Lower Pembina Watershed Riparian Area Assessment

FINAL REPORT

Project #2012
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Prepared for:

Athabasca Watershed Council

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FIERA Biological Consulting

Front Cover Photo: Pembina River
Credit: Robert Holmberg, from the repository of the Athabasca River Basin, Athabasca University

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The Athabasca Watershed Council would also like to acknowledge the financial assistance of the Government of Alberta, without which this project would not have been possible. The Government of Alberta contributed to the delivery of this project through the Watershed Resiliency and Restoration Program, which aims to restore or enhance previously degraded natural habitats, including riparian habitat, within priority watersheds across Alberta. Additionally, the Government of Alberta provided spatial data that was essential for the successful completion of this project. The AWC would also like to thank the many municipalities, industries, businesses, Indigenous communities, stewardship groups, and donors that support and contribute to the work of the watershed council.

Executive Summary

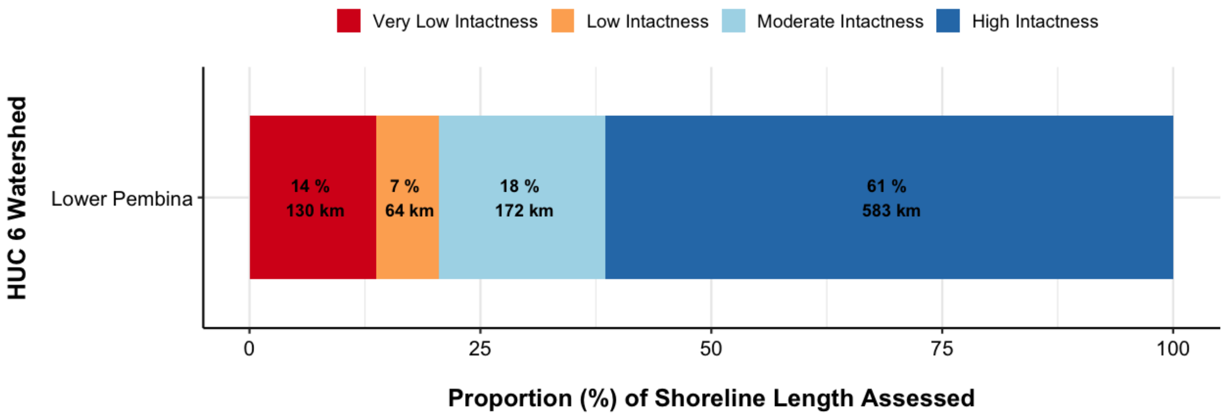
Riparian lands have substantial ecological, economic, and social value; for example, intact riparian habitats stabilize the banks of waterbodies and help modulate water velocities and high water events, thereby improving water quality and protecting surrounding lands from flooding. Intact riparian areas also play a vital role in the exchange of inorganic and organic material between terrestrial and aquatic ecosystems and regulate water temperature and the instream light environment, thereby ensuring suitable habitat for a range of aquatic species. Given the significant role that an intact riparian zone has on providing ecosystem services and supporting healthy and functional aquatic ecosystems, there is a need to effectively manage riparian areas. Thus, understanding the distribution of intact riparian habitat across the landscape and identifying areas where riparian intactness has been degraded is essential to improving conservation and management outcomes.

In an effort to better manage riparian habitats within the Lower Pembina watershed, the Athabasca Watershed Council (AWC) retained Fiera Biological Consulting to assess riparian habitat along approximately 949 km of river shoreline. The Lower Pembina is a very large (~3,935 km^2) HUC 6 watershed that is located in the south central portion of the Athabasca River (HUC 2) watershed. This HUC 6 watershed is made up of four smaller (HUC 8) subwatersheds: the Pembina River, French Creek, Dapp Creek, and Shoal Creek subwatersheds.

Riparian vegetation intactness was assessed along the shorelines of interest using a desktop-based assessment tool that utilizes a current land cover layer derived from satellite imagery. Intactness was assessed within riparian management areas (RMAs) that have a variable length, as determined by major breaks in the proportion of vegetation cover along the shoreline, and a fixed 50 m buffer that extends perpendicular to the shoreline. Within each RMA, intactness was assessed using a number of GIS metrics that quantified the type and extent of vegetation and human disturbance present. Intactness was used as the measure of riparian condition because the relationship between an intact riparian zone and the health or function of the aquatic environment is well established.

In addition to assessing riparian intactness, natural and anthropogenic pressure within local catchments was evaluated to identify riparian areas that may be functionally impaired due to surrounding land use activities. Each RMA within the Lower Pembina watershed was assigned an intactness and pressure score, and these scores were combined using a prioritization matrix that assigned a conservation or restoration priority to each RMA. This allows land managers to target specific areas within the watershed for conservation and restoration, as well as identify areas were more detailed, site-specific field assessments of riparian health or condition may be required.

A total of 11 waterbodies were assessed in the Lower Pembina watershed, including 8 creeks and rivers and 3 lakes. The majority (61%, 583 km) of the shoreline assessed was classified as High Intactness, with an additional 18% (172 km) of the shoreline classified as Moderate Intactness. The remaining shoreline was classified as either Low (7%, 64 km) or Very Low (14%, 130 km) Intactness.

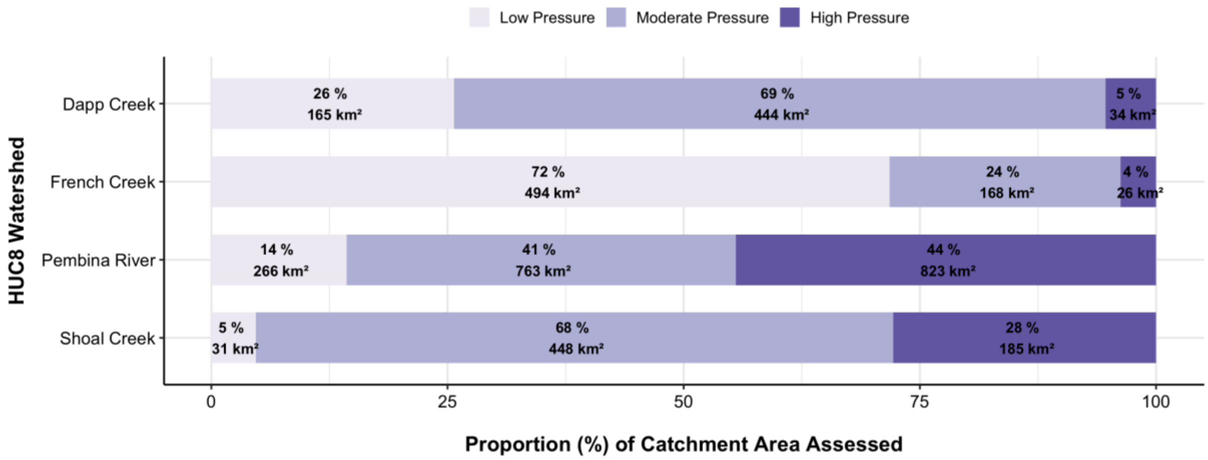


When intactness is compared by subwatershed, the French Creek subwatershed had the greatest proportion of shoreline rated as High Intactness (82%), followed by the Pembina River subwatershed (66%). The Shoal Creek subwatershed had the greatest proportion of shoreline rated Low and Very Low Intactness (34%).

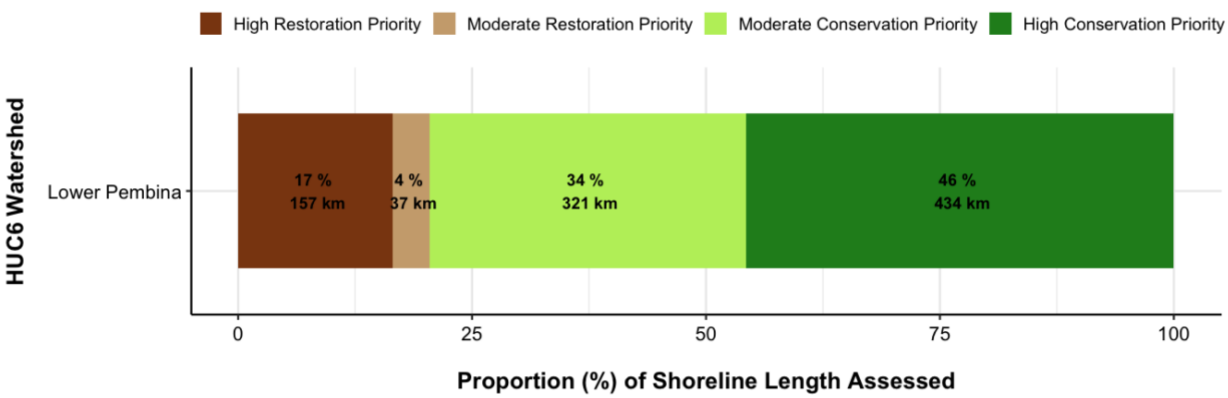
When intactness was evaluated for municipalities, the MD of Lesser Slave River had 89% of its shoreline classified as High Intactness, whereas the County of Barrhead had only 40% of its shoreline classified as High Intactness. Westlock County had the greatest proportion of shoreline rated Low and Very Low Intactness (26%).

		Proportion (%) of Shoreline within Intactness Category					
Spatial Extent	**Length Assessed (km)**	**Very Low**	**Low**	**Very Low + Low**	**Moderate**	**High**	**Moderate + High**
Lower Pembina Watershed	948.5	14	7	20	18	61	80
Dapp Creek Subwatershed	143.7	19	9	27	18	55	73
French Creek Subwatershed	135.1	5	4	9	8	82	91
Pembina River Subwatershed	531.5	13	5	18	16	66	82
Shoal Creek Subwatershed	138.2	21	13	34	37	29	66
Athabasca County	62.5	17	4	22	8	70	78
County of Barrhead	112.1	17	7	24	36	40	76
MD of Lesser Slave River	220.8	3	2	5	5	89	95
Westlock County	553.2	17	9	26	21	54	74

Pressure on riparian system function was assessed for 436 local catchment areas within the watershed. The Pembina River subwatershed had the greatest proportion of its area classified as High Pressure (44%). The Dapp Creek and Shoal Creek subwatersheds had the majority of their catchment areas classified as Moderate Pressure, and French Creek had the greatest proportion of its area (72%) classified as Low Pressure.



Within the Lower Pembina watershed, 80% (755 km) of the shoreline assessed was classified as either High (46%; 434 km) or Moderate (34%; 321 km) priority for conservation. Conversely, 20% of the shoreline was classified as either High (17%; 157 km) or Moderate (4%; 37 km) priority for restoration.

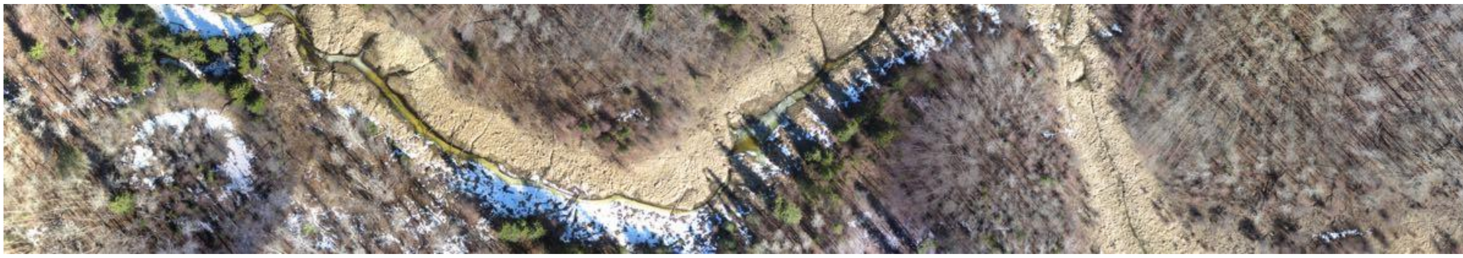


When conservation and restoration priority is compared by subwatershed, the French Creek subwatershed had the greatest proportion of shoreline rated as High Conservation Priority (78%), followed by the Dapp Creek subwatershed (57%). The Shoal Creek subwatershed had the greatest proportion of shoreline rated High Restoration priority (28%).

When conservation and restoration priority was evaluated for municipalities, Brazeau County and Yellowhead County had the greatest proportion of shoreline classified as High Conservation priority, while Parkland County had the greatest proportion of shoreline classified as either High or Moderate priority for restoration.

Spatial Extent	Length Assessed (km)	Proportion (%) of Shoreline					
		High Restoration	Moderate Restoration	Restoration Priority	Moderate Conservation	High Conservation	Conservation Priority
Lower Pembina Watershed	948.5	17	4	20	34	46	80
Dapp Creek Subwatershed	143.7	17	10	27	16	57	73
French Creek Subwatershed	135.1	7	2	9	12	78	91
Pembina River Subwatershed	531.5	16	2	18	40	42	82
Shoal Creek Subwatershed	138.2	28	6	34	48	18	66
Athabasca County	62.5	8	14	22	2	76	78
County of Barrhead	112.1	20	3	24	51	26	76
MD of Lesser Slave River	220.8	4	2	5	11	83	95
Westlock County	553.2	22	4	26	43	31	74

This project has generated scientific information that can be used as the basis for the development and implementation of an evidence-based framework for adaptively managing riparian areas within the Lower Pembina watershed. Through the commissioning of this study, the Athabasca Watershed Council and its stakeholders now have an important foundation of scientific evidence upon which to target restoration and conservation activities that will improve water quality, biodiversity, and drought and flood resilience in the watershed. The next step in the advancement of meaningful riparian management and conservation in the Lower Pembina watershed will be to formalize a framework for action that includes a consideration of the current conditions and defining achievable outcomes and measurable targets that can be used by key stakeholders to inform management decisions. These actions can then be monitored on a regular basis to provide an evaluation of outcomes that feed into an adaptive and reflexive approach to riparian management over time within the watershed.



List of Terms

Abbreviations

AAFC: Agriculture and Agri-food Canada
ABMI: Alberta Biodiversity Monitoring Institute
AGS: Alberta Geological Survey
ARHMS: Alberta Riparian Habitat Management Society (Cows & Fish)
AWC: Athabasca Watershed Council
BMP: Best Management Practice
DEM: Digital Elevation Model
HUC: Hydrologic Unit Code
RMA: Riparian Management Area

Glossary

Aerial Videography: Video captured from a low flying aerial platform, such as helicopter or ultra light aircraft.

Catchment: Small local drainage areas ranging in size from 1.0 to 48 km^2 that were acquired as part of this study to assess pressure on riparian system function. The catchment data used in this study are freely available from the provincial government as part of Alberta ArcHydro Phase 2 spatial dataset (Government of Alberta 2018).

Conservation Priority: A riparian management area that has been assessed as being moderately to highly intact and is associated with a catchment assessed as moderately to low pressure. Because these areas are largely in a natural state, they are considered to be targets for conservation and/or protection to maintain their current state of function and ecological value.

Hydrologic Unit Code: The Hydrologic Unit Code Watersheds of Alberta (HUC) represent a collection of nested hierarchically structured drainage basin feature classes that have been created using the Hydrologic Unit Code system of classification developed by the United States Geological Survey (USGS), with accommodation to reflect the pre-existing Canadian classification system. The HUC Watersheds of Alberta consist of successively smaller hydrologic units that nest within larger hydrologic units, resulting in a hierarchal grouping of alphanumerically-coded watershed feature classes. The hydrological unit codes include HUC 2, HUC 4, HUC 6, HUC 8, and HUC 10 with HUC 2 being the coarsest level of classification and HUC 10 being the finest level of classification.

Indicator: A measurable or descriptive characteristic that can be used to observe, evaluate, or describe trends in ecological systems over time.

Intactness: In reference to the condition of natural habitat, intactness refers to the extent to which habitat has been altered or impaired by human activity, with areas where there is no human development being classified as high intactness.

Left Bank: The bank of a river, stream, or creek that is on the left when facing downstream.

Metric: A qualitative or quantitative aspect of an *indicator*; a variable which can be measured (quantified) or described (qualitatively) and demonstrates either a trend in an indicator or whether or not a specific threshold was met.

Resilience: The capacity of an ecosystem to resist, absorb, and recover from the effects of natural and human-caused disturbance to preserve ecological and hydrological services and functions.

Restoration Priority: A riparian management area that has been assessed as being of low or very low intactness and that is associated with a catchment assessed as high pressure. Because these areas are largely in a modified or disturbed state, they should be targets of restoration to improve their current state of function and ecological value.

Right Bank: The bank of a river, stream, or creek that is on the right when facing downstream.

Riparian Area, Riparian Habitat, Riparian Land, or Riparian Zone: Riparian lands are transitional areas between upland and aquatic ecosystems. They have variable width and extent both above and below ground. These lands are influenced by and/or exert an influence on associated waterbodies, which includes alluvial aquifers and floodplains, when present. Riparian lands usually have soil, biological, and other physical characteristics that reflect the influence of water and/or hydrological processes (Clare and Sass 2012).

Riparian Management Area: As per Teichreb and Walker (2008), and for the purpose of this report, a riparian management area is defined as an area along the shoreline of a waterbody that includes near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone.

Strahler Order: A method of classifying and assigning a numeric order to streams in a network based on the number of tributaries. First order streams are dominated by overland flow and have no upstream concentrated flow; whereas higher order streams have a greater number of upstream tributaries. Stream order increases when stream of the same order intersect.

Waterbody: Any location where water flows or is present, whether or not the flow or the presence of water is continuous, intermittent or occurs only during a flood. This includes, but is not limited to lakes, wetlands, aquifers, streams, creeks, and rivers.

Watercourse: A natural or artificial channel through which water flows, such as in creeks, streams, or rivers.

Watershed: An area that, on the basis of topography, contributes all water to a common outlet or drainage point. Watersheds can be defined and delineated at multiple scales, from very large (e.g., thousands of square kilometers, such as the Red Deer River watershed) to very small local watersheds (e.g., square metres, such as a small prairie wetland).

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1.0 Introduction

1.1. Background

Riparian areas are highly complex and dynamic "transitional habitats" that are found along the edge of waterbodies, including rivers, streams, lakes, wetlands, and springs. Riparian areas show steep hydrological and environmental gradients from the water's edge to the adjacent uplands, and are critical for facilitating the transfer of energy and materials between terrestrial and aquatic ecosystems (NRC 2002). Hydrology (both groundwater and surface water) is the driving force behind the physical, chemical, and biological processes that characterize riparian habitats, and because riparian lands are under the influence of both terrestrial and aquatic processes (e.g. nutrient and sediment transfer), these areas tend to be more biologically productive and have higher levels of biodiversity than other habitats of comparable size (Ibid).

From the perspective of human communities, riparian areas provide a multitude of beneficial ecosystem functions and services, and the relationship between an intact riparian zone and the integrity of the aquatic environment is well established (Pusey and Arthington 2003). For example, intact riparian zones play a vital role in the exchange of inorganic and organic material between the terrestrial and aquatic ecosystems, via the interception of sediments and nutrients that runoff from adjacent upland habitats and through the supply of leaf litter and woody debris. Furthermore, intact riparian vegetation can modulate the transfer of solar energy to the aquatic ecosystem, regulating water temperatures and the instream light environment, ensuring suitable habitat for a range of aquatic species (Pusey and Arthington 2003). Riparian habitats stabilize the banks of waterbodies and help modulate water velocities and high water events, thereby improving water quality and protecting surrounding lands from flooding (Orewole et al. 2015; Olokeogun et al. 2020). Riparian vegetation also slows floodwater and increases floodplain residence times, which increases recharge to groundwater aquifers (Swanson et al. 2017). In turn, this allows water to seep back into streams during low water or drought periods (Blackport et al. 1995), thereby stabilizing base water flows (Caissie 1991; Blackport et al. 1995).

Despite the importance of these habitats, the loss and impairment of riparian lands in Alberta over the last century has been significant (Clare and Sass 2012), and as a result, recent watershed management efforts throughout the province have been focused on identifying priority areas for riparian restoration and habitat management. In order to efficiently target habitat restoration efforts and resources across large spatial extents, however, there first needs to be reliable information about the location, condition, and function of riparian habitats.

1.2. Methods for Assessing Riparian Areas

The finest scale and most detailed evaluations of riparian condition come from “boots-on-the-ground” site-specific field assessments and/or inventories of riparian areas. In this type of assessment, such as the Alberta Riparian Habitat Management Society (ARHMS, also known as “Cows & Fish”) Riparian Health Assessment, detailed and local-scale traits of riparian areas are evaluated by trained practitioners, and a comprehensive and thorough assessment of riparian condition is made. Metrics evaluate a wide range of riparian attributes including: vegetation type, structure, and composition; bank characteristics; soil attributes; and land use and disturbance. The final compiled score provides a snapshot of whether a riparian area is “Healthy”, “Healthy, but with problems”, or “Unhealthy”, and gives a land-owner or other interested stakeholders an idea of where to focus management activities. To date, the vast majority of the field-based riparian assessments completed by Cows and have been in central and southern Alberta, and while the site-specific detail offered by this approach cannot be matched, these assessments are limited in their ability to provide information for planning and management at municipal, regional, or larger scales.

As an alternative to the highly detailed information required and the substantial time and cost investment associated with field assessments, alternative approaches that utilize recorded video have been applied to assess riparian areas over larger spatial extents. Aerial videography is a tool for assessing riparian habitat where a trained analyst uses spatially referenced continuous video to evaluate a hydrologic system. Instead of walking around and observing the site, the observation takes place through video images acquired from an oblique angle at altitudes of 60 m or less. Riparian condition is assessed within a “riparian management area” (RMA) polygon, and like the field-based Alberta Riparian Habitat Management Society Riparian Health Assessment, the evaluator answers a series of questions about the functional attributes of the riparian lands to derive a score that is then classified according to three health categories that are akin to the field-based approach.

Videography has been applied by various organizations across Alberta using a variety of airborne video platforms (e.g., Mills and Scrimgeour 2004, AENV 2010, NSWA 2015). The benefit of videography is that the entire riparian area of a lake or river can be assessed at one time, while providing a permanent geo-referenced video record of the current status of shoreline. It provides a relatively rapid method to produce a “coarse filter” assessment of riparian health. This approach is not intended to replace field-based assessments, but rather, complement them by allowing larger areas to be evaluated in an approximate fashion, to be followed by more detailed checks on the ground. The goal of the videography assessments is to provide low cost information of large areas so that management at larger scales (i.e. entire lake or river system) can be directed by standardized measurements. In many cases, videography can be very cost-effective per kilometer of shoreline observed. At a certain scale, however, the size of the study area and the width of the stream or river make assessments by videography cost prohibitive.

Although existing ground-based assessment methods are useful for gathering information about the general condition of riparian habitat at small spatial extents, the site-specific delineation employed for these assessments cannot be scaled up to provide information about riparian condition across larger geographic areas. Further, the results of these assessments are typically not available publicly due to confidentiality agreements with landowners. Compared to ground-based methods, aerial videography offers a broader scale and relatively coarse assessment of riparian condition; however, at larger scales, such as for entire watersheds, this method becomes limited in practicality and efficiency (i.e., time and cost). As a result, developing a new method for assessing riparian habitats at large spatial extents has been identified as a critical need for Alberta (Clare and Creed 2012).

In response to this need, Fiera Biological developed a Geographic Information System (GIS) method that can be used to assess thousands of kilometers of shoreline in a reliable and cost-effective way. This method was developed using metrics comparable to existing ground-based and aerial videography methods, and the results have been validated using both aerial videography (Fiera Biological 2018a) and field data (Fiera Biological 2019). The assessment method uses automated and semi-automated GIS techniques to quantify the intactness of riparian management areas and pressure on riparian system function using freely available or low cost spatial data. Consequently, this GIS method allows for the assessment of riparian condition over large spatial extents, and to date, the method has been used to assess over 30,000 km in the North Saskatchewan, Battle, and Red Deer River watersheds. Within the Athabasca River watershed, nearly 2,800 km of shoreline in the Mid-Pembina and Upper Pembina watersheds have also been assessed (Fiera Biological 2020b; Fiera Biological 2021).

1.3. Study Objectives

The overall goal of this project is to contribute to the improvement of watershed health in the Lower Pembina by identifying riparian areas that can be targeted for habitat restoration and/or conservation. In order to achieve this goal, this study had the following primary objectives:

1) Create a recent land cover for the Lower Pembina watershed and use this layer to assess the intactness of riparian areas along major waterbodies.
2) Quantify both natural and anthropogenic pressures within catchments adjacent to riparian areas to generally assess factors that may contribute to the impairment of riparian system function.
3) Provide guidance on how the results from the intactness and pressure assessments can be used in combination to prioritize conservation and restoration efforts within the watershed.

The results of this study provide stakeholders with an overview of the status of riparian management areas within the watershed. This in turn allows organizations throughout the watershed to focus restoration, management efforts, and/or resources in areas of greatest need. Further, this approach has been adapted and applied in other watersheds throughout the province, thereby allowing for a standardization of the methods used to conduct large-scale riparian assessments in Alberta.

1.4. Purpose and Intended Use

This assessment synthesizes data from a variety of sources, with the goal of generally characterizing the current condition of riparian management areas within the Lower Pembina watershed. Readers are asked to consider the following points regarding the scope of this assessment as they review the methods and interpret the results of this study:

- Assessments characterize the relative intactness of riparian areas or pressure within local catchments using a collection of indicators and associated metrics that are measurable in a GIS environment at a pixel resolution of 6 m. These assessments do not provide a statement on the absolute condition of riparian areas or catchments, and do not reflect the influence of factors that were not or cannot be included or considered for analysis. For example, this analysis cannot assess the occurrence or abundance of weeds within a riparian area, nor does it consider the location or density of structures such as culverts or outfalls on riparian intactness or water quality.
- In completing these assessments in a number of watersheds throughout Alberta, we have found that higher riparian intactness scores are more frequently associated with higher-order Strahler streams and rivers, whereas lower-order streams (many of which are unnamed) tend to have a much greater proportion of their shorelines assessed as Low or Very Low condition, particularly in agricultural landscapes. Thus, the overall intactness values for a watershed may be strongly influenced by the order of streams included in the assessment, as well as the dominant land use within the watershed.
- Intactness and pressure ratings are intended to support a screening-level assessment of management and/or conservation priorities across broad geographic areas (e.g., HUC 8 subwatershed, municipality, stream reach). *The tool assessments are not meant to replace more detailed, site-specific field assessments of riparian health or condition*. Instead, intactness and pressure ratings should be used to highlight smaller, more localized areas where field assessments and further validation may be required. Further, higher levels of intactness tend to be associated with
- The provincial hydrography data for streams, creeks, rivers, and lakes was used to delineate the shoreline of the waterbodies included in this assessment. Because waterbodies are dynamic and their boundaries change seasonally and annually, the boundaries for the waterbodies included in this study had to be manually adjusted to ensure that the boundary was reflective of the current location of the shoreline, as well as consistent with the imagery that was used to complete the riparian assessment. Notably, the location of the boundaries used in this assessment may not be representative of the location of these same waterbodies in the future. Further, the spatial boundaries of waterbodies within the watershed that were not assessed as part of this study have not been updated.
- The municipal summaries in this report were based on the boundaries available in the Alberta Base Features dataset and were generated using a spatial intersect rule in the GIS (i.e., if the riparian management area was within the municipality or touched the boundary of the municipality, then it was used to tabulate summaries for that municipality). It should be noted that where a watercourse defines the boundary between municipalities, there is often a substantial spatial offset between the base features municipal boundary and the water boundary digitized in this project for the riparian assessment. Further, it is often unclear which municipality is responsible for the management of the left or right bank of a waterbody that defines the boundary of more than one municipality. Editing municipal boundaries to conform with the water boundaries applied in this project was beyond the scope of work, and as such, there may be instances where the spatial intersect rule applied to generate the summaries does not precisely reflect the riparian areas associated with a municipality. Consequently, the municipal summaries provide a general estimate of the amount of shoreline that was assessed in the study, as well as the condition of the associated riparian management areas within each municipality.

