NOTE TO READERS:

This report describes a method to develop a wetland probability map in a low relief landscape by terrain analysis techniques involving LIDAR and soils data. Suggestions are provided concerning the integration of wetland probability, wetland functional assessment and wetland management zones.

We believe the methodology described therein has applicability to other landscapes.

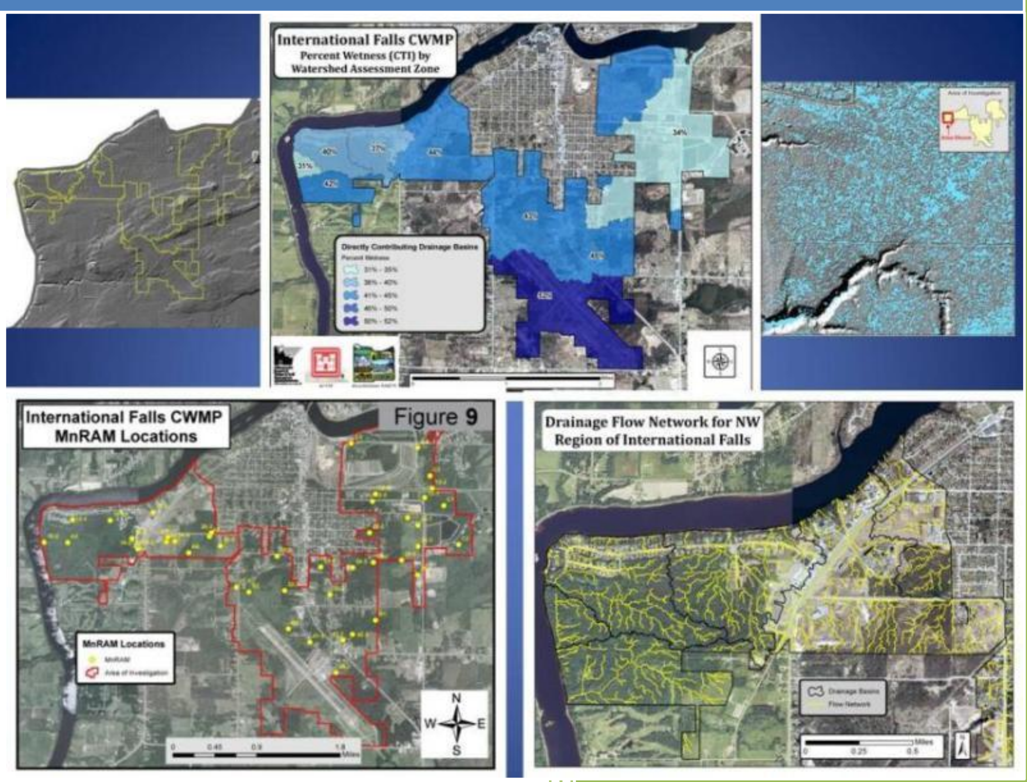
Readers are encouraged to contact me for additional information.

Greg Larson
Greg Larson
Senior Ecologist and Soil Scientist
Regulatory Branch
US Army Corps of Engineers—St. Paul District
(651) 290-5666 (Office)
(612) 751-3060 (Cell)

2011

International Falls Comprehensive Wetland Management Plan

Technical Report



US Army Corps of Engineers,

MN Board of Water & Soil Resources,

Koochiching County SWCD, and the City of International Falls

9/26/2011

Contents

Acknowledgements:

Funding for this project was provided by the Corps of Engineers, Board of Water and Soil Resources, Koochiching County Soil and Water Conservation District and the City of International Falls.

Principal Investigators were:

Aaron Spence, GIS Specialist, BWSR

Justin Berg, District Technician, Koochiching County SWCD

Greg Larson, Soil Scientist and Senior Ecologist, Corps of Engineers

With technical support from the CWMP Technical Work Group:

Dale Krystosek, Senior Wetland Specialist, BWSR

Larry Puchalski, Project Manager, CORPS of Engineers

Dave Serrano, Consultant to the City of International Falls

Frank Svoboda, Consultant to the City of International Falls

Special thanks to:

Steve Kloiber, IT Specialist / Wetland Monitoring Coordinator, MN DNR

Joel Nelson, GIS Specialist, University of Minnesota

Steve Eggers, Senior Ecologist, US Army Corps of Engineers

Technical Report

The purpose of this Corps Regulatory Branch project is to assist the City of International Falls, Minnesota and the Minnesota Board of Water and Soil Resources in developing a comprehensive wetland management plan (CWMP). International Falls is located in a wetland-rich landscape and has had permitting challenges concerning development. The plan is intended to streamline the permitting processes under the Federal Clean Water Act and the State of Minnesota Wetland Conservation Act and meet CWA Section 404 criteria, including identifying least damaging practical alternatives. Further, the CWMP is intended to serve as a model for use elsewhere in Minnesota.

Project Methodology

Objective: To provide data to support policy and permitting procedures for the CWMP, this report provides the following data: (a) Wetland probability. Terrain analysis-derived landscape wetness and hydric soils were used to determine the distribution and density of wet areas –and likely wetlands-- by watershed. (b) Drainage flow network. Drainage flow network for the City was mapped using LIDAR (Light Detection and Ranging) techniques. (c) Functional assessments. The Minnesota Routine Assessment Method was used to characterize the function of wetlands in the plan area. (d) Extent of Impervious Surface. Given its detrimental effect to wetland function, impervious surface was determined by watershed. (e) Environmental Corridors. Using MnRAM data, example corridors are shown. (f) Environmental Stressor Determination. Using a subset of MnRAM functions, the impact of development and human influence on overall wetland function is illustrated. **Taken together (emphasis added)**[1], these data offer several possible uses including: determining the extent and location of non-wetland sites, determining the complexity of wetland delineations, aiding in the analysis of alternatives and identifying possible wetland management zones.

Inputs[2]**:**

- **MN Routine Assessment Method (MnRAM) for wetlands**
- **Compound Topographic Index (CTI / Wetness Index)**
- **Soil Survey Geographic Database (SSURGO) Soils**
- **Impervious Surface Analysis**

[1] Although individual data elements have value, the utility of the data increases and better reflect a landscape view if they are used together as complementary pieces.

[2] Maps in this report are generally shown at a planning scale. As discussed later, implementation scale maps may be developed.

Light Detection and Ranging (LiDAR) Data:

LiDAR is high resolution elevation data used for GIS analysis including hydrologic modeling. LiDAR data for portions of Koochiching County including the city of International Falls were collected and processed by Fugro-Horizons through funding from the Army Corps of Engineers as an add-on to an existing project headed by the ACOE and the International Water Institute (IWI) to collect LiDAR for the Red River Valley. Koochiching LiDAR became available for this project in early February of 2010. Subsequent quality assurance performed by the International Water Institute showed the data to have an overall vertical accuracy of +/- 12.5cm (approximately 5 inches). Bare earth LiDAR data (where non surface factors such as vegetation and buildings have been removed) were used to create a 1-meter resolution digital elevation model (DEM) for use in this project. See Figure 1.

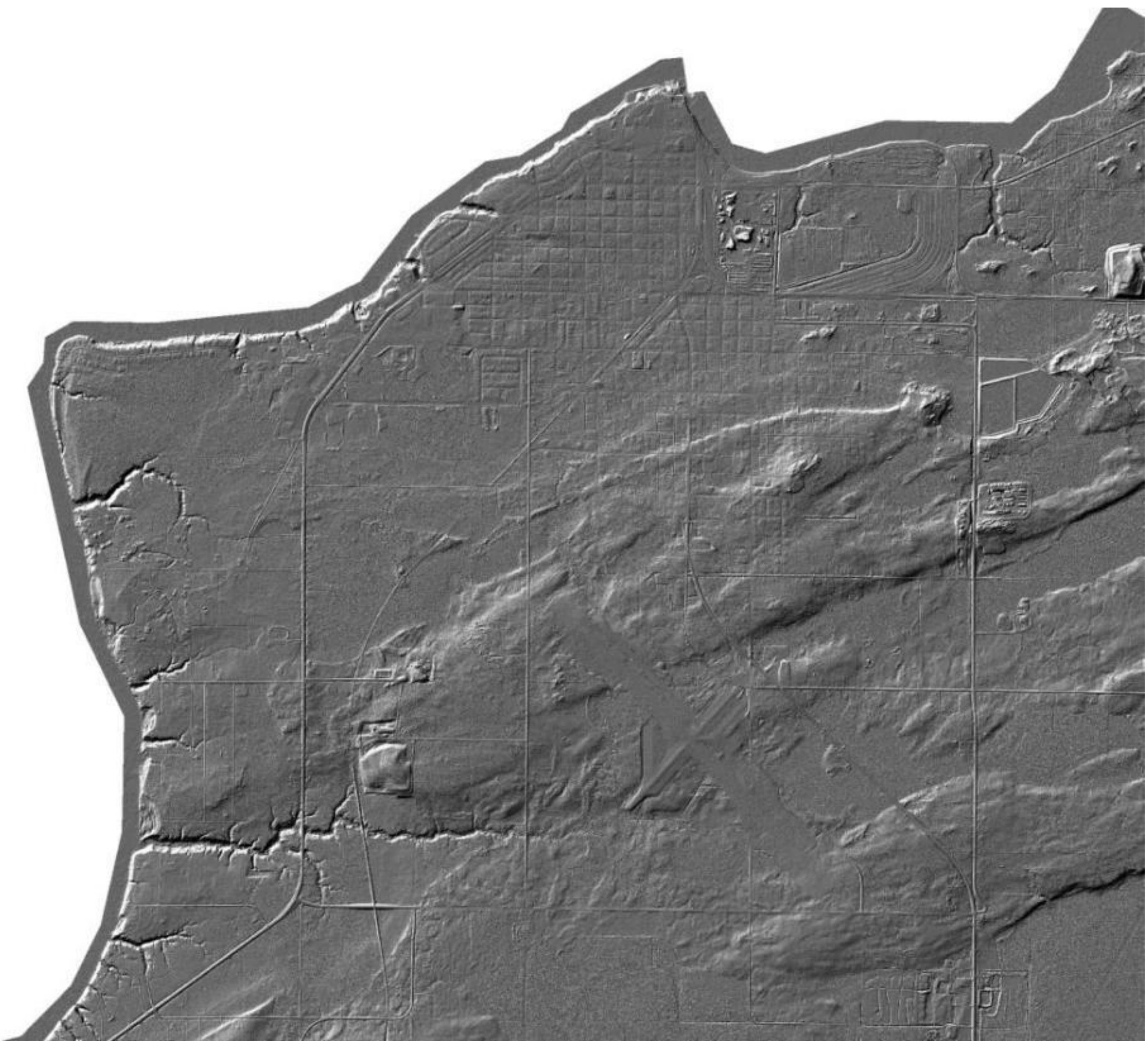


Figure 1: Hill shade relief created from LiDAR derived 1m DEM.

Watershed Assessment Zones:

The basin tool within the ArcGIS Spatial Analyst extension was used to delineate drainage basins within the city of International Falls. The following excerpt from ESRI's help documentation describes how the software calculates drainage basins.

- The drainage basins are delineated within the analysis window by identifying ridge lines between basins. The input flow direction raster is analyzed to find all sets of connected cells that belong to the same drainage basin. The drainage basins are created by locating the pour points at the edges of the analysis window (where water would pour out of the raster), as well as sinks, then identifying the contributing area above each pour point. This results in a raster of drainage basins.

Nine distinct drainage basins were identified within the study area. These drainage basins were used as the basis for assessment zones (Figure 2). Hereinafter, these areas will be referred to as "watershed assessment zones" (WAZ). The above-listed four inputs were summarized by WAZ. This process will be described later in more detail.

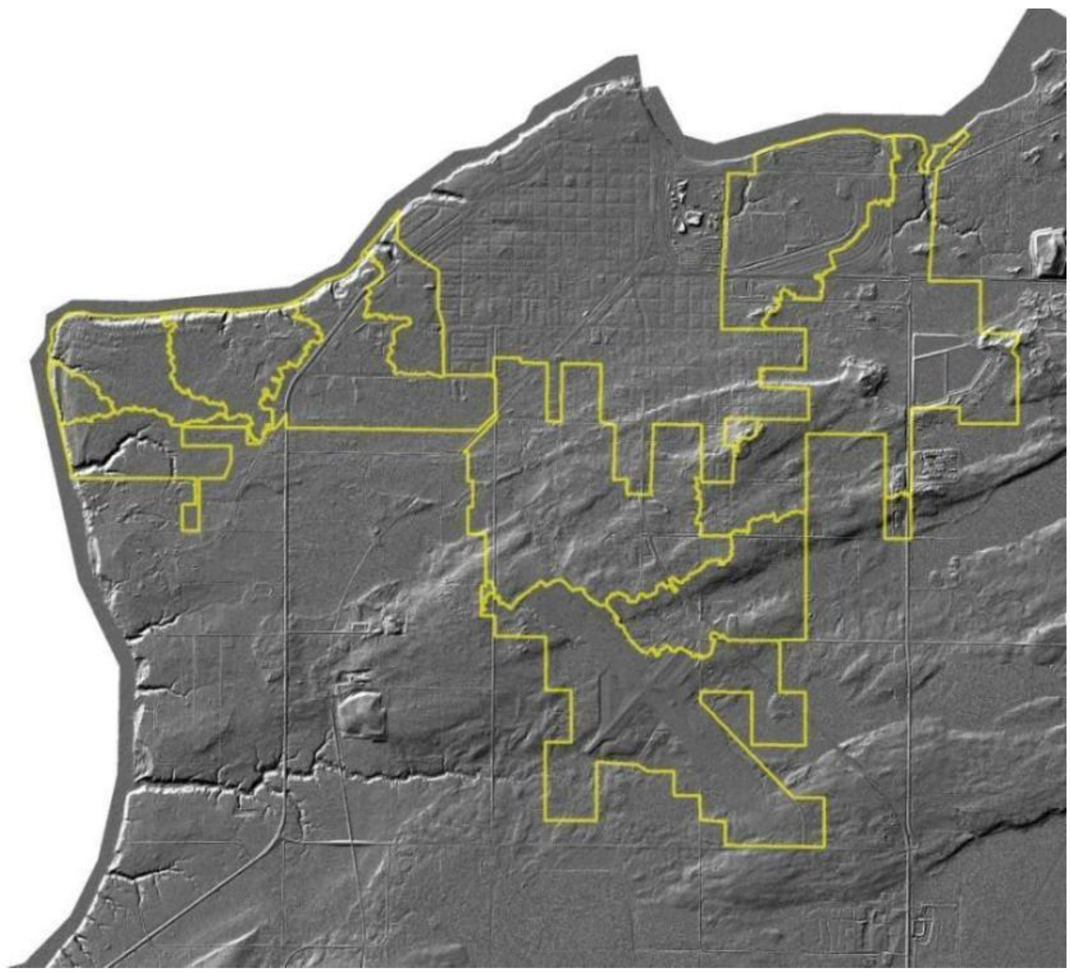


Figure 2: Watershed assessment zones within the city of International Falls. Note that the north central portion of the city was not included in the area of analysis since the landscape is already significantly developed.

Compound Topographic Index (CTI):

The compound topographic index (often referred to as the steady state wetness index) is a measure of the likelihood of water to pond in any given location on the landscape. CTI is a function of slope and specific catchment. Specific catchment is defined as the upstream contributing area per unit width (in this case square meters) orthogonal to the flow direction. In general, areas with a relative low slope and relative high catchment area are more prone to surface water accumulation. CTI was calculated using raster elevation data. While this can be done using 30 meter USGS digital elevation models, using high resolution LiDAR derived data produced vastly superior results.

