

Appendix D:

Edge-of-Field and EVAAL Analysis

The Lake Pepin TMDL:

Total Maximum Daily Loads for Total Phosphorus

Contents:

This appendix summarizes a project, funded through U.S. EPA grants, to summarize agricultural crop rotations and practices, perform an edge-of-field analysis with SnapPlus, and conduct an EVAAL analysis for six TMDL subbasins/HUC12 subwatersheds.

The edge-of-field phosphorus loss estimates (lb./acre/yr) uses SnapPlus software to evaluate all agricultural fields in the TMDL study area. The results are used to estimate the target phosphorus loss for achieving the load allocation. An additional analysis was completed to ensure that the phosphorus targets are achievable using typical management practices.

Erosion vulnerability: An analysis of erosion potential in six high priority TMDL subbasins was conducted using the EVAAL tool to aid with the prioritization for management practice implementation in vulnerable areas. The six subbasins/HUC12 subwatersheds:

- TMDL Subbasin 14: Little Trimbelle River (HUC 070400010302)
- TMDL Subbasin 4: Cave Creek (HUC 070400010503)
- TMDL Subbasin 15: Crystal Springs Coulee-Rush River (HUC 070400010507)
- TMDL Subbasin 12: Spring Creek-Trimble River (HUC 070400010303)
- TMDL Subbasin 16: Isabelle Creek (HUC 070400010701)
- TMDL Subbasin 10: Lake Pepin (HUC 070400010705)

To: Andrew Craig and Kevin Kirsch, Wisconsin Department of Natural Resources (WDNR)
Donna Keclik and David Werbach, Region 5 Environmental Protection Agency (EPA)
Emily Cira and Tom Wall, EPA Office of Water

From: Maddie Keefer, Cole Blasko, and Aileen Molloy, Tetra Tech

Date: May 26, 2023

Subject: Refinement and implementation targeting of phosphorus allocations in the Wisconsin Lake Pepin TMDL

1.0 INTRODUCTION

The purpose of this project was to provide support to the Wisconsin Department of Natural Resources (WDNR) in developing and implementing nutrient reduction strategies and frameworks for the Wisconsin Lake Pepin phosphorus TMDL. The analysis was two-fold, 1) develop batch-process data for WDNR to evaluate on-farm soil and nutrient runoff losses for several implementation scenarios and 2) conduct an analysis of erosion potential and the causes of erosion in several high priority subwatersheds to help WDNR better target implementation in vulnerable areas.

Lake Pepin, part of the Mississippi River, is the border of Minnesota and Wisconsin, and the lake is impaired due to excess phosphorus. Minnesota has finalized the Lake Pepin Watershed TMDL, and a portion of the watershed extends into Wisconsin. The TMDL that was developed by Minnesota only addresses the Minnesota portion of the watershed but also accounted for the Wisconsin drainage portion. While both states are now working on implementation to achieve the targets required by the Minnesota TMDL, Wisconsin is also planning to develop TMDLs for their portion of the Lake Pepin Watershed. As part of this effort, WDNR is looking to develop detailed nonpoint source loads by utilizing State-developed software models to analyze phosphorus runoff from agricultural lands. The watershed scale load allocations contained in the Minnesota TMDL will be expressed in the Wisconsin TMDLs as an edge of field target consistent with other Wisconsin TMDLs. These results will ensure that nonpoint source reductions are achievable, and water quality standards can be attained and maintained.

SnapPlus (Soil Nutrient Application Planner) is Wisconsin's nutrient management planning software. The program helps farmers make the best use of their on-farm nutrients, as well as make informed and justified commercial fertilizer purchases. By calculating potential soil and phosphorus runoff losses on a field-by-field basis while assisting in the economic planning of manure and fertilizer applications, SnapPlus provides Wisconsin farmers with a tool for protecting soil and water quality. SnapPlus is being used for the Lake Pepin project to establish baseline loads for typical fields in the Lake Pepin study area and to explore benefits of various agricultural management strategies.

WDNR's Erosion Vulnerability Assessment for Agricultural Lands (EVAAL) tool identifies areas vulnerable to erosion by assessing the risk for sheet and rill erosion and gully erosion based on topography, soils, rainfall, and land cover. Results from the tool can be used to prioritize implementation of best management practices at the field scale. The tool is being used for the Lake Pepin project to characterize erosion risk and sources in high priority subwatershed to allow for targeted implementation approaches.

2.0 DETERMINATION OF TARGET SUBWATERSHEDS

In consultation with the U.S. Environmental Protection Agency (EPA) and WDNR, Tetra Tech used the Hydrologic Unit Code 12 (HUC12)¹ delineations shown in Figure 1 as the basis for SnapPlus analysis efforts. These HUC12s were selected by WDNR, and the Lake Pepin study area boundary for Wisconsin was provided to Tetra Tech.

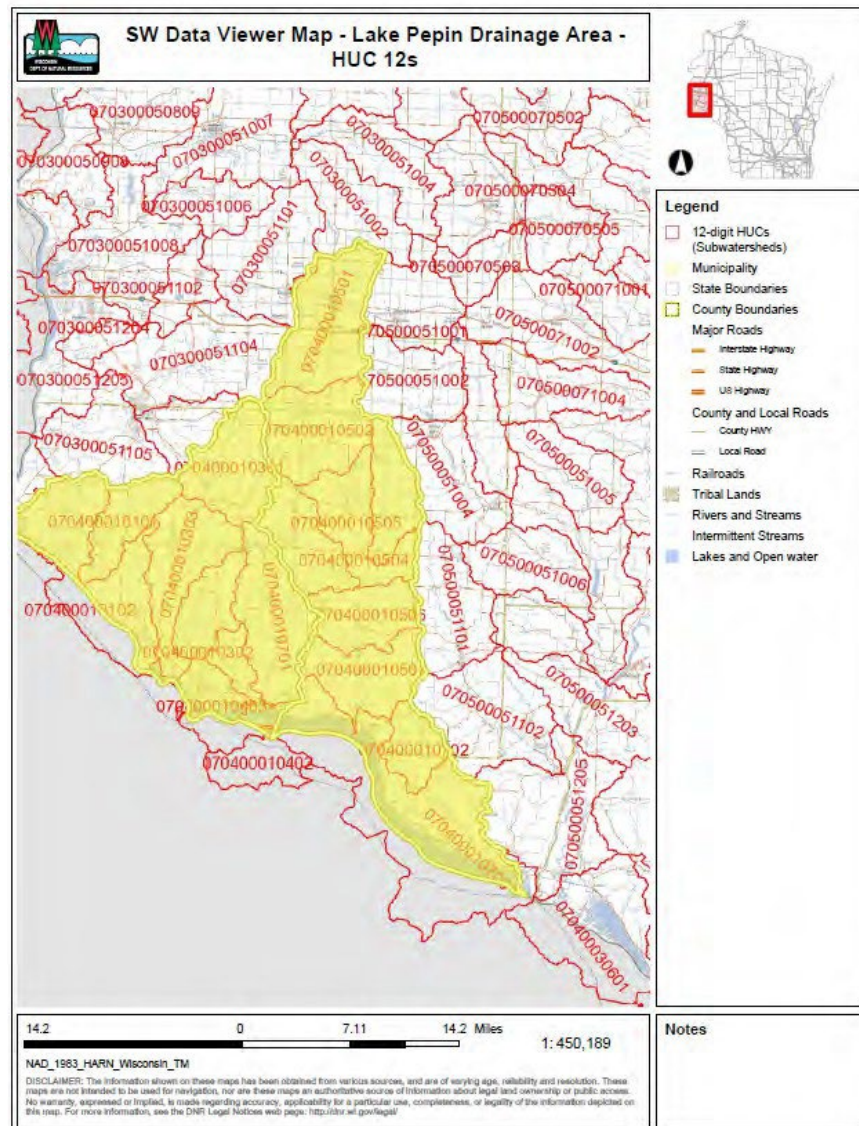


Figure 1. HUC12 Watersheds in the Lake Pepin Study Area

There are sixteen subwatersheds located within the Lake Pepin study area for Wisconsin. Table 2-1 summarizes these HUC12s by number, name, and county they are located in.

¹ United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA). Watershed Boundary Dataset for HUC# [Online WWW]. Available URL: <https://datagateway.nrcs.usda.gov>

Table 2-1. Summary of HUC12 Subwatersheds in Wisconsin's Lake Pepin TMDL Study Area

HUC12	Name	County Name(s)
70400010101	Big River	Pierce
70400010102	Lock and Dam No. 3-Mississippi River	Pierce
70400010301	Goose Creek-Trimbelle River	Pierce, St. Croix
70400010302	Little Trimbelle River	Pierce
70400010303	Spring Creek-Trimbelle River	Pierce
70400010403	City of Red Wing-Mississippi River	Pierce
70400010501	Village of Baldwin-Rush River	St. Croix
70400010502	Town of Martell-Rush River	Pierce, St. Croix
70400010503	Cave Creek	Pierce
70400010504	Lost Creek	Pierce
70400010505	Brush Creek-Rush River	Pierce
70400010506	Township of Salem-Rush River	Pierce
70400010507	Crystal Springs Coulee-Rush River	Pierce
70400010701	Isabelle Creek	Pierce
70400010702	Pine Creek	Pierce, Pepin
70400010705	Lake Pepin	Pierce, Pepin

3.0 DEVELOPMENT OF SNAPPLUS DATABASES FOR NONPOINT SOURCE LOADINGS

3.1 LAND COVER AND LAND USE

Tetra Tech reviewed the existing Minnesota Lake Pepin TMDL to determine if any existing data regarding land cover and land uses could be used in the project. However, more specific data were available from Wisconsin datasets and were used instead. The WiscLAND 2.0² GIS database, developed by the University of Wisconsin-Madison and WDNR, was obtained and analyzed to evaluate land cover and crop rotation information within the Lake Pepin study area. Tetra Tech also utilized WDNR's Erosion Vulnerability Assessment for Agricultural Lands (EVAAL) model to extract USDA-NASS National Cropland Data Layer (CDL) data to evaluate and compare additional crop rotation information. A map of EVAAL Cropland Data Layer crop rotations within the selected HUC12 boundaries is shown in Figure 2.

² Wisconsin Department of Natural Resources, WiscLAND 2.0, <https://dnr.wisconsin.gov/maps/WISCLAND>

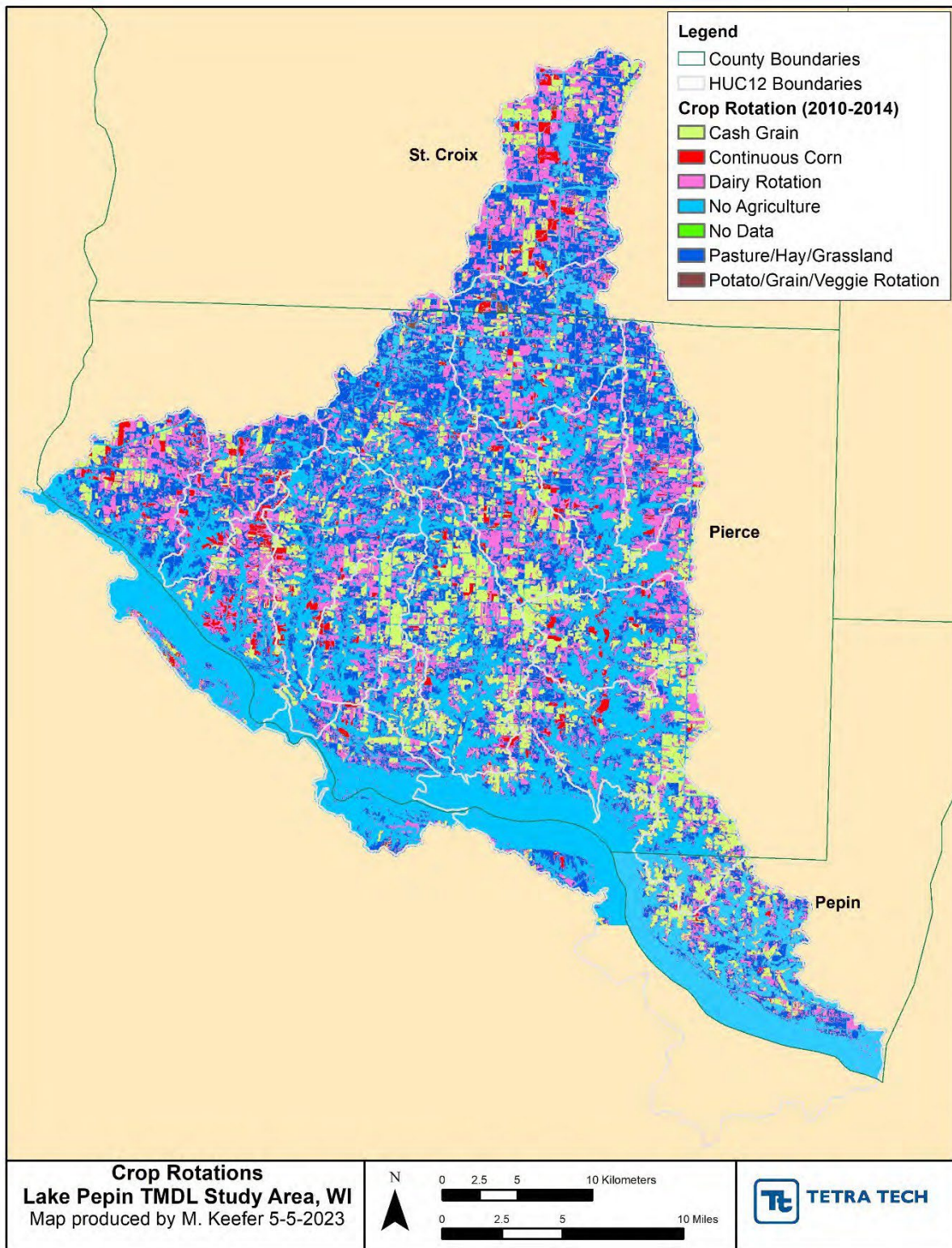


Figure 2. EVAAL/Cropland Data Layer Rotations for Lake Pepin Study Area

The EVAAL Cropland Data Layer (CDL) crop rotation information was analyzed for area, percent of study area, and percent of agricultural land within each county and HUC12 subwatershed in GIS. Summary tables of this information are provided in Table 3-1 and Table 3-2.

Table 3-1. Summary of Crop Rotations for Lake Pepin Study Area Counties (2010-2014)

Period: 2010-2014	Area (acres)			Percent of Study Area by County		
	Pepin County	Pierce County	St. Croix County	Pepin County	Pierce County	St. Croix County
Cash Grain	4,080.3	38,976.9	4,796.7	12.3%	14.9%	12.9%
Continuous Corn	19.4	7,114.0	1,398.2	0.6%	2.7%	3.8%
Daily Potato Year	-	0.2	-	0.0%	0.0%	0.0%
Dairy Rotation	4,640.4	66,188.0	12,001.4	14.0%	25.3%	32.4%
No Agriculture	19,665.8	89,399.7	5,810.9	59.4%	34.1%	15.7%
No Data	-	0.1	0.1	0.0%	0.0%	0.0%
Pasture/Hay/Grassland	4,475.0	60,010.2	12,738.9	13.5%	22.9%	34.4%
Potato/Grain/Veggie Rotation	70.9	374.6	312.8	0.2%	0.1%	0.8%

Table 3-2. Summary of Crop Rotations for Lake Pepin Study Area HUC12s (2010-2014)

HUC12	HUC12 Name	Area in acres (Percent of HUC12)						
		Cash Grain	Continuous Corn	Dairy Potato Year	Dairy Rotation	No Agriculture	Pasture/ Hay/ Grassland	Potato/ Grain/ Veggie
70400010101	Big River	1,207.8 (9.0%)	632.8 (4.7%)	-	3,547.9 (26.3%)	3,681.0 (27.3%)	4,391.2 (32.6%)	10.0 (0.1%)
70400010102	Lock and Dam No. 3-Mississippi River	3,259.8 (10.9%)	1,757.3 (5.9%)	0.2 (0.0%)	8,547.7 (28.5%)	9,814.5 (32.8%)	6,546.6 (21.9%)	30.9 (0.1%)
70400010301	Goose Creek-Trimbelle River	1,942.0 (9.3%)	181.5 (0.9%)	-	4,489.1 (21.6%)	6,264.9 (30.1%)	7,858.7 (37.7%)	90.3 (0.4%)
70400010302	Little Trimbelle River	2,515.1 (19.8%)	303.5 (2.4%)	-	3,560.1 (28.0%)	3,626.5 (28.5%)	2,710.6 (21.3%)	7.3 (0.1%)
70400010303	Spring Creek-Trimbelle River	2,886.2 (12.7%)	730.2 (3.2%)	-	5,893.1 (25.9%)	8,033.3 (35.4%)	5,132.0 (22.6%)	35.9 (0.2%)
70400010403	City of Red Wing-Mississippi River	678.0 (7.9%)	137.9 (1.6%)	-	1,394.4 (16.2%)	5,215.0 (60.4%)	1,149.7 (13.3%)	59.0 (0.7%)
70400010501	Village of Baldwin-Rush River	4,123.1 (14.4%)	1,244.8 (4.3%)	-	9,763.1 (34.1%)	4,079.5 (14.2%)	9,270.1 (32.3%)	186.8 (0.7%)
70400010502	Town of Martell-Rush River	1,835.4 (7.7%)	429.5 (1.8%)	-	6,077.8 (25.6%)	6,498.4 (27.3%)	8,761.2 (36.9%)	162.0 (0.7%)
70400010503	Cave Creek	1,656.2 (11.8%)	232.3 (1.7%)	-	4,883.0 (34.8%)	3,003.3 (21.4%)	4,255.1 (30.3%)	18.5 (0.1%)
70400010504	Lost Creek	3,082.3 (18.5%)	476.9 (2.9%)	-	5,238.5 (31.5%)	3,557.7 (21.4%)	4,248.7 (25.6%)	14.5 (0.1%)
70400010505	Brush Creek-Rush River	2,104.1 (11.2%)	416.4 (2.2%)	-	5,806.0 (30.9%)	6,215.0 (33.1%)	4,229.6 (22.5%)	8.3 (0.0%)
70400010506	Township of Salem-Rush River	3,063.3 (19.0%)	598.4 (3.7%)	-	4,222.9 (26.2%)	5,600.4 (34.7%)	2,610.3 (16.2%)	21.6 (0.1%)
70400010507	Crystal Springs Coulee-Rush River	4,181.0 (21.6%)	510.9 (2.6%)	-	4,131.9 (21.3%)	7,575.8 (39.1%)	2,953.0 (15.3%)	6.6 (0.0%)
70400010701	Isabelle Creek	6,108.4 (23.9%)	570.0 (2.2%)	-	5,844.0 (22.8%)	8,099.0 (31.7%)	4,946.0 (19.3%)	13.0 (0.1%)
70400010702	Pine Creek	3,257.7 (32.5%)	49.0 (0.5%)	-	1,966.9 (19.6%)	3,380.7 (33.7%)	1,367.1 (13.6%)	4.5 (0.0%)
70400010705	Lake Pepin	5,181.7 (10.9%)	364.4 (0.8%)	-	6,313.3 (13.3%)	29,559.9 (62.4%)	5,873.3 (12.4%)	78.6 (0.2%)
Crop Rotation Percent of Study Area		14.3%	2.6%	0.0%	24.9%	34.8%	23.2%	0.2%

3.2 DATA COLLECTION FOR EDGE OF FIELD ANALYSIS

3.2.1 County Surveys

Once the HUC12 subwatersheds land use was characterized, Tetra Tech reviewed the data needs for SnapPlus to be used. Data requirements for SnapPlus modeling and the sources for that data are summarized in Table 3-3 below. As mentioned in Section 3.1, data on cropping rotations was obtained through EVAAL/CDL. Surveys adapted by Wisconsin DNR to fit the study area and data needs for SnapPlus were sent to Pierce, St. Croix, and Pepin counties.

