Aquatic Ecosystem Health of the Peace Watershed Project

Final Report, June 2012

prepared for the

by

CharettePellPoscente Environmental Corp

in partnership with

Hutchinson Environmental Sciences Ltd

Acknowledgements

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1.0 EXECUTIVE SUMMARY

The Mighty Peace Watershed Alliance (MPWA), a watershed planning advisory council created in 2011 under Alberta's Water for Life Strategy, is seeking to develop a thorough understanding of information available on all aspects of water in the Peace River watershed. As part of this effort, the MPWA retained the team of CharettePellPoscente Environmental Corp. and Hutchinson Environmental Sciences Ltd. to provide an integrated overview of the current state of knowledge with respect to Aquatic Ecosystem Health (AEH) in the Alberta portion of the watershed. The objective of this report is to present issues affecting aquatic health, to identify key information gaps and to suggest strategies to resolve these, in preparation of the State of the Watershed report.

The Peace River basin is the largest and one of the northernmost watersheds in Alberta, covering approximately one-third of Alberta. Predominant natural regions in this basin are dry and central mixedwoods, but also include Rocky Mountains, foothills, boreal, parkland and parts of the Peace-Athabasca Delta. The largest rivers in the basin are the Peace River mainstem and its tributary the Smoky River. A large number of smaller rivers and streams drain the watershed and the landscape is dotted with hundreds of lakes and wetlands. For the purpose of this review, rivers and lakes in the six sub-basins were assessed individually in order to accommodate regional differences in natural features, human activities and therefore major stressors, and the state of knowledge of aquatic ecosystems.

The main anthropogenic activities that affect AEH in the Peace River basin are urban development, agriculture, forestry, mining, oil and gas operations, hydroelectric development and fisheries, along with linear features, such as roads and cutlines, that result from a number of these activities. Most of the human population is concentrated in the Smoky/Wapiti and Upper and Central Peace River sub-basins, where naturally rich soils support an active agriculture. This leads to cumulative pressures on surface waters, such as excess nutrient loading, pathogens, changes in hydrology and instream barriers, resulting in eutrophication, oxygen deficits and reduced or extirpated fish populations.

There is coal mining in the north-eastern slopes, locally affecting fish health. Forestry and oil and gas operations in the vast forests across the basin represent another land disturbance. Hydroelectric development in British Columbia has changed flow patterns in the mainstem of the Peace River, altering sediment patterns and channel morphology and thereby aquatic habitat. A combination of domestic, recreational and commercial fisheries put pressure on fish populations, which have been particularly affected in lakes.

The status of AEH and associated data quality can be summarized as follows:

1) The AEH of the Peace River mainstem is relatively well known, with generally good water quality, healthy fish populations and benthic biota that are mainly controlled by habitat characteristics. The main human impact is that of flow regulation from the upstream Bennett Dam that has changed flow and sedimentation patterns.
2) The northern part of the Wapiti/Smoky River system has the highest concentration and diversity of human impact from land clearance, municipal and industrial effluent discharges, agriculture, and water withdrawals. Impacts of these activities on rivers and streams have been well defined as eutrophication (increased algae growth due to nutrient enrichment) in small and large rivers, while small streams suffered, in addition, low oxygen levels, decreased fish habitat quality and resulting declines or extirpations of local fish populations. While the effects of point discharges in the lower Wapiti River are well studied and major upgrades are being implemented to improve effluent quality, diffuse sources of nutrients and other pollutants to smaller agricultural streams and their

cumulative downstream effects are not well quantified and it is uncertain what efforts have been made to mitigate agricultural non-point-source effects.

3) Medium-to small sized streams and tributaries of the Peace River are relatively poorly known in terms of biotic communities, with limited information on water quality and fish populations. It is these tributaries, however, that are most exposed and likely susceptible to the cumulative effects of land use and population patterns, in particular in the settled and cleared zone ("White Zone") in the Smoky/Wapiti, Upper and Central Peace sub-basins, and to some extent the western Wabasca sub-basin.
4) Lakes in the Peace River Basin are also enriched in nutrient concentrations, leading to algae blooms and low oxygen concentrations that in turn result in fish kills. Many of these lakes are naturally nutrient rich and it is unknown to what extent human activities in the watersheds have contributed to the high lake nutrient status. Fish harvest from commercial, domestic and recreational fisheries also have had significant detrimental effects on lake fish populations.

We identified eleven high-priority data and knowledge gaps for the assessment and management of AEH in the Peace River Basin. Five data gaps address aquatic ecosystem structure and function, e.g. tributary water quality, fish populations, fish contaminants, wetland coverage and health and instream flow needs. The remaining six data gaps address stressor-effect relationships, such as impacts of agricultural non-point sources on AEH, cumulative effect of linear features on stream water quality and fish habitat and risk from agricultural practices to drinking water resources, as well as the quantification of stressors, such as calculating the non-point nutrient loads to rivers, the relative importance of water allocations on flows and fishing pressure.

Strategies to address these data gaps include literature reviews, data collection from existing sources, monitoring programs, spatial data analysis including GIS and modeling approaches. Conducting any of the recommended studies and combining them with the results of other ongoing projects will further increase the knowledge base required to prepare a State of the watershed Report. The MPWA may, however, choose to prepare a State of the Basin Report at any time, with the recognition that collecting information on the state of the watershed is an ongoing effort. Collecting more knowledge and developing and implementing management strategies will always be parallel activities of the MPWA that affect each other and together with periodic reporting on progress, these activities will serve the goal of protecting a sustainable, healthy watershed.

LIST OF ABBREVIATIONS

AB	Alberta
AEH	Aquatic Ecosystem Health
AESA	Aquatic Environmentally Significant Area
AEW	Alberta Environment and Water
Al	Aluminum
ARWQI	Alberta River Water Quality Index
ASRD	Alberta Sustainable Resource Development
ASWQG	Alberta Surface Water Quality Guideline
BC	British Columbia
BOD	Biological Oxygen Demand
CCME	Canadian Council of Ministers of the Environment
DMI	Daishowa-Marubeni International Ltd. (Pulp Mill near Peace River)
DO	Dissolved Oxygen
EEM	Environmental Effects Monitoring
EPT	Ephemoptera, Plecoptera, Trichoptera *(a group of benthic invertebrates indicative of good water quality)*
FN	First Nation
FWMC	Flow-Weighted Mean Concentration
HWY	Highway
LTRN	Long-Term River Monitoring Network
MPWA	Mighty Peace Watershed Alliance
NPS	Non-Point Source
NRBS	Northern River Basin Study
NREI	Northern River Ecosystem Initiative
PCB	Polychlorinated Biphenyls
PR	Peace River
SOW	State Of the Watershed
SQG	Sediment Quality Guideline
SR	Slave River
TDP	Total Dissolved Phosphorus
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
WPAC	Watershed Planning and Advisory Council
WQG	Water Quality Guideline
WWTP	Wastewater Treatment Plant

INTRODUCTION

PROJECT BACKGROUND

The Mighty Peace Watershed Alliance (MPWA) is one of several Watershed Planning Advisory Councils (WPACs) created under Alberta's Water for Life strategy. The MPWA is a multi-stakeholder group whose goal is to work together to ensure safe, secure drinking water, healthy aquatic ecosystems and reliable quality water supplies for a sustainable economy. In order to guide their work towards these goals, the MPWA currently seeks to develop a thorough understanding of the types, amount, quality and sources of information available on all relevant components of the Peace River watershed. This information will be required to complete State Of the Watershed (SOW) reports under the Water For Life strategy. A critical component of this effort is to summarize, synthesize and interpret information related to AEH in the Peace River watershed.

Healthy ecosystems are the foundation of sustainable watersheds that support social, environmental and economic objectives. They could be called the ultimate indicator of watershed health as they integrate water quantity and quality as well as biological communities and are susceptible to stressors that affect any of these components. There is an appreciable amount of information from a variety of sources on different components of AEH in the Peace River Basin and their response to different human activities in the watershed, but this information has not been synthesized on a basin scale. The goal of this project therefore, is to develop an integrated overview of the status of AEH in the Peace River watershed.

AQUATIC ECOSYSTEM HEALTH - A DEFINITION

The definition of AEH has varied among authors and has been subject to debate (Rapport et al 1998). For the purpose of this report, we adopted the definition that was developed by a working group of the Alberta Water Council (2008):

> ***"A healthy aquatic ecosystem is an aquatic environment that sustains its ecological structure, processes, functions, and resilience within its range of natural variability. "***

This definition contains a few key words that must be explained to allow a full understanding of the AEH definition (Alberta Water Council 2008):

1) ***Ecological Structure*** is the form and organization of the parts that constitute an ecosystem. These parts are typically characterized as physical, chemical and biological, while their organization is described by attributes, such as species composition, abundance, food webs and biodiversity. In other words, structure is the "inventory" of which parts are there and how they are organized.

2) ***Ecological Processes*** are the activities and sequences of observable changes in the structural elements of an ecosystem. In other words, the processes are ways in which ecosystem parts move or are transformed. Examples of aquatic ecological processes include transporting sediment, capturing nutrients, and absorbing floodwater.

3) ***Ecological Functions*** are the effects or results of ecological processes on the physical and chemical conditions of their environment. Aquatic ecosystem functions include sediment storage, water filtration, carbon storage, and groundwater recharge, among many others.

4) ***Resilience*** is the ability of an ecosystem to recover from a natural or anthropogenic (human) disturbance. Resilience is highest in ecosystems of high biodiversity and when the degree of disturbance and the rate of change are low. In other words, if the structure of an ecosystem is impaired, it becomes less capable of handling stressors.

5) ***Natural Variability*** acknowledges that "healthy" is a range of conditions in all four previously discussed components, due to natural changes in time and space. These can include seasonal or long-term climate variations or spatial differences due to differing local factors, such as geology.

The first three parts of AEH are closely related: processes describe the interaction between the structural parts of an ecosystem that result in ecological functions. Resilient ecosystems are able to return to or maintain their structure, processes and functions within their natural range of variability after or during the impact of a disturbance.

For the purpose of State-of reporting on AEH, the basic and most important requirement is to describe the structure of aquatic ecosystems, as processes, functions and resilience directly depend on it. Once the structure is well known, processes, functions and resilience can be inferred from general scientific knowledge of similar ecosystems or, if site-specific processes or functions are suspected, can be investigated in a targeted study. The collection of information in this report and the discussion of information and data gaps therefore focuses mainly on ecosystem structure. We do, however, discuss cases where damaged ecosystem structure or certain human disturbance has the potential to impair ecological processes, functions and resilience.

Objectives and Scope

The objective of this report is to provide the MPWA with a thorough overview of the current state of knowledge with respect to AEH in the Peace watershed. It describes present and anticipated issues affecting aquatic health, identifies key information gaps and suggests strategies to resolve these.

The geographical scope of this project is the Peace River watershed within the boundaries of the Province of Alberta. However, any upstream activities located in British Columbia that have a potential or proven significant impact on aquatic habitat in the Alberta portion of the watershed, are being considered in this assessment.

As an exhaustive literature search and synthesis was not possible within the scope of this assignment, the information and data gathering focused on the most relevant and up-to date information as well as on predictions for the near future. We present the gathered information and provide interpretation where possible, but the quantification of risk level, status of ecosystem components and impacts were beyond the scope of this study.

Methodology

The main method to acquire the information summarized in this report was a review of available literature. Documents and spatial data for mapping purposes were solicited from members of the MPWA and their contacts, obtained from online sources or from collections held by the authoring consultants. Prioritization and structuring of the review was developed in collaboration with the Technical Committee of the MPWA responsible for this project. Most of the collected information is presented on the subwatershed scale, in order to more readily identify spatial patterns in AEH, as well as any major issues and data gaps. A large amount of information was extracted from the North/South Consultants (2007) report, which provided a recent and comprehensive overview of water quality, sediment quality and non-fish biota in the Peace River basin.

For the purpose of reporting on fish populations in the Peace River basin, four native fish species from the Peace watershed were selected for more detailed descriptions of their distribution within the watershed, and their general stock status: Arctic Grayling, Bull Trout, Walleye, and Goldeye (Johnson and Wilcox 2012). These species were chosen because they occupy different habitats (cold versus cool water, lotic versus lentic environments, high to low elevation grades, and large to small water bodies) throughout the Peace River watershed and because they represent general stock status' that ranged from 'Sensitive' to 'Secure'. Selection of these focal species ensured that the entire Peace watershed was represented, and also reflected their social importance; these species provide most of the many important recreational fisheries in the watershed. Because focal species are found at or near the top of aquatic trophic levels in this watershed, population changes can have dramatic effects on the remainder of the aquatic ecosystem. Stock status for the focal species first required determination of the presence and distribution of fish in the Peace River and Slave River watersheds using capture information reported in Fish and Wildlife Management Information System (FWMIS, Government of Alberta 2012). This was then mapped using ArcGIS (Esri copyright 1995 – 2012).

In order to report species stock status at a watershed level (the Peace Watershed in this case) or at a provincial scale (such as a species management plan), a standardized, and thus consistent, process of assessment, called the Fish Sustainability Index (FSI) has been developed and is now being used by the Alberta Fisheries Management Branch. For the purposes of this report, Water Survey of Canada tertiary watershed boundaries have been used to report FSI scores, which represent one level higher detail than the MPWA sub-basins. When estimating the FSI scores, road density was used as a surrogate for degree of anthropogenic impact on fish, as it is associated with nearly all human activities whether for settlement, industrial or recreational purposes (Johnson and Wilcox 2012).

2.0 THE PEACE RIVER BASIN

2.1 Watershed

The Peace River Basin spans British Columbia and Alberta, and is the largest watershed in Alberta. The total drainage area covers 326,000 km^2, with 40% of this area occurring in British Columbia (BC) (Hatfield Consultants 2009). The Peace River begins as streams in the Rocky Mountains of British Columbia. The Finlay River (elevation 1,140 m) and Parsnip River (elevation 5,630 m) discharge into Williston Lake (elevation 748 m), the largest freshwater body in BC, which feeds the WAC Bennett Dam. From the Williston Lake reservoir, the Peace River travels through the boreal plains ecozone, cutting briefly into the Boreal Northlands Ecoregion in Wood Buffalo National Park and joining with Lake Athabasca outflows to form the Slave River Basin approximately 30 km northwest of Lake Athabasca (Mitchell and Prepas 1990).

The natural regions present in the watershed are the Alpine and Subalpine regions, Upper and Lower Boreal Highlands, Boreal subarctic, Peace River Parkland, Foothills Parkland, Lower Foothills, Northern Mixedwood, Dry Mixedwood, Central Mixedwood, and Althabasca Plain (Figure 1).

Figure 1. Natural Regions and Subregions in the Peace River Basin

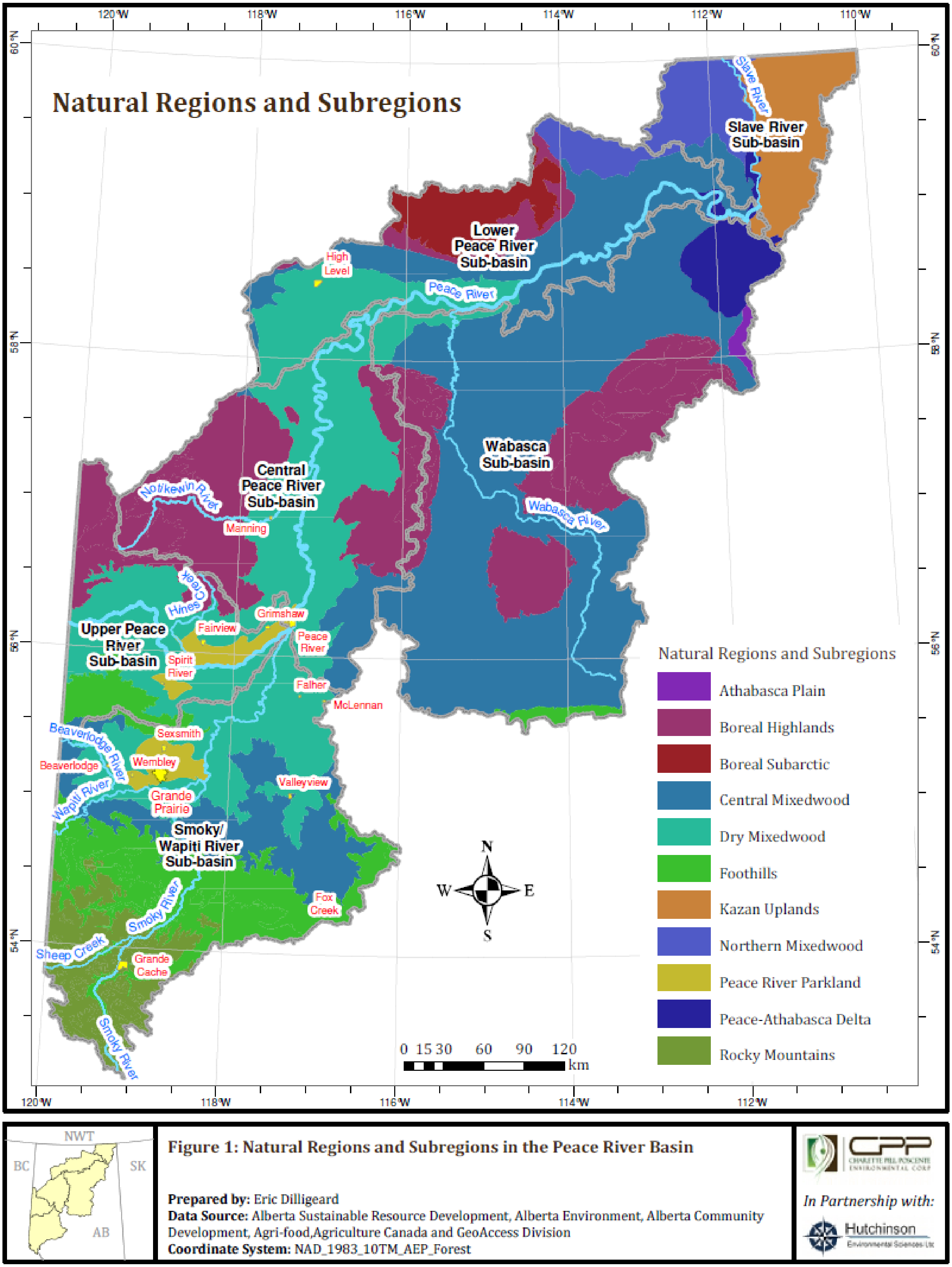

Figure 1: Natural Regions and Subregions in the Peace River Basin

Prepared by: Eric Dilligeard
Data Source: Alberta Sustainable Resource Development, Alberta Environment, Alberta Community Development, Agri-food,Agriculture Canada and GeoAccess Division
Coordinate System: NAD_1983_10TM_AEP_Forest

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2.2 Rivers

Most of the flow (76%) of the Peace River originates in British Columbia (Alberta Environment and Environment Canada 2004). The mean annual discharge of the Peace River at Peace Point, in Wood Buffalo National Park, is 68.2 10^9 m^3 (Alberta Environment 2011). The Smoky River, with headwaters in the Rocky Mountains near Mount Robson, is a major tributary of the Peace River, contributing 11 x 10^9 m^3 annually. It drains the Wapiti River, Little Smoky River, and a number of smaller rivers. The headwaters of the Wapiti also originate in the Rocky Mountains, and it has a mean annual flow of 3.1 x 10^6 m^3 when it joins the Smoky River (Alberta Environment and Environment Canada 2004). The Wabasca River is another major tributary and other smaller major tributaries within Alberta include the Whitemud, Cadotte, Notikewin, and Mikkwa rivers.

2.3 Lakes

The Peace River basin is dotted with hundreds of lakes, ponds, wetlands and muskegs. The lakes in these northern basins are numerous and varied in character. Most of them are nutrient rich and support a lush growth of rooted plants and algae (Mitchell and Prepas 1990).

Table 1. Lakes discussed in this report and their Peace Basin Subwatershed location

Lake Name	Surface Area (km^2)	Subwatershed
Figure Eight Lake	0.37	Central Peace
Iosegun Lake	13	Smoky River
Moonshine Lake	0.28	Upper Peace
Peerless Lake	82.6	Wabasca
Utikuma Lake	288	Wabasca
Musreau Lake	5.5	Smoky River
Saskatoon Lake	7.5	Smoky River
Smoke Lake	9.6	Smoky River
Sturgeon Lake	49.1	Smoky River
North Wabasca Lake	99.4	Wabasca
South Wabasca Lake	61.6	Wabasca
Cardinal Lake	50	Central Peace
Lake Claire	1436	Wabasca
Note: The selection of lakes was based mainly upon availability of data due to their inclusion in the "Atlas of Alberta Lakes" and monitoring efforts of the Alberta Government. It does not represent a judgement on the AEH status or level of risk to which these lakes are exposed. Data source for Lake areas: Mitchell and Prepas (1990)		

2.4 Wetlands

Most of Alberta's wetlands can be found in the northern third of the province, which includes the Peace River basin (Alberta Environment, Ducks Unlimited, Undated). These wetlands are mostly bogs and fens, which accumulate peat over time. Wetlands play an important buffering role in the hydrology of a watershed, as they store water when water is in excess and are a source of water when water is scarce. They also provide food and habitat for a variety of important and rare species, such as the trumpeter swan, whooping crane, moose, woodland caribou and piping plover. We have excluded wetlands from our assessment due to very limited data. For the purpose of SOW reporting, however, it will be critical to prepare an inventory of the presence, size and status of wetlands in the Peace River Basin.

About 35% of the entire area of the Peace and Slave River Basins has been identified as Aquatic Environmentally Significant Areas (AESAs) based on criteria relating to aquatic species, habitat, peatlands, biological connectivity and features supporting water quality and quantity (Fiera Biological Consulting 2010). The watershed ranks amongst the basins with the highest percentage of AESAs in Alberta, mostly due to large intact areas in remote locations

2.5 Climate

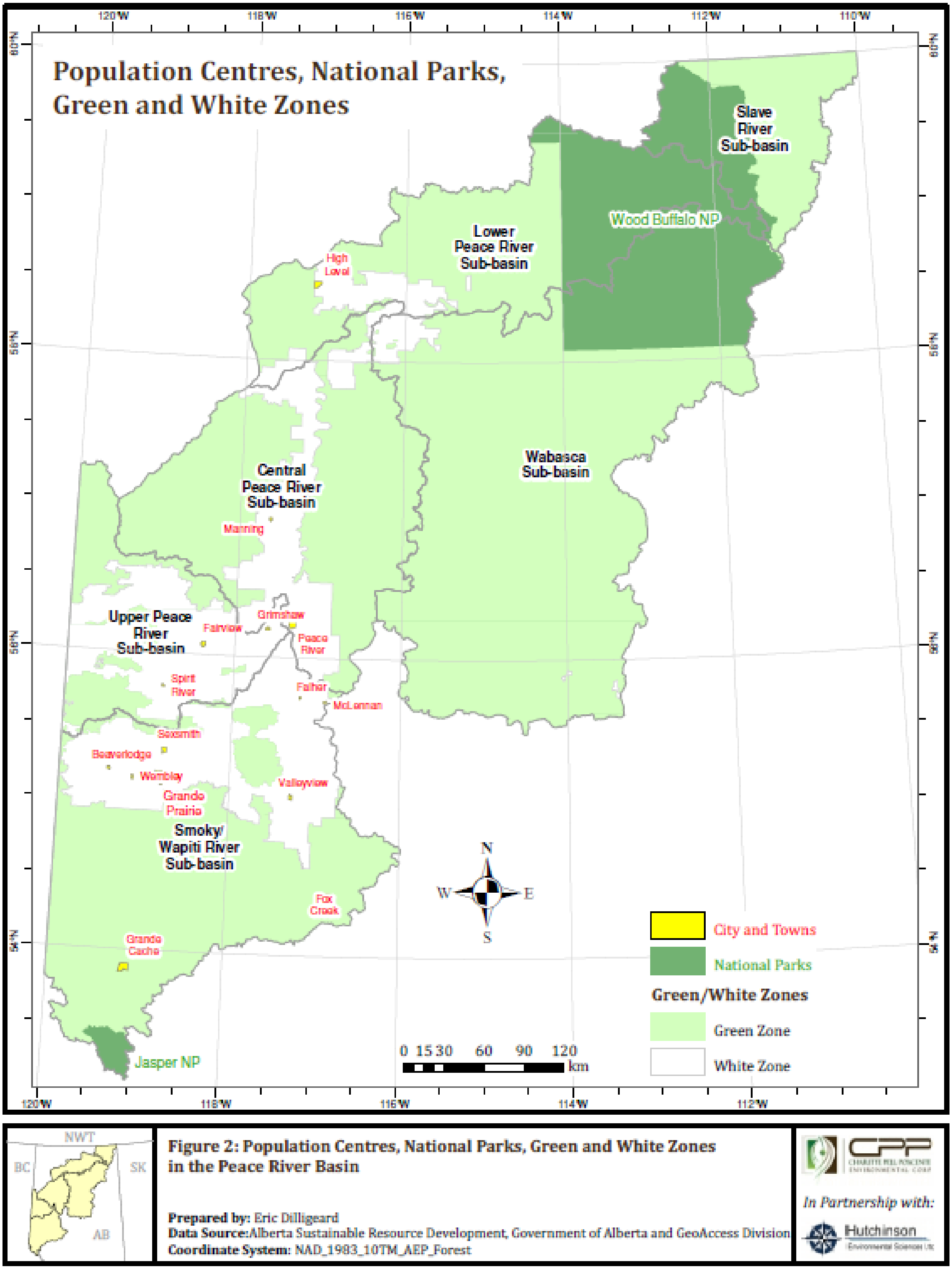
The climate in the Peace watershed is predominantly subarctic with cool short summers, but a pocket of humid continental climate with longer summers stretches from Fort St. John in BC to Peace River on the east and Grande Prairie in the south (NRC 2012). The natural vegetation is boreal mixed-wood forest, predominately trembling aspen, and white and black spruce.

2.6 Land Use and Population

Major land use activities in the watershed include forestry, agriculture, oil and gas exploration and extraction, coal mining (eastern slopes of the Rocky Mountains) and urban development. Traditional land use activities by Aboriginal communities include fishing, trapping, hunting and gathering. Detailed descriptions of land use activities with potentially significant impacts on aquatic ecosystems are provided in section 3.0 below. The settled and cleared zone is often referred to as the “White Zone” while the forested areas, which represent the major land cover type, are referred to as the “Green Zone” (Figure 2).

The human population of the basin is concentrated in the farming areas. The region from the town of Peace River south into the Smoky River sub-basin is the most populated portion of the Peace River Basin. Fort St. John (BC, pop. 22,000), Dawson Creek (BC, pop. 11,529), and Grande Prairie (AB, pop. 55,227) are the major cities on the Peace River and its tributaries. Other towns in the Alberta part of the drainage basin include Spirit River, Grande Cache, Beaverlodge, Sexsmith, Fairview, Grimshaw, Valleyview, Fox Creek, Peace River, Manning, Paddle Prairie, High Level, and Fort Vermillion. There are a number of Aboriginal communities in the Peace River Basin, some of which include Paddle Prairie Métis settlement, Little Red River Cree First Nation (FN) (Lower Peace subwatershed), Sturgeon Lake FN, Tallcree FN (Fort Vermillion Area), Woodland Cree FN (east of Peace River), Whitefish FN (near Utikuma Lake), Bigstone Cree FN (Wabasca), Beaver FN (NW of Fort Vermillion), and the Athabasca Chipewyan FN in the Slave River subwatershed (Aboriginal Canada Portal 2012).

Figure 2. Population centres and Green and White Zones in the Peace River Basin.



3.0 STRESSORS ON AQUATIC ECOSYSTEM HEALTH

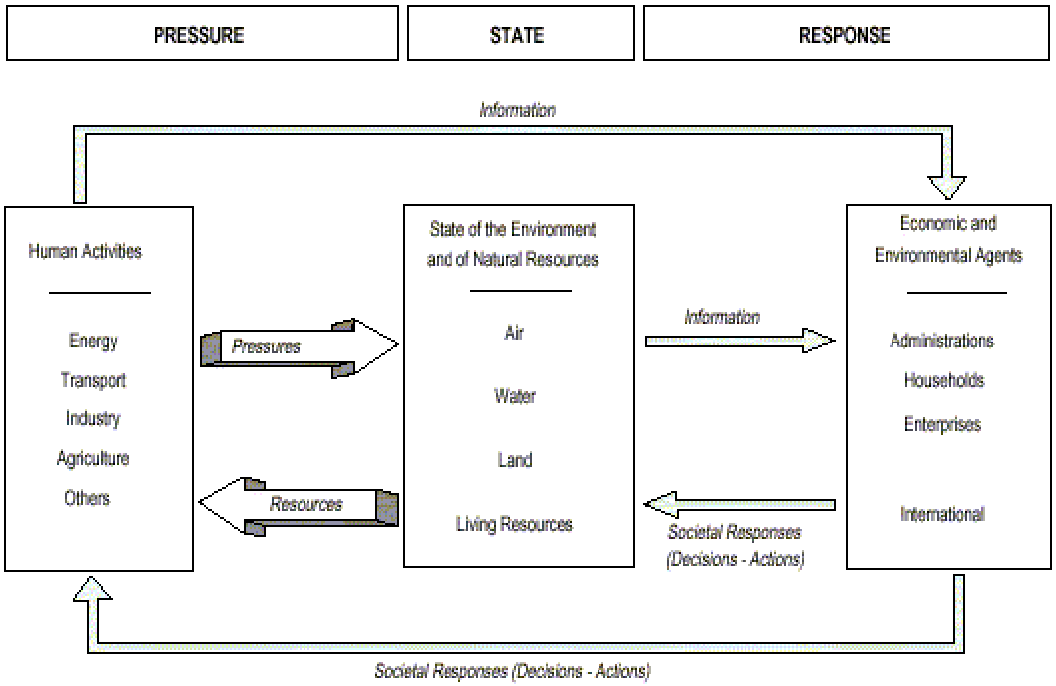
OVERVIEW

In order to fully understand the status of AEH in a watershed and to develop strategies to manage and protect it, knowledge of all factors that may potentially threaten AEH (e.g., stressors) is vital. Such stressors usually result from human activity in the watershed, but can also have global causes, such as climate change. In this section we identify which stressors are relevant in the Peace River watershed, where and to what extent they occur and how they affect AEH. Where available, we discuss information on the anticipated future impact of each stressor as a result of growth or expansion of human influence. Specifics of stressors at the sub-basin level will be discussed in section 4.0

The types of effects on aquatic ecosystems are varied, ranging from point-source (discharge from industrial and municipal effluent pipes) and non-point source pollution (diffuse pollution from larger areas), to habitat effects, and alteration of the hydrological cycle. The stressors or human activities discussed below result in at least one of these effects. In most cases, several stressors act on a particular water body or reach in the watershed, resulting in the expression of cumulative effects, to which we dedicated a separate section in this report chapter (section 3.12).

