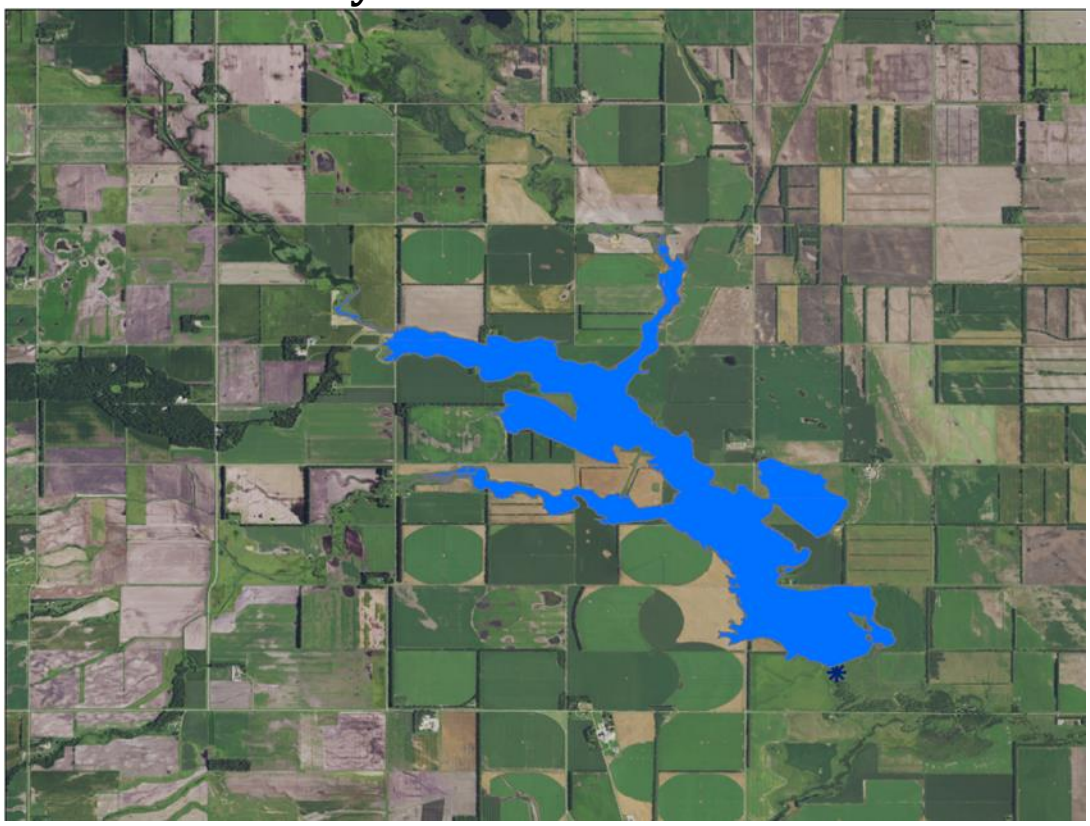
# UPPER TURTLE RIVER DAM 10

# Economics Analysis



*Aerial image of proposed UTR Dam 10 flood pool*

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## I. Introduction

This economic analysis summarizes the methodology used to estimate the flood damages under the existing condition and under the proposed alternative and provides the results. The benefit-cost analysis follows the guidance provided by the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G), the subsequent *Principles, Requirements, and Guidelines* (PR&G), the *National Watershed Program Manual* as revised in 2024, and the *National Resource Economics Handbook Part 611 – Water Resource Handbook for Economics*.

Throughout the report, the analysis is provided in 2023 values unless stated otherwise. The analysis was conducted using the fiscal year (FY) 2025 federal discount rate for water resources projects of 3.00%.

The reader will note the use of acronyms throughout this report; they are identified in the table below.

*Table 1- Acronyms*

| | |
|---|---|
| AAE | Average Annual Equivalent |
| BCR | Benefit-Cost Ratio |
| BEA | Bureau of Economic Analysis |
| BU | Bushel |
| CCI | Construction Cost Index |
| CDF | Crop Damage Factors |
| CDL | Crop Data Layer |
| CDL-E | Crop Data Layer enhanced by machine learning |
| CWT | Hundredweight |
| DRV | Depreciated Replacement Value |
| EAD | Expected Annual Damages |
| ERS | Economic Research Service |
| FY | Fiscal Year |
| GDP | Gross Domestic Product |
| GIS | Geographic Information System |
| H&H | Hydrology and Hydraulics |
| HEC-FIA | Hydrologic Engineering Center-Flood Impact Analysis |
| HEC-RAS | Hydrologic Engineering Center-River Analysis System |
| IPD | Implicit Price Deflator |
| LF | Linear Foot |
| LPYL | Late Plant Yield Loss |
| NASS | National Agricultural Statistics Service |
| NFIP | National Flood Insurance Program |
| NRCS | Natural Resources Conservation Service |
| P&G | Principles and Guidelines |
| PPRI | Producer Prices Received Index |
| PR&G | Principles, Requirements, and Guidelines |
| RT | Replant Threshold |
| SCS | Soil Conservation Service |
| USACE | U.S. Army Corps of Engineers |

## II. Study Area Inventory

The study area for this analysis is effectively set the by modeled inundation of the 500-year floodplain under the currently existing conditions. This area is contained within Grand Forks and Walsh Counties, North Dakota.

Damages – and the benefits from damage reductions – accrue primarily in three categories: structures and vehicles, agricultural land, and roadway infrastructure. The remainder of Part II of this analysis will introduce each category to the set the stage for the estimation, in Part III, of the expected damages to each category under existing and proposed conditions – the economic analysis.

In common terminology, flood events are commonly referred to by interval: a 2-year or 100-year flood event, for example. More precise terminology identifies flood events by the annual exceedance probability (0.5, or 0.01 event probability). This analysis aims to use them together for clarity but does treat the terms as interchangeable.

## A. Structures and Vehicles

This section reviews the structures present in the watershed and the associated contents and vehicle valuations, as well as the data collection methods. The economic analysis of the structure and vehicle data will be discussed in Part III.

*Methodology*

The Natural Resources Conservation Service (NRCS) utilized aerial photographs and the National Structure Inventory data (current as of March 2023) from the U.S. Army Corps of Engineers (USACE) to develop a database of structures within the study area. More details on the structure shapefile and the River Analysis System (RAS) models are included in the Hydrology and Hydraulics (H&H) report.

Damages to structures and vehicles are calculated independently from the damages to agricultural land and to roadway infrastructure. Structure type was verified through aerial imagery; the results are summarized in Table 2. 196 structures were identified within the study area and, of these, up to 188 could be subject to damages due to flooding. The impacted structures in Table 2 are situated within the 500-year flood extents.

*Table 2- Summary of Structure Inventory*

| Structure Type | Within Study Area | Impacted |
|---|---|---|
| Residential | 39 | 34 |
| Commercial | 129 | 127 |
| Industrial | 9 | 9 |
| Educational | 1 | 0 |
| Government | 1 | 1 |
| Agricultural Storage | 17 | 17 |
| **Total** | 196 | 188 |

Assessment values of the structures were not available; this report relies on estimated depreciated replacement values (DRV). The area of each structure was estimated using Geographic Information System (GIS) data, and then the structure area and occupancy type were entered into the SwiftEstimator tool (Marshall and Swift, 2023). This tool, from Marshall and Swift, was used to estimate the DRV for all of the building types except for the grain storage facilities.

Interviews were conducted with local producers as part of a similar project proposal in the same region of the state to determine grain storage DRV and to determine the contents values for all structures (Gannett Fleming, 2022). Grain storage bins were classified into one of three sizes based on the structure diameter. The values for grain storage facilities were indexed to reflect 2023 values using the Construction Cost Index (CCI).[1] The contents

[1] Grain facility structure values increased by 18.41% on the basis of the CCI annual values from 2019 and 2023.

values were updated based on the normalized national price indices from the Economic Research Service (ERS); this calculation utilized the average price change of the four crops grown within the study area that would be stored in bins or silos (corn, dry beans, soybeans, and wheat) between 2019 and 2023 (ERS, 2024). Table 3 summarizes the average DRV and contents values.[2]

*Table 3- Structure DRV and Contents Values ($2023)*

| Structure Type | Average DRV | Contents Value |
|---|---|---|
| Residential | $64.35 per sq ft | 50% of structure value |
| Residential Outbuildings | $22.17 per sq ft | $264.00 per sq ft |
| Educational | $77.95 per sq ft | 50% of structure value |
| Post Office, Commercial | $217.60 per sq ft | 75% of structure value |
| Industrial | $69.05 per sq ft | 75% of structure value |
| Agricultural Outbuildings | $23.47 per sq ft | $264.00 per sq ft |
| Grain Storage Silo 12 ft diameter | $53,244 | $44,970 |
| Grain Storage Bin 15 ft diameter | $17,383 | $25,077 |
| Grain Storage Bin 21 ft diameter | $22,036 | $69,566 |
| Grain Storage Bin 36 ft diameter | $49,002 | $217,619 |

*[1] The values for structure types other than grain storage facilities are from Marshall and Swift, 2023.*

*[2] Values for grain storage facilities are based on regional producer interviews by Gannett Fleming economists, 2019. They have been updated to 2023 values as described in the text.*

Vehicle damages from flooding were added to the model on the basis of the Federal Emergency Management HAZUS-MH MRC Technical Manual methodology, which estimates the vehicle average values based on the local market (FEMA, 2018). Vehicle valuation and assignment by structure type are summarized in Table 4.[3]

*Table 4- Vehicle Valuation Summary ($2023)*

| Structure Type | Number of Vehicles | Type of Vehicle | Value |
|---|---|---|---|
| Residential | 1 | Passenger Car | $16,415 |
| Residential Outbuildings | 0 | NA | $0 |
| Educational | 0 | NA | $0 |
| Post Office, Commercial | 0 | NA | $0 |
| Industrial | 0 | NA | $0 |
| Agricultural Outbuildings (< 500 sf) | 1 | Light Truck | $29,200 |
| Agricultural Outbuildings (500 < sf < 1,000) | 2 | Light Truck | $67,507 |
| Agricultural Outbuildings (1,000 < sf < 2,000) | 3 | Light Truck | $101,260 |
| Agricultural Outbuildings (2,000 < sf < 3,000) | 4 | Light Truck | $135,015 |
| Agricultural Outbuildings (3,000 < sf < 4,000) | 5 | Light Truck | $168,767 |
| Agricultural Outbuildings (> 4,000 sf) | 6 | Light Truck | $202,520 |
| Grain Storage | 0 | Not Used | $0 |

[2] The contents values for grain storage facilities were updated on the basis of the average price change between 2019 and 2023 – an increase of 4.3%.

[3] Vehicle assignments were based on regional producer interviews by Gannett Fleming economists.

The type of vehicle and the number of vehicles lost to flooding varied depending on the structure type. Agricultural equipment (harvesters, tractors, attachments, etc.) values were factored into the content value based on the earlier operator interviews (Gannett Fleming, 2022).

## B. Agricultural Land

Corn, soybeans, wheat, dry beans, potatoes, sugar beets, and sunflowers are grown within the study area, comprised of land in Grand Forks and Walsh Counties, ND.[4] North Dakota NRCS Engineers utilized the 2020 Crop Data Layer (CDL) to determine the acres of each crop affected by flooding. 2020 was a representative spring planting with typically seen flooding extents, such that farming decisions were not altered based on abnormal weather within the area of interest.

The CDL was enhanced through a machine-learning algorithm to purge erratic and erroneous raster cells to conform to the predominant crop type for each farmed tract. This enhanced CDL will be referred to as CDL-E through the remainder of the document.

*Basic Crops*

According to the 1983 P&G 2.3.2(b): "Basic crops […] are crops that are grown throughout the United States in quantities such that no water resources project would affect the price and thus cause transfers of crop production from one area to another." Basic crops are distinguished from non-basic crops by the fact that their production is "limited primarily by the availability of suitable land". Production of crops other than basic crops is more typically limited by other factors, such that any increased production of these crops in the study area would lead to an offsetting decrease in the production somewhere else (NRCS, 1983).

Table 5 summarizes the acres of the seven crops that were planted in North Dakota during the period 2018 – 2022 (NASS, 2024).[5]

*Table 5- Crop Acres Planted in North Dakota, Summary Statistics*

| Crop | 5 yr Average[6] | Low Value | High Value | Range |
|---|---|---|---|---|
| Corn | 3,130,000 | 1,950,000 | 4,100,000 | 2,150,000 |
| Soybeans | 6,240,000 | 5,600,000 | 7,250,000 | 1,650,000 |
| Wheat | 5,950,000 | 5,300,000 | 6,700,000 | 1,400,000 |
| Dry Beans | 658,800 | 570,000 | 820,000 | 250,000 |
| Potatoes | 73,900 | 72,000 | 76,000 | 4,000 |
| Sugar Beets | 222,400 | 202,000 | 251,000 | 49,000 |
| Sunflowers | 525,000 | 395,000 | 660,000 | 265,000 |

The 5-year average values from Table 5 contribute to the next step in the discussion of basic crops: exploring the potential impact of the proposed project on these crops to establish whether any of these crops should not be considered as basic crops.

The affected acres value is the number of acres modeled to be inundated for at least one day from a flood event with an exceedance probability of 0.5 or less (a 2-year or more severe flood event). Table 6 reports the total

[4] Corn was measured as corn grain, wheat as spring wheat, and sunflowers as oil sunflowers, based on the crop proportions detailed in the National Agricultural Statistics Service (NASS) ND Agricultural Statistics bulletins.
[5] This period (2018 – 2022) matches the 5-year period used by the ERS in the 2024 report on normalized prices.
[6] Values in this and remaining tables are presented as rounded to the nearest whole number. This may lead to small differences in the values presented compared to by-hand calculations as you work through the report.

affected acres of each crop, and the change in affected acres of each crop, as a share of the total acres of that crop planted in North Dakota.

*Table 6- Affected Crop Acres in the Watershed as a Share of Acres Planted in North Dakota*

| Crop | ND Acres Planted (average 2018 - 2022) | Total Affected Acres under Existing Condition | Total Affected Acres as Share of ND Planted Acres | Decrease in Affected Acres under Proposed Condition | Decrease as Share of ND Planted Acres |
|---|---|---|---|---|---|
| Corn | 3,130,000 | 4,523 | 0.14% | 366 | 0.01% |
| Soybeans | 6,240,000 | 7,156 | 0.11% | 723 | 0.01% |
| Wheat | 5,950,000 | 8,685 | 0.15% | 1,099 | 0.02% |
| Dry Beans | 658,800 | 6,164 | 0.94% | 452 | 0.07% |
| Potatoes | 73,900 | 16 | 0.02% | 1 | 0.00% |
| Sugar Beets | 222,400 | 5,127 | 2.31% | 664 | 0.30% |
| Sunflowers | 525,000 | 1,695 | 0.32% | 181 | 0.03% |

For example, during the period 2018 – 2022, there were an average of 3,130,000 acres planted to corn in North Dakota each year. Over the same period, planted acres ranged from 1,950,000 to 4,100,000 acres. Within the study area, there were 4,523 acres of corn (using the 2020 CDL-E) projected to be inundated for at least one day from a 2-year or more significant flood event. Those 4,523 acres constitute 0.14% of the average corn acres planted in North Dakota. Should the proposed project be completed, the corn acres vulnerable to inundation per the 2020 CDL-E are modeled to decrease from 4,523 to 4,157: a decrease of 366 acres. Those acres that are no longer vulnerable to inundation as a result of the project represent 0.01% of the average corn acres planted annually in our state.

For each of the crops considered in this report, the decrease in acres affected by flooding as a share of acres planted in North Dakota is less than 1%.

Corn, soybeans, and wheat are all identified within the 1983 P&G as examples of basic crops.

We can consider the reduction in affected acres against the range in planted acres statewide to gain additional perspective on the magnitude of potential impact. Over the 5-year period 2018 – 2022, dry bean planted acres in North Dakota varied from a low of 570,000 to a high of 820,000 acres: a range of 250,000 acres. The 452 acres of dry beans potentially removed from risk of inundation constitute less than 1% of the range in variation.

When we consider only the acreage impacted by a 2-year flood event (0.5 annual exceedance probability), we can see that the existing acres vulnerable to inundation do not exceed one-quarter of one percent for any of the crops in the study area.

*Table 7- Affected Acres in the Watershed from a 2-year Event as a Share of North Dakota Planted Acres*

| Crop | ND Acres Planted (2018 - 2022 average) | Affected Acres, 2 yr Flood Event (existing condition) | Affected Acres as Share of ND Planted Acres |
|---|---|---|---|
| Corn | 3,130,000 | 653 | 0.02% |
| Soybeans | 6,240,000 | 883 | 0.01% |
| Wheat | 5,950,000 | 374 | 0.01% |
| Dry Beans | 658,800 | 828 | 0.13% |
| Potatoes | 73,900 | 3 | 0.00% |
| Sugar Beets | 222,400 | 137 | 0.06% |
| Sunflowers | 525,000 | 242 | 0.05% |

The acreage impact to dry bean and sunflower production is minimal; the modeled impact of the project shows a reduction in affected acres from the proposed project as less than 1% of the total planted North Dakota acres for each crop. Potato and sugar beet production within the study area are constrained by contract systems. The market for potatoes is structured by contracts with potato processors. Sugar beet production is organized and controlled through producer cooperatives. No net change to contracted potato or sugar beet acreage would be realized since contracts dictate acreage planted.

All of the crops in this analysis are treated as basic crops. This proposed flood control project in the Upper Turtle River is not expected to result in any change to crop prices or to crop patterns. Agricultural benefits will be measured as the reduction in expected damages modeled to result from the proposed project (NRCS, 1983).

### C. Roadway Inventory

For this analysis, roadways were divided into two categories: paved or gravel. Both paved and gravel roads require repair if damaged, but the repair process and expense is significantly greater for paved roads. Both are also vulnerable to embankment loss from flooding, though at different rates. The road network was overlaid on existing and proposed flooding extents to derive impacted distances.

*Table 8- Roadways in the Floodplain, Existing Condition*

| Existing Condition, 100 yr Event | | Existing Condition, 500 yr Event | |
|---|---|---|---|
| Roadway Type | Length (miles) | Roadway Type | Length (miles) |
| Paved | 2.27 | Paved | 3.95 |
| Unpaved / Gravel | 16.92 | Unpaved | 29.96 |

There are several bridges and culverts downstream within the watershed. Impacts to these structures are not expected to be significant. Any damages that would occur due to flooding are anticipated to be covered within the overtopping damages applied to flooded roadways. The rates for the overtopping damages were developed based on historical repair costs. While there are railroads within the watershed, none are modeled to experience meaningful damage from the expected flooding.

## III. Flood Damage Reduction Benefits

Benefits are measured as a reduction in expected damages from flooding as a result of the proposed project, compared to the baseline of the existing condition. For each of the three damage categories (structures and vehicles, agricultural land, and roadway infrastructure), the expected flood damages are first calculated for the currently existing condition and then calculated under the proposed condition. The difference between the two expected damage levels represents the impact of the proposed project. The economic analysis for each of the three categories, starting with structures and vehicles, will first introduce the baseline data necessary for the

calculations, then calculate the expected flood damages under the existing condition, calculate the expected flood damages under the proposed condition, and summarize the difference – the benefit in terms of reduction of expected flood damages.

