APPENDIX D-5
INVESTIGATION AND ANALYSIS - ECONOMICS

Supplemental Watershed Plan – Environmental Assessment for the Rehabilitation of North Branch Forest River Watershed Dam No. 1 (Bylin Dam)
Walsh County, North Dakota

May 2024

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Prepared for:
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GANNETT FLEMING

APPENDIX D-5. INVESTIGATION AND ANALYSIS – ECONOMICS

I. Introduction

A. Alternatives Evaluated

The economic investigation and analysis summarize the flood damage estimation methodology and results for three alternatives: Alternative 1: Future Without Federal Investment (FWOFI), Alternative 2: Structural Rehabilitation (Preferred Alternative) and Alternative 3: No Action.

Based on requirements outlined in PR&G, existing conditions should be projected into the future to establish a benchmark against which alternatives can be evaluated. This benchmark is referred to as FWOFI (Alternative 1). Under Alternative 1, continued deterioration of the dam would require significant modifications and the Sponsor would need to implement a solution to address safety concerns and meet design standards. The Sponsor's most likely course of action in this case would be a controlled breach of the dam. As part of the controlled breach, the road atop Bylin Dam would be realigned to its original location west of the dam embankment. Downstream flooding, conditions would be similar to those that existed prior to the construction of the dam. Therefore, this alternative was modeled as a without-dam condition.

Alternative 2: Structural Rehabilitation is the preferred alternative for Bylin Dam. This alternative would encompass raising the top of dam elevation to accommodate the appropriate design event for a high-hazard dam, hardening the auxiliary spillway by using articulated concrete block within the spillway chute, replacing the existing principal spillway conduit and riser tower, and reducing the downstream embankment slope at the dam to improve slope stability.

Alternative 3: No Action represents a and a no-action scenario where the existing dam remains in place with no measures taken to address the dam safety inadequacies associated with the dam. The dam would remain in place and would function as it currently does for the 2- through 500-year flood events. Flood reduction benefits would remain in place, as no changes would be made to the outlet works of the structure. Recreation activities would continue while the dam is intact. Under Alternative 3: No Action, an uncontrolled breach could result during a 625-year flood event. The flood damage resulting from this breach was modeled as part of the economic analysis for Alternative 3.

B. Methodology

The benefit-cost analysis follows the procedures outlined in:

- *Principles and Requirements for Federal Investments in Water Resources* (2013) and *Interagency Guidelines* (2014)
- *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (1983)
- *National Watershed Program Manual* (2014).

Unless otherwise noted, values in the analysis are in 2023 prices and annual values have been discounted using the Fiscal Year (FY) 2023 federal discount rate for water resources projects of 2.5 percent.

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The original watershed plan for the North Branch Forest River Watershed was prepared in April 1959. The plan covers an area of approximately 167 square miles (107,014 acres). Three floodwater retarding structures and 25 miles of channel improvement were included in the plan. The three dams were planned as single purpose structures designed to protect against damage from spring snowmelt and summer rainfall runoff flood events. North Branch Forest River Dam #1 (Bylin Dam) was constructed in 1964 and classified as a significant hazard dam. Due to subsequent downstream development, Bylin Dam is currently classified as high hazard.

Within the original Work Plan, benefits attributed to Bylin Dam consisted of flood damage reduction to downstream properties, cropland, and roadway infrastructure. Indirect benefits consisted of reducing the flood-related effects of extra travel, loss of productive time and delays in business activity (SCS 1959).

This analysis updates the flood damage reduction benefits quantified in the original watershed plan using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Center Flood Impact Analysis software (HEC-FIA) to estimate structures and vehicle damages, and Geographic Information System (GIS) analysis to estimate damages to study area infrastructure.

Two benefit categories were added to the current analysis: 1) incidental recreation benefits are estimated using USACE unit day values for recreation activities, and 2) administrative cost savings to the National Flood Insurance Program (NFIP) are measured from a reduction in the number of properties that must participate.

II. Study Area Inventory

The study area for the analysis was defined as the inundation limits of the floodplain resulting from an uncontrolled breach of the dam. A breach is estimated to occur during the 625-year flood event. This boundary encompasses the farthest extent of flooding for the flood events examined within the scope of the project. All other flood events examined for the analysis (2-year through 500-year flood events for with- and without-dam scenarios) fell within the breach floodplain. The study area is approximately 5,683 acres (8.9 square miles), beginning at Bylin Dam, continuing downstream along the North Branch of the Forest River, Walsh County, ND and extending to the town of Fordville, ND (see *Attachment D-5-1, Economic Analysis Study Area Boundary*). Study area land use consists of rural residential properties, active agricultural fields, open space, and roadway infrastructure.

A. Structures and Vehicles

Study area structures were identified and categorized by land use type using GIS tax parcel data obtained from the Walsh County Tax Assessors Office. The accuracy of the parcels database was verified via an examination of aerial photography. A total of 49 structures or structure groups are present within the breach floodplain. A structure group was defined as multiple structures of the same type on the same property, such as several agricultural buildings on a property, or two buildings associated with a commercial business. A total of 43 structures or structure groups are affected by the 500-year without dam scenario. A total of 21 structures or structure groups are affected by the 100-year without-dam scenario.

Properties within the breach floodplain boundary consisted of 12 residences, 39 agricultural properties and 37 grain storage bins. Properties within the 500-year without-dam floodplain boundary consisted of four residences, 23 agricultural properties and 16 grain storage bins. Properties within the 100-year without-dam floodplain boundary consisted of one residential property, 15 agricultural properties and 5 grain storage bins. No affected properties within the breach floodplain, 500-year or 100- year without-dam floodplain are characterized as critical facilities under 7 CFR 650.25, Floodplain Management. Properties that contained both residential and agricultural structures were subdivided within the inventory to correctly assess damage to each structure type.

Tax assessment data for structure values was either not available, or not considered representative of replacement value. Therefore, the outline of each building was delineated and included in a GIS polygon shapefile. Replacement values were determined on a square foot basis using Marshall Valuation Service data and were based on land use, class, and type of structure (Marshall Valuation Service 2023). Replacement values and contents values for structures are shown in Exhibit D5.1. Contents values for grain storage bins were developed using a composite of study area crops. The2022 normalized crop prices were multiplied by the maximum bushel capacity for each bin size to estimate the value of stored crops. Because it is possible that an individual bin could be full, partially full or empty depending on when a flood event occurs, the total value in each bin was then divided in half. This assumption provides a more conservative estimate of potential flood damage.

