



Investigation and Analyses Report for the Lower Bear River Watershed Project

Appendix D

Lower Bear River Watershed
Box Elder County, Utah

The purpose of the Investigation and Analysis Appendix is to present information that supports the formulation, evaluation, and conclusions of the Watershed Plan–Environmental Impact Statement (EIS).

March 2026

TABLE OF CONTENTS

TABLE OF TABLES.....II

TABLE OF FIGURES.....II

D.1.0 INTRODUCTION1

 D.1.1 AGRICULTURAL WATER MANAGEMENT1

 D.1.2 WATERSHED PROTECTION.....1

D.2.0 DESIGN AND CRITERIA2

D.3.0 AGRICULTURAL WATER MANAGEMENT AND WATERSHED PROTECTION ANALYSIS3

 D.3.1 AGRICULTURAL WATER MANAGEMENT HYDROLOGIC AND HYDRAULIC ANALYSIS.....4

 D.3.2 WATERSHED PROTECTION ANALYSIS6

 D.3.2.1 *Levee Improvements*6

 D.3.2.2 *Sediment Basin*.....7

D.4.0 ALTERNATIVES AND ECOSYSTEM SERVICE EVALUATED8

 D.4.1 ALTERNATIVES8

 D.4.1.1 *Proposed Project Measures and Formulation*8

 D.4.1.2 *Alternatives Evaluated*8

 D.4.2 ECOSYSTEM SERVICES.....11

 D.4.2.1 *Types of Ecosystem Services Impacted*.....11

 D.4.2.2 *Ecosystem Services Flow*12

 D.4.2.3 *Prioritizing Ecosystem Services*.....13

 D.4.2.4 *Ability to Characterize, Quantify, and Monetize Ecosystem Services*.....13

 D.4.2.5 *Metrics to Evaluate Ecosystem Services*.....13

 D.4.2.6 *Summary and Comparison of Ecosystem Service Changes*14

D.5.0 BENEFIT-COST ANALYSIS DATA AND METHODOLOGY.....14

 D.5.1 PROJECT ECOSYSTEM SERVICES BENEFITS14

 D.5.1.1 *Reduced Farm Income (Agricultural) Damages*.....14

 D.5.1.2 *Reduced Water Treatment Costs*18

 D.5.1.3 *Reduced Damage to Wetlands*.....20

 D.5.1.4 *Increased Farm Income from Use of Conserved Water*.....25

 D.5.2 PROJECT COSTS.....27

 D.5.2.1 *Preferred Alternative Costs*28

 D.5.2.2 *Installation Costs*.....28

 D.5.2.3 *Other Direct Costs & Adverse Effects*28

Once the works of improvement are28

 D.5.2.4 *Current Economic Damages*29

 D.5.3 ECONOMIC AND STRUCTURAL TABLES.....30

D.6.0 SOURCES.....31

Table of Tables

TABLE 3-1. TECHNICAL MEMORANDA BY NUMBER, NAME, AND KEY INFORMATION CONTENT	3
TABLE 4-1. COMPARISON OF INITIAL MEASURES AND COMPATIBILITY	9
TABLE 4-2. WORKS OF IMPROVEMENT PROPOSED AS PART OF THE LOWER BEAR RIVER WATERSHED PLAN-EIS, UTAH	10
TABLE 5-1. CROPS GROWN IN BEAR RIVER CANAL COMPANY SERVICE AREA, BY ACRE	16
TABLE 5-2. MODELED ACRES OF CROPLAND IMPACTED BY CANAL FAILURES BY CROP TYPE ON THE BRCC SYSTEM	16
TABLE 5-3. CROP YIELDS, GROSS REVENUES, AND EXPECTED LOSSES OF MAIN CROPS GROWN IN BRCC SERVICE AREA UNDER SUPPLY CANAL FAILURES	17
TABLE 5-4. CROP YIELDS, GROSS REVENUES, AND EXPECTED DAMAGES OF MAIN CROPS GROWN IN BRCC SERVICE AREA UNDER SUPPLY CANAL AND FLUME FAILURES	17
TABLE 5-5. CHANGE IN EXPECTED ANNUAL DAMAGES (WITH-PROJECT CONDITION)	18
TABLE 5-6. WATER RATES FOR BEAR RIVER CITY	18
TABLE 5-7. WATER RATES FOR TREMONTON	19
TABLE 5-8. ANNUAL WATER TREATMENT COST SAVINGS (WITH-PROJECT VS. WITHOUT-PROJECT)	20
TABLE 5-9. ANNUAL PROBABILITY OF LEVEE FAILURES IN LOWER BEAR RIVER WATERSHED	21
TABLE 5-10. ACRES OF WETLAND, WETLAND ACRES CURRENTLY INVADDED BY PHRAGMITES, AND WETLAND AREA THAT WOULD BE INVADDED BY PHRAGMITES UNDER THE FWOFI	22
TABLE 5-11. ACRES OF WETLAND DAMAGED BY INVASIVE SPECIES AND INVASIVE SPECIES MANAGEMENT COSTS UNDER THE FWOFI	22
TABLE 5-12. NATIONAL AVERAGE BENEFIT VALUE PER ACRE FOR INDIVIDUAL WETLAND ECOSYSTEM SERVICES PRODUCED BY WETLAND MITIGATION (2025 DOLLARS)	23
TABLE 5-13. EXPECTED ANNUAL DAMAGES FROM LEVEE FAILURES IN LOWER BEAR RIVER WATERSHED (2025 DOLLARS)	24
TABLE 5-14. ANNUAL WETLAND DAMAGE REDUCTION (WITH-PROJECT VS. WITHOUT-PROJECT)	24
TABLE 5-15. AVERAGE YIELD, CROP WATER REQUIREMENT, CROP PRODUCTION FUNCTION, AND ADDITIONAL CROP YIELD FOR HAY IN THE BENEFIT-COST ANALYSIS	25
TABLE 5-16. MARGINAL PRODUCTION COSTS FOR IRRIGATED HAY USED IN THE BENEFIT-COST ANALYSIS (2025 DOLLARS)	26
TABLE 5-17. NORMALIZED PRICES, GROSS REVENUES, GROSS COSTS, AND NET OPERATING INCOME FOR HAY GROWN IN THE LOWER BEAR RIVER WATERSHED (2025 DOLLARS)	27
TABLE 5-18. ANNUALIZED INCREASED FARM INCOME FROM CONSERVED WATER (WITH-PROJECT VS. WITHOUT-PROJECT)	27
TABLE 5-19. PREFERRED ALTERNATIVE CAPITAL COST ESTIMATE	28
TABLE 5-20. ESTIMATED CONSTRUCTION AND ANNUAL OPERATIONS, MAINTENANCE, AND REPAIR COSTS FOR WORKS OF IMPROVEMENT INCLUDED IN THE PREFERRED ALTERNATIVE (2025 DOLLARS)	28
TABLE 5-21. AVERAGE ANNUALIZED DAMAGES UNDER THE FWOFI (2025 DOLLARS)	29

Table of Figures

FIGURE 1. ECOSYSTEM SERVICES OF THE ACTION ALTERNATIVES	13
---	----

D.1.0 Introduction

This document summarizes the investigations and analysis completed for the planning and engineering for agricultural water management and watershed protection in preparation for the Lower Bear River Watershed Plan–Environmental Impact Statement (Plan-EIS). This information includes a summary of the design and criteria, agricultural water management, and watershed protection analysis, alternatives and ecosystem services evaluated, the benefit-cost analysis data and methodology, and information sources.

Multiple analyses were completed for the Proposed Project, from which this document draws much of its content, and the complete analyses can be found in Appendix E1 of the Plan-EIS. Of note, J-U-B ENGINEERS, Inc. (J-U-B) prepared two Technical Memoranda (TM): TM-001 Agricultural Water Management and TM-002 Watershed Protection, and BBC Research & Consulting prepared the Lower Bear River Watershed Plan–Environmental Impact Statement National Economic Efficiency Benefit–Cost Analysis of Alternatives (Benefit-cost Analysis [BCA]). Additional information relevant to each of the sections provided in this report is available in the Plan-EIS, Appendix E1, and as part of the administrative record for the project.

The Lower Bear River Watershed Project (Proposed Project) is located within the Lower Bear River Watershed in the vicinity of Fielding, Garland, Tremonton, Elwood, Bear River City, and unincorporated areas of Box Elder County, Utah. The Proposed Project consists of two project purposes: agricultural water management and watershed protection.

D.1.1 Agricultural Water Management

One of the purposes of the Proposed Project is to improve irrigation efficiency and water conservation and to maintain and enhance environmental conditions and beneficial water use in the form of instream flows for the shareholders in the Bear River Canal Company (BRCC) service area and the larger Lower Bear River Watershed, with the authorized purpose being Agricultural Water Management (rural and agricultural water supply, irrigation, water conservation, and water quality improvement).

The existing agricultural water delivery system is aging, deteriorating, and in need of optimization and modernization. Each of the repair, enclosure, and replacement projects are necessary to increase the safety, efficiency, and reliability of the delivery system to secure the agricultural water supply and develop secondary water systems for growing communities with limited water resources. The aging infrastructure is at risk of failure in many locations and is decreasing the efficiency of the irrigation supply. Over the last few decades many hillside failures in the canyon below Cutler Reservoir have hindered the ability of BRCC to deliver water through the two main canals that support the 65,500 acres of agricultural land. The two canals in the canyon supply essentially all the agricultural water in the watershed. Improvements to these two canals would improve the reliability of this supply. The secondary water projects would decrease the demand on the rural water systems which have limited ground water quality and sources.

D.1.2 Watershed Protection

The other purpose of the Proposed Project is to improve water quality, maintain and enhance wetlands and wildlife habitat, and reduce erosion and sedimentation into Salt

Creek, with the authorized purpose being Watershed Protection (reducing offsite floodwater, erosion, sediment, and agriculture-related pollutants).

Within the Lower Bear River Watershed, the Lower Bear River and other waterways drain to the Great Salt Lake. This intersection is characterized by extensive wetlands that serve as critical habitats for millions of migratory birds and other ecologically important species. Managed by local entities, including bird refuges and hunting clubs, these wetlands rely on carefully regulated water levels to promote the growth of native vegetation and sustain biodiversity. However, erosion, sediment, and agriculture-related pollution have diminished the capability to regulate water levels and maintain the quality of water essential for sustaining the thousands of acres of wetlands and habitat.

The management of the Bear River wetlands involves a network of canals that facilitate the controlled flow of water between the Bear River and the wetland areas. The canals are protected by levees that safeguard this vital habitat, however, these levees are aging and failing to allow managers to manage the flow of water. The Bear River Club Company (Bear River Club) and the Chesapeake Duck Club (CDC) propose to repair and stabilize levees along the Bear River.