## A. Structures and Vehicles

We utilized the Hydraulic Engineering Center's Flood Impact Analysis (HEC-FIA) software (version 3.3) to estimate flood damages to structures and vehicles. The HEC-FIA software calculates a damage elevation at each structure location, such that inundation above that level would result in structural damage. The damage elevation incorporates both terrain elevation and foundation heights.

In feet, the foundation heights for structures were set to be:

*Table 9- Foundation Height Settings for Structures*

| | |
|---|---|
| Residential Structures | 1.0 |
| Grain Storage | 0.0 |
| Remaining Structure Types | 0.5 |

HEC-FIA uses gridded flood depth, duration, and arrival time rasters to estimate flood damages. The FIA estimate of flood damages relies on the following structure variables: type, DRV, content and vehicle value, and foundation height.

### 1. Existing Condition

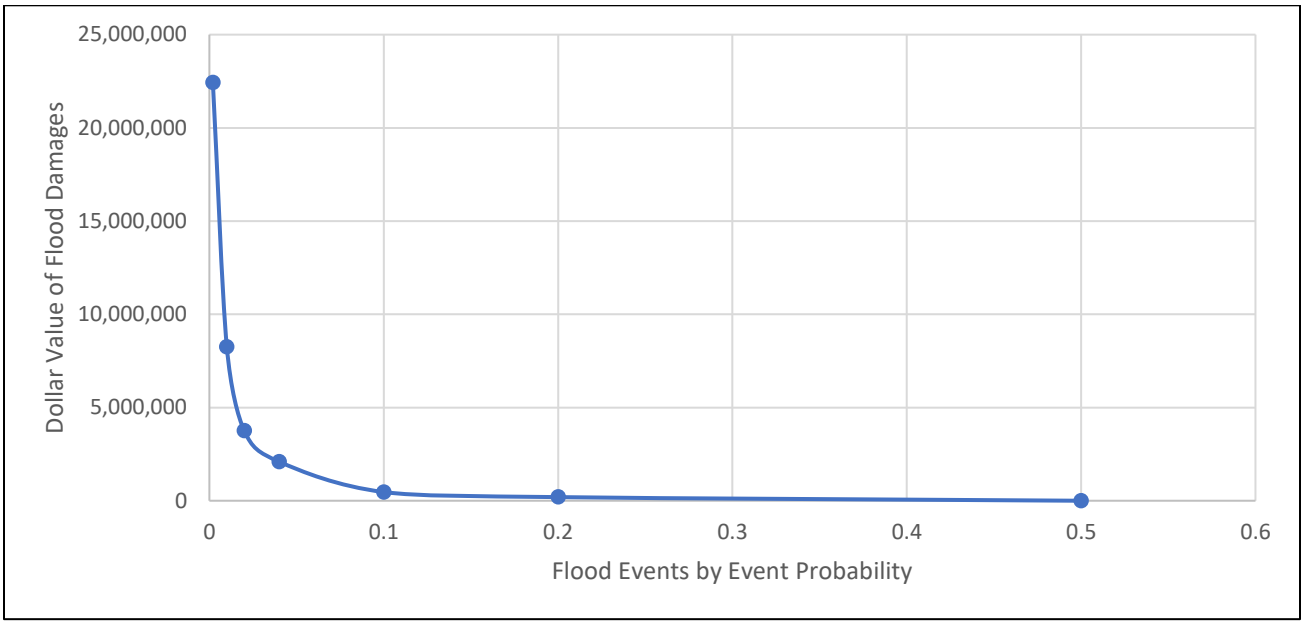
The existing condition is the baseline against which proposed changes will be compared. Table 10 summarizes the modeled damages resulting from each flood event by category: structures, contents, and vehicles.

*Table 10- HEC-FIA Model Results for Structures and Vehicles, Existing Condition*

| Flood Event (probability) | Number of Structures Affected | Total Damage by Category | | | Total Damage |
|---|---|---|---|---|---|
| | | Structures | Contents | Vehicles | |
| 2 yr (0.5) | 1 | $0 | $946 | $0 | $946 |
| 5 yr (0.2) | 9 | $5,343 | $171,111 | $18,654 | $195,108 |
| 10 yr (0.1) | 16 | $31,165 | $389,662 | $46,027 | $466,854 |
| 25 yr (0.04) | 35 | $105,725 | $1,721,129 | $268,963 | $2,095,817 |
| 50 yr (0.02) | 66 | $176,788 | $3,129,445 | $452,114 | $3,758,347 |
| 100 yr (0.01) | 132 | $432,883 | $6,784,953 | $1,034,618 | $8,252,454 |
| 500 yr (0.002) | 188 | $993,548 | $17,909,589 | $3,520,185 | $22,423,322 |
| **Total** | | $1,745,452 | $30,106,835 | $5,340,561 | $37,192,848 |

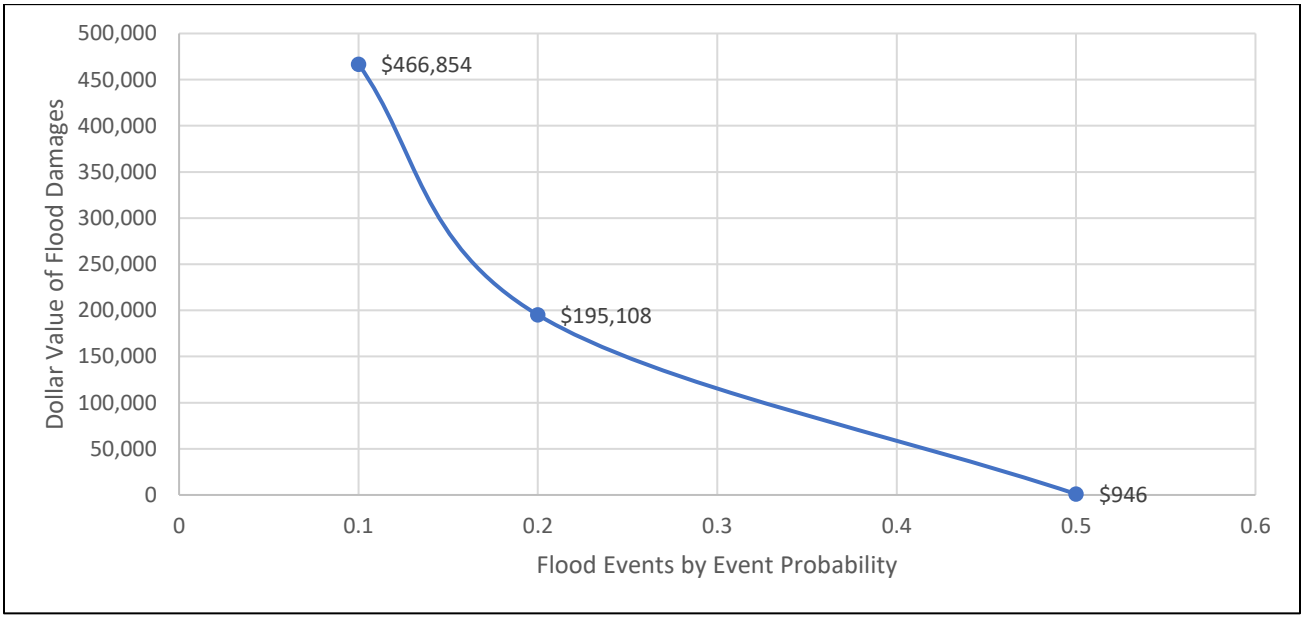
Figure 1 illustrates the total modeled damages to structures and vehicles for each event probability under the existing condition. Figure 3 will show the same information as modeled under the proposed alternative.

*Figure 1- Frequency Damage Curve for Structures and Vehicles, Existing Condition*




The relatively high value of damages occurring from the 500-year flood event masks the variation of the higher-probability flood events. Figure 2 shows only the damages, under existing conditions, for flood events with an exceedance probability of at least 0.1 (a 10-year event or more frequent).

*Figure 2- Frequency Damage Curve for Structures and Vehicles (event probability ≥ 0.1)*




The data points in Figures 1 and 2 correspond to the specific damage values in Table 10. For example, the dollar value of expected flood damages for a 5-year event (0.2 probability) is $195,108, which is also identified as the damage value for a 5-year flood in Table 10.

The expected damage for a given event is the probability occurrence multiplied by the damage if it occurs. The expected annual damage (EAD) calculations use the mid-point method to account for a complete range of probabilities of occurrence and damage. This can be visually thought of as the area under the frequency damage curve (see Figures 1 and 2). Table 11 provides the calculations and values for the EAD to structures and vehicles under the existing condition.

The calculations underlying Table 11 value the area under the curve from Figure 1. The total expected annual damages under the existing condition from the range of flood events is estimated at $425,532. The tables in the next section will reproduce these values as modeled under the proposed condition. The difference between the total expected annual damages under the existing and proposed condition is the annual benefit (from structures and vehicles), measured as a reduction in EAD, of the project.

For each level of flood event (identified by common terminology in the first column and exceedance probability in the second), column 3 reports the difference in probability between that flood event and the next (0.5 – 0.2 = 0.3). Column 4 reports the estimated annual damages. For example, for a 2-year event, this value is $946, consistent with the data in Table 10 and Figure 2. Column 5 reports the average damages, calculated as the average between the damages for the 2-year and 5-year events ($98,027 is the average of $946 and $195,108). The EAD in column 6 is the product of the difference in probabilities and the average damage value.

*Table 11- Expected Annual Damages to Structures and Vehicles, Existing Condition*

| Expected Annual Damages: Existing Condition | | | | | | |
|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Flood Event | Probability | Difference | Damages | Average Damages | EAD | Cumulative EAD |
| 2 | 0.5 | | 946 | | 29,408 | 29,408 |
| | | 0.3 | | 98,027 | | |
| 5 | 0.2 | | 195,108 | | 33,098 | 62,506 |
| | | 0.1 | | 330,981 | | |
| 10 | 0.1 | | 466,853 | | 76,880 | 139,386 |
| | | 0.06 | | 1,281,335 | | |
| 25 | 0.04 | | 2,095,817 | | 58,542 | 197,928 |
| | | 0.02 | | 2,927,082 | | |
| 50 | 0.02 | | 3,758,347 | | 60,054 | 257,982 |
| | | 0.01 | | 6,005,401 | | |
| 100 | 0.01 | | 8,252,454 | | 122,703 | 380,685 |
| | | 0.008 | | 15,337,888 | | |
| 500 | 0.002 | | 22,423,321 | | 44,847 | 425,532 |
| | | | | | | |
| **Total** | | | | | $425,532 | |

The sum of the EAD for each flood event is the total EAD value for structures and vehicles under the existing condition: $425,532.

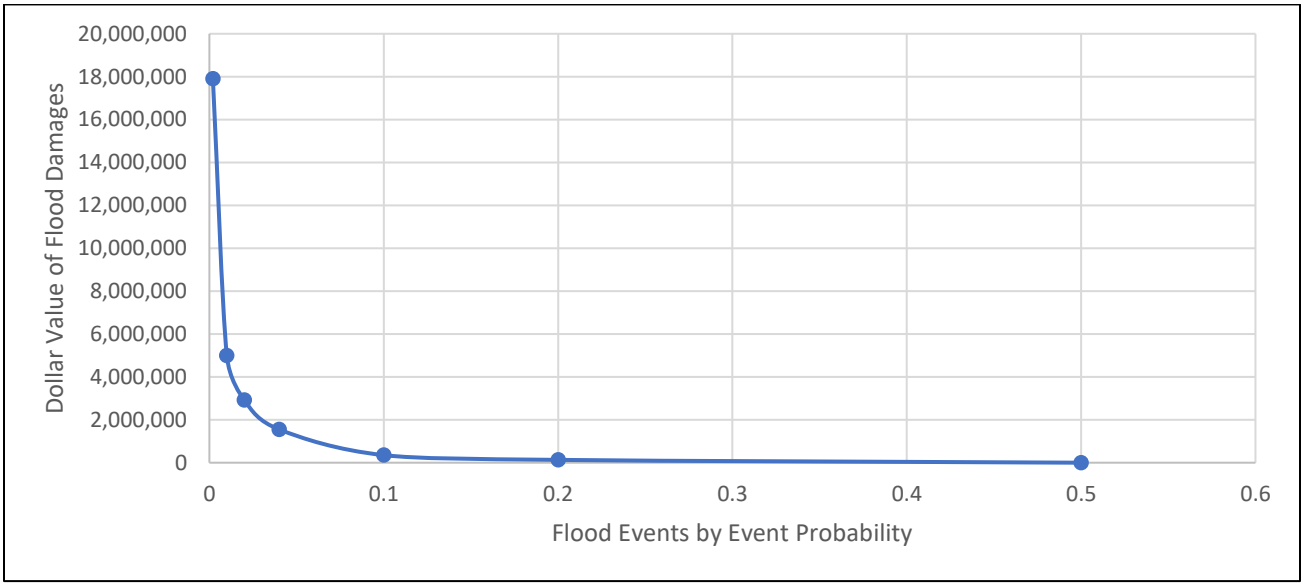
## 2. Proposed Condition

An alternative plan was developed to reduce the impact of flooding in the watershed. The project benefits are based on the reduction of expected annual flood damages modeled to occur under the proposed plan. Table 12 and Figure 3 in this section were developed in the same manner as the calculations in the previous section.

*Table 12- HEC-FIA Model Results for Structures and Vehicles, Proposed Condition*

| Flood Event (probability) | Number of Structures Affected | Total Damage by Category | | | Total Damage |
|---|---|---|---|---|---|
| | | Structures | Contents | Vehicles | |
| 2 yr (0.5) | 0 | $0 | $0 | $0 | $0 |
| 5 yr (0.2) | 6 | $2,489 | $117,593 | $11,743 | $131,825 |
| 10 yr (0.1) | 13 | $18,604 | $300,963 | $33,788 | $353,355 |
| 25 yr (0.04) | 23 | $89,288 | $1,268,154 | $195,344 | $1,552,786 |
| 50 yr (0.02) | 33 | $131,382 | $2,420,384 | $372,322 | $2,924,088 |
| 100 yr (0.01) | 75 | $206,877 | $4,085,459 | $701,358 | $4,993,694 |
| 500 yr (0.002) | 175 | $794,729 | $14,391,668 | $2,724,575 | $17,910,972 |
| **Total** | | $1,243,369 | $22,584,221 | $4,039,130 | $27,866,720 |

*Figure 3- Frequency Damage Curve for Structures and Vehicles, Proposed Condition*




Following the same methods outlined in the discussion of the EAD under the existing condition, the total EAD under the proposed condition is estimated at $313,015.

*Table 13- Expected Annual Damages to Structures and Vehicles, Proposed Condition*

| Expected Annual Damages: Proposed Condition | | | | | | |
|---|---|---|---|---|---|---|
| Flood Event | Probability | Difference | Damages | Average Damages | EAD | Cumulative EAD |
| 2 | 0.5 | | 0 | | 19,774 | 19,774 |
| | | 0.3 | | 65,913 | | |
| 5 | 0.2 | | 131,825 | | 24,259 | 44,033 |
| | | 0.1 | | 242,590 | | |
| 10 | 0.1 | | 353,354 | | 57,184 | 101,217 |
| | | 0.06 | | 953,070 | | |
| 25 | 0.04 | | 1,552,786 | | 44,769 | 145,986 |
| | | 0.02 | | 2,238,437 | | |
| 50 | 0.02 | | 2,924,088 | | 39,589 | 185,575 |
| | | 0.01 | | 3,958,891 | | |
| 100 | 0.01 | | 4,993,694 | | 91,619 | 277,193 |
| | | 0.008 | | 11,452,333 | | |
| 500 | 0.002 | | 17,910,972 | | 35,822 | 313,015 |
| | | | | | | |
| **Total** | | | | | $313,015 | |

## 3. Summary

With respect to structures and vehicles, the proposed project is modeled to reduce expected annual flood damages by $112,516. This value is the difference between the total EAD values found in Table 11 and Table 13.

*Table 14- Summary of Expected Annual Damages to Structures and Vehicles ($2023)*

| Flood Event (probability) | Existing Condition | | Proposed Condition | | Estimated Reduction in EAD under Proposed Condition |
|---|---|---|---|---|---|
| | Damages | Contribution to EAD | Damages | Contribution to EAD | |
| 2 yr (0.5) | $946 | $29,408 | $0 | $19,774 | $9,634 |
| 5 yr (0.2) | $195,108 | $33,098 | $131,825 | $24,259 | $8,839 |
| 10 yr (0.1) | $466,853 | $76,880 | $353,354 | $57,184 | $19,696 |
| 25 yr (0.04) | $2,095,817 | $58,542 | $1,552,786 | $44,769 | $13,773 |
| 50 yr (0.02) | $3,758,347 | $60,054 | $2,924,088 | $39,589 | $20,465 |
| 100 yr (0.01) | $8,252,454 | $122,703 | $4,993,694 | $91,619 | $31,084 |
| 500 yr (0.002) | $22,423,321 | $44,847 | $17,910,972 | $35,822 | $9,025 |
| **Total** | $37,192,846 | $425,532 | $27,866,719 | $313,015 | $112,516 |

## B. Agricultural Land

There are four categories of flood damage costs that accrue on agricultural land: land rehabilitation costs, costs due to late planting, damages to planted crops after the planting window has closed, and damage to planted crops within the replant window.

The necessary information to estimate flood damages on agricultural land includes prices, data on yield and yield impact, planting and replant cost data, and the historical monthly flood pattern. This information is detailed below.

*Price and Yield*

This analysis was conducted using the state-level normalized prices from the ERS (ERS, 2024; USDA, 2017; NRCS, 1998). The ERS reports normalized prices as 5-year lagged averages. The 2024 report utilizes the data from 2018 – 2022 (ERS, 2024). Average yield for each of the study area crops was calculated over the same period; this information is provided in Tables 15 and 16 (NRCS, 1998).

*Table 15- Crop Yield and Price Values*

| | Corn | Soybeans | Wheat | Dry Beans | Potatoes | Sugar Beets | Sunflowers[7] |
|---|---|---|---|---|---|---|---|
| Units | bu | bu | bu | cwt | cwt | ton | cwt |
| Yield (units per acre) | 142.52 | 34.10 | 54.71 | 17.01 | 320.00 | 27.00 | 19.90 |
| Price per unit | $4.67 | $10.55 | $6.80 | $31.50 | $11.42 | $53.09 | $23.22 |
| Revenue per acre | $665.57 | $359.76 | $372.03 | $535.82 | $3,654.40 | $1,433.43 | $462.08 |

[3] *Revenue per acre is calculated as the product of the price and yield values for each crop.*

The National Agricultural Statistics Service (NASS) provides county-level planting and yield data for most of the crops over the relevant period; potatoes and sugar beets are the exceptions. For most crops, yield was calculated as a weighted average utilizing county-level data. Yields for potatoes and sugar beets were calculated on a state-wide basis, as that was the best data available. Table 16, below, compares the county-level and statewide yield values.