Exhibit D5.1. Replacement and Contents Value by Structure Type

<table>
<tr><th>Structure Type</th><th>Replacement Value</th><th>Contents Value</th><th>Sources</th></tr>
<tr><td>Residential (single family)</td><td>$167.20 per sq. ft.</td><td>50% of structure value</td><td rowspan="4">• NRCS Principles and Guidelines
• Marshall Valuation Service
• Study area producer interviews
• NASS 2022 normalized prices</td></tr>
<tr><td>Agricultural</td><td>$28.98 per sq. ft.</td><td>$299 per sq. ft.</td></tr>
<tr><td>Grain Storage Bin 15 ft. diam.</td><td>$17,900</td><td>$15,600</td></tr>
<tr><td>Grain Storage Bin 21 ft. diam.</td><td>$22,700</td><td>$43,200</td></tr>
</table>

Cropland is the dominant land use in Walsh County. Based on a review of Walsh County's comprehensive plan (July 1994), future development will be concentrated near existing development to preserve the robust agricultural activity in the area. Population in study area communities is forecast to be stable based on an increase in farm size and populations of incorporated towns. No major development or redevelopment plans were identified for inclusion in the flood damage estimate. Future infrastructure development activities are concentrated on maintaining existing roads and agricultural infrastructure. No major infrastructure projects were identified for inclusion in the flood damage estimate.

Vehicles were added to the inventory using HEC-FIA default settings for number of vehicles per property and corresponding to study area residents' interview responses about vehicle ownership and experience in prior flood events. The Federal Emergency Management Agency (FEMA) HAZUS-MH MR3 Technical Manual methodology was used to estimate personal vehicle value (FEMA, 2018). The FEMA methodology provides vehicle age distribution data by vehicle classification. Based on Kelley Blue Book transaction price data and the FEMA methodology, the average study area vehicle was assumed to be valued at $17,500.

Study area agricultural operations were assumed to have between one and four pick-up trucks, depending on outbuilding square footage and total agricultural acreage. Using the FEMA HAZUS methodology, light truck values within the study area were estimated to average $23,800.

B. Agricultural Land

Agricultural land was categorized by field crop using the National Agricultural Statistics Service (NASS) crop data layer (NASS 2023). Data was collected for five years from 2018-2022 (Exhibit D5.2). Agricultural land in the study area consists of nine major crops comprising more than 99% of active agricultural land. Total agricultural acres for the nine major crops in the study area were 3,888 acres on average during the five-year period of analysis. Crops consisting of less than one percent of the study area were removed from the analysis. Within the analysis, all crops were treated as basic crops.

Exhibit D5.2. Study Area Agricultural Crops

Crop	Acres Planted					Average Acres Planted
	2018	2019	2020	2021	2022	2018-2022
Spring Wheat	1,065	1,559	1,325	1,236	1,315	1,300
Dry Beans	830	545	855	363	644	647
Soybeans	1352	992	912	1,348	1,026	1,126
Potatoes	18	91	42	15	62	46
Other Hay	103	93	89	36	65	77
Corn	396	546	242	624	348	431
Alfalfa	60	83	78	52	71	69
Canola	75	87	63	62	125	82
Sunflower	101	29	74	205	135	109

Total	**4,000**	**4,024**	**3.682**	**3,943**	**3,792**	**3,888**

Source: NASS, 2023.

C. Roadways and Roadway Bridges

Roadways were divided into three categories: paved, graded and drained/gravel and unimproved. Total mileage for each roadway type in the study area was estimated using ArcGIS. Total mileage for each roadway type in the study area was estimated using ArcGIS and shown in Exhibit D5.3. There were railroad lines in the study area affected by flooding. Three bridges were identified as potentially impacted in the uncontrolled breach scenario (625-year flood event). No bridges were affected in the other events modeled.

Exhibit D5.3. Roadways within the Without-Dam Floodplain

Dam Breach		500-Year Without-Dam		100-Year Without-Dam	
Roadway Type	**Roadway Length (Miles)**	**Roadway Type**	**Roadway Length (Miles)**	**Roadway Type**	**Roadway Length (Miles)**
Paved	0.35	Paved	0.35	Paved	0.23
Graded and Drained/ Gravel	3.76	Graded and Drained/ Gravel	2.91	Graded and Drained/ Gravel	1.42
Unimproved	0.98	Unimproved	0.62	Unimproved	0.43

D. Recreation

The land surrounding Bylin Dam is owned by the Walsh County Water Resource District. Bylin Dam is not a designated park, nor is recreation a designated PL 83-566 use of the dam impoundment. However, the 60-acre lake at Bylin Dam serves as a locally important recreational resource. The normal pool upstream of Bylin Dam has an average depth of nine feet and is one of only four available public fisheries in Walsh County, ND (North Dakota Game and Fish Department, 2020). Recreation sites like this are relatively uncommon in the region.

The lake is stocked annually by the North Dakota Game and Fish Department (NDGFD) with walleye. Public access is provided primarily on the north and east sides of the lake. An unpaved parking lot with a fishing pier, boat ramp and public restroom is present at the east end of the lake and is accessible from 121st Avenue NE. Approximately 3.3 miles of shoreline is accessible.

Fishing, recreational boating and hunting are the predominant activities at the lake, with fishing and boating occurring mainly in the summer months. Boating activities include canoeing, wake boarding, tubing, water skiing and motor boating. Ice fishing occurs during the winter. Duck hunting is seasonal and mainly along the northern side of the lake due to the presence of several farms adjacent to the south side of the lake.

Interviews were conducted with residents, the NDGFD, and Natural Resources Conservation Service (NRCS) Park River field office to estimate the annual number of user days of recreation that occur at the lake (Bylin 2020, Hiltner 2019, Sveen 2019).

Alternate fishing opportunities are present in the region; Matejcek Dam (14 miles), Whitman Dam (17 miles away), Fordville Dam (27 miles away) and Renwick Dam (41 miles away) are also stocked for fishing and provide similar public access and facilities.

The United States Army Corps of Engineers (USACE) unit day values for recreation were used to estimate the recreation benefit. The USACE guidance uses a point rating method to provide unit day values based on the quality and type of recreation. Criteria consist of 1) number of recreation activities present at a site, 2) availability of similar opportunities at nearby sites, 3) carrying capacity or quality of facilities, 4) accessibility, and 5) environmental quality. Exhibit D5.4 shows the annual recreation benefit provided by Bylin Dam, calculated at $12,100.

Duck hunting was categorized as specialized hunting because the state and region are a destination for duck hunting in the Upper Midwest. The North American Central Flyway goes through the state and is one of the busiest routes for migratory birds traveling between northern Canada and the Gulf Coast. Duck species in the region include mallards, scaup, wood ducks, redheads, pintails, canvasbacks, blue-winged teal and mergansers, and may include coots, wigeon, buffleheads, goldeneye, gadwalls, green-winged teal, northern shovelers, ring-necked ducks and ruddy ducks (Ducks Unlimited 2023).

The study area is one of a regional network of duck hunting areas and was categorized as mid-range in quality relative to other regional hunting opportunities. Nine U.S. Fish and Wildlife Waterfowl Production Areas are open to hunting in the region. Within an hour drive, Devil's Lake (to the southwest) and Ardoch National Wildlife Refuge (to the southeast) provide duck hunting. Devil's Lake is a premier duck hunting location providing professional guide services on site. Ardoch National Wildlife Refuge is a limited-interest national wildlife refuge, which is a combination of privately owned parcels that have easements on them to continue to protect wildlife and habitat, specifically migrating waterfowl and other birds. This land is not federally owned, therefore access to these lands is granted by the private landowner.

