# Parkland County Wetland Inventory & Historical Loss Assessment

**Prepared for:**
Parkland County

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# Executive Summary

Wetlands are vital to the long-term maintenance of biological diversity, water quality, flood mitigation and a host of other natural processes. Despite the importance of these habitats, there have been high rates of wetland loss across Alberta over the last century. In an effort to reduce the rates of wetland loss in the province, the Government of Alberta introduced a new wetland policy in September 2013. This policy aims to conserve, restore, protect, and manage Alberta's wetlands, and as part of the policy implementation, the government has developed new tools to assess the relative value of wetlands across the province. This relative wetland value assessment uses 65 indicators to assess wetland value at the quarter section scale, and was completed using the available spatial wetland inventory for Alberta.

While the provincial merged wetland inventory and relative wetland value assessment can be used to inform wetland management decisions at the provincial scale, further work is required to improve the accuracy of the provincial wetland inventory, as well as to identify ecologically significant wetlands at the local and regional scales. In particular, developing more accurate wetland inventories and undertaking wetland ecological value assessments at the municipal scale results in datasets that better reflect local socioeconomic and environmental priorities. In turn, this information can be used to inform local land use decisions, with the ultimate aim of improving wetland conservation and management outcomes at the municipal scale.

Parkland County is a rural municipality located in central Alberta that is currently in the process of preparing an Integrated Community Sustainability Plan (ICSP) and a conventional Municipal Development Plan (MDP), which will set the land use development and sustainability goals of the County into the future. Foundational to the development of the ICSP is the creation of reliable wetland mapping data, including both a current and historic spatial wetland inventory that can be used to inform on-going land-use planning, policy development, and wetland conservation efforts, including the Alternative Land Use Services Program and the Green Acreages Program. As such, Parkland County retained Fiera Biological Consulting Ltd. to complete a Wetland Inventory and Historical Loss Assessment. The overall goal of this study is to provide a thorough assessment of the current and historical status of wetlands within Parkland County. Specifically, the objectives of the study included:

1) Map the current extent of wetlands in Parkland County;
2) Assess the ecological value of wetlands in Parkland County using a scientifically valid framework that aligns with the existing provincial relative wetland value assessment, and;
3) Determine the historical distribution of wetlands and calculate the area of wetlands that have been lost within Parkland County.

## Methods

To achieve the goal and specific objectives of this study, we undertook four major methodological steps. Each step was necessary in order to create new datasets that were critical to the success of the study. These steps included:

1) Create a current wetland inventory
2) Create a historic wetland inventory
3) Quantify historic wetland loss
4) Assign ecological value to wetlands in the current inventory

### Step 1: Create a Current Wetland Inventory

A current wetland inventory for Parkland County was created using a combination of remote sensing and terrain processing techniques. We created nine different datasets that included information that would help us differentiate wetlands from non-wetland areas within Parkland County. These new datasets included information about the location of depressions and low lying areas, the abundance and permanence of water, and the presence and vigour of vegetation. All of this information was combined into a single spatial dataset, which allowed us to use specialized computer software to group regions that shared similar characteristics together into "objects". The creation of these objects then allowed us to classify each object into "wetland" or "non-wetland" classes, on the basis of the object's characteristics (e.g., objects in a depression with permanent water were wetland objects, while objects on a steep slope with no vegetation were non-wetland objects). Once wetland objects were identified, we then assigned a wetland class to each of the objects (marsh, open water, swamp, fen, bog) based upon the presence and permanence of open water, the type of vegetation present, as well as other characteristics. The 2013 air photograph was used to create the current wetland inventory.

### Step 2: Create a Historic Wetland Inventory

In order to better understand wetland loss in Parkland County, we created a historic inventory using the Alberta Biodiversity Monitoring Institute (ABMI) historic orthophoto. The ABMI historic orthophoto for Parkland County is a mosaic of imagery taken at different time periods ranging between 1941 and 1962. Given the age of the orthophotos, the quality, resolution, and positional accuracy of the historic imagery made it very challenging to work with, and we used a combination of unsupervised (computer) and supervised (human) methods for creating the inventory.

Wetlands within the black and white historic photograph typically appeared as dark circular or oval objects, while agricultural fields or developed areas are more typically white or grey. Due to the sharp contrast in colour between wetland and non-wetland areas, we first used a semi-automated computer processing approach to group pixels that shared similar colour (spectral) properties into objects. Large white objects, which were agricultural fields and developed lands, were deleted, leaving only dark objects. While wetlands appear as dark objects in black and white images, forested upland areas also appear as dark objects. In order to eliminate areas that may have been upland forest, we used terrain information from current day, and overlaid this data onto the historic inventory to identify areas of depression. Any dark objects that were not located within a depression were deleted. Once we had automatically removed what were likely to be non-wetland objects, the remaining objects were manually and systematically checked by air photo interpreters, and adjustments were made, as required. This included deleting any remaining non-wetland objects or manually delineating and adding in wetlands that were missed by the automated analysis.

### Step 3: Quantify Historic Wetland Loss

Once a current (2013) and historic (circa 1950) wetland inventory had been created, the next step was to compare the area of wetlands in each inventory to calculate the difference (loss or gain) in wetland area between the two time periods. In order to account for spatial offsets between the two inventories (i.e., the location of the wetland boundaries was not in exactly the same location in each inventory), we created “wetland objects”, which were then used to conduct the historical loss assessment. To create the wetland objects, we merged the historic and the current inventories together and the boundary of the wetland object was defined by the maximum extent of all overlapping wetland polygons. For each unique wetland object, we then calculated the area of current wetlands and historic wetlands, and compared these areas to calculate the difference between the current and historic extent of wetlands.

Instances where there was a wetland polygon in the historic inventory, but no overlapping wetland polygon in the current inventory, were classified as complete wetland losses. For instances where there was a reduction in wetland area between the historic and current inventories, we calculated the percent change in area. Where the percent change between the historic and current area was greater than 40%, we classified this as a “partial loss” of wetland area. Complete and partial gains in wetland areas were calculated in the same manner. Complete and partial gains and losses were then calculated separately by wetland category (marsh/open water and bog/fen/swamp), and summarized at the County scale and by major watershed unit.

### Step 4: Assign Ecological Value to Wetlands

One of the main objectives of this project was to assign an ecological value to each wetland identified in the current wetland inventory using rigorous, objective, relevant, and scientifically defensible methodology. Key criteria for identifying ecologically important wetlands in Parkland County were identified, and included: Biodiversity Value; Ecological Function, and; Hydrologic Function and Water Quality Improvement. Within each criteria, a number of indicators were selected to represent key wetland ecological and hydrological functions that were considered to be important for wetland and watershed condition.

In order to ensure that the list of criteria and indicators were relevant to, and reflective of, local conditions within Parkland County, we presented the criteria and indicators framework at a workshop that was attended by a range of stakeholders. The stakeholders were identified by Parkland County administration, and included representation from local watershed groups, members of the agricultural community, and the provincial government. In total, 35 indicators were selected to define, measure, and map the ecological value of wetlands in Parkland County, including 26 indicators that have been previously used by the Government of Alberta to assign wetland value at the provincial scale.

Using the selected indicators, all wetlands in the current inventory were assessed and assigned an Ecological Value score. These scores were then used to divide the wetlands into a value category of “Excellent”, “Very Good”, “Good”, “Moderate”, or “Poor”. Wetland ecological value was then summarized at the County scale and by major watershed unit.

## Results

### Wetland Ecological Value

The current wetland inventory for Parkland County identified 17,264 wetlands and wetland complexes that were either completely contained within Parkland County, or that intersected the County boundary. In total, 35,406 ha of wetlands and wetland complexes were evaluated and assigned a Wetland Ecological Value score. Of these, 11,118 ha (31%) were classified as either Marsh or Open Water wetlands, and 24,287 ha (69%) were classified as treed wetland (Bog, Fen, or Swamp). A further 1,569 ha (5%) was classified as “anthropogenic”, meaning that the water bodies identified by the inventory appeared to have been in some way modified by human activity (e.g., shoreline straightening, excavation, etc.). Generally, the extent of Marsh and Open Water wetland cover is greatest in the eastern portion of the County, with peatlands (bogs and fens) dominating the wetland cover in the western portion of the County. Named Lakes cover an additional 10,772 ha of the County.

At the County scale, approximately 6% of the total number of wetlands assessed for ecological value received a score of Excellent, with the majority (57%) being assigned an score of either Moderate or Poor. The watershed unit that had the highest proportion of wetlands that received a score of Excellent was the North Saskatchewan Above Wabamun (A) (59%), with the Upper Pembina/Lower Pembina/Sturgeon River watershed having the second highest proportion (13%) of Excellent wetlands. Conversely, the Atim Creek watershed unit had the lowest number of Excellent wetlands (2%) and the largest number of wetlands that received a score of Poor (32%).

### Historic Wetland Loss Assessment

The historical extent of wetlands in Parkland County circa 1950 was estimated to be 72,323 ha, with 62% of the area classified as treed wetlands (Bog, Fen, and Swamp), and the remaining 38% being classified as Marsh and Open Water wetlands. The current extent of wetlands within Parkland County was estimated to be 32,158 ha, with 73% of the area classified as treed wetlands (Bog, Fen, and Swamp) and 27% classified as Marsh and Open Water wetlands. Between 1950 and 2013, there was an overall reduction in wetland area of 56,530 ha, constituting a -56% change in wetland area.

The analysis of wetland loss in Parkland County revealed that the majority of loss can be attributed to the partial loss of treed wetlands, which appears to have been driven by a variety of different factors, including urbanization, agriculture, and peat mining. In many cases, these partial losses have caused fragmentation of remaining wetland habitat, which in turn has resulted in an overall reduction in the average size of wetlands in the County. When complete wetland loss is considered, it is apparent that Marsh and Open Water wetlands have been disproportionately impacted, with approximately 80% of the complete losses being attributed to these wetland types.

Within the County, the highest rates of complete and partial loss on a watershed area basis have occurred in the North Saskatchewan Below Strawberry / Sturgeon River watershed unit, followed by the North Saskatchewan Above Wabamun (A), and Wabamun Creek / Sturgeon River watershed units. When loss is considered separately for treed and non treed wetlands, the watershed unit that experienced the highest Marsh and Open Water wetland area loss per hectare was also the North Saskatchewan Below Strawberry / Sturgeon River, while the highest area loss of treed wetlands per hectare was in the North Saskatchewan Above Wabamun (A) watershed unit.

## Conclusion

From the perspective of water resource management and maintaining aquatic and terrestrial ecosystem health in Parkland County, wetlands are of critical importance. Ecologically, wetlands are key habitats for a large number of aquatic and terrestrial species, and are significant components of larger hydrologic systems that provide important ecosystem services to human communities. The results of this study will allow decision makers in Parkland County to identify wetlands that are high priority for conservation or special management, based upon transparent and objective ecological value scores. Further, the results of the historic loss assessment will allow Parkland County to target on-going wetland conservation and restoration efforts in areas where wetland losses have been high. Finally, the wetland inventories created as part of this study provides Parkland County with important baseline information that can be used to track change in wetland area and value into the future, such that the success of restoration and environmental policies can be tracked and evaluated over time.

# 1.0 Introduction

## 1.1. Background

Wetlands are vital to the long-term maintenance of biological diversity, water quality, flood mitigation and a host of other natural processes. Despite the importance of these habitats, there have been high rates of wetland loss across Alberta, and it is estimated that two thirds of wetlands have been lost in the settled region of the province (Government of Alberta 2013). In recognition of the environmental, social, and economic values that wetlands provide, the Provincial government released a new provincial wetland policy in September 2013, which aims to conserve, restore, protect, and manage Alberta's wetlands. As part of the implementation of the this new Wetland Policy, an extensive provincial wetland relative value assessment has been developed to inform land management decisions and wetland conservation efforts at the provincial scale. This relative wetland value assessment uses 65 indicators to assess wetland value at the quarter section scale, and was completed using the available spatial wetland inventory for Alberta. This provincial wetland inventory is a composite layer that was derived from numerous sources, many of which used different mapping methods and classification standards. As a result, the provincial wetland inventory has known accuracy issues, and in some regions of the province, very high rates of error (Alberta Biodiversity Monitoring Institute 2016).

While the provincial merged wetland inventory and relative wetland value assessment can be used to inform wetland management decisions at the provincial scale, further work is required to improve the accuracy of the provincial wetland inventory, as well as to identify ecologically significant wetlands at the local and regional scales. Developing more accurate wetland inventories and undertaking wetland ecological value assessments at the municipal scale, allows for the refinement of the criteria and indicators used to assess ecological value to better reflect local socioeconomic and environmental priorities. In turn, creating more accurate data that better reflects local environmental, social, and economic priorities will result in more informed and meaningful land use decisions, and ultimately, better wetland conservation and management outcomes. Further, mapping the current and historic extent of wetlands within municipal boundaries allows for the tracking of wetland loss, which is a key component and indicator of ecosystem health. Understanding where wetland loss has occurred, as well as the extent and magnitude of that loss, allows for the identification of areas where high rates of loss may be a concern. This information can then be used to prioritize areas for conservation, as well as target restoration efforts, such that the limited resources available for wetland conservation and restoration can be maximized for the best possible outcomes.

## 1.2. Study Objectives

The overall goal of this study is to provide a thorough assessment of the current and historical status of wetlands within Parkland County. In order to achieve this, the following objectives were identified:

1) Map the current extent of wetlands in Parkland County;
2) Assess the ecological value of wetlands in Parkland County using a scientifically valid framework that aligns with the existing provincial relative wetland value assessment, and;
3) Determine the historical (circa 1950) distribution of wetlands and calculate the area of wetlands that have been lost within Parkland County.

Parkland County is currently in the process of preparing an Integrated Community Sustainability Plan (ICSP) and a conventional Municipal Development Plan (MDP), which will set the land use development and sustainability goals of the County into the future. Foundational to the development of the ICSP is the creation of reliable wetland mapping data, including both a current and historic spatial wetland inventory. These inventories will provide information about the extent, distribution, and ecological value of existing wetlands, as well as the area and location of wetlands that have been lost or impacted over time. This information can then be used to inform on-going land-use planning, policy development, and wetland conservation efforts, including the Alternative Land Use Services Program and the Green Acreages Program.

# 2.0 Study Area

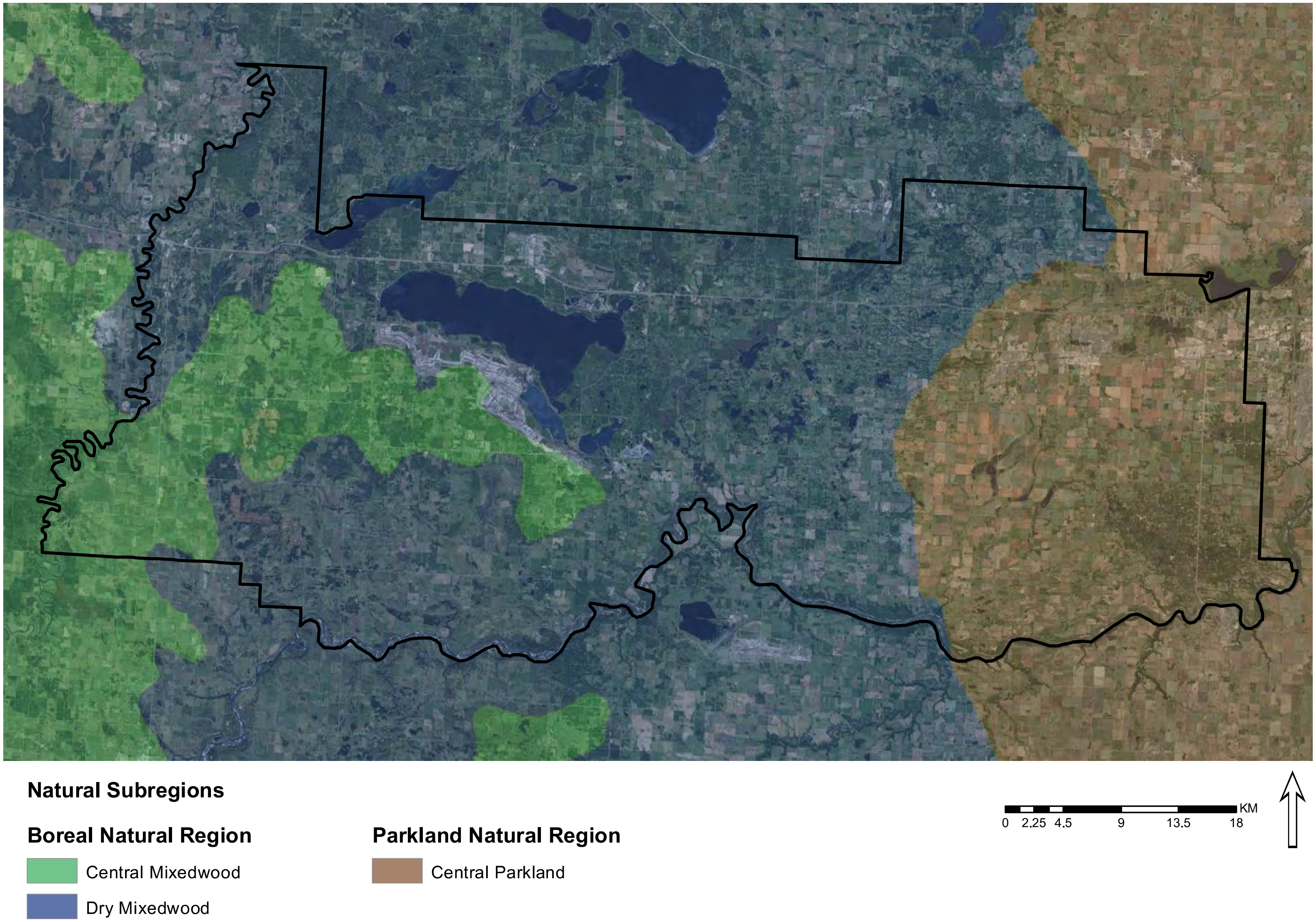
Parkland County is a rural municipality in central Alberta, located within the transition zone between the Aspen Parkland and Boreal Natural Regions (Map 1). The County is home to nearly 31,000 residents (2011 Federal Census), and has a mix of agricultural, residential, industrial, and commercial land uses. The southern boundary of the County is primarily defined by the North Saskatchewan River, while the western boundary is defined by the Pembina River. Other large and notable water bodies in the County include Wabamun Lake and Isle Lake, located in the north western portion of the County.

The County intersects seven unique Hydrologic Unit Code 8 (HUC 8) watersheds, including: Atim Creek, Lower Pembina River, Upper Pembina River, North Saskatchewan Above Wabamun, North Saskatchewan Below Strawberry, Sturgeon River, and Wabamun Creek. For this study, we combined several of the HUC 8 watersheds, in addition to splitting the North Saskatchewan Above Wabamun watershed, to create six distinct watershed units (Map 2). This was done to simplify the presentation and communication of the study results.

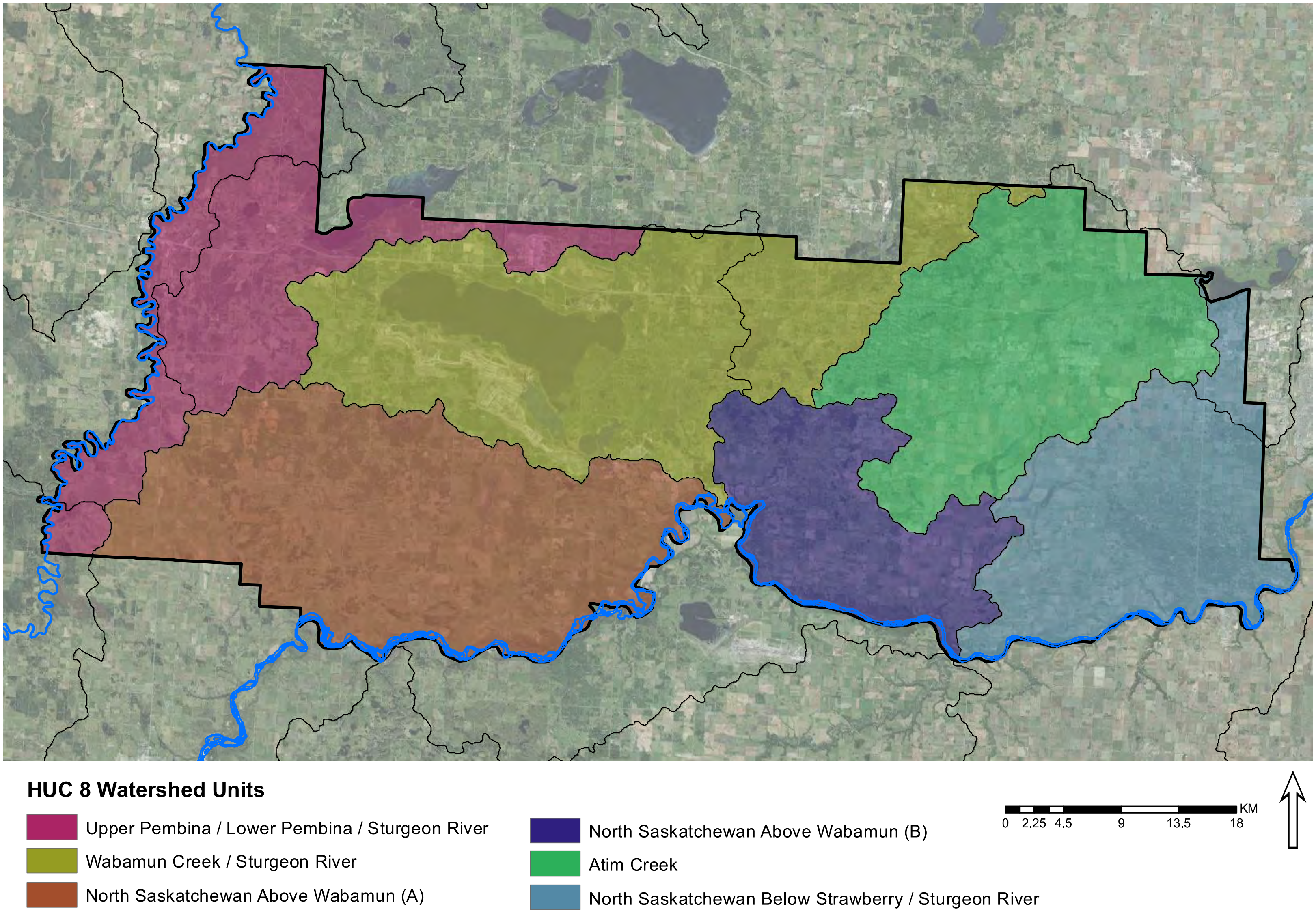
Land cover in the County includes a range of different natural, semi-natural, and anthropogenic land cover types, with agricultural cropland dominating in the eastern portion of the County and agricultural pastureland dominating in the west (Map 3). Large urban residential communities located within the County include the City of Spruce Grove and the Town of Stony Plain, with a number of smaller villages and hamlets scattered throughout the County. The Atim Creek watershed, located in the north eastern portion of the county, has the highest proportion of human land cover types (e.g., agriculture, urban, and exposed) and the lowest cover of natural land cover types (e.g., forest, shrubland, water, and wetlands), while Upper Pembina/Lower Pembina/Sturgeon River watershed unit, located along the western boundary, has the highest proportion of natural land cover types (Figure 1).

For a more detailed description of the geology and environmental context of Parkland County, please refer to the Parkland County Environmental Conservation Master Plan (O2 Planning + Design 2014).


Figure 1. Land cover proportion by major land cover category. Terrestrial land cover classes were defined using the 2014 Agriculture and Agri-Food Canada (AAFC) spatial dataset. Water and wetland areas were using the 2013 Parkland County wetland inventory spatial dataset.

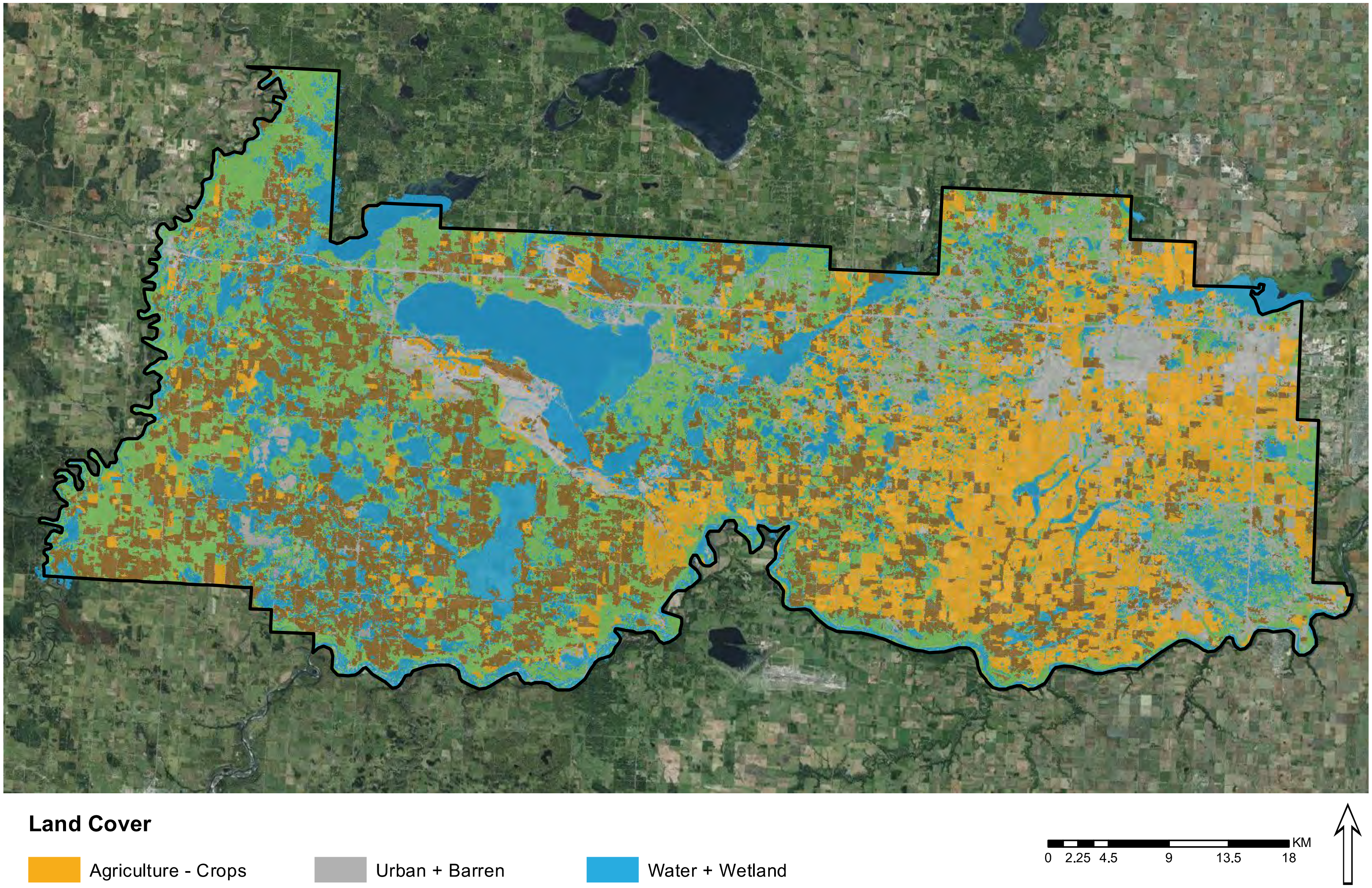



Map 1. Natural regions and natural subregions in Parkland County.

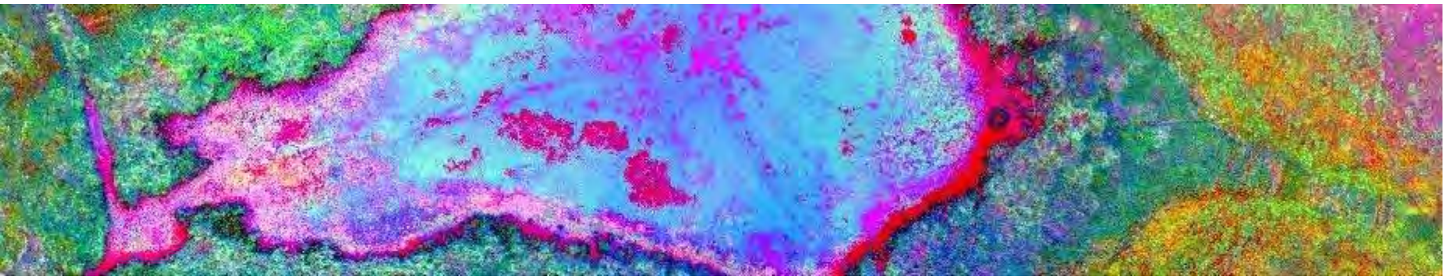




Map 2. Hydrologic Unit Code 8 watersheds and watershed units for Parkland County.




Map 3. Land cover in Parkland County. Terrestrial land cover classes were defined and mapped using the 2014 Agriculture and Agri-Food Canada (AAFC) spatial dataset; water and wetland areas were identified and mapped using the 2013 Parkland County wetland inventory spatial dataset.



# 3.0 Methodology

There were four major methodological steps that were required to create the datasets that were needed to achieve the objectives set forth by this study. These major methodological steps included:

1) Create a Current Wetland Inventory
2) Create a Historic Wetland Inventory
3) Quantify Historic Wetland Loss
4) Assign Ecological Value to Wetlands in the Current Inventory

Each of these major steps are described in more detail below.

## Step 1: Create a Current (2013) Wetland Inventory

A current wetland inventory for Parkland County was created using a combination of remote sensing and terrain processing techniques that were based upon methodologies that have been published in the scientific literature (Sass & Creed 2011; Creed & Sass 2011; Serran & Creed 2016). As part of the creation of a current wetland inventory, all wetlands and lakes that were greater than 0.01 ha were identified and classified according to the Alberta Wetland Classification System (Alberta Environment & Sustainable Resource Development 2015). For the purpose of this inventory "current" was defined as 2013, which was the most recent 4-band orthomosaic available for use at the time the project was initiated.

The current wetland inventory was created using a multi-step process that involved the creation of several intermediate spatial datasets that provided information about the location of areas in the County that possessed properties characteristic of a wetland habitat. This included creating datasets that could help answer the following questions:

1) Is there a depression?
2) How wet is it?
3) Are the colour (spectral) properties characteristic of a wetland?
4) Where is the vegetation and how vigorous is it?

These derived datasets were required to create distinct spectral and terrain data layers that were then combined and used to identify the location and class of each wetland (Figure 2). A detailed description of the data processing steps that were required to create each of these spatial datasets is provided below.

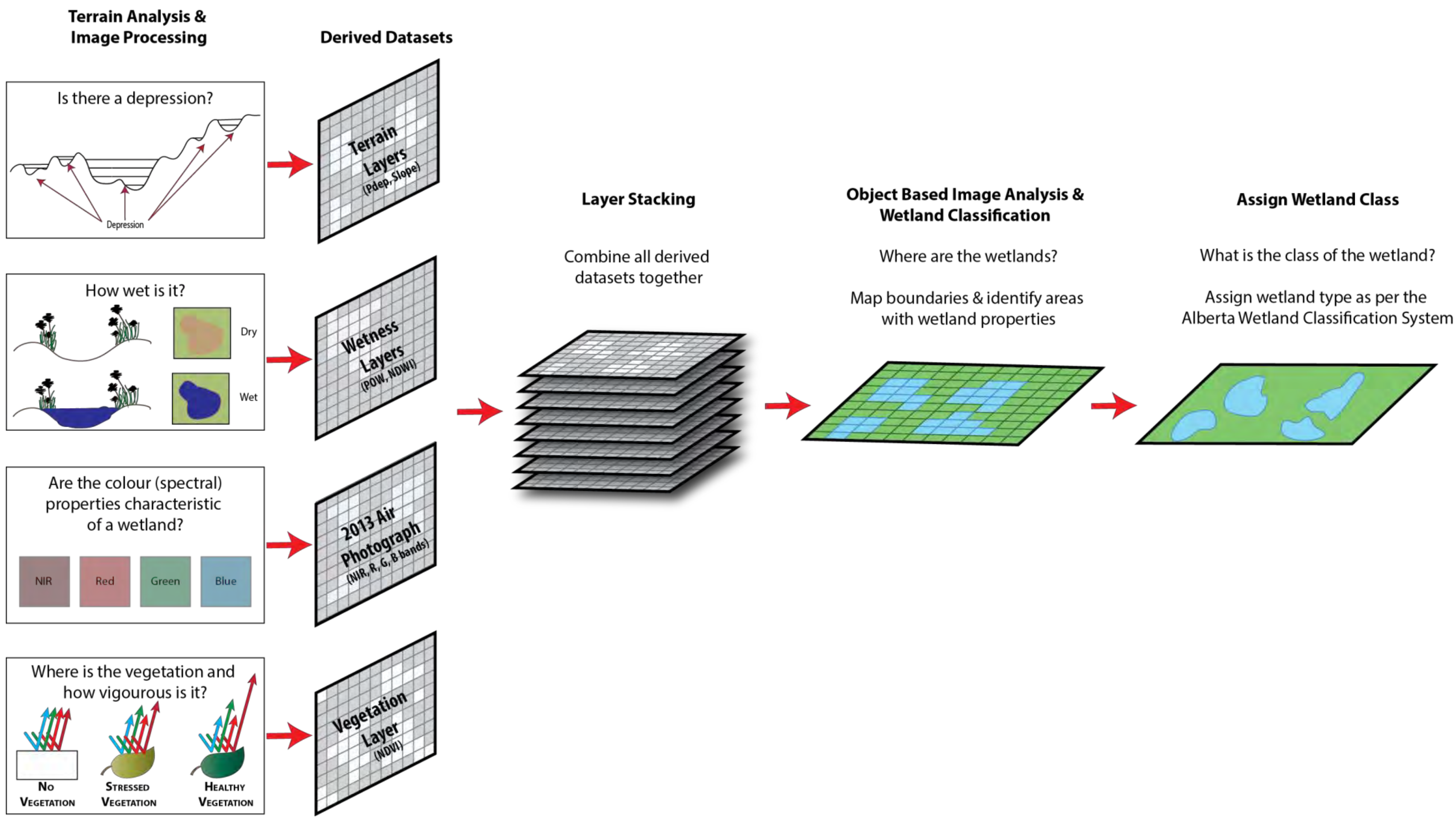



Figure 2. The major steps and work flow associated with the creation of a current wetland inventory for Parkland County.

## Is there a Depression?

Elevation and terrain information from LiDAR can be used to identify depressional areas on the landscape that often correspond to the location of a wetland. A probability of depression (Pdep) analysis is a terrain processing technique that identifies depressional areas contained within a Digital Elevation Model (DEM), and this analysis is often used to identify depressional wetland features because there is a strong correlation between wetland features and depressions in a DEM (Serran and Creed 2016; Lindsay et al. 2004). We used a 15 meter resolution LiDAR DEM of Parkland County to undertake a Pdep analysis to help identify depressional basin locations. Using the stochastic depression mapping procedure in Whitebox GAT geospatial tools software, a random raster of values with the same standard error as the vertical accuracy of the LiDAR was added to the bare ground DEM. Depressional basins within the modified DEM were then identified, and any pixel identified as a depression was flagged. This process was repeated 100 times, and the number of times that each pixel was identified as a depression was calculated to provide a final probability of depression layer. In addition to using the LiDAR 15 meter DEM to calculate the probability of depression, the LiDAR data was used to calculate slope using standard terrain processing techniques.

## How Wet is it?

Wetland permanence and hydroperiod was assessed for all water bodies identified within Parkland County by deriving a map of water permanence (probability of open water) using a time series of air photographs and satellite imagery. There were five very high resolution (<1 meter) air photographs that were available for Parkland County for the years 2004, 2007, 2009, 2011, and 2013. All high resolution air photographs were panchromatic (black and white), with the exception of the 2013 image, which was colour with a near infrared (NIR) band. This near infrared band was used in the analysis, as NIR is very sensitive to the detection of surface water, and thus, is able to accurately detect open water. All imagery was resampled to 5 meter resolution to reduce the effects of shadow and noise. For each image, open water was identified using a band thresholding technique, with the thresholds identified heuristically based on the image histogram and visually checking the values needed to capture water within the image. All pixels that did not fall within an area with a probability of depression of 0.4 were removed. All remaining pixels that were identified as water were grouped into regions. Only regions that had a low standard deviation were retained as open water areas. Standard deviation was calculated using a 3x3 pixel moving window, and all regions with at least 1 pixel with a low standard deviation were retained. The five resulting open water layers (one layer for each year included in the analysis) were summed, with final values ranging from 0 to 5 (Figure 3). Pixels with a score of zero (0% probability of open water) were those that did not have open water detected in any of the years assessed, while pixels with a score of five (100% probability of open water) were those that were assessed as open water in all five images.

While the high resolution imagery available represented a reasonably good range of climatic conditions (and thus, wetland hydroperiod), it was important to ensure that a range of climatic condition were captured when undertaking the probability of open water analysis. As such, additional imagery was required to capture years with average and above average annual precipitation. Historic climate records for Parkland County (taken from the Stony Plain climate station) were analyzed, and the annual precipitation values for each of the years for which high resolution air photographs were available were inspected. Upon review of the climate data, it was clear that many of the air photographs were taken in years with relatively low annual precipitation (Figure 4).

To ensure that a full range of climatic conditions were captured in the probability of open water analysis, 11 additional Landsat images covering the period of 1997 to 2015 were acquired and processed (Figure 4; Table 1). While Landsat imagery has a much coarser spatial resolution (30 m) than air photographs (<1 m), the high spectral resolution of the imagery makes these images suitable for mapping larger open water areas. In order to detect open water within the Landsat Imagery, we applied a Normalized

Difference Water Index (NDWI) to each of the Landsat images. The NDWI is based upon the large difference in reflectance between the green and near infrared wavelengths that is common to open water. When calculating the NDWI, open water features are highlighted due to the high absorption of radiation in the NIR wavelength by water, thus open water features are enhanced (McFeeters 1996). The Normalized Difference Water Index is calculated as follows:

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)}$$

*Where*: NIR is the near infrared spectral reflectance (750 – 950 nm) and Green is the reflectance between 490 nm and 610 nm.

The NDWI was used to classify open water features by applying a band threshold that was chosen by inspecting both the NDWI histogram and open water features. Each of the eleven classified open water Landsat images were summed to derive a score that ranged between 0 and 11. The final Probability of Open Water layer was created by combining both the Landsat derived and air photo derived open water layers, to create a layer with a score that ranged between 1 and 16. All areas with a probability of open water of at least two were grouped into regions, and the average and maximum probability of open water within each of these regions was calculated.

Table 1. Dates of imagery selected for use in the probability of open water analysis.

| Year | Month | Image Type | Sensor/Spectral Resolution |
|---|---|---|---|
| 1997 | August | Landsat Satellite | TM 5 |
| 1999 | September | Landsat Satellite | ETM+ |
| 2001 | August | Landsat Satellite | ETM+ |
| 2002 | June | Landsat Satellite | ETM+ |
| 2004 | June | Landsat Satellite | TM 5 |
| 2004 | Unknown | Air Photograph | Black and White |
| 2007 | July | Landsat Satellite | TM 5 |
| 2007 | Unknown | Air Photograph | Black and White |
| 2008 | August | Landsat Satellite | TM 5 |
| 2009 | Unknown | Air Photograph | Black and White |
| 2011 | Unknown | Air Photograph | Black and White |
| 2013 | June | Landsat Satellite | LC8 |
| 2013 | Unknown | Air Photograph | RGB NIR |
| 2014 | October | Landsat Satellite | LC8 |
| 2015 | April | Landsat Satellite | LC8 |
| 2015 | May | Landsat Satellite | LC8 |

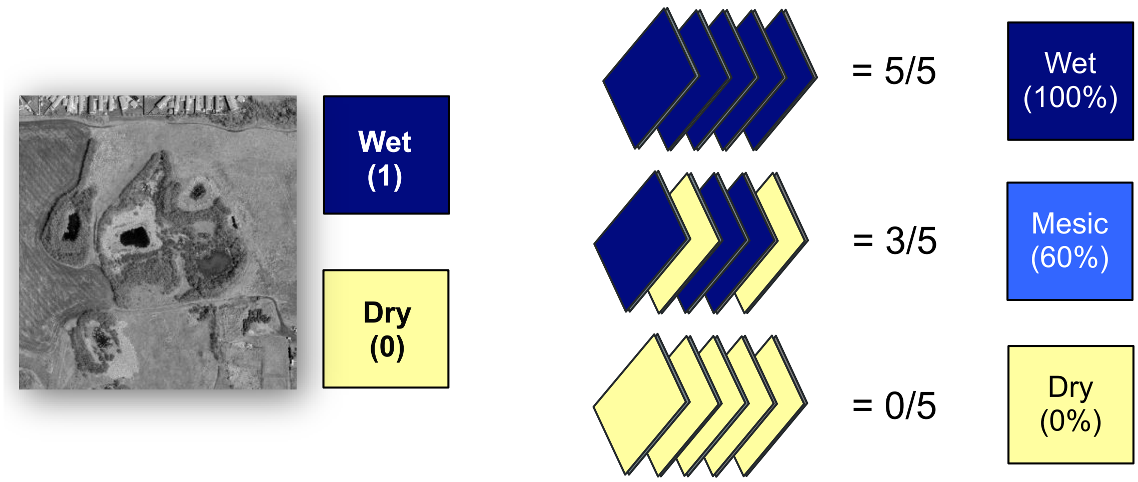



Figure 3. Wetland hydroperiod and permanence was estimated using a probability of open water analysis. This analysis utilizes imagery from different time-steps, and classifies each pixel in the image as wet (1) or dry (0). The scores for each pixel is summed and an average "wetness" is calculated, with low scores representing drier pixels, and higher scores representing wetter pixels.

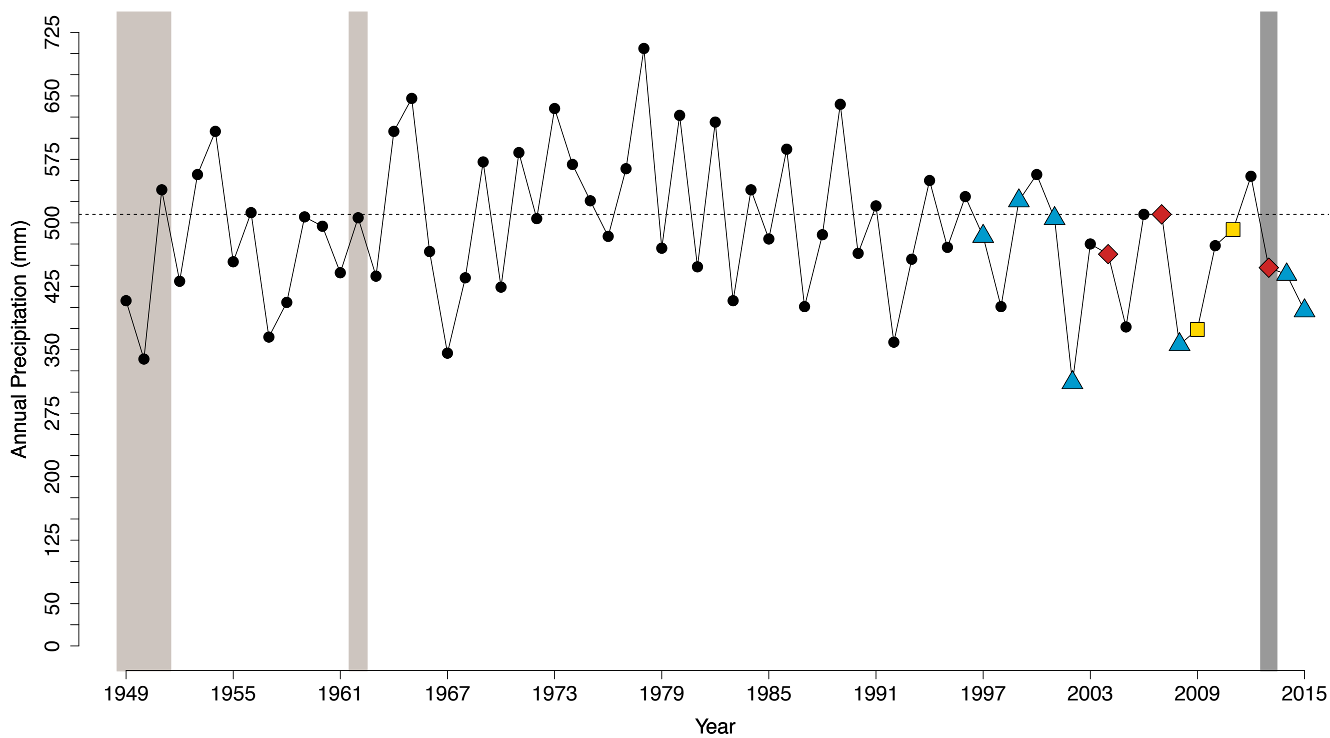



Figure 4. Annual precipitation values for Stony Plain from 1949 to 2015. The years for which imagery was used to assess the probability of open water are indicated as yellow squares (high resolution air photos), blue triangles (Landsat imagery), and red diamonds (both air photos and Landsat imagery). The dashed line indicates the climate normal precipitation value (510 mm) for this station, with values falling above this line indicating wetter than average years, and values falling below the line indicating years with lower than average precipitation. Years that were used to develop the historical wetland inventory are highlighted (1949-1951 and 1962), along with the year used to develop the current wetland inventory (2013).

## Are the Colour (Spectral) Properties Characteristic of a Wetland?

The Parkland County 2013 air photograph was used for all subsequent processing. This image was chosen as the basis for creating the "current" wetland inventory because it contained the usual red (R), green (G), and blue (B) wavelengths that our eyes use to see colour, in addition to having near-infrared (NIR) wavelength. Having a photograph with RGB and NIR wavelengths is particularly useful for mapping wetlands because the NIR band is very good at detecting water, and can also be used to map vegetation. Before we could use the 2013 image to create a wetland inventory, we first had to process the image. This included mosaicking the image into a single scene and resampling the image to a 5 meter resolution to reduce the effect of shadow, remove noise, and speed up all subsequent image processing. This resampled and processed image was used in all subsequent image processing steps.

## Where is the Vegetation and How Vigorous is it?

The NIR band on the 2013 photograph was used to create a Normalized Difference Vegetation Index (NDVI) for Parkland County. An NDVI identifies areas within an image with high chlorophyll (or vegetation) concentrations (Rouse Jr. et al. 1974). This index makes use of the low spectral reflectance of vegetation in the red wavelengths due to photosynthetic absorption, and the high reflectance of vegetation to wavelengths in the near infrared. In simple terms, an NDVI measures the amount of light that is reflected by plants in the NIR wavelength, as vigorous, healthy plants absorb a great deal visible light for use in photosynthesis. When a plant becomes stressed or dehydrated, the spongy layer on the back of the leaf collapses, and the leaves reflect less of the NIR light, but absorb the same amount of visible light. Using this information, we can calculate a mathematical index to differentiate between healthy plants, unhealthy plants, and areas that have no vegetation on the surface of the ground. Given that different wetland vegetation species have different NDVI values, an NDVI can be useful in differentiating between non-wetlands and wetlands, as well as between different wetland classes (e.g., marsh wetland dominated by graminoids versus peatlands dominated by black spruce). An NDVI is calculated as follows:

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}$$

*Where*: NIR is the near infrared spectral reflectance and VIS is the spectral reflectance acquired in the visible (red) wavelength regions.

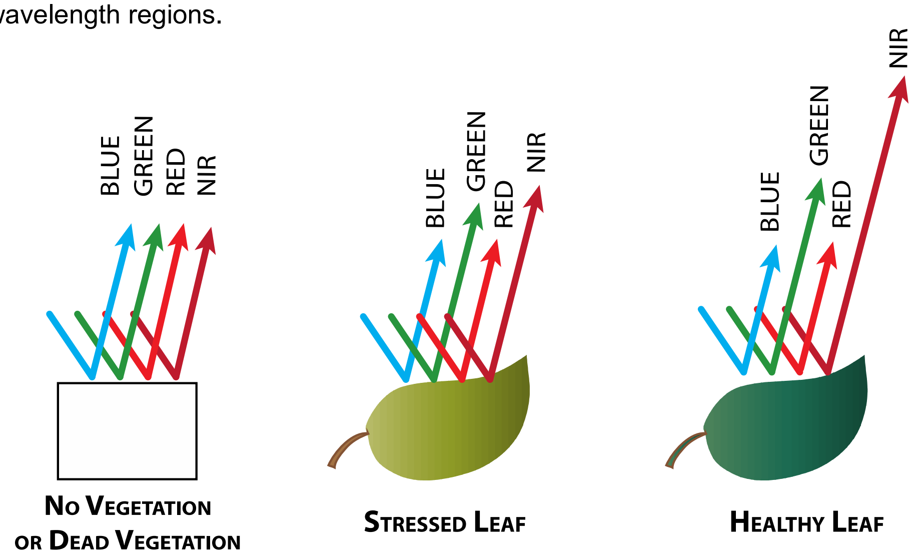



Figure 5. Illustration of how an NDVI uses spectral reflectance to characterize vegetation.

## Derived Datasets

The terrain and image processing described above resulted in the creation of nine separate derived datasets, which were subsequently combined and used to identify the location and class of wetlands in Parkland County. These derived datasets included:

1) Probability of Depression
2) Slope
3) Probability of Open Water
4) Normalized Difference Water Index
5) Normalized Difference Vegetation Index
6) Near-infrared Band
7) Red Band
8) Green Band
9) Blue Band

## Layer Stacking

All of the newly derived spatial datasets were fused with the processed Parkland County imagery to create a stacked image. This stacked image contained all of the information from the derived datasets, allowing us to use a wide range of information, including elevation, colour, slope, and other spectral data, to detect, map, and classify wetlands in Parkland County. All input data layers were re-projected to NAD 1983 UTM 10TM AEP and stacked in the image processing software ENVI using the nearest neighbour method.

## Where are the Wetlands?

The staked image was used in an object based image analysis (OBIA) classification to identify areas in Parkland County that had properties that are characteristic of wetland habitats. An OBIA first aggregates pixels that share similar spectral characteristics into regions or objects, and these objects are then used in a classification. An OBIA is generally preferred over pixel based classification methods, because it reduces noise and “salt and pepper effects”, and allows for the use of shape and texture metrics to assist in the classification of the object(s) of interest (Liu and Xia 2010).

We used the ENVI Feature Extraction (ENVI FX) module to conduct the OBIA. Within ENVI FX, the final fused data layer was used as the input for the image segmentation. Scale and merge levels were heuristically determined for the study area, with the scale and merge statistics being calculated from the RGB and NIR image only. A final scale level of 60 and merge level of 90 were selected and used to create image objects, which ensured that individual features were polygonised, while reducing over segmentation and reducing the number of small polygons. Attributes of each segment were calculated as the mean of each of the nine image bands from the fused input layer. In addition, texture and shape attributes were calculated for each image object.

Once the data was processed and stacked, a decision tree classification was used to map current wetlands. A rule based decision tree classification is a multistage classifier that can be applied to a single image or image stack. The rule based classification is created from a series of binary statements or decisions that are used to determine the correct class for each image object. Rule based classification techniques have been shown to consistently outperform unsupervised classification methods (Friedl and Brodley 1997). We applied a decision tree classification to the segmented stacked imagery that was designed to exploit spectral, terrain, and hydrological differences in expected wetland classes. Key decision points included:

1) Distinguishing upland from lowland using the probability of depression;

2) Identifying open water areas using the probability of open water;
3) Differentiating marsh and open water wetlands using a combination of the probability of depression and the probability of open water, and ;
4) Identifying treed wetlands (bogs, fens, swamps) using the NDVI and the probability of depression.

## What is the Class of the Wetland?

The resulting classification was converted to a polygon, and the classification classes were collapsed into the five wetland classes (e.g., Bog, Fen, Swamp, Marsh, Open Water), as per the Alberta Wetland Classification System. This classification output was visually checked against the high resolution air photograph, and any class modifications or boundary adjustments were made. Upon inspection of the wetland inventory, it was determined that there were significant omission errors associated with open fens and ephemeral or seasonal wetlands. To ensure that these areas were being adequately captured in the current inventory, we systematically checked the inventory at a scale of 1:10,000 and manually added any features that were missed in the unsupervised classification, in addition to removing any polygons that did not appear to correspond to a wetland that was visible in the air photograph.