The ND statewide yield data is an average of the statewide yields from 2018 – 2022, as reported in the 2024 North Dakota Agricultural Statistics Bulletin. The county-level yield data is based on the county yields from Grand Forks and Walsh counties, over the same 5-year period, weighted by the share of total acreage planted in each county.

[7] The normalized price data from the ERS does not include sunflowers. This price is the 5-year average, 2018 – 2022, of the marketing year average price for oil sunflowers from the 2024 ND Agricultural Statistics Bulletin (NASS, 2024; NRCS, 1998).

*Table 16- Statewide and County-level Yield Comparison*

| Crop (units) | ND statewide yield | County-level yield |
|---|---|---|
| Corn (bu) | 131.60 | 142.52 |
| Soybeans (bu) | 32.20 | 34.10 |
| Wheat (bu) | 46.10 | 54.71 |
| Dry Beans (cwt) | 15.32 | 17.01 |
| Potatoes (cwt) | 320.00 | NA |
| Sugar Beets (ton) | 27.00 | NA |
| Sunflowers (cwt) | 17.30 | 19.90 |

*[4] Sources: (NASS, 2019, 2020, 2021, 2022, 2023)*

*Crop Damage Factors*

The crop damage factors (CDF) in Table 17 identify, by crop and by month, the percentage reduction in yield in response to specific inundation durations (SCS, 1981).[8] Crops are anticipated to only incur yield reductions in response to inundation during the months of the growing season identified in Table 17; the damage factor is presumed zero for the months outside of this period.

*Table 17- Crop Damage Factors for ND (percent decrease in yield by number of days inundated)[9]*

| Corn (bu) | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| 1 day inundation | 13.0% | 13.0% | 18.0% | 11.0% | 5.0% | 5.0% |
| 2 days inundation | 31.0% | 31.0% | 45.0% | 19.0% | 13.0% | 19.0% |
| 3 days inundation | 66.0% | 66.0% | 72.0% | 46.0% | 19.0% | 36.0% |
| 4 days inundation | 70.0% | 70.0% | 78.0% | 57.0% | 33.0% | 44.0% |
| 5 days inundation | 100.0% | 100.0% | 100.0% | 72.0% | 44.0% | 51.0% |
| 6 days inundation | 100.0% | 100.0% | 100.0% | 76.0% | 68.0% | 65.0% |
| 7+ days inundation | 100.0% | 100.0% | 100.0% | 100.0% | 71.0% | 77.0% |

| Soybeans (bu)[10] | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| 1 day inundation | NA | 7.0% | 13.0% | 4.0% | 4.0% | 10.0% |
| 2 days inundation | NA | 8.0% | 16.0% | 17.0% | 16.0% | 62.0% |
| 3 days inundation | NA | 16.0% | 32.0% | 34.0% | 30.0% | 83.0% |
| 4 days inundation | NA | 29.0% | 58.0% | 56.0% | 50.0% | 83.0% |
| 5 days inundation | NA | 36.0% | 71.0% | 81.0% | 69.0% | 83.0% |
| 6 days inundation | NA | 40.0% | 79.0% | 81.0% | 83.0% | 83.0% |
| 7+ days inundation | NA | 40.0% | 79.0% | 81.0% | 83.0% | 83.0% |

[8] Resource and interpretation assistance from (Nichols, 2023 and 2024).
[9] Original data from Soil Conservation Service (SCS), 1981. Per Gannett Fleming, 2022: original SCS tables did not include damage factors for April, or May factors for soybeans. May factors are set at half of June factors, per consultation with L. Mairs (2017). Dry bean factors were not included with original SCS. Per consultation with S. Lahman (2018), damage factors for dry beans are set halfway between the factors for potatoes and soybeans.
[10] Per the 2024 ND Agricultural Statistics Bulletin, planting for soybeans and for dry beans did not occur until May. Therefore, the CDF values for those crops for April is listed as NA.

| Wheat (bu) | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| 1 day inundation | 14.0% | 14.0% | 17.0% | 20.0% | 30.0% | 30.0% |
| 2 days inundation | 29.0% | 29.0% | 34.0% | 43.0% | 65.0% | 65.0% |
| 3 days inundation | 44.0% | 44.0% | 54.0% | 65.0% | 75.0% | 75.0% |
| 4 days inundation | 60.0% | 60.0% | 75.0% | 90.0% | 80.0% | 80.0% |
| 5 days inundation | 80.0% | 80.0% | 100.0% | 100.0% | 90.0% | 90.0% |
| 6 days inundation | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| 7+ days inundation | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

| Dry Beans (cwt)[11] | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| 1 day inundation | NA | 11.0% | 28.5% | 24.5% | 26.0% | 24.5% |
| 2 days inundation | NA | 14.5% | 48.5% | 49.5% | 49.5% | 57.5% |
| 3 days inundation | NA | 21.5% | 66.0% | 67.0% | 65.0% | 71.0% |
| 4 days inundation | NA | 31.5% | 79.0% | 78.0% | 75.0% | 72.0% |
| 5 days inundation | NA | 37.0% | 85.5% | 90.5% | 79.5% | 72.0% |
| 6 days inundation | NA | 40.5% | 89.5% | 90.5% | 91.5% | 72.0% |
| 7+ days inundation | NA | 40.5% | 89.5% | 90.5% | 91.5% | 72.0% |

| Potatoes (cwt) | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| 1 day inundation | 15.0% | 15.0% | 44.0% | 45.0% | 48.0% | 39.0% |
| 2 days inundation | 21.0% | 21.0% | 81.0% | 82.0% | 83.0% | 53.0% |
| 3 days inundation | 27.0% | 27.0% | 100.0% | 100.0% | 100.0% | 59.0% |
| 4 days inundation | 33.0% | 33.0% | 100.0% | 100.0% | 100.0% | 61.0% |
| 5 days inundation | 38.0% | 38.0% | 100.0% | 100.0% | 100.0% | 61.0% |
| 6 days inundation | 38.0% | 38.0% | 100.0% | 100.0% | 100.0% | 61.0% |
| 7+ days inundation | 38.0% | 38.0% | 100.0% | 100.0% | 100.0% | 61.0% |

| Sugar Beets (ton) | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| 1 day inundation | 15.0% | 15.0% | 15.0% | 20.0% | 15.0% | 15.0% |
| 2 days inundation | 25.0% | 25.0% | 30.0% | 40.0% | 25.0% | 25.0% |
| 3 days inundation | 40.0% | 40.0% | 65.0% | 70.0% | 40.0% | 45.0% |
| 4 days inundation | 60.0% | 60.0% | 100.0% | 100.0% | 55.0% | 60.0% |
| 5 days inundation | 80.0% | 80.0% | 100.0% | 100.0% | 70.0% | 70.0% |
| 6 days inundation | 100.0% | 100.0% | 100.0% | 100.0% | 85.0% | 80.0% |
| 7+ days inundation | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 85.0% |

[11] See note for soybeans.

| Sunflowers (cwt) | April | May | June | July | August | September |
|---|---|---|---|---|---|---|
| 1 day inundation | 0.0% | 17.0% | 11.0% | 13.0% | 20.0% | 19.0% |
| 2 days inundation | 0.0% | 34.0% | 23.0% | 27.0% | 38.0% | 36.0% |
| 3 days inundation | 0.0% | 54.0% | 38.0% | 42.0% | 55.0% | 51.0% |
| 4 days inundation | 0.0% | 76.0% | 55.0% | 58.0% | 71.0% | 65.0% |
| 5 days inundation | 0.0% | 100.0% | 74.0% | 77.0% | 85.0% | 77.0% |
| 6 days inundation | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% | 89.0% |
| 7+ days inundation | 0.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

[5] *Sunflower data were not provided in the original SCS documentation. Values set per consultation with A. Wittenberg (2024).*

*Late Plant Yield Loss*

Table 18 summarizes crop progress, yield losses, and replant decisions. In the table, percent planted is a measure of crop planting progress, and the late plant yield loss is the percentage yield loss that results from planting late. The replant threshold is the damage value that, when exceeded, would indicate that producers should replant the crop, and the expected replant crop is provided in the following row. In North Dakota the planting season is generally considered over, for these crops, by the end of June.

*Table 18- Crop Progress, Yield Losses, and Late Plant Thresholds*

| Corn | April | May | June |
|---|---|---|---|
| Percent Planted | 0.67% | 38.00% | 96.50% |
| Late Plant Yield Loss | 20.00% | 30.00% | NA |
| Replant when damage exceeds | 30.00% | 30.00% | 75.00% |
| Replant with | Corn | Corn | Soybeans |
| Soybeans | April | May | June |
| Percent Planted | 0.00% | 24.00% | 91.50% |
| Late Plant Yield Loss | NA[12] | 10.00% | 30.00% |
| Replant when damage exceeds | NA | 30.00% | 65.00% |
| Replant with | NA | Soybeans | Soybeans |
| Wheat | April | May | June |
| Percent Planted | 3.67% | 55.50% | 98.00% |
| Late Plant Yield Loss | 10.00% | 20.00% | NA |
| Replant when damage exceeds | 40.00% | 30.00% | 65.00% |
| Replant with | Wheat | Wheat | Soybeans |
| Dry Beans | April | May | June |
| Percent Planted | 0.00% | 15.50% | 90.50% |
| Late Plant Yield Loss | NA | 10.00% | 30.00% |
| Replant when damage exceeds | NA | 25.00% | 65.00% |
| Replant with | NA | Dry Beans | Dry Beans |

[12] When 0% of the crop is planted in April, the following variables (late plant yield loss, replant threshold, and replant crop) are not applicable (NA).

| Potatoes[13] | April | May | June |
|---|---|---|---|
| Percent Planted | 0.33% | 43.50% | 96.00% |
| Late Plant Yield Loss | NA | 50.00% | NA |
| Replant when damage exceeds | NA | NA | NA |
| Replant with | NA | NA | NA |
| Sugar Beets | April | May | June |
| Percent Planted | 1.67% | 71.50% | 99.50% |
| Late Plant Yield Loss | 1.00% | 15.00% | NA |
| Replant when damage exceeds | 25.00% | 75.00% | 90.00% |
| Replant with | Sugar Beets | Sugar Beets | Soybeans |
| Sunflowers | April | May | June |
| Percent Planted | 0.00% | 8.00% | 82.00% |
| Late Plant Yield Loss | NA | 10.00% | 30.00% |
| Replant when damage exceeds | NA | 25.00% | 65.00% |
| Replant with | NA | Sunflowers | Sunflowers |

*[6] The sunflower data in this table is from consultation with ND NRCS State Agronomist.*

*[7] The percent planted is calculated as the average of the middle two or middle 3 weeks percent planted value, 5-year average (2018 - 2022), from the 2024 Agricultural Statistics Bulletin, per consultation with ND NRCS State Agronomist.*

*Unit Costs*

Table 19 reports cost factors that will impact the final flood damage estimations. Seed and planting costs are estimated per acre, as planting costs are incurred at that level. Harvest costs are also measured per-acre. Hauling, drying, and additional post-harvest costs that the producer may incur, such as cleaning and storage, are measured per-unit (Gannett Fleming, 2022).

In addition to the costs identified in Table 19, all cropland inundated from flooding will incur additional costs as the land is rehabilitated after the water subsides. Land rehabilitation efforts may involve subsequent clean-up efforts such as removing silt, or actions to prepare the soil for a return to cropping activities. This cost is estimated at $20 per acre during the growing season, and half that rate ($10 per acre) during the remaining months (Gannett Fleming, 2022).

[13] Per discussion with State Agronomist, potato crops are distinctive and would not offer the same replant opportunities as other crops (Wittenberg, 2024).

*Table 19- Cost Factors*

| | Corn (bu) | Soybeans (bu) | Wheat (bu) | Dry Beans (cwt) | Potatoes (cwt) | Sugar Beets (ton) | Sunflowers (cwt) |
|---|---|---|---|---|---|---|---|
| Replant Cost Factors ($/acre) | | | | | | | |
| Seed[14] | $94.50 | $65.80 | $30.00 | $86.63 | NA | $277.44 | $41.04 |
| Planting | $22.96 | $21.02 | $22.79 | $27.24 | NA | $24.60 | $23.60 |
| Avoided Cost Factors | | | | | | | |
| Harvest Cost[15] | $44.30 | $40.29 | $12.61 | $46.53 | $126.11 | $78.82 | $40.54 |
| Additional Post-Harvest Costs | $0.20 | $0.00 | $0.00 | $0.00 | $1.19 | $0.00 | $0.40 |
| Hauling Cost[16] | $0.21 | $0.21 | $0.23 | $0.79 | $0.39 | $3.53 | $0.59 |

[8] *Based on consultation with (Buland, 2024) and with (Wittenberg, 2024).*

*Seasonal Flood Distribution*

Agricultural damages due to flooding will vary over the months of the year; in this analysis, the damages are weighted by the historical frequency of flood events to account for this variation. The National Oceanic and Atmospheric Administration (NOAA) maintains records of four-day rain events. These records, dating back to 1966, were used to identify the historical pattern of counted rainfall events by month; the data is outlined in Table 20.

*Table 20- Historical Flood Event Distribution by Month*

| | April | May | June | July | August | September | Other Months | **Total** |
|---|---|---|---|---|---|---|---|---|
| Number | 6 | 18 | 32 | 32 | 24 | 20 | 9 | 141 |
| Percent | 4.26% | 12.77% | 22.70% | 22.70% | 17.02% | 14.18% | 6.38% | 100.00% |

[9] *Source: NOAA Hydrometeorological Design Center Precipitation Frequency Data Server. Annual Maximum Series files at Grand Forks International Airport and Grand Forks University.*

The percentages from Table 20 were used to weight the damage values, so that the final damage estimates reflect the historical pattern of flood events in the region of the watershed.

## 1. Existing Condition

The enhanced CDL (CDL-E), overlaid on the range of flood intervals, allowed NRCS Engineers to develop a dataset of flood event affected acres. Table 21 reports the total number of acres of each crop that would be inundated for at least one day under each flood event magnitude.

[14] Seed costs for all crops except sugar beets are from the 2024 NDSU Projected Crop Budget for the North Valley region of North Dakota. The seed cost for sugar beets is an indexed update of the price from Gannett Fleming, 2022. It was indexed using the Producer Prices Paid Index (PPPI) from the Water Resource Planning Discount Rates, 2023 annual value.

[15] Harvest costs come from the NDSU Late Custom Rates Survey (2020) (soybeans, dry beans) and the Gannett Fleming 2022 report (corn, wheat, potatoes, and sugar beets). Sunflower data is from the NRCS ND State Agronomist.

[16] Hauling costs for all except sunflowers are from Gannett Fleming, 2022. Sunflower data is from the NDSU Late Custom Rates Survey (2020). All are indexed to 2023.

Table 21 summarizes the acres modeled to be inundated for at least one day, by flood event and by crop; these are the affected acres.[17] The data for each crop and flood event reports the total acreage inundated, suppressing the variation of inundation duration. A 100-year flood event (0.01 annual exceedance probability) is modeled to inundate a total of 3,122 acres of corn.

*Table 21- Affected Acres by Crop and Flood Magnitude, Existing Condition (2020 CDL-E)*

| Crop | Affected Acres, Existing Condition | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
| Corn | 653 | 972 | 1,260 | 2,002 | 2,514 | 3,122 | 4,523 |
| Soybeans | 883 | 1,432 | 1,847 | 2,680 | 3,467 | 4,471 | 7,156 |
| Wheat | 374 | 753 | 1,195 | 2,242 | 3,118 | 4,459 | 8,685 |
| Dry Beans | 828 | 1,429 | 1,830 | 2,632 | 3,403 | 4,235 | 6,164 |
| Potatoes | 3 | 5 | 6 | 9 | 11 | 14 | 16 |
| Sugar Beets | 137 | 243 | 443 | 1,078 | 1,664 | 2,532 | 5,127 |
| Sunflowers | 242 | 420 | 571 | 867 | 918 | 995 | 1,695 |
| **Total** | 3,120 | 5,253 | 7,150 | 11,509 | 15,095 | 19,827 | 33,365 |

Modeling indicates that 653 acres of corn would be inundated for at least one day during a 2-year flood event. The detailed modeling breaks those 653 acres down per Table 22, below. The same methodology was used for each of the seven crops in the study area, for both the existing and proposed conditions.

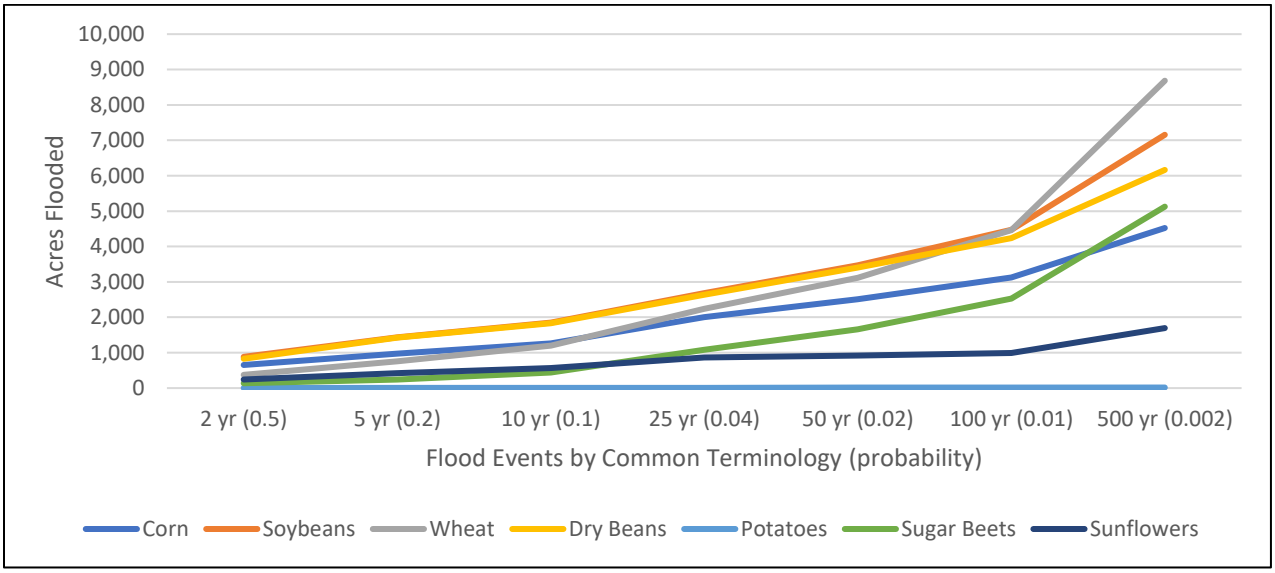
*Table 22- Affected Acres by Flood Event, Corn, Existing Condition*

| Corn (bu) Affected Acres, Existing Condition | | | | | | | |
|---|---|---|---|---|---|---|---|
| Inundation Duration | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.4) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
| 1 day | 173 | 223 | 262 | 331 | 458 | 583 | 673 |
| 2 days | 111 | 166 | 200 | 262 | 338 | 513 | 919 |
| 3 days | 43 | 123 | 159 | 261 | 232 | 274 | 602 |
| 4 days | 68 | 73 | 134 | 228 | 241 | 244 | 422 |
| 5 days | 104 | 70 | 107 | 326 | 337 | 417 | 371 |
| 6 days | 14 | 164 | 243 | 438 | 752 | 933 | 1,360 |
| 7+ days | 139 | 154 | 154 | 155 | 156 | 157 | 177 |
| **Total** | 653 | 972 | 1,260 | 2,002 | 2,514 | 3,122 | 4,523 |

[17] Inundated acres and affected acres mean the same thing; they are used interchangeably in this report.

