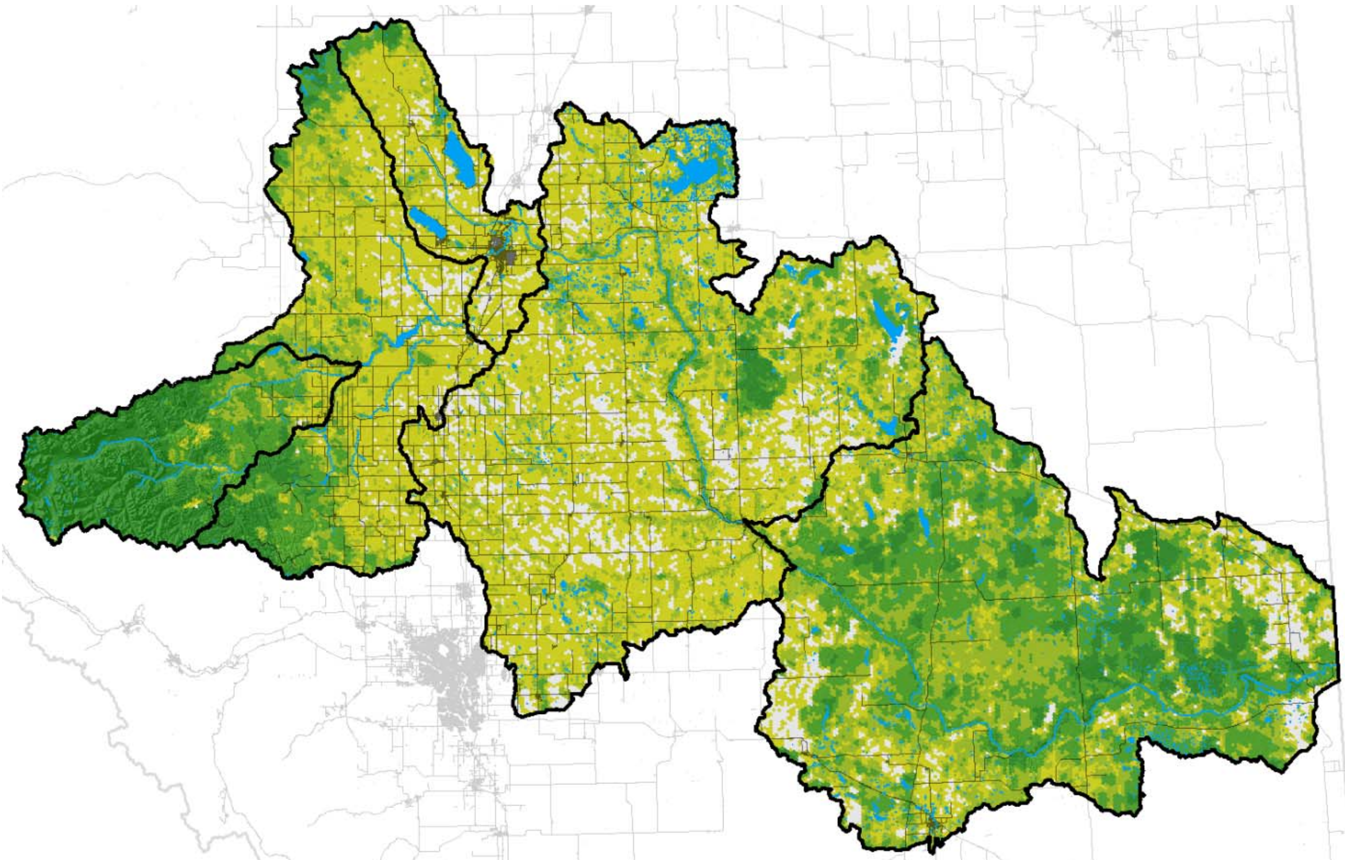
Background Technical Report:

Terrestrial and Aquatic Biodiversity

Prepared for the Red Deer River
Integrated Watershed
Management Plan



Prepared by: O2 Planning + Design Inc. (O2)

Prepared for: The Red Deer River Watershed Alliance (RDRWA)
in association with Alan Dolan Associates

August 25 | 2014

August 25, 2014

Re: "Background Technical Report on Surface Water Quantity and Groundwater Resources"

Dear reader,

The Red Deer River Watershed Alliance (RDRWA) gratefully acknowledges O2 Planning + Design's project team, who researched and wrote the appended report titled, "Background Technical Report on Terrestrial and Aquatic Biodiversity." O2's work benefited greatly from the assistance of public and stakeholders, who took part in the consultation process, and from the involvement of members of the Technical Team, who contributed their time and advice at various stages in the preparation of this report. Alan Dolan, Alan Dolan & Associates, facilitated the community engagement process and chaired the Technical Advisory Committee and Technical Teams.

The report is the fourth and final document in a series of Background Technical Reports that provide critical information for the development of the RDRWA's Integrated Watershed Management Plan. Each of the Background Technical Reports is independently authored and the recommendations are those of the author and not necessarily those of the Watershed Alliance.

During the public and stakeholder consultation process, overall response to the report was positive. A number of important technical comments were put forward at workshops and in an online response form. Members of the Technical Team, and the IWMP Project Management Unit reviewed the comments and provided advice to O2 Planning + Design.

We thank NOVA Chemicals and Conoco Phillips for their generous financial contributions to RDRWA for the preparation of the Background Technical Report. A special thank you also goes out the RDRWA members, board members, volunteers and staff who have helped to guide the process to date and continue to support the Alliance.

This report is available for downloading at www.rdrwa.ca

Yours truly,

Jeffrey Hanger

Jeff Hanger, Executive Director
Chair, Project Management Unit
Integrated Watershed Management Plan

cc: RDRWA Board of Directors, Technical Team

Red Deer River Watershed Alliance 4918 59th Street Red Deer, Alberta T4N 2N1 T. 403.340.7379 F. 403.356.9189 E. info@rdrwa.ca www.rdrwa.ca

EXECUTIVE SUMMARY

The Red Deer River Watershed Alliance (RDRWA) is a multi-sector, non-profit organization that promotes watershed health and guides proper resource management in the Red Deer River watershed. Currently, the RDRWA is in the process of developing an Integrated Watershed Management Plan (IWMP) for the Red Deer River basin. The IWMP requires an comprehensive and accessible process to integrate science, policy, and stakeholder and public participation in a flexible manner. The RDRWA and Alan Dolan and Associates commissioned O2 Planning + Design Inc. (O2) to prepare this Background Technical Report to support the development of the IWMP. The report focuses on developing draft indicators and targets for terrestrial and aquatic biodiversity in the Red Deer River Basin.

