Appendix D.4: Economics Evaluation Technical Memorandum

North Branch Park River Flood Damage Reduction Project
Pembina and Walsh Counties, North Dakota

May 2022

Prepared for:

Park River Joint Water Resource District

In Cooperation with the:

Natural Resources Conservation Service
U.S. Department of Agriculture

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I. INTRODUCTION

The economic analysis was prepared in support of the North Branch Park River Watershed Plan and Environmental Assessment (EA). This memorandum describes the flood damage estimation methodology and summarizes the analysis results for flood damages under existing and proposed conditions.

The analysis follows the procedures outlined in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G), the *National Resource Economics Handbook Part 611 – Water Resource Handbook for Economics*, and the *National Watershed Program Manual*.

Unless otherwise noted, all values in the analysis are in 2019 prices and all annual values have been discounted using the Fiscal Year (FY) 2019 federal discount rate for water resources projects of 2.875 percent. The study area for the economic analysis encompasses approximately 29.1 square miles (18,605 acres) of the North Branch Park River Watershed, including the Cart Creek Subwatershed, beginning east of Mountain, ND and ending northwest of Grafton, ND in Pembina and Walsh Counties (see Appendix A: Damage Center Boundary and Flood Extents). To define the study area, damage center boundaries were first identified within the North Branch Park River Watershed. Damage centers are areas most heavily impacted by repeated flooding. Damage center boundaries were delineated by project engineers based on data from a 2011 preliminary watershed assessment, as well as public involvement activities prior to and during the NEPA scoping process, including a community survey.

Within the damage center boundary, the study area for the economic analysis was defined as the inundation limits of the 100-year flood event under existing conditions. This boundary encompasses the farthest extent of flooding for the flood events examined within the scope of the project. The study area consists primarily of agricultural land and the population centers of Crystal and Hoople, ND. Study area land uses include agriculture, residential, commercial, institutional, and infrastructure.

Hydrologic and hydraulic modeling was conducted in support of the economic analysis. The objectives of the hydrologic and hydraulic analyses were as follows:

- Prepare existing and future conditions hydrologic models for the Cart Creek Watershed.
- Utilize the existing and future conditions hydrologic models to characterize the 1-, 1.5-, 2-, 5-, 10-, 25-, 50-, and 100-year, flood frequency events, based on flow and volume frequency analysis at U.S. Geological Survey Gage Number 05090000 (Park River at Grafton, North Dakota).
- Prepare hydraulic models for the downstream area to delineate inundation limits
- Prepare input for the HEC-FIA flood damage assessment model based on the results of the hydraulic modeling

II. STUDY AREA INVENTORY

A. Structures

To identify study area structures, Geographic Information System (GIS) tax parcel data was obtained from the Pembina and Walsh Counties Tax Assessors Offices. The database of tax parcels within the study area limits was analyzed using ArcGIS. The parcels were then allocated using the Assessor's Use Code descriptions into the following categories:

- Residential structures
- Commercial/Industrial structures
- Institutional structures (K-12 schools, churches, government-owned properties)
- Agricultural structures (active agricultural land, agricultural buildings and grain storage)
- Infrastructure (roads and utilities)

The accuracy of the parcels database and Use Codes was verified through a field view and examination of aerial photography.

A total of 49 tax parcels containing flooded structures fell within the inundation limits of the 100-year flood event under existing conditions. The 49 tax parcels consist of 24 residential parcels, 16 agricultural parcels, six commercial parcels, a post office, municipal park and elementary school. Impacted properties were concentrated in downtown Crystal, ND (Appendix A). A total of 136 structures are located within the 100-year floodplain on the 49 affected tax parcels. Affected structures consist of 37 residential structures (homes and garages), 49 agricultural structures, 37 grain storage containers, 10 commercial structures, and three institutional structures. Properties that contained both residential and agricultural structures were subdivided within the model, in order to assign the correct depth-damage factor to each structure.

Tax assessment data for structure values was either not available, or not considered representative of replacement value. Therefore, the outline of each building was delineated and included in a GIS polygon shapefile. Replacement values were determined on a square foot basis using Marshall Valuation Service data and were based on land use, class and type of structure (Marshall Valuation Service 2019).

Replacement values and contents values for structures are shown in **Exhibit D.4-1**. Contents values for agricultural outbuildings were based on a *North Dakota Farm Business Management Education Program 2014 Annual Report* estimate for value of machinery and equipment assets, average of all farms (North Dakota Farm Management Education Association 2014). The estimate was then adjusted based on study area interviews. Typical contents for large operations consisted of up to four combines, four tractors, sprayer, two air seeders, tools and other miscellaneous contents, valued at approximately $3.65 million for 16,000 square feet of outbuilding space (Pembina County WRD 2017, Walsh County WRD 2017). Smaller study area operations contents values were scaled down based on a value of $228 per square foot.

Grain elevator and agricultural warehouse contents damages were estimated for machinery and equipment. Based on study area interviews, the four agricultural warehouses were assumed to contain specialized potato storage machinery, including bin pilers, conveyors, washing equipment and potato sorters.

Exhibit D.4-1. Replacement and Contents Value by Structure Type

Structure Type	Replacement Value	Contents Value	Sources
Residential	$125.25 per sq. ft.	50% of structure value	• NRCS Principles and Guidelines • Field view • Marshall Valuation Service • Study area producer interviews • NASS 2018 normalized prices
Elementary School	$146.73 per sq. ft.	50% of structure value	
Post Office, General Commercial	$84.30 per sq. ft.	75% of structure value	
Agricultural Outbuildings	$25.55 per sq. ft.	$228 per square foot	
Grain Elevators	Determined individually based on components	25% of structure value	
Commercial Agricultural Warehouses	$37.02 per sq. ft.	$620,000 per structure	
Grain Storage Silo 12 ft. diameter	$38,900	$37,300	
Grain Storage Bin 15 ft. diameter	$12,700	$20,800	
Grain Storage Bin 21 ft. diameter	$16,100	$57,700	
Grain Storage Bin 36 ft. diameter	$35,800	$180,500	

Contents values for grain storage bins were developed using a composite crop of soybean and corn. The 2018 normalized crop prices were multiplied by the maximum bushel capacity for each bin size to estimate the value of stored crops. Because it is possible that an individual bin could be full, partially full or empty depending on when a flood event occurs, the total value in each bin was then divided in half. This assumption provides a more conservative estimate of potential flood damages.

No contents value was included for the municipal park. The replacement value of recreation equipment and structures present at the park were included in the park's structure value. Vehicle damages were added to the model, based on interview responses about study area property owners' vehicle ownership and experience in prior flood events. It was assumed that during flooding, each residential property would be unable to move one personal vehicle. The *Federal Emergency Management HAZUS-MH MR3 Technical Manual* methodology was used to estimate personal vehicle value (FEMA, 2018). The FEMA methodology provides vehicle age distribution data by vehicle classification, and uses half of the average new car value for average used car vehicle values, based on National Automobile Dealers Association (NADA) data. Based on a 2019 average transaction price for a new mid-sized car (Kelley Blue Book, 2019), the average study area vehicle was assumed to be valued at $14,200.

The number of vehicles at agricultural properties were estimated based on study area interview responses (PRJWRD, 2017). A large scale agricultural operation (greater than 2,000 acres) was assumed to own up to six light trucks. Study area agricultural operations were assigned between one and six pick-up trucks, depending on outbuilding square footage and total agricultural acreage. Using the FEMA HAZUS methodology, light truck values within the study area were estimated to average $29,200.

B. Agricultural Land

Agricultural land was categorized by field crop using the National Agricultural Statistics Service (NASS) crop data layer (NASS 2019). Data was collected for five years from 2014 through 2018 (**Exhibit D.4-2**). Agricultural land in the study area includes seven major crops comprising more than 96% of active agricultural land (Appendix B - Agricultural Land Use Mapping). Total agricultural acres for the seven major crops in the study area were 14,264 acres on average during the five-year period of analysis. Crops consisting of less than one percent of the study area agricultural land were removed from the analysis. Additionally, two percent of the study area was categorized as grassland/pasture. Further investigation determined that this land use consisted mainly of various conservation easements (Nichols 2017). The grassland/pasture layer was therefore removed from the analysis. Within the analysis, all crops were treated as basic crops. See Section V.C.3 for a discussion of basic vs. non-basic crops.

Exhibit D.4-2. Study Area Agricultural Crops

Crop	Acres Planted					Average 2014-2018
	2014	2015	2016	2017	2018	
Spring Wheat	6,721	5,808	6,325	4,487	5,577	5,784
Dry Beans	1,928	2,252	2,726	2,442	1,909	2,251
Soybeans	2,829	2,581	2,080	3,793	3,832	3,023
Potatoes	1,092	1,367	1,011	1,438	942	1,170
Sugarbeets	967	1,236	976	523	1,145	969
Corn	506	680	914	1,406	799	861
Alfalfa	79	279	243	232	197	206
Total	**14,122**	**14,203**	**14,275**	**14,321**	**14,401**	**14,264**

Source: NASS, 2019.

C. Infrastructure Parcels

Study area infrastructure consists of roadways, three bridges, railroad lines and utilities. Roadways were divided into three categories: paved, graded and drained/gravel and unimproved. Total mileage for railroad lines and each roadway type in the study area was estimated using ArcGIS. Based on flood depths and velocities for the various storms, it was assumed that transmission poles would not be damaged.

III. STRUCTURE AND VEHICLE EXISTING CONDITION FLOOD DAMAGES

Flood damages to structures were estimated using the United States Army Corps of Engineers (USACE) Hydrologic Engineering Centers Flood Impact Analysis Software (HEC-FIA) version 3.0. The HEC-FIA model uses the following parameters to estimate the flooding depth and cost of damages to structures and vehicles:

- Flood frequency and depth, duration and arrival time gridded data from the output flood model (HEC-RAS).
- Terrain elevation grid in combination with user defined parameters to determine first floor elevation. Foundation heights were assumed to be either 0.5 feet or 1.0 feet from ground elevation, depending on structure type.
- Point locations of all structures.

- Type and value of each structure and contents within the structure
- Damage coefficient data for each type of structure and contents

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

Depth-damage factors for the various structure types and contents were obtained from USACE data provided by NRCS (NRCS 2018). Because the USACE data did not provide depth damage factors for parks, agricultural structures or grain bins, depth damage factors were adapted from NRCS-provided data for campgrounds (park) and shop/equipment/light industrial structures (agricultural structures). Based on study area interviews, the depth damage relationship for grain storage facilities was adjusted to show damages beginning at zero feet to account for below ground infrastructure.

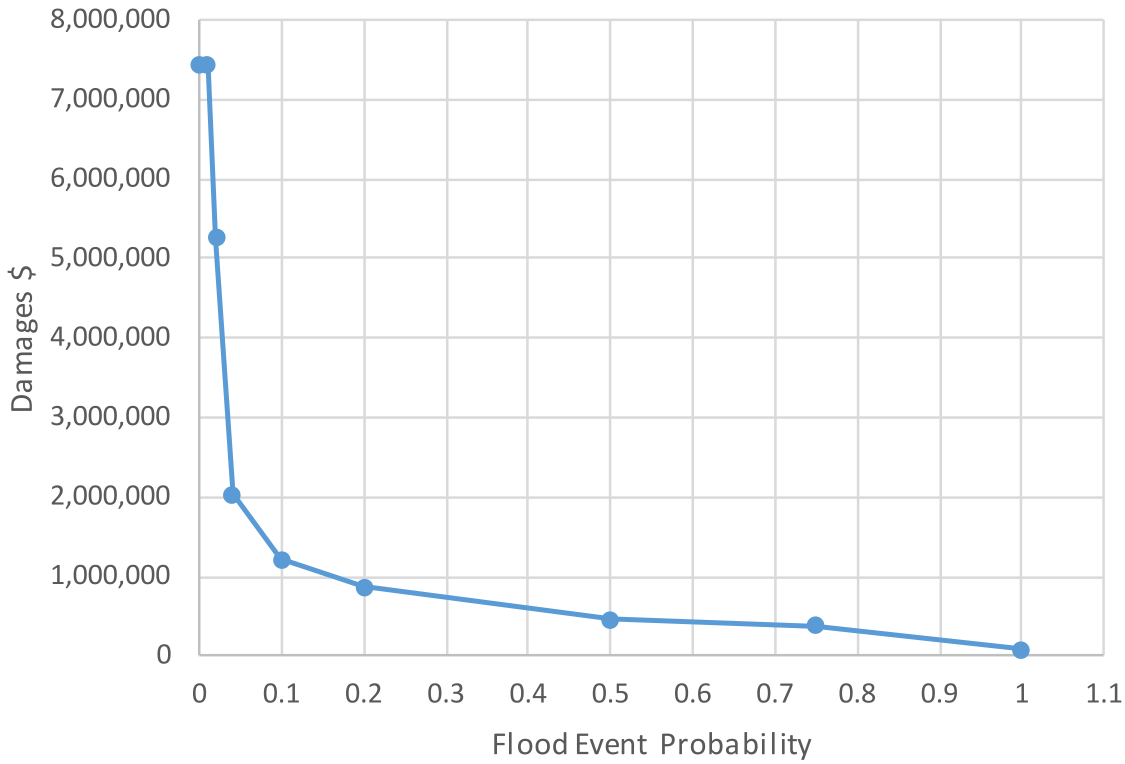
The 1-year through 100-year flood events were modeled for existing conditions. Model results are shown in the damages column of **Exhibit D.4-3**. Please refer to Appendix C for HEC-FIA input and output summaries, including number of structures inundated by event. Please refer to Appendix A for floodplain delineation mapping showing the inundation limits for the flood events modeled.

Calculation of the expected annual damage accounts for the probability of exceedance of each flood event magnitude. The expected annual damage is the area under the frequency-damage curve. **Exhibit D.4-4** presents the frequency-damage relationship for structure damages. This curve traces out, for each damage magnitude, the probability in any given year of a flood incurring at least this much damage. For this analysis, the points on the curve are connected by straight lines, allowing for a straightforward summation of the areas of the parallelograms under each curve segment. The conservatism of the calculation is made evident in how the lines drop directly to the axis beyond the limits of the hydrologic modeling. That is, damages are not estimated to increase for floods more severe than the 100-year event. **Exhibit D.4-3** presents the calculation of the expected annual damage for structures and vehicles, which was estimated at $770,800.

Exhibit D.4-3. Expected Annual Flood Damages to Structures and Vehicles under Existing Conditions

Flood Event	Exceedance Probability	Damages	Average Height	Width	Area
100	0.01	$7,441,509	$7,441,509	0.01	$74,415
50	0.02	$5,262,028	$6,351,768	0.01	$63,518
25	0.04	$2,029,888	$3,645,958	0.02	$72,919
10	0.1	$1,212,240	$1,621,064	0.06	$97,264
5	0.2	$865,902	$1,039,071	0.1	$103,907
2	0.5	$454,224	$660,063	0.3	$198,019
1.5	0.75	$373,152	$413,688	0.25	$103,422
1	1.0	$85,629	$229,391	0.25	$57,348
				Total	**$770,811**

Exhibit D.4-4. Frequency Damage Relationship for Structures and Vehicles



IV. INFRASTRUCTURE EXISTING CONDITION FLOOD DAMAGES

A. Roadways

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

Repair costs per linear foot were estimated by project civil engineers for roadways in the study area. Repair costs for paved roads were estimated at approximately $114 per linear foot, based on removing flood debris, milling and paving damaged roadway. Repair costs for gravel and graded and drained roadways were estimated at approximately $46 per linear foot, based on removing flood debris and resurfacing damaged roadway. Repair costs for unimproved roadways were estimated at $23 per linear foot, based on removing flood debris. Based on stakeholder interviews, it was assumed that a portion of the flooded and damaged roadways would experience wash outs, requiring more extensive embankment repair. Embankment replacement was estimated at $133 per linear foot. Please refer to Appendix D: Infrastructure Repair Costs for the detailed cost estimates.

Average flood velocity for all storm events ranged from 1.2 – 1.5 ft/s, and average flood depth was 1.0 foot. Because of the study area's flat topography, while the area inundated increases with flood event size, the velocity and depth of flooding does not vary substantially. Project engineers' assumptions of the percentages of the inundated roadway that would be damaged are shown in **Exhibit D.4-5**.

Exhibit D.4-5. Repair Costs for Study Area Roadways

Roadway Type	% Damage	% Wash Out	Repair cost $/LF	Embankment Replacement Cost $/LF
Paved	10%	1%	$114	$133
Gravel/Graded and Drained	20%	2%	$46	$133
Unimproved	20%	2%	$23	$133

Source: Gannett Fleming, Inc., 2019.

Using ArcGIS, the roadway mileage inundated under each storm event was calculated under existing conditions. Mileage inundated was multiplied by the percentage of flooded surface that would require repair. Damaged surface (feet) was multiplied by the repair cost (per foot) to obtain repair cost damages. Expected annual damages to roadways under existing conditions was estimated at $79,600 (**Exhibit D.4-6**).

Exhibit D.4-6. Expected Annual Flood Damages to Roadways under Existing Conditions

Flood Event	Exceedance Probability	Damages	Average Height	Width	Area
100	0.01	$348,260	$348,260	0.01	$3,483
50	0.02	$284,603	$316,431	0.01	$3,164
25	0.04	$237,446	$261,024	0.02	$5,220
10	0.1	$147,814	$192,630	0.06	$11,558
5	0.2	$99,847	$123,831	0.1	$12,383
2	0.5	$48,865	$74,356	0.3	$22,307
1.5	0.75	$44,300	$46,583	0.25	$11,646
1	1.00	$34,791	$39,545	0.25	$9,886
				Total	**$79,647**

B. Railroads

Railroad lines are present in the study area, including lines that cross study area streams. GIS analysis was conducted to determine that no study area railroads are impacted by flooding. For each storm event, the Digital Elevation Model-based (DEM) elevation of rail lines was above the flood depth.

C. Bridges

Three roadway bridges are present in the study area. GIS analysis was conducted to determine that no study area roadway bridges are impacted by flooding. For each storm event, the DEM-based elevation of the bridge deck was above the flood depth.

V. AGRICULTURAL CROP EXISTING CONDITION FLOOD DAMAGES

A. Input Data

The USACE HEC-FIA model was used to calculate, for each inundation duration and each crop, the acreage under water for that duration. HEC-FIA was run once for each flood magnitude, from the 100-year to 1-year flood events. HEC-FIA can also be used to calculate estimated damages from crop losses. However, for this analysis, an Excel spreadsheet crop damage model was developed. The model has more flexibility and detail to better account for specific agricultural economic parameters. Another advantage is that, compared to the crop loss estimator within HEC-FIA, the spreadsheet model provides greater transparency with respect to the assumptions and calculations used to estimate damages.

Flood and Crop Mapping. Hydraulic data output from HEC-RAS maps the flood extent, by eight-hour duration increments, for inundation durations from one to eleven days. USDA's NASS crop data layers map the land use and crop type coverage at a 30 meter resolution. Crop data layers for 2014 through 2018 were used in separate analyses in order to capture possible variations due to crop rotations.

Price and Yield. The yield and price data input into the crop damage spreadsheet model and their sources are indicated in **Exhibit D.4-7**.

Exhibit D.4-7. Crop Yield and Price Inputs

	Spring Wheat	Dry Beans	Soybeans	Potatoes	Sugar Beets	Corn	Alfalfa
Units	bushels	cwt	bushels	cwt	tons	bushels	tons
Yield (units/acre)[1]	52	14.6	34.2	240	25.9	125	2.7
Price[2]	$6.06	$29.93	$10.57	$9.77	$47.59	$3.97	$86.40
Revenue/acre	$346	$472	$401	$2,314	$1,532	$603	$215

[1] Source: USDA. Five year average for Pembina and Walsh counties, weighted by acreage planted.

[2] Source: USDA. North Dakota normalized price, 2018.

Crop Damage Factors. The crop damage factors recognize that the chief determinant of crop damage is not depth of flooding but duration that the crop is under water. The crop damage factors vary by month of the growing season. **Exhibit D.4-8** presents the crop damage factors. HEC-FIA model output produces numbers of acres of each crop inundated in 8 hour intervals. The fractional day crop damage factors are calculated by linear interpolation of the daily crop loss percentages shown in **Exhibit D.4-8**.

Late Plant Yield Loss. Late planting that results in yield loss may occur if flooding delays planting beyond the optimal time window or if early growing season flooding is sufficiently damaging to a planted crop that it is dug up and the acreage replanted. The assumed replant thresholds and late plant yield losses are shown below in **Exhibit D.4-9**. The Exhibit also shows the assumed percent of the crop planted at the time of the flood.

Replant Costs. For flooding that occurs early enough in the growing season and where crop loss exceeds certain crop loss thresholds, the flooded acreage is assumed to be replanted. Replanting cost factors used in the model are as shown in **Exhibit D.4-10**.

Exhibit D.4-8. Crop Damage Factors for North Dakota
(Percent Decrease in Yields by Number of Days Inundated)

Wheat

Days	April & May	June	July	August	September
1 day	14	17	20	30	30
2 days	29	34	43	65	65
3 days	44	54	65	75	75
4 days	60	75	90	80	80
5 days	80	100	100	90	90
6 days+	100	100	100	100	100

Dry Beans

Days	May	June	July	August	September
1 day	11	28.5	24.5	26	24.5
2 days	14.5	48.5	49.5	49.5	57.5
3 days	21.5	66	67	65	71
4 days	31	79	78	75	72
5 days	37	85.5	90.5	79.5	72
6 days+	40.5	89.5	90.5	91.5	72

Soybeans

Days	May	June	July	August	September
1 day	7	13	4	4	10
2 days	8	16	17	16	62
3 days	16	32	34	30	83
4 days	29	58	56	50	83
5 days	36	71	81	69	83
6 days+	40	79	81	83	83

Potatoes

Days	April & May	June	July	August	September
1 day	15	44	45	48	39
2 days	21	81	82	83	53
3 days	27	100	100	100	59
4 days	33	100	100	100	61
5 days	38	100	100	100	61
6 days+	38	100	100	100	61

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Exhibit D.4-8. Crop Damage Factors for North Dakota (Continued)
(Percent Decrease in Yields by Number of Days Inundated)

Sugar Beets

Days	April & May	June	July	August	September
1 day	15	15	20	15	15
2 days	25	30	40	25	25
3 days	40	65	70	40	45
4 days	60	100	100	55	60
5 days	80	100	100	70	70
6 days	100	100	100	85	80
7 days+	100	100	100	100	85

Corn

Days	April & May	June	July	August	September
1 day	13	18	11	5	5
2 days	31	45	19	13	19
3 days	66	72	46	19	36
4 days	70	78	57	33	44
5 days	100	100	72	44	51
6 days	100	100	76	68	65
7 days+	100	100	100	71	77

Alfalfa

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

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

Exhibit D.4-9. Late Plant Thresholds, Yield Losses, and Crop Progress

Month	Spring Wheat	Dry Beans	Soybeans	Potatoes	Sugar Beets	Corn	Alfalfa
April							
Percent Planted	25%	0%	0%	10%	40%	25%	100%
Late Plant Yield Loss	10%	0	0	0	1%	20	NA
Replant when damage over:	40%	NA	NA	NA	25%	30%	NA
May							
Percent Planted	80%	40%	50%	50%	100%	80%	100%
Late Plant Yield Loss	20%	10%	10%	50%	15%	30%	NA
Replant when damage over:	30%	25%	30%	NA	75%	30%	NA
June							
Late Plant Yield Loss	NA	30%	30%	NA	NA	NA	NA
Replant when damage over:	65%	65%	65%	NA	90%	75%	NA
Replant with…	soybeans	same	same	NA	soybeans	soybeans	NA
August							
Percent Harvested	35%	0%	0%	0%	0%	0%	67%
September							
Percent Harvested	90%	50%	5%	25%	10%	0%	75%

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

Exhibit D.4-10. Cost Factors

	Spring Wheat	Dry Beans	Soybeans	Potatoes	Sugar Beets	Corn	Alfalfa
Replant Cost Factors							
Seed ($/acre)[1]	20.00	56.10	68.71	NA	220.00	93.13	NA
Planting ($/acre)[1]	18.07	21.60	16.67	NA	19.51	18.21	NA
Avoided Cost Factors							
Harvest ($/acre)[1]	10.00	NA	NA	100.00	62.50	35.13	NA
Hauling ($/unit)[2]	0.18	0.63	0.17	0.31	2.80	0.17	3.33[5]
Other Costs ($/unit)				0.95[3]		0.21[2]	10.00[4]

[1] *Source: NRCS 2019.*

[2] *Source: NRCS 2019 cost per acre divided by estimated yield per acre.*

[3] *UC Cooperative Extension 2015 Sample Costs to Produce Potatoes. $68/acre to dig and harvest. $442/acre other: bulk haul to storage, clean, store. Divided by 485 cwt/acre equates to about 90 cents/cwt post-harvest unit costs.*

[4] *NDSU Custom Farm Work Rates: Mow at $10, Rake at $5, Large bale (over 1,500) at $10/bale, say one ton bale at $10.*

[5] *Using NDSU Customer Farm Work Rates wheat haul cost reported at 10 cents/bushel. Using bulk density of 60 pounds/bushel equates to approximately 17cents/cwt or $3.33/ton.*

Unit Costs. While flood damage reduces crop revenues, it can also reduce some of the costs of bringing that crop to market. **Exhibit D.4-10** shows the cost factors used for avoided costs. Harvests costs are only treated as avoided on analysis cells with 100% yield loss. Therefore, harvest costs are not shown for crops that have no damage factors of 100%.

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

Seasonal Flood Distribution. Crop damages are estimated specific to each month. The seasonal distribution of flood events, shown in **Exhibit D.4-11**, is used to compute a weighted average damage for the year.