Figure 4 is a visual representation of the total acres of each crop affected by each flood event magnitude.

*Figure 4- Affected Acres by Crop and Flood Magnitude, Existing Condition (2020 CDL-E)*




*Sample Damage Calculations*[18]

There are four types of costs that accrue as a result of flooding on agricultural land; examples of the calculations are provided below.

Land Rehabilitation Costs

Land rehabilitation costs, set at a flat rate per acre, cover the cost to return the flooded acres to a productive state. This cost is estimated at $20 per acre during the growing season, and $10 per acre outside of that season.

For a corn crop, a 2-year flood in May is modeled to leave 173 acres inundated for one day. Because it occurs during the growing season, the rehabilitation cost is $20 per acre. The resultant land rehabilitation cost is:

(1) 173 * 20.00 = $3,460

Late Plant Costs

This category captures crop damages from late plant yield losses for crops not yet planted. This damage category only returns non-zero values for the months in the planting season (April – June). Broadly, these damages are measured as the flooded (affected) acres multiplied by the percent yet to plant; this captures the acres that are vulnerable to delayed planting from flooding. This value is multiplied by the full yield, the late plant yield loss, and the price, reduced by the avoided per-unit costs of hauling and drying.

[18] Assistance in developing and organizing calculations provided by (Nichols, 2023 and 2024) and (Wittenberg, 2024).

For a corn crop that experienced a 2-year flood event in May, leaving 173 acres inundated for one day, these calculations look like:

(1) 173 * 62% (percent yet to plant) = 107 *acres vulnerable to delayed plant*
(2) 107 * 142.52 (yield) * 30% (late plant yield loss) = 4,575 *bushels lost*
(3) 4,575 * $4.26[19] (price) = $19,489.50 *dollar value of the bushels lost*

Planted, Outside of the Replant Window

This category captures the damages to planted crops when a flood occurs outside of the replant window; $0 damages will be returned for months when replant is possible. These damage calculations begin with the flooded (affected) acres multiplied by the percent planted; this captures the acres vulnerable to damages. This value is then multiplied by the full yield and the crop damage factor (CDF) to calculate the bushels lost. Finally, this is multiplied by the price (reduced by avoided per-unit costs), with the harvest cost deducted if the CDF is equal to 1 (such that the entire crop is lost).

Continuing the example of a corn crop that has experienced a 2-year flood, with 173 acres inundated for one day, but this time in July:

(1) 173 * 100% (percent planted) = 173 *acres vulnerable to damages*
(2) 173 * 142.52 * 11% = 2,712 *bushels lost*
(3) 2,712 * $4.26 (price) = $11,553.12 *dollar value of the bushels lost*
(4) At this point, the crop damage factor is less than 1, and so the producer will still incur harvest costs

Planted, Within the Replant Window

The final category captures damages from floods that occur during the months when it is possible to replant. These damages are calculated in three steps: 1) the initial loss, 2) the offsetting revenue impacts from subsequent replanting, and 3) calculation of total damages from the flood event.

Both the initial loss and the offsetting revenue impacts from subsequent replanting are calculated on a per-acre basis; the final step incorporates acreage to calculate the total damages.

The initial losses from a 2-year flood event, inundating 173 acres of corn for one day in May, are dependent on whether the CDF is less than the replant threshold (RT). If the CDF is less than the RT, the loss per acre is the full yield * CDF * price; otherwise, the loss per acre is the full yield * price.

In this example, the CDF = 13% and the RT = 30%. This means that the crop will not be replanted.

(1) 142.52 (yield) * 13% * $4.26 = $78.93 *dollar value of the initial loss*
(2) ** Because the RT was not exceeded, the crop will not be replanted; there is no offsetting revenue

The final calculation in this example will take the difference between the initial loss and any offsetting revenue (in this case, there was none), multiplied by the inundated acres and the percent planted.

(3) ($78.93 – $0) * 173 * 38% (percent planted) = $5,188.86 *total estimated damages*

If we consider the same event, but for acres inundated for 3 days, the acreage value will drop to 43 and the CDF increases to 66% (which exceeds the RT of 30%), and so there now will be offsetting revenue from a subsequent replant to consider in the calculations.

[19] The $4.26/bu value is the $4.67 price, minus the per-bushel hauling and drying costs (as these costs would not be paid for the bushels that are lost).

The initial loss calculations are now the full yield * price, minus the harvest cost (as that will be avoided):

(4) 142.52 * $4.26 = $607.14 - $44.30 (harvest cost per acre) = $562.84 *initial loss per acre*

The offsetting revenue is calculated as the yield, reduced by the late plant yield loss factor of 30%, multiplied by the price. That value will be reduced by the sum of the replant costs (replanting and seed costs) and the harvest cost per acre. This value is different in construct than others in this section because it is calculated as revenue coming in, where other values are calculated as losses.

(5) 142.52 * (1 – 0.3) = 99.764 *reduced yield, given late plant*
(6) 99.764 * $4.26 = $424.99 *dollar value of replant crop*
(7) $424.99 – $117.46 (replant cost) = $307.53
(8) $307.53 - $44.30 (harvest cost) = $263.23 *offsetting revenue per acre*

The final calculation here, as in the preceding example, will take the difference between the initial loss and the offsetting subsequent revenue per acre, multiplied by the affected acres and the percent planted.

(9) ($562.84 - $263.23) = $299.61
(10) $299.61 * 43 (acres) * 38% = $4,896 *total estimated damages*

In some cases, though, it may be not feasible to replant a crop when it would otherwise be an appropriate step, given the relative values of the crop damage factor and the replant threshold: where it is not an easy or a distinct section of the field, for example.[20] The difficulty facing the producer is magnified by time pressure, particularly as the crop is inundated for an extended period. In these cases, when the CDF exceeds the RT, and acres have been inundated for 4 or days, the producer is assumed able to only replant 80% of the acres eligible for replant, with costs as described above.[21] The remaining 20% incurs losses per the CDF and would still be harvested.

*Estimated Damages*

Table 23 summarizes the damages to each crop by flood event and damage source (land rehabilitation, late plant, and losses of planted crops with and without the possibility of replant). The damages reported in Table 23 are weighted by the historical monthly likelihood of flood events.

*Table 23- Summary of Damages to Agricultural Land by Crop, Existing Condition*

| Corn | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $12,640 | $13,315 | $85,743 | $56,961 | $168,659 |
| 5 yr (0.2) | $18,824 | $19,829 | $131,963 | $87,661 | $258,277 |
| 10 yr (0.1) | $24,392 | $25,695 | $173,498 | $116,489 | $340,075 |
| 25 yr (0.04) | $38,759 | $40,829 | $290,990 | $195,577 | $566,156 |
| 50 yr (0.02) | $48,677 | $51,277 | $371,875 | $242,725 | $714,554 |
| 100 yr (0.01) | $60,460 | $63,689 | $447,373 | $296,271 | $867,793 |
| 500 yr (0.002) | $87,587 | $92,265 | $631,579 | $434,229 | $1,245,661 |
| **Total** | $291,340 | $306,901 | $2,133,021 | $1,429,913 | $4,161,175 |

[20] This may result from the distribution of the inundated acres across a larger field, or from areas of shorter flooding durations that are closely mixed (Gannett Fleming, 2022).
[21] Based on (Gannett Fleming, 2022) and further consultation with (Wittenberg, 2024).

| Soybeans | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $17,097 | $4,823 | $74,738 | $24,796 | $121,454 |
| 5 yr (0.2) | $27,724 | $7,821 | $145,148 | $46,424 | $227,117 |
| 10 yr (0.1) | $35,762 | $10,089 | $206,121 | $65,091 | $317,063 |
| 25 yr (0.04) | $51,890 | $14,638 | $294,985 | $95,083 | $456,596 |
| 50 yr (0.02) | $67,139 | $18,940 | $382,716 | $124,109 | $592,905 |
| 100 yr (0.01) | $86,588 | $24,427 | $481,799 | $153,965 | $746,779 |
| 500 yr (0.02) | $138,585 | $39,096 | $737,437 | $235,236 | $1,150,354 |
| **Total** | $424,785 | $119,835 | $2,322,945 | $744,703 | $3,612,269 |

| Wheat | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $7,239 | $2,258 | $44,314 | $16,067 | $69,879 |
| 5 yr (0.2) | $14,586 | $4,550 | $97,015 | $35,381 | $151,532 |
| 10 yr (0.1) | $23,139 | $7,218 | $149,734 | $54,403 | $234,495 |
| 25 yr (0.04) | $43,415 | $13,542 | $258,011 | $93,426 | $408,393 |
| 50 yr (0.02) | $60,383 | $18,835 | $364,078 | $131,160 | $574,456 |
| 100 yr (0.01) | $86,347 | $26,934 | $546,874 | $196,718 | $856,872 |
| 500 yr (0.002) | $168,185 | $52,461 | $1,120,316 | $408,264 | $1,749,226 |
| **Total** | $403,293 | $125,798 | $2,580,342 | $935,419 | $4,044,853 |

| Dry Beans | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $16,038 | $7,467 | $145,556 | $46,029 | $215,091 |
| 5 yr (0.2) | $27,674 | $12,885 | $268,148 | $82,491 | $391,198 |
| 10 yr (0.1) | $35,434 | $16,498 | $355,330 | $107,660 | $514,922 |
| 25 yr (0.04) | $50,977 | $23,735 | $518,323 | $156,108 | $749,142 |
| 50 yr (0.02) | $65,890 | $30,678 | $662,143 | $200,097 | $958,810 |
| 100 yr (0.01) | $82,006 | $38,182 | $821,488 | $249,422 | $1,191,097 |
| 500 yr (0.002) | $119,361 | $55,574 | $1,181,037 | $360,077 | $1,716,049 |
| **Total** | $397,380 | $185,019 | $3,952,025 | $1,201,884 | $5,736,309 |

| Potatoes | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $65 | $379 | $6,018 | $0 | $6,462 |
| 5 yr (0.2) | $90 | $531 | $9,202 | $0 | $9,823 |
| 10 yr (0.1) | $116 | $682 | $11,870 | $0 | $12,668 |
| 25 yr (0.04) | $168 | $985 | $17,927 | $0 | $19,080 |
| 50 yr (0.02) | $215 | $1,263 | $22,783 | $0 | $24,261 |
| 100 yr (0.01) | $267 | $1,566 | $28,583 | $0 | $30,416 |
| 500 yr (0.002) | $306 | $1,794 | $33,208 | $0 | $35,308 |
| **Total** | $1,227 | $7,200 | $129,592 | $0 | $138,019 |

| Sugar Beets | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $2,644 | $1,136 | $46,048 | $27,197 | $77,025 |
| 5 yr (0.2) | $4,703 | $2,021 | $108,494 | $63,137 | $178,354 |
| 10 yr (0.1) | $8,570 | $3,683 | $194,203 | $110,570 | $317,025 |
| 25 yr (0.04) | $20,878 | $8,971 | $383,427 | $213,070 | $626,347 |
| 50 yr (0.02) | $32,226 | $13,848 | $601,968 | $340,443 | $988,485 |
| 100 yr (0.01) | $49,026 | $21,067 | $886,593 | $496,584 | $1,453,270 |
| 500 yr (0.002) | $99,275 | $42,659 | $1,915,249 | $1,119,283 | $3,176,466 |
| **Total** | $217,323 | $93,384 | $4,135,982 | $2,370,284 | $6,816,973 |

| Sunflowers | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $4,694 | $2,574 | $16,959 | $4,355 | $28,582 |
| 5 yr (0.2) | $8,131 | $4,459 | $36,932 | $9,459 | $58,980 |
| 10 yr (0.1) | $11,051 | $6,060 | $60,427 | $15,420 | $92,957 |
| 25 yr (0.04) | $16,787 | $9,206 | $117,239 | $29,988 | $173,220 |
| 50 yr (0.02) | $17,782 | $9,752 | $142,044 | $36,203 | $205,780 |
| 100 yr (0.01) | $19,259 | $10,562 | $160,800 | $40,306 | $230,927 |
| 500 yr (0.002) | $32,820 | $17,999 | $247,998 | $61,301 | $360,117 |
| **Total** | $110,524 | $60,612 | $782,398 | $197,032 | $1,150,565 |

*Expected Annual Damages, Existing Condition*

Table 24 reports the EAD for agricultural lands under the existing condition. The damages reported for each flood event are the sum of the damages to each crop from that flood event. The $687,152 in damages from a 2-year event is the estimated sum of the damages to corn, soybeans, wheat, dry beans, potatoes, sugar beets, and sunflowers from a 2-year event.

*Table 24- Expected Annual Damages to Agricultural Land, Existing Condition*

| Expected Annual Damages: Existing Condition | | | | | | |
|---|---|---|---|---|---|---|
| Flood Event | Probability | Difference | Damages | Average Damages | EAD | Cumulative EAD |
| 2 | 0.5 | | 687,152 | | 294,365 | 294,365 |
| | | 0.3 | | 981,217 | | |
| 5 | 0.2 | | 1,275,281 | | 155,224 | 449,589 |
| | | 0.1 | | 1,552,244 | | |
| 10 | 0.1 | | 1,829,207 | | 144,844 | 594,434 |
| | | 0.06 | | 2,414,071 | | |
| 25 | 0.04 | | 2,998,936 | | 70,582 | 665,016 |
| | | 0.02 | | 3,529,093 | | |
| 50 | 0.02 | | 4,059,251 | | 47,182 | 712,198 |
| | | 0.01 | | 4,718,203 | | |
| 100 | 0.01 | | 5,377,155 | | 59,241 | 771,439 |
| | | 0.008 | | 7,405,168 | | |
| 500 | 0.002 | | 9,433,180 | | 18,866 | 790,305 |
| | | | | | | |
| **Total** | | | | | $790,305 | |

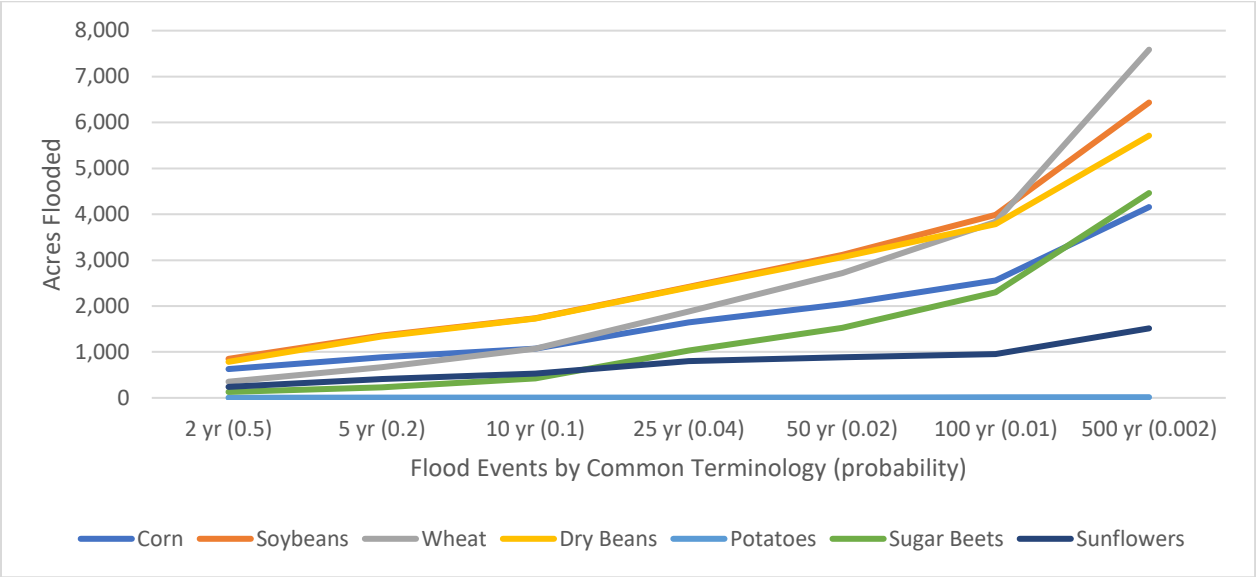
## 2. Proposed Condition

Table 25 and Figure 5 report the total acres modeled to be inundated for at least one day under the proposed condition.

*Table 25- Affected Acres by Crop and Flood Magnitude, Proposed Condition (2020 CDL-E)*

| Crop | Affected Acres | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
| Corn | 628 | 885 | 1,070 | 1,641 | 2,040 | 2,555 | 4,157 |
| Soybeans | 850 | 1,361 | 1,738 | 2,418 | 3,116 | 3,986 | 6,434 |
| Wheat | 352 | 667 | 1,076 | 1,882 | 2,717 | 3,834 | 7,586 |
| Dry Beans | 785 | 1,335 | 1,726 | 2,405 | 3,064 | 3,782 | 5,712 |
| Potatoes | 3 | 5 | 6 | 8 | 9 | 12 | 15 |
| Sugar Beets | 129 | 226 | 427 | 1,028 | 1,528 | 2,301 | 4,462 |
| Sunflowers | 240 | 409 | 529 | 799 | 888 | 951 | 1,514 |
| **Total** | 2,988 | 4,888 | 6,572 | 10,182 | 13,362 | 17,422 | 29,880 |

*Figure 5- Affected Acres by Crop and Flood Magnitude, Proposed Condition (2020 CDL-E)*




*Estimated Damages*

Table 26 summarizes the damages to each crop by flood event and damage source (land rehabilitation, late plant, and losses of planted crops with and without the possibility of replant) under the proposed condition.