Exhibit D5.4. Annual Recreation Benefits, Bylin Dam

Structure	Annual General Recreation Days[1]	Unit Day Value[2] (2023 $)	Annual Value	Annual Hunting Recreation Days[1]	Unit Day Value[3] (2023 $)	Annual Value	TOTAL Annual Value
Bylin Dam	743	$9.13	$6,784	142	$37.44	$5,316	$12,100

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[1] *Based on interviews with residents, NDGFD, and NRCS.*
[2] *FY 2023 mid-range unit day value for general recreation, USACE 2023.*
[3] *FY 2023 mid-range unit day value for specialized fishing and hunting, USACE 2023.*

III. Flood Damage Reduction

A. Structures and Vehicles

Flood damage to structures was estimated using HEC-FIA version 3.0. The HEC-FIA model uses the following parameters to estimate the flooding depth and cost of damages to structures and vehicles:

- Flood frequency and depth, duration, and arrival time gridded data from the output flood model
- Terrain elevation grid in combination with user defined parameters to determine first floor elevation
- Foundation heights, which were assumed to be 1.0 feet from ground elevation
- Point locations of all structures
- Type and value of each structure and contents within the structure
- Damage coefficient data for each type of structure and contents

HEC-FIA uses gridded data to determine depth, arrival, and duration of water at each structure point. The model then analyzes the water depth and first floor elevation with the default or user defined depth damage curve to determine damages for each flood event.

Using the output hydraulic data, the 2-year, 5- year, 10-year, 25-year, 50-year, 100-year, and 500-year flood events were modeled in HEC-FIA for without-dam and Preferred Alternative conditions. A breach scenario, estimated to occur at the 625-year flood event, was also modeled. Depth-damage factors for the various structure types and contents were obtained from USACE data provided by NRCS (NRCS 2018). The model extents continue to the point at which flow becomes channelized, and no more damage occurs. The without-dam condition presents a baseline for comparison to estimate flood protection being provided by rehabilitation.

Model results for Alternative 1: FWOFI (without-dam conditions) are shown in Exhibits D5.5, including damages by structure type and number of structures inundated for the seven flood events modeled. Damages and structures inundated under the Alternative 2: Structural Rehabilitation (Preferred Alternative) and Alternative 3: No-Action are shown in Exhibit D5.6 and Exhibit D5.7 respectively. Please refer to Attachment D-5-2 for floodplain delineation mapping showing the inundation limits for the flood events modeled. Please refer to HEC-FIA Model Output Exhibits in Plan-EA Appendix C for model output.

Damages and structures inundated under the Preferred Alternative are shown in Exhibit D5.6.

Exhibit D5.5. HEC-FIA Model Results, Alternative 1. FWOFI (Without Dam Conditions)

Flood Event	No. of Structures Affected[1]	Structures by Type		Total Structure Damage	Total Contents Damage	Total Vehicle Damage	Total Damage
		Ag.	Res.				
625-yr[2]	>38	>30	>8	$1,508,550	$10,229,642	$276,674	$12,014,867
500-yr	38	30	8	$1,436,714	$9,742,516	$263,499	$11,442,730
100-yr	21	17	4	$577,204	$4,553,016	$152,769	$5,282,989
50-yr	17	13	4	$438,476	$2,929,436	$107,847	$3,475,760
25-yr	15	12	3	$293,992	$1,741,076	$65,225	$2,100,293
10-yr	11	9	2	$168,633	$723,784	$32,304	$924,721
5-yr	3	3	0	$26,251	$244,395	$15,022	$285,668
2-yr	0	0	0	$0	$0	$0	$0

[1] A total of 43 structures are located in the 500-year floodplain, but flood depths were below levels that would result in damages for some structures.

[2] – Flood damages for the 625-year event under the FWOFI were extrapolated from the 500-year modeling based on the expected increase in rainfall.

Exhibit D5.6. HEC-FIA Model Results, Alternative 2. Structural Rehabilitation (Preferred Alternative)

Flood Event	# of Structures Damaged	Structures by Type		Total Structure Damage	Total Contents Damage	Total Vehicle Damage	Total Damage
		Ag.	Res.				
625-yr[1]	>17	>13	>4	$354,873	$2,495,349	$67,497	$2,917,719
500-yr	17	13	4	$337,974	$2,376,523	$64,283	$2,778,780
100-yr	6	4	2	$129,540	$833,830	$27,827	$991,197
50-yr	6	4	2	$112,505	$639,133	$18,260	$769,898
25-yr	5	3	2	$78,542	$473,741	$9,723	$562,005
10-yr	2	2	0	$11,913	$199,260	$1,681	$212,854
5-yr	0	0	0	$0	$0	$0	$0
2-yr	0	0	0	$0	$0	$0	$0

[1] *– Flood damages for the 625-year event under Alternative 2 were extrapolated from the 500-year modeling based on the expected increase in rainfall.*

Exhibit D5.7. HEC-FIA Model Results, Alternative 3. No Action

Flood Event	# of Structures Damaged	Structures by Type		Total Structure Damage	Total Contents Damage	Total Vehicle Damage	Total Damage
		Ag.	Res.				
625-yr	54	42	12	$3,372,972	$20,148,849	$624,507	$24,146,329
500-yr	17	13	4	$337,974	$2,376,523	$64,283	$2,778,780
100-yr	6	4	2	$129,540	$833,830	$27,827	$991,197
50-yr	6	4	2	$112,505	$639,133	$18,260	$769,898
25-yr	5	3	2	$78,542	$473,741	$9,723	$562,005
10-yr	2	2	0	$11,913	$199,260	$1,681	$212,854
5-yr	0	0	0	$0	$0	$0	$0
2-yr	0	0	0	$0	$0	$0	$0

Exhibit D5.8 presents the calculation of the expected annual damage for structures and vehicles under the three alternatives. Calculation of the expected annual damage (EAD) accounts for the probability of exceedance of each flood event magnitude. The expected annual damage is the area under the frequency-damage curve. The difference in damages between the without-dam conditions and the Preferred Alternative conditions, **$321,400,** represents the annual benefit of implementing the Preferred Alternative. Benefits are rounded to the nearest hundred dollars per NRCS guidance.