Exhibit D.4-11. Flood Event Distribution by Month

	April	May	June	July	August	September	Other Months	Total
Number[1]	8	26	58	46	28	15	9	190
Percent	4.2%	13.7%	30.5%	24.2%	14.7%	7.9%	4.7%	100%

Source: NOAA Hydrometeorological Design Center Precipitation Frequency Data Server. Annual Maximum Series files for Langdon, Cavalier NNW, Park River, and Pembina.

[1] Number of 4-day maximum rainfall events occuring in the month for the annual Maximum Series for 1960-2010

B. *Crop Damage Calculations*

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

Step 1: Cost of Additional Land Treatment

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

Step 2: Revenue Lost from Crop Yield Reduction

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

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

b. Revenue loss is calculated as lost crop units multiplied by the price per crop unit.

Step 3: Savings from Avoided Costs

Deduct from the damage estimate the costs that are reduced due to having less crop to harvest. Avoided cost factors were shown in Exhibit D.4-10 above.

a. For all crop losses, deduct avoided variable costs, calculated as the variable avoided costs per crop unit multiplied by the crop units lost.

b. For any acreage where the crop is completely lost (100% damage factor), harvest cost is also deducted. Conversely, for any flooded acreage for which any crop remains, the full harvest cost is assumed to be incurred, and therefore is not deducted or reduced.

Step 4: Net Loss from Replanting

For some crops the model provides for replanting in April, May, and June, when the flood damage factor exceeds a specified percentage. The replanting thresholds are listed above in Exhibit D.4-9. Whether the replanting threshold applies depends on the damage factor applied to the specific duration of inundation. That is, crop acreages below a certain inundation duration may be modeled as experiencing crop yield loss while acres under water longer are modeled as being replanted. The replanting loss estimate replaces the other revenue and cost impacts calculated at steps 2 and 3 above.

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

(1) the net revenue lost from the crop that is replaced

(2) *plus* the replanting cost

(3) *minus* the net revenue gained from the replacement crop. The net revenue gained from the replacement crop takes into account the late plant yield loss affecting the replacement crop.

Exhibits D.4-12 and **D.4-13** present illustrative examples of the calculations.

For clarity of presentation, the illustrative sugar beet replanting example leaves out an additional damage calculation step. This step is added to recognize that replanting is not feasible in all instances. For example, in some cases the acreage that is modeled as subject to severe flooding is angled diagonally across a field. In other instances the modeling shows tightly intermixed areas of varying flooding durations. In these types of scenarios it may be impractical to isolate area of severe crop damage for replanting. To account for such scenarios, all acreages that are found to exceed the duration threshold for replanting are reduced by 20 percent. Losses on these segments will be subject to the full duration damage factor applicable to that crop, season, and duration. Applying this 20 percent adjustment to the illustrative example above, eight acres would be subject to the replant loss of $559 per acre, and the other two acres would be subject to costs associated with the 80 percent yield loss.

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

Exhibit D.4-12. Illustrative Damage Calculation: Soybean Damages in May

Scenario: 10 Acres Soybeans Inundated for 3 Days	
Input Data:	
Price/bushel:	$10.57
Base Yield:	34.2 bushels per acre
Avoidable Cost (hauling):	$0.17/bushel
Percent Planted:	50%
Damage Factor for 3-days inundation in May:	16%
May Late Plant Yield Loss:	10%
Loss on Planted Crop (50% is planted)	
Acres Planted (50% x 10 acres) =	5 acres
Crop Lost (34.2 bu/acre x 16% yield loss rate x 5 acres) =	27.36 bushels
Revenue Lost (27.36 bushels x $10.57/bushel) =	$ 289.20
Avoidable Costs Saved (27.36 bushels x $0.17/bu) =	(4.65)
Net Loss ($289.20 – $4.65) =	$ 284.54
Late Plant Loss (50% is not yet planted, and has delayed plant loss)	
Acres Planted (50% x 10 acres) =	5 acres
Crop Lost (34.2 bu/acre x 10% yield loss rate x 5 acres) =	17.1 bushels
Revenue Lost (17.1 bushels x $10.57/bushel) =	$ 180.75
Avoidable Costs Saved (17.1bushels x $0.17/bushel) =	(2.91)
Net Loss ($180.75 – $2.91) =	$ 177.84
Total Damages for the 10 acres flood for three days:	
Crop Inundation	$ 284.54
Late Plant	177.84
Additional miscellaneous flood response costs @ $20/acre	200.00
Total loss over the 10 acres	$ 662.38

Exhibit D.4-13. Illustrative Damage Calculation: Sugar Beet Damages in May

Scenario: 10 Acres Sugar Beets Inundated for 5 Days	
Input Data:	
Price/ton:	$47.59
Base Yield:	25.9 tons/acre
Avoidable Cost (hauling):	$2.80/ton
Replant Cost ($220/acre seed + $19.51/acre planting):	$239.51/acre
Percent Planted:	100%
Replant Threshold for May:	75%
Damage Factor for 5-days inundation in May:	80%
May Late Plant Yield Loss:	15%
Replant Net Revenue Loss per Acre	
Crop Revenue Loss per Acre replanted (25.9 tons/acre x $47.59/ton) =	$ 1,232.58
Less: Avoidable Costs (25.9 tons/acre x $2.80/ton) =	(72.52)
Net Revenue Lost/acre ($1,232.58 - $72.52) =	$ 1,305.10
Replant Net Revenue Gain per Acre	
Yield on replanted with late plant loss(25.9 tons/acre x (100%-15%))=	22.0 tons/acre
Crop revenue per acre from Replant (22.0 tons/acre x $47.59/ton) =	$ 1,046.98
Less: Variable Cost per acre (haul) (22.0 tons/acre x $2.80/ton) =	(61.60)
Less: Replanting Cost per Acre (seed and planting) =	(239.51)
Net Gain per Acre Replanted ($1,046.98 – 61.60 – 239.51) =	$ 745.87
Net Loss per Acre	
Net revenue loss from dug up crop	$ 1,305.10
Net revenue gain from replanted crop	(745.87)
Net loss per acre replanted	$ 559.23
Additional miscellaneous flood response cost per acre	20.00
Total Loss per Acre	$ 579.23
Total Damages for the 10 acres flooded for five days:	
Total Loss over the 10 acres ($579.23/acre x 10 acres) =	$ 5,792.30

C. *Crop Damage Estimates*

Damage estimates were calculated for each of the crop data layers for years 2014-2018. The results for one of the layers (2018) are shown to illustrate the typical comparison of damages among crops, flood magnitudes, and months.

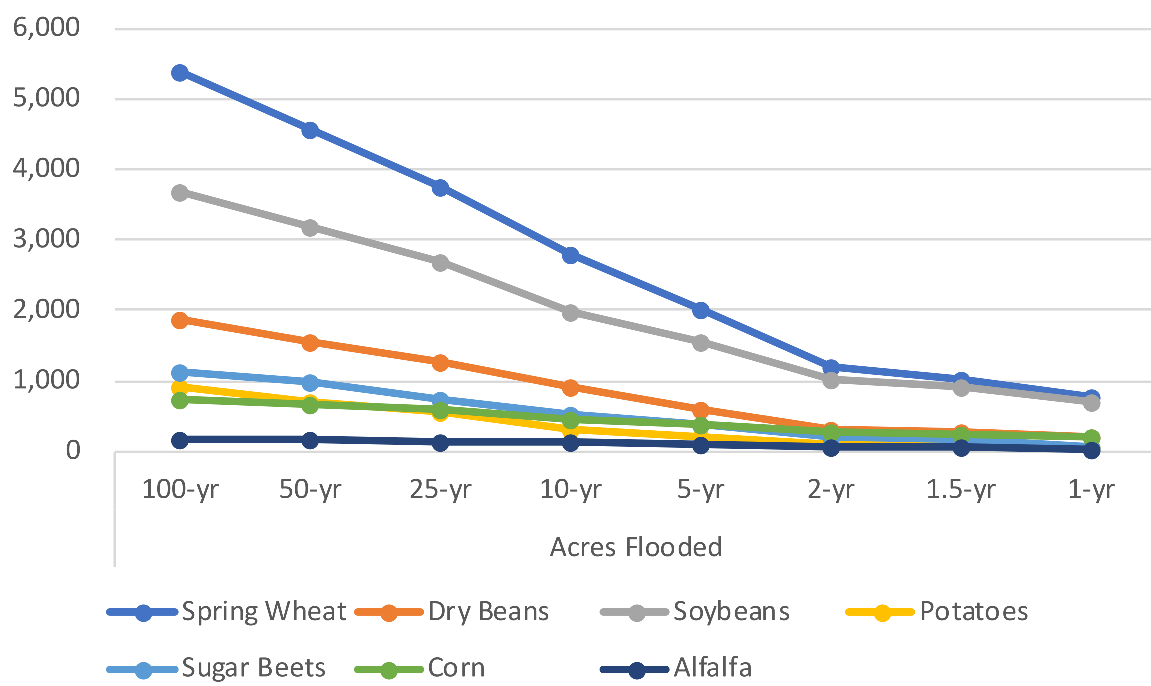
1. Acreage Flooded under Existing Conditions

The extent of flooding for the different flood event magnitudes based on the 2018 crop data layer is illustrated in **Exhibit D.4-14** and **Exhibit D.4-15**. The exhibits indicate the prevalence of spring wheat and soybean cropland impacts when measured by acreage inundated. Mere acreage inundated does not capture the full damage potential. Inundation durations, combined with the month of flooding, are important determinants of damage severity.

Exhibit D.4-14. Acres Flooded by Crop under Existing Conditions - 2018 Crop Data Layer

Crop	Acres Flooded							
	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr	1.5-yr	1-yr
Spring Wheat	5,401	4,572	3,753	2,803	2,000	1,183	1,035	759
Dry Beans	1,862	1,545	1,264	898	584	328	281	189
Soybeans	3,676	3,197	2,698	1,996	1,552	1,026	913	688
Potatoes	922	689	570	327	205	105	88	63
Sugar Beets	1,118	1,004	739	538	376	196	157	68
Corn	732	669	611	460	368	272	251	216
Alfalfa	174	166	149	119	95	67	56	42
Subtotal	**13,884**	**11,843**	**9,784**	**7,141**	**5,182**	**3,178**	**2,780**	**2,026**

Exhibit D.4-15. Crop Acres Flooded by Flood Magnitude



2. Damages by Month for Existing Conditions

Exhibits D.4.-16 through **D.4-27** present, for each month, the estimated crop damages, measured as reduction in net crop revenues, using the 2018 data layer. Note that there is a net revenue loss shown for all crops in April, even those that are not yet planted in April because of the application of the uniform cost factor of $20 per acre for additional operating costs to deal with the inundation.

The exhibits below illustrate the different level of crop damage for floods occurring in different months. The charts also help to illustrate how crop damage shares shift among crops when comparing a small, high frequency flood event with a large flood event. The share of potato crop damage in growing and harvest season damages is considerably higher in the 100-year flood than in the 2-year flood, while the share of spring wheat drops considerably. Potato growing is more concentrated in more upland areas, as reflected in the higher share of potato acreage flooded with the 100 year flood than with the two-year and smaller flood events. The soybean acreage share moves opposite of the potato share. This is to be expected, given the very high value of potato crop per acre, combined with the high flood sensitivity of potatoes in the main growing months.

3. Basic vs. Non-Basic Crops

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

Sugar beet production in the Red River Valley watershed is controlled by producer cooperatives. These cooperatives limit beet production under a contract system that assigns sugar beet acreage allocations for each producer-member. A water resources project in the study area would not increase or decrease land in production of sugar beets and is not expected to affect sugar beet market conditions. The largest impact on sugar beet production in this study area, mitigation of the 100-year event, affects approximately 2% of sugar beet acreage in the two counties of the study area. For the one-year event, less than one-tenth of one percent of sugar beet acreage in the two counties would be affected by the structure's reduction in flooding.

Potatoes are sold under contracts to potato distributors. Similar to sugar beets, mitigation of the 100-year event is modeled as affecting approximately 7% of all potato acreage in the two counties of the study area. Less than one-tenth of one percent of acreage would be affected by the structure's reduction in flooding for the one-year event.

While the structure would have a somewhat measurable effect on the acreage of these crops that would be inundated in a 100-year event, it is not realistic to expect this change to have an effect on planting or contracting practices because the event is so unlikely. The possibility of a flood mitigation structure causing changes to cropping patterns for sugar beets and potatoes is so unlikely and the effect on NED benefit calculations if practices *would* change is so small that the computational effort of treating them as non-basic crops is not warranted. Therefore, the crop damage analysis treats sugar beets and potatoes as basic crops, meaning that the acreage planted in these crops is not changed for the with structure alternative.

Exhibit D.4-16. Crop Damages in April under Existing Conditions - 2018 Crop Data Layer

Crop	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr	1.5-yr	1-yr
Spring Wheat	$328,853	$277,851	$228,286	$170,244	$121,652	$71,971	$62,986	$46,582
Dry Beans	37,237	30,892	25,282	17,965	11,682	6,560	5,619	3,780
Soybeans	73,511	63,950	53,966	39,921	31,033	20,522	18,260	13,759
Potatoes	67,836	50,249	39,801	20,870	12,593	5,996	5,031	3,438
Sugar Beets	37,675	33,701	24,628	17,757	12,407	6,360	4,941	2,168
Corn	92,989	85,666	78,229	57,855	46,636	34,505	31,986	27,543
Alfalfa	9,052	8,412	7,001	5,404	4,402	3,188	2,810	2,258
Total	**$647,153**	**$550,722**	**$457,194**	**$330,016**	**$240,405**	**$149,102**	**$131,633**	**$99,528**

Exhibit D.4-17. Crop Damages by Flood Magnitude, April

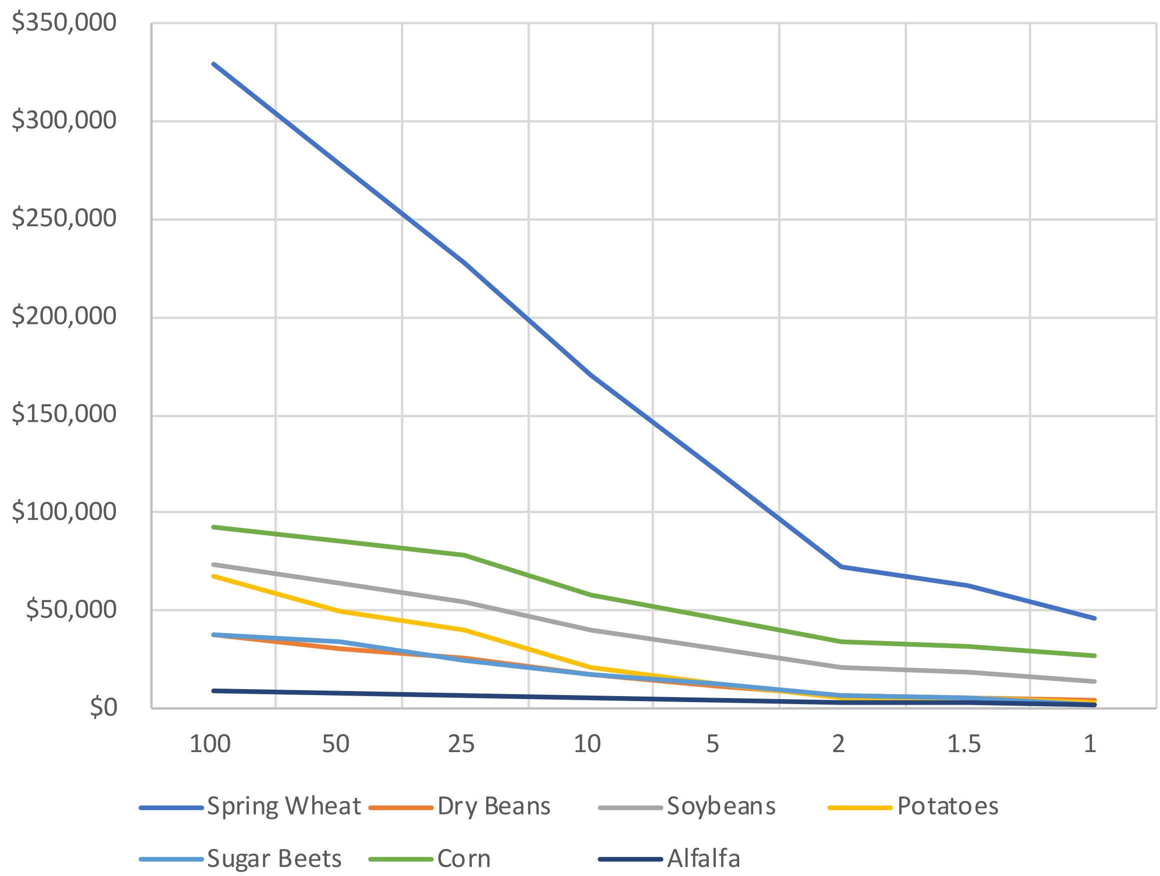


Exhibit D.4-18. Crop Damages in May under Existing Conditions - 2018 Crop Data Layer

Crop	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr	1.5-yr	1-yr
Spring Wheat	$539,533	$455,302	$374,563	$278,046	$198,787	$116,956	$102,648	$76,881
Dry Beans	138,594	114,008	92,621	64,454	41,325	22,966	19,630	13,466
Soybeans	244,565	209,729	174,972	130,328	100,927	63,727	56,945	44,871
Potatoes	735,652	547,773	444,329	245,087	151,362	75,221	63,110	44,258
Sugar Beets	417,525	366,923	253,874	172,186	115,230	56,582	41,606	20,140
Corn	124,603	116,051	105,999	77,011	62,633	46,113	43,044	36,929
Alfalfa	9,052	8,412	7,001	5,404	4,402	3,188	2,810	2,258
Total	**$2,209,523**	**$1,818,197**	**$1,453,360**	**$972,515**	**$674,668**	**$384,754**	**$329,792**	**$236,802**

Exhibit D.4-19. Crop Damages by Flood Magnitude, May

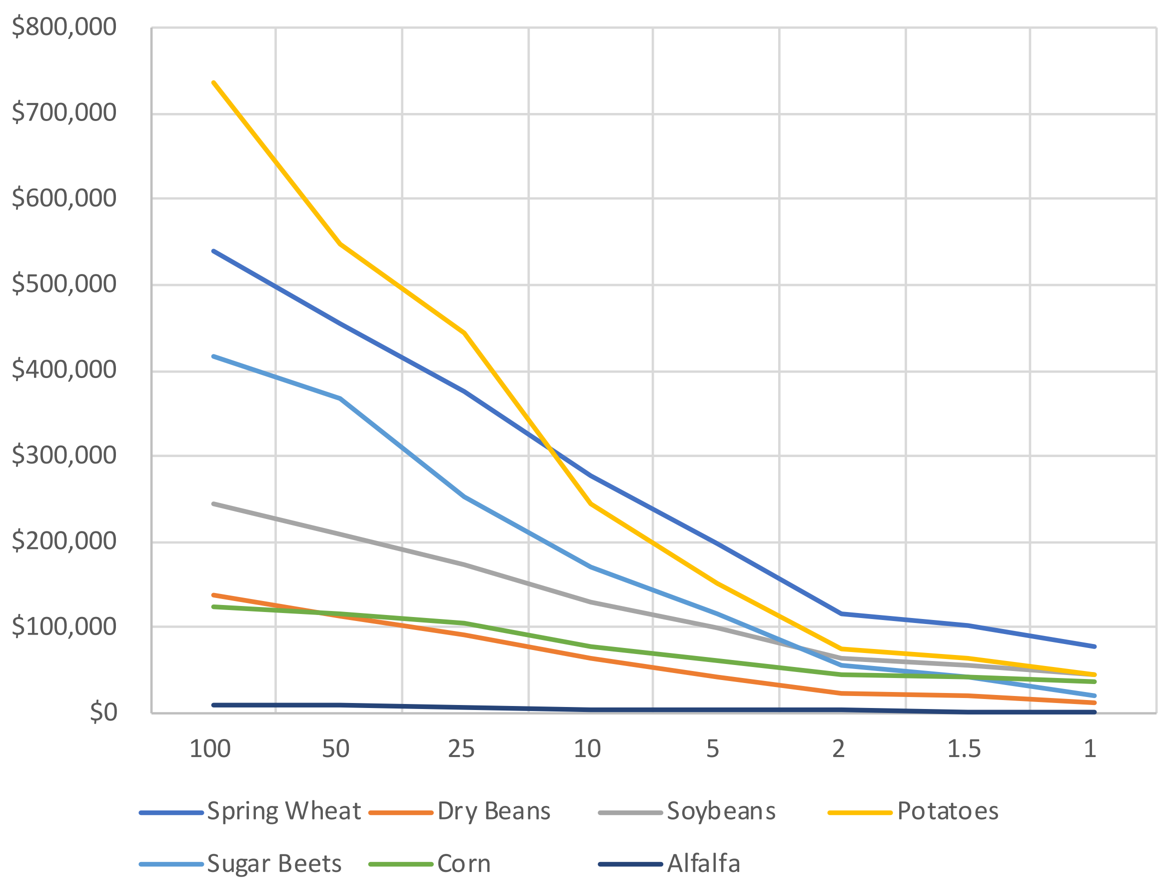


Exhibit D.4-20. Crop Damages in June under Existing Conditions - 2018 Crop Data Layer

Crop	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr	1.5-yr	1-yr
Spring Wheat	$734,358	$620,832	$512,576	$378,424	$270,123	$156,788	$138,010	$104,038
Dry Beans	358,303	294,036	234,469	161,798	101,854	56,700	48,469	33,163
Soybeans	458,568	389,688	321,087	241,039	184,665	125,187	112,415	93,487
Potatoes	1,454,272	1,090,533	891,141	456,984	275,678	132,324	112,307	74,585
Sugar Beets	772,853	649,933	480,772	308,647	202,459	81,935	61,179	32,927
Corn	169,640	158,829	145,368	103,931	84,758	63,370	59,177	50,725
Alfalfa	14,842	13,598	10,714	8,480	6,836	4,483	3,898	3,011
Total	**$3,962,835**	**$3,217,449**	**$2,596,127**	**$1,659,302**	**$1,126,374**	**$620,786**	**$535,455**	**$391,936**

Exhibit D.4-21. Crop Damages by Flood Magnitude, June

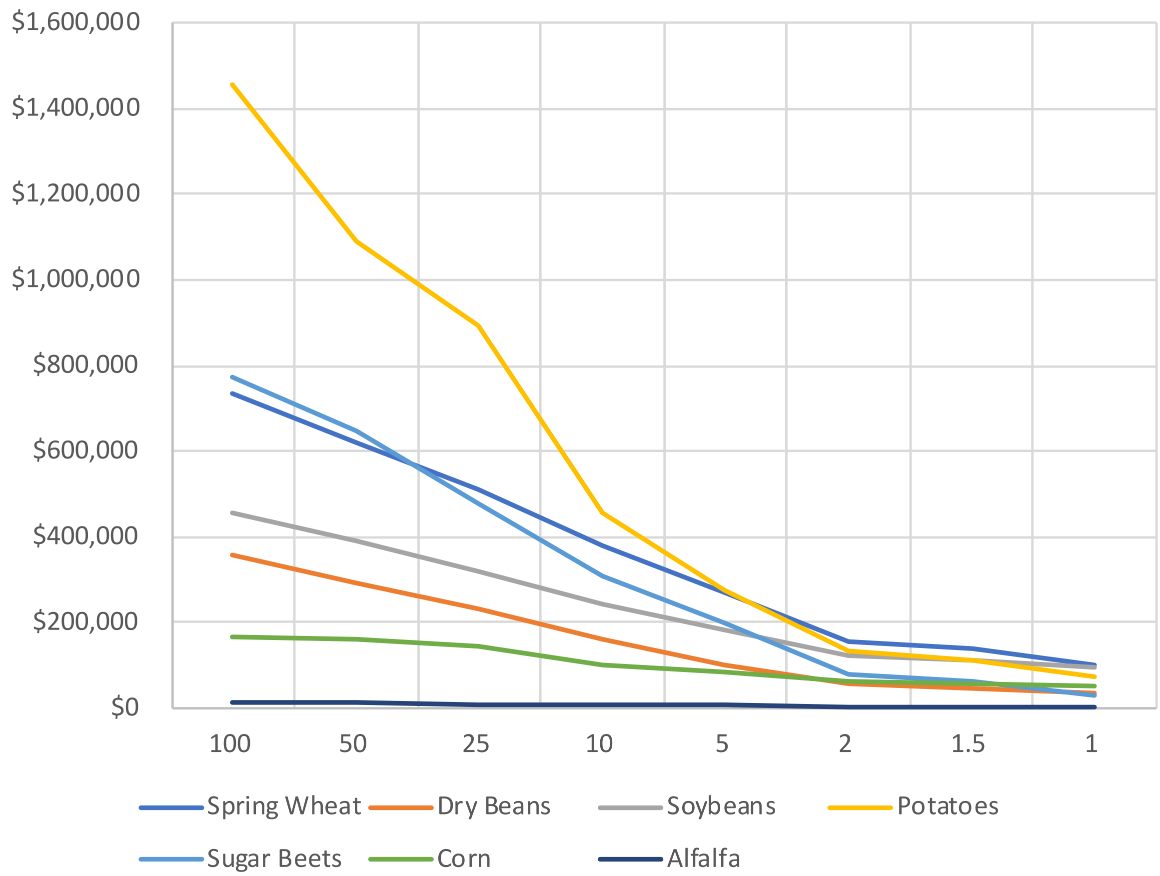


Exhibit D.4-22. Crop Damages in July under Existing Conditions - 2018 Crop Data Layer