Purpose of this Report

This report provides a foundation for strategies related to terrestrial and aquatic biodiversity to protect and enhance the Red Deer River watershed. All information in this report is based on available data, and is intended for broad regional watershed-scale visioning purposes. Thus, site-specific applications should be conducted with caution and a scale effect should be considered. Targets are also expected to be refined over time following the framework of adaptive management.

Baseline conditions in the watershed were integrated and summarized using Geographic Information Systems (GIS) mapping tools that facilitated specific draft targets for selected indicators. This report builds on and complements the information in the 2009 State of the Watershed Report, as well as previous Background Technical Reports in: i) water quality; ii) riparian areas, wetlands, and land use; and iii) surface water quantity and groundwater resources. The analysis relies on assembled spatially explicit data on species observations and the most current land cover data that could be compiled at this time. While anthropogenic footprint data is available at a very fine resolution, the natural cover classes are less refined. The present information should serve as a general assessment at the watershed scale, and would not be sufficient for fine-scale planning exercises.

Targets and management objectives must differ in a watershed in response to natural and spatial land use patterns. With this in mind, five watersheds were used as reporting units for terrestrial biodiversity following the RDRWA Background Technical Report on riparian areas, wetlands and land use approach. Criteria applied in defining the units included sub-watershed boundaries, natural regions and sub-regions, primary land management issues and land use patterns, and the location of water quality monitoring stations.

The reporting units for aquatic biodiversity were based on seven reaches as defined by the Background Technical Report: Draft Site-Specific Water Quality Objectives for the Red Deer River Basin with Emphasis on Main Stem. The reaches were delineated based on broad ecoregional changes, changes in land use, and the location of long-tem water quality monitoring stations. In addition to reaches, five lakes were included as complementary reporting units for aquatic biodiversity. The lakes were selected based on size—no background information for particular lakes was available in previous Background Technical Reports.

Recommended goals, indicators and targets are summarized below. The goals aim to be in close alignment with the latest draft of the Province of Alberta's Biodiversity Management Framework as summarized for the South Saskatchewan Region. The report also outlines recommendations for improved monitoring and data acquisition, research needs, and key Beneficial Management Practices (BMPs) for implementation.

The recommended draft goals for biodiversity are provided below:

- Terrestrial and aquatic biodiversity (at all levels of diversity — genetic, species, habitat and ecosystems) are maintained
- Species at risk are recovered
- Key grasslands habitat is sustained
- Key wetland complexes are retained and land uses surrounding them are managed according to best practices
- Long-term forest ecosystem health and resiliency is monitored and maintained
- Areas important for biodiversity are identified and assessed as potential designated conservation areas

- Biodiversity and healthy functioning ecosystems continue to provide a range of benefits and ecological services to communities in the region and the province

Key recommended draft indicators and targets for biodiversity are grouped in environmental, programmatic and social indicators. Key draft indicators are highlighted in orange:

Draft Environmental Indicators (key draft indicators are highlighted in orange)

Indicator	Target	Notes
Amount of native land cover	No net loss from current amounts, implementation of rangeland assessment protocol across the watershed	Recovery of previously disturbed grasslands unlikely, making the long term preservation of remaining natural grasslands a high priority
Percentage of total territory identified for conservation through land protection and land stewardship programs	At least 17 per cent of terrestrial areas and waterways in the watershed are conserved through networks of protected areas and other area-based conservation measures	The percentages of area protected are currently reported by the Canadian Environmental Sustainability Indicators (CESI) initiative (hereafter CESI indicators)
Total wetland area	100 per cent of existing natural wetlands are conserved or enhanced to sustain their ecosystem services, total wetland area in the watershed is increased	This aligns with new provincial wetland policy, and is a change from the Background Technical Report on Riparian Areas, Wetlands, and Land Use (O2 Planning + Design Inc., 2013). Explore conservation tools such as mitigation banking
Degree of landscape connectivity	By 2020, develop a spatially explicit assessment of connectivity. Implement best practices to maintain connectivity on all private land	Requires a species specific assessment of fragmentation impacts
Nutrient concentrations of rivers, streams and lakes	By 2020, implement the narrative statements developed for nutrient levels as in Environmental Quality Guidelines for Alberta Surface Waters (Alberta ESRD, 2014). Spatially explicit data is made easily accessible to the public	This is a CESI indicator and Alberta ESRD has a comprehensive monitoring system in place. Increases in nutrient concentrations can result in increased growth of opportunistic species, lowering the diversity of communities present, and reducing the value of habitat.
Species at risk population trends	Species at risk listed under federal law meet the recovery objectives of federal and provincial strategies	Data on population trends are extracted from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessments and the General Status of Alberta Wild Species reports
Number and location of invasive alien species in the RDRW	Development of an invasive species management program, including definition and identification of pathways of invasive alien species introductions, and a risk-based intervention plan for priority	Requires collaboration with provincial programs such as the Alberta Invasive Species Council

Indicator	Target	Notes
	pathways and species	
Area and number of important and representative species habitats	Selection and ranking of appropriate keystone and indicator species to allow for species prioritization and spatially explicit identification of key habitat	Systematic gap analysis will be essential to target conservation effort

Draft Programmatic Indicators (key draft indicators are highlighted in orange)

Indicator	Target	Notes
Centralized, comprehensive monitoring and inventory program	RDRW has established a comprehensive inventory of protected spaces that includes private conservation areas, and an ongoing methodology for assessing their significance and value	Mainly driven by the province, ABMI and AEMERA
Number of commercial operations that incorporate sustainable forest management practices	The suite of indicators in the Canadian Council of Forest Ministers (CCFM) Criteria and Indicators (C&I) Framework is actively used to inform management decisions	Coordination between Canadian Forest Service, Alberta ESRD, Foothills Research Institute, and the forestry industry
Number of commercial operations that incorporate sustainable rangelands management practices	Rangeland assessment protocol is implemented and grazing is actively managed across the watershed to maintain healthy grasslands	Coordination between CPAWS, private land owners, and government agencies will be required
Number of commercial operations that incorporate sustainable farmland management practices	≥ 50 percent of farms adopt sustainable farmland management practices, and provide an increased contribution to biodiversity and habitat quality	Preparation of Environmental Farm Plans does not guarantee improved practices or positive effects on biodiversity. BMPs related to biodiversity would rely on data from the province
Number of commercial operations that incorporate sustainable aquaculture management practices	≥ 50 percent of all aquaculture operations adopt best management practices to reduce impacts on aquatic biodiversity	This indicator would require baseline research to assess current conditions
Number of land use and development plans that consider climate adaptation	Frameworks for monitoring and long term trend analyses are in place, explicitly incorporating adaptive management into watershed and regional planning	Requires collaboration with broader monitoring and management groups, latitudinal coordination in response to changing growth conditions
Motorized access to public land	Existing uses are identified and compiled in a spatial inventory. Recreational activities are clustered away from sensitive areas and access restrictions are installed. Public education on potential impacts is in place	Public participation necessary to establish preferred areas for recreation
Extent and duration of linear disturbances	A comprehensive reclamation program is in place whereby existing disturbed areas, priorities, and actions are defined. Best practices for future disturbances are established	Project specific, long term assessment of impacts. Requires industry participation and project approval conditions. Best practices must be habitat specific.