Tetra Tech evaluated the agricultural management survey results against the WiscLAND and EVAAL CDL land management and crop rotation data for several years to characterize crop rotations and agricultural practices being employed within the counties. Agricultural land cover and crop rotations, in addition to SSURGO soil attributes and slopes, were summarized by HUC12 watershed. Other management information, such as tillage and fertilizer application, were summarized by county.

Table 3-3. Summary of Data needed for SnapPlus Model Runs

Data Needs	Data Sources
Agricultural Land Cover	WiscLAND2.0
Crop Rotations	EVAAL/WiscLAND2.0
Tillage Types and Timing	County Surveys
Fertilizer Applications	County Surveys, USDA Economic Research Service Application Rates
Manure Applications	County Surveys
Planting and Harvesting	County Surveys
Crop Yields	County Surveys, NASS Crop Yield Data
Livestock Grazing	County Surveys
Soil Phosphorus Levels	County Surveys
Soil Attributes and Slopes	SSURGO Soil Surveys

3.2.2 Edge of Field Agriculture Matrix

When the county surveys for agricultural management practices were received, Tetra Tech reviewed the responses and asked for clarification where necessary. Then, the responses were consolidated into an aggregated agricultural management matrix for use when developing the SnapPlus input files. Rotations are typically divided into dairy rotations, corn-soybean rotations, continuous corn, and continuous pasture, both grazed and not grazed. Based on county survey responses, the rotations chosen for the aggregated matrix were dairy, corn-soybean, continuous corn, and vegetable rotations (Table 3-4).

Table 3-4. Crops Modeled in SnapPlus Rotations

Name	Crops							
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Dairy Sequence 1 - Till 1	Cs	Cs	Cs	Cs	A	A	A	
Dairy Sequence 1 - Till 2	Cs	Cs	Cs	Cs	A	A	A	
Dairy Sequence 1 - Till 3	Cs	Cs	Cs	Cs	A	A	A	
Dairy Sequence 1 - Till 4	Cs	Cs	Cs	Cs	A	A	A	
Dairy Sequence 2 - Till 1	Cg	Cg	Cs	O	A	A	A	
Dairy Sequence 2 - Till 2	Cg	Cg	Cs	O	A	A	A	
Dairy Sequence 2 - Till 3	Cg	Cg	Cs	O	A	A	A	
Dairy Sequence 2 - Till 4	Cg	Cg	Cs	O	A	A	A	
Dairy Sequence 3 - Till 1	Cg	Cg	Cs	Cs	A	A	A	
Dairy Sequence 3 - Till 2	Cg	Cg	Cs	Cs	A	A	A	
Dairy Sequence 3 - Till 3	Cg	Cg	Cs	Cs	A	A	A	
Dairy Sequence 3 - Till 4	Cg	Cg	Cs	Cs	A	A	A	
Dairy Sequence 4 - Till 1	Cs	Cs	Cs	Cs	A	A	SOY	Cs
Dairy Sequence 4 - Till 2	Cs	Cs	Cs	Cs	A	A	SOY	Cs
Dairy Sequence 4 - Till 3	Cs	Cs	Cs	Cs	A	A	SOY	Cs
Dairy Sequence 4 - Till 4	Cs	Cs	Cs	Cs	A	A	SOY	Cs
Cash Grain Sequence - Till 1	Cg	SOY	Cg	SOY	Cg	SOY	Cg	SOY
Cash Grain Sequence - Till 2	Cg	SOY	Cg	SOY	Cg	SOY	Cg	SOY
Cash Grain Sequence - Till 3	Cg	SOY	Cg	SOY	Cg	SOY	Cg	SOY
Cash Grain Sequence - Till 4	Cg	SOY	Cg	SOY	Cg	SOY	Cg	SOY
Cash Grain Sequence - Till 5	Cg	SOY	Cg	SOY	Cg	SOY	Cg	SOY
Continuous Corn Sequence - Till 1	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg
Continuous Corn Sequence - Till 2	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg
Continuous Corn Sequence - Till 3	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg
Continuous Corn Sequence - Till 4	Cg	Cg	Cg	Cg	Cg	Cg	Cg	Cg
Vegetable - Till 1	P	V	P	V	P	V	P	V
Vegetable - Till 2	P	V	P	V	P	V	P	V

A = alfalfa; Cs = corn silage; Cg = corn grain; O = oats; SOY = soybeans; P = potato; V = vegetable

These rotations were further distinguished based on tillage practice and timing, chemical nitrogen (N) and phosphorus (P) fertilizer application practices, and manure application practices. Crop yield and a HUC12-aggregated average soil phosphorus level were also used for development of the crop rotations and management strategies within the SnapPlus input database. A list of till practices and frequencies for each crop rotation is provided in Table 3-5.

Table 3-5. Crop Rotation Tillage Practices and Frequencies

Rotation Name	Fall Tillage	Spring Tillage	Till Frequency
Dairy Sequence 1 - Till 1	Chisel Plow	Cultivator, x2	2 out of 6 years
Dairy Sequence 1 - Till 2	None	Vertical Till	
Dairy Sequence 1 - Till 3	Cultivator	None	
Dairy Sequence 1 - Till 4	None	None	
Dairy Sequence 2 - Till 1	Chisel Plow	Cultivator, x2	
Dairy Sequence 2 - Till 2	None	Vertical Till	
Dairy Sequence 2 - Till 3	Cultivator	None	
Dairy Sequence 2 - Till 4	None	None	
Dairy Sequence 3 - Till 1	Chisel Plow	Cultivator, x2	
Dairy Sequence 3 - Till 2	None	Vertical Till	
Dairy Sequence 3 - Till 3	Cultivator	None	
Dairy Sequence 3 - Till 4	None	None	
Dairy Sequence 4 - Till 1	Chisel Plow	Cultivator, x2	Tilled every year
Dairy Sequence 4 - Till 2	Vertical Till	Cultivator	
Dairy Sequence 4 - Till 3	None	Vertical Till	
Dairy Sequence 4 - Till 4	None	None	
Cash Grain Sequence - Till 1	Chisel Plow	Cultivator, x2	Tilled every other year
Cash Grain Sequence - Till 2	Vertical Till	Cultivator	
Cash Grain Sequence - Till 3	None	Vertical Till	
Cash Grain Sequence - Till 4	Cultivator	None	
Cash Grain Sequence - Till 5	None	None	
Continuous Corn Sequence - Till 1	Chisel Plow	Cultivator, x2	Tilled every year
Continuous Corn Sequence - Till 2	Vertical Till	Cultivator	
Continuous Corn Sequence - Till 3	None	Vertical Till	
Continuous Corn Sequence - Till 4	None	None	
Vegetable - Till 1	Moldboard Plow	Cultivator, x2	Tilled every year
Vegetable - Till 2	Disk and Chisel plow	Cultivator, x2	

3.3 SNAPPLUS MODELING

3.3.1 SnapPlus Database Creation

SnapPlus input files, in the form of an overall input database, were generated to run in batch mode by WDNR. Each agricultural land management class (e.g. Dairy Sequence 1-Till 1) was designated as a field in SnapPlus and assigned a multi-year rotation of crop type, tillage practice, and nutrient management plan starting in year 2008 and ending in year 2015. Each rotation's year, crop, and management strategy follow the patterns described in Section 3.2.2.

3.3.2 Rotation and Soil HSG Table for Batch Process

Tetra Tech overlaid GIS coverages for land cover and land management, SSURGO map units, HUC12 subbasins, and county boundaries to develop a table for WDNR containing the following information:

1. Unique landcover/land management ID associated with a crop rotation (referred to as field in SnapPlus) in SnapPlus.
2. SSURGO MUKEY (soil type, slope, organic matter)
3. HUC12 ID
4. County Name
5. Average Soil Phosphorus (ppm)
6. Contour Farming Practice
7. Polygon area

This table will be used to loop through the batch mode run of the SnapPlus model. Each row of the table corresponds to a unique combination of items 1-7 in the list above. A sample of the table contents are provided in Table 3-6.

Table 3-6. Sample of Table Provided to WDNR for Batch Process

NAME	HUC12_CODE	AVG_SOIL_P	MUSYM	MUKEY	COMPNAME	HSG	AREA_SQ_M	ROTATION	CONTOUR
Pepin	70400010702	40	826B2	1693133	Hersey	B	0.016125689	Cash Grain Sequence - Till 1	No contour
Pepin	70400010702	40	125C2	2503780	Pepin	B	0.02794278	Cash Grain Sequence - Till 1	No contour
Pepin	70400010702	40	826B2	1693133	Hersey	B	0.047865139	Cash Grain Sequence - Till 1	On contour
Pepin	70400010702	40	125C2	2503780	Pepin	B	0.082941266	Cash Grain Sequence - Till 1	On contour
Pepin	70400010702	40	114C2	2504322	Mt. Carroll	B	0.122480396	Cash Grain Sequence - Till 1	No contour
Pepin	70400010702	40	125C2	1690928	Pepin	B	0.323778638	Cash Grain Sequence - Till 1	No contour
Pepin	70400010702	40	114C2	2504322	Mt. Carroll	B	0.363552922	Cash Grain Sequence - Till 1	On contour
Pepin	70400010702	40	115C2	2497467	Mt. Carroll	B	0.444231225	Cash Grain Sequence - Till 1	No contour
Pepin	70400010702	40	125C2	1690928	Pepin	B	0.961057227	Cash Grain Sequence - Till 1	On contour
Pepin	70400010702	40	115C2	2497467	Mt. Carroll	B	1.318591097	Cash Grain Sequence - Till 1	On contour
Pepin	70400010702	40	115B	2501403	Blackhammer	B	1.630314808	Cash Grain Sequence - Till 1	No contour

3.3.3 BMP Scenario Modeling

Once the baseline SnapPlus input database was created and approved by Wisconsin DNR, additional SnapPlus databases were created for nine best management practice (BMP) scenarios selected by WDNR with feedback from Pepin, Pierce, and St. Croix counties. These BMP scenarios are described in Table 3-7. Each scenario input database was provided in a uniquely named folder along with a csv file to use for the batch model run process.

Table 3-7. List of BMP Scenarios Modeled in SnapPlus

Scenario	Description
1	Add cover crops (and amend tillage as necessary) to selected years on all crop rotations
2	Add contour farming; set all crop rotations on C or D hydrologic soil group (HSG) to use the contour practice vs. only a percentage of cropland using contour practice on C or D HSG (i.e., baseline for HUC12 was 50% contour; 50% no contour or other percentage split based on HUC12 guidance from Pierce County)
3	Add no-till practice on all crop rotations (amend manure and fertilizer application method as appropriate to reflect no-till)
4	Reduce Soil Test Phosphorus (STP) levels: -HUC12s with 30-40 ppm average reduced to 25 ppm -HUC12s with 50-75 ppm average reduced to 35 ppm
5	Add cover crops and no-till practices (merging Scenarios 1 and 3 above)
6	Add cover crops, no-till practices, and contour farming
7	Add cover crops, no-till practices, and STP level reduction
8	Add cover crops, no-till practices, STP level reduction, and contour farming
9	Add cover crops, no-till practices, STP level reduction, and edge of field filter strip

3.4 PRIORITIZATION OF CATCHMENTS FOR EVAAL MODELING

One of the major end goals of this project was to utilize EVAAL on watersheds prioritized for implementation efforts in the Lake Pepin study area. The watershed prioritization for EVAAL modeling was accomplished through an evaluation of SnapPlus nutrient model results and looking at satellite imagery to determine if there are areas where significant residue is evident.

3.4.1 Evaluation of SnapPlus Results

Using the SnapPlus databases developed by Tetra Tech, WDNR ran the baseline Lake Pepin scenario, analyzed the output for normalized phosphorus and sediment losses, and provided preliminary model output to Tetra Tech., Table 3-8 shows these results with a distribution of higher to lower baseline phosphorus losses. The results were used to help inform the prioritization of HUC12 subwatersheds for EVAAL model analysis. HUC12 subwatersheds shaded in green and bolded were prioritized and selected for EVAAL modeling. Although further down in the ranking list, Lake Pepin (HUC 070400010705) was also selected based on conversations with Wisconsin DNR about proximity to impaired waterbodies and county interest. Wisconsin DNR plans to complete SnapPlus BMP Scenario modeling results by the end of calendar year 2023, and those SnapPlus results will be relayed in future Lake Pepin Phosphorus TMDL reports.

Table 3-8. Preliminary results of the baseline SnapPlus runs for Lake Pepin

		Model runs with missing area			Area comparison		High level check to account for missing areas		
HUC12	Rank	Area (acres)	P loss (lb/ac/yr)	Sed loss (ton/ac/yr)	TT GIS area (acre)	% Area missing	Avg. P Loss of Adjacent Watersheds	Adjusted P Loss (lb/ac/yr)	Adjusted Rank
070400010302	1	4978	5.3	4.2	6386	-22%	3.8	4.9	2
070400010503	2	6644	5.1	4.3	6790	-2%	3.6	5.0	1
070400010507	3	8030	4.9	4.6	8831	-9%	4.3	4.9	3
070400010303	4	8529	4.9	3.7	9545	-11%	3.6	4.8	4
070400010701	5	11885	4.8	3.7	12535	-5%	4.5	4.7	6
070400010501	6	15209	4.8	3.9	15318	-1%	3.5	4.7	5
070400010702	7	4527	4.6	4.5	5278	-14%	4.3	4.5	7
070400010506	8	7677	4.5	3.3	7906	-3%	4.3	4.5	8
070400010301	9	6668	4.4	3.4	6703	-1%	4.1	4.4	9
070400010504	10	8545	3.9	3.4	8812	-3%	4.2	3.9	10
070400010102	11	12487	3.9	3.6	13596	-8%	3.4	3.8	11
070400010705	12	10012	3.7	3.5	11938	-16%	4.3	3.8	12
070400010505	13	8163	3.7	3.1	8335	-2%	4.3	3.7	13
070400010101	14	5223	3.6	3.1	5398	-3%	4.4	3.7	14
070400010502	15	8471	3.5	2.7	8505	0%	4.4	3.5	15
070400010403	16	1897	1.7	1.6	2269	-16%	4.5	2.2	16

3.4.2 Satellite Imagery Derived Vegetation Indices

The Mississippi River Basin Healthy Watersheds Initiative (MRBI) encouraged an increase in best management practice (BMP) implementation in the Lake Pepin watershed circa 2016. To help prioritize watersheds for EVAAL modeling it is helpful to know where and at what rate BMP implementation is occurring in the watershed. As such, pre-MRBI and post-MRBI years were examined using satellite imagery to estimate BMP implementation specifically for conservation tillage and cover crop planting.

Vegetation indices were derived from readily available satellite imagery to identify cropping practices (such as tillage methods and cover crops) in the Lake Pepin watershed. The analysis can be used to identify fields that would be good candidates for implementation of reduced tillage practices and cover crops and assess the progress of implementation in past and future years. Tetra Tech followed guidance provided by WDNR to calculate the minimum Normalized Difference Tillage Index (minNDTI).³

³ WDNR provided Tetra Tech with two slide decks in PDF format with guidance on how to calculate the minNDTI:

- *How to Calculate Vegetation Indices Using ArcMap and Earth Explorer (Landsat 8)*
- *Evaluating and Utilizing NDTI Raster Data*

Additional information is provided below on how the guidance was used to estimate the minNDTI throughout the

watershed.

3.4.2.1 The Normalized Difference Tillage Index (NDTI)

The Normalized Difference Tillage Index was derived using the shortwave infrared (SWIR) bands of satellite imagery to exploit the differences in reflectance in the spectral signature of crop residue. Imagery was potentially available from two sources – Landsat 8 and Sentinel 2. The equations below calculate NDTI values using Landsat 8 and Sentinel 2 imagery respectively:

$$\text{Landsat 8 NDTI} = \frac{\text{band 6} - \text{band 7}}{\text{band 6} + \text{band 7}}$$

$$\text{Sentinel 2 NDTI} = \frac{\text{band 11} - \text{band 12}}{\text{band 11} + \text{band 12}}$$

Both Landsat 8 and Sentinel 2 imagery can be used interchangeably because, although their bands are numbered differently, the bandwidth between the two satellites are similar (Table 3-9). These wavelength ranges do not directly correspond to crop residue and bare soil themselves. Rather, they detect differences in moisture content between crop residue and bare soil and can therefore serve as a proxy in determining relative amount of crop residue and bare soil. One advantage of Sentinel 2 imagery is the finer spatial resolution of 20m vs. 30m of Landsat 8.