2.0 Study Area

The Lower Pembina is a very large (~3,935 km^2) HUC 6 watershed located in central Alberta (Map 1) that has an extensive hydrological network that flows almost entirely through the Boreal Forest Natural Region (Map 2). The Lower Pembina is composed of four smaller (HUC 8) watersheds: the Pembina River, French Creek, Dapp Creek, and Shoal Creek subwatersheds (Map 3).

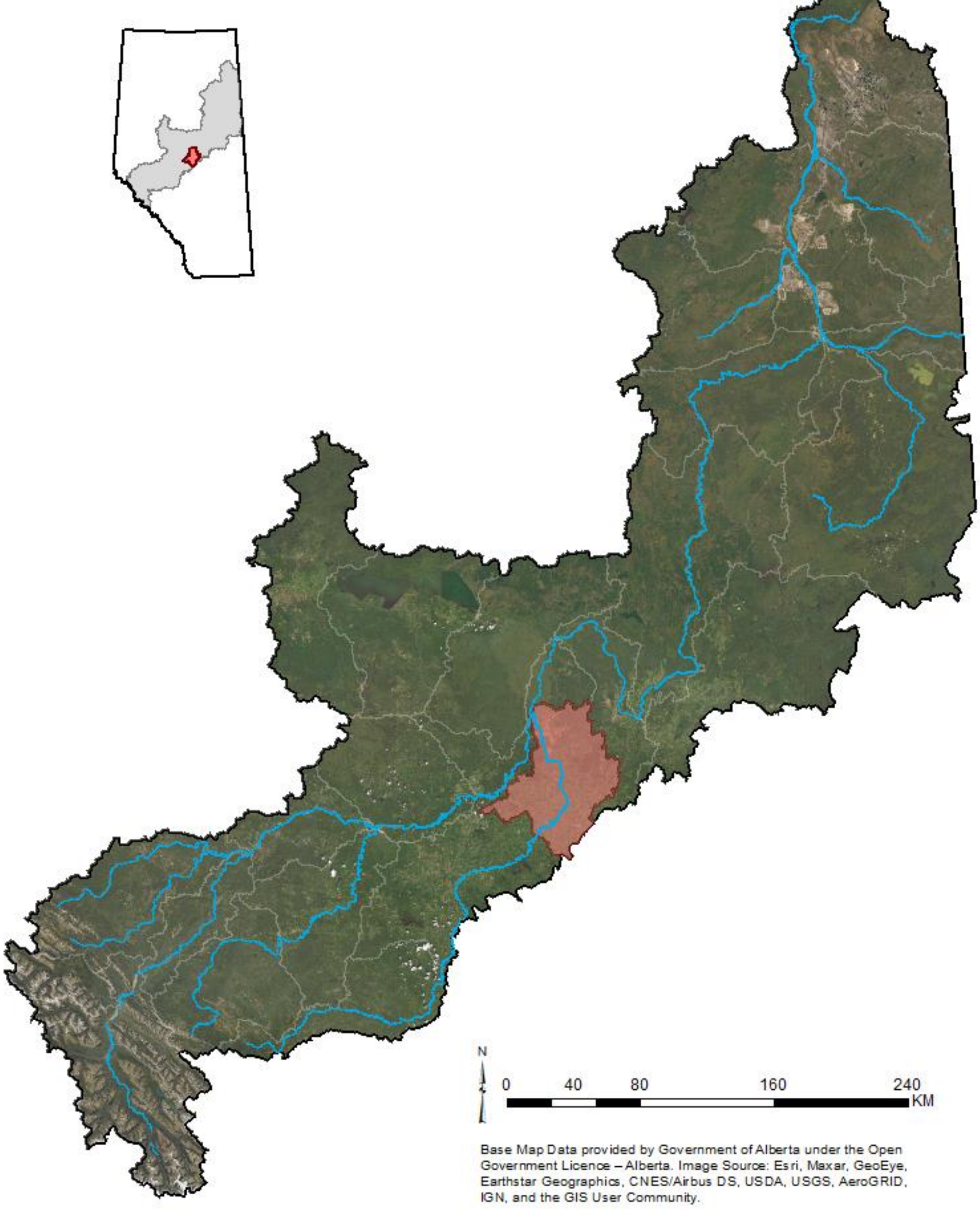
Human activity is prevalent throughout this watershed, with 61% of the lands classified into anthropogenic land cover types (Map 4). Agriculture (cropland and pasture) make up the largest proportion of the lands modified by human activity (58%). The remaining human land cover is comprised of Disturbed Vegetation (1.6%) and Built Up/Exposed (0.9%). The remaining 39% of the watershed consists of natural land cover types, such as wetlands, forests, open water, and other low and open natural vegetative cover. Areas of natural cover are generally concentrated, with notable areas of forest and wetland habitat located in the northern portion of the watershed. The predominant wetland land cover types include woody fen (13%), with other wetland land cover types making up roughly 5% of the watershed. Open water accounts for roughly 2% of the land cover in the watershed.

Four rural counties intersect the Lower Pembina watershed, including Westlock County, the County of Barrhead, Athabasca County, and the M.D. of Lesser Slave River (Map 5).

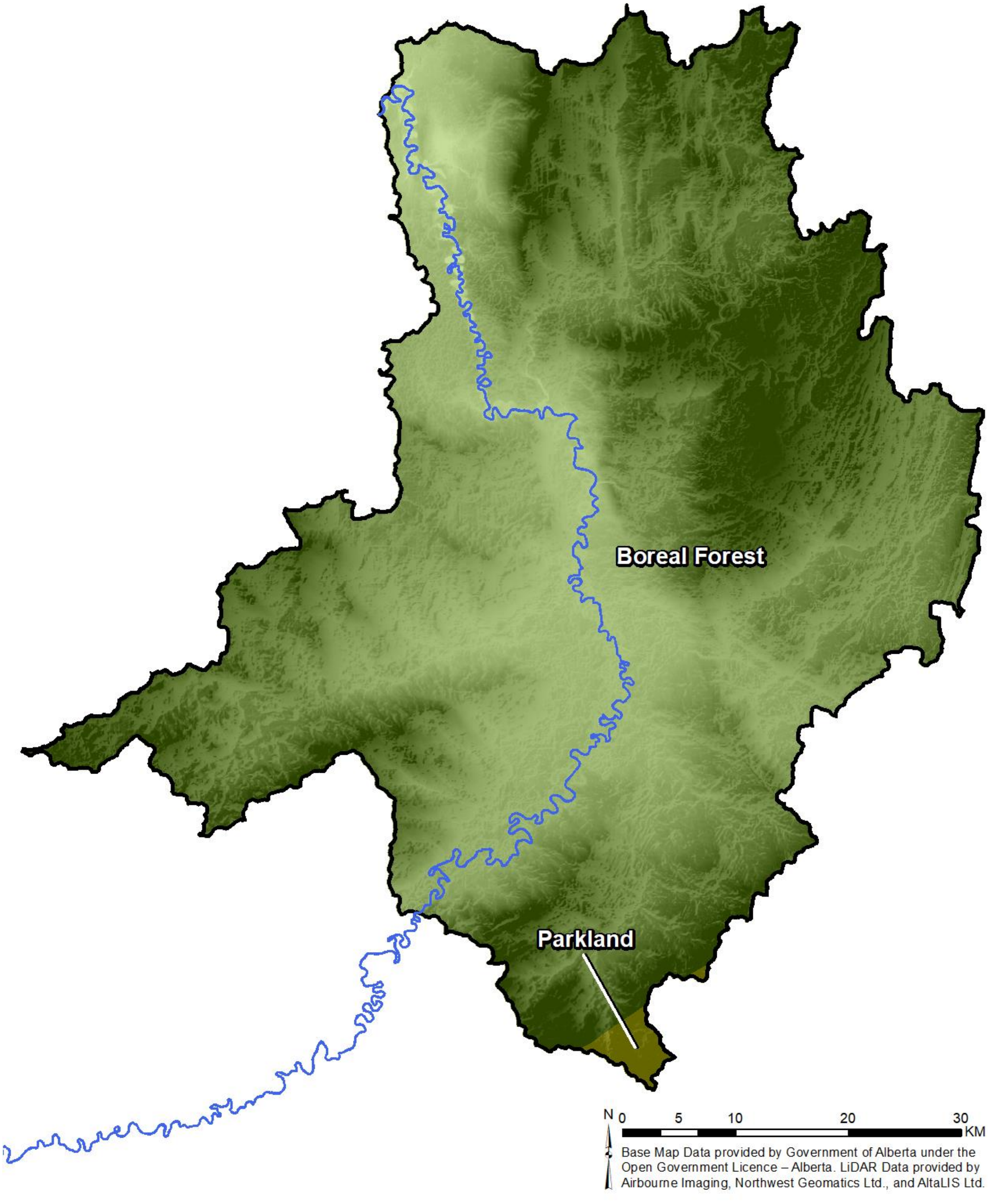
Approximately 950 km of shoreline was assessed as part of this study, including the left and right banks of the major watercourses in the watershed, as well as three named lakes (Table 1; Map 6).

Table 1. Waterbodies in the Lower Pembina watershed that were assessed as part of this project. The shoreline length listed for each creek and river represents the total length of the shoreline that was assessed on both the left and right banks.

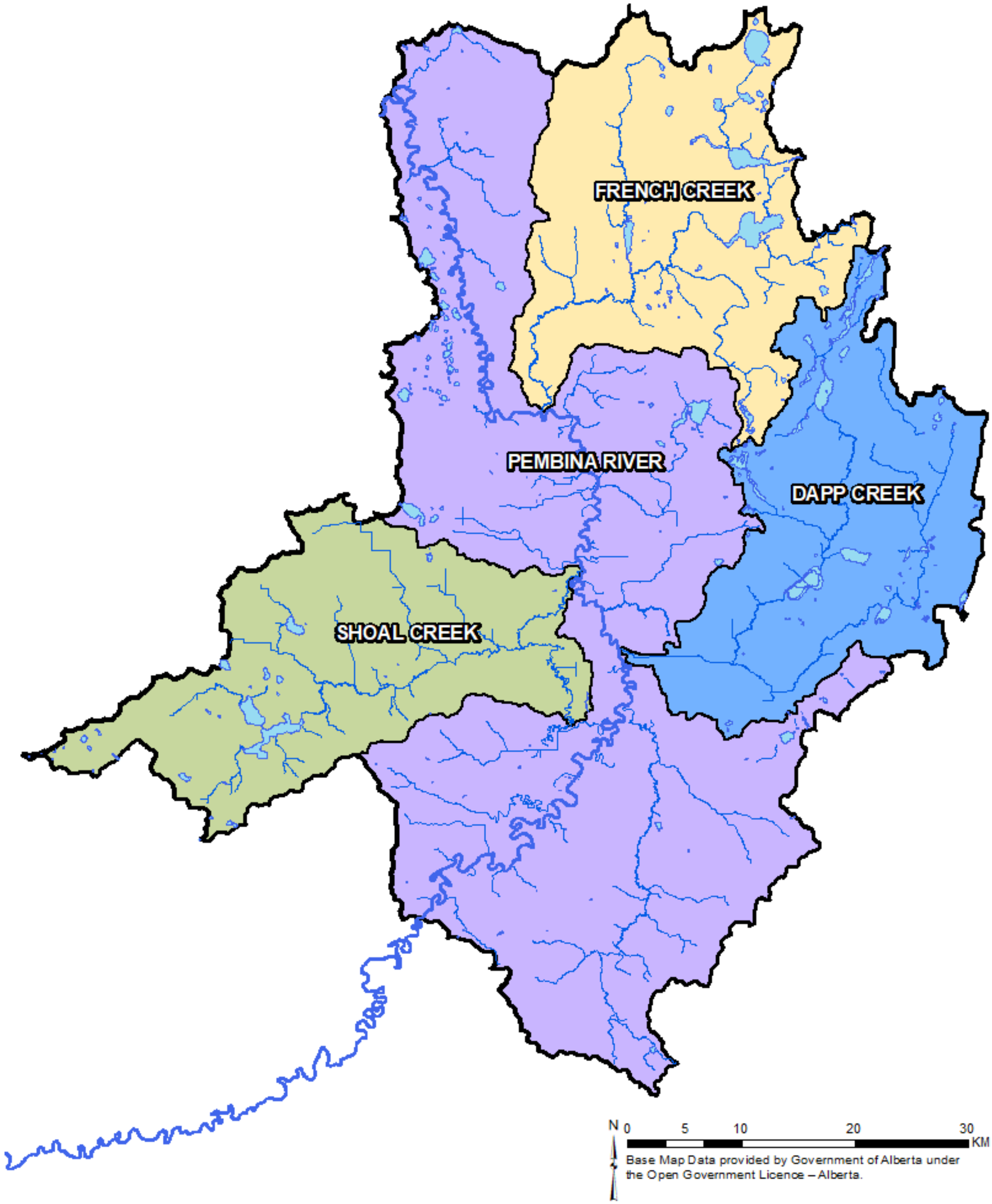
Waterbody Name	Length of Shoreline Assessed (km)
Creeks & Rivers	
Bolloque Creek	96.8
Dapp Creek 1	22.6
Dapp Creek 2	8.4
Flatbush Creek	33.6
French Creek	135.1
Pembina River	380.8
Shoal Creek	109.4
Wabash Creek	108.7
Lakes	
Bolloque Lake	12.7
Muskeg Lake	11.6
Shoal Lake	28.8
TOTAL	**948.5**



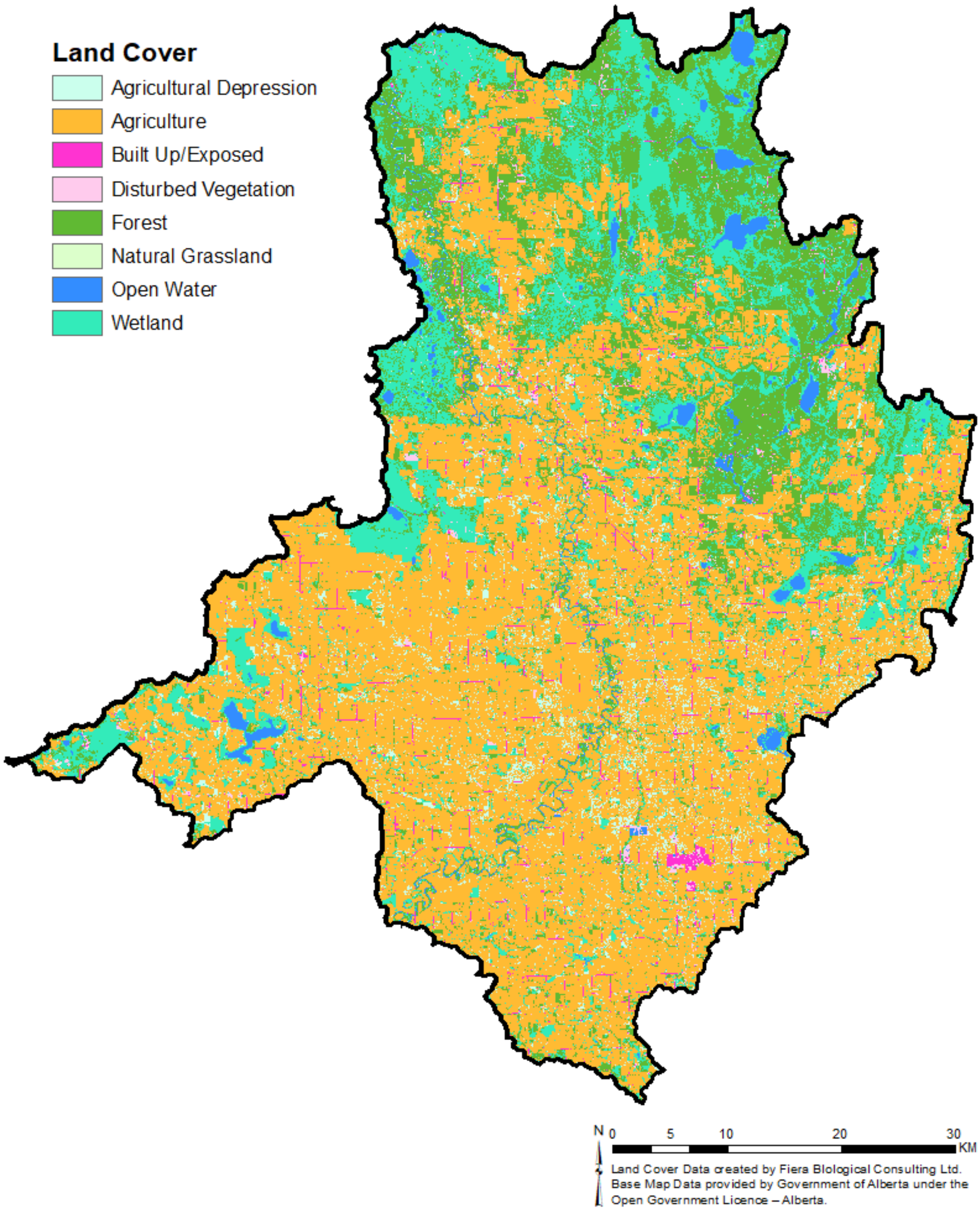
Map 1. The Lower Pembina HUC 6 watershed located within in the Athabasca River watershed.



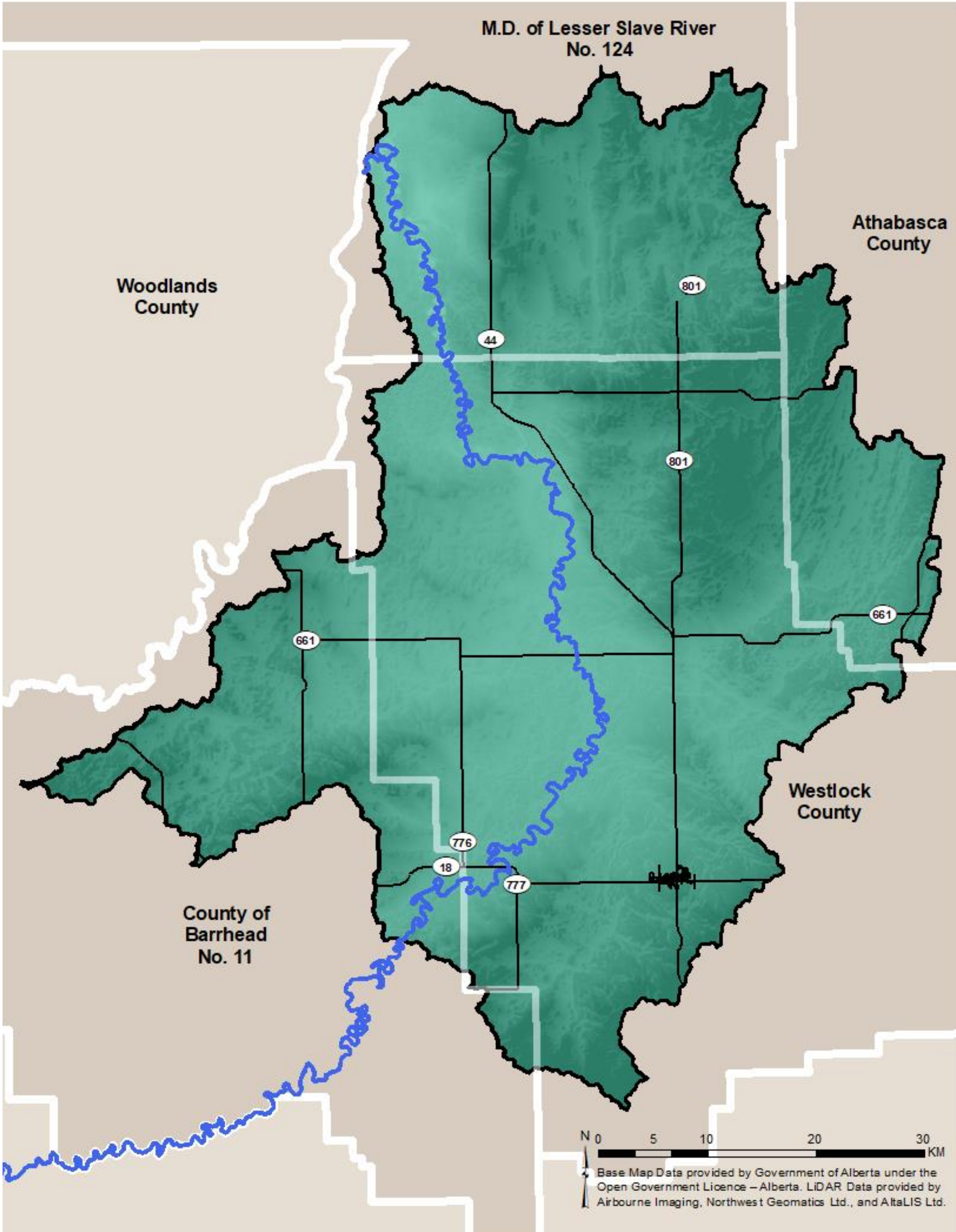
Map 2. The Lower Pembina watershed in central Alberta includes areas that fall within the Boreal Forest and Parkland Natural Regions.



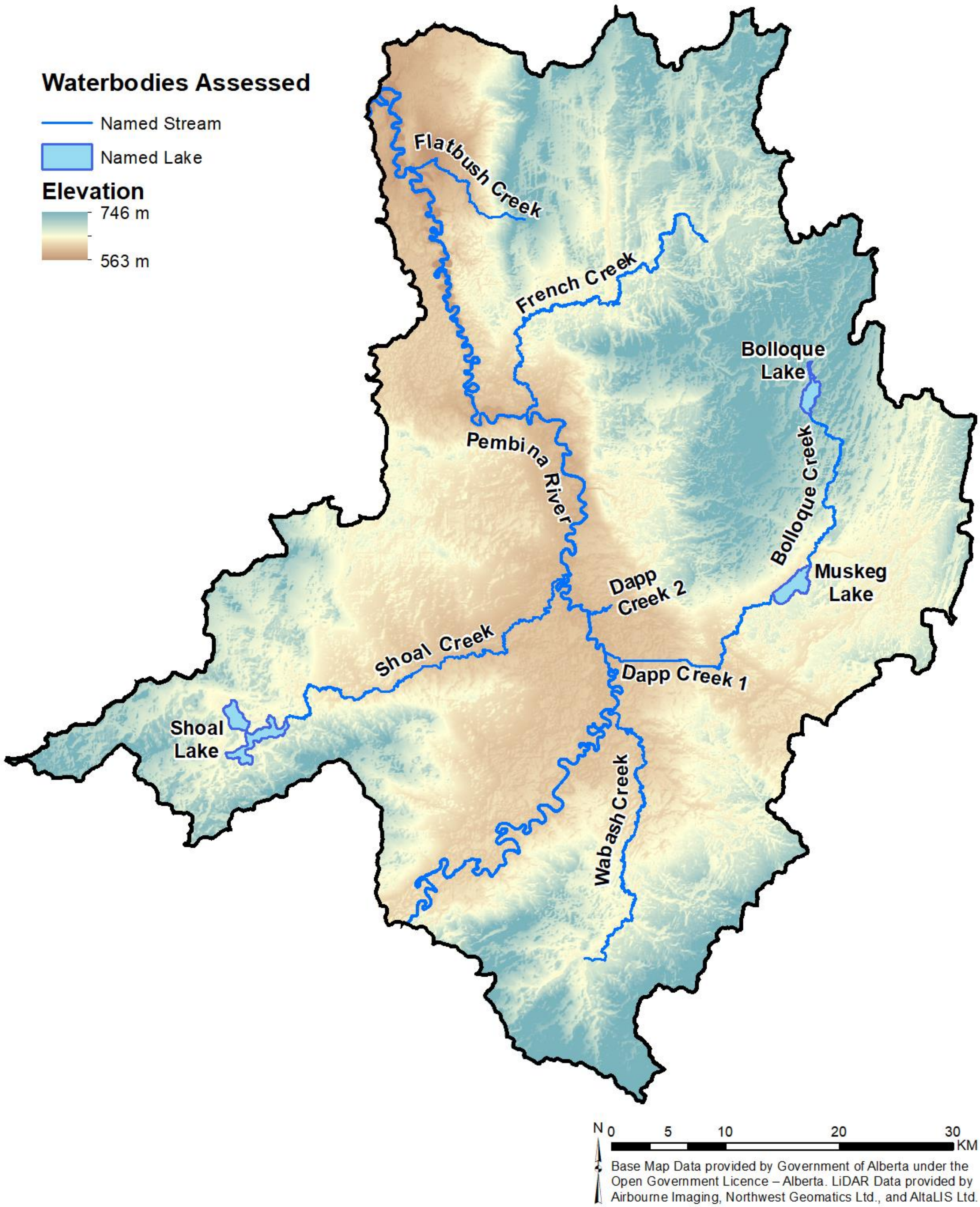
Map 3. The Lower Pembina consists of four smaller (HUC 8) subwatersheds.



Map 4. Land cover in the Lower Pembina watershed, created using SPOT6/7 imagery from 2017 and 2018.



Map 5. Major highways and municipalities located within and surrounding the watershed.



Map 6. Location of waterbodies that were assessed in this study.

3.0 Methods

3.1. Assessing Riparian Intactness

3.1.1. Land Cover Classification

To quantify riparian intactness in a GIS environment, several data sets are required, including a current land cover layer. While a freely available and current land cover layer is available from Agriculture and Agri-Food Canada (AAFC) for this watershed, the resolution of this data (30 m pixel size) is too coarse to accurately assess vegetation within riparian management areas. Consequently, a 6 m pixel resolution land cover layer was created using SPOT 6 and SPOT 7 satellite imagery from 2017 and 2018, which was obtained by the AWC free of charge from the Government of Alberta.

The 6 m land cover classification was created for the entire watershed and consisted of six separate SPOT 6/7 image scenes. Because of differences in date of acquisition and image quality, each scene was classified individually, but using the same classification methodology. For each satellite image, the four SPOT 6/7 bands were combined with a set of ancillary raster data products that were specifically generated for use in the classification (Table 2). The SPOT 6/7 imagery was used to generate layers for Normalized Difference Vegetation Index (NDVI), Blue Normalized Difference Vegetation Index (BNDVI), Green Ratio Vegetation Index (GRVI), and Iron Oxide Index (IOI), and a 15 m LiDAR DEM was used to derive terrain layers including Probability of Depression, Cost Distance to Water, and Deviation from Mean Elevation. As well, historic image analysis was performed in Google Earth Engine to generate mean summer temperature maps from Landsat 8 imagery and mean and standard deviation maps of NDVI from Sentinel 2 imagery (Table 2). Land cover classes were chosen and organized hierarchically into nested levels to facilitate training data selection and modelling (Table 3). Training data were manually selected for each SPOT 6/7 scene for the following classes: Coniferous; Deciduous; Shrub; Bog; Fen; Marsh; Swamp; Agricultural Depression; Open Water; Agriculture Pasture; Cropland; Human Built; Natural Bare Ground. A random forest classification was performed on each SPOT 6/7 band stack, which included the four SPOT 6/7 bands and additional ancillary layers. Random forest is a classification algorithm that is based on a set of decision trees derived by repeatedly selecting random subsets of training data and applying them to the layers in the band stack to create predictive models. By creating multiple models of decision trees, the best model and combination of information from the information in the band stack is determined and better prediction performance is obtained (Ho 1995). For this classification, 70% of the training data was used to train the classifier and the remaining 30% of the data was held back to validate the preliminary results.

Following the first stage of the classification, decision rules and manual editing were used to fix general classification errors. During this stage, the Natural Grassland class was added to the classification to account for areas of natural, non-woody low cover vegetation, and the Disturbed Vegetation class was added to account for non-agricultural human impacted low vegetation cover and areas with managed or manicured vegetation. Once the quality control and editing for each scene were completed, the seven scenes were mosaicked together to create a complete classified land cover layer for the entire watershed, and the Alberta Base features Roads layer was used to add in a Roads class to complete the 17-class "Level 2" land cover classification (Table 3).