Pre -processing the DEM:

Any DEM product derived from LiDAR will contain some spurious errors. Sinks may appear in the landscape where a pixel has no outlet to adjacent pixels, i.e. its elevation is lower than all neighboring pixels. Although in some landscapes some of these sinks, or pits, may be legitimate, often they are a result of errors in the DEM. Even where pits are legitimate, it is useful to fill pits in the DEM to allow subsequent calculation of flow networks to have adequate connectivity rather than letting flow terminate at sink locations.

In some landscapes it is appropriate to determine how deep a pit must be before it is no longer appropriate to fill, i.e. flow of water does in fact terminate at the location of pits of a certain depth (this is related rainfall factors and the capacity of the pit to retain water). However in the extremely low relief landscape of International Falls, it is assumed that any amount of water accumulation on the landscape will fill any given pit and continue flowing to the next lowest location. Therefore the pit fill tool in the spatial analyst extension to ArcGIS Desktop was used to fill all pits within the DEM.

Infrastructure data provided by the city was used as a starting point to create culvert and storm drain data that was then used to modify the DEM further. Culvert locations in the infrastructure data were refined and supplemented via field verification.[3] Culverts and the storm drainage system were then "burned" into the DEM to reflect the altered drainage in those locations. This was done by first converting culvert and storm drain locations to raster and expanding the cells. Elevation values representing the lowest possible elevation within the DEM were then assigned to the culvert/storm drain raster. The pit filled DEM was then overlain with the culvert/storm drain raster using the raster mosaic tool within ArcGIS Desktop. Minimum value was selected as the output pixel value so that all locations where culverts and storm drains occur within the DEM were given the lowest possible elevation value effectively making them into pits within the DEM. The DEM was then pit filled a second time to bring the elevations of the culverts and storm drains to the lowest elevation of the surrounding pixels. This accommodates flow through the culverts and storm drains.

[3] Refinement involved field- verification of the location of the culverts and adding additional culverts. Data points were documented by GPS coordinates and added to the GIS files. This work was done by staff of the BWSR and Koochiching SWCD, with assistance from the City of International Falls.

Calculation of terrain attributes:

The primary terrain attributes slope, flow direction and flow accumulation were calculated using the 1-meter DEM. Slope was calculated in percent rise units and then divided by 100 for subsequent processing.

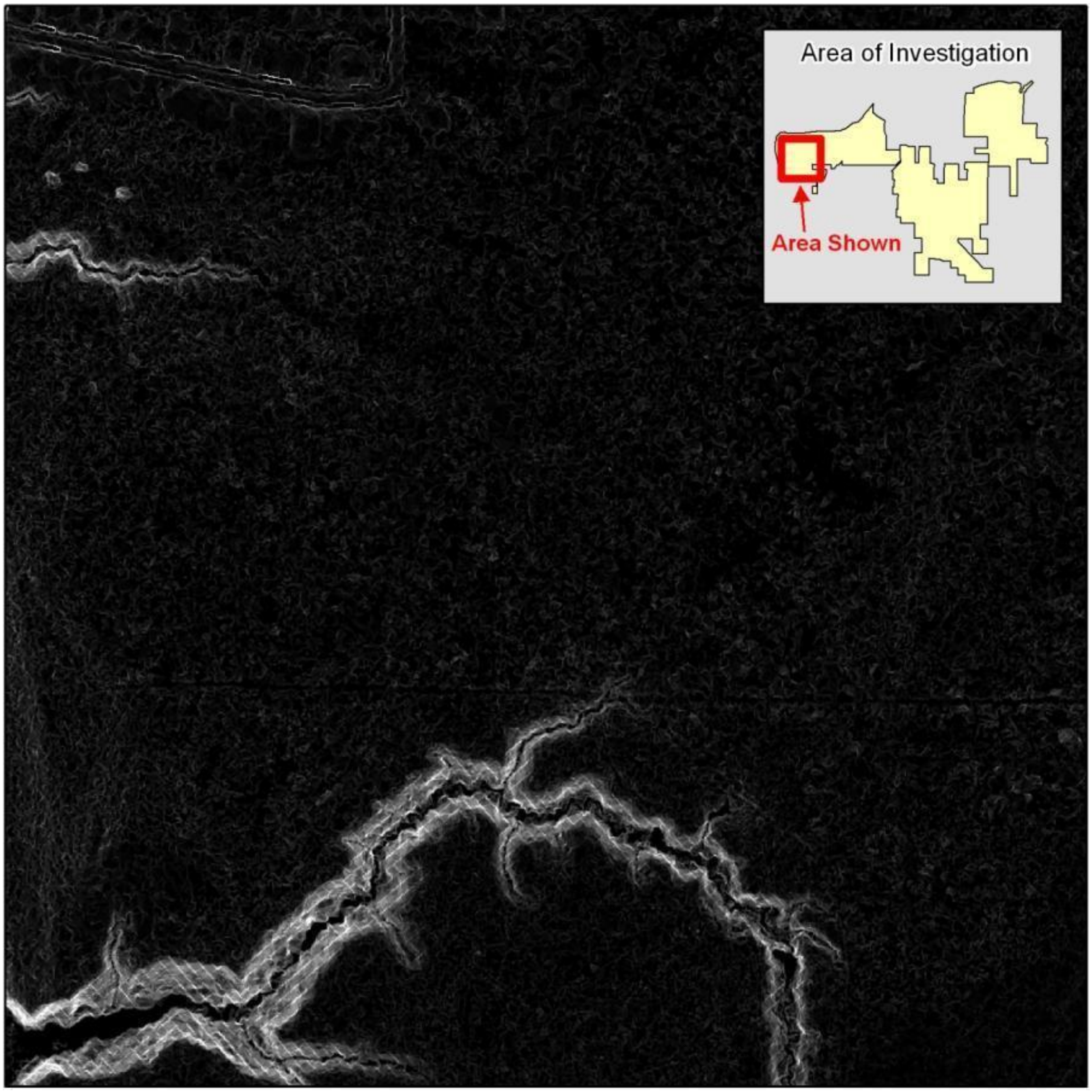


Figure 3: Slope derived from DEM in a portion of International Falls. The lighter areas indicate areas of higher slope.

All attributes were calculated using the TauDEM (**T**errain **A**nalysis **U**sing **D**igital **E**levation **M**odels) extension to ESRI ArcGIS Desktop software. This extension was created by David Tarboton of Utah State University. Similar tools within the ArcGIS Desktop Spatial Analyst extension may be used to calculate primary and secondary terrain attributes however TauDEM tools were used for this analysis due to their ability to calculate flow direction with the D-Infinity algorithm rather than the more common D-8 algorithm. (Note: due to restrictions on the maximum grid size for TauDEM processing the city was split into four separate grids for all processing then re-assembled at the end).

Flow direction determines the direction water will flow from cell to cell within the DEM. Using the D-8 algorithm each pixel in the DEM has a single flow direction. This means that all flow leaving any given pixel is forced to flow into a single adjacent downstream pixel. This approach can lead to serious misrepresentations of flow on the landscape when a subsequent flow accumulation grid is calculated. The D-Infinity method allows water from one pixel to flow to multiple adjacent pixels which better represents true landscape drainage scenarios and results in a more realistic flow accumulation grid. See Figure 4.

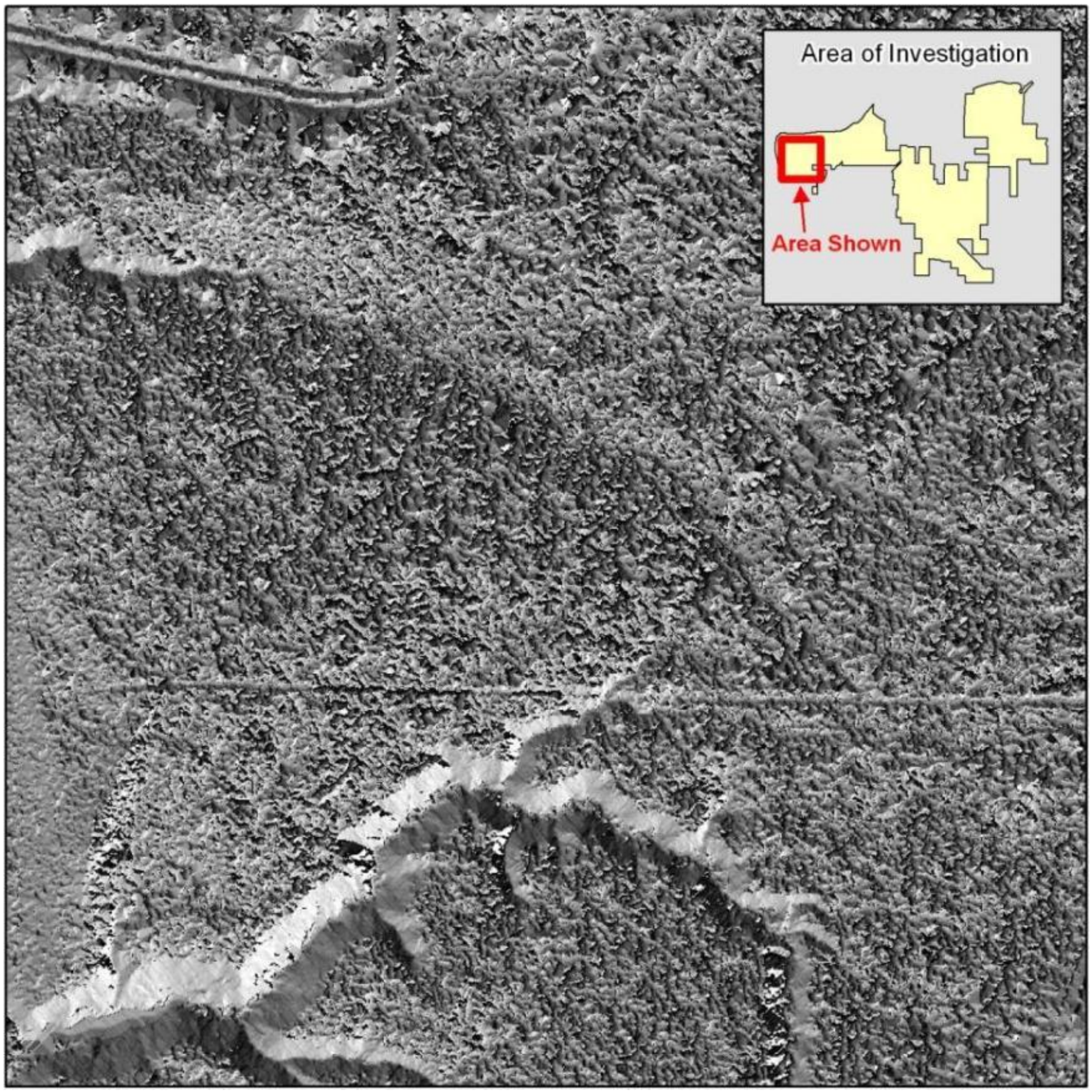


Figure 4: Flow direction grid in same portion of International Falls.

The flow accumulation grid represents the number of upstream $1m^2$ pixels that flow into a given pixel, and depicts flow channels across the landscape (Figure 4). This was calculated using slope and flow direction as inputs. The flow accumulation value in a given pixel is analogous to its upstream catchment area, i.e. the value equals the number of $1m^2$ pixels flowing to that cell and therefore the catchment area in square meters. See Figure 5.

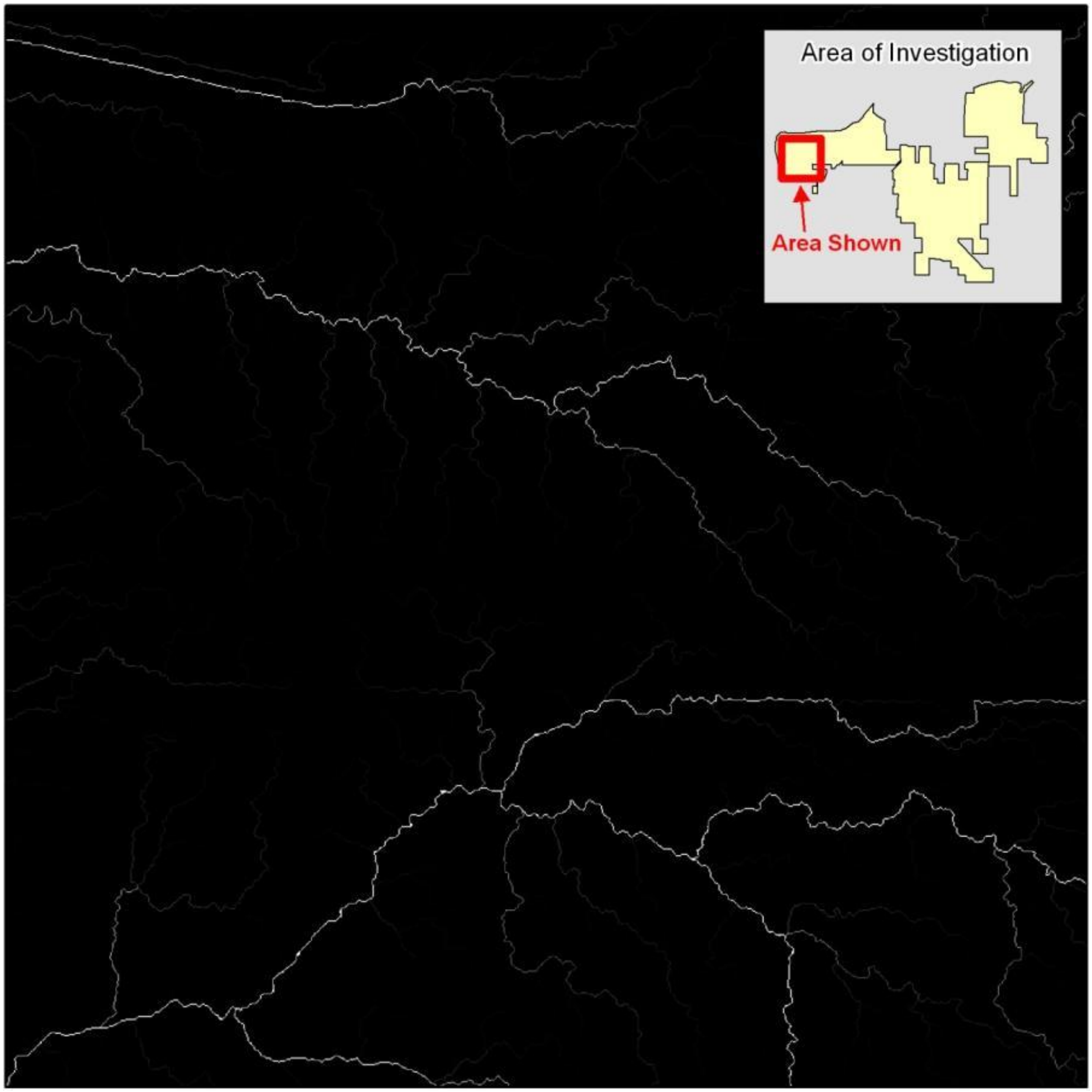
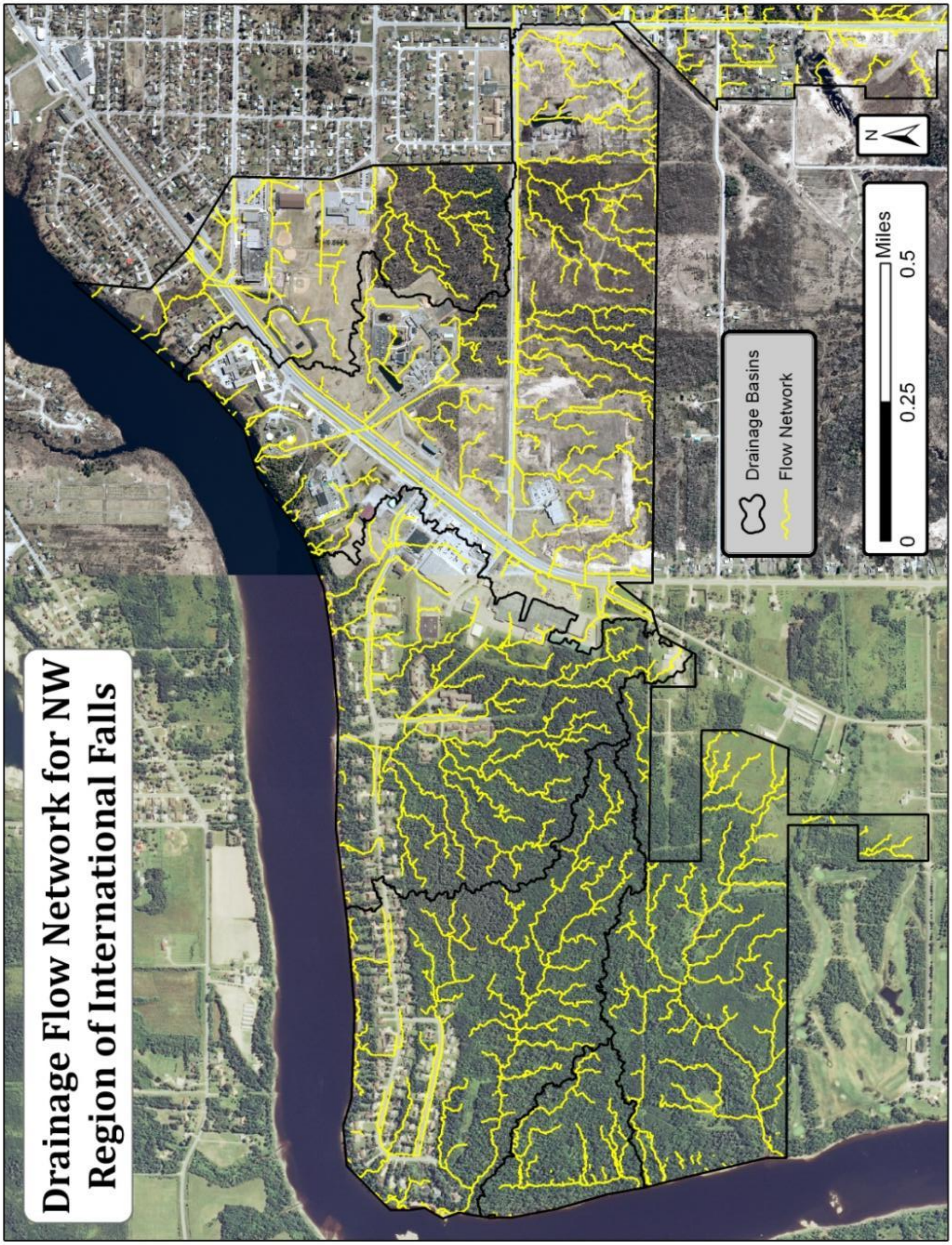