Salt Creek is a small creek within the Lower Bear River Watershed that terminates in wetlands. These wetlands are managed similarly to the wetlands at the intersection of the Great Salt Lake and the Bear River. The canals and levees in this area also serve as crucial infrastructure for management and protection of the wetlands and their inhabitants, yet are aging and failing, as well. Additionally, sediment along Salt Creek from upstream erosion processes—including agricultural practices—accumulates in the wetlands, decreasing their functionality. The Utah Division of Wildlife Resources (UDWiR), which manages the Salt Creek Waterfowl Management Area (WMA), proposes to repair and stabilize the levee to protect the wetlands and develop a debris basin upstream in Salt Creek to prevent sediment from entering the wetlands. Improvements such as levee construction, sediment removal, and bank stabilization are needed to reduce erosion, sediment, and agriculture-related pollution, and maintain and enhance wetlands and wildlife habitat.

D.2.0 Design and Criteria

The Proposed Project will be designed to meet the Natural Resources Conservation Service (NRCS) and Utah state requirements and other applicable design requirements and standards. Other Utah or NRCS codes as applicable would also be followed along with Tremonton City, Bear River City, and Box Elder County Public Works standards for construction and stormwater management.

The design of the proposed systems will meet the requirements of the NRCS and Utah State Code. Design requirements are identified in NRCS Practice Standards Codes 430 and 533, American Concrete Institute (ACI) Code 350, Hydraulic Institute (HI) Standards, Utah Rules R309-510, R317-3-9, R317-3-11, American Public Works Association (APWA) 2017 standards and specifications, and supplier requirements.

D.3.0 Agricultural Water Management and Watershed Protection Analysis

The following TMs have been prepared to document the current conditions and the effects of agricultural water management and watershed protection activities within the Proposed Project Area (Project Area) (Table 3-1), and are located in Appendix E1 of the Plan-EIS.

Table 3-1. Technical Memoranda by Number, Name, and Key Information Content

TM Number	Name	Key Information Content
001	<i>Agriculture Water Management</i>	<p>Agricultural water analysis including need, considered measures, preferred alternative, and hydrologic and hydraulic analysis model inputs and results for the BRCC Irrigation System Delivery Improvement and Tremonton measures.</p> <p>The TM evaluates the following projects under the agricultural water management purpose:</p> <ul style="list-style-type: none"> • BRCC Irrigation System Delivery Improvements—Canyon Improvements (Siphons Installation AND Hammond and West Main Canals Improvements) • BRCC Irrigation System Delivery Improvements—Red Siphon • BRCC Irrigation System Delivery Improvements—Bear River City Pressure Irrigation • BRCC Irrigation System Delivery Improvements—Highland Ditch Piping • BRCC Irrigation System Delivery Improvements—Central Canal Company Piping • Tremonton Pressure Irrigation and Storage. <p>Each project is analyzed for its need, considered alternatives, preferred solutions, and hydraulic modeling results.</p> <p>The proposed measures would enhance water delivery reliability, reduce system losses, and support sustainable agricultural water use in the watershed.</p>
002	<i>Watershed Protection</i>	<p>Watershed protection analysis for Bear River Club, Chesapeake Duck Club, and Salt Creek WMA Levee Improvements, and Salt Creek WMA Sediment (Debris) Basin, including need, design considerations, considered measures, preferred alternative, and summary.</p> <p>The TM evaluates four projects under the watershed protection purpose:</p> <ul style="list-style-type: none"> • Bear River Club Levee Improvements • Chesapeake Duck Club Levee Improvements • Salt Creek WMA Levee Improvements • Salt Creek WMA Sediment (Debris) Basin <p>The proposed measures would invest in preserving and enhancing the ecological integrity of the Lower Bear River wetlands. By reinforcing levees and managing sediment, the proposed measures would reduce erosion and pollution, support biodiversity, and ensure long-term sustainability of these vital habitats.</p>

TM Number	Name	Key Information Content
<p><i>Terracon Project No. 61235120 (in TM-001)</i></p>	<p><i>Geological Hazard Review Hammond, West and East Main Canals; Cutler Dam to SR-30 Box Elder County, Utah</i></p>	<p>Terracon Consultants, Inc. (Terracon) performed a geological hazard review for the Hammond, West Main, and East Main Canals in Box Elder County, Utah, to support early-stage planning for canal system improvements (Terracon 2024). The review identified significant geologic risks—including seismic hazards, landslides, and rockfall—that may impact canal stability and constructability within the canyon. The assessment provided insights into surface conditions and potential hazards in the canyon area; it did not include subsurface exploration or detailed geotechnical analysis.</p> <p>Terracon recommended, as the project advances into early design, a preliminary geologic investigation to evaluate excavation feasibility, seepage and erosion risks, and constructability constraints associated with canal and levee improvements.</p>

D.3.1 Agricultural Water Management Hydrologic and Hydraulic Analysis

The Lower Bear River Watershed falls within the Central Basin and Range Level III ecoregion and within the Malad and Cache Valleys Level IV ecoregion, except for the locations of the Salt Creek WMA, the Bear River Club, and the CDC, which fall into the Wetlands Level IV ecoregion (EPA 2024). The majority of the Lower Bear River Watershed contains wide terraces, narrow floodplains, and alluvial fans, as well as mountain fed perennial streams and canals, has a cooler, shorter growing season than other ecoregions in the area, and is extensively farmed and more densely populated than other ecoregions in the area. The Lower Bear River Watershed has a drainage area of 249,087 acres.

For each proposed measure, J-U-B conducted detailed analysis to ensure the proposed measures would address the identified need appropriately.

For the **BRCC Irrigation System Delivery Improvement—Hammond and West Main Canals** and **BRCC Irrigation System Delivery Improvement—Siphons Installation** measures, J-U-B analyzed the conditions of the canals to determine the sizes of box culvert required to deliver the required irrigation water. Innovyze’s modeling software, InfoSWMM, was used for the analysis along with Excel spreadsheets to do preliminary calculations and validate model calculations.

A detailed topographical survey was completed using Light Detection and Ranging (LiDAR) technology for each canal to determine their existing size, shape, and slope. The Manning’s roughness coefficient for the existing earthen channels was assumed to be 0.035, and the roughness for concrete sections was assumed to be 0.015 in the box culvert installation. Excel spreadsheets were used to estimate the size of box culvert needed to effectively pass the design flows of 200 cubic feet per second (cfs) in the Hammond Canal and 750 cfs in the West Main Canal. A hydraulic model was created to validate the Excel calculations and verify that the proposed improvements of the two canals would maintain proper functionality with the addition of the new infrastructure.

For the **BRCC Irrigation System Delivery Improvements—Red Siphon Installation**, J-U-B analyzed the proposed siphon to determine the pipe size required to deliver the same capacity of irrigation water currently being transported by the existing flume. Innovyze’s modeling software, InfoSWMM, was used for the analysis. J-U-B developed the model to include the existing conditions a few hundred feet upstream and downstream of the existing structure. LiDAR data was used to understand the shape and slope of the existing structure, as well as understand the elevation difference between the existing canal and the Malad River. A Manning’s Roughness coefficient of 0.035 was assumed for the existing earthen channel where the calculations use the Manning’s Equation. The Hazen-Williams Equation was used to perform calculations within the siphon. The Hazen-Williams C value was assumed to be 140 for the siphon piping. The model is set to accommodate 250 cfs in the system. This is the peak value expected at this location according to BRCC.

For the **BRCC Irrigation System Delivery Improvements—Bear River City Pressure Irrigation and Storage** measure, J-U-B analyzed the canal to be piped to determine the pipe sizes required to deliver the same capacity of irrigation water currently being transported by the ditch as well as deliver water to an equalization storage facility. Innovyze’s modeling software, InfoSWMM, was used for the analysis.

The InfoSWMM model was created to model the full length of the canal. The entire canal is planned to be piped. The canal is required to deliver 24 cfs from the East Main Canal turnout to the river drain near the park. After that point, the canal is only required to deliver 14 cfs. The City Officials provided the flow requirements based on water rights and demands. All the existing agricultural turnouts on the canal need to be maintained. This leaves 1.5 cfs of continuous delivery to supply the city’s pressurized secondary water system. The proposed system will use a weir and orifice to ensure that proper quantities of flow supply the pressure irrigation system and the agricultural water users.

The assumptions for InfoSWMM model include the pipe shape, manning’s n value for roughness, orifice coefficient, and weir coefficient. All the conduits in the model are circular with a manning’s n value of 0.012 to represent plastic pipe. The orifice coefficient is assumed to be 0.67. The weir coefficient is assumed to be 3.3. The elevations of key junctions and elements were derived from open source 1 meter LiDAR.

For the **BRCC Irrigation System Delivery Improvements—Highland Ditch Piping** measure, J-U-B analyzed the Highland Ditch to determine the pipe sizes required to deliver the same capacity of irrigation water currently transported by the ditch. Innovyze’s modeling software, InfoSWMM, was used for the analysis.

The InfoSWMM model was created to model the full length of the Highland Ditch including existing infrastructure that would remain and proposed new infrastructure. The information for the existing infrastructure was received from the Highland Ditch manager and collected during a visit to the site. A section of 48” concrete pipe and two sections of parallel 36” concrete pipes occur near and along 9600 North. The existing concrete pipe was assumed to have a Manning’s Roughness (roughness) of 0.013. The proposed pipe was assumed to be 36” plastic pipe with a roughness of 0.012. An existing section of 27” plastic pipe near the south end of the pipe system was assumed to have a roughness of 0.012. Lastly, a proposed section of 18” plastic pipe was assumed to have the same roughness as the other plastic pipes. The required flow in the system, as reported by the ditch company,

is 13.72 cfs. These flow requirements are based on water rights and demands.

For the **BRCC Irrigation System Delivery Improvements—Central Canal Company Piping** measure, J-U-B analyzed the Central Canal Company Canal to determine the pipe sizes required to deliver the same capacity of irrigation water currently being transported by the canal. Innoyze’s modeling software, InfoSWMM, was used for the analysis.

The InfoSWMM model was created to model the full length of the canal including existing infrastructure that would remain and proposed infrastructure. The information for the existing infrastructure was received from the Chair of the Central Canal Company Board. Currently, two sections of 42” concrete pipe exist. The existing concrete pipe was assumed to have a Manning’s Roughness (roughness) of 0.013. The proposed pipe was assumed to be 36” plastic pipe with a roughness of 0.012. Lastly, a proposed section of 18” plastic pipe would have the same roughness as the other plastic pipes. The required flow, as reported by the canal company, in the system is 20 cfs. These flow requirements are based on water rights and demands.

For the **Tremonton Pressure Irrigation Improvement and Irrigation Storage** measure, the pipe, pump, and equalization storage sizes were determined using information provided within the Facilities Plan for Tremonton City. The average yearly demand, the peak day water use, the peak instantaneous demand, and the irrigated acreage per acre of developed land were calculated for each service area in the Facilities Plan. The Facilities Plan uses state regulations and local data to determine these factors. The average yearly demand was determined to be 3 acre-feet (ac-ft)/irrigated acre. The peak day water use and peak instantaneous demand were determined to be 7 and 14 gallons per minute (GPM) per irrigated acre, respectively. The irrigated acreage was determined to be equal to 50% of the total developed land. Each of these factors represent different constraints on the system and guide the sizing of the system’s components. Explanations of the determinations of these factors can be found in the Facilities Plan in the administrative record.