Crop	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr	1.5-yr	1-yr
Spring Wheat	$987,432	$836,350	$689,735	$504,259	$356,849	$208,265	$183,887	$140,733
Dry Beans	427,371	347,665	275,792	185,760	116,958	64,771	55,576	39,163
Soybeans	500,642	422,622	348,381	261,577	200,980	141,043	128,206	109,981
Potatoes	1,460,695	1,094,961	895,709	460,213	277,781	133,457	112,987	75,042
Sugar Beets	806,105	683,600	499,070	319,460	206,834	87,810	65,399	34,588
Corn	156,454	145,474	129,919	90,626	75,207	58,133	54,683	47,915
Alfalfa	9,357	8,687	7,144	5,630	4,542	3,083	2,658	2,069
Total	**$4,348,055**	**$3,539,361**	**$2,845,750**	**$1,827,526**	**$1,239,150**	**$696,563**	**$603,396**	**$449,490**

Exhibit D.4-23. Crop Damages by Flood Magnitude, July

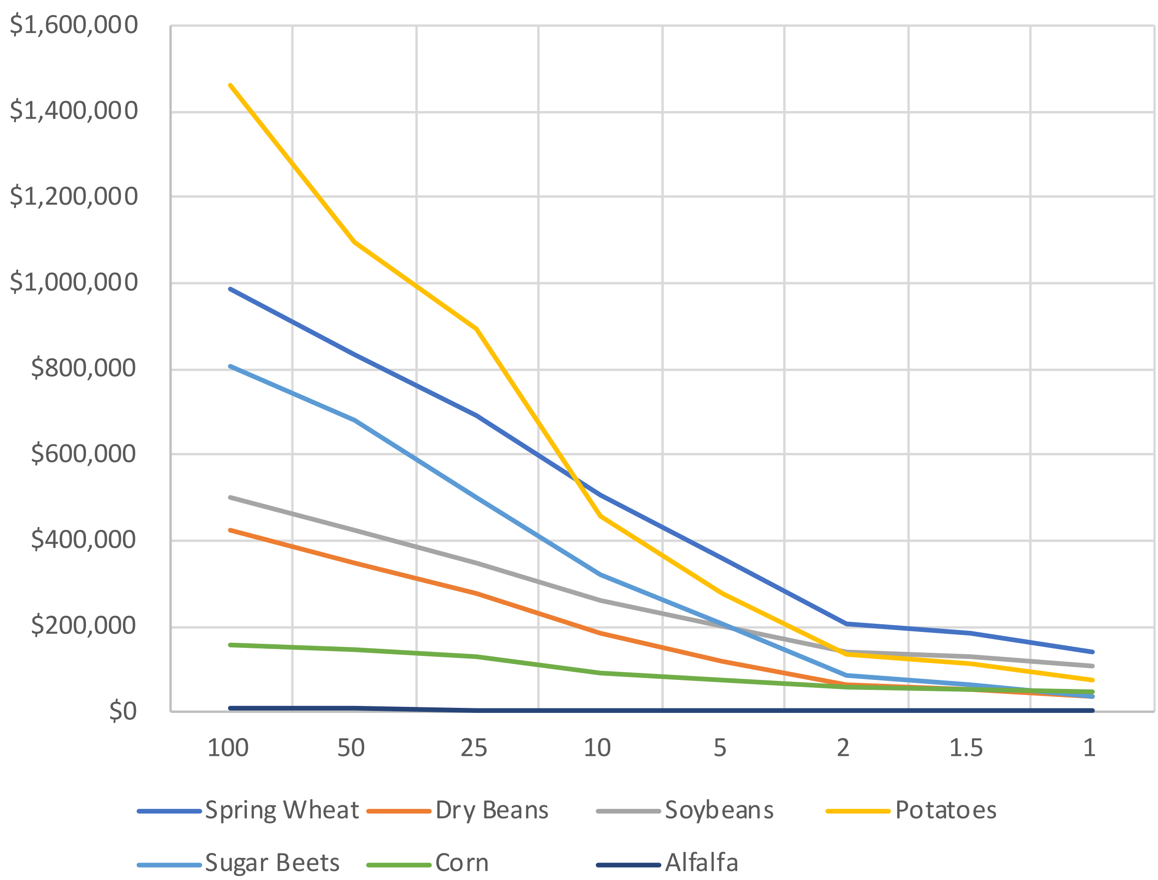


Exhibit D.4-24. Crop Damages in August under Existing Conditions - 2018 Crop Data Layer

Crop	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr	1.5-yr	1-yr
Spring Wheat	$742,634	$626,188	$515,746	$382,390	$273,710	$160,691	$141,049	$106,044
Dry Beans	421,563	342,129	271,453	183,852	116,319	64,805	55,680	39,394
Soybeans	471,388	399,841	330,529	247,886	192,974	137,254	125,644	108,824
Potatoes	1,473,602	1,104,038	904,057	466,625	282,111	135,883	115,130	76,582
Sugar Beets	588,417	494,146	346,570	208,243	134,061	60,292	46,110	24,971
Corn	112,802	104,790	92,397	63,810	53,110	41,175	38,763	34,264
Alfalfa	7,960	7,436	6,241	4,843	3,909	2,761	2,398	1,891
Total	**$3,818,367**	**$3,078,568**	**$2,466,992**	**$1,557,648**	**$1,056,194**	**$602,861**	**$524,774**	**$391,971**

Exhibit D.4-25. Crop Damages by Flood Magnitude, August

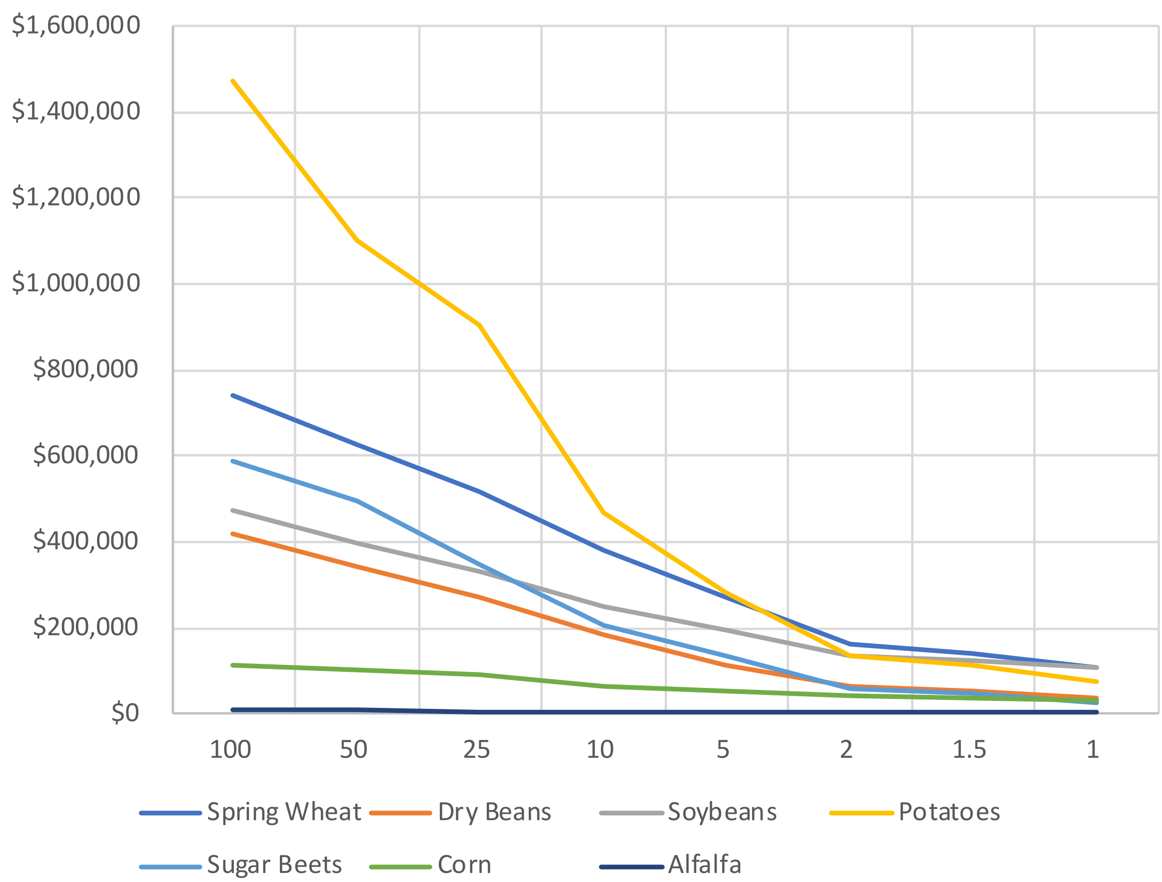
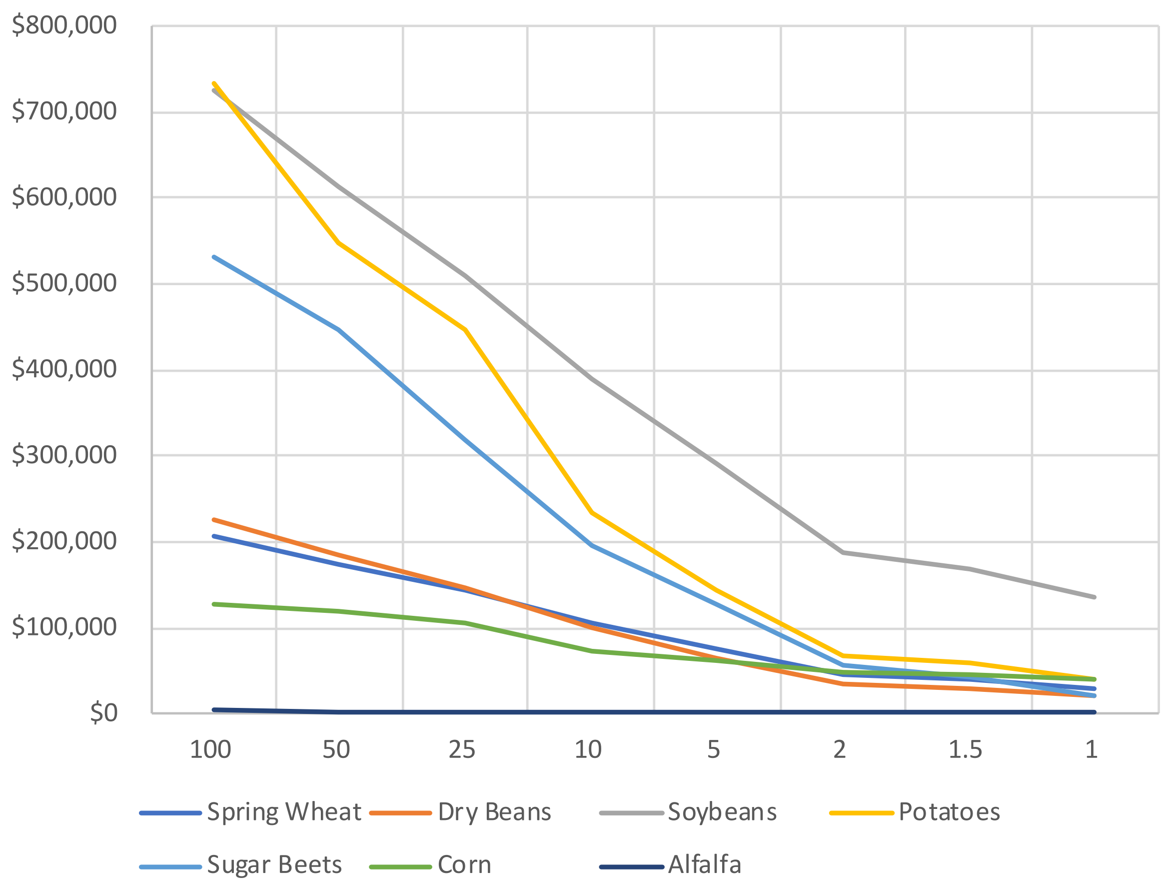


Exhibit D.4-26. Crop Damages in September under Existing Conditions - 2018 Crop Data Layer

Crop	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr	1.5-yr	1-yr
Spring Wheat	$205,657	$173,710	$142,854	$106,265	$75,963	$44,748	$39,213	$29,167
Dry Beans	225,826	184,504	147,001	100,930	63,822	35,235	30,142	20,642
Soybeans	724,078	614,043	509,203	388,859	290,312	188,202	168,907	136,971
Potatoes	732,269	546,937	446,406	235,225	142,834	69,075	58,408	39,338
Sugar Beets	532,220	447,029	319,536	196,781	127,169	55,484	42,223	22,664
Corn	128,555	119,266	106,256	74,238	61,656	47,600	44,852	39,452
Alfalfa	3,661	3,489	3,109	2,475	1,985	1,403	1,185	904
Total	**$2,552,266**	**$2,088,977**	**$1,674,364**	**$1,104,773**	**$763,741**	**$441,747**	**$384,931**	**$289,138**

Exhibit D.4-27. Crop Damages by Flood Magnitude, September



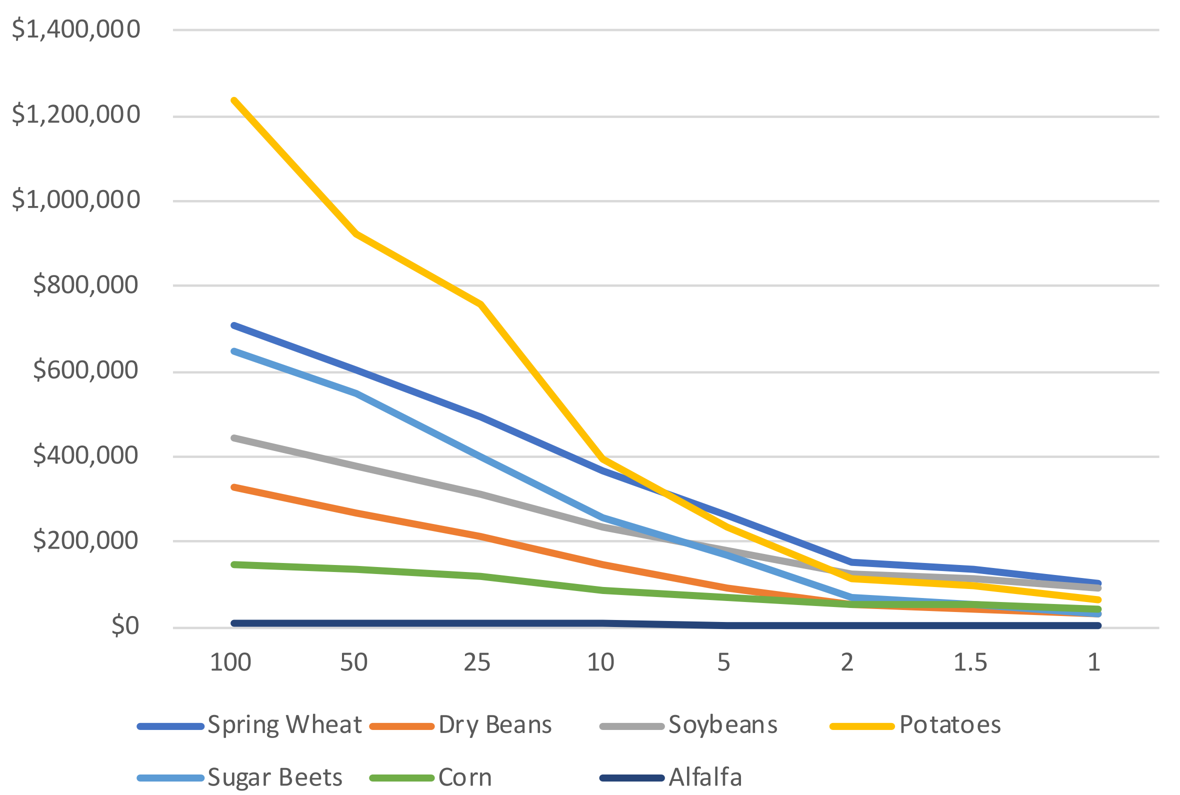
D. Weighted Average Annual Damages by Crop under Existing Conditions

The distribution of flood events among the growing season months is applied to the monthly crop damages to compute a weighted average damage for each crop. **Exhibits D.4-28** and **D.4-29** present a table and chart of the weighted average annual damage for each crop and flood event magnitude. The exhibits reveal that the value of potato damage is the largest category for the the 25 to 100-year events, followed by spring wheat and sugar beets. Damage to spring wheat is a major component of crop damage in all flood events, due chiefly to the abundance of acreage planted in spring wheat in the study area boundaries. Soybeans are also extensively planted and therefore show a relatively high level of flood damages despite relatively low crop value per acre and low flood sensitivity. The high damage to potatoes stems from the high value of potatoes combined with the crop's extreme flood sensitivity.

Exhibit D.4-28. Weighted Average Damage, by Crop - 2018 Crop Data Layer

Crop	100-yr	50-yr	25-yr	10-yr	5-yr	2-yr	1.5-yr	1-yr
Spring Wheat	$710,231	$600,441	$495,060	$364,843	$259,819	$151,719	$133,556	$101,029
Dry Beans	328,912	268,537	213,822	145,915	92,098	51,164	43,835	30,486
Soybeans	445,488	377,974	312,279	234,775	180,033	122,851	111,027	93,148
Potatoes	1,234,554	924,753	755,633	391,204	236,713	114,135	96,642	64,588
Sugar Beets	649,294	549,684	398,545	254,133	165,820	70,906	53,052	28,072
Corn	144,234	134,418	121,383	85,979	70,657	53,544	50,170	43,524
Alfalfa	10,369	9,585	7,787	6,118	4,941	3,362	2,922	2,282

Exhibit D.4-29. Crop Damage by Month and Flood Magnitude, Existing Conditions



VI. REDUCTION IN FLOOD DAMAGES UNDER THE PREFERRED ALTERNATIVE

Through the NEPA process, alternative plans were developed in accordance with NRCS guidance, and a preferred alternative, Cart Creek Site 1, was selected. The No Action, or Future Without Project (FWOP) alternative was also developed by the Sponsor in coordination with NRCS, and represents the Sponsor's most likely course of action in the absence of federal funding. Expected annual flood damages under the No Action alternative would be equivalent to the existing condition flood damages measured in this analysis.

Benefits for the project are based upon the reduction of flood damages. Flood damages were estimated under each of the two alternatives studied in detail. The difference in flood damages between the two alternatives can be considered a benefit of providing flood protection under the Preferred Alternative.

Exhibits D.4-30 and **D.4-31** present flood damages to structures and vehicles and infrastructure under the Preferred Alternative. **Exhibit D.4-32** presents flood damages to crops under the Preferred Alternative.

Exhibit D.4-30. Expected Annual Damage to Structures and Vehicles

Flood Event	Exceedance Probability	No Action		Preferred Alternative		Reduction in Flood Damages under Preferred Alternative
		Damage	Contribution to Expected Annual Damage	Damage	Contribution to Expected Annual Damage	
100	1%	$7,441,509	$74,415	$6,168,509	$61,685	$12,730
50	2%	5,262,028	63,518	2,848,838	45,087	18,431
25	4%	2,029,888	72,919	1,456,674	43,055	29,864
10	10%	1,212,240	97,264	937,860	71,836	25,428
5	20%	865,902	103,907	785,981	86,192	17,715
2	50%	454,224	198,019	438,749	183,710	14,309
1.5	67%	373,152	103,422	237,321	84,509	18,913
1	100%	85,629	57,348	84,911	40,279	17,069
Total			**$770,811**		**$616,352**	**$154,459**

Exhibit D.4-31. Expected Annual Damage to Infrastructure

Flood Event	Exceedance Probability	No Action		Preferred Alternative		Reduction in Flood Damages under Preferred Alternative
		Damage	Contribution to Expected Annual Damage	Damage	Contribution to Expected Annual Damage	
100	1%	$348,260	$3,483	$290,866	$2,909	$574
50	2%	284,603	3,164	251,740	2,713	451
25	4%	237,446	5,220	195,746	4,475	746
10	10%	147,814	11,558	122,842	9,558	2,000
5	20%	99,847	12,383	80,028	10,144	2,240
2	50%	48,865	22,307	42,828	18,428	3,878
1.5	67%	44,300	11,646	39,130	10,245	1,401
1	100%	34,791	9,886	30,937	8,758	1,128
Total			**$79,647**		**$67,229**	**$12,418**

Exhibit D.4-32. Expected Annual Crop Damage

Flood Event	Exceedance Probability	No Action		Preferred Alternative		Reduction in Flood Damages under Preferred Alternative
		Damage	Contribution to Expected Annual Damage	Damage	Contribution to Expected Annual Damage	
100	1%	$3,500,305	$35,003	$3,271,581	$32,716	$2,287
50	2%	2,885,165	31,927	2,723,804	29,977	1,950
25	4%	2,297,309	51,825	2,216,929	49,407	2,417
10	10%	1,541,737	115,171	1,449,824	110,003	5,169
5	20%	1,081,010	131,137	1,044,014	124,692	6,445
2	50%	614,725	254,360	607,184	247,680	6,681
1.5	67%	547,563	96,857	529,771	94,746	2,111
1	100%	412,667	160,038	402,947	155,453	4,585
Total			**$876,320**		**$844,674**	**$31,646**

Administrative Cost Savings to the National Flood Insurance Program (NFIP): By reducing the size of the 100-year floodplain, the Preferred Alternative would reduce the number of properties that must participate in the NFIP, which enables a savings in the administrative costs of the program. According to NRCS technical guidance based on a FEMA actuarial rate review, each policy is estimated to incur an administrative cost of $330.44 per year (**Exhibit D.4-33**) (Townsley, 2016).

The 100-year floodplains under the No Action and Preferred Alternatives were compared using ArcGIS. It was determined that the Preferred Alternative would reduce the number of tax parcels required to participate in the NFIP by 19 parcels. This reduction represents a savings in administrative costs of $6,300 per year.

Exhibit D.4-33. Estimation of Average Administrative Costs Associated with the NFIP Per Policy

Average Administrative Cost Per Policy (2015 dollars)	$308.53
GDP-Implicit Price Deflator (2019/2015)	1.071
Average Administrative Cost Per Policy (2019 dollars)	$330.44

Notes:

1. *Adapted from Townsley 2016 at: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/references/?cid=nrcs143_009725*
2. *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)*
3. *GDP-IPD 2019 Q2 data from BEA 2019. 2012 is base year.*

A summary of flood damages under each alternative is shown in **Economic Table 5** below. Benefits have been converted to their average annual equivalents using the FY 2019 project discount rate. Implementation of the Preferred Alternative would reduce flood damages by an average of $204,800 annually, or $197,800 in annual average equivalents over the 50-year life of the project.

Economic Table 5 - Estimated Average Annual Flood Damage Reduction Benefits (Dollars)[1]

Item	Estimated Average Annual Damage		Damage Reduction Benefit	Damage Reduction Benefit, Average Annual Equivalent Value[3]
	Without Project (Agriculture-Related)	With Project (Agriculture-Related)		
Floodwater[2]				
Crop and Pasture	$876,300	$844,600	$31,700	$30,600
Other Agricultural	$473,600	$378,600	$95,000	$91,600
Residential	$270,800	$225,500	$45,300	$43,700
Commercial	$4,500	$2,200	$2,300	$2,200
Institutional	$21,900	$10,100	$11,800	$11,400
Infrastructure	$79,600	$67,200	$12,400	$12,000
Subtotal	**$1,726,700**	**$1,528,200**	**$198,500**	**$191,500**
Insurance Administration Costs	$6,300	$0	$6,300	$6,300
Total	**$1,733,000**	**$1,528,200**	**$204,800**	**$197,800**

Prepared: September 2019.

[1] *Price Base 2019; 2018 normalized prices for cropland.*

[2] *Because all floodwater damages occur within rural communities; all floodwater damages are considered agriculture-related.*

[3] *Amortized for 52 years at 2.875 percent.*

VII. COSTS: PREFERRED ALTERNATIVE AND NO ACTION ALTERNATIVE

Costs are shown in **Economics Table 1**; **Economics Table 2** shows the costs by category. Total annual costs are shown in **Economics Table 4** along with the estimated costs for operation and maintenance. A 2019 price base was used and amortized at 2.875 percent interest for the 52-year period of analysis, which includes a 2-year design and installation period and 50 years of expected useful life.

Costs are allocated by the project purposes of flood control and watershed protection. In accordance with NWPM guidance, watershed protection cost-share funds are being used for this project in the absence of other available NRCS conservation programs' "ability to reduce severe problems and meet the major land treatment needs within a reasonable time frame (NWPM 500.42.D(3))." Cost-sharing under the watershed protection purpose is also available for this project because the rate of NRCS cost sharing does not exceed the rate of assistance for similar practices under other existing national programs. In addition, cropland conversions are permanent and will result in primary tree or grass cover (NWPM 500.42.D).

Economic Table 1 - Estimated Installation Cost (Dollars)[1]

Work of Improvement	Unit	Number (Non-Federal Land)	Estimated Cost[1]		
			Public Law 83-566 Funds	Other Funds	Total
Cart Creek Mutiple Purpose Structure					
FRS	No.	1	$8,412,600	$704,100	$9,116,700
Watershed Protection			$1,248,400	$1,863,600	$3,112,000
Total Project			**$9,661,000**	**$2,567,700**	**$12,228,700**

Prepared: May 2022.

[1] Price base: 2019; 2018 normalized prices for cropland.

Economic Table 4 - Estimated Average Annual National Economic Development (NED) Costs (Dollars)[1]

Works of Improvement	Project Outlays		Total
	Amortization of Installation Cost[2]	Operation, Maintenance and Replacement Cost	
Cart Creek Mutiple Purpose Structure			
FRS No. 1	$326,900	$5,000	$331,900
Watershed Protection No. 2	$111,600	$12,400	$124,000
Total	**$438,500**	**$17,400**	**$455,900**

Prepared: May 2022.

[1] Price Base 2019; 2018 normalized prices for cropland.

[2] Amortized for 52 years at 2.875 percent.

The planning costs for the proposed rehabilitation measures are estimated costs only. Detailed structural designs and construction cost estimates would be prepared prior to contracting for the work to be performed. The final cost would be the low price received by competitive bidding plus or minus the amounts of contract modifications.