An illustration of a conceptual model of the interaction of stressors (also called pressures) with the status of an ecosystem and the resulting societal response is displayed in Figure 3. This model demonstrates that human activities impact ecosystems by putting pressures on them, for example in the form of pollution or habitat deterioration, as well as resource extraction, such as fishing or water withdrawals. Using the information on known pressures and the state of the environment, the society can then respond to take action directly on the state of the environment to reverse negative effects, or on the human activities that apply pressures on the ecosystem. Examples of such actions are habitat restoration efforts, discharge limits for wastewater treatment plants set by provincial government agencies, and Best Management Practices (BMP) in agricultural and urban areas to minimize non-point source pollution. The purpose of this section of the report is to describe human activities that put pressure on aquatic ecosystems and thereby potentially impair the state of AEH.

Figure 3. The Pressure-State-Response model as a concept to describe the interaction of human activities and AEH.



3.1 Linear Features

Linear features impact aquatic ecosystems in various ways during construction and once installed. The main effect of land clearing and construction activities is erosion and discharge of sediments to surface water. Crossings of small upstream water courses, including fords constructed in agricultural areas, lead to fish habitat fragmentation, destruction and alteration. Habitat fragmentation is the blockage of fish movement by barriers, such as culverts or weirs. Habitat destruction is the removal of stream sections used by fish, such as the loss of a certain stream section due to construction of a crossing. Alteration is a modification of stream habitat, for example due to increased sedimentation or reduced riparian vegetation leading to higher temperatures.

The effects of stream crossings on stream fish communities in northern boreal systems are not well understood (Tchir et al 2004), but effects are well established elsewhere and include habitat fragmentation and increased sediment input. Cutlines cleared for seismic surveys conducted by the oil and gas industry lead to vegetation removal on an extensive network of line cuts, which provide access for recreational vehicles (see section 3.5). The major effects of cutlines are on terrestrial ecosystems, but they are an indicator of accessibility and density of oil and gas operations.

Given the large size of the watershed and the need to interconnect population centers, agricultural areas, multiple resource extraction operations (forestry, oil and gas, coal mining) as well as remote recreational areas, the number and length of linear features such as seasonal and permanent roads, electric transmission lines, cutlines and pipelines is proportionally significant in certain areas of the Peace River watershed (Figures 4, 5 and 6). Road density is most concentrated in the Wapiti sub-basin, where it is high enough to potentially impair biological integrity of fish communities, based on the Index of Biological Integrity (Stevens and Council 2009, see section 4.1.1.4). Road densities in the reminder of the Basin are low and therefore represent a minor risk to biological integrity, based on this index. Note that line widths on Figure 4 are not to scale and exaggerated to make them visible on the map.

Cutline density is highest in the central Peace Basin and the Little Smoky sub-basin, with elevated cutline density in part of the Wapiti, upper Peace and Wabasca sub-basins and the lowest densities in the lower Peace and Slave sub-basins. Note that the map displays relative differences in seismic cutline density throughout the basin (Figure 6), but no data were available to assess the level of risk associated with these densities.

Figure 4. Road Network, Powerlines and Railways in the Peace River Basin.

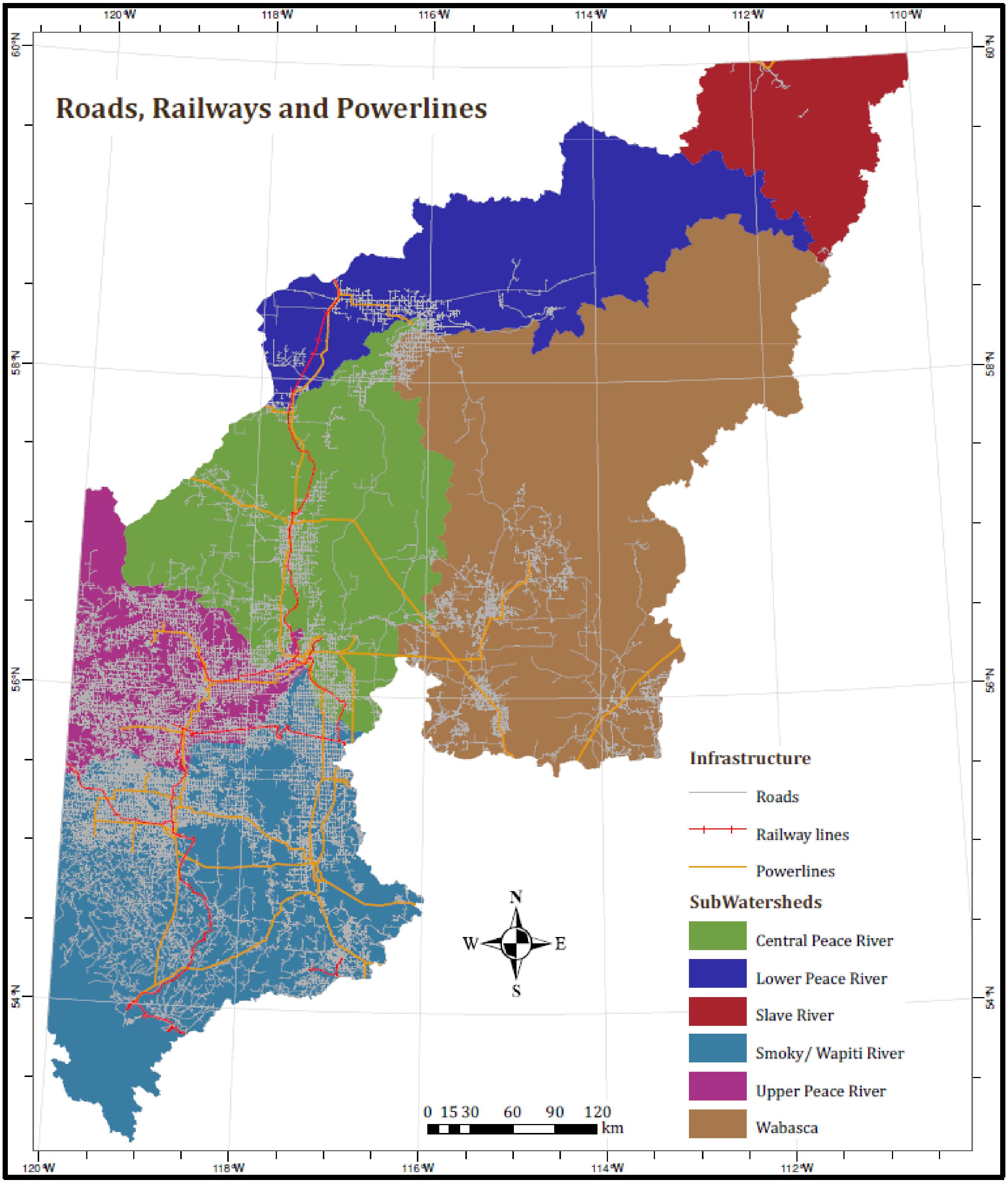


Figure 4: Roads, Railways and Powerlines in the Peace River Basin

Prepared by: Eric Dilligeard
Data Source: Alberta Sustainable Resource Development, Government of Alberta and GeoAccess Division
Coordinate System: NAD_1983_10TM_AEP_Forest

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Figure 5. Road densities (km/km^2) mapped by tertiary watershed in the Peace. (*Road density categories were adapted to conform with an index of biological integrity for fish, developed by Stevens and Council (2008).)*

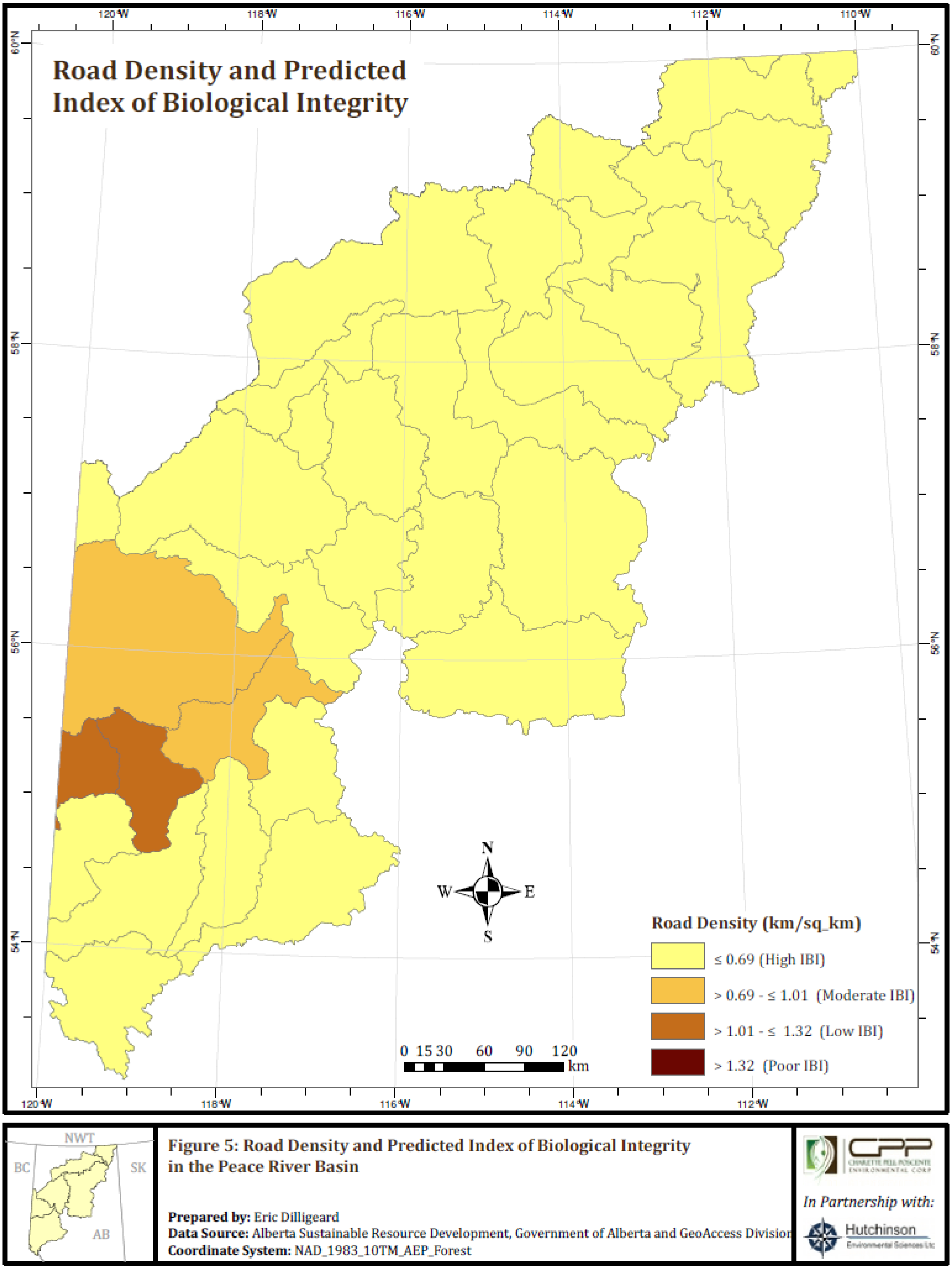
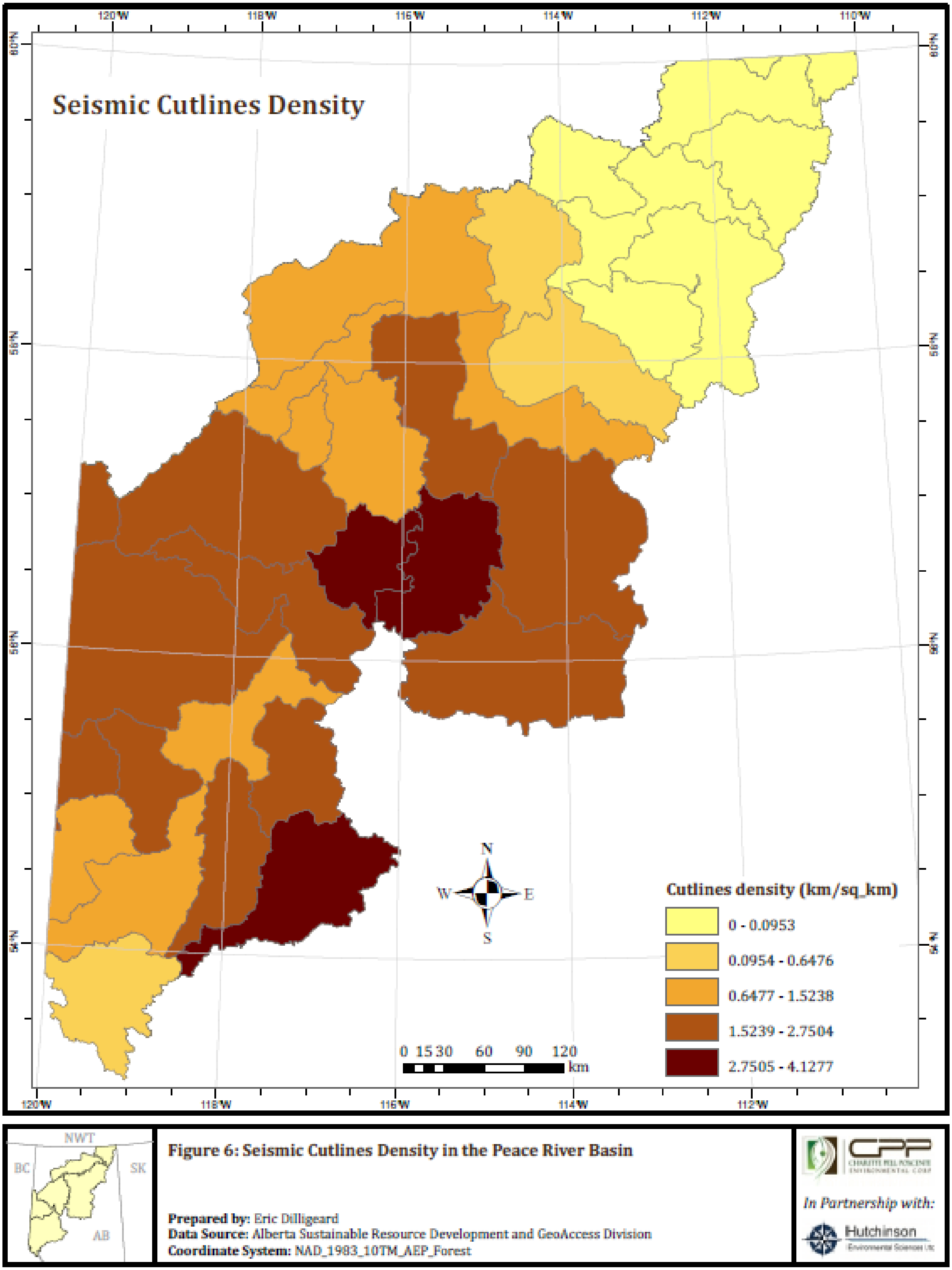


Figure 6. Seismic Cutline Density in the Peace River Basin



3.2 Agriculture

Agriculture is the major land use in the area around the town of Peace River and the city of Grande Prairie and generally is related to the White Zone, following the banks of the Peace River mainstem, extending as far north as Fort Vermillion. The Peace River country is the most northerly wheat-growing area in the world. Although the winters are cold and the growing season is short, crops grow fast during the long summer days (Mitchell and Prepas 1990). Agricultural land accounts for 23% of all land within the Peace River Basin (MRBB 2004) with much higher percentages in the sub-basins of Upper and Central Peace as well as the Smoky/Wapiti sub-basin.

Environmental risks to the aquatic environment are associated with land disturbance, animal and plant wastes, and substances applied to enhance production, including fertilizers (e.g. manure or chemical fertilizers) and pesticides. Grain, vegetable, and hay crops are the main activity, and are accompanied by heavy use of fertilizers and herbicides. Cattle operations are a source of animal waste to surface waters through overland run-off from feed lots or direct access of cattle to water courses. The latter also results in stream bank erosion and consequently enhanced sediment input to the water, thereby decreasing water quality and fish habitat quality.

Fertilizers are a significant source of nutrients (e.g. nitrogen and phosphorus) to surface waters and therefore lead to nutrient enrichment (eutrophication) in lakes and streams. Nutrient enrichment results in increased algae and plant growth, which in turn can lead to nuisance algae blooms, taste and odour in water sources and to oxygen depletion. Low oxygen can occur in rivers and streams when the plants decay at the end of the season or under ice, at night in shallow waters when plants consume, not produce oxygen, or in the deep waters of lakes, where algae that settle to the bottom waters decay and consume essential oxygen for cold-water fish species and benthic organisms.

Pesticides can be toxic to aquatic life, leading to direct mortality in invertebrates and fish, if they accumulate sufficiently or are present in high enough concentrations in surface runoff. Suspended sediments reach surface waters due to agricultural soil disturbance and lead to turbid water and increased sediment deposition, which deteriorates aquatic habitat and has direct negative effects on fish. Pathogens originating from livestock operations pose a risk to drinking water resources.

Diffuse losses from agriculture have been identified as the largest non-point source (NPS) of phosphorus to water bodies in the United States (USEPA 2002). In Alberta, it is also clear that agricultural activities contribute NPS nutrient pollution to aquatic ecosystems. The primary concern about agricultural NPS pollution, from a provincial perspective, is related to the build-up of nutrients in soil when manure and other fertilizers are applied at rates faster than can be used by crops (Soil Phosphorus Limits Committee and Landwise, Inc. 2006, Olson et al. 2010a). Organic (manure) fertilizer rates are often calculated in Alberta based on nitrogen requirements of crops, and this may occasionally lead to an excess of soil phosphorus (Miller et al. 2011). As application rates of manure tend to be less in the Peace Region than in the agricultural areas further south in the province, the effect should be less frequent in this region. With ongoing intensification of agriculture, however, the effects of fertilizers may increase in the future.

Three watersheds in the Peace River Basin were part of a provincial program named The Alberta Environmentally Sustainable Agriculture program (AESA): Hines Creek (low agricultural intensity), Bear Creek (moderate agricultural intensity) and Kleskun Drain (moderate agricultural intensity). Relationships established through the AESA program can be applied to agricultural areas in the Peace River Basin. In general, as agricultural intensity increases:

- Dissolved nutrient export increases;
- Concentrations of phosphorus and nitrogen (mainly the dissolved fraction) in streams increases; Dissolved nitrogen and phosphorus fractions were positively correlated with agricultural intensity metrics (chemical and fertilizer expenses and manure production percentiles); and
- Compliance with provincial and national surface water quality guidelines for the protection of aquatic life decreases.
- Pesticide detection frequency, total pesticide concentration, and the total number of compounds detected increases significantly

Impacts to Aquatic Ecosystem Health

Given that most surface runoff in Alberta's agricultural areas occurs during spring snowmelt, phosphorus export is primarily expected in spring or during unusually pronounced summer rainstorm events. During these events, substantial amounts of phosphorus are found in runoff water. Further, as the amount of phosphorus in the upper soil profile increases, so does the concentration of phosphorus in runoff water. It is recognized that agriculture contributes to NPS pollution in the Peace River Basin, but the extent of this contribution is currently unknown. In general, current studies demonstrate that NPS pollution increases as agricultural intensity increases and that the potential for NPS pollution from agricultural land is greatest in spring.

Cattle have had unrestricted access to rivers and streams for watering and grazing in many areas of the Redwillow watershed, which has caused degradation of the riparian zone (AECOM 2009). Feedlots have been located along banks of the Beaverlodge River with little to no riparian buffer, allowing runoff carrying manure and feed debris to enter the stream directly. This and other activities, such as gravel removal, heavy equipment working in streams and destruction of riparian vegetation, affect all aspects of fish habitat, such as overwintering, food (benthic invertebrate) production as well as spawning capability, and increase silt loads in the river (AECOM 2009). It can probably be assumed that similar practices are used elsewhere in the Peace River agricultural region.

Much of the undeveloped land in the agricultural areas is found on marginal soils that may require modification such as clearing in order to support agricultural production. However, with proper agronomic practices and when economics allow, these marginal soils may be utilized, especially for grazing and forage production. If there continues to be a demand for the release of more agricultural land, the area under cultivation may expand in future. Such expansion would likely impact surface waters. Additionally, agricultural intensification, whether upon existing or newly modified lands, may occur, and could lead to increased pressure on surface waters, as nutrient and pathogen export from high and medium intensity agriculture is higher than from low-intensity agriculture (Anderson et al. 1998).

Increased water demand from agriculture for irrigation is a large concern in the drier regions of central and southern Alberta. The cumulative effect of water withdrawals for a variety of uses can have profound effects on streams in highly developed agricultural watersheds, as discussed in section 3.9. Detailed information on water use and quantity in the Peace River watershed will be available in a report produced from a parallel project conducted by the MPWA.

Another emerging issue is the input of pharmaceuticals to surface waters from livestock operations, which may cause feminization of fish. Similar to municipal effluent sources, the effects of pharmaceuticals on aquatic ecosystems have not been characterized well enough to evaluate current and future risk of these substances, but the presence of these substances has been confirmed in Alberta agricultural streams (Forrest et al 2011).

3.3 Forestry

Forests are the main natural vegetation cover in the Peace River Basin and their harvest for timber, pulp and paper and other products is a major economic sector. Ten percent of Northern Alberta workers are directly or indirectly employed by the forestry industry (Northern Alberta Development Council 2003). Canada is one of the world leaders in the export of newsprint and market pulp and the industry ranks second to domestic sewage in wastewater output to the Canadian environment (McMaster et al. 2004).

Forest harvest and wood processing have different but important effects on surface water quality and quantity.

Forest harvesting effects depend on many factors, such as the density of disturbance, slope, the presence of wetlands in the watershed, and differences in forest management practices. Forestry companies are required to maintain riparian buffer areas around permanent and intermittent watercourses and are not permitted to operate within ephemeral water bodies (Alberta Sustainable Resource Development 2008). Furthermore, logging companies have to develop and follow forest management plans that address the full range of forestry activities that can cause NPS pollution. These clearly identify areas to be harvested, locate areas of protection, plan for proper timing of forestry activities and describe management measures for road layout, design, construction, and maintenance

The impacts of forest clearing activities have been and are being well studied in northern Alberta, particularly in the Peace and Athabasca River Basins. The impacts of logging on aquatic ecosystems have been studied in parallel with wildfire in the Boreal Plain and the Peace River Basin. Catchment disturbance can affect the quality and quantity of receiving waters. Since trees take up water, their removal results in excess soil water. Soil saturation can cause greater export of water and nutrients (through both subsurface and overland flow) from the catchment after snowmelt and rainstorms. Potential hydrologic impacts from timber harvesting include reduced infiltration, increased surface runoff and increased export of major nutrients such as nitrogen, phosphorus and base cations. Mechanical compaction, increased soil saturation, reduced evapotranspiration, and changes in biotic activity in soils are some of the causes for increased water and solute flux following harvesting. Wildfire, in particular, can increase the availability of water-soluble nutrients, because fire mineralizes organic nutrients contained in vegetation. Severe fires can burn off the surface organic layer of soils, exposing the underlying mineral soil. Such an increase in soil nutrient availability can further increase nutrient export from catchments (Lamontagne et al. 2000). Nutrients can even be directly deposited into aquatic systems through smoke and ash (Spencer and Hauer 1991).

Studies show that, in general, land clearing tends to exhibit a local effect (i.e., small scale) that is less disruptive than natural disturbance (wildfire). This effect tends to be accentuated in small streams whereas large scale systems tend to be more resilient. Also, the manner in which logging practices are carried out have been shown to be extremely important in terms of how they affect aquatic systems because road construction and use pose the largest risk associated with logging. In general, in watersheds that have high logging density (e.g., greater than 50% of watershed logged has been proposed, Prepas et al. 2008), water yield and NPS pollution tends to be adversely affected. Below this value, effects can occur, but they are likely to be relatively minor. An important finding from logging-related studies that is extremely important for northern environments is that wetlands often reduce the expression of NPS pollution, acting as sinks for chemical constituents.

Log yards servicing the logging industry in Alberta can be a source of a variety of organic compounds to surface waters. Phenolic compounds, resins and fatty acids, and tannins are common in runoff water from log yards, all of which can be toxic to aquatic life. Measured levels of total organic carbon in log yard leachate can range from 20 to 2,230 mg/L. Log yards are located throughout Alberta's forested natural subregions – many within 500 m of surface water bodies (McDougall 1996).

Pulp mill effluents are point source discharges to rivers. In the Peace Basin, there are two mills: the Weyerhaeuser Grande Prairie mill discharging to the Wapiti River and the Daishowa-Marubeni International Ltd. (DMI) mill, discharging to the Peace River. Upstream within BC, the Peace River receives effluent discharges from three other pulp and paper mills. Pollutants of concern in pulp mill effluents include organic matter, suspended solids, nutrients (in particular phosphorus), dioxins and furans and other chemicals. Historically, pulp mill effluents were acutely toxic, but since the introduction of effluent limits for BOD, TSS and dioxins and furans in 1992, the quality of effluent has improved dramatically, with virtual elimination of dioxins and furans, reduction of BOD by 94% and TSS reduction of 70% (Environment Canada 2012). At present, the discharged nutrients and organic matter are the main concern associated with pulp mill effluents, as they cause eutrophication in receiving waters. Research on the identification and effect of different pulp mill effluent constituents is ongoing (McMaster et al. 2004).

3.4 Urban Development

The development of urban centers has a number of impacts on aquatic ecosystems, the most well-known and well studied being the discharge of municipal and industrial wastewater effluents (point-source pollution) and stormwater (non-point source pollution). These discharges have a direct impact on the receiving surface waters by increasing the load of suspended matter, organic matter, nutrients, bacteria and other substances, thereby potentially decreasing oxygen in the water which can be lethal to fish, increasing algae growth and deteriorating fish habitat. There are six major municipal effluent discharges in the Peace River basin that continuously discharge to surface waters (Table 2) with at least secondary treatment level. Numerous smaller wastewater systems also discharge into water bodies within the Peace River basin one to three times per year (Hatfield 2009). The location of municipal wastewater discharges to surface water in the Peace River basin are displayed in the sub-basin maps that are included with the sections on individual sub-basins.

Table 2. Major effluent discharges in the Peace River Basin. (adapted from Hatfield 2009)

Facility and EffluentType	Facility Name	Effluent Discharge Stream	Effluent Treatment Level	Average Annual Effluent Flow (m^3/day)	Ultimate Receiving Stream
Municipal Wastewater Discharge (treated municipal wastewater)	Aquatera Utilities, Grande Prairie	continuous	Primary-secondary-tertiary	12,771	Wapiti River
	Peace River	continuous	Primary-secondary	3,057	Peace River
	Manning	continuous	Primary-secondary	1,009	Notikewin River/Peace River
	Wabasca	continuous	Primary-secondary	n/a	North Wabasca Lake
	Peace River Correctional Centre	continuous	Primary-secondary	n/a	Peace River
	Grande Cache	continuous	Secondary	8,111	Smoky River
	48 small communities	1 – 2 times per year	Lagoon stabilization or mechanical aeration	5,706,897**	various streams and rivers
Pulp and Paper Mills (final effluent)	Weyerhaeuser Grande Prairie	continuous	Secondary	52,103*	Wapiti River
	Daishowa-Marubeni Inc.	continuous	Secondary	62,210*	Peace River
Coal-fired Power Generation (surface runoff)	Grande Cache Power /Atco Electric H.R. Miner	continuous	Settling ponds	1,772	Smoky River
Coal Mines (surface runoff)	Smoky River Coal Mine	intermittent	Settling ponds	7,940	Smoky River

* Pulp mill data are from 2007: other data from 2007 or earlier
** Total annual discharge (m^3)

While WWTPs discharge within the limits set out in their Water Licences issued by Alberta Environment and Water, not all parameters, and nutrients in particular, are generally regulated. Consequently, WWTP discharges contribute to downstream changes in aquatic ecosystems, such as the enrichment effects observed in the Wapiti River downstream of the Grande Prairie WWTP (Golder Associates Ltd. 2004a, Hatfield Consultants 2007, Hutchinson Environmental Sciences 2012). In exceptional cases, WWTP effluent can cause significant damage to the aquatic ecosystem, if the effluent is toxic, such as the fish kill caused by the Town of Beaverlodge wastewater treatment plant release to the Beaverlodge River in 2006 (see section 4.1.1).

An emerging concern associated with municipal effluents are the remains of cosmetic and pharmaceutical products ("microconstituents") in municipal effluents, which are not generally removed and have the potential for feminization of fish, conferring antibiotic resistance and other effects that are not yet well understood. Feminization is of concern as it reduces the reproductive capacities of a fish population. Pharmaceuticals and personal care products have not been studied beyond academic research as sample analysis is very costly. To date, there is no guidance or regulation from federal or provincial governments.

Other impacts of population and growth include water withdrawals, landscape conversion to urban or rural residential development, and increased demand for recreational use of near-by surface waters (see section 3.5).

Population in the Peace watershed has increased recently, with major population growth in the cities. Grande Prairie, for example, has seen a 61% growth in population from 1994 to 2007 (City of Grande Prairie 2008). A large proportion of the population is in the 20 to 44 year-old age group (47.42%). It can be expected that this growth will continue due to further economic activity from increased resource development.

3.5 Recreation

The numerous lakes, rivers and streams in the Peace River Basin attract recreational users for a variety of activities. Some recreational activities, such as camping, hiking and boating have not been considered to impact AEH, although extensive marina development impacts fish habitat. The use of ATVs and 4X4s in streams and rivers, can destruct and alter aquatic habitat but this activity is difficult to quantify, control and therefore manage. Lakeshore development also disrupts shoreline habitat and contributes nutrient loading from septic systems or landscape alteration to lakes.

Fish can be overharvested through recreational, commercial, and domestic fishing. As a result, restrictive sport fishing regulations were implemented in 1995 to manage harvests (Berry 1995) and restrictions on commercial and domestic fisheries have also been implemented for conservation purposes. Lentic Walleye systems can experience extremely high pressure from fishing mortality. For example, many lake Walleye systems in Alberta had reached a collapsed status in the 1980s and 1990s (Berry 1995) requiring extreme conservation measures. Some of those lakes are found within the study area. Increased and easier access as well as lakeshore development are the primary reasons for these declines.

As the human population is expected to increase, it should be expected that pressures on aquatic systems from recreational activities will increase accordingly.

3.6 Oil and Gas

The exploration and extraction of oil and gas reservoirs is a major income source in the Peace River Basin. Conventional oil and gas wells are located all over the basin, whereas the Peace River Oil Sands deposit is located in the Central Peace and Wabasca sub-basins. Oil and gas exploration and development have increased recently due to the development and refinement of new in-situ technologies, for example hydraulic fractioning ("fracking") that allow recovery of previously difficult-to-obtain oil sands reserves. Oil sands reserves are mainly concentrated in the Wabasca sub-basin (Figure 7), which is therefore the most likely location for future in-situ development.