Additional detailed project information about hydrology and the proposed agricultural management measures can be found in TM-001 Agriculture Water Management, prepared by J-U-B, located in Appendix E1 of the Plan-EIS, including the characteristics of the Lower Bear River Watershed, project need, considered measures, preferred alternative, and hydrologic and hydraulic analysis model inputs and results for the BRCC Canyon Improvements and Red Siphon, Tremonton and Bear River City Pressure Irrigation, and Highland and Central Canal Company Piping measures.

D.3.2 Watershed Protection Analysis

The analysis methodology for the watershed protection measures involved two factors, the levee improvement projects, and the sediment basin design.

D.3.2.1 Levee Improvements

For the levee improvement projects, the primary focus was on the reconstruction and stabilization of levees to protect wetland habitats and improve water management. The design of the reconstructed levees faced several constraints. First, the top needed to be wide and strong enough for repair and maintenance equipment, requiring some reclamation within the existing water channel. Second, the area is prone to ice flows, which can damage materials on the bank, so the design had to withstand these and other debris flows. Third,

local wildlife such as beavers and muskrats poses a threat to any large vegetation, compounded by saline soils limiting plant types. Fourth, the design had to endure high spring runoff flows. Finally, the solution is needed to promote the growth of native species.

The two primary measures considered to repair or rebuild the levees for the Bear River Club, the CDC, and the Salt Creek WMA were soil lifts and rock rip rap. The soil lifts would be composed of coconut mats rolled into one-foot-tall bundles with soils and seeds. The bundles would be built in a stepped manner from the existing channel bed above the typical high-water mark. The coconut mats allow for vegetation to establish strong root networks that will support the bank once the blankets have degraded. A structural fill would be placed in one-foot lifts between the bundles and the existing bank to fill in and establish the necessary width for the levee. Coconut mats promote the growth of vegetation, which is one of the most effective forms of erosion control, but are subject to moving and shifting after installation, especially when ice flows occur, reducing their applicability in the current situation.

The other measure evaluated using rock rip rap to stabilize the levees. The rock rip rap involves placing 18-inch minimum rock at a two-to-one slope along the banks of the levee. This rock bank would be roughly two feet deep and extend from just above the high-water mark down three feet below the existing channel bottom. This would give the rock a strong foundation. The rock would be installed with structural fill to bridge the gap from the new bank to the existing bank. Topsoil and seeding would be applied to the disturbed areas to establish new vegetation. This alternative prioritizes structural integrity and provides for vegetation above the water surface that is known to work in these areas. This method is a combination of a structure with the integrity to withstand the ice flows, while still allowing for vegetation growth to provide bank stability in the long term.

D.3.2.2 Sediment Basin

The WMA sediment (debris) basin will have a single purpose of settling the transported sediment in Salt Creek before it enters the WMA. The debris basin was designed and sized to hold ten years of sediment. Every ten years the debris basin will need to be dredged, and the deposited sediment will need to be removed. The design of the debris basin needed to protect the WMA from filling with sediment, increasing the UDWiR's ability to control the water within the WMA and decrease the required dredging within the WMA.

The Revised Universal Soil Loss Equation (RUSLE) was used to estimate the erosion potential from the contributing watershed based on the parameters listed below. The Universal Soil Loss Equation was used with Geographic Information System (GIS) instead of using the RUSLE1 or RUSLE2 computer programs to generate the soil loss parameters.

$$A = R * K * LS * C * P$$

A = Average Annual Soil Loss (mass / area · year)

R = Rainfall Erosivity Factor (erosivity unit / area · year)

K = Soil Erosivity Factor (mass / erosivity unit)

L = Slope Length Factor

S = Slope Steepness Factor

C = Cover Management Factor (>=0)

P = Management Factor (>=0)

Additional details about the analysis and model of the Watershed Protection measures can be found in TM-002 Watershed Protection located in Appendix E1 of the Plan-EIS.

D.4.0 Alternatives and Ecosystem Service Evaluated

D.4.1 Alternatives

Multiple alternatives were investigated as part of the study, and the alternative formulation process is described thoroughly in Chapter 4 of the Plan-EIS and summarized here.

D.4.1.1 Proposed Project Measures and Formulation

Based on PL 83-566 authorized purposes and the need for actions in the Project Area, specific works of improvement (“measures”) were identified. The list of initial approaches and management measures is presented in Section 4.1.2 in the Plan-EIS.

The measures that the project team carried forward were then compared pairwise to determine which were mutually exclusive or unnecessarily redundant and which could be combined into alternatives (Table 4-1 below).

Sections 4-1 through 4-4 in the Plan-EIS detail the measures’ eventual formulation into alternatives.

D.4.1.2 Alternatives Evaluated

All reasonable alternatives were evaluated in the Plan-EIS to determine the locally preferred, agency preferred, environmentally preferred, and economic efficient alternatives. While a standalone nonstructural alternative could not be formulated to address the watershed problems while meeting the Sponsor’s and Co-sponsor’s objectives and avoiding constraints, nonstructural measures to meter water were included in the action alternatives.

The five alternatives considered in the Draft Plan-EIS include the No Action Alternative or Future without Federal Investment (FWOFI), and four action alternatives, of which two action alternatives were analyzed in detail (Alternatives 1 and 2), and two action alternatives (Alternatives 3 and 4) were analyzed and considered, but eliminated from detailed study based on multiple considerations regarding the Proposed Project objectives and constraints.

Alternative 1 is the Siphons Installation Alternative and Alternative 2 is the Hammond and West Main Canals Improvements Alternative. Table 4-2 (below) provides a list of the measures included in these two alternatives evaluated in detail in the Plan-EIS and for the Benefit-cost Analysis.

The FWOFI describes the most likely future if no federal investment is made in the watershed. Under the FWOFI, agricultural water management in the Lower Bear River Watershed would be at continued risk of supply disruption from infrastructure failures and inefficiencies caused by poorly lined canals. Additionally, water supplies would be strained by the increasing demand for water used for outdoor irrigation of homes. The watershed’s wetlands would also be at continued risk from levee failures. Under the action alternatives each of these challenges would be addressed through specific works of improvement.

Table 4-1. Comparison of Initial Measures and Compatibility

Initial Approaches and Management Measures C = compatible /combinable, M = mutually exclusive or unnecessarily redundant			Agricultural Water Management							Flood Prevention	Watershed Protection						
			Bear River Canal Company (BRCC)			Tremonton		Bear River City	Highland Ditch Company	Central Canal Company	Bear River Water Conservancy District (BRWCD)	Bear River Duck Club (BRDC)		Chesapeake Hunt Club (CHC)		Salt Creek Wildlife Management Area (WMA)	
			BRCC Bear River Canyon Improvements Siphons Installation	BRCC Bear River Canyon Improvements Hammond Canal Improvements	BRCC Red Siphon	Tremonton Pressure Irrigation Improvement (Project 6)	Tremonton Irrigation Storage (Project 8)	Bear River City Pressure Irrigation	Highland Ditch Piping	Central Canal Company Piping	BRWCD Bothwell Pocket Flood Prevention	BRDC Bear River Levee Improvements-Coconut	BRDC Bear River Levee Improvements-Riprap	CHC Bear River Levee Improvements-Coconut	CHC Bear River Levee Improvements-Riprap	Salt Creek WMA Levee Improvements-Coconut	Salt Creek WMA Levee Improvements-Riprap
Agricultural Water Management	BRCC	BRCC Bear River Canyon Improvements Siphons Installation															
		BRCC Bear River Canyon Improvements Hammond Canal Improvements	M														
		BRCC Red Siphon	C	M													
	Tremonton	Tremonton Pressure Irrigation Improvement (Project 6)	C	C	C												
		Tremonton Irrigation Storage (Project 8)	C	C	C	C											
		Bear River City	Bear River City Pressure Irrigation	C	C	C	C	C									
		Highland Ditch Company	Highland Ditch Piping	C	C	C	C	C	C								
Central Canal Company	Central Canal Company Piping	C	C	C	C	C	C	C									
Flood Prevention	Bear River Water Conservancy District (BRWCD)	BRWCD Bothwell Pocket Flood Prevention	C	C	C	C	C	C	C								
Watershed Protection	Bear River Duck Club (BRDC)	BRDC Bear River Levee Improvements-Coconut	C	C	C	C	C	C	C								
		BRDC Bear River Levee Improvements-Riprap	C	C	C	C	C	C	C	C	M						
	Chesapeake Hunt Club (CHC)	CHC Bear River Levee Improvements-Coconut	C	C	C	C	C	C	C	C	C						
		CHC Bear River Levee Improvements-Riprap	C	C	C	C	C	C	C	C	C	M					
	Salt Creek Wildlife Management Area (WMA)	Salt Creek WMA Levee Improvements-Coconut	C	C	C	C	C	C	C	C	C	C					
		Salt Creek WMA Levee Improvements-Riprap	C	C	C	C	C	C	C	C	C	C					
		Salt Creek WMA Salt Creek Settlement Basin	C	C	C	C	C	C	C	C	C	C	C				
Alternatives																	
		Alternative 1-Siphons w/Riprap	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	Yes	Yes
		Alternative 2-Hammond w/Riprap	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	Yes	Yes
		Alternative 3-Siphon w/Coconut (Soil Lifts)	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	No	Yes
		Alternative 4-Hammond w/Coconut (Soil Lifts)	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Table 4-2. Works of Improvement Proposed as Part of the Lower Bear River Watershed Plan-EIS, Utah

Work of Improvement	Description	Included in Alternative	
		Siphons Installation Alternative	Hammond and West Main Canals Improvements Alternative
Purpose: Agricultural Water Management			
BRCC Irrigation System Delivery Improvements—Siphons Installation	The BRCC would abandon a large section of the Hammond Canal by installing a siphon from the Hammond Canal to the West Main Canal, box culverts in three critical locations along the West Main Canal, a siphon back to the Hammond Canal, and a box culvert on the Hammond Canal from the second siphon downstream along the canyon hillside.	Yes	No
BRCC Irrigation System Delivery Improvements—Hammond and Main Canal Improvements	Multiple breaches have occurred within the Hammond Main Canal over the years and are becoming increasingly more significant each time. This project would address the reliability of the water supply with a focus on the canals that are on the steep hillsides. BRCC would construct a box culvert along the Hammond Canal at five key locations based on a geotechnical study, ending after the canal bends out of the canyon, and would construct box culvert through the Camp Fife area and along two other key locations on the West Main Canal.	No	Yes
BRCC Irrigation System Delivery Improvement—Red Siphon Replacement	Currently, BRCC operates a 450-foot suspended flume to transport the flow in the East Canal over the Malad River. The preferred alternative for replacement of the existing flume is to replace it with a siphon. Siphons, in comparison to bridged flumes, require less maintenance because they are beneath ground.	Yes	Yes
BRCC Irrigation System Delivery Improvement—Bear River City Pressure Irrigation	Bear River City residents and the surrounding cropland currently receive irrigation water from a concrete lined canal. The existing delivery canal is in poor condition. There are sections at risk of failure due to the concrete liner being cracked and broken allowing for seepage. The preferred alternative includes construction of a pressure irrigation network fed by gravity flow through a new pipe along the delivery canal and an equalization storage facility and pumping facility located at the city park.	Yes	Yes
BRCC Irrigation System Delivery Improvement—Highland Ditch Piping	Currently, the Highland Ditch delivers irrigation water to approximately 3,000 acres of cropland. The existing concrete liner was installed in 1961 and is in poor condition due to its age. The condition is decreasing efficiency of delivery and allowing excess loss. The preferred alternative is to pipe the canal by constructing a gravity piped system.	Yes	Yes