*Table 26- Summary of Damages to Agricultural Land by Crop, Proposed Condition*

| Corn | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $12,157 | $12,807 | $94,291 | $59,448 | $178,703 |
| 5 yr (0.2) | $17,132 | $18,047 | $141,392 | $90,142 | $266,712 |
| 10 yr (0.1) | $20,728 | $21,835 | $183,363 | $110,164 | $336,089 |
| 25 yr (0.04) | $31,787 | $33,485 | $269,695 | $166,481 | $501,448 |
| 50 yr (0.02) | $39,508 | $41,619 | $354,149 | $215,611 | $650,887 |
| 100 yr (0.01) | $49,478 | $52,121 | $421,649 | $259,706 | $782,954 |
| 500 yr (0.002) | $80,499 | $84,798 | $621,609 | $410,205 | $1,197,110 |
| **Total** | $251,289 | $264,711 | $2,086,147 | $1,311,756 | $3,913,902 |

| Soybeans | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $16,464 | $4,645 | $76,290 | $24,978 | $122,377 |
| 5 yr (0.2) | $26,356 | $7,435 | $146,028 | $46,941 | $226,760 |
| 10 yr (0.1) | $33,660 | $9,496 | $201,772 | $63,368 | $308,296 |
| 25 yr (0.04) | $46,830 | $13,211 | $266,446 | $84,821 | $411,307 |
| 50 yr (0.02) | $60,339 | $17,022 | $346,757 | $111,911 | $536,030 |
| 100 yr (0.01) | $77,195 | $21,777 | $438,453 | $140,985 | $678,411 |
| 500 yr (0.002) | $124,589 | $35,147 | $691,575 | $221,504 | $1,072,816 |
| **Total** | $385,434 | $108,733 | $2,167,322 | $694,508 | $3,355,997 |

| Wheat | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $6,826 | $2,129 | $44,409 | $16,129 | $69,493 |
| 5 yr (0.2) | $12,924 | $4,031 | $88,137 | $32,198 | $137,291 |
| 10 yr (0.1) | $20,835 | $6,499 | $141,913 | $51,676 | $220,924 |
| 25 yr (0.04) | $36,447 | $11,369 | $215,147 | $77,726 | $340,688 |
| 50 yr (0.02) | $52,613 | $16,412 | $305,681 | $110,604 | $485,310 |
| 100 yr (0.01) | $74,241 | $23,158 | $451,425 | $162,876 | $711,699 |
| 500 yr (0.002) | $146,897 | $45,821 | $994,871 | $364,997 | $1,552,586 |
| **Total** | $350,783 | $109,419 | $2,241,583 | $816,207 | $3,517,991 |

| Dry Beans | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $15,206 | $7,080 | $147,783 | $45,370 | $215,439 |
| 5 yr (0.2) | $25,852 | $12,037 | $263,235 | $79,388 | $380,513 |
| 10 yr (0.1) | $33,415 | $15,558 | $345,474 | $103,214 | $497,660 |
| 25 yr (0.04) | $46,580 | $21,688 | $478,843 | $143,068 | $690,178 |
| 50 yr (0.02) | $59,332 | $27,625 | $601,579 | $180,369 | $868,904 |
| 100 yr (0.01) | $73,242 | $34,101 | $743,979 | $223,686 | $1,075,008 |
| 500 yr (0.002) | $110,614 | $51,502 | $1,122,305 | $338,126 | $1,622,547 |
| **Total** | $364,241 | $169,590 | $3,703,198 | $1,113,221 | $5,350,250 |

| Potatoes | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $60 | $354 | $6,097 | $0 | $6,511 |
| 5 yr (0.2) | $90 | $531 | $9,353 | $0 | $9,973 |
| 10 yr (0.1) | $112 | $657 | $11,293 | $0 | $12,062 |
| 25 yr (0.04) | $155 | $909 | $15,694 | $0 | $16,758 |
| 50 yr (0.02) | $177 | $1,036 | $19,017 | $0 | $20,230 |
| 100 yr (0.01) | $241 | $1,415 | $25,399 | $0 | $27,055 |
| 500 yr (0.002) | $289 | $1,693 | $31,835 | $0 | $33,816 |
| **Total** | $1,124 | $6,593 | $118,689 | $0 | $126,406 |

| Sugar Beets | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $2,502 | $1,075 | $47,679 | $27,474 | $78,730 |
| 5 yr (0.2) | $4,384 | $1,884 | $106,909 | $61,053 | $174,230 |
| 10 yr (0.1) | $8,269 | $3,553 | $192,967 | $108,206 | $312,995 |
| 25 yr (0.04) | $19,905 | $8,553 | $366,906 | $202,509 | $597,873 |
| 50 yr (0.02) | $29,595 | $12,717 | $525,722 | $292,605 | $860,639 |
| 100 yr (0.01) | $44,556 | $19,146 | $743,486 | $410,050 | $1,217,238 |
| 500 yr (0.002) | $86,416 | $37,133 | $1,735,399 | $1,016,760 | $2,875,707 |
| **Total** | $195,626 | $84,061 | $3,719,068 | $2,118,657 | $6,117,412 |

| Sunflowers | | | | | |
|---|---|---|---|---|---|
| Flood Event (probability) | Land Rehabilitation | Late Plant | Planted, No Replant | Planted, Replant Possible | **Total** |
| 2 yr (0.5) | $4,638 | $2,544 | $17,708 | $4,573 | $29,463 |
| 5 yr (0.2) | $7,915 | $4,341 | $33,801 | $8,352 | $54,410 |
| 10 yr (0.1) | $10,245 | $5,619 | $52,150 | $12,742 | $80,756 |
| 25 yr (0.04) | $15,465 | $8,481 | $93,205 | $23,582 | $140,733 |
| 50 yr (0.02) | $17,188 | $9,426 | $130,088 | $32,085 | $188,787 |
| 100 yr (0.01) | $18,419 | $10,101 | $160,568 | $39,646 | $228,735 |
| 500 yr (0.002) | $29,323 | $16,081 | $236,408 | $57,513 | $339,325 |
| **Total** | $103,194 | $56,592 | $723,927 | $178,495 | $1,062,208 |

*Expected Annual Damages, Proposed Condition*

*Table 27- Expected Annual Damages to Agricultural Land, Proposed Condition*

| Expected Annual Damages: Proposed Condition | | | | | | |
|---|---|---|---|---|---|---|
| Flood Event | Probability | Difference | Damages | Average Damages | EAD | Cumulative EAD |
| 2 | 0.5 | | 700,717 | | 292,591 | 292,591 |
| | | 0.3 | | 975,303 | | |
| 5 | 0.2 | | 1,249,889 | | 150,934 | 443,524 |
| | | 0.1 | | 1,509,335 | | |
| 10 | 0.1 | | 1,768,782 | | 134,033 | 577,557 |
| | | 0.06 | | 2,233,884 | | |
| 25 | 0.04 | | 2,698,986 | | 63,098 | 640,655 |
| | | 0.02 | | 3,154,886 | | |
| 50 | 0.02 | | 3,610,786 | | 41,659 | 682,315 |
| | | 0.01 | | 4,165,942 | | |
| 100 | 0.01 | | 4,721,099 | | 53,666 | 735,981 |
| | | 0.008 | | 6,708,249 | | |
| 500 | 0.002 | | 8,695,400 | | 17,391 | 753,371 |
| | | | | | | |
| **Total** | | | | | $753,371 | |

## 3. Summary

Table 28 summarizes the reduction in EAD for agricultural lands. The proposed project is modeled to reduce the expected annual damages to agricultural land by $36,934.

*Table 28- Summary of Expected Annual Damages to Agricultural Land ($2023)*

| Flood Event (probability) | Existing Condition | | Proposed Condition | | Estimated Reduction in EAD Under Proposed Condition |
|---|---|---|---|---|---|
| | Damages | Contribution to EAD | Damages | Contribution to EAD | |
| 2 yr (0.5)[22] | $687,152 | $294,365 | $700,717 | $292,591 | $1,774 |
| 5 yr (0.2) | $1,275,281 | $155,224 | $1,249,889 | $150,934 | $4,291 |
| 10 yr (0.1) | $1,829,207 | $144,844 | $1,768,782 | $134,033 | $10,811 |
| 25 yr (0.04) | $2,998,936 | $70,582 | $2,698,986 | $63,098 | $7,484 |
| 50 yr (0.02) | $4,059,251 | $47,182 | $3,610,786 | $41,659 | $5,523 |
| 100 yr (0.01) | $5,377,155 | $59,241 | $4,721,099 | $53,666 | $5,575 |
| 500 yr (0.002) | $9,433,180 | $18,866 | $8,695,400 | $17,391 | $1,476 |
| **Total** | $25,660,162 | $790,305 | $23,445,658 | $753,371 | $36,934 |

[22] The relational difference between the damages and the contribution to EAD from a 2-year flood event come from the fact that the contribution to EAD calculation utilizes an average of the estimated damages from pairs of flood events.

*Comparison of Expected Damages under Existing and Proposed Conditions, by Growing Season Month*

The six pairs of tables and figures in this section report crop damages by flood magnitude for each month of the growing season (April through September). The values for existing and proposed conditions are provided on the same page for ease of comparison.[23]

*Table 29- Crop Damages by Flood Magnitude in April, Existing Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $3,953 | $5,888 | $7,631 | $12,132 | $15,236 | $18,922 | $27,415 |
| Soybeans | $752 | $1,220 | $1,573 | $2,283 | $2,954 | $3,810 | $6,097 |
| Wheat | $925 | $1,872 | $2,966 | $5,541 | $7,716 | $11,063 | $21,570 |
| Dry Beans | $706 | $1,218 | $1,559 | $2,243 | $2,899 | $3,608 | $5,252 |
| Potatoes | $3 | $5 | $6 | $9 | $11 | $14 | $16 |
| Sugar Beets | $225 | $410 | $747 | $1,785 | $2,763 | $4,201 | $8,514 |
| Sunflowers | $207 | $358 | $486 | $739 | $782 | $847 | $1,444 |
| **Total** | $6,770 | $10,969 | $14,968 | $24,732 | $32,362 | $42,466 | $70,308 |

*Table 30- Crop Damages by Flood Magnitude in April, Proposed Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $3,805 | $5,365 | $6,493 | $9,955 | $12,378 | $15,495 | $25,200 |
| Soybeans | $724 | $1,160 | $1,481 | $2,060 | $2,655 | $3,396 | $5,482 |
| Wheat | $875 | $1,661 | $2,679 | $4,653 | $6,709 | $9,491 | $18,845 |
| Dry Beans | $669 | $1,137 | $1,470 | $2,049 | $2,610 | $3,222 | $4,867 |
| Potatoes | $3 | $5 | $6 | $8 | $9 | $12 | $15 |
| Sugar Beets | $214 | $385 | $724 | $1,703 | $2,524 | $3,786 | $7,425 |
| Sunflowers | $204 | $348 | $451 | $680 | $756 | $810 | $1,290 |
| **Total** | $6,495 | $10,060 | $13,303 | $21,109 | $27,642 | $36,213 | $63,123 |

[23] The values in this set of tables (April – September) do not account for the land rehabilitation charges for the six months outside of the growing season.

*Figure 6- Crop Damages by Flood Magnitude in April, Existing Condition (2020 CDL-E)*

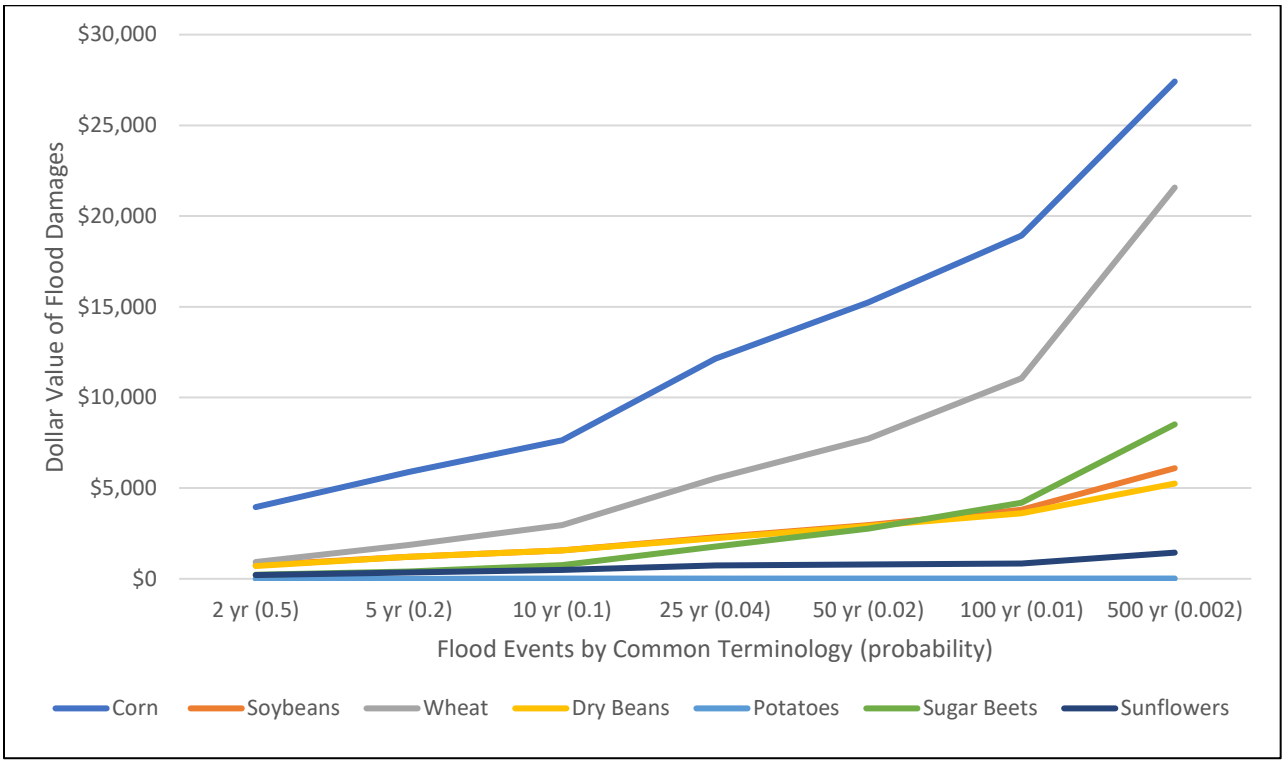



*Figure 7- Crop Damages by Flood Magnitude in April, Proposed Condition (2020 CDL-E)*

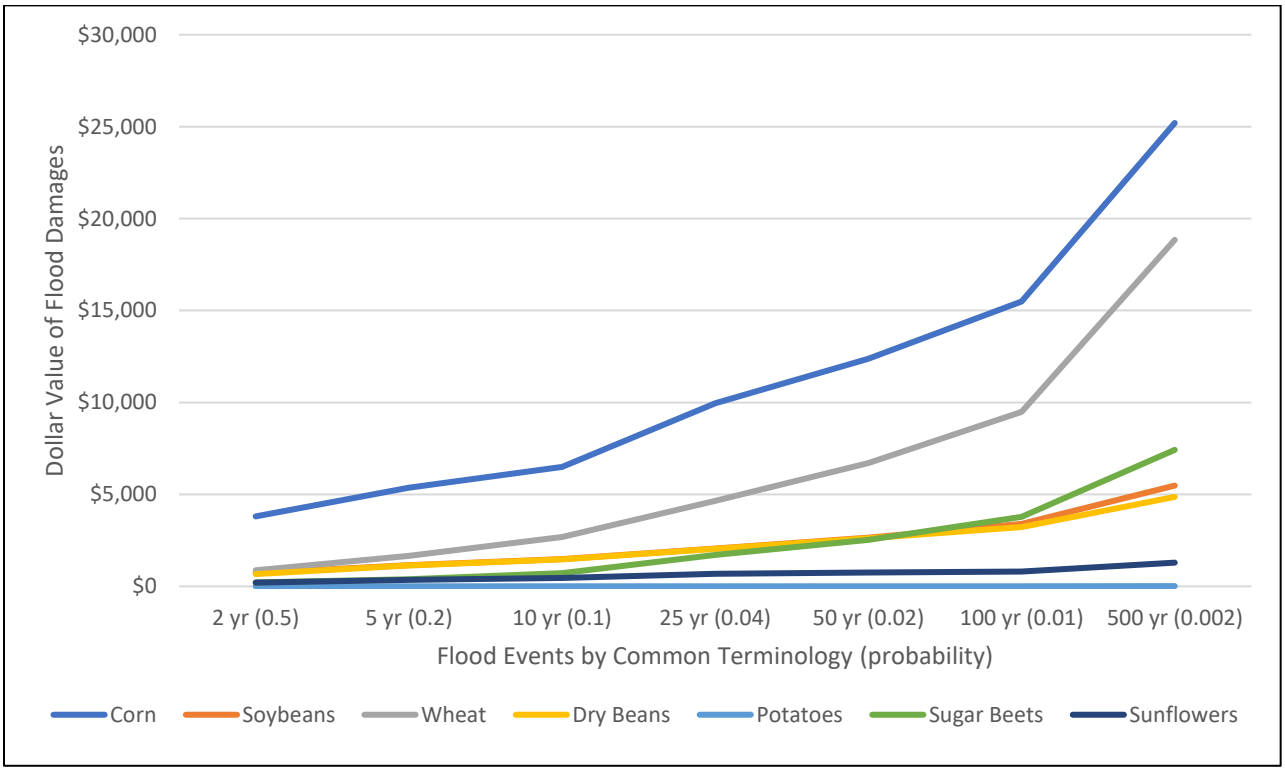


*Table 31- Crop Damages by Flood Magnitude in May, Existing Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $19,564 | $29,491 | $38,555 | $62,545 | $78,320 | $96,939 | $141,540 |
| Soybeans | $7,176 | $12,119 | $16,092 | $23,405 | $30,357 | $38,700 | $60,898 |
| Wheat | $5,390 | $11,303 | $17,702 | $31,815 | $44,617 | $65,474 | $130,523 |
| Dry Beans | $8,803 | $15,428 | $19,961 | $28,822 | $37,137 | $46,128 | $66,839 |
| Potatoes | $531 | $785 | $1,009 | $1,510 | $1,921 | $2,377 | $2,764 |
| Sugar Beets | $7,207 | $15,001 | $26,439 | $54,287 | $87,430 | $127,898 | $283,534 |
| Sunflowers | $2,111 | $3,720 | $5,106 | $7,886 | $8,479 | $9,242 | $15,596 |
| **Total** | $50,781 | $87,848 | $124,864 | $210,270 | $288,261 | $386,759 | $701,696 |

*Table 32- Crop Damages by Flood Magnitude in May, Proposed Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $19,532 | $28,089 | $34,276 | $52,091 | $65,664 | $80,912 | $130,469 |
| Soybeans | $7,008 | $11,761 | $15,374 | $21,098 | $27,373 | $34,898 | $55,641 |
| Wheat | $5,251 | $10,157 | $16,384 | $26,675 | $38,175 | $55,125 | $114,883 |
| Dry Beans | $8,462 | $14,630 | $19,009 | $26,460 | $33,591 | $41,426 | $62,498 |
| Potatoes | $512 | $798 | $981 | $1,374 | $1,606 | $2,151 | $2,635 |
| Sugar Beets | $6,922 | $14,193 | $25,591 | $51,538 | $75,893 | $108,381 | $253,355 |
| Sunflowers | $2,089 | $3,599 | $4,719 | $7,186 | $8,155 | $8,876 | $14,017 |
| **Total** | $49,777 | $83,227 | $116,334 | $186,421 | $250,458 | $331,769 | $633,498 |

*Figure 8- Crop Damages by Flood Magnitude in May, Existing Condition (2020 CDL-E)*