Indicator	Target	Notes
Number of licenses with water conservation objectives (WCO)	Existing management plans for water licensing incorporate river flow WCO that scientifically determine sustainable natural aquatic ecosystems over the long term	Incorporate the estimated effects of river flows on the aquatic environment of the Red Deer River as developed by Goater et al. (2007)
Stream continuity	Best management practices are established for stream crossings. Multiple disturbances are concentrated to one area. High quality stream habitat is avoided	Requires assessment of stream function prior to disturbance
Natural disturbance intensity, frequency and extent	A toolbox of BMPs with disturbances that mimic natural succession regimes is developed. Areas with homogeneous age structures are identified	With reference to historic patterns of disturbance, but may be influenced by changing environmental conditions (i.e., drought cycles, etc)
Number of ecosystem goods and services that are actively monitored and valued	Implementation of an ecosystem goods and services valuation program	Community and industry focus, cross-sector collaboration
Number of land management plans that incorporate biodiversity conservation strategies	All future land management plans explicitly incorporate biodiversity management frameworks	Municipality focus, requires cross-sector support and involvement of RDRWA. Indicators rely on the cooperation of all jurisdictions to review and report progress.
Incorporation of national and provincial biodiversity indicators with regional planning frameworks	RDRW Integrated Watershed Management Plan includes language which aligns with broader Red Deer and South Saskatchewan regional frameworks	Broad scale, community focus. Existing and proposed indicators do not address traditional or community knowledge. It is important to explore the possibility of developing an appropriate indicator for traditional knowledge, which involves discussions with Aboriginal Organizations

Draft Social Indicators (key draft indicators are highlighted in orange)

Indicator	Target	Notes
Degree of public participation in monitoring and preservation of biodiversity	Citizen science programs are designed and implemented. Public participation in environmental monitoring activities is encouraged. Information on biodiversity is distributed	Standardized monitoring programs require sound scientific and statistical methods to ensure that observations are stratified, and that observer effort is accounted for
Number of schools that have biodiversity activities in their curricula	Biodiversity is explicitly incorporated into all elementary and secondary school curricula	Combined effort between the RDRWA and Alberta Education
Percentage of RDRW residents who report that they take action to protect their watershed	An increase in participation of watershed residents in biodiversity conservation activities. Increase in public engagement events within the watershed.	RDRW co-ordinate with surveys such as the Households and the Environment Survey
Public perception of biodiversity value	Publish and distribute educational material that results in increased public understanding of the valuation of natural capital and the economic costs of environmental degradation.	Outreach efforts must be targeted across a broad demographic range, urban rural gradient, age and education

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ACKNOWLEDGEMENTS

This report was prepared by O2 Planning + Design Inc. The following individuals are acknowledged for contributing writing, editing, mapping, analysis, and graphics for this draft: Pablo Pina Poujol, Leif Olson, Jen Barker and Caitlin Smith.
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1. INTRODUCTION AND CONTEXT

The Red Deer River Watershed Alliance (RDRWA) is a multi-sector, non-profit organization that promotes watershed health and guides proper resource management in the Red Deer River watershed. In 2005, the RDRWA was granted the status of the Watershed Planning and Advisory Council (WPAC) by Alberta Environment as part of the province's "Water for Life" initiative. The fundamental goal of the Water for Life Strategy (GOA, 2008b) is to ensure sustainable management of the province's water resources so Albertans are assured of:

- Safe and secure drinking water supply
- Healthy aquatic ecosystems
- Reliable quality water supplies for a sustainable economy

As indicated in Alberta's Water for Life Strategy, WPACs are responsible for "leading watershed planning, developing best management practices, fostering stewardship activities within the watershed, reporting on the state of the watershed and educating users of the water resource."

In 2009, the RDRWA released its State of the Watershed Report (SOW) (Aquality, 2008). Currently, the RDRWA is in the process of developing an Integrated Watershed Management Plan (IWMP) for the Red Deer River basin that transforms the information in the SOW report into a planning process that will establish desired outcomes, indicators and targets.

The terms of reference as approved by the RDRWA Board of Directors state that the objectives of the IWMP are:

- To set targets and thresholds for land use, biological, and water quantity indicators as reported in the State of the Watershed Report
- To work out mutually acceptable solutions with stakeholders for the protection, restoration, and/or maintenance of the health of the individual sub-watersheds as well as the Red Deer River watershed as a whole through the process of identifying targets and thresholds
- To make recommendations such as Beneficial Management Practices, market-based instruments, monitoring strategies, and future research priorities that may eventually be reflected in policies
- To provide information and guidance to stakeholders in developing their action plans to implement the recommendations of the IWMP
- To provide decision-makers with the relevant information specific to the Red Deer River watershed essential for its effective protection, restoration, and/or maintenance as a healthy watershed

1.1 Study Scope and Objectives

The RDRWA's vision is that the IWMP will help to achieve or exceed requirements under government regulations. Moreover, management efforts will be directed towards maintaining high quality natural habitat where it exists, while improving conditions where they have deteriorated because of human activities. The RDRWA has commissioned three background reports to date to support the development of the IWMP that collectively aims to provide a solid scientific basis for the IWMP, which ultimately will help meet the RDRWA's vision:

"The Red Deer River Watershed will be healthy, dynamic and sustainable through the efforts of the entire community."