Table 2. Description of the spatial data obtained or derived for use in the assessment of riparian management area Intactness.

Data Layer	Year	Source	Usage
SPOT 6/7 Satellite Imagery	2017/2018	Government of Alberta	Derivation of land cover classification
15 m LiDAR DEM	n/d	Government of Alberta	Derivation of data products for classification
Normalized Difference Vegetation Index (NDVI)	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta	Derivation of land cover classification
Blue Normalized Difference Vegetation Index (BNDVI)	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta	Derivation of land cover classification
Green Ratio Vegetation Index (GRVI)	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta	Derivation of land cover classification
Iron Oxide Index (IOI)	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta	Derivation of land cover classification
Probability of Depression	n/d	Fiera Biological. Layer was created using LiDAR DEM data provided by the Government of Alberta	Derivation of land cover classification
Cost Distance to Water	n/d	Fiera Biological. Layer was created using LiDAR DEM data provided by the Government of Alberta	Derivation of land cover classification
Deviation from Mean Elevation	n/d	Fiera Biological. Layer was created using LiDAR DEM data provided by the Government of Alberta	Derivation of land cover classification
Roads	2014	Alberta Base Features	Derivation of land cover classification
Mean Summer Temperature	2013-2018	Fiera Biological. Layers created using Landsat 8 imagery	Derivation of land cover classification
Mean and Standard Deviation of NDVI	2013-2018	Fiera Biological. Layers created using Sentinel 2 imagery	Derivation of land cover classification
ABMI Human Footprint	2016/2017	Alberta Biodiversity Monitoring Institute	Semi-automated clean-up of classification
6 m Land Cover	2017/2018	Fiera Biological. Layer was created using SPOT 6/7 satellite data provided by the Government of Alberta and derived layers	Derivation of RMAs and quantification of intactness metrics

Table 3. Land cover classes that were used to derive the land cover classification for the Lower Pembina watershed.

Level 1	Level 2	Description
Forest	Coniferous	Coniferous trees (needle-leaf) cover greater than 75% of treed area.
	Deciduous	Broadleaf trees covering greater than 75% of treed area.
	Shrub	Vegetation cover that is at least 1/3 shrub (low/short woody plants), with little or no presence of tress (<10% tree crown closure). Includes upland shrub and riparian shrub (e.g. shrub on gravel bars, shrub around marshes).
Natural Grassland	Natural Grassland	Naturally grassy areas with <1/3 shrub cover and <10% tree cover.
Open Water	Open Water	Any open water (lakes, permanent wetlands, standing water) and flowing water. Includes artificial waterbodies (e.g., dugouts and reservoirs).
Wetland*	Marsh	Low lying areas dominated by emergent or graminoid vegetation and depressional areas adjacent to streams/creeks and lakes.
	Swamp	Depressional areas dominated by deciduous tree or shrub cover.
	Bog	Areas that appear to be dominated by black spruce cover where no water flow is apparent.
	Woody Fen	Depressional areas dominated by woody vegetation cover (trees or shrubs) where surface water flow is apparent.
	Graminoid Fen	Depressional areas dominated by graminoid vegetation cover where surface water flow is apparent.
Agricultural Depression	Agricultural Depression	Human impacted/altered wetland basins in agricultural areas lacking intact emergent vegetation. In croplands these basins are typically cultivated and/or drained, and in pasture these low lying areas may be drained and/or utilized for agricultural purposes such as providing water for cattle.
Natural Bare Ground	Natural Bare Ground	Naturally occurring bare soil, sand, sediment, banks, and beaches.
Agriculture	Pasture	Agricultural areas used primarily as pasture or hayland.
	Cropland	Agricultural areas used primarily as cereal crop. Tilled most years.
Disturbed Vegetation	Disturbed Vegetation	Non-agricultural human-impacted or managed non-woody vegetation.
Built Up/Exposed	Human Built	Human built features and human-caused exposed/bare areas.
	Roads	Paved and unpaved roads.

*NOTE: The wetland class names included in this land cover classification are similar to those used in the Alberta Wetland Classification System; however, this land cover classification should not be considered to be a wetland inventory.

3.1.2. Land Cover Classification Accuracy Assessment

Accuracy of the land cover was assessed using traditional remote sensing techniques, which provide a measure of accuracy for each land cover class, as well as an overall accuracy for all classes combined. Accuracy of the land cover layer was assessed at Level 1 using a stratified validation dataset that was a combination of held back training data points (samples collected at the same time as training data was selected, but were not used to train the random forest model) and randomly selected points that were collected by a trained photo interpreter. A total of 320 samples were used to assess accuracy, with a minimum number of 10 samples validated for each class.

Overall accuracy at Level 1 for the classification was 93.4% with a Kappa statistic of 0.91 (Table 4). Class accuracies were high for all classes. Some confusion occurred between natural grassland and the forest class, which corresponded to areas where small natural clearings occurred along stream and river banks, or to small openings in the forest canopy where the cover was classified as shrub instead of being identified as low vegetation cover. Minor confusion occurred between the wetland (marsh) and agricultural depression categories, which can be expected given the difficulty in discerning between these two classes without confirmation from a field visit. Minor confusion also occurred between the Disturbed Vegetation and Agriculture classes, which primarily occurred at the interface between farmyards and pasture areas. A qualitative review of the land cover classification was also performed. Users of this land cover classification may want to consider that many riparian areas next to streams and rivers are classified as wetland cover classes (e.g., marsh, graminoid fen, treed/shrubby fen) throughout many parts of the watershed.

While the land cover and riparian assessment results for the Lower Pembina watershed were not validated using field data, previous riparian assessments completing using this GIS method have been validated using aerial videography data (Fiera Biological 2018a), as well as high resolution imagery and data collected in the field (Fiera Biological 2019). In each case, the riparian assessment results were considered to be very robust when compared against the validation data.

Table 4. Accuracy assessment results for the Level 1 land cover classes.

	Agricultural Depression	Agriculture	Built Up / Exposed	Disturbed Vegetation	Forest	Natural Bare Ground	Natural Grassland	Open Water	Wetland	User Accuracy
Agricultural Depression	6	1	0	0	0	0	0	0	0	86%
Agriculture	2	133	0	2	1	1	0	0	0	96%
Built Up / Exposed	0	1	10	1	0	0	0	0	0	83%
Disturbed Vegetation	0	0	0	6	0	0	0	0	0	100%
Forest	0	0	0	1	49	0	3	0	2	89%
Natural Bare Ground	0	0	0	0	0	9	0	0	0	100%
Natural Grassland	0	0	0	0	0	0	7	0	0	100%
Open Water	0	0	0	0	0	0	0	10	1	91%
Wetland	2	0	0	0	3	0	0	0	69	93%
Producer Accuracy	60%	99%	100%	60%	92%	90%	70%	100%	96%	93%

NOTE: Producer accuracy measures errors of omission, which is a measure of how well real-world land cover types can be classified. User accuracy measures errors of commission, which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location.

3.1.3. Editing Water Boundary Data

The provincial hydrography data for the waterbodies of interest were used to delineate the shorelines included in this assessment. Due to the dynamic nature of waterbodies and the vintage of the provincial dataset, the location of the hydrography feature does not always correspond well with shorelines in current satellite imagery. In order to ensure the generation of RMAs and quantification of the intactness metrics were accurate, the hydrography data was manually edited, where necessary, to ensure that the boundaries corresponded with the SPOT 6/7 imagery and the land cover classification. For streams, the edited water boundary represents the approximate centreline of the watercourse. Where the width of a stream or creek was greater than 20 m for a distance of more than 50 m in the SPOT imagery, or the stream passed through an area of open water greater than 1.0 ha, the stream was split and edited to have a unique left and right bank. Lake and open water shorelines were edited to approximate the location of the boundary between the upland and riparian zone. The edited water boundaries for assessed features have an approximate mean accuracy of +/- 5 m relative to their location in the SPOT imagery that was used to derived the land cover layer for this project.

Figure 1. Example of the spatial inaccuracies associated with stream boundaries, where the location of the stream centre line does not match the actual location of the stream and exceeds the 5 m accuracy tolerance in the SPOT imagery. In this example, the yellow lines represent the location of the streamline from the provincial data and the blue line represents the manually edited location of the new stream centre line.

3.1.4. Delineating Riparian Management Area Width and Length

In order to allow for comparisons between watersheds, the GIS methods that were developed to assess riparian areas in the Modeste watershed (Fiera Biological 2018a) were applied in this watershed. As per the GIS method, which was developed to closely match previously developed aerial videography methods (Teichreb and Walker 2008), riparian intactness was assessed within a “riparian management area” (RMA).

An RMA is defined as an area along the shoreline of a waterbody that includes near-shore emergent vegetation zone, the riparian zone, and a riparian protective (buffer) zone (Figure 2). An RMA has two spatial components: width and length. For this assessment, riparian intactness was evaluated within RMAs that had a static 50 m wide buffer that was applied to the left and right banks of each watercourse. In the case of lakes, a single 50 m wide buffer was applied to the shoreline. When assessing riparian condition using aerial videography, RMA length is determined by a change in the score of any single metric, and is thus variable. In order to replicate this approach, we chose to delineate the upstream and downstream extents of each RMA based upon major changes in the proportion of natural cover along the shoreline.

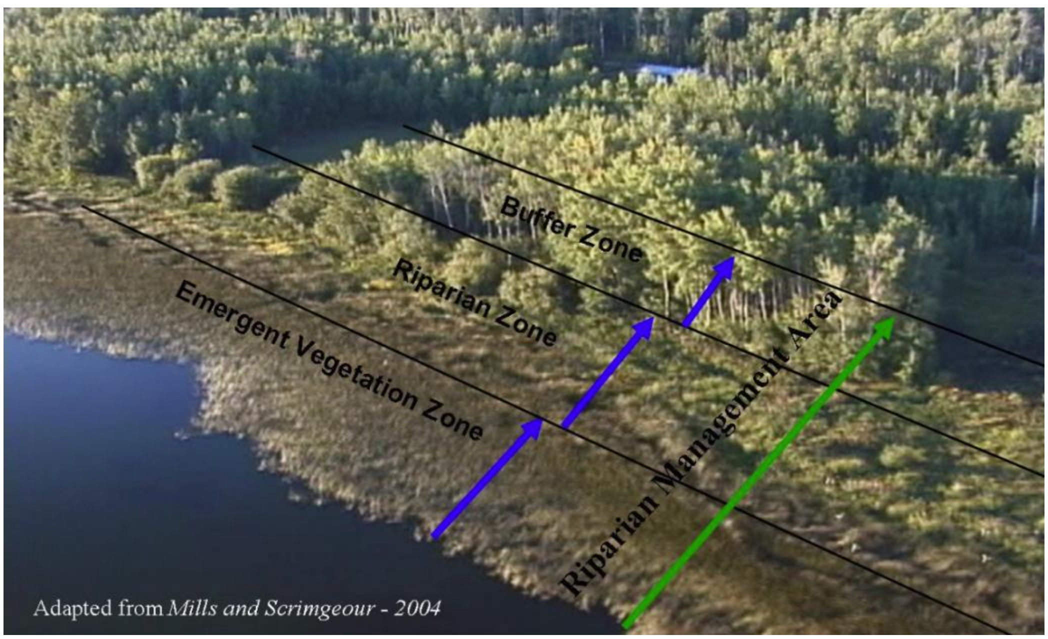


Figure 2. Schematic showing the different shoreline components included in a “riparian management area” (image taken from Teichreb and Walker 2008).

In order to determine the longitudinal extent of each RMA, the proportion of all natural cover types along the shoreline was evaluated, with the start and end points of each RMA corresponding with locations where there were major changes in the proportion of natural cover. To calculate the proportion of natural cover, all natural cover classes in the land cover (i.e., Wetland, Open Water, Natural Grassland, Natural Bare Ground, Forest) were selected and exported as a single layer. The stream layer was then divided into 10-meter segments on the left and right banks and the proportion of natural cover within a 25 m moving window was calculated for each segment. A threshold was used to identify locations along the shoreline within the moving window where there was greater than or less than 55% natural cover. All adjoining homogeneous segments of less than or more than 55% natural cover were then merged to became a single RMA. This threshold value was selected based upon an iterative threshold testing procedure to determine the percent of natural vegetative cover that best approximated the videography RMA boundaries (Fiera Biological 2018a). To reduce error associated with misclassification in the 6 m land cover, very small RMAs (≤10 m) were merged and dissolved with neighbouring segments.

3.1.5. Indicator Quantification and Riparian Intactness Scoring

Intactness with each riparian management area was quantified using the following metrics:

Metric 1: Percent cover of natural vegetation;
Metric 2: Percent cover of woody species;
Metric 3: Percent cover of all human impact and development (human footprint).

To quantify Metric 1, all natural cover classes were selected from the land cover layer and the proportion of the RMA covered by those cover classes was calculated. The natural classes used to quantify this metric included: Treed Wetland (Bog, Swamp, Woody Fen), Graminoid Fen, Marsh, Forest, and Natural Grassland. To quantify Metric 2, the percent cover of Forest and Treed Wetland land cover classes was quantified for each RMA. For Metric 3, the percent cover of the following land cover classes were used to calculate human footprint within each RMA: Cropland, Pasture, Agricultural Depression, Disturbed Vegetation, and Built Up/Exposed.

Once each metric was quantified, the values were range standardized and were aggregated using a weighting comparable to the aerial videography methods. The metrics were weighted as follows: Metric 1: 0.15; Metric 2: 0.25; Metric 3: 0.60. The weighted scores were aggregated to derive a final RMA score that ranged between 0 and 100, and these scores were converted into intactness categories using the following categorical breaks:

- High Intactness (≥75-100): Vegetation within the RMA is present with little or no human footprint.
- Moderate Intactness (≥50-75): Vegetation within the RMA is present with some human footprint.
- Low Intactness (≥25-50): Vegetation cover within the RMA is limited and human footprint is prevalent.
- Very Low Intactness (0-25): Vegetation cover within the RMA is mostly cleared and human footprint is the most dominant land cover.

3.2. Assessing Pressure on Riparian System Function

We adapted the Watershed Integrity scoring methodology (Flotemersch et al. 2016) to assess Pressure on Riparian System Function in the HUC 6 watershed. In this method, Watershed Integrity, *WI*, is the product of different watershed functions, with the underlying premise being that *"A high level of integrity exists when all functions are operating at levels that support and maintain the full range of ecological processes and functions essential to the long-term sustainability of biodiversity and ecosystem services" (*Flotemersch et al. 2016, pg. 1660).

With this approach, when any one of the functional components are compromised, the integrity of the watershed is also compromised, and as more functions are compromised, the integrity is compromised in a multiplicative way. We applied this watershed integrity approach to define and calculate Catchment Pressure, *CP*, with the objective of measuring the factors that increase or decrease the ecological and hydrological function of riparian habitats.

In our model, catchment pressure is the product of two functions that describe pressures that may occur within a local catchment area: Natural Resilience (*NR*) and Human Impacts (*HI*). Catchment pressure was calculated using the following equation, with higher scores indicating areas where there may be heightened pressure on riparian system function:

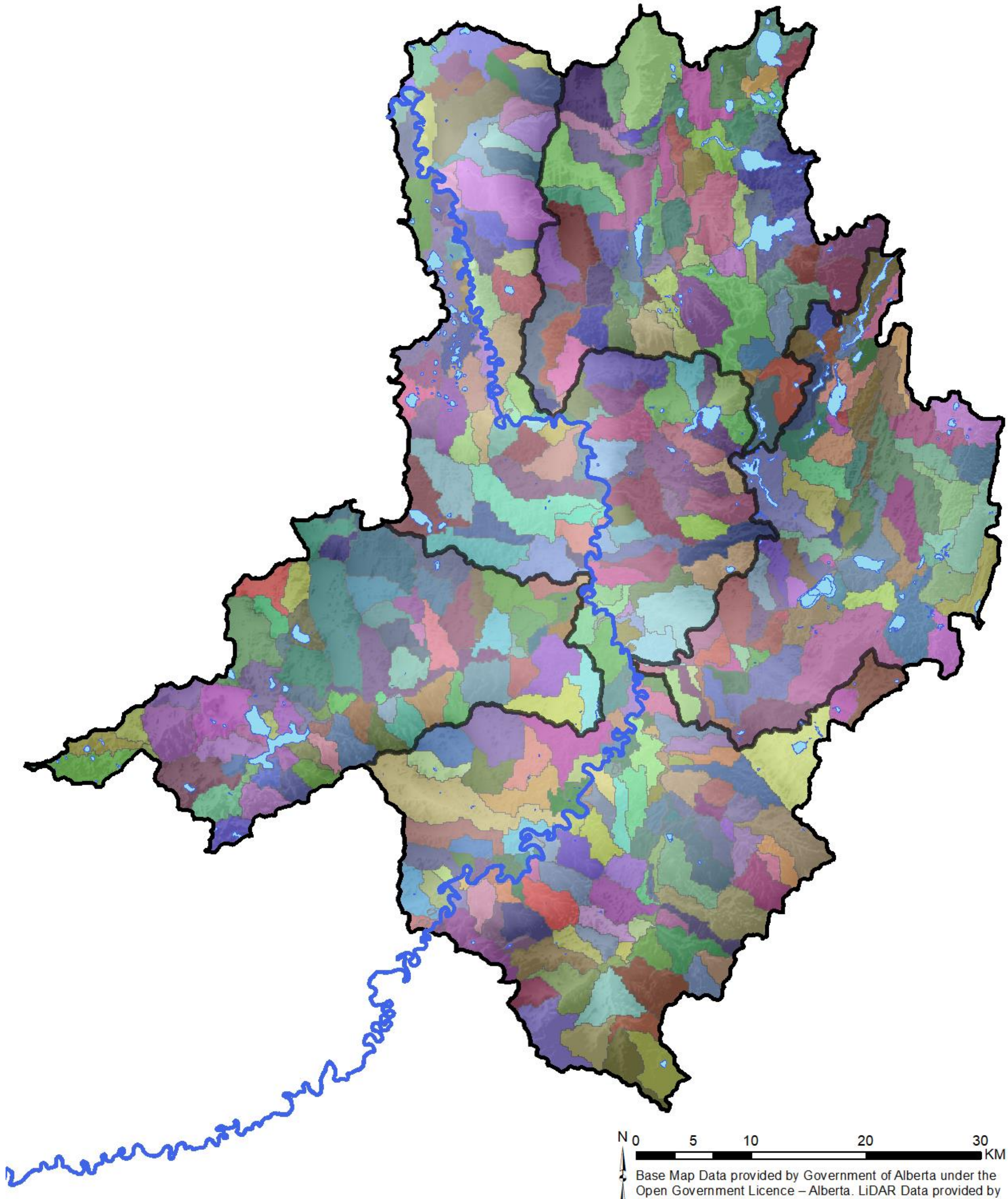
$$CP = CP_{NR} \times CP_{HI}$$

Natural Resilience (*NR*) and Human Impact (*HI*) function scores were calculated from a set of associated stressor metrics (S_i) that are known to affect riparian function and are measurable in a GIS environment. A list of the stressor metrics associated with each function, along with a description of how each stressor was quantified and the data used for the quantification, is provided in Table 5.

Variables that exert pressure on riparian system function range spatially from large-scale to site-specific. We conducted a pressure assessment at a local "catchment" scale, which we considered to be a scale that was meaningful both from the perspective of ecological and hydrological processes, as well as from the perspective of land management. Local catchment areas were identified using the Government of Alberta ArcHydro Phase 2 dataset (GOA 2018; Map 7). Catchments were edited to reflect the left and right contributing areas of the streams in the assessment by splitting them with the streams of interest. Local catchment areas that intersected the RMAs of the waterbodies included in this study were used as the unit of analysis for the pressure assessment.

Table 5. List of metrics used to assess pressure on riparian system function, along with a description of the methods used to assess each metric and the source and vintage of the data used for metric quantification. Each metric was quantified within local catchment areas that were derived specifically for this assessment using LiDAR 15 m data provided by the Government of Alberta.

Function	Stressor Metric	Metric Quantification	Data Source & Date
Natural Resilience (*NR*)	Natural Cover	Percent cover by natural vegetation cover classes	Fiera Biological Lower Pembina watershed Land Cover (2017/2018)
	Slope	Mean cover of steep slopes (>5°)	Fiera Biological, derived from Government of Alberta 15 m DEM
	Landslide Susceptibility	Area weighted average	Alberta Geological Survey (2016)
Human Impacts (*HI*)	Land Use Intensity	Zonal average of land use intensity values	Fiera Biological Lower Pembina watershed Land Cover (2017/2018) and ABMI Human Footprint (2016)
	Stream Crossing Density	Area weighted average of linear features that intersect major streams	Government of Alberta base features (2018)
	Road Density	Area weighted average of roads	Government of Alberta base features (2018)
	Density of Other Linear Disturbance Types	Area weighted average of non-road linear features	Government of Alberta base features (2018)



Map 7. Local catchment areas in the Lower Pembina watershed.

3.2.1. Quantifying Stressor Metrics & Calculating Function Scores

In order to quantify the Land Use Intensity stressor metric, a land use intensity value was assigned to each land cover and human footprint type present in the watershed. To quantify this metric, the SPOT land cover and ABMI human footprint layers were used together, which allowed for intensity characterization by human use type. High intensity of use values were assigned to land cover types that are known to be more impactful on riparian system function, and all values were assigned using best professional judgment informed by a literature review (Donahue 2013). We tested several different schemes for assigning intensity of land use values, and an appropriate range of values and magnitudes was selected by iteratively inspecting output maps and intensity values and ranges. Where the SPOT land cover and ABMI human footprint overlapped, the maximum Intensity of Use value was applied. The final intensity value assignments for land cover in the watershed are provided in Table 6.

Table 6. Intensity of use values assigned to the various land cover classes present in the HUC 6 watershed.

Land Cover Class	Intensity of Use Value
Agriculture – Crop	50
Agriculture – Pasture/Forage	50
Airport	1000
Canals	10
Cultivation (Crop/Pasture/Bare Ground)	50
Cut Block	50
Dugout/Burrow-Pit/Sump	10
Exposed/Barren	1000
High-Density Livestock Operation	1000
Industrial Site (Urban/Heavy Industry)	1000
Industrial Site (Rural)	500
Mine Site	1000
Municipal Water/Sewage	50
Disturbed Vegetation (Other)	25
Peat Mine	100
Pipeline	50
Rail – Hard Surface	100
Rail – Vegetated Verge	50
Reservoir	10
Road – Hard surface	100
Road Vegetated Verge	50
Road/Trail – Vegetated	100
Rural Residential	50
Seismic Line	50
Transmission Line	25
Urban/Developed	1000
Well Site	100

Scores for each of the GIS stressor metrics were calculated using ArcGIS 10.8 in one of two ways. For stressors that have a known measurable biological response, literature-derived thresholds were used to define the maximum feasible value (Table 7). This threshold is the value above which the stressor impairs function beyond a repairable or reversible state. For example, forest cover of at least 25% is required to minimize water quantity/quality issues (Adams and Taratoot 2001), so any catchment with ≤25% cover of forest cover is under maximum pressure for this stressor. For stressors with a known threshold, scores were calculated as:

$$S_i = 1 - \left(\frac{S_{observed}}{S_{threshold}}\right)$$

For stressors that are physical variables (e.g., slope), or for variables for which the biological response threshold value is not known (e.g., intensity of land use), the catchment stressor values were scored against the maximum value from the stressor's range of values within the watershed (i.e., a range standardized score was calculated). For these stressors, scores were calculated as:

$$S_i = 1 - \left(\frac{S_{observed}}{S_{maximum}}\right)$$

A description of the stressor threshold values used in this assessment, and the method used to derive each threshold, is provided in Table 7.

Once stressors were quantified, the values were compiled within their associated pressure function (CP_{NR} and CP_{HI}) and were combined mathematically to calculate a final catchment pressure score. Previously, the natural cover and terrain (slope, landslide susceptibility) metrics have been weighted equally; however, after reviewing the initial model outputs, it was apparent that because of the high degree of topographic variation in the watershed (i.e., hilliness) the terrain metric was penalizing catchments with high amounts of natural cover and high amounts of relief. Thus different weightings for these two metrics were tested and adjusted to better capture the relationship between natural cover and terrain in this watershed. The formulas used are as follows:

$$CP = CP_{NR} \times CP_{HI}$$

for which,

$$NR = (1.4 * \%Natural\ Cover) + (0.6 * \min(Slope, Landslide\ Susceptibilty))$$

and,

$$HI = (Intensity\ of\ Use + average(Stream\ Crossing\ Density, Road\ Density, Linear\ Density))$$

Once calculated, the raw catchment pressure scores were scaled to allow for better interpretation of the values. Scaling can be performed and applied in different ways, and for this study, a percentage score was calculated by taking the ratio of the raw catchment pressure score to the theoretical maximum possible score. For the Lower Pembina watershed, there are two stressor scores for each function, and all stressors have a maximum score of 1, so the maximum possible score is (1+1) x (1+1) = 4. Dividing the raw catchment pressure score by the theoretical maximum (4) and multiplying by 100 gives a percent score. In order to have high scores representing areas of High Pressure and low scores representing areas of Low Pressure, values were reversed by subtracting the percentage score from 100.

3.2.2. Assigning Pressure Categories

Catchment integrity was translated into catchment pressure by taking the percent scores and grouping the scores into three pressure categories (Low, Moderate, High) based on the quartile percentile breaks for the distribution of scores. Breaks between categories were adjusted manually slightly up or down to give more meaningful breaks between scores. Catchments in the Low Pressure group roughly correspond to the catchments with the top 25% of scores, catchments in the High Pressure group roughly correspond to the catchments with the bottom 25% of scores, and Moderate Pressure catchments roughly correspond to the remaining 50% of scores (i.e., scores between the 25^{th} and 75^{th} percentiles).

Table 7. Thresholds and scoring types used to calculate stressor scores for pressure metrics.

Function	Stressor Metric	Threshold	Scoring Type	References
Natural Resilience *(NR)*	Natural Cover	Minimum 25% cover	Literature review	Target forest cover of 25% for water quantity/quality (Adams and Taratoot 2001) 30% cover at watershed scale supports less than one half of the potential species richness and marginally healthy aquatic systems (Environment Canada 2014) Target cover of at least 35% for subbasins to prevent moderate extirpation of bull trout (Ripley et al. 2005) Threshold of 30% natural cover correlated with riverine ecological condition (Deegan et al. 2010) 6% loss of aquatic species for every 10% loss of natural land cover (Weijters et al. 2009)
	Slope	Maximum value	Range of values	N/A
	Landslide Susceptibility	Maximum value	Range of values	N/A
Human Impact *(HI)*	Land Use Intensity	Maximum value	Range of values	N/A
	Stream Crossing Density	0.6/km^2	Literature review	Stream crossings impede fish passage, affect water flow, and water quality - adapted thresholds from bull trout and general fish road density thresholds of 0.6km/km^2 and 0.7km/km^2 (Tchir et al. 2004)
	Road Density	1.0 km/km^2	Literature review	Extirpation of bull trout at 1.0 km/km^2 (AESRD 2012) Large mammals affected at various thresholds:0.4 km/km^2 for grizzly bear; 1.25 km/km^2 for black bear (AESRD 2012); 0.62 km/km^2 for elk (AESRD 2012)
	Density of Other Linear Disturbance Types	3.0 km/km^2	Literature review	Adapted general density threshold for watershed health, where >3 km/km^2 is used as an indicator for poor health (AESRD 2012)

3.3. Management Prioritization

While riparian intactness and catchment pressure scores on their own provide land managers with important information about riparian condition, combining these scores together to create a prioritization matrix that identifies high priority areas for both conservation and restoration allows land managers to more precisely target areas for management.