Table 3-9. Wavelength range of Landsat 8 and Sentinel 2 bands used in NDTI calculation

Satellite	Resolution	SWIR 1	SWIR 2
Landsat 8	30 m	Band 6: 1560 – 1660 nm	Band 7: 2100 – 2300 nm
Sentinel 2	20 m	Band 11: 1566 – 1655 nm	Band 12: 2100 – 2280 nm

3.4.2.2 Data Collection

Tetra tech obtained Landsat 8 and Sentinel 2 data from the USGS *EarthExplorer* portal (<https://earthexplorer.usgs.gov/>). To complete the NDTI analysis, an evaluation needed to be conducted to determine which satellite imagery was available for the period of interest. WDNR identified a set of years that best represent typical weather and precipitation conditions for NDTI analysis, which are presented in Table 3-10. Additionally, because tillage and cover crop practices occur while the ground is not frozen, snow covered, or excessively wet before crops are planted in the spring and after crops are harvested in the fall, the ideal seasonal time-period is April 1 – 15 in spring and November 1 – 15 in fall. Because only one pre-MRBI spring and fall season and one post-MRBI spring and fall season are needed, WDNR identified a priority order to indicate which years are preferable for representing typical weather and precipitation. The spring and fall data do not need to be from the same year. Satellite imagery data that covers the above requirements were sought for further review to select the best coverage.

Table 3-10. Years considered for pre- and post-MRBI implementation NDTI analysis

	Year	Priority
Pre-MRBI	2010	Sentinel 2 and Landsat 8 not operational
	2013	Last priority
	2014	Top priority
	2015	Second priority
Post-MRBI	2019	Last priority
	2020	Second priority
	2021	Top priority

Sentinel 2 image selection rationale:

Sentinel 2 became operational in June of 2015. Since an NDTI analysis is unable to be conducted for 2010-2014 time-period (pre-MRBI implementation) using Sentinel 2 imagery, no further imagery search was conducted for this satellite.

Landsat 8 image selection rationale:

Landsat 8 became operational in February of 2013. Imagery was searched for in the spring of 2013 and moving forward (Table 3-11 and Table 3-12). When usable imagery was not found within the ideal seasonal time-period specified (April 1 – 15 and November 1 – 15) in a particular year, search criteria was expanded by 16 days both prior to, and following the dates provided.

3.4.2.3 Final Image Selection for Further NDTI Analysis:

Dates of available imagery were rejected due to the following reasons listed in the rationale column in Table 3-11 and Table 3-12 below:

- The ground being wet and/or frozen in a portion or the entire watershed
- Cloud cover over a portion or the entire watershed,
- In a few special cases an image was usable, meaning the ground was not wet/frozen and there was no cloud cover, but rejected because the data was too far outside of the ideal seasonal time-period or because imagery from another year was determined to be more suitable and from a higher priority year.

Two images were selected to characterize pre-MRBI implementation conditions: October 27th, 2013 and April 21st, 2014. Although these dates are outside of the ideal seasonal time-period, they do not have cloud cover, and the ground is not wet/frozen. Additionally, 2014 is the top priority year for characterizing pre-MRBI conditions.

Two images were selected to characterize post-MRBI implementation conditions: April 5th and December 1st, 2020. The spring image is within the ideal seasonal time-period. December was confirmed to be abnormally warm and as such, field conditions on December 1st are conducive to NDTI analysis even though it is outside the typical ideal seasonal time-period.

Table 3-11. Pre-MRBI Landsat 8 Image Selection Rationale

Year	Season	Date	Status	Rationale	Notes
2010	--	--	--	--	Sentinel 2 and Landsat 8 were not yet operational in 2010.
2013	Spring	<i>3-22</i>	Rejected	Cloud cover	Imagery that covered the entire extent of the watershed was not available in the ideal seasonal time-period, likely due to dates being shortly after the launch of Landsat 8. The time-period was therefore expanded in the search criteria and three images were found but all were rejected due to cloud cover.
		<i>3-27</i>	Rejected	Cloud cover	
		<i>4-18</i>	Rejected	Cloud cover	
	Fall	<i>10-27</i>	<u>Usable</u>	--	The image available within the ideal seasonal time-period was rejected due to partially wet/frozen ground conditions. The time-period was therefore expanded in the search criteria and two images were found; one of which is usable for further NDTI analysis despite being slightly outside of the ideal seasonal time-period by 4 days.
		11-12	Rejected	Wet/frozen ground	
		<i>11-28</i>	Rejected	Wet/frozen ground and cloud cover	
2014	Spring	<i>3-20</i>	Rejected	Wet/frozen ground	The image available within the ideal seasonal time-period was rejected due to wet/frozen ground conditions. The time-period was therefore expanded in the search criteria and two images were found; one of which is usable for further NDTI analysis despite being slightly outside of the ideal seasonal time-period by 6 days.
		4-5	Rejected	Wet/frozen ground	
		<i>4-21</i>	<u>Usable</u>	--	
	Fall	<i>10-30</i>	Rejected	Cloud cover	All images in the fall of 2014 were rejected due to cloud cover or wet/frozen ground conditions.
		11-15	Rejected	Cloud cover	
		<i>12-1</i>	Rejected	Wet/frozen ground	
2015	Spring	<i>3-23</i>	Rejected	Cloud cover	All images in the spring of 2015 were rejected due to cloud cover.
		4-8	Rejected	Cloud cover	
		<i>4-24</i>	Rejected	Cloud cover	
	Fall	<i>10-17</i>	Usable but rejected	Early in fall season – 13 days outside of ideal time-period	The image available within the ideal seasonal time-period was rejected due to partial cloud cover. The time-period was therefore expanded in the search criteria and two images were found; neither of which were used in further NDTI analysis.
		11-2	Rejected	Cloud cover	
		<i>11-18</i>	Rejected	Cloud cover	

Notes:

Dates in *red italics* are outside of the suggested seasonal range (April 1 – 15 and November 1 – 15).

A **bold and underlined** status indicates the date of imagery that was downloaded for Pre-MRBI NDTI analysis.

Table 3-12. Post-MRBI Landsat 8 Image Selection Rationale

Year	Season	Date	Status	Rationale	Notes
2019	Spring	<i>3-18</i>	Rejected	Wet/frozen ground	The image available within the ideal seasonal time-period was rejected due to cloud cover. The time-period was therefore expanded in the search criteria and two images were found; neither of which were used in further NDTI analysis.
		4-3	Rejected	Cloud cover	
		<i>4-19</i>	Usable but rejected	Low priority year – 2020 has better imagery and is more recent	
	Fall	<i>10-28</i>	Rejected	Cloud cover	All images in the fall of 2019 were rejected due to cloud cover.
		11-13	Rejected	Cloud cover	
		<i>11-29</i>	Rejected	Cloud cover	
2020	Spring	4-5	<u>Ideal</u>	--	One image was found in the ideal seasonal time-period and is ideal for NDTI analysis.
	Fall	<i>10-30</i>	Rejected	Wet/frozen ground	The image available within the ideal seasonal time-period was rejected due to cloud cover. The time-period was therefore expanded in the search criteria and two images were found; one of which is usable for further NDTI analysis despite being outside of the ideal seasonal time-period. WDNR confirmed weather and field conditions were abnormally warm in December of 2020, and thus, this date of imagery can be used.
		11-15	Rejected	Cloud cover	
		<i>12-1</i>	<u>Usable</u>	--	
2021	Spring	<i>3-23</i>	Rejected	Cloud cover	All images in the spring of 2021 were rejected due to cloud cover.
		4-8	Rejected	Cloud cover	
		<i>4-24</i>	Rejected	Cloud cover	
	Fall	<i>10-17</i>	Usable but rejected	Early in fall season – 13 days outside of ideal time-period	The image available within the ideal seasonal time-period was rejected due to cloud cover. The time-period was therefore expanded in the search criteria and two images were found; neither of which were used in further NDTI analysis.
		11-2	Rejected	Cloud cover	
		<i>11-18</i>	Rejected	Cloud cover	

Notes:

Dates in *red italics* are outside of the suggested seasonal range (April 1 – 15 and November 1 – 15).

A **bold and underlined** status indicates a date of imagery that was downloaded for Post-MRBI NDTI analysis.

3.4.2.4 NDTI Results

Reliable assessments of tillage practices cannot be provided by a single Landsat image because there are differences in the timing of tilling, planting, and soil moisture over time. A more accurate estimate of tillage practices utilizes multiple images from different dates that capture the variability of these conditions listed above. The minimum NDTI across multiple dates is therefore calculated as a worst-case scenario and can be thought of as the most tillage present in that location over the given time period.

Since higher NDTI values indicate increased reduced tillage and cover crop practices, the goal, from a watershed planning standpoint, is to see an increase in NDTI values over time. A histogram showing pre- and post-MRBI implementation NDTI distribution is a useful way to conduct this assessment. The pre-MRBI imagery minNDTI distribution is bimodal, with peaks in the 0.065 – 0.07 and 0.085 – 0.09 minNDTI ranges and a mean of 0.078 (Figure 3). On the other hand, the post-MRBI imagery minNDTI distribution is unimodal that peaks in the 0.085 – 0.095 minNDTI range and has a mean of 0.079 (Figure 3). The post-MRBI imagery, in addition to having its mode at a higher minNDTI value than the pre-MRBI imagery, also has a larger amount of area in the highest minNDTI bins of 0.12 and 0.125 in the histogram. These two patterns indicate that reduced tillage and cover cropping practices have slightly increased over time in the watershed. Ideally, further successful implementation of these practices will lead to NDTI values that continue to increase over time.

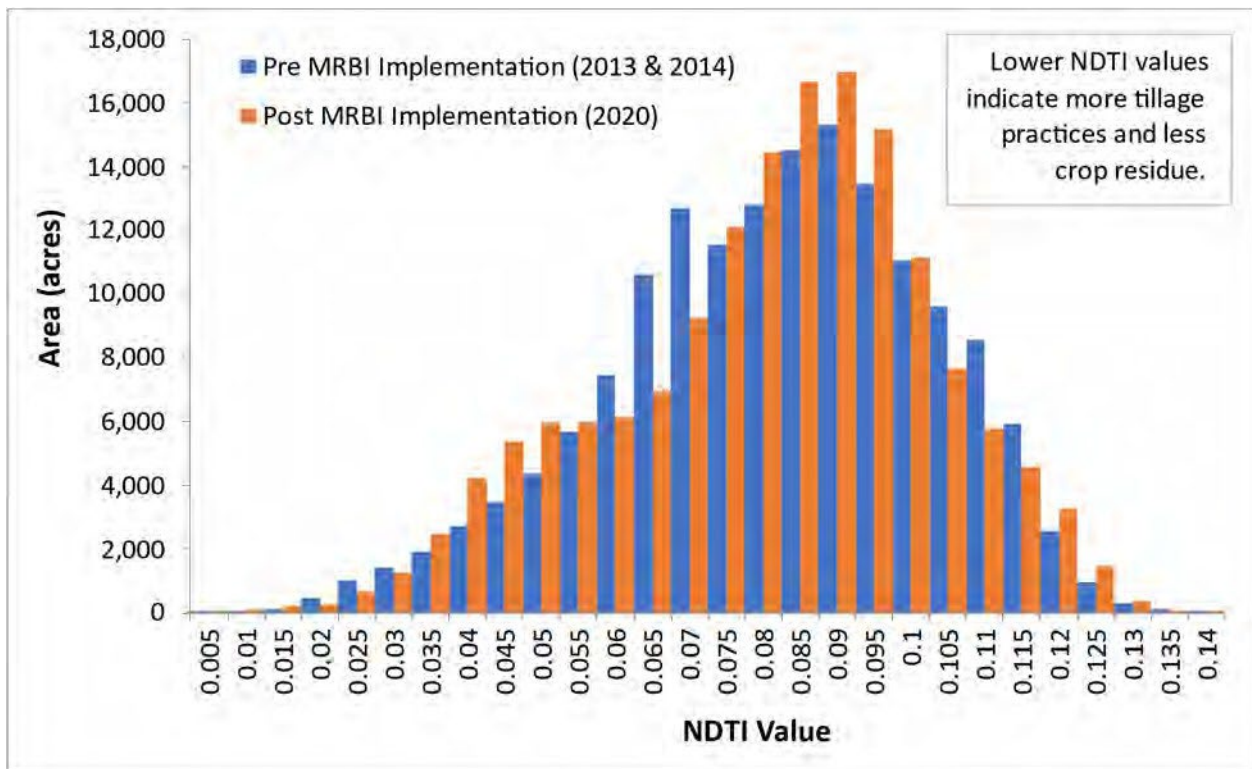


Figure 3. Minimum NDTI distribution in pre- and post-MRBI implementation time periods

Since reduced tillage and cover crop practices are commonly performed on a field-wide basis, it can also be informative to view field averaged minNDTI as shown in Table 3-13 and Figure 4 for post-MRBI imagery. Red, yellow, and blue symbology represent the bottom, middle, and top third of the sample set's field averaged minNDTI value, respectively. The southeast portion of the watershed has the highest degree of BMP implementation as indicated by the high density of blue fields while the northern tip and western portion adjacent to Lake Pepin have the lowest degree of BMP implementation as indicated by the high density of red fields (Figure 4). This, however, only provides a snapshot of relative field performance in 2020.

To view fields that have seen an increase or decrease in BMP implementation over time, the difference between post-MRBI and pre-MRBI minNDTI was calculated and averaged on a field-by-field basis. Positive values therefore indicate an increase in NDTI and, as such, an increase in crop residue on the field between the two time periods. As seen in Table 3-14 and Figure 5 below, spatial distribution between increased and decreased minNDTI on a field-by-field basis over time is heterogeneous throughout the watershed. Due to the lack of spatial patterns in changes in BMP implementation as indicated by this NDTI analysis, the selection of watersheds for further EVAAL modeling was based solely on the results from SnapPlus as shown in Table 3-8. However, the results of the NDTI analysis could be re-visited for further subwatershed evaluation using EVAAL, with a focus placed on HUC12s containing fields with an indication of more tillage practices and less crop residue.

Table 3-13. Summary of field-averaged minNDTI values by HUC12 for the post-MRBI time period

HUC12	Low minNDTI (0.016-0.076)		Moderate minNDTI (0.077-0.087)		High minNDTI (0.088-0.119)	
	Acres	% area	Acres	% area	Acres	% area
070400010705	3,586	23%	5,920	39%	5,769	38%
070400010702	233	4%	2,623	46%	2,821	50%
070400010701	5,287	38%	5,963	43%	2,696	19%
070400010507	3,168	34%	3,880	42%	2,258	24%
070400010506	2,439	30%	3,965	49%	1,711	21%
070400010505	4,123	37%	3,970	36%	2,938	27%
070400010504	3,052	35%	3,220	37%	2,535	29%
070400010503	2,196	27%	3,074	38%	2,812	35%
070400010502	3,276	24%	4,125	31%	6,008	45%
070400010501	12,157	57%	3,044	14%	5,990	28%
070400010403	965	57%	679	40%	46	3%
070400010303	4,245	39%	4,515	41%	2,216	20%
070400010302	1,639	36%	2,058	45%	843	19%
070400010301	2,505	26%	2,676	28%	4,321	45%
070400010102	8,340	55%	4,314	29%	2,405	16%
070400010101	2,137	38%	2,032	36%	1,484	26%

Table 3-14. Summary of field-averaged difference in minNDTI for pre-MRBI and post-MRBI time periods

HUC12	Increase in NDTI			Decrease in NDTI		
	# Fields	Acres	% area	# Fields	Acres	% area
070400010705	178	7,391	48%	214	7,885	52%
070400010702	84	3,621	64%	52	2,056	36%
070400010701	174	6,630	48%	168	7,315	52%
070400010507	97	4,240	46%	121	5,066	54%
070400010506	96	3,661	45%	106	4,454	55%
070400010505	121	3,975	36%	190	7,056	64%
070400010504	126	4,471	51%	125	4,336	49%
070400010503	94	3,354	42%	134	4,727	58%
070400010502	163	5,582	42%	213	7,826	58%
070400010501	286	11,136	53%	277	10,055	47%
070400010403	18	619	37%	25	1,072	63%
070400010303	150	5,179	47%	155	5,797	53%
070400010302	63	2,141	47%	72	2,399	53%
070400010301	130	4,103	43%	150	5,399	57%
070400010102	128	5,097	34%	214	9,962	66%
070400010101	50	1,752	31%	101	3,902	69%