One of the main limitations of using an automated remote sensing approach to identify wetlands is the inclusion of anthropogenic (human-created) wetlands or water bodies (e.g., dugout) in the wetland inventory. Anthropogenic wetlands were identified based upon the location of known lagoons and water treatment facilities within Parkland County. Any polygons in the wetland inventory that intersected a known anthropogenic waterbody were identified and flagged for further inspection. Any wetland polygon that appeared to be anthropogenically modified in the high resolution inventory (e.g., straight shorelines, visible infill or excavation) was re-classed as anthropogenic. In addition, the wetland inventory was systematically checked at a scale of 1:10,000, and any wetland that appeared to be anthropogenically modified in the high resolution air photograph was re-classed as anthropogenic. In addition, lakes were identified and differentiated from wetlands in the current inventory. Lakes were initially identified using the provincial hydropolygon layer, which was then visually inspected against the 2013 high resolution image to delete out any polygons that did not contain open water. This list was sent to Parkland County representatives for review and approval. In total, 28 named lakes were identified in Parkland County and these lakes were reclassified in the inventory as “Named Lake”. The final step in the creation of the 2013 Parkland County Wetland Inventory was to remove any wetland polygon that was smaller than the minimum mapping unit of 0.01 hectares. The resulting final Parkland County wetland inventory was systematically checked using a grid search to perform a final QA/QC check.

## Step 2: Create a Historic Wetland Inventory

A historic inventory of wetlands (circa 1950) was created using a semi-automated wetland delineation approach. Wetlands were identified using the ABMI Historic Orthophotos of Alberta spatial data product (ABMI 2015), which was created using imagery taken between 1949 and 1962 (Figure 6). Using this imagery, we identified historic wetlands within the County that were greater than 0.01 hectares in size.

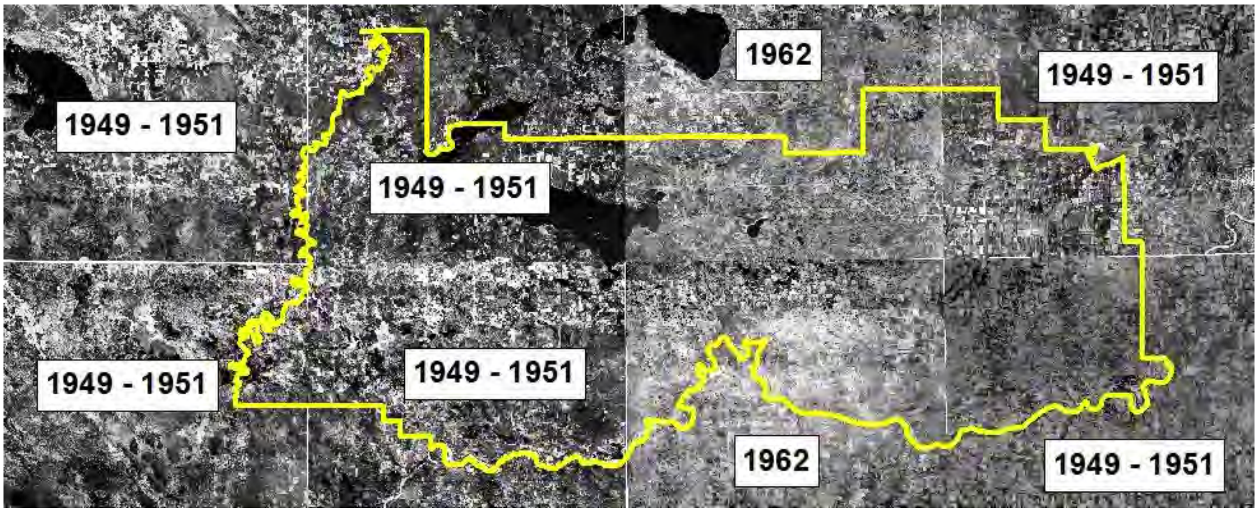



Figure 6. ABMI Historic Ortho Imagery tiles that were used to create a historic wetland inventory for Parkland County. The date(s) for the images used to create each of the tiles is indicated, with the majority of the images coming from the years 1949 to 1951.

### Image Georectification

The ABMI historic orthophoto imagery has been georectified by the ABMI with a positional horizontal accuracy of 206 m at a 95% confidence level (ABMI 2015). While this level of horizontal accuracy is sufficient for many purposes, it was deemed to be too large for this study, where positional accuracy is needed to accurately identify wetland losses between the historic and current time-steps. In order to reduce the horizontal offset between the ABMI orthophoto imagery and the 2013 Parkland County air photograph, each of the ABMI orthophoto imagery tiles was georeferenced against the high resolution Parkland County 2013 air photograph. For each historical image tile, over 100 tie points were selected at identifiable locations (e.g., highway intersections) that were visible in both the current and historic imagery. Tie points were well distributed throughout the image tile, and all tie point root-mean-square error (RMSE) values were assessed. Any tie point with a large RMSE were inspected and removed, if necessary. Historic imagery was then georeferenced using a third order polynomial transformation. Following this second georectification process, the average horizontal offset between the current and the historic imagery was significantly reduced.

While the second georeferencing of the imagery reduced the offset between the current air photograph and the historic orthophoto imagery, some offset issues remained. These offset issues were largely due to the absence of features that could be used to tie the historic and current imagery in areas of significant natural cover, i.e. there were no roads or clear quarter section boundaries that could be used to georeference the imagery. Additionally, the large size of the ABMI historic orthophoto imagery tiles introduced some warping and offset errors. In order to address these issues, we split each of the newly georectified historic image tiles into 30 sections. Each of these smaller sections were then georeferenced a second time, reducing the offset between the current and historic imagery to less than 20 meters.

## Object Based Image Analysis

An object based image analysis was used to group pixels with similar spectral characteristics into segments. These segments generally corresponded with the boundary of wetlands within the historic imagery, reducing the need to manually delineate wetland boundaries. Image segmentation was performed in ENVI FX using the smaller georeferenced tiles. Scale and merge levels were heuristically determined for the study area, and a final scale level of 40 and a merge level of 90 was used for each image tile. This scale and merge level adequately captured all of the small wetlands within the imagery without introducing large over-segmentation errors. The probability of depression layer was used in this segmentation as an auxiliary dataset, and the average Pdep for each image segment was calculated in addition to the average pixel value of the black and white image. Texture and shape attributes were also calculated for each image object.

Using the segmented historical imagery, we identified historic wetlands using a semi-automated approach. Firstly, all non-wetland objects were automatically removed based upon their reflectance, size, and probability of depression. Wetlands within the historical imagery appeared as dark objects, while fields and agricultural areas were often brighter and tended to be larger objects. We automatically removed any objects that met the following condition:

Reflectance value >150 AND Area >20,000 m2 AND Pdep <60

Once these non-wetland objects were removed, wetland objects were identified from the segmented imagery manually. Each segmented image tile was systematically examined at a scale of 1: 10,000 using both the current and original historic imagery as a guide, and all wetland objects were identified and flagged as potential historic wetlands. These historic wetland polygons were then visually checked against the original historic and current imagery, and adjusted as necessary. Any historic wetlands that were not captured in the first pass were manually digitized and all non-wetlands were removed. The resulting historic inventory was systematically checked at a scale of 1:10,000 by a second independent analyst, and manual adjustments were made, as necessary. All wetlands identified from each historic segmented tile were merged to represent the final Parkland County Historic Wetland Inventory.

Due to the low quality of the historic image, it was not possible to automatically assign wetland class to objects in the historic wetland inventory. Rather, wetland class was assigned to historic wetlands based upon the adjacency of historic polygons to current wetland polygons of known class. All historic wetland polygons were spatially joined to the Parkland County current wetland inventory using a one to many spatial relationship. For each historic wetland, the number and area of all intersecting current wetlands within 30 meters classed as “bog/fen/swamp” and “marsh/open water” was calculated. The historic inventory was assigned the class of the most common intersecting current wetland type ( bog/fen or marsh/open water). For wetlands within the historic inventory that had no current wetlands intersecting within 30 meters, wetland class was assigned based upon the size of the historic wetland object, with historic wetlands ≥1 ha being classed as bog/fen and all historic wetlands <1 ha being classed as marsh/open water. This automatic assignment of wetland class in the historic inventory led to some class assignment errors. To correct these errors, the inventory was manually checked using a systematic grid search at a scale of 1:25,000, and historic wetland classes were re-assigned as necessary based upon visual inspection of the historic and current imagery. Polygons in the historic inventory that intersected polygons in the current inventory that were classified as a named lake were reclassified as “Named Lake”. The final processing step in the creation of the Historic Wetland Inventory was to remove all wetland polygons smaller than the minimum mapping unit of 0.01 hectares. The inventory was then QA/QC checked against both the current and historic imagery using a systematic grid search at a scale of 1:15,000.

# Step 3: Quantify Historic Wetland Loss

Wetland loss within Parkland County was quantified by comparing the Parkland County Current Wetland Inventory to the Parkland County Historic Wetland Inventory. Prior to undertaking this comparison, several processing steps were required to ensure that the results of the comparison were reliable. These steps are described in more detail below.

## Data Processing

In order to undertake a fair comparison between the current and historic inventories, it was necessary to ensure that the same number of wetland classes were being used in both the current and historic inventory. The historic inventory has two wetland classes ( "Bog/Fen" and" Marsh/Open Water"), and thus, it was necessary to reduce the number of classes in the current inventory to match the historic inventory. Within the current inventory, all Marsh and Open Water wetlands were identified and re-classed as "Marsh/Open Water", and all Bog, Fen, and Swamp wetlands were identified and re-classed as "Bog/Fen". Once the classes were re-assigned to match the historic inventory classes, the current wetland inventory was dissolved by class. The resulting collapsed inventory was converted from a multipart to a single part inventory, and the area of each new polygon was calculated. The extent of both the current and historic inventories were then clipped by the Parkland County boundary to ensure a consistent extent between the two inventories prior to analysis. Finally, all named lakes were removed from both the current and historic inventories, and these lakes were analyzed separately.

## Calculation of Complete Wetland Loss

Due to the remaining offset between the current and historic wetland inventories that was introduced by image alignment error in the historical orthophoto, we could not directly compare the current and historic wetland polygons to calculate wetland loss. Instead, we calculated wetland losses using a wetland object approach, which partially accounted for these offset errors (Figure 7). Wetland objects were created by merging the current and historic inventories together. Once merged, the inventories were dissolved into single part polygons that represented the maximum extent of the two combined inventories, and these new larger boundaries were considered the wetland objects.

Within each wetland object, the total number and area of historic and current polygons was calculated using a spatial join and a sum merge rule. Any wetland object where the total historic area was greater than zero, but the total current area was equal to zero was considered a complete wetland loss (Figure 8A). Conversely, any wetland object where the total current wetland area was greater than zero, but for which the total historic area was equal to zero was considered a complete wetland gain. All wetland object polygons that were identified as complete wetland losses or gains were exported for further analysis.

## Calculation of Partial Wetland Loss

Wetland objects were also used to calculate partial loss of wetland area (Figure 8B). For each wetland object, the percentage change in wetland area was calculated as follows:

$$\frac{2013\ Area - Historical\ Area}{Historical\ Area} * 100$$

Due to the alignment issues between the current and historical images, and the potential for this misalignment to erroneously influence partial loss calculations, we applied a change threshold of 40% to the calculation of partial loss. This threshold was considered sufficient to remove any error that might be attributed to misalignment, and ensured that only true partial losses were calculated.

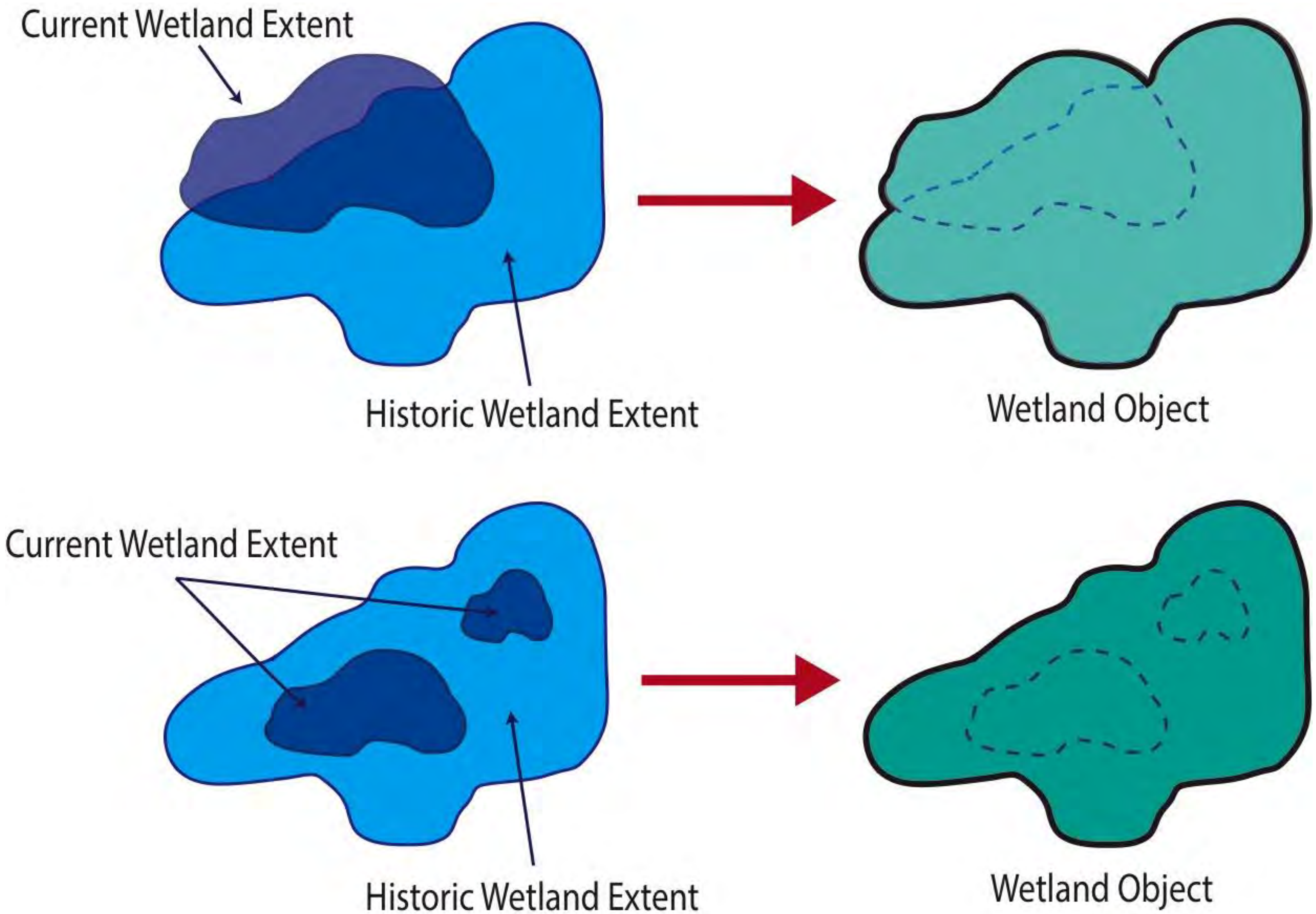



Figure 7. Wetland objects were created by merging the historic and the current inventory together and taking the maximum extent of either the current or the historic wetland boundary to define the boundary of the wetland object.

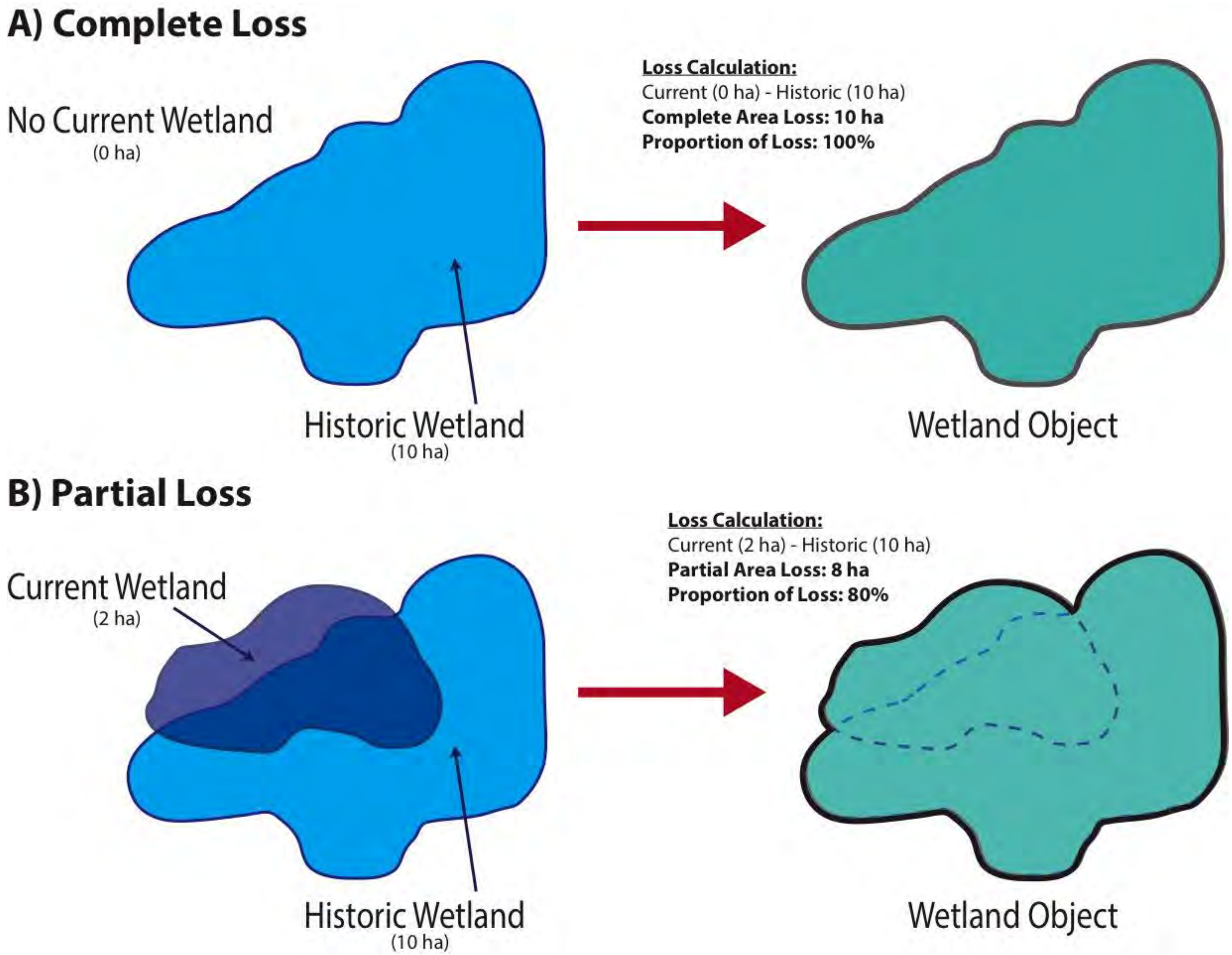



Figure 8. Examples of how complete wetland loss (A) and partial wetland loss (B) were calculated for this study, using a wetland object approach.

# Step 4: Assign Ecological Value to Wetlands

One of the main objectives of this project was to assign an ecological value to each wetland identified in the current wetland inventory using rigorous, objective, relevant, and scientifically defensible methodology. We used a GIS-based multi-criteria decision analysis (GIS-MCDA) as the foundation for identifying wetlands with high ecological value in Parkland County. Multi-criteria decision analysis is a method that is commonly used to conceptualize and structure complex decisions or problems that involve multiple criteria, through the development of decision rules that are used to aggregate and rank criteria (Mendoza & Martins 2006; Malczewski 2006; Greene et al. 2011).

## Selection of Criteria and Indicators to Assess Wetland Ecological Value

Key criteria for identifying ecologically important wetlands in Parkland County were identified and organized into a hierarchy of sub-criteria and indicators. At the highest level, the identification of ecologically important wetlands was represented by criteria that characterized important conditions or processes, and each criteria was broadly representative of specific environmental elements of interest (e.g. biodiversity, ecological integrity, etc.). Each criterion was associated with one or more sub-criterion, which in turn, was represented by one or more specific indicator that was measureable in a GIS environment. Given that a single criteria is unlikely to be representative of all desired components of an ecologically important wetland, we incorporated multiple criteria, sub-criteria, and indicators into the framework. This multi-tiered approach incorporated a broad set of environmental indicators at a variety of spatial scales, thereby identifying important ecological and evolutionary processes at different levels of organization (Groves et al. 2000; Poiani et al. 2000).

The criteria selected to identify ecologically important wetlands in Parkland County included both coarse-filter and fine-filter indicators. Coarse-filter criteria were developed with the goal of maintaining native biota and natural ecosystem function, while fine-filter criteria were developed to capture environmental features that are required to maintain populations, species, ecosystems, or other special features that are not accounted for under coarse filter criteria (Groves et al. 2000). In order to maintain some consistency between this study and provincial initiatives that have been undertaken as part of the new provincial wetland policy implementation, several of the indicators selected to evaluate the ecological value of wetlands in Parkland County were included and/or adapted from indicators that have been used by the Government of Alberta to assess wetland value within the province. In addition, new indicators were added to address ecological and hydrological processes and conditions that were unique to Parkland County.

In order to ensure that the list of criteria and indicators were relevant to, and reflective of, local conditions within Parkland County, we presented the criteria and indicators framework at a workshop that was attended by a range of stakeholders. The stakeholders were identified by Parkland County administration, and included representation from local watershed groups, members of the agricultural community, and the provincial government. The feedback that was gathered at the stakeholder workshop was summarized, and where appropriate, the criteria and indicator framework was revised to reflect suggestions and feedback from the stakeholder workshop.

In total, three criteria, 11 sub-criteria, and 35 indicators were selected to define, measure, and map the ecological value of wetlands in Parkland County. A complete list of the proposed criteria, sub-criteria, and indicators is provided on the following page.

CRITERION

# 1.0 Biodiversity value

**1a** Sub-criterion 1a: Fish habitat

- 1a(i): Surface connection to fish-bearing waterbody**

**1b** Sub-criterion 1b: Amphibian habitat

- 1b(i): Road density within 300m**
- 1b(ii): Wetland-wetland connectivity within 300m
- 1b(iii): Wetland density within 300m**
- 1b(iv): Cover of natural upland habitat within 300m

**1c** Sub-criterion 1c: Waterbird habitat

- 1c(i): Road density within 500m**
- 1c(ii): Area of open water within 500m**
- 1c(iii): Waterfowl staging areas*
- 1c(iv): Waterfowl breeding areas*

**1d** Sub-criterion 1d: Songbird, raptor & mammal habitat

- 1d(i): Stepping stone habitat**
- 1d(ii): Sensitive raptor habitat*

**1e** Sub-criterion 1e: Rare species habitat

- 1e(i): Known locations of Rare, Threatened or Endangered species*

CRITERION

# 2.0 Ecological function

**2a** Sub-criterion 2a: Habitat patch size & complexity

- 2a(i): Wetland or wetland complex size*
- 2a(ii): Wetland-upland complex size
- 2a(iii): Wetland shoreline complexity*
- 2a(iv): Wetland habitat richness within 1km*

**2b** Sub-criterion 2b: Habitat intactness

- 2b(i): Linear disturbance within 1km
- 2b(ii): Road density within 1km*
- 2a(iii): Distance to nearest road*
- 2a(iv): Distance to developed land*
- 2a(v): Land use intensity within 1km*

**2c** Sub-criterion 2c: Landscape Habitat Connectivity

- 2c(i): Wetland -upland connectivity
- 2c(ii): Wetland-wetland connectivity within 1km
- 2c(iii): Wetland density within 1km*
- 2c(iv): Cover of natural upland habitat within 1km

CRITERION

# 3.0 Hydrologic function & water quality improvement

**3a** Sub-criterion 3a: Water storage

- 3a(i): Depressional basin area
- 3a(ii): Groundwater recharge areas*
- 3a(iii): Wetlands upslope of flood risk areas*
- 3a(iv): Relative wetland elevation within watershed

**3b** Sub-criterion 3b: Stream flow support

- 3b(i): Springs & groundwater discharge areas**
- 3b(ii): Surface channel connection*
- 3b(iii): Riverine & lacustrine wetlands**

**3c** Sub-criterion 3c: Sediment & nutrient reduction

- 3b(i): Slope surrounding wetland**
- 3c(ii): Vegetated area within basin*
- 3c(iii): Wetlands located in floodways or riparian areas*

Indicators marked with * are indicators that are included in the Alberta Wetland Relative Value Evaluation Tool (ABWRET-E).

Indicators marked with ** are ABWRET-E indicators that have been modified to be more applicable to the scale of analysis and data available for Parkland County.

Indicators without an asterisk are new indicators that are unique to Parkland County.

## Quantifying Indicators

In order to quantify indicators, we first had to define wetland boundaries, which would serve as the unit of analysis for the ecological value assessment. We adopted the same method for defining wetland boundaries in this study as has been used by the Government of Alberta to define wetland boundaries for provincial wetland value assessments (Creed and Aldred 2014). This approach involves aggregating wetland polygons of different classes into a single wetland object if individual wetland polygons share a common boundary, i.e., an open water polygons touches a fen polygon. Further, open water polygons were merged with adjacent open water if they shared a common node. Using this approach, large wetland complexes containing bogs, fens, and open water were considered to be a single wetland object if they were part of a continuous region that shared a boundary (i.e., a wetland complex) . At the same time, marsh and open water polygons remained as individual wetland objects if they were not adjacent to other wetland polygons. Although these wetland objects were created by aggregating polygons of different wetland types, the information of all wetlands contained within the wetland object were retained, and the total area and number of wetland classes present within each wetland object was calculated.

Once wetland objects were defined, indicators were quantified and scored for each wetland object. A detailed description of the methods used to calculate each indicator is provided in Appendix A. In order to allow for direct comparisons between indicators, all metrics were standardized to a score that ranged between 1 (low value) and 100 (high value). Indicator scores were then aggregated within each criterion, with each indicator receiving an equal weighting. Criteria scores were range standardized between 0 and 100, and each of the three criterion scores were aggregated together to calculate a final Ecological Value score for each wetland object.

## Assigning Wetland Ecological Value

Once a wetland ecological value score had been calculated for every wetland object in the current inventory, the scores were split into one of five condition categories: Excellent, Very Good, Good, Moderate, or Poor. The cut-off values used to define each condition category were determined using a five-class Jenks Natural Breaks Classification (Jenks 1977). A Jenks classification statistically breaks data into "natural" classes by minimizing the average deviation from the class mean, and maximizing the deviation from the means of the other groups, thereby reducing variance within classes and maximizing variance between classes (Jenks 1977).

# 4.0 Wetland Ecological Value

## 4.1. Parkland County

The current wetland inventory for Parkland County identified 17,264 wetlands and wetland complexes, that were either completely contained within Parkland County, or that intersected the County boundary, such that a portion of the area fell within and a portion fell outside the County. In these cases, we assigned ecological value scores to the entire wetland area (both within and outside the County), and included the entire wetland area in our area summaries. In addition, in all cases except Wabamun and Isle Lake, an ecological value score was included in a wetland object if the lake was directly adjacent to a wetland polygon, and in these cases, the lake was considered part of the wetland complex and was assigned an ecological value score.

In total, 35,406 ha of wetlands and wetland complexes were evaluated and assigned a Wetland Ecological Value score. Of these, 11,118 ha (31%) were classified as either Marsh or Open Water wetlands, and 24,287 ha (69%) were classified as treed wetland (Bog, Fen, or Swamp). A further 1,569 ha (5%) was classified as "anthropogenic", meaning that the water bodies identified by the inventory appeared to have been in some way modified by human activity (e.g., shoreline straightening, excavation, etc.). Generally, the extent of Marsh and Open Water wetland cover is greatest in the eastern portion of the County, with peatlands (bogs and fens) dominating the wetland cover in the western portion of the County (Map 4). Named Lakes cover an additional 10,772 ha of the County.

At the County scale, approximately 6% of the total number of wetlands assessed for ecological value received a score of Excellent, with the majority (57%) being assigned an score of either Moderate or Poor (Figure 9; Map 5). The watershed unit that had the highest proportion of wetlands that received a score of Excellent was the North Saskatchewan Above Wabamun (A) (59%), with the Upper Pembina/Lower Pembina/Sturgeon River watershed having the second highest proportion (13%) of Excellent wetlands. Conversely, the Atim Creek watershed unit had the lowest number of Excellent wetlands (2%) and the largest number of wetlands that received a score of Poor (32%) (Figure 9).

When wetland ecological value scores were summarized by area, it is apparent that larger wetlands and wetland complexes tended to score higher than smaller wetlands (Figure 10; Map 5). While Excellent wetlands made up only 6% of the wetlands by number, they accounted for 43% of the wetland area. Conversely, Poor and Moderate wetlands made up 57% of the wetlands by number (Figure 9), but accounted for only 14% of the wetlands by area (Figure 10).

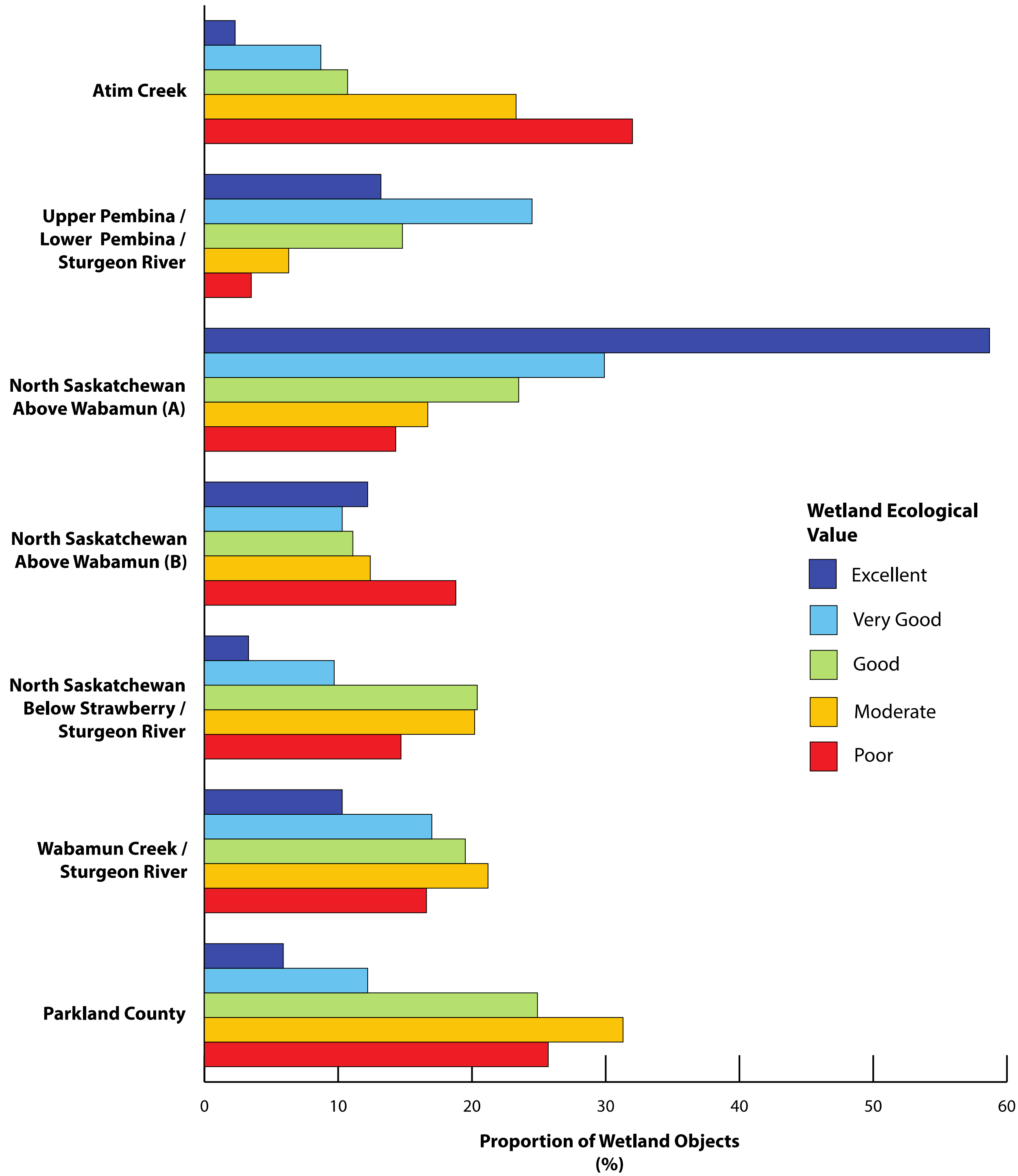



Figure 9. Aggregated wetland Ecological Condition Scores for Parkland County, summarised by the proportion of wetland objects classified into one of five condition categories.

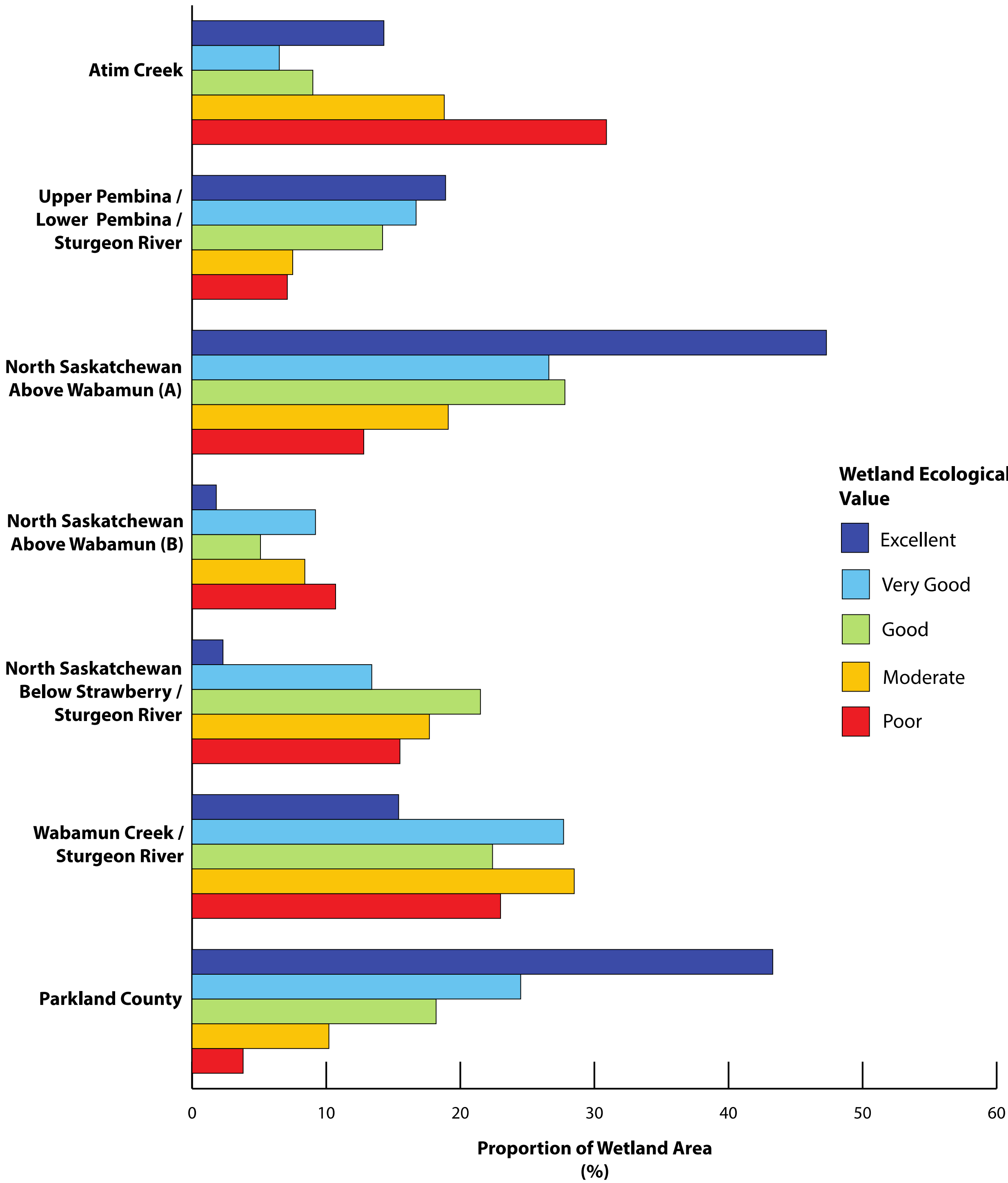
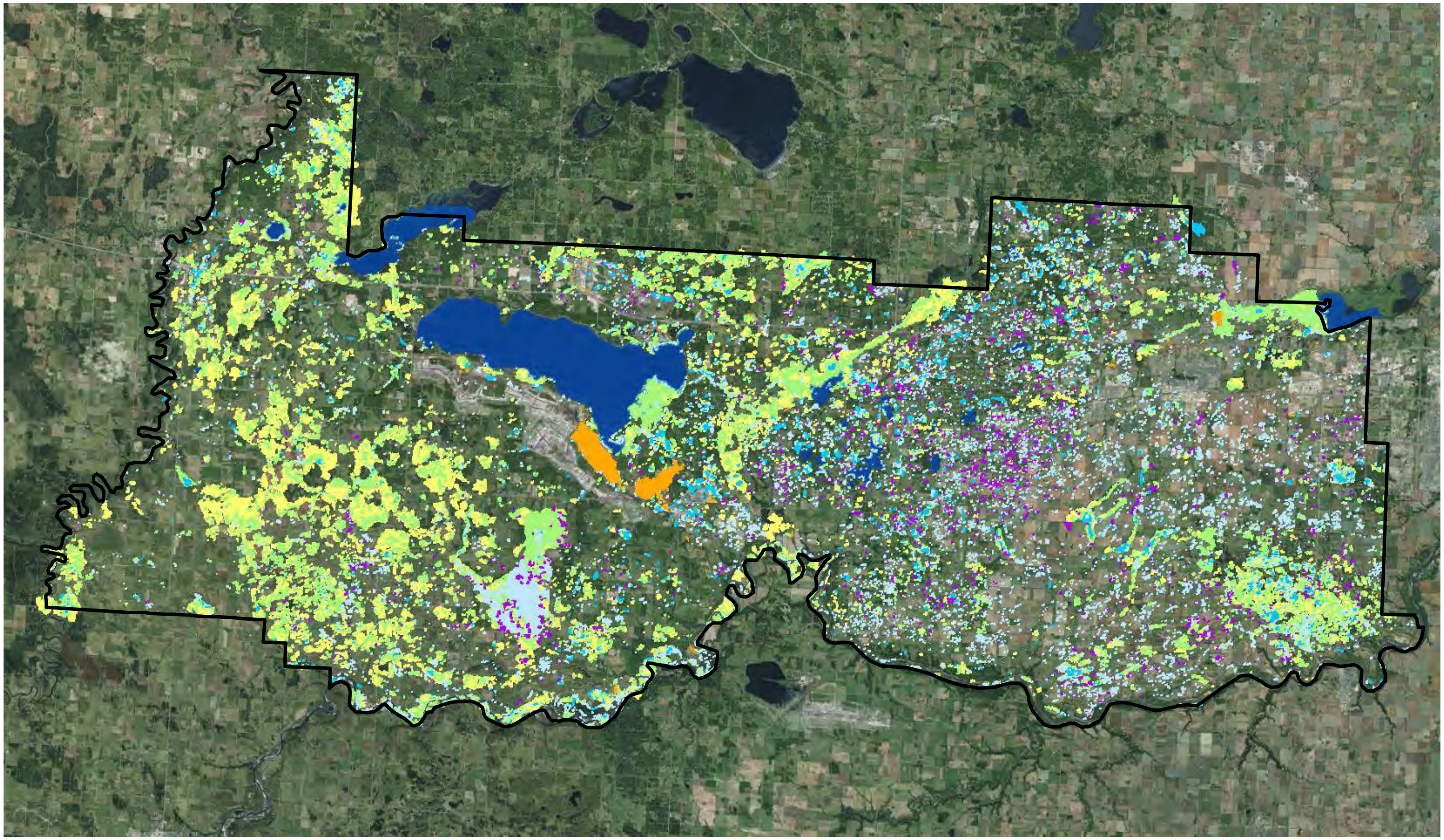


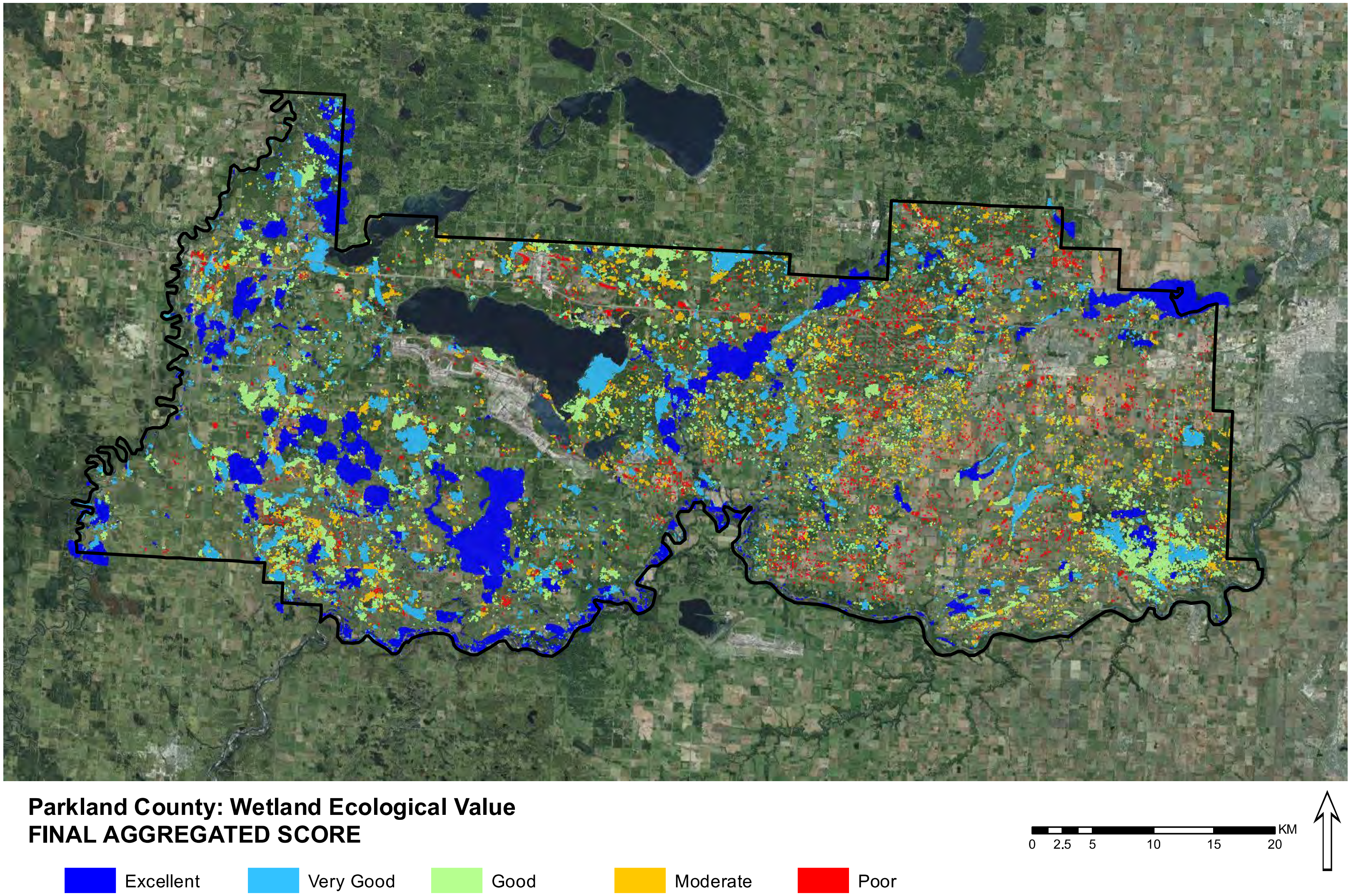

Figure 10. Aggregated Wetland Ecological Condition Scores for Parkland County, summarised by the proportion of wetland area classified into one of five condition categories.



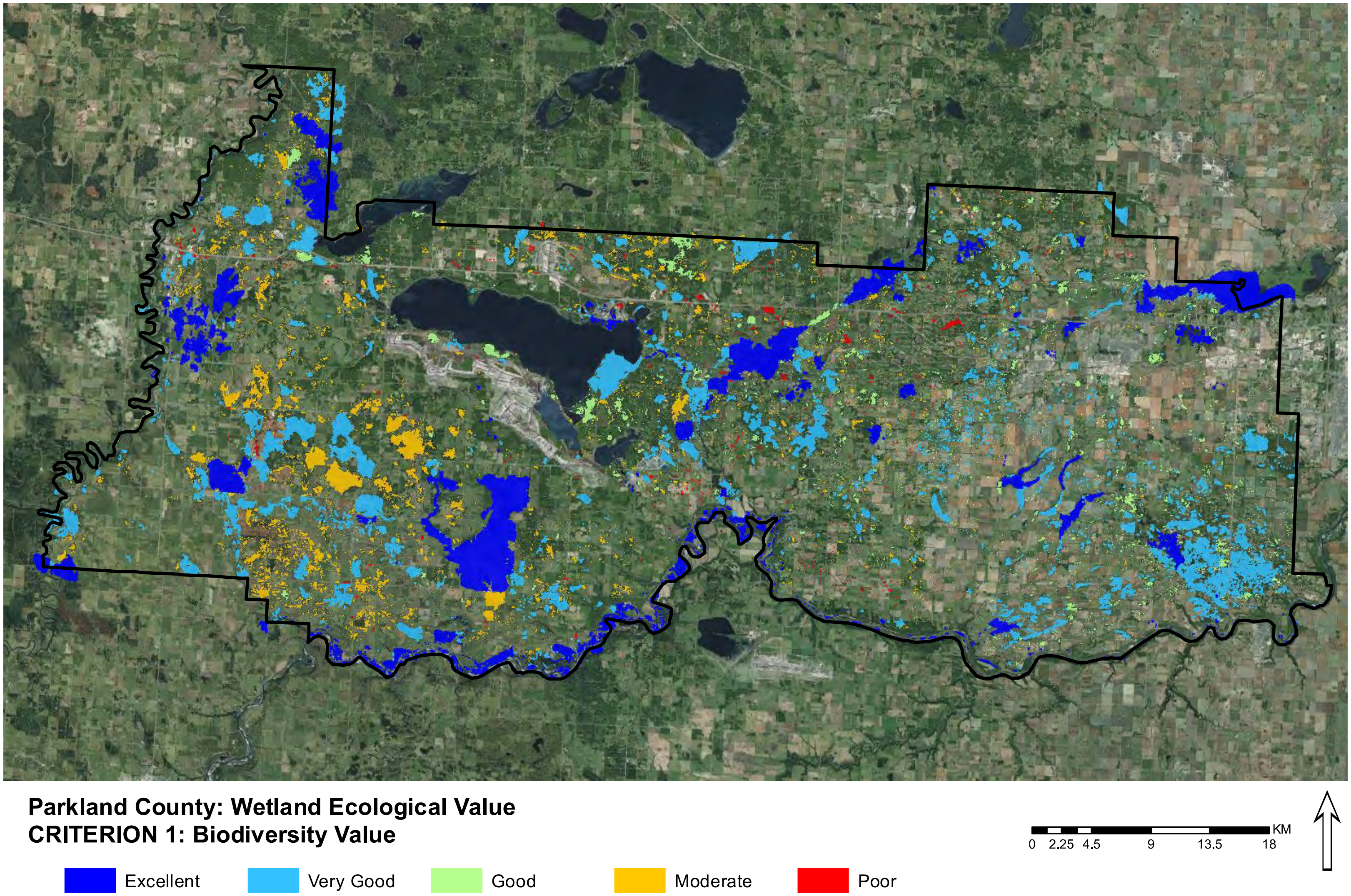
## 2013 Wetland Invenotry - Parkland County



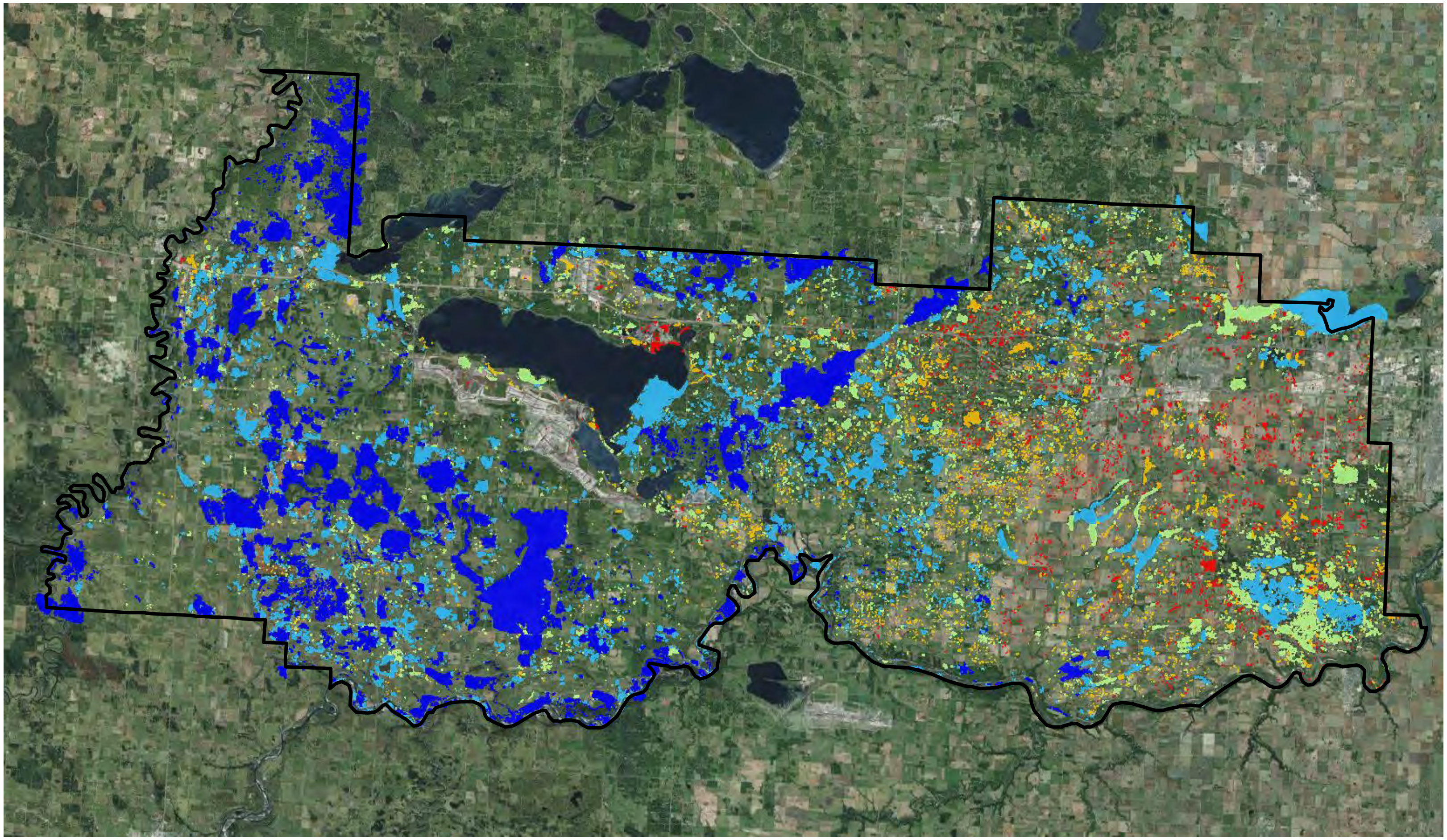
Map 4. Current (2013) wetland inventory.




Map 5. Parkland County Wetland Ecological Value: Final Aggregated Score.