Work of Improvement	Description	Included in Alternative	
		Siphons Installation Alternative	Hammond and West Main Canals Improvements Alternative
BRCC Irrigation System Delivery Improvement— Central Canal Company Piping	Currently, the Central Canal Company delivers irrigation water to 1,400 acres of cropland. The canal receives 20 cfs of water from the BRCC East Main Canal. The water is delivered to users through a concrete lined ditch, which is aging and deteriorating. The preferred alternative is to pipe the canal by constructing a gravity piped system.	Yes	Yes
Tremonton Pressure Irrigation Improvements and Storage	Tremonton City currently offers its residents access to secondary water for outdoor use through a pressurized irrigation network that they have been constructing in phases. The continued expansion of the pressure irrigation networks in Tremonton City is necessary to meet the current water demands as well as those demands associated with growth of development.	Yes	Yes
Purpose: Watershed Protection			
Bear River Club Levee Improvements	The Bear River Club manages approximately 14,000 acres of wetland along which the Bear River flows for approximately 1.5 miles on its southern side. The levee between the Bear River Club’s wetland and the Bear River is actively deteriorating. The preferred alternative for the Bear River Club levee reconstruction is rock rip rap.	Yes	Yes
Chesapeake Duck Club Levee Improvements	The CDC manages 4,000 acres of wetland habitat along the Bear River. The wetland is separated from the river by approximately two miles of levee on the southern border. The rock rip rap is the preferred alternative to reconstruct the levee for the CDC.	Yes	Yes
Salt Creek Waterfowl Management Area Levee Improvements and Sediment Removal	The Salt Creek WMA covers approximately 6,000 acres of wetland habitat in Box Elder County. It is managed by the UDWiR for the purpose of providing and protecting wetland habitat for migratory birds and other species native to wetland ecosystems. The rock rip rap is the preferred alternative for the Salt Creek WMA levee reconstruction project. In addition to improving the levee, a sediment basin would be constructed.	Yes	Yes

Source: J-U-B ENGINEERS, Inc.

D.4.2 Ecosystem Services

D.4.2.1 Types of Ecosystem Services Impacted

Public scoping comments, planning documents, watershed plans from surrounding areas, and discussions with the project sponsors helped to identify the types of ecosystem services present in the watershed and then specifically identify those that could interact with (impact or be impacted by) the works of improvement proposed as part of the Preferred Alternative.

In the Lower Bear River watershed, ecosystem service benefits come from cultivated farmland, irrigation water supplies, and wetland habitats. These resources deliver a range of services, including regulation of both natural and human processes, direct consumption, and cultural values.

D.4.2.1.1 Regulating Ecosystem Services

Regulating services are critical ecosystem functions that maintain environmental conditions beneficial to people and other organisms. Within the Lower Bear River Watershed, these ecosystem services are primarily related to agricultural and rural water management, including water filtration, nutrient removal, sediment trapping, and pollutant breakdown performed by wetlands, and flood prevention. These services include regulating water quality by preventing contamination and sustaining clean water supplies; reducing the risk of transmission failure and improving water delivery to ensure reliable irrigation for agriculture and rural communities; and minimizing wetland damage to protect habitat integrity and prevent ecological degradation.

Together, the regulating functions support the watershed's resilience and contribute to economic and social benefits. The change in watershed structure from the action alternatives would regulate water quality by reducing the risk of transmission failure, improving water delivery, and reducing risk of wetland damage which would reduce farm income damage, reduce water treatment costs, and reduce damage to wetlands.

For example, the action alternatives would improve multiple sections of the BRCC Irrigation Delivery System, reducing the chance of failure. They would also implement water delivery improvements for rural water currently used for outdoor irrigation in Bear River City and Tremonton, reducing water treatment costs. Additionally, the action alternatives would replace at-risk levees and construct a sediment basin, mitigating damage to wetland habitats and lowering costs for invasive species management. Though the action alternatives do not directly address flood prevention, proposed actions would result in reduced flooding.

D.4.2.1.2 Provisioning Ecosystem Services

Provisioning ecosystem services in the watershed mainly arise from the use of water from the Lower Bear River for agricultural activities and consumption. The watershed provides irrigation water for agricultural production. About 65,000 acres of productive farmland rely on the infrastructure managed by the project sponsors. These agricultural areas are primarily used to grow hay and haylage, which serve as silage for livestock raised in the watershed. This contributes to both direct outputs, such as harvested crops, and indirect benefits, such as the production of meat.

The change in watershed structure would provide water, and the action alternatives would conserve the water supply contributing to an increase in farm income.

D.4.2.1.3 Cultural Ecosystem Services

Notably, the Lower Bear River is recognized as an important recreational resource in the region. Cultural ecosystem services in the watershed are largely linked to the recreational opportunities provided by its wetland ecosystems. These areas support activities such as waterfowl hunting and bird watching, with organizations like the Salt Creek WMA, Bear River Club, and CDC benefiting from the wetlands' ecological services.

D.4.2.2 Ecosystem Services Flow

Figure 1 shows the causal chain describing how the action alternatives would create social benefits and costs as part of the Lower Bear River Watershed Project for the monetized benefits. Other non-monetary ecosystem services (i.e., flood prevention and recreation opportunities) are described in the Plan-EIS. Causal chains are models describing how

changes to the structure of an ecosystem affect its functioning and the goods and services it provides to society (Olander et al. 2016). When used as part of a Benefit-Cost Analysis (BCA), a causal chain assessment of ecosystem services impacts traces changes in ecosystem composition including, effects on social outcomes and human well-being.

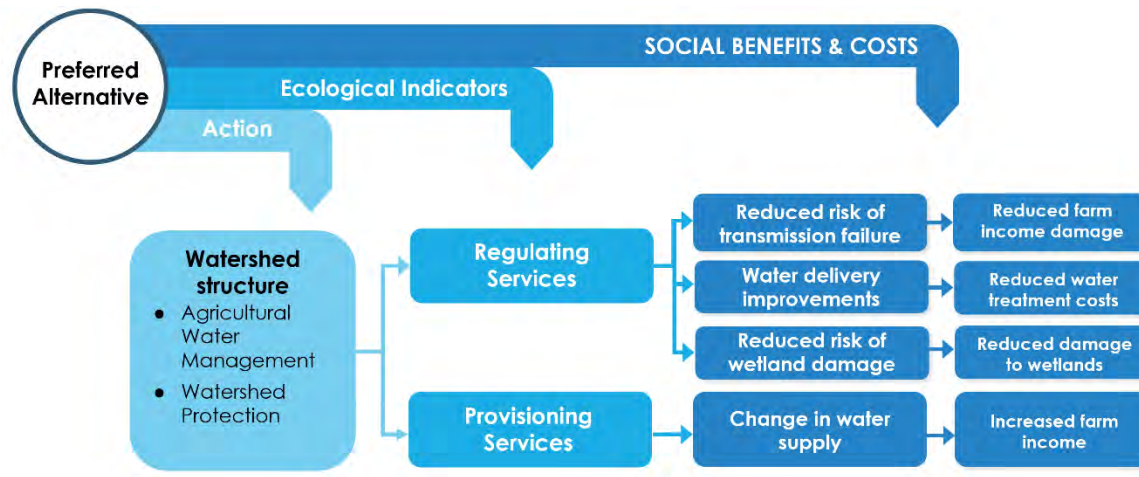


Figure 1. Ecosystem Services of the Action Alternatives

D.4.2.3 Prioritizing Ecosystem Services

Services were prioritized based on their expected contribution to the project's primary purposes of improving agricultural water management and watershed protection. As a result, the regulating and provisioning services shown in Figure D-1 were prioritized for analysis as part of the evaluation of the benefit-cost analysis of the action alternatives. Other non-monetary ecosystem services (i.e., flood prevention and recreation opportunities) are described in the Plan-EIS.

D.4.2.4 Ability to Characterize, Quantify, and Monetize Ecosystem Services

The ecosystem services described in Figure D-1 can all be characterized, quantified, and monetized using publicly available information and accepted methodologies that relate biophysical values to economic values.

D.4.2.5 Metrics to Evaluate Ecosystem Services

The metrics used to evaluate the change in ecosystem service values under the action alternatives are shown in the social benefits and costs displayed in Figure 1. Regulating services were evaluated by quantifying and valuing changes to farm income damages caused by failing infrastructure; the reduced costs of water treatment based on estimated water savings; and reduced damage to wetlands.

To quantify and monetize the effects to wetlands, the lost benefits from diminished opportunities for recreational activities, such as birdwatching and hunting, as well as the decrease in ecosystem functions like water filtration and flood regulation, were quantified in terms of acres and monetized using per-acre wetland values reflecting the value of different services. In addition, the costs of treating wetland ecosystems for invasive species were quantified and monetized on a per-acre basis.

Changes in provisioning services were evaluated using the increase in irrigation water supply, measured in acre-feet, and net crop revenue changes resulting from the crops produced with the

additional irrigation water.

D.4.2.6 Summary and Comparison of Ecosystem Service Changes

A summary of the action alternatives' impacts on ecosystem services in the watershed and fulfillment of federal investment principles in water resources are shown in Table 5-2 of the Plan-EIS. The Hammond and West Main Canal Improvements Alternative was determined to be the Preferred Alternative due to several factors, including because it offers the greatest annualized net benefits.

D.5.0 Benefit-Cost Analysis Data and Methodology

To evaluate the extent to which the action alternatives would increase public benefits relative to costs, the BCA analysis compared the action alternatives to the FWOFI or No Action Alternative, quantifying and valuing expected effects over a 100-year evaluation period. Since all the project elements have design lives of 100-years, replacement costs were not included in the analysis as the project time horizon does not exceed the life of the measures (PR&G Section 9, NWPM 501.37.B and the Economics Handbook, Part 611, 1.12.).

The benefits were calculated for regulating ecosystem services (reducing farm income damages, reducing water treatment costs, and reducing damage to wetlands), and provisioning ecosystem services (increasing farm income). Costs included engineering, permitting, administration, and construction, as well as separate O&M costs as a percentage of the construction cost.

Projected benefits and costs are based on a full employment economy and assume no change in relative prices during the period of analysis. All values were discounted at 3.25 percent for fiscal year 2026 and are reported in 2025 dollars. An incremental analysis for each work of improvement was also performed, beginning with the most beneficial improvement and ending with the least beneficial improvement, as part of the incremental analysis (390-NWPH, Part 606, Subpart B, Section 606.20).