The number of conventional oil and gas wells has increased from 5000 in 1990 to approximately 20,000 in 2010 (NADC 2011) and further development can be expected. The proposed Northern Gateway pipeline that is intended to transport bitumen from the Athabasca oil sands to the Pacific coast will pass through the Smoky/Wapiti River sub-basin. The proposed Mackenzie Pipeline passes through the Peace River Basin as well.

Figure 7. Location of oil sands deposits in northern Alberta.

Contamination from spills, leakage or stormwater from pipelines, well pads and processing plants are a potential threat to surface waters, as most hydrocarbons, which are the main constituents of oil and gas, are toxic to aquatic life. Another major impact from in-situ (underground) oil and gas extraction activity is water use. Details of this impact are discussed in the water quantity report, a parallel project conducted by the MPWA. Oil sands recovery is highly energy intensive, contributes to air pollution, and requires a lot of water. Water withdrawals can potentially reduce the availability of surface and groundwater resources, thereby negatively affecting aquatic habitat and reducing their capacity to assimilate pollution from any human activity. The effect of construction and operation of pipelines and exploration (seismic or cutlines) is discussed in section 3.1.

3.7 Mining

The predominant mining activity in the Peace River basin is coal mining. Coal mines are located in the Rocky Mountains, in the headwaters of the Peace and Smoky Rivers. Major environmental concerns associated with coal mines are acid mine drainage, selenium, and cadmium. Elevated selenium concentrations were found in aquatic environments downstream of coal mines on the Alberta Eastern Slopes and negative effects on fish embryos and fry and aquatic invertebrate communities were detected (Klaverkamp et al. 2005). There are also a number of coal mines in the upper Peace River watershed in British Columbia.

Peat is mined for a variety of reasons: for use in gardening or as fuel or simply to make space for agricultural operations. The removal of peat through peat mining results in the loss of both the positive regulating functions of wetlands for the hydrological cycle as well as the loss of habitat for important aquatic and terrestrial species. It is likely that a large number of wetlands were lost in the Peace watershed during the development of agrarian land and urban centres, but we were not able to locate a study that quantified the extent of wetland loss in the area.

Diamonds are another potential mining resource in the Peace River Basin. The Buffalo Head Hills area is the third largest district of significantly diamond-bearing kimberlites in Canada after Lac de Gras in the Northwest Territories and Fort à la Corne in Saskatchewan (Diamondex website 2012). Exploration activities have been ongoing since at least 2007 and new exploration drilling holes appear to be planned. Birch Mountains were mentioned as another potential location for diamond mining (Grizzly Discoveries 2012). Diamond mining is associated with discharge of nutrient rich water to the environment.

3.8 Hydroelectric Development

Flow in the Peace River is regulated by the upstream Bennett Dam in B.C., which has altered flow patterns since its construction in 1968. Although annual flow has not changed significantly since dam construction, there has been a 25% to 50% reduction in mean monthly summer flows and an increase of 175% to 250% in mean monthly winter flows, at Peace Point (Alberta Environment and British Columbia Ministry of Environment 2009). Associated with modified seasonality of flow, seasonal patterns in dissolved water quality parameters have also changed (Glozier et al. 2009). Reduction in summer flow can reduce the assimilative capacity for effluent discharges. The largest point discharge in the Peace River in Alberta is the DMI pulp mill, but thanks to the very large volumes of the Peace River, no water quality impacts of this effluent in terms of nutrients were detected in the river during the EEM studies (Stantec 2004).

The capacity of the Peace River to transport sediments has also been lessened, with a gradual filling of the river with silt and sediment (North/South Consultants 2007). Large concerns associated with these changes are travel capacity of Aboriginal communities to traditional hunting and fishing grounds and reduced ice-jam flooding of the lower Peace River that are needed to sustain valuable wetland habitats of the Peace-Athabasca Delta.

Effects of the Bennett Dam on fish habitat include an altered water temperature regime, reduced capacity to transport sediment, changes to the ice regime, and diurnal water level fluctuations. The amplitude of these effects, however, is reduced with distance downstream because of the addition of unregulated tributary inputs (North/South Consultants 2007).

The Peace Canyon Dam, located 23 km downstream of the W.A.C. Bennett Dam, is a run-of the river project and therefore does not regulate flow. The erection of this facility had a minor impact on fish spawning habitat in the tributaries between both dams by inundating part of these water courses (Department of Fisheries and Oceans Canada, 1991), but any downstream effects in the Province of Alberta are likely dominated by the effects of the larger Bennett Dam.

Northern rivers have a large potential for future hydroelectric developments, with 75% of the total Alberta hydroelectric energy potential present in the Athabasca, Peace and Slave River Basins (Hatch Ltd. 2010). The authors of that report believe that major projects in the northern basins and smaller projects in the southern basins may be developed in the next 30 years. In the early 1980's there were studies completed for both the Dunvegan hydro project on the Peace River and Slave River hydro project. Although these projects appeared feasible they have not been developed further as large hydro projects. The Dunvegan site has recently been approved for a 100 MW low head run of river development which is not yet under construction. The project will create a head pond of 26 km length and 6m higher than current levels. Impacts to fish communities in this river reach are estimated to be minor, though other information sources may indicate otherwise (Wilcox pers. comm.). (see section 4.2.1.5)

The Slave River hydro project has been considered again recently by private developers (Hatch Ltd. 2010). A dam on the Slave would be limited to the Slave River area and would not affect any other sub-basins of the Peace Basin, as there is the entire Peace Athabasca Delta at the downstream end of the Peace River that is very flat and that is protected by national park and international convention.

3.9 Water Use

Water is taken from surface and groundwater sources for a variety of human uses: drinking water for communities, for irrigation and lifestock watering, for use in industrial operations. In the Peace River Basin, a large amount of diversions are used to maintain wetlands for waterfowl production, including trumpeter Swans. A large portion of water withdrawals are returned to surface waters via effluent discharges and agricultural runoff, and the portion that is not returned is the net water use. The water diversions for wetland maintenance are permanent. A detailed discussion of water use is provided in the parallel project # 3, conducted for the MPWA. (Watrecon Consulting, The Peace Watershed – Current and Future Water Use and Issues, 2011).

Excessive water use without return to the aquatic ecosystem can influence flow patterns and can affect habitat quality for aquatic life. It also reduces the capacity of surface waters to assimilate wastewater discharges. These changes can affect AEH by affecting fish populations and decreasing water quality.

Water withdrawals are currently managed on a case by case basis by issuing approvals or licences under the Water Act. Some licences have a minimum instream flow objective set by Alberta Environment and Water, in order to protect flows required for aquatic life. In their 2009 report on the Beaverlodge and Redwillow Rivers, AECOM recognized water use as a significant threat to aquatic health and therefore recommended developing water balance models, developing and implementing minimum instream flows for water bodies and to revise the licensing system to better manage multiple water withdrawals.

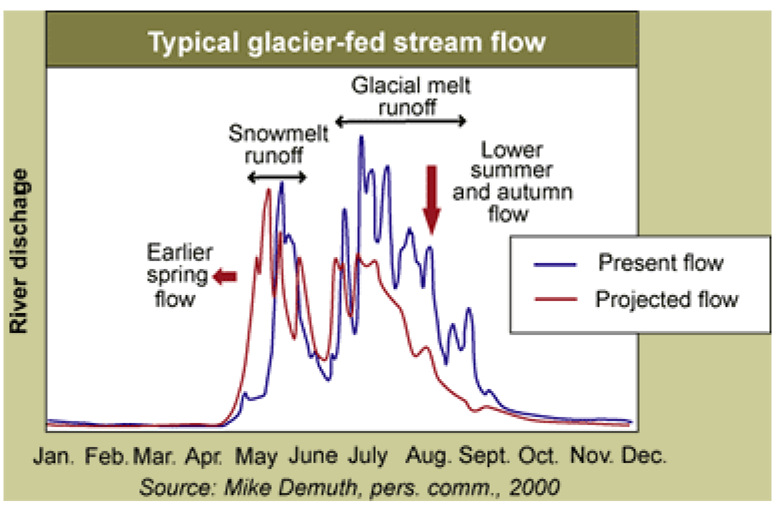
3.10 Climate Change

It is generally accepted that global climate change will have important consequences for the hydrological cycle and that temperature changes will be most pronounced in high latitudes (IPCC 2007). The climate and runoff in the Peace River Basin will therefore undergo a number of significant changes that will in turn affect the health of the aquatic ecosystem.

The fourth Intergovernmental Panel on Climate Change (IPCC) Assessment Report concluded, on the basis of a combination of global climate models, that the mean annual temperature for Alberta will increase 0.6°C to 0.85°C from the period of 1990–2000 to the period 2011–2030 (IPCC 2007). Annual precipitation will increase by 4% to 9% in northern Alberta. Climate change projections differ significantly between seasons, with the highest temperature increases occurring in winter and the largest precipitation increases occurring in summer. The predicted winter increase in temperatures will lead to shorter ice cover on the Peace River (Andrishak and Hicks 2005). The same is likely to be true for lakes and has already been observed during the past decade in lakes across the Northern Hemisphere (Magnuson et al. 2000). The intensity of rain events is predicted to increase, with a greater chance of flooding and water quality effects from urban and rural stormwater runoff.

The IPCC projects, with a high degree of confidence (eight out of ten), concluded that water supplies stored in glaciers and snow cover will decline in the course of the 21st century, thus reducing water availability during warm and dry periods in regions supplied by melt water from major mountain ranges. Retreat of these glaciers would lead to increased river flows in the short term, but the contribution of glacier melt would gradually fall over the next few decades (Bates et al. 2008, Figure 8). These long-term effects may offset the effect of higher precipitation in northern Alberta to some degree. The headwaters of the Smoky River, a major tributary of the Peace River and important subwatershed in the Peace Basin, are fed in part by glaciers and will therefore likely be subject to these predicted changes in flow patterns. These changes will affect both water quantity, seasonal flow patterns and water quality, with potentially significant effects on AEH.

Figure 8. Projected Patterns in Stream Flow of Glacier-Fed Streams Resulting from Climate Change. (*From NRC (2001***)**



3.11 Other Potential Future Stressors

Since 2007, there have been proposals to build a nuclear power plant near the town of Peace River. Nuclear plants can have an effect on the aquatic environment by discharging warm water as a result of required cooling, which in turn deteriorates fish habitat. These projects, however, have been put on hold due to “changing market conditions” (World Nuclear Association 2012).

3.12 Cumulative Effects

While most of the above discussed stressors have well-defined, well-studied, individual effects on aquatic ecosystems, their cumulative effect on surface waters depends on local settings and is generally much less well understood. Pioneering work on cumulative effects in the Peace River basin was done in the 1990s by the Northern Rivers Basin Study (NRBS), where the combined effects of multiple anthropogenic stressors on rivers were studied, including complex industrial effluents, flow regulation, long-range atmospheric transport and changes to climate (Culp et al 2000). The NRBS program attempted to assess the cumulative effects of three types of environmental effects: incremental (accumulating over time, such as bioaccumulation), multiple source (several sources of the same stressor), and multiple stressor (several different stressors) impacts.

Examples for cumulative effects in the Peace River basin include the following:

1) The Wapiti River has shown increased aquatic productivity due to the cumulative effect of increased nitrogen from the Grande Prairie WWTP and increased phosphorus and organic matter from the Weyerhaeuser pulp mill (Golder Associates Ltd. 2004a, Hatfield Consultants 2007). Additional effects of stormwater from Grande Prairie have been hypothesised but not studied so far (Alberta Environment, personal communication) (multiple stressors).
2) Pulp mill effluent contains large amounts of organic matter that can cause low oxygen, nutrients that cause eutrophication and contaminants that may be toxic to aquatic life. This means that multiple stressors are present in this type of discharge, which can potentially affect the environment in several different ways. The use of experimental approaches has allowed to identify the main effect of pulp mill effluent, which is nutrient enrichment (Culp et al. 2000) (multiple stressors).
3) Beaverlodge fish kill was caused by WWTP effluent and an unusually high pH in the river due to an algae bloom (Grande Prairie Daily Herald Tribune 2008), which in turn was promoted by stagnant water due to low flow conditions and possibly excess nutrients from agriculture (multiple stressors).
4) Climate overlies and influences everything else, as it influences the hydrological regime that accounts for river habitat and dilution capacity for pollutants. For example climate change recently led to decreased Peace River tributary discharge in spring that, together with upstream river regulation (Bennett Dam) decreased the probability of river ice jam floods that are needed to sustain wetland ecosystems in the PAD (Prowse and Conly 2000) (multiple stressors).
5) Multiple stream crossings in headwater streams: one crossing represents a minor impact, but many such crossings on one stream can have a combined significant impact on aquatic habitat (multiple source).
6) Forestry and mining in upstream watersheds in which each operation is assessed individually, but not together with existing or other proposed developments which may produce similar stresses.
7) Instream flow objectives for water diversions are established for each new water license in isolation from all other licenses. The cumulative effect of water licensing on instream flow is not tracked (AECOM 2009).

In this report, we mapped major anthropogenic stressors by sub-basin, in order to display regional differences in the overlay of several stressors. This will facilitate the identification of "hot spots", i.e. locations where a number of stressors are concentrated and therefore human impacts on AEH potentially are most prevalent.

3.13 Stressor Summary

The sections above demonstrate that there are a number of stressors that have an impact on AEH. An overview of human activities in the Peace Basin that apply pressures to the state of AEH shows that the main potential issues in the basin related to human activities are eutrophication, increased sediment from erosion and habitat degradation that affect aquatic life and, taken together, are most prevalent in their effect on fish populations.

Figure 9. Summary of anthropogenic activities, pressures and impacts on the state of Aquatic Ecosystem Health in the Peace River Basin

Anthropogenic Activity	Pressures	Impacts on State of AEH
• Urban • Agriculture • Forestry • Mining • Oil and Gas • Linear Features • Recreation • Hydroelectric Development	• Nutrients • Sediments • Pathogens • Toxic Contaminants • In-stream Barriers • Changes in Hydrology • Fishing Pressure • Climate Change	• Eutrophication • Anoxia • Nuisance algae • Altered benthic community structure & diversity • Reduced fish abundance, diversity

4.0 SUB BASINS

Background

For the purpose of this review, the Peace River Basin was divided into six subwatersheds: the Upper Peace River, Smoky/Wapiti River, Central Peace River, Wabasca, Lower Peace River and Slave River Basins. These watersheds differ in their coverage of natural regions and degree and type of human stressors on the watershed.

4.1 SMOKY/WAPITI

Overview

The Smoky/Wapiti sub-basin is a large and diverse sub-basin in terms of natural regions and land uses. The southern part of this basin is situated in the alpine and subalpine regions, to the north followed by foothills and then Dry and Central Mixedwood and also includes Peace Parkland. There is coal mining in the northeastern slopes of the Rocky Mountains, forest harvest and oil and gas extraction in the foothills and Mixedwoods, and agriculture in the Parkland. It contains the most densely populated and most fragmented areas in terms of road density west of Grande Prairie (Figure 5) and high densities of cutlines in the south-eastern part of the sub-watershed (Figure 6).

The Smoky River is an unregulated river that originates in the Rocky Mountains northwest of the Town of Jasper. Together with its tributaries, this river drains an estimated 20% of the Peace River Basin, and flows into the upper Peace River (at the Town of Peace River). This is the largest of the Peace River tributaries within Alberta. The Smoky River receives inputs from four major tributaries; the Wapiti River, Simonette River, Little Smoky River and Kakwa River. The unregulated Wapiti River has an average discharge at Grande Prairie of 88 m^3/s (1996- 2010) and has seven major tributaries. Important tributaries for this aquatic health summary include the Redwillow River that also drains the Beaverlodge River watershed, and Bear Creek, which flows through Grande Prairie (Chambers and Guy 2004, Golder Associates Ltd. 2004a). Discharge in the Smoky and Wapiti Rivers typically peaks in June, while minimum low flows tend to occur in February.

Historically, the Wapiti River was identified as one of the northern rivers most at risk of environmental deterioration from anthropogenic nutrient inputs (NRBS 1996). The lower Wapiti River receives point source discharges from the Grande Prairie wastewater treatment plant (WWTP) operated by Aquatera Utilites, and the Weyerhaeuser Company pulp mill (located 10 km downstream of the WWTP). Both dischargers are currently implementing process and treatment improvements to reduce water quality impacts of effluents in the River. They are monitoring river effects through a Coordinated Monitoring Approach Program, which was recently developed to harmonize previously different monitoring programs required by the federal Environmental Effects Monitoring Program for the pulp mill and the provincial licence compliance monitoring required for the WWTP (Hutchinson Environmental Sciences 2010, 2012).

Sheep Creek flows through an active coal mining area. Grande Cache Coal is currently operating an active mine (formally the Smoky River Mine) within upper Smoky River Basin, and has started open pit mining (Casey 2005). Sheep Creek joins the upper Smoky River upstream of the Wapiti River confluence.

Water use has been identified as a concern in the Redwillow watershed, as reduced flows can decrease the capacity of streams to handle pollutants, which are abundant in this agricultural watershed, and impair fish habitat (AECOM 2009). Registered traditional agricultural users have the most licenses in this watershed, however, Ducks Unlimited Canada has the largest allotted volume of water use (75%) for stabilization and wetlands, with the intend to protect waterfowl habitat, e.g., for Trumpeter Swans. There are also unregistered water users, as licence requirements were only introduced in 1999.

The largest individual surface water allocations in the Wapiti River basin are for point dischargers in the lower Wapiti River (Aquatera Utilities to supply drinking water for the region and Weyerhaeuser Company for pulp mill operations). They do return a large volume of water (77 and 90%, respectively) to the river in form of wastewater effluent (Alberta Environment and Water 2012). The net amount of these water withdrawals, taken together, is still lower than the total net allocation to Ducks Unlimited (Alberta Environment and Water 2012). The MPWA, in collaboration with Alberta Environment and Water, is planning to prepare a Wapiti River Water Management Plan to address concerns of cumulative water use in this important sub-watershed.

Figure 10. Map of the Smoky/Wapiti River Sub-basin indicating major anthropogenic stressors.

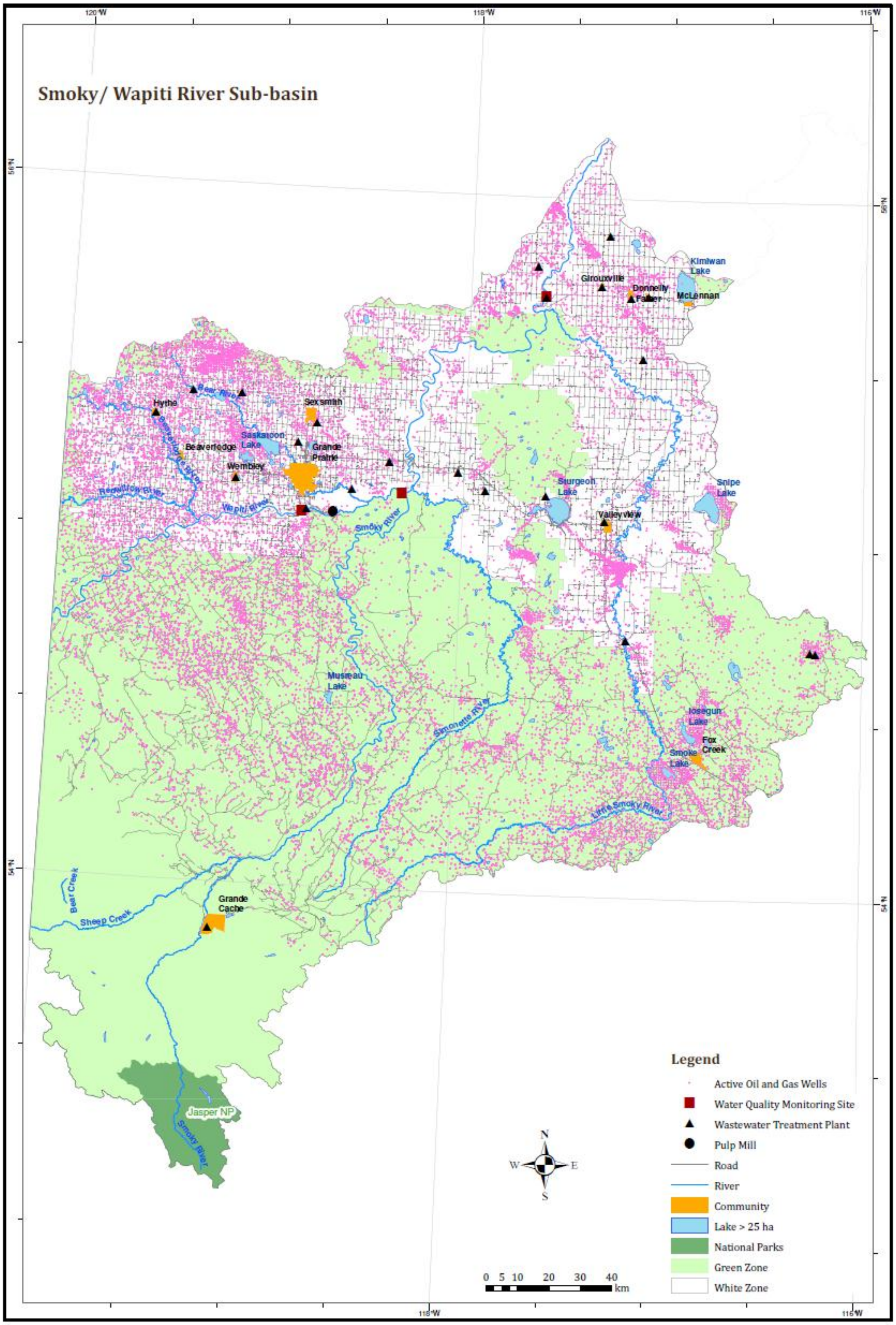


Figure 10: Map of the Smoky/ Wapiti River Sub-basin indicating major anthropogenic stressors

Prepared by: Eric Dilligeard
Data Source: Alberta Sustainable Resource Development, Government of Alberta and GeoAccess Division
Coordinate System: NAD_1983_10TM_AEP_Forest

In Partnership with:

Redwillow River, which also drains the Beaverlodge watershed, is a main tributary of Wapiti River and drains a total of ca. 2000 km^2. There is 50% agricultural land use in this tributary watershed, 8188 km linear features (cutlines, roads, pipelines, powerlines, railway tracks) and a number of oil and gas wells. This watershed has continuously seen a trend towards increased crop areas and decreased forest cover since the mid-20th century (AECOM 2009).

4.1.1 Rivers

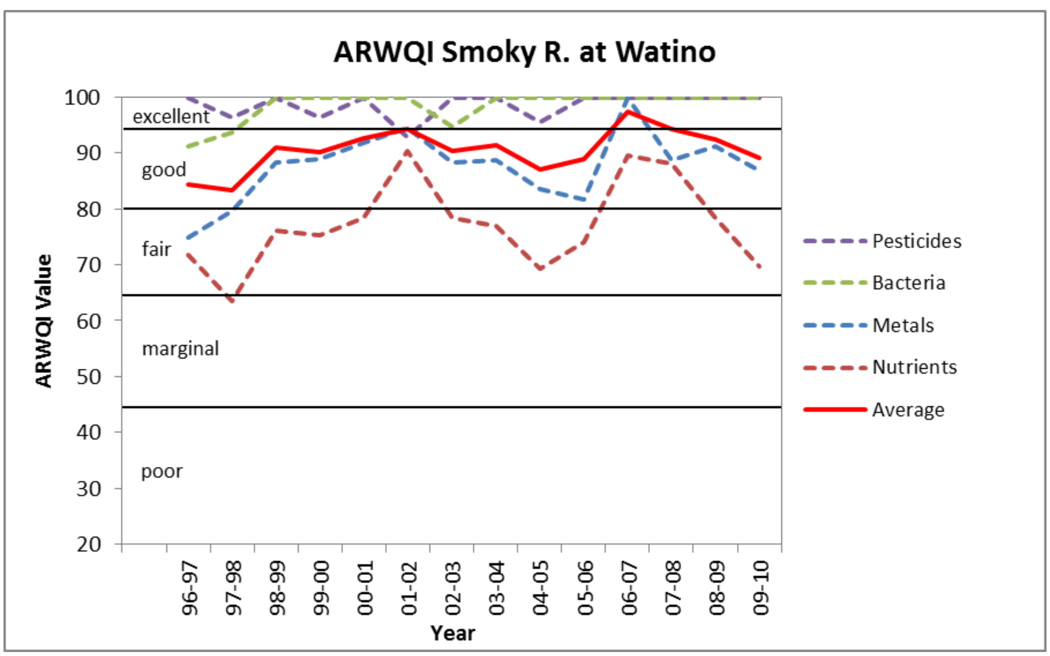
4.1.1.1 Water Quality

Smoky River

The Alberta River Water Quality Index (ARWQI) is a variant of the CCME WQI that summarises water quality as a function of the number of parameters that exceed a water quality objective, the number of exceedances and the magnitude of exceedances. ARWQI is calculated by AEW for three long term water quality monitoring sites in this subbasin: (a) Wapiti River at HWY 40, (b) Wapiti River at the confluence with the Smoky River and (c) Smoky River at Watino.

The ARWQI has consistently rated water quality in the Smoky River at Watino as 'good' (1996-2010) (Alberta Environment 2011, Figure 11). While average water quality was rated as 'excellent' by pesticide, and bacteria sub-indices; metal and nutrient sub-indices gave 'good' or 'fair' ratings, respectively. Lower nutrient and metal sub-index values were likely due to noncompliance of total nutrient and metal forms with relevant WQGs during high flow periods, due to elevated TSS loads (North/South Consultants 2007). Downstream of the confluence of the Wapiti River, however, at a site ca. 80 km upstream of Watino, nutrient effects from the Wapiti River, such as increased TP, TKN, periphyton biomass and benthic invertebrate densities, have also been observed during low flow (Hutchinson Environmental Sciences Ltd. 2012).

Figure 11. Alberta River Water Quality Index for the Smoky River at Watino, 1996-2010.



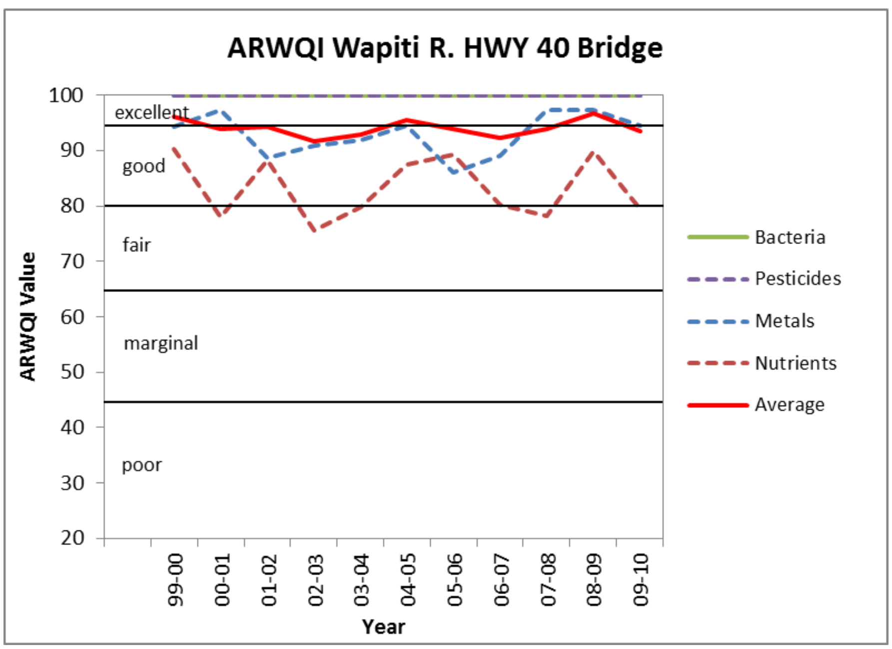
Concentrations of TSS in the Smoky River were lower than the Peace River, but still relatively high compared to other rivers in the province. The lowest CCME WQG compliance rates for total metals at this site between 1999 and 2003 were observed for Ag, Al, Cd, Cu and Fe (≤50% compliance) (North/South Consultants 2007).

Dissolved oxygen concentrations complied with Alberta Surface Water Quality Guidelines (ASWQGs). With regard to pesticides, Anderson (2005) did not detect any significant changes in 2,4-D concentration, total pesticide concentration per sample, or number of pesticide per sample, between 1995 and 2002. Three pesticides, 2,4-D, MCPA and triclopyr, were detected within this time period, which were present in low concentrations below available CCME WQGs. As the pesticide subindex of the ARWQI consistently rated the Smoky River as excellent, pesticides are not an issue in the Smoky River.

WAPITI RIVER

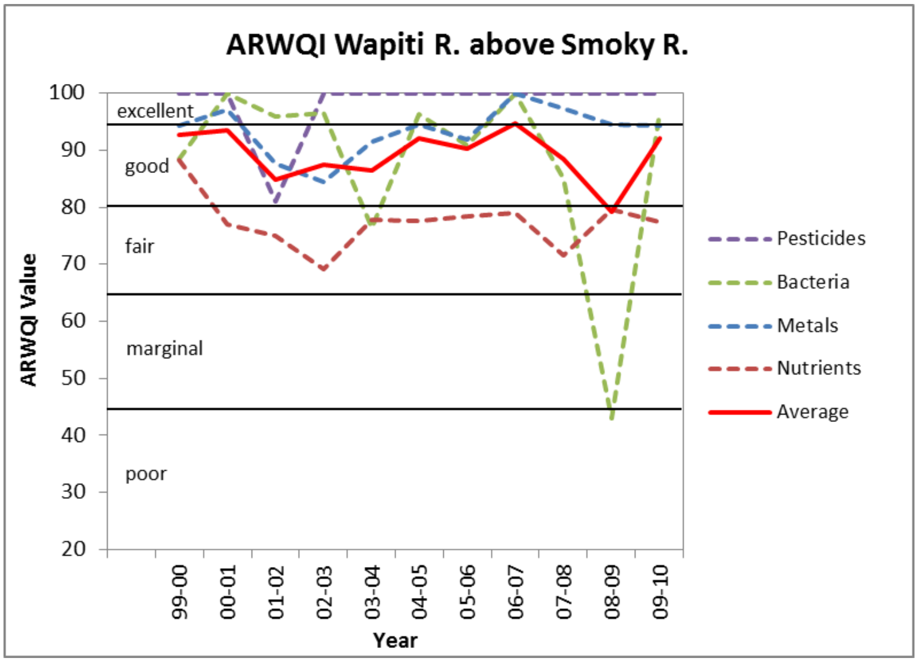
According to the ARWQI, water quality has been 'good' in the lower Wapiti River since 1999, although higher index values within this category have been scored at HWY 40 (upstream of the Grande Prairie WWTP and the Weyerhaeuser pulp mill, Figures 12 and 13). Water quality at both sites has been most affected by nutrient concentrations, but more so close to the Wapiti River mouth, where nutrient quality has mostly been rated as 'fair'. Water quality at these sites has been mostly rated as either 'excellent' or 'good' by the other three sub-indices, except a one-time fair rating for bacteria in 2008-2009. The ARWQI clearly demonstrates the nutrient enrichment effect of the WWTP and the pulp mill on Wapiti River, as discussed more in detail below.