Combining intactness and pressure scores results in prioritization matrix with 12 scoring categories, and we assigned a unique score ranging between 1 and 12 to each category using best professional judgement (Table 8). The numeric scores were then combined and assigned to one of four prioritization categories, as follows:

- **High Conservation Priority (Category 1-3):** High/Moderate Intactness and Low/Moderate Pressure
- **Moderate Conservation Priority (4-6):** High/Moderate Intactness and Moderate/High Pressure
- **Moderate Restoration Priority (7-9):** Low/Very Low Intactness and Low/Moderate Pressure
- **High Restoration Priority (10-12):** Low/Very Low Intactness and Moderate/High Pressure

For each riparian management area, the pressure score was determined by intersecting the RMA polygons with the catchment polygons. This ensured that the pressure scores, which were calculated as polygons, could be accurately assigned to the RMA polygons. The resulting prioritization polygons were then scored, and the length of each RMA assigned to each priority category was calculated.

Table 8. Riparian prioritization matrix for RMAs in the Lower Pembina watershed.

		RIPARIAN INTACTNESS			
		High	**Moderate**	**Low**	**Very Low**
CATCHMENT PRESSURE	**Low**	1	3	7	9
	Moderate	2	5	8	11
	High	4	6	10	12

High Conservation Priority
Moderate Conservation Priority
High Restoration Priority
Moderate Restoration Priority

3.4. Data Summaries

All municipal data summaries were generated using a spatial intersect rule in ArcGIS, where the results from each analysis (i.e., intactness, pressure, priority) were intersected with the municipal boundary layer. Summarizing the data in this way captures the assessed shorelines that fall within the municipal boundary; however, it should be noted that there are spatial discrepancies between the municipal boundary data and the provincial hydrography data that are freely available from AltaLIS. For example, in many instances, municipal boundaries follow the boundary of a waterbody (e.g., the boundary between two Counties follows a creek or river) and often, the boundary topology of these two features do not match. In these instances, some minor edits may have been made to correct the intersection outputs and reassign results from one municipality to another, but in most cases, municipal boundary layers were not extensively edited to correct topological errors. As a result, the municipal summaries of shoreline length for intactness and priority are approximate and should be considered estimates that reflect relative differences between municipalities.

4.0 Results

4.1. Riparian Management Area Intactness

Riparian intactness was calculated for approximately 949 km of shoreline in the Lower Pembina watershed (Map 8 and Map 9). Overall, 61% of the shoreline that was assessed was classified as High Intactness, with a further 18% was classified as Moderate Intactness (Figure 3; Table 9). Approximately 21% of the shoreline was classified as either Low (7%) or Very Low (14%) Intactness.

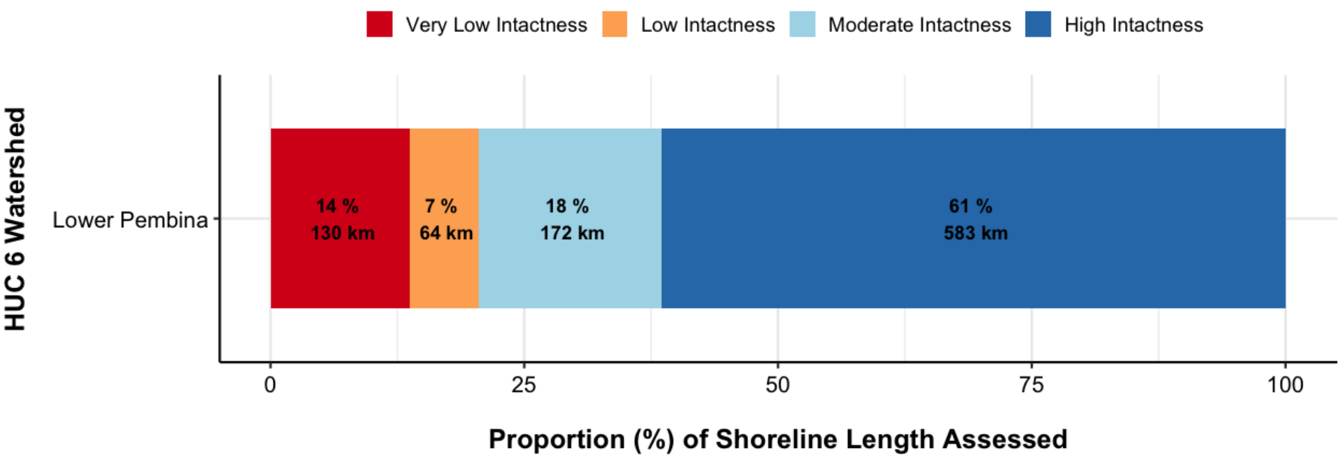
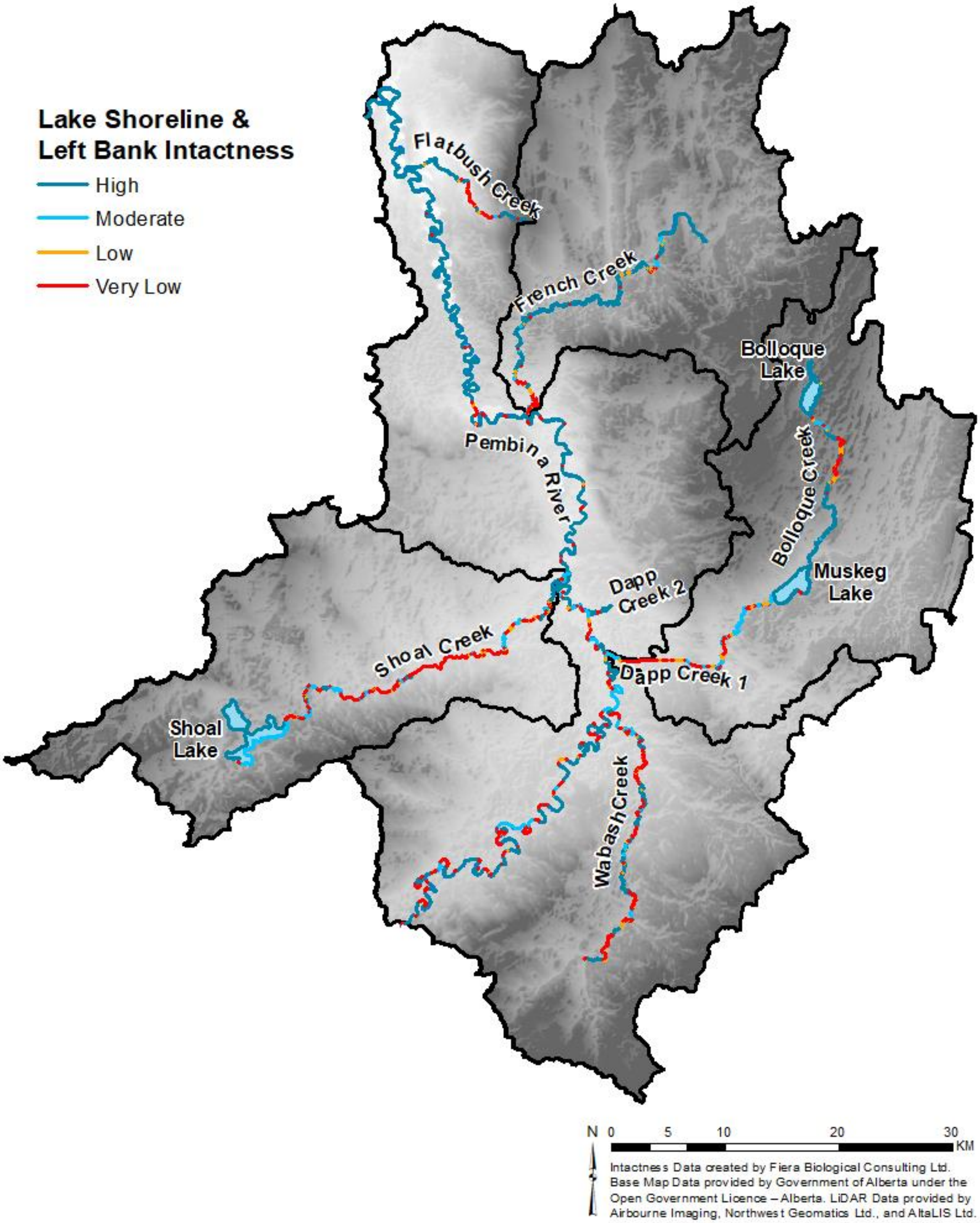
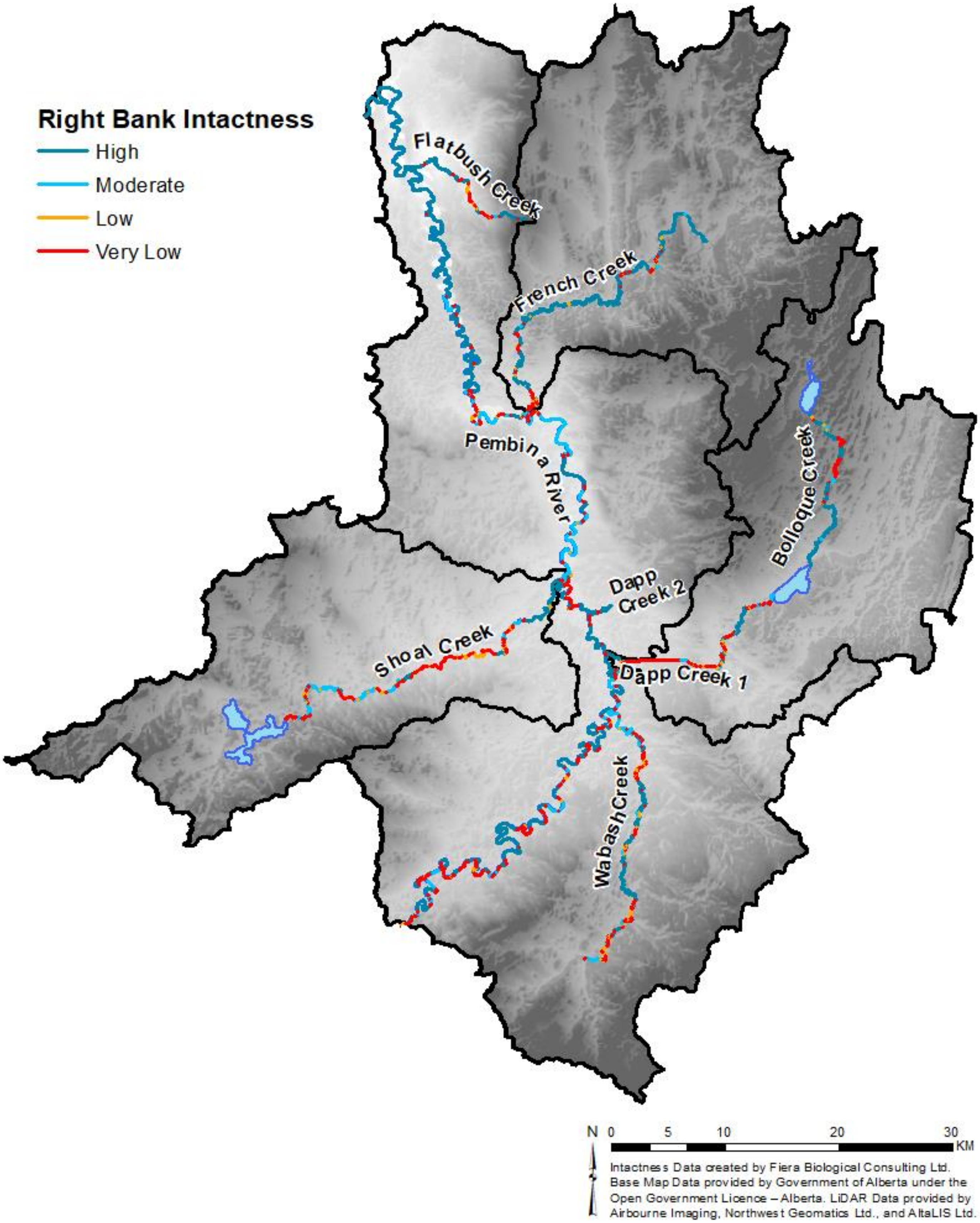


Figure 3. The total proportion of shoreline within the Lower Pembina watershed assigned to each riparian intactness category. Numbers indicate the total length (km) of shoreline associated with each category



Map 8. Intactness for lake shorelines and the left bank of rivers and creeks that were included in this study.



Map 9. Intactness for the right bank of rivers and creeks that were included in this study.

The Pembina River HUC 8 subwatershed had the greatest length of shoreline assessed in the study (532 km), which represents 56% of all of the shoreline assessed in the Lower Pembina watershed (Table 9; Figure 4). Overall, the French Creek subwatershed had the greatest proportion (91%) of shoreline assessed as High or Moderate Intactness (Figure 5). The Shoal Creek subwatershed had the greatest proportion (34%) of shoreline assessed as Low or Very Low Intactness, while the Pembina River had the greatest length (95 km) (Figure 4; Figure 5). The areas of low intactness are generally concentrated in the southern part of the watershed (Map 8; Map 9).

Table 9. Total length of shoreline assessed within each HUC 8 subwatershed, along with a summary of the length and proportion of shoreline assigned to each riparian intactness category.

Subwatershed Name	Total Length Assessed (km)	Intactness							
		Very Low		Low		Moderate		High	
		km	%	km	%	km	%	km	%
Dapp Creek	143.7	26.7	19	12.4	9	26.2	18	78.4	55
French Creek	135.1	7.0	5	5.8	4	11.3	8	111.0	82
Pembina River	531.5	67.3	13	27.8	5	83.4	16	353.0	66
Shoal Creek	138.2	29.1	21	18.1	13	50.8	37	40.2	29
Watershed Total	**948.5**	**130.1**	**14**	**64.1**	**7**	**171.7**	**18**	**582.6**	**61**

Of the eight named streams in the watershed, Dapp Creek 2, French Creek, Flatbush Creek, and Pembina River all had more than 70% of their shorelines assessed as High Intactness (Figure 6). Dapp Creek 1 had the greatest proportion of shoreline assessed as Very Low Intactness (50%), while the Pembina River had the greatest amount of shoreline assessed as Very Low Intactness (41 km) (Figure 6).

The three named lakes in the watershed all had very little shoreline assessed as Very Low or Low Intactness. Bolloque Lake and Muskeg Lake had more than 98% of their shorelines assessed as High Intactness, while Shoal Lake had 69% of its shoreline assessed as High Intactness and 30% assessed as Moderate (Figure 6).

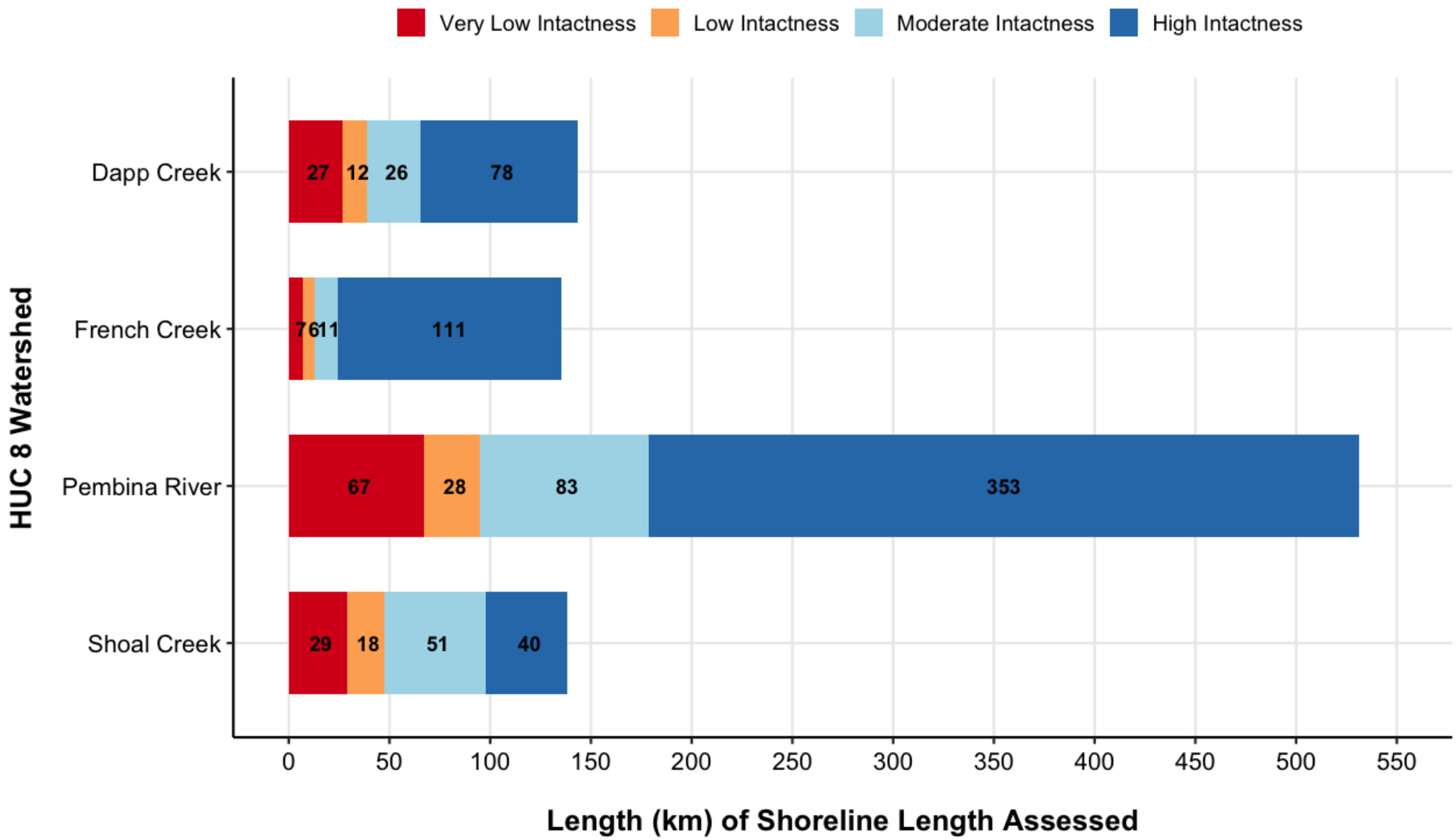


Figure 4. The total length of shoreline within the Lower Pembina watershed assigned to each riparian intactness category, summarized by HUC 8 subwatershed. Numbers indicate the total length (km) of shoreline associated with each intactness category.

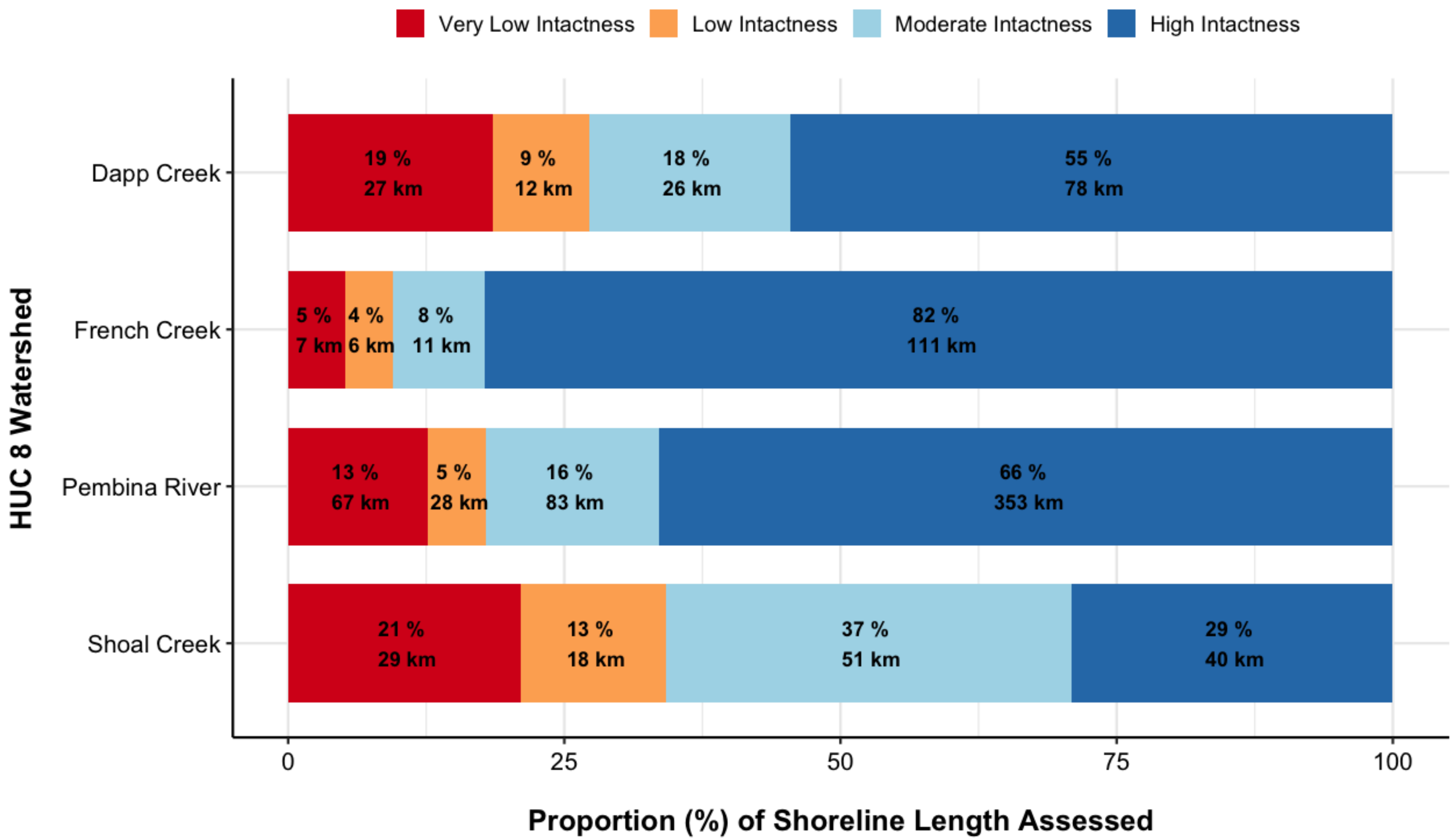


Figure 5. The total proportion of shoreline within the Lower Pembina watershed assigned to each riparian intactness category, summarized by HUC 8 subwatershed. Numbers indicate the total length (km) of shoreline associated with each intactness category.

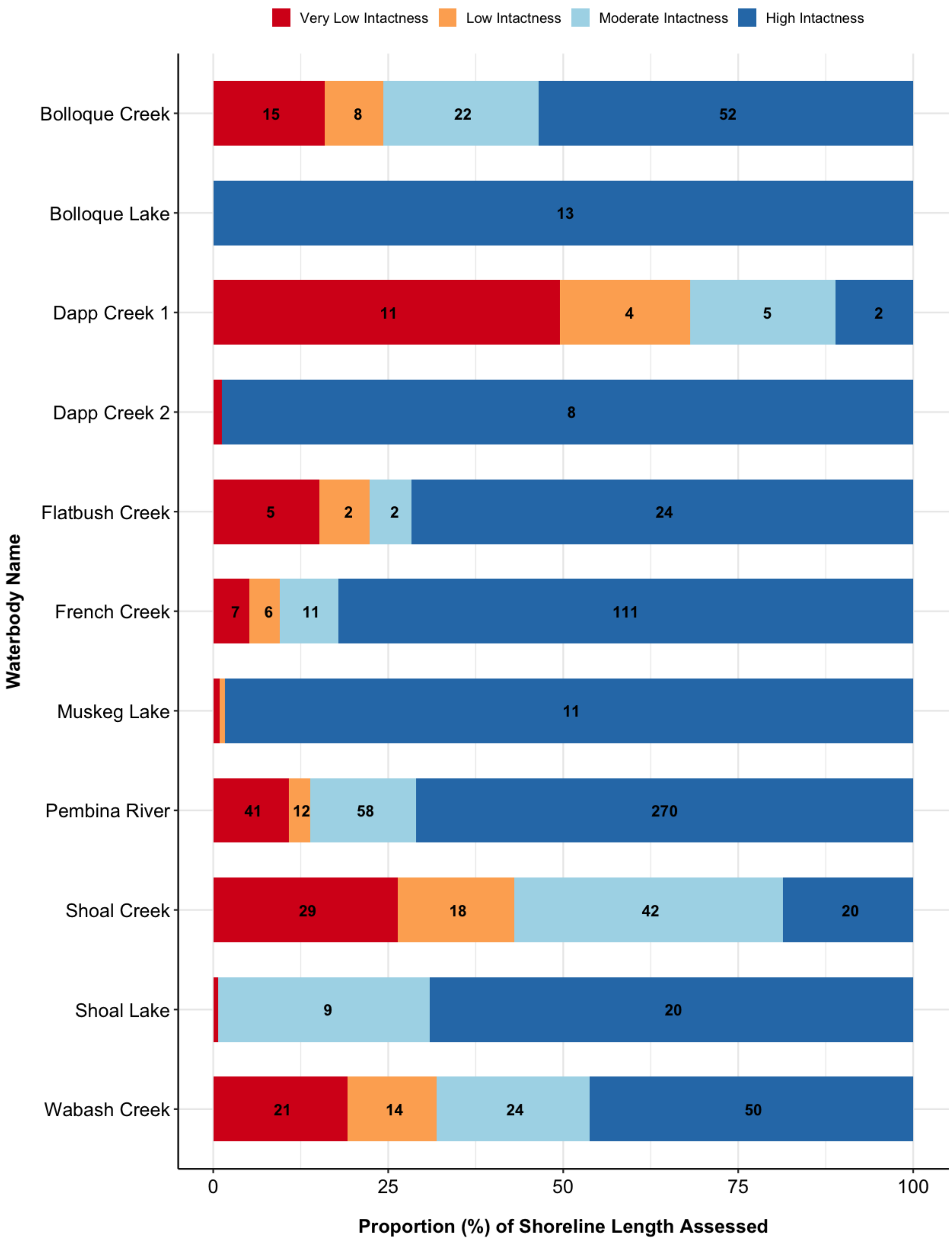


Figure 6. The total proportion of shoreline assigned to each riparian intactness category for named creeks, rivers, and lakes assessed in the Lower Pembina watershed. Numbers indicate the total length (km) of shoreline associated with each category. No label indicates the category had less than 1 km of shoreline length assigned to it.

4.2. Pressure on Riparian System Function

Pressure on riparian system function was assessed for 436 local catchment areas within the Lower Pembina watershed (Figure 7). Of the area assessed, 28% was classified as High Pressure, with the majority (47%) of local catchments being classified as Moderate Pressure and the remaining 25% being classified as Low Pressure.

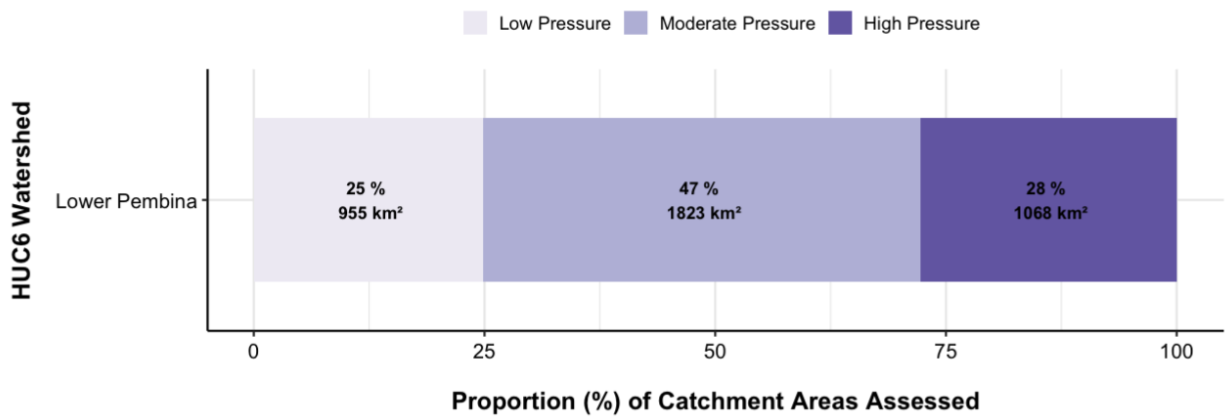


Figure 7. The proportion and area of local catchments within the Lower Pembina watershed assigned to each pressure category.