Exhibit D5.8. Expected Annual Flood Damages to Structures and Vehicles

Flood Event	Ex. Prob.	Alt.1. FWOFI (Without Dam)		Alt.2. Structural Rehab (Preferred Alternative)		Alt.3. No Action	
		Damages	Contrib. to EAD	Damages	Contrib. to EAD	Damages	Contrib. to EAD
625-yr	0.0016	$12,014,867	$19,224	$2,917,719	$4,668	$24,146,329	$38,634
500-yr	0.002	$11,442,730	$22,885	$2,778,780	$5,558	$2,778,780	$5,558
100-yr	0.01	$5,282,989	$66,903	$991,197	$15,080	$991,197	$15,080
50-yr	0.02	$3,475,760	$43,794	$769,898	$8,805	$769,898	$8,805
25-yr	0.04	$2,100,293	$55,761	$562,005	$13,319	$562,005	$13,319
10-yr	0.1	$924,721	$90,750	$212,854	$23,246	$212,854	$23,246
5-yr	0.2	$285,668	$60,519	$0	$10,643	$0	$10,643
2-yr[1]	0.5	$0	$42,850	$0	$0	$0	$0
		TOTAL	**$402,686**	**TOTAL**	**$81,319**	**TOTAL**	**$115,285**

[1] – Although damages in the 2-yr event are $0, the contribution to EAD comes from events less than the 5-yr and greater than the 2-yr events.

Under an uncontrolled breach scenario (625-year flood event under the No Action Alternative), damages to structures and vehicles were estimated at $24,146,300. The expected annual damage from this event would be $38,600.

Flood damages were also estimated for the 625-year event under Alternatives 1 and 2 by extrapolating model results from the 500-year event. While substantial flood damage would still occur at the 625-year event under these alternatives, fewer damages accrue in comparison to an uncontrolled breach. Under Alternative 1: FWOFI, the dam would have already been breached in a controlled manner by the Sponsor. Under Alternative 2, the rehabilitated dam would be designed to withstand a Probable Maximum Precipitation (PMP) event, substantially reducing the likelihood of a breach in any year.

B. Agriculture

The USACE HEC-FIA model was used to calculate, for each inundation duration and each crop, the acreage under water for that duration. HEC-FIA was run once for each flood magnitude, from the 625-year breach event, to the 500-year to 2-year flood events for the FWOFI/without-dam and Preferred Alternative. HEC-FIA can also be used to calculate estimated damages from crop losses. However, for this analysis, an Excel spreadsheet crop damage model was developed. The model has more flexibility and detail to better account for specific agricultural economic parameters. Another advantage is that, compared to the crop loss estimator within HEC-FIA, the spreadsheet model provides greater transparency with respect to the assumptions and calculations used to estimate damages.

Flood and Crop Mapping. Hydraulic data output from HEC-RAS maps the flood extent, by eight-hour duration increments, for inundation durations from one to fifteen days. USDA’s NASS crop data layers map the land use and crop type coverage at a 30-meter resolution. Crop data layers for 2018-2022 were used in separate analyses to capture possible variations due to crop rotations (see Attachment D-5-3 National Cropland Data Layers).

Price and Yield. The yield and price data input into the crop damage spreadsheet model and their sources are indicated in Exhibit D5.9. Flooded sunflower and canola acreage is included with the spring wheat damage estimation throughout the analysis.

Exhibit D5.8. Crop Yield and Price Inputs

	Spring Wheat[3]	Dry Beans	Soybeans	Potatoes	Other Hay	Corn	Alfalfa
Units	bushels	cwt	bushels	cwt	tons	bushels	tons
Yield (units/acre)[1]	45	14	32	320	1.5	132	1.6
Price[2]	$6.67	$36.30	$10.54	$11.43	$114	$4.59	$114
Revenue/acre	$300	$508	$337	$3,658	$171	$606	$182

[1]Source: USDA. Five-year average for Walsh County, weighted by acreage planted.
[2] Source: USDA. North Dakota normalized price, 2022.
[3] Flooded sunflower and canola acreage is included with the spring wheat damage estimation.

Crop Damage Factors. The crop damage factors recognize that the chief determinant of crop damage is not depth of flooding but duration that the crop is under water. The crop damage factors vary by month of the growing season. Exhibit D5.10 presents the crop damage factors. HEC-FIA model output produces numbers of acres of each crop inundated in 8-hour intervals. The fractional day crop damage factors are calculated by linear interpolation of the daily crop loss percentages shown in Exhibit D5.11.

Exhibit D5.10. Crop Damage Factors for North Dakota
(Percent Decrease in Yields by Number of Days Inundated)

Spring Wheat					
Days	**April & May**	**June**	**July**	**August**	**September**
1 day	14	17	20	30	30
2 days	29	34	43	65	65
3 days	44	54	65	75	75
4 days	60	75	90	80	80
5 days	80	100	100	90	90
6 days+	100	100	100	100	100
Dry Beans					
Days	**May**	**June**	**July**	**August**	**September**
1 day	11	28.5	24.5	26	24.5
2 days	14.5	48.5	49.5	49.5	57.5
3 days	21.5	66	67	65	71
4 days	31	79	78	75	72
5 days	37	85.5	90.5	79.5	72
6 days+	40.5	89.5	90.5	91.5	72

Exhibit D5.10. Crop Damage Factors for North Dakota
(Percent Decrease in Yields by Number of Days Inundated)

Soybeans					
Days	**May**	**June**	**July**	**August**	**September**
1 day	7	13	4	4	10
2 days	8	16	17	16	62
3 days	16	32	34	30	83
4 days	29	58	56	50	83
5 days	36	71	81	69	83
6 days+	40	79	81	83	83
Potatoes					
Days	**April & May**	**June**	**July**	**August**	**September**
1 day	15	44	45	48	39
2 days	21	81	82	83	53
3 days	27	100	100	100	59
4 days	33	100	100	100	61
5 days	38	100	100	100	61
6 days+	38	100	100	100	61
Other Hay					
Days	**April & May**	**June**	**July**	**August**	**September**
1 day	15	15	20	15	15
2 days	25	30	40	25	25
3 days	40	65	70	40	45
4 days	60	100	100	55	60
5 days	80	100	100	70	70
6 days	100	100	100	85	80
7 days+	100	100	100	100	85
Corn					
Days	**April & May**	**June**	**July**	**August**	**September**
1 day	13	18	11	5	5
2 days	31	45	19	13	19
3 days	66	72	46	19	36
4 days	70	78	57	33	44
5 days	100	100	72	44	51
6 days	100	100	76	68	65
7 days+	100	100	100	71	77

Exhibit D5.10. Crop Damage Factors for North Dakota
(Percent Decrease in Yields by Number of Days Inundated)

Alfalfa					
Days	**May**	**June**	**July**	**August**	**September**
1 day	5	11	11	5	0
2 days	10	37	27	10	0
3 days	16	38	29	15	3
4 days	30	49	35	22	5
5 days	35	63	43	28	7
6 days	56	63	41	35	10
7 days+	63	63	59	40	12

Source: SCS 1981. North Dakota Crop Damage Factors. Damage factors for April are not in the original SCS tables; May factors are used. Original SCS did not have May factors for soybeans; May factors used are half of June factors, per consultation with L. Mairs (2017). SCS did not provide damage factors for drybeans; drybean damage factors are midway between those of potatoes and soybeans, per consultation with S. Lahman (2018).

Late Plant Yield Loss. Late planting that results in yield loss may occur if flooding delays planting beyond the optimal time window or if early growing season flooding is sufficiently damaging to a planted crop that it is dug up and the acreage replanted. The assumed replant thresholds and late plant yield losses are shown below in Exhibit D5.11. The exhibit also shows the assumed percent of the crop planted at the time of the flood.