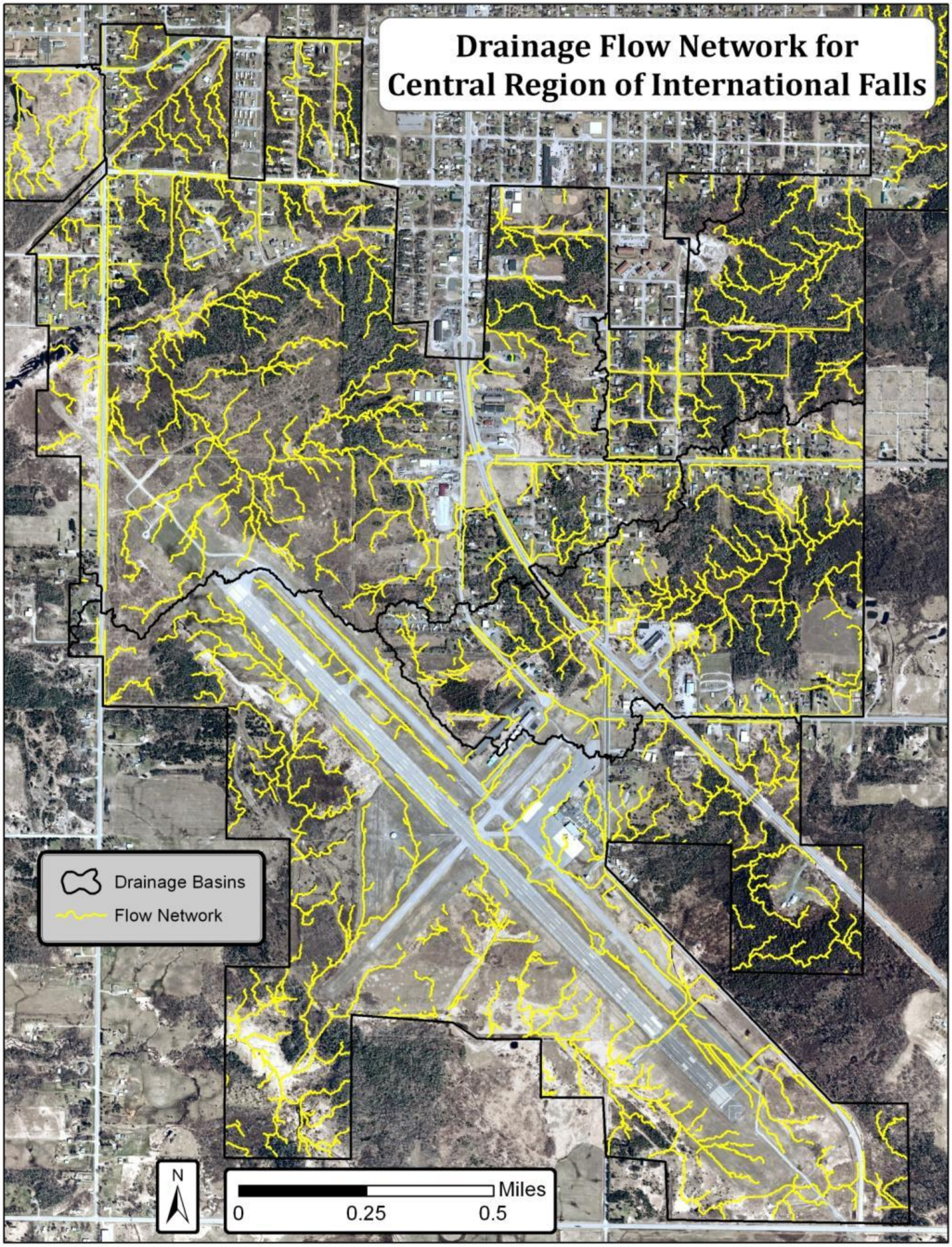
Figure 5: Flow accumulation grid in same portion of International Falls.

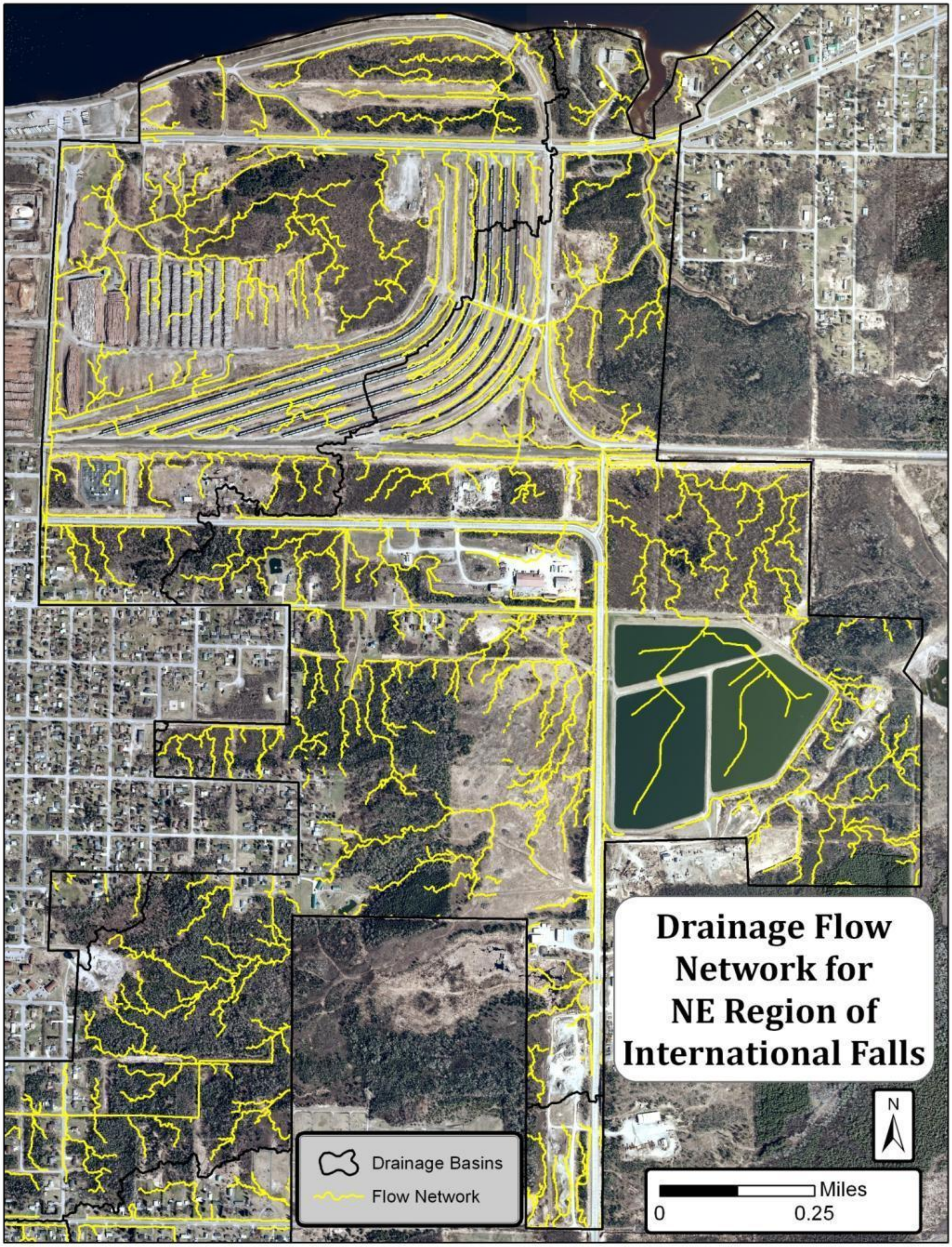
The lighter areas represent areas of greater upstream catchment area. Notice the flow channels.

From the flow accumulation grid, a flow network can be determined by pulling out the highest values. Observing Figure 5 one can clearly see these flow networks. The next three pages depict the flow network of International Falls within the area of investigation.



Drainage Flow Network for NW
Region of International Falls
Drainage Basins
Flow Network
0
0.25
0.5
Miles
N


Drainage Flow Network for
Central Region of International Falls
Drainage Basins
Flow Network
N
Miles
0
0.25
0.5


Drainage Flow
Network for
NE Region of
International Falls
N
Miles
0
0.25
Drainage Basins
Flow Network

After slope and flow accumulation were calculated, CTI was then calculated with the Spatial Analyst raster calculator using the following formula:

Ln((C + 0.001) / (S + 0.001))

Where C is specific catchment (represented by the flow accumulation grid) and S is slope. A value of 0.001 is added to the grid values to avoid division by 0. Although the raster calculator can be used to calculate CTI, this analysis used the wetness index calculator within the TauDEM tools to calculate CTI (Figure 6).

After CTI was calculated, impervious areas were removed from the data to avoid building foundations, roads and other man made features being displayed as wetland area. This process will be explained later in the section discussing impervious surface analysis.

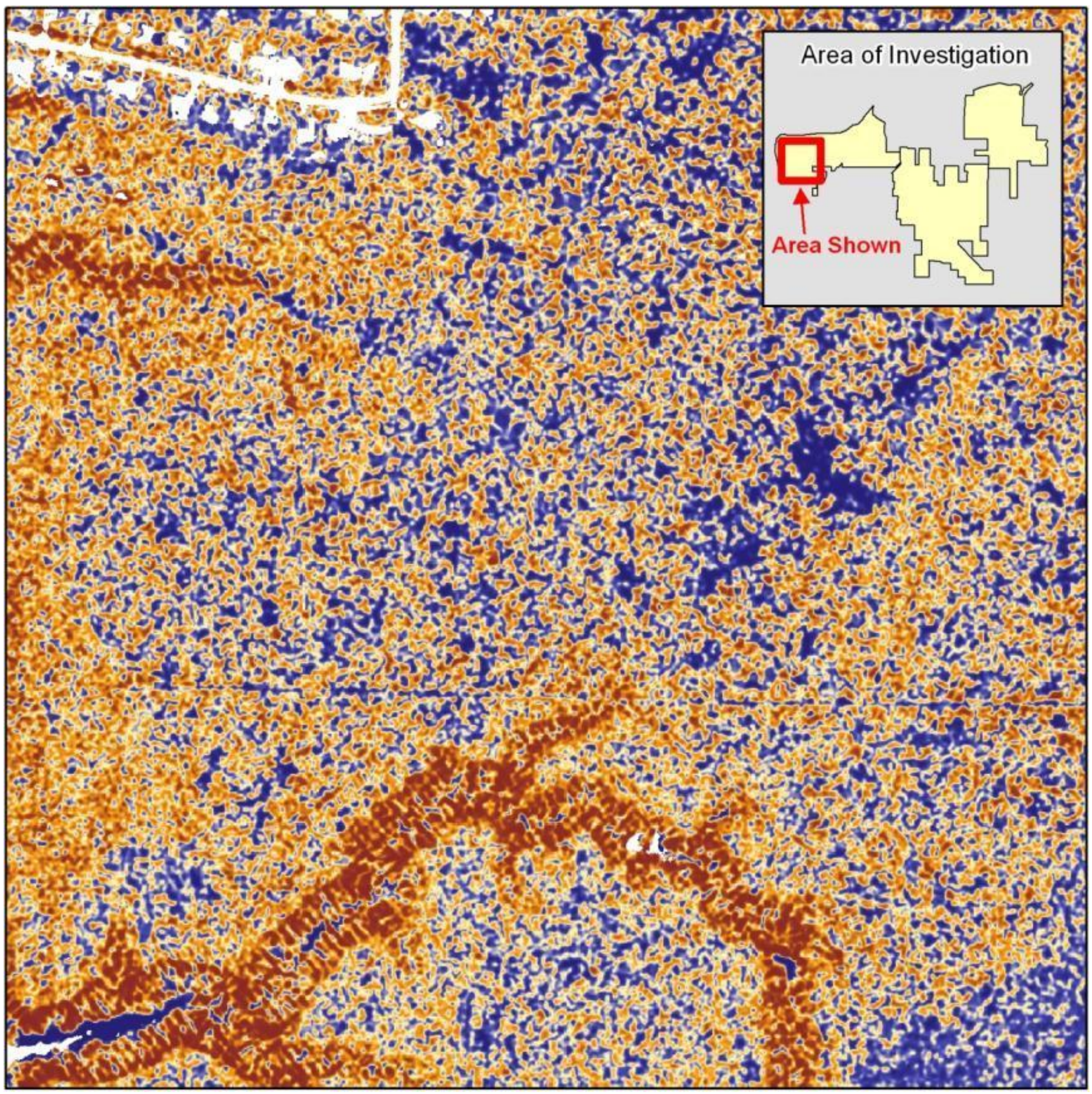


Figure 6: Compound topographic index in same portion of International Falls.