D.5.1 Project Ecosystem Services Benefits

D.5.1.1 Reduced Farm Income (Agricultural) Damages

Several components of the action alternatives are designed to reduce the risk of irrigation infrastructure failing, including:

- BRCC Irrigation System Delivery Improvement—Hammond and Main Canals Improvements;
- BRCC Irrigation System Delivery Improvement—Siphons Installation;
- BRCC Irrigation System Delivery Improvement—Red Siphon Installation;
- BRCC Irrigation System Delivery Improvement—Bear River City Piping;
- BRCC Irrigation System Delivery Improvement—Highland Ditch Piping; and
- BRCC Irrigation System Delivery Improvement—Central Canal Piping.

These upgrades target aging and weakened infrastructure to reduce the risk of irrigation, repair costs, and farm incomes losses.

The benefit of replacing or improving the infrastructure was estimated by calculating the difference in the average annualized expected damage between the FWOFI and action alternatives. This was done by multiplying the annual probability of infrastructure failure by the

associated damage costs and then comparing the results for each alternative.

D.5.1.1.1 Bear River Canal Company (BRCC) Delivery System

BRCC delivers water to many users throughout Box Elder County. This delivery system includes canals, ditches, and systems directly operated by BRCC, and other entities that operate systems that deliver BRCC water, such as Bear River City, Highland Ditch, Central Canal Company, and Tremonton. These entities must work together to provide agricultural producers with the water that they need. Without BRCC, the smaller entities would not be able to receive the water that they deliver. Without the smaller entities, BRCC would not be able to deliver the water to the end user. This relationship is necessary for delivery, but it is also necessary for maintaining the water rights. If BRCC is unable to deliver the water to the end user through the smaller entities, they may be unable to demonstrate that the water is being put to beneficial use. This situation could potentially lead to the forfeiture of their water rights.

D.5.1.1.2 Breach History and Failure Probabilities

Multiple breaches have occurred within the BRCC Hammond Canal over the years and are becoming increasingly more significant each time. Since 1980, the canal has breached 18 times, with 15 failures occurring on the Hammond Canal and three occurring on the West Main Canal. Of the 18 failures, BRCC estimates that thirteen have been major canal failures based on the timing, the cost, and the service disruption. The repair costs of the past 18 failures ranged from \$5,000 to \$2.87 million dollars, with an average of approximately \$268,250 dollars. Costs were based on repair expenses or estimates derived based on the amount of fill material required to repair the canal section and assuming a crew can move 50 cubic yards of material with a crew cost of \$550 per hour. The failures generally occur in the spring and last about four weeks, on average with approximately 0.4 failures per year. See full history of canal failures and repair costs in Table 4 of the BCA (Appendix E1 of the Plan-EIS).

The BRCC also operates the Red Flume, which was assessed in 2020, and determined that without significant repairs, the flume would fail sometime in the next five to 10 years¹. Based on the assessment, the annual probability of failure of the Red Flume is 10 to 20 percent. In addition to the condition of the flume itself, the flume is also at risk of being catastrophically damaged by seismic activity in the watershed. The Little Bear River watershed is located along the Wasatch Fault one of the most active fault systems in the United States. Given its current structural state, a major earthquake along the Wasatch Fault would cause extensive damage to the Red Flume, which would lead to a considerable impact on the watershed's agricultural producers.

A significant cost of canal breaches and flume failures are the damages from the disruption in water supplies to agriculture. Within BRCC's service area, water supplies are invaluable to agriculture. Table 5-1 shows the primary crops grown in BRCC's service, which account for 94 percent of acreage served by BRCC.

¹ Slater, Chris. 2020. *Red Flume Site Visit* [Memorandum]. J-U-B ENGINEERS Inc.

Table 5-1. Crops Grown in Bear River Canal Company Service Area, by Acre

Crop	West Canal	Hammond Canal	Red Flume	Total Acres
Hay/Haylage	26,812	5,716	4,833	32,528
Wheat	16,051	3,422	2,893	19,472
Corn	9,811	2,091	1,768	11,902
Other	3,378	720	609	4,098
Total	56,051	11,949	10,103	68,000

Source: Bear River Canal Company.

According to BRCC, disruptions in the water supply from canal breach generate hay/haylage yield losses starting at 10 percent after one week and increasing gradually, reaching 50 percent after five weeks, with the loss remaining the same at six weeks. Hay is relatively resilient to short-term disruptions but suffers significant losses after prolonged ones. Wheat follows a similar trend, with a 10 percent yield loss after one week, but its losses increase more sharply, reaching 30 percent after four weeks and 50% after six weeks. Corn, however, is the most sensitive crop, with a 10 percent loss after just one week. After three weeks, the yield loss jumps to 50 percent, and by four weeks, it reaches 100 percent. See Table 6 in the BCA (Appendix E1 of the Plan-EIS for details).

D.5.1.1.3 Damage Calculations

Under the FWOFI, a canal failure is expected to occur about 0.4 times per year for a duration of four weeks. Failures generally occur on the Hammond Canal, but occasionally the West Main Canal is impacted. Based on the data from Table 4 of the BCA (in Appendix E1), the Hammond Canal has an annual failure probability of about 0.35 times per year compared to the West Main Canal's failure probability of about 0.07 failures per year. The Hammond Canal serves about 12,000 acres while the West Main Canal serves 56,000 acres. Hay is the most impacted crop, followed by wheat, and corn, which results in acres impacted by a failure as shown in Table 5-2.

Table 5-2. Modeled Acres of Cropland Impacted by Canal Failures by Crop Type on the BRCC System

Canal	Hay	Corn	Wheat	Total
Hammond	5,974	2,390	3,585	11,949
West Main	28,026	11,210	16,815	56,051
Red Flume	2,416	967	1,450	4,833

Source: Bear River Canal Company

To estimate the value of crop damage that would occur under a canal failure, ten years of yield data for hay, corn, and wheat were collected from the U.S. Department of Agriculture, National Agricultural Statistics Service (NASS) database for Box Elder County, Utah and are summarized in Table 5-3.

Table 5-3. Crop Yields, Gross Revenues, and Expected Losses of Main Crops Grown in BRCC Service Area Under Supply Canal Failures

Year	Hay (Ton/Acre)	Corn (Bu/Acre)	Wheat (Bu/Acre)
Average Yield Per Acre (1999-2008)	3.6	164.0	53.6
Normalized Crop Price	\$220.83	\$5.44	\$6.30
Gross Revenue Per Acre	\$794.98	\$892.16	\$340.20
Percent Reduction from 4-week Irrigation Disruption	25%	100%	30%
Expected Loss from 4-week Irrigation Disruption (\$/Acre)	\$198.75	\$892.16	\$102.06

Source: United States Department of Agriculture (USDA) National Agricultural Statistics Service (2011-2021). NASS - Quick Stats. USDA National Agricultural Statistics Service. <https://data.nal.usda.gov/dataset/nass-quick-stats>. Accessed January 2025.

See Table 8 of the BCA for yearly details (Appendix E1 of the Plan-EIS).

The average crop losses per event in Table 5-3 were multiplied by the number of acres served by each canal to estimate the total crop loss that would result from a failure of the Hammond and West Main canals and the Red Flume. Each canal failure event would incur emergency costs of approximately \$268,250 dollars based on the average repair cost of previous failures. The annual probability of a failure of the Hammond Canal is about 35 percent, meaning a failure of the Hammond Canal would result in approximately \$4.8 million dollars in direct damages and the expected annual loss would be approximately \$1.7 million dollars. The annual probability of a failure on the West Main Canal is about 7 percent, meaning a failure of the West Main Canal would result in \$21.6 million dollars direct damages and the expected annual loss is approximately \$1.5 million dollars. The Red Flume has an annual probability of failure of 10 percent, meaning the expected annual loss is \$183,582 dollars. See Table 5-4 for details.

Table 5-4. Crop Yields, Gross Revenues, and Expected Damages of Main Crops Grown in BRCC Service Area Under Supply Canal and Flume Failures

Loss from Canal Failure	Canal		
	Hammond	West Main	Red Flume
Repair Costs	\$268,250	\$268,250	Unknown
Hay	\$1,187,365	\$5,569,965	\$480,250
Corn	\$2,132,018	\$10,001,358	\$862,331
Wheat	\$1,219,477	\$5,720,603	\$493,238
Total Loss Per Failure	\$4,807,110	\$21,560,176	\$1,835,819
Annual Failure Probability	35%	7%	10%
Expected Annual Loss	\$1,682,489	\$1,509,212	\$183,582
Total Annual Loss	\$3,375,300 (rounded to nearest 100)		

D.5.1.1.4 Preferred Alternative Changes

The Preferred Alternative would improve the Hammond and West Main Canals by installing box culvert at five key locations based on geotechnical study on the Hammond Canal, and constructing box culvert through the Camp Fife area and two other key locations on the West Main Canal through the Bear River canyon area, thus eliminating or reducing the areas of previous canal breach and reducing the annual failure probability to near zero. These actions would reduce the expected annual damages as shown in Table 5-5. In the benefit-cost

analysis, these FWOFI damages are treated as reduced damage benefits of the Preferred Alternative—i.e., the benefit equals the FWOFI value minus any residual with-project damages—because the infrastructure improvements are intended to prevent the breach potential that drives these damages.

Table 5-5. Change in Expected Annual Damages (With-Project Condition)

Scenario	Expected Annual Loss from Infrastructure Failure
Without-Project (Baseline)	\$3,375,300
With-Project (Preferred Alternative)	~\$0
Ecosystem Services Benefit (Annual Reduced Farm Income Damage Avoided)	\$3,375,300

The benefit of replacing or improving the infrastructure for the BRCC Irrigation Delivery System Improvements would reduce farm income damage by \$3,375,300.

D.5.1.2 Reduced Water Treatment Costs

Under the action alternatives, the existing water delivery systems in Bear River City and Tremonton would be replaced with a gravity flow piping system, accompanied by the construction of storage and pumping facilities. These improvements would provide pressurized water to a new secondary irrigation network, resulting in more efficient water use and lower water treatment costs. The implementation of these systems is expected to conserve a significant amount of water annually as described below.

D.5.1.2.1 Bear River City

Bear River City residents and the surrounding cropland currently receive irrigation water from a concrete lined canal, which is at risk of failure due to cracks and seepage. The action alternatives would conserve approximately 175 acre-feet of water per year and relieve pressure on the culinary water supply, extending its availability.² The value of the conserved water is based on local water rates, which reflect both fixed and variable costs. The utility uses a tiered pricing structure: the low initial rate helps distribute fixed costs like infrastructure and maintenance across all users, making basic water access affordable while encouraging efficient use, as shown in Table 5-6.

Table 5-6. Water Rates for Bear River City

Water Rate	Usage Tier (Gallons)			Estimated Variable Cost
	0 to 24,000	24,000 to 40,000	40,001+	
Price per 1,000 gal	\$1.25	\$2.00	\$3.00	\$2.50

Source: Acme Water Company

As water consumption increases, Bear River City faces higher variable costs due to the added expenses of sourcing, treating, and distributing larger quantities of water. These are reflected in the City's tiered pricing, with higher rates for greater usage. Using \$2.50 per 1,000 gallons as a representative variable cost is appropriate, as it sits between the middle and upper pricing tiers.