Figure12. Alberta River Water Quality Index for Wapiti River at HWY 40, 1999-2010.



A recent study of aquatic health in the Wapiti and Smoky Rivers showed higher ratings (excellent at HWY 40 and good at the downstream station) for the nutrient sub-index during the low-flow periods of 2011, when highest effects of effluents are expected due to the lowest seasonal dilution capacity in the river. This indicates that the lower ARWQI ratings are not solely related to effluent effects in the lower Wapiti, but that high suspended sediment concentrations during high flow events are in part responsible for the lower ARWQI calculated by AEW, which is based on all seasons (Hutchinson Environmental Sciences 2012).

Figure 13. Alberta River Water Quality Index for Wapiti River above the Smoky River Confluence, 1999-2010.



The lower Wapiti River, downstream of effluent discharges, can be classified as mesotrophic (intermediate nutrient levels) based on TP and periphyton biomass, as opposed to upstream of Highway 40, where the river is oligotrophic (nutrient poor). Nutrient water quality, specifically P concentrations, has been of most concern in the Wapiti River, particularly during lower flows (North/South Consultants 2007). Both the Wapiti and Smoky rivers are inherently nutrient poor which also makes them more vulnerable to impacts of anthropogenic nutrient enrichment. Between 1999 and 2003, TP concentrations at the mouth of the Wapiti River were non-compliant with the ASWQG of 50 ug/L about half of the time. In contrast, nitrate and ammonia concentrations remained below respective CCME WQGs, of 13 and 0.02 mg/L but the TN ASWQG was exceeded on some occasions.

Recent seasonal monitoring of Wapiti River water quality under low flow by Golder Associates Ltd. (2004a) in 2002, confirmed that the main water quality impact due to the Grande Prairie WWTP was nutrient enrichment (mostly nitrogen). This impact was further amplified by the downstream pulp mill effluent discharge, resulting in a further downstream increase in nutrient concentrations (both nitrogen and phosphorus). . Both the Grande Prairie WWTP and the Weyerhaeuser mill are undergoing treatment upgrades to reduce nutrient inputs.

Dissolved oxygen concentrations in this river typically remain above 9.5 mg/L, and even though they tend to decline under ice-cover during the winter months, concentrations have met the chronic ASWQG (Chambers et al. 2006). Concentrations of TSS spanned a wide range in the Wapiti River with high values during high spring/summer flows, although not to the same extent as the Peace and Smoky rivers. A slight increase in some trace metal concentrations (i.e., Al, Fe, Mn, Sr, Zn) was observed by Golder Associates Ltd. (2004a) under low flow conditions in winter 2002, downstream of the WWTP that further increased downstream from the pulp mill. However, all trace metal concentrations complied with CCME WQGs with the exception of Al downstream from the mill. The only organic compounds reported above detection concentrations in the lower Wapiti River by Golder Associates Ltd. (2004a), were trace concentrations of fatty acids. With respect to pesticide concentrations, Anderson (2005) did not identify any significant changes in detected 2,4-D concentrations, total pesticide concentration per sample, or number of pesticides per sample from 1995-2002 .

SMALL TRIBUTARIES

A field-scale study was conducted in the Bear Creek, as part of the Phosphorus Limits Project (Little et al. 2006). In general, this study showed that field-scale concentrations of total phosphorus from non-manured sites exceeded the Alberta water quality guideline for the protection of aquatic life by 3 to 16 times in all three years of the study. The concentrations of total phosphorus from non-manured sites were similar to watershed-scale values of total phosphorus measured in first-order streams that drain high intensity agricultural watersheds in Alberta.

A study of the small agricultural streams Kleskun Drain and Bear Creek in the Wapiti River subwatershed showed that these water bodies were enriched in nutrients and pesticides and classified as eutrophic. The streams were consistently non-compliant with TP and TN ASWQGs, but compliant with the ammonia and nitrate CCME WQGs. High pesticide concentrations and relatively high detection frequencies were observed, but have been attributed to weed control efforts along a highway construction zone in the watershed (Depoe and Westbrook 2003, in North/South Consultants 2007). TSS flow-weighted mean concentrations between 1999 and 2002 were not related to agricultural intensity. Although these streams were located in high run-off watersheds, TSS concentrations were relatively low compared to streams with high or moderate run-off watersheds located in other river basins, such as the North Saskatchewan River Basin.

Similar results were observed in the Beaverlodge River (Redwillow watershed), where total phosphorus exceeded the AWQG in almost 90% of samples collected from 1977 to 2007 (AECOM 2009). Dissolved oxygen measurements were below guidelines in about 30% of the samples. Iron WQG exceedance was frequently associated with low oxygen concentrations caused by high biological oxygen demand (due to eutrophication) and was therefore attributed to altered redox conditions in the river. The degraded water quality has likely contributed to the decline and in some cases, extirpation of fish population in these reaches (AECOM 2009). Water quality improved, however, in a downstream direction and was mostly below WQGs at the confluence with the Redwillow River, likely thanks to less intense land use in downstream reaches and biological assimilation (AECOM 2009). The spatial and temporal distribution of exceedances showed that the primary water quality issue in the Beaverlodge River Watershed is nutrient enrichment, mainly from multiple, agricultural non-point sources along the upper and middle reaches of the river.

Overall, it appears that agricultural streams in the Smoky/Wapiti sub-basin are subject to water quality impairments that already have had a negative impact on the biota in these streams, as demonstrated by algae blooms observed since the 1990s and the declining sport fish abundance and diversity in the Beaverlodge River and its tributaries (AECOM 2009, see section on fish below). These and similar other agricultural streams, however, have small watersheds and low individual discharge in comparison to the large downstream rivers such as the Wapiti or Smoky Rivers, and it remains unknown if their combined load of nutrients actually has any notable combined, or cumulative effect on downstream waters. A sub-watershed-scale assessment, possibly including modeling, would be required to estimate the effect of small, headwater agricultural stream water quality to downstream river reaches.

Streams in the vicinity of coal mining activities were monitored by AEW from 1999-2003. Local increases in selenium in Beaverdam and Sheep Creeks downstream from the mines were detected, but these effects diminished further downstream (North/South Consultants 2009). In selenium-enriched sites, deformities were detected in rainbow trout and brook trout larvae (Holm et al 2003). Effects from coal mines generally do not extend as far downstream as the main stem of the Peace River (BC Ministry of Environment and AEW 2009).

A study on the impacts of oil and gas operations in the Bridlebit Creek watershed did not detect any effect of such operations on water quality (Cygna Environmental 2007), however the authors indicated the limited power of their statistical inferences due to limited reference data and variables analyzed.

4.1.1.2 Sediment Quality

Lower Wapiti River sediment quality was monitored in fall 1998 and 2002 by Golder Associates Ltd. (2000, 2004a) for Weyerhaeuser, to fulfill EEM monitoring requirements and in 2011 by Aquatera Utilities to fulfill provincial Water Licence requirements (HESL unpubl). Sediments upstream and downstream of the WWTP were monitored, along with sediments downstream of the pulp mill discharge. In 2003, sediments downstream of the WWTP were enriched with nutrients and most trace metals relative to upstream (Golder Associates Ltd. 2004a). Similarly, sediments directly downstream from the pulp mill were enriched with nutrients and some metals (e.g., Al, As, Fe, Se). Notably, sediment phosphorus was elevated downstream from the mill but not downstream from the WWTP, whereas nitrogen and TOC were elevated in sediments downstream of both discharges. For the most part, sediment metals concentrations were compliant with available SQGs. There was no observed increase in trace organic compounds (i.e., chlorinated phenolics; dioxins and furans; resin and fatty acids) downstream of either discharge (North/South Consultants 2007).

Hazewinkel and Noton (2004) conducted a comprehensive 1997 survey of sediment PCB concentrations in the Wapiti River and its tributary, Bear Creek which flows through Grande Prairie. The survey was commissioned to identify potential PCB sources within the Wapiti system that might explain the occurrence of PCBs in fish populations. Although PCB concentrations were low throughout the Wapiti River, concentrations notably increased downstream of the Bear Creek confluence. A subsequent study in 1998, revealed that sediment PCB concentrations were elevated downstream of Grande Prairie, but still remained below CCME SQGs. The authors discuss possible sources of PCBs, including the pulp mill (specifically a historic spill), and historic and/or persistent sources within Grande Prairie.

Trace organic contaminants have also recently been detected at elevated concentrations within Bear Creek downstream of Grande Prairie. In a 1998-2000 survey, Alaee et al. (2004) detected concentrations of dioxins and furans in suspended sediments at various sites in the lower Wapiti River, with the highest concentrations measured in Bear Creek below the CNR bridge. The main dioxins and furans present were indicative of a pesticide source (a wood preservative), and a pulp mill source (historical use of elemental chlorine at the Weyerhaeuser mill), respectively. Nevertheless, concentrations of trace organic compounds in suspended sediments from the lower Wapiti River were substantially lower than those measured in a historical 1992 survey. Suspended sediment mercury concentrations were low and similar to other pristine rivers.

Recent monitoring of PCB concentrations in Smoky River sediments between 1988 and 2000 revealed that low PCB concentrations (close to detection limits) that likely originated from a diffuse atmospheric source as a result of long-range transport from distant point sources (Hazewinkel and

Noton 2004). These low concentrations were similar to Wapiti and upper Peace River background PCB concentrations.

Oxygen concentrations in sediment pore waters were studied in the Wapiti River and were found to be lowest downstream of the pulp mill compared to the reference site upstream and the site downstream of the WWTP (Culp et al. 2004). Sediment oxygen demand increased from upstream sites towards downstream sites in the Wapiti River, and was related to increased organic and silt content in the sediments (Casey 1990).

4.1.1.3 Non-Fish Biota

Benthic invertebrate and periphyton data were extensively studied in the Wapiti-Smoky River system, to fulfill requirements of EEM for the pulp mill of Weyerhaeuser Company Ltd. as well as for the Water Licence of Aquatera Utilities, the operator of the Grande Prairie WWTP. Field surveys of benthic invertebrates were completed in 1994 and 1998 by Weyerhaeuser and in 2008 and 2011 by Aquatera Utilities. Mesocosm studies using Wapiti River and waste water from both discharges were completed in 2002 by Weyerhaeuser. Periphyton surveys were completed in 1998 and 2002 by Weyerhaeuser and in 2011 by Aquatera. During EEM cycles 4 and 5, several modelling approaches were used to investigate details of periphyton response to both effluents. In addition, some data on non-fish biota is available from AEW LTRN sites in the Wapiti and Smoky Rivers.

The Smoky River at Watino was classified as oligotrophic according to TP and TN, as well as planktonic and benthic algal biomass, though benthic algal data were limited (North/South Consultants).

Benthic invertebrate communities downstream of the Grande Prairie WWTP and the pulp mill in the Wapiti and Smoky Rivers showed impacts consistent with the typical nutrient enrichment response pattern. Total abundance increased downstream from the WWTP and the mill, compared to upstream of the WWTP, though the relative increase downstream from the WWTP was greater. The Bray-Curtis dissimilarity index confirmed that benthic community structure was significantly different downstream of the WWTP relative to upstream. Further downstream, below the mill, community structure changed further but to a lesser degree. The 1998 EEM study concluded that the WWTP exerted a nutrient enrichment impact on downstream benthic communities that was sustained by the pulp mill, but not greatly exacerbated and that nutrient enrichment effects were sustained until locations in the Smoky River (Golder Associates Ltd. 2002).

Upstream of point source discharges, benthic algal biomass is inherently low in the Wapiti River (<30 mg/m^2 chlorophyll *a*; Chambers and Guy 2004). Benthic algal biomass tends to be substantially greater close to the mouth (downstream of point source discharges), compared to the upstream Long Term River Network (LTRN) site at HWY 40 (Chambers and Guy 2004, Evans and Muir 2004). Golder Associates Ltd. (2000) showed that algal biomass was significantly greater downstream of the WWTP, but did not increase further downstream from the pulp mill, consistent with benthic invertebrate monitoring results, while a more detailed periphyton survey in 2002 showed significant increases in periphyton biomass downstream of both discharges (Golder Associates Ltd. 2004a). Algal species characteristic of nutrient enriched environments were more prevalent in areas exposed to pulp mill effluent, as were cyanobacteria. Periphyton biomass was also significantly elevated downstream of the Wapiti River confluence.

The riverside mesocosm study conducted in fall 2002 demonstrated a nutrient enrichment impact in all treatments consisting of different mixtures of river water, WWTP and pulp mill effluent. The study showed that the WWTP was a significant source of nitrogen, while the mill was a significant source of phosphorus and carbon. A combined assessment of field studies, mesocosm studies and modelling concluded that periphyton growth in the Wapiti River is limited by both nitrogen and phosphorus upstream of point sources, nitrogen-saturated immediately downstream of the WWTP, and nitrogen- and phosphorus-saturated immediately downstream of the pulp mill (Hatfield Consultants 2007).

4.1.1.4 Fish

FISH POPULATION

A large number of the 42 fish species that have been encountered throughout the Peace River Basin were recorded in the Smoky-Wapiti River sub-basin (Table 3). This is probably due to the large size of the watershed, the large variety in aquatic habitats and a high level of harvest and study effort that increase the chance of detecting rare species.

A very comprehensive study on fish communities and the factors that impact them is presented in a report which focuses on the Redwillow watershed (AECOM 2009). It links watershed disturbances to declining fish populations of Arctic Grayling, northern pike, Walleye, Bull Trout and mountain white fish. It identified reduced stream flow, reduced water quality, obstruction of fish migration by weirs and direct damage to fish habitat and the riparian zone by agricultural activities as the main reasons for declining populations. This is a well documented cause and effect study that may contain information that is transferrable to other sub-basins where similar stressors are present (agriculture, flow regulation).

Scrimgeour and Hvenegaard (2000) showed that watershed disturbance resulting from forestry and oil and gas activity has detectable cumulative effects on stream fish communities in the Kakwa and Simonette River basins. While fish abundance and community structure was overall not controlled by watershed characteristics, a few relationships indicated some impacts of watershed disturbance. For example, Bull Trout presence had a negative relationship with cumulative percent watershed disturbance in the Kakwa River Basin and density of stream crossings in the Simonette River Basin (Scrimgeour and Hvenegaard 2000).

Table 3. Fish species captured in the Peace and Slave River watersheds in Alberta (*based on records in the Government of Alberta's Fish and Wildlife Information Management System [Government of Alberta (b) 2012]).*

		Sub-basin					
Common Name	Scientific Name	Smoky-Wapiti	Upper Peace	Central Peace	Lower Peace	Wabasca	Slave River
	Sport Species						
Arctic Grayling[1]	*Thymallus arcticus*	▲	▲	▲	▲	▲	
Brook Trout[2]	*Salvelinus fontinalis*	▲	▲	▲	▲		
Brown Trout[2]	*Salmo trutta*	▲	▲	▲			
Bull Trout[1]	*Salvelinus confluentus*	▲	▲				
Burbot	*Lota lota*	▲	▲	▲	▲	▲	▲
Cutthroat Trout[2]	*Oncorhynchus clarki*	▲					
Goldeye	*Hiodon alosoides*	▲	▲	▲	▲	▲	▲
Lake Trout[1]	*Salvelinus namaycush*		▲		▲	▲	▲
Lake Whitefish	*Coregonus clupeaformis*	▲	▲	▲	▲	▲	▲
Mountain Whitefish	*Prosopium williamsoni*	▲	▲	▲	▲		
Northern Pike	*Esox lucius*	▲	▲	▲	▲	▲	▲
Rainbow Trout[2]	*Oncorhynchus mykiss*	▲	▲	▲	▲	▲	
Walleye	*Sander vitreus*	▲	▲	▲	▲	▲	▲
Yellow Perch	*Perca flavescens*	▲	▲	▲		▲	▲
	Non-Sport Species						
Brassy Minnow[1]	*Hybognathus hankinsoni*	▲		▲			
Brook Stickleback	*Culaea inconstans*	▲	▲	▲	▲	▲	
Cisco	*Coregonus artedi*	▲			▲	▲	▲
Emerald Shiner	*Notropis atherinoides*	▲	▲	▲	▲	▲	
Fathead Minnow	*Pimephales promelas*	▲	▲	▲	▲	▲	
Finescale Dace	*Phoxinus neogaeus*	▲	▲	▲	▲	▲	
Flathead Chub	*Platygobio gracilis*	▲	▲	▲	▲	▲	▲
Grass Carp[2]	*Ctenopharyngodon idella*	▲	▲		▲		
Iowa Darter	*Etheostoma exile*	▲		▲		▲	
Kokanee[2]	*Oncorhynchus nerka*		▲	▲			
Lake Chub	*Couesius plumbeus*	▲	▲	▲	▲	▲	
Largescale Sucker	*Catostomus macrocheilus*	▲	▲				
Longnose Dace	*Rhinichthys cataractae*	▲	▲	▲	▲	▲	
Longnose Sucker	*Catostomus catostomus*	▲	▲	▲	▲	▲	▲
Ninespine stickleback	*Pungitius pungitius*				▲		▲
Northern Redbelly Dace	*Phoxinus eos*	▲	▲	▲	▲		
Northern Pikeminnow	*Ptychocheilus oregonensis*	▲	▲	▲			
Peamouth	*Mylocheilus caurinus*	▲					
Pearl Dace	*Semotilus margarita*	▲	▲	▲	▲	▲	▲
Prickly Sculpin	*Cottus asper*		▲				
Redside Shiner	*Richardsonius balteatus*	▲	▲	▲			
Round Whitefish	*Prosopium cylindraceum*						▲
Shortjaw Cisco[1]	*Coregonus zenithicus*						▲
Slimy Sculpin	*Cottus cognatus*	▲	▲	▲	▲	▲	▲
Spoonhead Sculpin	*Cottus ricei*	▲	▲	▲			
Spottail Shiner	*Notropis hudsonius*	▲	▲	▲	▲	▲	▲
Trout Perch	*Percopsis omiscomaycus*	▲	▲	▲	▲	▲	▲
White Sucker	*Catostomus commersoni*	▲	▲	▲	▲	▲	▲

1 - Species of management concern or species at risk
2 - Non-native; naturalized, stocked, or downstream dispersal from British Columbia

High to moderate densities of Arctic Grayling (i.e., low to moderate risk) tend to occur in more remote locations, while densities were low in areas with increased access and land use, or possibly where habitats are less suitable (Figure 14). Local extirpations are suspected in the areas adjacent to Grande Prairie, including the Redwillow and Beaverlodge rivers (AECOM 2009) in the Smoky-Wapiti sub-basin. The population in the Little Smoky River represents an exception where the population has persisted at higher levels despite land use. Notably, the Little Smoky River population in the Smoky-Wapiti sub-basin is catch and release for angling (2011 Alberta Sportfishing Regulations) which likely contributes to the sustainability of higher densities.

Bull Trout is present in the upper Smoky-Wapiti sub-basin and several small lakes in the Smoky-Wapiti sub-basin support small populations of Bull Trout (e.g., A la Peche, Musreau, Nose, and Long lakes). Populations to the east and north tend to be at lower densities, with some populations at high risk or expected extirpated. As with Arctic Grayling, Bull Trout populations at risk tend to be associated with the settled areas adjacent to Grande Prairie and agricultural land north of it (Figure 15).

The estimated densities of Walleye in river and stream habitats vary throughout the study area (Figures 16 & 18). The lowest densities were estimated in the upper portions of the Smoky-Wapiti sub-basin and moderate to high densities were estimated for the remainder of the study area, which is consistent with the preference of Walleye for larger and deeper river habitat.

Densities of Goldeye vary from low in upper reaches of the Smoky-Wapiti to moderate and high in lower reaches of the study area (Figure 17), which may also be related to habitat preferences of this species. Very little detailed sampling has occurred for Goldeye in the study area.

Using road density, the index of biological integrity (Table 4) was calculated for the tertiary subwatersheds in the Peace River Basin. The IBI scores showed low and moderate integrity in the northern part of the Wapiti-Smoky River sub-basin and high integrity in the southern part of the sub-basin (Figure 5). The densities of the four focal species in general confirm these results. Fish populations in the south-eastern part of this sub-basin, however, show opposing results, with high Arctic Grayling densities and low Bull Trout densities. More data for Bull Trout in this sub-basin is required, as data uncertainty is currently high to moderate in most areas.

Table 4. Index of biological integrity scores and their descriptions used to characterize aquatic health in the study area. *Table adapted from Golder (2008). Relationship to predict IBI score is y=5.196 (0.3169*road density m/ha) (Stevens and Council 2008).*

Predicted IBI	Category	Associated Road Density
3	High Biological Integrity (perfect)	≤ 0.69 km/km^2
2	Moderate Biological Integrity	> 0.69 and ≤ 1.01 km/km^2
1	Low Biological Integrity	>1.01 and ≤ 1.32 km/km^2
0	Poor Biological Integrity	>1.32 km/km^2

Figure 14. Estimated and categorized densities of adult Arctic Grayling (*Thymallus arcticus*) presented by tertiary watershed in Alberta's Peace River and Slave River watersheds. [*Densities were categorized using Alberta's FSI process (Coombs, 2010; Coombs and Sullivan, 2010). Data certainty is presented using the hatched marks described in the legend.]*

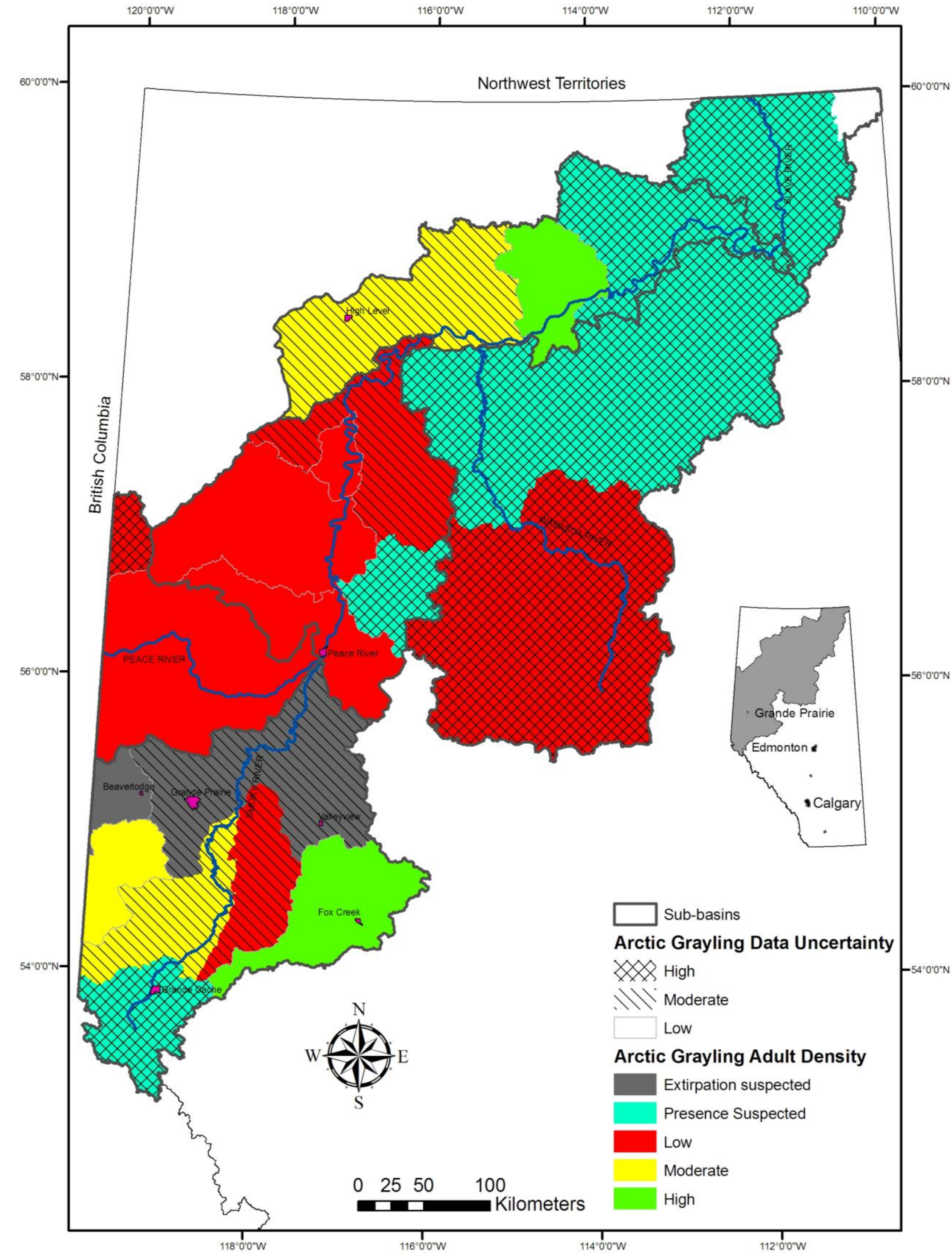


Figure 15. Estimated and categorized densities of adult Bull Trout (*Confluentus salvelinus*) presented by tertiary watershed in Alberta's Peace River and Slave River watersheds. [*Densities were categorized using Alberta's FSI process (Coombs, 2010; Coombs and Sullivan, 2010). Data certainty is presented using the hatched marks described in the legend.]*

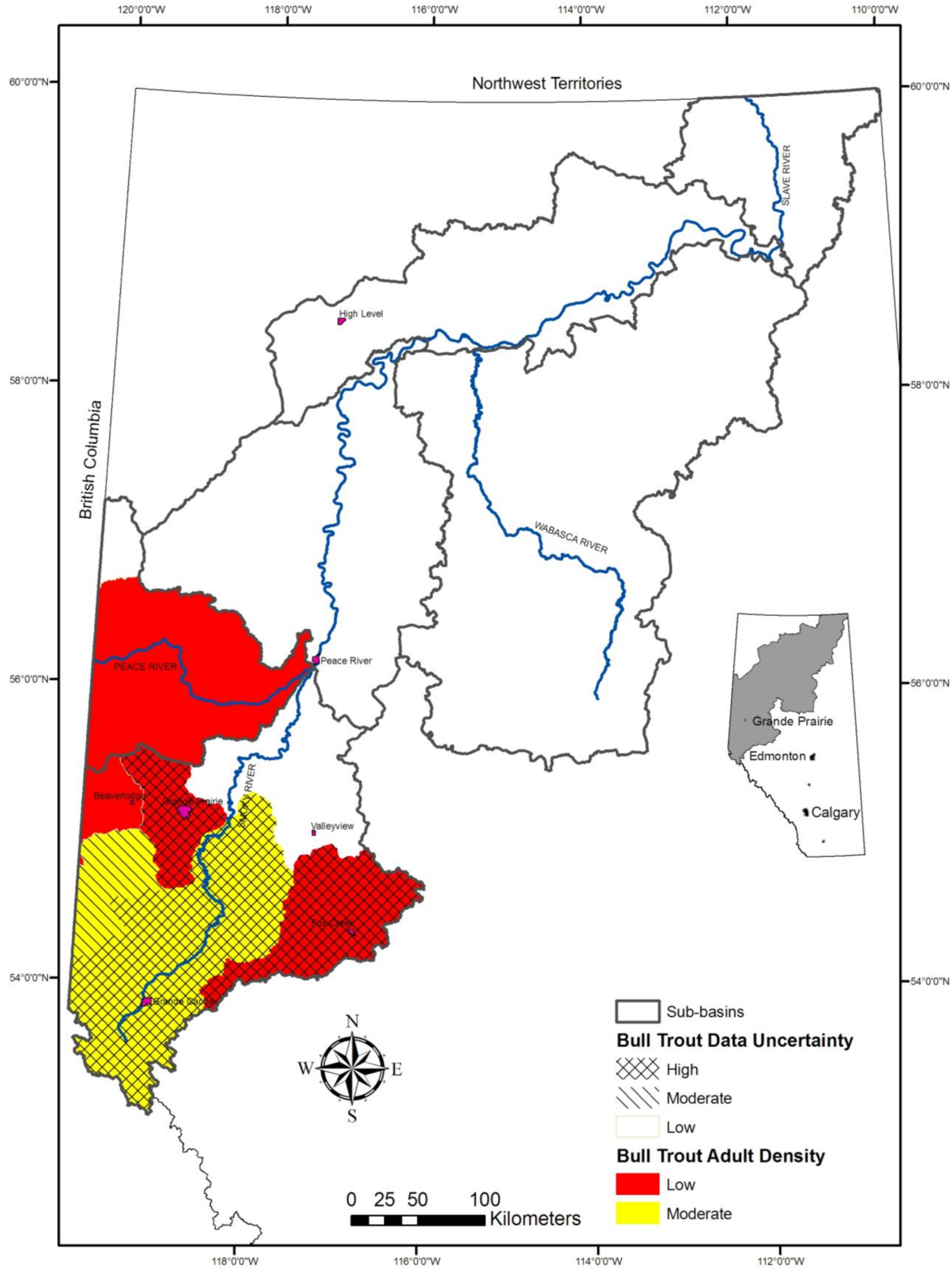


Figure 16. Estimated and categorized densities of adult Walleye (Sander vitreus) in lotic (river) habitats are presented by tertiary watershed in Alberta's Peace River and Slave River watersheds. [*Densities were categorized using Alberta's FSI process (Coombs, 2010; Coombs and Sullivan, 2010). Data certainty is presented using the hatched marks described in the legend.]*