Exhibit D5.11. Late Plant Thresholds, Yield Losses, and Crop Progress

Month	Spring Wheat	Dry Beans	Soybeans	Potatoes	Corn	Alfalfa and Other Hay
April						
Percent Planted	25%	0%	0%	10%	25%	100%
Late Plant Yield Loss	10%	0	0	0	20	NA
Replant when damage over:	40%	NA	NA	NA	30%	NA
May						
Percent Planted	80%	40%	50%	50%	80%	100%
Late Plant Yield Loss	20%	10%	10%	50%	30%	NA
Replant when damage over:	30%	25%	30%	NA	30%	NA
June						
Late Plant Yield Loss	NA	30%	30%	NA	NA	NA
Replant when damage over:	65%	65%	65%	NA	75%	NA
Replant with…	soybeans	same	same	NA	soybeans	NA
August						
Percent Harvested	35%	0%	0%	0%	0%	67%
September						
Percent Harvested	90%	50%	5%	25%	0%	75%

Source: Personal communications with Chris Nelson, NRCS (2017), and Loren Mairs, Mairs Agricultural Consulting (2017), Samantha Lahman, Pembina County Extension (2018), Muhamed Khan, NDSU Extendion (2019).

Replant Costs. For flooding that occurs early enough in the growing season and where crop loss exceeds certain crop loss thresholds, the flooded acreage is assumed to be replanted. Replanting cost factors used in the model are as shown in Exhibit D5.12.

Unit Costs. While flood damage reduces crop revenues, it can also reduce some of the costs of bringing that crop to market. Exhibit D5.12 shows the cost factors used for avoided costs. Harvests costs are only treated as avoided on analysis cells with 100% yield loss. Therefore, avoided harvest costs are not shown for crops that have no damage factors of 100%.

Exhibit D5.12. Cost Factors

	Spring Wheat	Dry Beans	Soybeans	Potatoes[3]	Corn[2]	Alfalfa & Other Hay[4,5]
Replant Cost Factors						
Seed ($/acre)[1]	20.50	60.23	65.80	NA	84.74	NA
Planting ($/acre)[1]	25.00	20.00	20.00	NA	20.00	NA
Avoided Cost Factors						
Harvest ($/acre)[1]	36.50	35.80	31.30	68.00	31.30	16.30
Hauling ($/unit)[2]	0.10	0.17	0.10	NA	0.10	4.30
Other Costs ($/unit)				0.90	0.18	10.00

[1] Source: NRCS 2019.
[2] Source: NRCS 202222 cost per acre divided by estimated yield per acre.
[3] UC Cooperative Extension 2015 Sample Costs to Produce Potatoes. $68/acre to dig and harvest. $442/acre other: bulk haul to storage, clean, store. Divided by 485 cwt/acre equates to about 90 cents/cwt post-harvest unit costs.
[4] NDSU Custom Farm Work Rates: Mow at $10, Rake at $5, Large bale (over 1,500) at $10/bale, say one ton bale at $10.
[5] Using NDSU Customer Farm Work Rates wheat haul cost reported at 10 cents/bushel. Using bulk density of 60 pounds/ bushel equates to approximately 17 cents/cwt or $3.33/ton

Additional Operating Cost. All crop acreage that is inundated is estimated to incur a flood damage cost arising from additional efforts necessitated by the inundation. Depending on the time of occurrence, this additional effort may include additional tillage and/or a cultivation or other treatment to break up crust and re-level the soil, an additional chemical application, operations to remove debris and silt, and added difficulty in harvest operations. A uniform $20 cost is applied to all acres inundated in the growing season (April-September) and $10 per acre in the other months.

Seasonal Flood Distribution. Crop damages are estimated specific to each month. The seasonal distribution of flood events, shown in Exhibit D5.13, is used to compute a weighted average damage for the year.

Exhibit D5.13. Flood Event Distribution by Month

	April	May	June	July	August	September	Other Months	Total
Number[1]	16	39	107	79	49	32	23	345
Percent	4.6%	11.3%	31.0%	22.9%	14.2%	9.3%	6.7%	100%

Source: NOAA Hydrometeorological Design Center Precipitation Frequency Data Server. Annual Maximum Series files for Adams, Petersburg, Park River, Pisek, Larimore, Grafton, Edmore, and Argyle.
[1] Number of 4-day maximum rainfall events occurring in the month for the annual Maximum Series for 1960-2010

Crop Damage Calculations

For each crop and each month, the damage estimation proceeds as described below.

Step 1: Cost of Additional Land Treatment

Calculate an additional operating cost of $20 per acre for every acre inundated.

Step 2: Revenue Lost from Crop Yield Reduction

Estimate crop revenue loss from late plant or from inundation damage.

a. For each duration, crop units lost is calculated as the damage factor (in percent) multiplied by yield per acre multiplied by number of acres. The acreage is allocated among two damage factors, depending on the month: (1) late plant and (2) flood damage crop loss factor. Input assumptions regarding the percentage of crop planted in each month (and therefore subject to crop damage) and the acres not planted (and therefore potentially subject to late plant loss) are applied within the model.
b. Revenue loss is calculated as lost crop units multiplied by the price per crop unit.

Step 3: Savings from Avoided Costs

Deduct from the damage estimate the costs that are reduced due to having less crop to harvest. Avoided cost factors were shown in Exhibit D5.12 above.

a. For all crop losses, deduct avoided variable costs, calculated as the variable avoided costs per crop unit multiplied by the crop units lost.
b. For any acreage where the crop is completely lost (100% damage factor), harvest cost is also deducted. Conversely, for any flooded acreage for which any crop remains, the full harvest cost is assumed to be incurred, and therefore is not deducted or reduced.

Step 4: Net Loss from Replanting

For some crops the model provides for replanting in April, May, and June, when the flood damage factor exceeds a specified percentage. The replanting thresholds are listed above in Exhibit D5.11. Whether the replanting threshold applies depends on the damage factor applied to the specific duration of inundation. That is, crop acreages below a certain inundation duration may be modeled as experiencing crop yield loss while acres under water longer are modeled as being replanted. The replanting loss estimate replaces the other revenue and cost impacts calculated at steps 2 and 3 above.

The dollar damage estimate for replanted acreage is calculated as follows:

1) the net revenue lost from the crop that is replaced
2) *plus* the replanting cost
3) *minus* the net revenue gained from the replacement crop. The net revenue gained from the replacement crop takes into account the late plant yield loss affecting the replacement crop.

Replanting is not feasible in all instances. For example, in some cases the acreage that is modeled as subject to severe flooding is angled diagonally across a field. In other instances, the modeling shows tightly intermixed areas of varying flooding durations. In these types of scenarios, it may be impractical to isolate area of severe crop damage for replanting. To account for such scenarios, all acreages that are found to exceed the duration threshold for replanting are reduced by 20 percent. Losses on these segments will be subject to the full duration damage factor applicable to that crop, season, and duration.