The blue areas are areas of water accumulation on the landscape, i.e. potential wetland. Notice impervious area is removed.

Using CTI to compare watershed assessment areas:

The resulting values in the CTI grid ranged from 0 to 7.7310. In order to facilitate using the wetness data to compare relative amounts of wetness between respective WAZ, the grid needed to be converted to a shapefile. To do this, the floating point grid needed to be converted to an integer grid. Converting the grid to integer with the existing values resulted in a generalized version of the grid since the narrow range of high precision decimal values was rounded to whole integers between 1 and 7. To compensate for this all values were multiplied by 10,000 in order to stretch the values such that when converted to integer, the grid still represented the same range of values as the floating grid.

The resulting integer grid contained values from 0 – 77310. Aerial image interpretation along with SWCD local knowledge of the landscape revealed that values of 200 or less represented (quite well) areas of water accumulation on the landscape. Studies in other areas of the state have shown that CTI values above the 85^{th} percentile best represented water accumulation areas. In this low relief landscape, this was not the case. Regardless, it was not critical to find a precise breakpoint of wet vs. non-wet for this analysis since the data were ultimately used as a **relative measure of wetness** between watershed analysis zones rather than an exact measure of wetness.

Once the stretched integer grid was created, the CTI grid was converted to shapefile, and values of 200 or less were extracted creating a shapefile of wet polygons throughout the city. These polygons were then intersected with the International Falls watershed assessment zones described above. The percent total area occupied by wet polygons was then calculated for each WAZ. Again, since these percentages are later normalized for analysis with other model inputs, having precise wetness percentages for the zones are not necessary. See Figure 7 and the corresponding map of percent wetness by WAZ.

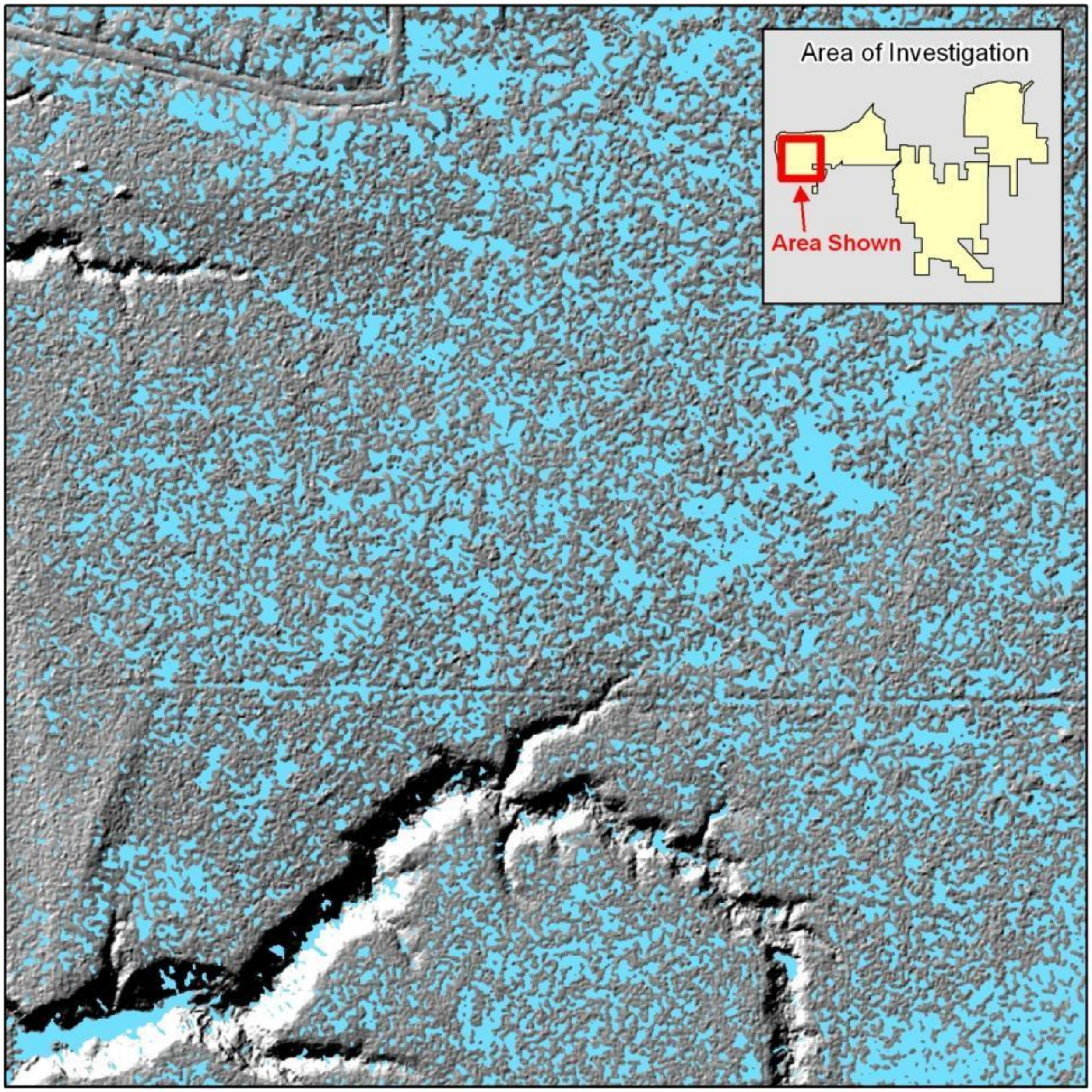
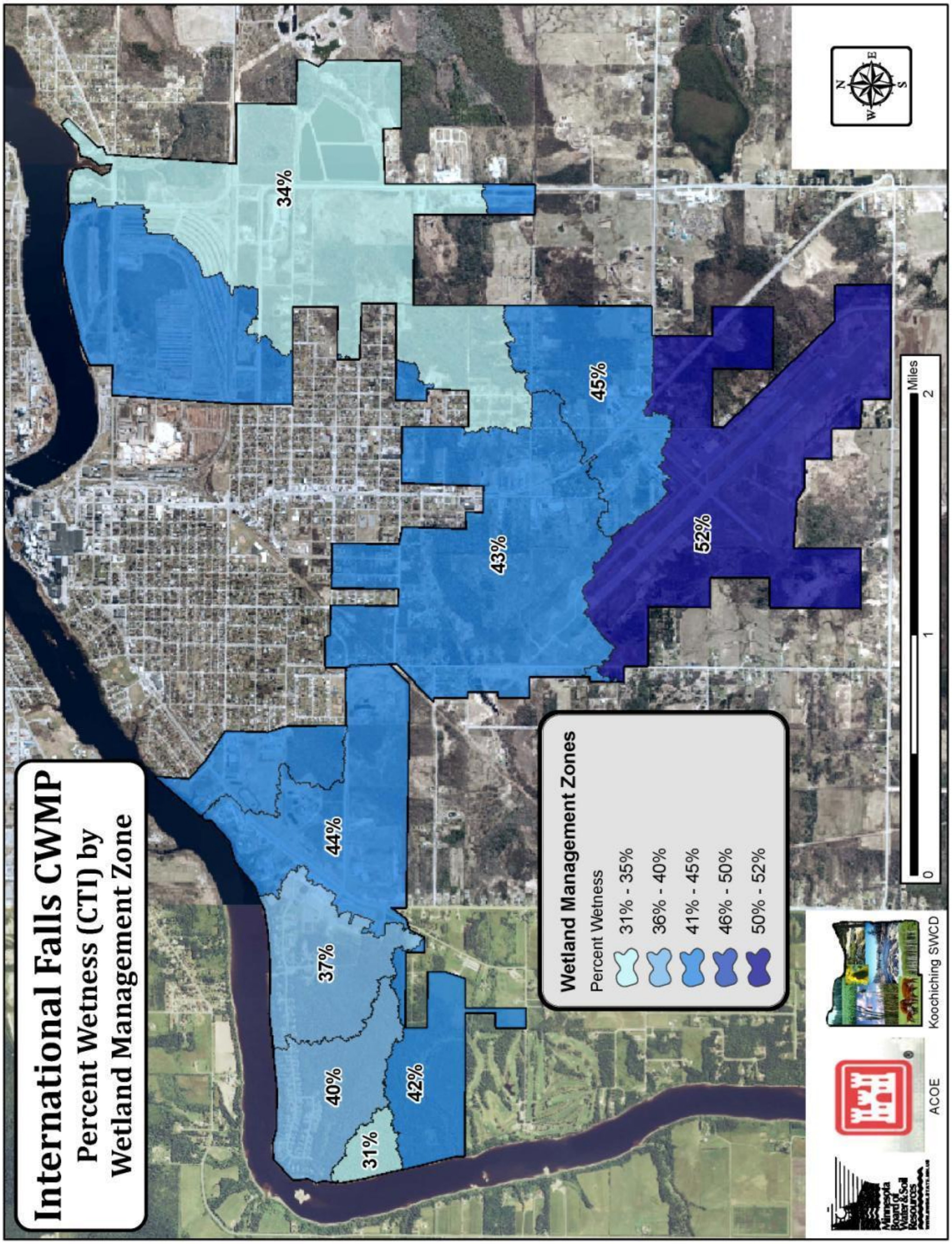


Figure 7: CTI based polygons representing areas of water accumulation in light blue.


International Falls CWMP
Percent Wetness (CTI) by
Wetland Management Zone
34%
45%
43%
52%
44%
37%
40%
42%
31%
Wetland Management Zones
Percent Wetness
31% - 35%
36% - 40%
41% - 45%
46% - 50%
50% - 52%
0
1
2
Miles
N
E
S
W
ACOE
Koochiching SWCD

Soil Survey:

Soil Survey Geographic Database (SSURGO) certified data became available from the NRCS for Koochiching County in August of 2010, however preliminary copies of the data were available earlier. Percent hydric soil for each soil map unit within the city were determined and joined to the spatial soil survey polygon data (Refer to Table 1, page 31) .These data were then intersected with the WAZ.

Area weighted average percent hydric soil was then calculated for each WAZ by multiplying the percent hydric for each soil polygon within the zone by that soil polygon area. Those values were then summed and divided by the total area of the zone. The zones were subsequently classified by percent area hydric. See Figure 8 and the corresponding map of percent hydric by WAZ. LIDAR coupled with soil maps illustrate the complex soil patterns and isolated nature of potential non-wetland sites. This is illustrated in Appendix A.

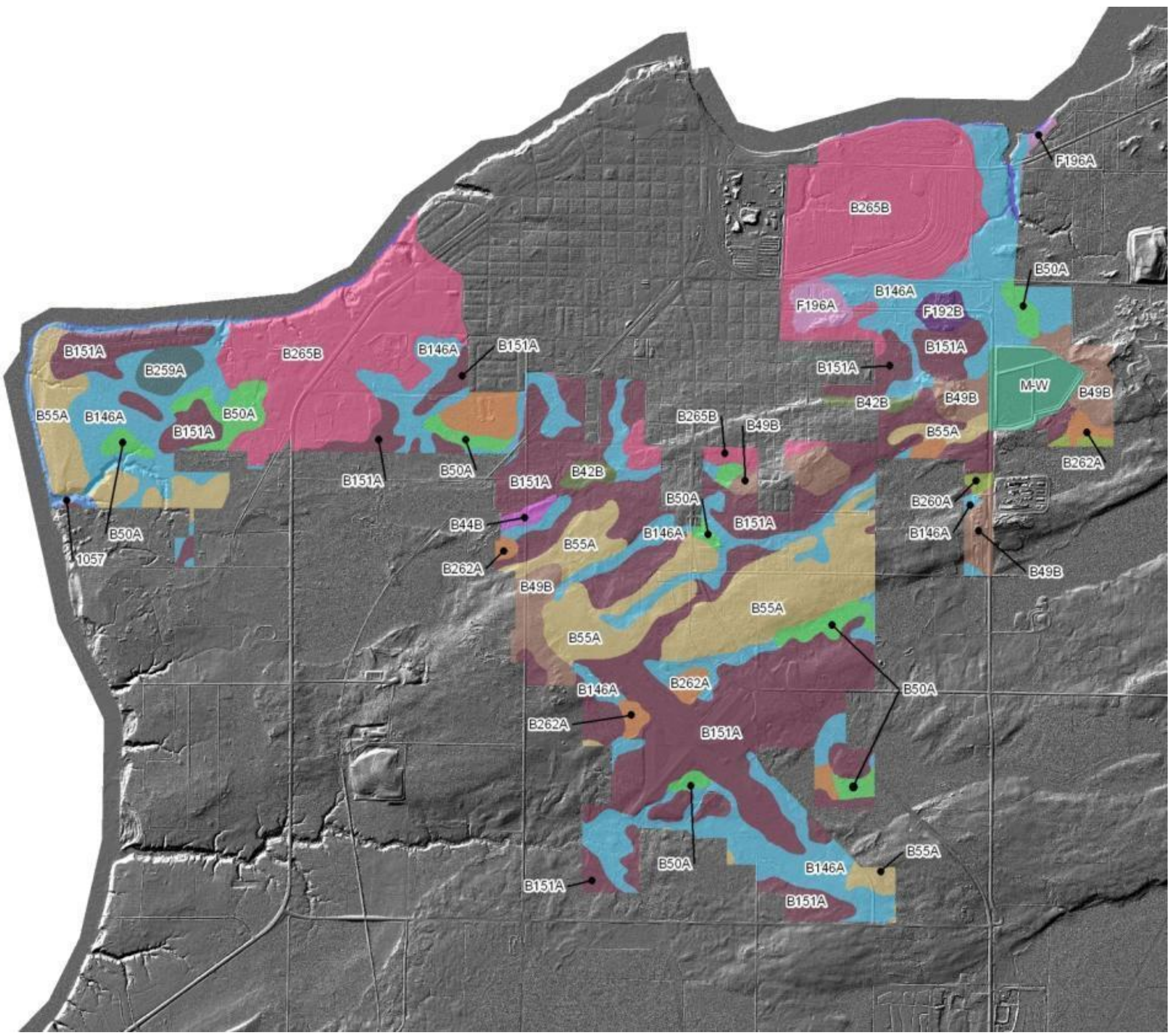
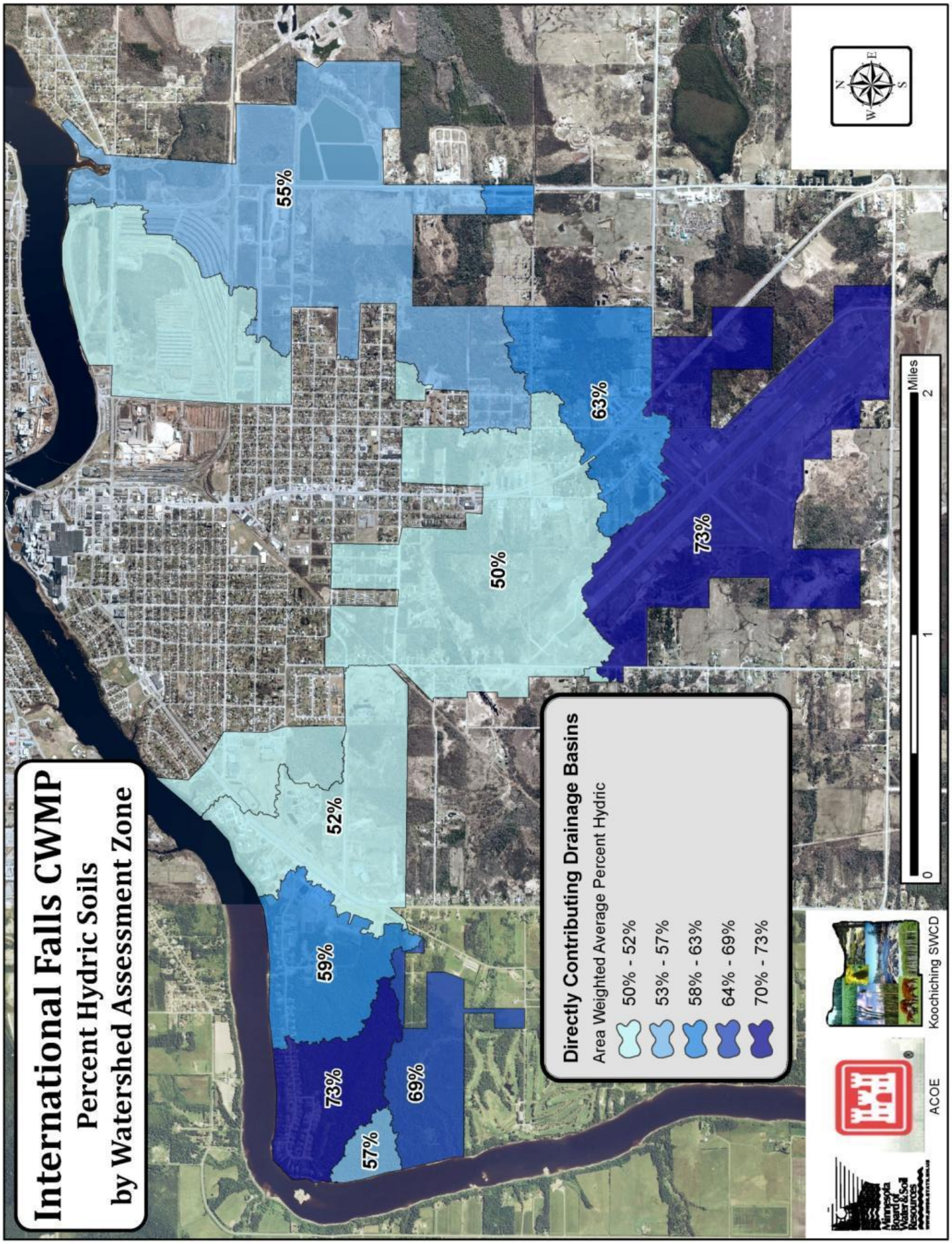