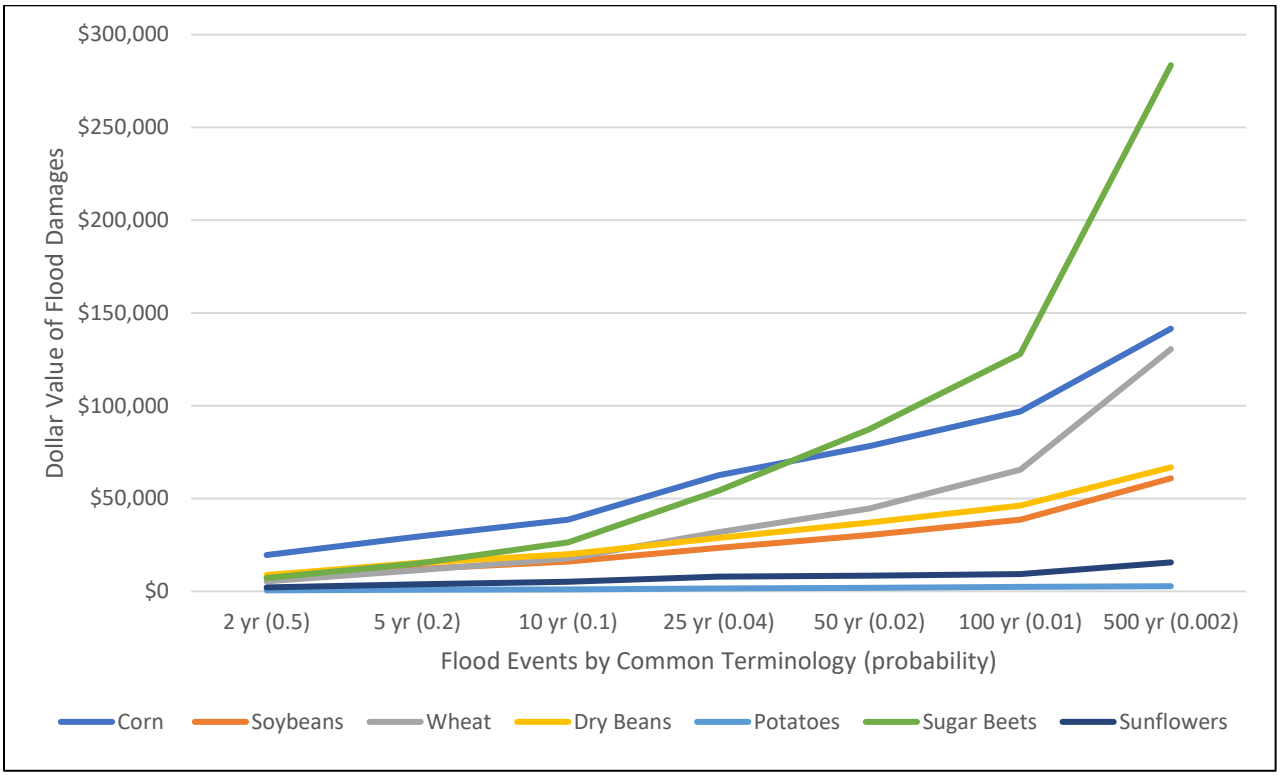



*Figure 9- Crop Damages by Flood Magnitude in May, Proposed Condition (2020 CDL-E)*

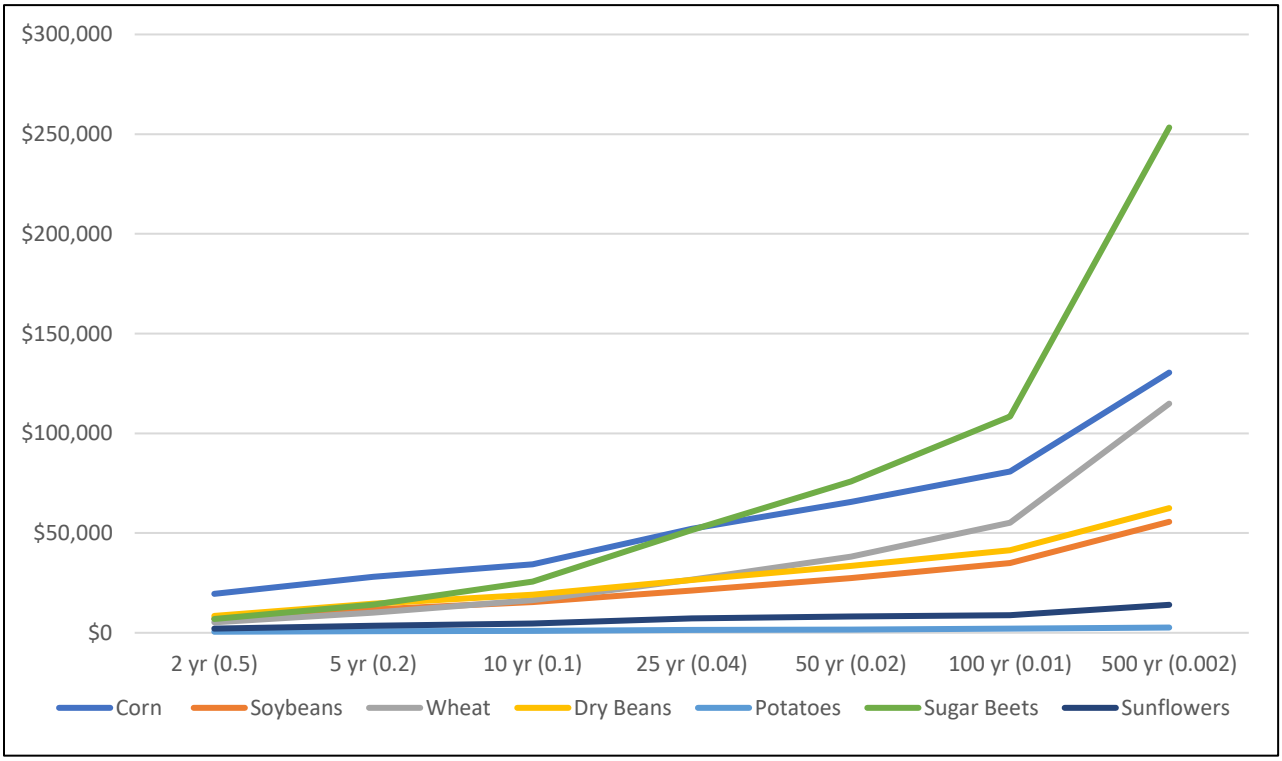


*Table 33- Crop Damages by Flood Magnitude in June, Existing Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $51,945 | $79,835 | $106,008 | $177,633 | $220,420 | $268,907 | $393,478 |
| Soybeans | $28,706 | $52,281 | $72,188 | $105,326 | $137,287 | $171,412 | $264,201 |
| Wheat | $14,981 | $32,741 | $50,448 | $87,427 | $122,439 | $182,545 | $377,643 |
| Dry Beans | $50,569 | $90,086 | $117,178 | $169,695 | $217,777 | $271,517 | $392,537 |
| Potatoes | $1,804 | $2,768 | $3,574 | $5,400 | $6,864 | $8,622 | $10,018 |
| Sugar Beets | $21,987 | $51,677 | $90,583 | $174,536 | $277,321 | $405,668 | $910,629 |
| Sunflowers | $6,538 | $13,176 | $20,423 | $37,458 | $43,989 | $48,681 | $75,727 |
| **Total** | $176,529 | $322,564 | $460,401 | $757,473 | $1,026,098 | $1,357,350 | $2,424,232 |

*Table 34- Crop Damages by Flood Magnitude in June, Proposed Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $53,906 | $81,764 | $99,735 | $150,963 | $195,399 | $235,722 | $372,364 |
| Soybeans | $28,646 | $52,270 | $69,821 | $94,089 | $123,664 | $156,144 | $246,652 |
| Wheat | $14,933 | $29,715 | $47,662 | $72,722 | $103,720 | $151,880 | $337,366 |
| Dry Beans | $49,558 | $86,266 | $112,003 | $155,359 | $196,137 | $243,192 | $367,651 |
| Potatoes | $1,838 | $2,814 | $3,392 | $4,709 | $5,730 | $7,647 | $9,609 |
| Sugar Beets | $22,440 | $50,158 | $88,837 | $165,989 | $239,048 | $335,311 | $828,572 |
| Sunflowers | $6,727 | $11,994 | $17,395 | $30,542 | $39,652 | $47,619 | $70,319 |
| **Total** | $178,048 | $314,981 | $438,846 | $674,373 | $903,351 | $1,177,515 | $2,232,533 |

*Figure 10- Crop Damages by Flood Magnitude in June, Existing Condition (2020 CDL-E)*

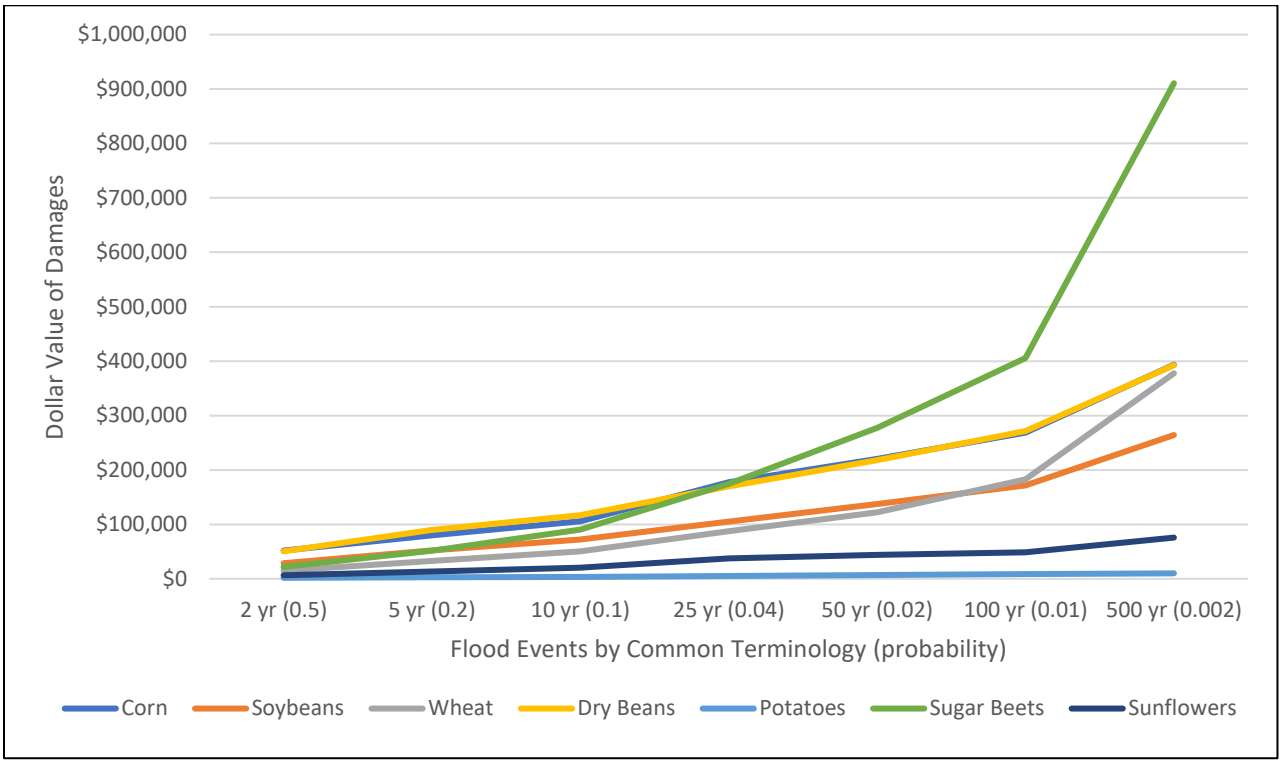



*Figure 11- Crop Damages by Flood Magnitude in June, Proposed Condition (2020 CDL-E)*

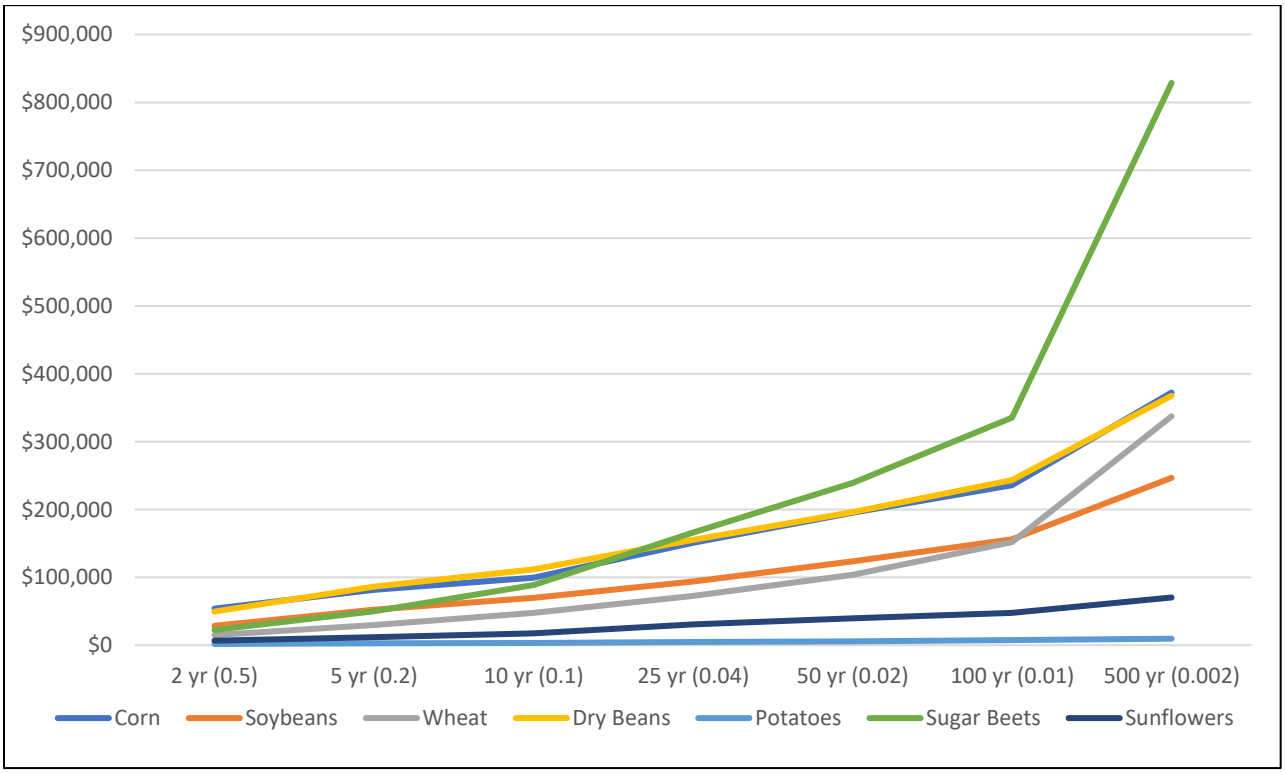


*Table 35- Crop Damages by Flood Magnitude in July, Existing Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $46,154 | $69,418 | $91,307 | $153,453 | $192,966 | $232,246 | $327,976 |
| Soybeans | $32,633 | $62,771 | $89,766 | $129,732 | $168,591 | $211,145 | $319,317 |
| Wheat | $19,135 | $42,393 | $64,975 | $111,555 | $156,139 | $233,079 | $483,362 |
| Dry Beans | $67,287 | $123,498 | $164,243 | $239,624 | $305,942 | $378,720 | $543,872 |
| Potatoes | $1,891 | $2,893 | $3,734 | $5,636 | $7,164 | $8,999 | $10,448 |
| Sugar Beets | $24,732 | $56,398 | $99,042 | $194,670 | $310,319 | $459,820 | $1,014,008 |
| Sunflowers | $7,161 | $15,510 | $25,247 | $49,612 | $60,537 | $68,903 | $106,497 |
| **Total** | $198,992 | $372,882 | $538,315 | $884,282 | $1,201,658 | $1,592,911 | $2,805,479 |

*Table 36- Crop Damages by Flood Magnitude in July, Proposed Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $48,941 | $73,740 | $93,018 | $137,589 | $179,713 | $214,375 | $321,096 |
| Soybeans | $33,266 | $63,757 | $88,733 | $117,094 | $153,291 | $194,537 | $302,317 |
| Wheat | $19,184 | $38,598 | $62,078 | $93,108 | $132,226 | $194,172 | $433,671 |
| Dry Beans | $67,882 | $121,684 | $160,075 | $221,653 | $278,372 | $343,734 | $518,007 |
| Potatoes | $1,922 | $2,938 | $3,544 | $4,918 | $5,973 | $7,982 | $10,018 |
| Sugar Beets | $24,987 | $54,521 | $97,011 | $185,019 | $267,852 | $379,859 | $914,010 |
| Sunflowers | $7,502 | $14,502 | $22,157 | $39,262 | $55,720 | $69,163 | $102,037 |
| **Total** | $203,684 | $369,740 | $526,616 | $798,643 | $1,073,147 | $1,403,822 | $2,601,157 |

*Figure 12- Crop Damages by Flood Magnitude in July, Existing Condition (2020 CDL-E)*

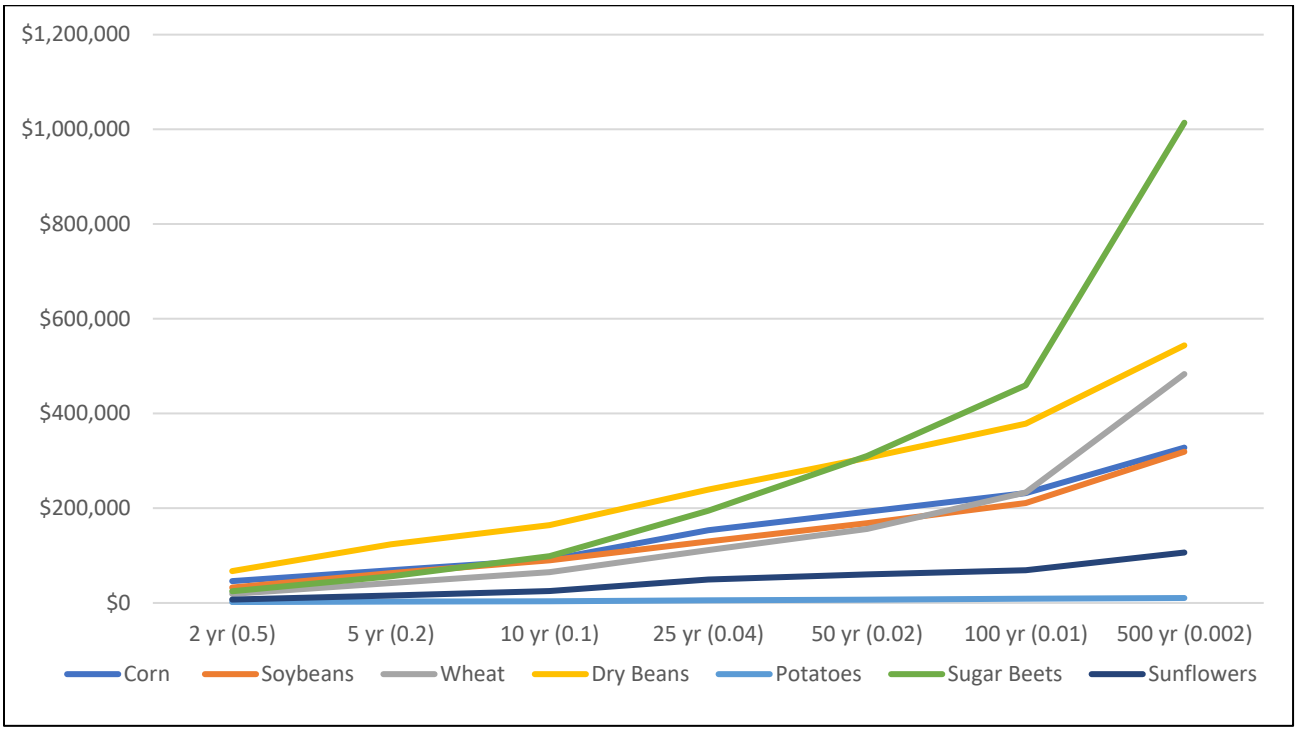



*Figure 13- Crop Damages by Flood Magnitude in July, Proposed Condition (2020 CDL-E)*