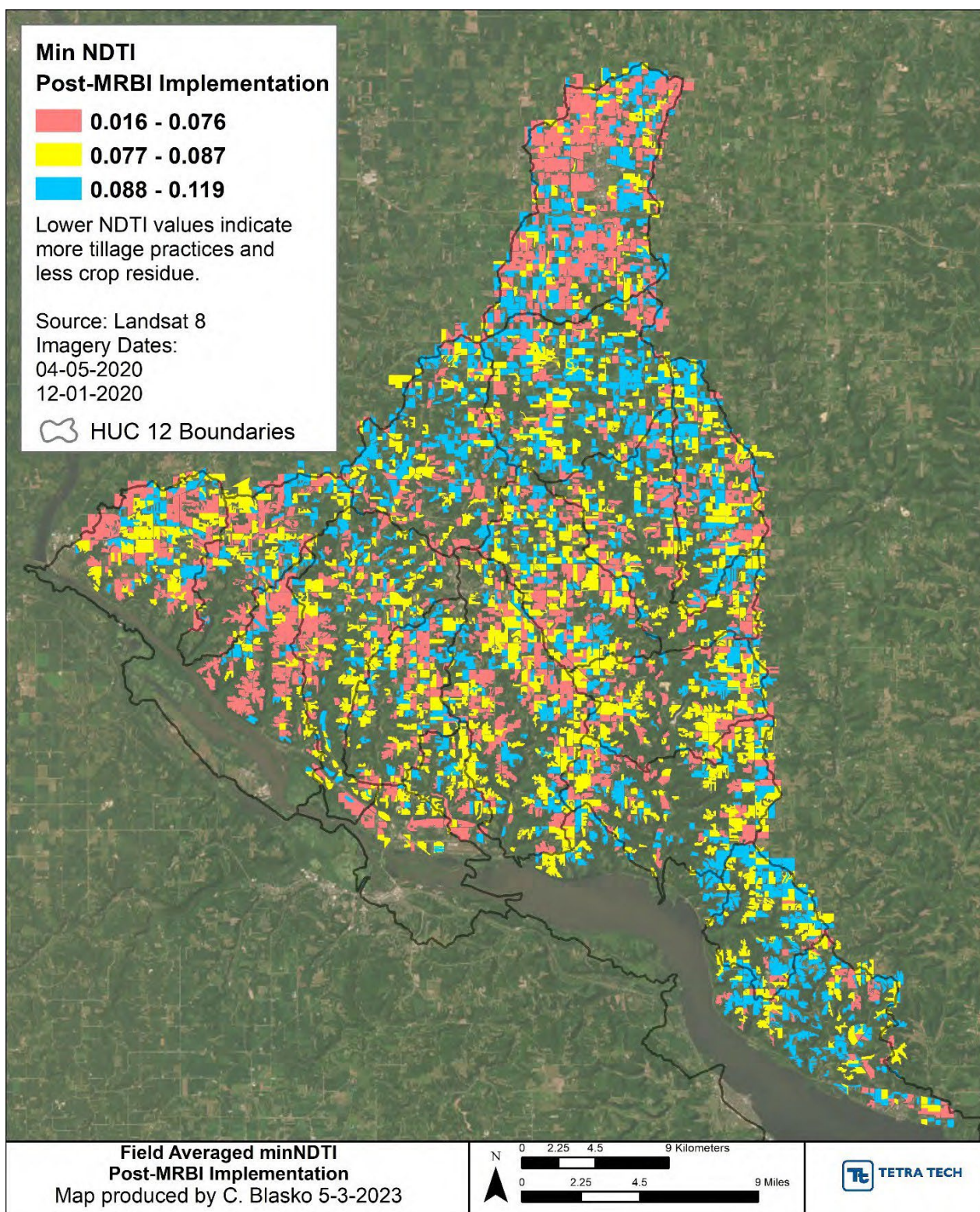


Figure 4. Field average minimum NDTI values for the post-MRBI time period

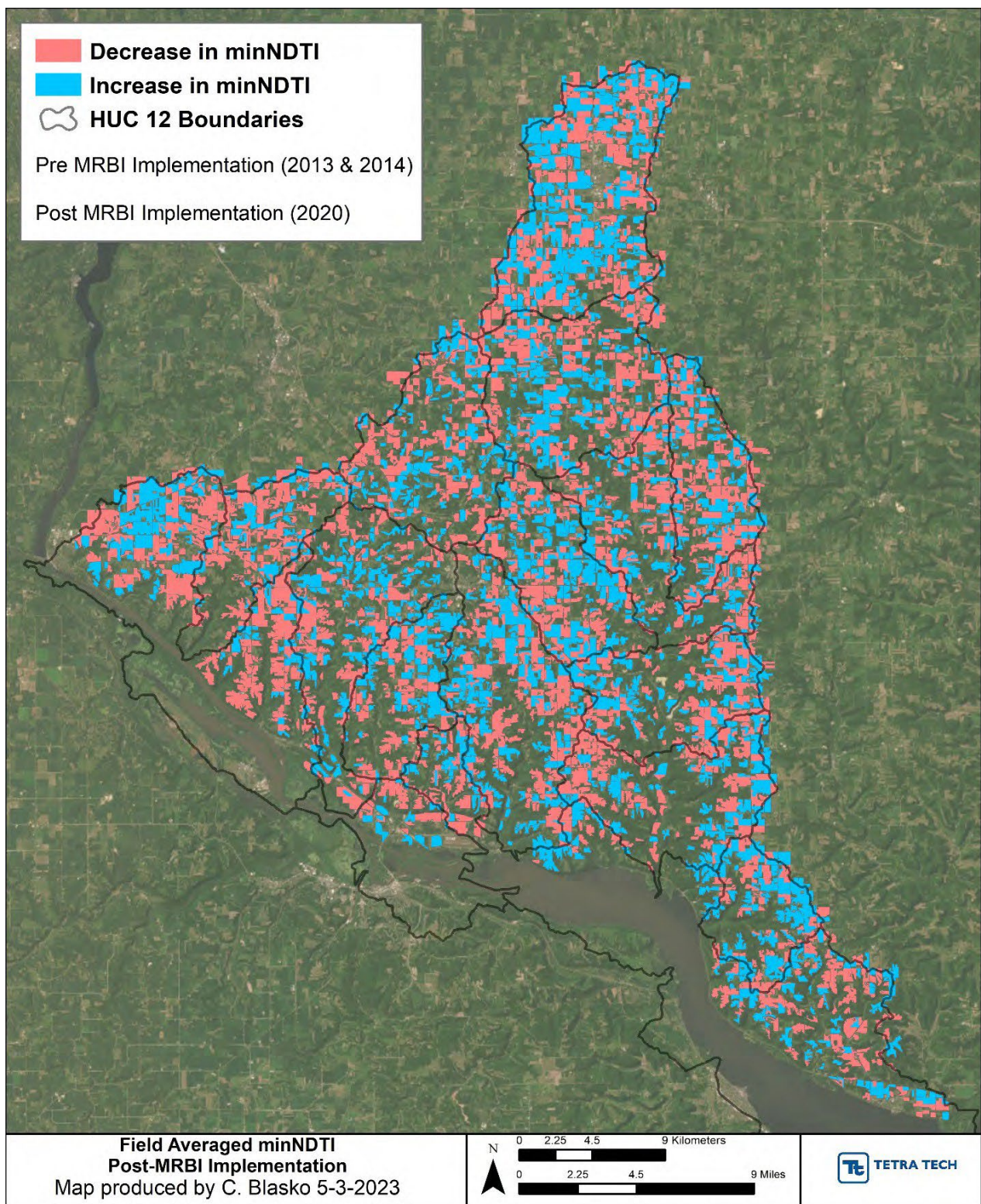


Figure 5. Field averaged increase or decrease in minNDTI between pre- and post-MRBI implementation

3.5 EVAAL MODELING FOR PRIORITY WATERSHEDS

Tetra Tech ran the EVAAL model toolbox to deliver final outputs of erosion vulnerability for the watersheds of interest, prioritized for implementation based on conversations with WDNR, County Land Conservation District (LCD) Offices, and the results of the analysis described in Sections 3.3 and 3.4 above.

Based on SnapPlus modeling results and conversations with Wisconsin DNR and EPA, six watersheds were prioritized for EVAAL modeling to identify areas vulnerable to erosion. EVAAL assists watershed managers in prioritizing areas within a watershed that may be vulnerable to water erosion (and associated nutrient export) and may contribute to downstream water quality problems. These EVAAL results can be applied in the Lake Pepin Phosphorus TMDL implementation plans that will be developed across the study area.

The hydrologic unit codes (HUC12) for the six subwatersheds analyzed are:

- Little Trimbelle River (HUC 070400010302)
- Cave Creek (HUC 070400010503)
- Crystal Springs Coulee-Rush River (HUC 070400010507)
- Spring Creek-Trimble River (HUC 070400010303)
- Isabelle Creek (HUC 070400010701)
- Lake Pepin (HUC 070400010705)

3.5.1 Methodology

EVAAL evaluates locations of relative vulnerability to sheet, rill, and gully erosion using information about topography, soils, rainfall, and land cover. The tool estimates vulnerability by separately assessing the risk for sheet and rill erosion (via the Universal Soil Loss Equation, USLE), and gully erosion (via the Stream Power index, SPI), while deprioritizing those areas that are internally drained. The date range used to calculate C-factors and rasterize them across the study area for USLE analysis in EVAAL was 2008-2015, which aligns with the crop rotation years simulated in SnapPlus.

Because EVAAL is intended for relatively small watersheds (less than 75 km²), considerations had to be made due to the larger size of the Lake Pepin (HUC 070400010705) subwatershed that was prioritized for EVAAL modeling. In particular, the first EVAAL tool, “Condition the LiDAR DEM” would not run successfully given the size of the Lake Pepin digital elevation model (DEM) raster. This issue was addressed by splitting the Lake Pepin HUC12 into two separate areas. The watershed was split near the border between Pepin and Peirce counties down the east-west running centerline of Pine Creek. This location was determined to be ideal for splitting the watershed because it does not intersect through concurrently draining areas and is not adjacent to any agricultural or pasture fields. EVAAL tools were then run for each portion of the Lake Pepin HUC12 separately. The remaining priority subwatersheds were sufficiently small to each be run as single subwatersheds.

The final outputs of the EVAAL toolbox are:

- Erosion vulnerability index for the area of interest (raster and tabular summary)
- Areas vulnerable to sheet and rill erosion
- Areas of potential gully erosion
- Areas hydrologically disconnected from surface waters
- Ranking of potential improvements from high and low C-factor runs (portrayed as USLE soil loss difference index)

3.5.2 Culvert Layer Creation for DEM Hydro-Conditioning

With high resolution LiDAR DEMs, roads and highways are shown in high relief. When modeling water flow over the landscape, this creates “digital dams” that artificially impound the water; however, there are often culverts or bridges that allow water to flow through road berms and other barrier features. To address this phenomenon, it is necessary for an EVAAL user to create a layer of digitized “culverts” so that water can flow unimpeded across the landscape. Culvert layers were manually created for each HUC12 according to the guidelines in the EVAAL Users Guide⁴. The number of digitized “culverts” created for each HUC12 ranged from 41 to 400+, depending on the size of the watershed and flow network complexity. This aligns with WDNR’s previous experience with hydro-conditioning HUC12 watersheds, which typically ranged from 25-75 obvious digital dams per watershed area.

3.5.3 EVAAL Results

Successful runs of the EVAAL model toolbox for the six prioritized subwatersheds produced several outputs, including an erosion vulnerability and soil loss coverages for high and low curve number (CN) scenarios and high and low C-factor scenarios.

The results from erosion vulnerability index calculations were run through zonal statistics using the Agricultural Conservation Planning Framework (ACPF)⁵ field boundaries⁶ marked as “1” or “2” under the “isAg” field to indicate field boundaries for agricultural coverage only. The erosion vulnerability zonal statistics tables were then joined to the field boundary polygon layer to aggregate the erosion index by agricultural field. In this way, it is possible to identify the tracts with the highest mean erosion index (first map in each subsection below, e.g., Figure 6).

Similarly, the resulting USLE soil loss index rasters were manually aggregated to agricultural field boundaries using zonal statistics. A soil loss difference calculation was then made by computing the maximum difference between the high and low C-factor runs to display the ranking of potential improvements by field (second map in each subsection below, e.g., Figure 7).

Lastly, maps of the model-derived stream power index (SPI) for the high CN scenario were developed for the six priority HUC12s and aggregated to agricultural field boundaries using zonal statistics. SPI values are summarized over the full drainage area (third map in each subsection below, e.g. Figure 8).

3.5.3.1 Little Trimble River (HUC 070400010302)

In the Little Trimble River (HUC 070400010302) watershed, erosion vulnerability index score classifications for the high C-factor scenario suggest that agricultural and pasture fields on the western side of the river mainstem are prone to the highest mean erosion vulnerability overall (Figure 6). High erosion vulnerability also exists in a handful of fields on the eastern side of the river.

The map of maximum USLE soil loss difference (high C-factor raster – low C-factor raster) shows that several agricultural and pasture fields within the watershed boundary have little difference in the estimated soil loss risk generated for the low and high C-factor scenarios (Figure 7). For the fields displayed in red on the map, the larger difference in soil loss between the two scenarios suggests that these fields are more heavily influenced by soil-intensive management practices. Sheet and rill erosion risk is likely higher for the fields classified as medium to high soil loss difference (i.e. yellow to red symbology).

⁴ Wisconsin Department of Natural Resources. (2019). EVAAL V1.0, WI DNR. <https://geodata.wisc.edu/catalog/WIDNR-41983ced80674b6d89ecbef6ad308b25>

⁵ Tomer, M. D., Porter, S. A., Boomer, K. M. B., James, D. E., Kostel, J. A., Helmers, M. J., Isenhardt, T. M., & McLellan, E. (2015). Agricultural Conservation Planning Framework: 1. Developing Multipurpose Watershed Planning Scenarios and Assessing Nutrient Reduction Potential. *Journal of Environment Quality*, 44(3), 754. <https://doi.org/10.2134/jeq2014.09.0386>

⁶ ACPF Core Data Download. (2022). <https://acpfdata.gis.iastate.edu/acpf/download/>

The SPI score classifications for the high CN scenario show that about half of the agricultural and pasture fields within the watershed boundary rank as medium to high risk (Figure 8). This suggests that the fields symbolized in yellow, orange, and red color are more susceptible to gully erosion compared to blue-colored fields.

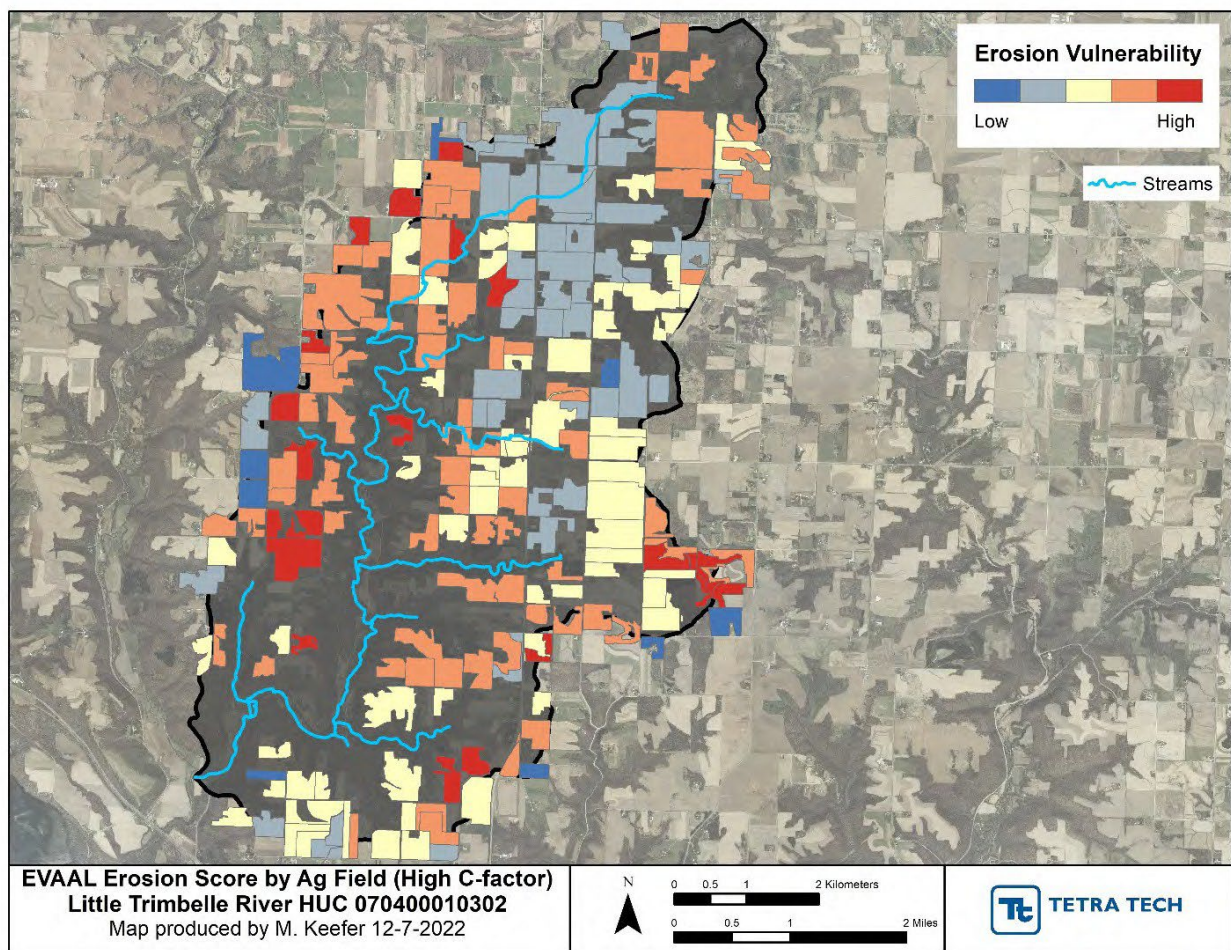


Figure 6. Map of mean erosion vulnerability score for Little Trimbelle River (High C-factor Scenario)