The first Background Technical Report for the IWMP focused on surface water quality, and was completed in early 2012 (Anderson, 2012). The second Background Technical Report summarized information on surface water quantity and groundwater resources (O2 Planning + Design Inc., 2013a); the third Background Technical Report addressed the topics of land use, riparian areas, and wetlands

(O2 Planning + Design Inc., 2013b). This study constitutes the fourth Background Technical Report, and addresses the topics of Terrestrial and Aquatic Biodiversity. All IWMP components are intimately related and consistent links and interrelationships among the different topic areas will be critical for crafting a successful IWMP.

This document aims to:

- Ensure that the state of terrestrial and aquatic biodiversity is comprehensively described and mapped using the best available information and data
- Define outcomes, propose indicators, and suggest potential targets for managing terrestrial and aquatic biodiversity in the basin at multiple scales
- Build on and complement the information in the State of the Watershed Report (Aquality, 2008) as well as the first, second, and third Background Technical Reports

1.2 Technical Input

The RDRWA expanded its Technical Advisory Committee (TAC) by assembling additional Technical Team members who were consulted for their expertise in terrestrial and aquatic biodiversity, and familiarity with the Red Deer River basin. Engagement and input from the Technical Team took the form of an on-line survey, distributed in March 2014. The Technical Team also reviewed the first draft of this report and made valuable suggestions for improvement.

1.3 Report Structure

This report is structured as a series of chapters.

- **Chapter 1: Introduction** provides an introduction to the context and scope
- **Chapter 2: Outcomes, Indicators, and Targets** provides some additional background information on outcomes, indicators, targets, and risk management in a watershed planning process
- **Chapter 3: Fundamentals of Biodiversity** focuses on key concepts, definitions, metrics, services, and overall global, regional, and local status pertaining to biodiversity
- **Chapters 4: Terrestrial Biodiversity:** focuses on background information and baseline data related to terrestrial biodiversity
- **Chapter 5: Aquatic Biodiversity** focuses on background information and baseline data related to aquatic biodiversity.
- **Chapter 6: Recommendations** focuses on draft targets for indicators, and recommendations for monitoring and data acquisition, research needs, and suggested Beneficial Management Practices for different stakeholder and industry groups.
- **Appendix 1** contains the compiled species occurrence information for each of the identified reporting units.

2. OUTCOMES, INDICATORS, TARGETS, AND REPORTING UNITS

Outcomes, indicators and targets are important tools that enable the effective synthesis of information on the many complex, interrelated variables that characterize watersheds. Indicators are critical to measure an organization's progress towards achieving its vision, as well as specified outcomes and goals. This contributes to performance management systems that gauge success over time. Throughout the watershed planning and implementation process, indicators and targets should be selected, refined and modified to reflect changing conditions and priorities. As the watershed planning process proceeds, a measureable target is set for each indicator, which allows for measuring progress and ultimately reaching the target (USEPA, 2008).

Watershed management plans should aim to provide a set of environmental, programmatic, and social indicators. In addition, selected indicators must be influenced by several considerations including validity, clarity, and practicality.

2.1 Environmental Indicators

Environmental indicators are based on observed variables of concern in the watershed as well as sources of degradation that contribute to impacts on the aquatic and terrestrial environments. For example, the extent of a human modified landscape and associated land use activities provide estimates of landscape integrity and biodiversity degradation at a regional level. Previous work in the watershed listed 20 recommended indicators in four major categories, including indicators and metrics related to terrestrial and aquatic biodiversity (Aquality, 2008). The prominent essay by Noss (1990) on "Indicators for Monitoring Biodiversity: A Hierarchical Approach" was also consulted as a basis for rationalizing indicators.

2.2 Programmatic and Social Indicators

Technical watershed reports often neglect or overlook "softer" programmatic and social indicators. These are important to establish and track in addition to environmental indicators (Davenport, 2003).

Programmatic indicators measure actions taken that are intended to achieve a goal. Examples include:

- Number of municipalities adopting biodiversity conservation and management bylaws or policies
- Number of monitoring programs implemented to assess management practices and status of vulnerable areas

Social indicators measure changes in social or cultural practices, such as increased awareness of watershed issues, and behavioural changes that lead to implementation of management measures, increased stewardship, and lower risks of impacts. Examples of social indicators include:

- Rates of citizen participation in watershed restoration activities
- Knowledge / attitudes among resource industries and/or field staff

2.3 Appropriate Reporting Units

2.3.1 Terrestrial Units

2.3.1.1 Natural Delineations

We use the term ***biodiversity management unit*** to refer to an ecosystem-based classification — easily recognized area, mapped terrain, or vegetation boundaries — that would be appropriate for managing biodiversity based on biotic, climatic, and physical (e.g., landform) characteristics. In general, there is coherence within and conformance of biotic elements among ecological vegetation classes (Mac Nally et al., 2002). However, while ecological vegetation classes may be used as planning units in lieu of very detailed information of all biodiversity components, the distribution of vegetation classes across the landscape may not be representative of the underlying distribution of biodiversity as a whole (Margules & Pressey, 2000).

Use of single surrogates or classification schemes is unlikely to satisfy the conservation objective of representing overall patterns of biodiversity. Hierarchies of classification and special provisions for certain taxa are still needed to augment broader planning bases (Noss, 1990). Such a requirement should be expressed in the recommendations of the integrated watershed management plan (IWMP) by the RDRWA.

2.3.1.2 Human Usage Delineations

Land-cover is one of the most important pieces of information used in conservation assessments. In the absence of consistent biodiversity data across regions we can still make inferences about the state of the natural environment based purely on land-cover (Theobald, Reed, Fields, & Soulé, 2012). An up-to-date representation of current land-cover is of key importance to the conservation and planning of terrestrial biodiversity in the Red Deer River watershed. A complete and comprehensive land-cover map will help inform future decisions on land use and in setting conservation priorities.

A comprehensive land-cover map is critical in developing a strategy for the conservation of biodiversity in the region (North West Department of Agriculture & Environment and Rural Development, 2009). Targets and management objectives must differ in a watershed in response to natural and spatial patterns. The Headwaters, Central Parkland, and Grassland landscapes of the Red Deer River watershed differ substantially from one another, and consequently require different targets and management approaches. In addition, more pristine areas with intact natural assets require different targets than landscapes with substantial human activity. With this in mind, the reporting units for terrestrial biodiversity (i.e., five watersheds) are the same as those identified in the RDRWA background report on riparian areas, wetlands and land use (O2 Planning + Design Inc., 2013a). Criteria applied in defining the units were sub-watershed boundaries (Aquality, 2008), natural regions and sub-regions (Natural Regions Committee & NRC, 2006), primary land management issues and land use patterns, and the locations of water quality monitoring stations (Figure 1, Table 1).