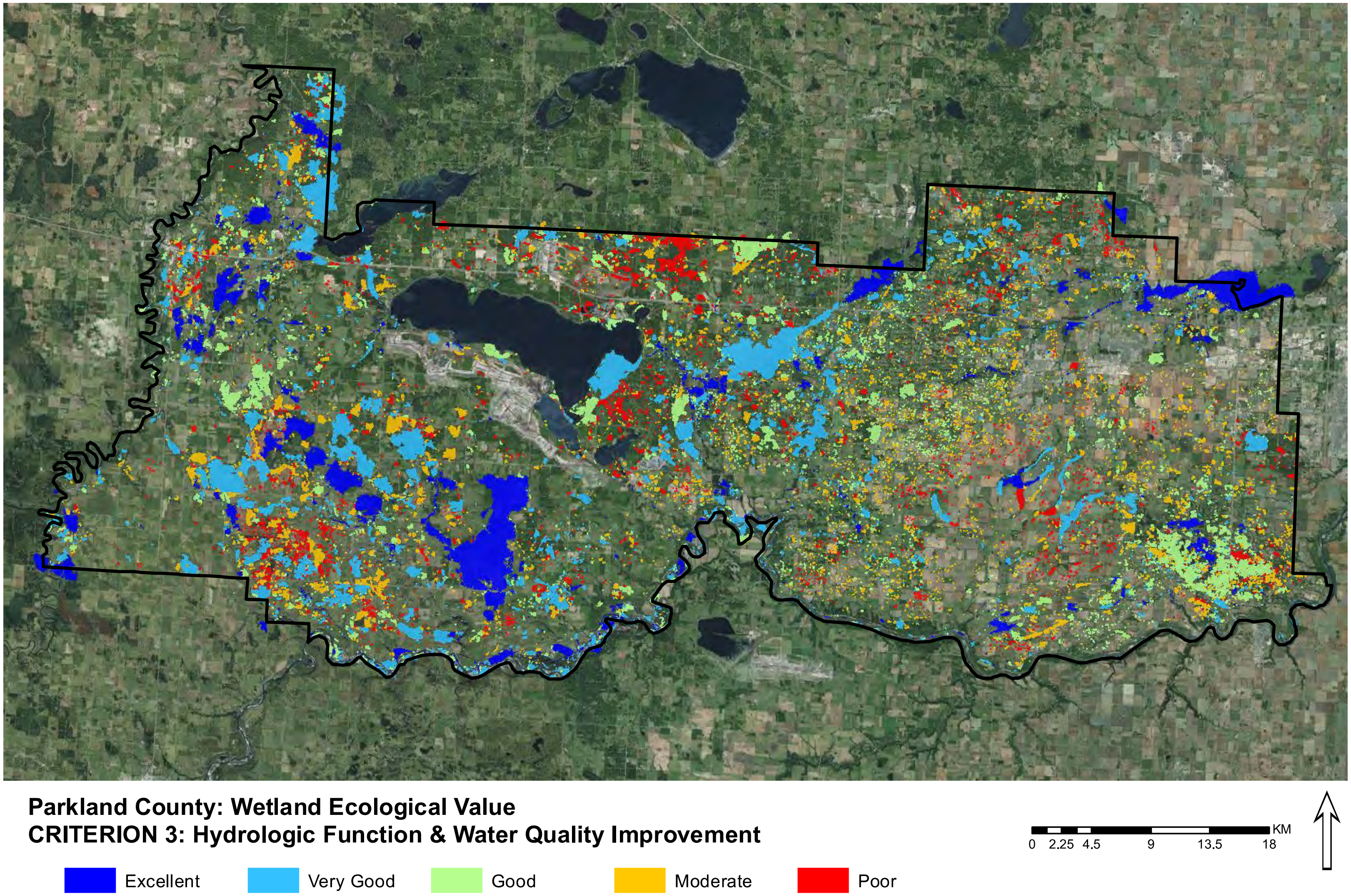

Map 6. Parkland County Wetland Ecological Value Criterion 1: Biodiversity Value.



**Parkland County: Wetland Ecological Value**
**CRITERION 2: Ecological Function**



Map 7. Parkland County Wetland Ecological Value Criterion 2: Ecological Function.




Map 8. Parkland County Wetland Ecological Value Criterion 3: Hydrologic Function & Water Quality Improvement.

## 4.2. Atim Creek

**Watershed Area**: 44,780 ha
**Proportion of Total Wetland Cover in Parkland County**: 10%

**2013**

**1,733 (56%)** Bog/Fen/Swamp

**3,100 ha**

**1,367 (44%)** Marsh/Open Water

The Atim Creek watershed unit contains approximately 10% of the current wetland cover in Parkland County, with a nearly even split between treed wetlands (Bogs, Fens, Swamps) and Marsh/Open Water wetlands (Map 9). Within the watershed unit, approximately 2.3% of the wetlands and wetland complexes assessed for ecological value received a score of Excellent, with the majority being assigned an ecological value score of either Poor (42%) or Moderate (38%) (Figure 11; Map 11).

While the number of wetlands and wetland complexes assigned to the Excellent category is quite small, the area of Excellent wetlands accounts for nearly 50% of the total wetland area in the watershed unit (Figure 11). This large area of Excellent wetlands is in part driven by the inclusion of the western basin of Big Lake in the ecological value assessment, which accounts for nearly 600 ha of the area.

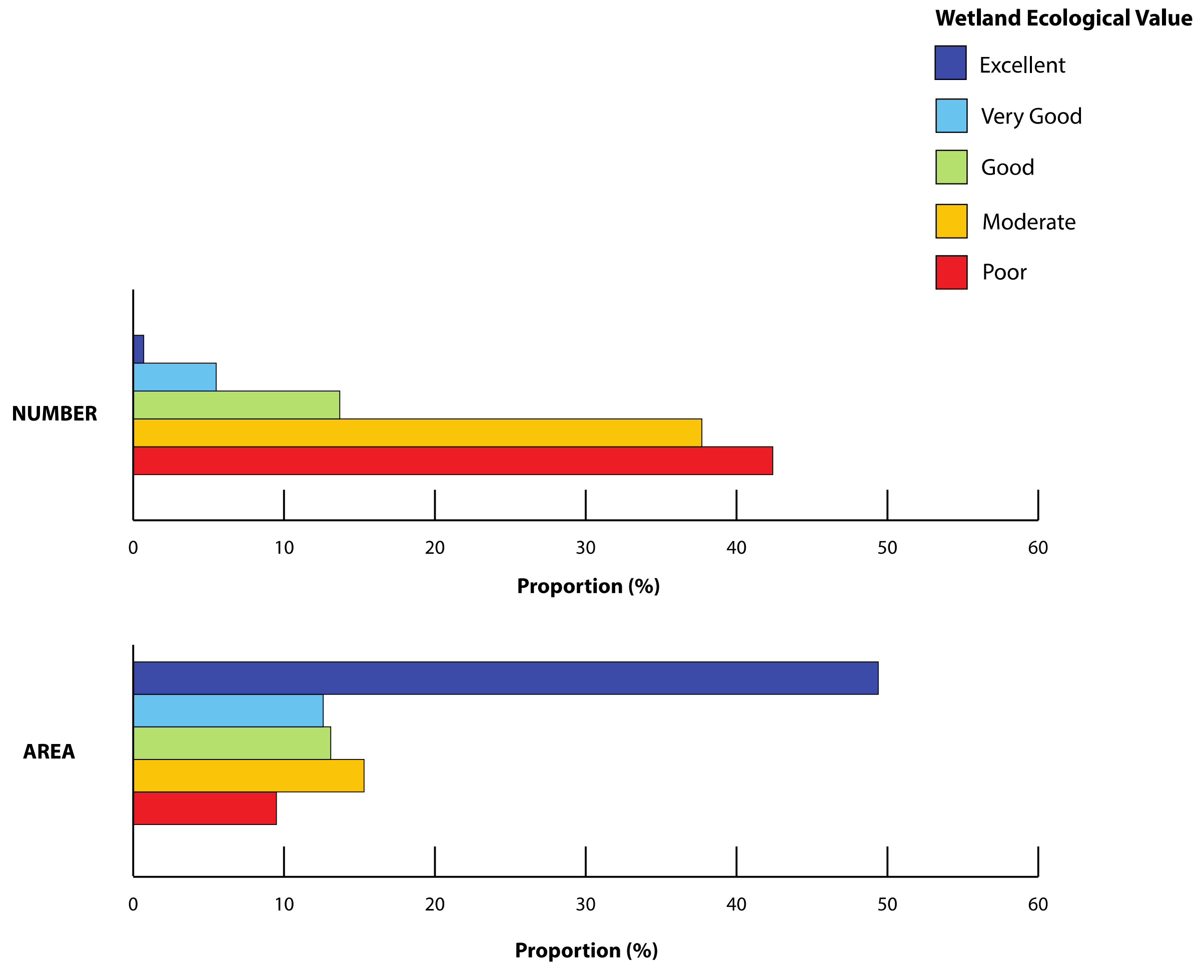
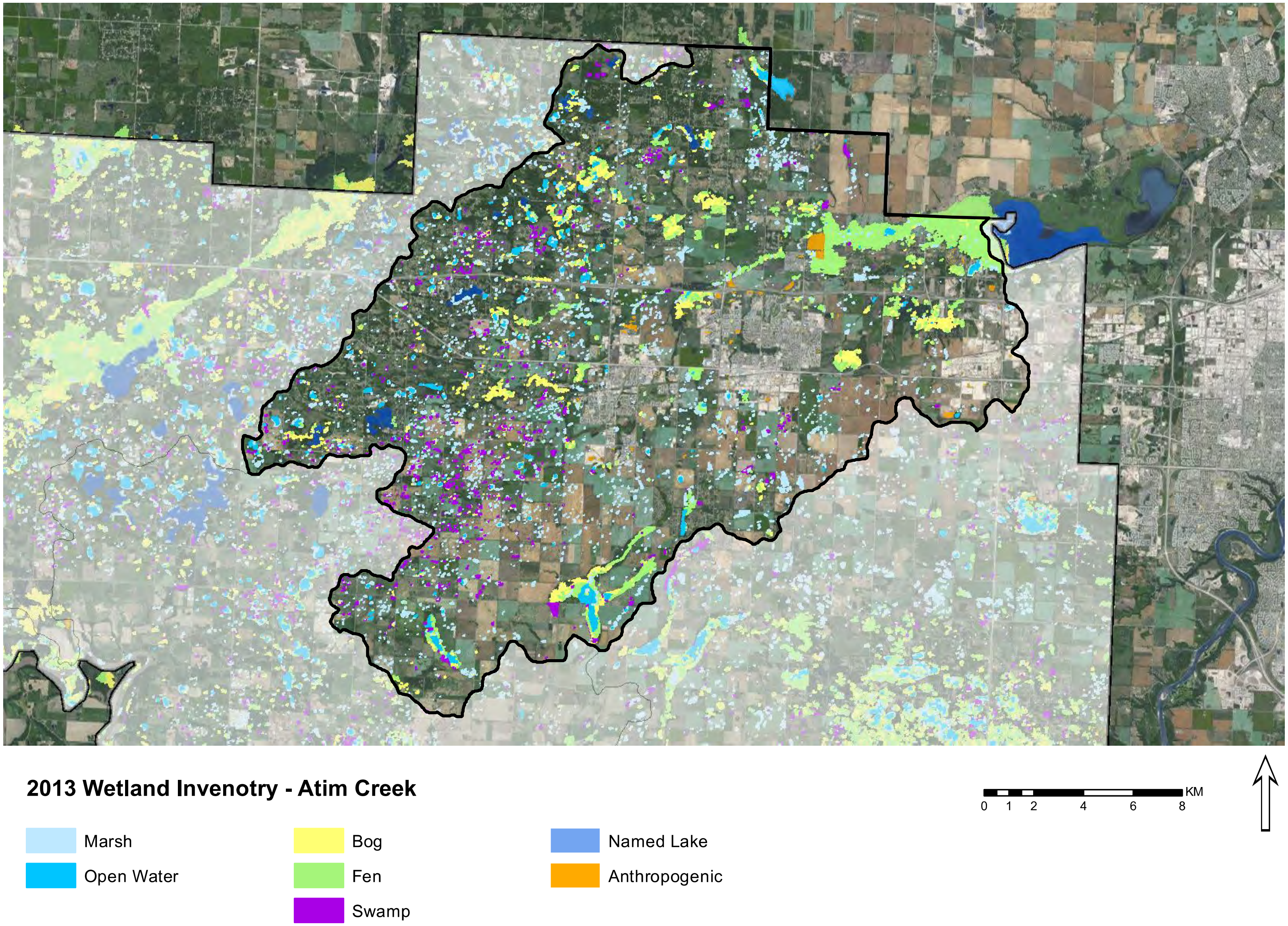
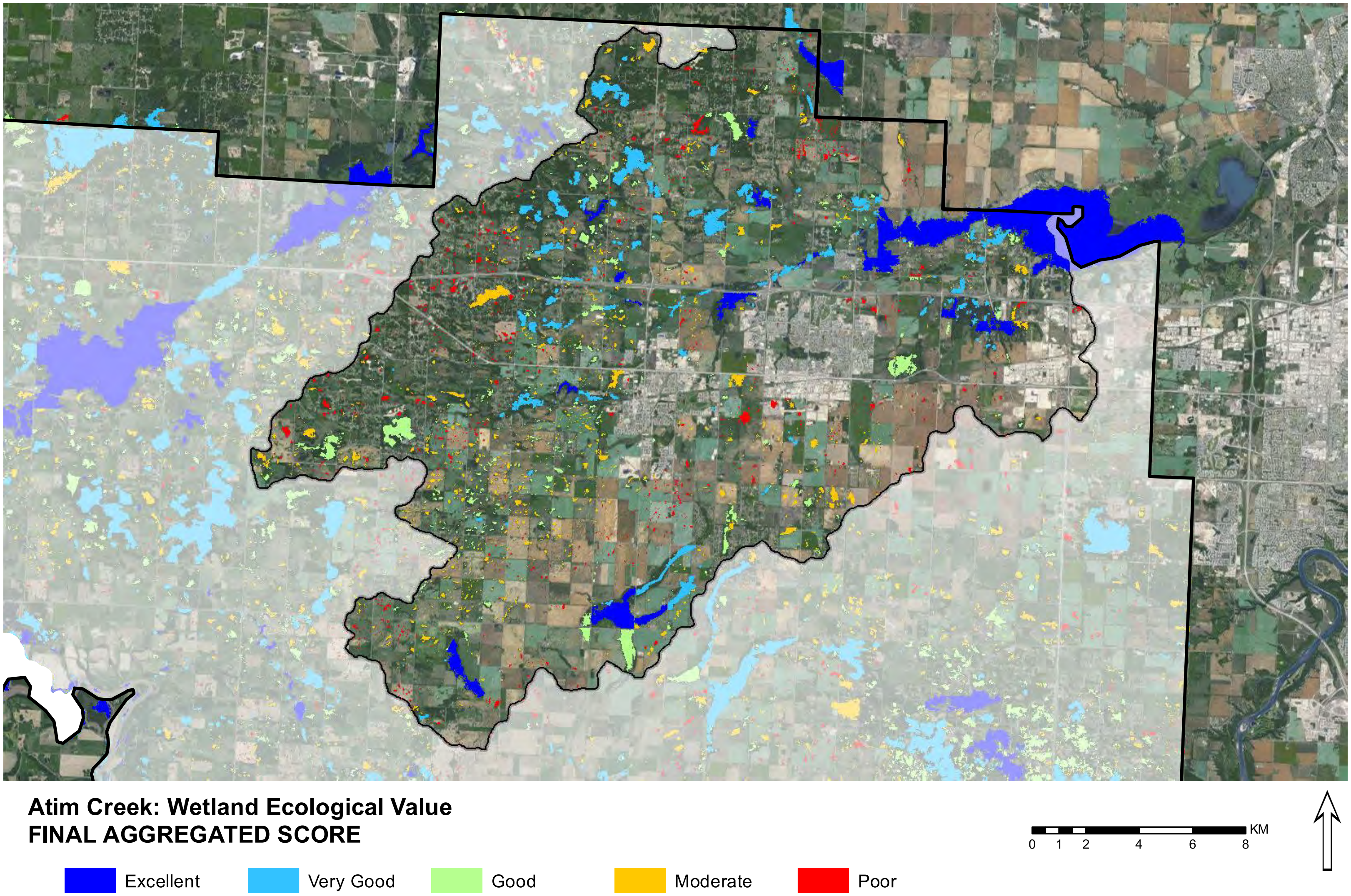


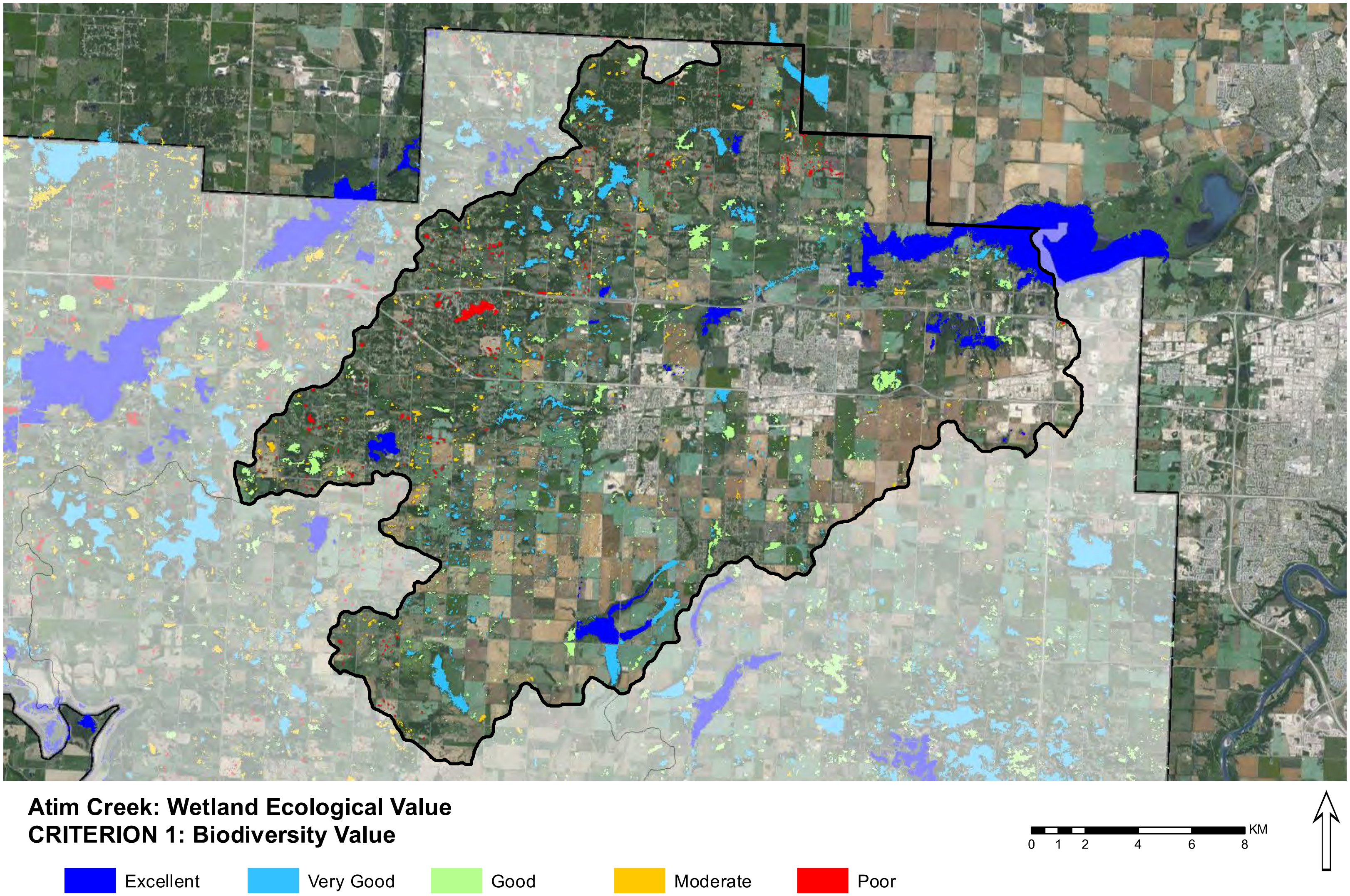

Figure 11. Aggregated Wetland Ecological Value scores, summarized by the number and area of wetlands in Atim Creek that were assigned to each of the Wetland Ecological Value categories.




Map 9. Current wetland inventory for Atim Creek.

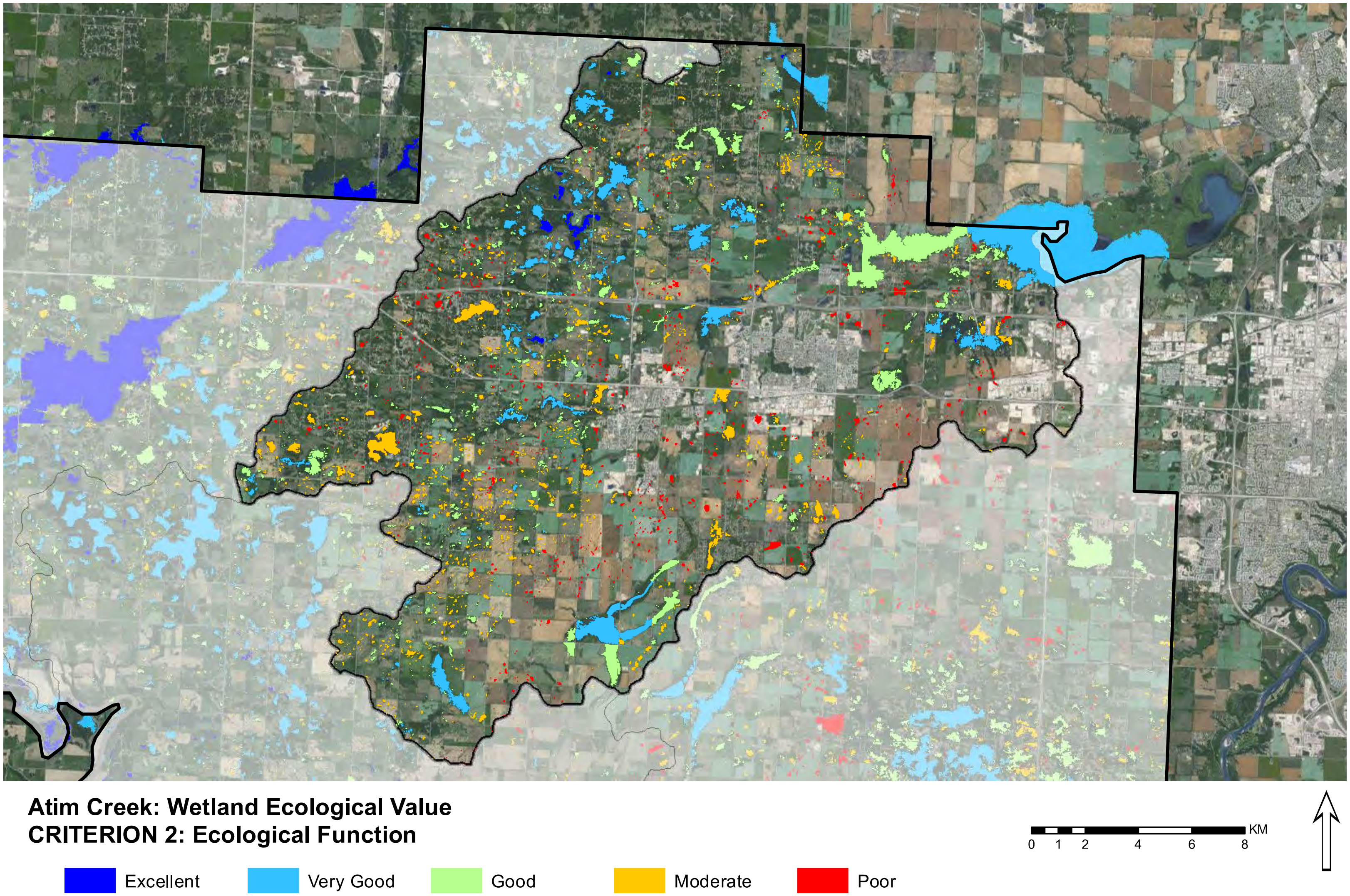



Map 10. Atim Creek Wetland Ecological Value: Final Aggregated Score.

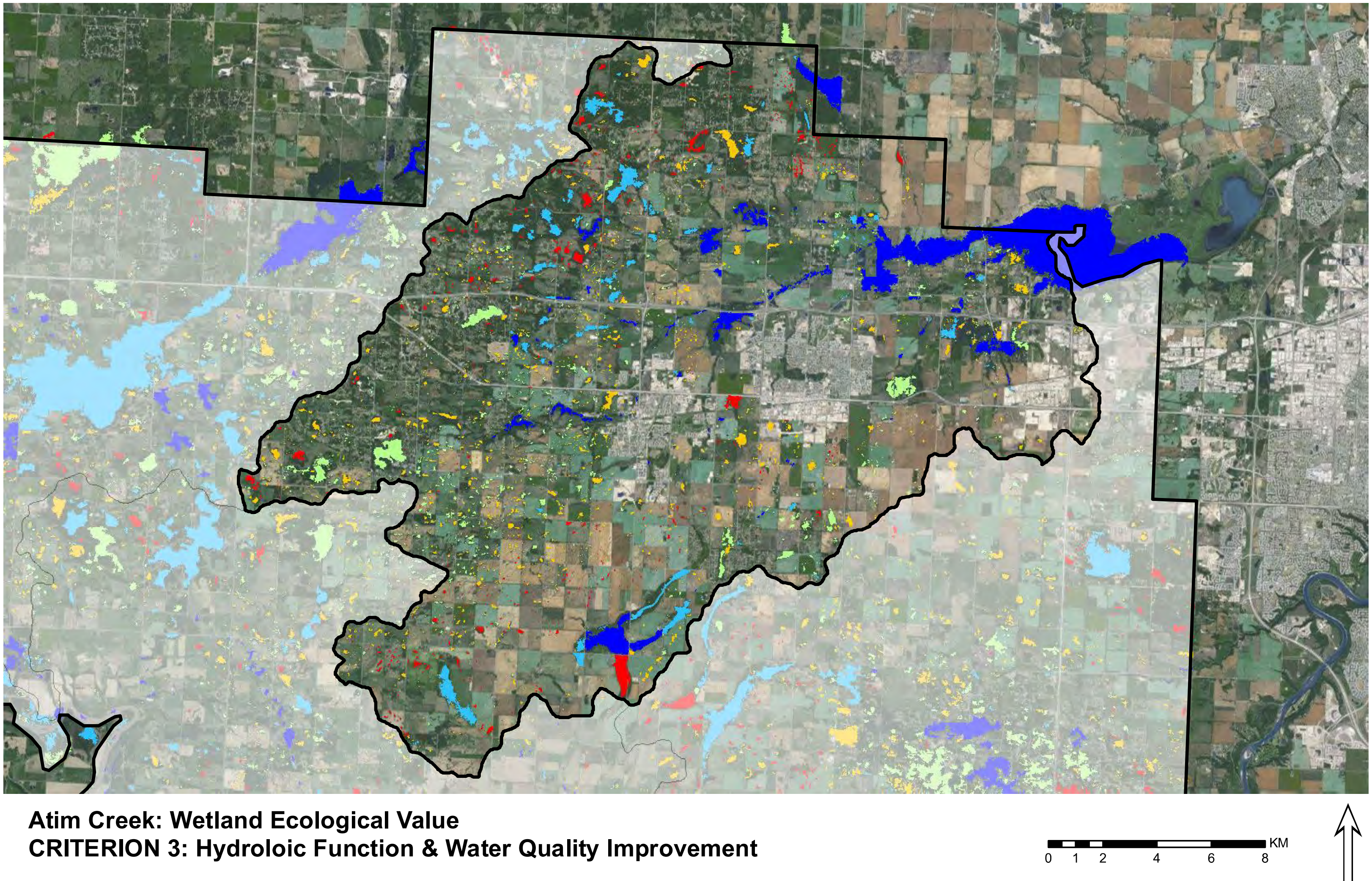




Map 11. Atim Creek Wetland Ecological Value Criterion 1: Biodiversity Value.




Map 12. Atim Creek Wetland Ecological Value Criterion 2: Ecological Function.





Map 13. Atim Creek Wetland Ecological Value Criterion 3: Hydrologic Function & Water Quality Improvement.

## 4.3. North Saskatchewan Above Wabamun (A)

**Watershed Area**: 63,213 ha
**Proportion of Total Wetland Cover in Parkland County**: 37%


This watershed unit contains the largest proportion of total wetland cover in Parkland County (37%), the majority of which (79%) is composed of treed wetlands (Bogs, Fens, Swamps), with the remaining 21% being composed of Marsh and Open Water wetlands (Map 14). At the County scale, this watershed represents the greatest proportion of Excellent wetlands by both number and area (Figure 9 and Figure 10). At the watershed scale, wetlands rated as Good make up the greatest proportion by number (27%), while wetlands in the Excellent category make up the greatest proportion by area (60%) (Figure 12; Map 15).

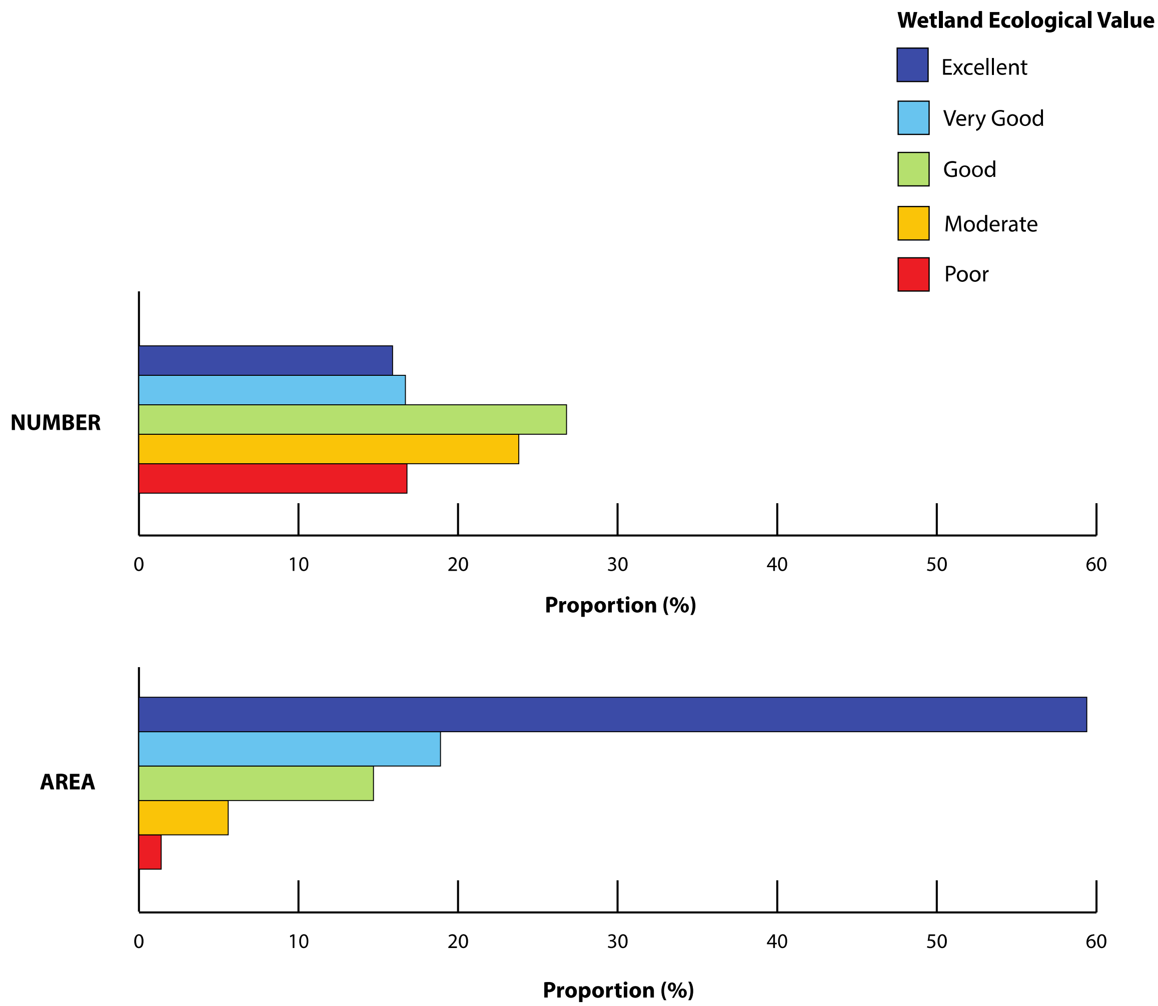
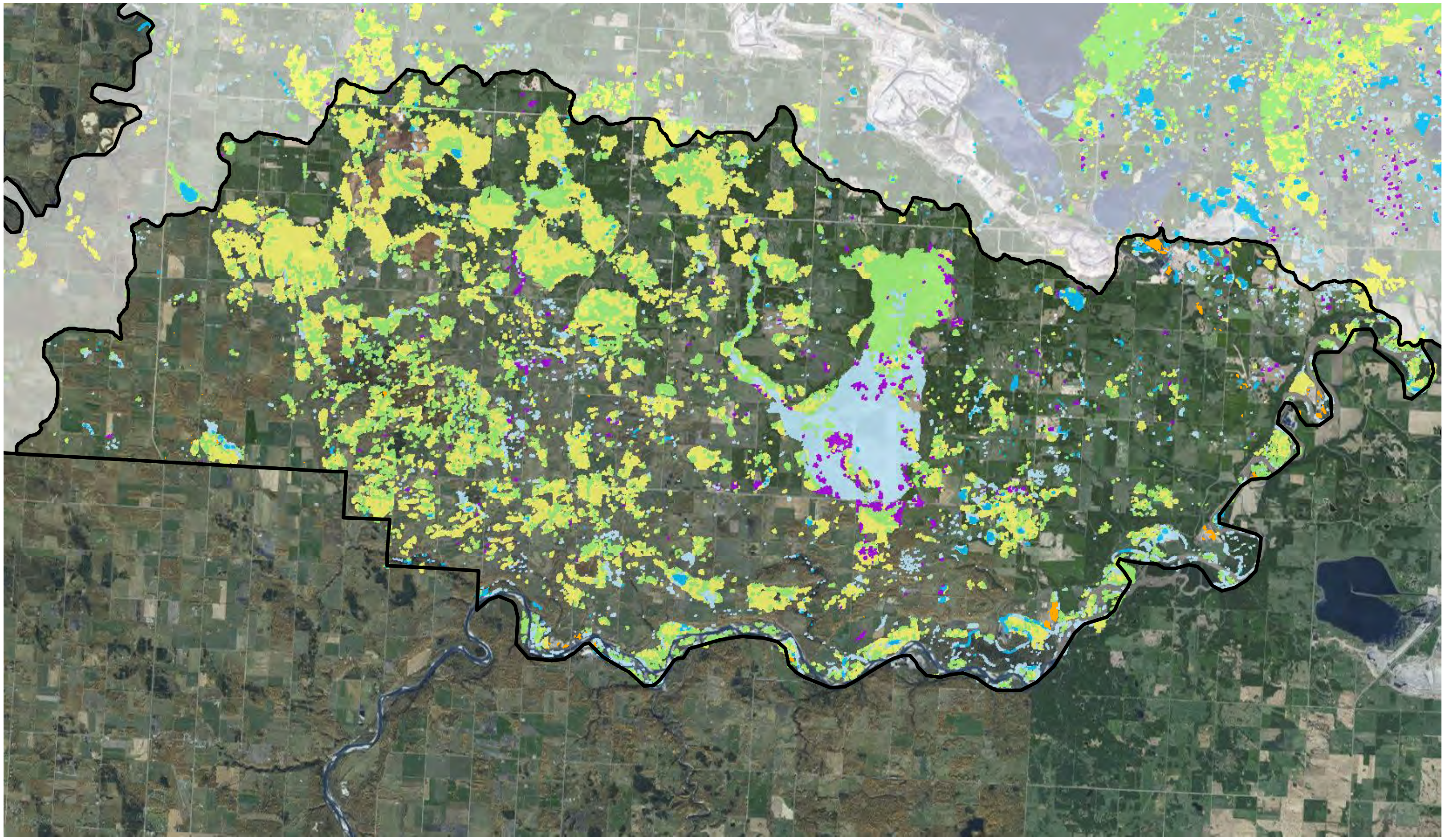
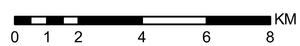
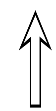



Figure 12. Aggregated Wetland Ecological Value scores, summarized by the number and area of wetlands in the North Saskatchewan Above Wabamun (A) watershed unit that were assigned to each of the Wetland Ecological Value categories.



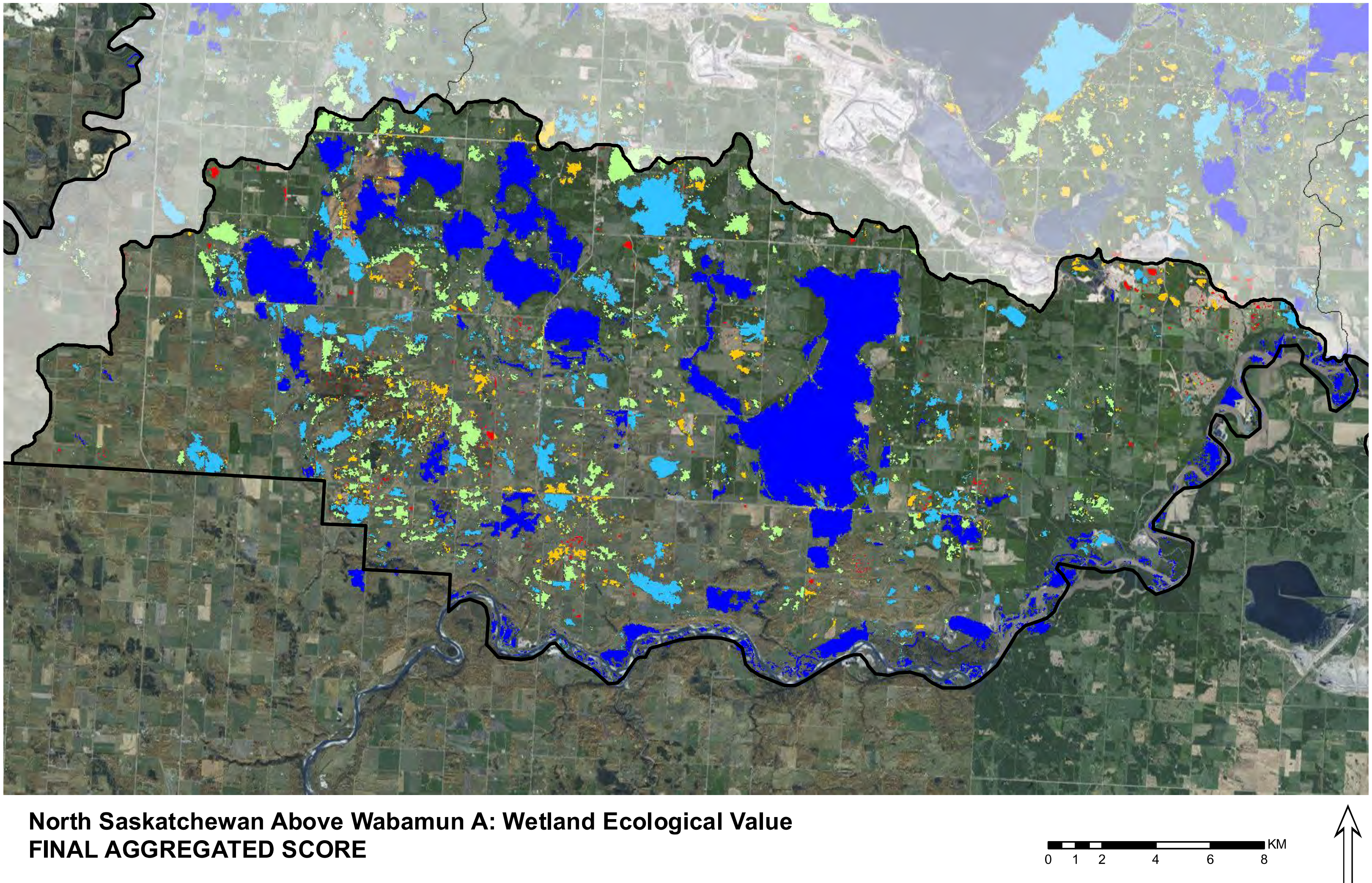
## 2013 Wetland Invenotry - North Saskatchewan Above Wabamun (A)



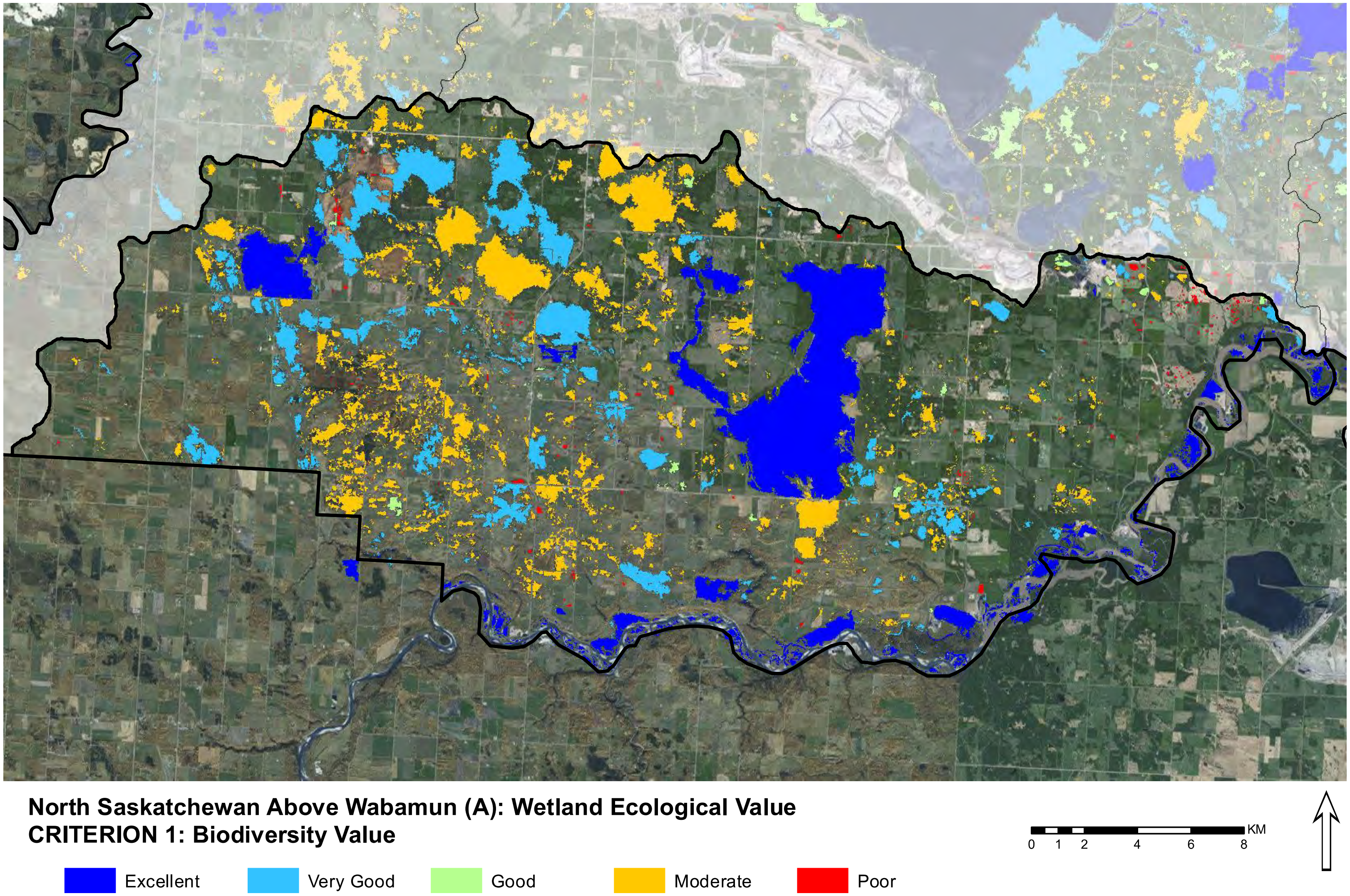



| | | |
|---|---|---|
| Marsh | Bog | Named Lake |
| Open Water | Fen | Anthropogenic |
| | Swamp | |

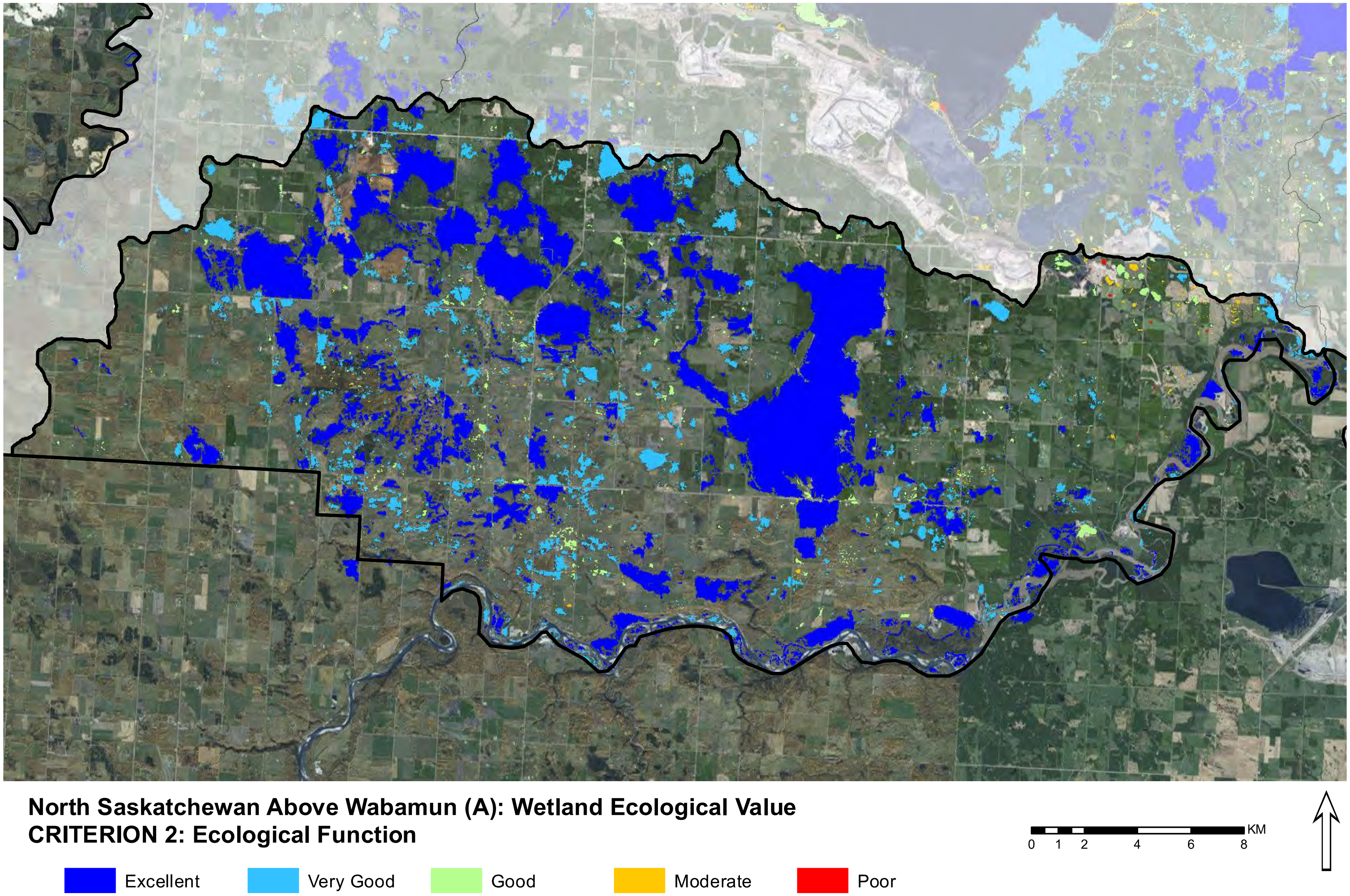
Map 14. Current wetland inventory for North Saskatchewan Above Wabamun (A).



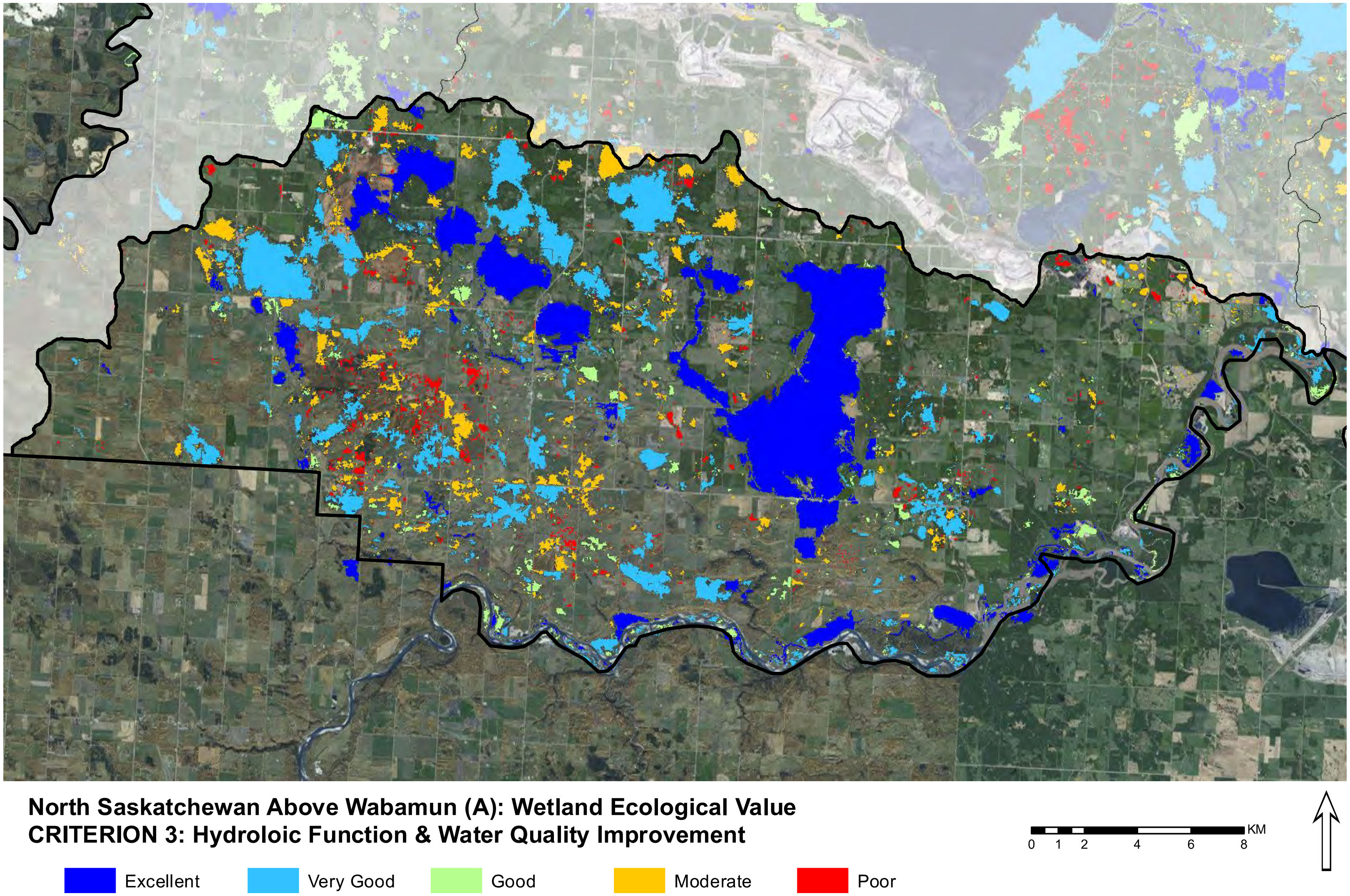

Map 15. North Saskatchewan Above Wabamun (A) Wetland Ecological Value: Final Aggregated Score.




Map 16. North Saskatchewan Above Wabamun (A) Wetland Ecological Value Criterion 1: Biodiversity Value.




Map 17. North Saskatchewan Above Wabamun (A) Wetland Ecological Value Criterion 2: Ecological Function.




Map 18. North Saskatchewan Above Wabamun (A) Wetland Ecological Value Criterion 3: Hydrologic Function & Water Quality Improvement.

## 4.4. North Saskatchewan Above Wabamun (B)

**Watershed Area**: 26,952 ha
**Proportion of Total Wetland Cover in Parkland County**: 4%

**2013 Wetland Cover**

**382 (29%)** **1,323 ha** **941 (71%)**

The North Saskatchewan Above Wabamun (B) watershed is the smallest watershed unit in Parkland County, and contains only 4% of the total wetland cover (Map 19). Wetland cover in this watershed unit is dominated by Marsh and Open Water wetlands (71%), and there are several medium sized named lakes in this watershed unit, including Jackfish and Hasse Lake. Within the watershed unit, wetlands ranked as Poor make up the largest proportion by number (36%); however, wetlands ranked as Very Good are most abundant by area (43%) (Figure 13; Map 20).