Economic Table 2 - Estimated Cost Distribution, Water Resource Project Measures (Dollars)[1]

Works of Improvement	Installation Costs									Total Installation Cost
	Federal Funds[2,3,4]				Other Funds					
	Construction	Engineering Services	Conservation Easement[5]	Total Public Law 566	Construction	Real Property Rights[6]	Conservation Easement[5]	Project Admin.[7]	Total Other Funds	
Cart Creek Mutiple Purpose Structure										
FRS No. 1	$6,725,000	$1,682,000	$5,600	$8,412,600	$0	$429,500	$5,600	$269,000	$704,100	$9,116,700
Watershed Protection No. 2	$1,098,000	$148,000	$2,400	$1,248,400	$366,000	$1,495,200	$2,400	$0	$1,863,600	$3,112,000
Total	**$7,823,000**	**$1,830,000**	**$8,000**	**$9,661,000**	**$366,000**	**$1,924,700**	**$8,000**	**$269,000**	**$2,567,700**	**$12,228,700**

Prepared: May 2022.

[1] *Price Base: 2019.*

[2] *Federal cost share for FRS-related construction costs is 100%. Federal engineering services costs, as well as real property acquisition costs, are not included when calculating eligible federal cost share. Therefore, federal cost share for FRS-related construction is based on total eligible project cost of $6,725,000.*

[3] *Federal cost share for watershed protection-related conststruction costs is 75%. Federal engineering services costs and real property acquisition costs are not included when calculating eligible federal cost share. Therefore, federal cost share for watershed protection-related construction is based on total eligible project cost of $1,098,000.*

[4] *Federal cost share for conservation easement acquisition is 50%.*

[5] *Land rights required for 1) wetland mitigation for embankment, diversion channels, and spillways under the flood prevention purpose, and 2) biomass harvest area under the watershed protection purpose.*

[6] *Includes land for embankment, diversion channels and spillways.*

[7] *Includes legal and administrative costs to establish local financing and secure land rights.*

VIII. BENEFIT COST RATIO AND RATIONALE FOR PLAN SELECTION

Alternative plans were formulated in consideration of the purposes of the project and concerns expressed during the public scoping process. Formulation of the alternative plans considered four criteria: completeness, effectiveness, efficiency, and acceptability.

According to P&G (Chapter 1, Section 2), Federal investments in water resources should strive to maximize public benefits, with appropriate consideration of costs. Public benefits encompass environmental, economic, and social goals, include monetary and non-monetary effects and allow for the consideration of both quantified and unquantified measures.

The preferred alternative shall be the alternative that meets the purpose and need for the project in an environmentally acceptable manner while maximizing net monetary benefits, unless there are compelling reasons (trade-offs) based on other non-monetary ecosystem service benefits. For projects primarily providing non-monetary benefits, such as ecosystem restoration, the preferred alternative shall be the alternative that achieves the purpose and need at the least cost (NWPM, Section 501.42).

Economics Table 6 displays a comparison of annual costs and benefits for the Preferred Alternative. Benefits and costs of the No Action Alternative (which are both $0) are not presented. The No-Action Alternative could be identified as the National Economic Development (NED) Alternative, however was not selected as the Preferred Alternative because it does not provide ecosystem services benefits. The Preferred Alternative, Cart Creek Site 1, was selected based on its ability to provide flood damage reduction as well as substantial non-monetized ecosystem services benefits to the study area. While the costs exceed the benefits regarding flood damage reduction, ecosystem services benefits are substantial. Non-monetized ecosystem services benefits include wildlife habitat creation, improvements to water quality, and an incremental contribution to regional water management plans.

Economic Table 6 - Comparison of NED Benefits and Costs (Dollars)[1]

Works of Improvement	Total Average Annual Agricultural Related Benefits[2,3]	Average Annual Costs[4]	Benefit Cost Ratio[5]
Cart Creek Mutiple Purpose Structure			
FRS No. 1	$197,800	$331,900	0.6 to 1.0
Watershed Protection No. 2	n/a	$124,000	n/a
Total	**$197,800**	**$455,900**	0.4 to 1.0

Prepared: May 2022.

[1] *Price Base 2019; 2018 normalized prices for cropland.*

[2] *Because all floodwater damage occurs within rural communities, all damages are considered agricultural-related.*

[3] *Benefits related to watershed protection are presented qualitatively in the Watershed Plan EA, and consist of water quality improvements and wildlife habitat.*

[4] *From Table 4.*

[5] *See Watershed Plan EA Rationale for Plan Section. Unquantified benefits for the project include watershed protection, and an incremental contribution to the Red River of the North Comprehensive Watershed Management Plan goal of a 20% reduction in peak flows on the Red River (USACE 2018).*

In comparing the Preferred Alternative and the No Action Alternative (NED plan), the Preferred Alternative has an increase in net benefits associated with the non-NED accounts greater than the reduction in net benefits associated with the NED account. The preferred alternative has been granted an exception based on its beneficial contribution to the Environmental Quality account (see **Appendix D**-7).

IX. RISK AND UNCERTAINTY

The areas of risk and uncertainty associated with the economic analysis include uncertainty associated with simplifying assumptions used to estimate benefits. The use of input assumptions supported by published data, aerial photography review, field verification, and interviews with local experts reduces the level of uncertainty to the extent possible.

Uncertainty is also present due to damages not captured within the analysis (e.g., erosion and sediment deposition on farmlands for which inadequate data was present to link to the inundation mapping). However, the impacts of the uncertainty are to a considerable degree mitigated by the fact that the same assumptions are applied for each alternative.

Uncertainty is present in relation to future changes in cost estimates as engineering design progresses. Costs can be influenced by several economic factors that cannot be predicted with certainty during the planning process. Fuel shortages, unforeseen labor and materials shortages, natural disasters, and international incidents can adversely affect costs and construction schedules.

This Plan-EA is based on a 52-year period of analysis, including a 50-year evaluated life, and two year implementation period. The life expectancy of the structure is expected to meet the minimum requirements of the evaluation period, but it has not been confirmed that the structure would last for a longer period. As the service life is extended, there is an increased risk that assumptions and conditions will be different than predicted.

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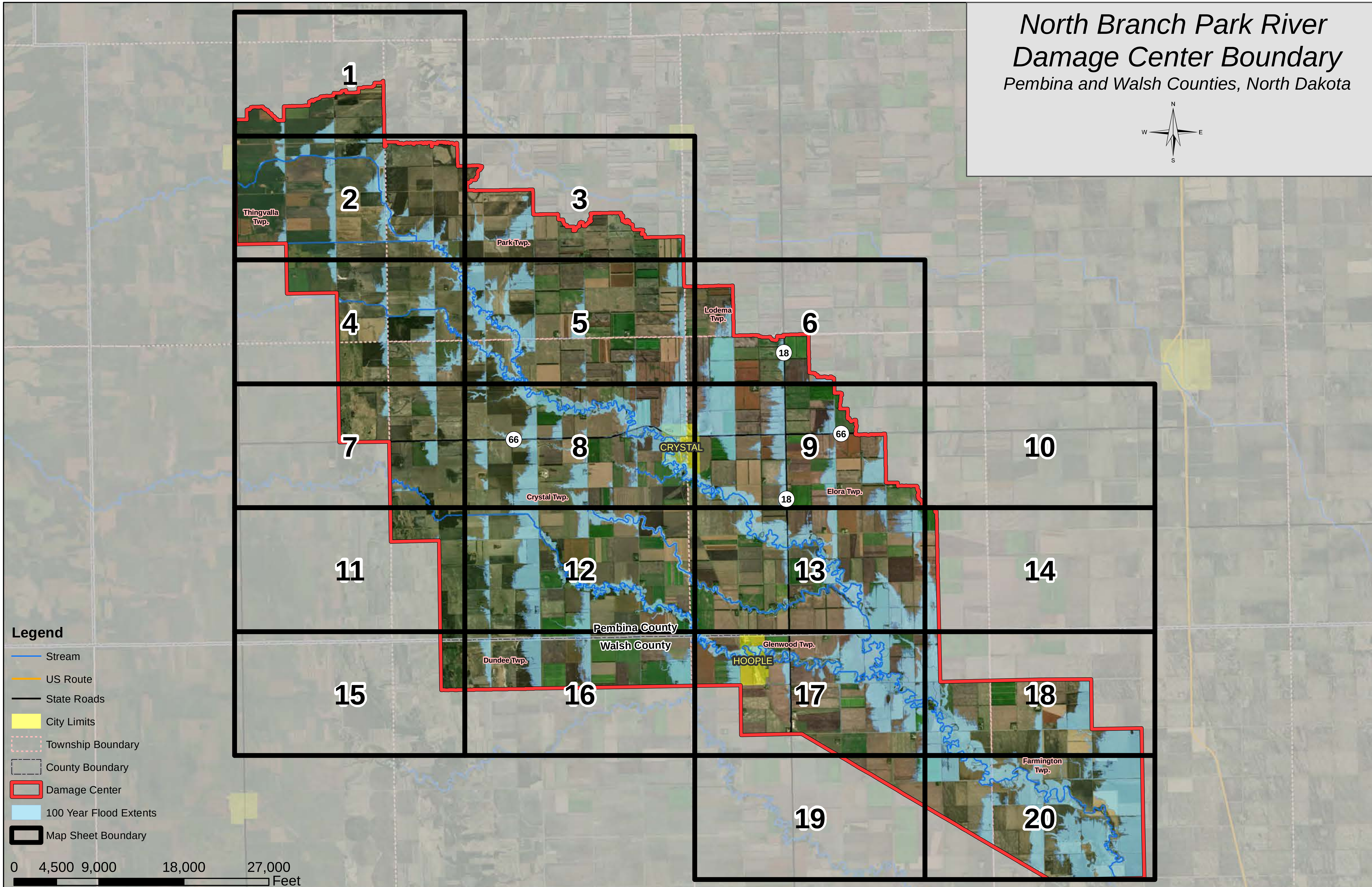
Appendix A

Damage Center Boundary and Flood Extents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Damage Center Boundary
Pembina and Walsh Counties, North Dakota
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Farmington Twp.
CRYSTAL
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Pembina County
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Legend
Stream
US Route
State Roads
City Limits
Township Boundary
County Boundary
Damage Center
100 Year Flood Extents
Map Sheet Boundary
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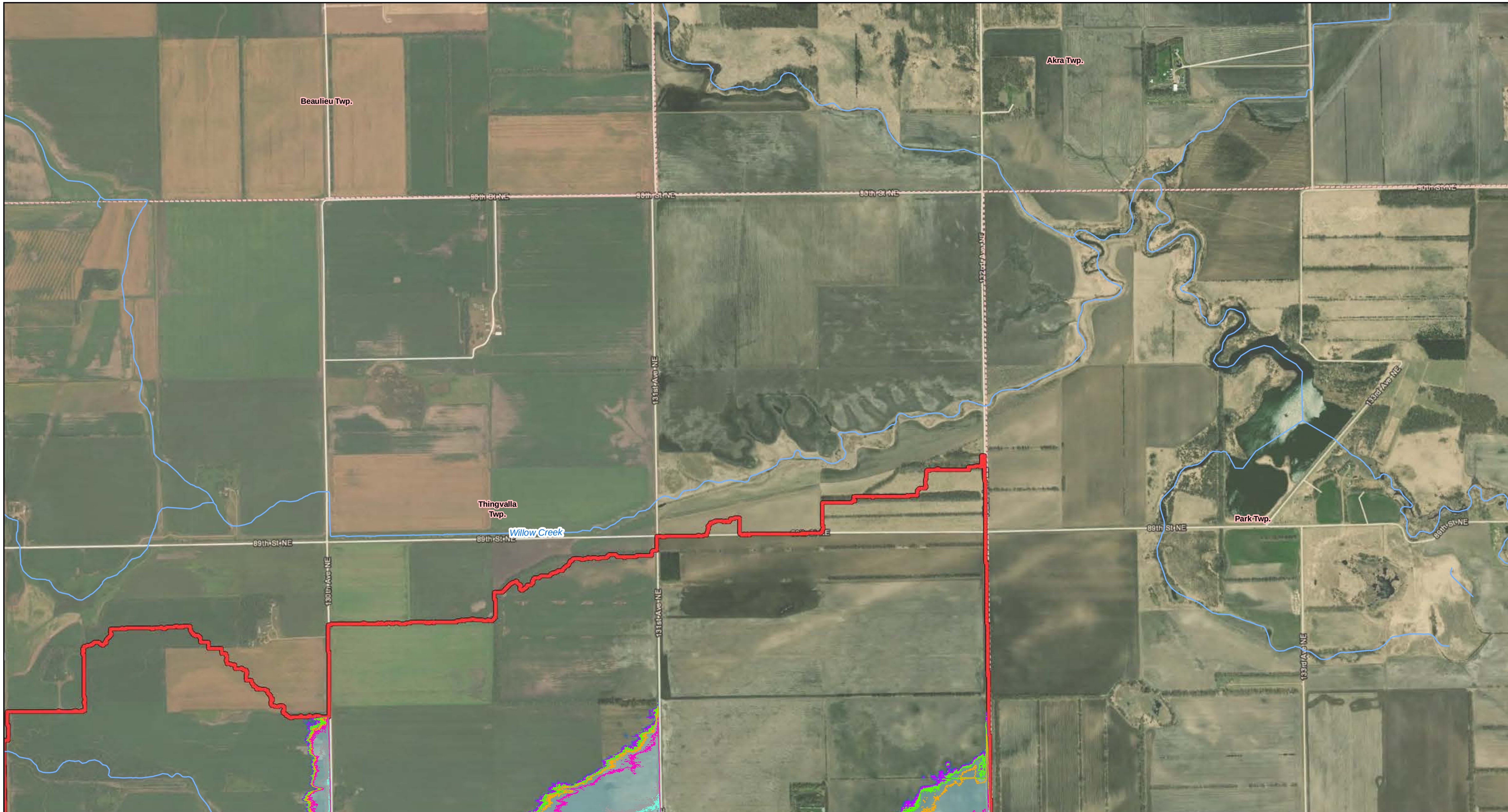

North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

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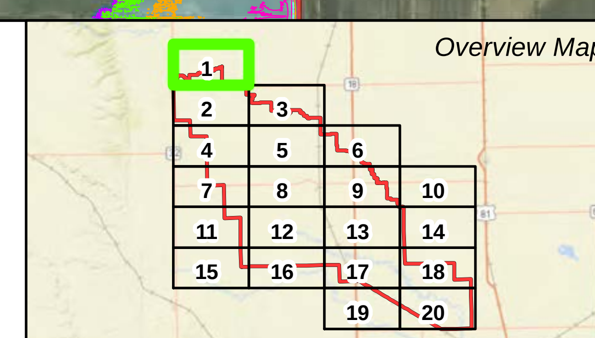
Legend

- NHD Streams
- 1 Year Flood Extents
- 1.5 Year Flood Extents
- 2 Year Flood Extents
- 5 Year Flood Extents
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center



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North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

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Legend

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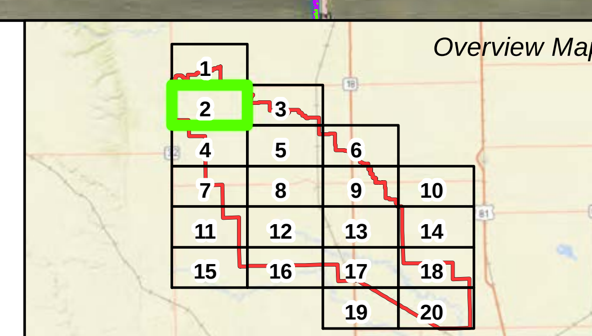

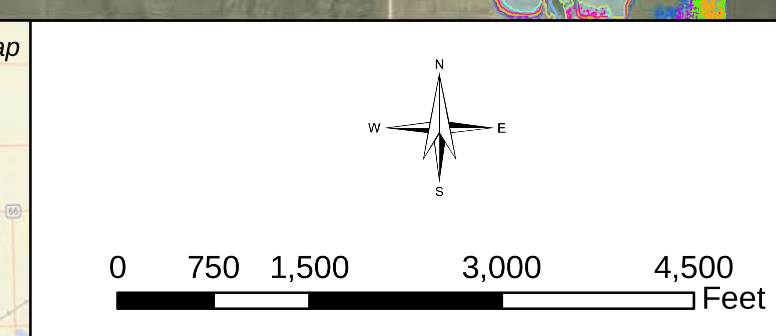

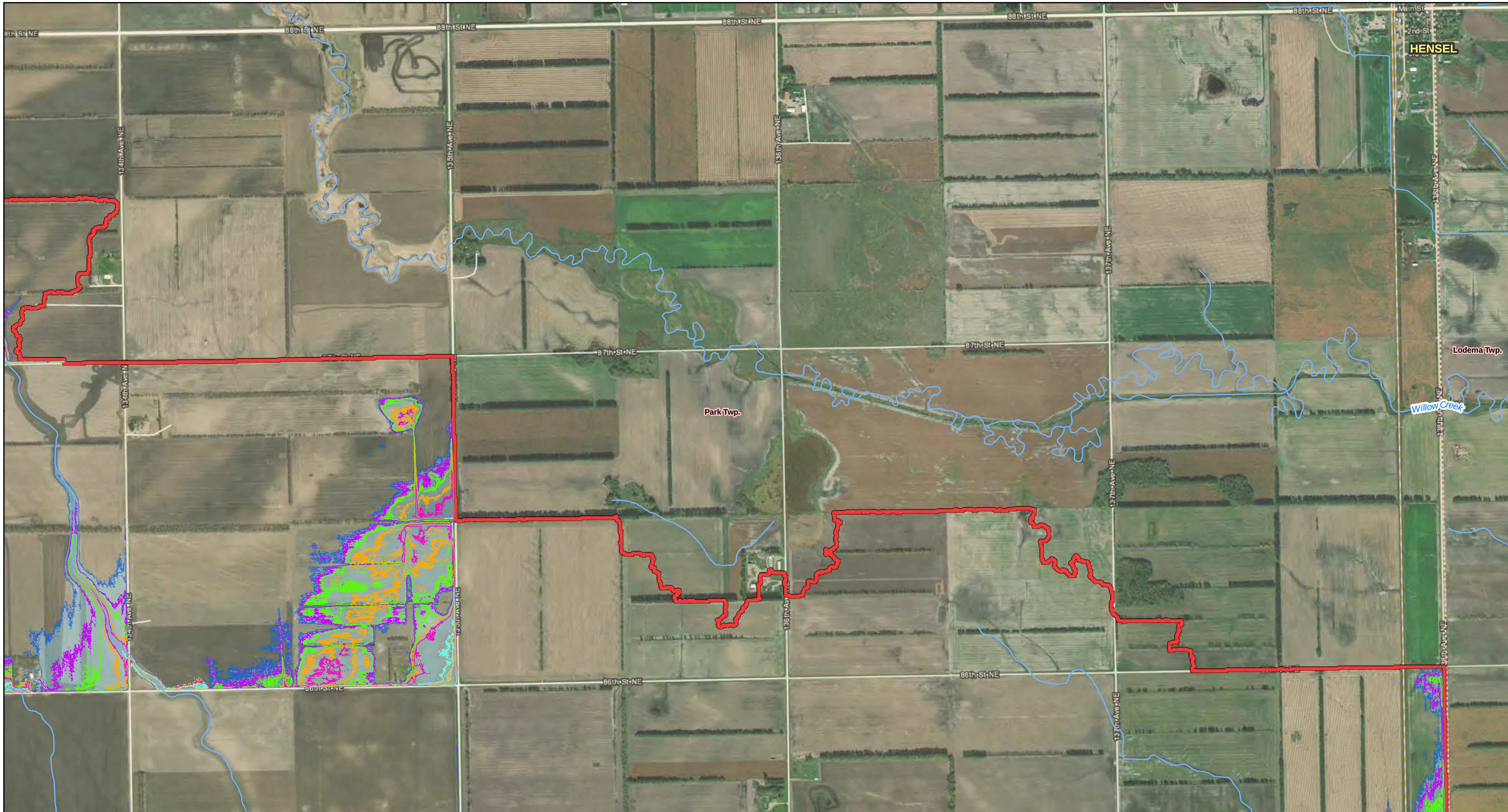

North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

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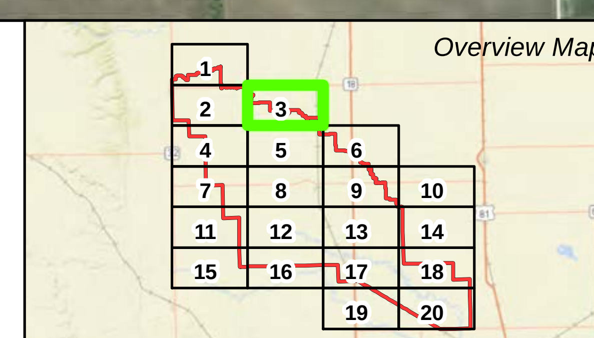
Overview Map



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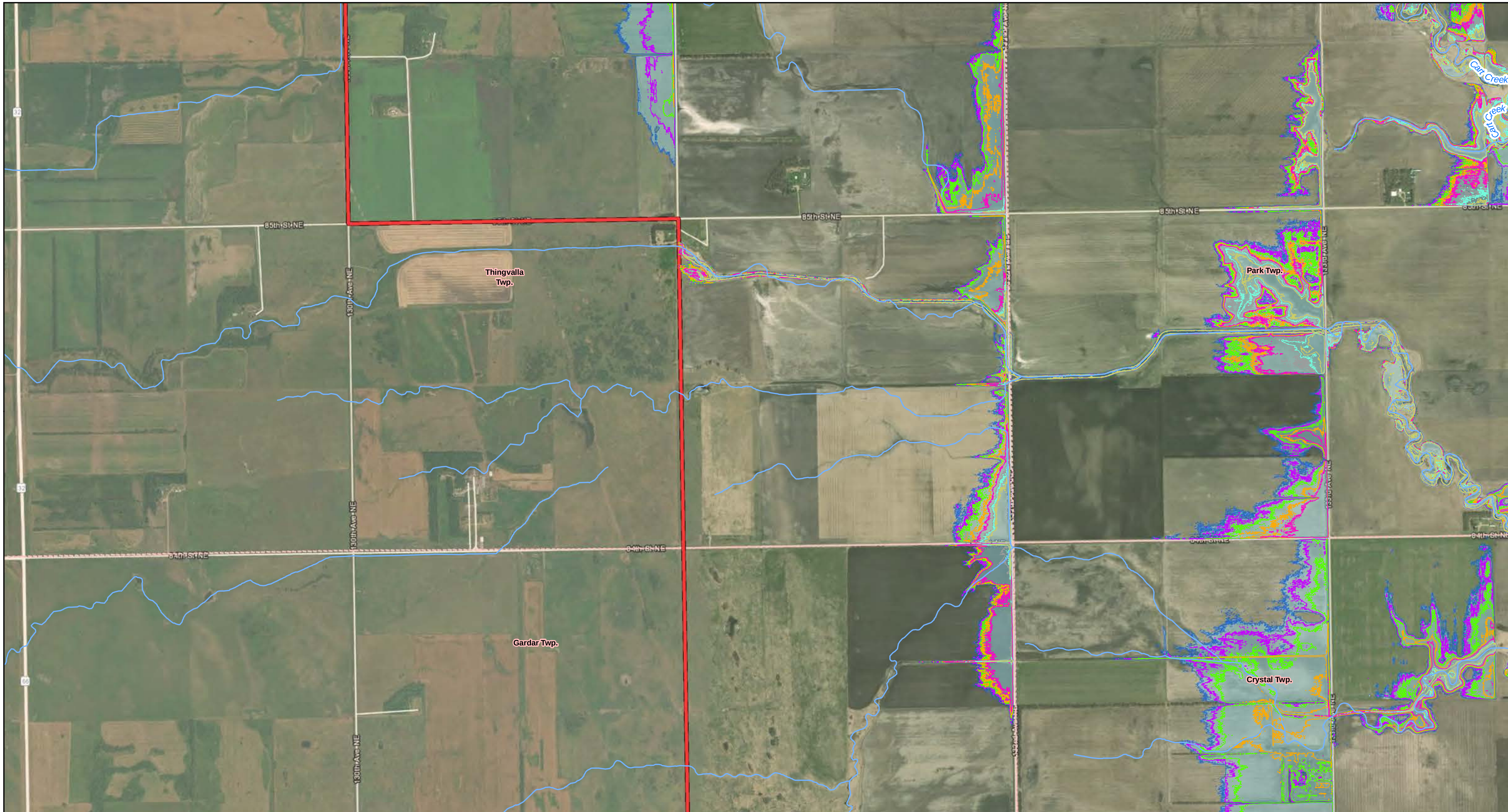

North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

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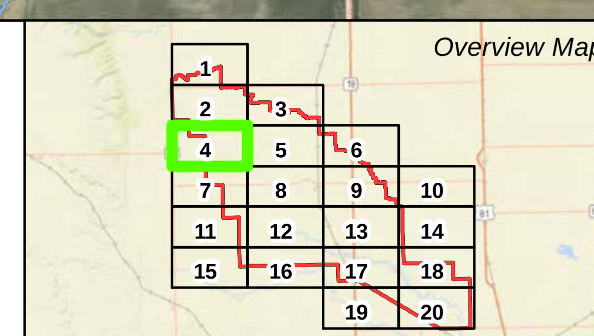