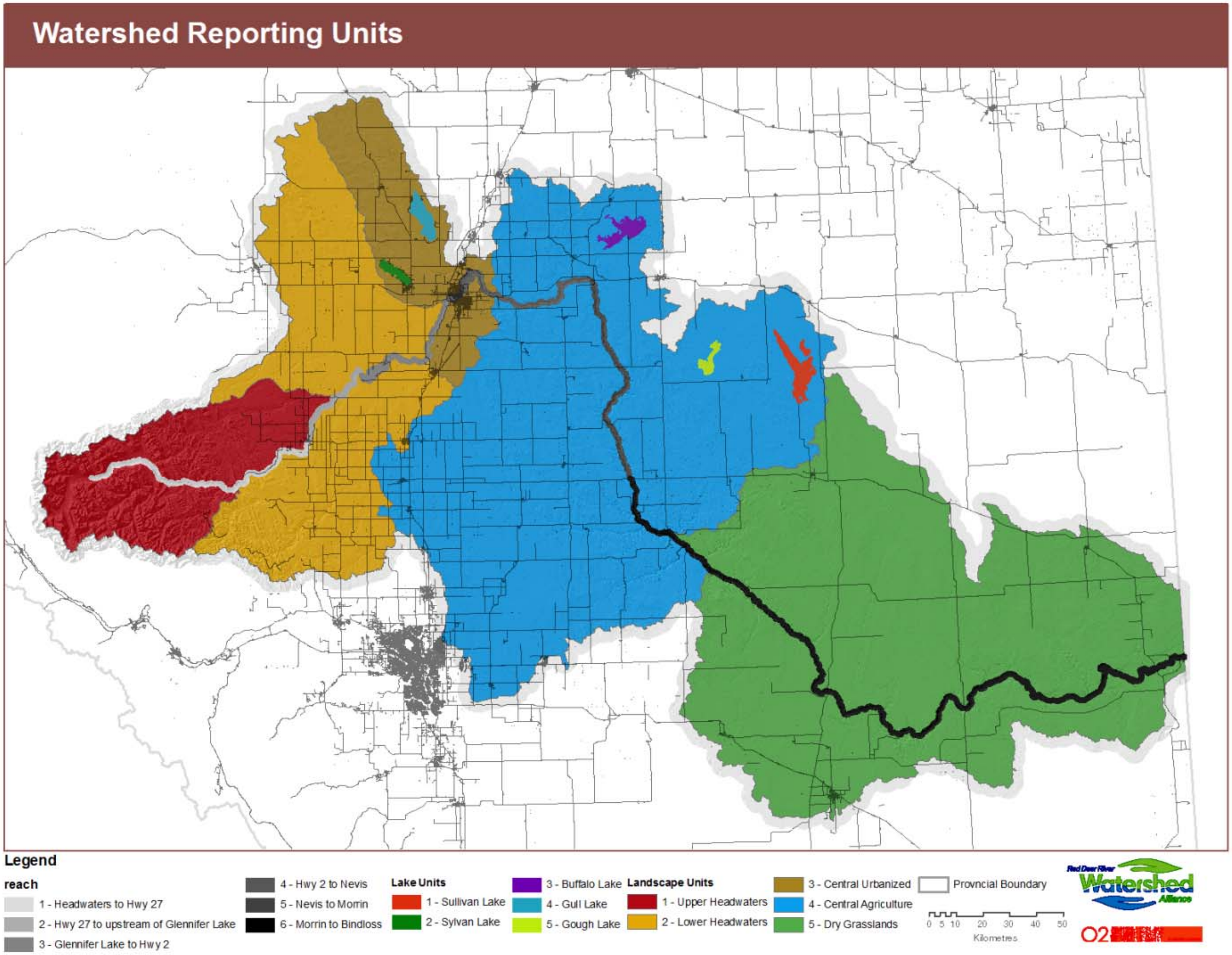

Figure 1. Map of Defined Reporting Units

Table 1. Reporting Units: Watershed-Based Landscape Units (O2 Planning + Design Inc., 2013a)

Watershed Landscape Unit	Rationale			
	Sub-Watersheds	**Natural Regions/ Sub-Regions**	**Primary Land Uses**	**Coordination with w/WQ Monitoring Stations**
1. A. Upper Headwaters (3,775 Km^2)	-Based on Panther and James sub-watersheds	-Primarily Rocky Mountain and Foothills	-Forestry -Oil and gas -Grazing -Recreation	Entirely upstream from Gleniffer Lake WQ monitoring station
2. B. Lower Headwaters (7,503 Km^2)	-Based on Raven, Medicine, Little Red Deer sub-watersheds (including Fallen Timber Creek)	-Primarily Dry Mixedwood, some Central Parkland	-Forestry -Agriculture -Oil and gas -Recreation	-Upstream from Red Deer at Hwy. 2 WQ monitoring station
3. C. Central Urbanizing (2,829 Km^2)	-Includes Blindman River, Wasksasoo	-Primarily Central Mixedwood Natural, some Central Parkland	-Concentrated urban development (e.g., Red Deer, Blackfalds, Penhold, Sylvan Lake, Gull Lake) -Agriculture -Petrochemical industry	-Upstream from Nevis WQ monitoring station
4. D. Central Agricultural (18,300 Km^2)	-Includes Buffalo, Threehills, Kneehill, Rosebud, Michichi sub watersheds	-Central Parkland in upper portions, Foothills Fescue and Northern Fescue in southernmost portions	-Agriculture	-Not ideal based on location of Morrin WQ station
5. Dry Grasslands (17,802 Km^2)	-Includes Berry, Matzihiwin, and Alkali sub-watersheds	-Primarily Dry Mixed Grass	-Oil and gas -Pasture/native prairies -Some irrigated agriculture	-Upstream from Blindloss however the Jenner station could also be used to further study/separate influences from the Alkali vs. Berry/Matzihiwin sub-watersheds

2.3.2 Aquatic Units

Though many land-based classifications could account for biodiversity in aquatic classifications, their ability to explain variation in aquatic community structure is generally low (Hawkins & Norris, 2000; Jenerette, Lee, Waller, & Carlson, 2002). This can be related to a lack of information on changing local variability in aquatic environmental characteristics. Although temperature regime, hydrology, elevation, and soils in the drainage basin are features of ecoregions that influence longitudinal patters in Alberta's large rivers, ecoregions do not account for causal factors or aquatic process that lead to variation in aquatic biota at different spatial scales. Broad regions cannot account for fine-scale (within watershed) variability in temperature, topography, geology and land cover (Snelder, Cattaneo, Suren, & Biggs, 2004). The presence or absence of lakes in adjacent watersheds from the same ecoregion can lead to very different ecological characteristics (e.g., the hydrothermal regime) within similar aquatic systems. Representation of aquatic biodiversity should be based on reporting units that adequately summarize aquatic ecosystems (Melles, Jones, & Schmidt, 2013). Proper reporting units encompass patterns and processes that allow links to be established between watershed health and aquatic biodiversity.