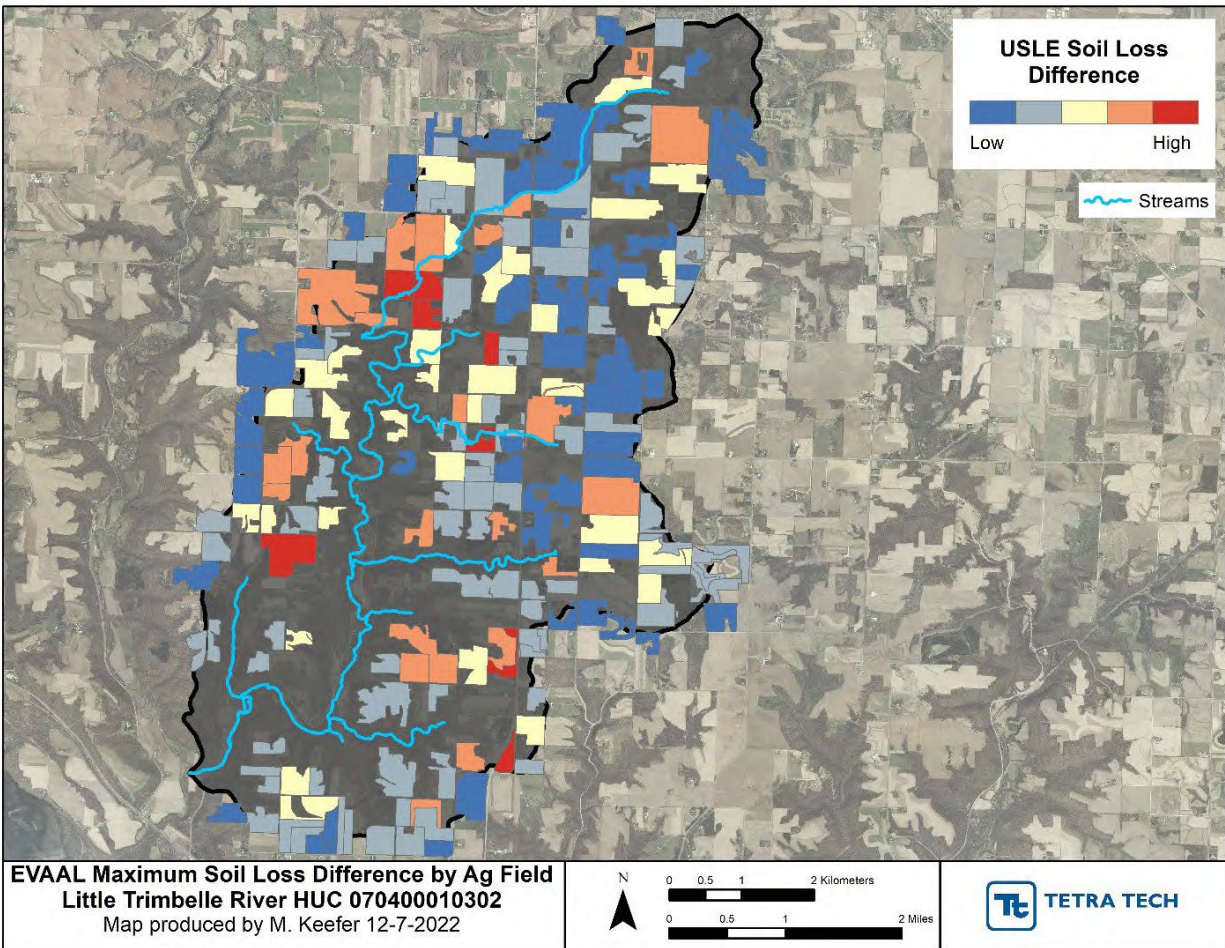


Figure 7. Map of USLE soil loss difference (High – Low C-factor runs) for Little Trimbelle River

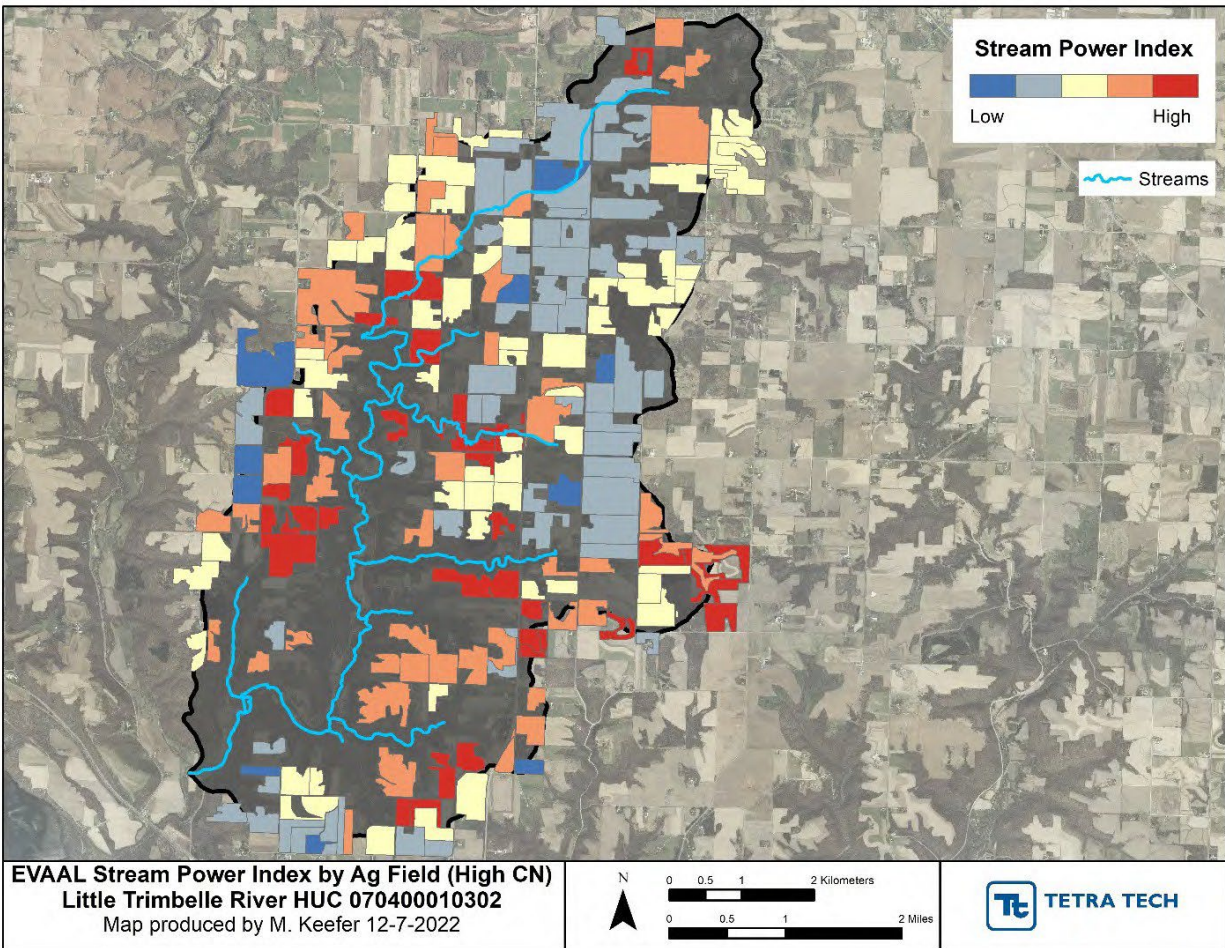


Figure 8. Map of stream power index (SPI) for Little Trimble River (High CN Scenario)

3.5.3.2 Spring Creek-Trimble River (HUC 070400010303)

In the Spring Creek-Trimble River (HUC 070400010303) watershed, erosion vulnerability index score classifications for the high C-factor scenario suggest that agricultural and pasture fields in the center of the watershed are most prone to the highest mean erosion vulnerability overall (Figure 9). High erosion vulnerability also exists in a handful of fields in the northern portion of the watershed while the downstream-most portion of the watershed has the lowest erosion vulnerability.

The maximum USLE soil loss difference (high C-factor raster – low C-factor raster) shows that most of the agricultural and pasture fields within the watershed boundary have little difference in the estimated soil loss risk generated for the low and high C-factor scenarios (Figure 10). These fields displayed in blue on the map have small differences in soil loss between the two scenarios suggesting that these fields are not greatly influenced by soil-intensive management practices. However, sheet and rill erosion risk is likely higher for the fields classified as medium to high soil loss difference (i.e. yellow to red symbology).

The SPI classifications for the high CN scenario are similar to the erosion vulnerability index in that the medium and higher risk agricultural and pasture fields are in the center and northern portions of the watershed. Similarly, the lowest risk fields are in the southern-most portion of the watershed (Figure 11). SPI is a metric related to gully erosion susceptibility and therefore, due to the similar spatial distribution of high-risk SPI fields and high-risk erosion vulnerability fields, erosion vulnerability in the watershed is likely driven primarily by gully erosion. This is further supported by the relatively low risk USLE soil loss difference (Figure 10). As such, BMPs to reduce nonpoint

source loading can be implemented accordingly to target areas most prone to gully erosion as this is the primary erosional risk in the Spring Creek-Trimbelle River watershed.

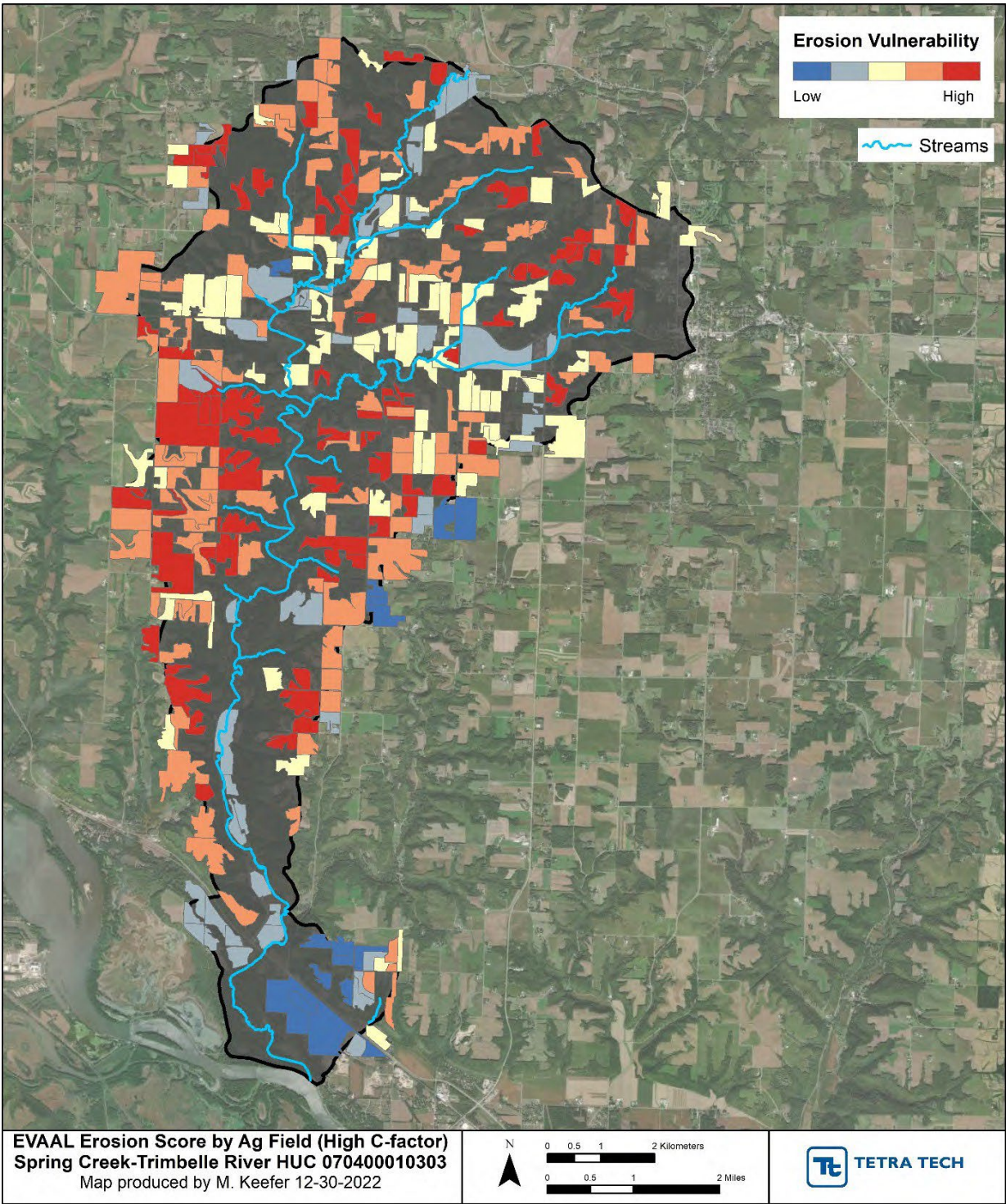


Figure 9. Map of mean erosion vulnerability score for Spring Creek-Trimbelle River (High C-factor Scenario)

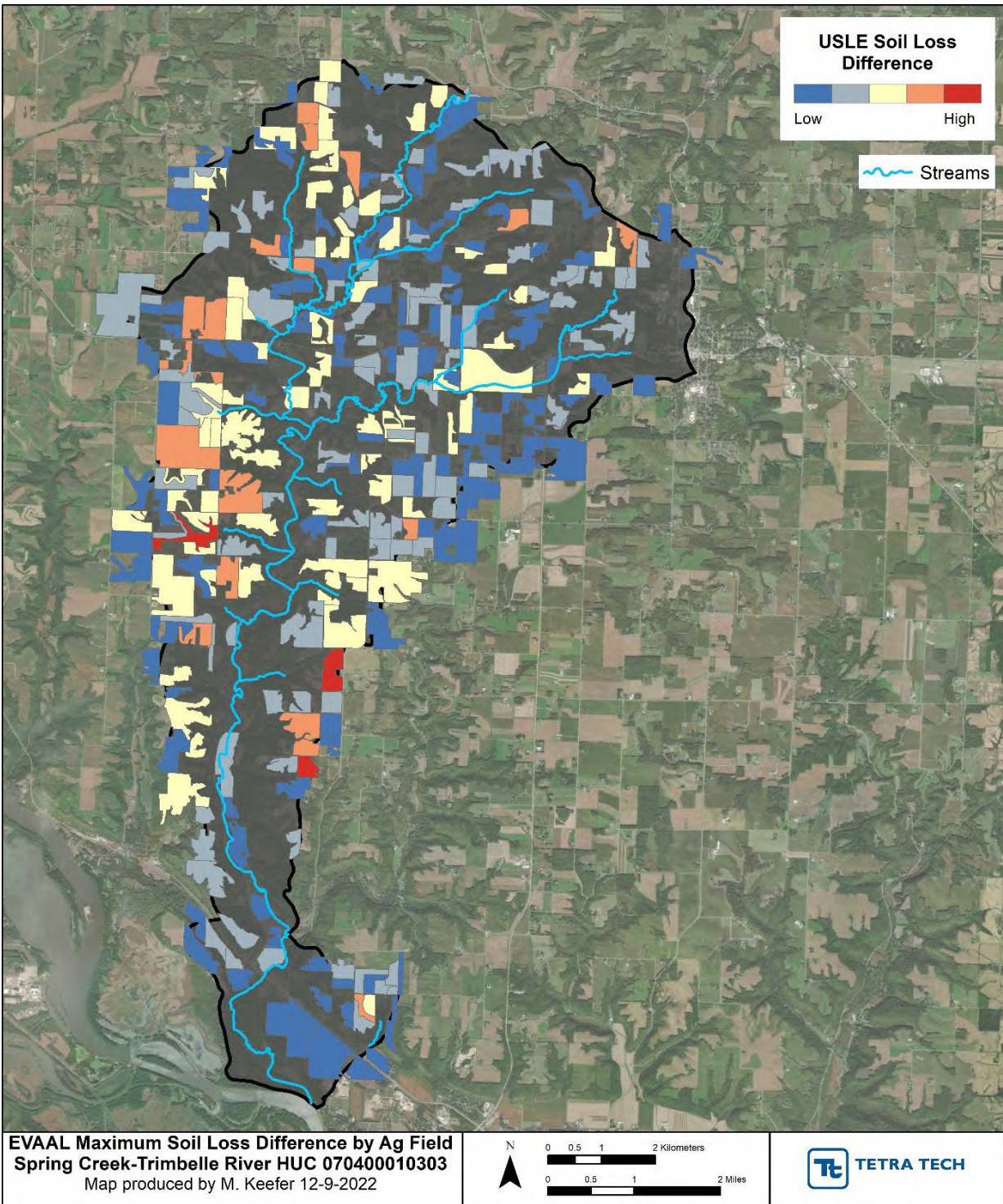


Figure 10. Map of USLE soil loss difference (High – Low C-factor runs) for Spring Creek-Trimbelle River

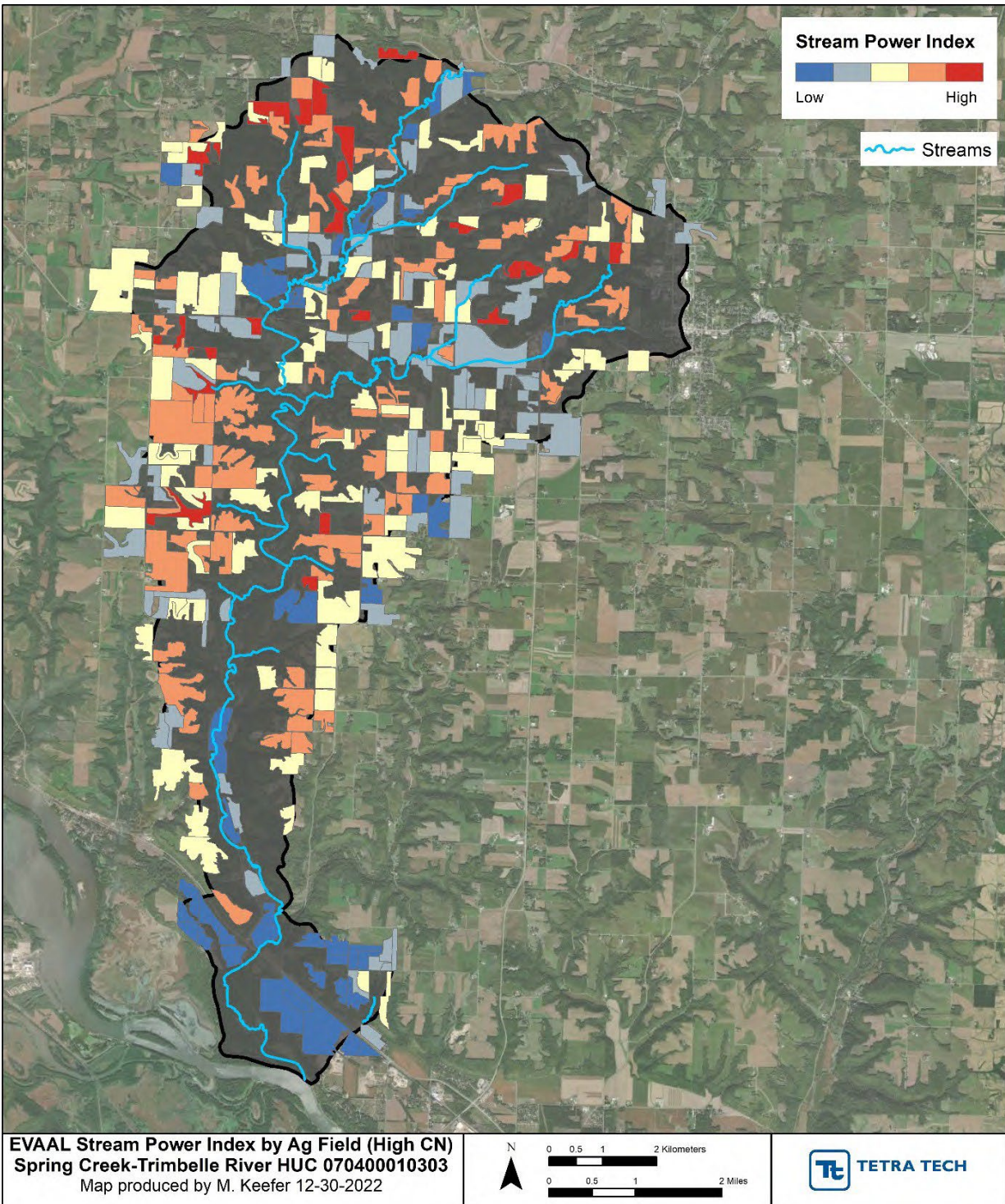


Figure 11. Map of stream power index (SPI) for Spring Creek-Trimbell River (High CN Scenario)

3.5.3.3 Cave Creek (HUC 070400010503)

In the Cave Creek (HUC 070400010503) watershed, the erosion vulnerability index (Figure 12), USLE soil loss difference (high C-factor raster – low C-factor raster; Figure 13), and SPI index (Figure 14) have similar spatial distributions of erosional risk for agricultural and pasture fields in that they are primarily at higher risk in the southern portion of the watershed.