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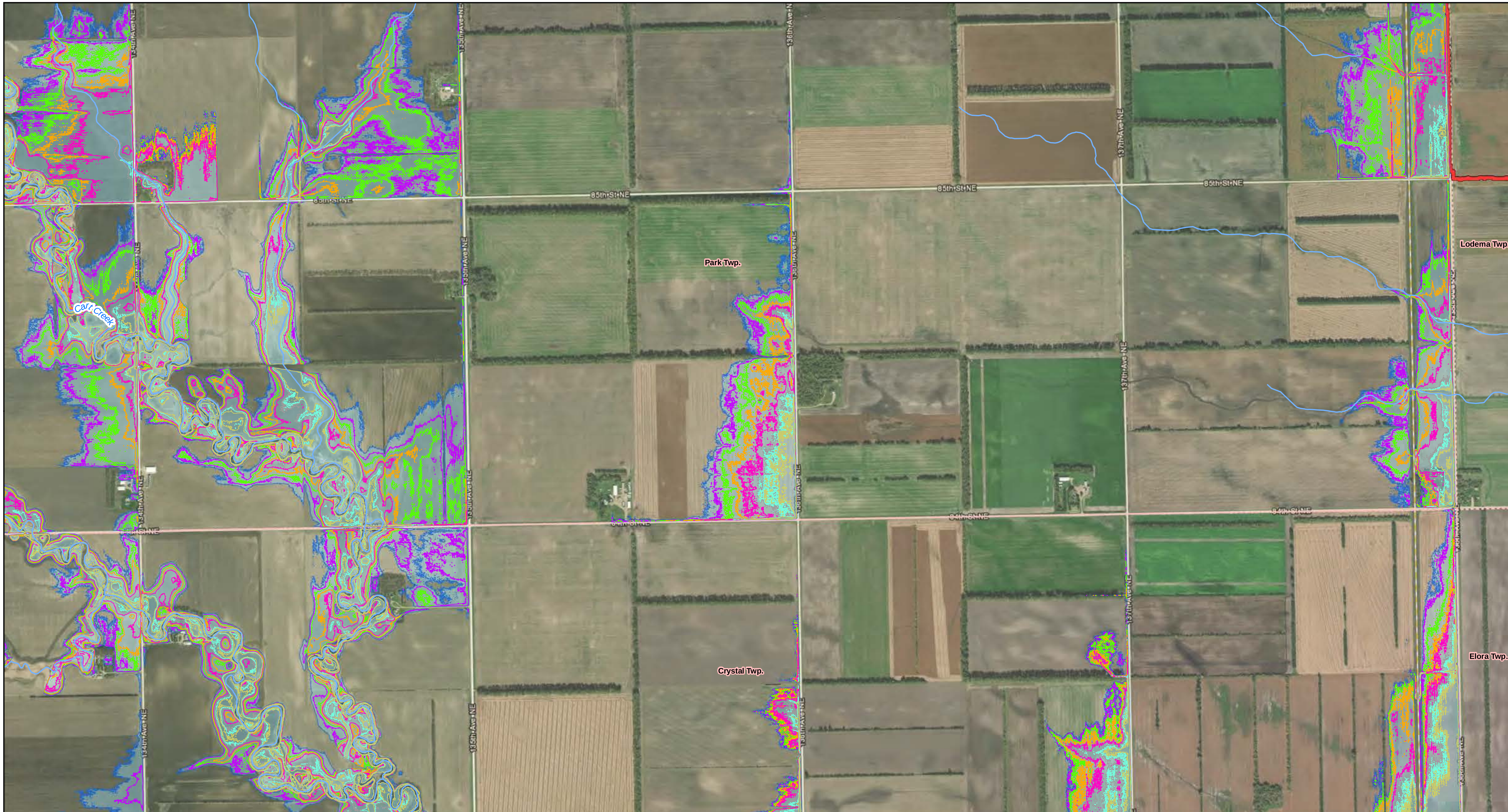

North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

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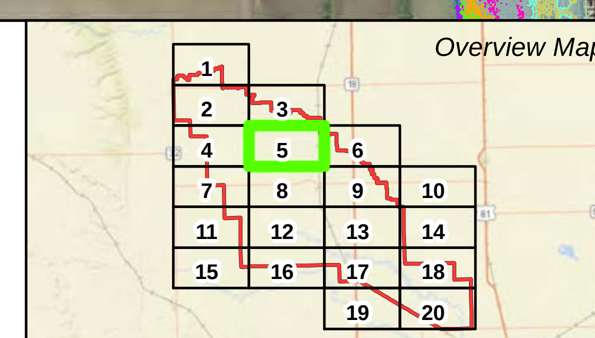

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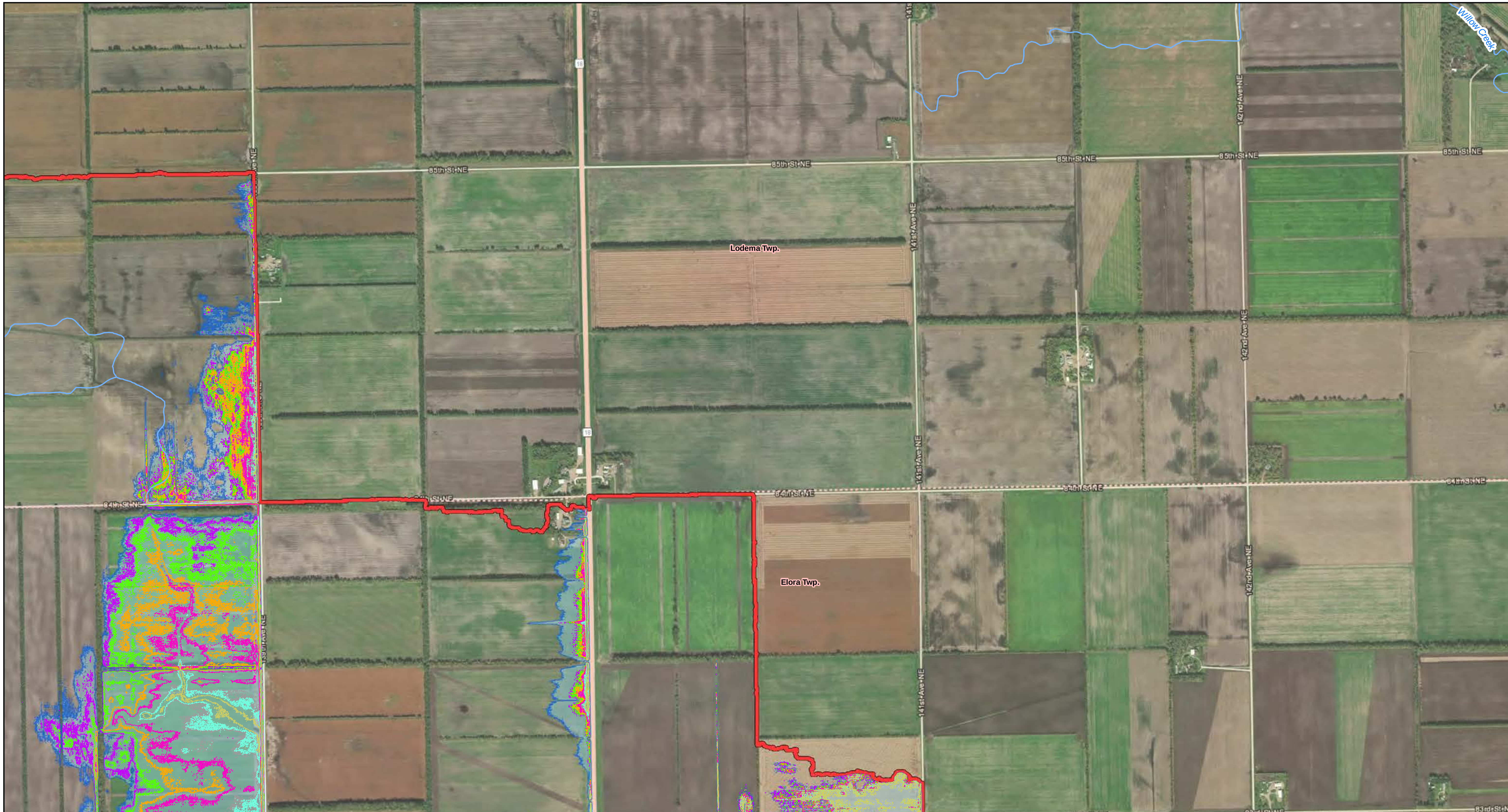

North Branch Park River
Flood Extents

Pembina and Walsh Counties, North Dakota

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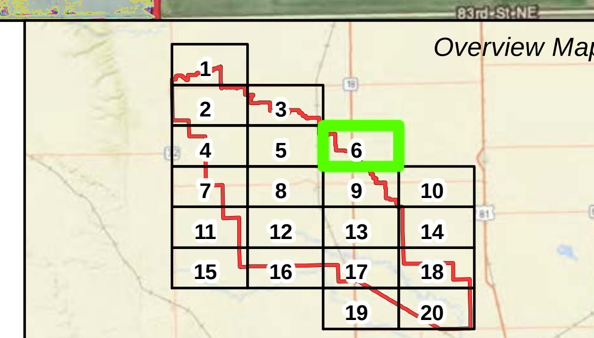

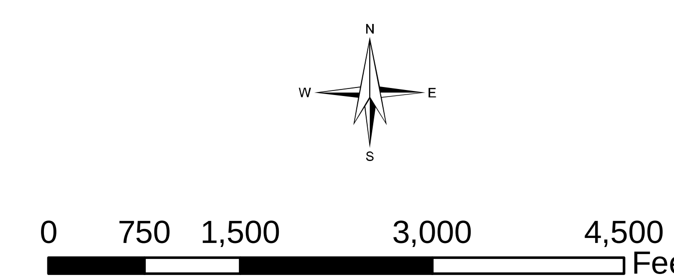

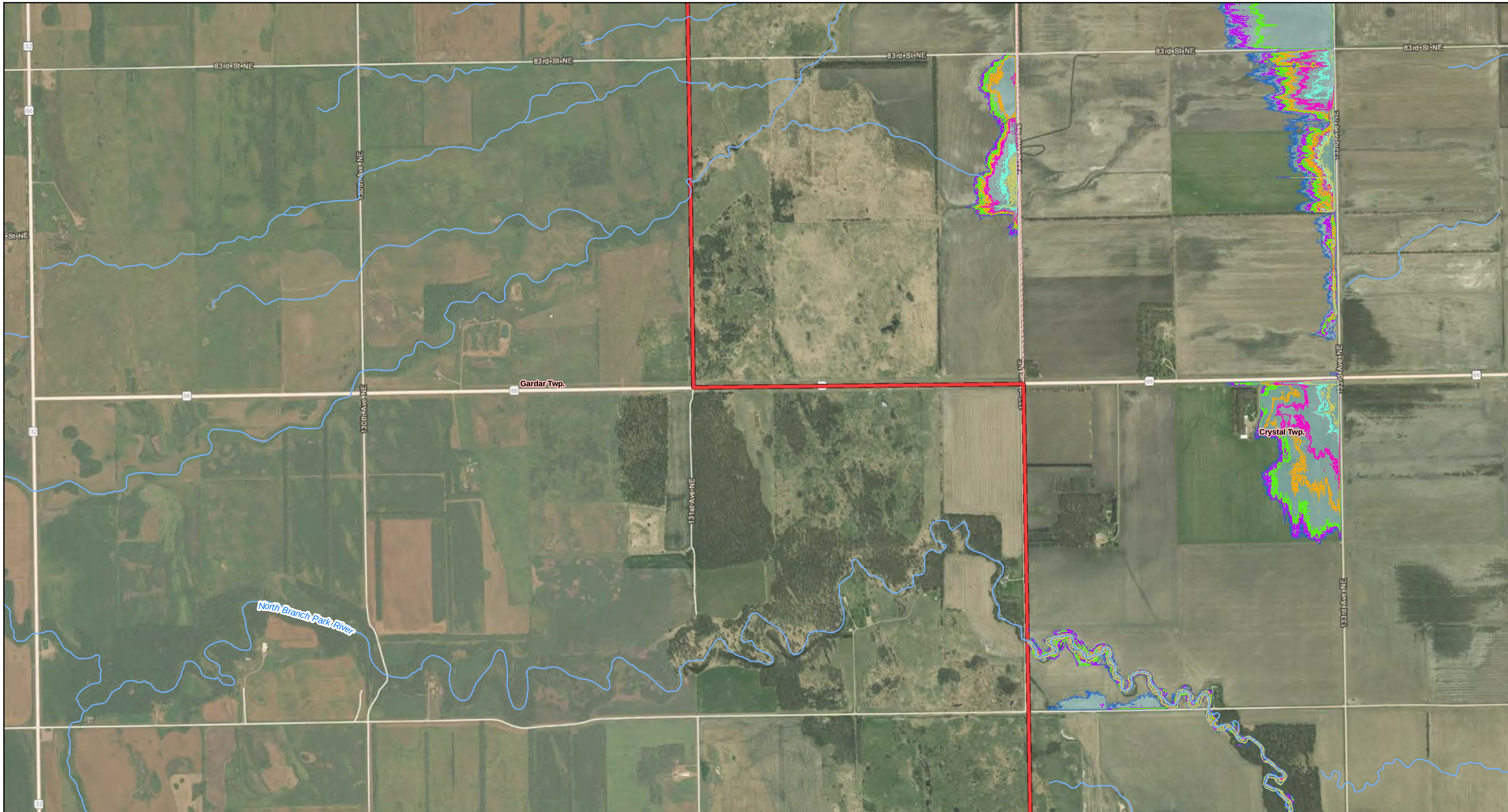

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Pembina and Walsh Counties, North Dakota

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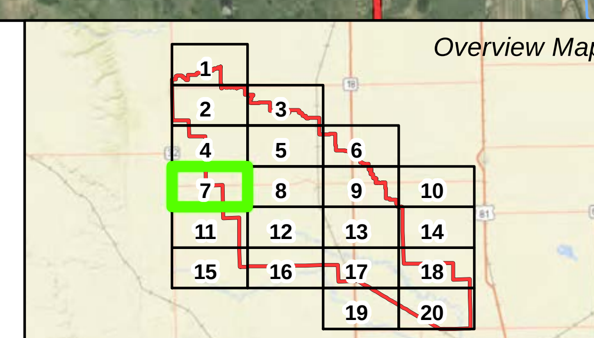

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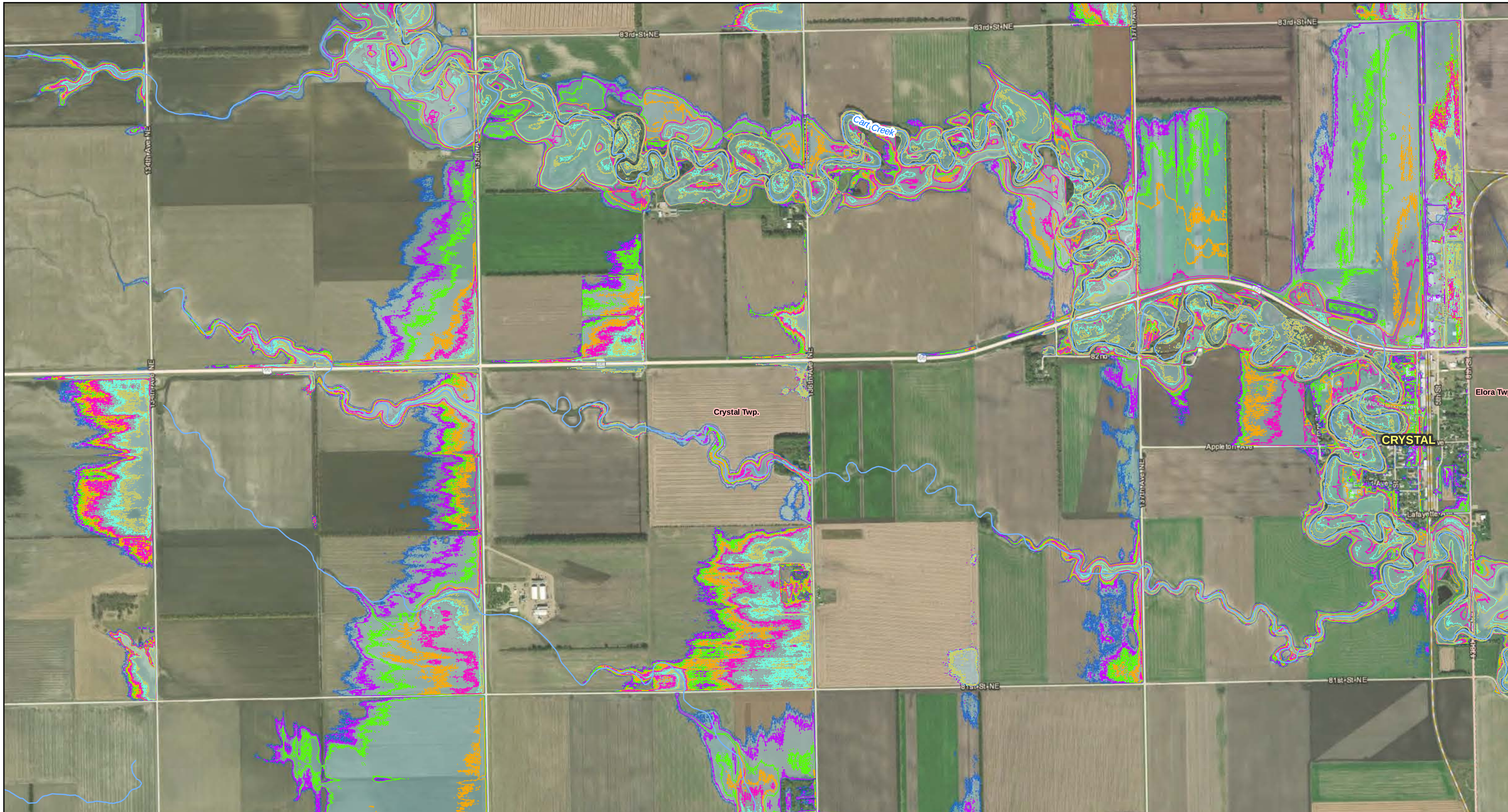

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Pembina and Walsh Counties, North Dakota

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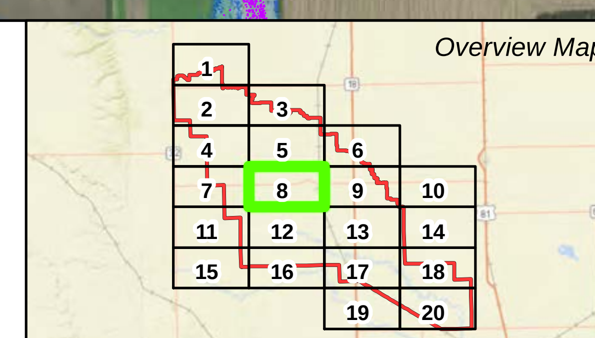
Overview Map



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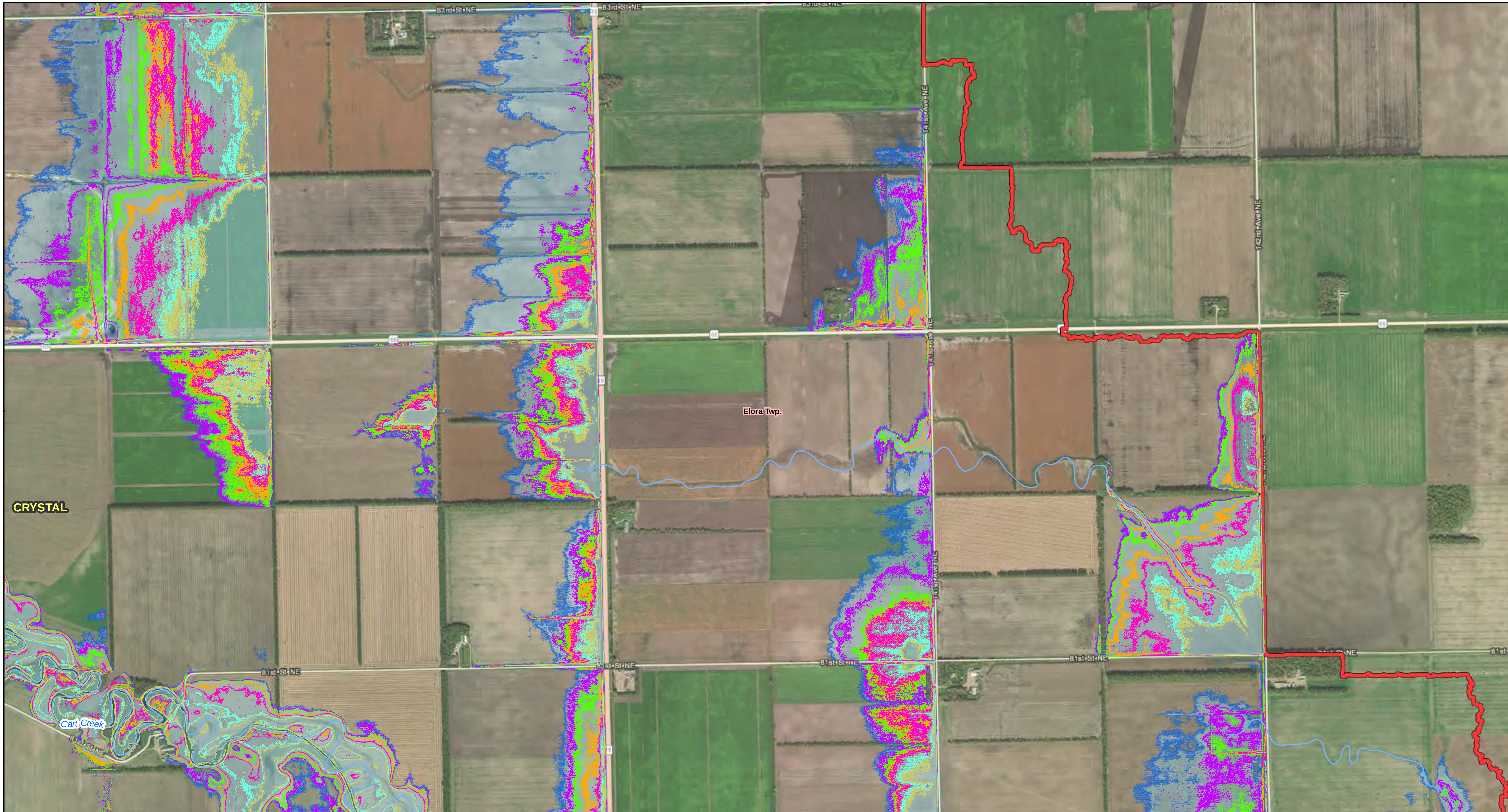

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Pembina and Walsh Counties, North Dakota

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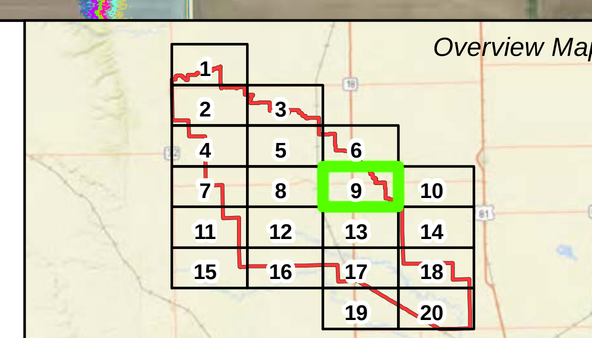

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North Branch Park River
Flood Extents
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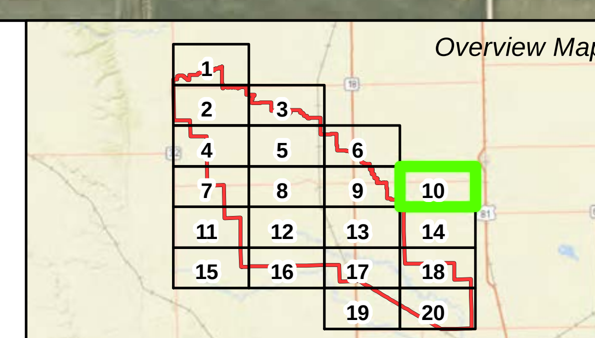

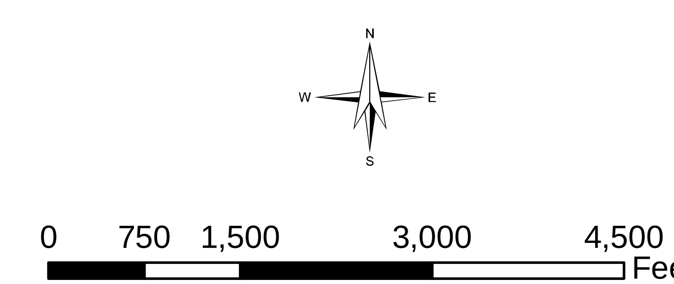

North Branch Park River Flood Extents

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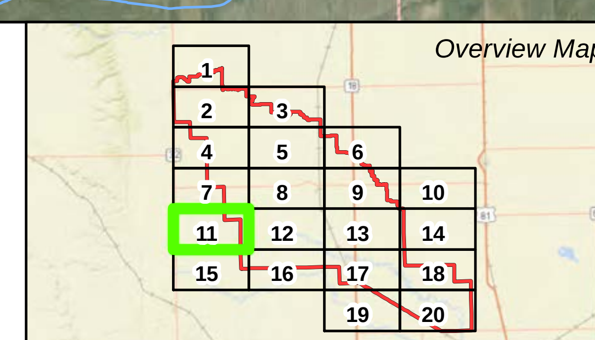
- Counties
- Damage Center