2.3.2.1 Reaches

Directs impacts of development on or near water resources tend to affect physical and chemical characteristics of the aquatic environment, which in turn influence aquatic biodiversity. Physical and chemical changes that occur as a result of impoundment, for instance, will lead to changes in the biological communities inhabiting the affected river reach. The significance of these changes depends on the state of existing conditions. Hence, the potential impact of any proposed development can alter the environment and greatly reduce the ability of some species to survive. Loss of suitable habitat could lead to threatening or endangering the continued existence of species (Bizer, 1997).

The reporting units for aquatic biodiversity were based on seven reaches as defined by the *Background Technical Report: Draft Site-Specific Water Quality Objectives for the Red Deer River Basin with Emphasis on Main stem* (Anderson, 2012). The reaches were delineated based on broad ecoregional changes, changes in land use, and the location of long-tem water quality monitoring stations (Figure 1):

- Reach 1 - Headwaters to Hwy 27
- Reach 2 - Hwy 27 to upstream of Gleniffer Lake
- Reach 3 - Gleniffer Lake to Hwy 2
- Reach 4 - Hwy 2 to Nevis
- Reach 5 - Nevis to Morrin
- Reach 6a - Morrin to Jenner
- Reach 6b Jenner to Bindloss

2.3.2.2 Lakes

Lakes form hydrologic networks essential to the meta-populations of many species, and provide important ecological, social and economic services such as wildlife habitat, livestock watering, fish production and recreational activities. At the regional scale, they collectively support uniquely biodiverse conditions, often biologically richer than those in running waters (Rosset et al., 2013). In contrast to other ecosystems, lakes tend to have more robust planning, management, and regulatory frameworks supported by different levels of government and organizations such as cottage associations and local charities. While lakes do not take on explicit sections in previous Background Technical Reports, there is value in considering them as reporting units for aquatic biodiversity and overall indicators of watershed health in the watershed. Five lakes were selected as additional reporting units for aquatic biodiversity, emphasizing context within reaches and watershed reporting units. Lakes were selected based on surface area, ranging from 42 to 143 km^2. The lake reporting units are:

- Sylvan Lake (42 km^2)
- Gull Lake (86 km^2)
- Buffalo Lake (96 km^2)
- Gough Lake (44 km^2)
- Sullivan Lake (143 km^2)

2.3.3 Riparian Areas

A huge variety of critical functional connections exist between aquatic and terrestrial habitats, including transfer of nutrients and water, the provision of conditions for species requiring both aquatic and terrestrial habitat, and the development of complex terrain as a function of water flow (Talley, Huxel, & Holyoak, 2006). These connections are mediated by both physical and biological processes spanning a wide range of spatial and temporal scales. Riparian areas referred to in this report are based mainly on the Riparian Areas, Wetlands, and Land Use Background Technical Report (O2 Planning + Design Inc., 2013a), within the context of both terrestrial (i.e., five watersheds as described in Table 1) and aquatic (i.e., six reaches and five lakes, as detailed in Figure 1) reporting units.

Riparian lands are found along the edge of waterbodies including rivers, streams, lakes, wetlands, springs, and ponds. Given the dynamic nature of these lands, there is currently no universally agreed on definition for riparian lands. This report follows the definition used in the Riparian Areas, Wetlands and Land Use report (O2 Planning + Design Inc., 2013b).

Hydrology (both groundwater and surface water) is the driving force behind physical, chemical, and biological processes occurring on riparian area lands (Clare & Sass, 2012). Riparian lands are highly interconnected habitats that allow for the transfer of energy and materials between terrestrial and aquatic ecosystems. Hence, riparian areas themselves are simultaneously under the influence of both terrestrial processes and aquatic processes (e.g., nutrient and sediment transfer). In drier regions, such as Alberta, riparian zones can be a source of water and nutrients to underlying aquifers and adjacent uplands, whereas in more humid climates, riparian lands are more often recipients of groundwater discharge (Clare & Sass, 2012). Riparian ecosystems play a more critical role in determining the dynamics and overall health of aquatic ecosystems than in other terrestrial areas. Well-vegetated riparian areas provide benefits to biodiversity in amounts disproportionate to their surface area. Approximately 80% of Alberta's species use riparian areas in all or part of their life cycle (AENV, 2008).

2.4 Scale and Geography

Identifying the forces that determine patterns of biodiversity constitutes a central issue in the field of ecology. While diversity patterns have been investigated at the scale of individual basins, stream reaches, and habitat units, results have been inconsistent. A variety of trends in species richness have been described in relation to habitat variables in other sources (Brosse, Arbuckle, & Townsend, 2003). The processes that govern diversity and habitat selection may vary across scales of analyses and, by ignoring scale, we risk drawing incorrect ecological conclusions.

2.5 Targets, Risks, and Cumulative Effects Management

Cumulative effects are the result of multiple human activities occurring on a landscape over time and space. The federal practitioners' guide defines cumulative effects as *"changes to the environment that are caused by an action in combination with other past, present and future human actions*" (Hegmann et al., 1999). Cumulative effects tend to occur as a result of mismatches in the scale at which impacts accumulate and the scale at which decisions are made. The consequences of human activities often appear insignificant on an individual project by-project basis, but accumulate to levels of significance when broader scales of time and space are considered (Kingsley, 1997).

Cumulative impacts are rarely linear, and are more often characterized by sudden non-linear shifts (Folke et al., 2004). Ecosystems are complex, dynamic, and adaptive systems, and rarely follow simple, predictable, linear changes through time. Long periods of stability, punctuated by abrupt, rapid, non-linear change to an alternative state are characteristic features of most ecosystems. These abrupt changes or shifts are caused by complex interactions between ecosystem resilience and the cumulative effects of multiple stressors. Often, ecosystems are resilient to a certain level of stressors and will show little change. However, if multiple stressors are crowded in space and time, a sudden "trigger" or critical threshold can be surpassed, causing the ecosystem to "flip" into an alternative state. Well documented examples of these non-linear changes include shifts from clear water to turbid water conditions in temperate lakes (Carpenter, Ludwig, & Brock, 1999) and shifts from hard corals to macroalgae in coral reef ecosystems (Hughes, 1994).