When pressure scores were compared between HUC 8 subwatersheds, the French Creek subwatershed had the greatest proportion (72%) of its area assessed as Low Pressure (Figure 8). Conversely, both the Pembina River and Shoal Creek subwatersheds had over 28% of their area assessed as High Pressure (Figure 8). Spatially, areas of High Pressure were concentrated in the central and southern portion of the watershed (Map 10).

Pressure on riparian system function varied widely for the creeks and rivers assessed in this study, with Dapp Creek 2, Pembina River, and Wabash Creek having over 50% of adjacent lands classified as High Pressure, while Bolloque Creek, Flatbush Creek, and French Creek all had less than 13% of adjacent lands classified as High Pressure (Figure 9; Map 11). No creek or river had greater than 35% of adjacent lands classified as Low Pressure. Conversely, all of the assessed lakes had very little adjacent land (<5%) classified as High Pressure. Of note, 100% of Bolloque Lake's adjacent lands were classified as Low Pressure (Figure 9).

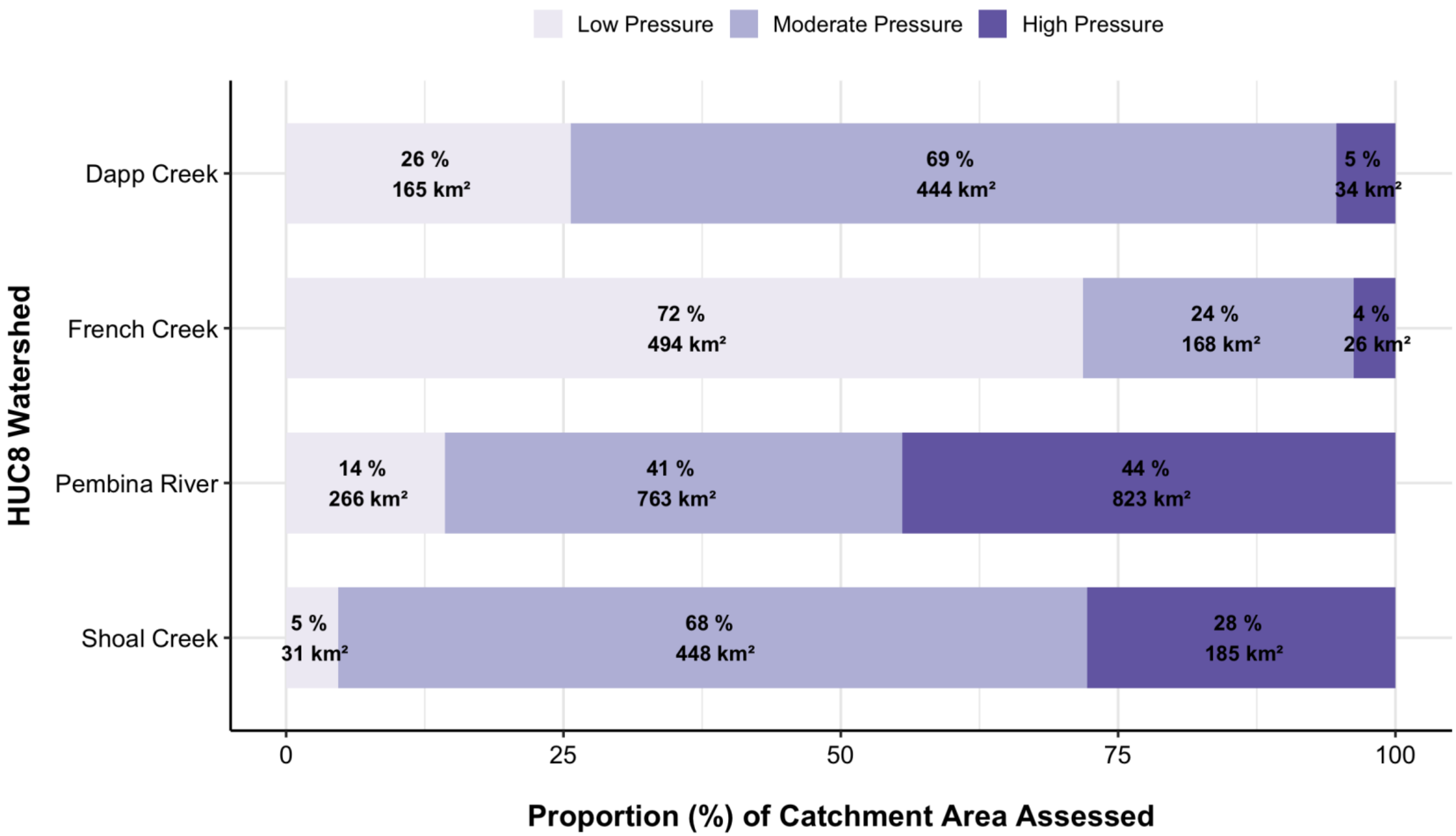
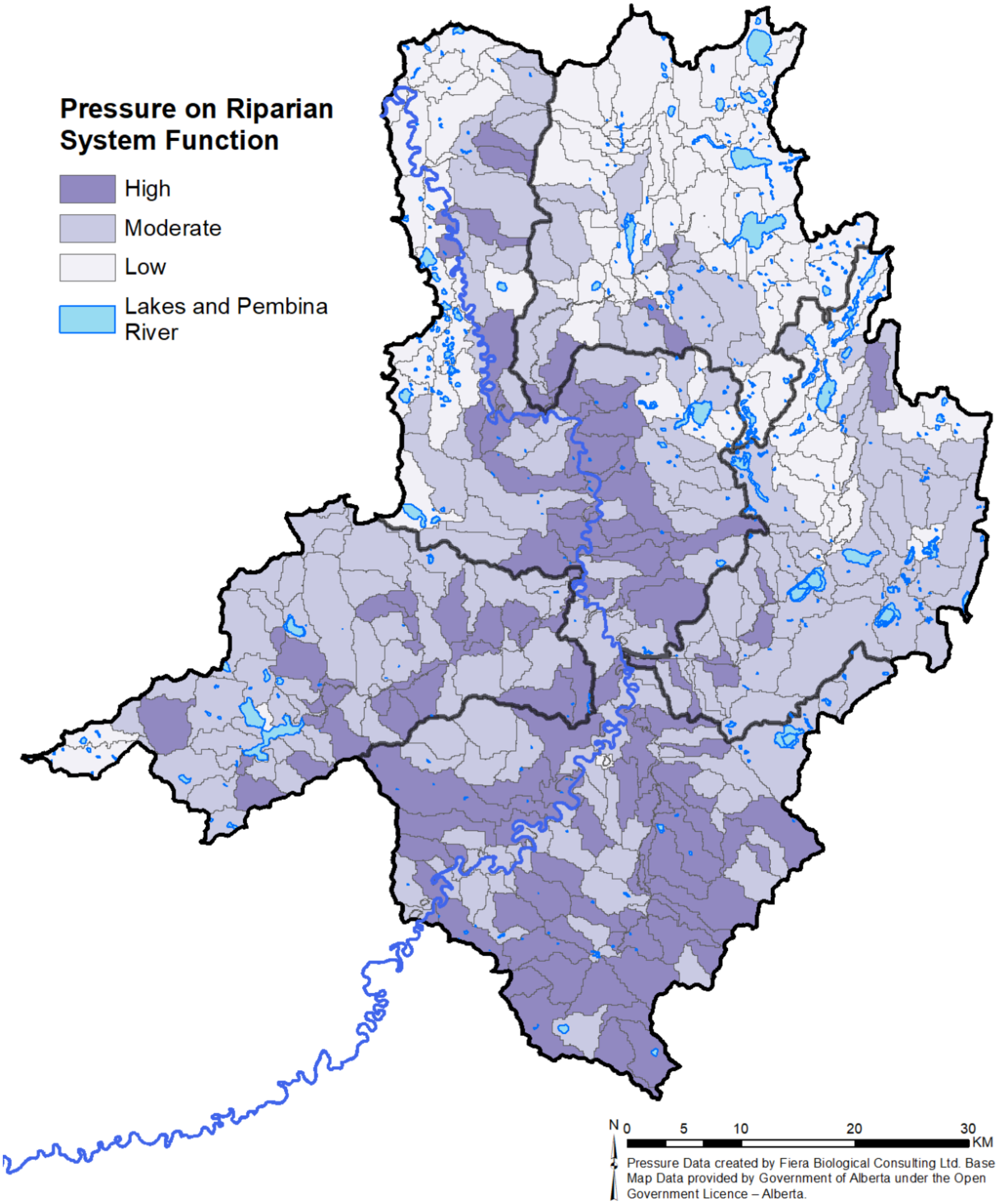
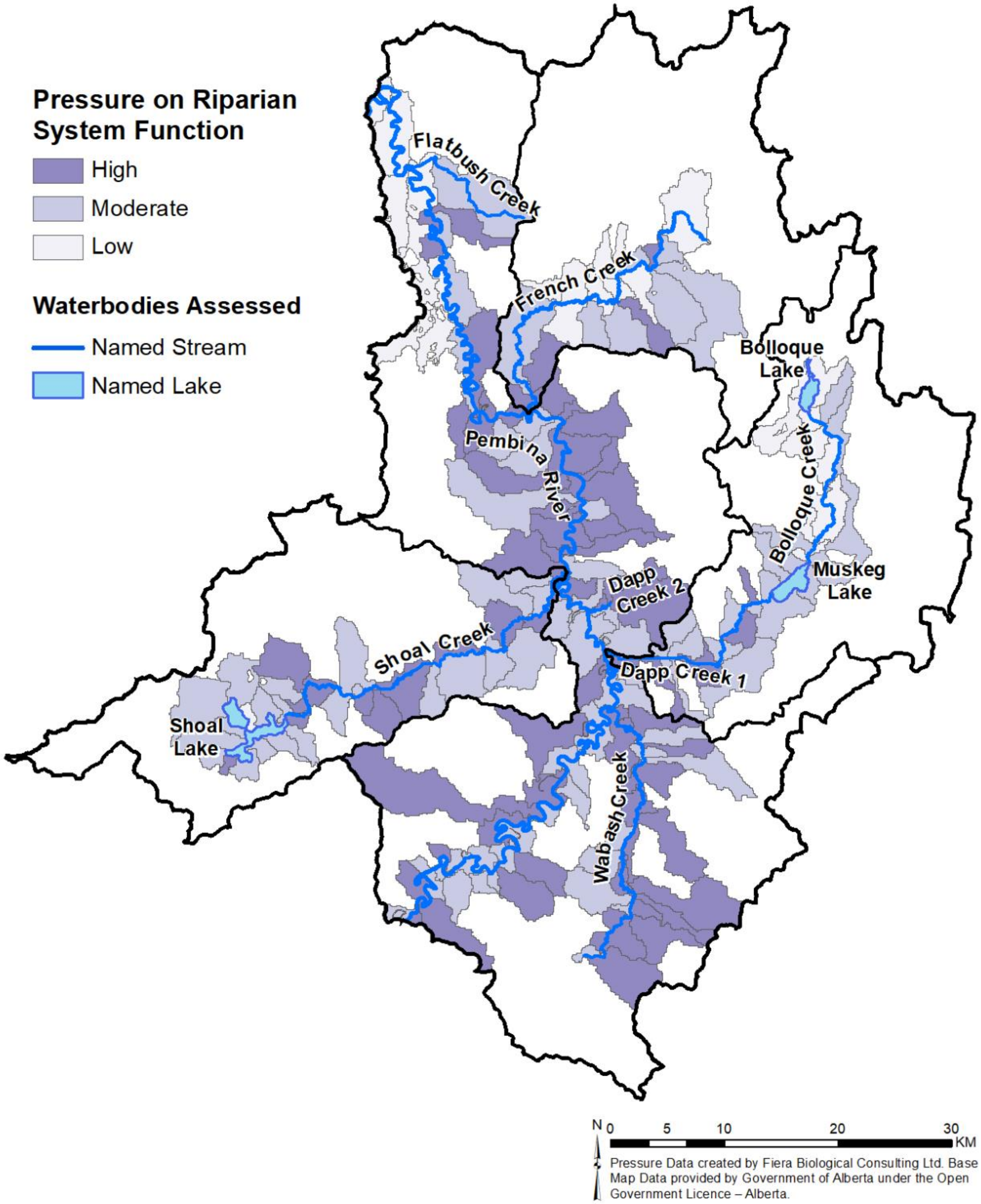


Figure 8. The proportion and area of local catchments assigned to each pressure category, summarized by HUC 8 subwatershed.



Map 10. Distribution of local catchments classified as High, Moderate, and Low Pressure within the Lower Pembina watershed.



Map 11. Pressure classification for local catchment areas that intersect the RMAs of waterbodies that were included in this study.

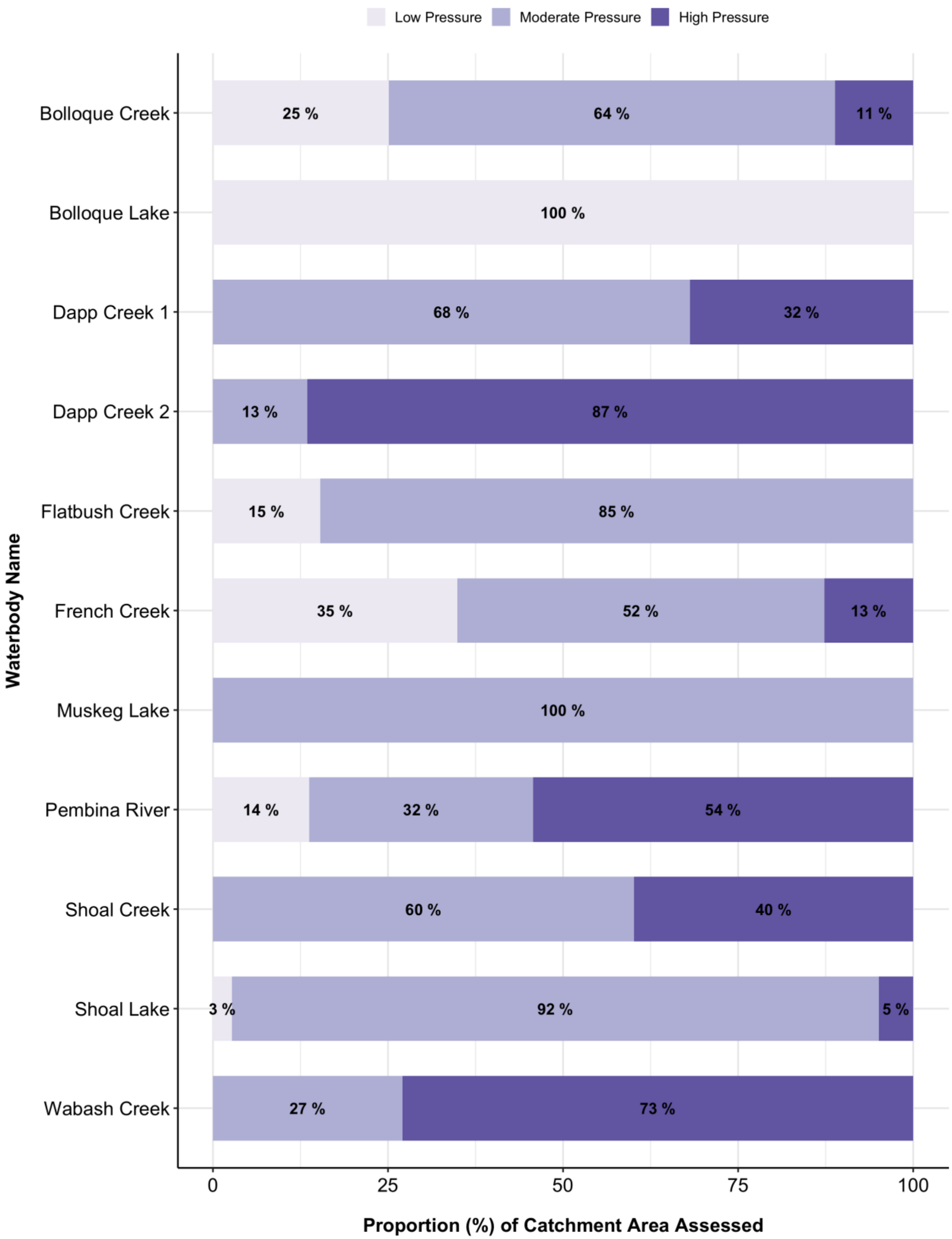


Figure 9. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of waterbodies assessed in the Lower Pembina watershed. Numbers indicate the proportion of area assigned to each category.

4.3. Conservation & Restoration Prioritization

Conservation and restoration priority was assigned to the RMAs of all waterbodies that were included in this study, and the results were summarized as the total length of shoreline that has been assigned to each priority category (Map 12; Map 13). Within the Lower Pembina watershed, 80% of the shoreline length that was assessed was classified as either High Conservation (46%) or Moderate Conservation (34%) Priority, representing approximately 754 km of shoreline (Figure 10). Conversely, 20% of the shoreline was classified as either High Restoration (17%) or Moderate Restoration (4%) Priority, representing approximately 194 km of shoreline.

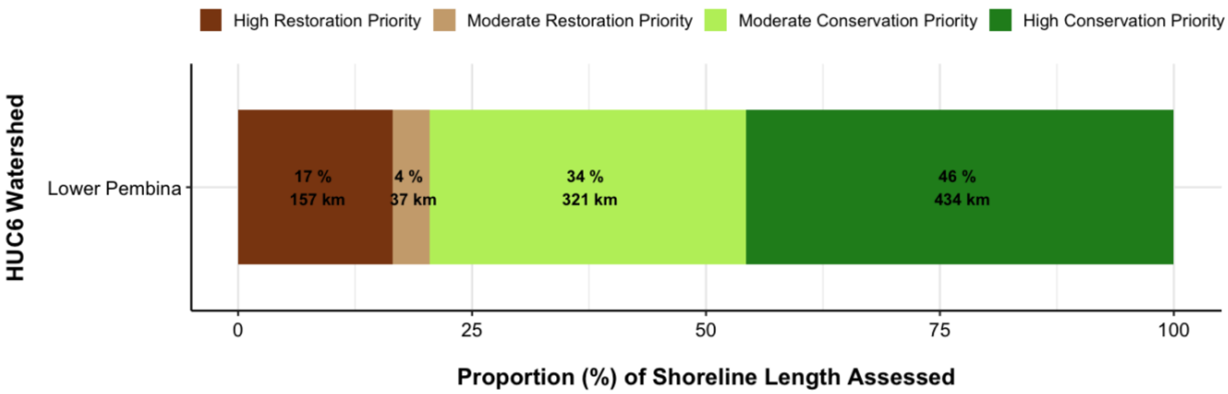


Figure 10. The total proportion of shoreline within the Lower Pembina watershed assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category.

When summarized by HUC 8 subwatershed, the Shoal Creek subwatershed had the highest proportion of shoreline prioritized for restoration (54%), representing 76 km of shoreline (Figure 11). Conversely, the Dapp Creek, French Creek, and Pembina River subwatersheds each had the majority of their shoreline (> 56%) prioritized for conservation. Notably, the French Creek subwatershed had 78% of its shoreline assessed as High Conservation Priority (Figure 11).

Of the eight named creeks and rivers that were assessed, seven had more than 50% of their shoreline classified as prioritized for conservation (Figure 12), with French Creek and Flatbush Creek each with over 70% of their shoreline classified as High Conservation Priority. Only Dapp Creek 1 had the majority of its shoreline prioritized for restoration, with 63% classified as High Restoration Priority and 5% classified as Moderate Restoration Priority (Figure 12). Pembina River had the greatest shoreline length classified as High Restoration Priority (46 km). When lakes are considered, all assessed lakes had over 98% of shoreline classified for conservation priority (Figure 12).

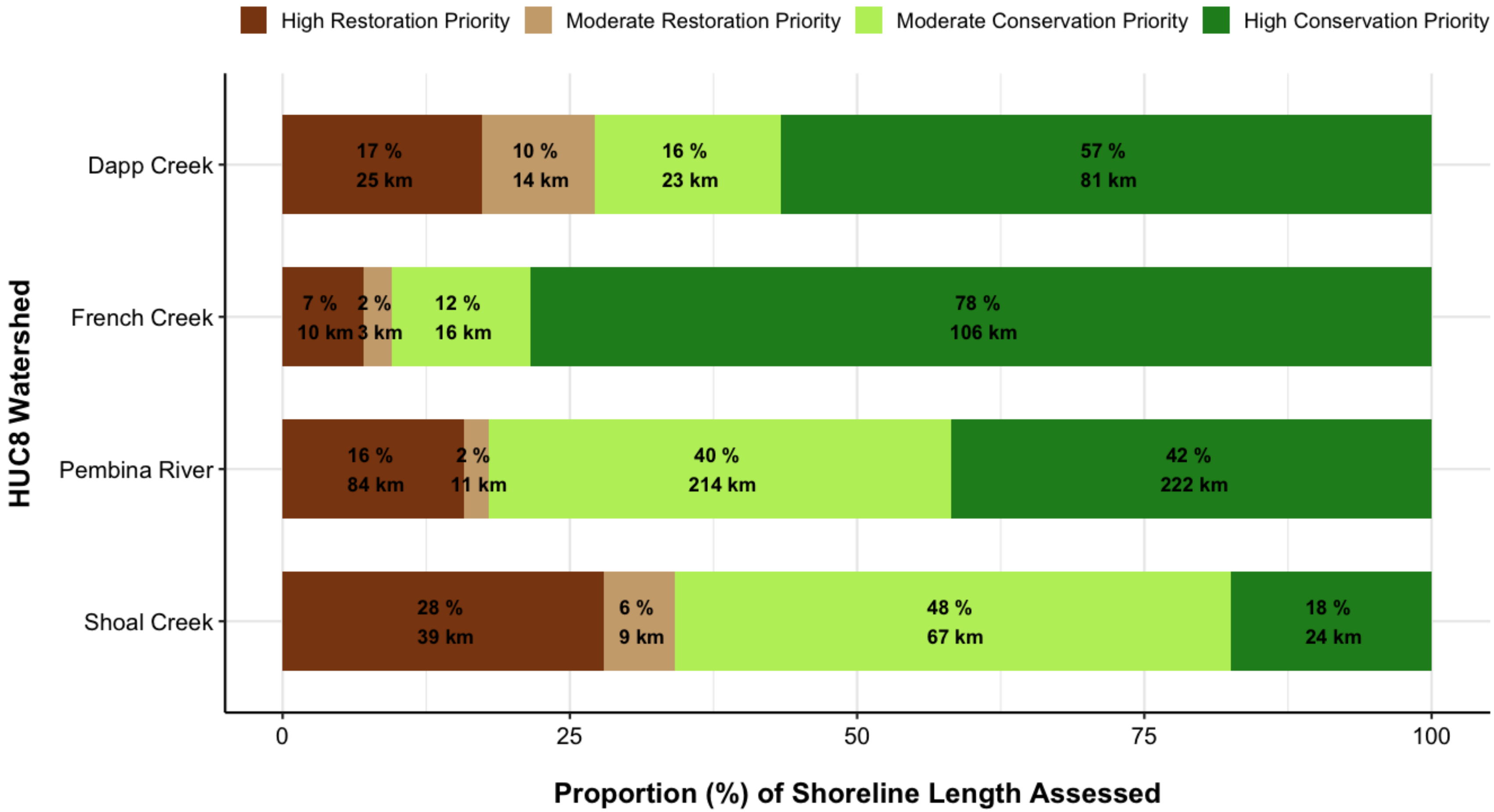
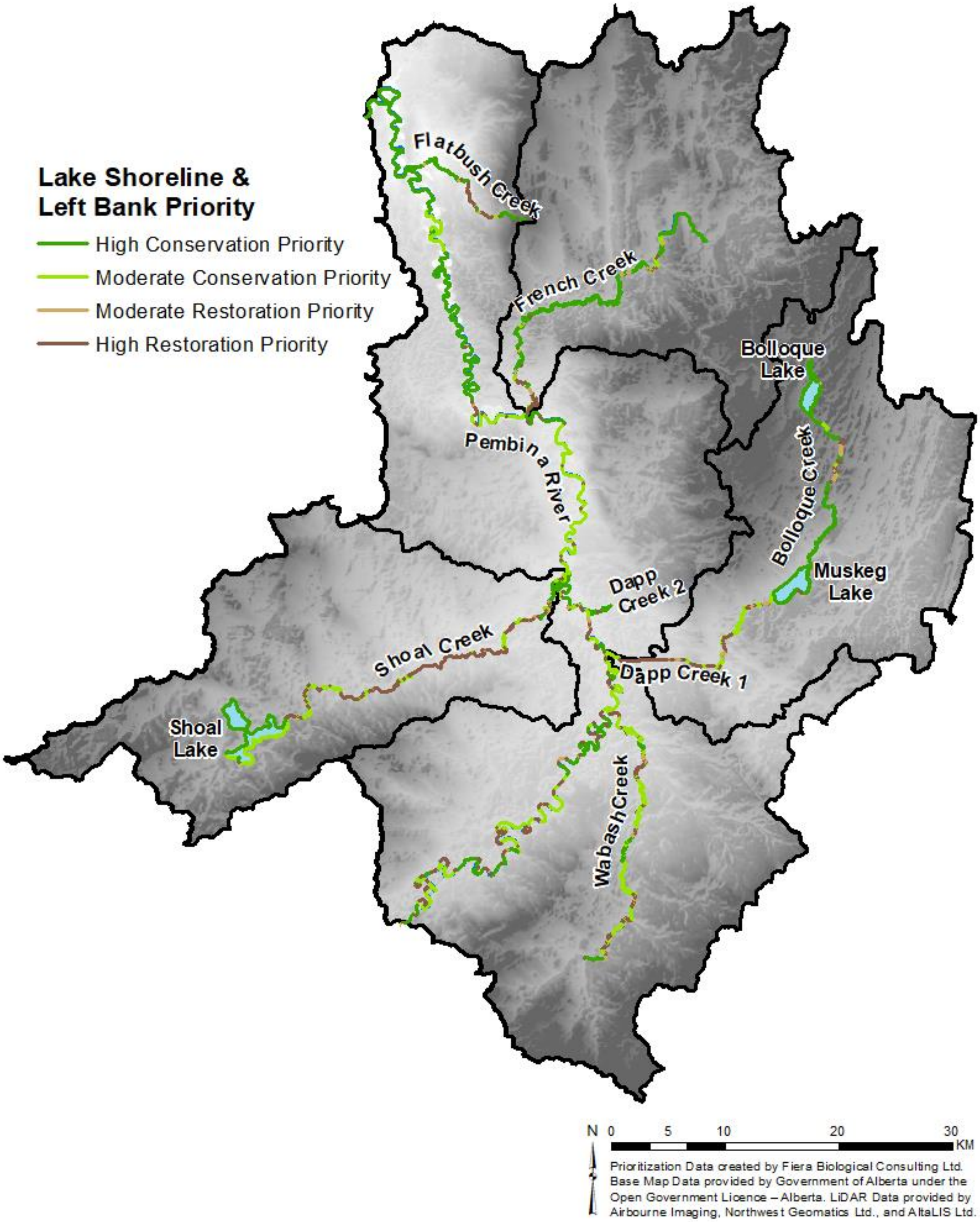
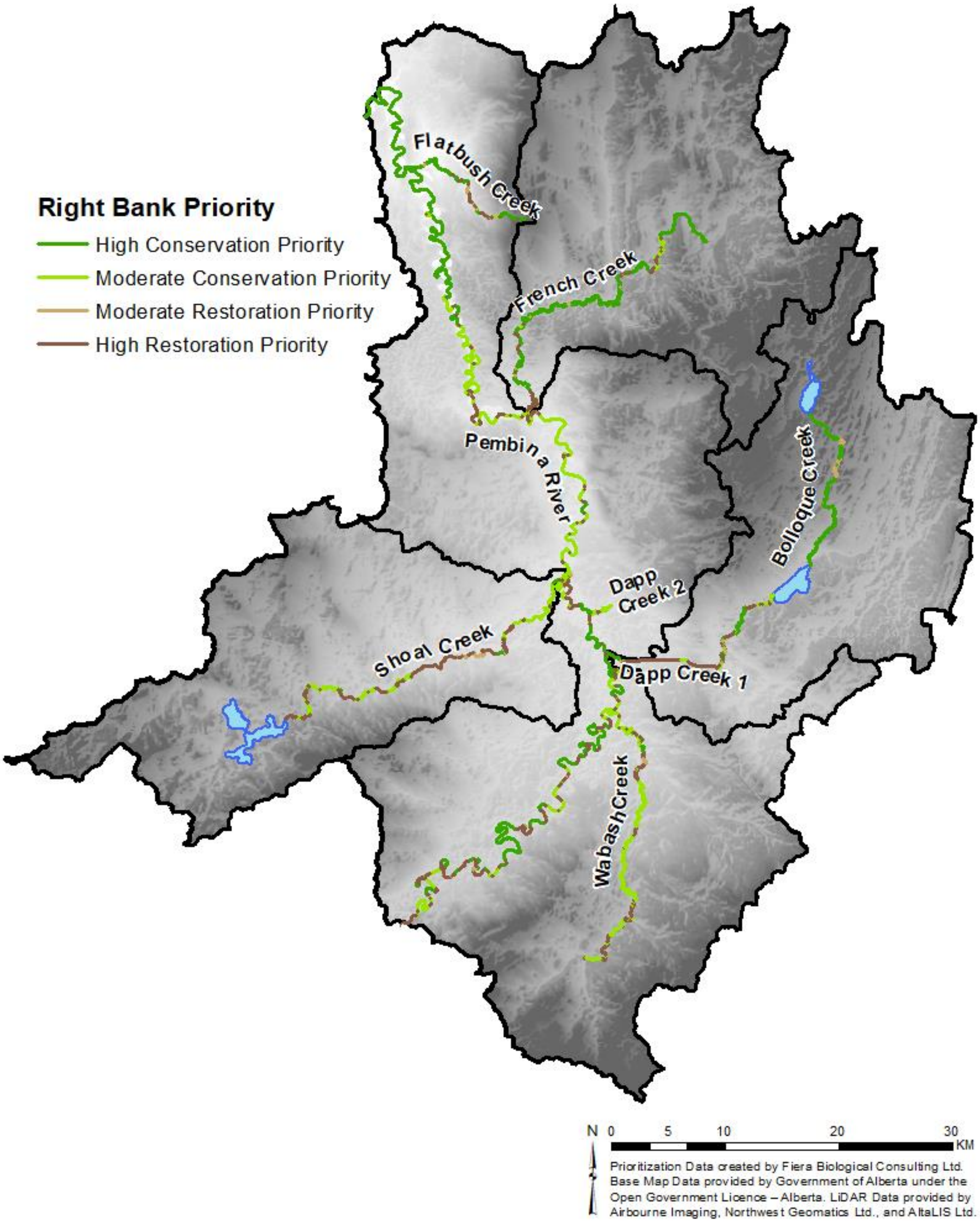


Figure 11. The total proportion of shoreline within the Lower Pembina watershed assigned to each priority category, summarized by HUC 8 subwatershed. Numbers indicate the total length (km) of shoreline associated with each category.