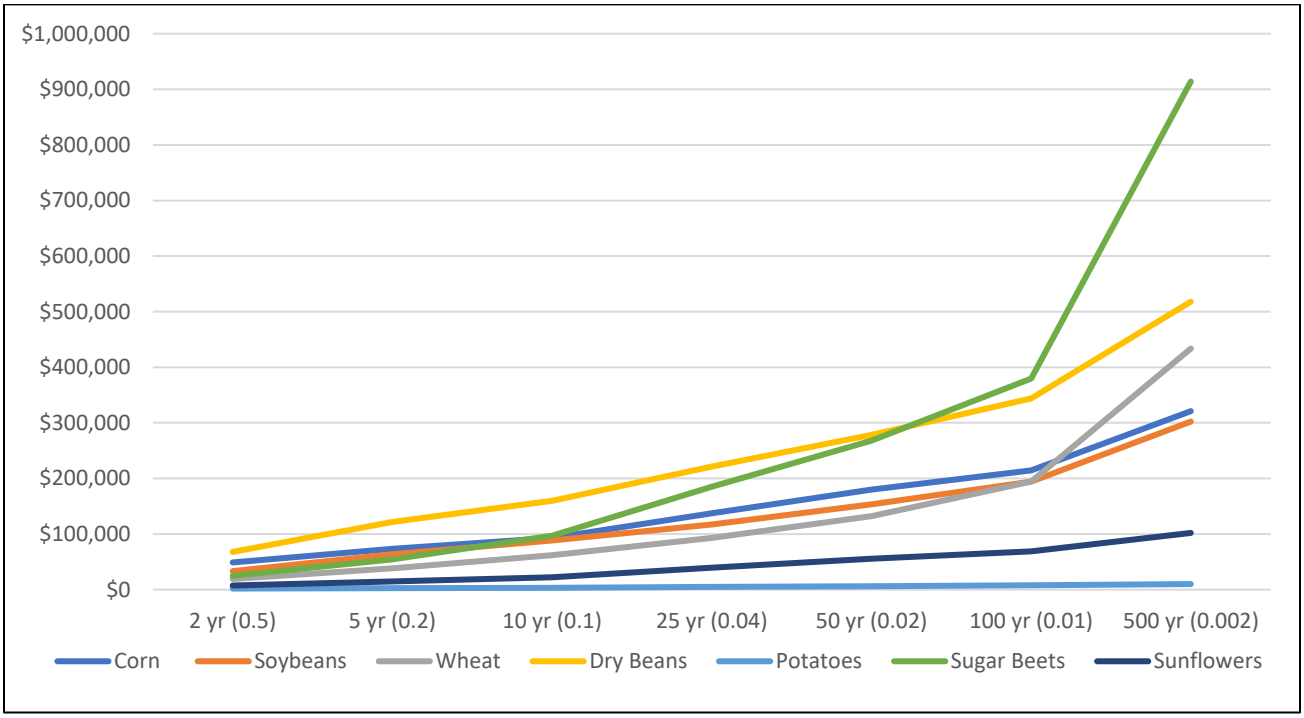


*Table 37- Crop Damages by Flood Magnitude in August, Existing Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $23,713 | $37,583 | $49,275 | $81,904 | $107,844 | $130,320 | $182,842 |
| Soybeans | $23,579 | $44,793 | $64,309 | $93,375 | $121,679 | $152,211 | $229,703 |
| Wheat | $15,934 | $34,226 | $53,264 | $93,077 | $131,770 | $197,400 | $398,540 |
| Dry Beans | $48,311 | $90,364 | $120,022 | $175,796 | $224,707 | $278,442 | $399,428 |
| Potatoes | $1,437 | $2,185 | $2,819 | $4,243 | $5,395 | $6,772 | $7,855 |
| Sugar Beets | $12,199 | $29,544 | $54,358 | $109,427 | $168,359 | $246,933 | $514,120 |
| Sunflowers | $6,941 | $14,513 | $23,118 | $43,032 | $51,122 | $57,441 | $89,329 |
| **Total** | $132,115 | $253,209 | $367,166 | $600,853 | $810,876 | $1,069,519 | $1,821,818 |

*Table 38- Crop Damages by Flood Magnitude in August, Proposed Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $26,921 | $39,739 | $53,975 | $79,193 | $104,141 | $124,683 | $180,354 |
| Soybeans | $24,442 | $45,752 | $64,350 | $85,577 | $111,568 | $141,303 | $218,303 |
| Wheat | $15,833 | $30,949 | $49,878 | $77,642 | $110,599 | $162,880 | $350,751 |
| Dry Beans | $49,864 | $88,837 | $117,415 | $163,474 | $205,488 | $253,360 | $380,328 |
| Potatoes | $1,451 | $2,216 | $2,677 | $3,715 | $4,493 | $6,013 | $7,524 |
| Sugar Beets | $12,996 | $29,802 | $54,971 | $105,612 | $149,738 | $212,202 | $467,405 |
| Sunflowers | $7,138 | $13,250 | $19,864 | $34,954 | $46,917 | $56,819 | $84,162 |
| **Total** | $138,645 | $250,545 | $363,132 | $550,166 | $732,945 | $957,260 | $1,688,828 |

*Figure 14- Crop Damages by Flood Magnitude in August, Existing Condition (2020 CDL-E)*

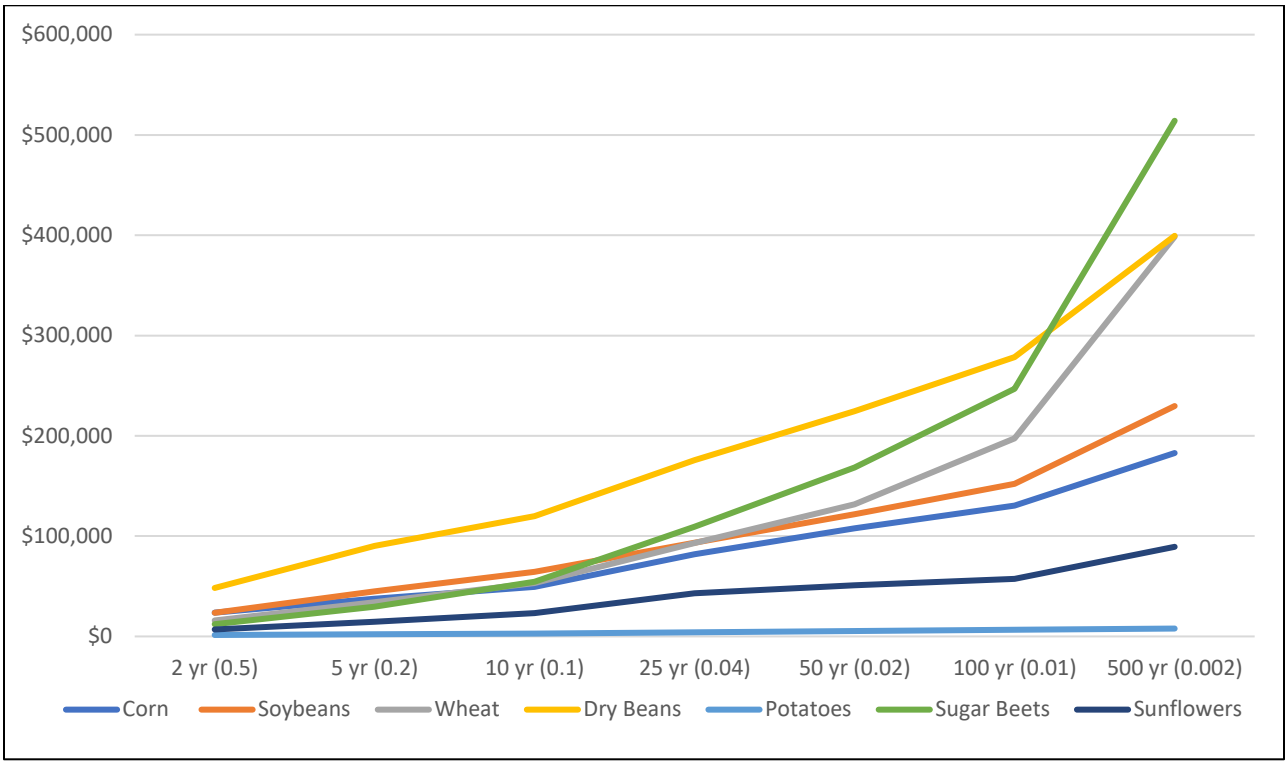



*Figure 15- Crop Damages by Flood Magnitude in August, Proposed Condition (2020 CDL-E)*

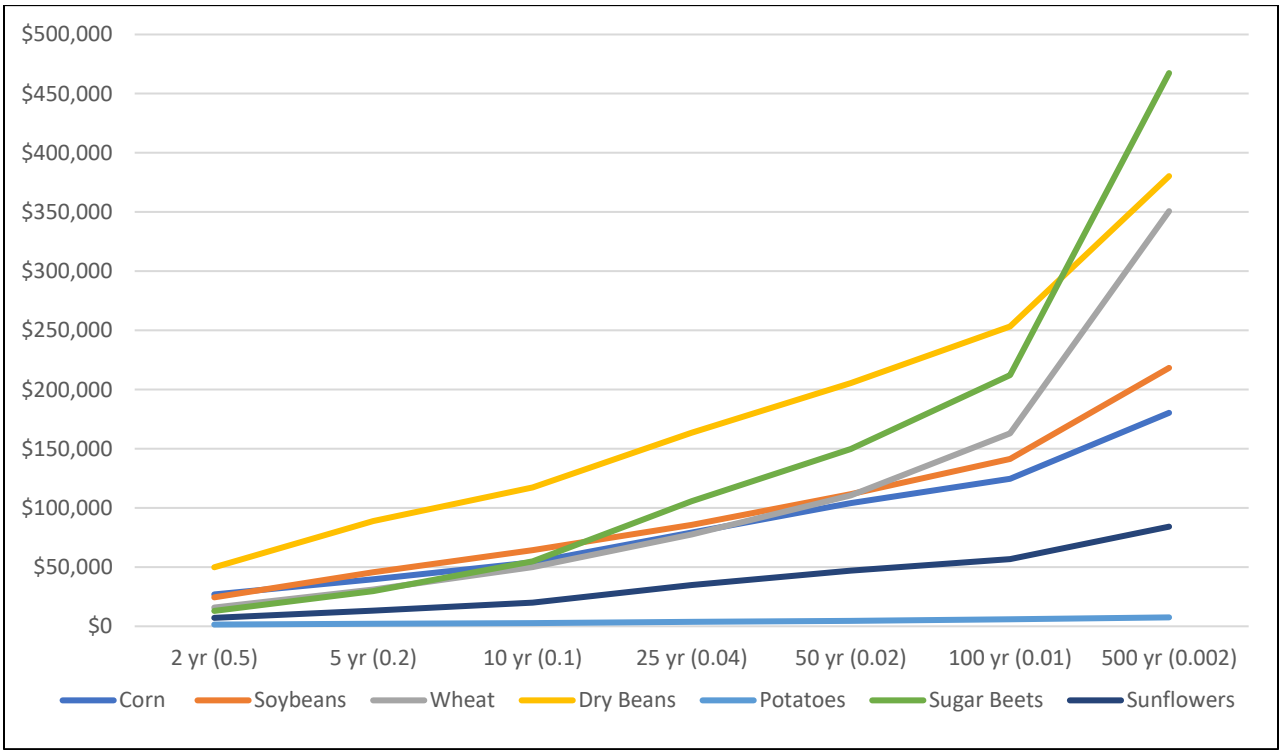


*Table 39- Crop Damages by Flood Magnitude in September, Existing Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $22,912 | $35,440 | $46,495 | $77,209 | $98,161 | $118,464 | $169,519 |
| Soybeans | $28,044 | $53,017 | $71,953 | $100,764 | $129,821 | $166,645 | $265,565 |
| Wheat | $13,275 | $28,515 | $44,376 | $77,546 | $109,783 | $164,462 | $332,038 |
| Dry Beans | $38,886 | $69,692 | $90,790 | $131,281 | $168,174 | $209,977 | $304,182 |
| Potatoes | $795 | $1,184 | $1,523 | $2,278 | $2,899 | $3,624 | $4,196 |
| Sugar Beets | $10,588 | $25,170 | $45,573 | $90,953 | $141,230 | $207,132 | $442,385 |
| Sunflowers | $5,470 | $11,435 | $18,213 | $33,940 | $40,283 | $45,177 | $70,442 |
| **Total** | $119,971 | $224,453 | $318,923 | $513,971 | $690,351 | $915,480 | $1,588,327 |

*Table 40- Crop Damages by Flood Magnitude in September, Proposed Condition (2020 CDL-E)*

| Crop | 2 yr (0.5) | 5 yr (0.2) | 10 yr (0.1) | 25 yr (0.04) | 50 yr (0.02) | 100 yr (0.01) | 500 yr (0.002) |
|---|---|---|---|---|---|---|---|
| Corn | $25,197 | $37,449 | $47,908 | $70,608 | $92,288 | $110,134 | $164,970 |
| Soybeans | $27,747 | $51,191 | $67,427 | $89,844 | $115,488 | $145,585 | $240,310 |
| Wheat | $13,191 | $25,785 | $41,556 | $64,686 | $92,144 | $135,701 | $292,223 |
| Dry Beans | $38,502 | $67,106 | $86,585 | $119,645 | $150,747 | $187,657 | $285,546 |
| Potatoes | $783 | $1,200 | $1,458 | $2,030 | $2,412 | $3,243 | $4,005 |
| Sugar Beets | $11,089 | $25,026 | $45,588 | $87,356 | $124,607 | $176,228 | $402,089 |
| Sunflowers | $5,650 | $10,456 | $15,831 | $27,598 | $37,019 | $44,840 | $66,531 |
| **Total** | $122,160 | $218,212 | $306,353 | $461,767 | $614,705 | $803,388 | $1,455,676 |

*Figure 16- Crop Damages by Flood Magnitude in September, Existing Condition (2020 CDL-E)*

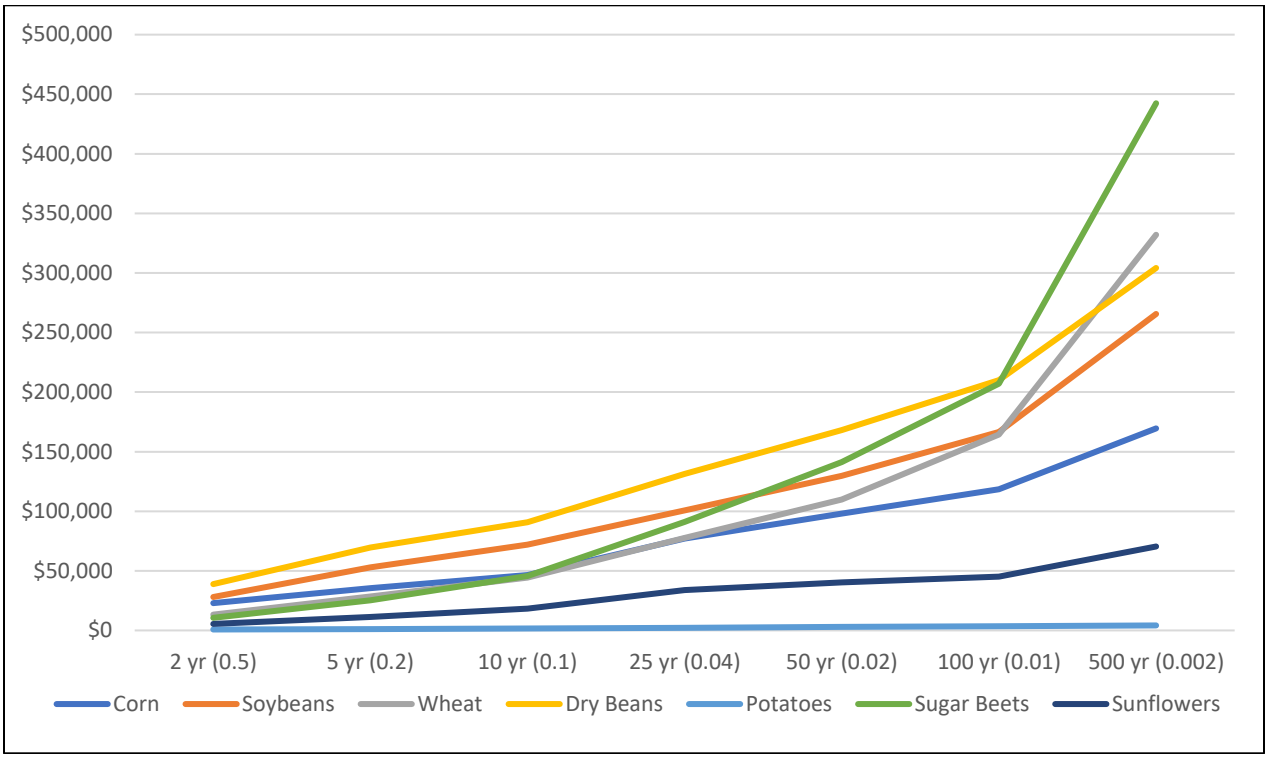
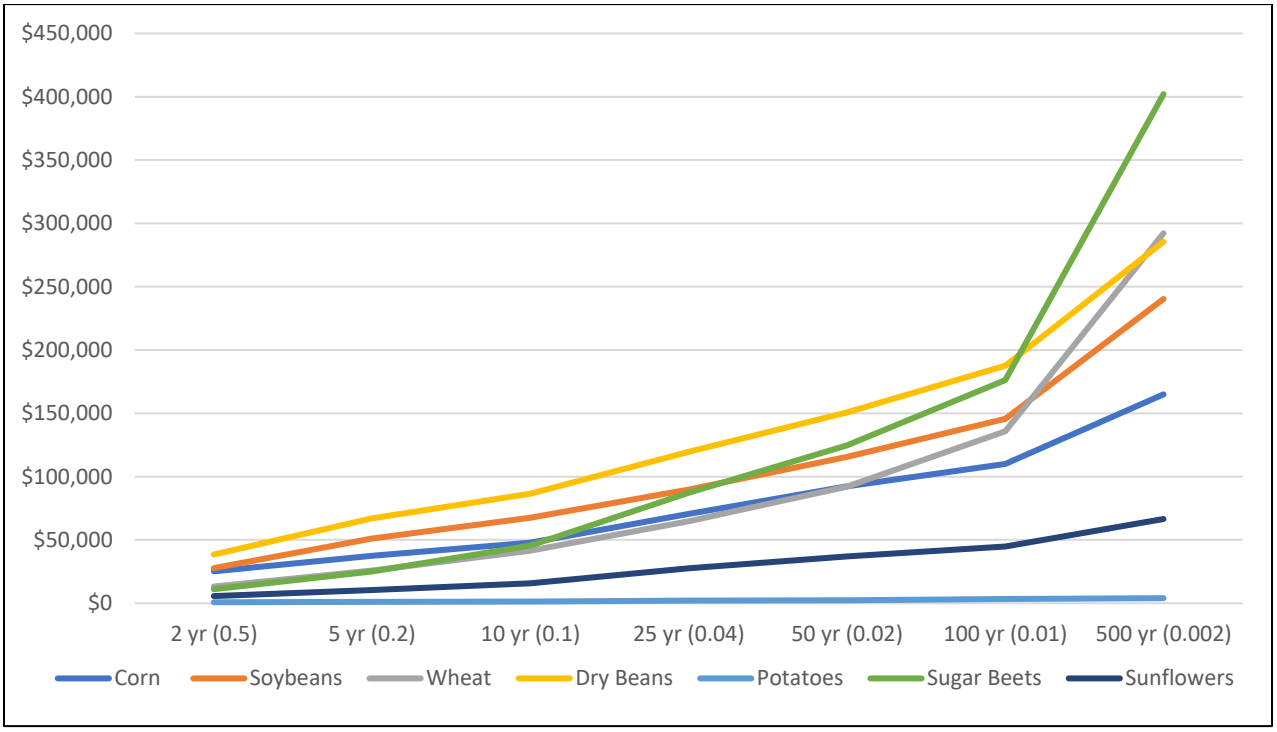



*Figure 17- Crop Damages by Flood Magnitude in September, Proposed Condition (2020 CDL-E)*



## C. Roadway Infrastructure

Roadways were measured and categorized as either paved or unpaved (gravel), to account for the differences in planning, materials, and repair time. The greater requirements for paved roads are evident in the repair costs: the cost to repair a paved road is estimated at $135 per linear foot (LF); the repair cost for a gravel road is $54 per linear foot. Flooding may also damage the roadway embankment; repair costs for embankment loss are estimated at $157 per linear foot. The embankment losses include breaching near bridges or culverts, as typical for this area per local highway engineers (West, 2023).