2.6 Targets and Management Responses

To achieve sustainable development, management responses need to be driven by and linked to established indicators and targets specifying the desired level or range that an indicator must achieve or maintain through time. The aim is to be proactive to help avoid reaching potential critical thresholds where undesirable conditions and unacceptable environmental, social, or economic impacts occur. Determining the appropriate target value for an indicator often requires a blend of science, planning, and social values. An ecological thresholds defined as a critical value at which sudden non-linear and often irreversible change occurs, (Folke et al., 2004) is notoriously difficult to quantify and predict, and is often site-specific or only relevant for locations in which the observed changes occur.

Data gaps and incomplete information are a challenge when formulating targets, particularly if planning exercises still require management targets. Adaptive management frameworks are useful in this regard. An adaptive management approach could guide the development of management targets that integrate robust scientific knowledge and changes in base information as they arise. Monitoring strategies, information trends, and values must be carefully implemented and tracked in order to ensure targets are up to date. Targets must be set by integrating existing knowledge and data, expert analysis, socioeconomic considerations and adjustments with experience. Effective adaptive management requires testing assumptions and iterative analysis through time to refine or change targets in response to gained data , information and management experience.

3. APPROACHES TO ASSESSING BIODIVERSITY

3.1 Classification of Biodiversity

While diversity refers to the range of variation or differences among a set of entities, biological diversity refers to variety within the living world. The term biodiversity is commonly used to describe the number, variety, and variability of living organisms. The Canadian Biodiversity Strategy defines biodiversity as “the variety of species and ecosystems on Earth and the ecological processes of which they are a part – including ecosystem, species, and genetic diversity components.” This very broad usage is essentially a synonym for ”Life on Earth” (UNEP, 2014).

Biodiversity is more than just the sum of its parts, as all of its elements, regardless of whether we understand their roles or know their status, are integral to maintaining functioning, evolving, resilient ecosystems. Complex concepts such as biodiversity are often easier to grasp if reduced to their component pieces. Furthermore, effective management often requires measurements and hence, quantitative values ascribed to biodiversity.

In general, measures of biodiversity involve the quantification of components such as the number of species present, the population of a species or its abundance, a habitat or the sum of all such components within a given area or site. Evaluations may be carried out on various components of biodiversity (i.e., from genetic variation within species, to individual species, species assemblages, biotopes and biomes) and at a variety of scales, from local to regional, and even at the global scale (Tucker, 2005). Approaches and criteria for biodiversity evaluations vary considerably depending upon their purpose, their scale and the biodiversity components in question. As a starting point, Spellerberg (2005) indicated six general best practices that would be useful to include in an evaluation framework for biodiversity:

- Evaluation objectives should be defined
- Criteria should be quantifiable, rather than subjective
- Evaluations should be repeatable
- Evaluations should be based on biological principles
- The methods, results and analysis should be explained so that they can be understood by everyone who has an interest in the area being evaluated
- Cost in time and money should take into account the depth and integrity of underlying surveys

3.1.1 Genetic Diversity

Genetic diversity refers to the diversity (or genetic variability) within a species. Each individual species possesses genes that are the source of its own unique features. The term genetic diversity also covers distinct populations of a single species, such as variations in susceptibility to pest species across broad stretches of forest. The huge variety of different gene sets defines an individual or a whole population's ability to tolerate stress from any given environmental factor (Vold & Buffet, 2008). For instance, while some individuals might be able to tolerate an increased load of pollutants in their environment, others, carrying different genes, might suffer from infertility or even die under the exact same environmental conditions.

The protection or management of genetic diversity is costly. The reduction and extinction of populations is far easier to analyze. Extinction is not only the loss of whole species, but is also preceded by a loss of genetic diversity within the species (Pasari, Levi, Zavaleta, & Tilman, 2013). This loss reduces the species’ ability to perform its inherent role in the ecosystem. The loss of genetic diversity within a species can result in the loss of useful and desirable traits (e.g., resistance to parasites).

3.1.2 Species Diversity

Species biodiversity primarily refers to the abundance of different animal, plant and microbial species. Species are a complete, self-generating, unique ensemble of genetic variation, capable of interbreeding and producing fertile offspring. They (and their subspecies and populations) are generally considered to be the only self-replicating units of genetic diversity that can function independently. The composition of species in a given ecosystem is the result of a long lasting adaptation to certain features such as temperature range, or availability of food or light. Furthermore, the function of a certain species emerges as a result of interactions with its environment, like increasing the light availability for plant growth or preventing sediment erosion. The loss of species is accompanied by a loss of functionality, some of which directly affects human life in a severe way. Examples include the reduction of commercially harvested fish stocks, and loss of soil and sediment used for agriculture. When species become extinct, the value and ecosystem services they provide are lost forever. Over-exploitation, pollution, habitat conversion, and introduction of non-native species into new ecosystems are the main threats to species diversity today.

3.1.3 Ecosystem Diversity

An ecosystem is a dynamic complex of plant, animal and microorganism communities and non-living (abiotic) elements, all interacting as a functional unit. An ecosystem's character changes as community members and physical contexts change. When a threshold of tolerance is reached in the system, it may result in the inability to return to its previous form (Vold & Buffet, 2008).

Ecosystem diversity is the relationship between landscapes, their territorial organization and dynamics, and inter-relationships as seen by individuals and societies through different local, regional and national cultures. There is a great diversity of ecosystems worldwide that function relative to their ecological regions.

Natural ecosystems, in all their quality and diversity, have been altered by human activities over thousands of years. They are continually evolving, owing to the constant changes in the way that different societies use land. Landscapes consequently embody the collective memory of nature and their inhabitants, forming a complex element of the environment. Natural ecosystems provide significant value and services but their individual tolerance levels to human disturbances are varied and often unknown. The measurement, management, and protection of ecosystems is a challenging practice that requires innovative and diverse approaches (Mahamane, 2012). In the absence of a strong understanding of ecosystem processes, it is often more appropriate to manage sources of anthropogenic disturbance, as these are often better known and more easily quantified.