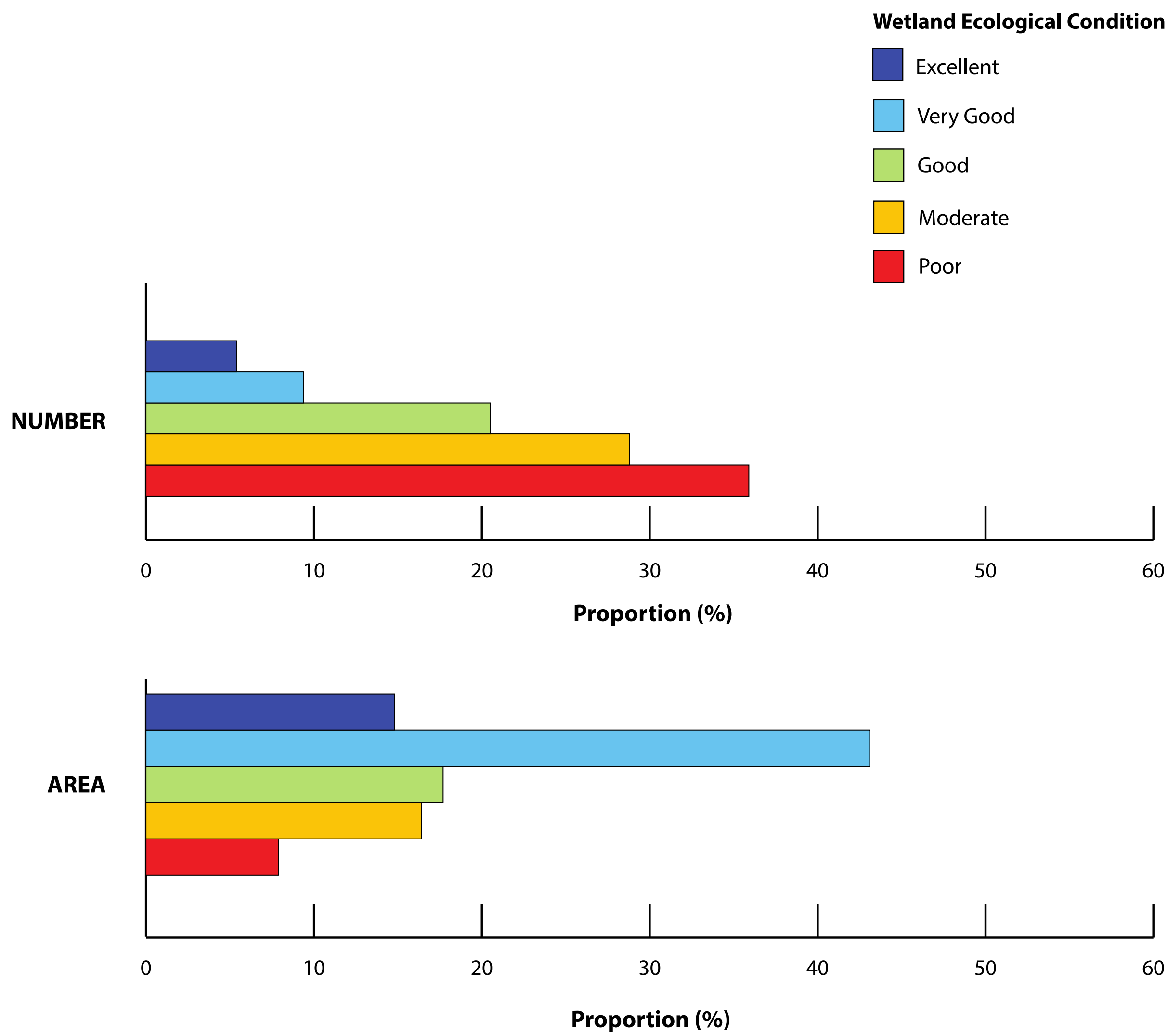
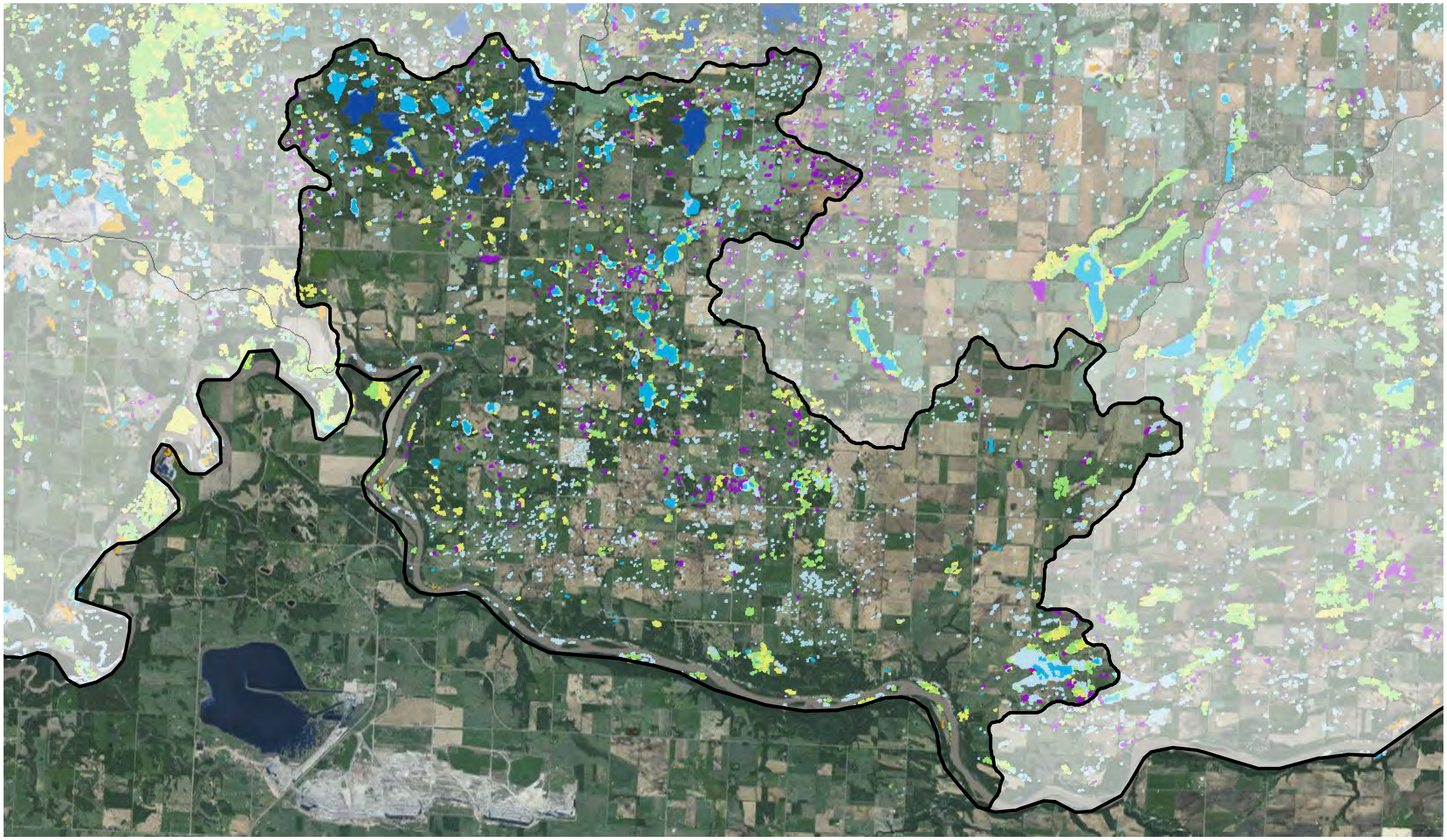



Figure 13. Aggregated Wetland Ecological Value scores, summarized by the number and area of wetlands in the North Saskatchewan Above Wabamun (B) watershed unit that were assigned to each of the Wetland Ecological Value categories.

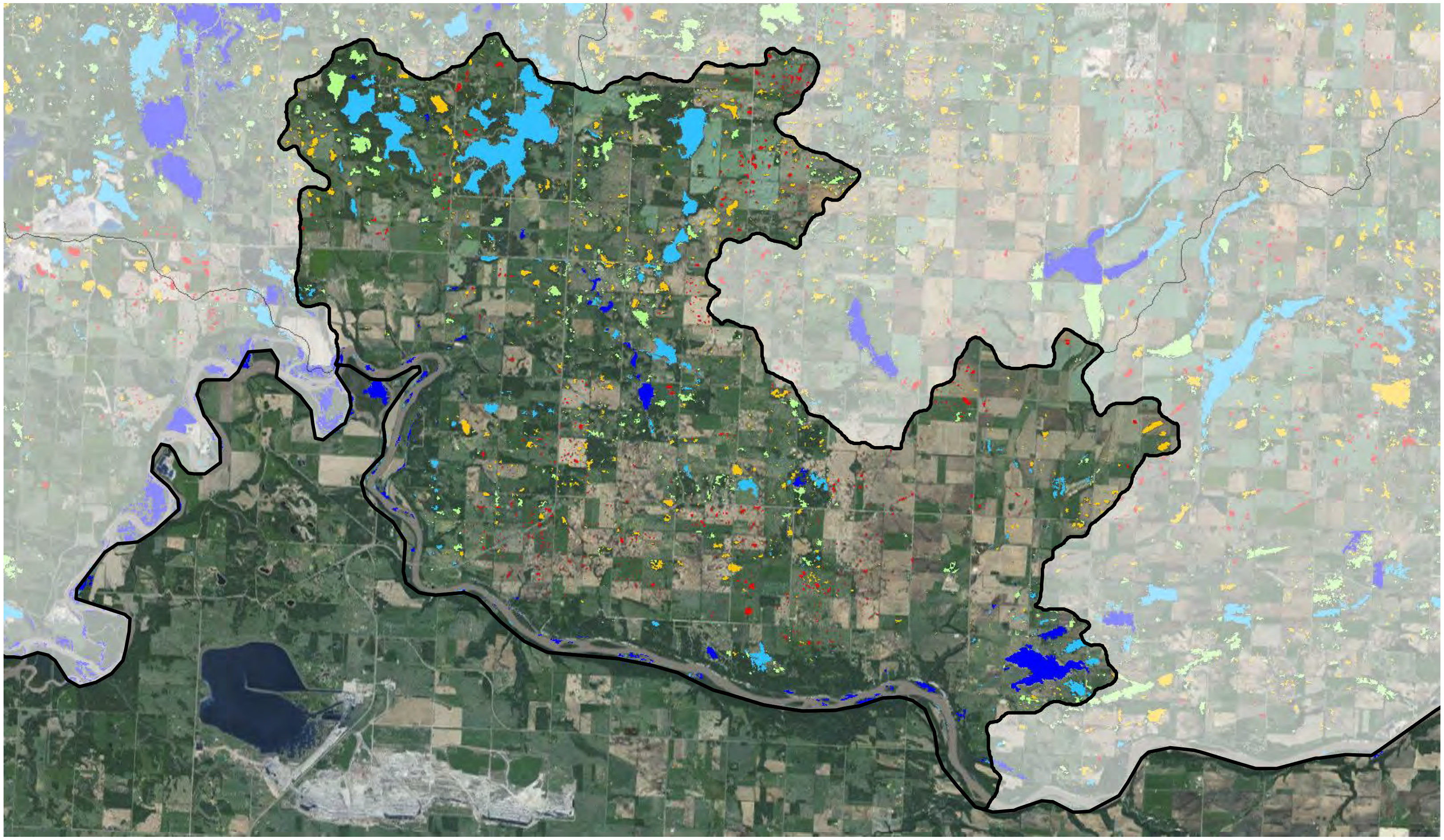


**2013 Wetland Invenotry - North Saskatchewan Above Wabamun (B)**

KM
0 0.75 1.5 3 4.5 6

- Marsh
- Open Water
- Bog
- Fen
- Swamp
- Named Lake
- Anthropogenic

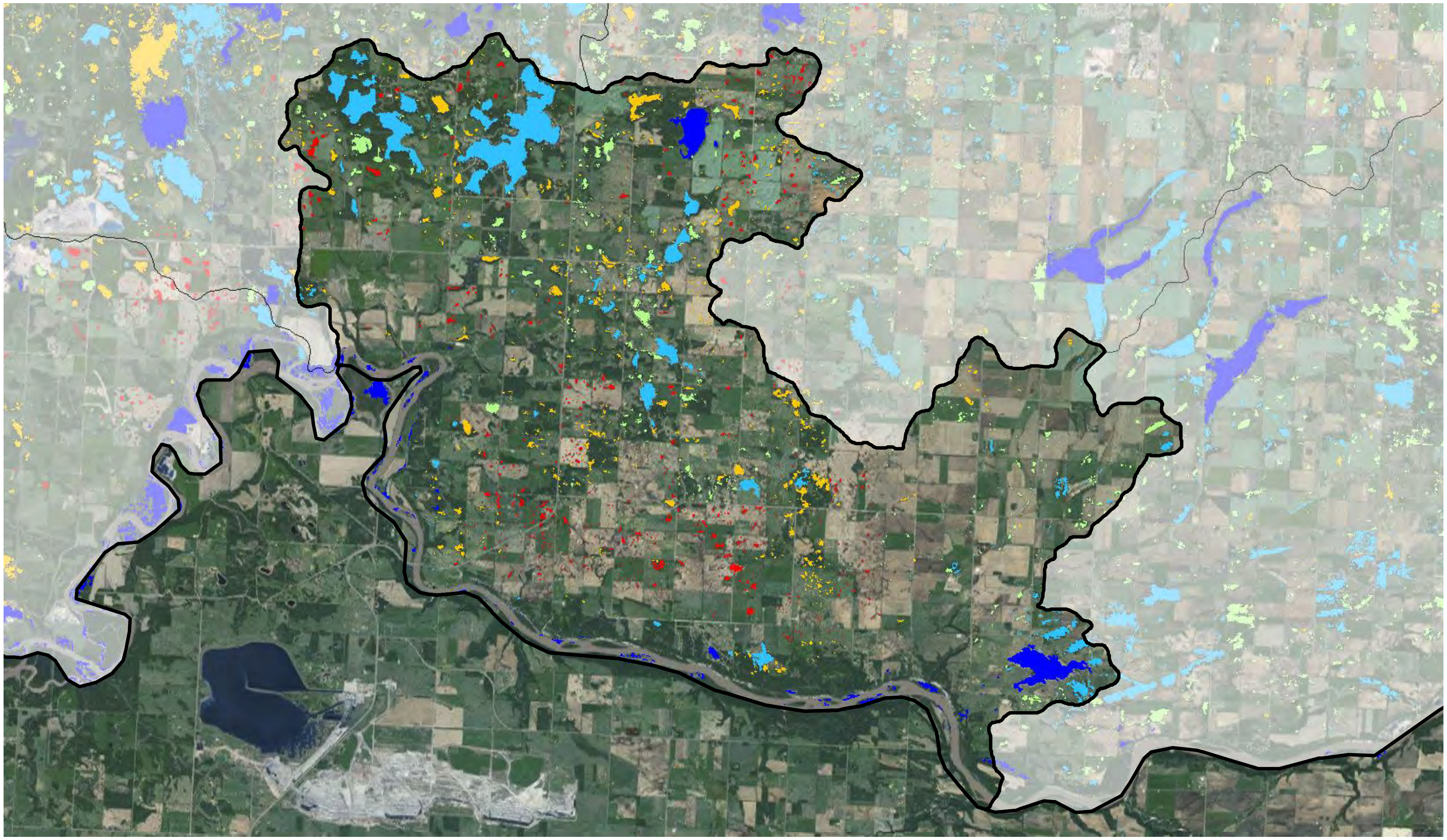
Map 19. Current wetland inventory for North Saskatchewan Above Wabamun (B).



**North Saskatchewan Above Wabamun (B): Wetland Ecological Value**
**FINAL AGGREGATED SCORE**



Map 20. North Saskatchewan Above Wabamun (B) Wetland Ecological Value: Final Aggregated Score.

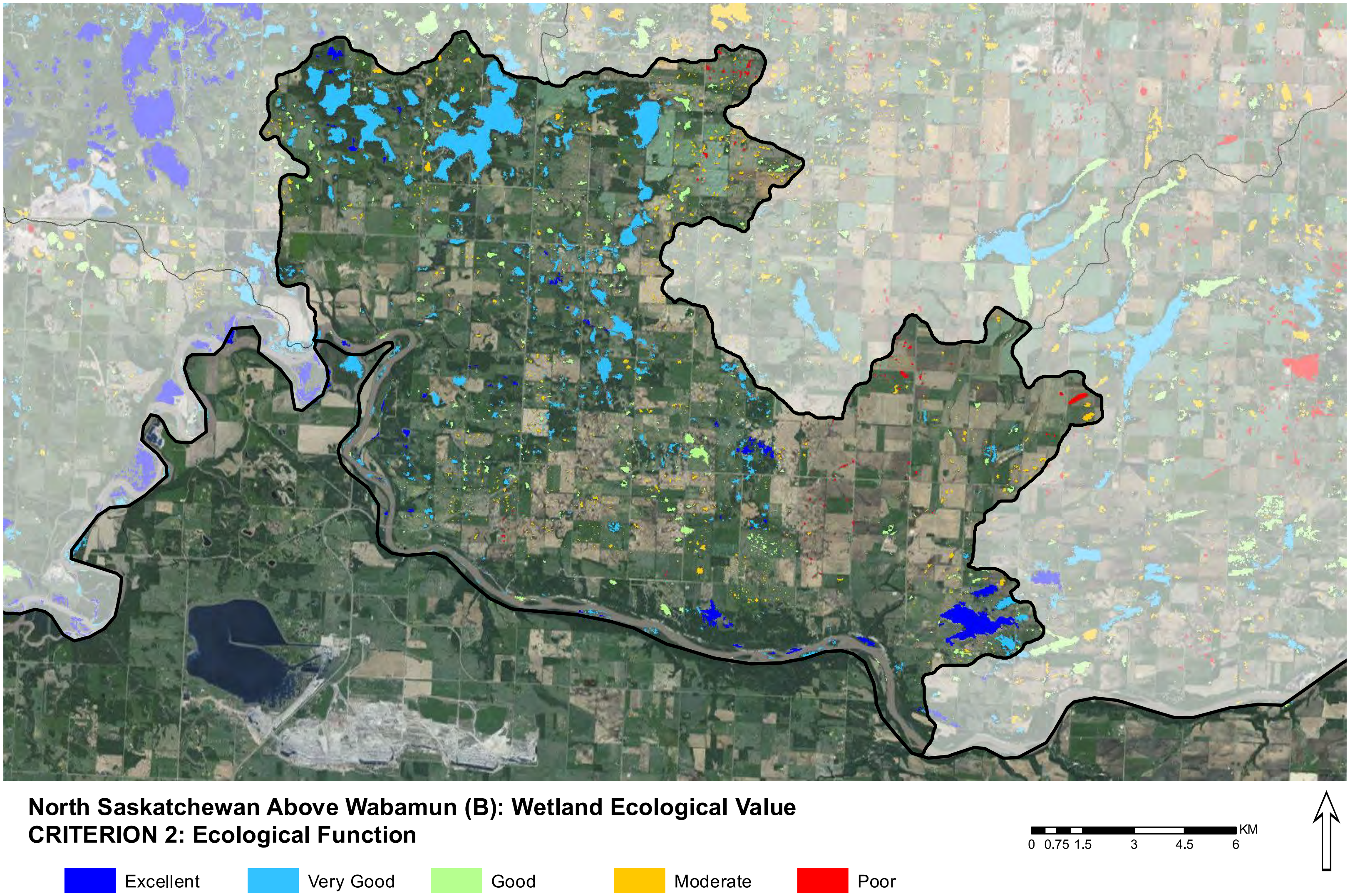


**North Saskatchewan Above Wabamun (B): Wetland Ecological Value**
**CRITERION 1: Biodiversity Value**

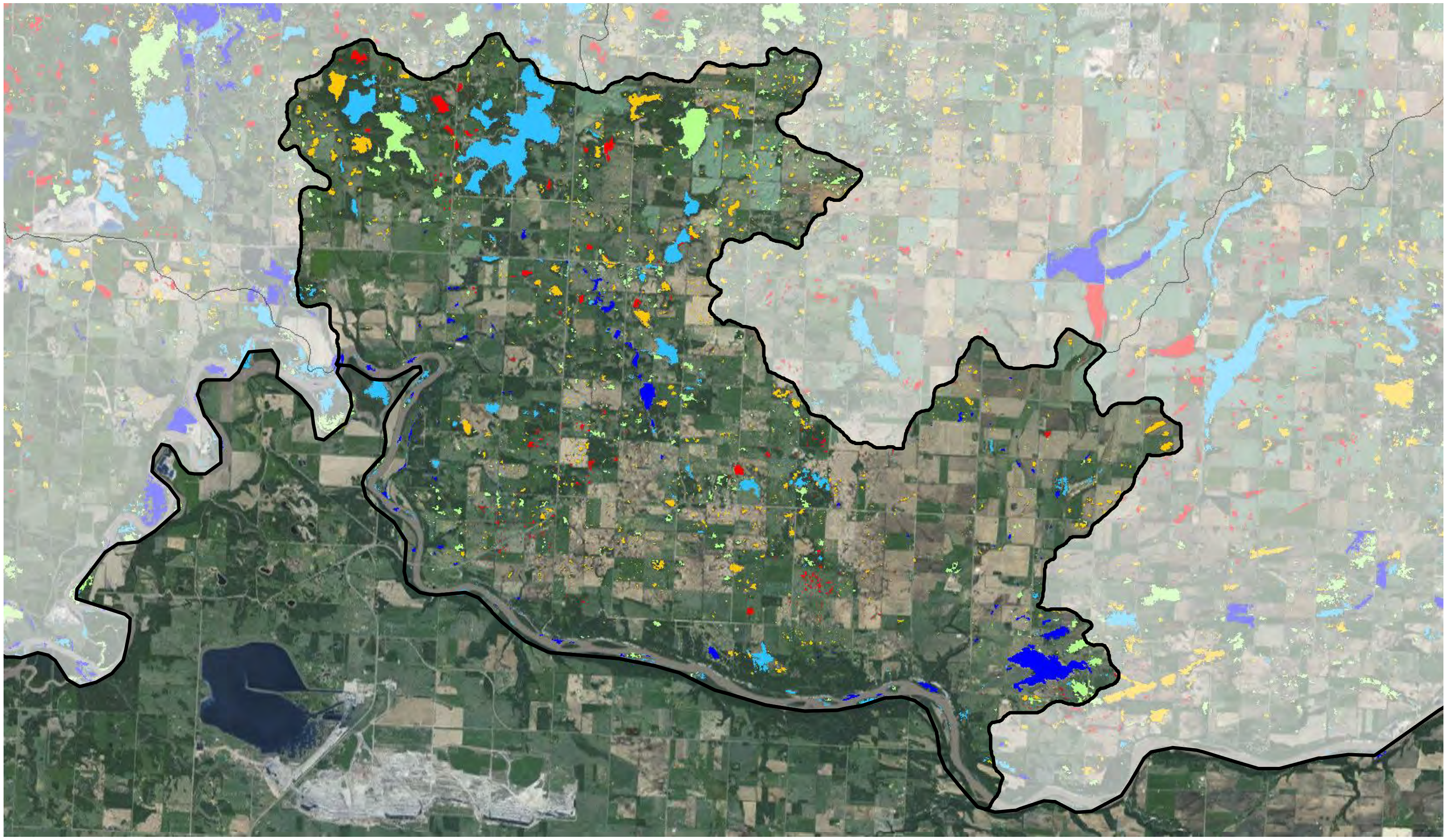
Excellent | Very Good | Good | Moderate | Poor

0 0.75 1.5 3 4.5 6 KM

Map 21. North Saskatchewan Above Wabamun (B) Wetland Ecological Value Criterion 1: Biodiversity Value.




Map 22. North Saskatchewan Above Wabamun (B) Ecological Value Criterion 2: Ecological Function.



**North Saskatchewan Above Wabamun (B): Wetland Ecological Value**
**CRITERION 3: Hydroloic Function & Water Quality Improvement**

KM
0 0.75 1.5 3 4.5 6

Excellent Very Good Good Moderate Poor

Map 23. North Saskatchewan Above Wabamun (B) Wetland Ecological Value Criterion 3: Hydrologic Function & Water Quality Improvement.

## 4.5. North Saskatchewan Below Strawberry / Sturgeon River

**Watershed Area**: 37,783 ha
**Proportion of Total Wetland Cover in Parkland County**: 12%

**2013 Wetland Cover**

**2,121 (54%)** | **3,895 ha** | **1,774 (45%)**

The North Saskatchewan Below Strawberry / Sturgeon River watershed unit is located in the eastern portion of the County, directly west of the City of Edmonton and north of the City of Devon. This watershed unit accounts for 12% of the total wetland area in the County, with treed wetlands (Bog, Fen, Swamp) making up 54% of the wetland area, and Marsh/Open Water wetlands making up the remaining 45% of wetlands (Map 24). A significant portion of the current wetland area is located in the central portion of the watershed unit, within and adjacent to the Clifford E. Lee Natural Area, the Devonian Botanical Gardens, and the Bunchberry Conservation Area. Within the watershed unit, Poor (23%), Moderate (38%), and Good (31%) wetlands make up the vast majority of the wetlands by number, while Very Good (31%) and Good (37%) wetlands make up the majority of the wetlands by area (Figure 14; Map 25).

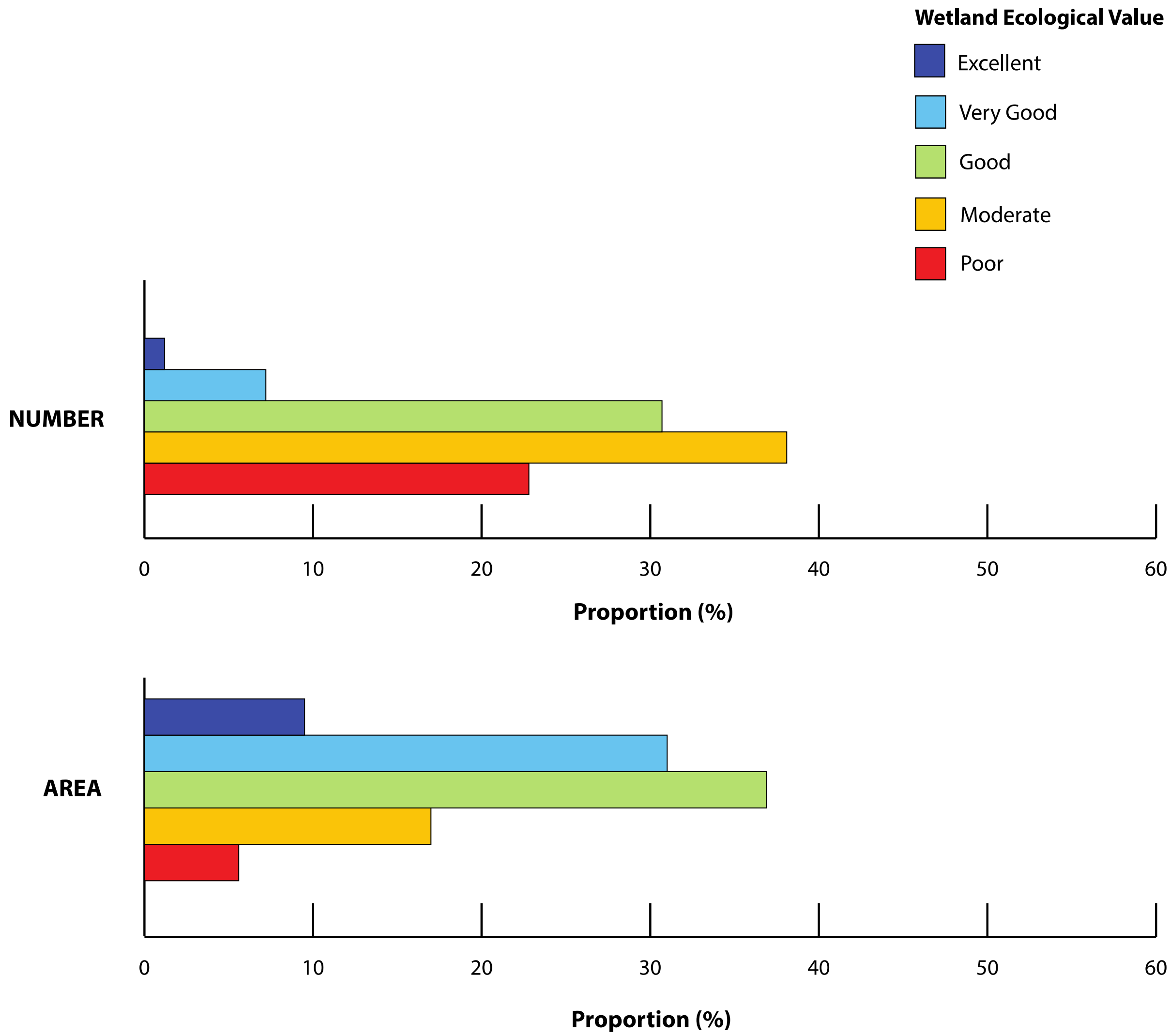
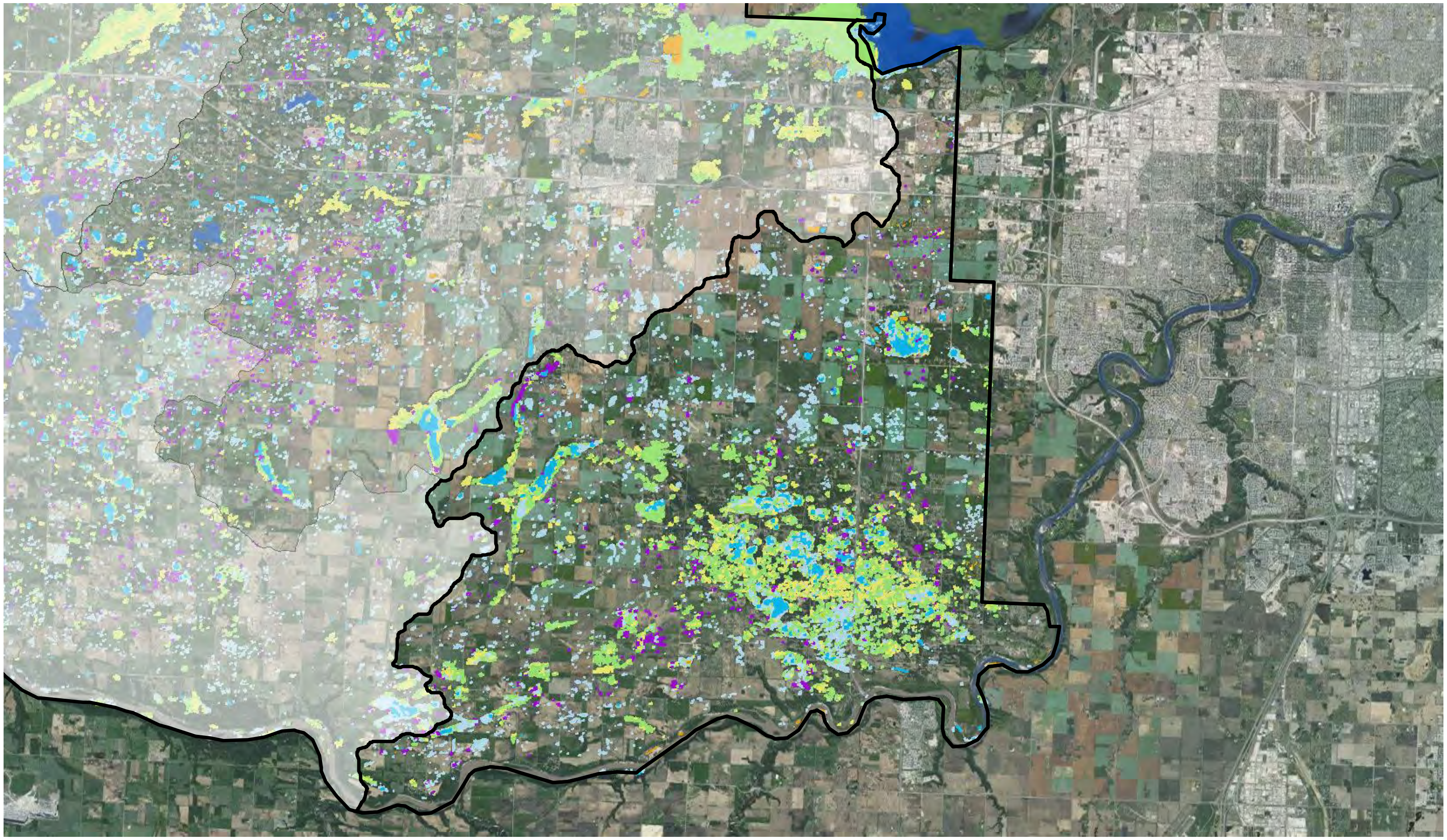



Figure 14. Aggregated Wetland Ecological Value scores, summarized by the number and area of wetlands in the North Saskatchewan Below Strawberry / Sturgeon River watershed unit.

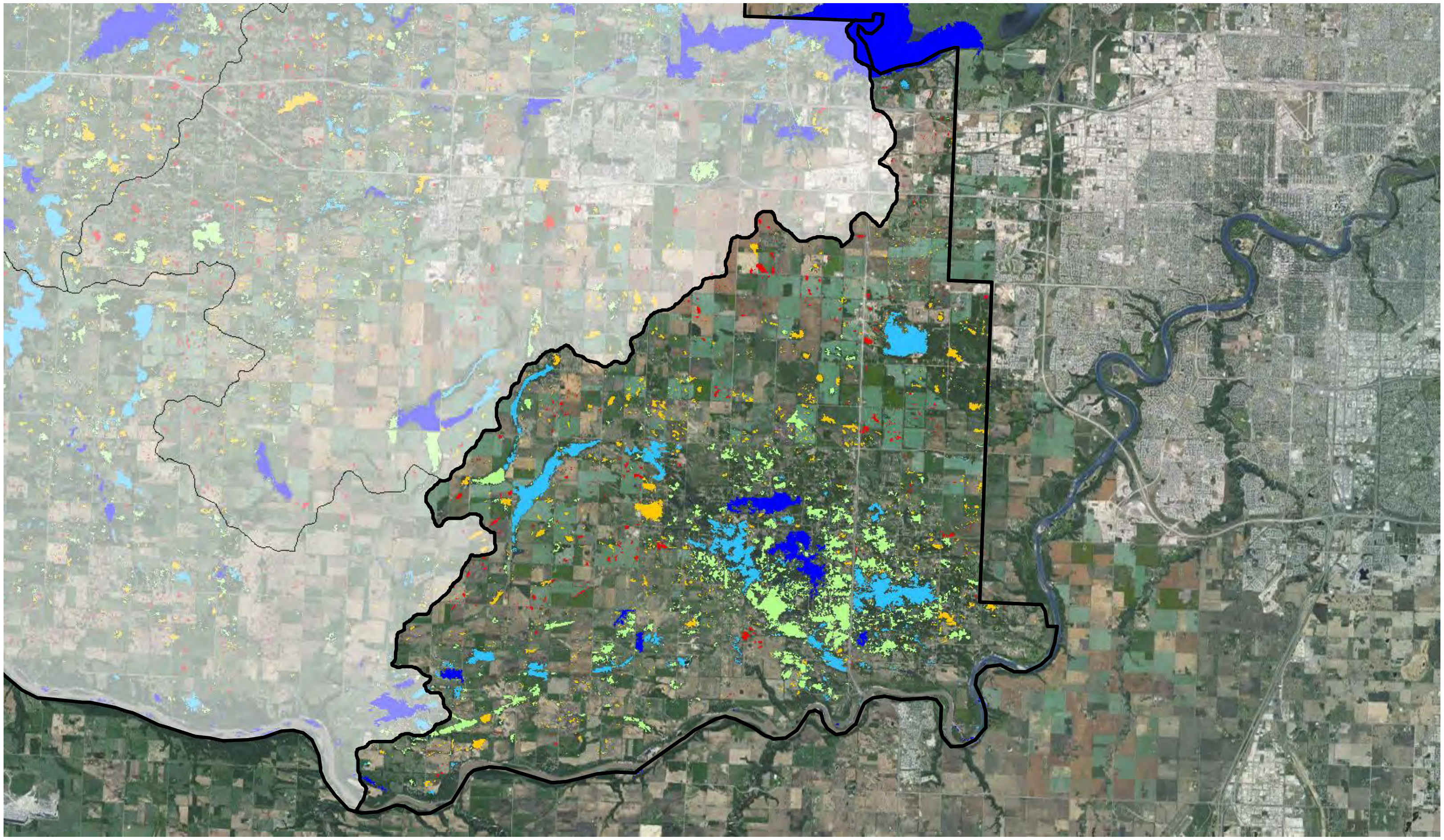


**2013 Wetland Invenotry - North Saskatchewan Below Strawberry / Sturgeon River**

0 1.25 2.5 5 7.5 10 KM

- Marsh
- Open Water
- Bog
- Fen
- Swamp
- Named Lake
- Anthropogenic

Map 24. Current wetland inventory for North Saskatchewan Below Strawberry / Sturgeon River.

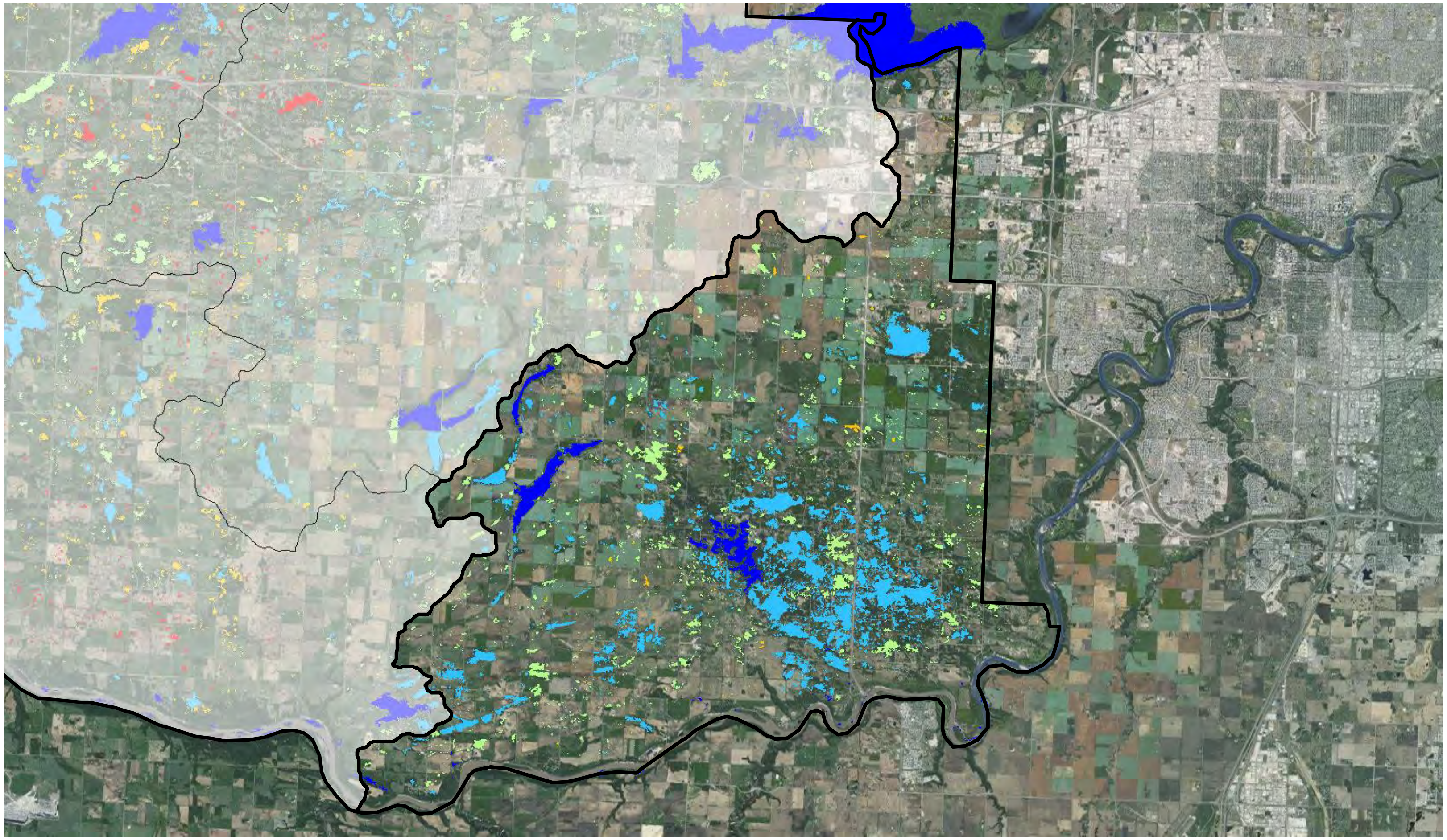


**North Saskatchewan Below Strawberry / Sturgeon River: Wetland Ecological Value**
**FINAL AGGREGATED SCORE**



Excellent Very Good Good Moderate Poor

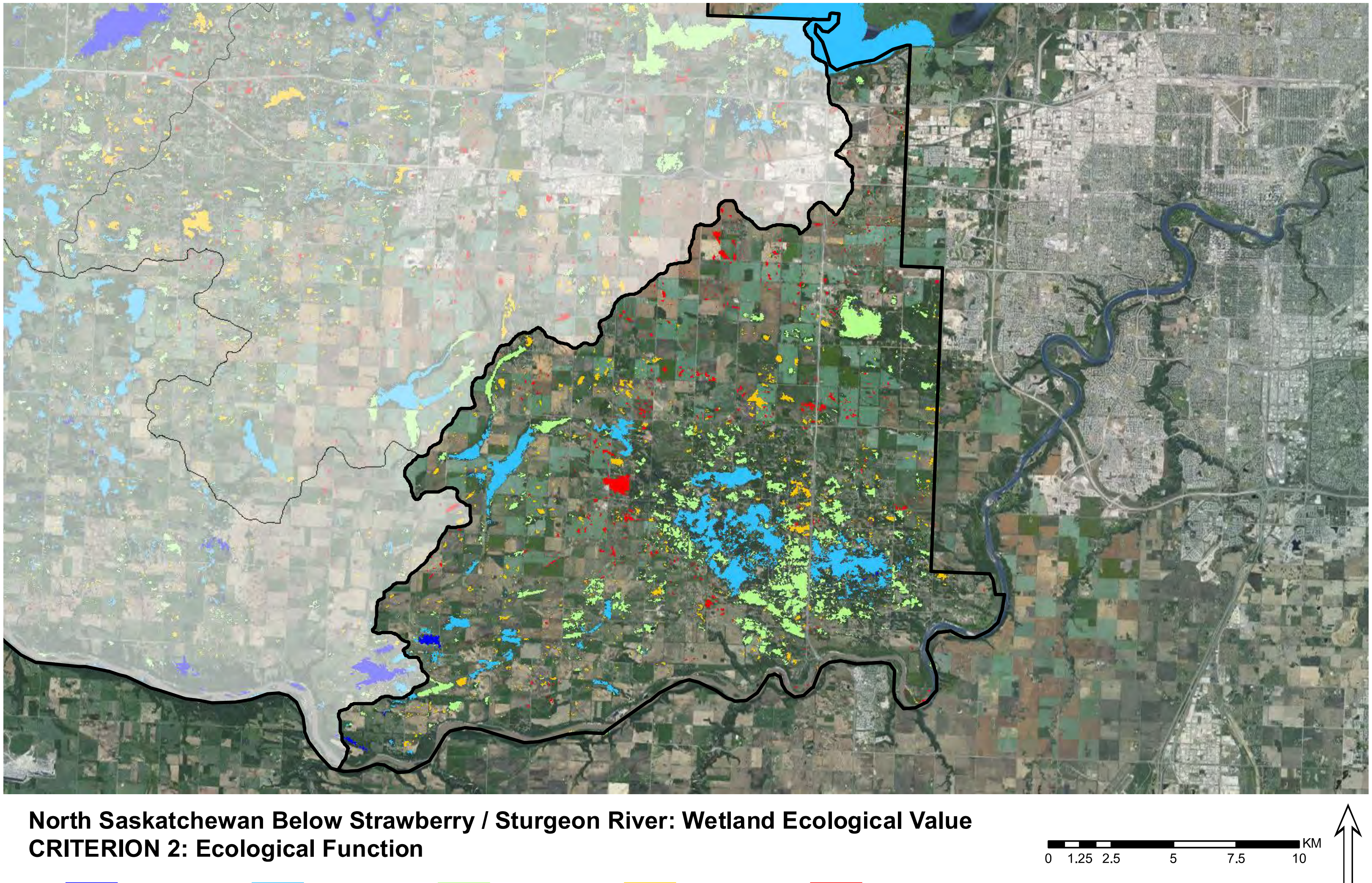
Map 25. North Saskatchewan Below Strawberry / Sturgeon River Wetland Ecological Value: Final Aggregated Score.



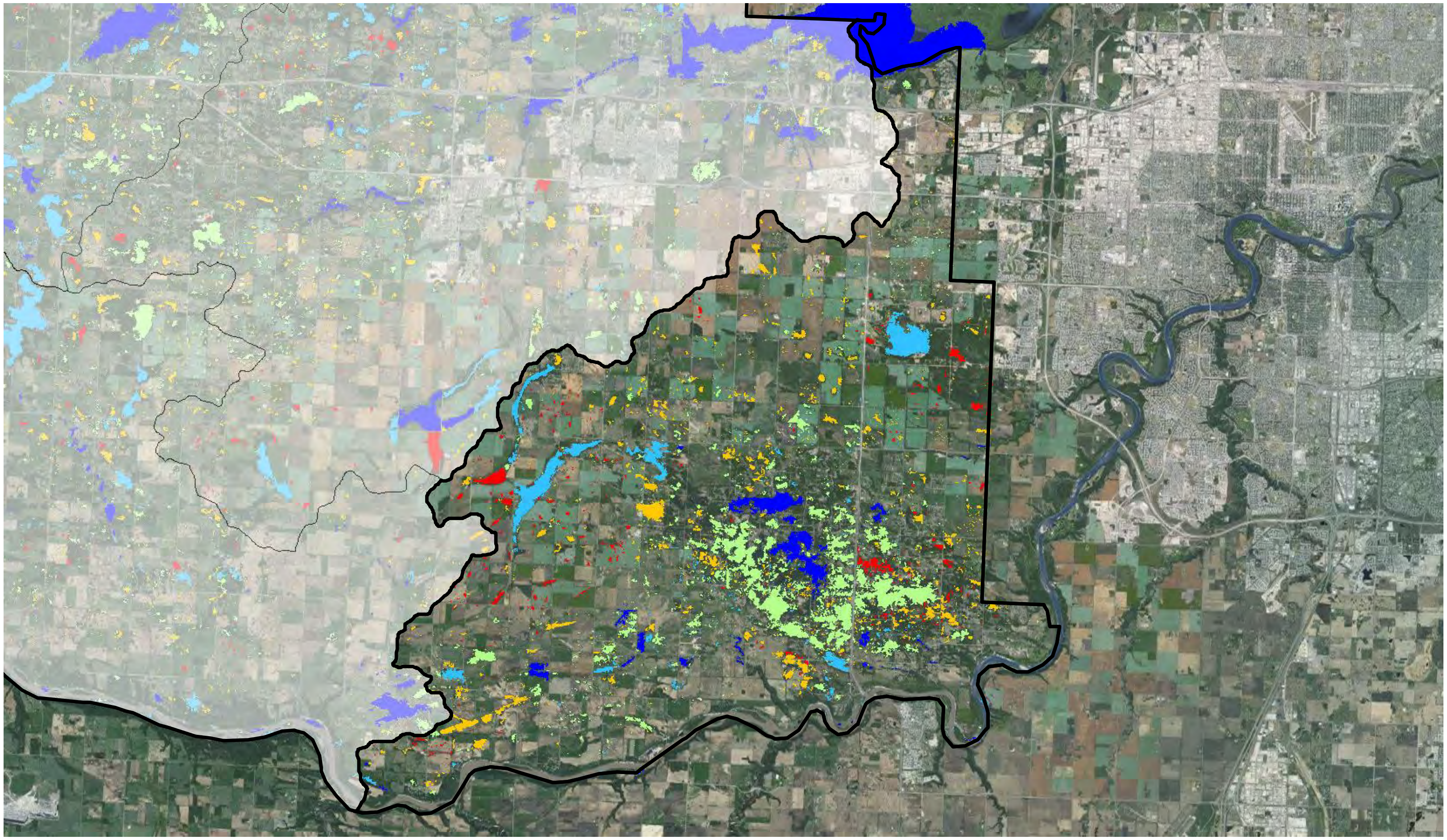
**North Saskatchewan Below Strawberry / Sturgeon River: Wetland Ecological Value**
**CRITERION 1: Biodiversity Value**



Map 26. North Saskatchewan Below Strawberry / Sturgeon River Wetland Ecological Value Criterion 1: Biodiversity Value.




Map 27. North Saskatchewan Below Strawberry / Sturgeon River Wetland Ecological Value Criterion 2: Ecological Function.



**North Saskatchewan Below Strawberry / Sturgeon River: Wetland Ecological Value**
**CRITERION 3: Hydroloic Function & Water Quality Improvement**

0 1.25 2.5 5 7.5 10 KM

Excellent | Very Good | Good | Moderate | Poor

Map 28. North Saskatchewan Below Strawberry / Sturgeon River Wetland Ecological Value Criterion 3: Hydrologic Function & Water Quality Improvement.

## 4.6. Upper Pembina / Lower Pembina / Sturgeon River

**Watershed Area**: 39,953 ha
**Proportion of Total Wetland Cover in Parkland County**: 15%

**2013 Wetland Cover**

**4,556 (91%)**  **4,970 ha**  **414 (8%)**

This watershed unit is one of the smallest in Parkland County, but has the third highest area coverage of wetlands (15%). The vast majority of wetland cover in this watershed unit (91%) is composed of treed wetlands (Bogs, Fens, and Swamps), with Marsh/Open Waters wetlands making up only 8% of the current wetland area. This watershed also contains several named lakes, the largest of which are Isle Lake and Round Lake (Map 29).

At the watershed scale, the majority of wetlands, both in terms of number and area, were assigned an ecological score of either Good, Very Good, or Excellent (Figure 15; Map 30). At the County scale, 19% of the wetland area assigned to the Excellent ecological value category is contained within this watershed, which is the second highest proportion of cover of Excellent wetlands by watershed unit (Figure 10).