Map 12. Restoration and conservation priority for the left bank of creeks that were included in this study.



Map 13. Restoration and conservation priority for the right bank of creeks that were included in this study.

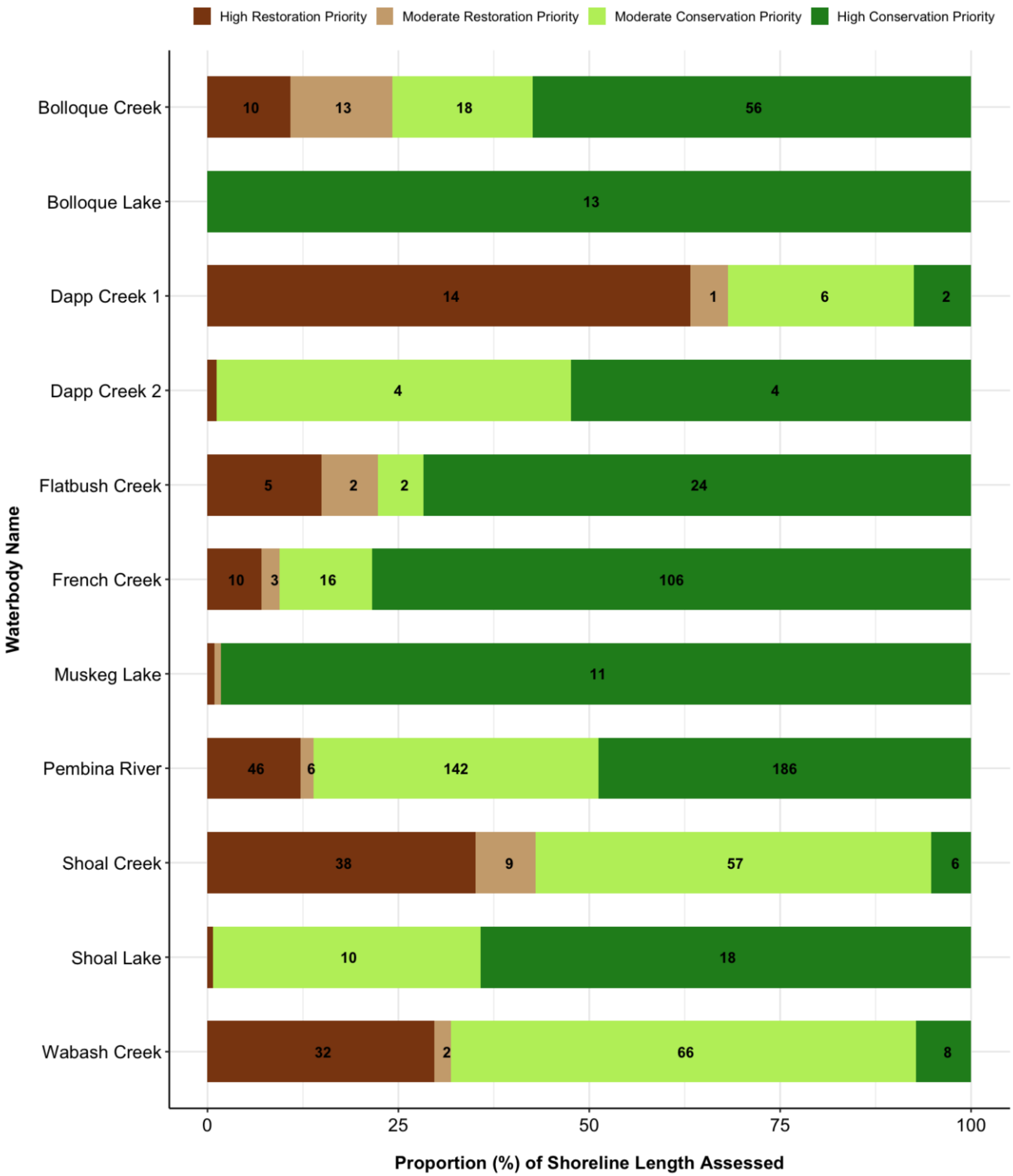


Figure 12. The total proportion of shoreline for named waterbodies assigned to each priority category. Numbers indicate the total length (km) of shoreline associated with each category. No label indicates the category had less than 1 km of shore length assigned to it.

5.0 Municipal Summary

In order to provide riparian assessment information that is relevant from a municipal planning and policy perspective, this section summarizes riparian intactness, pressure on riparian system function, and management prioritization within the Lower Pembina watershed by municipality. Specifically, results are summarized for the rural municipalities of Athabasca County, Westlock County, County of Barrhead, and M.D. of Lesser Slave River (Map 5).

5.1. Riparian Management Area Intactness

The total length of shoreline assessed varied considerably by municipality, with Westlock County having the greatest amount of shoreline assessed at 553 km and Athabasca County having the least (63 km) (Figure 13; Table 10).

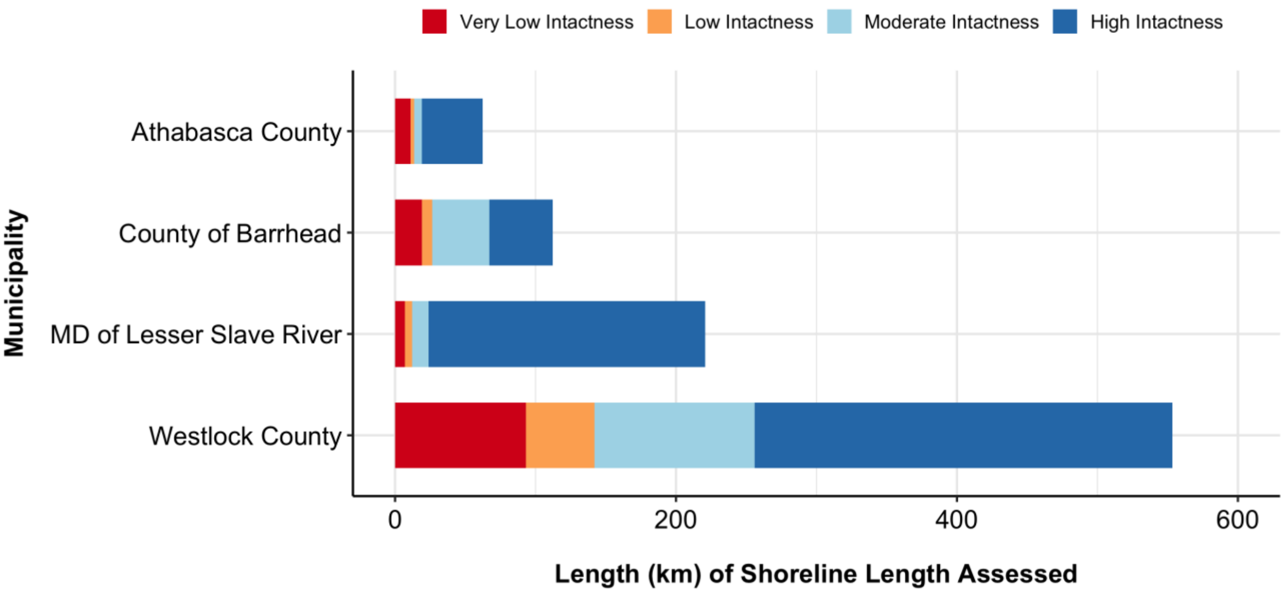


Figure 13. The total length of shoreline assigned to each riparian intactness category, summarized by municipality.

The MD of Lesser Slave River, which includes two creeks and the Pembina River, had the highest proportion of shorelines classified as High Intactness (89%) (Table 10; Figure 14). The other three municipalities had similar proportions of shoreline classified as High and Moderate Intactness (74-78%), with the County of Barrhead having the smallest proportion of High Intactness (40%) of all the municipalities (Table 10; Figure 14). Based on shoreline length, Westlock County had the highest amount of shoreline classified as High Intactness (297 km), which includes the Pembina River, two lakes, and six creeks (Table 11).

Table 10. Summary of shoreline intanctness by municipality.

Municipality	Length Assessed (km)	Proportion (%) of Shoreline within Intactness Category					
		Very Low	Low	Very Low + Low	Moderate	High	Moderate + High
Athabasca County	62.5	17	4	22	8	70	78
County of Barrhead	112.1	17	7	24	36	40	76
MD of Lesser Slave River	220.8	3	2	5	5	89	95
Westlock County	553.2	17	9	26	21	54	74

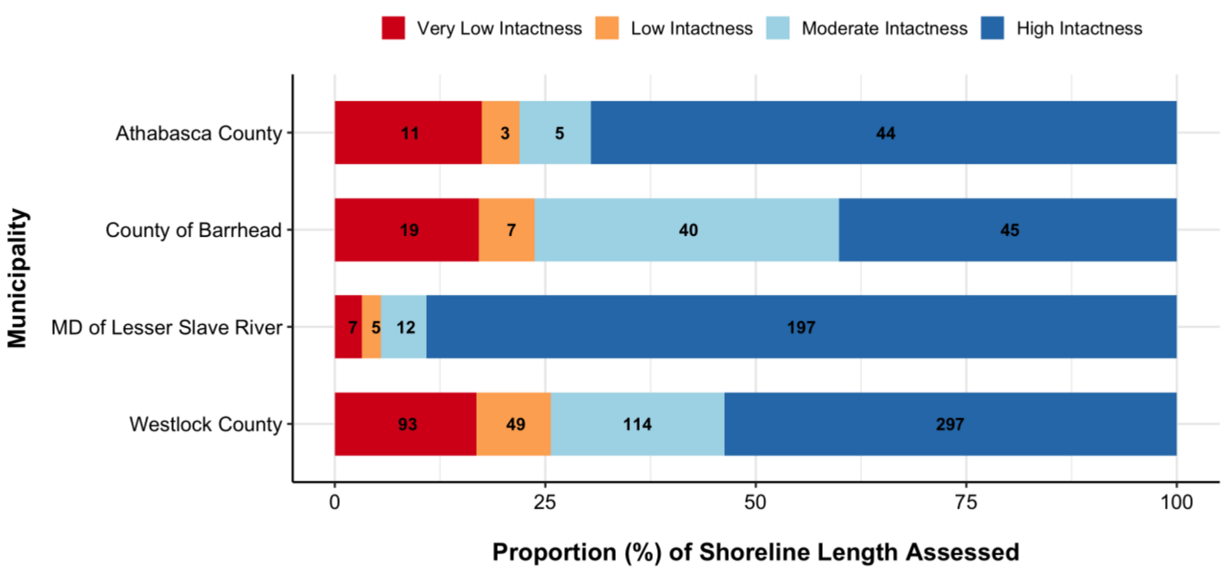
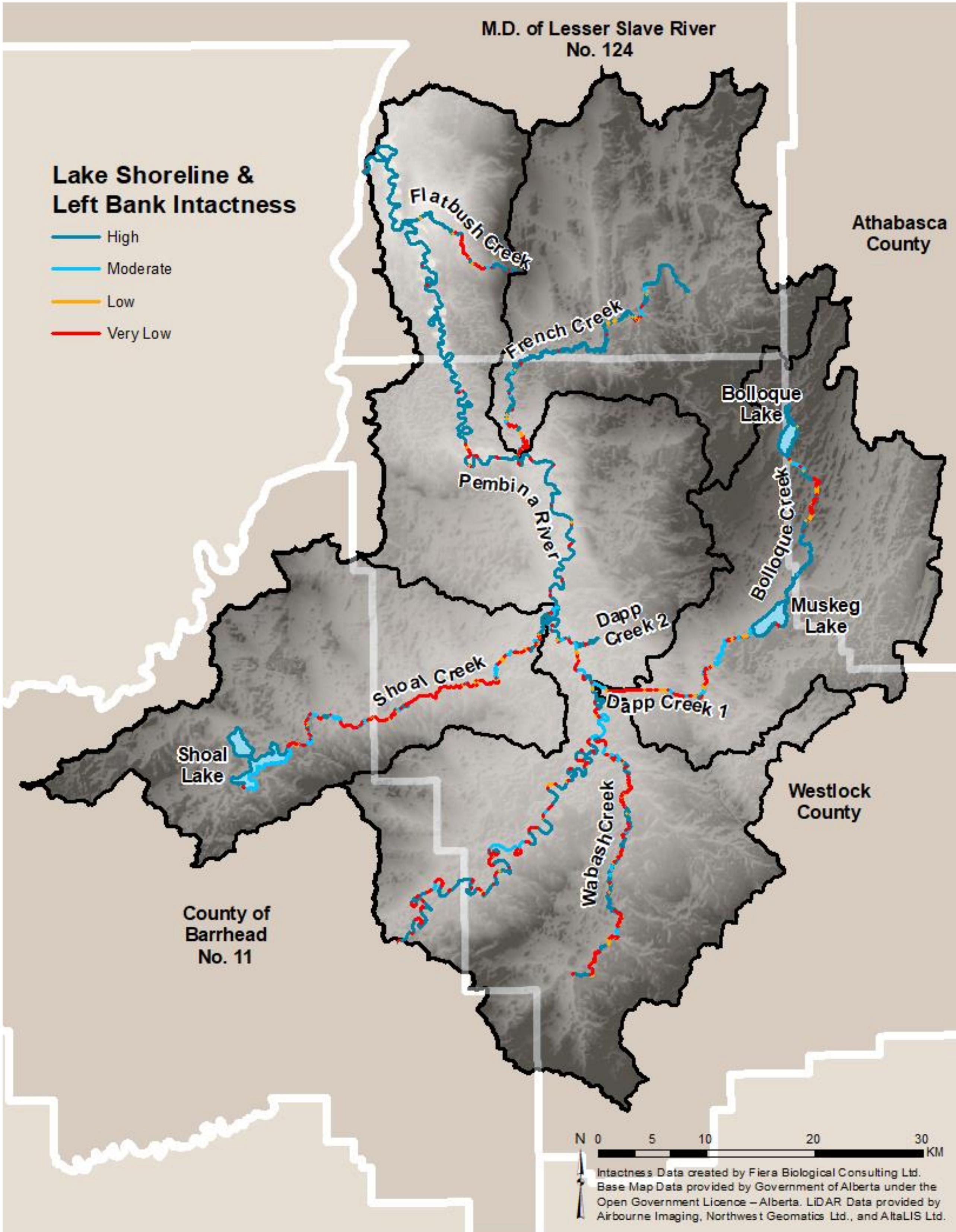


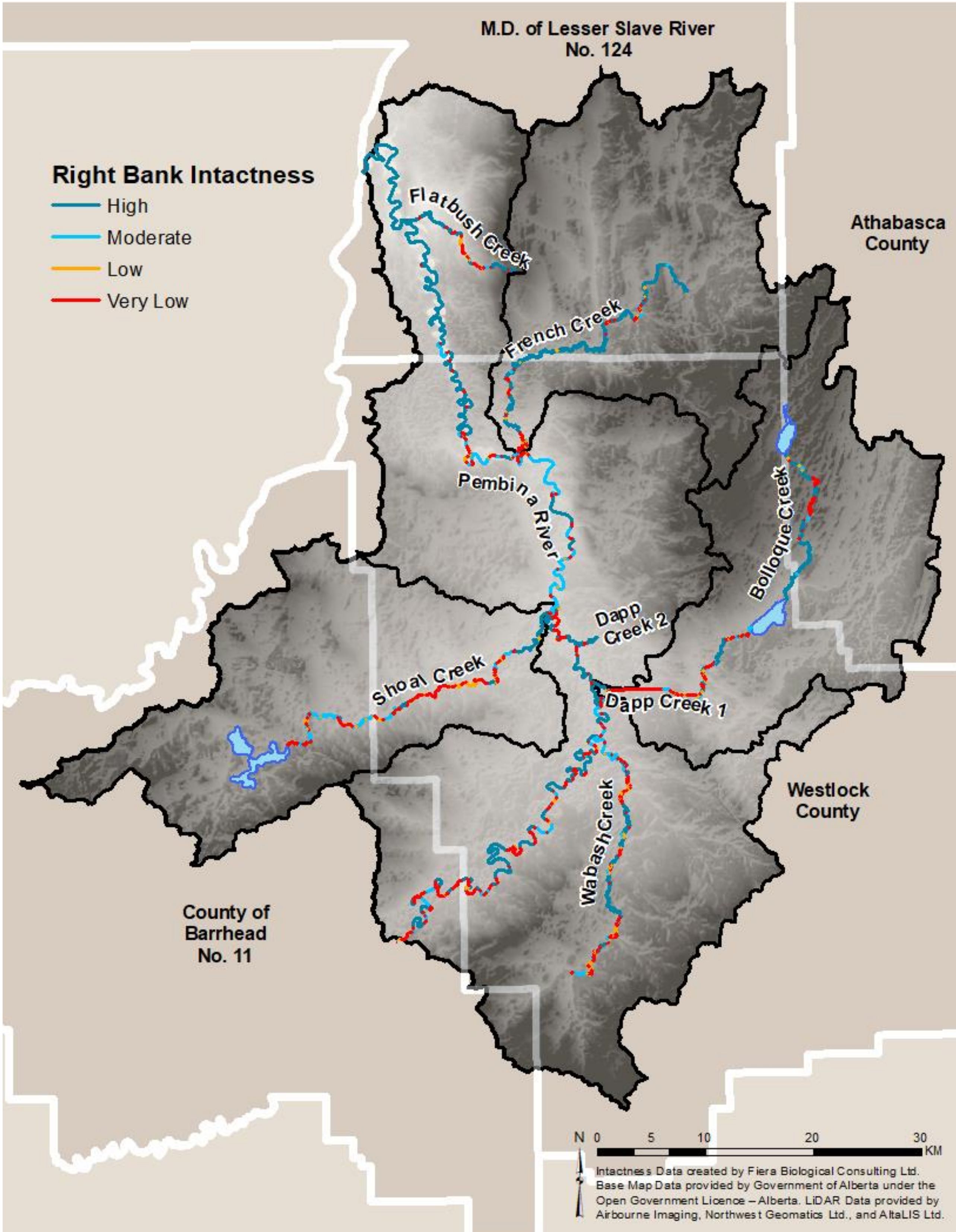
Figure 14. The proportion of shoreline length assigned to each riparian intactness category, summarized by municipality. Numbers indicate the approximate length (km) of shoreline associated with each intactness category.

Table 11. Shoreline intactness for each waterbody included in this assessment, summarized by municipality.

Municipality & Waterbody Name	Total Length Assessed (km)	Length of Shoreline (km) by Intactness Category			
		Very Low	Low	Moderate	High
Athabasca County	**62.5**	**10.9**	**2.8**	**5.3**	**43.5**
Bolloque Creek	53.8	10.9	3.0	5.3	34.8
Bolloque Lake	8.7	0.0	0.0	0.0	8.7
County of Barrhead	**112.1**	**19.2**	**7.4**	**40.5**	**45.0**
Pembina River	39	10.6	1.6	5.0	21.8
Shoal Creek	44.3	8.4	5.8	26.8	3.3
Shoal Lake	28.8	0.2	0.0	8.7	19.9
MD of Lesser Slave River	**220.8**	**7.1**	**5.0**	**11.9**	**196.8**
Flatbush Creek	33.6	5.1	2.4	2.0	24.1
French Creek	94.2	1.7	2.6	7.7	82.2
Pembina River	93	0.3	0.0	2.2	90.5
Westlock County	**553.2**	**93.0**	**49.0**	**114.0**	**297.2**
Bolloque Creek	43	4.5	5.3	16.2	17.0
Bolloque Lake	3.9	0.0	0.0	0.0	3.9
Dapp Creek 1	22.6	11.2	4.2	4.7	2.5
Dapp Creek 2	8.4	0.1	0.0	0.0	8.3
French Creek	40.9	5.3	3.2	3.6	28.8
Muskeg Lake	11.6	0.1	0.1	0.0	11.4
Pembina River	249	30.4	10.0	50.6	158.0
Shoal Creek	65.1	20.5	12.4	15.2	17.0
Wabash Creek	108.7	20.9	13.8	23.7	50.3



Map 14. Intactness for lake shorelines and the left bank of creeks that were included in this study, by municipality.



Map 15. Intactness for the right bank of creeks that were included in this study, by municipality.

5.2. Pressure on Riparian System Function

When pressure associated with RMAs was compared between municipalities, Westlock County and the County of Barrhead had the greatest proportion (53% and 32%, respectively) of local catchment areas classified as High Pressure (Figure 15; Map 16). Generally, catchments dominated by human disturbance (cutblocks, resource extraction) and agricultural land use (particularly cultivation) receive higher pressure scores than catchments with a higher proportion of natural cover. Athabasca County had the greatest proportion (74%) of local catchment areas classified as Low Pressure.