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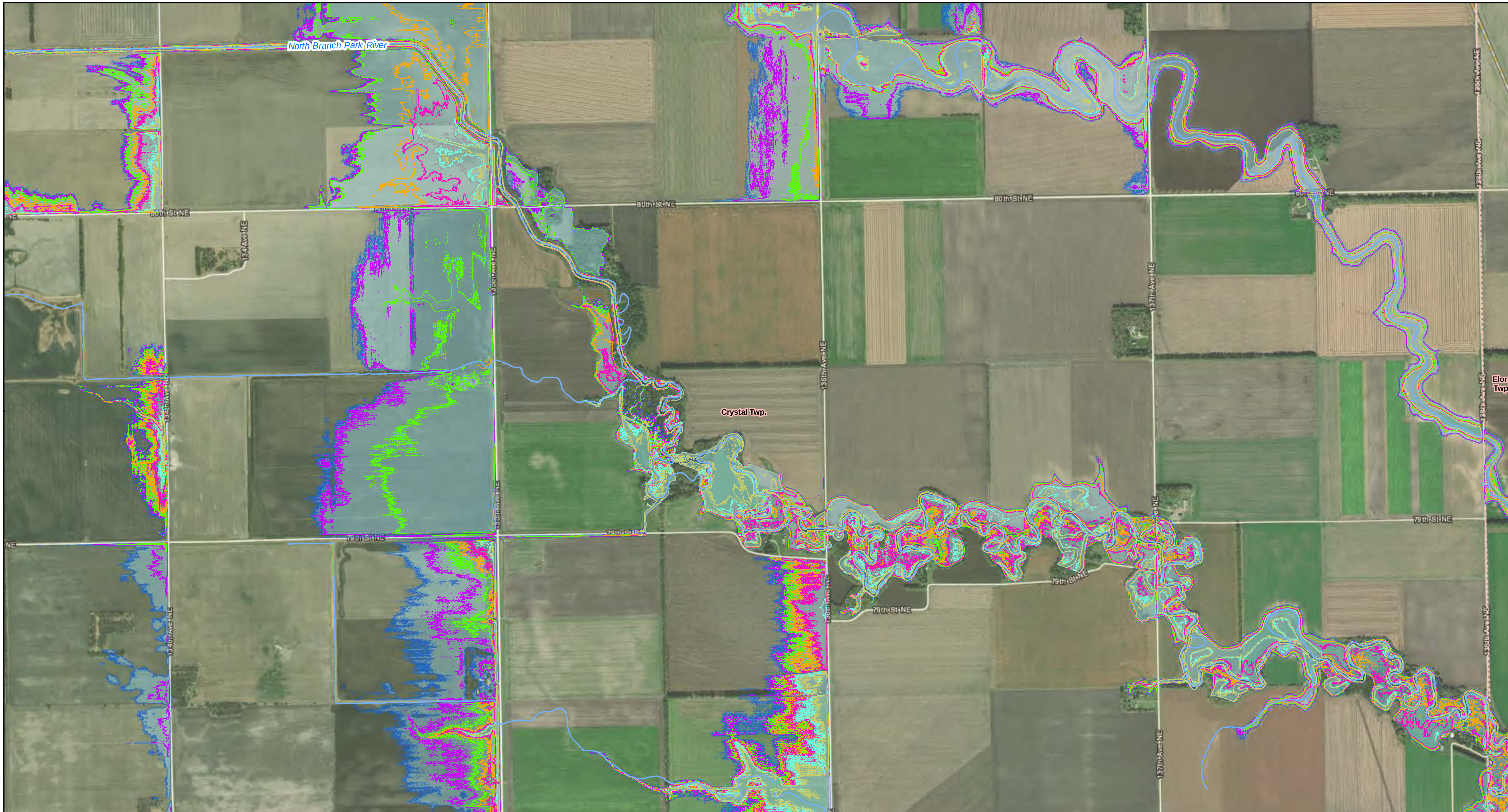


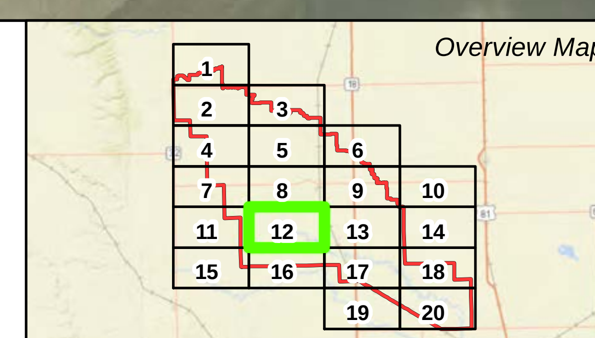
North Branch Park River
Flood Extents

Pembina and Walsh Counties, North Dakota

Sheet 12 of 20

Legend

- NHD Streams
- 1 Year Flood Extents
- 1.5 Year Flood Extents
- 2 Year Flood Extents
- 5 Year Flood Extents
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center



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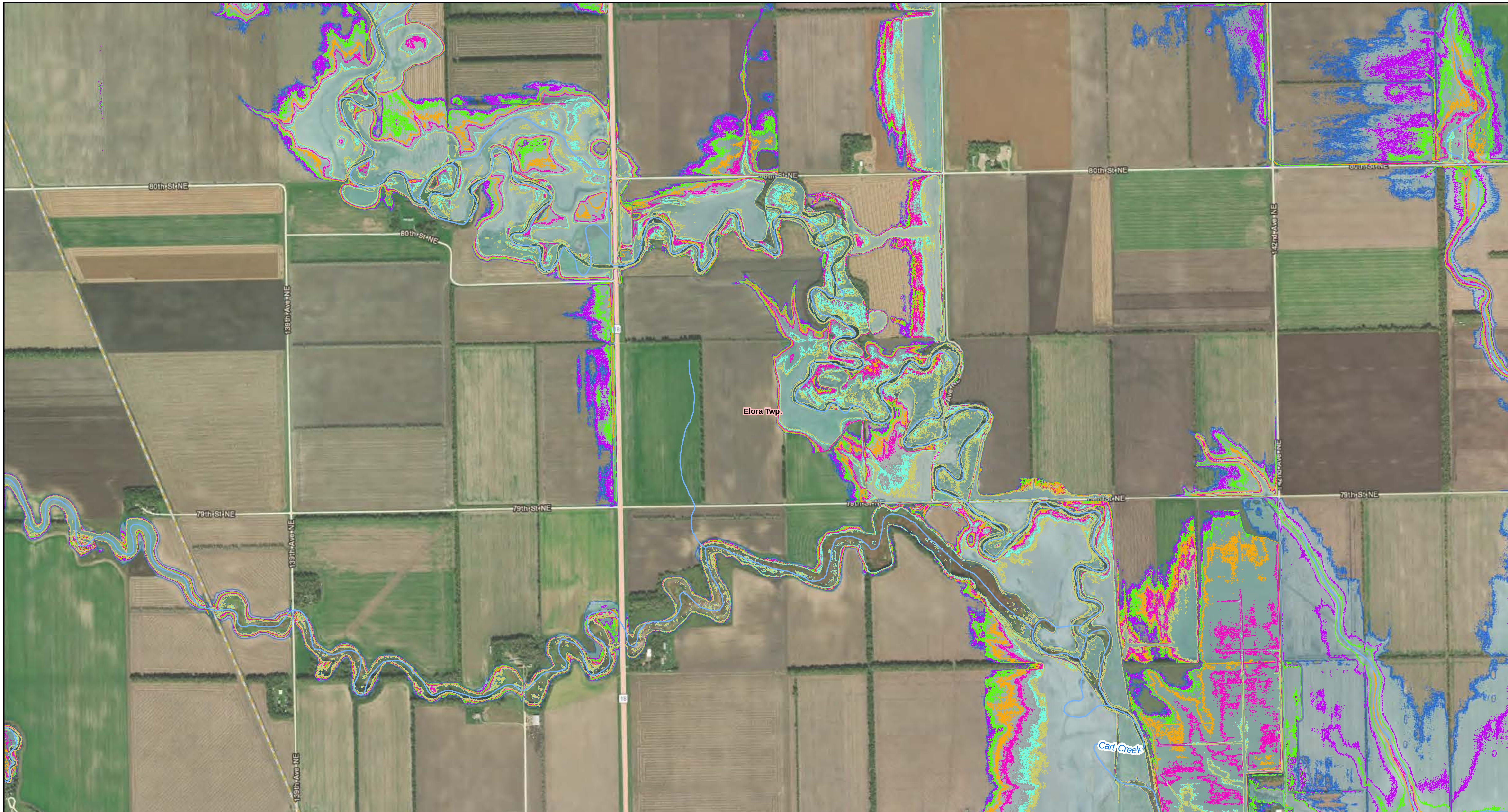


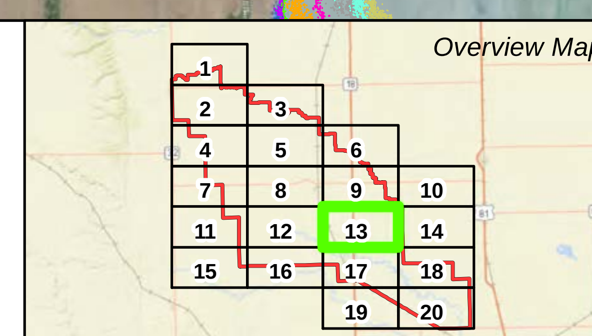
North Branch Park River Flood Extents

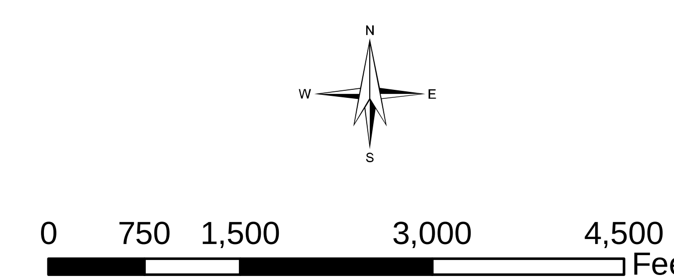
Pembina and Walsh Counties, North Dakota

Sheet 13 of 20

Legend

- NHD Streams
- 1 Year Flood Extents
- 1.5 Year Flood Extents
- 2 Year Flood Extents
- 5 Year Flood Extents
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center





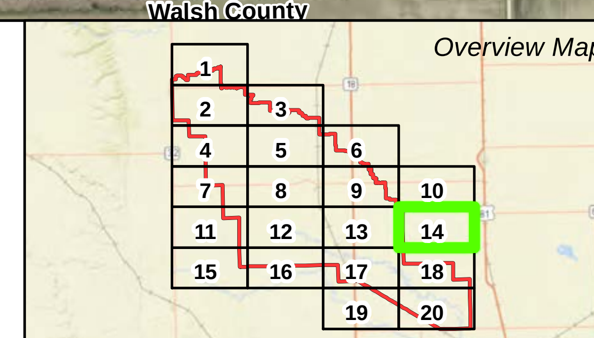
North Branch Park River Flood Extents

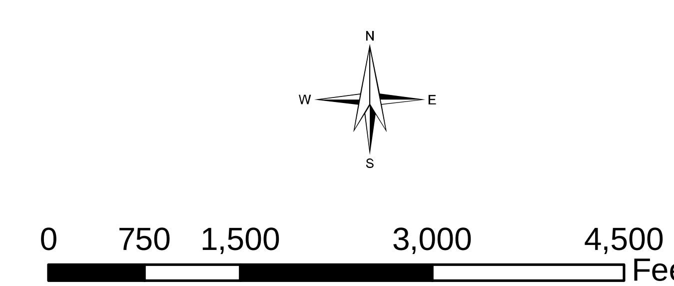
Pembina and Walsh Counties, North Dakota

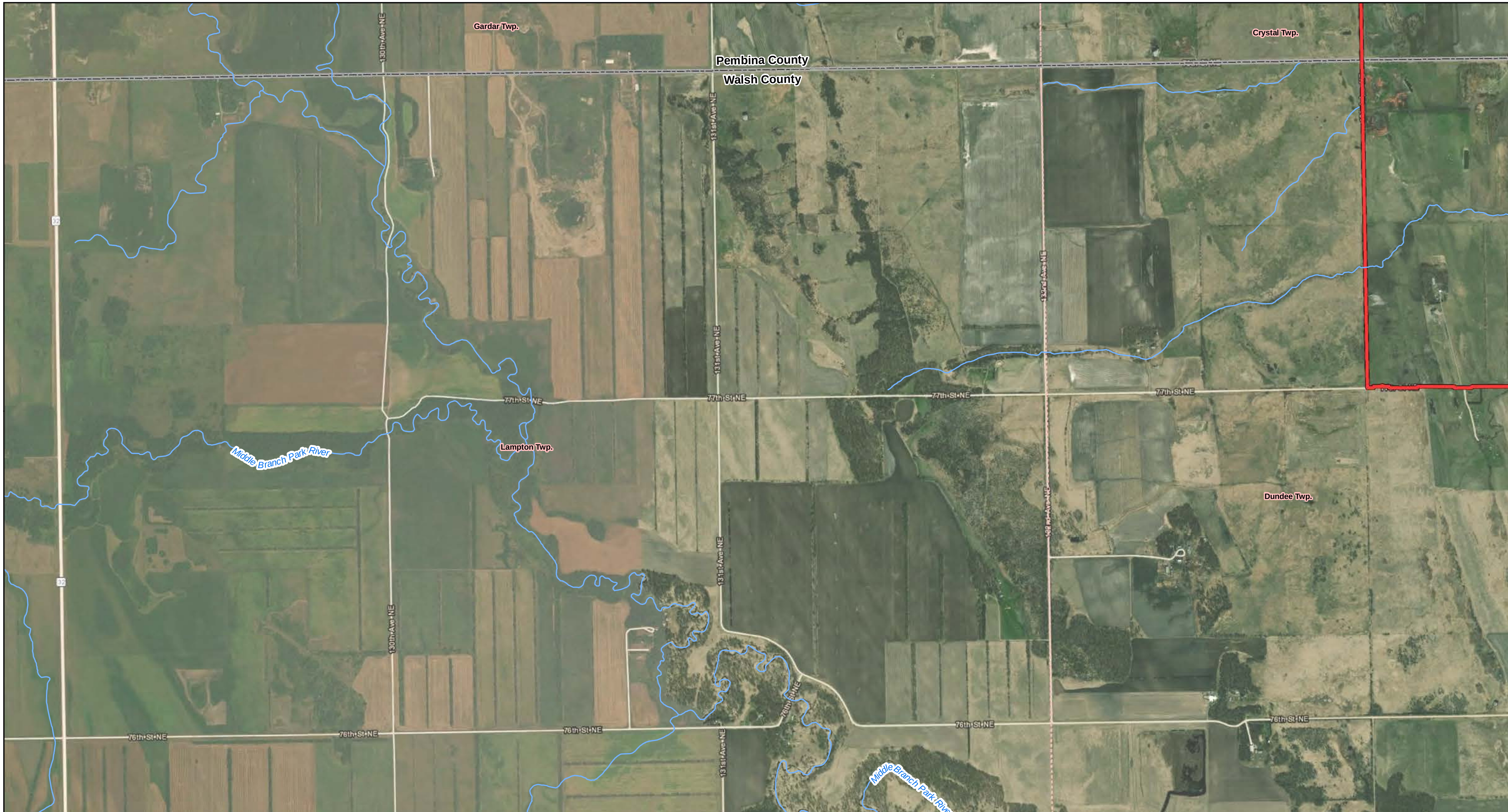
Sheet 14 of 20

Legend

- NHD Streams
- 1 Year Flood Extents
- 1.5 Year Flood Extents
- 2 Year Flood Extents
- 5 Year Flood Extents
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center







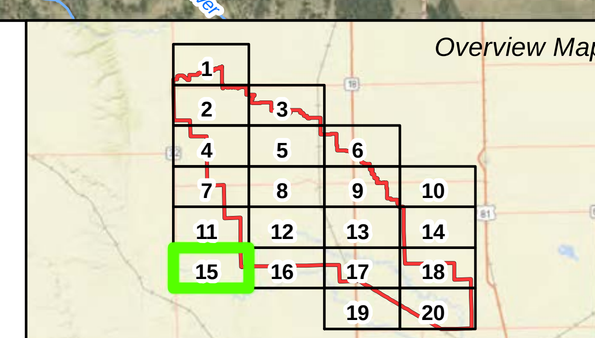
North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

Sheet 15 of 20

Legend

- NHD Streams
- Townships
- Counties
- Damage Center



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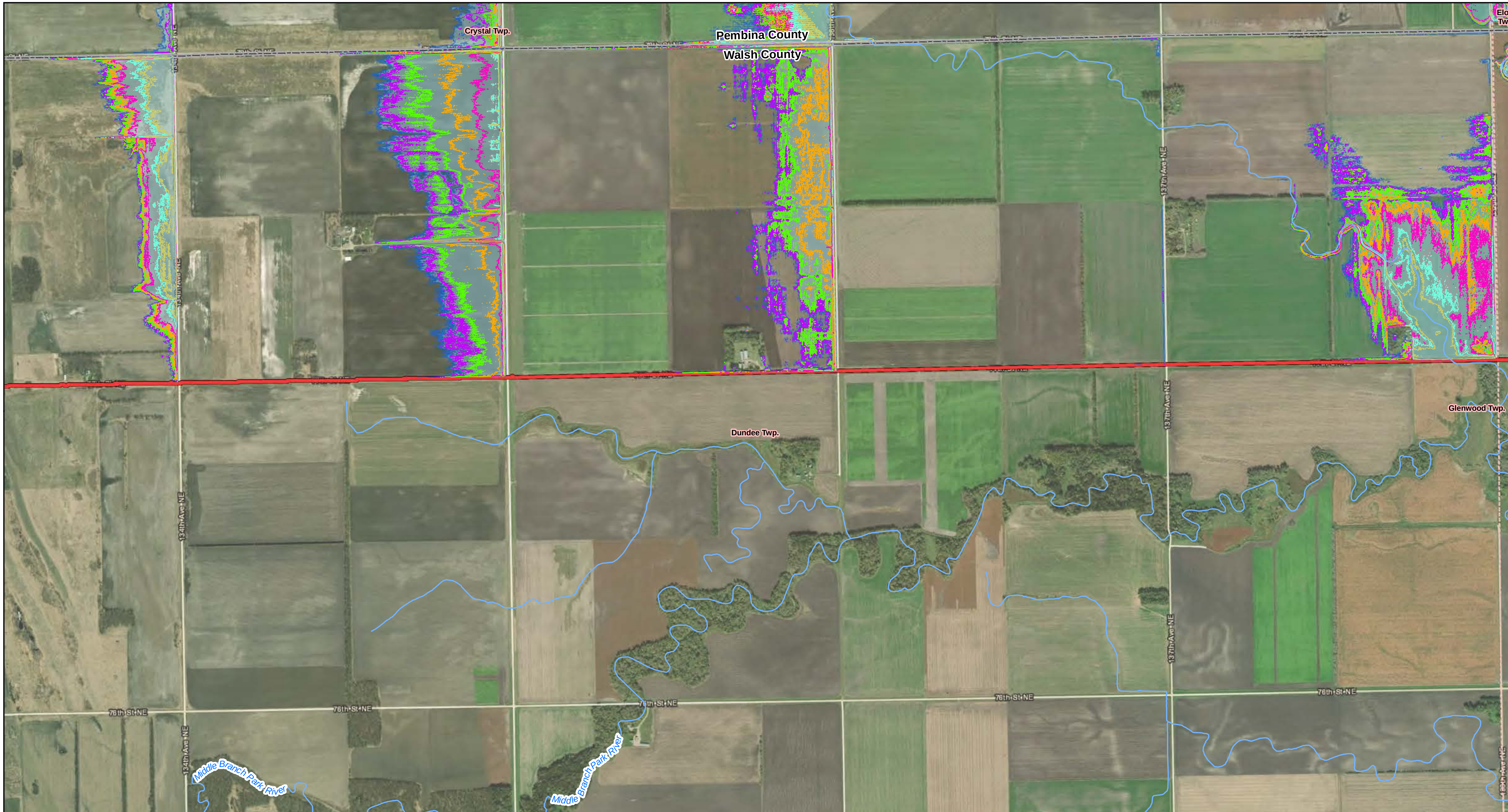


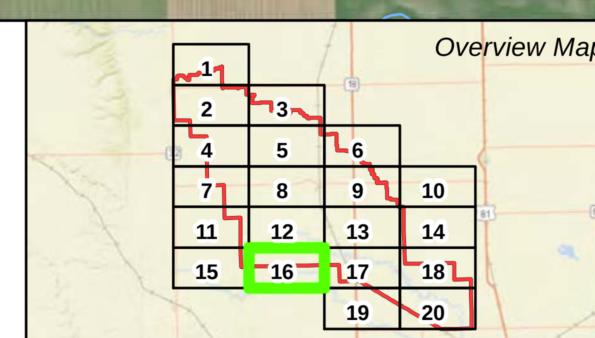
North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

Sheet 16 of 20

Legend

- NHD Streams
- 1 Year Flood Extents
- 1.5 Year Flood Extents
- 2 Year Flood Extents
- 5 Year Flood Extents
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center



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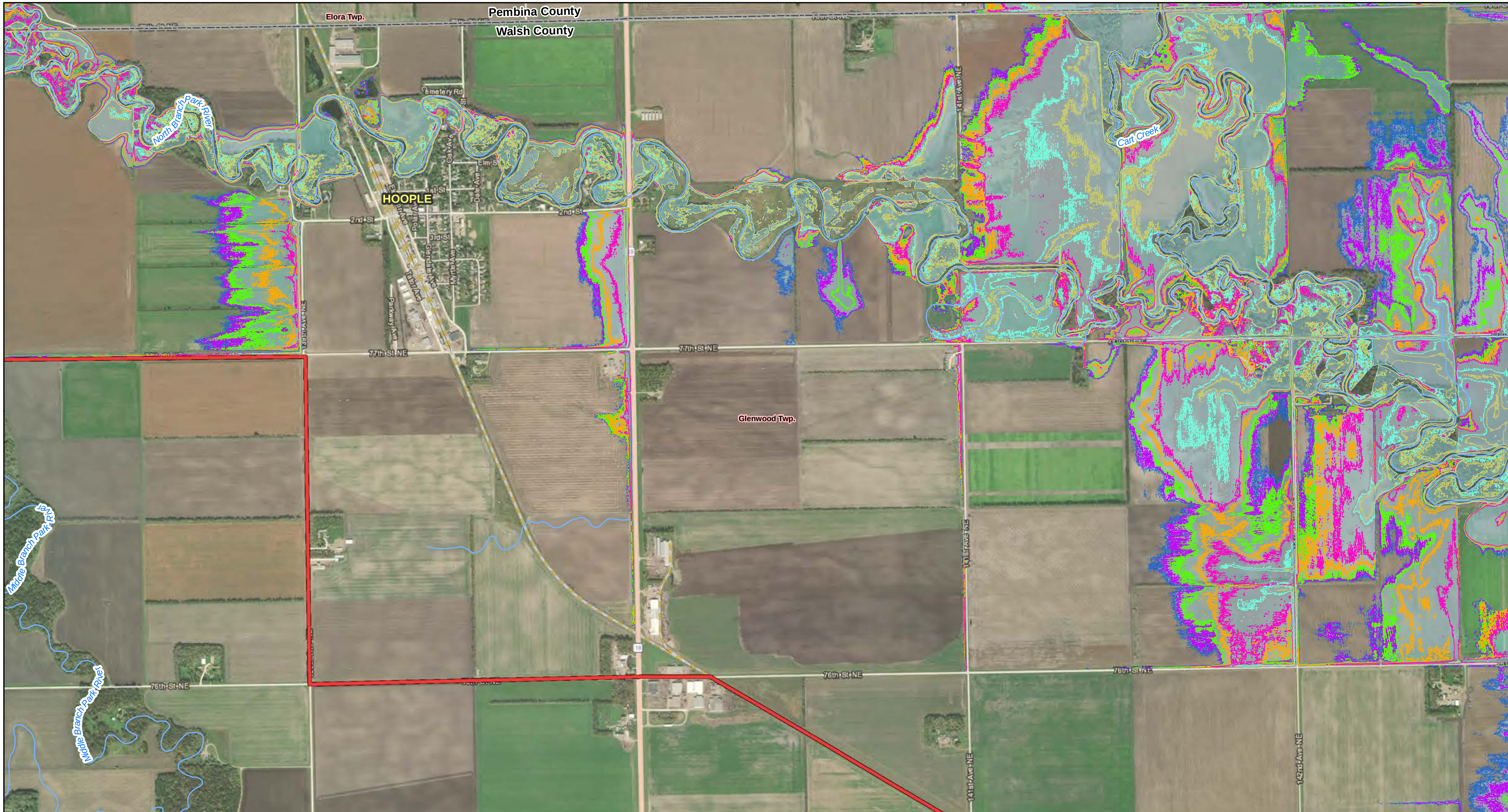


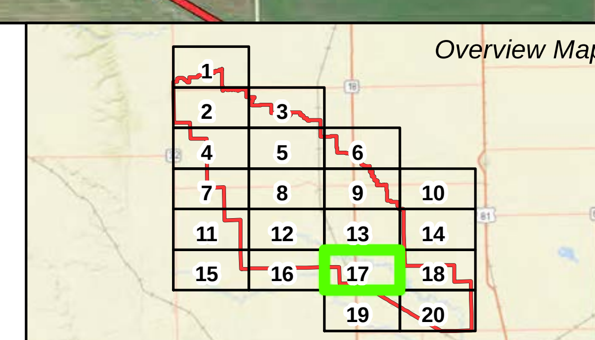
North Branch Park River
Flood Extents

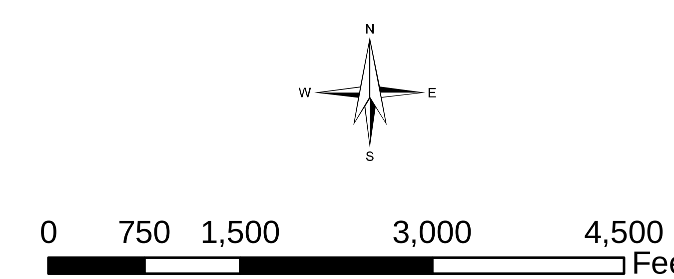
Pembina and Walsh Counties, North Dakota