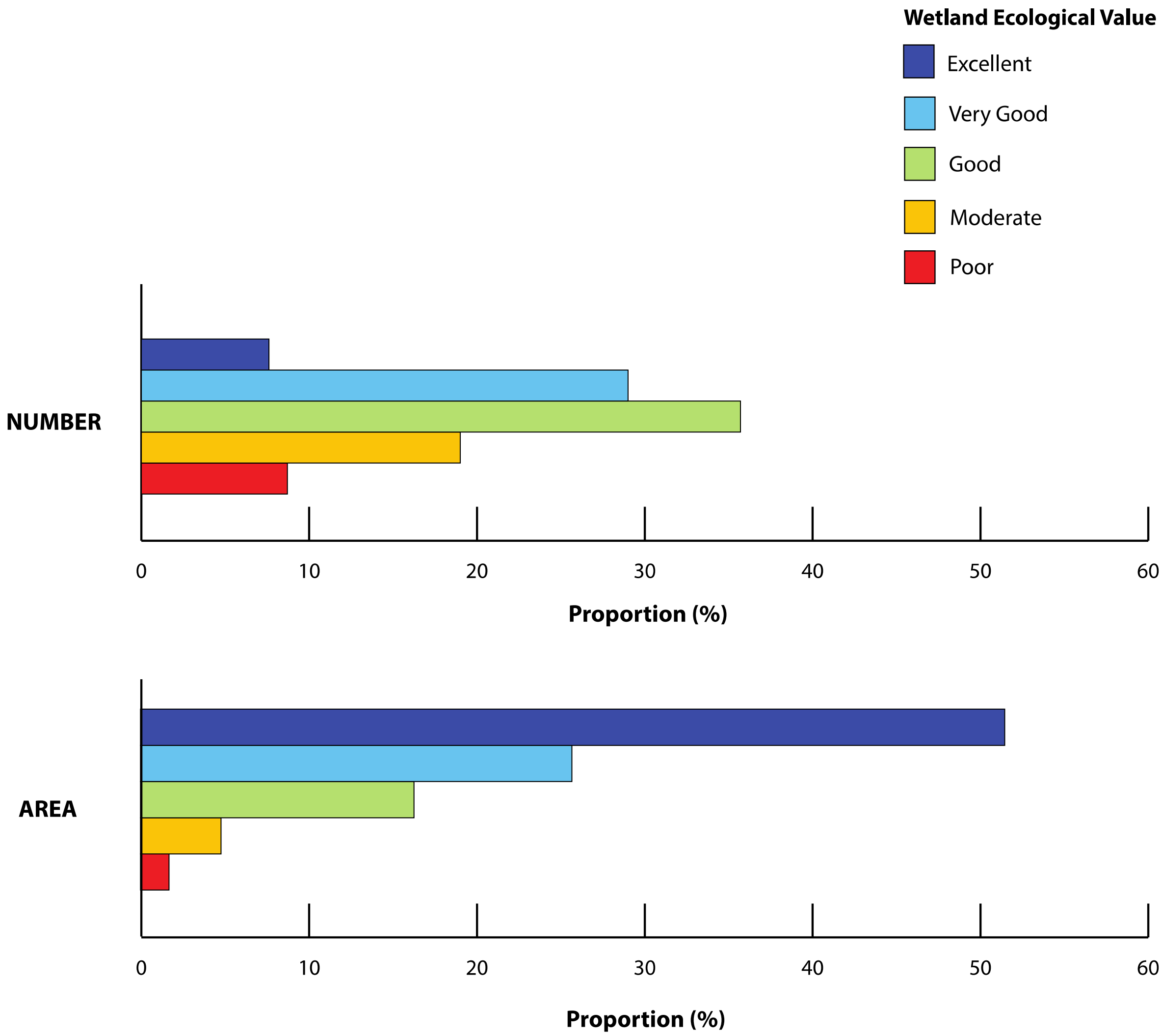
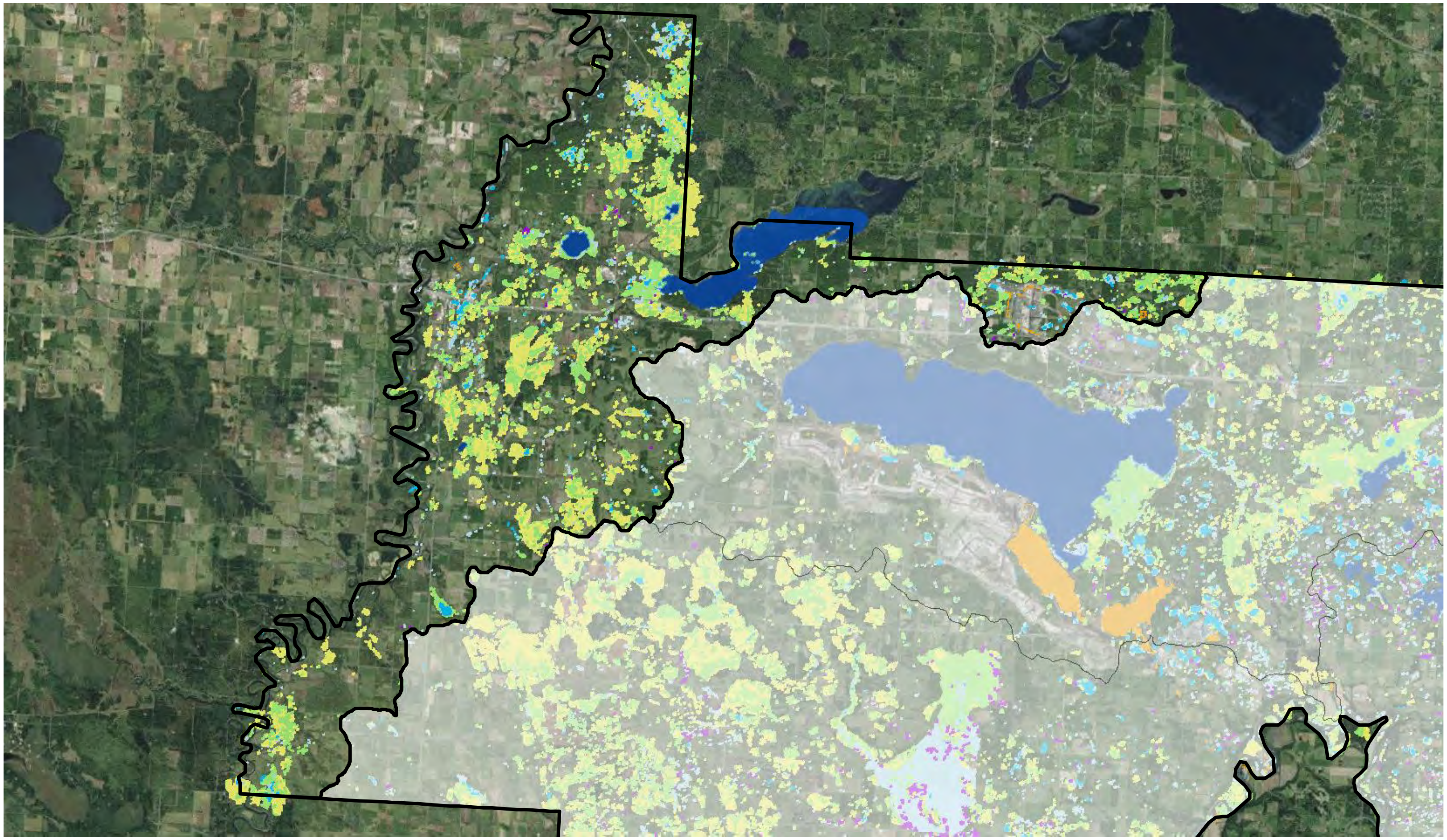



Figure 15. Aggregated Wetland Ecological Value scores, summarized by the number and area of wetlands, in the Upper Pembina / Lower Pembina / Sturgeon River watershed unit.

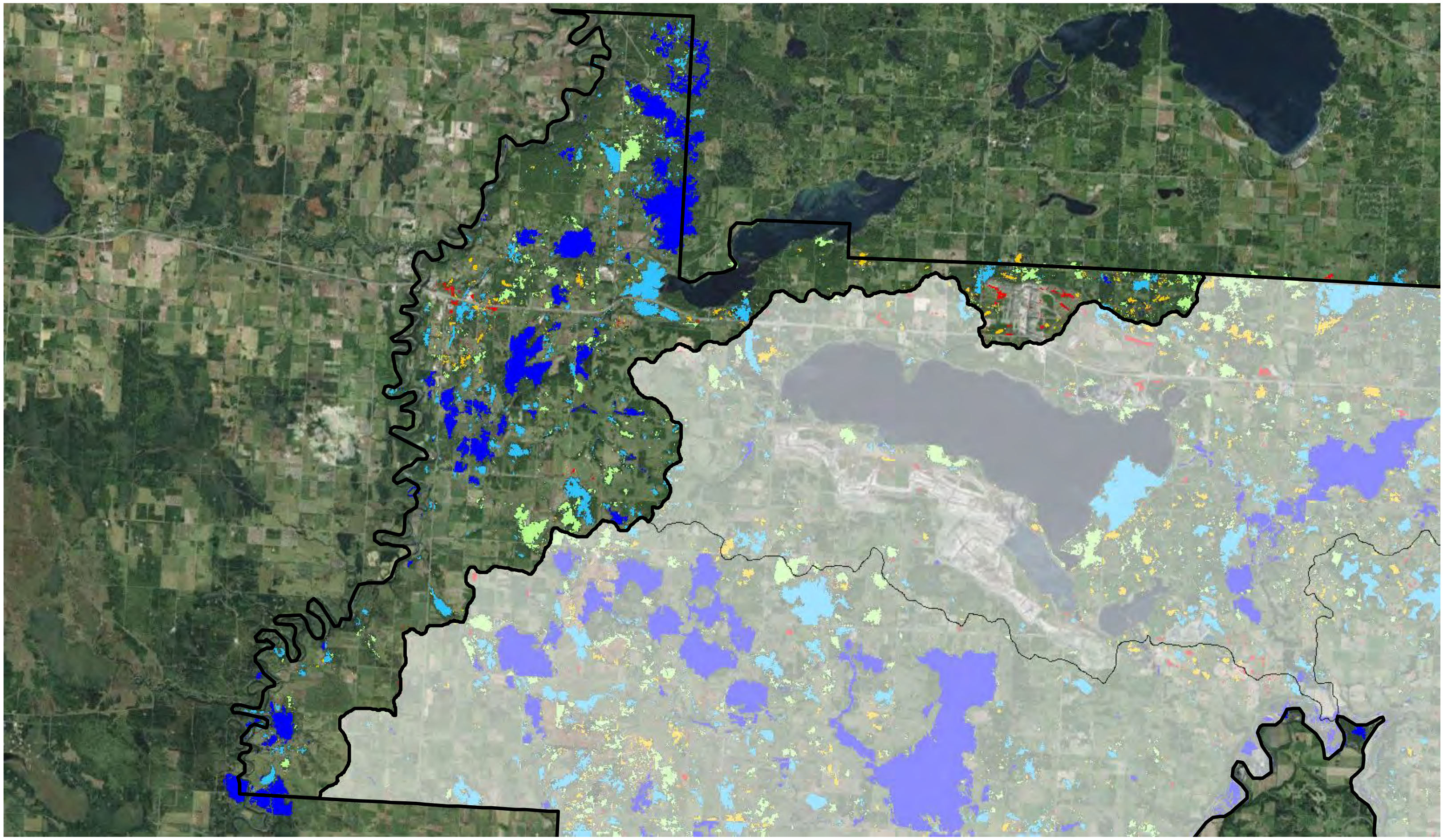


2013 Wetland Invenotry - Upper Pembina / Lower Pembina /Sturgeon River



| | | | | | |
|---|---|---|---|---|---|
| | Marsh | | Bog | | Named Lake |
| | Open Water | | Fen | | Anthropogenic |
| | | | Swamp | | |

Map 29. Current wetland inventory for Upper Pembina / Lower Pembina / Sturgeon River.

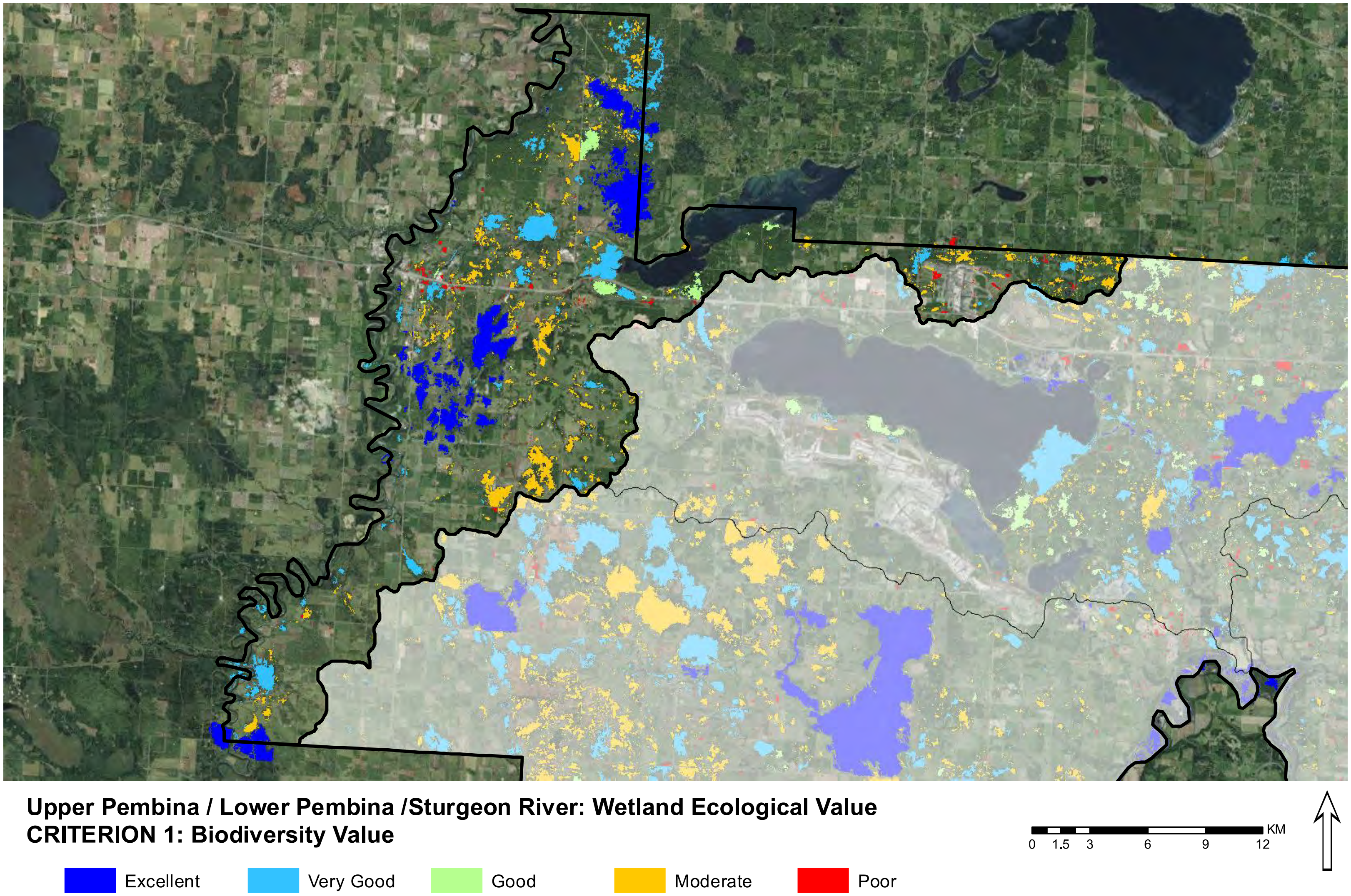


**Upper Pembina / Lower Pembina /Sturgeon River: Wetland Ecological Value**
**FINAL AGGREGATED SCORE**

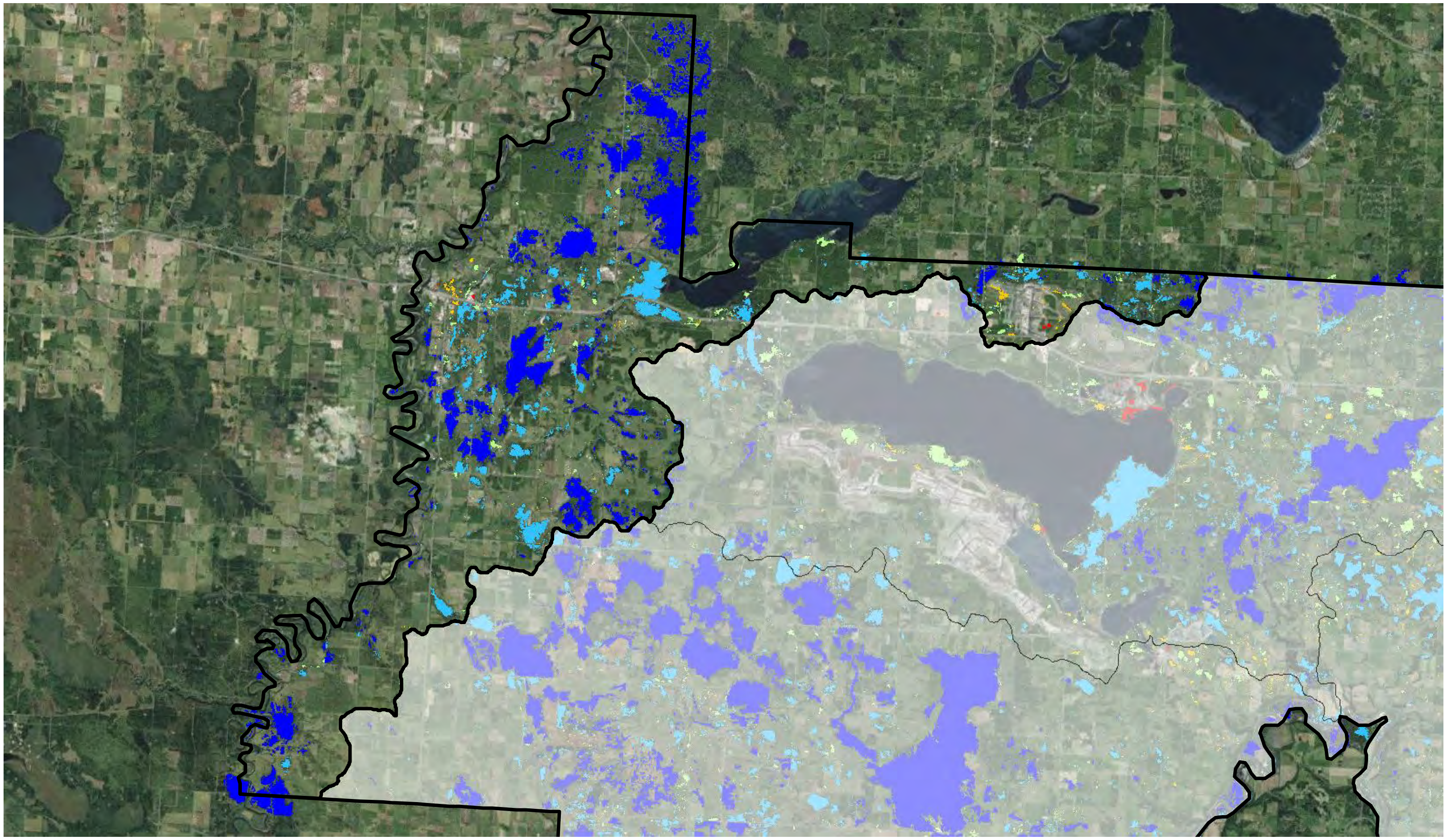
KM
0 1.5 3 6 9 12

Excellent | Very Good | Good | Moderate | Poor

Map 30. Upper Pembina / Lower Pembina / Sturgeon River Wetland Ecological Value: Final Aggregated Score.



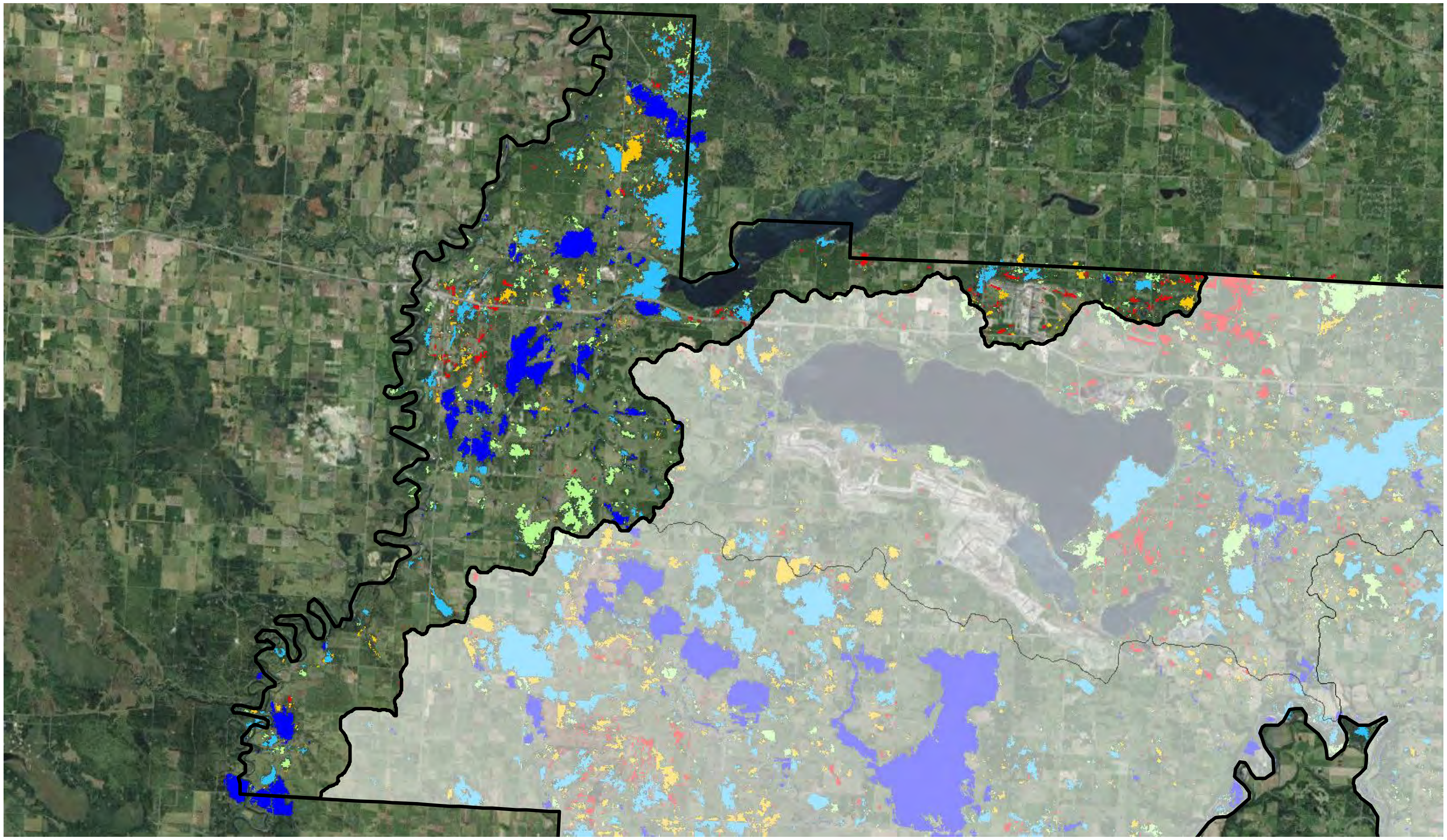

Map 31. Upper Pembina / Lower Pembina / Sturgeon River Wetland Ecological Value Criterion 1: Biodiversity Value.



**Upper Pembina / Lower Pembina /Sturgeon River: Wetland Ecological Value**
**CRITERION 2: Ecological Function**



Map 32. Upper Pembina / Lower Pembina / Sturgeon River Wetland Ecological Value Criterion 2: Ecological Function.



**Upper Pembina / Lower Pembina /Sturgeon River: Wetland Ecological Value**
**CRITERION 3: Hydroloic Function & Water Quality Improvement**

Excellent | Very Good | Good | Moderate | Poor

KM 0 1.5 3 6 9 12

Map 33. Upper Pembina / Lower Pembina / Sturgeon River Wetland Ecological Value Criterion 3: Hydrologic Function & Water Quality Improvement.

## 4.7. Wabamun Creek / Sturgeon River

**Watershed Area**: 65,137 ha
**Proportion of Total Wetland Cover in Parkland County**: 22%

**2013 Wetland Cover**

**5,296 (76%)** | **6,948 ha** | **1,652 (24%)**

Wabamun Creek / Sturgeon River is the largest watershed unit in Parkland County, and has the second highest area of wetland cover (22%). The majority of this cover (76%) is treed wetland (Bog, Fen, and Swamp), with only 24% cover by Marsh and Open Water wetlands (Map 34). This watershed also contains several lakes, the largest of which is Wabamun Lake. In addition, this watershed unit contains portions of the Highvale Coal Mine and TransAlta Power Plant, including two large cooling ponds for TransAlta located south of Wabamun Lake. At the County scale, this watershed unit contains the largest proportion of wetland area that has been ranked as Very Good (28%), as well as having the highest proportion of wetland area ranked as Moderate (29%), and the second highest proportion of wetland area ranked as Poor (23%) (Figure 10). At the watershed scale, the largest proportion of wetlands by number are ranked as Moderate (21%), while the highest proportion of wetlands by area are ranked as Very Good (32%) and Excellent (31%) (Figure 16; Map 35).

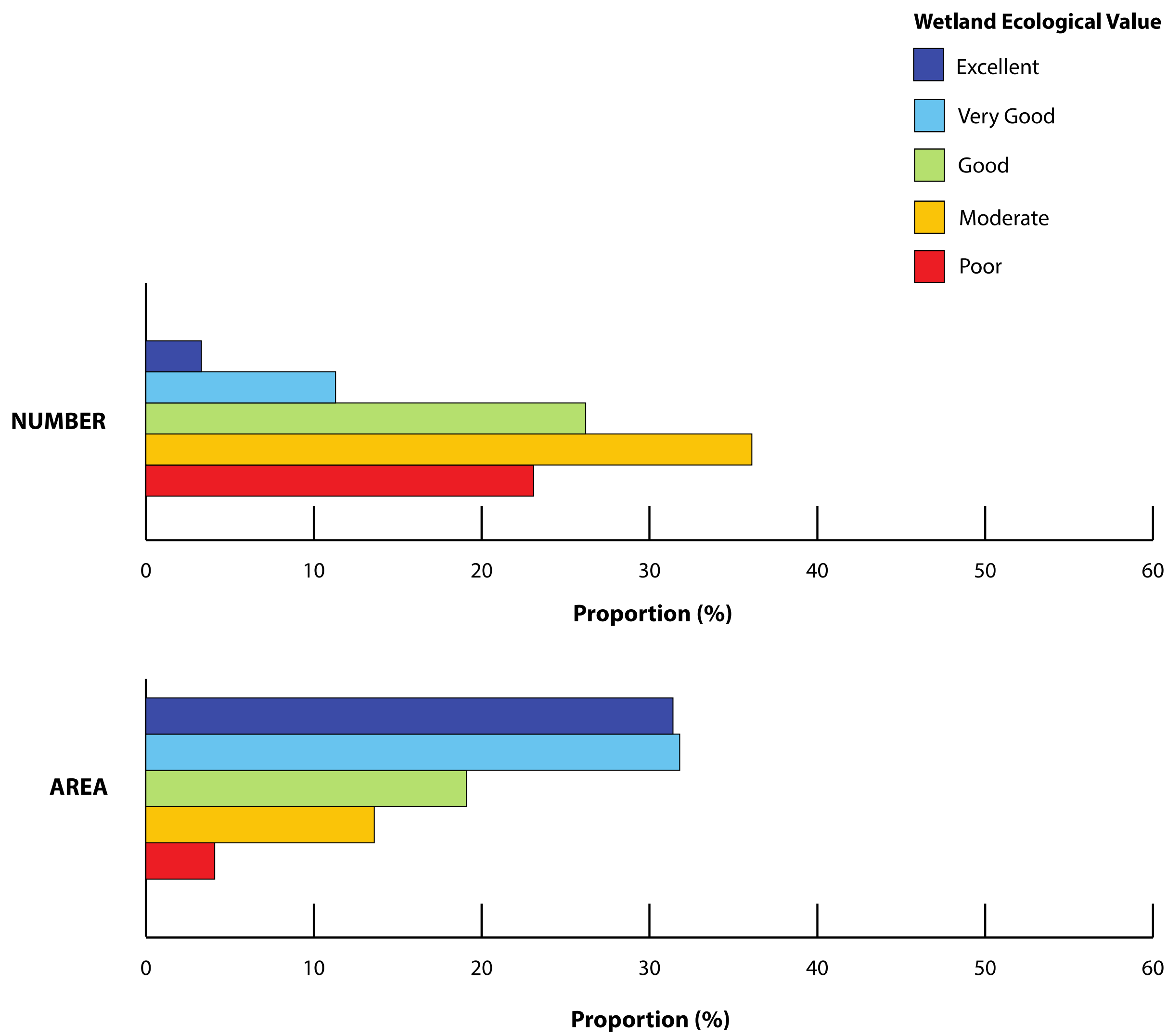
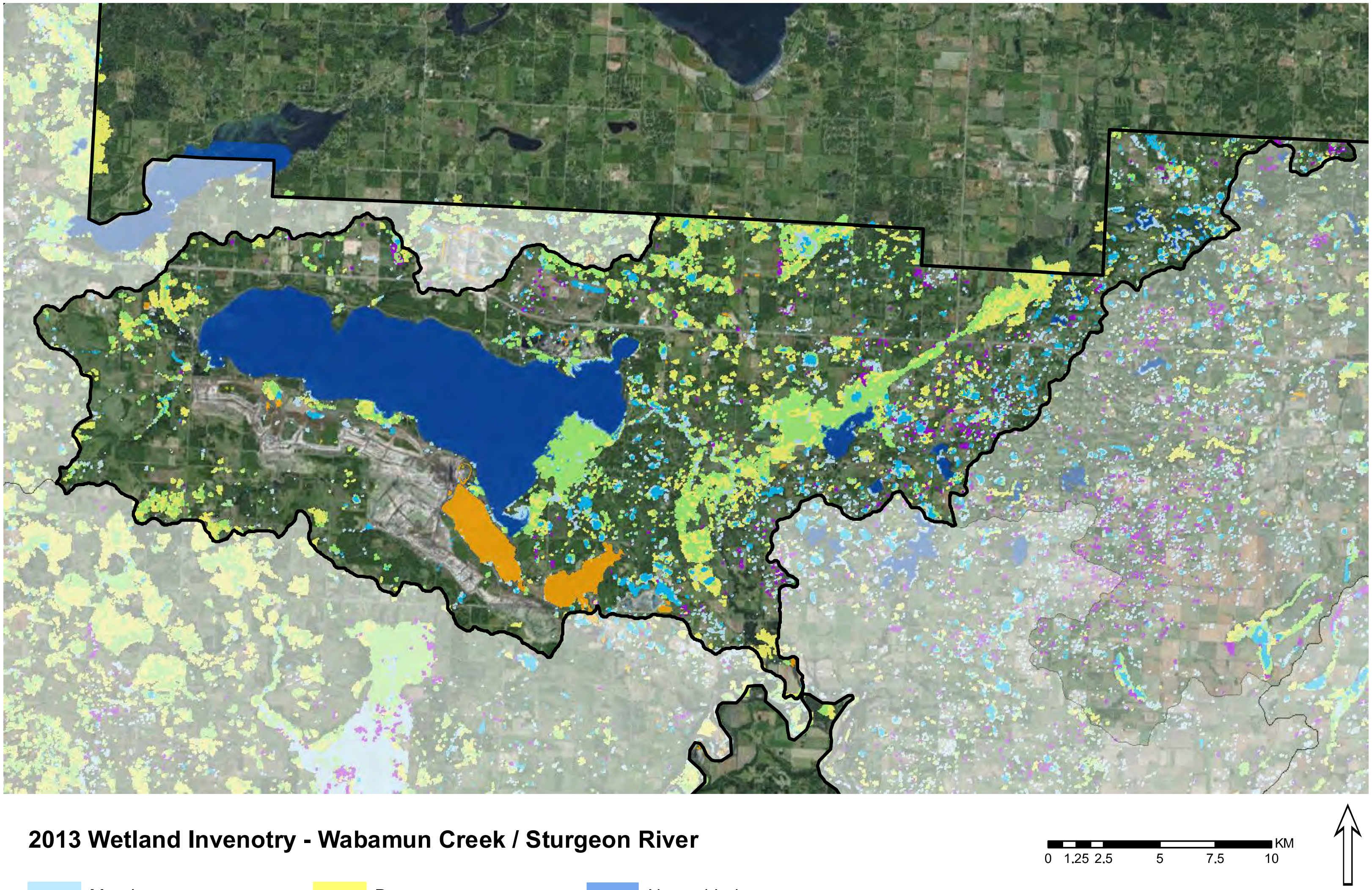
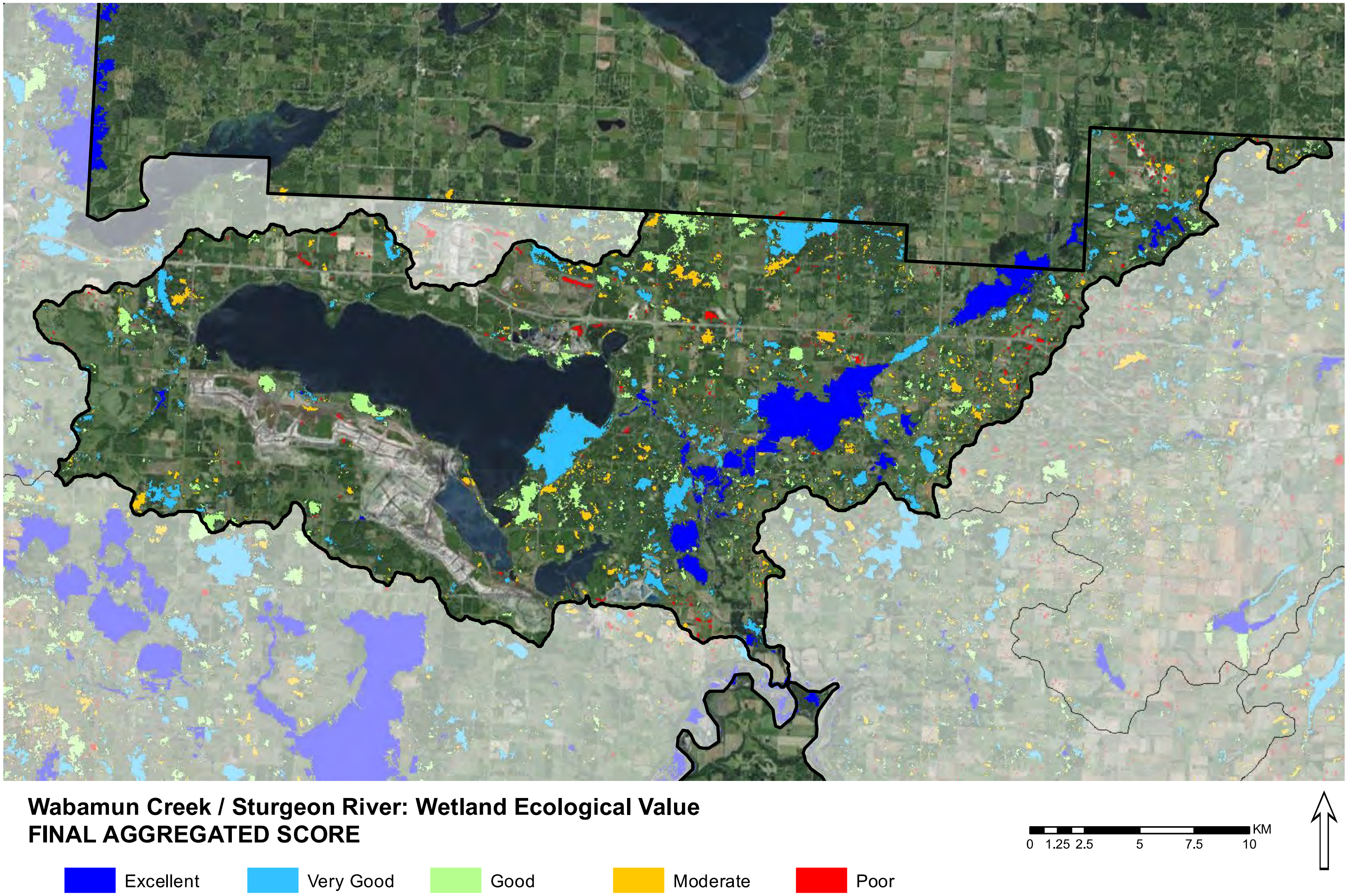


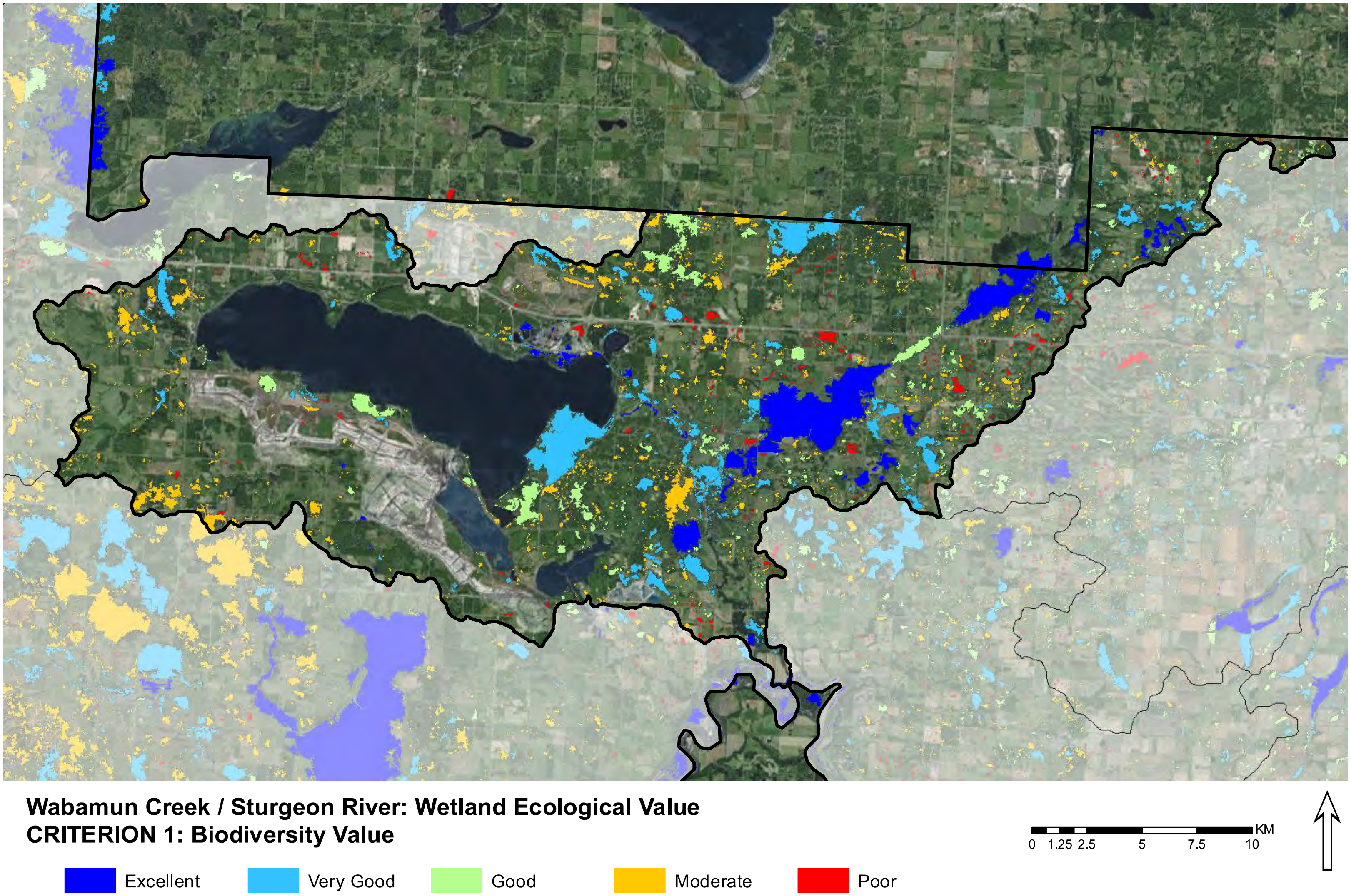

Figure 16. Aggregated Wetland Ecological Value scores, summarized by the number and area of wetlands in the Wabamun Creek / Sturgeon River watershed unit.



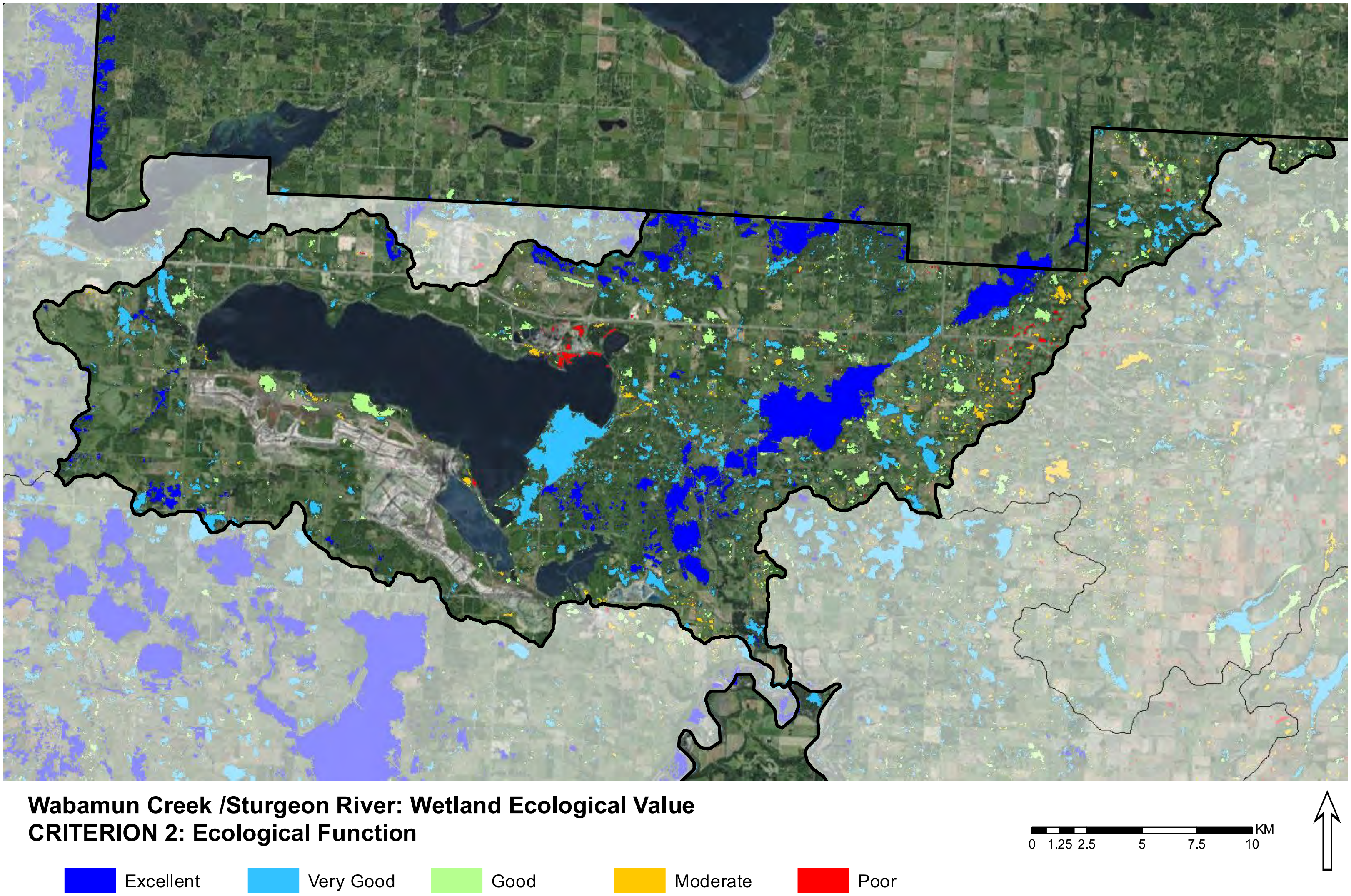

Map 34. Current wetland inventory for Wabamun Creek / Sturgeon River.



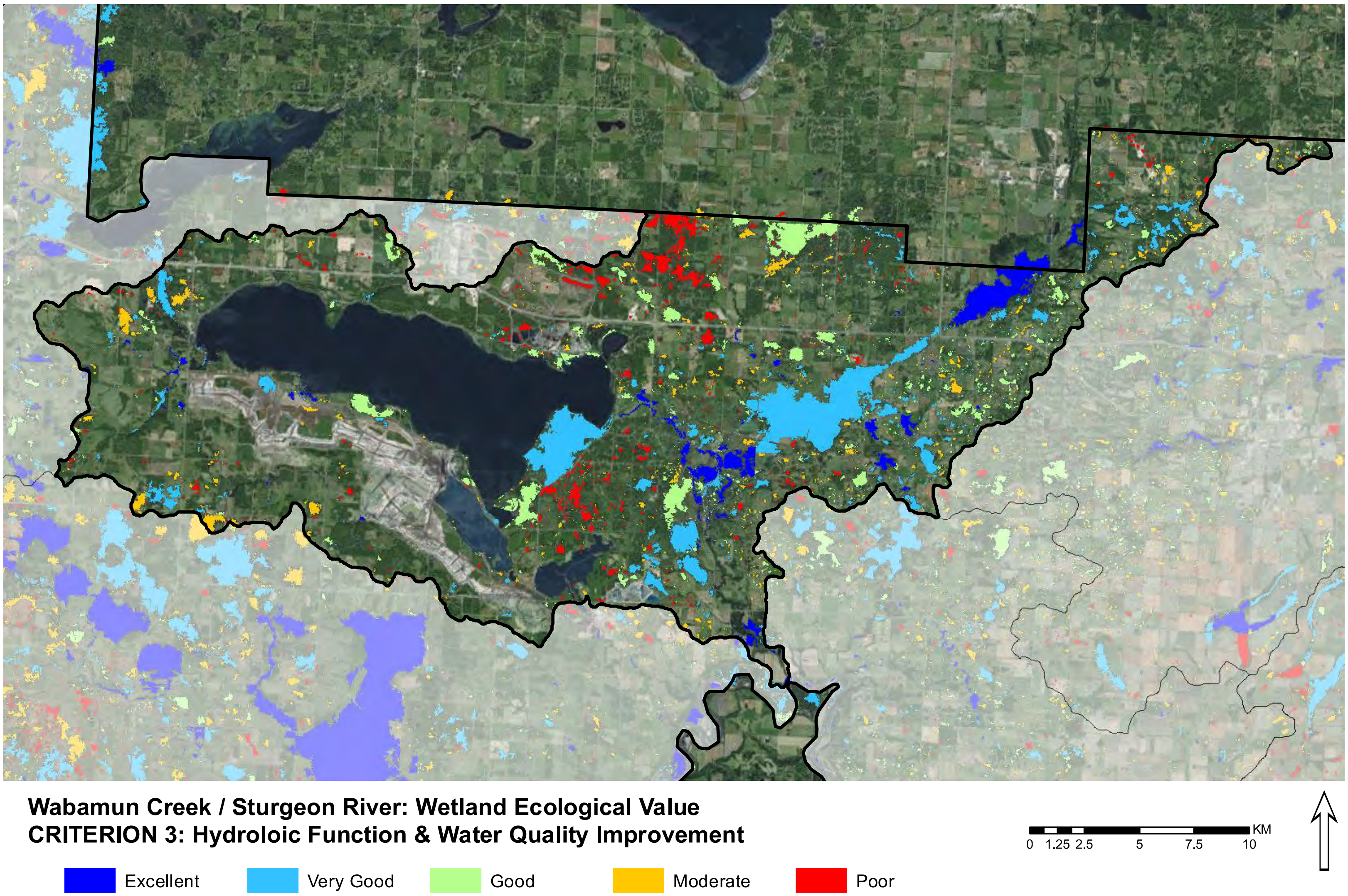

Map 35. Wabamun Creek / Sturgeon River Wetland Ecological Value: Final Aggregated Score.




Map 36. Wabamun Creek / Sturgeon River Wetland Ecological Value Criterion 1: Biodiversity Value.




Map 37. Wabamun Creek / Sturgeon River Wetland Ecological Value Criterion 2: Ecological Function.




Map 38. Wabamun Creek / Sturgeon River Wetland Ecological Value Criterion 3: Hydrologic Function & Water Quality Improvement.

# 5.0 Historic Wetland Loss Assessment

## 5.1. Parkland County

In order to evaluate wetland loss in Parkland County, we compared the extent of wetlands identified in the historical inventory (cira 1950) to the extent of wetlands identified in the current (2013) inventory. For the purpose of this comparison, all wetland polygons were clipped to the Parkland County boundary, and only those wetlands and wetland complexes contained entirely within the County boundary were considered. In addition to wetland loss, wetland area gains were also calculated over this time period. Wetland gains included instances where there was an increase in the size of an existing wetland area due to climate differences or human modification (e.g., excavation), as well as instances where there was the creation of a completely new wetland area as a result of changes to existing surface hydrology (e.g., new wetland areas along roads). Given that the current extent of wetland reported here includes wetland area gains, wetland losses could not be simply calculated as the difference between the historical and current wetland area values; rather the difference between the current and historical extent of wetland area reflects the *change* in wetland area over time, when accounting for both wetland area losses and gains.

To calculate wetland loss in Parkland County, we directly compared wetland objects between the historic and current inventories, and based on this comparison, we distinguished between two different types of wetland loss: complete loss and partial loss. Instances where wetland objects were present in the historic inventory but did not intersect a wetland polygon in the current inventory were considered complete losses, and the area of all historical polygons that did not have a contemporary equivalent was summed to determine the area of complete loss. Partial loss was calculated where historical and current wetland objects intersected, but the difference in area between the two polygons between the two time steps was ≥40%. In these cases, the total area of loss over the 40% threshold was calculated and summed to determine partial loss. It is important to note that because we used a wetland object approach to calculate partial loss, the combining of historic and current wetland polygons into objects often resulted in the creation of very large wetland objects that contained numerous individual wetlands. As a result of this grouping, wetland objects generally represent regions of wetland loss, and may include instances of both complete and partial loss of individual wetlands within the object. Using this wetland object approach, it is likely that there is an under reporting of complete loss, and an over reporting of partial loss, in instances where wetland objects are large and contain many individual wetlands. As such, wetland objects with very high partial loss (e.g., >80%) are likely those in which complete loss of individual wetlands is underreported.

The historical extent of wetlands in Parkland County circa 1950 was estimated to be 72,323 ha, with 62% of the area (44,514 ha) classified as treed wetlands (Bog, Fen, and Swamp), and the remaining 38% (27,809 ha) being classified as Marsh and Open Water wetlands (Figure 17). In contrast, the current extent of all wetlands contained within Parkland County was estimated to be 32,158 ha, with 73% of the area (23,457 ha) classified as treed wetlands (Bog, Fen, and Swamp) and 27% (8,701 ha) classified as Marsh and Open Water wetlands (Figure 17).

Between 1950 and 2013, there was an overall reduction in wetland area of 56,530 ha, constituting a -56% change in wetland area. Historically, treed wetlands (Bog, Fen, Swamp) comprised 62% of the total wetland area, and while there was an overall reduction of 21,057 ha in the area of treed wetlands, the proportion of wetland area comprised of treed wetlands in 2013 increased to 70%. Historically, Marsh and Open Water wetland area in Parkland County was estimated to be 27,809 ha (38% of the total wetland area), and between 1950 and 2013, there was an overall reduction in the area of Marsh and Open Water wetlands to 19,108 ha (-69% change). The current extent of Marsh and Open Water wetlands is estimated to be 8,701 ha, which constitutes only 27% of the total current wetland area.

The analysis of wetland loss in Parkland County revealed that the majority of loss can be attributed to the partial loss of treed wetlands (Figure 18 and Figure 19), which appears to have been driven by a variety of different factors, including urbanization, agriculture, and peat mining. In many cases, these partial losses have caused fragmentation of remaining wetland habitat, which in turn has resulted in an overall reduction in the average size of wetlands in the County (Map 39). When complete wetland loss is considered, it is apparent that Marsh and Open Water wetlands have been disproportionately impacted, with approximately 80% of the complete losses being attributed to these wetland types (Figure 19).

Within the County, the highest rates of complete and partial loss on a watershed area basis have occurred in the North Saskatchewan Below Strawberry / Sturgeon River watershed unit, followed by the North Saskatchewan Above Wabamun (A), and Wabamun Creek / Sturgeon River watershed units (Table 2; Map 40). When loss is considered separately for treed and non treed wetlands, the watershed unit that experienced the highest Marsh and Open Water wetland area loss per hectare was also the North Saskatchewan Below Strawberry / Sturgeon River (Map 40), while the highest area loss of treed wetlands per hectare was in the North Saskatchewan Above Wabamun (A) watershed unit (Table 2; Map 42).

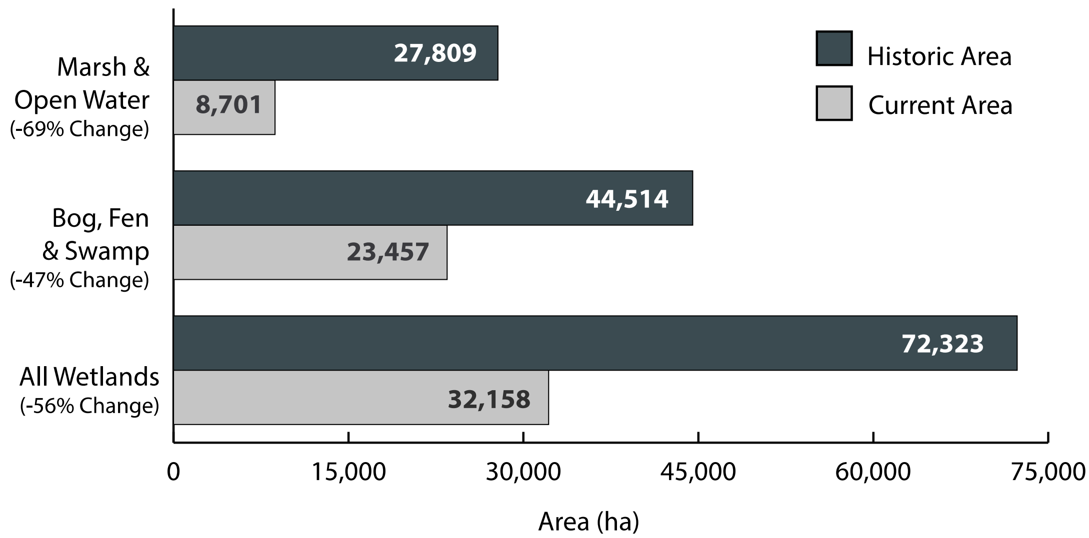



Figure 17. Summary of the wetland area change in Parkland County between cira 1950 and 2013.