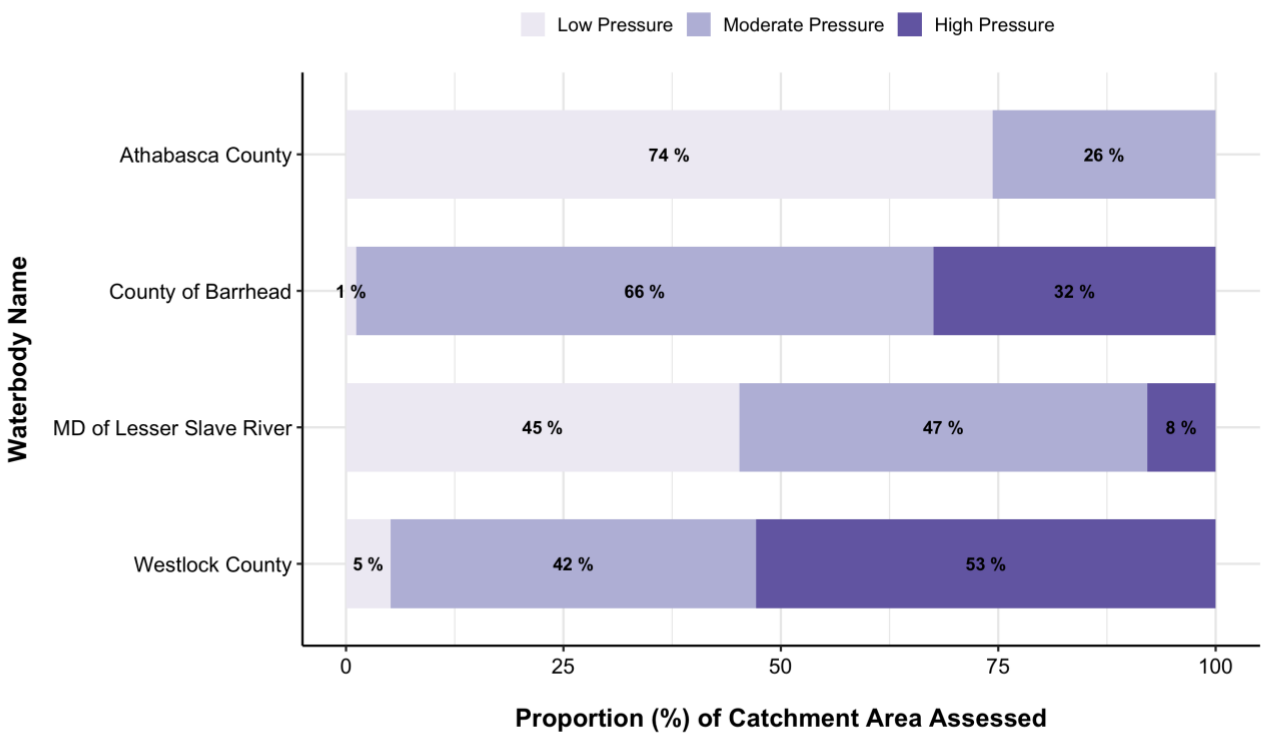
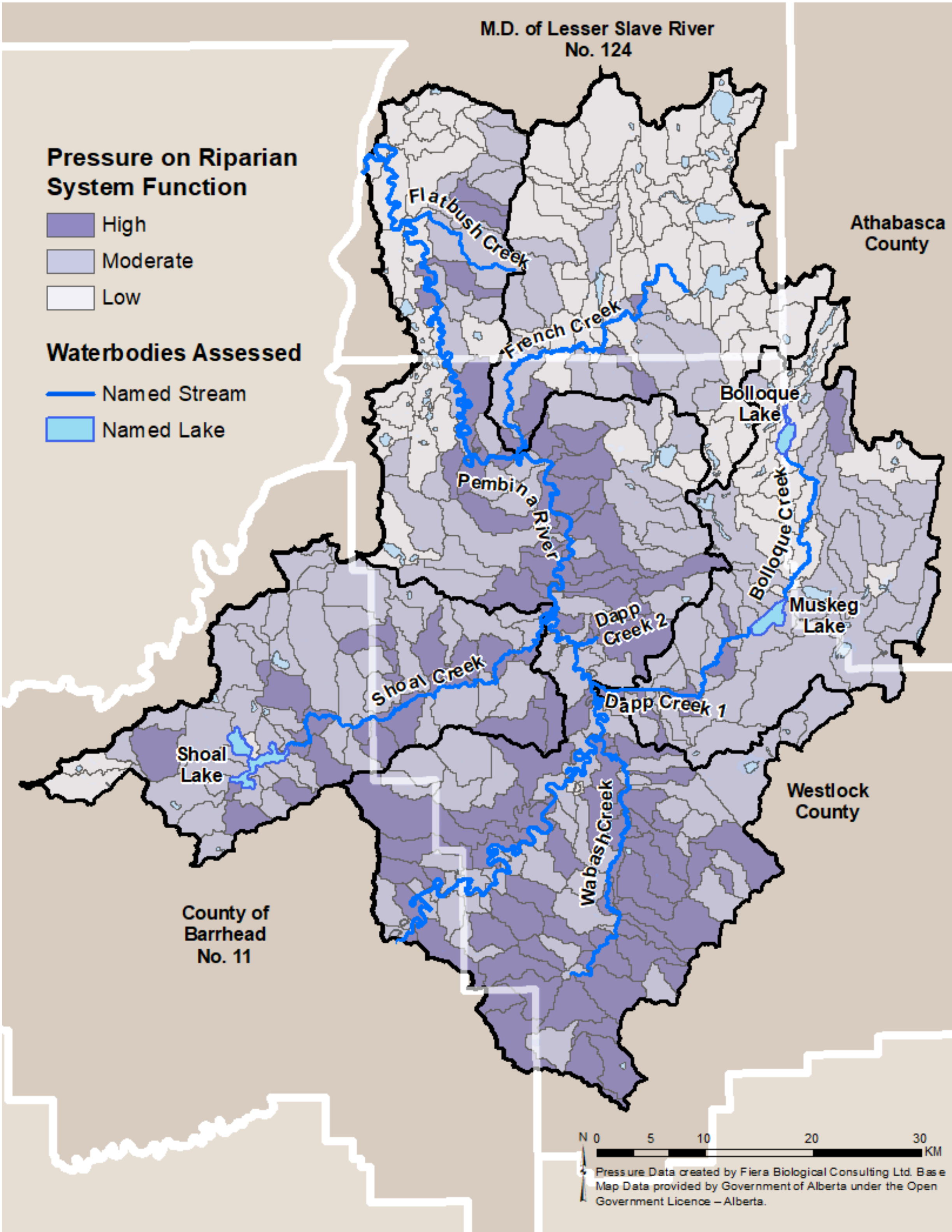


Figure 15. The proportion of catchment area by pressure category associated with RMAs that intersect the shorelines of waterbodies contained within each municipality. Numbers indicate the proportion of area assigned to each pressure category.



Map 16. Distribution of local catchments classified as High, Moderate, and Low Pressure, by municipality.

5.3. Conservation & Restoration Prioritization

All of the municipalities had more than 70% of their shorelines classified as Moderate or High Conservation Priority, and the MD of Lesser Slave River had the highest proportion (83%) and length of shoreline (184 km) classified as High Conservation Priority (Table 12; Table 13; Figure 16). The County of Barrhead and Westlock County had the greatest proportion of shoreline classified as High Restoration Priority (Table 12; Map 17; Map 18).

Table 12. Summary of restoration and conservation priority by municipality.

Municipality	Proportion (%) of Shoreline within Prioritization Category					
	High Restoration	**Moderate Restoration**	**Restoration Priority**	**Moderate Conservation**	**High Conservation**	**Conservation Priority**
Athabasca County	8	14	22	2	76	78
County of Barrhead	20	3	24	51	26	76
MD of Lesser Slave River	4	2	5	11	83	95
Westlock County	22	4	26	43	31	74

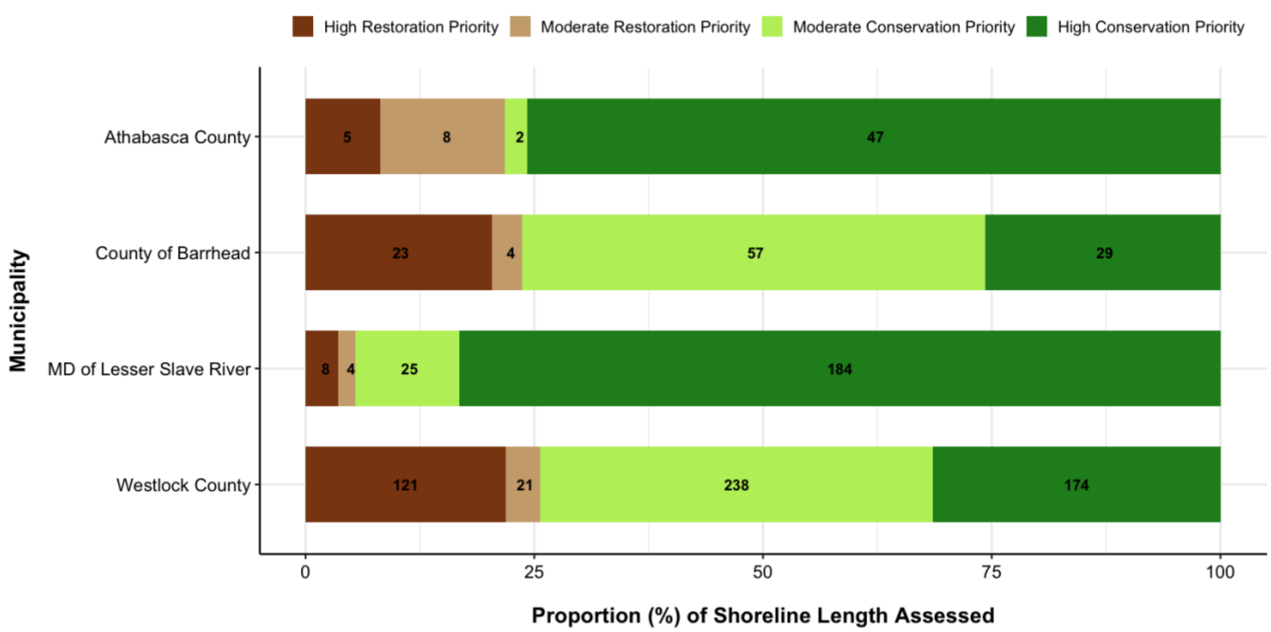
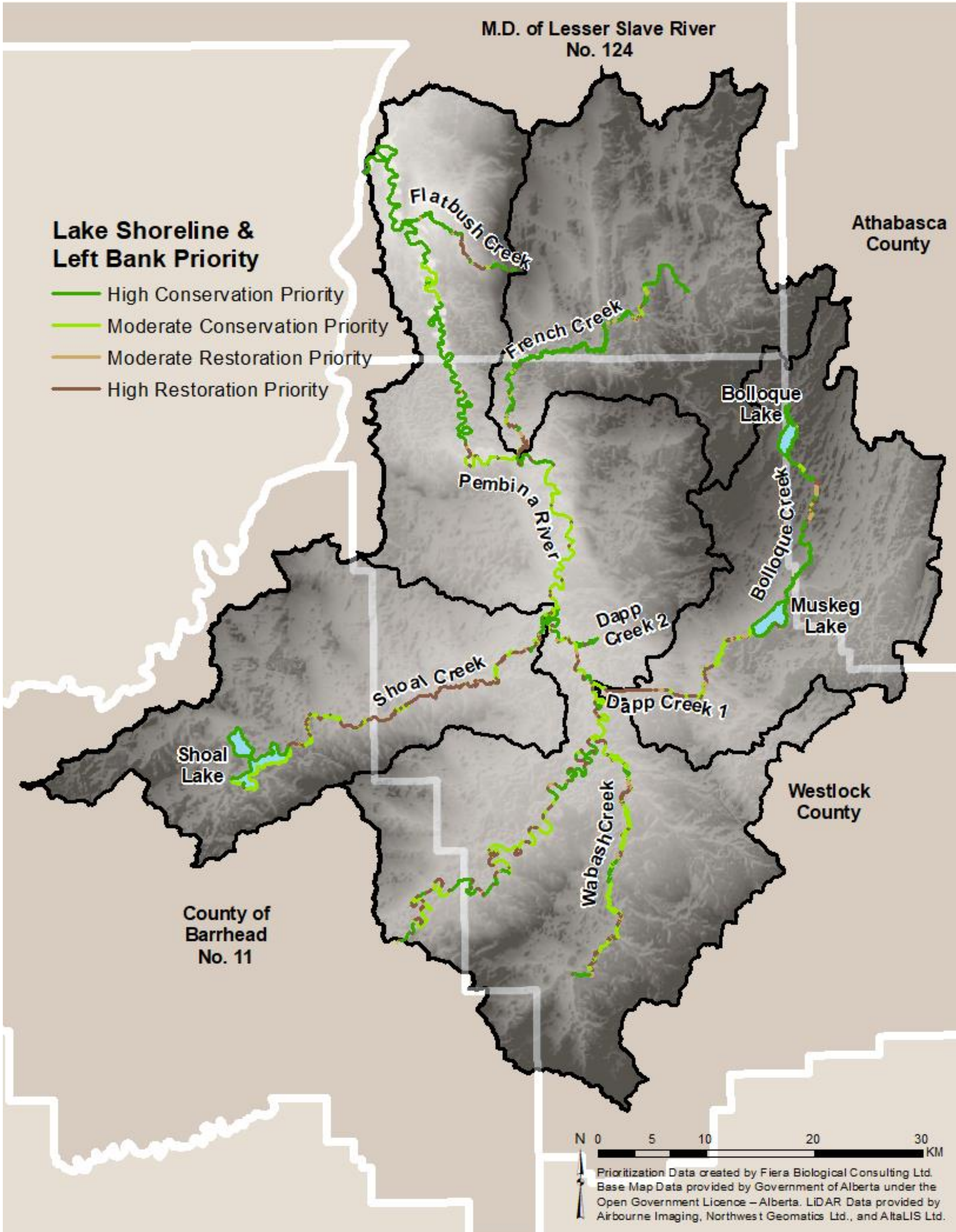


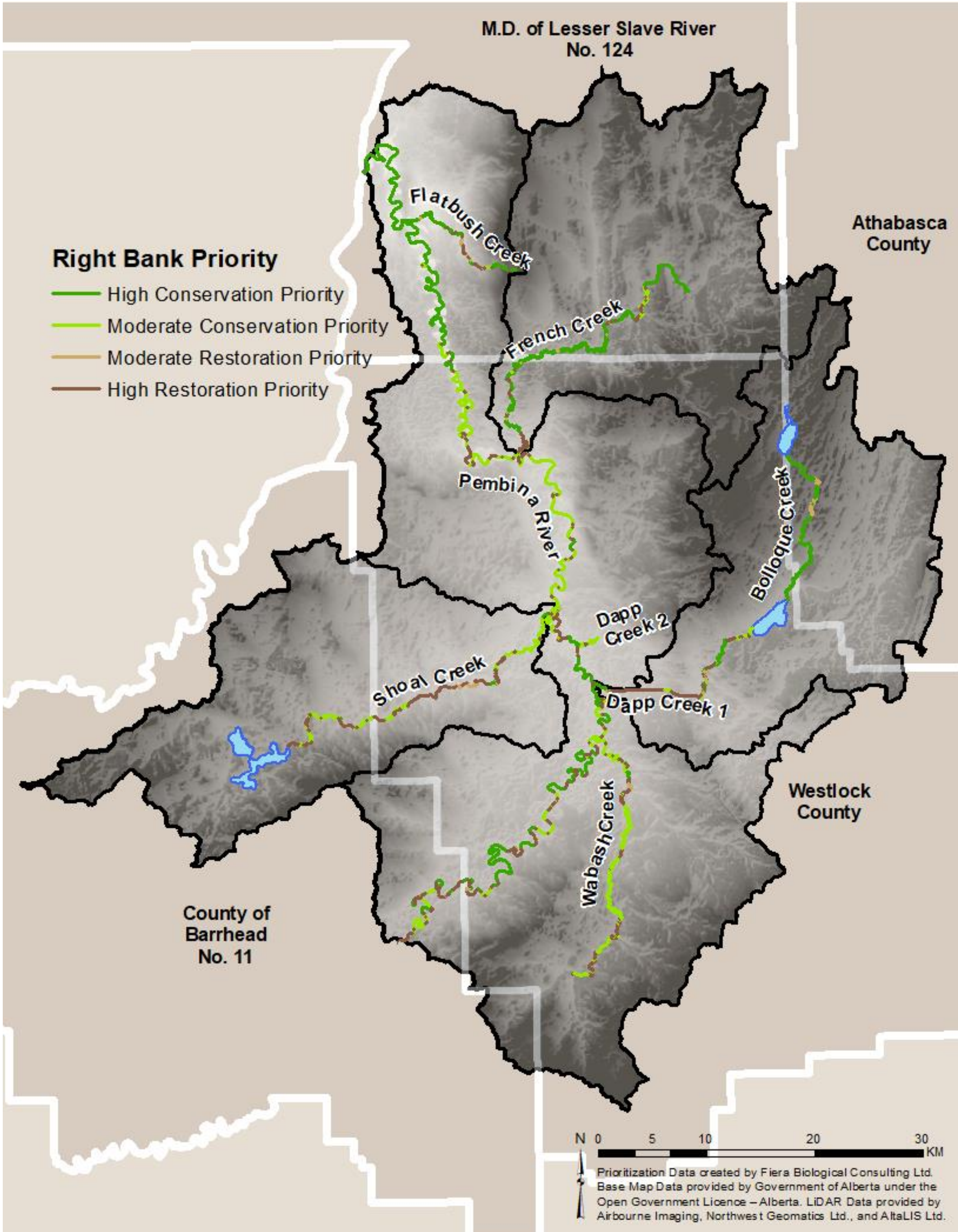
Figure 16. The proportion of shoreline length assigned to each priority category, summarized by municipality. Numbers indicate the approximate length (km) of shoreline associated to each priority category.

Table 13. Shoreline prioritization for each waterbody included in this assessment, summarized by municipality.

Waterbody Name	Length Assessed (km)*	Length of Shoreline (km) by Prioritization Category			
		High Restoration	Moderate Restoration	Moderate Conservation	High Conservation
Athabasca County	**62.4**	**5.1**	**8.5**	**1.5**	**47.3**
Bolloque Creek	53.7	5.1	8.5	1.5	38.6
Bolloque Lake	8.7	0	0	0	8.7
County of Barrhead	**112**	**22.8**	**3.7**	**56.7**	**28.8**
Pembina River	39	11.3	0.9	17.1	9.7
Shoal Creek	44.2	11.3	2.8	29.5	0.6
Shoal Lake	28.8	0.2	0	10.1	18.5
MD of Lesser Slave River	**220.7**	**7.8**	**4.3**	**25**	**183.6**
Flatbush Creek	33.6	5	2.5	2	24.1
French Creek	94.1	2.5	1.8	12.5	77.3
Pembina River	93	0.3	0	10.5	82.2
Westlock County	**553.2**	**121.2**	**20.8**	**237.5**	**173.7**
Bolloque Creek	43	5.4	4.4	16.2	17
Bolloque Lake	3.9	0	0	0	3.9
Dapp Creek 1	22.6	14.3	1.1	5.5	1.7
Dapp Creek 2	8.4	0.1	0	3.9	4.4
French Creek	41.1	7	1.6	3.8	28.7
Muskeg Lake	11.6	0.1	0.1	0	11.4
Pembina River	248.8	34.9	5.4	114.7	93.8
Shoal Creek	65.1	27.1	5.8	27.2	5
Wabash Creek	108.7	32.3	2.4	66.2	7.8



Map 17. Restoration and conservation priority for the lake shorelines and left bank of creeks that were included in this study, by municipality.



Map 18. Restoration and conservation priority for the right bank of creeks that were included in this study, by municipality.

6.0 Creating a Riparian Habitat Management Framework

Foundational to any conservation planning exercise is the collection and generation of scientific information that can be used as the basis for the development and implementation of an evidence-based adaptive management framework. Through the commissioning of this study, the AWC and its stakeholders have an important foundation of scientific evidence upon which to build a systematic and adaptive framework for riparian habitat management in the Lower Pembina watershed.

Importantly, the next step in the advancement of meaningful riparian management and conservation in the watershed will be to formalize a framework for action that includes a consideration of the current conditions (baseline) and defining achievable outcomes and measurable targets, which can then be used to inform relevant collective action by key stakeholders. These actions can then be monitored on a regular basis to provide an evaluation of outcomes that feed into an adaptive and reflexive approach to riparian land management through time.

Central to the goal of improving riparian habitat management and conservation outcomes in the watershed is the development of a framework with specific objectives for riparian land management. Objectives may address different types of goals, such as environmental (e.g., targets for amount of intact riparian area), social (e.g., increase in awareness), and/or programmatic (e.g., development of municipal policy or application of BMPs). Each defined objective should have associated measures, targets, and actions that are developed to ensure that the associated objective is achievable, and success towards achieving each objective can be measured. A definition for each of the key building blocks for the development of a riparian management framework for the watershed is provided below:

Objective:	High-level statements of desired future conditions (outcomes).
Measure:	Specific metrics that can be quantified to assess the progress towards, and the degree to which, desired future conditions have been achieved.
Target:	Values of measurable items (metrics) that indicate the attainment of a desired condition. In the current context these may be expressed as a single value or as a range to acknowledge the inherent variability of ecosystems.
Action:	Management actions, plans, or policies for achieving stated objectives.

While the development of a riparian management framework and associated objectives should be undertaken collectively by key stakeholders, we provide a number of key recommendations below that should be considered in the development of any riparian management plan.

6.1. Key Recommendations

The development of management objectives must consider ecological, social, and economic factors, and must acknowledge that maintaining functional and resilient ecological and hydrological systems is fundamental to maintaining healthy and vibrant human communities and economies. Below we outline what we consider to be important riparian management objectives for the Lower Pembina watershed, and offer considerations and suggestions for the selection of measures and targets for each objective. We also offer a list of high-level actions for each objective; further discussion about potential actions that can be undertaken to improve riparian habitat management is provided in Section 7. Note that this list of management objectives is not exhaustive, and there may be other important riparian habitat management objectives defined by stakeholders in the watershed.

Objective 1:

- Maintain or improve watershed resilience by conserving high quality riparian habitat.

Measure:

- Proportion (%) of shoreline assessed as Moderate and/or High Intactness.
- Total area of High or Moderate Conservation Priority lands secured through conservation easements or other mechanisms.

This objective can include a measure of conservation at multiple and nested spatial extents. For example, a target for conservation of high quality riparian habitat can be developed for the Lower Pembina watershed as a whole, and can also include measures and targets for riparian habitat conservation at the scale of the HUC 8 subwatershed, municipality, and/or individual stream. Measures for riparian habitat conservation may also be specific to the type (order) and the location (e.g., headwaters) of the stream. For example, riparian vegetation provides proportionately greater benefits to instream habitat within headwater streams specifically as it relates to the regulation of temperature, flow, and sediment regimes (Wipfli and Musslewhite 2004; Anonymous 2007). Because of this, there may be a desire to preferentially target riparian habitat along headwater streams for conservation. Alternatively, retention of riparian habitats along higher order streams could be prioritized in areas where habitat connectivity and biodiversity conservation is a priority.

Targets:

There is no universally accepted scientific target for the total amount of riparian habitat that should be maintained within a watershed; however, there is scientific consensus that the higher the quality and the greater the amount of riparian habitat that is maintained on the landscape, the better the outcomes for biodiversity, water quality, and water quantity. Further, there is no universal consensus on the width of vegetation along streams that should be maintained; however, there is general scientific agreement that factors such as the size (order) of the stream, the steepness of the banks, and the specific management concerns of the local system (e.g., soils, type of adjacent land use and land cover) should all be factors considered when determining the amount (width) of vegetation retained adjacent to a stream. For example, Environment and Climate Change Canada suggests as a riparian management guideline that 75% of a stream's length should be naturally vegetated, and that both sides of a stream should have a minimum 30-meter-wide naturally vegetated zone, while also acknowledging that wider buffers may be appropriate in some circumstances (Government of Alberta 2012; Environment Canada 2014).

Results from this study provide an important baseline that can be used to inform the selection of targets for this objective, as well as to measure improvement and progress towards achieving targets. For example, 61% of the shoreline that has been assessed within the Lower Pembina watershed has been classified as High Intactness, with an additional 18% classified as Moderate Intactness, for a combined total of 80% (Table 14). The target for this conservation objective could include specifying an individual target for the desired amount of Moderate and High Intactness separately (e.g., ≥25% Moderate and ≥70% High), or as a combined target (e.g., ≥85% Moderate + High). In addition, or as an alternative, overall targets for this objective can be set for each HUC 8 subwatershed and/or for each municipality. In this case, the Shoal Creek subwatershed and Westlock County may be spatially targeted for restoration activities, given that these areas have a lower proportion of Moderate/High Intactness shorelines than other location within the Lower Pembina watershed.

Table 14. Proportion of riparian areas that have been classified in each of the riparian intactness categories, summarised by various spatial extents (HUC 6 watershed, HUC 8 subwatershed, Municipality).

		Proportion (%) of Shoreline within Intactness Category					
Spatial Extent	**Length Assessed (km)**	**Very Low**	**Low**	**Very Low + Low**	**Moderate**	**High**	**Moderate + High**
Lower Pembina Watershed	948.5	14	7	20	18	61	80
Dapp Creek Subwatershed	143.7	19	9	27	18	55	73
French Creek Subwatershed	135.1	5	4	9	8	82	91
Pembina River Subwatershed	531.5	13	5	18	16	66	82
Shoal Creek Subwatershed	138.2	21	13	34	37	29	66
Athabasca County	62.5	17	4	22	8	70	78
County of Barrhead	112.1	17	7	24	36	40	76
MD of Lesser Slave River	220.8	3	2	5	5	89	95
Westlock County	553.2	17	9	26	21	54	74

Once watershed or municipal targets have been set, finer scale spatial targets can be set for individual lakes or creeks (Table 15). For example, riparian habitat along creeks in the headwaters of the Lower Pembina and/or each HUC 8 subwatershed could be prioritized for conservation, or as an alternative, riparian areas along creeks with important ecological values, such as threatened or sensitive fish, could be prioritized for conservation.

Alternatively, a target such as having ≥75% of each waterbody's shoreline classified as Moderate or High Intactness could be applied throughout the watershed (Environment Canada 2014). If such a target were to be adopted for the Lower Pembina watershed, data from this study suggests that 75% of the waterbodies assessed in the Dapp Creek subwatershed, 100% of the waterbodies in the French Creek subwatershed, 75% of the waterbodies in the Pembina River subwatershed, and 50% of the waterbodies in the Shoal Creek subwatershed meet or exceed this target (Table 15). If this target was reduced to 50%, then all waterbodies in this study, except for Dapp Creek 1 in the Dapp Creek subwatershed would meet or exceed this target (Table 15).

<u>Actions:</u>

There are a number of actions that could be taken to achieve conservation objectives, including (but not limited to):

- Incentivize voluntary conservation of riparian habitat on private land through payment for ecosystem services, changes to tax regimes, or other BMP programs.
- Develop education and outreach programs to encourage stewardship and conservation of riparian habitats on private land.
- Secure high conservation priority riparian habitats through purchase or through other land securement mechanisms available to conservation groups, land trusts, or municipalities.
- Develop provincial and/or municipal development setback and riparian land management policies.
- Create a municipal habitat conservation and restoration fund to allow for the securement of high priority riparian conservation areas.

Table 15. Proportion of shoreline length that has been classified in each of the riparian intactness categories, summarised by individual waterbodies within each of the HUC 8 subwatersheds.

HUC 8 Watershed	Waterbody	Length Assessed (km)	Proportion (%) of Shoreline within Intactness Category					
			Very Low	Low	Very Low + Low	Moderate	High	Moderate + High
Dapp Creek	Bolloque Creek	96.8	16	8	24	22	54	76
	Bolloque Lake	12.7	0	0	0	0	100	100
	Dapp Creek 1	22.6	50	19	68	21	11	32
	Muskeg Lake	11.6	1	1	2	0	98	98
French Creek	French Creek	135.1	5	4	9	8	82	91
Pembina River	Dapp Creek 2	8.4	1	0	1	0	99	99
	Flatbush Creek	33.6	15	7	22	6	72	78
	Pembina River	380.8	11	3	14	15	71	86
	Wabash Creek	108.7	19	13	32	22	46	68
Shoal Creek	Shoal Creek	109.4	26	17	43	38	19	57
	Shoal Lake	28.8	1	0	1	30	69	99

Objective 2:

- Reduce flood risk by restoring riparian habitats that have been impacted or impaired.

Measure:

- Proportion (%) of shoreline assessed as Very Low and/or Low Intactness.

Similar to Objective 1, this measure can include multiple and nested spatial extents, and can also include finer scale spatial targeting of particular regions or high-priority waterbodies.

Targets:

Riparian habitats stabilize the banks of waterbodies and help modulate water velocities and high water events, thereby protecting surrounding lands from flooding (Orewole et al. 2015; Olokeogun et al. 2020). Thus, limiting the amount and extent of riparian habitat that has been severely impacted and restoring these areas should be an important goal for riparian habitat management in the watershed, particularly in areas that are prone to flooding.

At present, 21% of the shoreline assessed in the Lower Pembina watershed has been classified as Low or Very Low Intactness (Table 14). A target for this objective could include specifying a desire to reduce to zero the length of shoreline that has been classified as Very Low Intactness at the watershed, sub-watershed, and/or municipal scale. Alternatively, individual targets could be specified at a range of landscape scales. As with Objective 1, finer scale targets can also be set for individual lakes or streams under this objective.

Actions:

There are a number of actions that could be taken to achieve the targets specified under Objective 2, including (but not limited to):

- Incentivize riparian habitat restoration on private land through payment for ecosystem services, changes to tax regimes, or other BMP programs.
- Develop education and outreach programs to encourage private land restoration, particularly for landowners located upstream of flood prone areas.
- Partner with conservation organizations to promote and encourage restoration on private lands.
- Create a municipal habitat conservation and restoration fund to pay for riparian habitat restoration on public lands, with a specific focus on restoring areas identified as Very Low or Low Intactness.

Objective 3:

- Manage external pressures on riparian system function.

Measure:

- Pressure score of local catchments adjacent to streams.

As part of this study, pressure scores have been assigned to local catchment areas, which broadly characterizes the existing condition of each catchment as it relates to the type of land cover and the intensity of land use that is present. These catchments and their associated scores offer measures for generally assessing and tracking land use and land cover changes through time.

Targets:

- No net increase in the pressure score of local catchments adjacent to streams.
- Net increase in the cover of natural vegetation (e.g., forest) and/or wetlands within High Pressure catchments adjacent to streams.