Figure 8: Soil Map Units in International Falls.

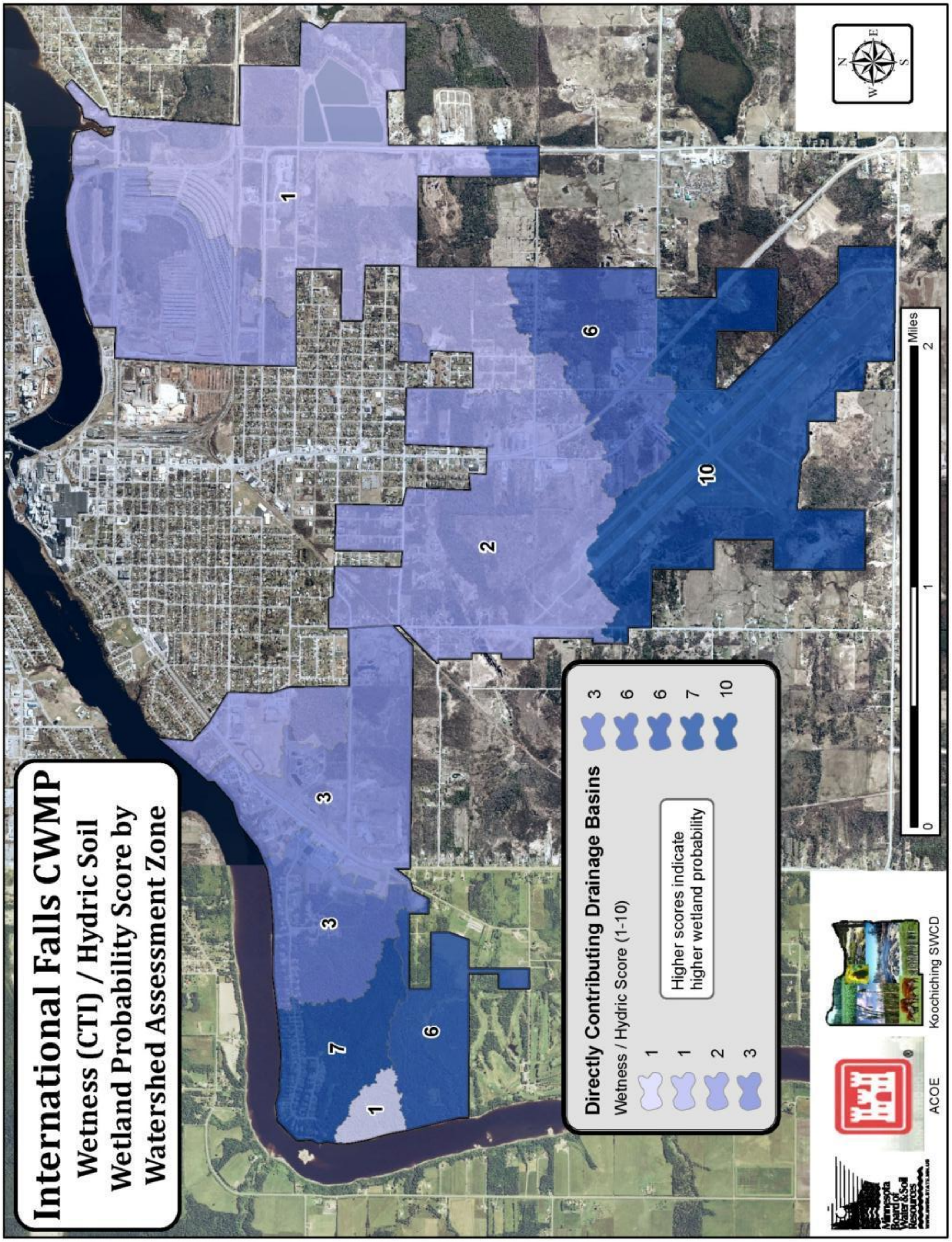

International Falls CWMP
Percent Hydric Soils
by Watershed Assessment Zone
55%
63%
73%
50%
52%
59%
73%
69%
57%
Directly Contributing Drainage Basins
Area Weighted Average Percent Hydric
50% - 52%
53% - 57%
58% - 63%
64% - 69%
70% - 73%
0
1
2
Miles
N
E
S
W
ACOE
Koochiching SWCD

Wetness (CTI) / Hydric Soils Wetland Probability:

By combining wetness (CTI) and hydric soils attributes by watershed a map of wetland probability was developed. This map depicts the probability that a wetland exists in the watershed based on a scale of 1-10 with 10 being highest probability of wetland occurrence.

The values per watershed analysis zone for percent wetness (CTI based) and area weighted average percent hydric (soils based), calculated as described in the sections above, were combined to create the wetland probability score. First, percent wetness per WAZ, which ranges from 31% - 52% and area weighted average percent hydric, which ranges from 50% - 73% were both normalized to a scale of 1-10 so they could be combined using a common scale. For each WAZ, these scores were then added together and re-normalized back to a 1-10 scale to create a combined score.

These numbers should not be interpreted as precise probability measurements, i.e. a WAZ with a score of 10 does not mean that WAZ is 10 times more likely to contain wetlands than a WAZ with a score of 1. Rather, the scores should be viewed as relative probability of wetland occurrence with 10 being highest probability of occurrence and 1 being the lowest. It should be recognized that although a WAZ with a score of 1 has a lower occurrence of wetland than a higher scoring WAZ, all of the zones have a high occurrence of wetlands when compared with other regions of the state, so that even a WAZ with a score of 1 is still likely to have more than 30% of its area containing wetlands. The map on the following page depicts the combined CTI / hydric soils wetland probability by WAZ.


International Falls CWMP
Wetness (CTI) / Hydric Soil
Wetland Probability Score by
Watershed Assessment Zone
Directly Contributing Drainage Basins
Wetness / Hydric Score (1-10)
1
1
2
3
3
6
6
7
10
Higher scores indicate
higher wetland probability
0
1
2
Miles
ACOE
Koochiching SWCD

Impervious Surface:

The Normalized Difference Vegetation Index (NDVI) was used to identify impervious surfaces within the city in order to quantify existing development.[4] The extent of impervious surface could also serve as a proxy of potential functional loss to a wetland. NDVI is a measure of greenness within remotely sensed imagery and is typically used to identify green vegetation on the landscape. However, it has also been used to map impervious surfaces. Imagery containing a near-infrared spectral band is required to perform this analysis. The formula for calculating NDVI is: NDVI = (NIR-VIS) / (NIR+VIS)

Where NIR stands for the near-infrared spectral band and VIS stands for the visible spectral band. Since these spectral bands are ratios of reflected over incoming radiation and therefore take on values between 0 and 1, the resulting NDVI values fall between -1 and 1.

Aerial imagery with 1 foot resolution was flown for Koochiching County (and others) using Minnesota Department of Natural Resources funding for their current update of the National Wetland Inventory (http://www.dnr.state.mn.us/eco/wetlands/nwi_proj.html). Imagery for the International Falls area was flown in May 2009 under leaf off conditions. The imagery contains 4 spectral bands and so includes the near-infrared band. [5]This imagery was used to calculate 1 ft resolution NDVI for the city.

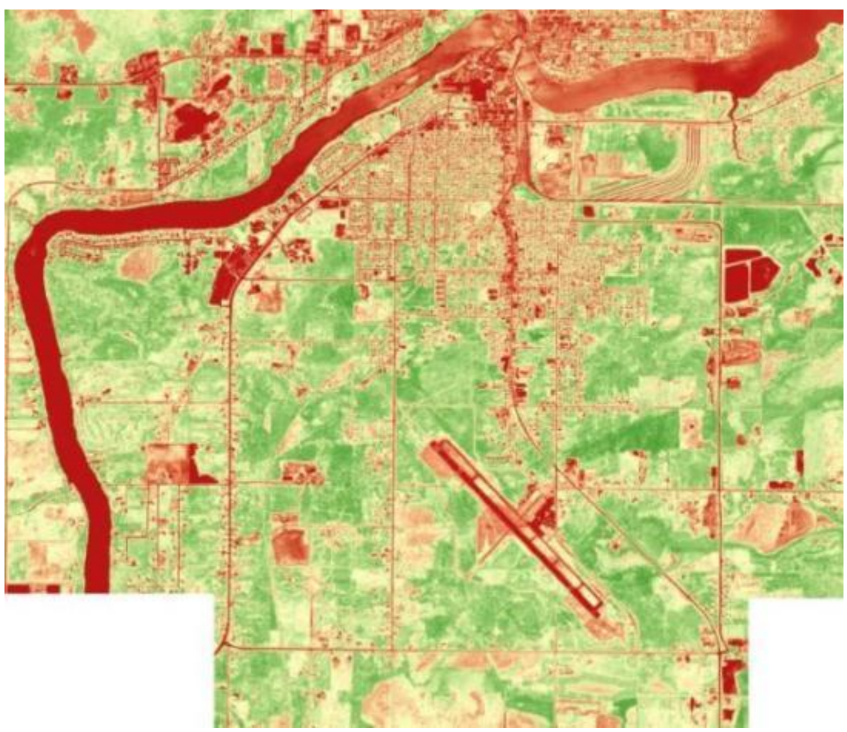


Figure 15: Normalized Difference Vegetation Index (NDVI) for International Falls.

Based upon aerial image interpretation it was found that NDVI values from-0.275 to -1.0 correlated well with impervious surface without including excessive non-impervious surfaces. Raster values in that range were extracted from the data to create an impervious surface raster. Note that these values also

[4] From numerous field visits, the influence of development on wetland functional status became evident.
[5] Thanks to Steve Kloiber of the DNR for providing this imagery.

capture open water. This is appropriate for this analysis since the open water being captured in International Falls is mainly the River and sewage lagoons which should not be included as wetland area.

Since some values in the transition zone correlated with both impervious and non-impervious areas, those values were excluded from the final raster to avoid including natural cover as impervious surface. Consequently there are some gaps in the impervious surface raster where impervious surface does exist on the landscape, but is not represented by the raster. However, the raster captures the majority of impervious surface and is still adequate for comparative impervious analysis between wetland management zones, i.e. the relative difference of impervious surface between management zones is still calculable without precise impervious area values.