Note that variable costs that have been incurred prior to the event (i.e., “sunk costs”), and costs that are incurred regardless of whether there is flood damage are not entered into any of the calculations because the flooding has no bearing on those costs. Also note that the analysis does not include collection of crop insurance because the aim of the calculations is to estimate the social costs that will be used in the benefits estimation. Crop insurance payments are a transfer from the insurance program (funded by premium payments and tax revenues) to the affected producers.

Crop Damage Estimates

Damage estimates were calculated for each of the crop data layers for years 20182018-2022. The results for one of the layers (2018) under without-dam conditions are shown to illustrate the typical comparison of damages among crops, flood magnitudes, and months.

1. Acreage Flooded

The extent of flooding for the different flood event magnitudes based on the 2018 crop data layer is illustrated in Exhibit D5.14 and Exhibit D5.15. The exhibits reflect the extensive acreage of spring wheat, soybean and dry bean crops in the study area. However, mere acreage inundated does not capture the full damage potential. Inundation durations, combined with the month of flooding, are important determinants of damage severity.

2. Basic vs. Non-Basic Crops

According to P&G 2.3.2(b)(1-2), basic crops are crops that are grown throughout the United States in quantities such that no water resource project would affect the price and thus cause transfers of crop production from one area to another. Non-basic crops are crops for which production is generally limited by market demand, risk aversion, and supply factors other than suitable land (NRCS, 1983). Potatoes have one of the characteristics fitting the definition of a non-basic crop: production nationally is not limited by the availability of suitable land. Rather, production is subject to a contract for purchase of the crop.

Potatoes are sold under contracts to potato distributors. The proposed project would not increase or decrease land in production of potatoes and is not expected to affect potato market conditions. The rehabilitated structure would have no measurable effect on planting or contracting practices. The possibility of a flood mitigation structure causing changes to cropping pattens for potatoes is unlikely and the effect on benefit calculations if practice *would* change is so small that the computational effort of treating them as a non-basic crop is not warranted. Therefore, this analysis treats all crops as basic crops – no change in prices received or in crop pattern in the study area is expected to result from a dam rehabilitation project.

3. Weighted Average Annual Damages by Crop

The distribution of flood events among the growing season months is applied to the monthly crop damages to compute a weighted average damage for each crop. Exhibits D5.16 and D5.17 present a table and chart of the weighted average annual damage for each crop and flood event magnitude for the 2018 without-dam condition crop data layer. Damage to spring wheat is a major component of crop damage in all flood events, due chiefly to the abundance of acreage planted in spring wheat in the study area boundaries.

Exhibit D5.14. Acres Flooded by Crop under Existing Conditions - 2018 Crop Data Layer

Crop	Acres Flooded							
	625-yr[1]	500-yr	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr
Spring Wheat	986	958	797	697	577	393	285	129
Dry Beans	677	638	517	454	370	204	108	57
Soybeans	1,044	994	754	640	496	344	222	93
Potatoes	15	14	12	11	11	9	8	3
Corn	323	303	242	205	166	96	51	16
Alfalfa	40	38	31	26	20	15	13	6
Other Hay	83	72	59	53	47	39	30	15
Subtotal	**3,168**	**3,016**	**2,413**	**2,087**	**1,686**	**1,101**	**719**	**318**

[1]625-yr results are derived from the without-dam scenario.

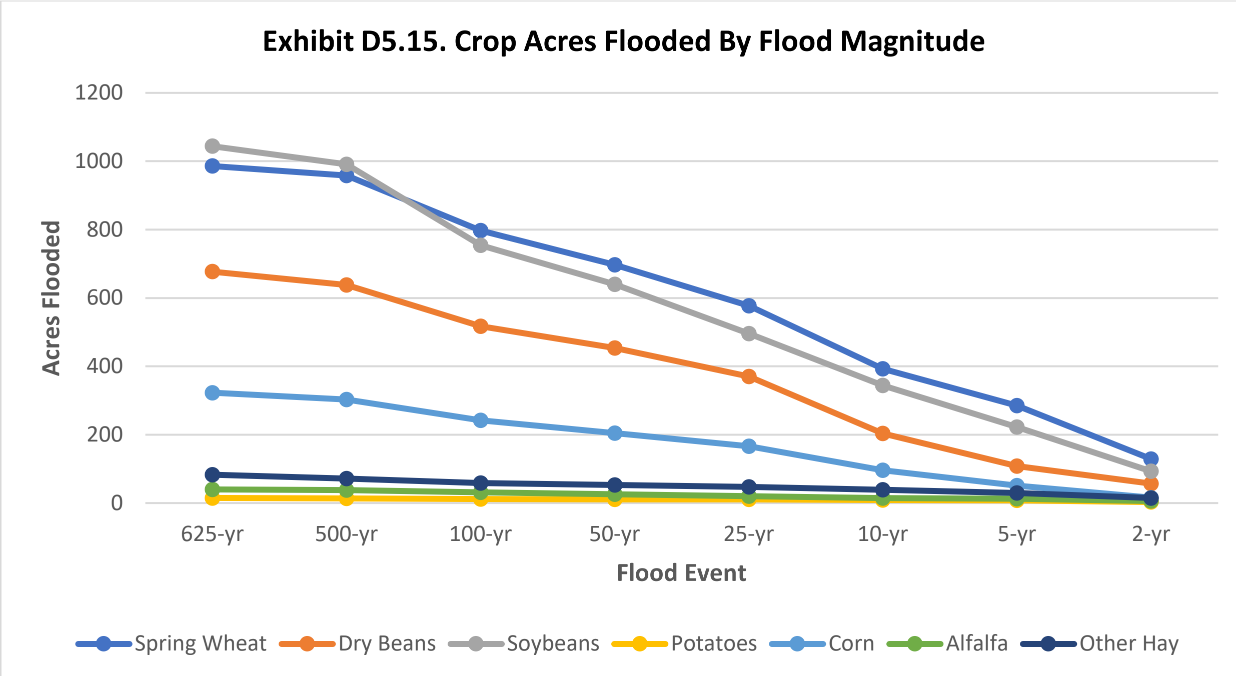

Exhibit D5.16. Annual Weighted Average Net Revenue Loss by Crop and Flood Event, 2018

Crop	625-yr	500-yr	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr
Spring Wheat	$112,903	$104,978	$85,392	$72,323	$58,449	$39,492	$27,708	$12,035
Dry Beans	$123,698	$116,949	$89,882	$76,134	$59,273	$33,545	$18,770	$9,161
Soybeans	$109,855	$99,715	$76,640	$63,347	$45,303	$28,172	$19,092	$7,005
Potatoes	$29,715	$28,325	$24,357	$22,007	$20,034	$15,382	$11,270	$4,087
Corn	$60,691	$0	$0	$0	$0	$0	$0	$0
Alfalfa	$2,132	$54,961	$38,015	$30,290	$23,841	$13,119	$6,957	$2,257
Other Hay	$2,941	$2,033	$1,721	$1,469	$1,130	$792	$685	$274
Subtotal	**$441,934**	**$409,474**	**$318,136**	**$267,473**	**$209,702**	**$131,849**	**$85,558**	**$35,310**