*Table 41- Damage Percentages and Repair Costs ($2023) for Watershed Roadways*

| Roadway Type | Damage (%) | Repair Cost ($/LF) | Wash Out (%) | Wash Out Repair Cost ($/LF) |
|---|---|---|---|---|
| Paved | 10% | $135 | 1% | $157 |
| Unpaved / Gravel | 20% | $54 | 2% | $157 |

[10] *Source: Gannett Fleming, 2022, referencing their earlier 2019 work. 2019 values were updated to 2023 values using the Construction Cost Index.*

Table 41, above, includes the percentages used in the damage estimates. For paved roads, 10% of the length of the road overtopped by flooding is estimated to incur damage; for gravel roads, damage is estimated at 20%. Of the damaged road lengths, 1% of the paved and 2% of the gravel roads are modeled to experience embankment loss.

### 1. Existing Condition

Table 42 reports the length of damages, in linear feet, to paved and gravel roads within the study area by flood event. The damage estimates here rely on the information from Table 41. The majority of the roads within the study area are unpaved; these incur more damage from a flood event than paved roads. Paved roads, though, have a higher per-LF repair cost.

*Table 42- Length of Roadway Damages, Existing Condition*

| Flood Event (probability) | Paved | | | Unpaved | | |
|---|---|---|---|---|---|---|
| | Overtop Length (LF) | Damaged Length (LF) | Embankment Lost[24] (LF) | Overtop Length (LF) | Damaged Length (LF) | Embankment Lost (LF) |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| 2 yr (0.5) | 574 | 57 | 1 | 5,765 | 1,153 | 23 |
| 5 yr (0.2) | 617 | 62 | 1 | 14,251 | 2,850 | 57 |
| 10 yr (0.1) | 1,355 | 135 | 1 | 25,609 | 5,122 | 102 |
| 25 yr (0.04) | 4,147 | 415 | 4 | 46,845 | 9,369 | 187 |
| 50 yr (0.02) | 6,765 | 676 | 7 | 66,611 | 13,322 | 266 |
| 100 yr (0.01) | 11,980 | 1,198 | 12 | 89,313 | 17,863 | 357 |
| 500 yr (0.002) | 20,852 | 2,085 | 21 | 158,200 | 31,640 | 633 |

[24] These are rounded to the nearest whole number.

The first step in estimating the damages from each type of flood event is to record the length of each type of roadway (paved or gravel) that was overtopped by the flood event. For example, using the information from Table 42, a 100-year flood event is modeled to overtop 11,980 linear feet of paved roads (column 2). We know from Table 41 that roughly 10% of paved roads will incur damages from overtopping: this leads to the estimate of 1,198 LF of paved roads incurring damage from the 100-year event. One percent of this damaged length is modeled to incur embankment loss: 12 linear feet. These damage lengths are multiplied by the appropriate repair cost as noted in Table 41; the damages for roadway infrastructure (including both paved and gravel roads) are reported in Table 43.

*Table 43- Summary of Damages to Roadway Infrastructure, Existing Condition ($2023)*

| Flood Event (probability) | Overtopping Damages | Embankment Damages | Total Damages |
|---|---|---|---|
| 2 yr (0.5) | $70,012 | $5,033 | $75,046 |
| 5 yr (0.2) | $162,233 | $12,208 | $174,440 |
| 10 yr (0.1) | $294,869 | $22,010 | $316,879 |
| 25 yr (0.04) | $561,912 | $40,748 | $602,660 |
| 50 yr (0.02) | $810,717 | $58,195 | $868,912 |
| 100 yr (0.01) | $1,126,306 | $78,878 | $1,205,184 |
| 500 yr (0.002) | $1,990,054 | $139,609 | $2,129,663 |
| **Total** | $5,016,103 | $356,681 | $5,372,784 |

Table 44 reports the EAD to roadway infrastructure under the existing condition.

*Table 44- Expected Annual Damages to Roadway Infrastructure, Existing Condition*

| Expected Annual Damages: Existing Condition | | | | | | |
|---|---|---|---|---|---|---|
| Flood Event | Probability | Difference | Damages | Average Damages | EAD | Cumulative EAD |
| 2 | 0.5 | | 75,046 | | 37,423 | 37,423 |
| | | 0.3 | | 124,743 | | |
| 5 | 0.2 | | 174,440 | | 24,566 | 61,989 |
| | | 0.1 | | 245,660 | | |
| 10 | 0.1 | | 316,879 | | 27,586 | 89,575 |
| | | 0.06 | | 459,769 | | |
| 25 | 0.04 | | 602,660 | | 14,716 | 104,291 |
| | | 0.02 | | 735,786 | | |
| 50 | 0.02 | | 868,912 | | 10,370 | 114,661 |
| | | 0.01 | | 1,037,048 | | |
| 100 | 0.01 | | 1,205,184 | | 13,339 | 128,001 |
| | | 0.008 | | 1,667,423 | | |
| 500 | 0.002 | | 2,129,663 | | 4,259 | 132,260 |
| | | | | | | |
| **Total** | | | | | $132,260 | |

## 2. Proposed Condition

Damages to paved and unpaved roadways were modeled for the proposed condition; those calculations rely on the same process described for the existing condition. The set of maps for the 25- and 100-year flood conditions included at the end of this report nicely illustrate the locations of the roadway infrastructure benefits.

*Table 45- Length of Roadway Damages, Proposed Condition*

| Flood Event (probability) | Paved | | | Unpaved | | |
|---|---|---|---|---|---|---|
| | Overtop Length (LF) | Damaged Length (LF) | Embankment Lost (LF) | Overtop Length (LF) | Damaged Length (LF) | Embankment Lost (LF) |
| 2 yrs (0.5) | 560 | 56 | 1 | 5,438 | 1,088 | 22 |
| 5 yrs (0.2) | 589 | 59 | 1 | 11,525 | 2,305 | 46 |
| 10 yrs (0.1) | 1,062 | 106 | 1 | 21,658 | 4,332 | 87 |
| 25 yrs (0.04) | 3,306 | 331 | 3 | 38,063 | 7,613 | 152 |
| 50 yrs (0.02) | 5,210 | 521 | 5 | 52,919 | 10,584 | 212 |
| 100 yrs (0.01) | 7,792 | 779 | 8 | 74,311 | 14,862 | 297 |
| 500 yrs (0.002) | 18,527 | 1,853 | 19 | 136,823 | 27,365 | 547 |

Table 46 records the total modeled damages, by flood event, under the proposed condition. The calculations here follow the calculations from the previous section.

*Table 46- Summary of Damages to Roadway Infrastructure, Proposed Condition ($2023)*

| Flood Event (probability) | Overtopping Damages | Embankment Damages | Total Damages |
|---|---|---|---|
| 2 yr (0.5) | $66,295 | $4,754 | $71,049 |
| 5 yr (0.2) | $132,427 | $9,899 | $142,326 |
| 10 yr (0.1) | $248,247 | $18,590 | $266,836 |
| 25 yr (0.04) | $455,710 | $33,090 | $488,800 |
| 50 yr (0.02) | $641,854 | $46,185 | $688,039 |
| 100 yr (0.01) | $907,751 | $64,994 | $972,744 |
| 500 yr (0.002) | $1,727,797 | $120,888 | $1,848,685 |
| **Total** | $4,180,080 | $298,399 | $4,478,480 |

The total damage values from Table 46 are used in Table 47 to calculate the EAD for roadway infrastructure under the proposed condition.

*Table 47- Expected Annual Damages to Roadway Infrastructure, Proposed Condition*

| Expected Annual Damages: Proposed Condition | | | | | | |
|---|---|---|---|---|---|---|
| Flood Event | Probability | Difference | Damages | Average Damages | EAD | Cumulative EAD |
| 2 | 0.5 | | 71,049 | | 32,006 | 32,006 |
| | | 0.3 | | 106,687 | | |
| 5 | 0.2 | | 142,326 | | 20,458 | 52,464 |
| | | 0.1 | | 204,581 | | |
| 10 | 0.1 | | 266,836 | | 22,669 | 75,133 |
| | | 0.06 | | 377,818 | | |
| 25 | 0.04 | | 488,800 | | 11,768 | 86,902 |
| | | 0.02 | | 588,419 | | |
| 50 | 0.02 | | 688,039 | | 8,304 | 95,206 |
| | | 0.01 | | 830,392 | | |
| 100 | 0.01 | | 972,744 | | 11,286 | 106,491 |
| | | 0.008 | | 1,410,715 | | |
| 500 | 0.002 | | 1,848,685 | | 3,697 | 110,189 |
| | | | | | | |
| **Total** | | | | | $110,189 | |

Table 47 reports the expected annual damages to roadway infrastructure, modeled with the proposed project, at $110,189.

### 3. Summary

The difference between the total EAD value under the existing and proposed condition is the benefit of the proposed project.

Table 48 compares the expected annual damages to roadway infrastructure under the existing and proposed conditions. As modeled, the proposed project would lead to a reduction in EAD to roadways of $22,071.

*Table 48- Summary of Expected Annual Damages to Roadway Infrastructure ($2023)*

| Flood Event (probability) | Existing Condition | | Proposed Condition | | Estimated Reduction in EAD under Proposed Condition |
|---|---|---|---|---|---|
| | Damages | Contribution to EAD | Damages | Contribution to EAD | |
| 2 yr (0.5) | $75,046 | $37,423 | $71,049 | $32,006 | $5,417 |
| 5 yr (0.2) | $174,440 | $24,566 | $142,326 | $20,458 | $4,108 |
| 10 yr (0.1) | $316,879 | $27,586 | $266,836 | $22,669 | $4,917 |
| 25 yr (0.04) | $602,660 | $14,716 | $488,800 | $11,768 | $2,947 |
| 50 yr (0.02) | $868,912 | $10,370 | $688,039 | $8,304 | $2,067 |
| 100 yr (0.01) | $1,205,184 | $13,339 | $972,744 | $11,286 | $2,054 |
| 500 yr (0.002) | $2,129,663 | $4,259 | $1,848,685 | $3,697 | $562 |
| **Total** | $5,372,784 | $132,260 | $4,478,480 | $110,189 | $22,071 |

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

The proposed alternative would reduce the number of residential structures in the 100-year floodplain, reducing the number of dwellings required to participation in the National Flood Insurance Program (NFIP). This would reduce the administrative costs of running the program – a project benefit.

A total of ten residential dwellings are modeled to come out of the 100-year floodplain as a result of the project. These structures were identified by comparing the list of structures in the 100-year floodplain under the existing condition, and the equivalent list modeled under the proposed condition.

Townsley (2016, as cited in the North Branch Park River Economics Evaluation) provided an estimate of the 2015 average administrative cost at $308.53 per NFIP policy (Gannett Fleming, 2022). Data from the GDP-Implicit Price Deflators (IPD) (2023/2015) was used to index this administrative cost to 2023 values.[25]

*Table 49- Estimated Average Administrative Costs per NFIP Policy*

| | |
|---|---|
| Average Administrative Cost per Policy ($2015)[26] | $308.53 |
| GDP-Implicit Price Deflator (2023/2015)[27] | 1.224 |
| 2015 IPD | 96.968 |
| 2023 IPD | 118.669 |
| Average Administrative Cost per Policy ($2023) | $377.64 |

The data for GDP, Government Consumption Expenditures and Gross Investment, Federal, Nondefense spending was used to calculate an indexed 2023 value of $377.64 in administrative cost savings per NFIP policy. The removal of ten residential structures from the floodplain leads to a project benefit in the form of the reduction in program administrative costs. As the average administrative cost per policy ($2023) is $377.64, the total estimated savings is $3,776.40.

(1) (118.669 / 96.968) = 1.224 * 308.53 = $377.64 — *administrative savings per policy*
(2) $377.64 * 10 = $3,776.40 — *total administrative savings*

## E. Summary of Project Benefits

The FY 2025 discount rate for watershed projects was set at 3.00% per National Bulletin 200-25-2 (NRCS, 2024).

Table 50 begins from the three benefit categories analyzed (structures and vehicles, agricultural land, roadway infrastructure); the damage reduction benefit is the difference in the expected annual damages under the existing and proposed conditions. The estimated annual damage reduction benefits, including NFIP savings, and costs were discounted over the 50-year evaluated life of the project to calculate the present value. The final step was to amortize the present value over the 50-year project lifespan to calculate the average annual equivalent (AAE) value. The benefit values were then compared to the estimated cost of the proposed project to calculate the project net benefit and benefit-cost ratio.

[25] The Bureau of Economic Analysis (BEA) defines an implicit price deflator as "the ratio of the current-year dollar value of a series, such as gross domestic product (GDP), to its corresponding chained-dollar value, multiplied by 100." (BEA, 2009)
[26] This is based on Exhibit D.4-33 "Estimation of Average Administrative Costs Associated with the NFIP Per Policy" (Gannett Fleming, 2022). Per that source, it was adapted from Townsley (2016) and utilized NFIP data from Actuarial Rate Review In Support of the Recommended October 1, 2011, Rate and Rule Changes; Thomas L. Hayes, ACAS, MAAA Actuary and D. Andrew Neal, FSA Actuary Federal Insurance and Mitigation Administration (FIMA).
[27] GDP-IPD annual data, 2015 and 2023, from BEA Table 1.1.9; 2017 is the base year.

*Table 50- Estimated Flood Damage Reduction Benefits ($2023, 3% Discount Rate)*

| Item | EAD | | Damage Reduction Benefits | Present Value Benefits | Average Annual Equivalent |
|---|---|---|---|---|---|
| | Existing | Proposed | | | |
| Structures and Vehicles | $425,532 | $313,015 | $112,516 | $2,497,261 | $97,069 |
| Agricultural Land | $790,305 | $753,371 | $36,934 | $819,740 | $31,863 |
| Roadway Inventory | $132,260 | $110,189 | $22,071 | $489,860 | $19,041 |
| NFIP Savings | | | $3,776 | $83,816 | $3,258 |
| **Total** | $1,348,097 | $1,176,575 | $175,297 | $3,890,677 | $151,231 |

## IV. Project Costs

The preliminary design report provides detailed cost breakdowns; a brief summary is provided in the table below.

*Table 51- Estimated Implementation Costs*

| Item | Estimated Cost |
|---|---|
| Dam Construction | $11,676,747 |
| Road and Bridge Construction | $795,385 |
| Engineering | $1,300,000 |
| Fee Title Property, House Relocation | $318,867 |
| Flowage Easements | $7,543,137 |
| Construction Easements | $11,036 |
| Sponsor Administrative, Legal | $310,000 |
| **Total** | $21,955,172 |

## V. Economic Analysis Results

Table 52, below, provides the summary of net benefits and the benefit-cost ratio (BCR). These values are based on the benefit and cost estimates identified above.

*Table 52- Benefit Cost Summary*

| **Analysis @ Discount Rate = 3.0%** | | | |
|---|---|---|---|
| Discount Rate | 3.00% | AAE Factor | 0.03887 |
| Construction Cost | $12,472,132 | Project Life | 50 years |
| **Summary** | | | |
| Item | Present Value (PV) | | Average Annual Equivalent (AAE) |
| *Increased Costs / Reduced Revenues* | | | |
| Construction Costs | ($11,125,268) | | ($432,439) |
| Final Engineering Design | ($529,739) | | ($20,591) |
| Construction Engineering | ($670,402) | | ($26,059) |
| Sponsor Legal / Contract Admin Costs | ($287,327) | | ($11,168) |
| Land Rights Costs | ($7,421,095) | | ($288,458) |
| Interest Charges | ($1,812,924) | | ($70,468) |
| Future Annual Operations & Maintenance Costs | $332,921 | | $12,941 |
| **Total Costs** | **($21,513,834)** | | ($836,243) |
| *Reduction in Damages* | | | |
| Damage Reduction: Structures & Vehicles | $2,497,261 | | $97,069 |
| Damage Reduction: Infrastructure | $489,860 | | $19,041 |
| Damage Reduction: Crops | $819,740 | | $31,863 |
| **Total Reduction in Damages** | $3,806,861 | | $147,973 |
| *Savings* | | | |
| NFIP Administration Savings | $83,816 | | $3,258 |
| **Total Savings** | $83,816 | | $3,258 |
| **Total Benefits** | **$3,890,677** | | $151,231 |
| | | | |
| **Net (Benefits - Costs)** | **($17,623,157)** | | **($685,012)** |
| **Benefit-Cost Ratio (Benefits/Costs)** | **0.2** | | **0.2** |

The economic analysis does not take into account increases or reductions in crop yields upstream of the dam due to increased frequency of inundation to the 1,043 acres of flowage easements. Production increases would occur, particularly on lower lying non-irrigated cropland that would be inundated in higher frequency floods, due to increased soil moisture in dry years. Decreases to production would occur dependent on flood magnitude and timing. Due to lack of available modeling techniques for the increased soil moisture, these effects could not be reasonably estimated.

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## VII. List of Preparers

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## VIII. Exhibits