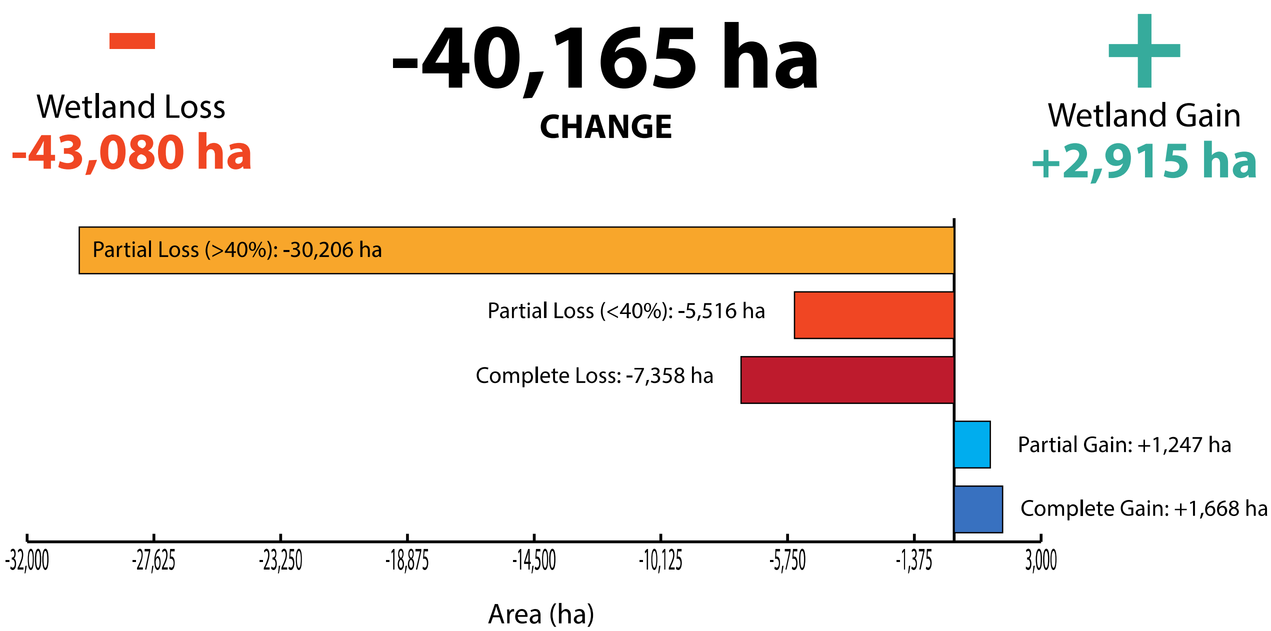



Figure 18. Wetland area change in Parkland County, summarized by the various types of wetland losses and gains measured as part of this study.

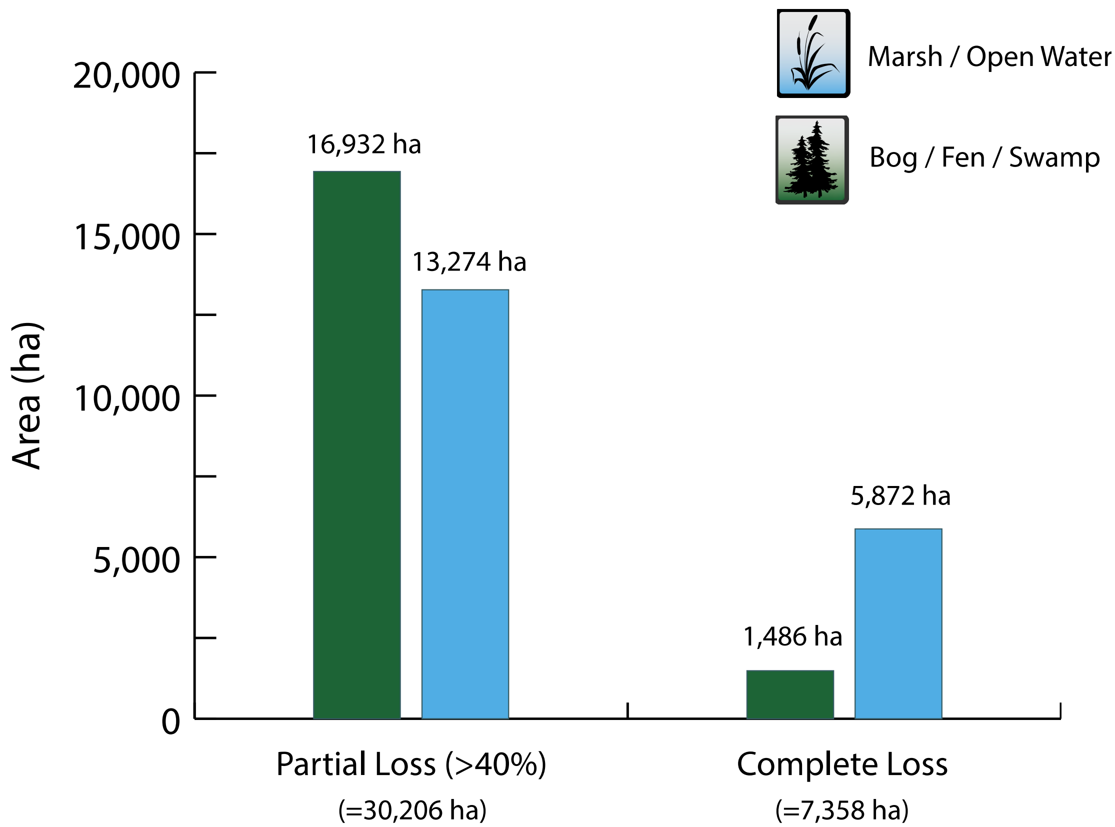
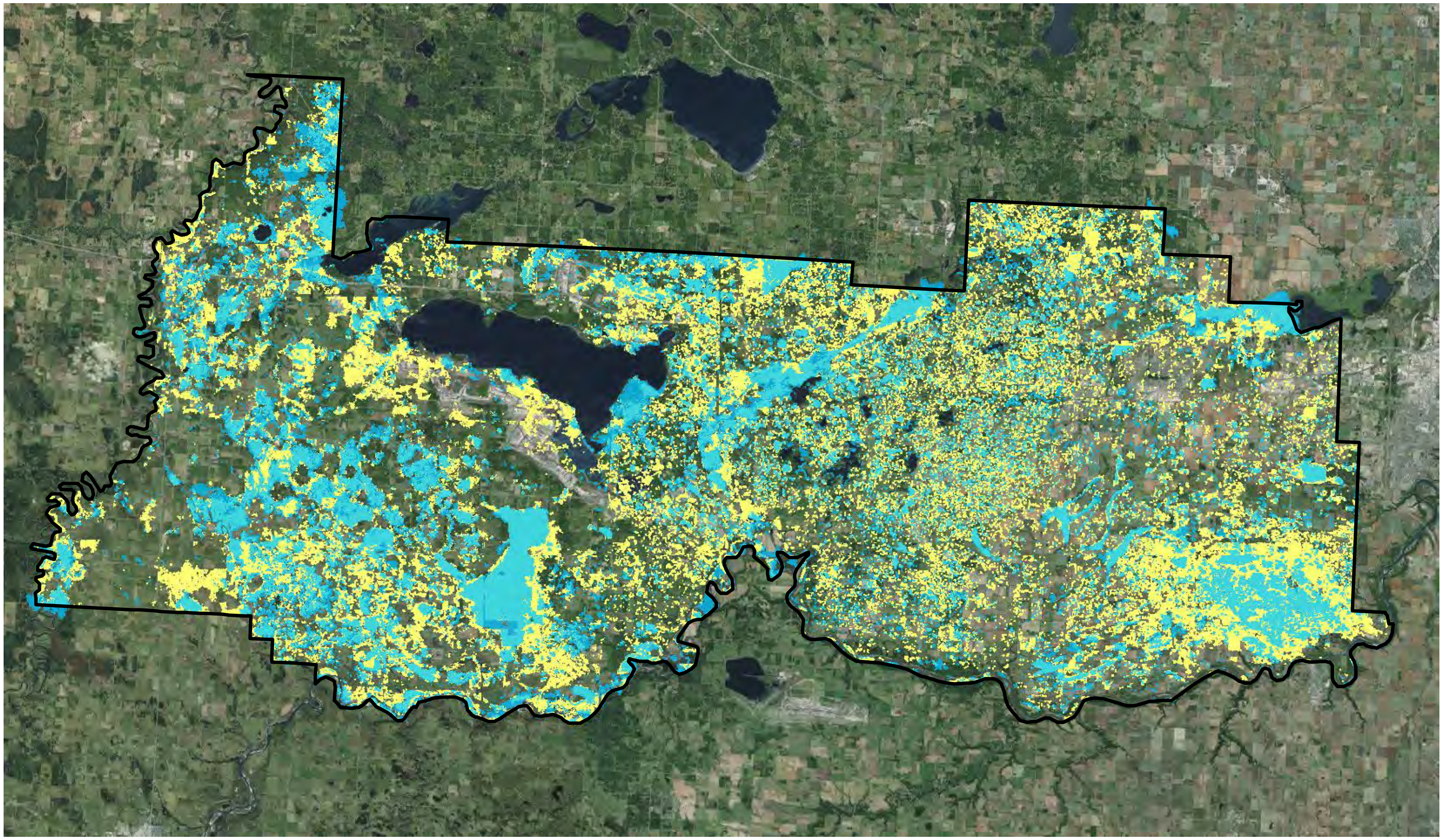



Figure 19. Summary of the estimated area of partial (>40%) and complete wetland loss in Parkland County between circa 1950 and 2013.

Table 2. Summary of historical wetland loss in Parkland County between ~1950 and 2013.

| HUC 8 Watershed Unit | Area (ha) | Historic Wetland Area Extent (ha) | Current Wetland Area Extent (ha) | Complete + Partial (>40%) Wetland Loss (ha) | Wetland Loss / ha | Marsh + Open Water Loss / ha | Bog, Fen, Swamp Loss / ha |
|---|---|---|---|---|---|---|---|
| Atim Creek | 44,780 | 7,731 | 3,100 | 4,841 | 0.11 | 0.08 | 0.03 |
| North Saskatchewan Above Wabamun (A) | 63,213 | 23,114 | 11,922 | 8,795 | 0.14 | 0.04 | 0.10 |
| North Saskatchewan above Wabamun (B) | 26,952 | 3,195 | 1,323 | 2,125 | 0.08 | 0.07 | 0.01 |
| North Saskatchewan below Strawberry / Sturgeon River | 37,783 | 13,126 | 3,895 | 9,255 | 0.24 | 0.16 | 0.08 |
| Upper Pembina / Lower Pembina / Sturgeon River | 39,953 | 9,547 | 4,970 | 4,191 | 0.10 | 0.03 | 0.08 |
| Wabamun Creek / Sturgeon River | 65,137 | 15,610 | 6,948 | 8,357 | 0.13 | 0.06 | 0.07 |
| Parkland County | 277,817 | 72,323 | 32,158 | 37,563 | 0.14 | 0.07 | 0.07 |



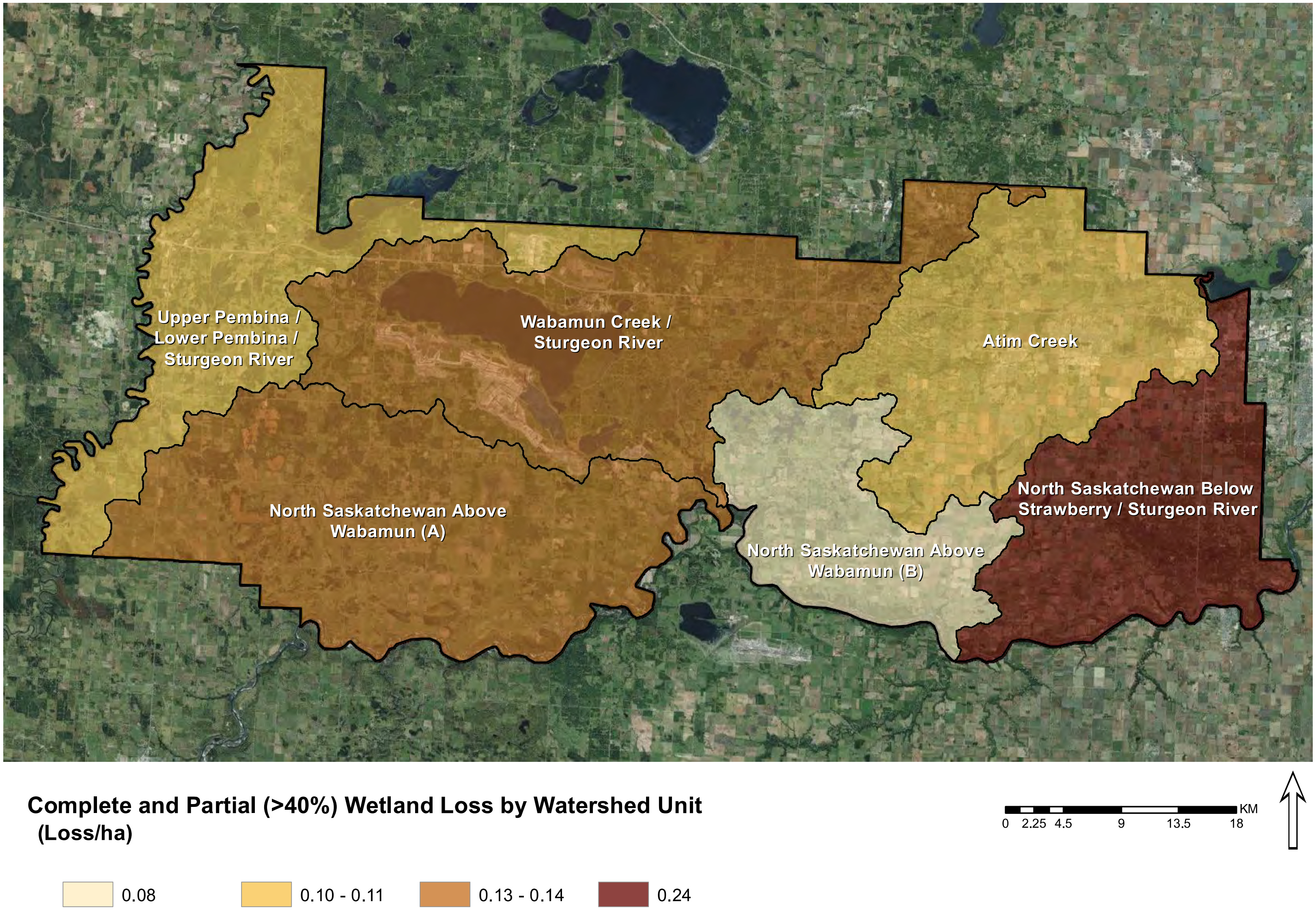
**Comparision of Historic & Current Wetland Extent**

Current (2013) Wetland Extent

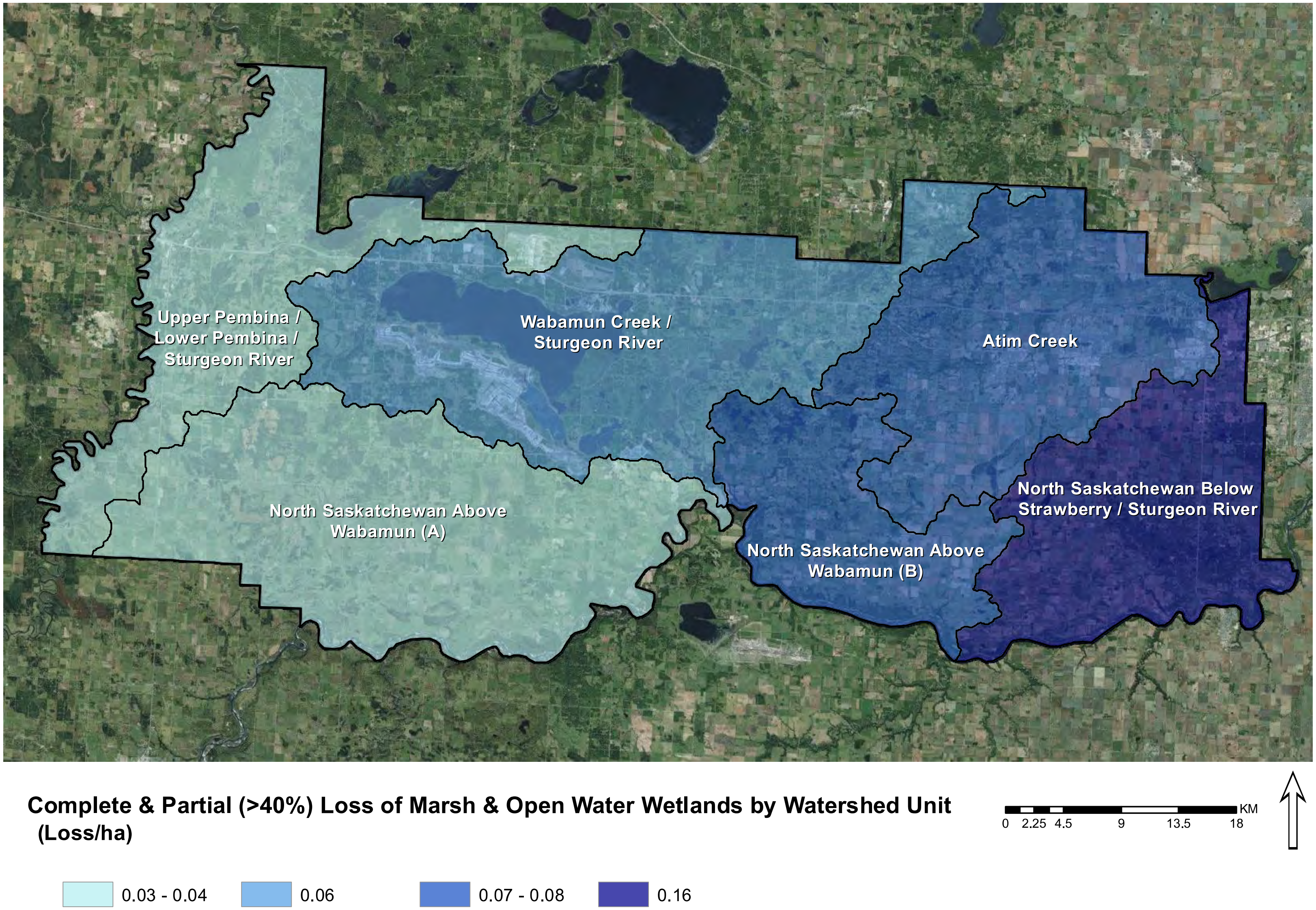
Historic (circa 1950) Wetland Extent



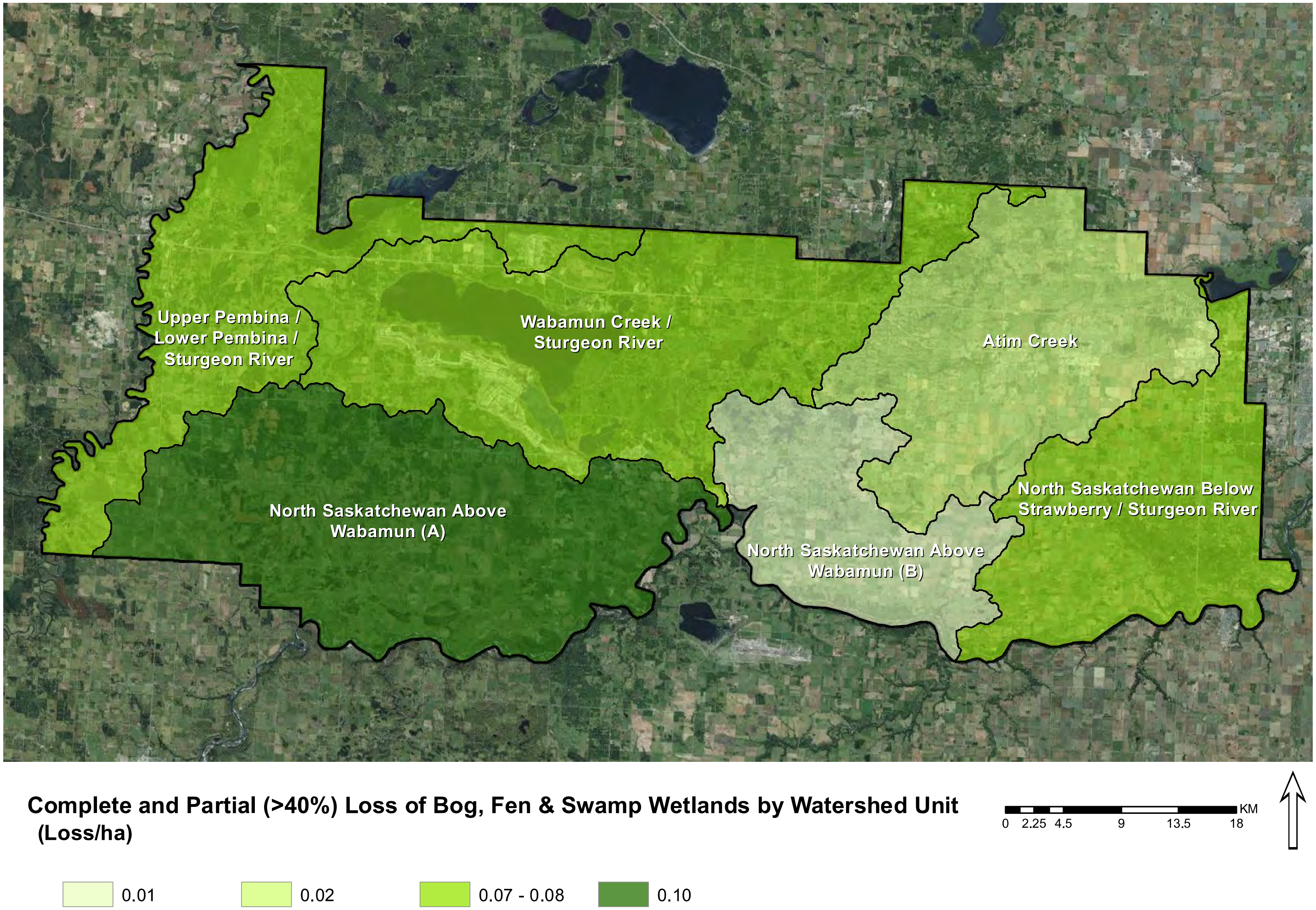
Map 39. Comparison of the historical (circa 1950) and current (2013) wetland extent in Parkland County..




Map 40. Total wetland loss (complete + partial) per hectare, summarized by watershed unit.




Map 41. Complete and partial (>40%) loss of Marsh and Open Water wetlands per hectare, summarized by watershed unit.




Map 42. Complete and partial (>40%) loss of Bog, Fen, and Swamp wetlands per hectare, summarized by watershed unit.

## 5.2. Atim Creek

**Area of Watershed Unit**: 44,780 ha
**Total Wetland Loss per Hectare**: 0.11
**Marsh & Open Water Loss per Hectare**: 0.08
**Bog, Fen & Swamp Loss per Hectare**: 0.03

The historical extent of wetlands in the Atim Creek watershed unit circa 1950 was estimated to be 7,731 hectares, with Marsh and Open Water wetlands making up a larger proportion of wetland area (64%) than treed wetlands (36%) (Figure 21). The current extent of all wetlands contained within the Atim Creek watershed unit was estimated to be 3,100 ha, with an overall reduction in wetland area of 4,631 ha (-60% change) (Figure 21). Marsh and Open Water wetlands experienced a greater change in area (-73%) than treed wetlands (-37%), which represented the second highest loss/ha rate for Marsh and Open Water wetlands in the County (Table 2).

The historical loss assessment revealed that the loss of Marsh and Open Water wetlands accounted for approximately 77% of the overall wetland losses in this watershed unit, with the loss of treed wetlands making up approximately 13% of wetland loss (Figure 22). Spatially, loss is concentrated in the northern and western portions of the watershed unit, with a number of wetland objects throughout the watershed unit experiencing high rates (>60%) of partial loss (Map 43 and Map 44).

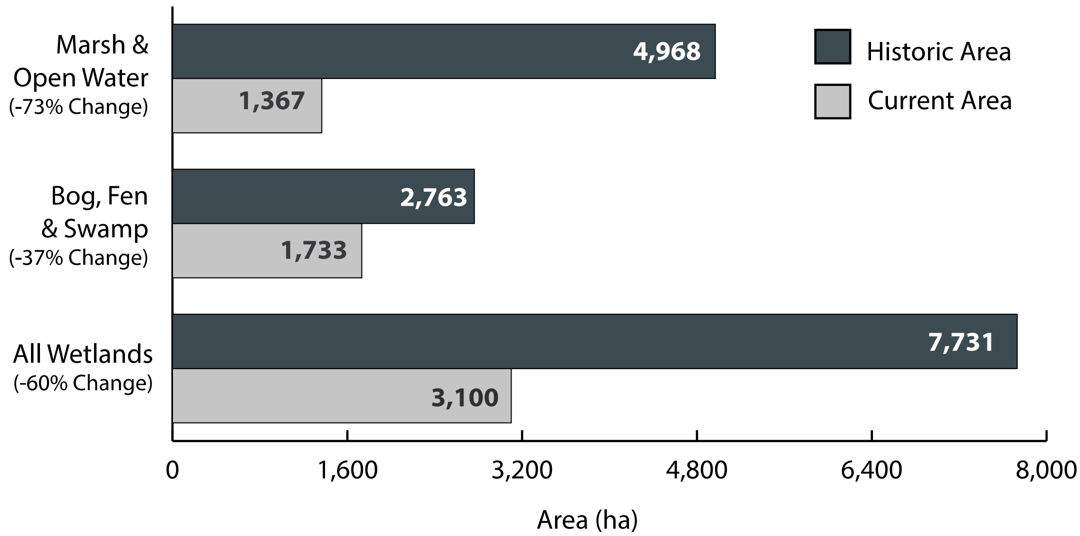



Figure 20. Summary of the wetland area change in the Atim Creek watershed unit between cira 1950 and 2013.

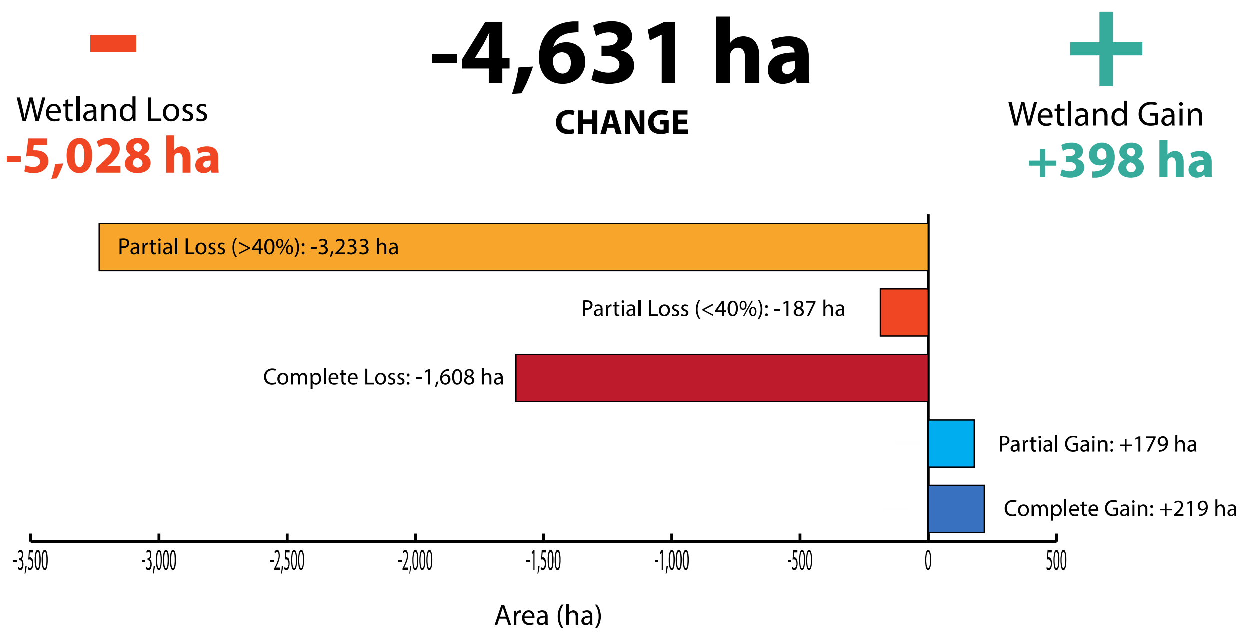



Figure 21. Wetland area change in Atim Creek watershed unit, summarized by the various types of wetland losses and gains measured as part of this study.

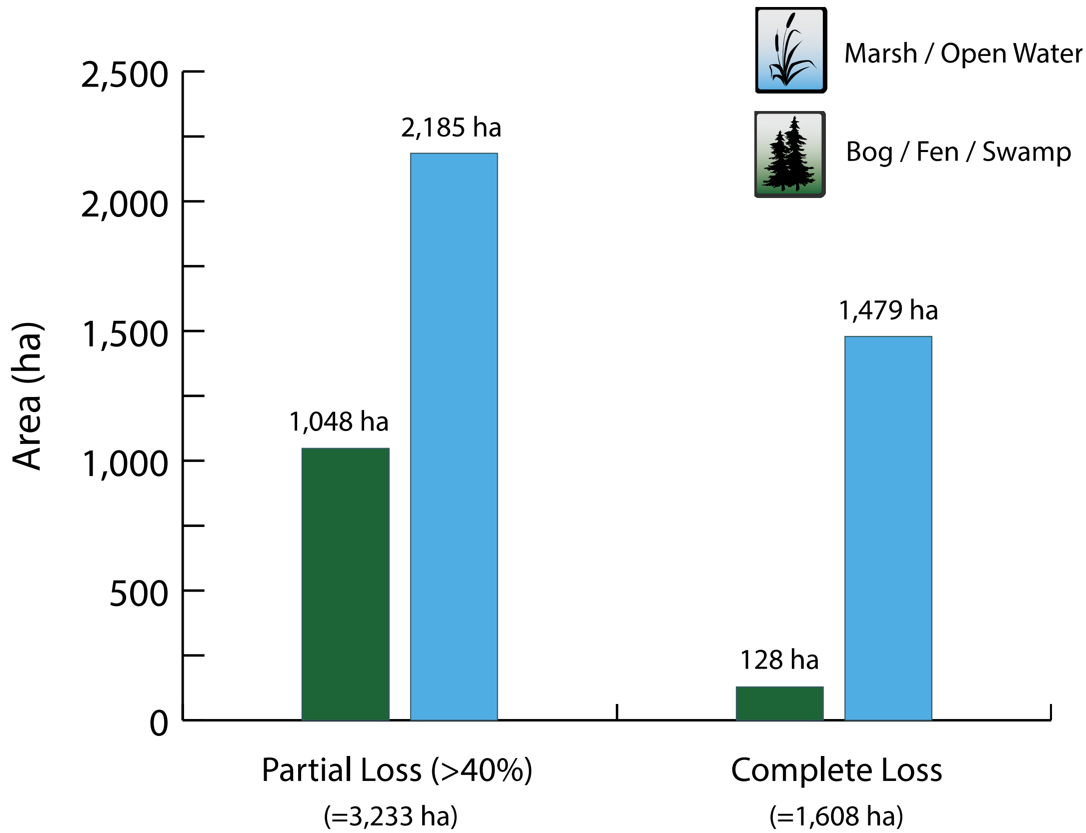
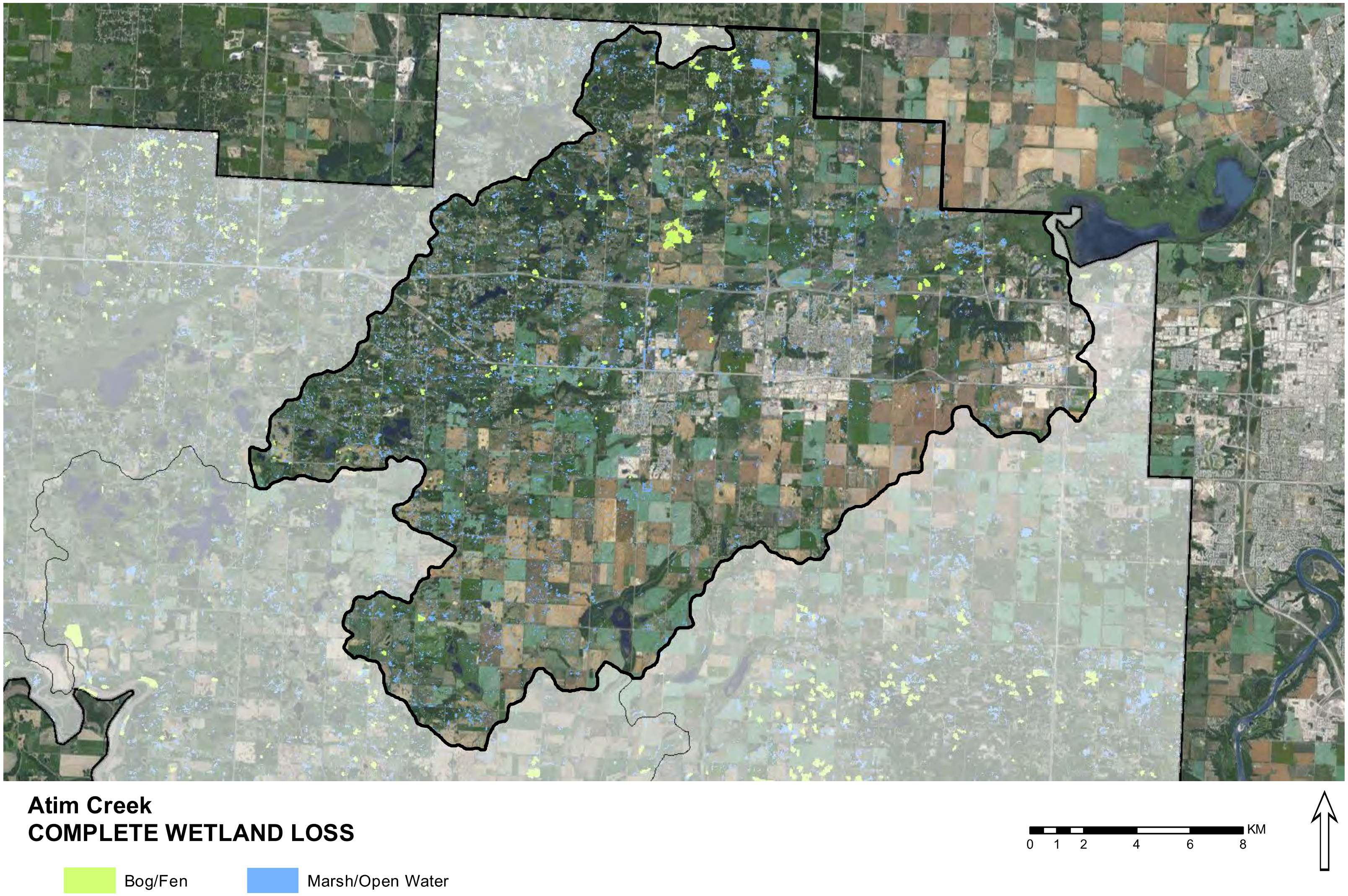
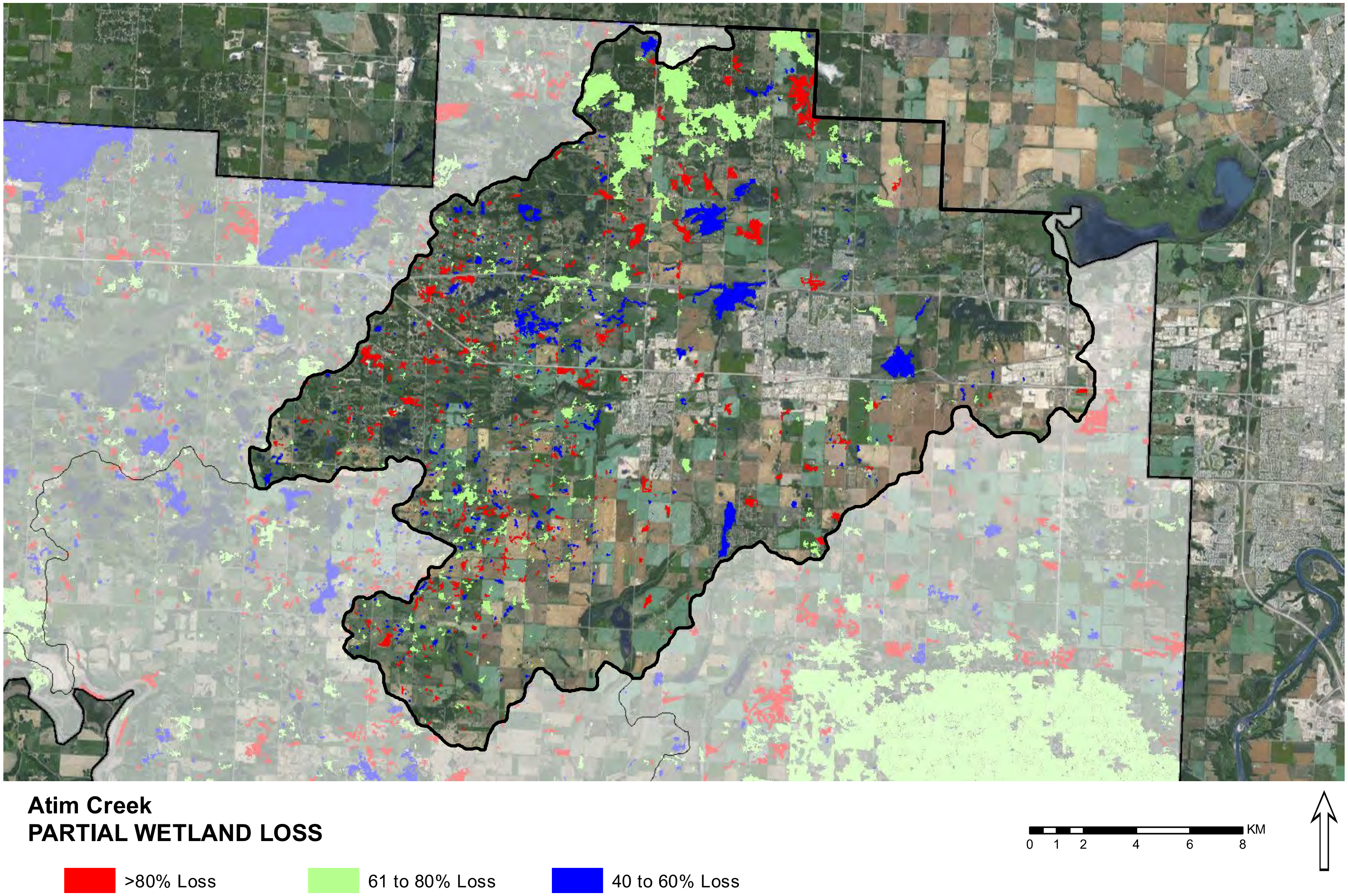



Figure 22. Summary of the estimated area of partial (>40%) and complete wetland loss in Atim Creek watershed unit between circa 1950 and 2013.




Map 43. Complete wetland loss in the Atim Creek watershed unit watershed unit.




Map 44. Partial wetland loss in the Atim Creek watershed unit..

## 5.3. North Saskatchewan Above Wabamun (A)

**Area of Watershed Unit**: 63,213 ha
**Total Wetland Loss per Hectare**: 0.14
**Marsh & Open Water Loss per Hectare**: 0.04
**Bog, Fen & Swamp Loss per Hectare**: 0.10

Historically, the North Saskatchewan Above Wabamun A watershed unit had the greatest extent of wetland cover (23,114 ha), the majority of which (78%) was classified as treed wetlands (Bog, Fen, Swamp) (Figure 23). In 2013, wetland area in this watershed unit was estimated to be 11,922 ha, a change of -48% (-11,192 ha; Figure 24). Both treed and Marsh/Open Water wetlands experienced a very similar proportional area change (-48% and -49%, respectively) between the two time periods (Figure 23).

Partial loss of treed wetlands accounted for the greatest proportion (64%) of total wetland loss in this watershed unit (Figure 25), and the loss of treed wetlands per hectare (0.10) was the highest in the County (Table 2). Combined loss of all wetland types in this watershed on a per area basis was 0.14, which was the second highest overall loss/ha measured in the County. Spatially, complete loss was detected throughout the basin (Map 45); however, partial loss was concentrated in the western portion of the watershed unit (Map 46). In these areas, partial loss appears to be driven primarily by peat extraction and land clearing activities associated with agriculture.

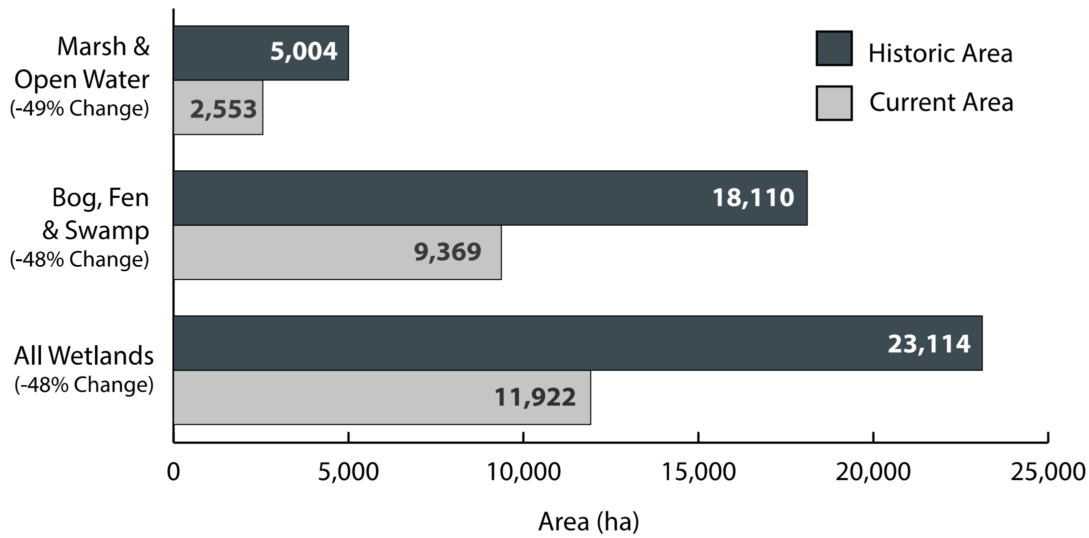



Figure 23. Summary of the wetland area change in the North Saskatchewan Above Wabamun (A) watershed unit between circa 1950 and 2013.

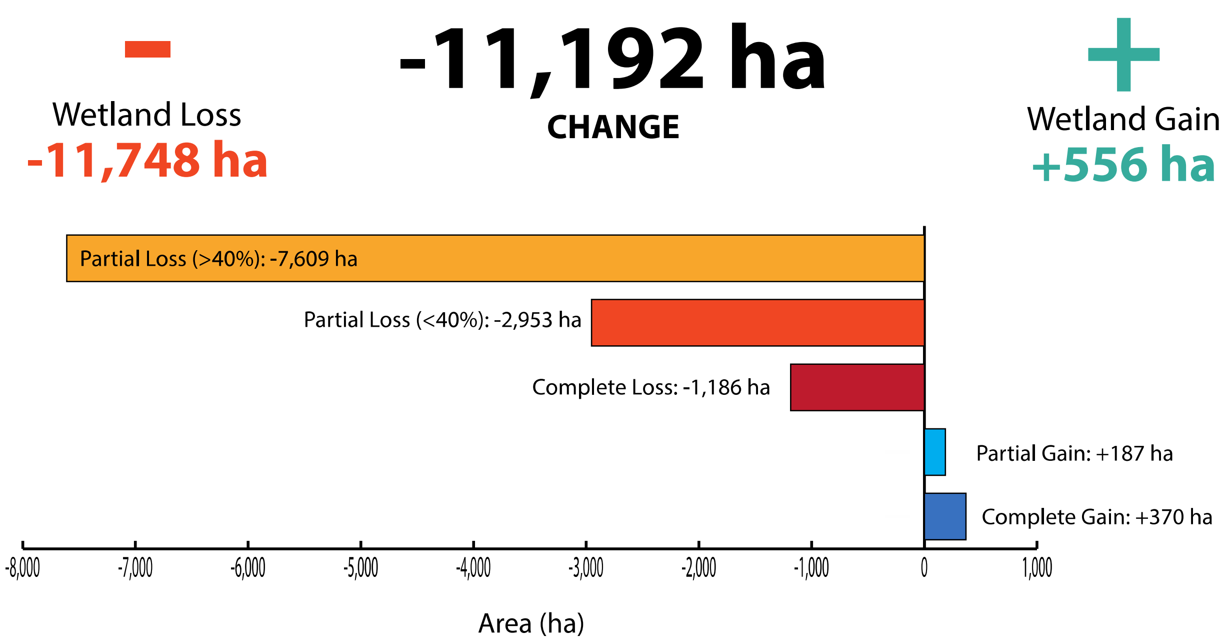



Figure 24. Wetland area change in the North Saskatchewan Above Wabamun (A) watershed unit, summarized by the various types of wetland losses and gains measured as part of this study.

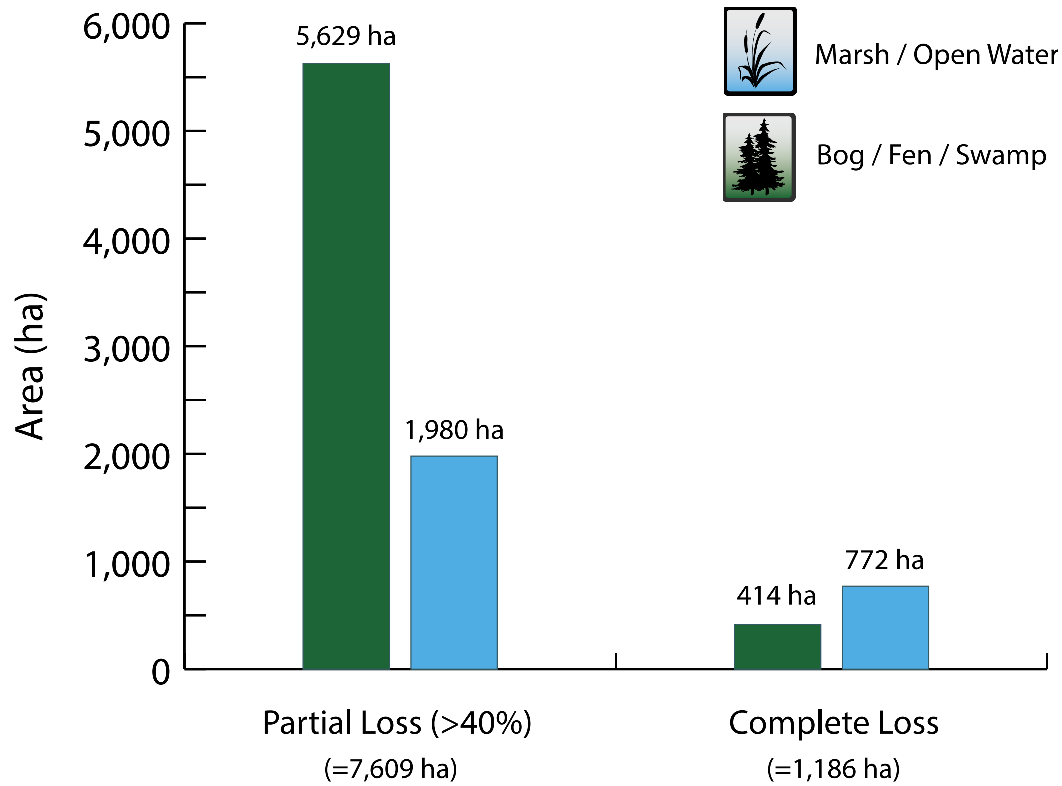
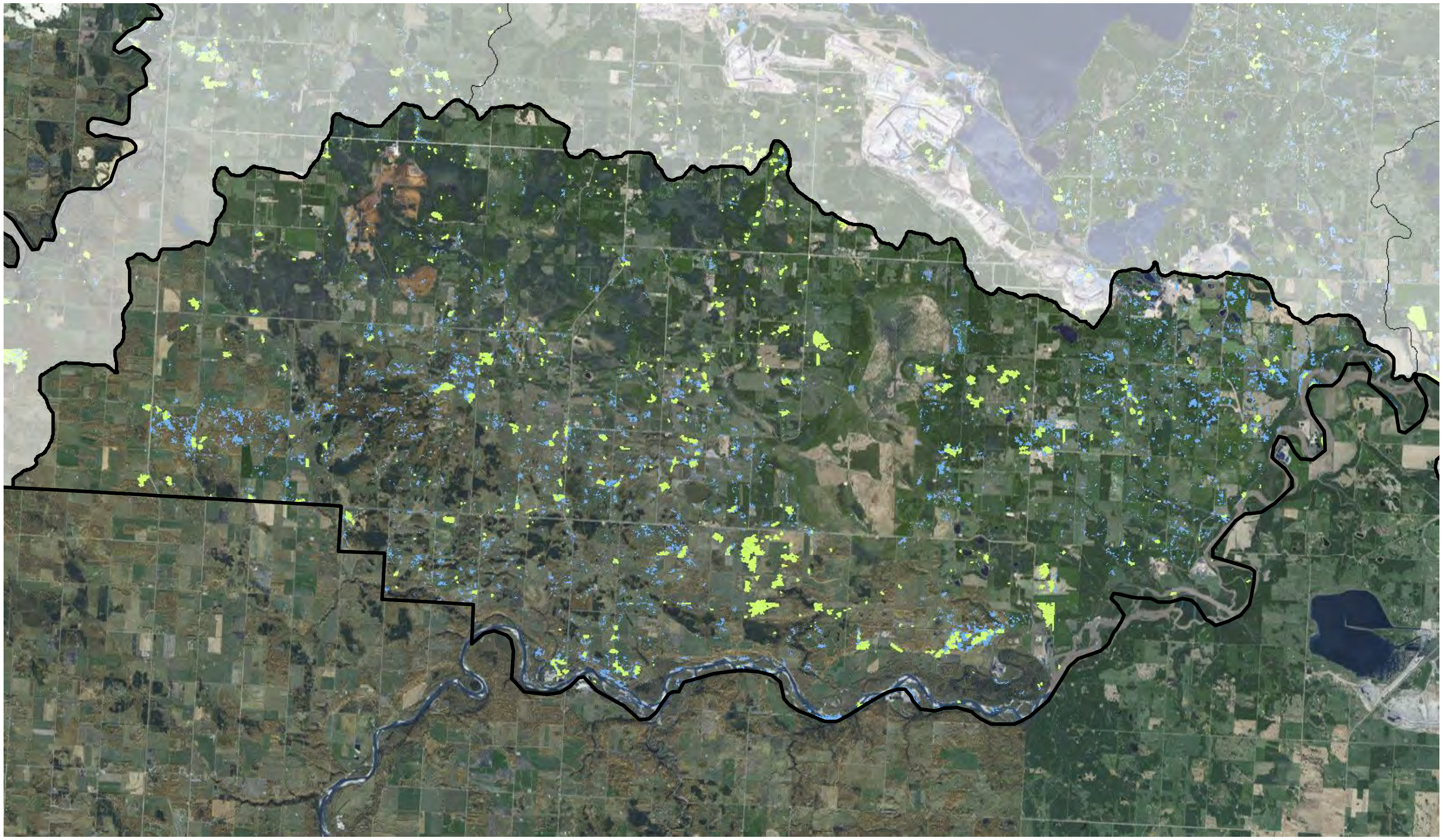


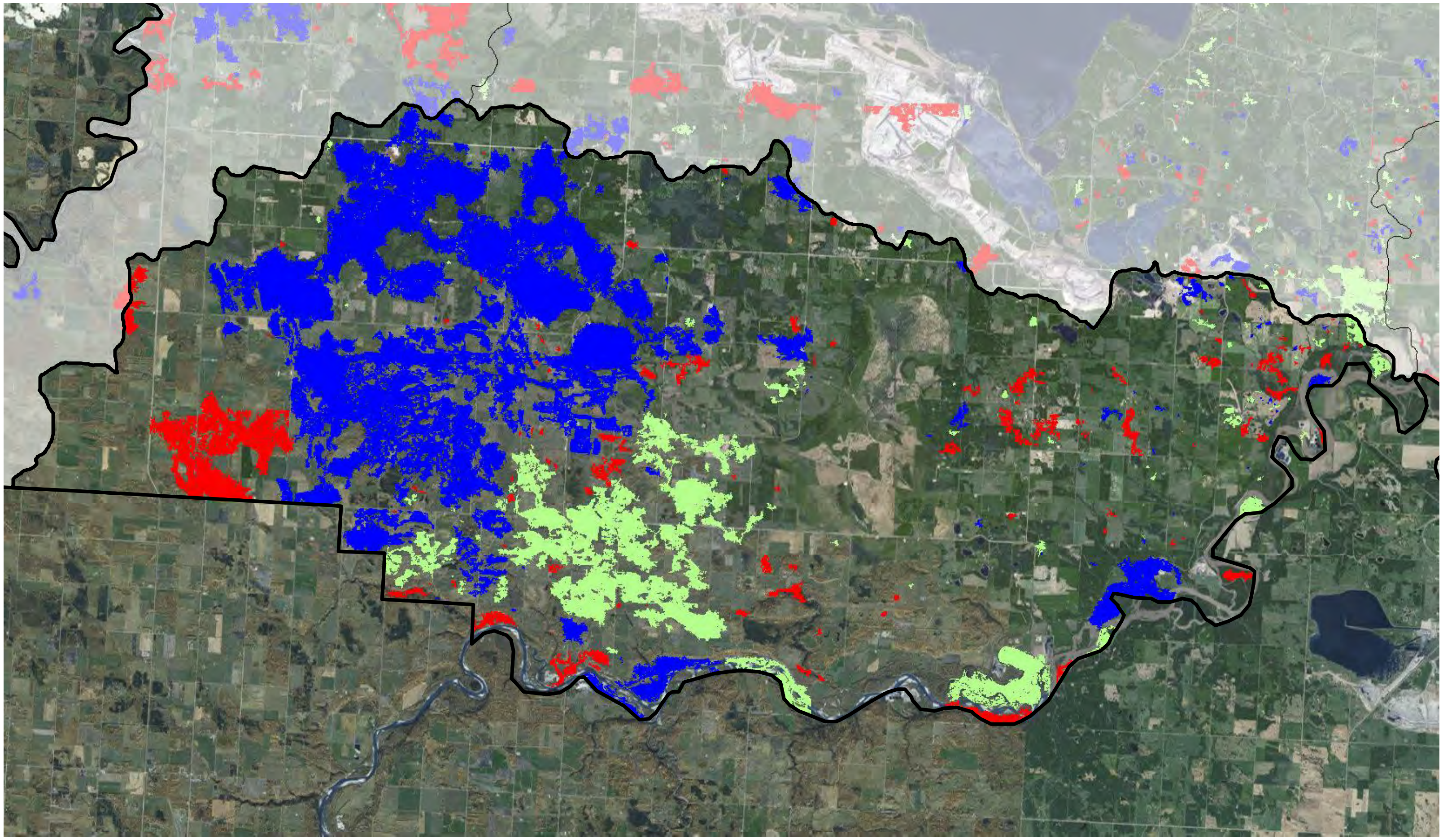

Figure 25. Summary of the estimated area of partial (>40%) and complete wetland loss in the North Saskatchewan Above Wabamun (A) watershed unit between circa 1950 and 2013.