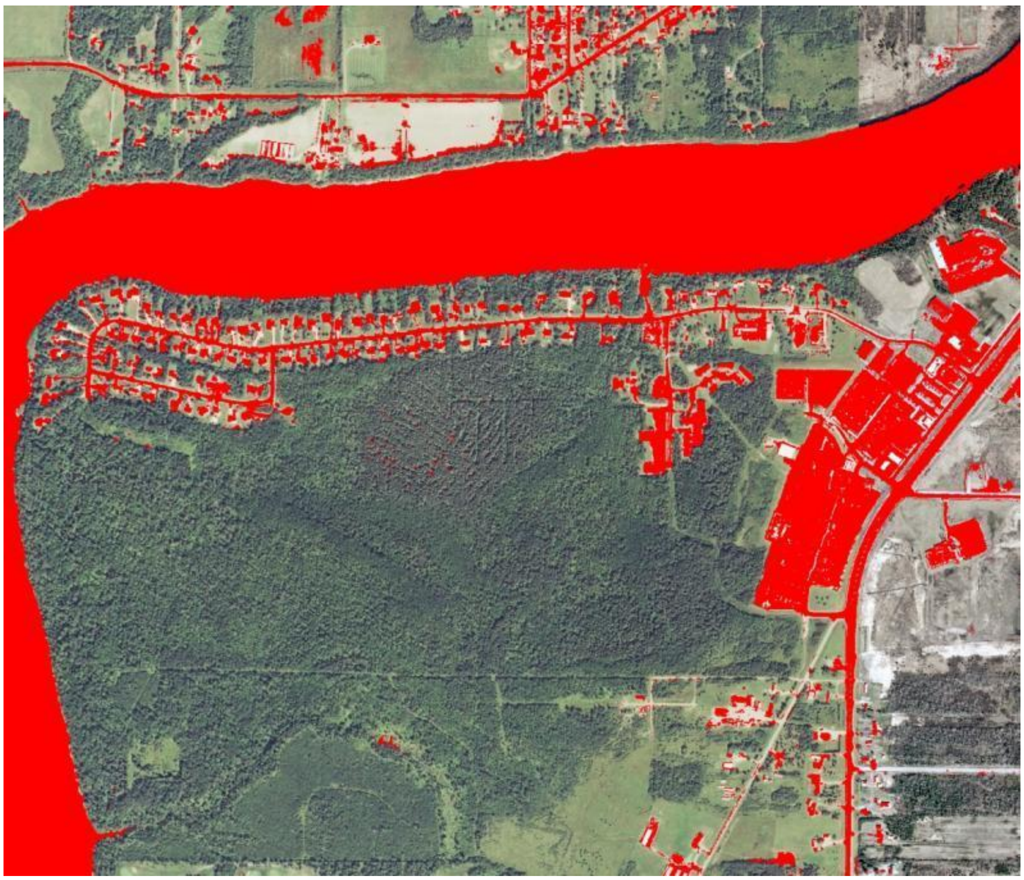
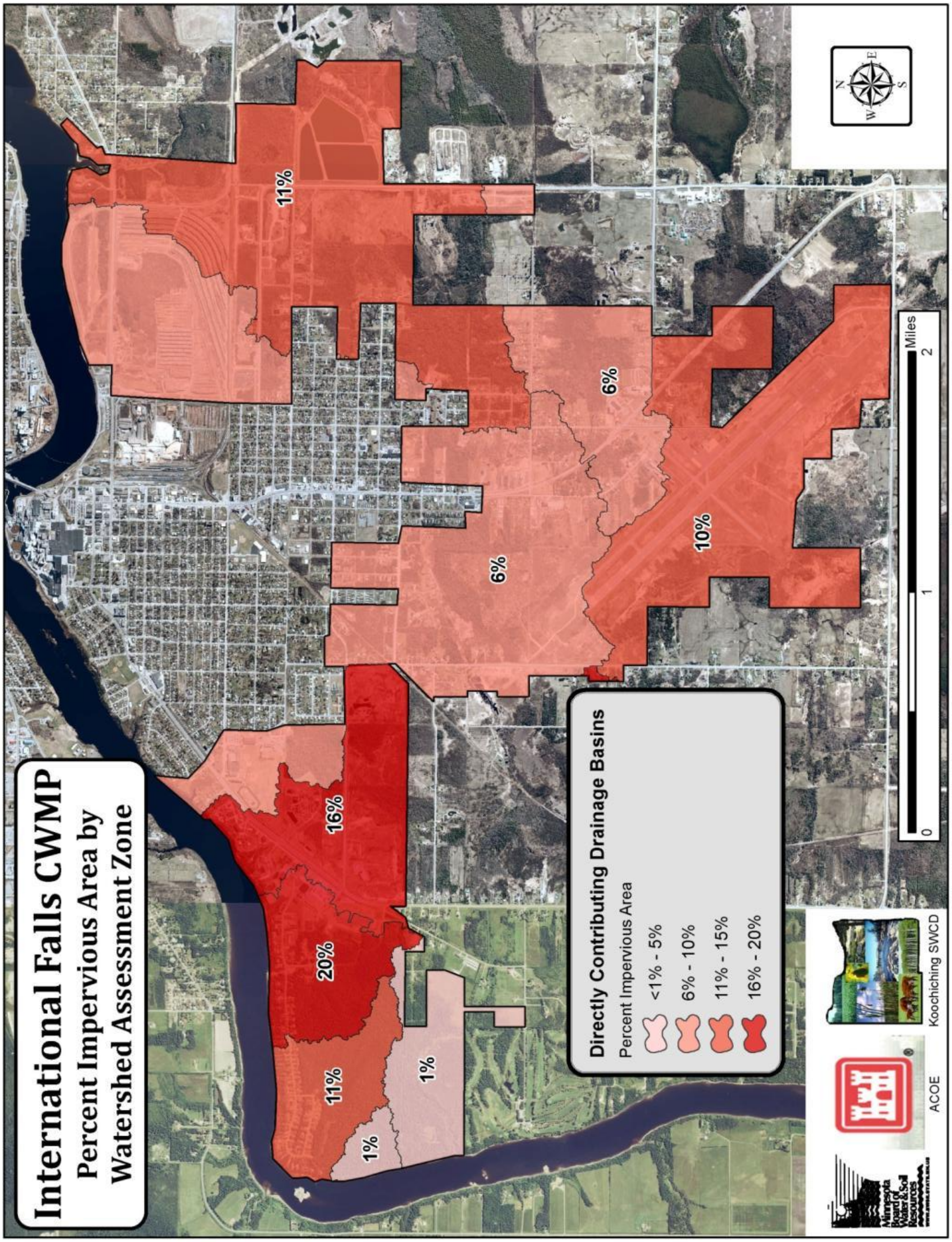


Figure16: Impervious surface and open water for a portion of International Falls.

In the same fashion as CTI, the impervious surface raster was stretched, converted to an integer and then converted to a shapefile. The shapefile was used to erase impervious surfaces and open water from the CTI raster as described in the CTI section. The shapefile was also used, in the same way as CTI, to calculate the percentage of impervious area within each zone. The zones were then classed by these percentages. See Figures 15 and 16 and the corresponding map (page 24). Zones with higher percentages of impervious surface exhibit a higher potential for contributing negative influences to wetland function.


International Falls CWMP
Percent Impervious Area by
Watershed Assessment Zone
11%
6%
10%
6%
16%
20%
11%
1%
1%
Directly Contributing Drainage Basins
Percent Impervious Area
<1% - 5%
6% - 10%
11% - 15%
16% - 20%
Miles
0
1
2
ACOE
Koochiching SWCD
Minnesota Board of Water & Soil Resources

MnRAM Assessment:

Minnesota Routine Assessment Method (MnRAM V. 3.3) was used to characterize function and degradation of wetlands within the area of investigation. Thirty- one functional assessments were performed by Svoboda Ecological Resources and the Koochiching County Technical Advisory Committee (TAC) during the summer of 2009.

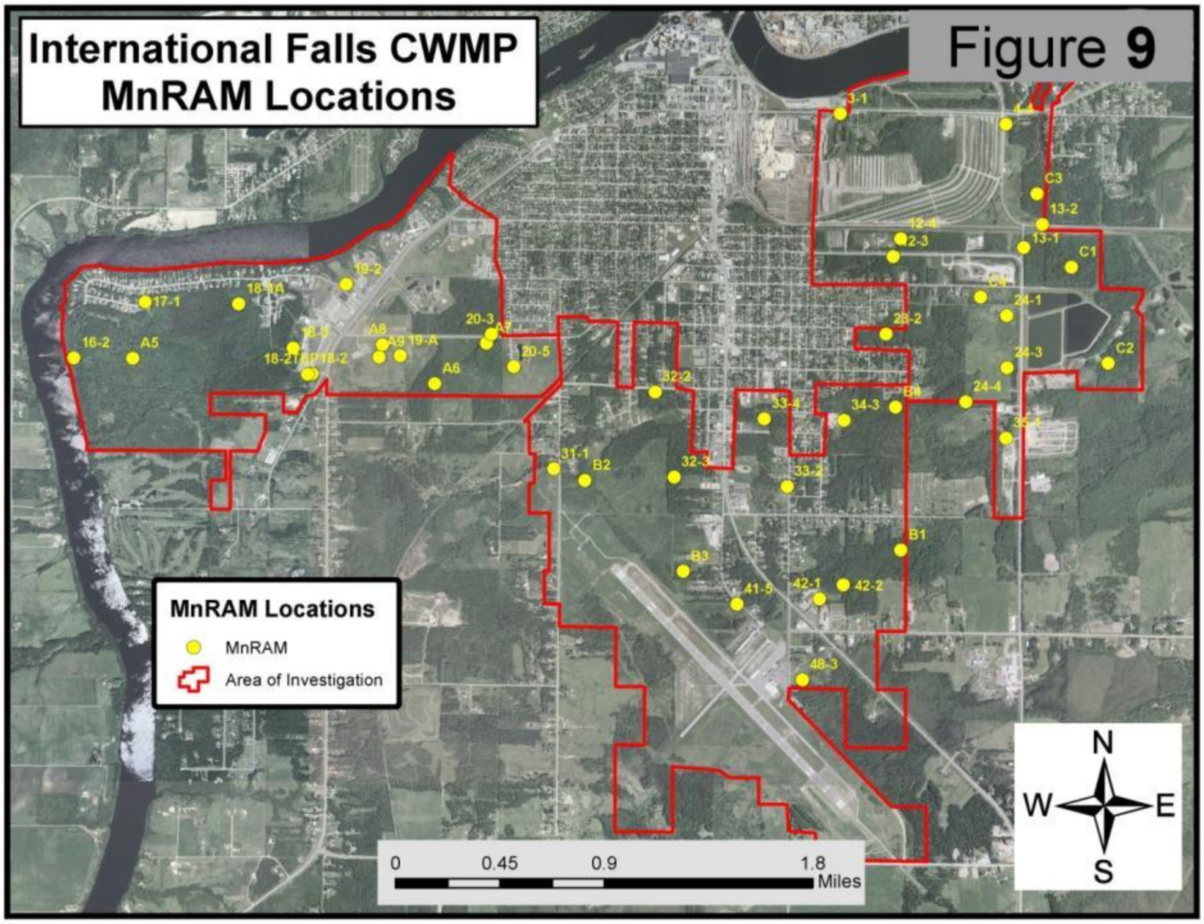


Figure 9: MnRAM assessment locations in International Falls.

After reviewing and evaluating these assessments and their locations, thirteen additional assessments were strategically conducted by the Koochiching SWCD to better represent the nature of the wetlands within the boundaries of the CWMP. A total of 44 functional assessments were conducted. See Figure 9. Once completed, a report was created to identify the results for all 10 parameters within MnRAM for each location. See Figure 10.

Figure 10

MnRAM ID	Vegetation Diversity/Integrity	Hydrology	Flood Attenuation	Water Quality - Downstream	Water Quality - Wetland	Wildlife Habitat Structure	Maintenance of Amphibian Habitat	Aesthetics/Recreation/ Education/Cultural
12-3	Medium	High	High	High	Medium	Medium	Low	Medium
12-4	Medium	High	High	High	Medium	Medium	N/A	Medium
13-1	Medium	Medium	High	Medium	Medium	Medium	N/A	Medium
13-2	Medium	High	High	High	High	High	Medium	Medium
16-2	Medium	High	High	High	High	High	High	Medium
17-1	Medium	High	High	High	Medium	High	N/A	Medium
18-1A	High	High	High	High	High	High	N/A	Medium
18-2	Medium	Low	Medium	Medium	Medium	Medium	N/A	Medium
18-2 TEP	Medium	High	High	High	Medium	Medium	N/A	Medium
18-3	Low	Medium	High	High	Medium	Medium	N/A	Medium
19-2	Low	Medium	High	High	Medium	Medium	N/A	Medium
19A	Low	Medium	Medium	High	Medium	Medium	N/A	Low
20-3	High	High	Medium	High	High	High	Medium	High
20-5	Low	Medium	Medium	High	Medium	Medium	N/A	Medium
23-2	Medium	Medium	High	Medium	Medium	Medium	N/A	Low
24-1	Low	Medium	Medium	Medium	Medium	Medium	N/A	Low
24-3	High	High	High	High	High	High	N/A	Medium
24-4	High	High	High	High	High	High	High	Medium
3-1	Medium	Low	Medium	Medium	Medium	Medium	Low	Medium
31-1	High	High	Medium	High	High	High	Medium	High
32-2	Medium	Medium	Medium	Medium	Medium	Medium	N/A	Medium
32-3	High	High	High	High	High	High	N/A	Medium
33-2	High	High	High	High	High	High	Medium	Medium
33-4	High	High	High	High	High	High	Medium	Medium
34-3	Medium	Medium	Medium	Medium	Medium	Medium	N/A	Medium
35-1	High	Medium	High	Medium	Medium	High	Low	Medium
41-5	High	Medium	High	Medium	High	High	N/A	Medium
42-1	Low	Medium	High	Medium	Medium	Medium	N/A	Medium
42-2	High	High	High	High	High	High	N/A	Low
4-4	High	Medium	High	High	Medium	Medium	N/A	Medium
48-3	High	High	High	Medium	High	High	Medium	Medium

MnRAM ID	Vegetation Diversity/Integrity	Hydrology	Flood Attenuation	Water Quality - Downstream	Water Quality - Wetland	Wildlife Habitat Structure	Maintenance of Amphibian Habitat	Aesthetics/Recreation/ Education/Cultural
A-5	High	High	High	High	High	High	N/A	Medium
A-6	Medium	High	High	High	High	Medium	N/A	Medium
A-7	Exceptional	High	Medium	High	Low	High	N/A	Medium
A-8	Low	Low	Medium	Medium	Medium	Low	N/A	Low
A-9	Low	Medium	Medium	High	Medium	Medium	Medium	Medium
B-1	High	High	High	High	High	High	High	Medium
B-2	High	High	High	High	High	High	N/A	High
B3	Medium	Medium	High	High	High	Medium	Medium	Medium
B4	High	High	Medium	High	High	High	Medium	Medium
C-1	High	High	High	High	High	High	N/A	Medium
C-2	High	High	High	High	High	High	Medium	Medium
C3	High	High	High	High	High	High	Medium	Medium
C4	Low	Medium	Medium	Medium	Medium	Medium	Medium	Low

While 10 functions were assessed, only one function was chosen to indicate the functional rating of each wetland. The “Vegetative Diversity/Integrity” function was chosen as the basis for functional status of each wetland. This was chosen because the results for the other nine functions were comparatively the same for each assessment. In other words, within the boundaries of the CWMP, the vegetative diversity/integrity parameter most accurately described differences between High, Medium, & Low functioning wetlands.

The primary difference between these wetlands within the CWMP was the amount of invasive species present. Wetlands with more invasive species were lower functioning. As stated in MnRAM guidance each wetland is part of an integrated ecological system that should not be thought of as a group of distinct functions, but as an interactive group of functions. It is then with caution that a MnRAM score should be modified by a subset of functions. That being said, an assessment of a subset of functions was performed to illustrate how development and other human influenced-disturbance affect the overall function of a wetland. This index, called a “stressor index”, is described in Appendix B. A wetland subject to more disturbance had more invasive species and was lower functioning.

The index is complementary to, and supports the location of, environmental corridors on the margins of the city and some distance from potential disturbance. Example environmental corridors are shown on Appendix C. Environmental corridors have been used as the basis for wetland management zones in other wetland management plans, and merit consideration in this plan.

Recommendations for use of data:

- A map of planned and future development would aid in determining wetland management zones. [6]
- Functional assessments and analyses demonstrating the impact that development poses to wetland function suggest that zones of maximum wetland protection should be located in areas less prone to impacts from existing and future development. To maximize wetland function and avoid fragmentation, wetland management corridors are suggested. Refer to Attachment C.
- Most of the maps in this report are at “planning” scale, not implementation scale.
- The data underlying the maps in this plan are available from Koochiching Soil and Water Conservation District and can be used to develop implementation scale maps. At an implementation scale, the probability of wetland and non-wetland areas are estimated well enough to (a) provide an advance analysis of alternatives and (b) provide flexibility with respect to the level of wetland delineation needed by an applicant, and (c) form the basis for a streamlined regulatory process.
- As with any map, and these maps are no different, there is an optimum scale of interpretation given the detail of the data used to generate the map. Users are cautioned against “enlarging” a map to increase the level of detail.
- The authors of this report intentionally avoided designating management zones or suggesting permitting methods and standards. These tasks rest with those developing the plan. These data are intended to support those efforts.

[6] In lieu of this data layer, a map of existing and planned utilities was provided by the City and is included as Appendix D.