Exhibit D5.17. Weighted Average Damage by Crop, 2018

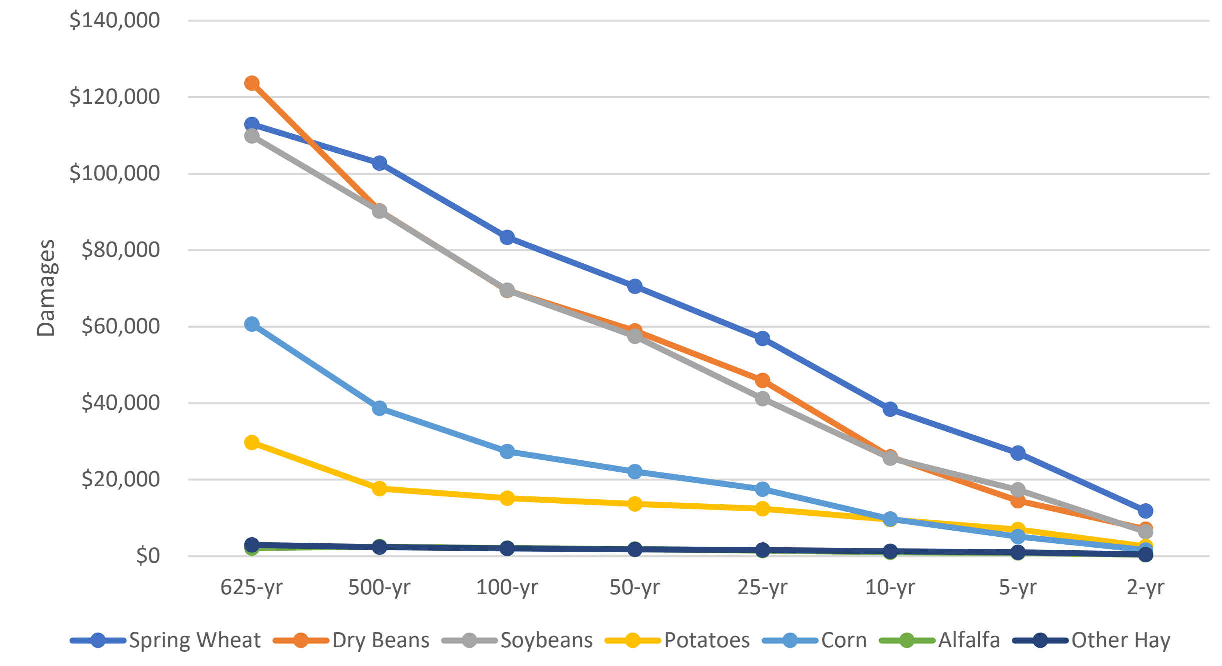

Exhibit D5.18 presents the calculation of the expected annual damage for crops under FWOFI/without-dam conditions and the Preferred Alternative. Calculation of the expected annual damage (EAD) accounts for the probability of exceedance of each flood event magnitude. The expected annual damage is the area under the frequency-damage curve. The difference in damages, **$13,50011,100,** represents the annual benefit of implementing the Preferred Alternative. Benefits are rounded to the nearest hundred dollars per NRCS guidance.

Exhibit D5.18. Expected Annual Flood Damages to Crops

Flood Event	Ex. Prob.	Alt.1. FWOFI (Without Dam)		Alt.2. Structural Rehab (Preferred Alternative)		Alt.3. No Action	
		Damages	Contrib. to EAD	Damages	Contrib. to EAD	Damages	Contrib. to EAD
625-yr[1]	0.0016	$409,931	$656	$349,407	$532	$15,904,414	$ $25,447
500-yr	0.002	$390,410	$781	$332,769	$666	$332,769	$666
100-yr	0.01	$302,234	$2,771	$223,983	$2,227	$223,983	$2,227
50-yr	0.02	$245,611	$2,739	$174,744	$1,994	$174,744	$1,994
25-yr	0.04	$189,240	$4,349	$131,305	$3,060	$131,305	$3,060
10-yr	0.1	$113,756	$9,090	$82,144	$6,403	$82,144	$6,403
5-yr	0.2	$71,339	$9,255	$48,256	$6,520	$48,256	$6,520
2-yr	0.5	$28,875	$15,032	$16,919	$9,776	$16,919	$9,776
		TOTAL	**$44,673**	**TOTAL**	**$31,178**	**TOTAL**	**$ $56,093**

[1] – Flood damages for the 625-year event under Alternatives 1 and 2 were extrapolated from the 500-year modeling based on the expected increase in rainfall.

Under an uncontrolled breach scenario (625-year flood event for Alternative 3: No Action), damages to crops were estimated at $419,414 based on the methods outlined in this section. An additional $15,485,000 of clean-up costs were estimated for repair of erosion and deposition on cropland to restore production and is included in Exhibit D5.18. These costs are expected to be in addition to the damages incurred in the other alternatives due to the extreme nature of the breach. The expected annual damage from this event would be **$25,447**.

C. Roadways and Roadway Bridges

Roadway damages from flooding depend on unique study area factors, such as the roadways' height, distance from and position relative to the flood water. Therefore, published damage factors for roadways were not readily available. To estimate roadway damages, project civil engineers used project data (fieldview, mapping, and hydraulic modeling) to develop a series of assumptions regarding flood impacts on study area roadways.

Repair costs per linear foot were estimated by project civil engineers for roadways in the study area, based on repairing damaged roadway and embankments. The cost assumptions for roadway and embankment repairs are summarized in Exhibit D5.19. Detailed cost estimates are shown in Exhibit D5.20. Exhibit D5.1918 has been escalated to 2023 dollars from the original 2019 estimate shown in D5.2019.

Exhibit D5.19. Cleaning and Repair Costs for Study Area Roadways

Roadway Type	% Embankment Damage	Embankment Length Damage $/LF	% Damage	Repair cost $/LF
Paved	2%	$159	20%	$136
Graded and Drained/ Gravel	1%	$159	10%	$55
Unimproved	2%	$159	20%	$28

Source: Gannett Fleming, 2023.

Using ArcGIS, the roadway mileage inundated under each flood event was calculated. Mileage inundated was multiplied by the percentage of flooded surface that would require repair. Damaged surface (feet) was multiplied by the repair costs (per foot) to obtain damages. Expected annual damages to roadways under FWOFI/without-dam conditions was estimated at $15,241 and at $7,888under the Preferred Alternative (Exhibit D5.2120). The difference in damages, **$7,700,** represents the annual benefit of implementing the Preferred Alternative. Benefits are rounded to the nearest hundred dollars per NRCS guidance.