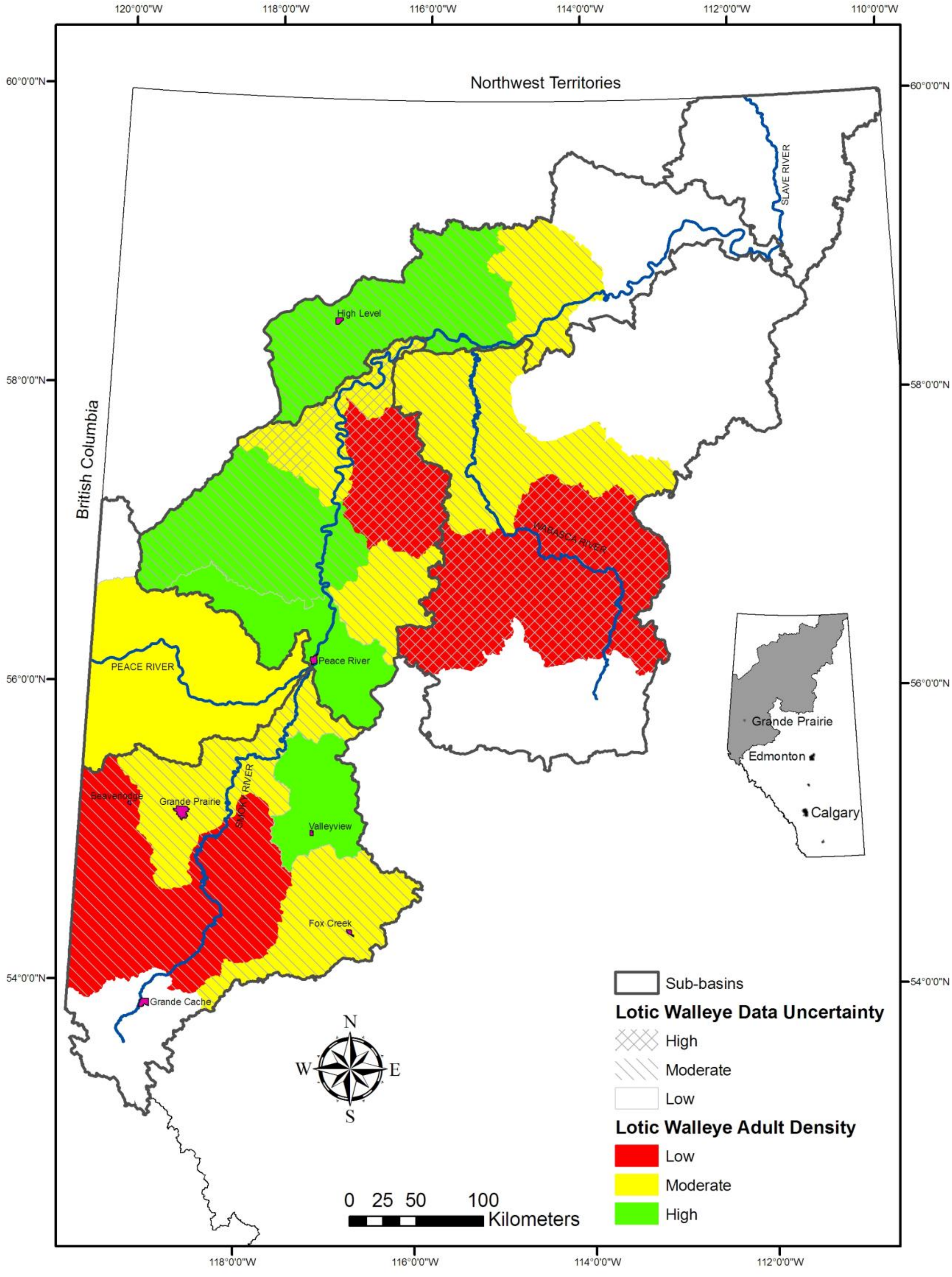
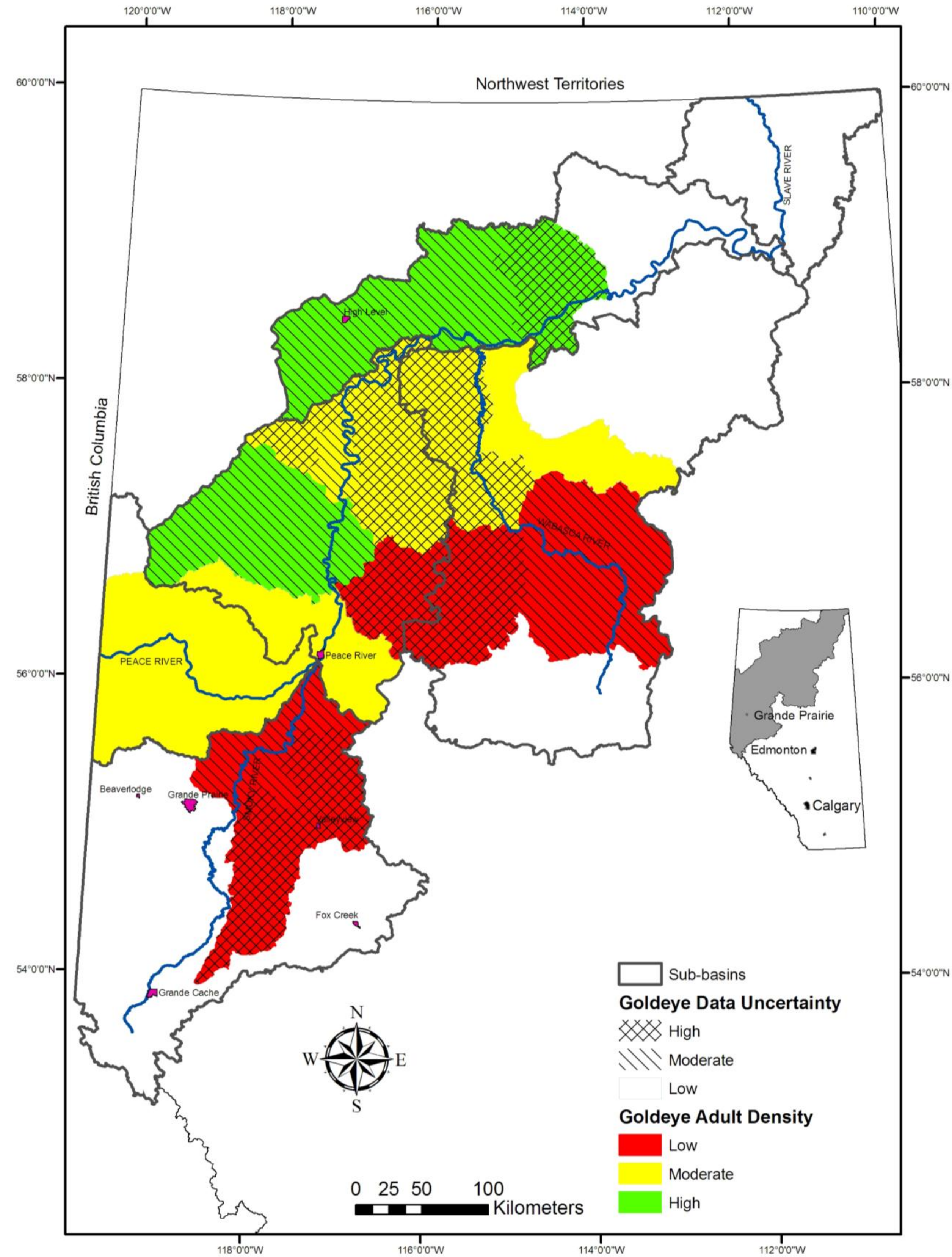


Figure 17. Estimated mean, categorized densities of adult Goldeye (Hiodon alosoides) are presented by tertiary watershed in Alberta's Peace River and Slave River watersheds. *[Densities were categorized using Alberta's FSI process (Coombs, 2010; Coombs and Sullivan,2010). Data certainty is presented using the hatched marks described in the legend.]*



Fish Health and Contaminants

Elevated concentrations of PCBs and organochlorine pesticides were observed in burbot liver, and to a lesser extent mountain whitefish and northern pike muscle, immediately downstream of BKM/municipal effluent sources on the upper Athabasca and Wapiti rivers (Pastershank and Muir 1996). These higher concentrations may be due to localized sources (e.g., chemical spills, pesticide use) and/or higher productivity in nutrient-rich effluents, possibly causing changes in feeding preferences and greater bioaccumulation of contaminants. Later studies done during the EEM program for Weyerhaeuser, however, showed that there was no effect of contaminants detectable in fish in the Wapiti River, and that the effect was rather limited to an effect of enrichment, leading to fatter fish (Golder Associates Ltd. 2004a). Process improvements have likely led to reduced contaminant load in fish.

There were a total of twelve contaminant monitoring studies identified by Golder Associates Ltd. (2007) that dealt with specific contaminants and locations in the Wapiti-Smoky River system. No comprehensive summary of these reports has been prepared, however, and was outside the scope of this report, therefore a review and synthesis of these studies would be useful to provide a basin-wide understanding of contaminant concentrations in fish in the Smoky-Wapiti basin.

The effects of coal mining on fish health were assessed by McKay Associates (2006). Elevated selenium concentrations (above threshold) in Rainbow Trout and Brook Trout in areas influenced by coal mining activity were found and from this, the author inferred deleterious effects in fish populations exposed to coal mining effluents. Another study on Bull Trout showed that most fish (>90%) captured immediately downstream from coal mining activity have concentrations of selenium that would be expected to impair recruitment (Palace et al 2004).

4.1.1.5 Aquatic Habitat

Detailed aquatic habitat assessments have been completed for the Redwillow and Beaverlodge Rivers as part of a study dealing with the status of fish and fish habitat in this watershed (AECOM 2009). It was concluded that habitat in these rivers is seasonally available, its quantity depending on the presence of suitable flow, but that many sites in the watershed, particularly in the Beaverlodge River Watershed, have been heavily impacted by poor agricultural practices such as trampling of the riparian zone, erosion of stream banks, and surface runoff from agricultural fields and livestock rearing facilities (AECOM 2009).

Minor improvements to aquatic habitat were achieved by restoration efforts of the Grande Prairie Riparian Action Team (GPRAT) and preceding watershed groups and programs, including beaver control (beaver trapping and dam destruction), stream bank fencing, tree planting and other best management practices (AECOM 2009). Beaver control was ineffective and was therefore abandoned, but riparian rehabilitation remains part of the local effort to improve aquatic habitat. While the improvements were small compared to the extent of riparian damage throughout the watershed, such efforts increase awareness and community inclusion, are invaluable for future management efforts, and contribute incrementally to improved fish habitat and a more visually appealing riparian area.

4.1.2 Lakes

The Beaverlodge River Watershed contains over 65 lakes and open water wetlands, many more than exist in the Redwillow River Watershed (van der Giessen 1978). Almost all of those lakes are less than 3 m deep and are largely covered by aquatic vegetation (AECOM 2009). Lakes in the Wapiti/Smoky River sub-basin that have been studied in detail include Saskatoon Lake, a slightly saline lake in the agricultural area west of Grande Prairie, as well as recreational lakes in the forested part of the sub-basin: Iosegun, Musreau, Smoke and Sturgeon lakes.

4.1.2.1 Water Quality

Saskatoon Lake has the highest nutrient concentrations within the Peace River Basin (TP = 0.8 mg/L) falling into the category of the most nutrient rich lakes, called hypereutrophic. Soils in the area usually produce naturally nutrient rich lakes, and Saskatoon Lake is shallow with a large rate of internal nutrient loading from the sediments (North/South Consultants 2007). This means that any additional inputs of nutrients, such as from agricultural lands around the lake, will have an even stronger effect on the nutrient status of the lake. Due to the shallow depth of the lake, the water is well mixed and therefore has high DO concentrations during the open-water season. Under ice in winter, however, anoxic conditions have occurred in the past (North/South Consultants 2007).

Sturgeon Lake is also hypereutrophic, despite its mostly forested drainage basin. Some of the high nutrient concentrations are the result of agricultural and wastewater effluent inputs, but the major source of nutrients is internal load from the sediments (Mitchell and Prepas 1990). Iosegun and Smoke Lake are eutrophic and Musreau Lakes is mesotrophic, but they count among the lakes with lowest nutrient concentrations in the Peace River watershed.

For all of these lakes it is not clear how much of the eutrophic to hypereutrophic status has been caused by natural versus anthropogenic factors, as no water quality data are available for the time period before major land clearance and development. The predominance of blue-green algae is an issue as this algae group can produce toxins. Paleolimnological studies that use the sedimentary record to describe past water quality and algae communities are a potential tool to fill this knowledge gap.

4.1.2.2 Sediment Quality

We were not able to locate sediment quality data for lakes in the Wapiti/Smoky River Basin.

4.1.2.3 Non-Fish Biota

Some phytoplankton and macrophyte data were collected in the 1980s in Saskatoon Lake. The phytoplankton community in August 1985 was dominated by the blue-green algae *Microcystis* sp, which is consistent with high nutrient concentrations. An extensive band of vegetation ringed the lake except for a few exposed portions along the south shore and in the northwest bay (Mitchell and Prepas 1990).

Phytoplankton communities in Smoke and Iosegun Lake were dominated by cryptophytes in spring, blue-green algae and diatoms in summer and diatoms in fall. Sturgeon Lake had similar phytoplankton communities, but diatoms also dominated in spring and blue-green algae and Chrysophytes were also abundant in fall (Mitchell and Prepas 1990).

4.1.2.4 Fish

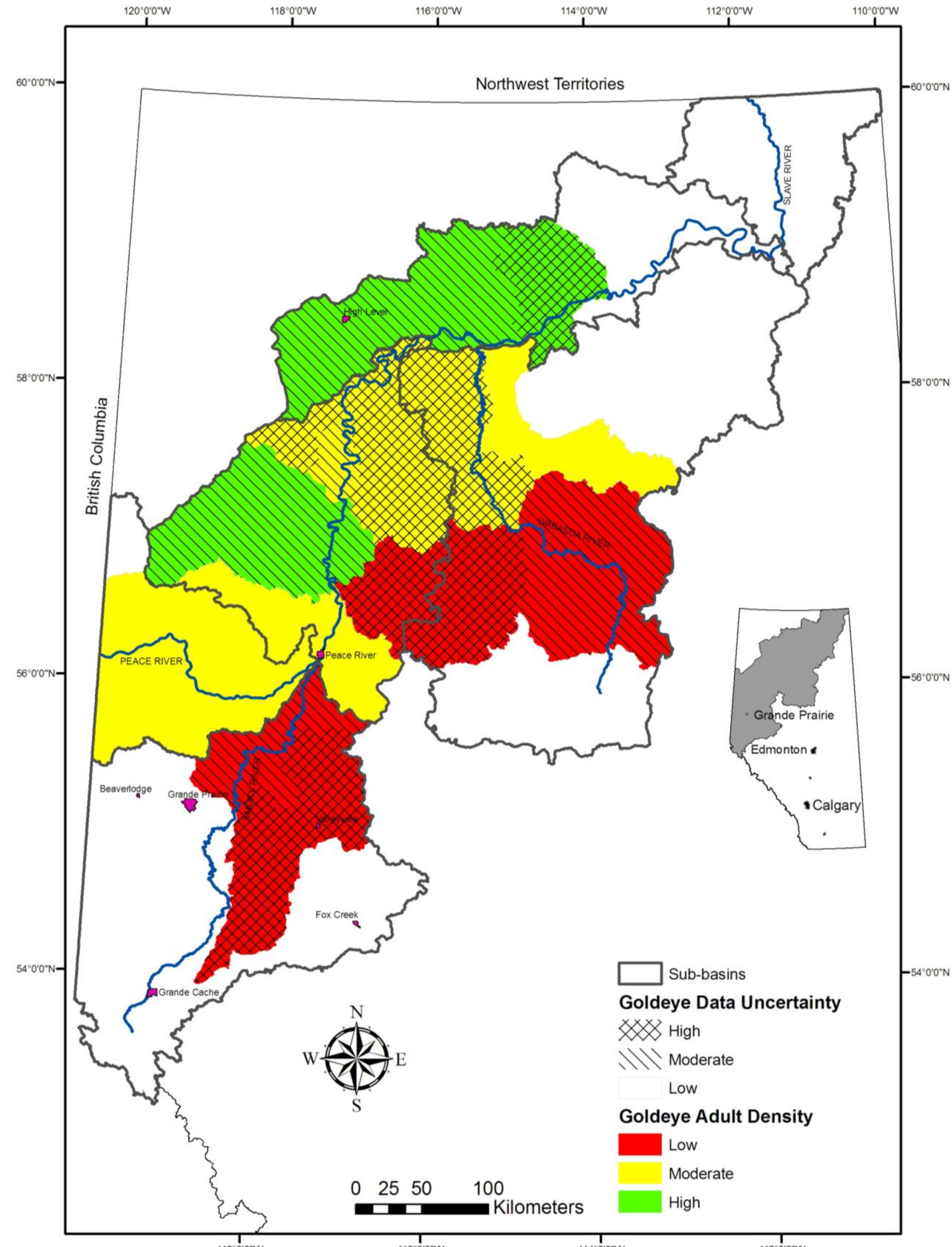
Information on fish species in Saskatoon, Smoke and Iosegun Lakes has been collected by the provincial government and is available in the Atlas of Alberta Lakes (Mitchell and Prepas 1990). The main water quality concern for fish communities in these lakes and other eutrophic lakes in the Peace Basin are the high algae productivity due to high nutrient concentrations that occasionally drive the oxygen low enough to cause fish kills (Saskatoon and Smoke Lakes), and overharvesting (Smoke and Iosegun Lake).

Walleye populations vary in density across lakes, with low densities in Snipe Lake, moderate densities in Iosegun Lake and high densities in Smoke and Sturgeon Lake (Table 5).

Table 5. Estimated densities of adult Walleye in lakes within the Peace River watershed study area.

Sub-basin	Lake	Adult Density Category	Adult Data Un-certainty
Smoky-Wapiti	Snipe	Low	Low
	Iosegun	Moderate	Low
	Smoke	High	Low
	Sturgeon	High	Low
Wabasca	Loon	Low	High
	Vandersteen	Low	High
	Wadlin	Low	Moderate
	Gods	Low	Low
	South Wabasca	Low	Low
	Utikuma	Low	Low
	Peerless	Moderate	High
	Graham	Moderate	Low
	North Wabasca	Moderate	Low
	Round	Moderate	Low
	Utikumasis	Moderate	Low
Central Peace	Sawn	Low	Low
	Haig	High	Low
Lower Peace	Wentzel	Low	High
	Caribou	Moderate	High

Figure 18. Estimated mean and categorized densities of adult Walleye (*Sander vitreus*) in lentic (lake) habitats presented by tertiary watershed in Alberta's Peace and Slave River watersheds. *[Densities were categorized using Alberta's FSI process (Coombs, 2010; Coombs and Sullivan,2010). Data certainty is presented using the hatched marks described in the legend.]*



4.1.2.5 Aquatic Habitat

A number of wetlands and lakes in the Wapiti River basin west of Grande Prairie are used by the Trumpeter Swan as breeding habitat, a species which is listed as vulnerable in Alberta (Hervieux 2000). Approximately 10% of the Rocky Mountain population of Trumpeter Swans and over 1% of the global population nest and stage in the Grande Prairie area of northwestern Alberta (Hervieux 2000). Ducks Unlimited erected 20 water control structures in the Beaverlodge and Redwillow River watersheds in order to sustain water levels for the swans (AECOM 2009), which are part of the implementation of the North American Waterfowl Management Plan (NAWMP) (Hervieux €2000).

4.1.3 Summary

The Wapiti/Smoky sub-basin is a naturally diverse area, has the largest concentration and number of anthropogenic stressors on AEH, and is by far, the most well-studied sub-basin in the Peace River watershed. There is an overall spatial difference between the southern portion of the sub-basin in the "green zone", which is generally healthy compared to the northern portion that has seen significant impacts from human activities. The southern areas have high biological integrity based on road density, a good presence of sensitive fish populations (although some data gaps remain), and only localized concerns over impacts of coal mining on streams in the foothills as well as overfishing in lakes. The northern areas north and west of Grande Prairie ("white zone") have low biological integrity as indicated by road density, impaired or locally extirpated sensitive fish populations, high nutrient levels in agricultural streams and most lakes and significant nutrient enrichment effects on the lower Wapiti River due to cumulative point-source discharges.

A good understanding of the effects of municipal and pulp mill effluent, and agricultural activities on the direct receiving waters has been developed by comprehensive case studies. In the Beaverlodge River subwatershed the water quality effects of agriculture appear to be limited to local surface waters due to higher dilution capacity and less intensive agriculture in lower reaches, but nutrient enrichment and habitat degradation of agricultural streams has been detrimental to fish populations over a larger area. The effects of the Grande Prairie WWTP and Weyherhaeuser pulp mill point discharges are detectable at a large distance downstream in the Smoky River. While the effects of point discharges in the lower Wapiti River are well studied and major upgrades are being implemented to improve effluent quality, non-point sources of nutrients and other pollutants to smaller agricultural streams and their cumulative downstream effects are not well quantified and it is uncertain what efforts have been made to mitigate agricultural non-point-source effects.

Another uncertainty is the combined effect of forestry, mining and linear features on AEH in smaller water courses in the foothills. Biological integrity based on road densities appears to be high, but high cutlines density and low Bull Trout densities in the south-eastern corner of the watershed may be an indication that AEH is under pressure.

Lakes in the area are important for recreational use and have great aquatic habitat value, in particular for the Trumpeter Swan, but it is not clear how much the lakes have changed compared to historical conditions and to what extent the eutrophic to hypereutrophic status has been caused by natural versus anthropogenic factors. Fish populations are threatened by the impacts of agriculture, roads and other land uses on aquatic habitat and the impact of overfishing on fish populations, in particular in the northern part of this sub-basin.

4.2 UPPER PEACE

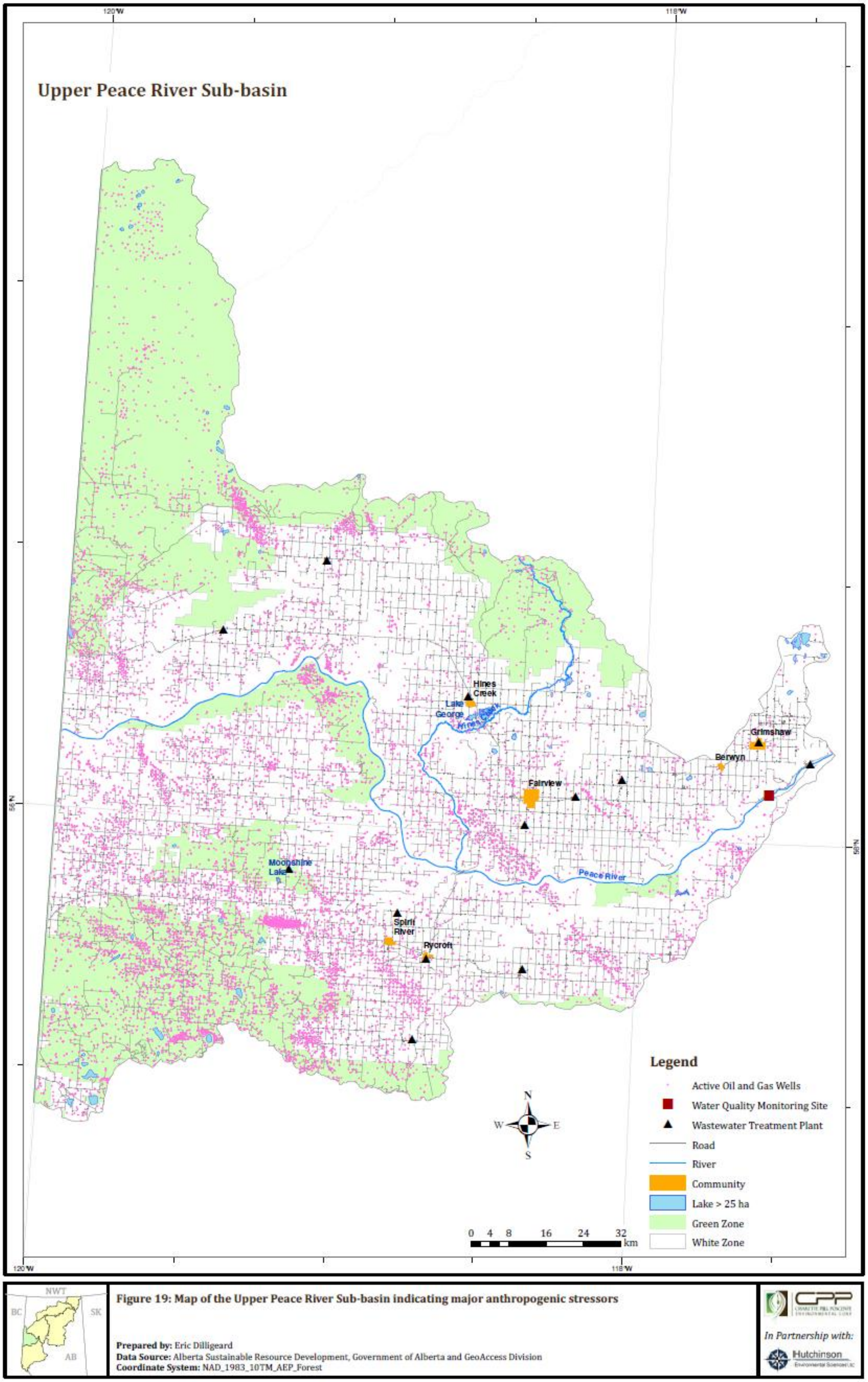
OVERVIEW

The Upper Peace sub-basin includes the reach of the Peace River stretching from the B.C. border to the Smoky River confluence and the area that drains to this reach. In this sub-basin, a number of small rivers and creeks are located, including Hines, Jack, McLean, Lathrop and Sweeney Creeks and Eureka, Clear, and Montagneuse Rivers, and a number of lakes, including George Lake.

The water quality conditions in the main reach are largely dictated by upstream water quality in B.C and to a smaller degree by tributary and non-point source inputs within Alberta (North/South Consultants 2007). In B.C. portion of the watershed, there is some agricultural and forestry land use, there are two pulp mills discharging to the Peace River and the Bennett Dam regulates water flow.

The headwater areas within this sub-watershed are partly forested, but agriculture is the main land use in lower reaches of tributaries and along the banks of the Peace River. Road density is moderately high, indicating moderate biological integrity in the tributaries (Figure 5). An active steward of the eastern portion of this sub-basin and the western portion of the Central Peace sub-basin is the Clear Hills Watershed Initiative.

Figure 19. Map of Upper Peace River Sub-basin and major anthropogenic stressors.



4.2.1 Rivers

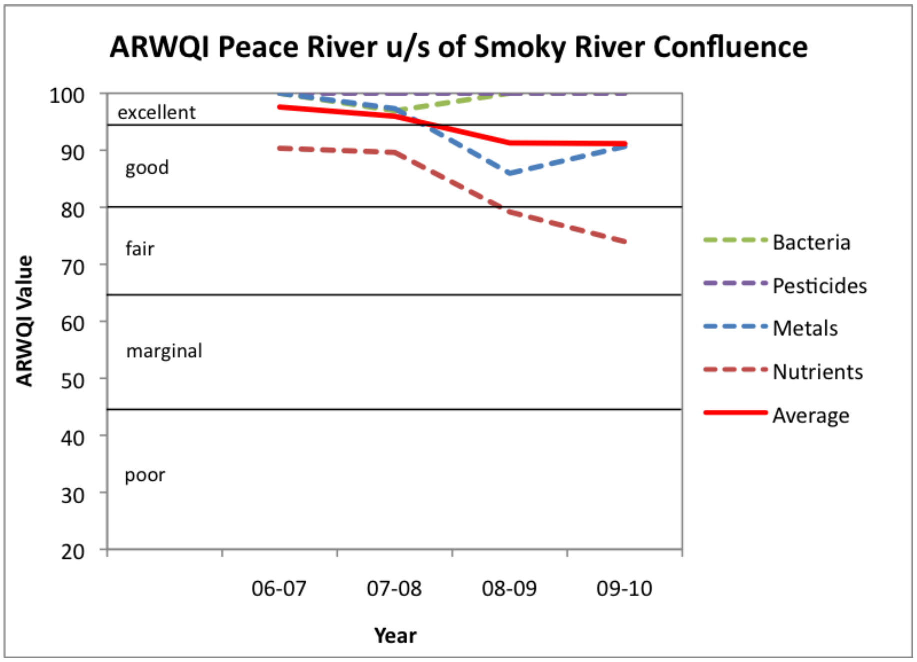
4.2.1.1 Water Quality

Water quality close to the provincial border on the BC side has been monitored weekly at a long-term federal site on the Peace River above the Alces River since 1984. While this station remains active, the corresponding long-term monitoring site on the Alberta side, at the Town of Dunvegan, was monitored monthly from 1978 to 1997, when it was deactivated (North/South Consultants 2007). A new LTRN station was established in 2006 just upstream of the Smoky River confluence, near Shaftesbury. In addition, the Clear Hills Watershed Initiative (CHWI) has monitored water quality in creeks and rivers in this sub-basin since 2007 (CHWI 2009), although some key water quality parameters, such as total phosphorus and total nitrogen, were not presented and data analysis was limited.

Data summarized by Shaw et al (1990) showed that the Peace River mainstem in this reach was characterized by low concentrations of many water quality parameters (e.g., TDS, nutrients, trace metals, TSS) for most of the year (North/South Consultants 2007). Suspended sediment concentrations were elevated during high flows, as were some total metals, due to B.C. tributaries that drained agricultural and forested land with highly erodible soils. With regard to dissolved constituents, the mainstem Peace River exhibited comparatively low seasonal and spatial variability that is attributed to the Cordilleran origin of the river (i.e., water from hundreds of mountain streams), the disproportionately large size of the river compared to its tributaries and point sources, and the release of fairly homogenous water from the WAC Bennett dam. Dissolved oxygen concentrations in this stretch of the river are typically high and compliant with the ASWQG during all seasons (Shaw et al. 1990, in North/South Consultants 2007).

Just upstream of the Smoky River confluence, water quality has been excellent in 2006-2008 and good in 2008-2010 according to the Alberta water quality index, (Figure 20). The nutrient index was consistently the lowest with good to fair ratings, again, likely due to high values associated with naturally high sediment content under high flow. A seasonal analysis of LTRN data would be required to confirm this pattern and to investigate the reasons of somewhat lower ratings in the last three years.

Figure 20. Alberta River Water Quality Index for the Peace River upstream of the Smoky Confluence.



An average of 'fair' water quality was found in the agricultural area of Hines Creek during a study from 1999-2002, compared to "poor" water quality in Bear Creek and Kleskun Drain in the Wapiti watershed. Hines Creek also had higher (better) scores according to the pesticide and bacteria sub-indices, than Bear Creek and Kleskun Drain (North/South Consultants 2007). This better rating was attributed to a larger watershed area and lower intensity-agricultural practices in Hines Creek compared to the other two creeks. Hines Creek was still consistently non-compliant with TP and TN ASWQGs, but compliant with the ammonia and nitrate CCME WQGs and was classified as eutrophic based on average total nutrient FWMCs.

The Eureka, Clear and Montagneuse Rivers showed elevated bacteria numbers (most samples ca. 2000 total coliforms/100 mL and two rivers with E.coli numbers of 200/100 mL and higher, CHWI 2009), both parameters exceeding the CCME WQGs for irrigation use, which are 1000/100mg/L for total coliforms and 100/100 mL for E.coli. While total nutrient values (TP, TN) were not presented, the orthophosphate concentrations were somewhat elevated, ranging from 0.008 to 0.07 mg/L (CHWI 2009) and with two out of five measurements exceeding the AWQG for *total* phosphorus. As orthophosphate is a fraction of TP, these samples exceeded the TP WQG at least in these samples.

The high pathogen numbers are of concern for the human population, as the majority of drinking water in the region is obtained from surface water, either from streams or from dugouts and lakes are used for recreation. High nutrient concentrations are of concern for AEH for their eutrophication effect and resulting low oxygen that can kill fish.