Larger differences in soil loss between the high and low C-factor scenarios indicated by orange and red symbology in Figure 13 suggests fields are more heavily influenced by soil-intensive management practices. As such, sheet and rill erosion risk is likely higher for the fields classified as medium to high soil loss difference. Additionally, high SPI index classifications indicated by orange and red symbology in Figure 14 suggests these fields are more prone to gully erosion. Therefore, the high erosion vulnerability in the southern portion of the watershed (Figure 12) can be attributed to both sheet and rill erosion from the USLE soil loss metric and the gully erosion from the SPI metric. As such, BMPs to reduce nonpoint source loading implemented in the southern portion of the Cave Creek watershed should address both of these erosional risks.

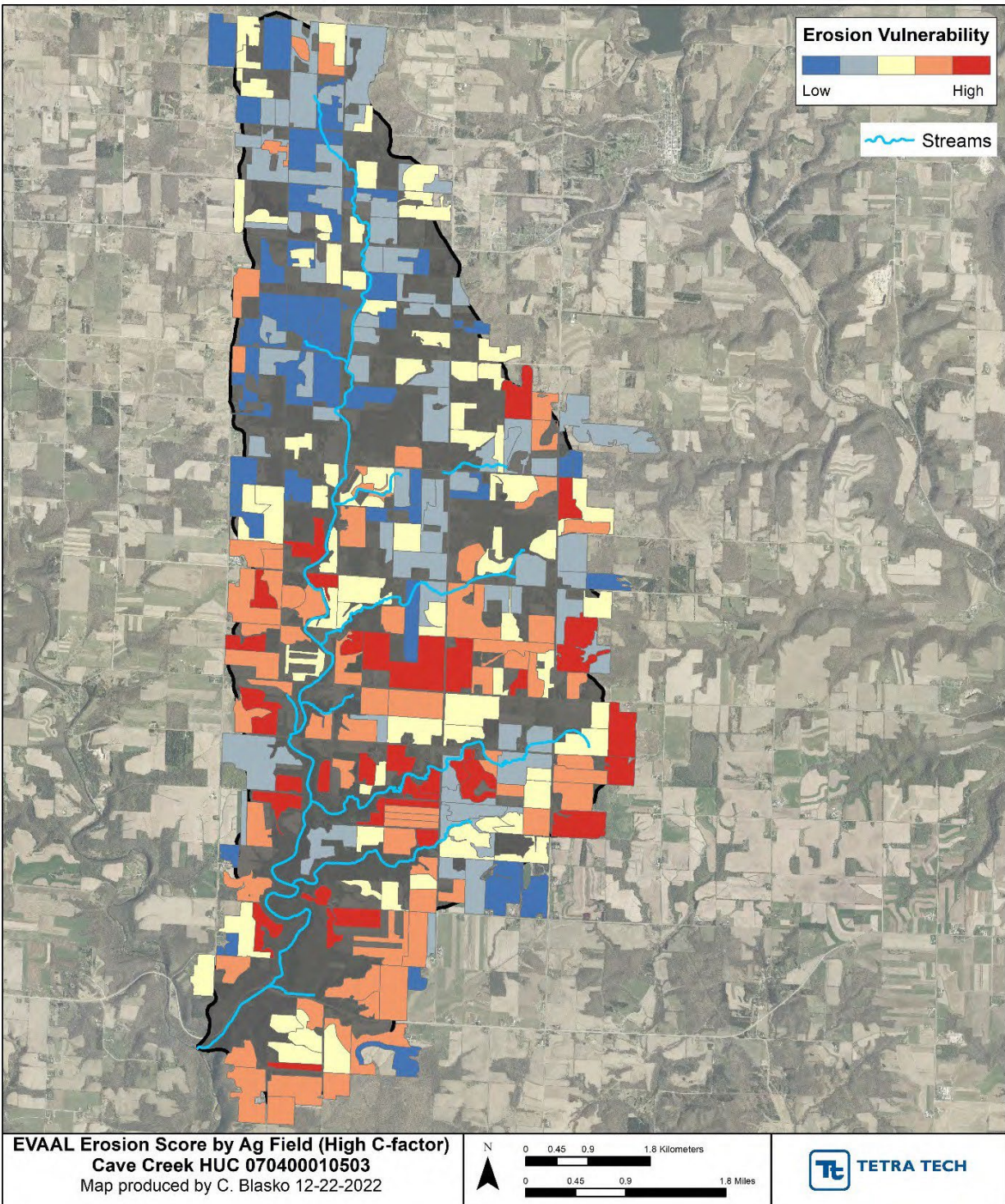


Figure 12. Map of mean erosion vulnerability score for Cave Creek (High C-factor Scenario)

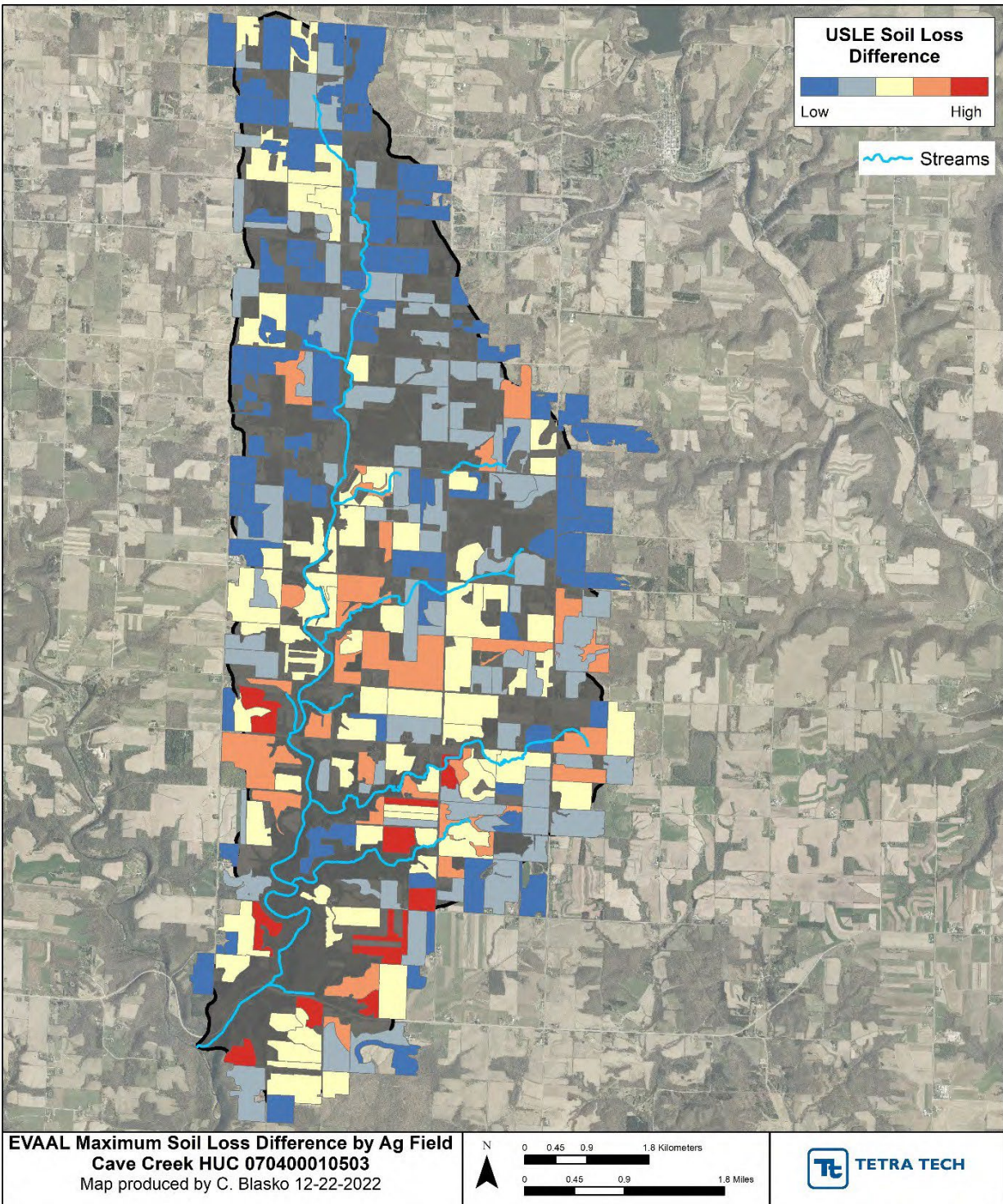


Figure 13. Map of USLE soil loss difference (High – Low C-factor runs) for Cave Creek

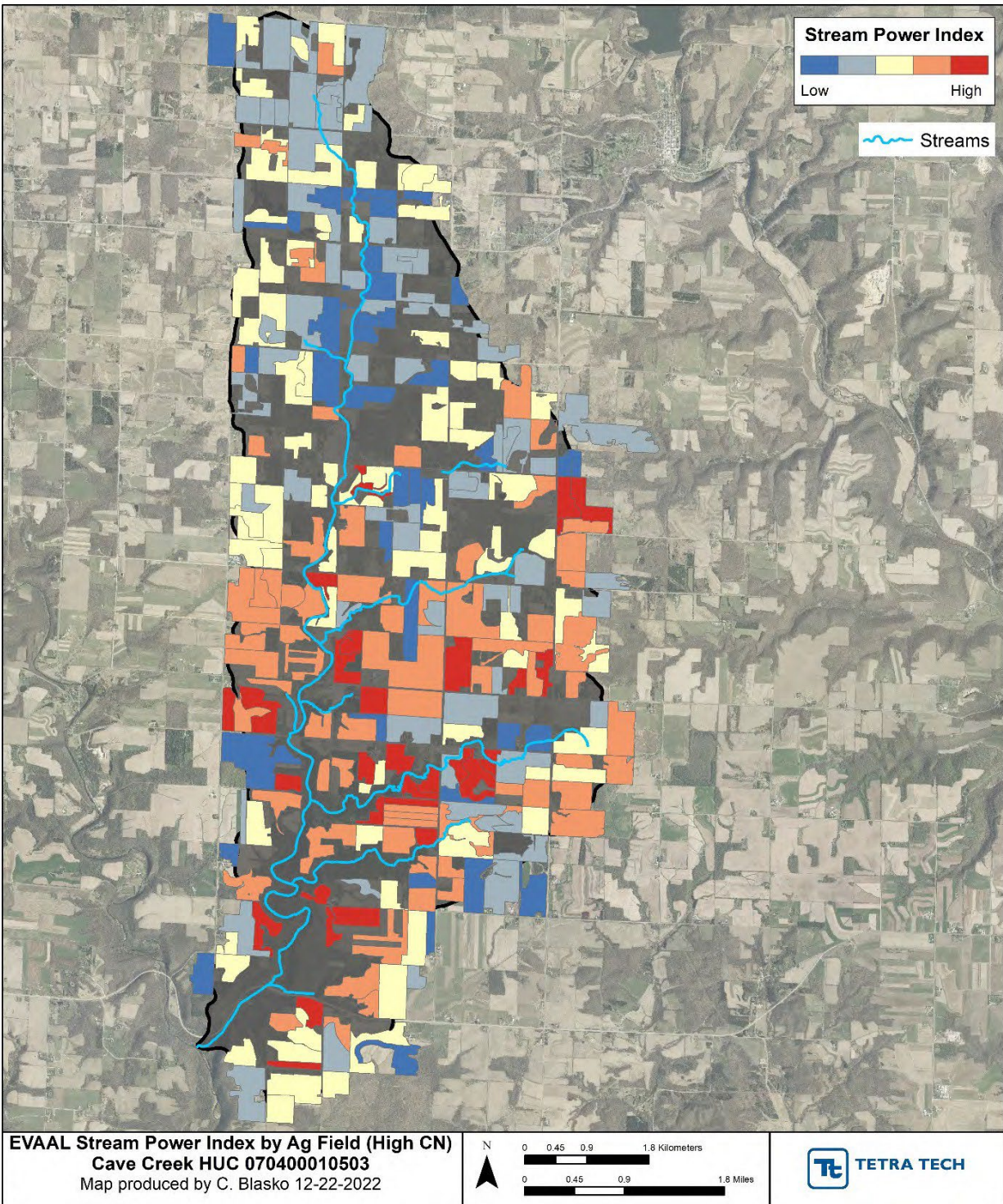


Figure 14. Map of stream power index (SPI) for Cave Creek (High CN Scenario)

3.5.3.4 Crystal Springs Coulee-Rush River (HUC 070400010507)

In the Crystal Springs Coulee-Rush River (HUC 070400010507) watershed, erosion vulnerability index score classifications for the high C-factor scenario suggest that agricultural and pasture fields in the center of the watershed are least prone to erosion vulnerability overall (Figure 15). The highest erosion vulnerability exists in the western and eastern portions of the watershed as indicated by fields with orange and red symbology.

The maximum USLE soil loss difference (high C-factor raster – low C-factor raster) shows that most of the agricultural and pasture fields within the watershed boundary have relatively little difference in the estimated soil loss risk generated for the low and high C-factor scenarios (Figure 16). These fields displayed in blue on the map have small differences in soil loss between the two scenarios suggesting that these fields are not greatly influenced by soil-intensive management practices. However, sheet and rill erosion risk is likely higher for the fields classified as medium to high soil loss difference (i.e. yellow to red symbology) that are interspersed throughout the watershed.

The SPI classifications for the high CN scenario is similar to the erosion vulnerability index in that the medium and higher risk agricultural and pasture fields are in the western and eastern portions of the watershed. Similarly, the lowest risk fields are in the center of the watershed (Figure 17). The similar spatial distribution of high-risk SPI fields and high-risk erosion vulnerability fields indicates overall erosion vulnerability in the watershed is likely driven primarily by gully erosion because SPI is a metric related to gully erosion susceptibility. This is further supported by the relatively low risk USLE soil loss difference map which is indicative of sheet and rill erosion (Figure 16). As such, BMPs to reduce nonpoint source loading can be implemented accordingly to target areas most prone to gully erosion as this is the primary erosional risk in the Crystal Springs Coulee-Rush River watershed.

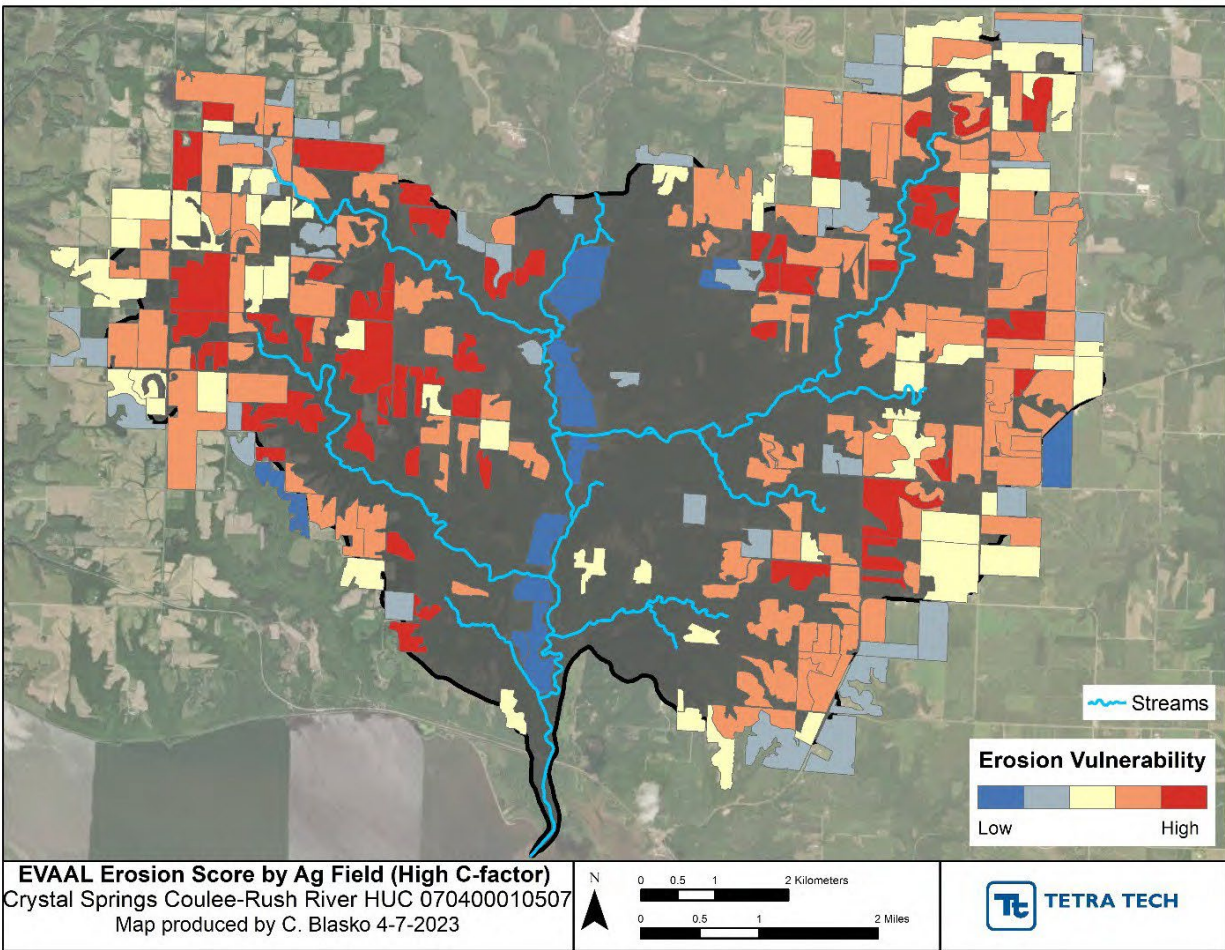


Figure 15. Map of mean erosion vulnerability score for Crystal Springs Coulee-Rush River (High C-factor Scenario)