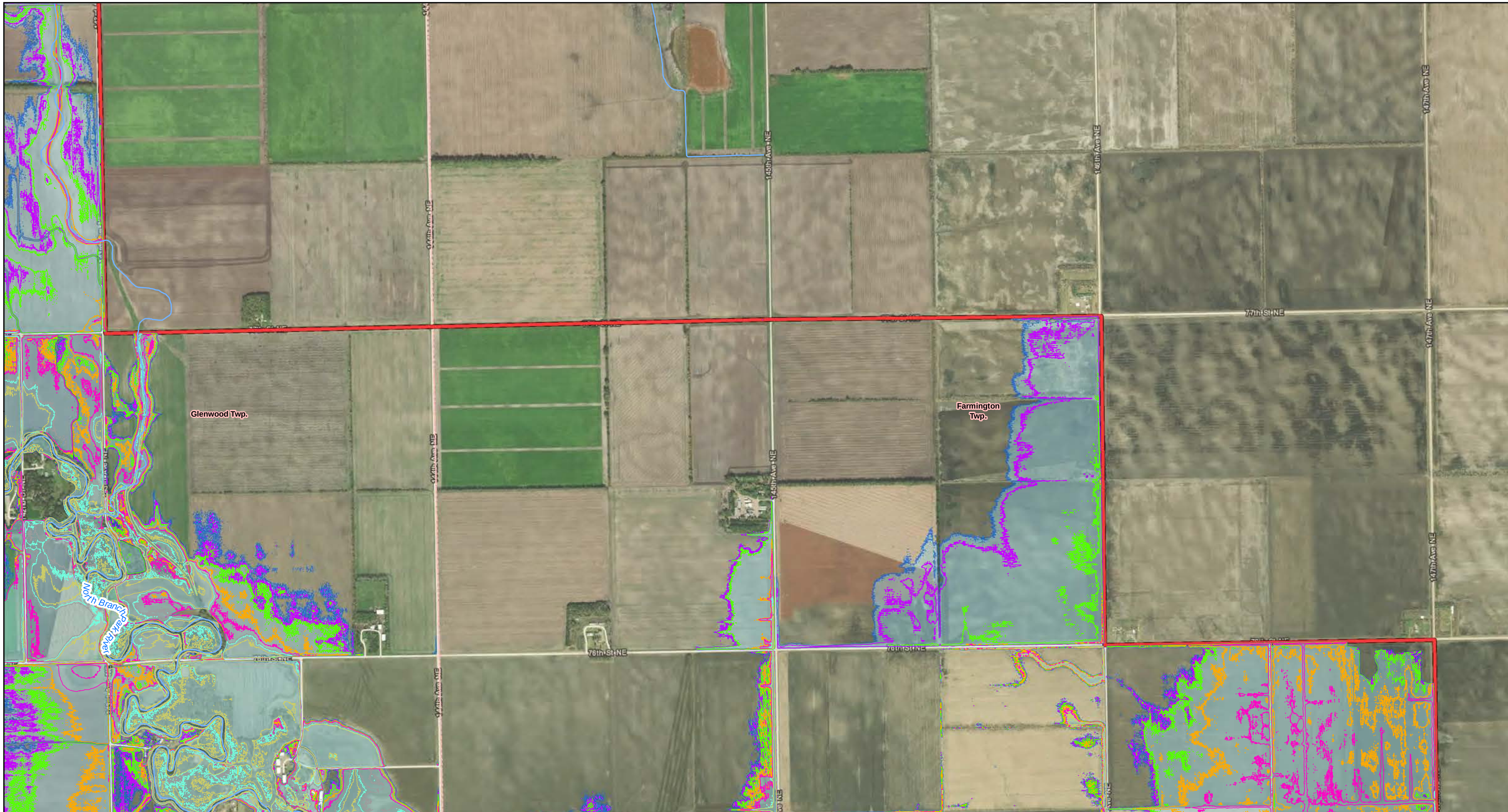
Sheet 17 of 20

Legend

- NHD Streams
- 1 Year Flood Extents
- 1.5 Year Flood Extents
- 2 Year Flood Extents
- 5 Year Flood Extents
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center







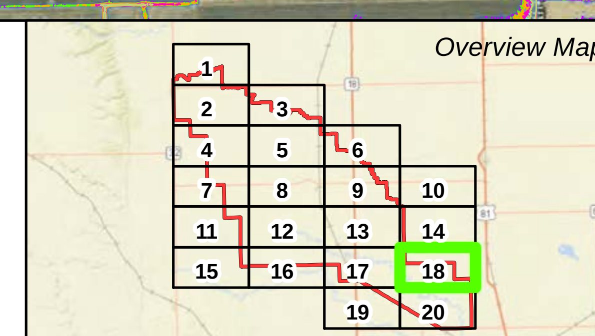
North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

Sheet 18 of 20

Legend

- NHD Streams
- 1 Year Flood Extents
- 1.5 Year Flood Extents
- 2 Year Flood Extents
- 5 Year Flood Extents
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center



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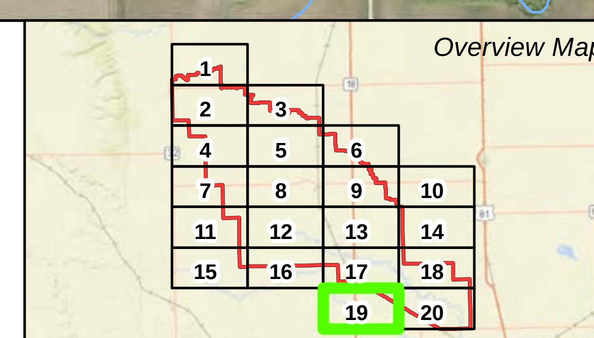
North Branch Park River Flood Extents

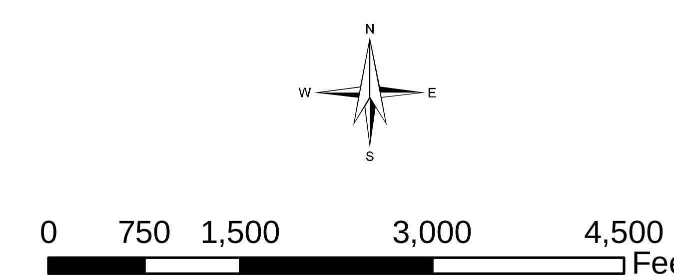
Pembina and Walsh Counties, North Dakota

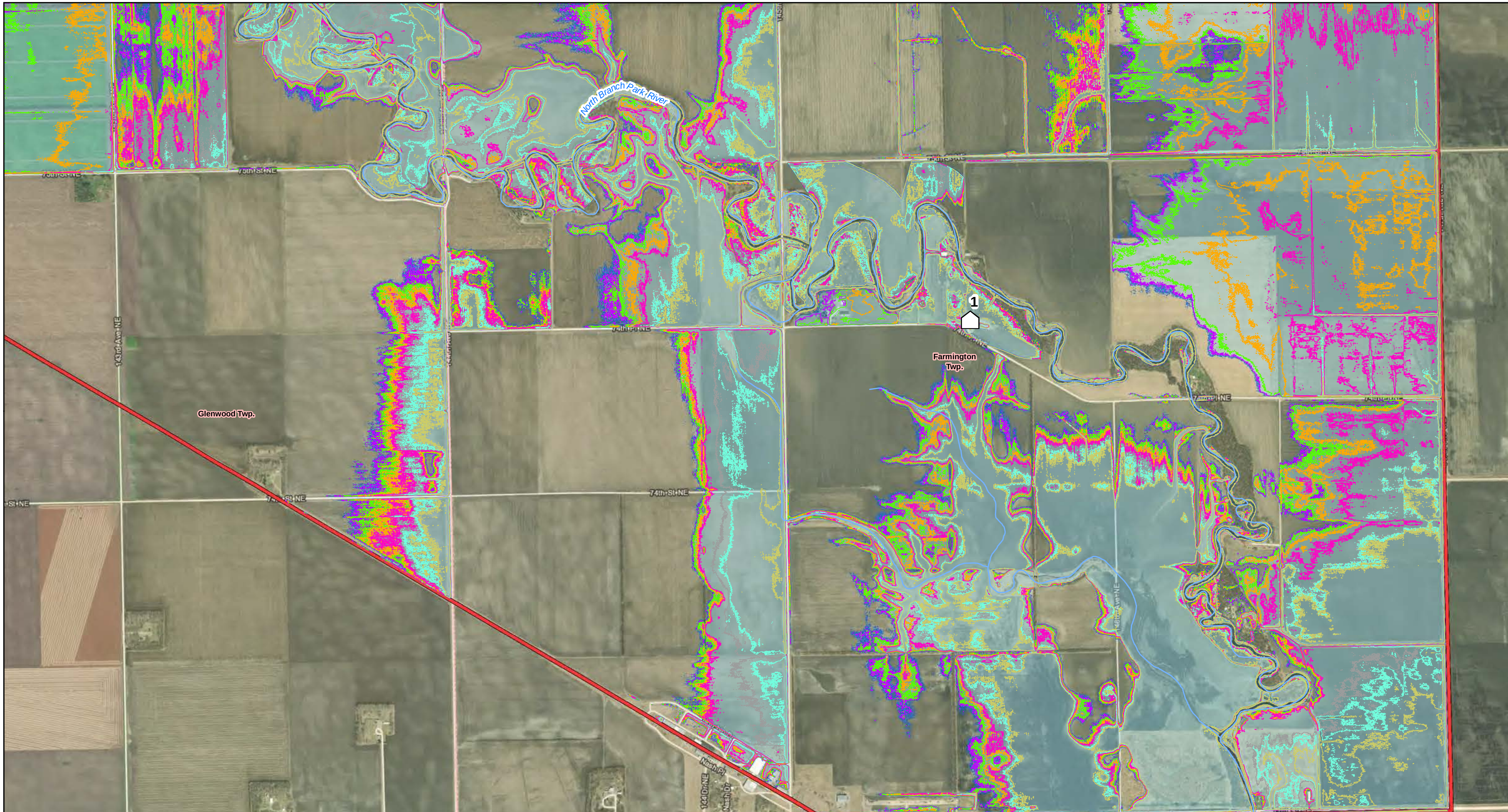
Sheet 19 of 20

Legend

- NHD Streams
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center







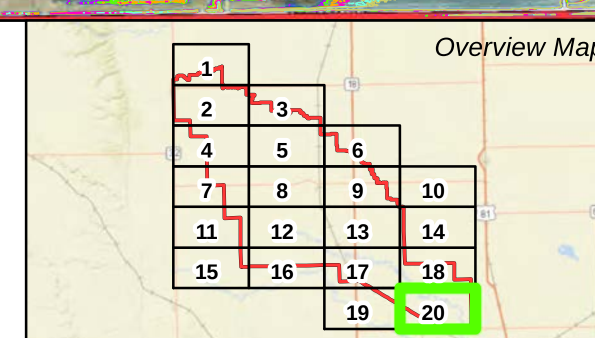
North Branch Park River Flood Extents

Pembina and Walsh Counties, North Dakota

Sheet 20 of 20

Legend

- NHD Streams
- Impacted Structures
- 1 Year Flood Extents
- 1.5 Year Flood Extents
- 2 Year Flood Extents
- 5 Year Flood Extents
- 10 Year Flood Extents
- 25 Year Flood Extents
- 50 Year Flood Extents
- 100 Year Flood Extents
- Townships
- Counties
- Damage Center



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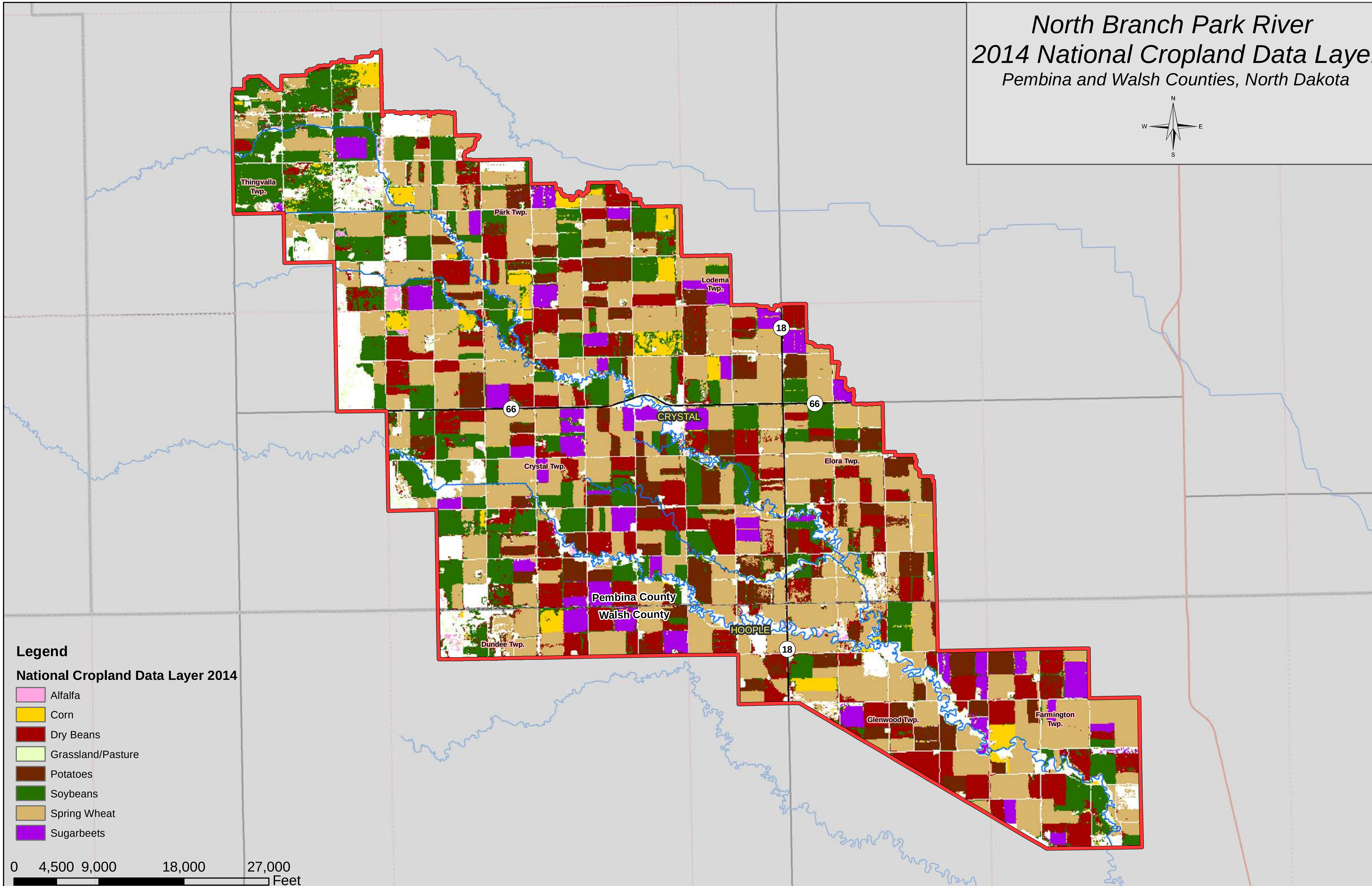
Feet

Appendix B

Agricultural Land Use Mapping


North Branch Park River
2014 National Cropland Data Layer
Pembina and Walsh Counties, North Dakota
N
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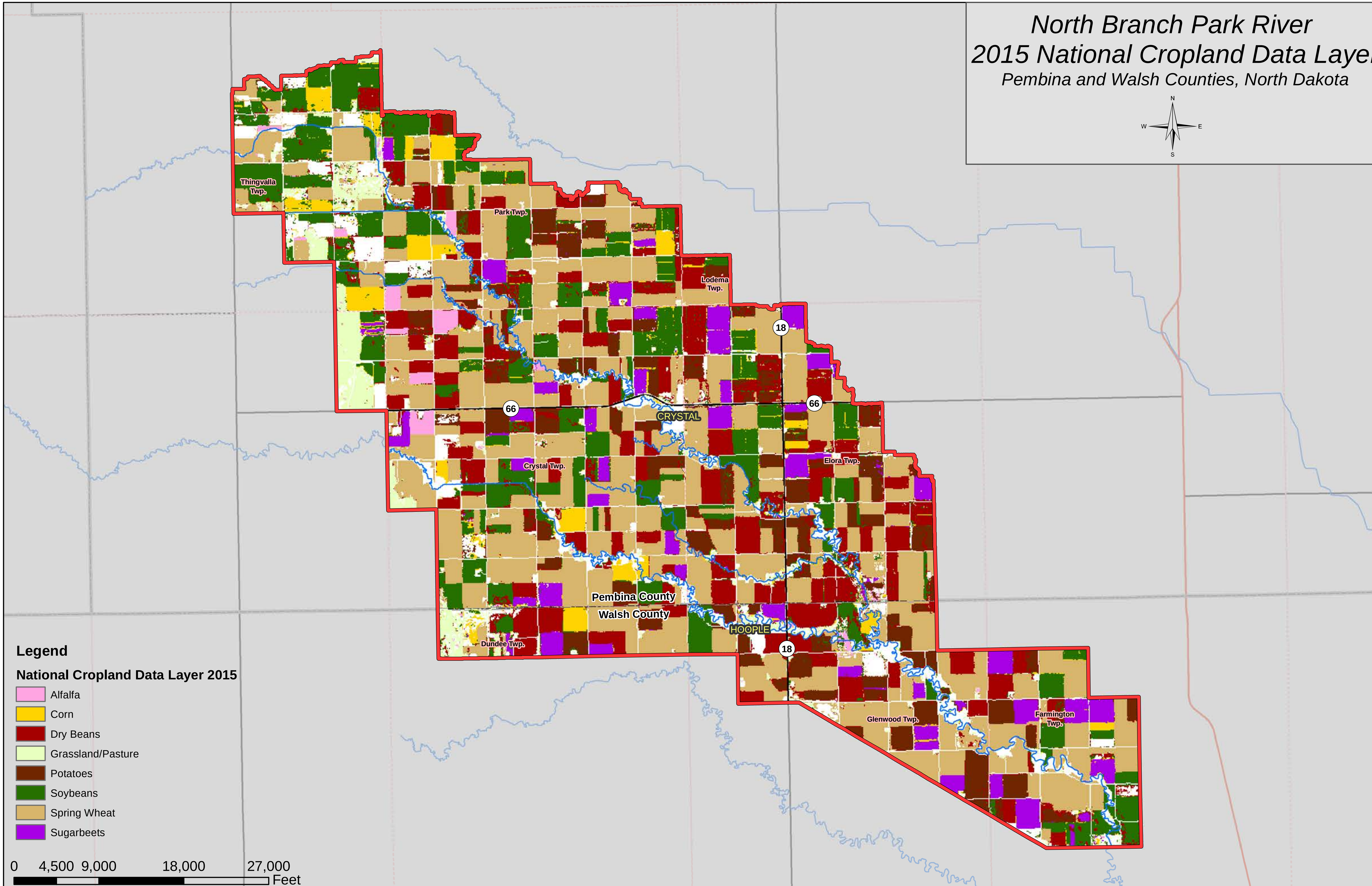
Thingvalla Twp.
Park Twp.
Lodema Twp.
18
66
66
CRYSTAL
Crystal Twp.
Elora Twp.
Pembina County
Walsh County
HOOPLE
18
Dundee Twp.
Glenwood Twp.
Farmington Twp.
Legend
National Cropland Data Layer 2014
Alfalfa
Corn
Dry Beans
Grassland/Pasture
Potatoes
Soybeans
Spring Wheat
Sugarbeets
0 4,500 9,000 18,000 27,000
Feet



North Branch Park River
2015 National Cropland Data Layer
Pembina and Walsh Counties, North Dakota
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Thingvalla Twp.
Park Twp.
Lodema Twp.
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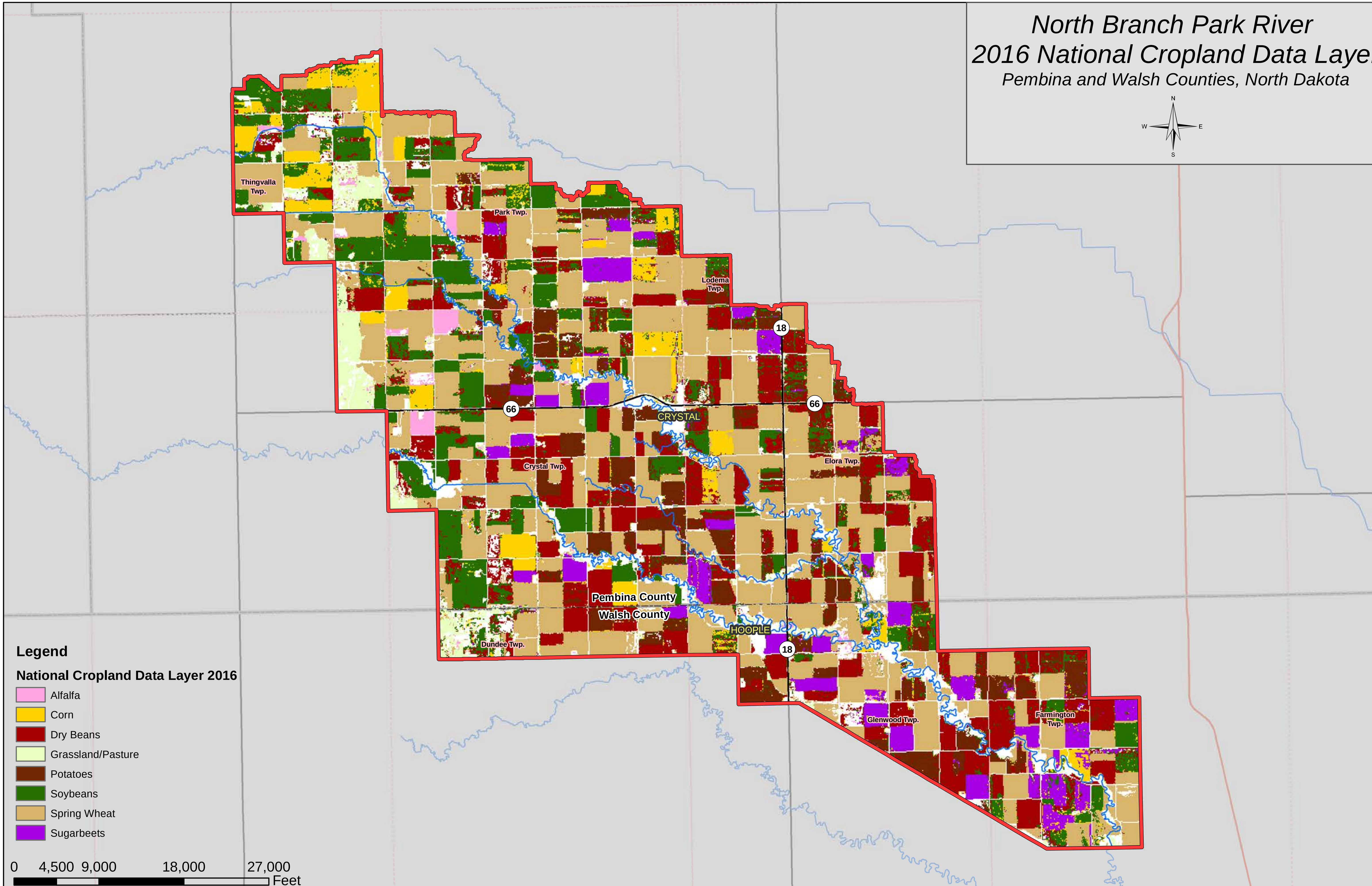
CRYSTAL
Crystal Twp.
Elora Twp.
Pembina County
Walsh County
HOOPLE
18
Dundee Twp.
Glenwood Twp.
Farmington Twp.
Legend
National Cropland Data Layer 2015
Alfalfa
Corn
Dry Beans
Grassland/Pasture
Potatoes
Soybeans
Spring Wheat
Sugarbeets
0 4,500 9,000 18,000 27,000
Feet