4.2.1.2 Sediment Quality

Recent monitoring revealed that PCB concentrations in the Peace River upstream of the Smoky River confluence in 1997 were low or close to detection limits (Hazewinkel and Noton 2004). This was in direct contrast to previously reported high concentrations at this site in 1994/1995 by Carey et al. (1997). In consideration of the comprehensive nature of the 1997 survey, Hazewinkel and Noton (2004) concluded that the elevated 1994/95 concentrations may have been anomalous.

A follow-up study may be required to confirm these conclusions. Overall, PCB concentrations in the upper Peace River appeared to be similar to background concentrations in the upper Wapiti and Smoky rivers (North/South Consultants 2007).

4.2.1.3 Non-Fish Biota

The Peace River upstream of the Smoky River confluence was classified as oligotrophic according to TP and TN, but mesotrophic according to available periphyton historical data (North/South Consultants 2007). Data collected in 1988-1991 showed that benthic algal biomass in the Peace River was still considerably lower than reported for other major rivers in the province, likely due to its low nutrient concentrations and large fluctuations in suspended sediment levels, causing unfavourable light conditions. Within the Peace River basin, benthic algal biomass was most prevalent upstream of the Smoky River confluence, most likely due to favourable habitat conditions (substrate and water clarity) (Carr and Chambers 1999 in North/South Consultants 2007).

Benthic invertebrate surveys were conducted in the entire Peace River in the 1980s by AEW. The proportion of Nematoda (round worms) and Chironomidae (midge larvae) of total abundance tended to increase with distance downstream. In general, Ephemoptera, Plecoptera, and Trichoptera (EPT) taxa were most prevalent in the upper reach close to the border. Benthic communities were most abundant upstream of the Smoky River (North/South Consultants 2007). Given the generally good water quality in the Peace River, these patterns are most likely due to differences in habitat

4.2.1.4 Fish

While we did not locate any fish-related literature specific to this basin, the transboundary report prepared by the BC Ministry of Environment and Alberta Environment (2009) quoted “The General Status of Alberta Wild Species (2000)”, which talks about fish communities in the Peace River at large. Five fish species designated as “sensitive” are found in the main stem Peace River and some of its tributaries – Bull Trout (*Salvelinus confluentus*), Arctic Grayling (*Thymallus arcticus*), largescale sucker (*Catostomus macrocheilus*), Northern pikeminnow (*Ptychocheilus oregonensis*), and Northern redbelly dace (*Chrosomus eos*). In the Peace River basin, habitat degradation due to flow regulation affects some species at risk, including the Bull Trout and the Williston watershed population of Arctic Grayling. The Peace River basin serves as critical habitat for the largescale sucker – this species is found only in the Peace River drainage. Its numbers are expected to be low, but there is no official count. The northern pikeminnow is found only in the Peace River – it is rare, but actual numbers are unknown (MRBB 2004).

Based on the information on focal species collected for this report, densities of Arctic Grayling and Bull Trout are low (Figures 14 and 15) while densities of Walleye and Goldeye are moderate (Figures 16 and 17). These patterns are similar to the Smoky/Wapiti Basin in that sensitive species adapted to smaller streams have low densities, likely due to the cumulative stressors from agricultural land use, while Walleye and Goldeye are less impacted because they inhabit larger rivers with good water quality, such as the Peace mainstem. Road densities indicate a moderate Index of biotic integrity (Figure 5) and the fish density data confirm this pattern.

4.2.1.5 Aquatic Habitat

Analysis of historical air photos indicates that the Bennett Dam in British Columbia has had a widespread effect on the downstream morphology of Peace River and that these changes are ongoing. Near the proposed Dunvegan hydroelectric development site in the Upper Peace reach, there has been a loss of sidechannels, a 10% reduction in average river width, vegetation development on former river bars, progradation of tributary fans and downcutting of the channels flowing over the fan surfaces. Analysis of historical river cross-section surveys and hydraulic geometry data collected at the Water Survey of Canada's Dunvegan stream gauging site indicate that progradation of the Hines Creek fan is locally resulting in a narrower and deeper river channel. Construction of the proposed Dunvegan Project will reduce the downstream supply of coarse sediment, but widespread channel degradation or other significant downstream morphologic changes are not expected (Miles and Associates 2000).

Additional data collected as part of the Environmental Impact Assessment for the Dunvegan project found that the mainstem Peace River provides limited amounts of high quality fish habitat in the Dunvegan study area. The channel is relatively shallow here and flow velocities are usually high, which limits its potential as overwintering habitat. Unique instream habitats like backwaters and shoals are present, but not abundant (BC Ministry of Environment and Alberta Environment 2009). Impacts to fish communities in this river reach have been estimated to be minor although other information sources may indicate otherwise (Wilcox pers. comm.)

4.2.2 Lakes

Lakes in the Upper Peace basin include Moonshine Lake, George Lake, and the smaller Black Duck, Gerry and Boundary Lakes. With the exception of Moonshine Lake, which is monitored by Alberta Environment and Water, water quality data on these water bodies is lacking.

4.2.2.1 Water Quality

Moonshine Lake is a small, shallow, eutrophic lake in the forested headwaters in the southern end of the Upper Peace sub-basin. Low oxygen events and resulting fish kills have occurred in the lake, in response to which an aeration system was installed in the lake (Mitchel and Prepas 1990). The shallow George Lake, located in the northern portion of the sub-basin displays similar problems, with frequent algae blooms. While data are lacking for this site, the George Lake Aquatic Society has been established not only to maintain the campground, but to also find solutions to water quality problems (CHWI 2008).

4.2.2.2 Sediment Quality

We are not aware of any sediment quality studies in lakes of the Upper Peace sub-basin, although some local data may be available from the environmental studies undertaken in the vicinity of the proposed Dunvegan hydropower development.

4.2.2.3 Non-Fish Biota

Apart from the observation of a dominance of the blue-green algae genus *Aphanizomenon* in Moonshine Lake 1987 by the Fish and Wildlife Division, no data are available for non-fish biota in lakes of the Upper Peace sub-basin. The blue-green algae dominance confirms the high nutrient status of Moonshine Lake.

4.2.2.4 Fish

Information on fish species in Moonshine Lake is available in the Atlas of Alberta Lakes (Mitchell and Prepas 1990). Walleye was not reported in lakes of the Upper Peace River basin, based on the FWMIS (Table 3).

4.2.2.5 Aquatic Habitat

We could not locate any information on habitat specific to lakes in this sub-basin.

4.2.3 Summary

The Upper Peace sub-basin is lacking any major point-sources of pollution in Alberta, with the major land uses being forestry, oil, gas, agriculture and the WAC Bennett dam. In the BC portion of the watershed upstream of this reach there are two pulp mills and agricultural and forestry land use. There is historical evidence for good water and sediment quality as well as health of aquatic biota for the upper Peace River reaches up to 1997. As the Peace River water quality in this reach mostly depends on upstream processes, monitoring at the federal site just upstream of the B.C. border provides useful data to characterize water quality of the Upper Peace mainstem on an ongoing basis and can be compared to data collected at the new LTRN site at Shaftesbury, which is located at the most downstream end of the sub-basin.

Information on the aquatic health of tributaries and lakes in the Upper Peace sub-basin is scarce. Limited data available from agricultural streams indicate enrichment in nutrients and bacteria. Low densities of sensitive fish species such as Bull Trout and Arctic Grayling demonstrate that aquatic health has been impaired. Lakes are nutrient rich, displaying algae blooms and occasional fish kills due to anoxia. The relative importance of naturally nutrient-rich soils and land use for these patterns, however, is unknown. Surface water quality issues are of great concern for the local population who depends upon surface water resources for drinking water, life stock watering and recreation.

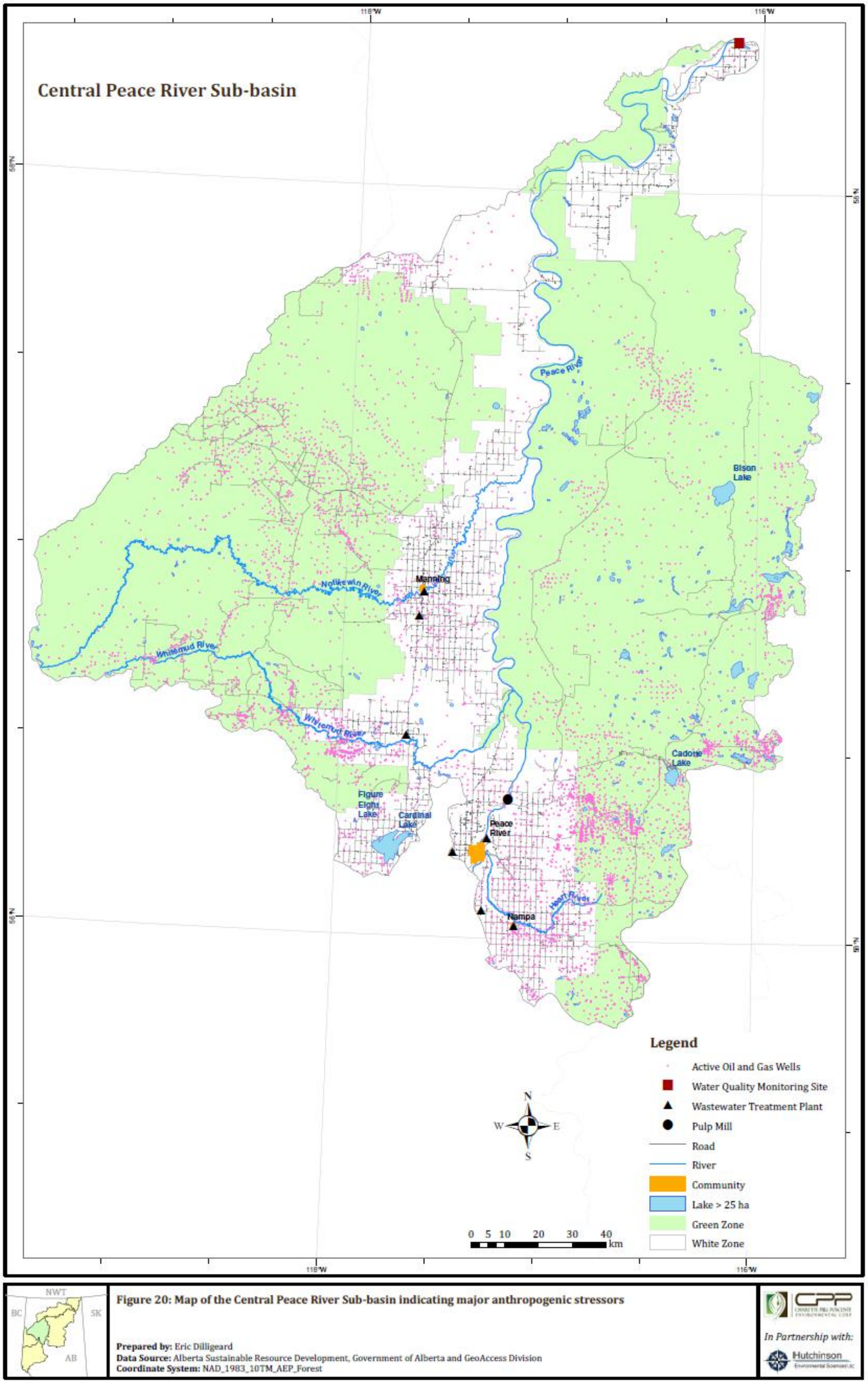
4.3 CENTRAL PEACE

OVERVIEW

The Central Peace sub-basin includes the Peace River between the confluence of the Smoky River at the upstream end and Fort Vermillion at the downstream end and the area draining to this reach. Important other tributaries in this sub-basin are the Whitemud, Notikewin and Heart Rivers and a number of creeks and lakes.

Major potential stressors in the Central Peace sub-basin include oil and gas exploration and extraction, forestry, agriculture (southern end of the watershed), and wastewater effluents from both the town of Peace River and the pulp and paper mill DMI. In situ oil sands development occurs in this sub-basin and is expected to expand in the future. Notably, cutline density is highest in the tertiary watershed north-east of the town of Peace River, along with the neighbouring watershed in the Wabasca sub-basin.

Figure 21. Map of Central Peace River sub-basin and major anthropogenic stressors.



4.3.1 Rivers

4.3.1.1 Water Quality

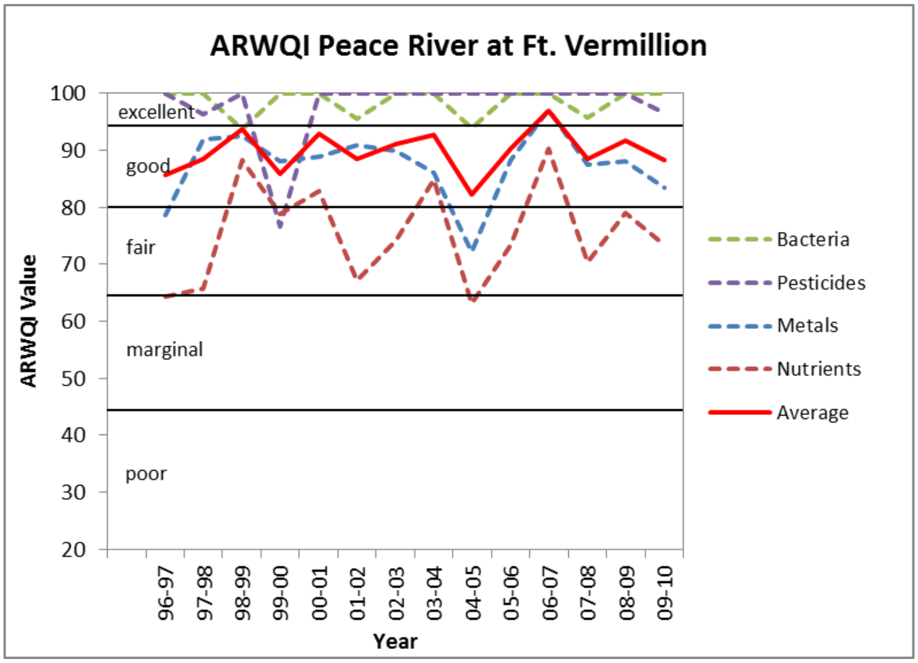
The concentration of most water quality parameters in the Peace River generally increase from the Smoky River confluence to Fort Vermilion, as part of a progressive longitudinal increase along the length of the river (Shaw et al. 1990). Thus, water quality in this middle reach tends to be intermediate, relative to that of the upper and lower reaches. Middle reach water quality is affected by several factors that include: upstream mainstem loads and water quality, tributary and diffuse non-point source inputs, point source inputs (Peace River WWTP and the DMI pulp mill), and groundwater inflow. Smoky River water does not mix fully with Peace River water for at least 100 km downstream (Shaw 1990), probably resulting in variable water quality across the river width.

Cumulative tributary inputs were thought by Shaw et al. (1990) to exert the largest influence on the Peace River mainstem water quality input. The Smoky River represents the largest tributary input, mainly based on its large discharge volume. Other tributaries tend to have higher concentrations of many water quality constituents, but relative to the Peace River mainstem, their discharge volume and therefore individual loading to the Peace River is small (North/South Consultants 2007).

In May 2005, low dissolved oxygen (DO) concentrations were measured under ice at Fort Vermillion and an investigation was completed in order to assess the likely causes. Results indicated that low DO was associated with a spring freshet peak from tributaries, mainly from the Smoky River. High spring temperatures caused early and high discharge containing high BOD, which consumed DO under ice in downstream Peace River (Charette and Friesenhan 2009). As accepted climate change scenarios for Alberta predict earlier spring thaw and increased extreme events (Sauchyn 2006), it is possible that a similar event will occur again.

According to the ARWQI, water quality at the LTRN site at Fort Vermilion has been 'good' since the index was first applied in 1996 (Figure 22). On average, water quality in terms of metals, pesticides and bacteria has been 'excellent' or 'good', whereas nutrient water quality has been 'fair'. The lower nutrient sub-index ratings have largely been due to frequent non-compliance with the TP ASWG likely during spring high flow events. Total and dissolved nitrogen forms have been low and generally compliant with relevant WQGs. Consequently, the Peace River at Fort Vermilion was classified as oligotrophic according to TP and TN concentrations. DO concentrations in recent years at Fort Vermilion have been compliant with the ASWQG (North/South Consultants 2007). Recently, in fall 2002 EEM by DMI found no clear difference in nutrient and DO concentrations between sites upstream of the mill effluent discharge and sites downstream (Stantec 2004). Recent median TSS concentrations at Fort Vermilion extended across a wider range of variability compared to upstream, while recent TDS concentrations were slightly higher (North/South Consultants 2007).

Figure 22. Alberta River Water Quality Index for the Peace River at Fort Vermillion, from 1998 to 2010.



In a recent review, Anderson (2005) reported no significant changes from 1996–2004 at Fort Vermilion, in individual pesticide concentration, total pesticide concentration per sample, or number of pesticides per sample. The majority of pesticides analysed at this site during this time period were below detection, except for 1999-2000, when five pesticides were detected, but these were below available CCME WQGs (North/South Consultants 2007).

Water quality was monitored from 2004 to 2009 in the watershed of the Heart River, which discharges to the Peace River in the town of Peace River (Aquality Environmental Consulting Ltd. 2010). Samples collected in spring and summer in Heart River and a tributary, Myrtle Creek, showed elevated nutrient, bacteria and pesticide concentrations. The high total coliform concentrations were of little concern, as the fecal coliform (*E. coli*) concentrations that are attributed to human and animal waste were below WQGs. Total phosphorus and total nitrogen, however, consistently exceeded the AWQGs and pesticide concentrations were high. These patterns are a concern for residents of Nampa and water Co-op users who acquire their drinking water from the Heart River (Aquality Environmental Consulting Ltd. 2010).

The tributaries Notikewin, Cadotte, Whitemud, Wolverine and Keg Rivers were sampled as part of the large 1988 survey completed by AEW (Shaw 1990). They were generally found to contain higher concentrations of TDS, colour, dissolved nutrients and dissolved organic carbon (DOC) than the Peace River. The main reason for this difference is the different geological and soil origin of Peace River water (Rocky Mountains) versus tributary water (sedimentary soils and wetland-rich forests), but agricultural land use may enhance these trends. More recent data are required to assess the current status of tributaries in the Central Peace sub-basin. Relationships between watershed properties (land cover, soils, etc) and tributary water quality should be examined in the future.

In response to health concerns associated with emissions from the Peace River oil patch and resulting complaints filed by residents of Three Creeks with the Energy Resources Conservation Board, AEW commissioned a monitoring study of snow, surface water and soil for contaminants in the area. Although hydrocarbons were detected in some of the samples, concentrations were below

Water and Soil Guidelines (Alberta Innovates – Technology Futures 2011). The study concluded that based on this evidence, there are no significant deposits of PAHs in the sampled areas to indicate any health issues originating from deposition to the surrounding communities from PAHs.

Another study targeted snow, soil and water in the Peace River Three Creeks area in response to public concerns and did not find any evidence of significant organic contaminant deposition on snow, water, and soil (Drozdowski et al 2011).

4.3.1.2 Sediment Quality

Sediment quality monitoring conducted by Stantec (2004) to meet the provincial monitoring requirements of the Daishowa-Marubeni International (DMI) pulp mill (1994-1999), reported that concentrations of dioxin, furans, and chlorinated phenolic compounds, were either low or undetectable, in sediments upstream and downstream from the mill (North/South Consultants 2007). Daishowa-Marubeni International Ltd. eliminated the use of elemental chlorine as a bleaching agent at the mill in 1998, in favour of chlorine dioxide, which minimizes the amount of organochlorine compounds produced. The following year there were no dioxin or furan congeners detected in sediments upstream or downstream of the effluent discharge (North/South Consultants 2007).

4.3.1.3 Non-Fish Biota

The Peace River at Fort Vermilion was classified as oligotrophic according to TP and TN concentrations, as well as planktonic and benthic algal biomass (North/South Consultants 2007). Within the Peace River, benthic algal biomass tended to decrease with distance downstream, in comparison with reaches upstream of the Smoky River confluence (Shaw et al. 1990). Peace River channel substrates changed with distance downstream from erosional to depositional, erosional substrates being more suitable for periphyton colonization. Furthermore, TSS/turbidity concentrations increased with distance downstream, leading to more scouring and lower light penetration. Therefore the spatial patterns in periphyton biomass within the Peace River are likely a result of different habitat conditions rather than nutrient concentrations.

Peace River benthic invertebrate communities were recently sampled (fall 1998, 2002) within the vicinity of the DMI pulp mill, downstream from the Smoky River Confluence. Historically, Peace River benthic communities were sampled at various sites by AEW in 1983 (spring, fall) and in 1988 (summer, fall; Noton et al. 1989, Shaw et al. 1990). Shaw et al. (1990) described longitudinal trends in Peace River benthic communities based on the historical fall 1988 synoptic survey. Benthic communities in the Peace River tend to reflect channel geomorphology, hydrological and water quality conditions, and substrate characteristics, along the length of the river.

The proportion of Nematoda (round worms) and Chironomidae (midge larvae) of total abundance tended to increase with distance downstream, likely due to changing substrate, with more sediment deposited downstream and more erosional habitat available upstream. Benthic communities were most abundant upstream of the Smoky River, likely due to favorable erosional habitat, but were most diverse within the middle section of the river, possibly due to a mix of erosional and depositional habitat.

4.3.1.4 Fish

A detailed report on fish communities and their relationship to landscape and aquatic habitat characteristics in the Notikewin River has been prepared by Scrimgour et al. (2003). The main predictors of fish communities were instream-habitat characteristics, such as slope, depth and substrate. The authors point to a paucity of data (monitoring) as being the largest impediment to managing fish and in assessing stress to fish populations. Results show potential for transfer of observed relationships between fish and land use in the Notikewin River to other watersheds.

All reports dealing with contaminant load in the Central Peace reach are based on data that are at least 20 years old (Golder Associates Ltd. 2007). Given the improvements in treatment processes of pulp mills and municipal sewage treatment plants, these are not relevant for an assessment of current AEH.

Densities of Arctic Grayling are mainly low (Figure 14) and Bull Trout is absent (out of distribution range) in the Central Peace River basin. Walleye is present in high densities and Goldeye is present in high to moderate densities (Figure 17). Although the Index of Biological Integrity based on road densities is high when averaged over tertiary watersheds, road density in smaller, populated areas as well as nutrient enrichment in agricultural streams may be sufficient to affect fish populations, as indicated by the low Arctic Grayling densities.

4.3.1.5 Aquatic Habitat

We could not locate any information on habitat specific to rivers in this sub-basin.

4.3.2 Lakes

Two lakes in this sub-basin are monitored by Alberta Environment and Water: Figure Eight Lake and Cardinal Lake. These data have been summarized in detail in the Atlas of Alberta Lakes (Mitchell and Prepas 1990) and briefly in North/South Consultants (2007). Also, six lakes were studied as part of a Master's thesis in the Boreal Uplands Region of the Buffalo Head Hills (Charette 2001).

4.3.2.1 Water Quality

Cardinal Lake is hypereutrophic and Figure Eight Lake is eutrophic (North/South Consultants 2007). Figure Eight is an important recreational site, where algae blooms and low oxygen concentrations caused concerns in the 1970s. Because of this, several techniques including chemical treatment, aeration, and liming were applied to control the water quality problems in the 1980 (Mitchell and Prepas 1990).

Six lakes studied in the Buffalo Head Hills (Charette 2001) have watersheds that have relatively little human disturbance. Perhaps because of this, lakes were for the most part on the upper end of mesotrophic, which seems consistent with natural lakes on the Boreal Plain.

4.3.2.2 Sediment Quality

We are not aware of any sediment quality data for lakes in the central Peace sub-basin at this point.

4.3.2.3 Non-Fish Biota

The dominant algae of Figure Eight Lake in most summers is the blue-green, *Aphanizomenon flos-aquae* (Mitchell and Prepas 1990), indicating a highly eutrophic environment.

4.3.2.4 Fish

Information on fish species in Figure Eight Lake is available in the Atlas of Alberta Lakes (Mitchell and Prepas 1990) and probably on several lakes in the basin from the FWMIS. Oxygen concentrations are often low enough to cause winter kills. Data on lake Walleye populations are scarce for this sub-basin, except a low density rating for the tertiary subwatershed north-east of Peace River.

4.3.2.5 Aquatic Habitat

We could not locate any information on habitat specific to lakes in this sub-basin.

4.3.3 Summary

The central Peace sub-basin is somewhat similar to the Upper Peace basin, in that water quality and likely aquatic health is much better in the Peace River mainstem when compared with tributaries and lakes in the basin. While the Peace River mainstem may show decreased water quality due to the input of its largest tributary, the Smoky River, these impacts have not been quantified and it may be difficult to do so due to the large volumes of the Peace River. Conditions leading to a low oxygen event in 2005 were associated with exceptionally early spring freshet in the Smoky basin, which could become more frequent under expected climate change.

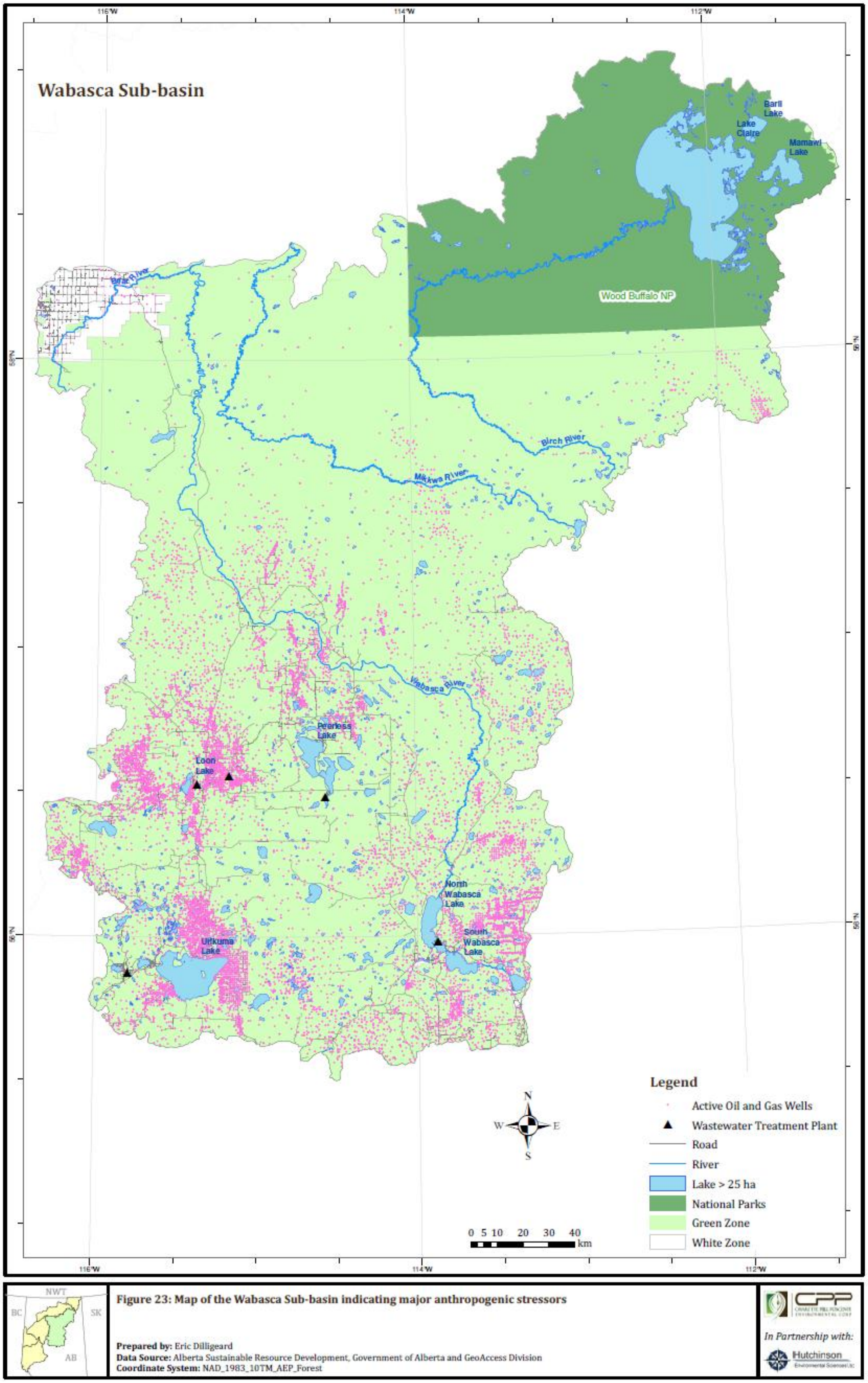
Lakes and Streams in the sub-basin, on the other hand, are naturally nutrient rich and if located in the "White Zone", receive additional nutrient loads from agriculture, and potentially, from land disturbance associated with forestry and oil and gas development. Problems associated with high nutrient concentrations in lakes, such as algae blooms and anoxia, are a concern for recreational use and fishing, but again, it is not known to what extent these problems are due to the natural or human-induced nutrient status. Knowledge about AEH is well-developed in the mainstem of the Peace River, and there is some information about water quality in the tributaries, but some of it is outdated. There is a general lack of information about non-fish biota in tributaries. Populations of sensitive fish occur in low densities, indicating that land use has impaired fish habitat in this sub-basin as well.

4.4 WABASCA

OVERVIEW

The Wabasca sub-basin is the largest sub-basin of the Peace watershed. It includes the drainage basins of the Peace tributaries Wabasca and Mikkwa Rivers as well as the Birch River that discharges to Lake Claire in the Peace-Athabasca Delta and a large number of lakes. The Wabasca sub-basin is mainly forested and therefore land use is restricted to oil and gas exploration, forestry, recreation as well as traditional land uses by the predominantly Aboriginal population. The headwaters of this basin are underlain by the north-eastern part of the Athabasca Oil Sands Reserve, including the Wabasca Oil Field, which provides for an active oil and gas industry.

Figure 23. Map of Wabasca Sub-basin and major anthropogenic stressors.



4.4.1 Rivers

4.4.1.1 Water Quality

The Wabasca River was sampled as part of the large 1988 survey completed by AEW (Shaw 1990). Similar to other tributaries, it was found to contain higher concentrations of TDS, colour, dissolved nutrients and dissolved organic carbon (DOC) than the Peace River. It had very high chlorophyll *a* concentrations, the second highest of the sampled tributaries (Shaw 1990). Given that this watershed is mainly forested, this pattern can at least in part be explained by naturally nutrient-rich soils. The impact of watershed disturbance is unknown.

In the literature that we reviewed, no data were available for water bodies in the Wabasca sub-basin for sediment quality as well as non-fish biota.