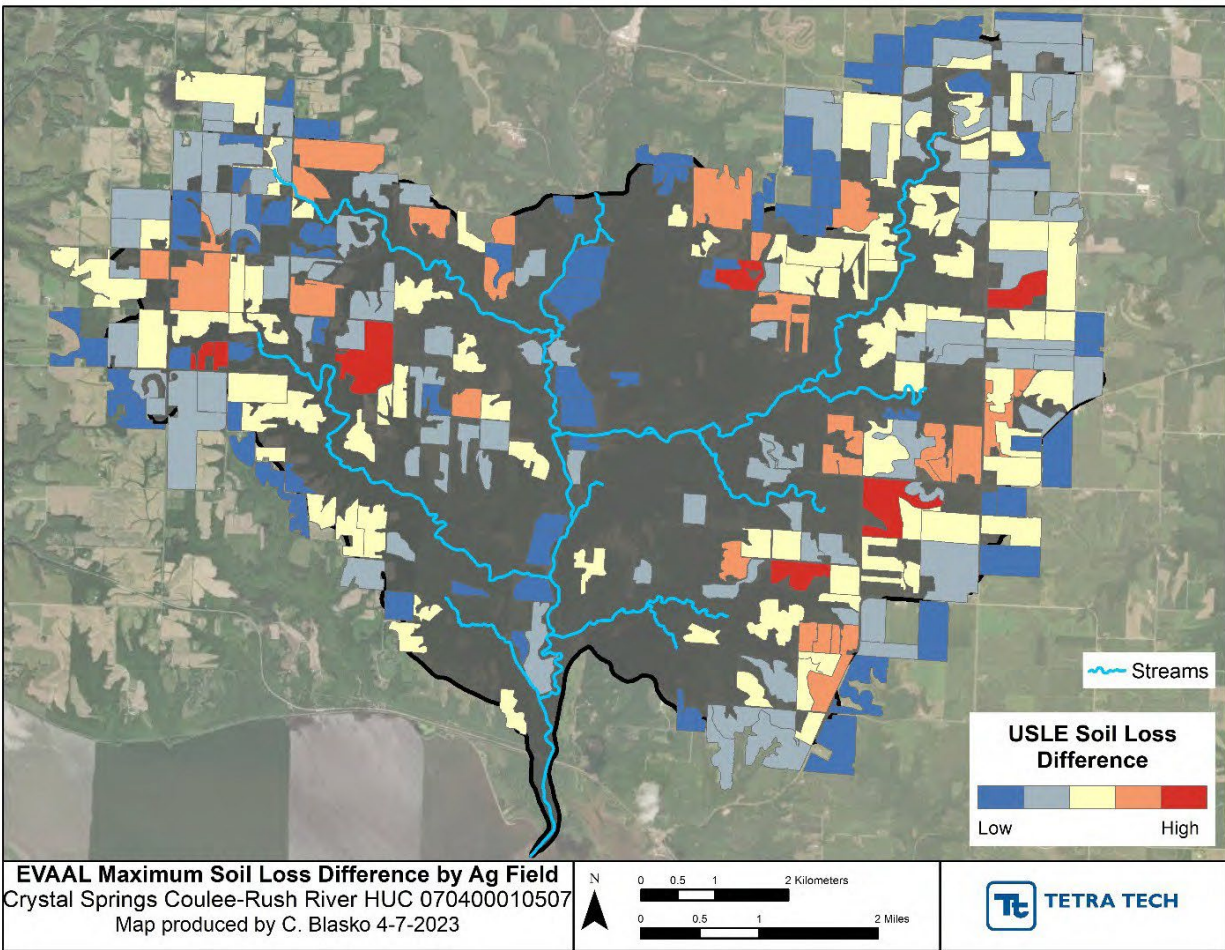


Figure 16. Map of USLE soil loss difference (High – Low C-factor runs) for Crystal Springs Coulee-Rush River

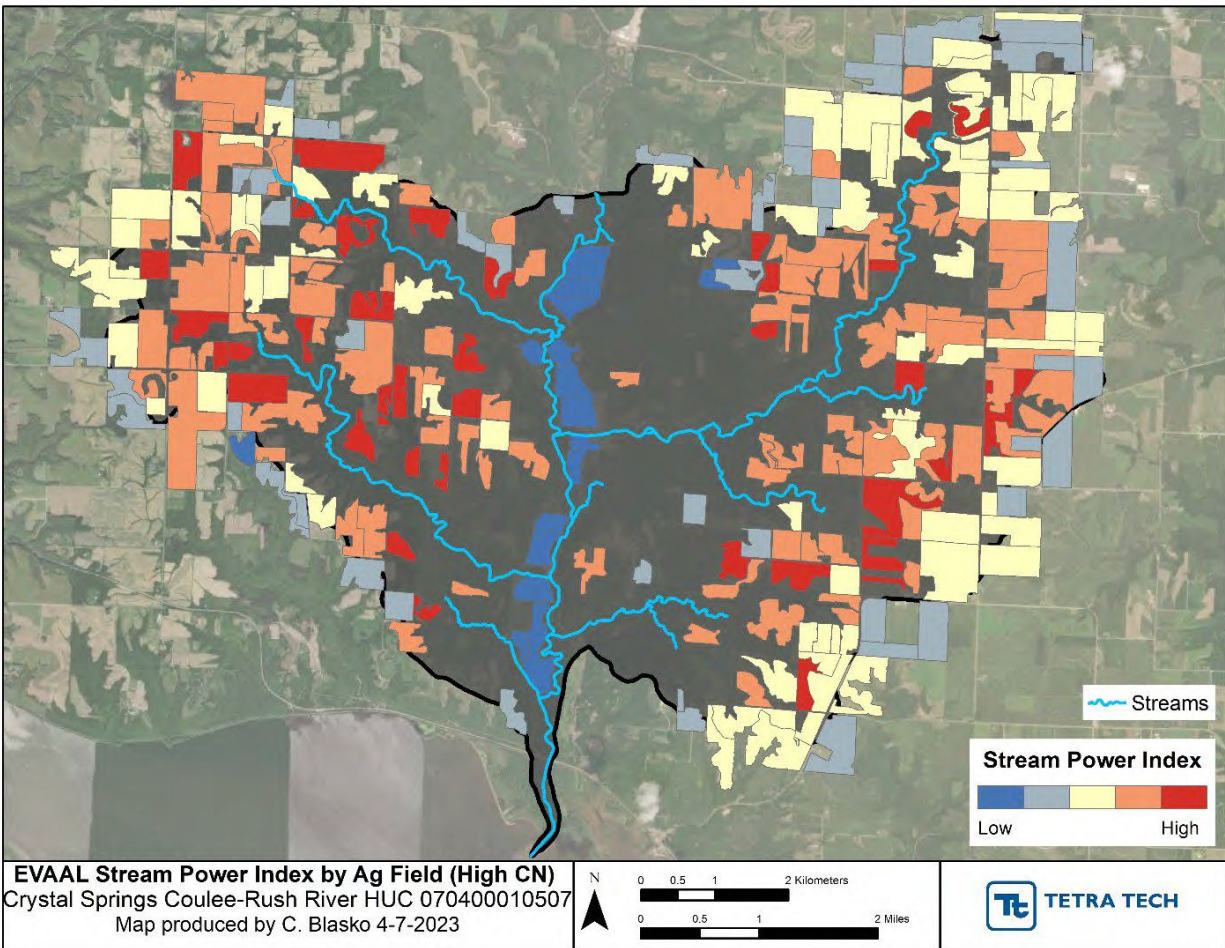


Figure 17. Map of stream power index (SPI) for Crystal Springs Coulee-Rush River (High CN Scenario)

3.5.3.5 Isabelle Creek (HUC 070400010701)

In the Isabelle Creek (HUC 070400010701) watershed, the erosion vulnerability index (Figure 18), USLE soil loss difference (high C-factor raster – low C-factor raster; Figure 19), and SPI index (Figure 20) have similar spatial distributions of erosional risk for agricultural and pasture fields in that they are primarily at higher risk in the southern and east-central portions of the watershed. There are also, however, interspersed fields in the northwest portion of the watershed with high erosional risk among the three metrics listed above.

Because the spatial distribution of high-risk agricultural and pasture fields are similar among these three metrics, the high erosion vulnerability in the southern and east-central portions of the watershed (Figure 18) can be attributed to both sheet and rill erosion from the USLE soil loss metric and the gully erosion from the SPI metric. However, because the SPI metric has more fields classified as medium to high risk as indicated by orange and red symbology, it can be inferred that gully erosion contributes more to the overall erosional vulnerability than sheet and rill erosion do. As such, BMPs to reduce nonpoint source loading implemented in the southern portion of the Cave Creek watershed should address both gully erosion and sheet/rill erosion but with an emphasis on the former.

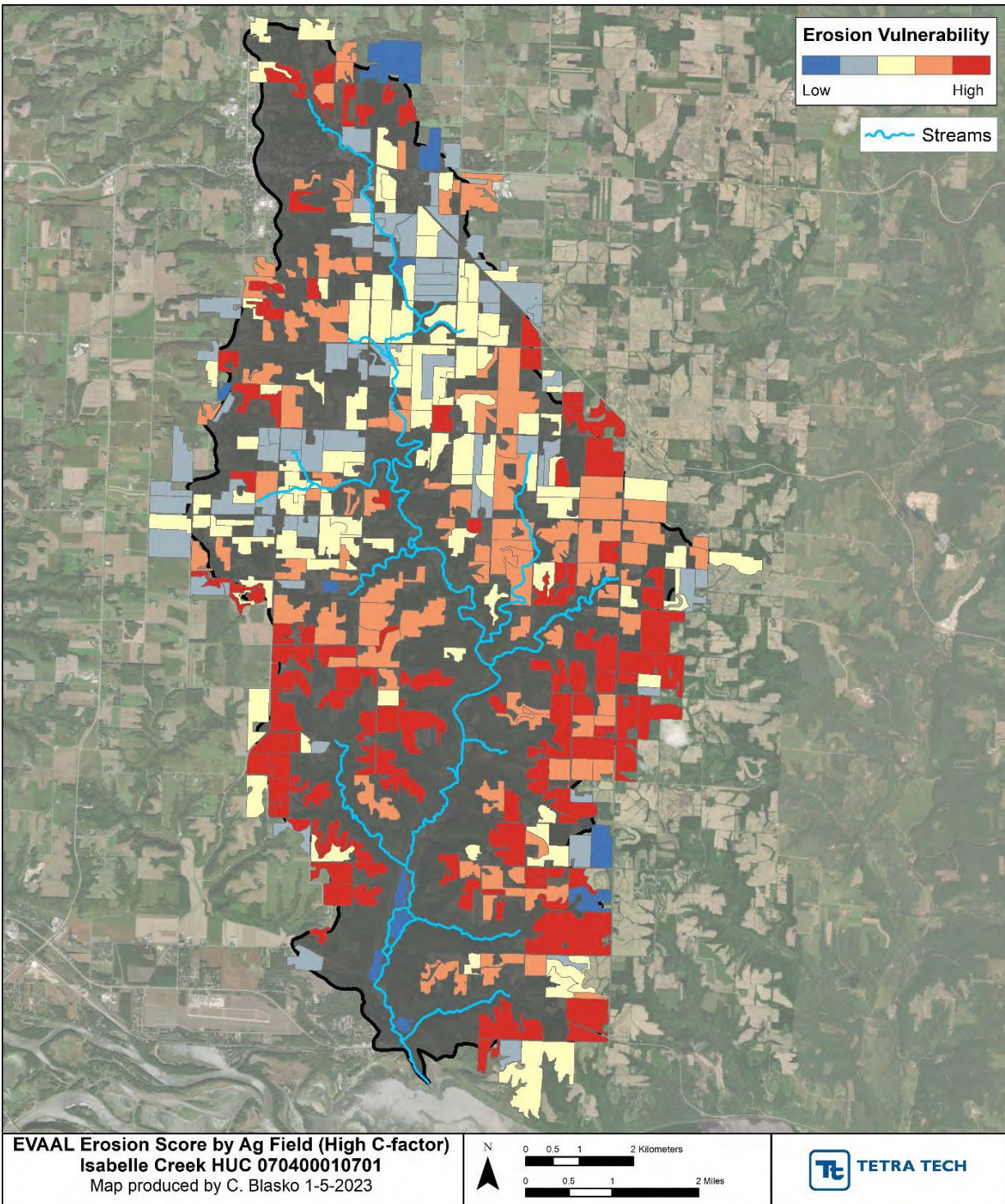


Figure 18. Map of mean erosion vulnerability score for Isabelle Creek (High C-factor Scenario)

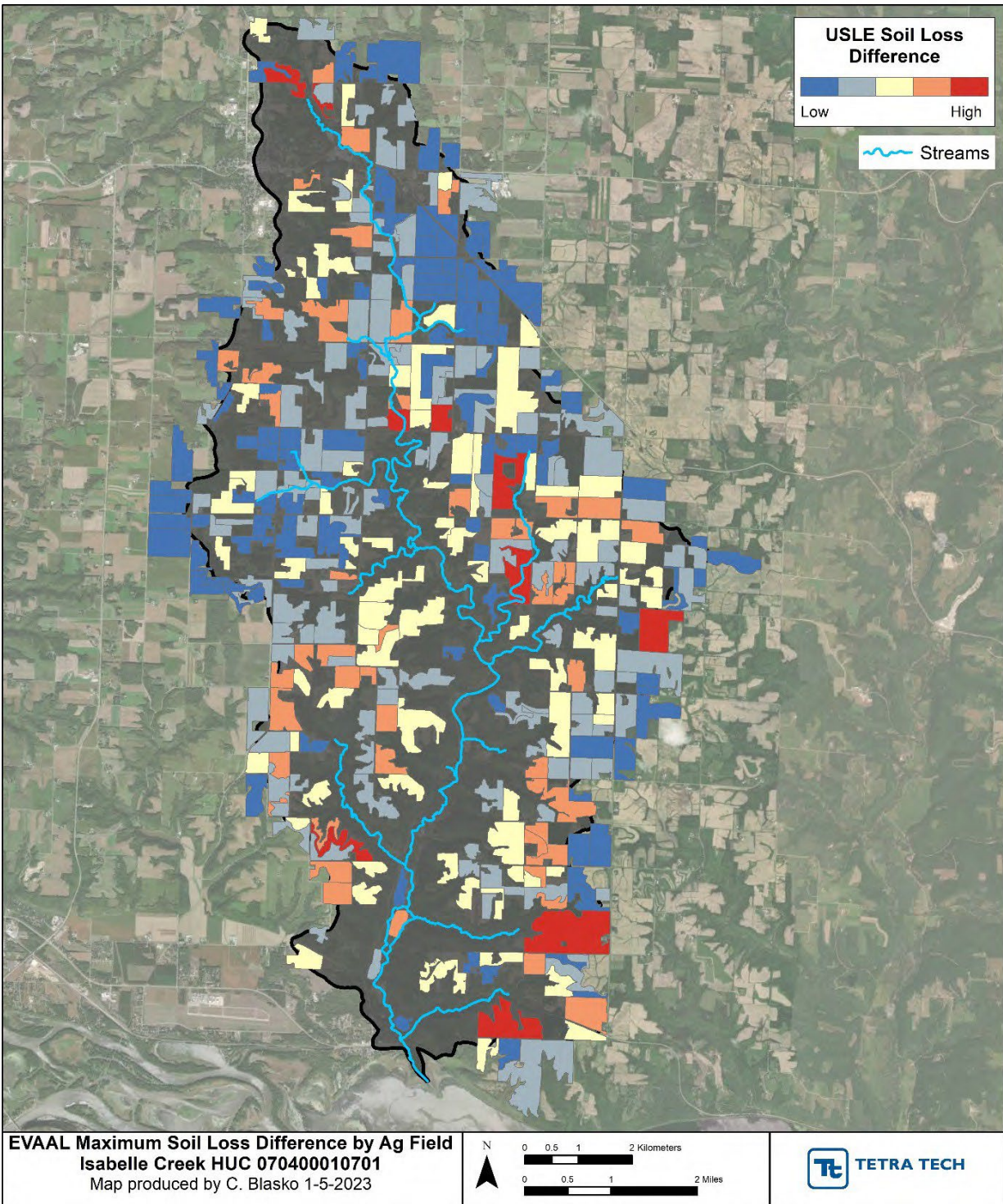


Figure 19. Map of USLE soil loss difference (High – Low C-factor runs) for Isabelle Creek