² J-U-B ENGINEERS, Inc., personal communication, January, 2025.

The information in Table 5-6 was used to estimate the value of conserving 175 acre-feet as part of the Bear River City pressure irrigation component of the action alternatives. Conserving water, which is estimated to save 57.02 million gallons annually, could save Bear River City about \$142,550 in yearly water supply expenses.

D.5.1.2.2 Tremonton

Tremonton City is growing and has a limited water supply as irrigated agricultural lands are converted into residential development. To address this shortage, Tremonton City plans to increase the existing pressurized irrigation system to service new development within city limits, including a new pressure irrigation distribution system and two equalization ponds, upgraded pump stations, and new piping to serve the growing neighborhoods. The new infrastructure would provide residents with more affordable secondary water for outdoor use and reduce the demand on the dwindling culinary water supply. These facilities would conserve approximately 500 acre-feet of water per year.³

The tiered water pricing for the water rates in Tremonton City are shown in Table 5-7. The utility likely has substantial fixed costs that remain constant regardless of water usage, such as infrastructure maintenance, administrative expenses, and capital investments in water treatment plants, distribution systems, and storage facilities. The low price of \$1.50 per 1,000 gallons for the first 10,000 gallons seems designed to recover these fixed costs across a broad customer base, making basic water access affordable for most households. This suggests that the utility spreads its fixed costs evenly among all customers, ensuring that everyone contributes to the essential infrastructure.

Table 5-7. Water Rates for Tremonton

Water Rate	Usage Tier (Gallons)						Estimated Variable Cost
	0 – 10,000	10,001– 40,000	40,001 – 70,000	70,001 – 100,000	100,001– 130,000	Above 130,001	
Price per 1,000 gal	\$1.50	\$1.75	\$2.50	\$3.00	\$3.50	\$4.00	\$2.95

Source: Tremonton City

Using a cost of \$2.95 per 1,000 gallons as an approximation of the City's variable costs is reasonable because it averages the price of water in all tiers beyond the first tier, the value of conserving 500 acre-feet as part of the Tremonton pressure irrigation component of the action alternatives can be estimated. In total, the pressure irrigation component would reduce demand on the water system by an estimated total of 162.9 million gallons per year, which is projected to save approximately \$480,630 per year in water supply expenses.

D.5.1.2.3 Preferred Alternative Changes

Under the FWOFI (baseline condition), Bear River City and Tremonton currently use potable (culinary) water for irrigation, increasing water treatment costs due to higher demand.

³ J-U-B ENGINEERS, Inc., personal communication, January, 2025. A detailed analysis of the anticipated water savings for the Tremonton projects was conducted to calculate the annual savings of 500 acre-feet per year. This estimate is based on the 2017 Tremonton Secondary Water Capital Facilities Plan and the corresponding projections outlined therein. For the purposes of this calculation, the assumption is that the improvements will implement 50% of the proposed infrastructure within Service Area 10 and 75% of the infrastructure within Service Area 9 of the 2017 plan.

Currently, secondary irrigation systems are limited to reduce this demand. The Preferred Alternative installs secondary irrigation systems, reducing the volume of potable water that must be treated for irrigation. This results in annual benefit for water treatment as shown in Table 5-8.

Table 5-8. Annual Water Treatment Cost Savings (With-Project vs. Without-Project)

Location	Water Treatment Cost (FWOFI)	Water Treatment Cost (Action Alternatives)	Ecosystem Services Benefit (Annual Reduced Water Treatment Costs)
Bear River City	\$142,550	\$0	\$142,550
Tremonton	\$480,630	\$0	\$480,630
Total	\$623,200	\$0	\$623,200

Under the FWOFI, Bear River City and Tremonton incur a combined \$623,200 per year in water treatment costs for outdoor irrigation. The Preferred Alternative eliminates these costs by providing secondary irrigation systems, resulting in a direct, annual ecosystem services benefit of \$623,200. The Action Alternatives reduce water treatment costs by \$623,200 (rounded to nearest 100) (\$142,550 for Bear River City and \$480,630 for Tremonton).

D.5.1.3 Reduced Damage to Wetlands

The wetlands in the lower Little Bear River watershed, including the Bear River Club, CDC, and Salt Creek WMA, provide vital ecological and recreational benefits, especially for migratory waterfowl and hunters. These areas rely on levees to maintain water levels and prevent erosion, degradation, and the spread of invasive species. However, deteriorating levees threaten ecological health and recreational values.

The wetlands are crucial habitats for migratory birds, especially along the Pacific and Central flyways, and support numerous species such as waterfowl, shorebirds, and other wildlife. They also offer recreational opportunities including bird watching, hunting, and photography, attracting nature enthusiasts and sportsmen. Waterfowl clubs like Bear River and Chesapeake Duck Club help manage these habitats to ensure their sustainability for both wildlife and recreation.

The levee serving the Salt Creek Waterfowl Management Area has already failed and the site is under pressure from invasive species, including phragmites. The Bear River Club's levee, which protects 14,000 acres, is deteriorating, and failure could drain thousands of acres of wetland habitat. Similarly, the Chesapeake Duck Club's levee along the Bear River is also at risk and requires repairs to prevent further erosion and safeguard 4,000 acres of wetland.

According to Ducks Unlimited staff, if the levees fail, it would prevent wetland managers from maintaining water levels, which is crucial for preventing the spread of invasive species. In wetlands, stable water levels help control the growth of invasive species such as cattails and phragmites, which thrive in stagnant, low-water conditions. Effective water management is essential to maintaining these areas as prime hunting destinations and preserving their ecological and recreational value.

D.5.1.3.1 Annual Probability of Levee Failures

The Bear River Club levee separates thousands of acres of wetland from the Bear River. This levee is narrowing due to erosion from river fluctuations and motorized boat waves and is no longer wide enough to allow necessary maintenance equipment on the levee making it

impossible to complete needed repairs. The continued narrowing and inability to repair the levee suggests that a failure is probable in the next 5-10 years based on annual soil width loss of a foot or more. Therefore, the failure probability of the Bear River Club levee is between 10-20 percent in any given year (average of 15 percent) as shown in Table 5-9.

Table 5-9. Annual Probability of Levee Failures in Lower Bear River Watershed

Wetland Name	Annual Failure Probability
Bear River Club	15%
Chesapeake Duck Club	32%
Salt Creek Waterfowl Management Area	100%

Source: Ducks Unlimited.

The CDC levee also separates thousands of acres of wetlands from the Bear River and is narrowing due to similar erosion factors. However, this levee contains water level control structures that are deteriorating, increasing the probability of levee failure. If corrective measures are not taken, the levee could completely fail. This would suggest that this structure and the levee are likely to fail in the coming years; the annual failure probability to be approximately 25-40 percent (average of 32 percent).

The Salt Creek WMA levee, managed by UDWiR, is currently in a failed state with holes in the west levee of the bypass channel. As a result, the levee no longer accomplishes its task of separating Salt Creek from the surrounding wetlands.

D.5.1.3.2 Invasive Species Spread and Eradication Costs.

At the CDC, the Main Marsh, which borders the Bear River, serves as the club's primary wetland unit. It spans an estimated 765 acres, with around 20 percent vegetated by invasive species. If a breach were to occur, allowing water to flow unchecked, the spread of invasive species could increase to approximately 30 to 40 percent within the first year. If the breach went untreated and unrepaired, the vegetation could potentially double again the following year, significantly altering the wetland's ecology and habitat quality.

Similarly, the Bear River Club, which also borders the Bear River, covers an estimated 7,934 acres of wetland. Currently, it is approximately 15–20 percent vegetated by invasive species. In the event of a levee breach, invasive species could spread rapidly, potentially increasing the vegetated area of invasive species to 30–40 percent within the first year. If left unaddressed, the vegetation percentage could increase dramatically the following year, further compromising the wetland's biodiversity and habitat suitability. Both areas highlight the pressing need for proper levee maintenance to prevent the spread of invasives and protect the ecological integrity of vital wetland habitats.

The levee protecting the Salt Creek WMA, which covers an area of about 5,500 acres, is currently in a failed state with holes in the west levee of the bypass channel. Currently, it is approximately 20 percent vegetated by invasive species. The failed state of the levee is opening the wetlands to the further possibility of invasive species expansion which requires costly treatment and time to eradicate.

Table 5-10 summarizes the area of wetland currently occupied by invasive species as well as the area expected to be invaded under the FWOFI. The estimates were created by Ducks Unlimited.

Table 5-10. Acres of Wetland, Wetland Acres Currently Invaded by Phragmites, and Wetland Area that Would be Invaded by Phragmites under the FWOFI

Wetland Name	Acres of Wetland	Wetland Acres Currently Damaged by Invasive Species	Wetland Acres Damaged by Invasive Species Under FWOFI	Net Change in Invaded Area
Bear River Club	7,934	1,587	2,380	793
Chesapeake Duck Club	765	153	230	77
Salt Creek Waterfowl Management Area	5,496	1,099	1,649	550
Total	14,195	2,839	4,259	1,420

Source: Ducks Unlimited.

Failure of the levees would disrupt the delicate balance of water levels and habitat conditions, creating conditions in the wetlands, creating conditions that favor the growth of invasive species, including cattails and phragmites, which thrive in disturbed or stagnant environments. Managers from waterfowl management areas and other wetland experts have noticed a rise in phragmites growth along canals as the water levels of the Great Salt Lake have decreased.⁴

Restoring the wetland and mitigating the impacts would be costly and time-consuming. Restoration costs could be significant, not only in terms of financial resources but also in the time required to return the wetland to a functional and productive state. The cost of habitat restoration in Utah's wetlands has been estimated to be about \$1,000 per acre.⁵ This value is used to estimate the cost of restoring wetlands in the study area following a levee failure. Moreover, it generally takes about five years of sustained effort to remove the invasive species and restore wetland habitat.⁶

Table 5-11 summarizes the annual cost of eradicating invasive species under the FWOFI should a levee fail. As the table shows, annual eradication expenses would range between \$77,000 dollars for CDC and \$793,000 dollars per year at the Bear River Club. The annual eradication cost at Salt Creek Waterfowl Management Area totals \$550,000 dollars.

Table 5-11. Acres of Wetland Damaged by Invasive Species and Invasive Species Management Costs Under the FWOFI

Wetland Name	Net Change in Wetland Acreage Damaged by Invasive Species Under FWOFI	Treatment Cost per Acre	Annual Invasive Species Treatment Cost
Bear River Club	793	\$1,000	\$793,000
Chesapeake Duck Club	77	\$1,000	\$77,000
Salt Creek Waterfowl Management Area	550	\$1,000	\$550,000
Total	1,420	\$1,000	\$1,420,000

⁴ ECONorthwest, Martin & Nicholson. 2019. *Assessment of Potential Costs of Declining Water Levels in Great Salt Lake*. (Note: This report cites personal communication from Rich Hansen, Utah Division of Wildlife, February 27, 2019.)