Appendix A

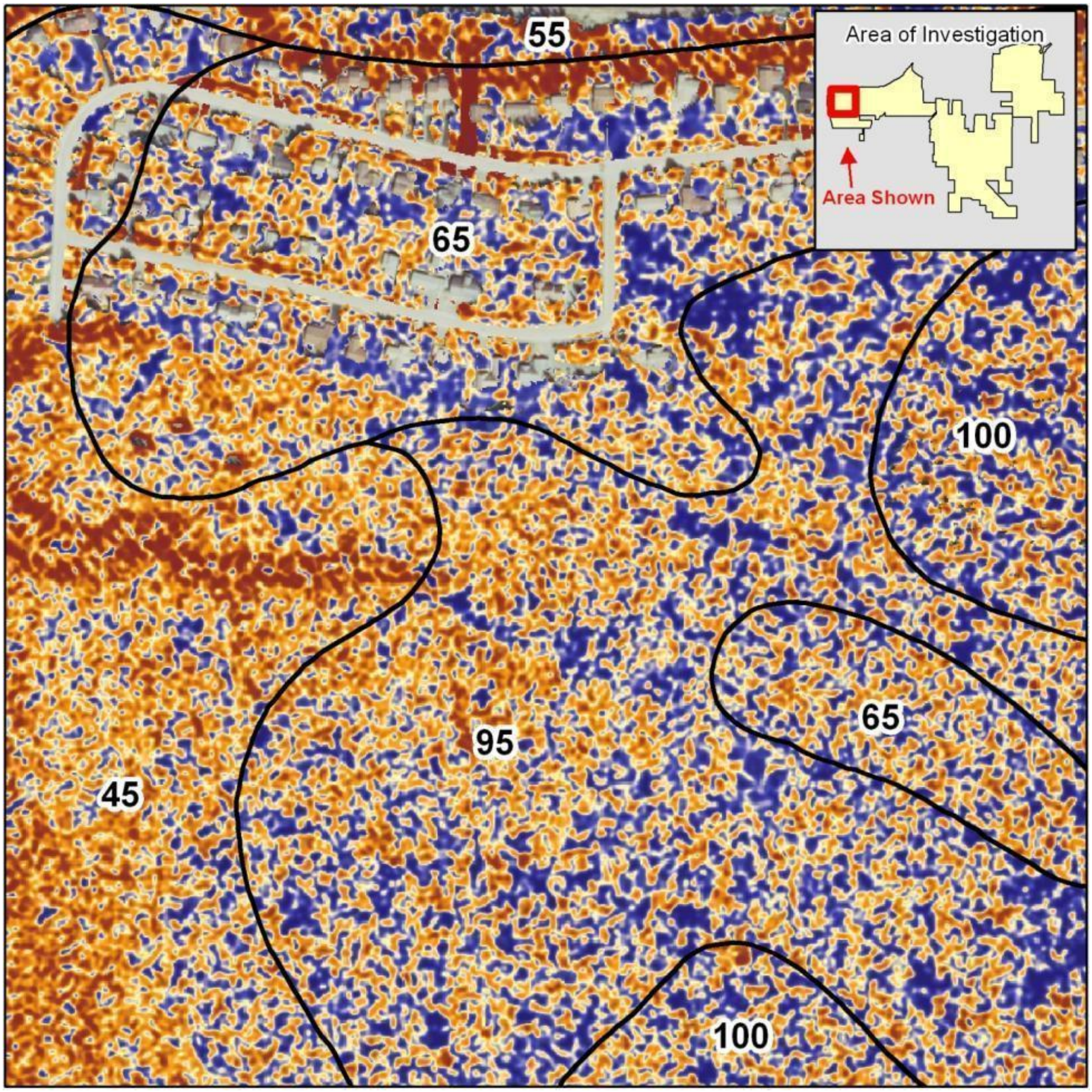
Soil Pattern and Landscape Wetness

As shown on Table 1 (page 30), many soil mapping units in the plan area consist of predominantly hydric soils, with some mapping units comprised of 100 percent hydric components. Hydric soils have a water table at or near the surface.[7] In this low relief landscape, the elevation difference between hydric and non-hydric soil components can vary in elevation by one foot or less. Further, the pattern of soils, including hydric and non-hydric components, resembles a mosaic.

Although the extent of landscape wetness complicates the siting of development and related infrastructure, it is the lack of consolidated, non-wetland areas that pose a bigger challenge. The map on page 29 depicts a LIDAR-CTI image with soil polygons (dark lines) superimposed[8]. Blue represents areas of lowest relative elevation (and ponding); those soils would likely be hydric. Dark brown represents areas of highest relative elevation; those soils would likely be non-hydric. Varying shades of brown indicate relative intermediate elevations and hydric to non-hydric soils. The numbers refer to the extent of hydric soil components in the mapping unit. As shown in the map, it would be difficult to site a project and avoid wetland impacts in most of the area, with the possible exception of the area on the west where only 45 percent of the soil mapping unit is hydric.

[7] As verified by field investigation, in this landscape hydric soils had wetland hydrology and supported a dominance of hydrophytic vegetation. Unless hydrologically altered, areas of hydric soils were wetlands.

[8] This map is for illustrative purposes only and is not intended to represent actual field scale conditions. The background imagery for the soil mapping was not LIDAR and the design of the soil survey was not intended to capture landscape details to the extent of CTI. Nevertheless, there is good visual agreement between the percent hydric soil components and landscape wetness .



CTI with soil map units. Numbers indicate the percentage of hydric components within that map unit.

Table 1.

MU Symbol	MU Name	% Hydric Components	Hydric Landform
1007	Udorthents, shallow(sanitary landfill)	N/A	
1057	Fluvaquents, frequently flooded-Hapludalfs complex, 0-35% slopes	55	Floodplains
B42B	Haystore-Kooch complex, 1-8% slopes	12	Till plains and depressions
B44B	Cutaway-Ricelake complex, mlra 88, 2-6% slopes	10	Moraines
B49B	Kooch-Hapludalfs complex, 1-8% slopes	12	Till plains and depressions
B50A	Ratroot-Dora complex, 0-1% slopes	100	Till plains and depressions
B55A	Kooch-Kab-Ratroot complex, 0-4% slopes	45	Till plains and depressions
B146A	Kab-Ratroot complex, 0-2% slopes	95	Till plains and depressions
B151A	Kab-Kooch complex, 0-4% slopes	65	Till plains and depressions
B257A	Greenwood-Lobo complex, kab catena, 0-1% slopes	100	Raised bogs
B259A	Greenwood soils, kab catena, 0-1% slopes	100	Raised bogs and depressions
B260A	Rifle soils, kab catena, 0-1% slopes	100	Depressions
B262A	Dora and Terric Haplohemist soils, kab catena, 0-1% slopes	100	Depressions
B265B	Urban land-Kooch-Kab complex, 0-4% slopes	27	Till plains and depressions
F21C	Quetico, stony-Rock outcrop complex, 2-15% slopes	0	N/A
F192B	Baudette-Littleswan complex, 1-8% slopes	15	Lake plains and depressions
F196A	Spooner-Sax complex, 0-1% slopes	99	Lake plains and depressions

Appendix B

Wetland Stressor Index

As previously discussed, in addition to classifying each wetland based on the vegetation diversity/integrity function, a stressor index was developed to assess human influence on wetland function. To do this, four questions (#14, #20, #23, & #53) were chosen from MnRAM that describe the wetlands watershed function and imply human influences. These questions are as follows.

#14: Describe the dominant land use and condition of the immediate upland drainage area of the wetland. If the immediate upland drainage is not evident, then within 500 ft.

A = Watershed conditions essentially unaltered; < 10% impervious (i.e. low density residential, >1 acre lots); land use development minimal, idle lands, lands in hay or forests or low intensity grazing.

B = Watershed conditions somewhat modified; e.g., 10–30 % impervious (i.e. medium density residential, 1/3 to 1 acre lots); moderate intensity grazing or haying with some bare ground; conventional till with residue management on moderate slopes, no-till on steep slopes.

C = Watershed conditions highly modified; e.g., >30 % impervious surfaces (i.e. high density residential, lots smaller than 1/3 acre, industrial, commercial, high impervious institutional) maximizing overland flow to the wetland; intensive agriculture or grazing with a high amount of bare ground, no residue management on moderate or steep slopes, intensive mining activities.

#20: Describe the characteristics of stormwater, wastewater, or concentrated agricultural runoff detention/water quality treatment prior to discharging into the wetland:

A = Receives significant volumes of untreated/undetained stormwater runoff, wastewater, or concentrated agricultural runoff directly, in relation to the wetland size.

B = Receives moderate volumes of directed stormwater runoff, wastewater, or concentrated agricultural runoff in relation to wetland size, which has received some treatment (sediment removal) and runoff detention.

C = Does not receive directed stormwater runoff, wastewater, or concentrated agricultural runoff; receives small volumes of one or more of these sources in relation to wetland size; or stormwater is treated to approximately the standards of the National Urban Runoff Program (NURP); and runoff rates controlled to nearly predevelopment conditions.

#23: Adjacent Buffer width: Average width of the naturalized buffer :_________(within 500 ft)

#53: What are the obvious human influences of the wetland itself, such as:

A = No structures, pollution, trash, or other alteration present in the wetland.

B = Wetland only moderately disturbed by structures, pollution, trash, or alteration.

C = Wetland has signs of extensive pollution/trash, severe vegetative alteration, or multiple structures.

A score was given (1-3), based on the answers to each MnRAM assessment and a total score was then tabulated. The maximum potential score was 12 (3 pts x 4 questions) and the minimum potential score was 4 (1 pt x 4 questions).

For instance, if a MnRAM assessment contained the following stressor answers:

#14 – 3pts, #20 – 2pts, #23 – 2pts, #53 – 3pts

The total stress score would be 3+2+2+3 = 10.

Once all of the total scores were tabulated, a Final Stressor Score was given based on:

Total Score	Final Stressor Score
4 – 6	Low
7 – 9	Medium
10 – 12	High

As an example, a MnRAM assessment with a score of 10 would be considered under “high” stress by its surroundings. See Figure 11 for stressor score results.

Figure11

MnRAM ID	#14 (A=1, B=2, C=3)	#20 (A=3, B=2, C=1)	#23 (>50=1, 25-50=2, <25=3)	#53 (A=1, B=2, C=3)	Total Score	Stressor Score
12-3	2	2	2	2	8	Medium
12-4	2	2	2	2	8	Medium
13-1	2	2	3	2	9	Medium
13-2	1	1	1	2	5	Low
16-2	1	1	1	1	4	Low
17-1	2	2	1	1	6	Low
18-1A	1	1	1	1	4	Low
18-2	3	3	1	2	9	Medium
18-2 TEP	2	2	2	2	8	Medium
18-3	3	3	2	2	10	High
19-2	3	3	2	2	10	High
19A	2	2	2	3	9	Medium
20-3	2	1	2	1	6	Low
20-5	2	2	1	2	7	Medium
23-2	3	2	2	2	9	Medium
24-1	2	2	1	3	8	Medium
24-3	1	1	1	2	5	Low
24-4	1	1	1	1	4	Low
3-1	3	2	1	2	8	Medium
31-1	1	1	2	2	6	Low
32-2	2	2	1	2	7	Medium
32-3	2	2	1	2	7	Medium
33-2	2	1	2	2	7	Medium
33-4	2	2	2	1	7	Medium
34-3	2	2	1	3	8	Medium
35-1	3	2	2	2	9	Medium
41-5	3	2	2	2	9	Medium
42-1	3	2	1	2	8	Medium
42-2	2	2	1	2	7	Medium
4-4	2	2	3	2	9	Medium
48-3	2	1	1	2	6	Low
A-5	2	1	1	2	6	Low
A-6	2	1	1	2	6	Low
A-7	1	1	1	2	5	Low
A-8	3	2	1	3	9	Medium
A-9	3	2	1	3	9	Medium
B-1	2	1	1	2	6	Low
B-2	1	1	1	1	4	Low
B3	2	1	2	1	6	Low
B4	1	1	1	1	4	Low
C-1	1	1	1	1	4	Low
C-2	1	3	1	2	7	Medium
C3	1	1	1	2	5	Low
C4	2	2	2	2	8	Medium

Development of Final Score:

To calculate the final score rating for each MnRAM assessment, a matrix was developed to compare and adjust the vegetation rating with the stressor rating.

MnRAM Assessment Final Score Matrix

<table>
<tr><th colspan="5">Final Score Rating</th></tr>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Vegetation Score</th></tr>
<tr><th>High (21)</th><th>Medium (14)</th><th>Low (9)</th></tr>
<tr><td rowspan="3">Stressor Score</td><td>Low (18)</td><td>High (13)</td><td>Medium (5)</td><td>Low (0)</td></tr>
<tr><td>Medium (24)</td><td>Medium (8)</td><td>Medium (9)</td><td>Low (7)</td></tr>
<tr><td>High (2)</td><td>Medium (0)</td><td>Low (0)</td><td>Low (2)</td></tr>
</table>

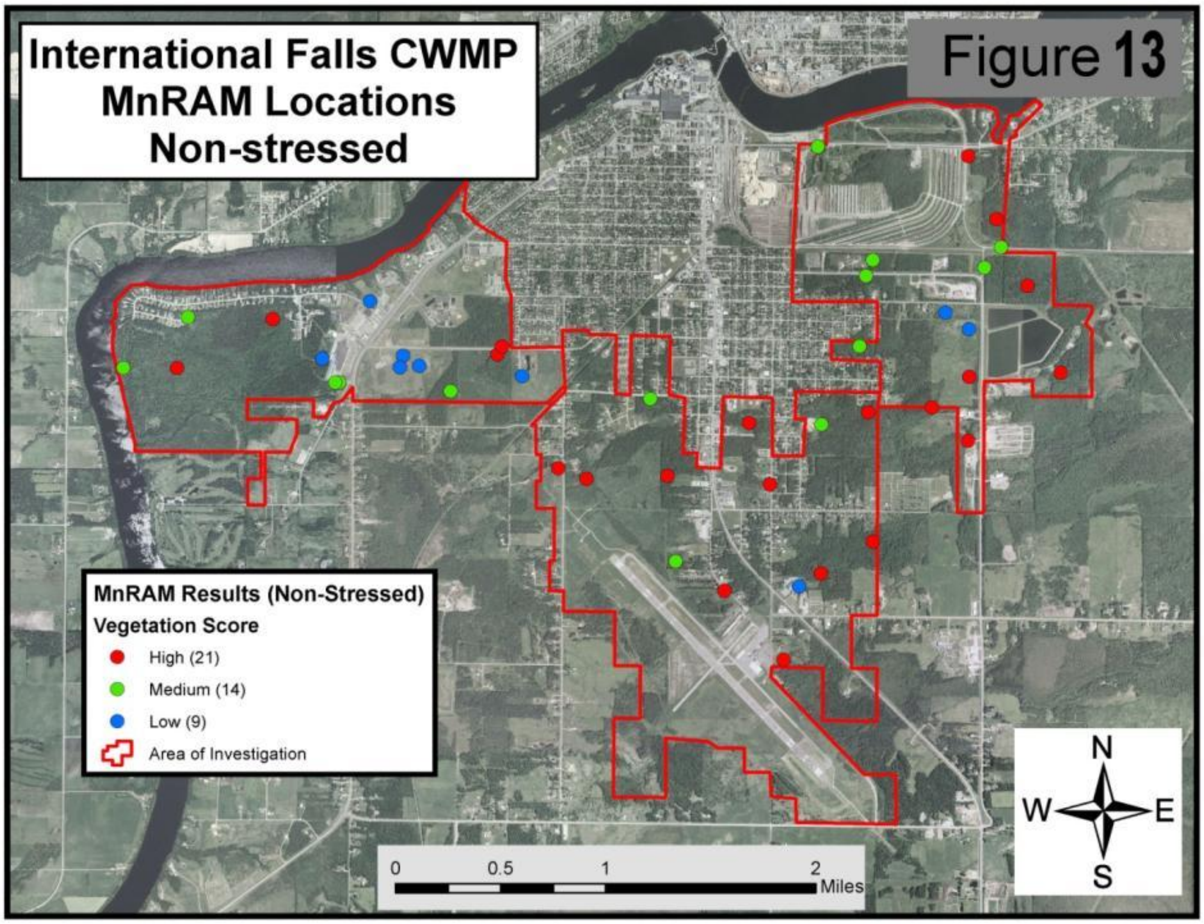
After incorporating the stressor rating into the vegetative integrity/diversity function, only one significant difference was noted: “High” vegetation ratings when combined with “Medium” stressor ratings produced a “Medium” adjusted rating. See Figure 12.