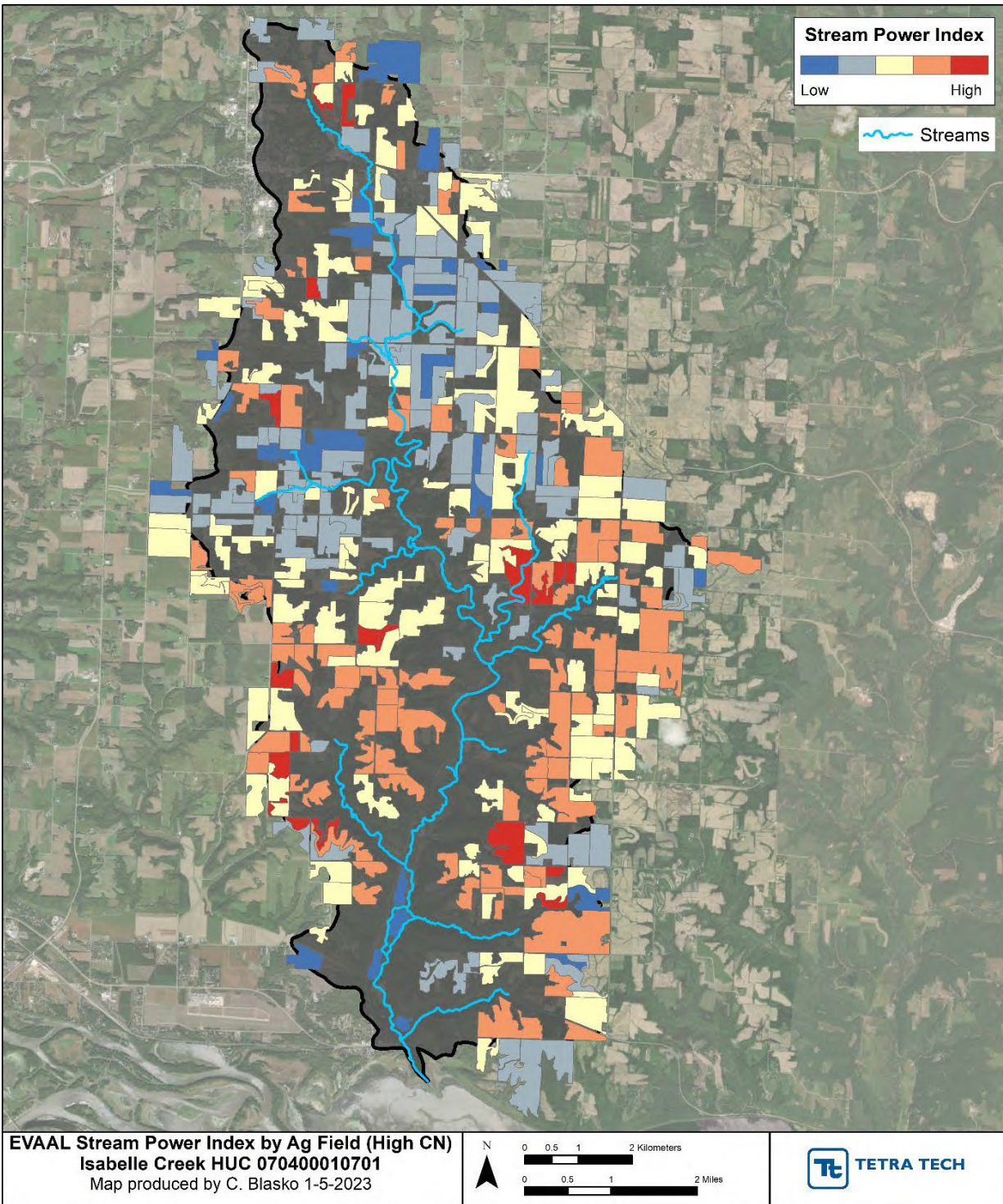


Figure 20. Map of stream power index (SPI) for Isabelle Creek (High CN Scenario)

3.5.3.6 Lake Pepin (HUC 070400010705)

As discussed above in Section 3.5.1, the Lake Pepin (HUC 070400010705) watershed was split into two separate areas near the border between Pepin and Peirce counties down the east-west running centerline of Pine Creek so that the EVAAL tools would run successfully for this large HUC12. As described in the EVAAL Methods Documentation⁷, the erosion vulnerability index is a relative index. This means two separate models cannot be compared directly because the “index value for each grid cell is calculated relative to all the other grid cells within the study area”. As such, the results presented below for the entire HUC12 are to be considered for each county separately where the HUC12 was split.

In the Lake Pepin (HUC 070400010705) watershed, erosion vulnerability index score classifications for the high C-factor scenario suggest that agricultural and pasture fields are at high risk to erosion vulnerability throughout the entire watershed besides two isolated areas (Figure 21). The two isolated areas with low erosion vulnerability exist in the southeastern-most portion of the watershed and at the downstream end of the northwest most portion of the watershed as indicated by fields with blue symbology.

The maximum USLE soil loss difference (high C-factor raster – low C-factor raster) shows that most of the agricultural and pasture fields within the watershed boundary have relatively little difference in the estimated soil loss risk generated for the low and high C-factor scenarios (Figure 22). These fields displayed in blue on the map have small differences in soil loss between the two scenarios suggesting that these fields are not greatly influenced by soil-intensive management practices. However, sheet and rill erosion risk is likely higher for the fields classified as medium to high soil loss difference (i.e. yellow to red symbology) that are interspersed throughout the watershed.

The SPI classifications for the high CN scenario are like the erosion vulnerability index classifications because the medium and higher risk agricultural and pasture fields are found throughout the entire watershed besides the two isolated areas of low risk that were previously mentioned (Figure 23). The similar spatial distribution of high-risk SPI fields and high-risk erosion vulnerability fields indicates overall erosion vulnerability in the watershed is likely driven primarily by gully erosion because SPI is a metric related to gully erosion susceptibility. This is further supported by the relatively low risk USLE soil loss difference map which is indicative of sheet and rill erosion (Figure 22). As such, BMPs to reduce nonpoint source loading can be implemented accordingly to target areas most prone to gully erosion as this is the primary erosional risk in the Lake Pepin watershed.

⁷ Wisconsin Department of Natural Resources. (2019). EVAAL V1.0, WI DNR. [EVAAL_Methods_v1_0.pdf \(wisconsin.gov\)](#)

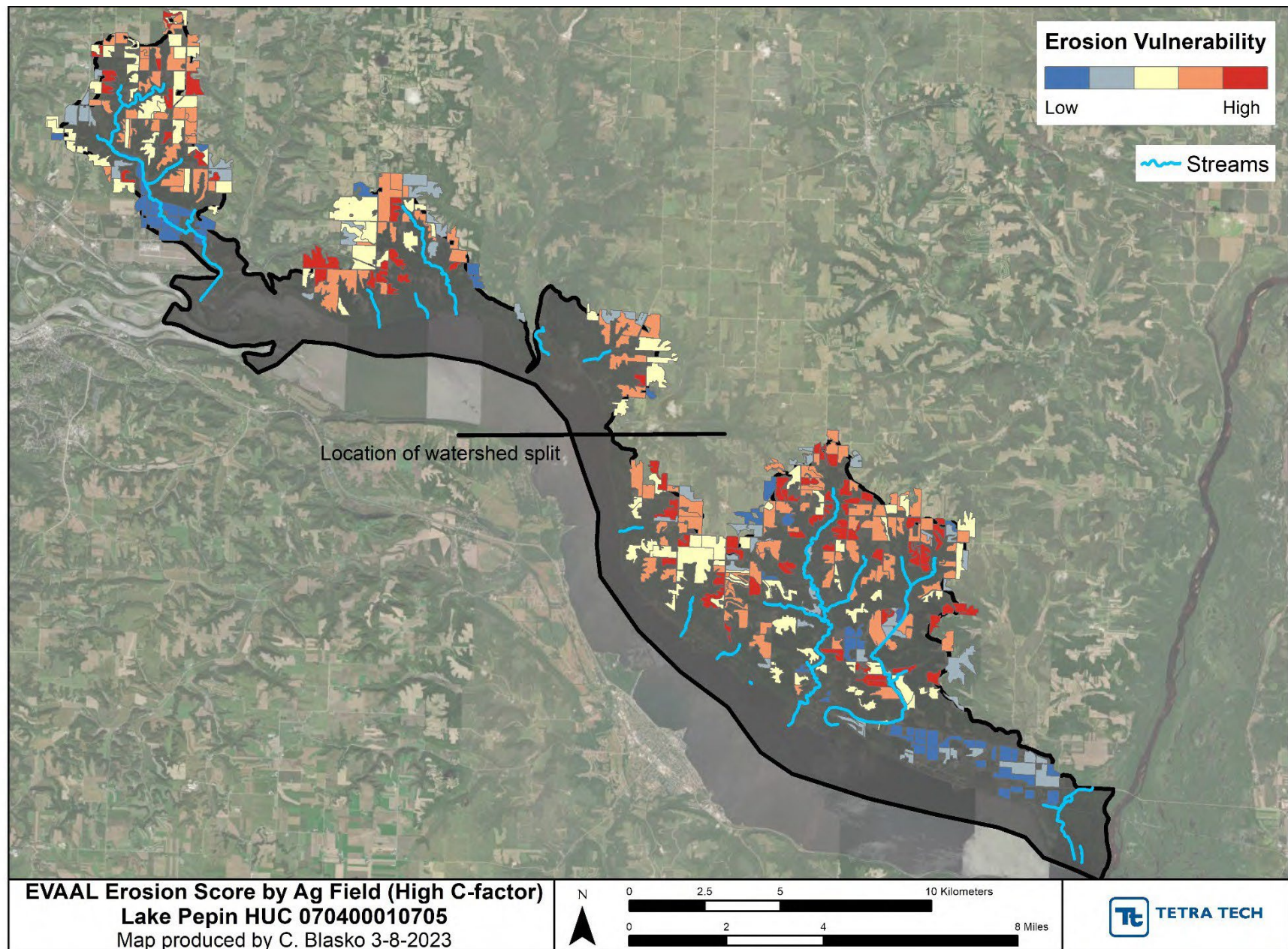


Figure 21. Map of mean erosion vulnerability score for Lake Pepin (High C-factor Scenario)

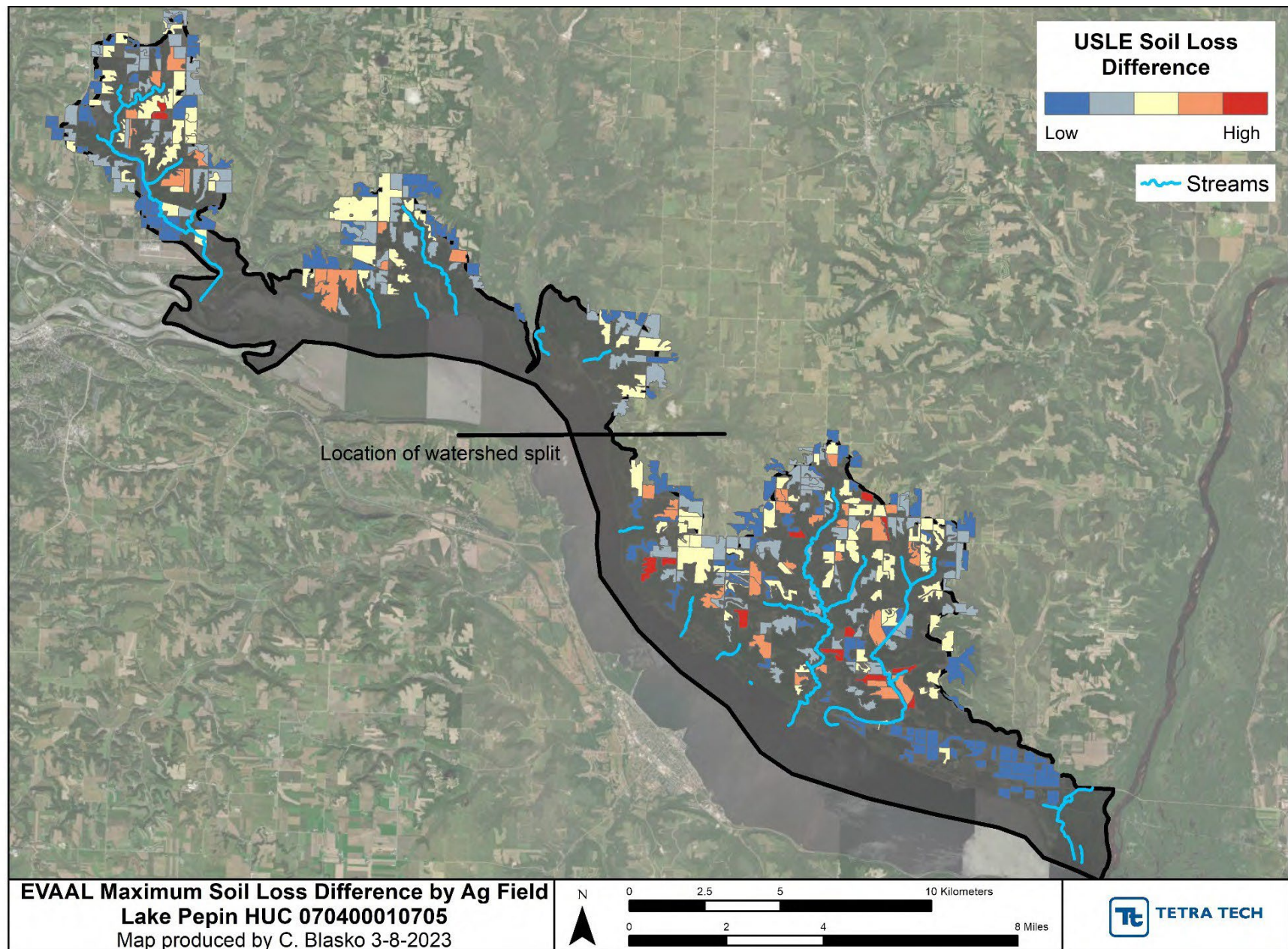


Figure 22. Map of USLE soil loss difference (High – Low C-factor runs) for Lake Pepin

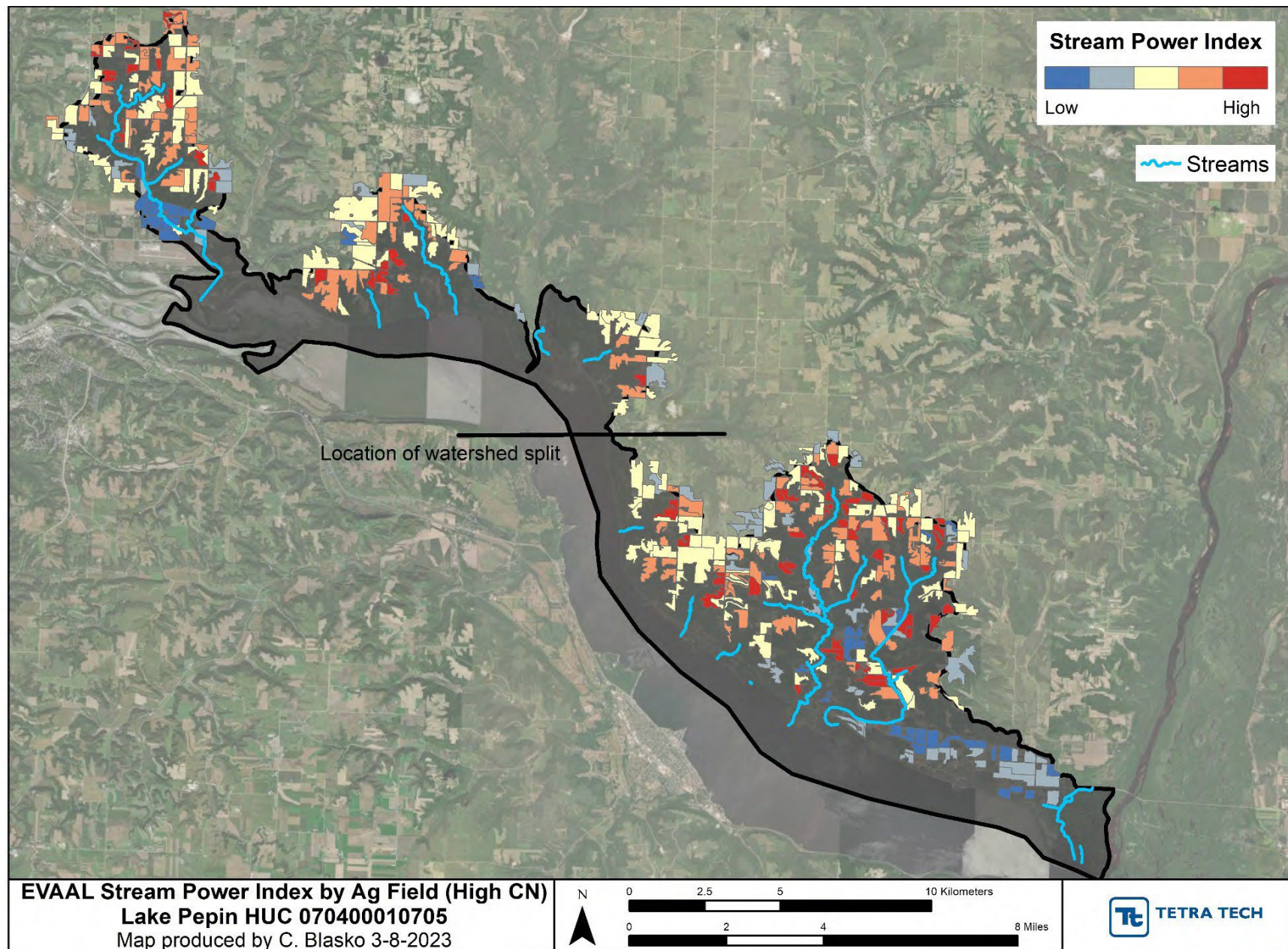


Figure 23. Map of stream power index (SPI) for Lake Pepin (High CN Scenario)

3.6 QUALITY ASSURANCE

Technical staff at Tetra Tech and WDNR reviewed SnapPlus baseline and BMP scenario databases for all crop rotation schemes and management practices across Pierce, Pepin, and St. Croix counties. For BMP scenario SnapPlus databases, Tetra Tech checked ten random field rotations within each scenario database for accuracy. Rotations, cover crops, management practices, and manure applications were spot checked as appropriate. Final approval of all SnapPlus input databases created by Tetra Tech was granted by Andrew Craig (WDNR) on September 7, 2022.

For EVAAL modeling, quality assurance entailed ensuring that manual culvert creation is adequate across digital dams for the EVAAL hydro conditioning process, ensuring components are reasonable for high and low CN/C-factor scenario, and ensuring that the agricultural field rankings make conceptual sense. Tetra Tech colleagues reviewed the EVAAL modeling work and approved the number and placement of culverts as being accurate for hydro conditioning the DEMs. Internal Tetra Tech staff also checked that the values of Erosion Vulnerability, SPI, and Soil Loss are within expected ranges for both CN and C-factor scenarios. Lastly, the zonal statistics completed by field boundary for ranking purposes were reviewed for conceptual sense.