⁵ ECONorthwest, Martin & Nicholson. 2019. *Assessment of Potential Costs of Declining Water Levels in Great Salt Lake*. (Note: This report cites personal communication from Keith Hambrecht, Utah Division of Forestry, Fire & State Lands, April 22, 2019.)

⁶ <https://extension.usu.edu/wetlands/research/how-to-restore-phragmites-invaded-wetlands.pdf>

D.5.1.3.3 Valuation of Wetland Habitat

Wetlands are extremely productive ecosystems, capable of producing a variety of public benefits, including recreational opportunities, such as fishing, bird watching, hunting, and boating; habitat for aquatic and avian species; regulating water flows and water quality improvement.

A 2015 wetland mitigation compliance study found that mitigated wetlands create similar values to natural wetlands when they are properly constructed and offer comparable values to natural wetlands. The study "Valuation of Ecosystem Services from Wetlands Mitigation in the United States" primarily focuses on estimating the economic value of ecosystem services generated by wetland mitigation projects using wetland permit data from the U.S. Army Corps of Engineers for the years 2010–2012. This data included details on the location, type, size, and impact of wetland losses, as well as the type and extent of mitigation measures taken to compensate for those losses. During this period, roughly 72,000 acres of wetland were restored or created to offset the impacts on 30,000 acres of wetlands across the U.S. The study found that wetlands created for mitigation create approximately \$8,000 to \$60,000 dollars per acre in annual ecosystem service benefits at a national level and between \$6,267 to \$14,413 dollars in Utah (Table 5-12).

Table 5-12. National Average Benefit Value Per Acre for Individual Wetland Ecosystem Services Produced by Wetland Mitigation (2025 dollars)

Ecosystem Service	Annual Average Benefit Per Acre	Annual Average Benefit Per Acre (Lower Bound)
Recreational Fishing	\$3,865	\$537
Bird Hunting	\$3,984	\$554
Bird Watching	\$18,865	\$2,623
Water Quality Protection	\$13,494	\$1,877
Water Supply Protection	\$9,938	\$1,382
Commercial Fishing	\$11,477	\$1,595
Flood Control	\$2,436	\$382
National Average	\$64,057	\$8,949
State of Utah	\$14,413	\$6,267

Source: Adusumilli 2015.

These estimates account for regional differences and wetland characteristics, providing reliable state-level values for project planning, while also acknowledging variability due to local conditions. The study's approach offers a scientifically grounded basis for evaluating the economic benefits of wetland protection and restoration in the Project Area.

D.5.1.3.4 Wetland Damage Reductions

By combining the projected increase in acres occupied by invasive species with the associated annual costs of control and the loss of wetland ecosystem services divided by the annual failure probability of the levees, the annual wetland damages under the FWOFI are expected to include Bear River Club levee failure damages of about \$865,000 dollars per year, the CDC damages of about \$177,900 dollars per year, and the Salt Creek WMA damages of about \$4.0 million dollars per year.

In the benefit–cost analysis, these FWOFI damages are treated as reduced damage benefits of the action alternatives—i.e., the benefit equals the FWOFI value minus any residual with-project damages—because the levee improvements are intended to prevent the invasive spread and wetland loss that drive these damages. In total, about \$5,042,700 (rounded to nearest hundred)

per year of reduced damage benefit is expected under the Action Alternatives, as shown on Table 5-13.

Table 5-13. Expected Annual Damages from Levee Failures in Lower Bear River Watershed (2025 dollars)

Wetland	Bear River Club	Chesapeake Duck Club	Salt Creek Waterfowl Management Area	Total
Net Change in Wetland Acreage Damaged by Invasive Species	793	77	550	1,420
Annual Cost of Invasive Species Management	\$793,000	\$77,000	\$550,000	\$1,420,000
Annual Loss of Wetland Ecosystem Services	\$4,972,238	\$479,426	\$3,444,343	\$8,896,007
Total Annual Wetland Damages from Levee Failures	\$5,765,638	\$555,926	\$3,993,943	\$10,315,507
Annual Failure Probability of Levee	15%	32%	100%	-
Expected Annual Damage (FOWFI)/ Reduced Damage (Preferred Alternative)	\$864,845	\$177,896	\$3,999,943	\$5,042,684

D.5.1.3.5 Preferred Alternative Changes

Under the FWOFI (baseline condition), levee failures at the Bear River Club, Chesapeake Duck Club (CDC), and Salt Creek Waterfowl Management Area (WMA) result in increased spread of invasive species, loss of wetland function, and high annual damages. These damages are calculated as the sum of invasive species control costs and lost ecosystem services, weighted by the annual probability of levee failure. The Preferred Alternative repairs and stabilizes these levees, reducing the probability of failure to near zero and preventing the spread of invasive species and loss of wetland function. This results in a substantial annual ecosystem services benefit for wetland protection as shown in Table 5-14.

Table 5-14. Annual Wetland Damage Reduction (With-Project vs. Without-Project)

Wetland Area	Annual Damage (FWOFI)	Annual Damage (Preferred Alternative)	Ecosystem Services Benefit (Annual Reduced Damage to Wetlands)
Bear River Club	\$864,845	\$0	\$864,845
Chesapeake Duck Club (CDC)	\$177,896	\$0	\$177,896
Salt Creek WMA	\$3,999,943	\$0	\$3,999,943
Total	\$5,042,684	\$0	\$5,042,684

Under the FWOFI, annual wetland damages total approximately \$5,042,700 (rounded to the nearest hundred) due to levee failures and resulting invasive species spread and loss of ecosystem services. The Preferred Alternative eliminates these damages by stabilizing the levees, resulting in a direct, annual ecosystem services benefit of \$5,042,700 (rounded to the nearest hundred).

D.5.1.4 Increased Farm Income from Use of Conserved Water

The Highland Ditch Company and Central Canal Company both operate existing concrete lined canals that are deteriorating and reducing the efficiency of operations and maintenance (O&M) and conveyance. Under the action alternatives, piping projects would increase water supply for irrigation by about 520 acre-feet per year, which includes 250 acre-feet per year for the Highland Ditch and 270 acre-feet per year for the Central Canal.

The water conserved by the action alternatives could be used as late-season finishing water, likely for hay and haylage.⁷ While agricultural producers could respond to the increased supply by planting higher value crops, this analysis assumes that they will adapt by applying any additional water to existing crops to avoid the costs of converting fields and limiting their financial exposure to uncertain conditions in the future.

D.5.1.4.1 Conveyance and On-farm Irrigation Efficiencies

The number of acres that can be irrigated with water conserved by the Proposed Project depends on the efficiency of the irrigation system, specifically conveyance efficiency and on-farm efficiency. Project sponsors indicate that flood irrigation would likely continue.⁸ The water conserved by the proposed improvements would be gained after the water is diverted from the river, but before the water is delivered to farm and ranch headgates. Based on these considerations, the average on-farm efficiency of flood irrigation is approximately 60 percent.⁹ Using this efficiency rate, the 520 acre-feet per year of conserved water would provide an additional 310 acre-feet of water available for consumptive use by crops.

D.5.1.4.2 Additional Agricultural Production

The primary benefit of finishing water is the marginal income it creates for producers by increasing crop production, particularly for hay and haylage. Late-season irrigation enables an additional cutting, allowing hay fields to regrow and be harvested more often during the growing season.

Crop production functions can be used to estimate the impact of additional water supplies to increase crop production yields. In the Lower Bear River Project Area, these functions were developed using average yield and water requirement data from Box Elder County between 1999 and 2008, as shown on Table 5-15. The table also shows the average crop irrigation requirements for hay based on information from Utah State University.

Table 5-15. Average Yield, Crop Water Requirement, Crop Production Function, and Additional Crop Yield for Hay in the Benefit-Cost Analysis

Item	Value
Average Yield Per Acre (1999-2008) (tons/acre)	3.6
Crop Irrigation Requirements (acre-feet/acre)	2.2
Crop Production Function (yield/acre-foot/acre)	1.6
Water Available from Highland Ditch (acre-feet)	150

⁷ J-U-B ENGINEERS, Inc., personal communication, January, 2025.

⁸ J-U-B ENGINEERS, Inc., personal communication, February, 2025.

⁹ NRCS. 2019. Utah Irrigation Efficiency Worksheet. Available at: https://www.nrcs.usda.gov/wps/PA_NRCSConsumption/download?cid=nrcseprd1442639&ext=pdf

Item	Value
Additional Crop Production from Highland Ditch (tons)	240 tons
Water Available from Central Canal (acre-feet)	162
Additional Crop Production from Central Canal (tons)	260 tons
Total Additional Crop Production from Highland Ditch and Central Canal (tons)	500 tons

Source: USDA National Agricultural Statistics Service (2011-2021). NASS - Quick Stats. See Table 10 in the BCA for yearly details (Appendix E1 of the Plan-EIS).

The estimated crop production function indicates that for every acre-foot of water consumed, yields increase by approximately 1.6 tons per acre.

Based on these calculations, approximately 240 tons would be produced with water conserved by piping the Highland Ditch while approximately 260 tons would be produced with water conserved by piping the Central Canal, and the hay production would increase by a total of 500 tons per year.

D.5.1.4.3 Valuation of Increased Crop Production

The additional hay yield produced under the action alternatives was valued by estimating gross revenue using USDA ERS normalized prices for hay in Utah and subtracting marginal production costs (ERS 2024).

The enterprise budget expresses crop production costs in terms of capital, labor, and materials, and then further categorizes by activity, including pre-planting, planting, growing, and harvesting. These cost categories were reviewed to determine which would apply to the application of finishing water. After reviewing cost categories, it was determined that costs related to irrigation and harvesting were the only cost categories that would increase as a result of applying finishing water. These costs were itemized and standardized to report expenses in terms of tons as shown in Table 5-16 below.

Table 5-16. Marginal Production Costs for Irrigated Hay Used in the Benefit-Cost Analysis (2025 dollars)

Cost Category	Hay (\$/ton)
Labor	\$8.68
Water assessment	\$3.47
Fuel	\$18.07
Baling	\$2.01
Other	\$1.74
Total	\$33.97

Source: Utah State University. 2019. Irrigated Oat Hay Enterprise Budget, Northern Utah. Utah State University, College of Agriculture and Applied Sciences.

Table 5-17 shows the normalized price for hay in Utah based on data from the USDA ERS. Gross crop revenues were estimated by multiplying the normalized price in Table 5-17 by the additional hay yield calculated in Table 5-15. Net revenue is the production costs subtracted from the gross revenue.

Table 5-17. Normalized Prices, Gross Revenues, Gross Costs, and Net Operating Income for Hay Grown in the Lower Bear River Watershed (2025 dollars)

Metric	Highland Ditch	Central Canal
Normalized Price	\$220.83	\$220.83
Marginal Production Cost	\$50.73	\$50.73
Additional Crop Production	240 tons	260 tons
Gross Revenue	\$53,000	\$57,415
Production Cost	\$8,150	\$8,830
Net Revenue	\$44,850	\$48,585

Source: ERS 2024. <https://www.ers.usda.gov/data-products/normalized-prices>

Based on these calculations, the action alternatives would increase farm income by approximately \$93,400 (rounded to nearest 100) per year. This includes \$44,850 for the Highland Ditch and \$48,585 for the Central Canal.