4.4.1.2 Fish

The data on fish occurrence in the Wabasca basin are in general associated with a high degree of uncertainty. From the available data it appears that all three focal species that naturally occur in the area are present in low densities. Exceptions are the lower reaches of the watershed where Goldeye and Walleye show moderate densities. For the latter the low densities may be due to habitat preferences for larger rivers. The low densities of Arctic Grayling in the western and southern portion of the sub-basin, however, may indicate that the population in these areas is under stress. Although road density is low and therefore the predicted IBI is high, there is a high to moderate cutline density, which may indicate a cumulative effect of linear features associated with oil and gas operations. From the little data available it appears that streams are naturally nutrient rich and therefore less suitable for fish. This sub-basin is also focus of large forestry operations that may have affected aquatic habitat. Still, data uncertainty for the Arctic Grayling densities is high, and therefore low densities would have to be confirmed first before investigating possible causes.

4.4.1.3 Aquatic Habitat

We could not locate any information on habitat specific to rivers in this sub-basin.

4.4.2 Lakes

Among the numerous lakes in the sub-basin, data are available for Utikuma, Peerless, North and South Wabasca Lakes and Lake Claire as well as a number of lakes with fish density information (see Table 5). As Lake Claire is part of the complex wetland system of the Peace-Athabaca Delta, information on Lake Claire is included in the section on Slave River and PAD (see section 4.6).

4.4.2.1 Water Quality

Utikuma Lake, one of Alberta's largest lakes, is shallow and located in a mostly forested watershed (North/South Consultants 2007). Data collected in 1996 indicate that it is naturally eutrophic to hypereutrophic. Nine lakes in this sub-basin (seven in the Birch Mountains and two near Wabasca) are monitored by the Regional Aquatics Monitoring Program (RAMP 2012) as part of the acid sensitive lakes program. This program is intended to assess the impact of atmospheric deposition from the Athabasca Oil Sands. The data are available from the RAMP website, and if analyzed with a focus on Peace Basin lakes, could provide a useful baseline on acid-sensitive lakes in the area.

4.4.2.2 Sediment Quality

The literature reviewed did not provide any data on sediment quality in lakes of this sub-basin.

4.4.2.3 Non-Fish Biota

In a survey from 1976, Utikuma Lake phytoplankton was dominated by the blue-green algae *Aphanizomenon*, consistent with the high nutrient status. Zooplankton and invertebrate data were last collected in 1968 and are presented in Mitchell and Prepas (1990).

Peerless Lake was dominated by the green algae *Ulothrix* and dinoflagellate *Ceratium*, with diatoms and blue-green algae present. While no nutrient data are available for this lake, the more diverse algal assemblage indicates that Peerless Lake is somewhat less eutrophic than most of the other lakes discussed in the Peace River basin.

4.4.2.4 Fish

A recent contaminant study in fish was completed by Golder Associates Ltd. (2004b) in lakes of the Treaty 8 Aboriginal communities, including Wabasca and Utikuma Lakes. The chemicals of concern included mercury, selenium, polychlorinated biphenyls (PCBs), dioxins and furans. The general finding was that most of the samples had contaminant concentrations below the consumption guidelines.

Walleye population densities in Wabasca basin lakes are generally low to moderate (Table 5). Reasons for these low densities have not been explicitly reported, but it is likely that they are the same as described for lakes with low densities elsewhere in the basin, e.g., high nutrient levels and overfishing.

4.4.2.5 Aquatic Habitat

We could not locate any information on habitat specific to lakes in this sub-basin.

4.4.3 Summary

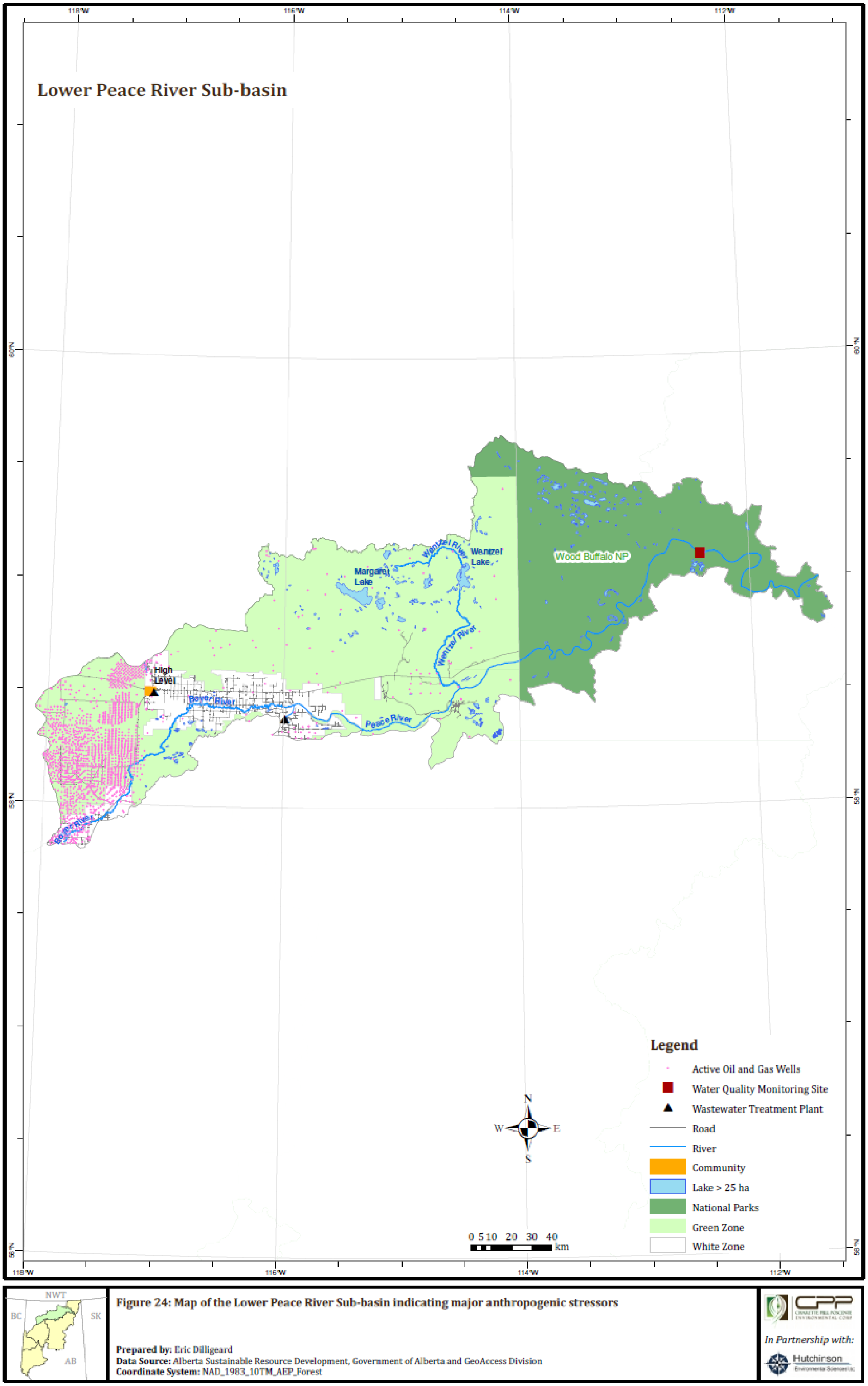
While the Wabasca sub-basin is the largest of the Peace River sub-basins, it is also one of the most remote and pristine, with a portion covered by the Wood-Buffalo National Park in the north-east. Data on water and sediment quality, and non-fish biota is lacking for most surface waters, except for two lakes. Local information on small head-water bodies may be available from monitoring reports produced for approval of oil and gas developments, but such data has not been compiled and interpreted on a watershed basis. There is increasing pressure from oil and gas development in the headwaters, which, in combination with ongoing forestry, results in increasingly numerous linear features. Impacts on aquatic habitat from river crossings and contamination are potential concerns for AEH in this watershed and for the Aboriginal Communities that depend on local aquatic resources. Low fish densities in most of the watershed, especially low Arctic Grayling densities in the headwaters may be a sign that fish populations have been impacted by these activities. Data uncertainty for fish populations, however, is high in this watershed, and data on water quality and non-fish biota is virtually absent; therefore more data on is required to assess the status of AEH in the Wabasca sub-basin.

4.5 LOWER PEACE

OVERVIEW

The Lower Peace watershed includes the reach of the Peace River from Fort Vermillion to the Peace Athabasca Delta, where the confluence with Lake Athabasca outflow forms the Slave River. The headwaters of the Peace River tributaries, such as the Ponton and Wetzel Rivers, are located in the Caribou Mountains to the north. This reach of the Peace River also receives discharge from tributaries in the Wabasca sub-basin. The Lower Peace sub-basin is mainly forested, with the exception of some agriculture to the north of the Peace River at Fort Vermillion stretching to High Level at the western end of the watershed and some cultivated fields around John D'Or Prairie. From satellite imagery it appears that there is ongoing forest harvesting in the central and eastern part of this sub-basin and oil and gas development in the western portion near High Level (2012 Google Maps). High Level is the largest community and there are a few smaller communities, such as John D'Or Prairie, Beaver FN, Tallcree FN and Fox Lake scattered across the sub-basin.

Figure 24. Map of Lower Peace River Sub-basin and major anthropogenic stressors.



4.5.1 Rivers

4.5.1.1 Water Quality

As discussed for the central Peace sub-basin, concentrations of TSS, TDS and total and dissolved constituents in the Peace River progressively increase downstream (North/South Consultants 2007), with relatively slow increase of dissolved constituents and relatively high increase of particulate matter (Shaw et al. 1990). Ultimately, many water quality parameters occur at higher concentrations in the lower Peace River, compared to upstream (Shaw et al. 1990). A summary of data collected at the long-term federal monitoring station at Peace Point indicated that median TSS concentrations are high (58 mg/L), while peak concentrations exceeded 2000 mg/L (Donald et al. 2004). As a result, this reach is characterized by higher concentrations of total nutrient and metals, as well as turbidity and BOD and WQGs are frequently exceeded for total nutrients and metals. This is particularly true under high flow events when downstream particulate transport is highest (Shaw et al. 1990, Donald et al. 2004). Based on median nutrient concentrations at Peace point from 1989-2002, the Peace River was classified as mesotrophic based on TP concentrations, but still remained oligotrophic based on TN (North/South Consultants 2007).

A detailed analysis of data collected at Peace Point from 1989 to 2006 showed that water quality at this site has generally been stable, except dissolved nitrogen and oxygen concentrations that have increased (Glozier et al. 2009).

The overriding influence on Peace River water quality has been natural changes in channel geomorphology with distance downstream. Specifically, natural scouring of the sandy to silty substrates in channel bed and river banks lead to high levels of suspended solids in this reach, as opposed to upstream reaches where gravel substrates dominate (Shaw et al. 1990).

In addition, Peace River tributaries and effluent inputs tend to have a cumulative influence on main-stem water quality, rather than an individual influence. This is primarily because of the sheer size of the Peace River relative to these inputs (North/South Consultants 2007). Due to the large influence of sediment-associated constituents and the lack of any watershed-scale assessment, the relative importance of cumulative tributary loads versus natural loads to the Peace River mainstem remains unknown.

The tributaries Wentzel and Boyer Rivers were sampled as part of the large 1988 survey completed by AEW (Shaw 1990). Similar to the other analysed tributaries, the Boyer River was generally found to contain higher concentrations of TDS, colour, dissolved nutrients, metals and dissolved organic carbon (DOC) than the Peace River. Wentzel River had the lowest total and dissolved phosphorus and nitrogen concentrations of all sampled tributaries and was also low in metals, while Boyer Creek ranged among tributaries with highest particulate and dissolved constituents (Shaw 1990). Since this survey was completed 24 years ago, renewed sampling of these tributaries would be required to assess current status.

4.5.1.2 Sediment Quality

We are not aware of any sediment quality data for the Lower Peace reach or any tributaries.

4.5.1.3 Non-Fish Biota

Planktonic and benthic biomass (as chlorophyll *a*) tends to be lower in the lower Peace River, primarily due to elevated turbidity concentrations (Shaw et al. 1990). For those reasons, periphyton biomass was not measured downstream of Fort Vermilion during the AEW synoptic surveys that provided data for the upper and central Peace reaches.

The lower reach of the Peace River supported benthic invertebrate communities low in abundance and diversity due to lower flow and sand/silt substrates (North/South Consultants 2007).

4.5.1.4 Fish

Four contaminant monitoring studies identified by Golder Associates Ltd. (2007) provided data for this reach of the Peace River, but they are all based on data from at least 20 years ago and are therefore not relevant for an assessment of current status. Given that Aboriginal communities in this sub-basin rely on fish for subsistence, an updated review of fish contaminants in the lower Peace sub-basin would be useful.

Goldeye, Walleye and Arctic Grayling were reported in high to moderate densities in the lower Peace sub-basin, indicating healthy fish populations.

4.5.1.5 Aquatic Habitat

One result of the Bennett Dam was a reduced sediment transport capacity of the Peace River, resulting in increased sediment deposition within Peace River reaches and reduced sediment transport downstream. Concerns have been voiced by Aboriginal people in the lower Peace River sub-basin about the increased occurrence of sand bars and shallow waters that impede travel to fishing grounds (Conroy Sewepagaham, Little Red River FN, personal communication). Most likely, these changes have also had an impact on aquatic habitat for fish and invertebrates in this area, but to our knowledge, no studies in this regard have been conducted thus far.

4.5.2 Lakes

There are numerous forested lakes scattered across the sub-basin, the largest of which are Margaret and Wentzel Lake. In the Caribou Mountains, twenty nine lakes were studied as part of a Ph.D. thesis that examined the impacts of forest fire on water quality of lakes and streams (McEachern 2002). Total phosphorus concentrations in reference lakes indicate mesotrophic to eutrophic conditions (32 µg/L on average). Forest fire facilitated a nutrient response, causing 2.6-fold greater phosphorus concentrations than in reference lakes.

4.5.2.1 Non-Fish Biota

Planktonic assemblages from 10 lakes in the Caribou Mountains (McEachern 2002) were comprised of, on average, 36 species per lake. Cyanobacteria made up the majority of total phytoplankton biomass, which is consistent with the mesotrophic to eutrophic nature of these lakes. The cyanobacteria genera Anabaena dominated total phytoplankton biomass

4.5.2.2 Fish

Walleye is present in low densities in Wentzel Lake and in moderate densities in Caribou Lake. (Table 5, Figure 18), although this information is associated with a high degree of uncertainty. More information would be available from Fishery and Wildlife offices and FWMIS.

4.5.2.3 Aquatic Habitat

We could not locate any information on habitat specific to lakes in this sub-basin.

4.5.3 Summary

The lower Peace River sub-basin is a fairly remote basin with a small and dispersed population. Water quality of the Peace River mainstem is well known due to a federal monitoring site at Peace Point, but information on AEH in tributaries and lakes in this area is scarce and outdated. Peace River water quality in this reach is controlled by an accumulation of sediments that the river picks up in upstream reaches and the cumulative influence of Peace River tributaries. Based on traditional knowledge, sediment accumulation appears to be increasing, which is likely due to the reduced sediment carrying capacity following the Bennett Dam erection. While the relative importance of these two factors has not been quantified, the patterns in suspended sediments associated with seasonal flows appears to be the dominant factor controlling the physical, chemical and non-fish components of AEH in this reach. High to moderate population densities of the three focal species that naturally occur in this sub-basins indicate healthy fish communities.

4.6 SLAVE RIVER and PEACE-ATHABASCA DELTA

The Slave River sub-basin and the Peace-Athabasca Delta (PAD) are located mostly in the Wood-Buffalo National Park. and ecosystem health is monitored and managed by Parks Canada and the recently established multi-stakeholder group PAD Environmental Monitoring Program. For these reasons, we present only a brief overview of recent data syntheses and major issues that the PADEMP and the MPWA have in common.

4.6.1.1 Slave River

Similar to the lower reach of its tributary, the Peace River (PR), the Slave River (SR) within Alberta is characterized by high TSS loads. Based on recent median nutrient concentrations, the SR at this site can be classified as eutrophic based on TP and oligotrophic based on TN. The disparity between these trophic classifications is due to the high concentrations of particulate phosphorus present in this river, particularly during high flow events. This was reflected by a greater degree of noncompliance with ASWQGs for TP compared to TN between 1999 and 2003.

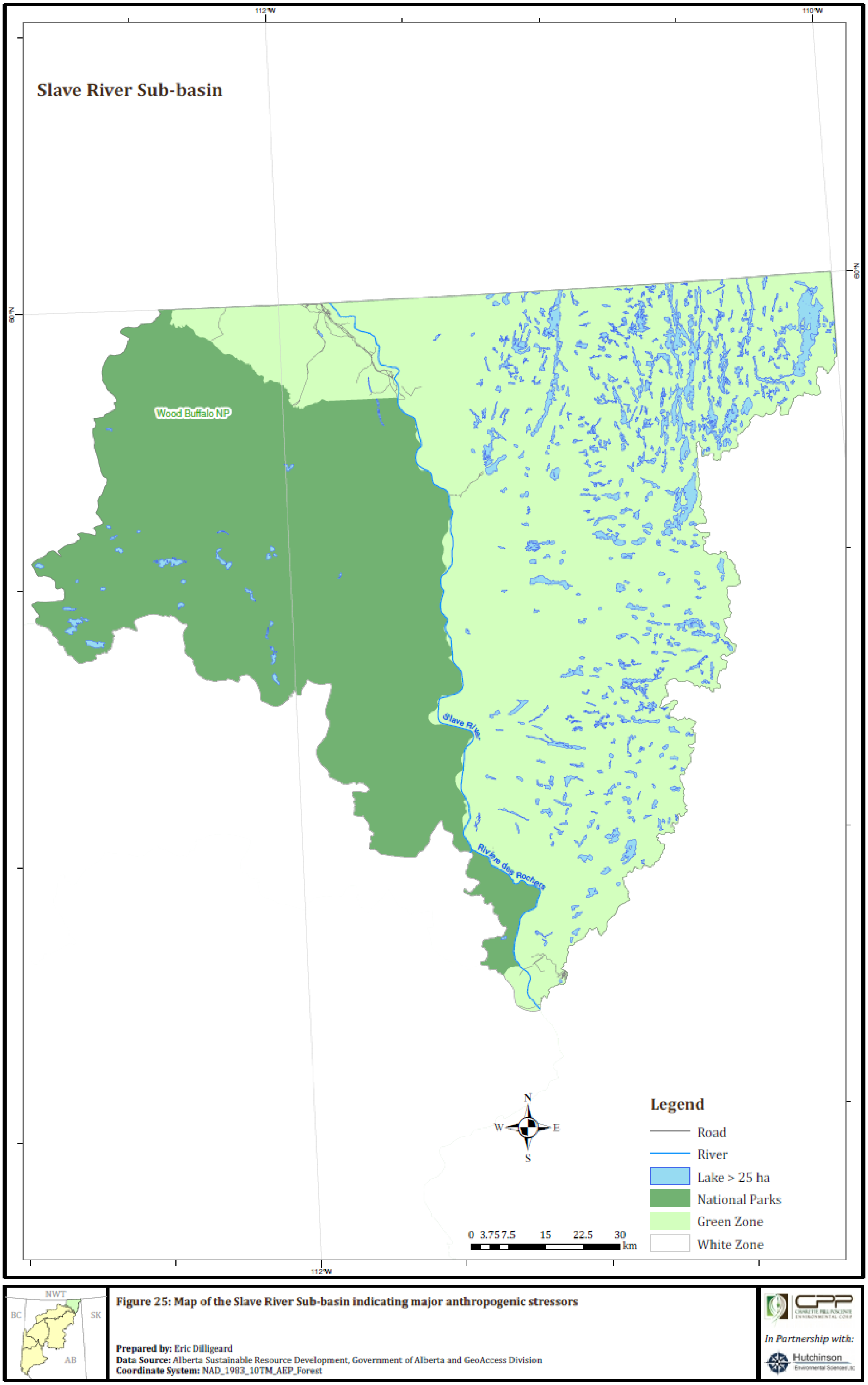
Similar to the PR, DO concentrations in the SR typically remained above the ASWQG. Monitoring of SR water and suspended quality downstream of the NWT/Alberta border at Fort Smith by McCarthy et al. (1997a) from 1990-1994, concluded that impacts from upstream sources were negligible (at that time), and SR water quality was pristine.

Total metals concentrations were relatively high and frequently exceeded relevant WQGs, though not by substantial amounts. Similar to the PR, these metals were largely in particulate forms and were associated with elevated TSS loads from natural sources. Furthermore, McCarthy et al. (1997a) speculated that aquatic biota resident in the SR had likely adapted to these concentrations. Trace metals in suspended sediments were variable and there was no overall increase or decrease over the 5-year monitoring period. Trace organics such as PAHs and dioxins and furans were detected in suspended sediment but at concentrations not considered a threat to the ecosystem.

There were no sediment quality data or information available for the Slave River within Alberta.

There were no benthic invertebrate data available for the SR within Alberta, but SR baseline data are available downstream from Fort Smith, NWT, as part of the Slave River Environmental Quality Monitoring Program (fall 1990, 1991; McCarthy et al. 1997b). In summary, total abundance was very low, likely due to natural factors, such as the oligotrophic nature of the river. Fish information for this river is available from earlier studies associated with the NRBS. There were no data or information related to algal or aquatic macrophyte communities available for the SR (North/South Consultants 2007).

Figure 25. Map of Slave River Sub-basin and major anthropogenic stressors.



4.6.1.2 Peace-Athabasca-Delta

The Peace-Athabasca Delta is an internationally recognized (RAMSAR) wetland of importance and a designated UNESCO World Heritage Site. It is one of the largest freshwater deltas in the world with valuable habitat for a variety of aquatic species, in particular waterfowl. Two major synthesis reports on the status of ecological integrity on the PAD were produced in 2010, one on western science information (AECOM 2010) and one on traditional ecological knowledge (Dillon 2010).

Similar to results in the Peace River, water quality in the Peace-Athabasca Delta is mainly related to sediment input. Any concerns regarding water quality and fish contaminant burden are related to development in the upstream Athabasca Oil Sands. Water quality, fish and waterfowl populations are overall in good condition, but there are uncertainties related to contaminants in sediments and aquatic biota (AECOM 2010). From the perspective of traditional knowledge, there are concerns that declining human health is in part due to lower water quality, caused by lower water levels and pollution.

The major concern shared between MPWA and PADEMP is the altered hydrology of the Peace River. Ice-jam floods on the Peace River are vital to the replenishment of many PAD wetlands and thereby the sustenance of the rich wetland ecosystems (AECOM 2010). Based on traditional knowledge, recent changes in PAD water levels have affected muskrat and water birds - the preferred country food source in the local communities (Dillon Consulting Ltd. 2010). Sediment core studies in the PAD, however, have shown that these water level changes were within the range of long-term (multi-century) natural variability (Wolfe et al. 2006). The factors that influence the creation of ice-jam floods have been well studied and show that a combination of high spring river flow, low ice thickness and low freeze-up levels led to major ice-jams. Freeze-up levels have increased as a result of river regulation and spring flows have decreased due to changing climate patterns. Therefore it can be expected that projected climate change together with current river regulation, will result in less frequent ice-jam flooding (Beltaos et al. 2006).

5.0 STEWARDSHIP/MANAGEMENT/MONITORING

There are many parties involved in the stewardship, management and monitoring of AEH in the Peace River basin. While a detailed analysis of objectives and responsibilities of each stakeholder would be a large undertaking, we will present the main types of stakeholders and their general area of expertise, concern or responsibility.

Stakeholders in the Peace River Basin include governmental agencies, non-governmental organizations, watershed groups, industries, Aboriginal communities and individual land owners. A summary of these is provided in Table 6.

While provincial and federal agencies have legislated authority over all natural resources, all other stakeholders have a mandate to manage aquatic resources and activities that may influence them and/or are required by regulation to do so (e.g. industries). The Water For Life Strategy was crafted to bring such stakeholders together to work towards common goals, which include healthy aquatic ecosystems.

From Table 6 it is clear that a large number of groups with often overlapping areas of interest and expertise are involved in either the protection of aquatic resources in the Peace River Basin or in an activity that potentially affects AEH. For the MPWA it will be important to engage these players in their future work of stewardship of the watershed.

For example, the Beaverlodge Drainage Riparian Program, in partnership with landowners, provincial and municipal governments and other conservation organizations, began riparian restoration and conservation projects along the Beavertail Creek, Steeprock Creek and Beaverlodge River in 2004 (AECOM 2009).

Table 6. Stakeholders in the Peace River Basin.

Type of Organization	Name of Organization	Sub-basins where active	Mandate/Area of Interest
Provincial Government	Alberta Sustainable Resource Development	all	fish and wildlife populations and habitat, forests, resource development
	Alberta Environment and Water	all	water, air and sediment quality, water licences, drinking water, waste-water, wetlands
	Alberta Agriculture and Rural Development	all	rural and environmental sustainability, Woodlot Extension Program, AESA program, AOPA, soil conservation, nutrient management, water quality for agriculture, land use, agricultural land management, research and extension.
	Alberta Energy	all	development of energy and mineral resources
	Energy Resources Conservation Board	all	oversight of oil and gas development, coal mining, pipelines
	Alberta Utilities Commission	Smoky/Wapiti, Upper & Central Peace	natural gas, electric and water (hydro) utilities, transmission lines
	BC Ministry of the Environment	Smoky/Wapiti, Upper Peace	trans-boundary agreements

Type of Organization	Name of Organization	Sub-basins where active	Mandate/Area of Interest
Federal Government	Fisheries and Oceans	all	fish habitat
	Environment Canada	all	water quality, wastewater systems on aboriginal lands, environmental effects monitoring program for pulp and paper mills
	Parks Canada	Slave, Upper Smoky/Wapiti	protection of unique natural and cultural heritage through National Parks
	Agriculture and Agri-Food Canada	all White Zone areas	farm best management practices
	Indian and Northern Affairs Canada	all	water and wastewater on Aboriginal lands
	Health Canada	all	drinking water in FN communities
	Navigable Waters, Transport Canada, NRCan		
Municipal Governments	Several	several	public utilities, business development, Agricultural Service Board
Aboriginal Communities	Several	all	water and wastewater, natural resources for traditional land use
Industry	Weyerhaeuser Company Ltd., DMI, Canfor, Manning Diversified Forest Products, Tolko	Wapiti/Smoky; Central Peace	forestry/pulp mills
	Aquatera Utilities	Wapiti/Smoky	water and waste water utility
	Canadian Association of Petroleum Producers	all	oil and gas
	Agricultural Research and Extension Council of Alberta	all agricultural areas	Alberta Environmentally Sustainable Agriculture Initiatives Program funding
	BC Hydro	Upper, Central, Lower Peace, PAD	hydroelectric development
	TransAlta	Upper Peace	hydroelectric development
Non-Governmental Organizations	Alberta Conservation Association	all	fish and fish habitat
	Ducks Unlimited	all	wetlands
	Alberta Riparian Habitat Management Society	Smoky/Wapiti	riparian habitats, mostly in agricultural watersheds
	Canadian Nature Federation, Bird Studies Canada, Federation of Alberta Naturalists	Wapiti-Smoky	trumpeter swan habitat
	Woodlot Association of Alberta	all	sustainable forestry
	Grande Prairie Riparian Action Team (inactive)	Wapiti-Smoky	riparian habitat

Type of Organization	Name of Organization	Sub-basins where active	Mandate/Area of Interest
	Cows and Fish	all	riparian habitat
	Boreal Research Institute	all	applied research of conventional forest land reclamation and education.
	Woodlot	all	riparian tree planting
	Academic Institutions (UofA, UBC, etc.)	various	various
Watershed Groups	Mighty Peace Watershed Alliance	All	watershed management
	Clear Hills Watershed Initiative	Upper Peace, Central Peace	water quality
	George Lake Aquatic Society	Upper Peace	George Lake
	Running Lake Aquatic Society	Upper Peace	Running Lake
	Heart River Watershed Advisory Committee	Central Peace	stewardship
	West County Watershed Society	Smoky/Wapiti	Beaverlodge Basin, riparian habitat
Others	Peace River Environmental Society	Central Peace	environmental sustainability; public input to development proposals
	Three Creeks Focus Group	Central Peace	work with oil industry to address environmental issues, mostly air quality
	Land Owners	All	Agriculture, Forestry, Riparian Habitat, Lakes

6.0 DATA GAPS and RECOMMENDATIONS FOR FUTURE WORK

In this section we list data gaps, identify why we consider them to be important, provide recommendations to prioritize and address them and discuss how filling these gaps would be expected to affect outcomes. We focus on the data gaps identified in this review and those which, in our opinion, are the most important to address in order to prepare a state of the basin report and in order to be able to identify and address the main issues associated with AEH in the watershed. . Our data gap table also includes the estimated degree of severity of data gaps and provides a rationale for prioritization. We categorized data gaps by the component of AEH or their interaction with stressors they address:

1) AEH Structure
is the basis to any understanding of AEH, and therefore most data gaps on structure received a high priority.

2) AEH Process and Function
can often be inferred from structure and therefore generally received less priority

3) Stressor-Impact Relationships
describe the type and degree of effect a stressor has on the state of AEH and therefore can be important to identify where management actions are most urgently needed to protect or restore AEH.

4) Stressor Quantification
although a stressor-effect relationship might be known, the relative importance of similar stressors of different source can be important to identify appropriate and effective management actions.

Table 7. Severity of data gaps for the assessment and management of Aquatic Ecosystem Health in the Peace River Basin.

		SMOKY / WAPITI	UPPER PEACE	CENTRAL PEACE	WABASCA	LOWER PEACE	SLAVE RIVER & PAD	Rationale	Strategy to Address Data Gap
AEH Structure	Tributary water quality	√	1	1	1	1	N/A	important fish habitat, multiple stressors	Develop harmonized tributary monitoring program; implement in partnership with stakeholders
	Fish population	1	1	1	1	1	1	important indicator for biological integrity of rivers and lakes, lots of data available for comparison	Monitor focal species in areas where data uncertainty is high.
	Fish contaminants	1	3	1	3	1	1	Important concern for human consumption	Summarize available reports and assess need for further monitoring
	Wetland Coverage & Health	1	3	3	3	3		high natural coverage in this ecoregion, important functions for hydrological cycle	Use methods covering large areas (remote sensing, aerial photography, GIS) to assess degree of wetland loss and status of wetland cover.
AEH Function & Processes	Instream Flow needs	1	2	2	2	2	2	required data for decision making regarding water allocations	Identify subwatersheds where flows have been affected by human activities; implement Instream Flow needs studies for these subwatersheds
Stressor-Effect Relationships	Impacts of agricultural non-point sources on AEH	√	1	1	N/A	N/A	N/A	a high-quality case study is available for the Redwillow River watershed, but it is important to assess the degree of impact in other agricultural watersheds	May be inferred from harmonized tributary water quality monitoring and filling of fish population gaps. May be augmented by waterhed modeling exercises.
	Cumulative effect of linear features on stream water quality and fish habitat	3	3	3	3	3	N/A	most linear features are in tributary watersheds, where fish populations may be locally impaired.	If water quality and fish data gaps are filled as well as information on barriers resulting from linear features (e.g. culverts), it can be inferred through mapping.
	Risk from agricultural practices to surface water drinking	1	1	1	N/A	3	N/A	Communities depend on dugouts for drinking and stock watering; health concern	Collect data on water sources used for drinking. Monitor pathogen concentrations.
Stressor Quantification	Non-point source nutrient loads to Rivers	3	3	3	3	3	3	important piece in the assessment of nutrient stress to rivers, has lots of potential for mitigation and management efforts	Model diffuse nutrient loads to surface water on the sub-watershed basis. Phoshorus coefficient modeling is simple but coarse, and watershed modeling would be more comprehensive and precise.
	Relative importance of water allocations on flows	1	3	3	3	3	N/A	Minimum flow requirements for aquatic habitat and assimilative capacity can only be managed when all water uses are quantified on a subwatershed basis	Collect information on water use and surface water flow. Compare current flows to historical flows, where available. Model flows under different land use and water use scenarios.
	Fishing Pressure	2	2	2	2	2	2	is an important factor in the decimation of fish stocks, potential for management	Collect information on recreational, domestic and commercial fish harvest across the basin. Assess where high harvest coincides with endangered fish stock.