**North Saskatchewan Above Wabamun A**
**COMPLETE WETLAND LOSS**



Map 45. Location of complete wetland loss in the North Saskatchewan Above Wabamun (A) watershed unit by wetland class.



**North Saskatchewan Above Wabamun A**
**PARTIAL WETLAND LOSS**



Map 46. Location and extent of partial loss in the North Saskatchewan Above Wabamun (A) watershed unit .

## 5.4. North Saskatchewan Above Wabamun (B)

**Area of Watershed Unit**: 26,952 ha
**Total Wetland Loss per Hectare**: 0.08
**Marsh & Open Water Loss per Hectare**: 0.07
**Bog, Fen & Swamp Loss per Hectare**: 0.01

The North Saskatchewan Above Wabamun (B) watershed unit has the lowest estimated area of historic (3,195 ha) and contemporary (1,323 ha) wetland cover in the County (Table 2; Figure 26). Marsh and Open Water wetlands comprise the largest area of wetlands in the watershed unit, both historically (2,660 ha) and currently (941 ha), and the extent of Marsh and Open Water wetlands between circa 1950 and 2013 has declined 65% (Figure 26). Comparatively, the area change of treed wetlands was much smaller (-29%), but treed wetlands are relatively rare in this watershed unit, making up less than 30% of the current wetland area. In comparison to other watershed units, complete wetland losses made up a large proportion (43%) of the area loss in this watershed unit (Figure 27).

Marsh and Open Water wetland loss accounted for 87% of the total wetland loss in this watershed unit (Figure 28). Combined loss of all wetland types in this watershed on a per area basis was 0.08, which was the lowest overall loss/ha measured in the County (Table 2). Spatially, complete loss was detected throughout the basin (Map 47), and compared to other adjacent watershed units, complete and partial losses were attributed to smaller wetlands and wetland complexes (Map 47; Map 48).

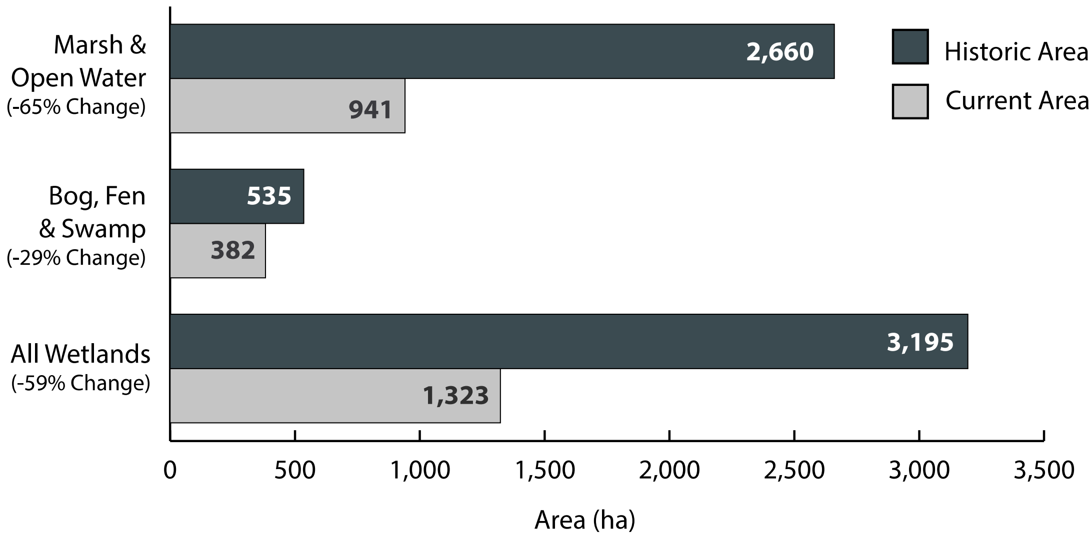



Figure 26. Summary of the wetland area change in the North Saskatchewan Above Wabamun (B) watershed unit between circa 1950 and 2013.

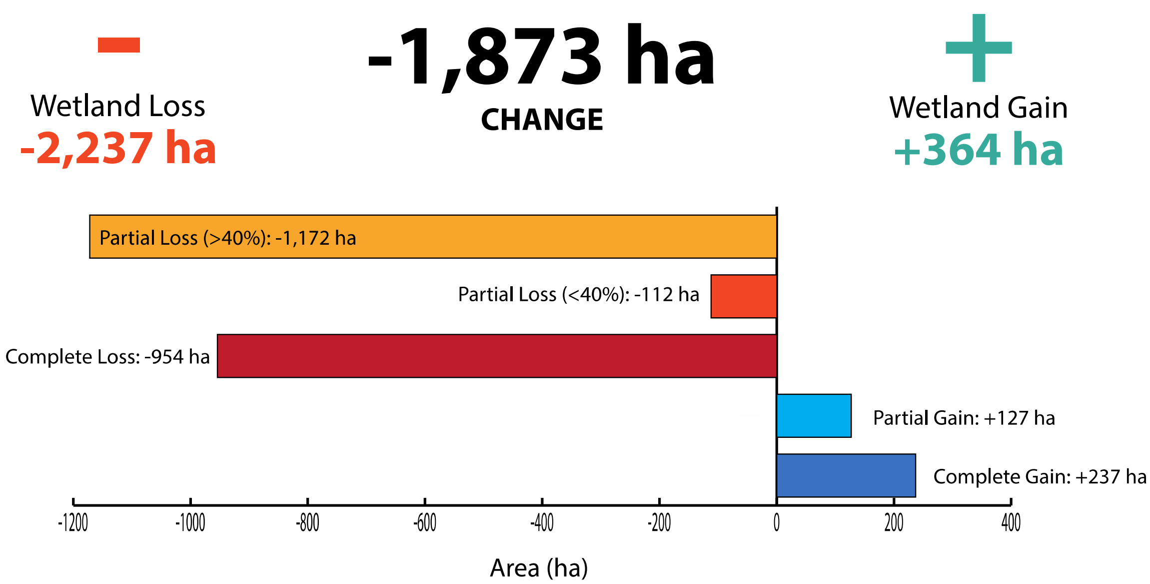



Figure 27. Wetland area change in the North Saskatchewan Above Wabamun (B) watershed unit, summarized by the various types of wetland losses and gains measured as part of this study.

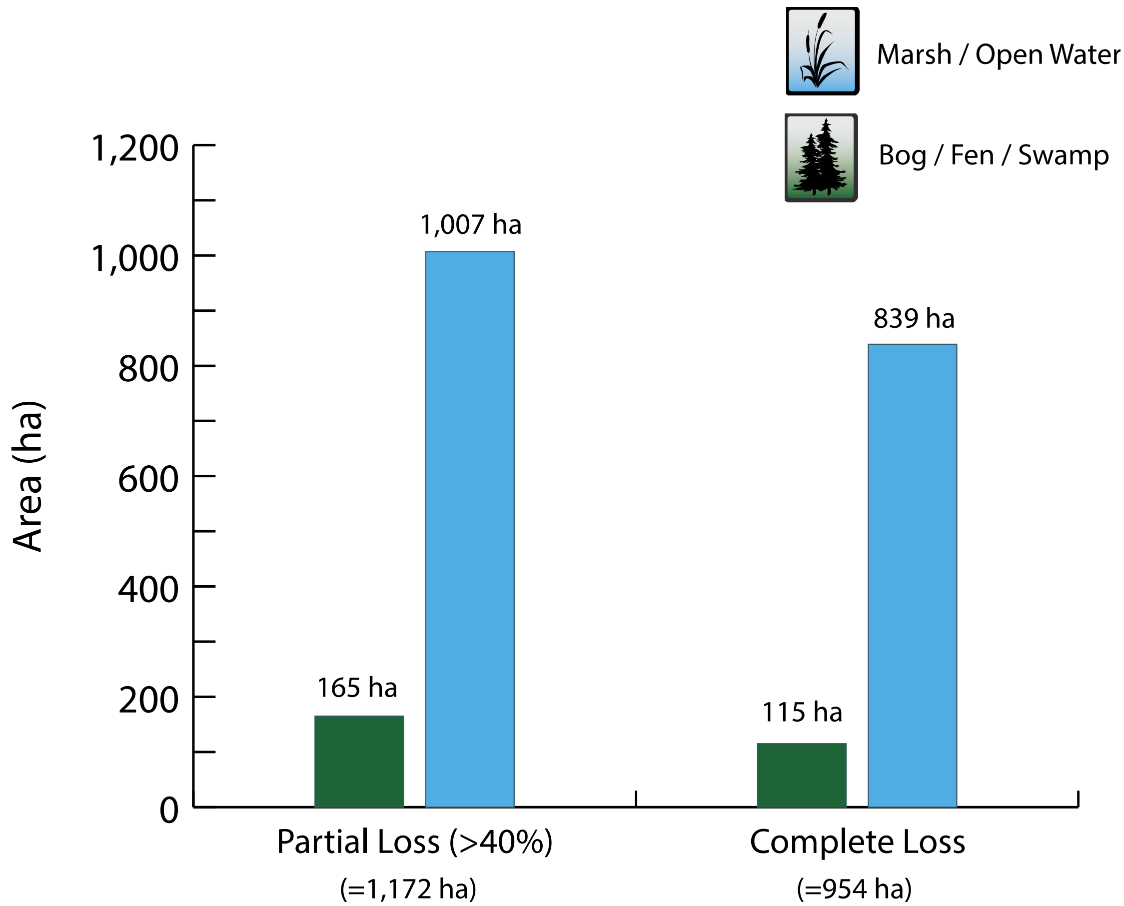
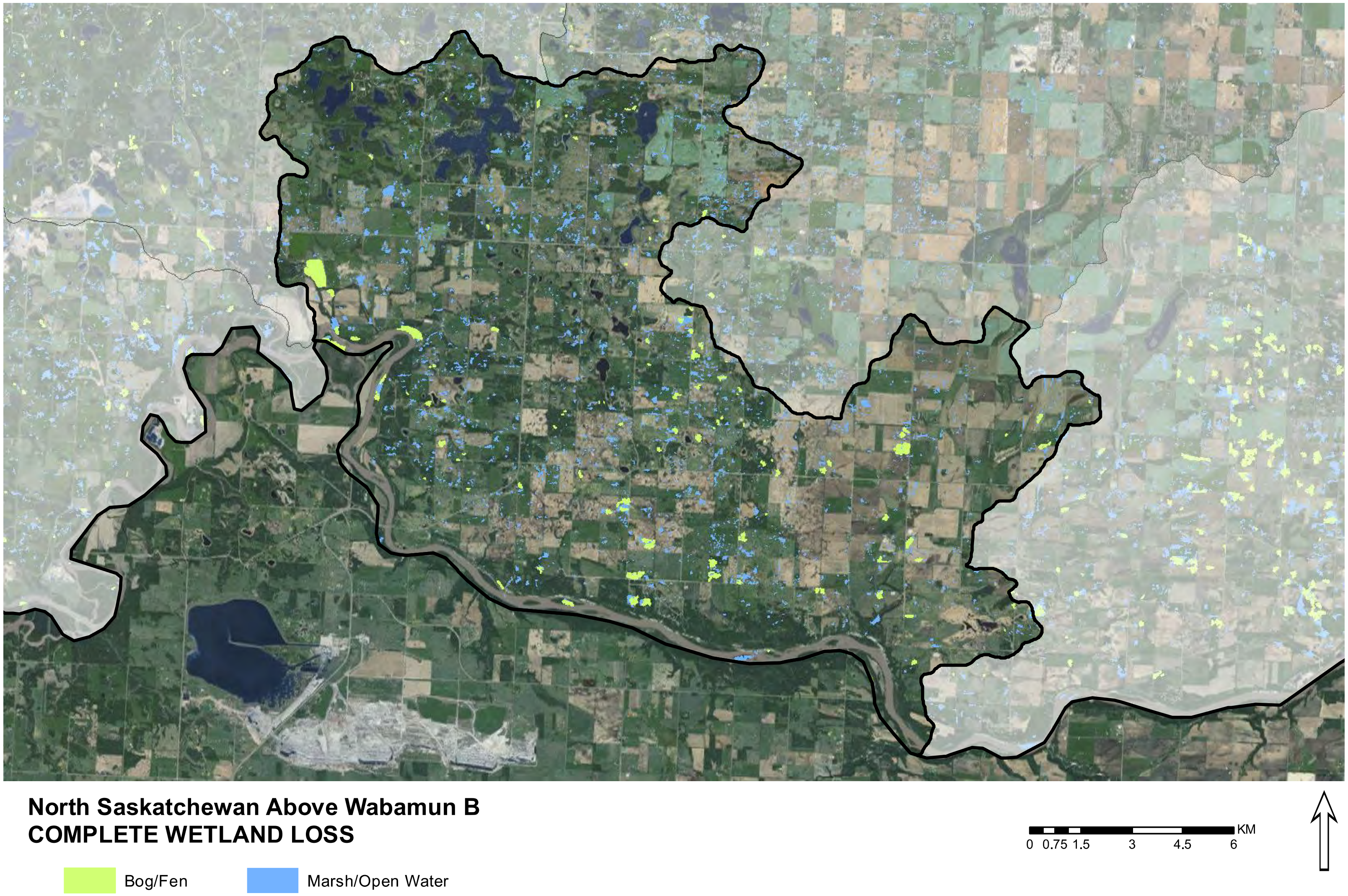
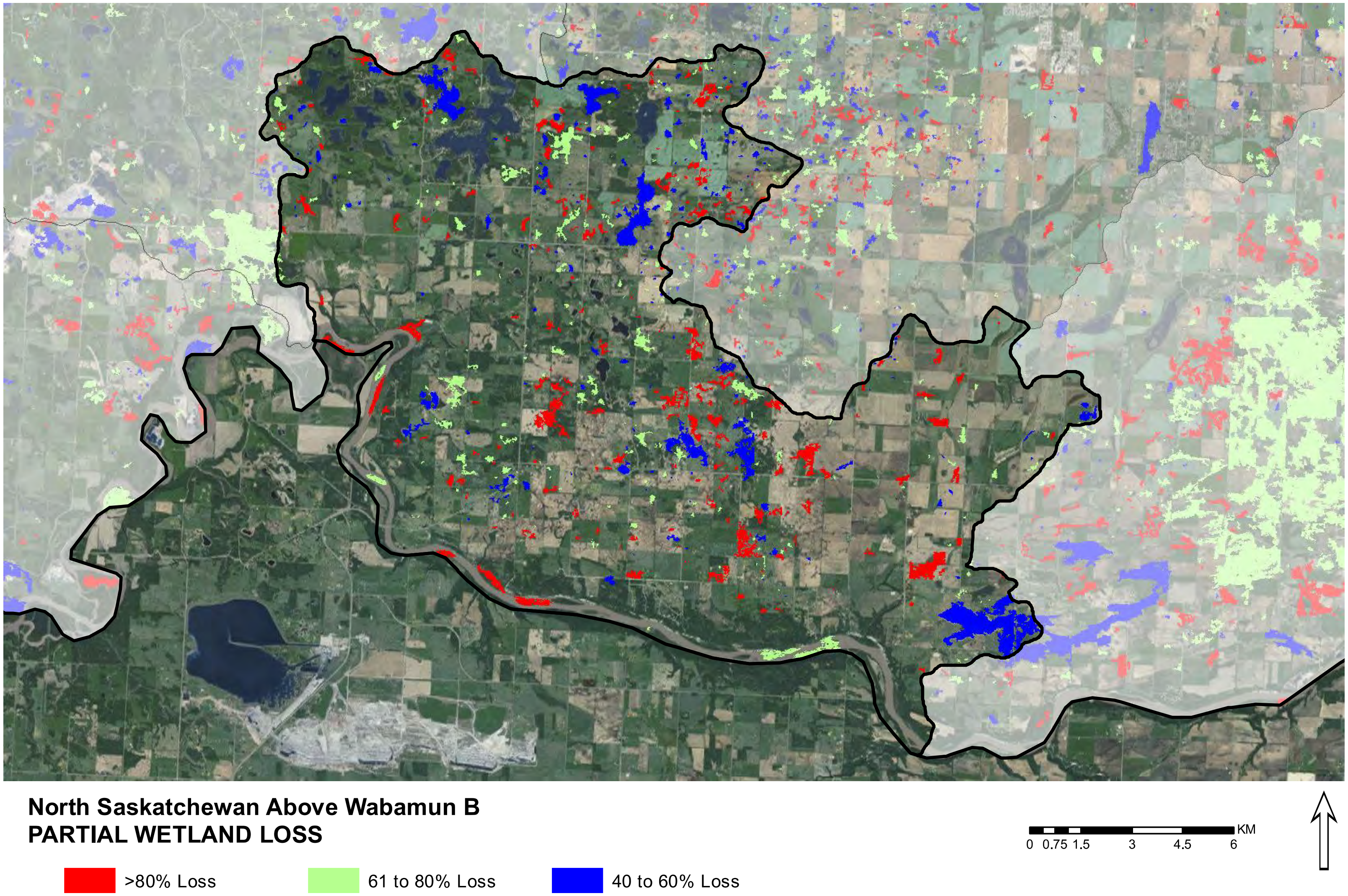



Figure 28. Summary of the estimated area of partial (>40%) and complete wetland loss in the North Saskatchewan Above Wabamun (B) watershed unit between circa 1950 and 2013.




Map 47. Location of complete wetland loss in the North Saskatchewan Above Wabamun (B) watershed unit by wetland class.




Map 48. Location and extent of partial loss in the North Saskatchewan Above Wabamun (B) watershed unit.

## 5.5. North Saskatchewan Below Strawberry / Sturgeon River

**Area of Watershed Unit**: 37,783 ha
**Total Wetland Loss per Hectare**: 0.24
**Marsh & Open Water Loss per Hectare**: 0.16
**Bog, Fen & Swamp Loss per Hectare**: 0.08

The North Saskatchewan Below Strawberry / Sturgeon River watershed unit has experienced the greatest change (-70%) in wetland area of all watershed units in the County. Historically, this watershed unit had an estimated wetland cover of 13,126 ha, which was substantially reduced to 3,895 ha in 2013 (Figure 29). The area of Marsh and Open Water wetlands changed by -77% between circa 1950 and 2013, while treed wetland area also changed considerably (-60%) over this time period. In total, there was an overall reduction of 9,231 ha of wetland area in this watershed unit between circa 1950 and 2013, with partial (>40%) wetland loss accounting for 87% of the overall loss (Figure 30).

Partial loss of Marsh/Open Water and treed wetlands accounted for the majority (57%) of the total wetland losses in this watershed unit (Figure 31). Combined loss of all wetland types on a per area basis was 0.24, and the loss per hectare of Marsh and Open Water wetlands was 0.16; both of these loss values were the highest calculated in the County (Table 2). Spatially, complete and partial losses were concentrated in the central portion of the watershed unit (Map 49; Map 50). In particular, there was a large wetland object identified in the south central portion of the watershed unit that was identified as having 61 to 80% loss, which appears to have been primary driven by land clearing activities associated with country residential and agricultural development (Map 50).

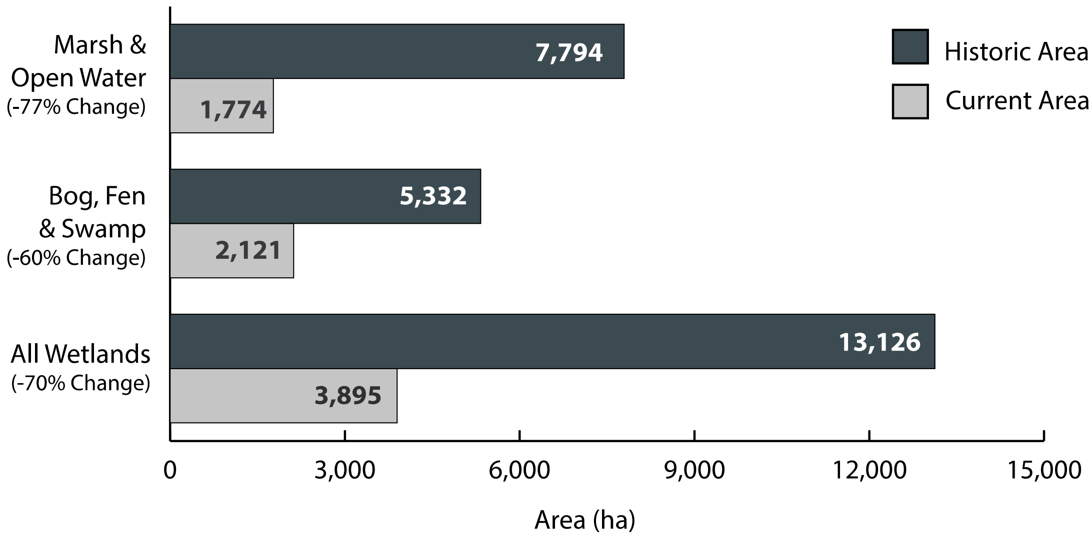



Figure 29. Summary of the wetland area change in the North Saskatchewan Below Strawberry / Sturgeon River watershed unit between circa 1950 and 2013.

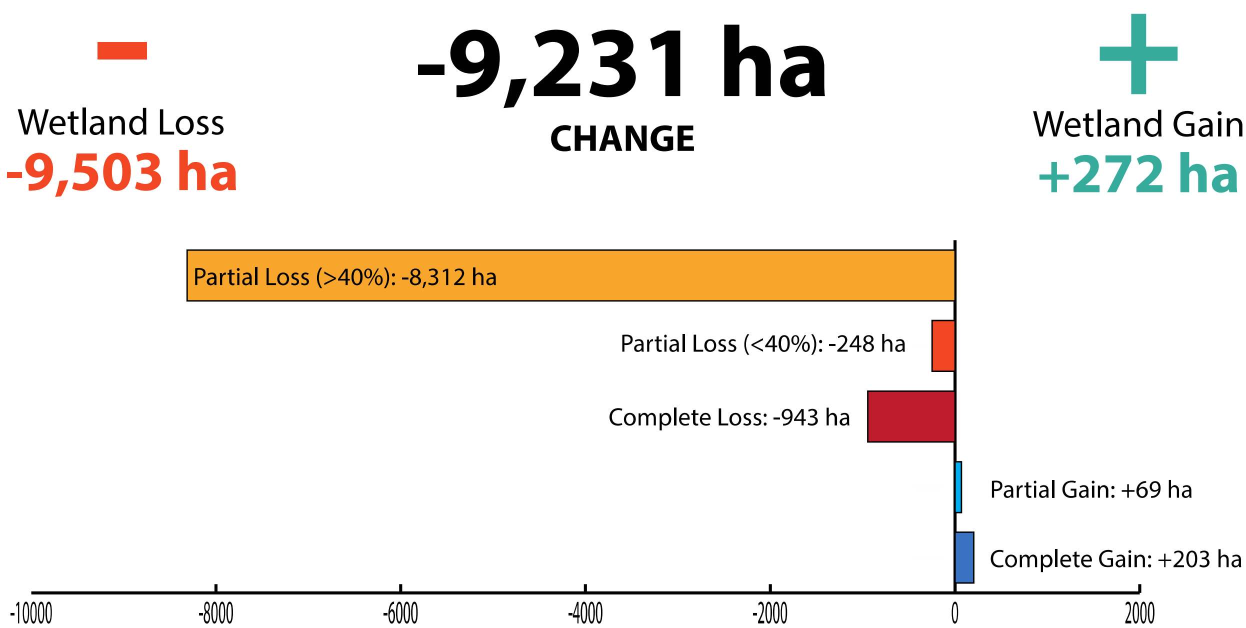



Figure 30. Wetland area change in the North Saskatchewan Below Strawberry / Sturgeon River watershed unit summarized by the various types of wetland losses and gains measured as part of this study.

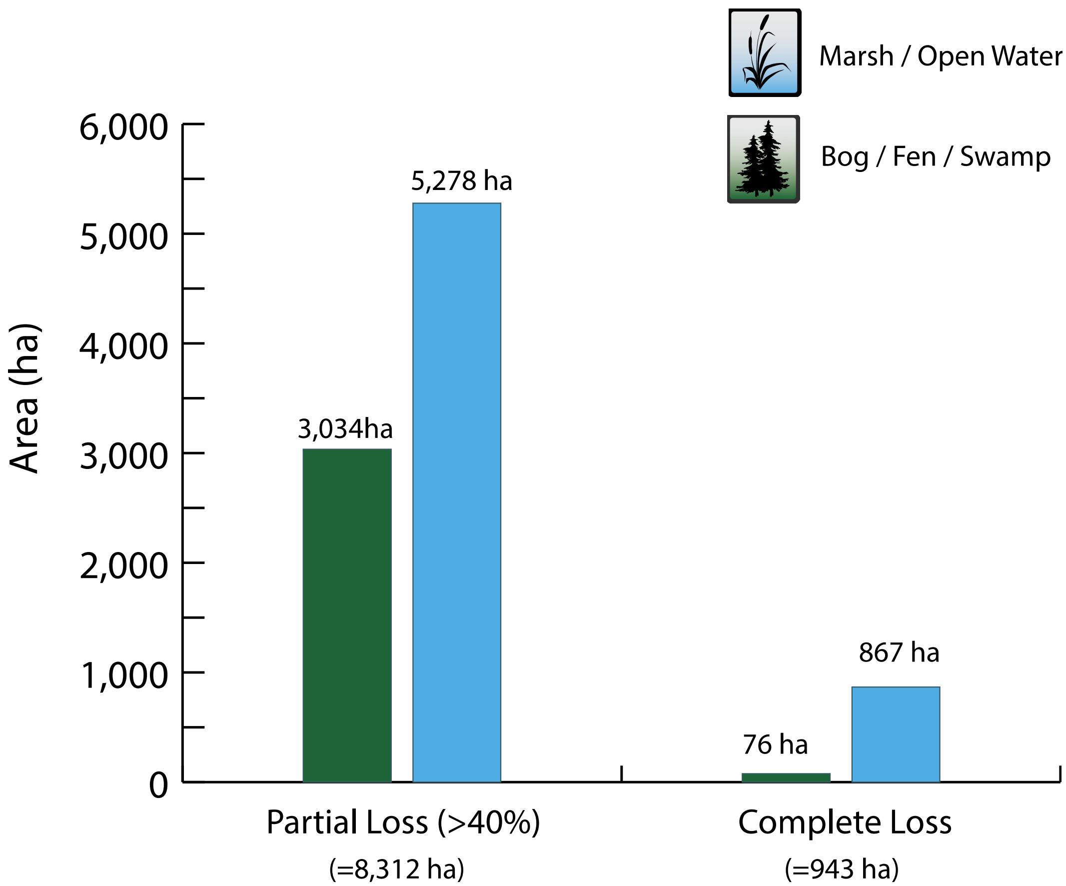
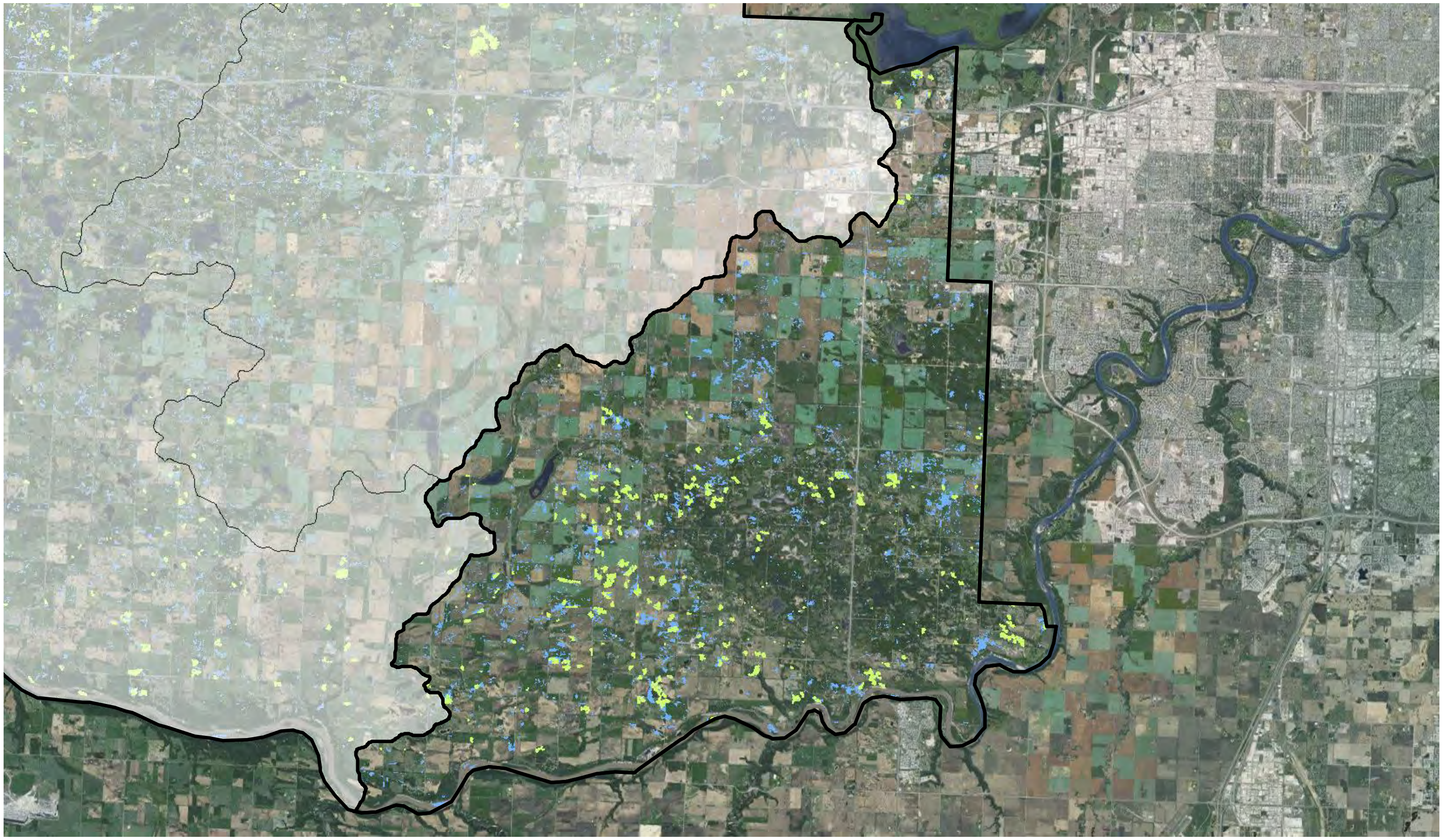



Figure 31. Summary of the estimated area of partial (>40%) and complete wetland loss in the North Saskatchewan Below Strawberry / Sturgeon River watershed unit between circa 1950 and 2013.

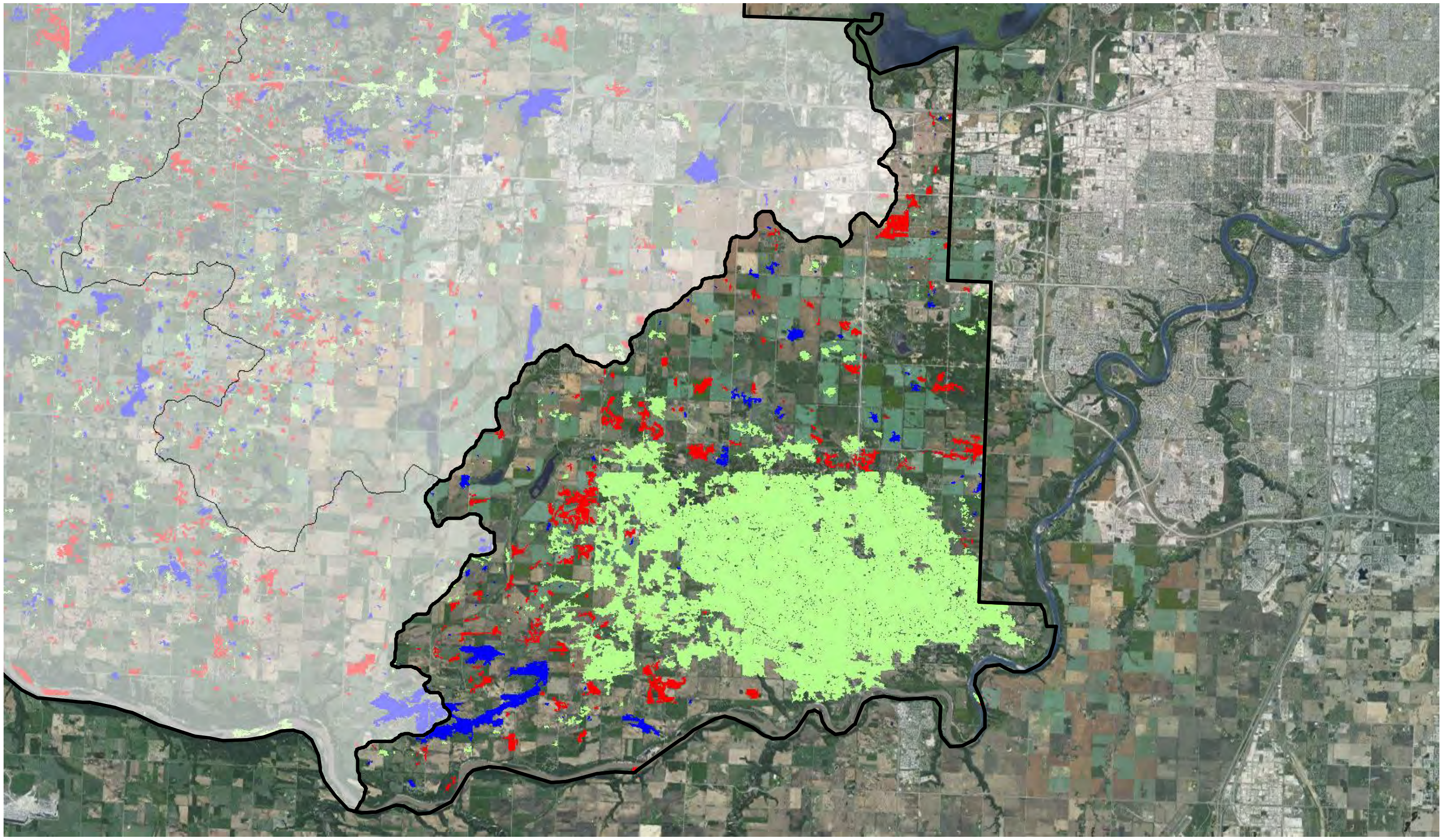


**North Saskatchewan Below Strawberry / Sturgeoon River**
**COMPLETE WETLAND LOSS**

KM
0 1.25 2.5 5 7.5 10

Bog/Fen
Marsh/Open Water

Map 49. Location of complete wetland loss in the North Saskatchewan Below Strawberry / Sturgeon River watershed unit by wetland class.



**North Saskatchewan Below Strawberry / Sturgeoon River**
**PARTIAL WETLAND LOSS**

KM
0 1.25 2.5 5 7.5 10

>80% Loss    61 to 80% Loss    40 to 60% Loss

Map 50. Location and extent of partial loss in the North Saskatchewan Below Strawberry / Sturgeon River watershed unit.

## 5.6. Upper Pembina / Lower Pembina / Sturgeon River

**Area of Watershed Unit**: 39,953 ha
**Total Wetland Loss per Hectare**: 0.10
**Marsh & Open Water Loss per Hectare**: 0.03
**Bog, Fen & Swamp Loss per Hectare**: 0.08

The Upper Pembina / Lower Pembina / Sturgeon River watershed unit has experienced a -48% change in wetland area, from 9,547 ha in circa 1950, to 4,970 ha in 2013 (Table 2; Figure 32). Over this time period, the area of Marsh and Open Water wetlands changed from 1,562 ha to 414 ha (-73%), while the area of treed wetlands changed from 7,985 ha to 4,556 ha (-43%) (Figure 32).

Partial loss (>40%) of wetland area was the primary driver of wetland loss in this watershed unit, accounting for 70% of the overall wetland area losses (Figure 33). The partial loss was greatest for treed wetlands (2,838 ha) (Figure 34), and the loss per hectare of treed wetlands was 0.08, which was the second highest of all watershed units in the County (Table 2). Spatially, complete losses were fairly concentrated in the central and northern portions of the watershed unit (Map 51), while partial losses were concentrated in the south western portion of the watershed unit, near the river, as well as the central portion of the watershed unit (Map 52).

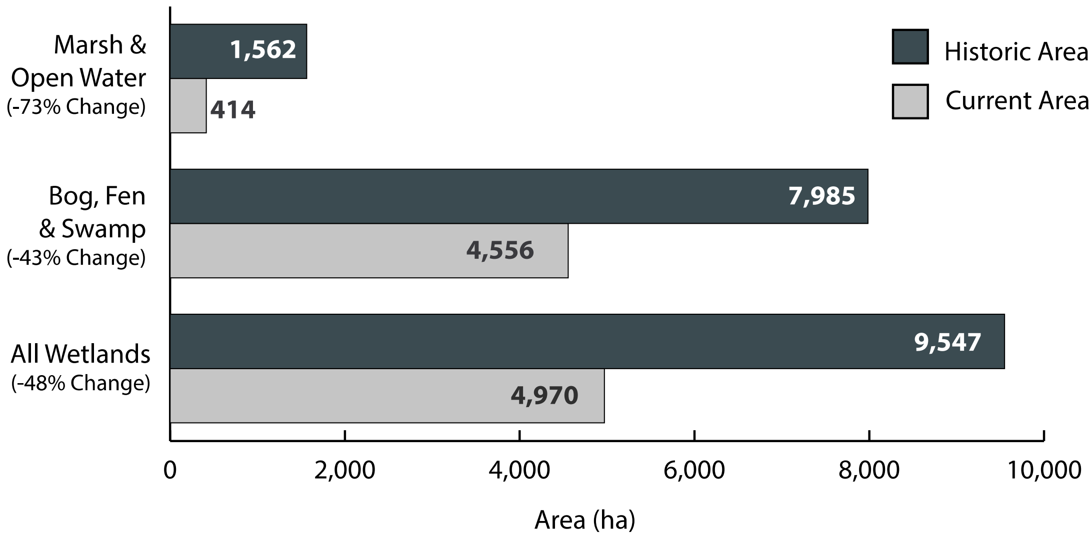



Figure 32. Summary of the wetland area change in the Upper Pembina / Lower Pembina / Sturgeon River watershed unit between circa 1950 and 2013.

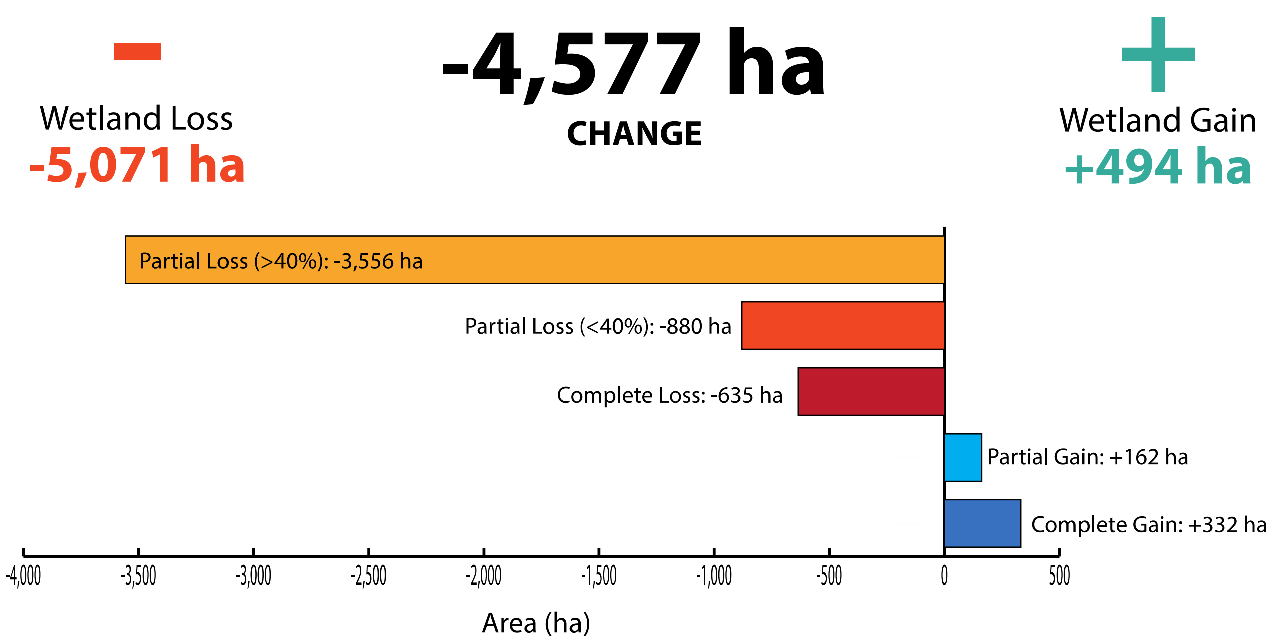



Figure 33. Wetland area change in the Upper Pembina / Lower Pembina / Sturgeon River watershed unit summarized by the various types of wetland losses and gains measured as part of this study.

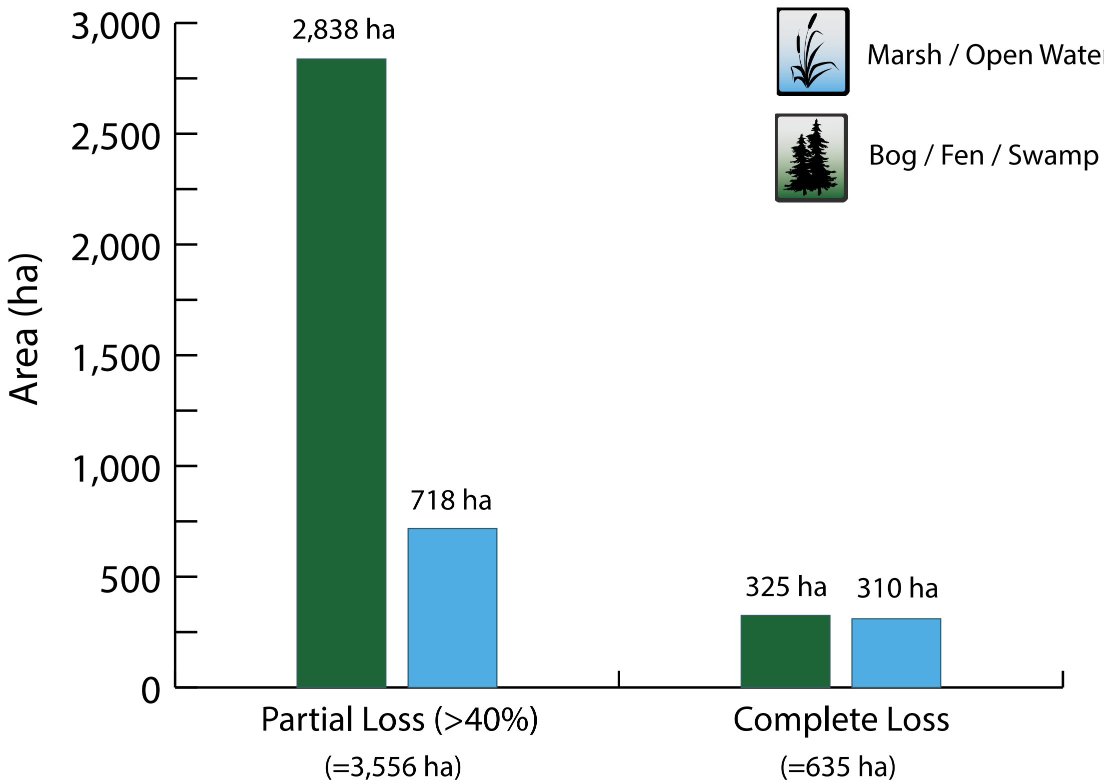
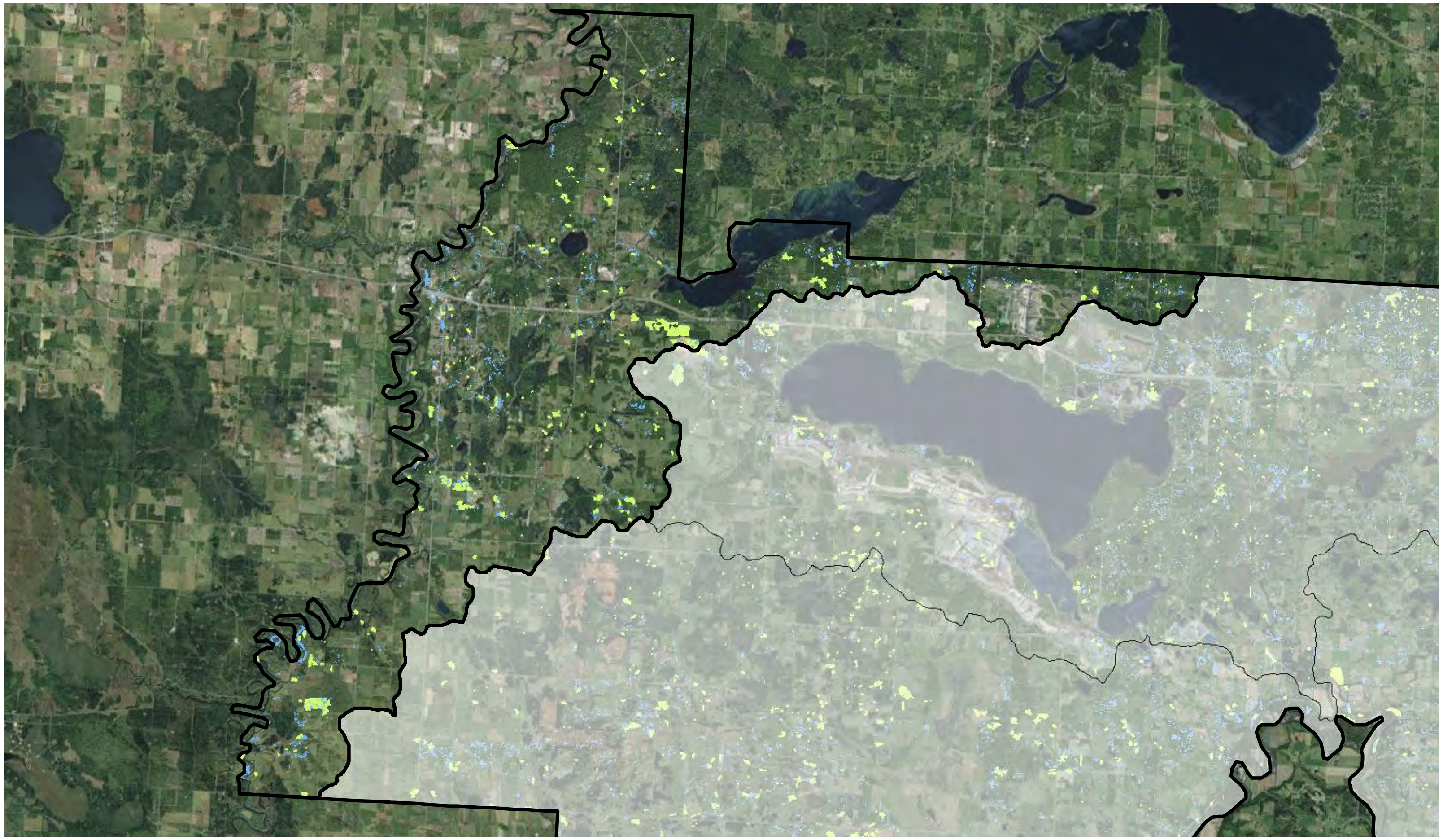


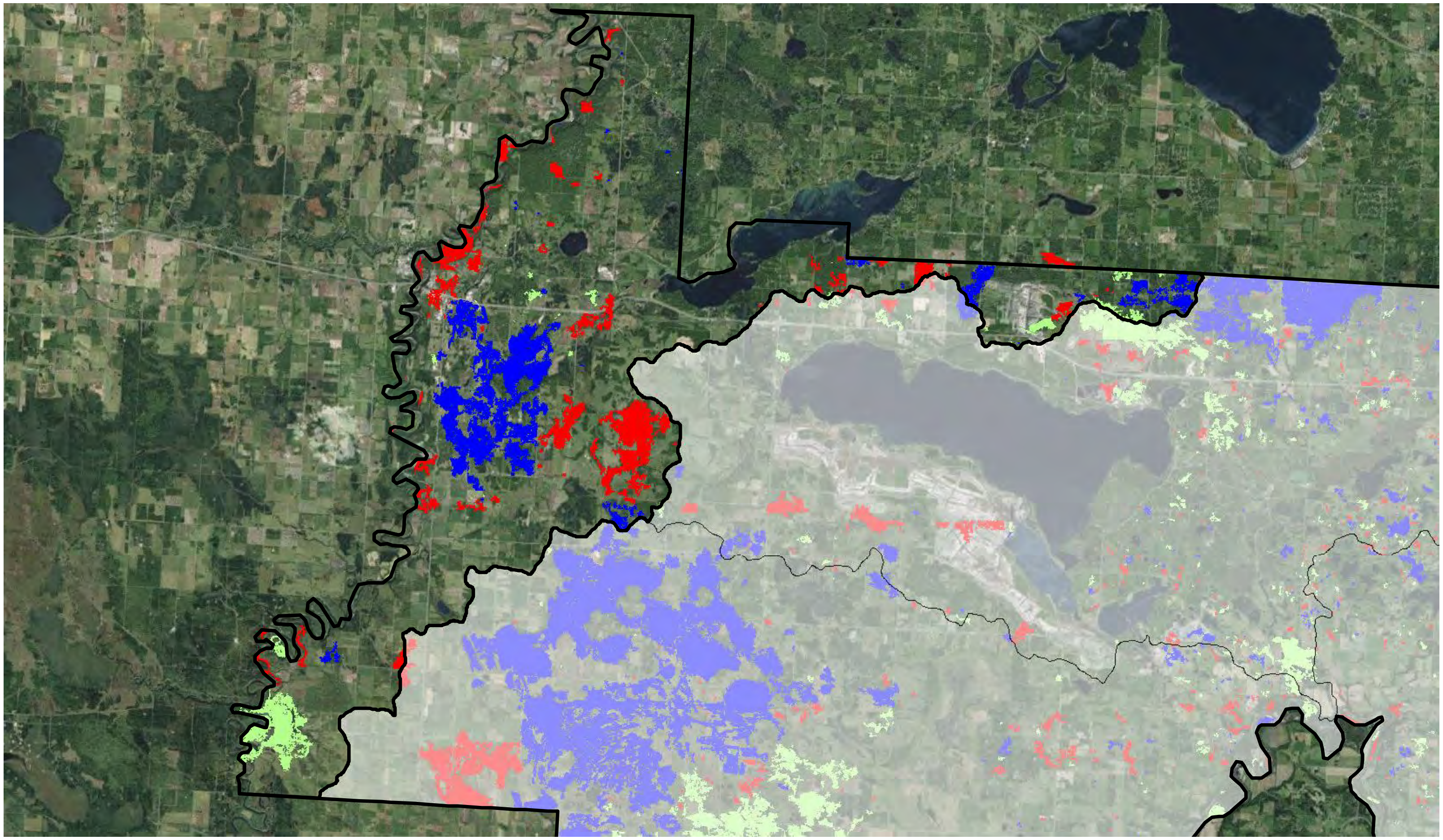

Figure 34. Summary of the estimated area of partial (>40%) and complete wetland loss in the Upper Pembina / Lower Pembina / Sturgeon River watershed unit between circa 1950 and 2013.