Figure 12

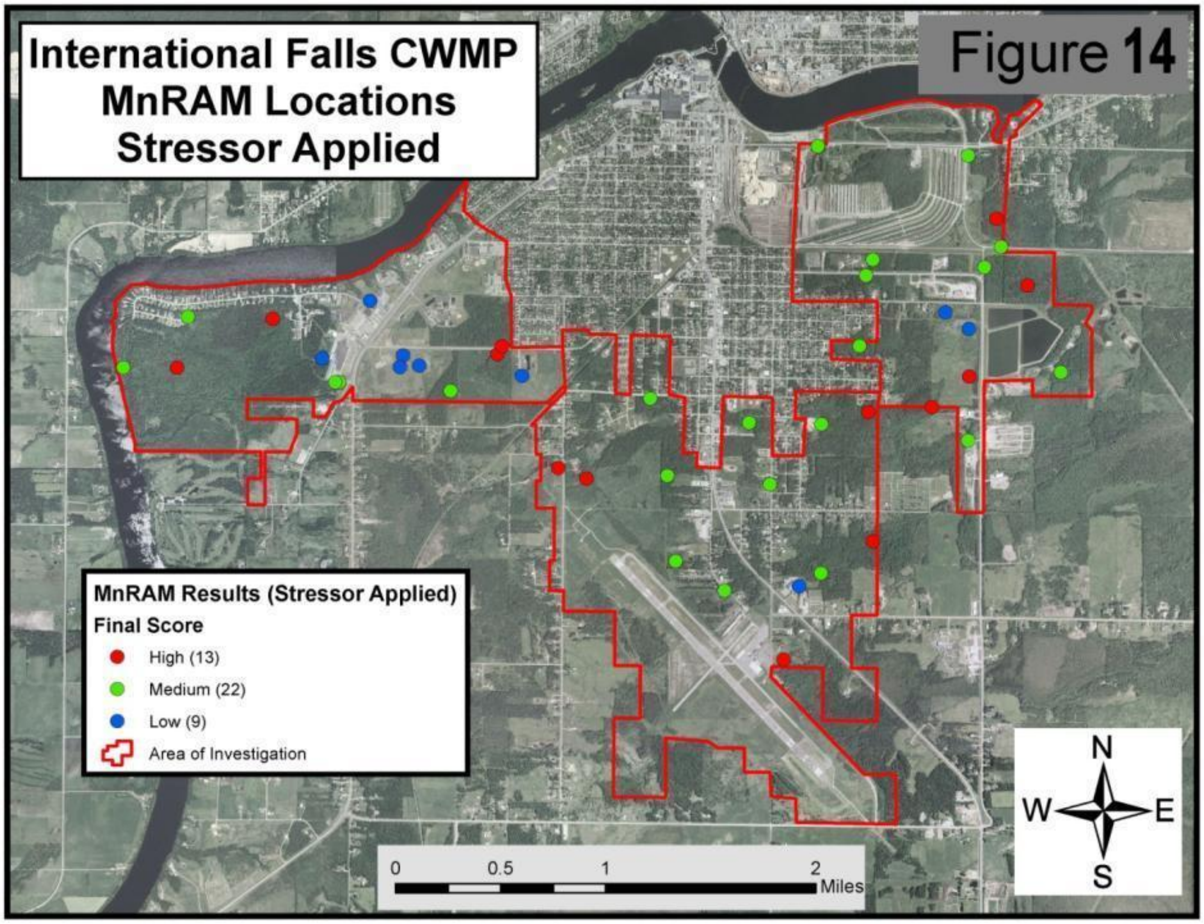
MnRAM ID	Vegetation Score	Stresser Score	Final Score
12-3	Medium	Medium	Medium
12-4	Medium	Medium	Medium
13-1	Medium	Medium	Medium
13-2	Medium	Low	Medium
16-2	Medium	Low	Medium
17-1	Medium	Low	Medium
18-1A	High	Low	High
18-2	Medium	Medium	Medium
18-2 TEP	Medium	Medium	Medium
18-3	Low	High	Low
19-2	Low	High	Low
19A	Low	Medium	Low
20-3	High	Low	High
20-5	Low	Medium	Low
23-2	Medium	Medium	Medium
24-1	Low	Medium	Low
24-3	High	Low	High
24-4	High	Low	High
3-1	Medium	Medium	Medium
31-1	High	Low	High
32-2	Medium	Medium	Medium
32-3	High	Medium	Medium
33-2	High	Medium	Medium
33-4	High	Medium	Medium
34-3	Medium	Medium	Medium
35-1	High	Medium	Medium
41-5	High	Medium	Medium
42-1	Low	Medium	Low
42-2	High	Medium	Medium
4-4	High	Medium	Medium
48-3	High	Low	High
A-5	High	Low	High
A-6	Medium	Low	Medium
A-7	Exceptional	Low	High
A-8	Low	Medium	Low
A-9	Low	Medium	Low
B-1	High	Low	High
B-2	High	Low	High
B3	Medium	Low	Medium
B4	High	Low	High
C-1	High	Low	High
C-2	High	Medium	Medium
C3	High	Low	High
C4	Low	Medium	Low

For instance, a wetland with a "High" vegetation score and a "Low" stressor score suggests that the wetland will likely continue to maintain high vegetative functions compared to a wetland with a "High" vegetation score and a "Medium" stressor rating. The negative relationship of disturbance to wetland function is also shown by the impervious surface map in the GIS analysis section. Therein, inference of human influence on wetland vegetation functions is illustrated.

Before applying the stressor index to each assessment, results were: 21 – High, 14 – Medium, & 9 Low. See Figure 13.



After applying the stressor index to each assessment, results were: 13 – High, 22 – Medium, & 9 – Low. See Figure 14.



Summary: By applying a subset of MnRAM questions that address development and other human influences to the vegetative integrity/diversity function, a functional shift from high to medium occurs. This exercise illustrates the negative influence of development to vegetative wetland functions in this plan area and suggests that wetland management zones of maximum protection should be located as far as practical from areas of planned development.

Appendix C

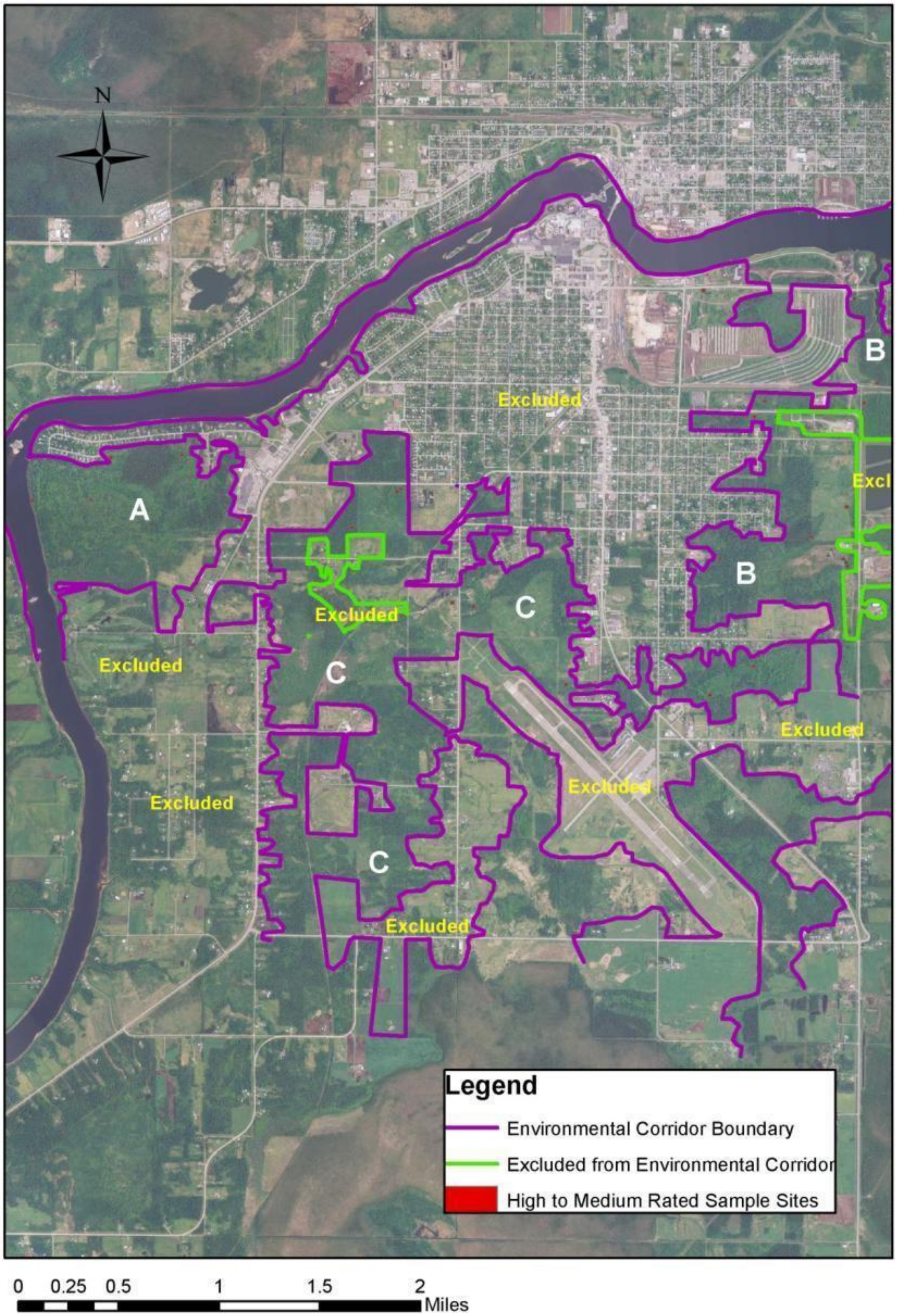
Environmental Corridors

(Comments and conceptual corridors provided by Steve Eggers, Senior Ecologist)

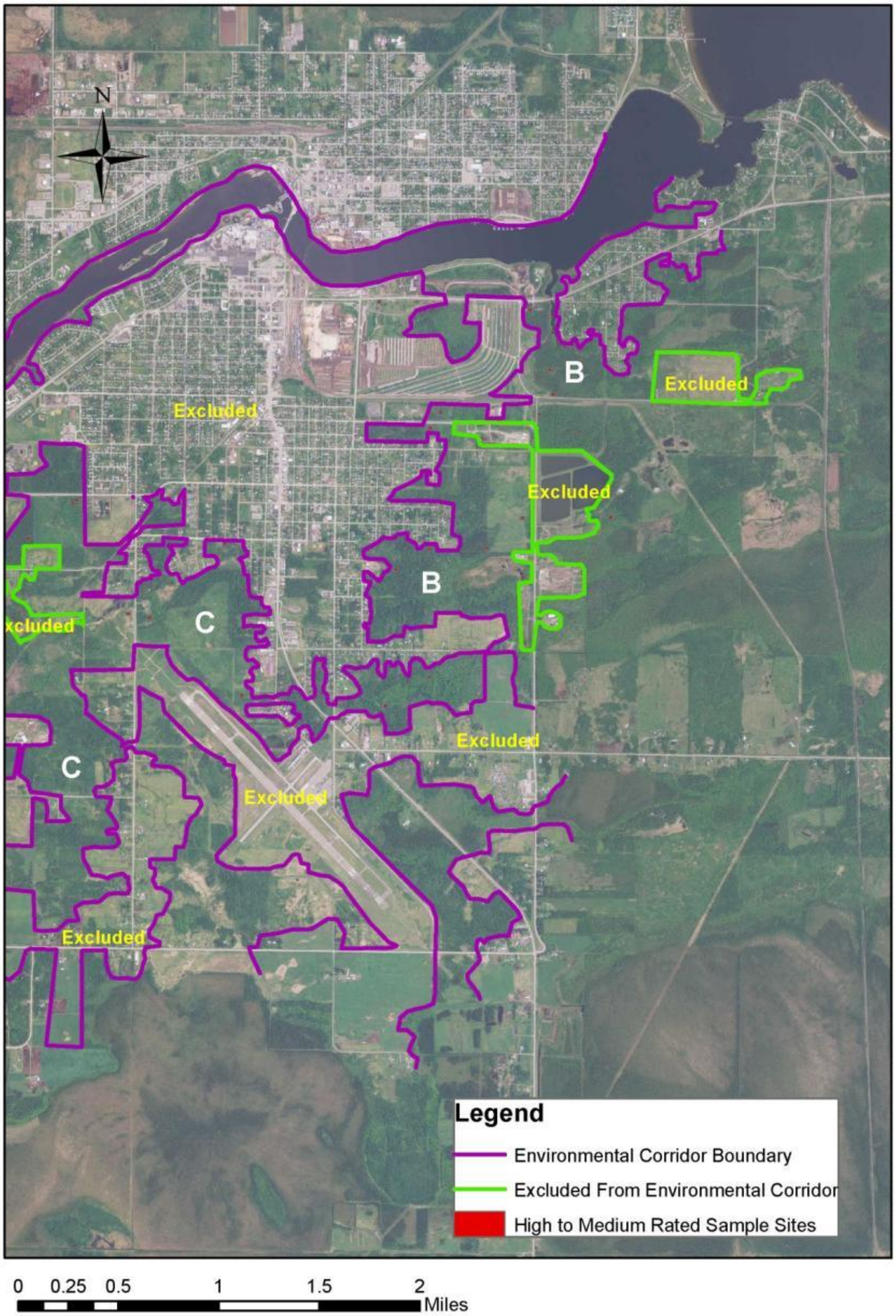
Based on the functional assessments, conceptual environmental corridors were developed as a means to designate areas for the categories of preserve, manage and develop. The focus is on wetlands/waters, but environmental corridors can also include upland forests or meadows (e.g., upland buffers). Disturbed areas can be included if they provide a connection and/or important function(s) (e.g., water quality, floodwater storage). The environmental corridor mapping process can identify fragmented/lower quality wetlands that may suitable for develop or manage categories, while higher functioning wetlands can be placed within environmental corridors for the preserve or manage categories. Such holistic natural resource mapping is clearly advantageous for planning purposes.

The river is an obvious corridor (the Canadian side of the river is included just to show the river as a corridor). The large, intact natural area in the northwest corner of the city (area A on the map) jumps out as primary environmental corridor, all the more so because it is immediately adjacent to the river. Area B in the northeast corner of the city includes an inlet to the river and a long, continuous corridor of wetlands going inland. Area C is a large, interconnected corridor located within the interior of the city. All but one of the I Falls functional assessment sample points rated high or medium are included within an environmental corridor.

Environmental Corridor Concept



Environmental Corridor Concept



Appendix D

International Falls Utilities Network