D.5.1.4.4 Preferred Alternative Changes

Under the FWOFI (baseline condition), deteriorating canals in the Highland Ditch and Central Canal result in water losses, limiting the amount of water available for late-season irrigation, and reducing potential farm income. The Preferred Alternative pipes the Highland Ditch and Central Canal, conserving water and allowing for additional late-season irrigation and increased hay production. This results in an annual benefit for farm income as shown in Table 5-18.

Table 5-18. Annualized Increased Farm Income from Conserved Water (With-Project vs. Without-Project)

Canal	Additional Crop Production FWOFI	Additional Farm Income FWOFI	Additional Crop Production Preferred Alternative	Additional Farm Income Preferred Alternative	Ecosystem Services Benefit (Annual Increased Farm Income)
Highland Ditch	0 tons	\$0	240 tons	\$44,850	\$44,850
Central Canal	0 tons	\$0	260 tons	\$48,585	\$48,585
Total	0	\$0	500 tons	\$93,400	\$93,400

Under the FWOFI, water losses in the Highland Ditch and Central Canal limit the ability of producers to irrigate late in the season, reducing potential farm income. The Preferred Alternative conserves water through piping, enabling additional hay production and resulting in a direct, annual ecosystem services benefit of \$93,400.

D.5.2 Project Costs

Project costs include all expenses incurred as part of the development, installation, operation, and maintenance of a project.

Preliminary engineering work was completed by J-U-B, who was hired by the Sponsoring Local Organization (SLO) to lead design and planning work on the project. J-U-B is the lead engineer on the project. Based on this work, J-U-B provided cost estimates for each of the alternatives.

The cost estimates were allocated to particular categories, which included:

- Permitting;
- Administration;
- Engineering and design;
- Construction; and

- Operations and Maintenance.

Each cost was allocated to federal sources or the project sponsor.

D.5.2.1 Preferred Alternative Costs

J-U-B developed installation costs for the Preferred Alternative using a bottom-up approach in which projects and structures were broken into lower-level components. Direct costs, including labor, materials, and professional services were then determined for each of those components. A cost contingency of 25 percent of construction costs was also added to the installation cost estimate for each component. Costs for O&M were estimated separately as a percentage of each work's construction cost. A summary of these costs is provided in Table 5-19.

Table 5-19. Preferred Alternative Capital Cost Estimate

Works of Improvement	Project Total
BRCC Irrigation System Delivery Improvements—Hammond and Main Canal Improvements	\$58,888,275
BRCC Irrigation System Delivery Improvements—Red Siphon	\$3,381,333
BRCC Irrigation System Delivery Improvements—Bear River City Pressure Irrigation	\$14,476,595
BRCC Irrigation System Delivery Improvements—Highland Ditch Piping	\$5,232,656
BRCC Irrigation System Delivery Improvements—Central Canal Company Piping	\$6,230,075
Tremonton Pressure Irrigation Improvements	\$9,955,937
Tremonton Irrigation Storage	\$3,013,627
Bear River Club Levee Improvements	\$4,045,706
Chesapeake Duck Club Levee Improvements	\$2,401,898
Salt Creek Waterfowl Management Area Levee Improvements and Sediment Removal	\$7,942,196
Total	\$115,568,297

Totals may not sum due to rounding. Prepared October 2025. Price base: 2025 dollars.

D.5.2.2 Installation Costs

The full installation cost estimates for each work of improvement are provided in Tables 20-31 in the BCA (in Appendix E1 of the Plan-EIS).

D.5.2.3 Other Direct Costs & Adverse Effects

The Preferred Alternative has only one primary category of other direct costs. The nature of and methods used to calculate these other direct costs are discussed in more detail, below.

Operations, Maintenance, and Repair

Once the works of improvement are built, overheads for operations, maintenance, and repair will be required for the works of improvement to continue generating the benefits for which they were designed. These costs were estimated to be 0.5 percent of each work of improvement's construction costs, which do not include costs for engineering, permitting, and administration. Estimated annual O&M costs for each work of improvement are shown in Table 5-20, below.

Table 5-20. Estimated Construction and Annual Operations, Maintenance, and Repair Costs for Works of Improvement Included in the Preferred Alternative (2025 dollars)

Work of Improvement	Construction Cost	Annual O&M Costs
BRCC Irrigation System Delivery Improvements—Hammond Improvements	\$50,749,375	\$253,747
BRCC Irrigation System Delivery Improvements—Red Siphon	\$2,898,563	\$14,493

Work of Improvement	Construction Cost	Annual O&M Costs
BRCC Irrigation System Delivery Improvements—Bear River City Pressure Irrigation	\$12,463,444	\$62,317
BRCC Irrigation System Delivery Improvements—Highland Ditch Piping ¹	\$4,494,531	\$3,000
BRCC Irrigation System Delivery Improvements—Central Canal Company Piping ¹	\$5,354,375	\$3,100
Tremonton—Pressure Irrigation Improvements and Storage	\$11,147,900	\$55,740
Bear River Club Levee Improvements	\$3,471,298	\$17,356
Chesapeake Duck Club Levee Improvements	\$2,054,222	\$10,271
Salt Creek Waterfowl Management Area Levee Improvements and Sediment Removal	\$6,813,962	\$34,070
Totals—Preferred Alternative	\$99,447,670	\$454,094

¹Costs are based on estimates from Highland Ditch Co. and Central Canal Co.

D.5.2.4 Current Economic Damages

Average annualized damages under the FWOFI were estimated to serve as a benchmark of comparison with the action alternatives and are shown in Table 5-21, below (NWPM 501.36). In total, average annualized damages under the FWOFI are approximately \$8.4 million per year, including \$3,375,300 of expected agricultural damages and \$5,042,700 in damage to wetlands.

Table 5-21. Average Annualized Damages Under the FWOFI (2025 dollars).

Alternative	Agricultural-related ¹		Average Annualized Damages ¹
	Farm Income Damage	Damage to Wetlands ²	Total
FWOFI	\$3,375,300	\$5,042,700	\$8,418,000
Total	\$3,375,300	\$5,042,700	\$8,418,000

Notes: Totals may not sum due to rounding (to nearest 100). Prepared: October 2025.

¹Price base: 2025 dollars; amortized over 100 years at a discount rate of 3.25 percent.

²Wetland damage in rural areas are included as agricultural-related per PL 83-566 and NWPM 506.0, Section 2, because these wetlands support agricultural production and rural community sustainability (NRCS 2015).

D.5.3 Economic and Structural Tables

The results of the benefit-cost analysis for the action alternatives were compared against the FWOFI or No Action Alternative and serve as the best estimate of the additional economic value that would be created under the action alternatives.

Results are presented in Section 6.11 of the Plan-EIS using the Economic and Structural Tables outlined in NWPM Part 506 (NRCS 2024) for the Preferred Alternative as shown below:

- Table 6-3. National Watershed Program Manual Economic Table 1—Estimated Preferred Alternative Installation Cost, Lower Bear River Watershed, Utah (2025 dollars) (NWPM 506.11)
- Table 6-4. National Watershed Program Manual Economic Table 2—Estimated Cost Distribution-Preferred Alternative, Lower Bear River Watershed, Utah (2025 dollars) (NWPM 506.12)
- Table 6-5. National Watershed Program Manual Economic Table 4—Estimated Average Annualized Costs, Lower Bear River Watershed, Utah (2025 dollars) (NWPM 506.18)
- Table 6-6. Economic Table 5a—Estimated Average Annualized Benefits and Reduced Damages by Increment, Lower Bear River Watershed Project, Utah (2025 dollars) (NWPM 506.20)
- Table 6-7. National Watershed Program Manual Economic Table 6—Comparison of Average Annualized Costs, Reduced Damages and Benefits, of the Preferred Alternative Lower Bear River Watershed, Utah (2025 dollars) (NWPM 506.21)
- Table 6-8. Structural Table 3—Dams with Planned Storage Capacity, Lower Bear River Watershed, Utah (NWPM 506.15)
- Table 6-9. Structural Table 3a—Dikes (Levees), Lower Bear River Watershed, Utah (NWPM 506.16)
- Table 6-10. Structural Table 3b—Channel Work, Lower Bear Watershed, Utah (NWPM 506.17)

D.6.0 Sources

- Adusumilli, N. 2015. Valuation of ecosystem services from wetlands mitigation in the United States. *Land* 4(1):182–196. <https://doi.org/10.3390/land4010182>
- Ducks Unlimited, personal communication, January, 2025.
- ECONorthwest, Martin & Nicholson. 2019. Assessment of Potential Costs of Declining Water Levels in Great Salt Lake. (Note: This report cites personal communication from Rich Hansen, Utah Division of Wildlife, February 27, 2019.)
- ECONorthwest, Martin & Nicholson. 2019. Assessment of Potential Costs of Declining Water Levels in Great Salt Lake. (Note: This report cites personal communication from Keith Hambrecht, Utah Division of Forestry, Fire & State Lands, April 22, 2019.)
- EPA (U.S. Environmental Protection Agency). 2024. Ecoregion Download Files by State—Region 8. Accessed November 10, 2024. <https://www.epa.gov/eco-research/ecoregion-download-files-state-region-8#pane-42>.
- ERS (U.S. Department of Agriculture, Economic Research Service). 2024. Normalized Crop Prices. Available at: <https://www.ers.usda.gov/data-products/normalized-prices>
- J-U-B ENGINEERS, Inc., personal communication, January, 2025.
- J-U-B ENGINEERS, Inc., personal communication, February, 2025.
- NASS (USDA National Agricultural Statistics Service) 2011-2021. NASS - Quick Stats. USDA National Agricultural Statistics Service. <https://data.nal.usda.gov/dataset/nass-quick-stats>. Accessed January 2025.
- NRCS (USDA Natural Resources Conservation Service). 2019. Utah Irrigation Efficiency Worksheet. Available at: https://www.nrcs.usda.gov/wps/PA_NRCSCConsumption/download?cid=nrcseprd1442639&ext=pdf
- NRCS (USDA Natural Resources Conservation Service). 2024. National Watershed Program Manual. Available at: <https://www.nrcs.usda.gov/sites/default/files/2024-07/national-watershed-program-manual-june-2024.pdf>.
- Olander, R.J. Johnson, H. Tallis, J. Kagan, L. Maguire, S. Polasky, D. Urban, J. Boyd, L. Wainger, and M. Palmer. 2016. Best Practices for Integrating Ecosystem Services into Federal Decision Making. Durham: National Ecosystem Services Partnership, Duke University.
- Slater, Chris. 2020. Red Flume Site Visit [Memorandum]. J-U-B ENGINEERS Inc.
- Terracon (Terracon Consultants, Inc.). 2024. *In* TM-001. Geological Hazard Review Hammond, West and East Main Canals; Cutler Dam to SR-30 Box Elder County, Utah. September 17, 2024. Terracon Project No. 61235120. Terracon.13 pp. plus Attachments
- Utah State University. 2019. Irrigated Oat Hay Enterprise Budget, Northern Utah. Utah State University, College of Agriculture and Applied Sciences.