**Upper Pembina / Lower Pembina /Sturgeon River**
**COMPLETE WETLAND LOSS**



Map 51. Location of complete wetland loss in the Upper Pembina / Lower Pembina / Sturgeon River watershed unit by wetland class.



**Upper Pembina / Lower Pembina /Sturgeon River**
**PARTIAL WETLAND LOSS**



Map 52. Location and extent of partial loss in in the Upper Pembina / Lower Pembina / Sturgeon River watershed unit.

## 5.7. Wabamun Creek / Sturgeon River

**Area of Watershed Unit**: 65,137 ha
**Total Wetland Loss per Hectare**: 0.13
**Marsh & Open Water Loss per Hectare**: 0.06
**Bog, Fen & Swamp Loss per Hectare**: 0.07

The Wabamun Creek / Sturgeon River watershed unit has experienced a -56% change in wetland area, from 15,610 ha to 6,948 ha, which represents the second highest historical and current wetland area extent measured in the County (Table 2). The area of Marsh and Open Water wetlands changed most substantially during this time period, from 5,820 ha to 1,652 ha (-72% change), while the area of treed wetlands changed from 9,789 ha to 5,296 ha (-46% change) (Figure 35).

Partial loss (>40%) accounted for the majority (67%) of the total wetland area losses in the watershed unit (Figure 36), and the majority of the partial losses (4,218 ha, 67%) were treed wetlands (Figure 37). The total area loss per hectare of all wetlands in the watershed unit was 0.13, which was the third highest in the County (Table 2). Spatially, complete losses were fairly concentrated in the eastern portion of the watershed unit (Map 53), while partial losses were concentrated along the northern boundary of the County, and in areas associated with mining activity and shoreline development along Wabamun Lake (Map 54).

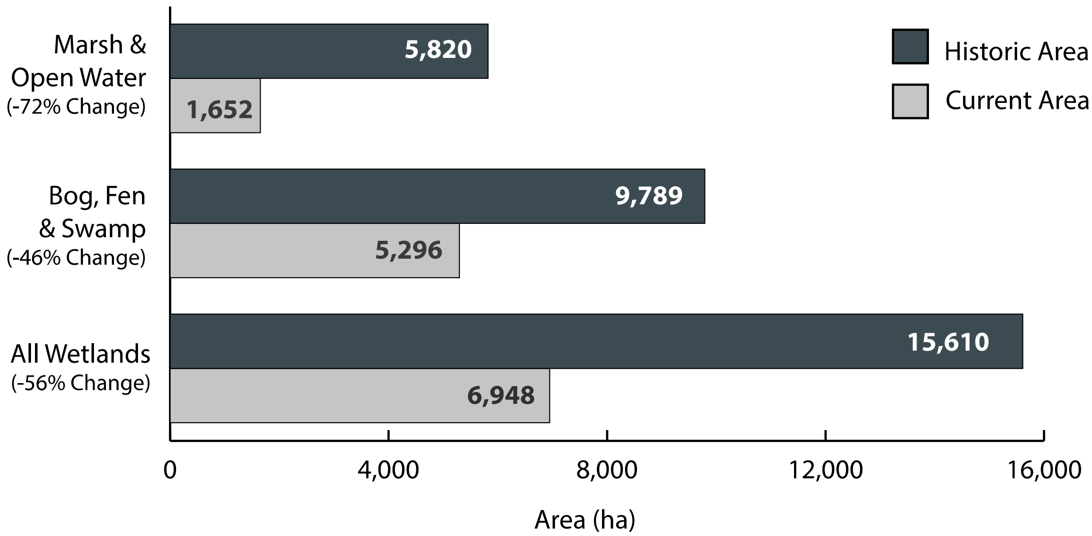



Figure 35. Summary of the wetland area change in the Wabamun Creek / Sturgeon River watershed unit between circa 1950 and 2013.

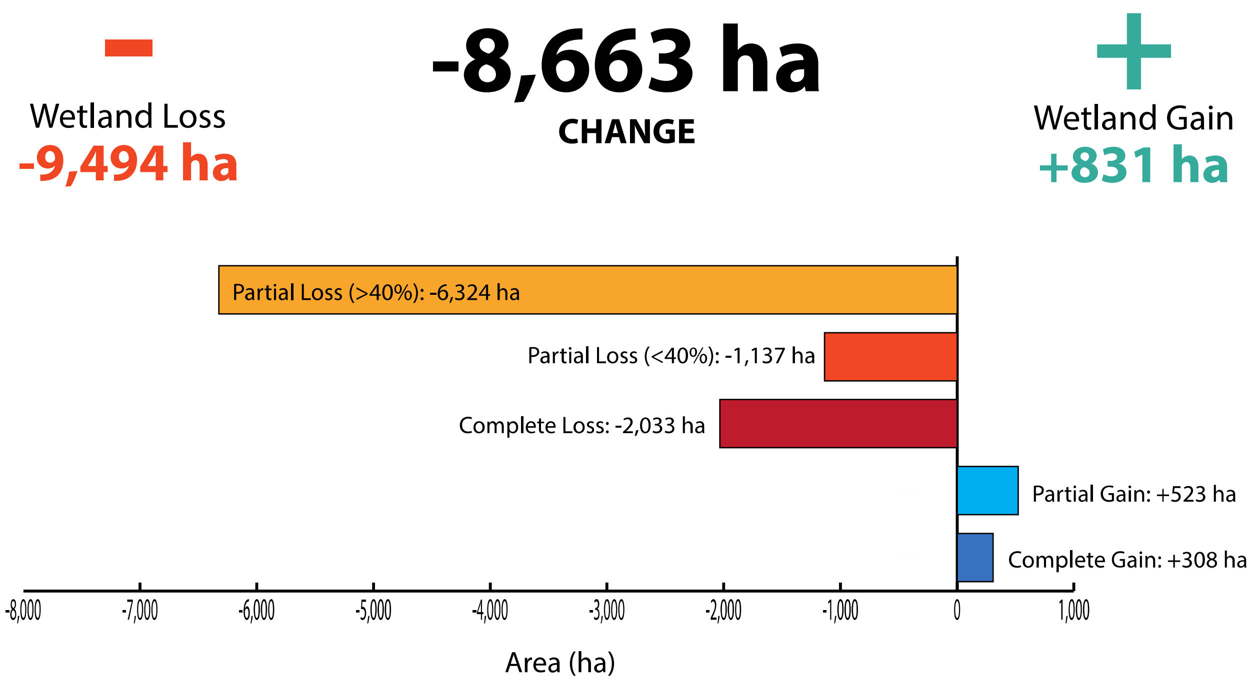



Figure 36. Wetland area change in the Wabamun Creek / Sturgeon River watershed unit, summarized by the various types of wetland losses and gains measured as part of this study.

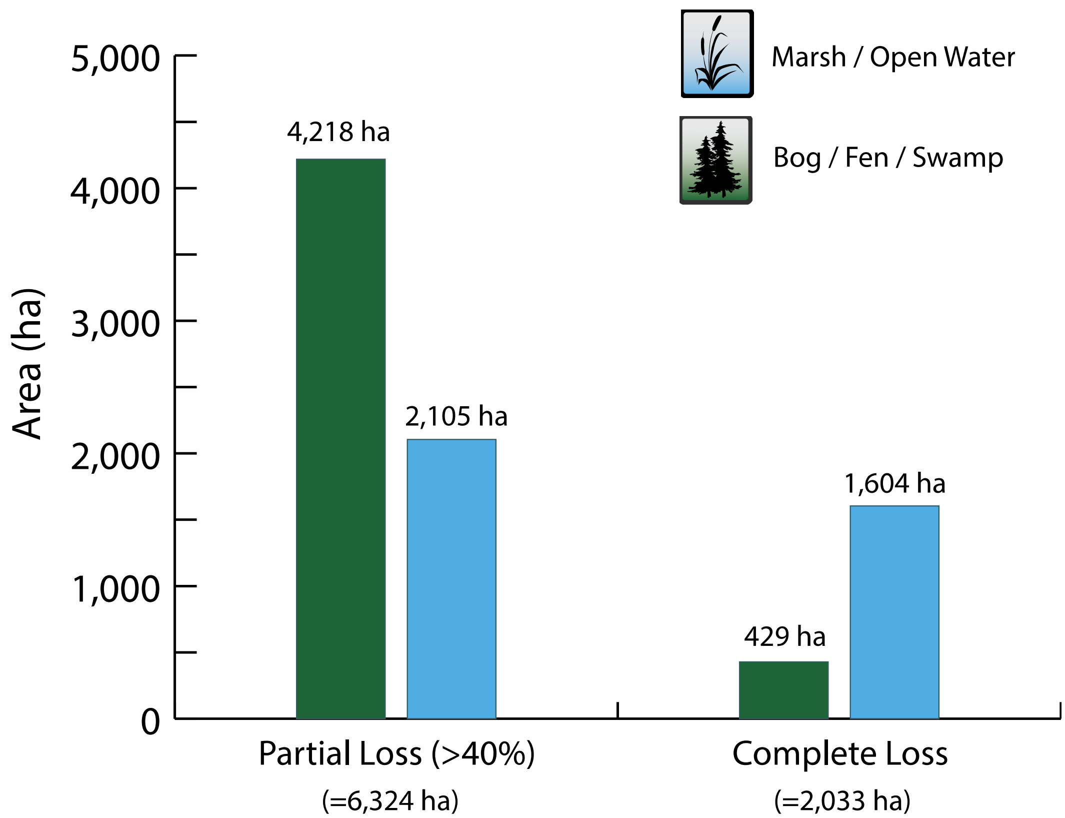
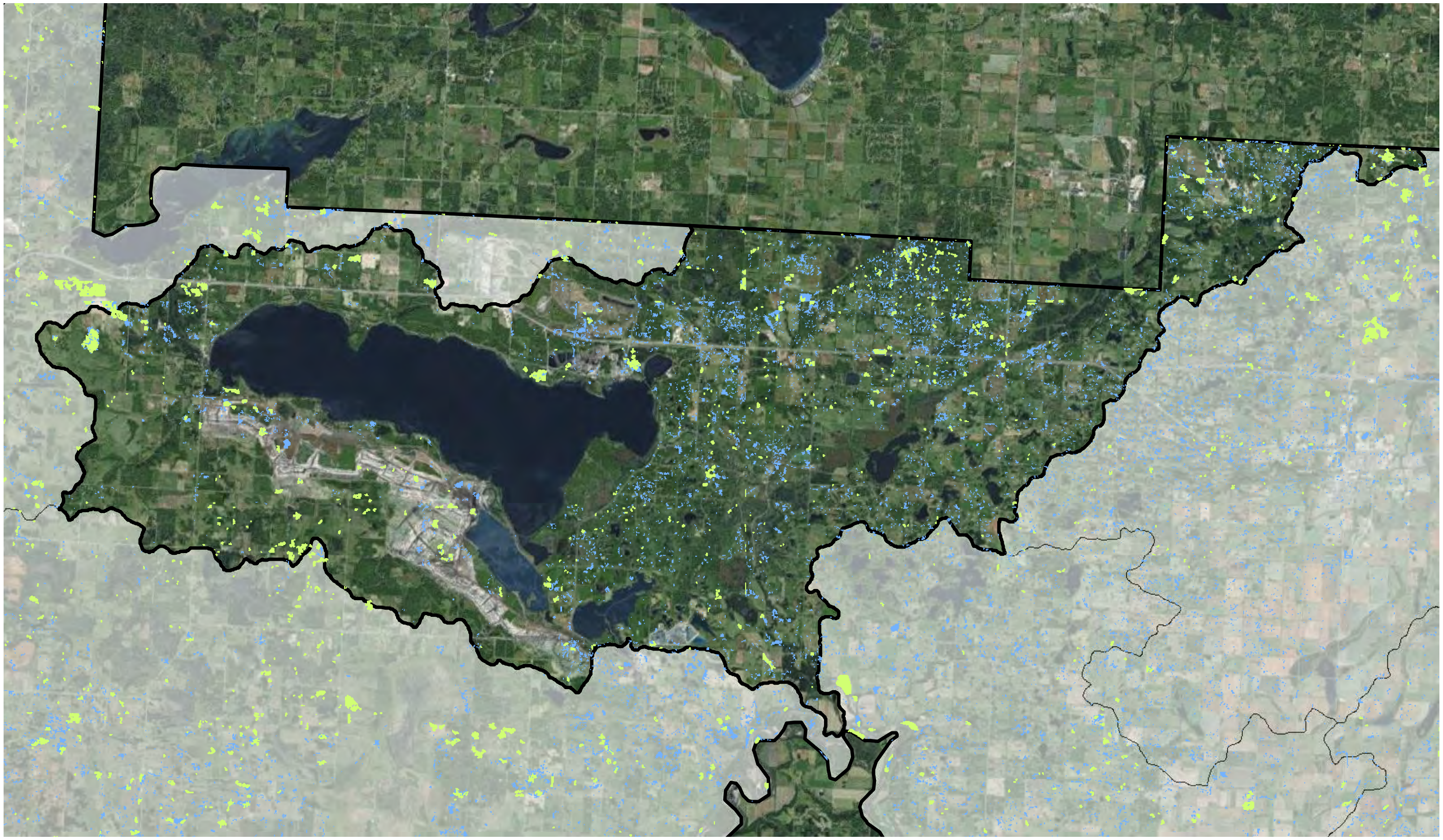


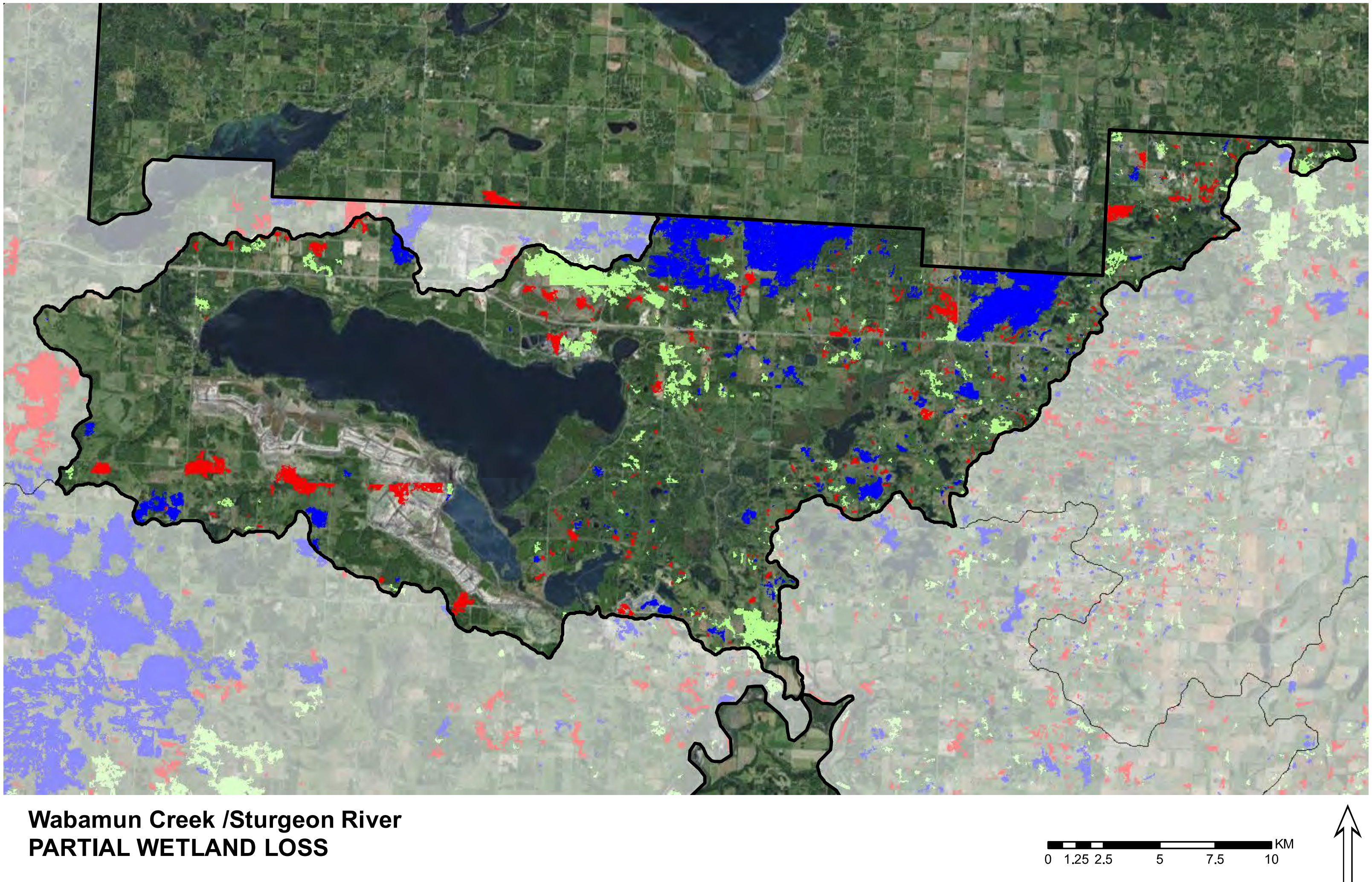

Figure 37. Summary of the estimated area of partial (>40%) and complete wetland loss in the Wabamun Creek / Sturgeon River watershed unit between circa 1950 and 2013.



## Wabamun Creek /Sturgeon River
## COMPLETE WETLAND LOSS



Map 53. Location of complete wetland loss in the Wabamun Creek / Sturgeon River watershed unit by wetland class.





Map 54. Location and extent of partial loss in the Wabamun Creek / Sturgeon River watershed unit.

# 6.0 Discussion

Like many rural municipalities in central Alberta, Parkland County has experienced a high degree of wetland loss since European settlement. While loss across the settled areas of the province has been high, there have been very few detailed studies that have quantified wetland loss over large geographic extents. One of the reasons for this is that wetlands are notoriously difficult to study remotely using air photos, primarily because the condition, size, and shape of wetlands is heavily influenced by climate and surrounding land use and management. As a result, these ecosystems are highly variable within and between years, and the temporal variation in open water and vegetative cover makes wetland identification, delineation, and mapping difficult, particularly when making comparisons between years. Nevertheless, the use of air photos and satellite imagery remains the only practical and cost effective means for mapping and assessing wetlands over large geographic extents, particularly when one is interested in tracking the change in wetland area over time.

For this study, we relied heavily upon air photographs to create both the current and historic wetland inventories for Parkland County. While other data sets were created and used to improve the identification and mapping of wetlands for the current inventory (e.g., LiDAR, Normalized Differenced Vegetation Index, etc.), we had to rely entirely upon historical air photographs to create the historic inventory. The poor quality of these historic photos, as well as the coarse resolution, made these images difficult to work with, and required a high degree of manual interpretation. Further, Parkland County is located in the boreal transition zone, where there is a diverse mix of different wetland types, each with their own unique challenges. For example, distinguishing and differentiating treed wetlands from treed upland habitats is difficult, particularly in poor quality, black and white historical air photographs. Ephemeral, seasonal, and temporary Marsh wetlands were also difficult to distinguish from agricultural fields, both in the current and historical air photographs, particularly because the years in which the imagery was taken for the two inventories tended to be drier than the climate normal, and standing water was not abundant on the landscape. While we made every effort to create highly accurate and reliable wetland inventories for Parkland County, there are several sources of error that should be noted and considered when interpreting the results of this study. We discuss these different types of error, and how it may have influenced the results of this study, in more detail below.

## Current Wetland Inventory

There are two main sources of error within the current wetland inventory: omission error and commission error. Omission error occurs when there is a wetland on the landscape, but the wetland is missed and is not included in the wetland inventory. Conversely, commission error occurs when there is a wetland included in the inventory, but in reality, there is no wetland on the landscape.

Omission errors in the current wetland inventory have been largely introduced by the mapping technique used to classify wetlands. In particular, the use of the probability of open water analysis led to the omission of small wetlands that only hold open water for short periods (e.g., ephemeral, temporary, and seasonal wetlands), and as a result, were not wet in any of the images that were used to create the probability of open water layer. Similarly, open fen wetlands that did not have open water in any of the images used in the probability of open water analysis may have been missed, as these wetland areas tend to be spectrally indistinct from agricultural areas. As a result, there may have been some class confusion between fens and agriculture, and there may be areas of open fen that have been classified as agriculture and thus, are not captured in the current wetland inventory. Finally, small treed wetlands (e.g., swamps) or “cryptic” marsh wetlands that are located entirely under tree canopy, are not captured in probability of open water mapping, due to the fact that the water cannot be detected in the image. In these instances, wetlands under tree canopy may have been omitted from the current inventory.

Commission errors are also apparent within the current wetland inventory, particularly with respect to the classification of bogs and fens. Bogs and fens share very similar depressional, spectral, and textural properties with upland areas that have sparse tree cover, or areas with large differences in tree heights that create shadow. As a result, the decision tree classification may have led to the commission of bogs and fens in treed upland areas. Marsh wetland areas with open water are also spectrally similar to shadow created by tall trees, and in some instances, shadow located along the edge of large tree stands may have been misclassified as a marsh wetland area.

## Historic Wetland Inventory

There are three main sources of error within the historic wetland inventory, including: omission error, commission error, and class confusion. The main source of omission error in the historic inventory is the inability to view or detect marsh wetlands under tree canopy. Given that the historical landscape in Parkland County had a greater proportion of forest cover, as compared to the current landscape, and given that we did not have LiDAR data from that period to detect depressional basins, it is likely that there were many cryptic marsh or swamp wetlands that were missed in the historic inventory. In addition, due to the very low quality of the air photo in some regions of the County, it is likely that small Bogs and Fens could not be distinguished from upland habitats, and were thus omitted. In terms of commission error, the primary source of error in the historic inventory is related to the misclassification of upland forest as Bog or Fen. Spectrally, the very low reflectance of upland forest in the black and white imagery is very similar to peatland habitats, and thus, it is likely that some areas of upland forest have been classified as treed wetland (Bog, Fen, Swamp) in the historic inventory.

Class confusion occurs when a wetland is classified as one class type (e.g., Marsh), when in reality, it is a different class (e.g., Bog). Class confusion errors in the historic inventory result from the automatic assignment of wetland class based on the class of any intersecting current wetland polygons. Given that the historic imagery is black and white, low quality, and coarse resolution, distinguishing between wetland classes is very difficult, and in many instances, class confusion may have resulted. Furthermore, it was not possible to identify anthropogenic wetlands within the historic inventory due to the poor resolution of the black and white imagery, and as a result, there may be some anthropogenic waterbodies in the historic inventory that have been classified as Marsh or Open Water wetlands. While every effort was made to manually check and ensure the correctness of the historic wetland inventory, there is no independent way to validate the inventory results, given that we only have a single image source, and there is no other independent data set that can be used to help validate the inventory.

### Historic Loss Assessment

The accuracy of the historic loss assessment is entirely driven by the accuracy of the input datasets; thus, commission and omission errors within the historic and current wetland inventories can lead to compounded error within the historic loss assessment. Furthermore, the image miss-alignment issues between the current and historical imagery made direct locational comparisons very difficult. This poor positional accuracy between the inventories eliminated the possibility of directly comparing individual wetland polygons, and instead, drove the need to create and compare larger wetland objects. The use of wetland objects, rather than individual wetland polygons, also made direct comparisons of wetland numbers difficult between the two inventories. Finally, it should be noted that in addition to the omission, commission, and inventory misalignment errors, the historic and current wetland inventories were created using very different mapping methods. Given that we did not have access to high resolution colour imagery to create the historic inventory, we had to rely on a semi-automated mapping approach to create the historic inventory, which required a large degree of manual photo-interpretation. In contrast, the current inventory was created using more automated methods, that utilized a wide range of other data sources to help improve the mapping accuracy. Ideally, the two inventories would have been created using the same methods to increase the comparability between the inventories.

In addition to commission, omission, and class confusion error, it is important to consider the effect of the 0.01 hectare minimum mapping unit on the assessment of historic wetland loss in Parkland County. The minimum mapping unit chosen likely excludes many small wetlands from both the current and historical inventories, which are likely to be ephemeral, temporary, or seasonal Marsh wetlands. Given that these small Marsh wetlands are highly sensitive to differences in climatic conditions, as well as being highly vulnerable to human impacts resulting from drainage or basin modification, the historic loss assessment presented in this report likely underestimates the loss of these types of wetlands in the County.

A final factor that should be considered when interpreting the historic loss assessment results is the difference in climate between the two inventory dates. Given that the ABMI historic orthophoto imagery for Parkland County is a mosaic that was compiled using images from multiple years (Figure 6), it is very difficult to know the exact climate conditions represented in the historic imagery. While we analyzed the climate for Parkland County between 1949 and 2013 in an effort to better understand how climate conditions compared between the different time periods, the lack of specificity in the historic orthophoto with respect to the exact month and year of image acquisition, makes a more detailed climate comparison impossible. While this more detailed climate comparison could not be completed, the annual precipitation values for the years that were used to create the historic and current inventory are generally comparable, with the majority of years falling below the climate normal precipitation value (Figure 4). Given that the majority of years used to create the inventories, as well as the satellite images that were used to conduct the probability of open water analysis represented relatively dry years, it is likely that the climate conditions reflected in the imagery used may have increased omission errors for small ephemeral, seasonal, and temporary marsh wetlands.

# 7.0 Conclusion

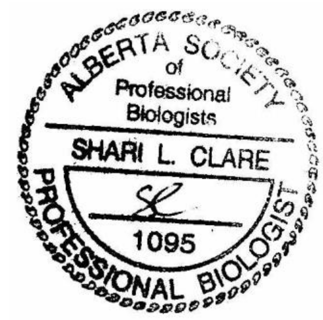
From the perspective of water resource management and maintaining aquatic and terrestrial ecosystem health in Alberta, wetlands are of critical importance. Ecologically, wetlands are key habitats for a large number of aquatic and terrestrial species, and are significant components of larger hydrologic systems that provide important ecosystem services to human communities. For example, wetlands serve a crucial role in water filtration and treatment, and stabilize water supplies through the amelioration of both floods and droughts. Wetlands also provide a number of other less recognized regulating, provisioning, cultural, and supporting services that significantly contribute to human well-being, such as nutrient cycling modulation, erosion control, pollination, and aesthetic appreciation (Millennium Ecosystem Assessment 2005). Further, within the larger ecosystem, the role and function of wetlands in the reception, storage, and release of surface and/or groundwater flows and atmospheric deposition, make them important sentinels of both local and regional ecosystem change.

Despite the ecological and economic value of wetlands, these ecosystems continue to be lost in Alberta as a result of human activity and development, and impacts to wetland ecosystems as a result of climate change are expected to increase throughout Alberta (Kettridge et al. 2015). This continued loss necessitates more thoughtful planning and prioritization, which would better facilitate the conservation or protection of wetlands with high ecological value. In order to conserve high value wetlands, however, they must first be identified and accurately mapped. Comprehensive and accurate wetland inventories are important if tracking change in the size, distribution, and type of wetlands within a specified area is desired, and having high quality wetland inventories is foundational to tracking physical changes to individual wetlands or wetland systems. Once wetlands are mapped, defining what constitutes a high value wetland on the landscape becomes possible. This information can then be used to inform land use planning initiatives and policy decisions, and consideration can be given to how future development may impact the value and function of these important habitats.

The overall goal of this study was to provide a thorough assessment of the current and historical status of wetlands within Parkland County. To achieve this, a historical (circa 1950) and current (2013) wetland inventory was created, and the ecological value of current wetlands was assessed using a criteria and indicators framework. The current and historical wetland inventories were then compared to assess the change in wetland area over time in Parkland County. This information will allow decision makers to differentiate between wetlands on the basis of transparent and objective ecological value scores, such that higher value wetlands can be prioritized for special management, if desired. Further, the results of this study will allow Parkland County to target on-going wetland conservation and restoration efforts in areas where wetland losses have been high. Finally, these wetland inventories provide Parkland County with important baseline information that can be used to track change in wetland area and value into the future, such that the success of restoration and environmental policies can be tracked and evaluated.

## 7.1. Closure

**This report was written by:**

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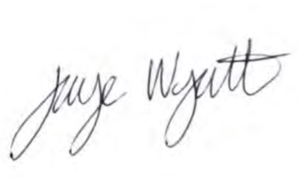

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# Appendix A

## Detailed Methods for the Quantification and Scoring of Wetland Ecological Value

### CRITERION 1: Biodiversity Value

#### Sub-Criterion 1a: Fish Habitat

#### Indicator 1a(i): Surface connection to fish-bearing waterbody

Description:
- Wetland objects that contain open water areas that have the potential to support fish

Data source:
- Parkland County wetland inventory, Stream network, Code of Practice streams

Quantification:
- Selected all Wetland Objects (WO) where the total area of open water within the Wetland Object was >0
- Identified wetlands that had a either a direct or indirect surface water connection to a water course identified as Class A, B, C, or D in the Code of Practice map.
- Wetland were scored as
  - Direct Surface Connection to COP stream = 100
  - Indirect Surface Connection to COP stream = 50
  - WO containing open water = 10
  - No Open Water in WO = 0

#### Sub-Criterion 1b: Amphibian Habitat

#### Indicator 1b(i): Road density within 300m

Description:
- Road density (km/km$^2$) within a 300m buffer surrounding Wetland Objects

Data source:
- Parkland County wetland inventory, Provincial base features (roads)

Quantification:
- Wetland objects were buffered by 300m
- Buffers were intersected with the provincial road layer and the total length of roads within each buffer was summed
- The total road length within each buffer was converted to a density by dividing by the wetland buffer area (km/km$^2$)
- Road density values were range standardized (to values between 0 and 100), and wetlands with lower road densities in the buffer were given higher scores

### Indicator 1b(ii): Wetland-wetland connectivity within 300m

Description:
- Wetland objects that have a continuous connection via a) natural upland vegetation and/or a b) surface water connection to other wetlands within 300m

Data source:
- Parkland County wetland inventory, AAFC land cover inventory, Provincial stream network

Quantification:
- For part a) wetland objects and natural habitats from the AAFC land cover were merged to identify natural upland-lowland complexes
- All wetland objects intersecting each upland-lowland complex were identified, and tagged to determine if there was natural habitat connectivity between 2 or more adjacent wetlands through natural habitats within 300m
- For part b) wetland objects and the provincial stream layer were merged to identify stream-wetland regions with hydrological connectivity
- All wetland objects intersecting each stream-wetland region were identified, and tagged to determine if there was hydrological connectivity between 2 or more adjacent wetlands through streams within 300m
- All wetlands with a continuous surface water and/or natural habitat vegetated connection were scored as:
  - Wetlands with a surface water connection = 50
  - Wetlands with a natural upland connection = 50
  - Wetlands with a natural upland & surface water connection =100
  - All other wetlands = 10

### Indicator 1b(iii): Wetland density within 300m

Description:
- Density (number) of wetlands located within 300m of all wetlands

Data source:
- Parkland County wetland inventory

Quantification:
- All wetland objects were buffered by 300m
- The total number of all wetlands within the buffer were quantified as wetland density (# of wetlands/km$^2$) in the buffer
- Wetland density values were range standardized (to values between 0 and 100), where wetlands with higher densities in the 300m buffer were given higher scores

### Indicator 1b(iv): Cover of natural upland habitat within 300m

Description:
- Percent cover of perennial natural upland vegetation within 300m of all wetlands

Data source:
- Parkland County wetland inventory, AAFC land cover inventory

Quantification:
- Natural upland vegetation cover classes from the AAFC landcover were extracted
- Wetland Objects were buffered by 300m
- Buffers were intersected with the AAFC natural vegetation layer, and the total area of natural habitat within each buffer was summed
- The total area of natural habitat within each buffer was converted to a proportion by dividing by the wetland buffer area (km/km$^2$)
- Proportional area of natural habitat values were range standardized (to values between 0 and 100), and wetland objects with higher proportional areas of natural habitat in the buffer were given higher scores

**Sub-Criterion 1c: Waterbird Habitat**

**Indicator 1c(i): Road density within 500m**

Description:
- Road density within a 500m buffer surrounding marsh or open water wetlands

Data source:
- Parkland County wetland inventory, Provincial base features (roads)

Quantification:
- Marsh or open water wetlands were buffered by 500m
- Buffers were intersected with the provincial base feature road layer and the total length of roads within each buffer were summed
- The total road length within each buffer was converted to a density by dividing by the wetland buffer area (km/km$^2$)
- Road density values were range standardized (to values between 0 and 100), and wetland objects with lower road densities in the were given higher scores

**Indicator 1c(ii): Area of open water within 500m**

Description:
- Areas of open water (wetlands and lakes) within a 500m buffer surrounding marsh or open water wetlands

Data source:
- Parkland County wetland inventory, Provincial hydro polygons

Quantification:
- Marsh or open water wetlands were buffered by 500m
- Buffers were intersected with lakes identified in the provincial hydro polygon layer and open water wetlands in the wetland inventory layer, and the total area of open water within each buffer was summed
- The total area of open water within each buffer was converted to a proportion by dividing by the wetland buffer area (km/km$^2$)
- The proportional area of open water values were range standardized (to values between 0 and 100), and wetland objects with higher proportional areas of open water in the buffer were given higher scores

**Indicator 1c(iii): Waterfowl staging areas**

Description:
- Wetlands intersecting waterfowl staging areas

Data source:
- Parkland County wetland inventory, Important Bird Areas of Canada (IBA), NAWMP staging areas, AESRD Colonial Nesting Birds,

Quantification:
- All layers were combined and merged
- All quarter sections touching a waterfowl staging and foraging area layer were identified, and then all wetland objects touching these selected quarter sections were identified
- Wetlands were scored as:
    - All selected wetland object intersecting waterfowl staging quarter sections = 100
    - All other wetlands = 10

### Indicator 1c(iv): Waterfowl breeding areas

Description:
- Wetlands intersecting waterfowl breeding areas

Data source:
- Parkland County wetland inventory, ACIMS, DUC Waterfowl Pair Distribution Model

Quantification:
- All quarter sections that touched any polygon identified by ACMIS as “bird colony” were identified. All wetlands intersecting these quarter sections were identified and scored
- The DUC Waterowl Pair Distribution Model was spatially joined to the quarter section layer and the area weighted average breeding density was calculated. The breeding density was reassigned to each wetland object within the quarter section. Where the wetland object fell in one or more quarter sections, the maximum quarter section score was assigned to the wetland object.
- Wetlands were scored as:
    - Wetlands with an average breeding density >50 = 100
    - Wetlands intersecting an ACIMS bird colony quarter section = 100
    - All other wetlands = 10

### Sub-Criterion 1d: Songbird, Raptor, and Mammal Habitat

### Indicator 1d(i): Stepping stone habitat

Description:
- Wetlands within 500m of a Key Wildlife Biodiversity Area or major (named) creek corridor (stepping stone habitat)

Data source:
- Parkland County wetland inventory, Provincial Key Wildlife Biodiversity Area layer, Provincial stream inventory

Quantification:
- Key Wildlife Biodiversity Areas and named creek corridors were buffered by 500m
- All wetlands that intersect the buffers were identified and scored as:
    - Wetlands that intersect stepping stone habitat buffers = 100
    - Wetlands that did not intersect stepping stone habitat buffers =10

### Indicator 1d(ii): Sensitive raptor habitat

Description:
- Wetlands within areas identified by AEP as Sensitive Raptor Habitat

Data source:
- Parkland County wetland inventory, Provincial Sensitive Raptor Habitat Area layer,

Quantification:
- All wetlands that intersect identified Sensitive Raptor Habitat Areas were identified and were given a score of 100
- All other wetlands were given a score of 10

### Sub-Criterion 1e: Rare Species Habitat

### Indicator 1e(i) Known locations of Rare, Threatened, or Endangered species

Data source:
- ACIMS, FWMIS

Quantification:
- Species with a ranking of S1, S1?, S2, S2?, S1S2, S2S3, G1?, G2?, G1G2, G2G3, or a Provincial/Federal ranking of Special Concern, Threatened, At Risk, or Endangered were identified
- All quarter sections that intersected a known location of a rare, threatened, or endangered species were identified and scored 100
- All other wetlands were given a score of 10

## CRITERION 2: Ecological Function

### Sub-Criterion 2a: Habitat Patch Size and Complexity

### Indicator 2a(i): Wetland or wetland complex size

Description:
- Total wetland area

Data source:
- Parkland County wetland inventory

Quantification:
- The total area of the wetland object was calculated
- Larger wetlands or complexes were range standardized (to values between 0 and 100), with larger wetlands given higher scores

### Indicator 2a(ii): Wetland-upland complex size

Description:
- Total area of wetland plus the total area of upland that is vegetated with natural cover and is directly adjacent to (touching) the wetland boundary

Data source:
- Parkland County wetland inventory, AAFC land cover inventory

Quantification:
- Wetlands were merged with any adjoining upland natural cover extracted from the AAFC land cover
- The total area of the wetland-upland complex was calculated
- Larger wetland-upland complexes were range standardized (to values between 0 and 100), and larger wetlands-upland complexes were given higher scores

### Indicator 2a(iii): Wetland shoreline complexity

Description:
- Perimeter to area ratio for all wetlands

Data source:
- Parkland County wetland inventory

Quantification:
- Calculate the ratio of wetland perimeter to wetland area using the shape index, or: (0.25*perimeter)/sqrt(area)
- Wetlands with higher shape index (more complex shorelines) were range standardized (to values between 0 and 100), and more complex shorelines were given higher scores

### Indicator 2a(iv): Wetland habitat richness within 1km

Description:
- Total number of different wetland habitat types within a 1 km buffer of each wetland

Data source:
- Parkland County wetland inventory

Quantification:
- Wetlands were buffered by 1 km
- The total number of wetland types within each buffer was calculated
- Wetlands were range standardized (to values between 0 and 100), and wetlands with higher wetland richness were given higher scores

### Sub-Criterion 2b: Habitat Intactness

### Indicator 2b(i): Linear disturbance density within 1km

Description
- The total density ($km/km^2$) of linear disturbances within a 1km buffer

Data source:
- Parkland County wetland inventory, Provincial base linear features (roads, rail lines, pipelines, power lines, seismic lines)

Quantification:
- Wetlands were buffered by 1km and buffers were intersected with the provincial base linear features
- The length of linear features within each buffer was summed and linear feature length within each buffer was converted to a density by dividing by the wetland buffer area ($km/km^2$)
- Linear feature density values were range standardized (to values between 0 and 100), and wetlands with lower linear feature densities in the buffer were given higher scores

### Indicator 2b(ii): Road density within 1km

Description
- The total density ($km/km^2$) of roads within a 1km buffer

Data source:
- Parkland County wetland inventory, Provincial base road features

Quantification:
- Wetlands were buffered by 1km, and buffers were intersected with the provincial base road features and the total length of roads within each buffer was summed
- The total road length within each buffer was converted to a density by dividing by the wetland buffer area ($km/km^2$)
- Road density values were range standardized (to values between 0 and 100), and wetlands with lower road densities in the buffer were given higher scores

### Indicator 2b(iii): Distance to nearest road

Description
- The shortest straight-line distance between the wetland boundary and the nearest road feature

Data source:
- Parkland County wetland inventory, Provincial base features (roads)

Quantification:
- The distance from each wetland boundary to the nearest road segment was calculated. Distance values were range standardized (to values between 0 and 100), and wetlands with high distance values (further away from) were given higher scores

### Indicator 2b(iv): Land use intensity within 1km

Description:
- The total intensity of land use within a 1 km buffer surrounding each wetland object

Data source:
- Parkland County wetland inventory, AAFC land cover inventory

Quantification:
- Intensity of use categories were assigned to each land cover class, where:
    - Natural Habitat (Forest, Grassland, Shrub, and Wetland) = 0
    - Pasture = 10
    - All Crops, Urban and Exposed (Mining) = 100
- Wetland object polygons were buffered by 1 km, buffers were intersected with the AAFC land cover, and the total area of each intensity of use categories was summed
- The total area of each intensity of use categories within each buffer was converted to a density by dividing by the wetland buffer area ($km/km^2$)
- The proportional area of each Intensity of use class category was multiplied by the intensity of use value (either 0,10, or 100)
- The total land use intensity for each wetland was calculated as the sum of all area weighted land use intensity categories
- Land use intensity values were range standardized (to values between 0 and 100), and wetlands with lower land use intensities in the buffer were given higher scores

### Sub-Criterion 2c: Landscape Habitat Connectivity

### Indicator 2c(i): Wetland-upland connectivity

Description:
- The total proportion of each wetland objects perimeter adjoining natural cover

Data source:
- Parkland County wetland inventory, AAFC land cover inventory

Quantification:
- Wetlands were be converted to polyline features, and natural upland vegetation cover classes from the AAFC land cover were extracted
- The natural upland vegetation layer and wetland perimeter polyline layer were intersected and the total length of the intersected polyline in natural habitat was calculated for each wetland
- The total length of the wetland perimeter adjoining natural upland habitat was converted to a proportion by dividing by the total perimeter length ($m/m^2$)
- The proportion of natural perimeter values were range standardized (to values between 0 and 100), and wetlands with high natural perimeter values were given higher scores

### Indicator 2c(ii): Wetland-wetland connectivity within 1km

Description:
- Wetland objects that have a continuous connection via a) natural upland vegetation and/or a b) surface water connection to other wetlands within 1 km

Data source:
- Parkland County wetland inventory, AAFC land cover inventory, Provincial stream network

Quantification:
- For part a) wetland objects and natural habitats from the AAFC land cover were merged to identify natural upland-lowland complexes
- All wetland objects intersecting each upland-lowland complex were identified, and tagged to determine if there was natural habitat connectivity between 2 or more adjacent wetlands through natural habitats within 1 km
- For part b) wetland objects and the provincial stream layer were merged to identify stream-wetland regions with hydrological connectivity
- All wetland objects intersecting each stream-wetland region were identified, and tagged to determine if there was hydrological connectivity between 2 or more adjacent wetlands through streams within 1 km
- All wetlands with a continuous surface water and/or natural habitat vegetated connection were be scored.
    - Wetlands with a surface water connection were given a score of 50
    - Wetlands with a natural upland connection were given a score of 50
    - Wetlands with both a natural upland and surface water connection were given a score of 100

### Indicator 2c(iii): Wetland density within 1km

Description:
- Density (number) of wetlands located within 1km

Data source:
- Parkland County wetland inventory

Quantification:
- All wetland object were buffered by 1 km
- The total number of all wetlands within the buffer was quantified as wetland density (# of wetlands/$km^2$) in the buffer
- Wetland density values were range standardized (to values between 0 and 100), and wetlands with higher densities in the 1 km buffer were given higher scores

### Indicator 2c(iv): Cover of natural upland habitat within 1km

Description:
- Percent cover of perennial natural upland vegetation within 1km of all wetland types

Data source:
- Parkland County wetland inventory, Parkland County land cover inventory

- Natural upland vegetation cover classes from the AAFC land cover were extracted
- Wetland Objects were buffered by 1 km
- Buffers were intersected with the AAFC natural vegetation layer, and the total area of natural habitat within each buffer was summed
- The total area of natural habitat within each buffer was converted to a proportion by dividing by the wetland buffer area (km/km$^2$)
- Proportional area of natural habitat values were range standardized (to values between 0 and 100), and wetlands with higher proportional areas of natural habitat in the buffer were given higher scores

## CRITERION 3: Hydrologic Function & Water Quality Improvement

### Sub-Criterion 3a: Water Storage

### Indicator 3a(i): Depressional basin area

Description:
- Total area of each depressional basin contributing to the wetland

Data source:
- Parkland County wetland inventory, Parkland County probability of depression layer, 15m LiDAR DEM

Quantification:
- For each wetland in the inventory, a depressional basins was defined using a probability of depression analysis. All probability value ≥0.1 were reclassified as 1 (depression), and all value <0.1 were reclassed as 0 (no depression). This binary raster was converted to a polygon and the areas of each continuous depression was calculated
- The maximum depressional area was assigned to each intersection wetland
- Maximum depressional area were range standardized (to values between 0 and 100), and wetlands with larger depression basins were given higher scores

### Indicator 3a(ii): Groundwater recharge areas

Description:
- Identification of important wetlands in the filtration of contaminants in regions with groundwater recharge potential

Data source:
- Parkland County wetland inventory, Alberta Groundwater Recharge/Discharge map and Aquifer Vulnerability Map

Quantification:
- Wetlands that intersect areas identified as groundwater recharge zones were identified, and the average Aquifer Vulnerability risk score for each wetland that intersects a groundwater recharge zone was calculated
- Wetlands with higher aquifer vulnerability received the highest scores to identify important wetlands for ecosystem filtration based on the range standardized (to values between 0 and 100) vulnerability scores

### Indicator 3a(iii): Wetlands upslope of flood risk areas

Description:
- Wetlands located within 1km upslope of areas prone to flooding, as identified through GOA flood hazard mapping

Data source:
- Parkland County wetland inventory, Digital Flood Hazard Mapping (Floodways and Flood Fringes) layer, Parkland County DEM

Quantification:
- Floodways were buffered by 1 km, and all wetlands intersecting the buffer were identified. Wetlands were scores as:
  - Wetland in the floodway buffer were given a score of 100,
  - All other wetlands were given a score of 10

### Indicator 3a(iv): Relative wetland elevation within the watershed

Description:
- Wetland position in the watershed based on relative elevation within the HUC8 watershed

Data source:
- Parkland County wetland inventory, Hierarchical Unit Code (HUC) watersheds of Alberta, Parkland County DEM, Provincial DEM

Quantification:
- For each HUC8 watershed, all the wetland occurring within were selected, and each wetland was ranked using the percentile of the elevation values within the HUC8
- As wetland percentile values were range standardized (to values between 0 and 100), and wetlands with lower elevation percentiles received higher scores

### Sub-Criterion 3b: Stream Flow Support

### Indicator 3b(i): Springs and groundwater discharge areas

Description:
- Wetlands with high groundwater discharge potential

Data source:
- Parkland County wetland inventory, Alberta Groundwater Recharge/Discharge map Alberta springs map, Parkland County Stream inventory

Quantification:
- Wetlands that intersect areas identified as groundwater discharge zones where a) they are adjacent to, and downstream of springs, and b) discharge wetlands with direct surface water connections.
- Any wetland within 300m downslope of a spring was identified for part a)
- For part b) all wetlands intersecting discharge zones AND the parkland county stream inventory (discharge wetlands that had a direct surface water connection) were selected
- Discharge wetlands were buffered by 300m and any wetlands intersected with the Parkland County stream inventory. Any discharge wetlands that had a surface water connection within 300m were identified. Wetlands were scored as:
- All wetlands within a discharge zone or 300m downslope of a spring with a direct surface water connection were given a score of 100
  - All wetlands within a discharge zone or 300m downslope of a spring with a surface water connection within 300m = 75
  - Wetlands within a discharge zone or 300m downslope of a spring with no surface water connection within 300m = 50
  - All other wetlands = 10

### Indicator 3b(ii): Surface channel connection

Description:
- Wetlands intersecting the provincial base stream network layer

Data source:
- Parkland County wetland inventory, Provincial base features single line stream network

Quantification:
- The provincial base features single line stream network were intersected with the wetland inventory
- Any wetland with a surface water channel connection were identified
  - Marsh or open water wetlands intersecting the stream network layer = 100
  - Bog/Fen/Swamp wetlands intersecting the stream network layer = 50
  - All other wetlands = 10

### Indicator 3b(iii): Riverine and lacustrine wetlands

Description:
- Wetlands identified as riverine (connected to a river or stream) or lacustrine (connected to a lake)

Data source:
- Parkland County wetland inventory, GoA Hydro polygons, Parkland County Stream Inventory

Quantification:
- All wetlands were intersected rivers or streams within the Parkland County stream inventory, and any wetlands intersecting a river or stream were identified
- All wetlands were intersected with any hydro polygons identified as "LAKE" in the hydro poly layer, and any wetlands intersecting lakes were identified
- Wetlands were scored as:
  - All wetlands intersecting EITHER the Parkland County stream inventory OR a lake in the Alberta Hydro Polygon Layer = 100
  - All other wetlands = 10

### Sub-Criterion 3c: Sediment and Nutrient Reduction

### Indicator 3c(i): Slope surrounding wetland

Description:
- Average slope within a 500m buffer surrounding wetlands

Data source:
- Parkland County wetland inventory, Parkland County DEM, AAFC land cover layer

Quantification:
- All wetlands were buffered by 500m; buffers were intersected with the AAFC natural vegetation layer and the total area of natural habitat within each buffer was summed
- The total area of natural habitat within each buffer was converted to a proportion by dividing by the wetland buffer area ($km/km^2$)
- All wetlands with <50% natural cover were selected, and the average slope for the area surrounding the wetland within the 500m buffer was calculated
- Average slope values were range standardized (to values between 0 and 100), and wetlands with higher average slopes in the buffer were given higher scores

### Indicator 3c(ii): Vegetated area within wetland basin

Description:
- Area of the wetland basin that is covered by trees, shrubs, or graminoid vegetation

Data source:
- Parkland County wetland inventory

Quantification:
- All natural vegetation cover categories was extracted from the land cover inventory
- Wetland basin boundaries were intersected with the extracted land cover layer
- The percent cover of trees, shrubs, and graminoid vegetation within each basin boundary was calculated and was multiplied by velocity reduction scores, with trees receiving the highest velocity reduction score (3), and graminoid vegetation receiving the lowest velocity reduction value (1), while shrubs were given a velocity reduction score of 2.
- Values were summed, then range standardized (to values between 0 and 100), and wetlands with higher vegetation values were given higher scores

### Indicator 3c(iii): Wetlands located in floodways or riparian areas

Description:
- Wetlands located within defined floodways, flood fringes, or within a specified distance from a major river or stream

Data source:
- Parkland County wetland inventory, Provincial stream inventory

Quantification:
- All rivers and major (named) streams were buffered. Major rivers (those with Strahler order>=4) were buffered by 500m on each bank and major streams (those with Strahler order =3) were buffered by 150m on each bank
- All wetlands located within major river or stream buffers were identified
    - Wetlands intersecting major river or major stream buffers = 100
    - All other wetlands = 10

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