North Branch Park River
2016 National Cropland Data Layer
Pembina and Walsh Counties, North Dakota
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Thingvalla Twp.
Park Twp.
Lodema Twp.
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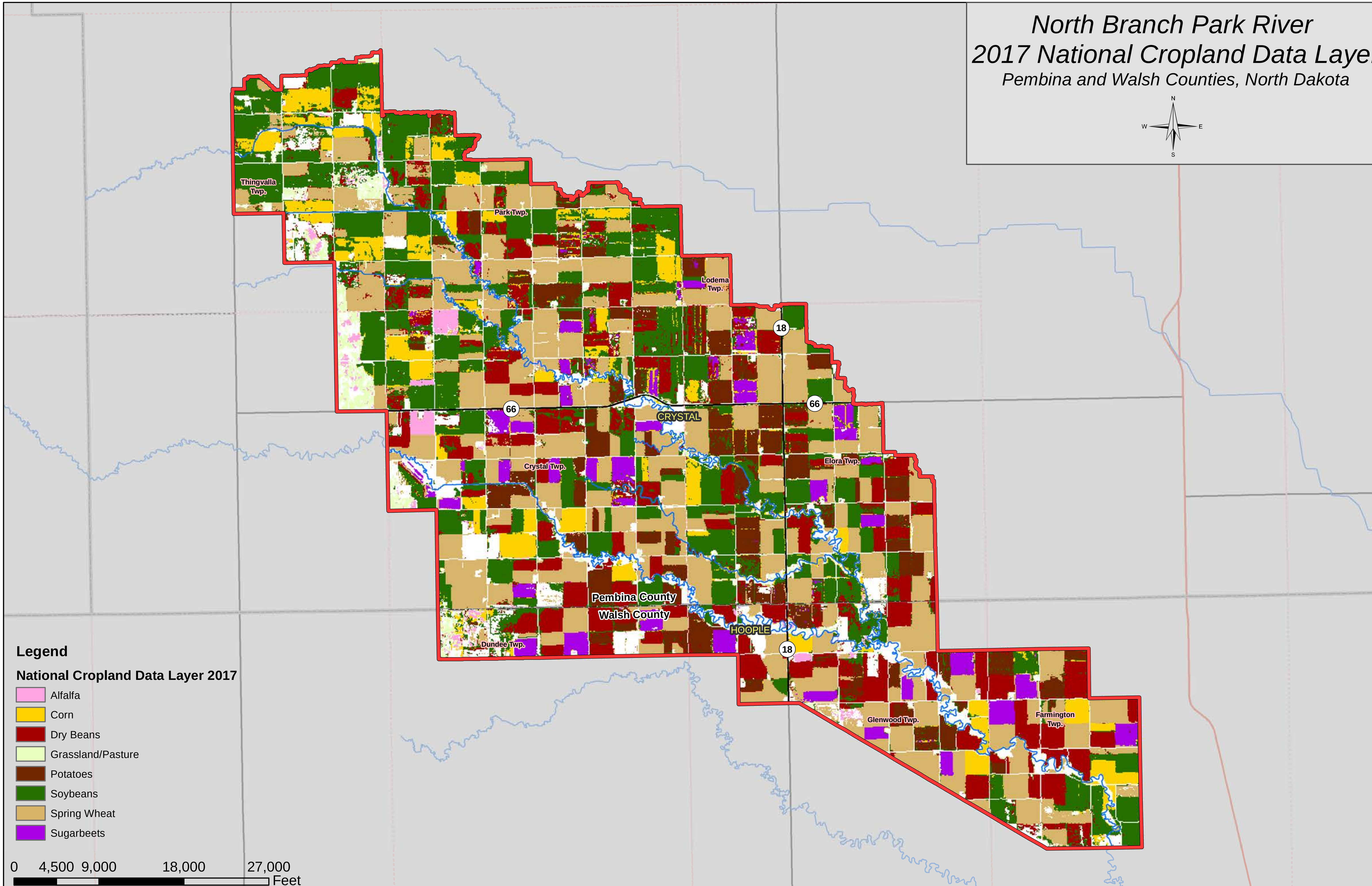
CRYSTAL
Crystal Twp.
Elora Twp.
Pembina County
Walsh County
HOOPLE
18
Dundee Twp.
Glenwood Twp.
Farmington Twp.
Legend
National Cropland Data Layer 2016
Alfalfa
Corn
Dry Beans
Grassland/Pasture
Potatoes
Soybeans
Spring Wheat
Sugarbeets
0 4,500 9,000 18,000 27,000
Feet


North Branch Park River
2017 National Cropland Data Layer
Pembina and Walsh Counties, North Dakota
N
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Thingvalla Twp.
Park Twp.
Lodema Twp.
18
66
CRYSTAL
Crystal Twp.
Elora Twp.
Pembina County
Walsh County
HOOPLE
Dundee Twp.
Glenwood Twp.
Farmington Twp.
Legend
National Cropland Data Layer 2017
Alfalfa
Corn
Dry Beans
Grassland/Pasture
Potatoes
Soybeans
Spring Wheat
Sugarbeets
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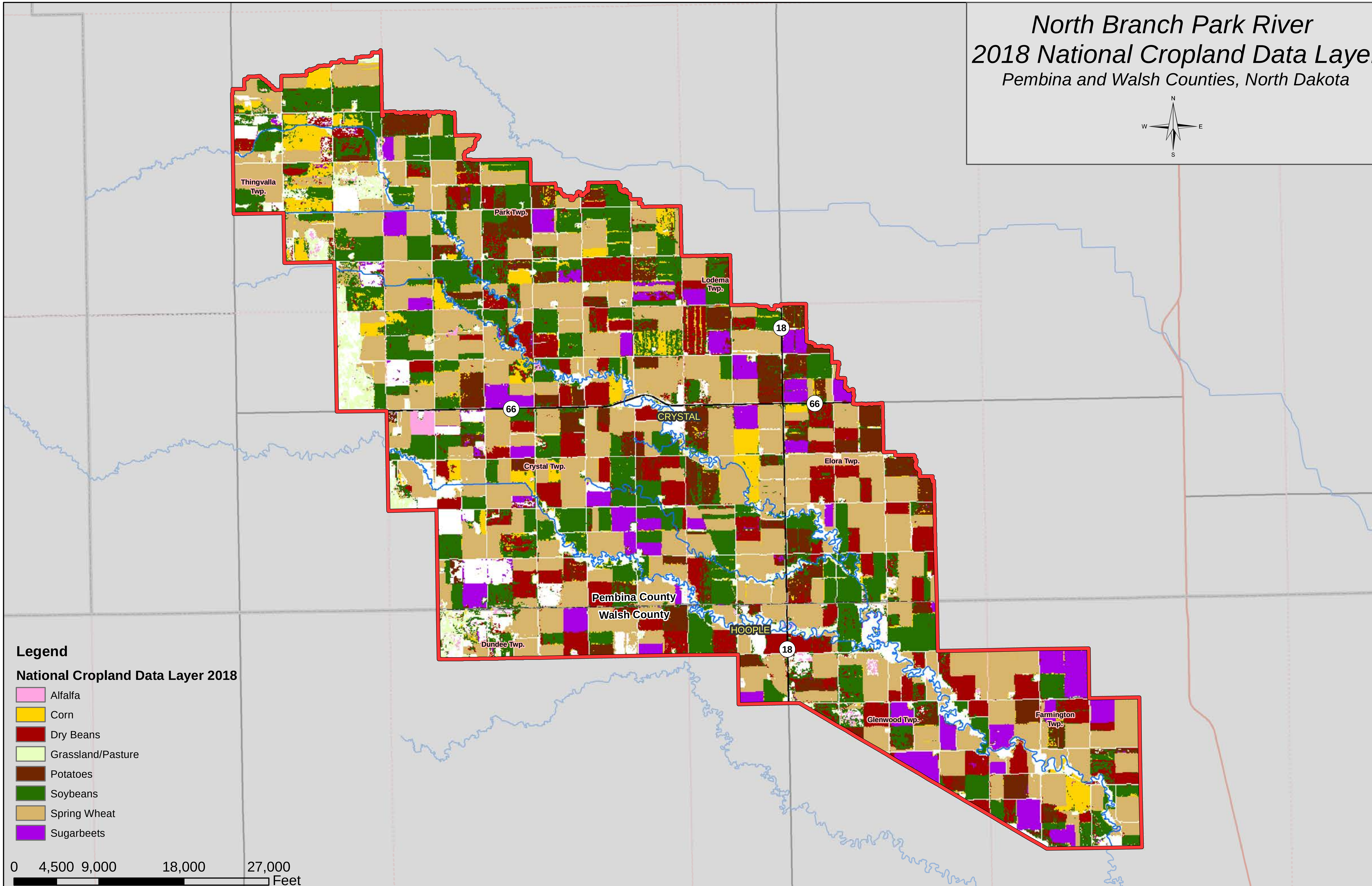
18,000
27,000
Feet


North Branch Park River
2018 National Cropland Data Layer
Pembina and Walsh Counties, North Dakota
N
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Thingvalla Twp.
Park Twp.
Lodema Twp.
18
66
66
CRYSTAL
Crystal Twp.
Elora Twp.
Pembina County
Walsh County
HOOPLE
18
Dundee Twp.
Glenwood Twp.
Farmington Twp.
Legend
National Cropland Data Layer 2018
Alfalfa
Corn
Dry Beans
Grassland/Pasture
Potatoes
Soybeans
Spring Wheat
Sugarbeets
0 4,500 9,000 18,000 27,000
Feet

Appendix C

HEC-FIA Results

APPENDIX C: HEC-FIA STRUCTURE DAMAGE RESULTS

Structure and Vehicle Damages, Existing Conditions 1-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
2	Residential	$64,445	$21,185	$0	$85,629	-0.14
Total		$64,445	$21,185	$0	**$85,629**	

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Preferred Alternative 1-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
2	Residential	$63,786	$21,125	$0	$84,911	-0.17
Total		$63,786	$21,125	$0	**$84,911**	0

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Existing Conditions 1.5-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$11,126	$212,589	$0	$223,714	0.09
2	Residential	$73,115	$31,241	$0	$104,356	0.14
49	Residential	$30,918	$14,164	$0	$45,082	-0.96
Total		$115,159	$257,993	$0	**$373,152**	

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Preferred Alternative 1.5-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$6,848	$130,858	$0	$137,707	0.05
2	Residential	$71,574	$28,041	$0	$99,615	0.09
Total		$78,422	$158,899	$0	**$237,321**	0

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

APPENDIX C: HEC-FIA STRUCTURE DAMAGE RESULTS (CONTINUED)

Structure and Vehicle Damages, Existing Conditions 2-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$19,517	$268,790	$0	$288,307	0.22
2	Residential	$77,244	$39,818	$0	$117,062	0.27
49	Residential	$34,377	$14,478	$0	$48,855	-0.79
Total		$131,138	$323,086	$0	**$454,224**	

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Preferred Alternative 2-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$17,144	$260,694	$0	$277,838	0.17
2	Residential	$76,011	$37,257	$0	$113,268	0.23
49	Residential	$33,266	$14,377	$0	$47,643	-0.84
Total		$126,421	$312,328	$0	**$438,749**	0

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Existing Conditions 5-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$46,270	$360,079	$9,409	$415,758	0.68
2	Residential	$96,637	$80,095	$3,147	$179,879	0.86
3	Residential	$39,008	$15,123	$0	$54,130	-0.6
38	Residential	$43,400	$18,636	$0	$62,037	-0.83
42	Agricultural	$4,980	$86,874	$0	$91,854	0.36
49	Residential	$46,650	$15,594	$0	$62,243	-0.2
Total		$276,945	$576,401	$12,555	**$865,902**	

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Preferred Alternative 5-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$44,736	$354,844	$8,699	$408,279	0.66
2	Residential	$94,543	$75,746	$2,778	$173,067	0.79
3	Residential	$38,304	$15,059	$0	$53,363	-0.64
42	Agricultural	$4,667	$85,128	$0	$89,796	0.33
49	Residential	$45,946	$15,530	$0	$61,476	-0.23
Total		$228,197	$546,307	$11,477	**$785,981**	0

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Existing Conditions 10-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$53,556	$384,940	$12,778	$451,274	0.81
2	Residential	$106,610	$97,805	$4,578	$208,993	1.23
3	Residential	$42,374	$15,429	$0	$57,802	-0.44
19	Agricultural	$11,375	$188,441	$0	$199,816	0.33
32	Residential	$33,169	$13,319	$0	$46,488	-0.69
38	Residential	$56,826	$19,857	$0	$76,683	-0.33
40	Residential	$1,603	$0	$0	$1,603	-0.93
41	Institutional	$406	$0	$0	$406	0.24
42	Agricultural	$6,472	$95,196	$1,584	$103,252	0.51
49	Residential	$50,022	$15,900	$0	$65,923	-0.03
Total		$362,412	$830,887	$18,941	**$1,212,240**	

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Preferred Alternative 10-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$51,956	$379,479	$12,038	$443,472	0.78
2	Residential	$104,619	$94,818	$4,352	$203,789	1.14
3	Residential	$41,634	$15,361	$0	$56,996	-0.48
38	Residential	$49,763	$19,215	$0	$68,978	-0.59
42	Agricultural	$6,144	$93,367	$0	$99,510	0.48
49	Residential	$49,282	$15,833	$0	$65,115	-0.07
Total		$303,398	$618,072	$16,390	**$937,860**	0

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

APPENDIX C: HEC-FIA STRUCTURE DAMAGE RESULTS (CONTINUED)

Structure and Vehicle Damages, Existing Conditions 25-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$59,546	$405,377	$15,548	$480,471	0.92
2	Residential	$114,463	$109,584	$5,470	$229,517	1.57
3	Residential	$45,190	$15,685	$0	$60,875	-0.31
6	Agricultural	$19,865	$202,166	$4,985	$227,016	0.61
10	Agricultural	$19,506	$63,411	$0	$82,917	0.63
19	Agricultural	$20,163	$232,962	$6,271	$259,397	0.68
20	Residential	$33,516	$12,696	$0	$46,211	-0.58
25	Residential	$12,312	$0	$0	$12,312	-0.67
29	Residential	$13,688	$5,779	$0	$19,467	-0.85
30	Institutional	$37,742	$42,459	$0	$80,201	0.09
31	Residential	$40,407	$15,761	$0	$56,168	-0.62
32	Residential	$48,944	$20,563	$0	$69,507	0.13
33	Residential	$22,275	$9,489	$0	$31,765	-0.87
34	Residential	$4,812	$0	$0	$4,812	-0.99
36	Residential	$13,210	$4,486	$0	$17,696	-0.27
38	Residential	$67,511	$24,600	$0	$92,111	0.06
40	Residential	$2,733	$0	$0	$2,733	-0.17
41	Institutional	$1,560	$0	$0	$1,560	0.91
42	Agricultural	$7,712	$102,113	$2,654	$112,479	0.63
43	Residential	$49,157	$19,051	$0	$68,208	-0.64
49	Residential	$53,239	$21,227	$0	$74,466	0.1
Total		$687,550	$1,307,410	$34,928	**$2,029,888**	

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

APPENDIX C: HEC-FIA STRUCTURE DAMAGE RESULTS (CONTINUED)

Structure and Vehicle Damages, Preferred Alternative 25-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$58,368	$401,359	$15,003	$474,730	0.89
2	Residential	$113,009	$107,403	$5,305	$225,717	1.51
3	Residential	$44,635	$15,634	$0	$60,269	-0.34
6	Agricultural	$8,232	$152,997	$0	$161,229	0.18
10	Agricultural	$19,660	$63,622	$0	$83,281	0.63
20	Residential	$33,546	$12,697	$0	$46,243	-0.58
32	Residential	$41,262	$14,055	$0	$55,317	-0.25
36	Residential	$11,041	$4,387	$0	$15,428	-0.7
38	Residential	$62,042	$20,331	$0	$82,373	-0.13
40	Residential	$2,108	$0	$0	$2,108	-0.59
41	Institutional	$945	$0	$0	$945	0.55
42	Agricultural	$7,468	$100,751	$2,443	$110,661	0.6
43	Residential	$46,984	$18,952	$0	$65,936	-0.74
49	Residential	$52,579	$19,856	$0	$72,435	0.08
Total		$501,879	$932,043	$22,751	**$1,456,674**	0

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

APPENDIX C: HEC-FIA STRUCTURE DAMAGE RESULTS (CONTINUED)

Structure and Vehicle Damages, Existing Conditions 50-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$62,362	$414,988	$16,850	$494,200	0.96
2	Residential	$118,196	$115,184	$5,894	$239,275	1.74
3	Residential	$46,533	$15,807	$0	$62,339	-0.25
4	Agricultural	$42,050	$578,302	$0	$620,352	0.42
6	Agricultural	$31,548	$258,799	$12,559	$302,906	1.08
10	Agricultural	$32,756	$88,628	$0	$121,383	1.27
11	Residential	$48,470	$16,189	$0	$64,659	-0.22
12	Residential	$22,715	$0	$0	$22,715	-0.86
13	Agricultural	$322,772	$163,338	$6,019	$492,129	1.02
15	Agricultural	$8,806	$176,382	$0	$185,188	0.27
16	Agricultural	$5,779	$148,599	$0	$154,378	0.16
19	Agricultural	$26,343	$264,268	$10,643	$301,255	0.93
20	Residential	$37,754	$12,888	$0	$50,643	-0.28
21	Agricultural	$356,615	$163,585	$0	$520,199	0.41
22	Institutional	$26,435	$61,208	$0	$87,643	1.08
25	Residential	$15,663	$0	$0	$15,663	-0.31
26	Commercial	$61,982	$81,448	$0	$143,431	1.43
27	Residential	$18,074	$7,490	$0	$25,563	-0.8
28	Residential	$22,722	$9,491	$0	$32,213	-0.82
29	Residential	$15,985	$5,883	$0	$21,868	-0.5
30	Institutional	$190,141	$213,908	$0	$404,049	0.43
31	Residential	$47,983	$16,450	$0	$64,434	-0.27
32	Residential	$56,595	$36,452	$0	$93,047	0.48
33	Residential	$26,058	$9,661	$0	$35,719	-0.52
34	Residential	$6,448	$0	$0	$6,448	-0.65
35	Residential	$28,953	$11,451	$0	$40,405	-0.69
36	Residential	$15,285	$5,919	$0	$21,204	0.09
38	Residential	$72,696	$35,369	$0	$108,065	0.22
39	Residential	$32,822	$13,274	$0	$46,096	-0.74
40	Residential	$3,524	$1,116	$0	$4,640	0.17
41	Institutional	$2,079	$0	$0	$2,079	1.22
42	Agricultural	$8,300	$105,393	$3,160	$116,853	0.69
43	Residential	$54,252	$19,282	$0	$73,534	-0.4
47	Agricultural	$7,250	$161,480	$0	$168,730	0.22

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APPENDIX C: HEC-FIA STRUCTURE DAMAGE RESULTS (CONTINUED)

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
48	Residential	$27,579	$11,775	$0	$39,354	-0.82
49	Residential	$54,832	$24,535	$0	**$79,367**	0.17
Total		$1,958,356	$3,248,545	$55,127	**$5,262,028**	

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Preferred Alternative 50-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$61,618	$412,448	$16,506	$490,572	0.95
2	Residential	$117,106	$113,549	$5,771	$236,425	1.69
3	Residential	$46,182	$15,775	$0	$61,956	-0.26
4	Agricultural	$31,140	$526,499	$0	$557,639	0.28
6	Agricultural	$22,754	$214,378	$6,873	$244,005	0.72
10	Agricultural	$32,716	$88,494	$0	$121,210	1.26
11	Residential	$48,460	$16,188	$0	$64,648	-0.22
12	Residential	$22,697	$0	$0	$22,697	-0.86
16	Agricultural	$1,132	$35,363	$0	$36,495	0.02
20	Residential	$37,800	$12,890	$0	$50,690	-0.28
21	Agricultural	$31,051	$27,170	$0	$58,221	0.02
25	Residential	$13,038	$0	$0	$13,038	-0.59
29	Residential	$14,187	$5,802	$0	$19,989	-0.77
30	Institutional	$70,265	$79,048	$0	$149,314	0.16
31	Residential	$42,015	$15,908	$0	$57,922	-0.54
32	Residential	$50,561	$23,919	$0	$74,480	0.2
33	Residential	$23,087	$9,526	$0	$32,613	-0.79
34	Residential	$4,948	$0	$0	$4,948	-0.96
36	Residential	$13,350	$4,492	$0	$17,843	-0.24
38	Residential	$68,610	$26,883	$0	$95,493	0.09
40	Residential	$2,776	$0	$0	$2,776	-0.14
41	Institutional	$1,611	$0	$0	$1,611	0.94
42	Agricultural	$8,145	$104,528	$3,027	$115,700	0.67
43	Residential	$52,607	$19,208	$0	$71,814	-0.48
47	Agricultural	$7,238	$161,416	$0	$168,654	0.22
49	Residential	$54,415	$23,668	$0	$78,083	0.15
Total		$879,509	$1,937,152	$32,176	**$2,848,838**	0

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Existing Conditions 100-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$64,783	$425,145	$17,957	$507,885	1.01
2	Residential	$121,891	$120,726	$6,314	$248,931	1.9
3	Residential	$47,853	$15,927	$0	$63,780	-0.18
4	Agricultural	$98,848	$934,052	$36,092	$1,068,992	1.31
5	Agricultural	$17,718	$271,584	$0	$289,302	0.14
6	Agricultural	$36,946	$315,589	$15,811	$368,346	1.48
7	Residential	$48,159	$20,132	$0	$68,291	-0.77
10	Agricultural	$33,035	$89,578	$0	$122,614	1.29
11	Residential	$54,033	$19,472	$0	$73,506	0.05
12	Residential	$35,558	$0	$0	$35,558	-0.22
13	Agricultural	$388,029	$206,026	$7,888	$601,944	1.47
15	Agricultural	$12,564	$197,342	$0	$209,906	0.45
16	Agricultural	$8,370	$163,050	$0	$171,420	0.29
19	Agricultural	$30,799	$307,427	$13,646	$351,872	1.22
20	Residential	$40,504	$13,013	$0	$53,518	-0.09
21	Agricultural	$880,070	$275,551	$15,031	$1,170,653	1.38
22	Institutional	$36,210	$80,061	$0	$116,272	1.54
23	Commercial	$131	$404	$0	$535	0.01
25	Residential	$17,896	$0	$0	$17,896	-0.07
26	Commercial	$61,982	$95,509	$0	$157,491	1.88
27	Residential	$20,227	$7,587	$0	$27,814	-0.55
28	Residential	$25,733	$9,628	$0	$35,361	-0.55
29	Residential	$17,503	$5,952	$0	$23,455	-0.27
30	Institutional	$294,984	$331,858	$0	$626,842	0.67
31	Residential	$53,169	$16,922	$0	$70,091	-0.04
32	Residential	$61,787	$47,235	$2,312	$111,334	0.71
33	Residential	$28,663	$9,780	$0	$38,443	-0.28
34	Residential	$7,604	$0	$0	$7,604	-0.41
35	Residential	$32,166	$11,598	$0	$43,764	-0.44
36	Residential	$17,418	$9,905	$0	$27,323	0.33
38	Residential	$75,241	$40,655	$0	$115,896	0.3
39	Residential	$36,846	$13,457	$0	$50,303	-0.48
40	Residential	$4,283	$2,707	$0	$6,990	0.41

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Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
41	Institutional	$2,468	$0	$0	$2,468	1.45
42	Agricultural	$8,879	$108,627	$3,660	$121,166	0.74
43	Residential	$59,087	$19,502	$0	$78,589	-0.18
45	Residential	$15,533	$7,159	$0	$22,692	-0.97
47	Agricultural	$12,913	$193,072	$0	$205,985	0.49
48	Residential	$30,453	$12,037	$0	$42,490	-0.65
49	Residential	$56,399	$27,791	$0	$84,190	0.23
Total		$2,896,739	$4,426,059	$118,711	**$7,441,509**	

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Structure and Vehicle Damages, Preferred Alternative 100-Year Flood Event

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
1	Agricultural	$64,585	$423,462	$17,872	$505,919	1.01
2	Residential	$121,373	$119,949	$6,255	$247,577	1.88
3	Residential	$47,666	$15,910	$0	$63,576	-0.19
4	Agricultural	$97,305	$915,821	$35,277	$1,048,404	1.27
5	Agricultural	$15,542	$264,817	$0	$280,359	0.11
6	Agricultural	$32,244	$266,124	$12,979	$311,347	1.14
10	Agricultural	$33,022	$89,532	$0	$122,554	1.29
11	Residential	$54,022	$19,451	$0	$73,473	0.05
12	Residential	$35,582	$0	$0	$35,582	-0.22
13	Agricultural	$324,467	$164,446	$6,068	$494,981	1.03
15	Agricultural	$7,242	$167,654	$0	$174,896	0.2
16	Agricultural	$6,357	$151,824	$0	$158,181	0.19
19	Agricultural	$6,061	$161,525	$0	$167,586	0.12
20	Residential	$40,556	$13,016	$0	$53,572	-0.09
21	Agricultural	$524,989	$189,893	$5,901	$720,783	0.66
22	Institutional	$26,689	$61,698	$0	$88,387	1.1
25	Residential	$15,903	$0	$0	$15,903	-0.28
26	Commercial	$61,982	$81,814	$0	$143,796	1.44
27	Residential	$17,862	$7,480	$0	$25,342	-0.83
28	Residential	$23,042	$9,506	$0	$32,548	-0.79
29	Residential	$16,151	$5,891	$0	$22,042	-0.48
30	Institutional	$202,036	$227,291	$0	$429,327	0.46

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APPENDIX C: HEC-FIA STRUCTURE DAMAGE RESULTS (CONTINUED)

Structure Name	Structure Type	Structure Damage	Content Damage	Car Damage	Total Damage	Depth of Flooding (ft)*
31	Residential	$48,574	$16,504	$0	$65,078	-0.25
32	Residential	$57,186	$37,680	$1,105	$95,971	0.5
33	Residential	$26,357	$9,675	$0	$36,031	-0.49
34	Residential	$6,351	$0	$0	$6,351	-0.67
35	Residential	$28,667	$11,438	$0	$40,106	-0.71
36	Residential	$15,094	$5,562	$0	$20,655	0.06
38	Residential	$73,153	$36,318	$0	$109,471	0.24
39	Residential	$33,252	$13,294	$0	$46,545	-0.72
40	Residential	$3,460	$983	$0	$4,443	0.15
41	Institutional	$2,056	$0	$0	$2,056	1.2
42	Agricultural	$8,797	$108,167	$3,589	$120,553	0.73
43	Residential	$58,165	$19,460	$0	$77,625	-0.22
47	Agricultural	$12,905	$193,029	$0	$205,934	0.49
48	Residential	$26,381	$11,667	$0	$38,048	-0.89
49	Residential	$56,177	$27,330	$0	$83,507	0.22
Total		$2,231,253	$3,848,209	$89,046	**$6,168,509**	0

** Negative flood depth indicates damage to basement or other infrastructure at or below ground level.*

Appendix D

Infrastructure Repair Costs

Gravel Roadway Replacement

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

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

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

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

Embankment Replacement

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

* embankment is excavated and stockpilied for drying

** placing dried stockpiled embankment

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

Total Cost of Repair	**$179**	**/LF**

Gannett Fleming

SUBJECT:____________________ SHEET NO.________ OF_______
JOB NO._______________
BY DRC DATE 7/26/2019 CHKD.BY DAH DATE 7/26/2019

Paved Replacement

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

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

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

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

Embankment Replacement

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

* embankment is excavated and stockpiled for drying

** placing dried stockpiled embankment

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

Total Cost of Repair	**$247**	**/LF**