Generally, the focus of this objective should be on minimizing the impacts of large scale and cumulative land cover or land use change on riparian areas and associated stream habitats. While it is unlikely that there will be reversals to existing land use or land cover to create an improvement to pressure scores, a realistic goal for this objective would be to identify high priority local catchments where the target for management is a no net increase in the current local catchment pressure score.

An additional target for this objective could include a net increase in the cover of natural vegetation (e.g., forest, shrubs, grassland), and/or wetlands. An increase in the amount of permeable surfaces and low intensity land uses in areas adjacent to riparian habitats will have a net positive effect on the function and condition of riparian and stream habitats.

Actions:

The following is a list of actions that could be undertaken to achieve the targets specified under Objective 3:

- Incentivize voluntary conservation of wetland habitat and natural vegetative cover on private land through payment for ecosystem services, changes to tax regimes, or other BMP programs.
- Develop education and outreach programs to encourage stewardship and conservation of wetlands and other natural vegetation on private land.
- Secure wetland and other natural habitats in high priority catchments through purchase or through other land securement mechanisms available to conservation groups, land trusts, or municipalities.
- Create municipal land use bylaws that restrict land clearing or high intensity land use activities in local catchments designated as high priority for conservation.

7.0 Existing Tools for Riparian Habitat Management

Riparian land management in Alberta falls under the jurisdiction of the federal, provincial, and municipal governments. While Alberta does not have legislation or policy that explicitly manages riparian lands, there are a number of laws, regulations, standards, policies, and voluntary programs that can be used to direct the management of riparian lands, or land that directly adjoins riparian lands. The following sections highlights the key legislation, policies, and programs that are currently in place for riparian land management in the province of Alberta. Note that this is not intended to be an exhaustive list; rather, it is intended to highlight legislation, policy, and programs that are considered to be the most relevant and commonly employed to achieve riparian land conservation in the province.

7.1. Guidelines, Policies, and Legislation

Federal jurisdiction over riparian areas in Alberta is somewhat limited in scope. Exceptions to this include the authority to manage natural habitats and associated wildlife on federal land (e.g., First Nation Reserves, National Parks), as well as the authority to regulate migratory birds, fish and fish habitat, navigable waters, and species at risk. A summary of relevant federal laws and regulations that may apply to riparian management in the watershed are listed in Table 16.

At the provincial level, there a number of statutory laws, regulations, and standards that directly or indirectly relate to the management of riparian habitat on both private and public land. The responsibility for managing riparian land falls to a number of provincial ministries and departments, and the mechanisms through which riparian lands are managed varies with respect to whether these habitats are located on private land (White Zone) or public land (Green Zone). In addition, the nature of the disposition and the activities associated with the land use(s) (e.g., forestry, oil and gas, agriculture, or urban development) influences how riparian lands are managed on both private and public land.

In instances of overlapping land use or activities (e.g., forest harvest operating together with oil and gas exploration), the manner in which riparian lands are managed is directed by the laws, regulations, and standards that are specific to that particular land use or activity. In these situations, coordination between the various government ministries responsible for enacting those laws, regulations, or standards is an important aspect of successful riparian management outcomes. Regardless of where the riparian land is located, or what the land use and associated activities may be, the provincial government has jurisdiction over the management of all water in the province under the *Water Act*, as well as all lands that are defined as “public” (regulated under the *Public Lands Act*), which includes the bed and shore of all permanent waterbodies, regardless of whether these waterbodies are located on private land.

In addition to provincial laws and regulations, the Government of Alberta has a wide range of policies, standards, or guidelines that provide direction for the management of natural areas, wildlife, and wildlife habitat. The majority of these policies are voluntary and require the application of best management practices to achieve the desired management goals. One exception to this is the provincial wetland policy. Wetlands are regulated as waterbodies under the *Water Act*, and as such, an approval is required to undertake any works that may impact a wetland. Thus, the principles and goals of the wetland policy and the associated wetland compensation guide are enforced through the *Water Act* application process.

A list and description of provincial laws, regulations, and policies that may apply to the management of riparian areas in the watershed is provided in Table 17.

Table 16. List and description of Federal laws and regulations that may apply to the management of riparian areas in the Lower Pembina watershed.

Federal Law or Regulation	Application to the Management of Riparian Areas
Migratory Bird Convention Act	This legislation is based on international treaty signed by Canada and the United States of America that aims to protect migratory birds from indiscriminate harvesting and destruction on all lands within Canada. Under this Act, efforts should be made to provide for and protect habitat necessary for the conservation of migratory birds, and to conserve habitats that are essential to migratory bird populations, such as nesting, wintering grounds, and migratory corridors.
Fisheries Act	Includes provisions for the protection of fish and fish habitat, and requires an authorization for activities that cause serious harm to fish.
Species At Risk Act	The Federal government has jurisdiction over all SARA-listed species on federally owned lands, including national parks, Department of National Defence lands, and First Nations Reserve lands. Management of SARA-listed species on provincial crown land, or on lands held by private citizens of Alberta, falls under the jurisdiction of the provincial government. In these cases, the provincial government is obligated to protect listed species to the same standards set forth by the Federal government. In cases where provincial governments do not meet these standards, the Federal Minister may issue an order in council to protect federally listed species that occur on provincial or private lands

Table 17. List and description of Provincial laws, regulations, and policies that may apply to the management of riparian areas in the Lower Pembina watershed.

Legislation, Regulation, or Policies	Application to the Management of Riparian Areas
Agricultural Operation Practices Act	Regulates and enforces confined livestock feeding operations planning for siting, manure handling/storage, and environment standards.
Alberta Land Stewardship Act	Creates authority of regional plans and enables the development of conservation and stewardship tools that can be used to acquire and manage natural areas. These tools include conservation easements, conservation directives, conservation offsets, and transfer of development credits.
Alberta Wetland Policy & Wetland Mitigation Directive	Pursuant to the *Water Act*, the provincial wetland policy prohibits the unauthorized drainage or disturbance of wetlands. The stated goal of the policy is to "conserve, restore, protect, and manage Alberta's wetlands to sustain the benefits they provide to the environment, society, and economy". If wetland loss or impacts are authorized by the province under the *Water Act*, the permittee is responsible for the replacement of lost wetland habitat at the ratio stipulated by the province. While this policy does not explicitly manage riparian land, there is opportunity within the stated goals and intent of this policy to extend the policy to include riparian lands.
Environmental Protection and Enhancement Act (EPEA)	This legislation aims to protect air, land and water by regulating the process for environmental assessments, approvals, and registrations. In particular, stormwater drainage that is directed to any surface waterbody requires an EPEA approval. Further, the Environmental Code of Practice for Pesticides provides a standard for operating practices that restrict the deposition of pesticides into or onto any open waterbody.
Municipal Government Act (MGA)	Updated in June 2018, the modernized MGA provides municipalities with the authority to adopt statutory plans and bylaws that direct land use and development at subdivision. The MGA also grants limited rights to designate reserves at subdivision that can be used to conserve natural areas, and gives municipalities authority to regulate water on municipal lands, manage private land to control non-point source pollution, and adopt land use practices that are compatible with the protection of the aquatic environment, including development setbacks on waterbodies
Municipal Land Use Policies	Pursuant to Section 622 of the MGA, these Policies were established by Municipal Affairs to supplement planning provisions in the MGA and the Subdivision and Development Regulation, and to create a conformity of standard with respect to planning in Alberta. Section 5 of the Land Use Policies encourages municipalities to identify significant waterbodies and watercourses in their jurisdiction, and to minimize habitat loss and other negative impacts of development through appropriate land use planning and practices. In addition, Section 6 encourages municipalities to incorporate measures into planning and land use practice that minimizes negative impacts on water resources, including surface and groundwater quality & quantity, water flow, soil erosion, sensitive fisheries habitat, and other aquatic resources.

Continued …

Table 17 *continued …* List and description of Provincial laws, regulations, and policies that may apply to the management of riparian areas in the Lower Pembina watershed.

Legislation, Regulation, or Policies	**Application to the Management of Natural Areas**
Public Lands Act	Regulates and enforces activities that affect the Crown-owned bed and shore of waterbodies, as well as Crown-owned riparian and upland habitats (e.g., forest and grazing leases).
Stepping Back from the Water: A Beneficial Management Practices Guide for New Developments Near Waterbodies	This document provides discretionary guidance to local authorities to assist with "decision making and watershed management relative to structural development near waterbodies", and includes recommendations for development setbacks (buffers) on waterbodies to protect aquatic and riparian habitats.
Soil Conservation Act & Regulations	Regulates activities that may cause erosion and sedimentation of a waterbody.
Surveys Act	Definitions for the "legal bank" of a waterbody, upon which the Crown-owned "bed and shore" is defined. The legal boundary between the bed and shore and the adjacent lands is the naturally occurring high water mark, and may not extend to include the full extent of riparian lands adjacent to a waterbody.
Water Act	The stated purpose of this Act is to support and promote water conservation and management. Under the Act, any activity that causes or has the potential to cause an effect on the aquatic environment requires an approval. Regulations and Codes of Practice under this Act apply to water and water use management, the aquatic environment, fish habitat protection practices, in-stream construction practices, and storm water management.
Weed Control Act	Noxious and prohibited noxious weeds listed under Schedule 1 must be controlled (noxious weed) or destroyed (prohibited noxious weed) by the owner of the land on which the listed weed occurs.
Wildlife Act & Species at Risk Program	Regulates and enforces protection of wildlife species and their habitats, which may include riparian dependent species

While the provincial government holds the authority to regulate water and public land throughout the province, municipalities are given the authority to manage lands within their jurisdiction under the *Municipal Government Act* (MGA), which was modernized and revised in July 2018. Under Part 1, Section 3, the Act outlines the following purposes of a municipality:

1) To provide good governance and foster the well-being of the environment;
2) To provide services that are in the opinion of council to be necessary or desirable;
3) To develop and maintain safe and viable communities; and
4) To work collaboratively with neighbouring municipalities to plan, deliver, and fund intermunicipal services.

A primary power given to municipalities is land use planning and development, which allows municipalities to set the conditions under which lands are subdivided and developed. Further, each municipality must develop statutory planning documents that provide a framework and vision for development and land use within their jurisdictions. Statutory planning documents that are required include:

- Municipal Development Plans
- Intermunicipal Development Plans
- Area Structure Plans
- Area Redevelopment Plans

Within these planning documents, municipalities can provide specific direction for development requirements that may influence the conservation of riparian habitat. In addition to statutory planning documents, municipalities can influence the management of riparian areas by enacting Land Use Bylaws that set forth requirements for development setbacks on environmentally sensitive lands. For example, municipalities can provide specific direction for development requirements in or near riparian habitat, or set forth minimum development setback widths on Environmental Reserve (ER), environmentally sensitive land, or waterbodies and watercourses.

The MGA also gives municipalities the power to enact land use bylaws, as well as the authority to designate land as Environmental Reserve at the time of subdivision. Environmental Reserves are defined in Section 664 as waterbodies or watercourses, lands that are unstable or subject to flooding, and lands "not less than 6 metres in width abutting the bed and shore" of a waterbody or watercourse. While the Act allows municipalities to take a 6 metre (or more) setback on Environmental Reserve lands, the conditions under which this taking is permitted is limited to cases where the setback is required to prevent pollution or provide public access to the bed and shore of the waterbody or watercourse. In addition to the limited opportunities that are available for conserving riparian land as Environmental Reserve, Section 640(4)(l) of the Act allows municipalities to establish development setbacks on lands subject to flooding, low lying or marshy areas, or within a specified distance to the bed and shore of any waterbody.

7.2. Acquisition of Riparian Lands

It is important to note that while there is a wide range of different federal, provincial, and municipal laws and policies that regulate activities within or near riparian areas, these regulations by themselves to do not necessarily result in the conservation of riparian habitat. In many cases, existing laws regulate *activities* that may impact riparian habitats (e.g., the provincial *Water Act*), but do not regulate the habitats themselves. As a result, many of the existing laws result in approvals that allow for the removal or alteration of riparian areas under certain conditions outlined within the approval. In some cases, these regulations require compensation or replacement of impacted habitats (e.g., the Provincial wetland policy and the federal *Fisheries Act*), but typically, existing laws and policies do not prevent land development, and there is very little provision for riparian habitat conservation in existing laws and policies, particularly as it relates to federal and provincial regulation.

At the municipal level, most municipalities have environmental and land use legislation, policies, and guidelines that provide direction for how to target riparian habitats and other natural areas for conservation, as well as guidance for how to integrate these habitats into a neighbourhood post-development. However, there are only a small number of tools or mechanisms available that enable the *acquisition* of lands by the municipality (or a third party) for the purpose of conservation. In some cases, these tools are only available to municipalities at particular times during the development process (e.g., at subdivision). In other instances, there may be restrictions on the amount of land that municipalities can set aside for conservation, as natural area conservation must be considered alongside other land use demands, such as school and park sites. In many cases, municipalities may have undertaken an ecological inventory to identify high priority areas for conservation, and have the appropriate legislation or policies in place to manage these areas, but may lack the appropriate tools (or associated resources) to acquire high priority conservation areas.

One of the most effective conservation mechanisms for aquatic habitats within municipalities is the *Public Lands Act*. Pursuant to this legislation, the Province of Alberta owns the bed and shore of all permanent and naturally occurring waterbodies, including lakes, rivers, streams, and wetlands. Under this Act, all permanent and naturally occurring waterbodies are Crown land, and development must avoid these features. If development can not be avoided, the Crown determines whether temporary construction or permanent occupation will be authorized, and in many cases, authorized activities that result in the loss of Crown land is subject to compensation. In the case of riparian habitats along streams and rivers and permanent wetlands, the determination of whether riparian areas are considered to be part of the Crown claimed waterbody is contingent on the existence of a legal survey, and the location of the water boundary that is determined by the surveyor, as per the Surveyors Act. In this regard there are known inconsistencies with respect to how surveyors determine the location of the water boundary, and this may or may not include riparian habitat.

The second provincial legislation that enables municipalities to develop and implement land conservation and stewardship tools is the *Alberta Land Stewardship Act* (ALSA). Under ALSA, the following tools may be utilized to conserve riparian areas in municipalities:

Conservation Easement:

A conservation easement is a voluntary contractual agreement between a private landowner and a qualified organization, such as a municipality, Land Trust organization, or conservation group. There are only three allowable purposes for a conservation easement under the *Alberta Land Stewardship Act*, and these include the protection, conservation and enhancement of 1) the environment, 2) natural scenic or aesthetic values, or 3) agricultural land or land for agricultural purposes. Under a conservation easement, the landowner retains title to the land, but certain land use rights are extinguished in the interest of conserving and protecting the land. The land use restrictions that apply to the property are negotiated and agreed to at the outset (for example, a restriction on subdivision), and the conservation easement (and the land use restrictions) are registered on title and are transferred to a new land owner if the land is sold. Conservation easements can be negotiated by a private land owner at any time, but the easement must be held by a qualified organization.

Conservation Directive:

A conservation directive allows the Alberta Government to identify private lands within a regional plan for the purpose of protection, conservation, or enhancement of environmental, natural scenic, or aesthetic values. Ownership of the lands is retained by the land owner, and the directive describes the precise nature and intended purpose for the protection, conservation, or enhancement of the lands. A conservation directive must be initiated by the provincial government, and to date, this tool remains largely untested (Environmental Law Centre 2015).

Conservation Offset:

A conservation offset is a tool that allows industry to offset the adverse environmental effects of their activities and development by supporting conservation activities and/or efforts on other lands. In order for conservation offsets to be effective, there must first be guidelines and rules for where offsets can be applied, and provisions for accountability, including monitoring and compliance. While conservation offsets are available as a tool for the conservation of natural areas in the Lower Pembina watershed, work would first have to be done to create a proper framework to create eligibility rules, pricing and bidding rules for selling and buying offsets, and rules for combining buyers and sellers.

Transfer of Development Credits (TDCs):

Transfer of development credits is a tool that creates and incentive to redirect development away from specific landscapes in order to conserve areas for agricultural or environmental purposes. This tool allows land development and conservation to occur at the same time, while also allowing owners of the developed and undeveloped lands to share in the financial benefits of the development activity. A TDC program can be used to designate lands as a conservation area for one or more of the following purposes:

- The protection, conservation and enhancement of the environment;
- The protection, conservation and enhancement of natural scenic or aesthetic values;
- The protection, conservation and enhancement of agricultural land or land for agricultural purposes;
- Providing for all or any of the following uses of the land that are consistent with the following purposes: recreational use, open space use, environmental education use, or use for research and scientific studies of natural ecosystems; and
- Designation as a Provincial Historic Resource or a Municipal Historic Resource under the *Historical Resources Act*.

Before TDCs can be used by municipalities as a conservation tool, they must be established through a regional plan, or they must be approved by the Provincial Government.

Outside of the conservation tools that have been created through the *Alberta Land Stewardship Act*, there are other mechanisms through which municipalities may acquire lands for conservation, most of which rely on voluntary conservation action taken by private land owners. These tools may be utilized at any time during the municipal planning and development process, and include:

Land Purchase:

Municipalities can purchase land from a private land owner at any time for the purpose of conservation. For example, the City of Edmonton established a Natural Areas Reserve Fund in 1999, with the purpose of using these funds to purchase and protect natural areas. While land purchase for conservation is an option that is available, many municipalities do not have the financial resources available to purchase lands within their municipal boundaries, as the market value for these lands can be very high.

Land Swap:

In some cases, a land developer may be willing to “swap” or exchange natural areas for other developable lands that are owned by the municipality. In this case, the municipality and the developer would enter into an agreement to exchange the lands, such that the natural areas can be conserved.

Land Donation:

Land donation involves the transfer of ownership from a private land owner to the municipality, or to a conservation organization or land trust, who would hold the land for conservation in perpetuity. Lands that are donated to a conservation organization or land trust are eligible for the federal government’s Ecological Gifts program which provides donors with significant tax benefits.

The final set of conservation tools are directly available to municipalities, and are the most common and frequently used tools for acquiring riparian areas as part of land development and planning. However, these tools are enabled through the *Municipal Government Act*, which only gives municipalities the authority to use these tools at the time of subdivision. Thus, municipalities can only utilize these tools through formal land development and planning processes.

Environmental Reserve (ER):

Environmental Reserves are defined in the Act as waterbodies, watercourses, lands that are unstable or subject to flooding, and lands “not less than 6 metres in width abutting the bed and shore” of a waterbody or watercourse. While the Act allows municipalities to take a *minimum* of a 6 metre setback on Environmental Reserve lands (with no stated maximum), the conditions under which this taking is permitted is limited to cases where the setback is required to prevent pollution or provide public access to the bed and shore of the waterbody or watercourse. In addition, Section 640(4)(l) of the Act allows municipalities to establish development setbacks on lands subject to flooding, low lying or marshy areas, or within a specified distance to the bed and shore of any waterbody.

Environmental Reserve Easement:

In instances where the municipality and the landowner agree, Environmental Reserve lands may be designated as an Environmental Reserve Easement. An ER Easement serves the same purpose as ER, but differs in that the title of the reserve lands remains with the land owner; however, ER easements are registered on title by caveat in favour of the municipality.

Conservation Reserve:

Under Section 664.2(1), municipalities may designate an area as a Conservation Reserve if the area contains significant environmental features that are not required to be provided as Environmental Reserve. Under the Act, the purpose of taking the Conservation Reserve is to protect and conserve the significant environmental features in a manner that is consistent with other statutory planning documents. In designating a Conservation Reserve, the municipality must compensate the landowner in an amount that is equal to the market value at the time of the subdivision approval application.

7.3. Public Engagement

Public engagement is a critical component to the successful conservation and management of riparian areas. Without the support of the public, successful implementation of restoration and management programs are not possible. Further, many of the acquisition tools outlined above rely on voluntary participation by the public (e.g., land donations and conservation easement). Thus, ensuring that the public are aware of the various voluntary programs that exist for riparian habitat conservation, as well as formulating active partnerships that can capitalize on the public’s willingness to participate in such programs, is critical to the conservation and restoration of riparian habitats. Public engagement can take several forms, including the following:

Education, Extension and Outreach:

Increasing public awareness and appreciation for natural areas is a critical component to effective conservation and management. Thus, creating educational opportunities and programs, as well as supporting local conservation and stewardship groups is critical to achieving desired riparian conservation and restoration objectives in the Lower Pembina watershed.

Partnerships:

Given the limited number of tools available to municipalities for the acquisition of riparian areas on private lands, engaging in strategic partnerships to promote voluntary land conservation and management activities is essential. Central to this is developing partnerships with land trusts and conservation organizations, developing strong inter-municipal policies, and partnerships with the provincial government to promote and enhance collaboration and improve conservation outcomes

All of the tools outlined in this section are currently available to stakeholders in the Lower Pembina watershed for the purpose of conserving and managing riparian habitats; however, in order to focus management action in the watershed, it is essential that the AWC and its partners first define objectives and targets for the conservation, restoration, and management of riparian habitats. Once these objectives and targets have been outlined, specific action and the relevant tools associated with those actions can be identified. In some cases, there may be existing tools in place to achieve the desired management outcomes. In other cases, there may be gaps in the available tools, and new policies, partnerships, or programs may need to be developed in order to achieve the desired management objectives.

8.0 Conclusion

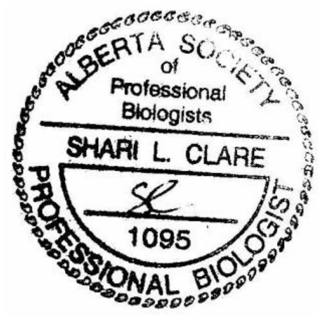
The overall goal of this project was to quantify and characterize the intactness of riparian management areas in the Lower Pembina watershed, and to further assess pressure on riparian system function by evaluating land use and land cover within local catchments immediately adjacent to the waterbodies included in this study. The results of this work provide the Athabasca Watershed Council and its stakeholders with an overview of the status of riparian areas within the watershed, and further provides a foundation of scientific evidence upon which to build a systematic and adaptive framework for riparian habitat management.

In total, approximately 949 km of shoreline was assessed in the Lower Pembina watershed as part of this study. Results indicate that 80% of the shoreline assessed is either High (61%) or Moderate (18%) Intactness, with the remaining 20% of the shoreline classified as Very Low (14%) or Low (7%) Intactness. Within the Lower Pembina watershed, the greatest length of shoreline classified as Very Low or Low Intactness was located within the Pembina River subwatershed, and primarily within the jurisdiction of Westlock County (greatest length and highest proportion).

The next step in the advancement of meaningful riparian management and conservation in the Lower Pembina watershed will be to formalize a framework for action that includes defining achievable management outcomes and measurable targets, which can then be used to inform relevant collective action by key stakeholders. These actions can then be monitored on a regular basis to provide an evaluation of outcomes that feed into an adaptive and reflexive approach to riparian management through time. Importantly, this study contributes to a larger riparian assessment initiative across central Alberta that has included a number of other Watershed Planning and Advisory Councils (North Saskatchewan Watershed Alliance, Battle River Watershed Alliance, Red Deer River Watershed Alliance, Lesser Slave Watershed Council), as well as the Government of Alberta. To date, this initiative has assessed over 9,000 km of shoreline, with more than 27,000 km currently in process and expected to be completed in 2021. Combined, these riparian assessments will significantly advance watershed planning and stewardship activities within the Athabasca watershed, and elsewhere in Alberta.

8.1. Closure

This report was written by:



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Appendix A: Intactness & Prioritization Summary Table

Table 18. Length (km) and proportion (%) of shoreline classified into each Intactness category, summarized by waterbody and municipality.

Waterbody Name	Length Assessed (km)*	Intactness Category: Very Low		Low		Moderate		High	
		km*	%	km*	%	km*	%	km*	%
Bolloque Creek									
Athabasca County	53.8	10.9	11	2.8	3	5.3	5	34.8	36
Westlock County	43	4.5	5	5.3	5	16.2	17	17	18
Bolloque Lake									
Athabasca County	8.7	0	0	0	0	0	0	8.7	69
Westlock County	3.9	0	0	0	0	0	0	3.9	31
Dapp Creek 1									
Westlock County	22.6	11.2	50	4.2	19	4.7	21	2.5	11
Dapp Creek 2									
Westlock County	8.4	0.1	1	0	0	0	0	8.3	99
Flatbush Creek									
MD of Lesser Slave River	33.6	5.1	15	2.4	7	2	6	24.1	72
French Creek									
MD of Lesser Slave River	94.2	1.7	1	2.6	2	7.7	6	82.2	61
Westlock County	40.9	5.3	4	3.2	2	3.6	3	28.8	21
Muskeg Lake									
Westlock County	11.6	0.1	1	0.1	1	0	0	11.4	98
Pembina River									
County of Barrhead	39	10.6	3	1.6	0	5	1	21.8	6
MD of Lesser Slave River	93	0.3	0	0	0	2.2	1	90.5	24
Westlock County	249	30.4	8	10	3	50.6	13	158	41
Shoal Creek									
County of Barrhead	44.3	8.4	8	5.8	5	26.8	24	3.3	3
Westlock County	65.1	20.5	19	12	11	15.2	14	17	16
Shoal Lake									
County of Barrhead	28.8	0.2	1	0	0	8.7	30	19.9	69
Wabash Creek									
Westlock County	108.7	20.9	19	14	13	23.7	22	50.3	46

*NOTE: All municipal data summaries were generated by using a spatial intersect rule in ArcGIS. Summarizing the data in this way captures the assessed shorelines that fall within the municipal boundary; however, it should be noted that there are spatial discrepancies between the municipal boundary data and the provincial hydrography data that are freely available from AltaLIS. As a result, the municipal summaries of shoreline length for intactness and priority are approximate and should be considered estimates that reflect relative differences between municipalities.

Table 19. Length (km) and proportion (%) of shoreline classified into each prioritization category, summarized by waterbody and municipality.

Waterbody Name	Length Assessed (km)*	High Restoration		Moderate Restoration		Moderate Conservation		High Conservation	
		km*	%	km*	%	km*	%	km*	%
Bolloque Creek									
Athabasca County	53.7	5.1	5	8.5	9	1.5	2	38.6	40
Westlock County	43	5.4	6	4.4	5	16.2	17	17	18
Bolloque Lake									
Athabasca County	8.7	0	0	0	0	0	0	8.7	69
Westlock County	3.9	0	0	0	0	0	0	3.9	31
Dapp Creek 1									
Westlock County	22.6	14.3	63	1.1	5	5.5	24	1.7	8
Dapp Creek 2									
Westlock County	8.4	0.1	1	0	0	3.9	46	4.4	52
Flatbush Creek									
MD of Lesser Slave River	33.6	5	15	2.5	7	2	6	24.1	72
French Creek									
MD of Lesser Slave River	94.1	2.5	2	1.8	1	12.5	9	77.3	57
Westlock County	41.1	7	5	1.6	1	3.8	3	28.7	21
Muskeg Lake									
Westlock County	11.6	0.1	1	0.1	1	0	0	11.4	98
Pembina River									
County of Barrhead	39	11.3	3	0.9	0	17.1	4	9.7	3
MD of Lesser Slave River	93	0.3	0	0	0	10.5	3	82.2	22
Westlock County	248.8	34.9	9	5.4	1	114.7	30	93.8	25
Shoal Creek									
County of Barrhead	44.2	11.3	10	2.8	3	29.5	27	0.6	1
Westlock County	65.1	27.1	25	5.8	5	27.2	25	5	5
Shoal Lake									
County of Barrhead	28.8	0.2	1	0	0	10.1	35	18.5	64
Wabash Creek									
Westlock County	108.7	32.3	30	2.4	2	66.2	61	7.8	7

Priority

*NOTE: All municipal data summaries were generated by using a spatial intersect rule in ArcGIS. Summarizing the data in this way assigns the entire length of an RMA that intersects a municipal boundary to a given municipality, even if the RMA extends beyond the municipal boundaries. Consequently, the sum of the shoreline length assessed for each intactness and prioritization category is greater than the values summarized by individual waterbody, HUC 8 and HUC 6.