KEY	
Severity of Gap:	
1	Data available, but outdated, incomplete or low quality
2	Unknown, but can be inferred from existing data/by modeling
3	Completely unknown
N/A	Not Applicable
√	D ta sufficient

Strategies to address data gaps include a variety of approaches, including literature reviews, data collection from existing sources, monitoring programs, spatial data analysis including GIS and modeling approaches. These studies vary greatly in their scope, required effort and expertise, as well as implementation time frame and will benefit from a collaboration of stakeholders. Some of this information may be available from two other projects that are currently underway on drinking water resources as well as water quantity and use in the Peace River Basin.

The large number or data gaps may create the impression that there is not enough knowledge about AEH in the Peace River basin to take any efficient action regarding its protection. One has to keep in mind however, that scientific knowledge and watershed management experience collected elsewhere can be transferrable. General impacts of the major human activities and stressors (especially from point sources) in the watershed are well understood and a variety of measures to mitigate, or remediate negative effects on aquatic ecosystems are well known and sufficient to identify potential problems and recommend management actions in the absence of complete and quantitative data.

In cases where detailed information is not available and also difficult to collect, such as is the case for non-point source pollution, "no regrets measures" or "best management practices" can be applied. These measures have an assumed, but difficult to assess positive impact on the environment. Good examples for such measures could include riparian restoration, sustainable forestry practices, run-off control from urban and rural development, or minimizing the effect of linear features, e.g. by "channelizing" them (put pipelines along existing roads etc.). In order to fulfill its goal to ensure healthy aquatic ecosystems, the MPWA can likely benefit from a combination of filling high-priority data gaps and parallel research and implementation of "no regrets measures".

7.0 SUMMARY OF AQUATIC ECOSYSTEM HEALTH IN THE PEACE RIVER BASIN

The status of AEH and the associated data quality in the running waters of the Peace River basin can be described by three areas of differing aquatic health and data quality and quantity.

First, the AEH of the Peace River mainstem is relatively well known, with generally good water quality, healthy fish populations and benthic biota mainly controlled by habitat characteristics. The main impact of human stressors appears to be that of flow regulation from the upstream Bennett Dam that has changed seasonality of flow and sedimentation patterns. These impacts extend as far downstream as the Peace-Athabasca Delta, where the altered flow patterns, together with climate change, have affected ice-dam floods that are required to maintain the rich wetland habitat of the Delta.

Second, the medium-sized to small tributaries are mostly relatively poorly understood in terms of biotic communities, with some information on water quality and fish. It is these tributaries, however, that are most exposed and likely susceptible to the cumulative effects of land use and population patterns, in particular in the White Zone in the Smoky/Wapiti, Upper and Central Peace sub-basins, and to some extent the western Wabasca sub-basin, by means of habitat fragmentation and non-point source pollution. To this is added the fact that they are often naturally very rich in nutrients, metals and other constituents.

Third, an exception to the large tributary data gap is represented by the Wapiti-Smoky River system, which has been well studied. Thorough studies have demonstrated the cumulative effects of agricultural land use, habitat fragmentation and water use on small rivers, resulting in low biological integrity, impaired or locally extirpated sensitive fish populations as well as high nutrient levels and low oxygen in agricultural streams. Significant nutrient enrichment effects due to cumulative point-source discharges have been well described in the lower Wapiti River. These case studies can serve as templates for studies elsewhere in the Peace River Basin. While the effects of point discharges in the lower Wapiti River are well studied and major upgrades are being implemented to improve effluent quality, diffuse sources of nutrients and other pollutants to smaller agricultural streams and their cumulative downstream effects are not well quantified and it is uncertain what efforts have been made to mitigate agricultural non-point-source effects.

Lakes in the Peace River Basin are also enriched in nutrient concentrations, leading to algae blooms and low oxygen concentrations that in turn result in fish kills. Many of these lakes are naturally nutrient rich and it is unknown to what extent human activities in the watersheds have contributed to the high lake nutrient status. Fish harvest from commercial, domestic and recreational fisheries also have had significant detrimental effects on lake fish populations.

Due to the presence of several federal and provincial long-term monitoring sites along the Peace River and a relatively comprehensive lake sampling program, the available water quality data for the Peace River mainstem and selected lakes were of high quality. This was in contrast to the limited data available for sediment quality and non-fish biota in the Peace River (North/South Consultants 2007) and the even more limited data on all components of AEH for tributaries of the Peace River, except the Smoky/Wapiti River system.

8.0 TOWARDS A STATE OF THE BASIN REPORT

The MPWA may choose to prepare a State of the Basin Report at any time, with the recognition that collecting information on the state of the watershed is an ongoing effort. A State of Report is NOT an endpoint or a plan; it is above all, “an objective tool that uses available data and information to assess conditions and concerns within a watershed, as well as identify information gaps” (Alberta Environment 2009). It always remains a living document that needs to be updated regularly as new information becomes available or conditions change. Given that one of the purposes of the State of Report is that of creating awareness and starting a conversation about watershed issues, it is never too early to initiate that process.

Conducting any of the studies recommended above and combining them with the results of other ongoing projects will make the State of Basin Report more complete. Major concerns of watershed stakeholders should be identified and addressed in the prioritization of additional studies, alongside with available resources and time considerations. The better the state of the watershed and the pressures that affect it are known, the easier it will become to encourage stewardship and develop watershed management strategies. Collecting more knowledge and developing and implementing management strategies, however, will always be parallel activities of the MPWA that affect each other. Together with periodic reporting on “where we are at” and “where do we go from here?”, these activities will serve the goal of protecting a sustainable, healthy watershed.

9.0 GLOSSARY AND ACRONYMS USED IN THIS REPORT

(adapted from the Government of Alberta, Water for Life website)

Alberta	**AB**	
Alberta Environment and Water	**AEW**	
Alberta River Water Quality Index	**ARWQI**	
Alberta Surface Water Quality Guideline	**ASWQG**	
Alberta Sustainable Resource Development	**ASRD**	
Algae		Simple single-celled (phytoplankton), colonial, or multi-celled, mostly aquatic plants, containing chlorophyll and lacking roots, stems and leaves. Aquatic algae are microscopic plants that grow in sunlit water that contains phosphates, nitrates, and other nutrients. Algae is either suspended in water (plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll *a* (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Algae are a essential part of the lake ecosystem and provides the food base for most lake organisms, including fish.
Algal Bloom		A heavy growth of algae in and on a body of water that is often triggered by environmental conditions such as high nitrate and phosphate concentrations. The decay of algal blooms may reduce dissolved oxygen levels.
All Terrain Vehicles	**ATVs**	
Aquatic Ecosystem		An aquatic area where living and non-living elements of the environment interact. This includes the physical, chemical, and biological processes and characteristics of rivers, lakes, and wetlands and the plants and animals associated with them.
Aquatic Ecosystem Health	**AEH**	A healthy aquatic ecosystem is an aquatic environment that sustains its ecological structure, processes, functions, and resilience within its range of natural variability.
Aquatic Environment		The components of the Earth related to, living in, or located in or on water or the beds or shores of a water body including (but not limited to) all organic and inorganic matter, living organisms and their habitat (including fish habitat), and their interacting natural systems.
Aquatic Macrophyte		Large (in contrast to microscopic) plants that live completely or partially in water.
Aquatic Species		The plants and animals living in, or associated with, water bodies, wetlands, and riparian areas.
Bacteria		A diverse group of microorganisms that occur naturally in aquatic environments. Bacteria that occur naturally in surface water generally are not harmful to humans, but pathogenic bacteria can be introduced into surface waters from wastewater, particularly from municipal sewage effluents.
Benthic Invertebrate (Zoobenthos)		Animals that live on river and lake bottoms. Many of these inhabitants are immature stages of insects such as mayflies, stoneflies, caddisflies, and midges. Other types of animals include aquatic earthworms or

		bristleworms, roundworms, snails and leeches. The variety and abundance of benthic invertebrates in a river reflects the habitat the river provides.
Best Management Practices (Beneficial Management Practices)	**BMPs**	Techniques and procedures that have been proven through research, testing, and use to be the most effective and appropriate for use in Alberta. Effectiveness and appropriateness are determined by a combination of: (1) the efficiency of resource use, (2) the availability and evaluation of practical alternatives, (3) the creation of social, economic, and environmental benefits, and (5) the reduction of social, economic, and environmental negative impacts.
Biological Diversity (Biodiversity)		The variability among living organisms and the ecological complexes of which they are a part. This includes the diversity found within and between species and ecosystems.
Biological Oxygen Demand	**BOD**	
Biomass		
Blue-Green Algae		A group of phytoplankton which often cause nuisance conditions in water. Some produce chemicals toxic to other organisms, including humans. They often form floating scum as they die. Many can fix nitrogen (N2) from the air to provide their own nutrient.
Bog		A wetland characterized by peat deposits, acidic water, and extensive surface mats of sphagnum moss. Bogs receive their water from precipitation rather than from runoff, groundwater, or streams, which decreases the availability of nutrients needed for plant growth.
British Columbia	**BC**	
Canadian Council Of Ministers Of The Environment	**CCME**	
Chlorophyll *a*		A photosynthetic pigment found in most algae. Concentrations of chlorophyll *a* in a water sample provide a good estimate of the amount of algae suspended in the water. Chlorophyll *a* may also be extracted from algae growing on rocks in the river.
Concentration		The amount of a substance in a given volume of water. For most substances, the concentration is expressed as milligrams per litre (mg/L), which is the same as parts per million (ppm). Technology now exists that can measure substances at the parts per trillion or quadrillion level.
Conservation		1. The planning, management, and implementation of an activity with the objective of protecting the essential physical, chemical, and biological characteristics of the environment against degradation. 2. The process of managing biological resources (e.g., timber, fish) to ensure replacement by re-growth or reproduction of the part harvested before another harvest occurs. A balance between economic growth and environmental and natural resource protection.
Contaminant		A substance that, in a sufficient concentration, will render water, land, fish, or other things unusable or harmful.
Cumulative Effects		The combined effects on the aquatic environment or human developments arising from the combined environmental impacts of several individual projects.
Daishowa-Marubeni International Ltd. (Pulp Mill Near Peace	**DMI**	

River)		
Dam		A barrier constructed on a water body for storage, control, or diversion purposes. A dam may be constructed across a natural watercourse or on the periphery of a reservoir. Natural barriers formed by ice, landslides, or earthquakes are excluded.
Discharge		Refers to the outflow, and is used as a measure of the rate at which a volume of water passes a given point. Therefore, the use of this term is not restricted as to course or location, and it can be used to describe the flow of water from a pipe or a drainage basins.
Dissolved Oxygen	**DO**	A measurement of the amount of oxygen available to aquatic organisms. Temperature, salinity, organic matter, biochemical oxygen demand, and chemical oxygen demand affect dissolved oxygen solubility in water.
Domestic Wastewater		A composite of liquid and water-carried wastes associated with the use of water for drinking, cooking, cleaning, washing, hygiene, sanitation or other domestic purposes, together with any infiltration and inflow wastewater, that is released into a wastewater collection system.
Domestic Water Use		Water used for drinking, cooking, washing, and yard use.
Drainage Basin		The total area of land that contributes water and materials to a lake, river, or other water body, either through streams or by localized overland runoff along shorelines.
Drinking Water		Water that has been treated to provincial standards and is fit for human consumption.
Ecological Integrity		An ecosystem exhibits integrity if, when it is subjected to stress, it is able to sustain a state that allows that ecosystem to thrive.
Ecosystem		A community of interdependent organisms together with the environment they inhabit and with which they interact.
Ecosystem Functions		Processes necessary for the self-maintenance of an Ecosystem such as primary production, nutrient cycling, decomposition, etc. The term is used primarily as a distinction from values.
Effluent		1. The liquid waste of municipalities, industries, or agricultural operations. Usually the term refers to a treated liquid released from a wastewater treatment process. 2. The discharge from any on-site sewage treatment component.
Environment		The components of the earth, including air, land, and water, all layers of the atmosphere, organic and inorganic matter, living organisms, and their interacting natural systems.
Environmental Effects Monitoring	**EEM**	
Environmental Quality		A measure of the status of the environment, overall or in relation to a media (air, water, land) or the needs of its inhabitants, including humans.
Ephemoptera, Plecoptera, Trichoptera	**EPT**	a group of benthic invertebrates indicative of good water quality
Erosion		The natural breakdown and movement of soil and rock by water, wind, or ice. The process may be accelerated by human activities.
Eutrophic		Pertaining to a lake or other body of water characterized by large nutrient concentrations such as nitrogen and phosphorous and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency.
Eutrophication		The process by which lakes and ponds become enriched with dissolved nutrients, either from natural sources or human activities. Nutrient enrichment may cause an increased growth of algae and other

		microscopic plants, the decay of which can cause decreased dissolved oxygen levels. Decreased oxygen levels can kill fish and other aquatic life.
Evapotranspiration		The combination of evaporation from the surface of soils and vegetation, plus the transpiration of water through plant leaves and vegetation.
Fen		A wetland characterized by slow internal drainage from groundwater movement and seepage from upslope sources. Fens are characterized by peat accumulation, but due to the seepage of nutrient-rich water, fens are typically less acidic and more nutrient-rich than bogs.
First Nation	**FN**	
Fish Habitat		Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes.
Flow-Weighted Mean Concentration	**FWMC**	
Green Area (Green Zone)		The mainly public, forested lands of northern Alberta and the Eastern Slopes that are not available for agricultural development, other than grazing.
Groundwater		All water under the surface of the ground whether in liquid or solid state. It originates from rainfall or snowmelt that penetrates the layer of soil just below the surface. For groundwater to be a recoverable resource, it must exist in an aquifer. Groundwater can be found in practically every area of the province, but aquifer depths, yields, and water quality vary.
Groundwater Recharge		Inflow of water to a ground water reservoir (zone of saturation) from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.
Habitat		The natural home of a living organism. The three components of wildlife habitat are food, water, shelter.
Habitat Fragmentation		Discontinuity in the spatial distribution of the resources and conditions that make up the habitat of a given species
Headwaters		The source and upper tributaries of a stream or river.
Highway	**HWY**	
Hydrology		The science dealing with the properties, distribution, and flow of water on or in the Earth.
Hypereutrophic		Pertaining to a lake or other body of water characterized by excessive nutrient concentrations such as nitrogen and phosphorous and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency
Industrial Wastewater		The composite of discarded liquids and unwanted water-carried substances resulting directly from a process carried on at a plant or facility.
Instream Flow Needs	**IFN**	The scientifically determined amount of water, flow rate, or water level that is required in a river or other body of water to sustain a healthy aquatic environment or to meet human needs such as recreation, navigation, waste assimilation, or aesthetics. An instream flow need is not necessarily the same as the natural flow.
Leachate		A liquid that has been in contact with waste in a landfill or other porous substrate and may have undergone chemical or physical changes as a result, and has subsequently seeped out.
Lentic		Pertaining to or living in still water.
Long-Term River Monitoring Network	**LTRN**	

Lotic		Pertaining to or living in flowing water.
Mainstem		1. The primary channel of a river. 2. The primary river in a drainage basin.
Mesocosm Study		A Mesocosm study is an experiment that mimics a natural ecosystem. In the case of the Wapiti River EEM studies, mesocosms were artificial streams that were fed different mixes of river water and effluents from the Grande Prairie sewage treatment plant and the Weyerhaeuser pulp mill. The development of water chemistry and aquatic biota was observed and allowed conclusions about the single and combined effects of both effluents on the aquatic ecosystem.
Mesotrophic		A descriptive term for water bodies that contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life.
Mighty Peace Watershed Alliance	**MPWA**	
Non-Compliance		Where legislative requirements, such as those found in an Act, regulation, Code of Practice, or authorization are not met.
Non-Point Source Pollution		Contaminants that enter a water body from diffuse or undefined sources and are usually carried by runoff. Examples of non-point sources include agricultural land, coal mines, construction sites, roads, and urban areas. Because non-point sources are diffuse, they are often difficult to identify or locate precisely, and are therefore difficult to control.
Northern River Basin Study	**NRBS**	
Northern River Ecosystem Initiative	**NREI**	
Nutrient		An element essential for plant or animal growth. Major plant nutrients include nitrogen, phosphorus, carbon, oxygen, sulphur, and potassium.
Oligotrophic		Pertaining to a lake or other body of water characterized by extremely low nutrient concentrations such as nitrogen and phosphorous and resulting very moderate productivity. Oligotrophic lakes are those low in nutrient materials and consequently poor areas for the development of extensive aquatic floras and faunas. Such lakes are often deep, with sandy bottoms and very limited plant growth, but with high dissolved-oxygen levels. This represents the early stages in the life cycle of a lake.
Organic Contaminants		Carbon-based chemicals, such as solvents and pesticides, which can get into water through runoff from cropland or discharge from factories.
Pathogen		A disease-causing biological agent such as a bacterium, parasite, virus or fungus.
Peatland		Permanent wetlands characterized by a bed made of highly organic soil (>50% combustible) composed of partially decayed plant material.
Periphyton		Periphyton are organisms, such as algae, small invertebrates, fungi and bacteria, that live attached to underwater surfaces. The biomass of the total periphyton is measured as Ash-free dry weight and the biomass of the algae portion of the periphyton is estimated by chlorophyll *a* measurements.
Pesticide		Any chemical compound used to control unwanted species that attack crops, animals, or people. This diverse group of chemicals includes herbicides, fungicides, and insecticides.
Point-Source Pollution		Pollution that originates from one, easily identifiable cause or location, such as a sewage treatment plant or feedlot.
Pollutant		A contaminant in a concentration or amount that adversely alters the

		physical, chemical, or biological properties of the natural environment.
Polychlorinated Biphenyls	**PCBs**	
Primary Wastewater Treatment		The removal of particulate materials from domestic wastewater, usually done by allowing the solid materials to settle as a result of gravity. Typically, the first major stage of treatment encountered by domestic wastewater as it enters a treatment facility. Primary treatment plants generally remove 25 to 35 percent of the Biological Oxygen Demand (BOD) and 45 to 65 percent of the total suspended matter. Also, any process used for the decomposition, stabilization, or disposal of sludges produced by settling.
Progradation		Growth of a beach, delta, fan, etc. by progressive deposition of sediment by rivers or shoreline processes.
Reach		A group of river segments with similar biophysical characteristics. Most river reaches represent simple streams and rivers, while some reaches represent the shorelines of wide rivers, lakes and coastlines.
Riparian		Pertaining to the banks of a river, stream, waterway, or other, typically, flowing body of water as well as to plant and animal communities along such bodies of water.
Riparian Area (Zone)		The area of water-loving vegetation beside a stream, river, lake, or pond. Riparian areas are critical in reducing the negative effects of various land-uses on adjacent waters.
River Basin		An area of land drained by a river and its associated streams or tributaries. Alberta's Water Act identifies seven Major River Basins within the province: (1) Peace/Slave River Basin, (2) Athabasca River Basin, (3) North Saskatchewan River Basin, (4) South Saskatchewan River Basin, (5) Milk River Basin, (6) Beaver River Basin, and (7) Hay River Basin.
Runoff		Water that moves across (or through) soils on the land during snowmelt or rainstorms.
Secondary Wastewater Treatment		Treatment (following Primary Wastewater Treatment) involving the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems and which generally removes 80 to 95 percent of the Biochemical Oxygen Demand (BOD) and suspended matter. Secondary wastewater treatment may be accomplished by biological or chemical-physical methods. Activated sludge and trickling filters are two of the most common means of secondary treatment.
Sediment		Eroded soil, rock and plant debris, transported and deposited by water.
Sediment Quality Guideline	**SQG**	
Sedimentation		The process of material settling out of water.
Septic System		A combination of underground pipe(s) and holding tank(s) which are used to hold, decompose, and clean wastewater for subsurface disposal.
Settling Pond		An open lagoon into which wastewater contaminated with solid pollutants is placed and allowed to stand. The solid pollutants suspended in the water sink to the bottom of the lagoon and the liquid is allowed to overflow out of the enclosure.
Sewage		1. The liquid waste from domestic, commercial, and industrial establishments. 2. Human excreta, or the water-carried wastes from drinking, bathing, laundering, or food processing.
Shore		The edge of a body of water and includes the land adjacent to a body of

		water that has been covered so long by water as to wrest it from vegetation or as to mark a distinct character on the vegetation where it extends into the water or on the soil itself.
Stakeholder		An individual, organization, or government with a direct interest in a particular process or outcome.
State Of The Watershed Report	**SOW**	A document that identifies the current condition of a watershed including the physical, chemical, and biological characteristics of its surface and groundwater and the pressures acting on it.
Stewardship		A principle or approach whereby citizens, industry, communities, and government work together as stewards of the province's natural resources and environment. In general terms, stewardship means managing one's life, property, resources, and environment with regard for the rights or interests of others. This can apply to a person, company, community, government or group. Stewardship is an ethic and a value that results from public education and partnerships. It is people-focused in the sense that it relies on the desire and ability of people to make good decisions on their own accord that help resource and environmental outcomes.
Stormwater		Water discharged from a surface as a result of rainfall or snowfall.
Sub-Basin		Part of a river basin drained by a tributary or with significantly different characteristics than the other areas of the basin.
Sub-Watershed		A smaller watershed that is a piece of a much larger watershed.
Surface Water		Water bodies such as lakes, ponds, wetlands, rivers, and streams. It may also refer to sub-surface water or groundwater with a direct and immediate hydrological connection to surface water (for example, water in a well beside a river).
Suspended Solids		Material, such as fine particles of soil, that neither dissolve nor settle out of water, but instead are held or carried along in the water.
Sustainability		The balancing of opportunities for growth with the need to protect the environment. It reflects a vision of a vibrant economy and a healthy environment. Regarding renewable resources (e.g.: water, timber, fish, and wildlife), sustainability involves managing renewable natural resources so that their status, condition, or use is maintained over time. In this context, the use of a renewable resource, or impacts on it from other human activities, should not exceed its capacity to maintain itself through re-growth, reproduction, and management practices. Regarding non-renewable resources (eg: coal, oil, gas, and minerals), sustainability involves the development of resources in a responsible manner. This means protecting the environment during the construction and operation phases and ultimately reclaiming the land disturbed by development. In this context, non-renewable resource development is a temporary land use.
Tertiary Wastewater Treatment		Selected biological, physical, and chemical separation processes to remove organic and inorganic substances that resist conventional treatment practices. Tertiary Treatment process consists of flocculation basins, clarifiers, filters, and chlorine basins or ozone or ultraviolet radiation processes. Tertiary techniques may also involve the application of wastewater to land to allow the growth of plants to remove plant nutrients.
Total Dissolved Phosphorus	**TDP**	
Total Dissolved Solids	**TDS**	
Total Dissolved Solids	**TDS**	1. A measure of the concentration of dissolved matter in water. Total

		Dissolved Solids measurements are often used to estimate a water body's salinity, which may affect the distribution of aquatic organisms. 2. Calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, and silica are typical dissolved solids.
Total Nitrogen	**TN**	
Total Phosphorus	**TP**	
Total Suspended Solids	**TSS**	
Total Suspended Solids	**TSS**	A measurement of the quantity of matter suspended, but not dissolved, in a unit of water. Suspended solids include a wide variety of materials such as silt, decaying plant matter, industrial wastes, and sewage.
Turbidity		The cloudiness of water. It is determined by the presence of suspended matter such as clay, silt, organic matter, and living organisms. High turbidity may reduce light transmission, and therefore reduce photosynthesis of aquatic plants.
Upland		An area of dry land surrounding or upstream of a waterbody.
Wastewater		A combination of liquid and water-carried pollutants from homes, businesses, industries, or farms; a mixture of water and dissolved or suspended solids.
Wastewater System		An organized process and associated structures for collecting, treating, and disposing of wastewater. It includes any or all of the following: 1. Sewers and pumping stations that make up a wastewater collection system. 2. Sewers and pumping stations that transport untreated wastewater from a wastewater collection system to a wastewater treatment plant. 3. Wastewater treatment plants. 4. Facilities that provide storage for treated wastewater. 5. Wastewater sludge treatment and disposal facilities. 6. Sewers that transport treated wastewater from a wastewater treatment plant to the place where it is disposed of. 7. Treated wastewater outfall facilities, including the outfall structures to a watercourse or any structures for disposal of treated wastewater to land or to wetlands
Wastewater Treatment		Any of the mechanical or chemical processes used to modify the quality of waste water in order to make it more compatible or acceptable to man and his environment.
Wastewater Treatment Plant	**WWTP**	Any structure, thing, or process used for the physical, chemical, biological, or radiological treatment of wastewater before it is returned to the environment. The term also includes any structure, thing, or process used for wastewater storage or disposal, or sludge treatment, storage, or disposal.
Water Act		A piece of provincial legislation in Alberta used to protect the quality of water and manage its distribution. The Water Act regulates all developments and activities that might affect rivers, lakes, or groundwater.
Water Allocation		The permitted volume, rate, and timing of a diversion of water outlined in a water license. When water is permitted to be redirected for a use other than for domestic purposes, it is referred to as an allocation. Agricultural, industrial, and municipal water users must apply to AEW for a license to use a set allocation of water.
Water Balance		(1) A measure of the amount of water entering and the amount of water leaving a system. Also referred to as Hydrologic Budget. Also see Hydrologic Equation. (2) The ratio between the water assimilated into the body and that lost from the body; also, the condition of the body

		when this ratio approximates unity.
Water Body		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, wetlands and aquifers.
Water For Life		The Government of Alberta's water management approach, outlining a comprehensive set of strategies and actions that will ensure Albertans have safe, secure drinking water, healthy aquatic ecosystems, and a reliable quality water supply for a sustainable economy.
Water License		A water license provides the authority for diverting and using surface water or groundwater allocation. The license identifies the water source, the location of the diversion site, an amount of water to be diverted and used from that source, the priority of the "water right" established by the license, and the condition under which the diversion and use must take place.
Water Management Plan		A document developed under the Water Act that provides broad guidance regarding water conservation and management, sets clear and strategic directions regarding how water should be managed, or results in specified actions. Alberta's Framework for Water Management Planning outlines the process for water management planning and the components required for water management plans. The process applies to all water bodies in Alberta, including streams, rivers, lakes, aquifers, and wetlands. The plans may be considered by a Director when making license and approval decisions. An Approved Water Management Plan must be considered by a Director when making license and approval decisions.
Water Quality		The chemical, microbiological, and physical characteristics of water.
Water Quality Guidelines	**WQG**	The allowable contaminant concentration in water. Guidelines are used to define water quality according to the use of the water source. For example, water quality guidelines are developed for drinking water, agricultural, industrial, and recreational water use and for the protection of aquatic life.
Water Quantity		The volume or amount of water.
Water Withdrawal		Describes the amount of water being removed from a surface or groundwater source, either permanently or temporarily.
Watercourse		The bed and shore of a river, stream, lake, creek, lagoon, swamp, marsh or other natural body of water, or a canal, ditch, reservoir or other artificial surface feature made by humans, whether it contains or conveys water continuously or intermittently.
Watershed		An area of land that catches precipitation and drains into a body of water, such as a marsh, stream, river or lake.
Watershed Approach		A way of thinking and acting that focuses efforts within a watershed, taking into consideration both ground and surface water flow. This approach recognizes and plans for the interaction of land, water, plants, animals, and people. Focusing efforts at the watershed level gives the local watershed community a comprehensive understanding of local management needs and encourages locally led management decisions.
Watershed Management		The protection and conservation of water and aquatic ecosystems, including their associated riparian area. Because land use activities on the uplands of a watershed can affect ground and surface water quality and quantity, a broader, more comprehensive approach to planning is often required. A Watershed Management Plan may look at water quantity, water quality, aquatic ecosystems, riparian area, as well as a variety of land use issues as they impact water. Watershed management

		plans require water and land use managers to work together to ensure healthy watersheds.
Watershed Management Plan		A comprehensive document that addresses many issues in a watershed including water quantity, water quality, point and non-point-source pollution, and source water protection. It may or may not include a Water Management Plan. It may also examine ways to better integrate land and resource management within a watershed.
Watershed Management Planning		A comprehensive, multi-resource management planning process involving all stakeholders within the watershed, who, together as a group, cooperatively work toward identifying the watershed's resource issues and concerns as well as develop and implement a watershed plan with solutions that are environmentally, socially and economically sustainable.
Watershed Planning And Advisory Council	**WPAC**	Collaborative, independent, volunteer organizations with representation from all key partners within the watershed. Their mandate is to engage governments, stakeholders, other partnerships, and the public in watershed assessment and watershed management planning, while considering the existing land and resource management planning processes and decision-making authorities.
Watershed Stewardship Group	**WSG**	Community-based groups made up of volunteer citizens, often supported by local businesses and industries, who have taken the initiative to protect their local creek, stream, stretch of river, or lake. These proactive groups develop on-the-ground solutions to ensure the protection of their specific watersheds.
Weir		An overflow structure frequently used for measuring discharge. 1. In dam terminology, the crest of a spillway controlling the upstream surface level. 2. A structure in a water body over which water flows, and whose prime purpose is to raise the water level, usually to divert water into a watercourse.
Wetland		Land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, water-loving vegetation, and various kinds of biological activity which are adapted to a wet environment.
Wetland Loss		Includes infilling, altering, or physically draining a wetland, any impact to the riparian area or buffer strips, and any type of interference with the hydrology to and from a wetland.
White Area (White Zone)		1. The settled regions of Alberta where agriculture is the most significant land use, including the grasslands and parklands of southern and central regions, and the Peace Country in the north. 2. The White Area includes nearly 40% of the total area of Alberta.

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