Exhibit D5.2019. Detailed Cost Estimates for Roadways

Paved Replacement

Assumed Roadway Lane Width	12	ft
Assumed Depth of Debris	1	ft
Assumed Depth of Roadway Repair	11.5	in
Assumed Road Embankment Damaged By High Water	3	ft depth
1.5" Bituminous Wearing Course	$11.00	/SY
4" Bituminous Base Course	$13.50	/SY
6" Subbase	$6.30	/SY

Volume of Debris	12	ft	*	1	ft	=	12	SF/(LF/Lane)	=	1.33	SY/(LF/Lane)	=	0.44 CY/(LF/Lane)
Volume of Roadway Repair	12	ft	*	0.958	ft	=	11.5	SF/(LF/Lane)	=	1.28	SY/(LF/Lane)	=	0.43 CY/(LF/Lane)

Excavation of Debris	$20.00	/CY	*	0.44	CY/(LF/Lane)	=	$8.89	/(LF/Lane)
Excavation of Roadway	$20.00	/CY	*	0.43	CY/(LF/Lane)	=	$8.52	/(LF/Lane)
Cost for Paving & Subbase	$30.80	/SY	*	1.28	SY/(LF/lane)	=	$39.36	/(LF/Lane)

Paved Repair Cost	$56.76	/(LF/Lane)			
SAY	$57	/(LF/Lane)	=	**$114**	/LF - For Section of Roadway

Embankment Replacement

Excavation*	$20	/CY	*	30	ft width	*	3	ft depth	=	$66.67	/LF
Embankment Placement**	$20	/CY	*	30	ft width	*	3	ft depth	=	$66.67	/LF

* embankment is excavated and stockpilied for drying

** placing dried stockpiled embankment

Embankment Repair Cost	$133.33	/LF
SAY	**$133**	/LF

Gravel Roadway Replacement

Assumed Roadway Lane Width	12	ft
Assumed Depth of Debris	1	ft
Assumed Depth of Roadway Repair	6	in
Assumed Road Embankment Damaged By High Water	3	ft depth
Selected Material Surfacing	$64.00	/CY

Volume of Select Material	12	ft	*	0.5	ft	=	6	SF/(LF/Lane)	=	0.67	CF/(LF/Lane)	=	0.22 CY/(LF/Lane)
Volume of Debris	12	ft	*	1.0	ft	=	12	SF/(LF/Lane)	=	1.33	SY/(LF/Lane)	=	0.44 CY/(LF/Lane)
Volume of Gravel Roadway	12	ft	*	0.5	ft	=	6	SF/(LF/Lane)	=	0.67	SY/(LF/Lane)	=	0.22 CY/(LF/Lane)

Excavation of Debris	$20.00	/CY	*	0.44	CY/(LF/Lane)	=	$8.89	/(LF/Lane)
Excavation of Gravel Roadway For Repair	$20.00	/CY	*	0.22	CY/(LF/lane)	=	$4.44	/(LF/Lane)
Placing Select Material Surfacing	$64.00	/CY	*	0.22	CY/(LF/lane)	=	$14.22	/(LF/Lane)

Roadway Replacement Cost	$23.11	/(LF/Lane)			
SAY	$23	/(LF/Lane)	=	**$46**	/LF - For Section of Roadway

Embankment Replacement

Excavation*	$20	/CY	*	30	ft width	*	3	ft depth	=	$66.67	/LF
Embankment Placement**	$20	/CY	*	30	ft width	*	3	ft depth	=	$66.67	/LF

* embankment is excavated and stockpilied for drying

** placing dried stockpiled embankment

Embankment Repair Cost	$133.33	/LF
SAY	**$133**	/LF

Exhibit D5.21. Expected Annual Flood Damages to Roadway Infrastructure

Flood Event	Ex. Prob.	Alt.1. FWOFI (Without Dam)		Alt.2. Structural Rehab (Preferred Alternative)		Alt.3. No Action	
		Damages	Contrib. to EAD	Damages	Contrib. to EAD	Damages	Contrib. to EAD
625-yr[1]	0.0016	$288,484	$462	$65,571	$105	$360,184	$600
500-yr	0.002	$274,747	$549	$62,449	$125	$62,449	$125
100-yr	0.01	$144,380	$1,677	$35,169	$390	$35,169	$390
50-yr	0.20	$91,230	$1,178	$27,143	$312	$27,143	$312
25-yr	0.40	$73,037	$1,643	$35,852	$630	$35,852	$630
10-yr	0.1	$42,978	$3,480	$21,825	$1,730	$21,825	$1,730
5-yr	0.2	$17,168	$3,007	$13,060	$1,744	$13,060	$1,744
2-yr	0.5	$7,543	$3,707	$6,652	$2,957	$6,652	$2,957
		TOTAL	**$15,703**	**TOTAL**	**$7,993**	**TOTAL**	**$8,488**

[1] – Flood damages for the 625-year event under Alternatives 1 and 2 were extrapolated from the 500-year modeling based on the expected increase in rainfall.

GIS analysis was conducted to determine if roadway bridges located within the study area would be impacted by flooding. No roadway bridges in the study area were affected by flooding.

Under an uncontrolled breach scenario (625-year flood event for Alternative 3: No Action), damages to infrastructure were estimated at $360,184. The expected annual damage from this event would be **$600**. Damages include three bridges that would be overtopped in the breach scenario.

D. Administrative Cost Savings to the National Flood Insurance Program (NFIP)

By reducing the size of the 100-year floodplain, Bylin Dam reduces the number of properties that must participate in the NFIP, which enables a savings in the administrative costs of the program. According to NRCS technical guidance based on a FEMA actuarial rate review, each policy is estimated to incur an administrative cost of $385385.32 per year (updated from the original 2015 NRCS estimate using the Bureau of Economic Analysis (BEA) Gross Domestic Product Implicit Price Deflator) (Townsley, 2016, FEMA 2011, BEA 20233).

The 100-year floodplain under the FWOFI/without-dam conditions and the Preferred Alternative were compared using ArcGIS. It was determined that the dam reduces the number of properties required to participate in the NFIP by six properties. This reduction represents a savings in administrative costs of **$2,300** per year.

E. Total Benefits

Bylin Dam provides a total of **$357,000** in annual flood damage reduction and recreation benefits (Exhibit D5.22). Under Alternative 1: FWOFI, these benefits would be reduced to zero. Under Alternative 2: Structural Rehabilitation, these benefits would continue throughout the life of the project. Under Alternative 3: No Action, these benefits would remain in place unless a 625-year flood event would occur in the study area. The 625-year event is expected to fail the dam, creating a life and safety risk to the downstream population, as well as substantial economic damage. After a 625-year event at any point in the evaluated life of the project, the dam would no longer be in place, and the benefits would be reduced to zero.

Exhibit D5.22. Bylin Dam Expected Annual Flood Reduction and Recreation Benefits

Benefit Category	EAD 2023 $
Structures and Vehicles Flood Damage Reduction	$321,400
Infrastructure Flood Damage Reduction	$7,700
Agricultural Flood Damage Reduction	$13,500
NFIP	$2,300
Recreation	$12,100
TOTAL	**$357,000**

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