 1	Average Annual Value of Production	$42,241,000
	Change in Average Annual Value of Production from Alternative 1	−$174,000
	Average of eight largest increase years over Alternative 1	$474,000
	Average of eight largest decrease years over Alternative 1	−$1,680,000

8.0 Other Social Effects

The OSE analysis for irrigation relied on the results of the NED and RED analysis to determine the scale of impacts that could occur to individual and community well-being, traditional ways of life, and economic vitality. A qualitative discussion of the OSE impacts on irrigation operations is provided in Chapter 3 of the MRRMP-EIS.

9.0 Environmental Quality Methodology

This account was not evaluated for irrigation operations.

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