3.1.4 Hierarchical Characterization of Biodiversity

An analytical framework for biodiversity that identifies the major ecosystem components at several levels of organization could be used for determining specific, measurable indicators for monitoring change and assessing the overall status of biodiversity (Noss, 1990). Following the hierarchal concept of ecosystems (O'Neill, DeAngelis, Waide, & Allen, 1986), biodiversity should be monitored at multiple levels of organization, and at multiple spatial and temporal scales. No single level of organization (e.g., gene, population, community) is fundamental, and the level of resolution is dependent on specific goals (Figure 2).

Biodiversity, as Franklin et al. (1981) recognized, could be further classified using three primary attributes: composition, structure, and function. This hierarchal characterization organizes biodiversity according to primary ecological attributes found on each level of organization (Figure 3). The hierarchy recognizes the relevance of capturing interactions with the environment in different ways at different levels of biological organization. Effects at one level can be expected to reverberate through other levels, often in unpredictable ways (Noss, 1990). Ultimately, the hierarchical framework should facilitate selection of biodiversity indicators in environmental monitoring and assessment programs (Noss, 1990).

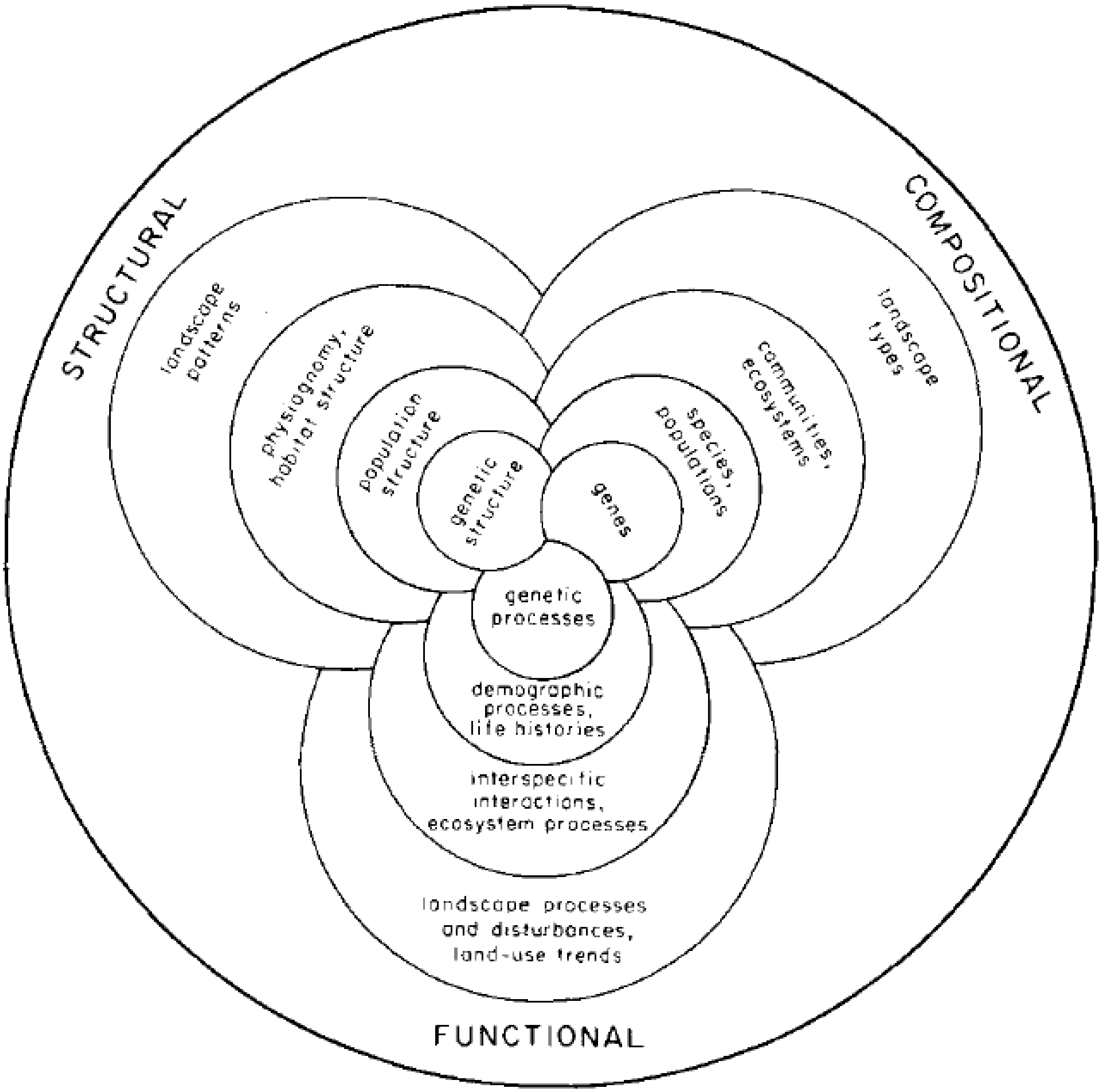

Figure 2. Compositional, Structural, and Functional Biodiversity, Shown as Interconnected Spheres, Each Encompassing Multiple Levels of Organization.

3.1.4.1 Compositional diversity

Composition measures the variety of species in an ecological system. Descriptors of composition include species richness and species diversity. While the concept of richness only involves the number of species found on a certain area, diversity usually includes a composed metric between number of species and the total number of individuals representing each of the species populations (i.e., abundance). Compositional diversity often considers each species on an equal basis (Péru & Dolédec, 2010; Vold & Buffet, 2008), without regard for the particular roles that individual species may play in a given ecosystem.

3.1.4.2 Structural diversity

Structure is the physical organization or pattern of an ecosystem. It is measured by communities, habitats (or patches) and other elements at a landscape scale (Noss, 1990). Measurements that quantify variability in community structure are important because these can describe habitat heterogeneity. In general, a more heterogeneous structure indicates a higher structural diversity. Structural diversity could also infer the interaction of a number of different physical landscape attributes, therefore, quantitative landscape structure evaluations tend to require a series of complex multivariate analysis (McElhinny, 2002).

3.1.4.3 Functional Biodiversity

Functions are the result of one or more biotic or evolutionary processes including predation, gene flow, natural disturbances and mycorrhizal associations; as well as abiotic processes such as soil development and hydrological cycles (Vold & Buffet, 2008). Examples of functions include predator-prey systems, meta-population dynamics[1], and habitat connectivity. While compositional diversity is a common and simple metric for assessing human impacts on ecosystems, functional diversity is scarcely employed because of the difficulty involved in measuring and assessing it across broad areas. Where it can be carried out, it is a highly desirable metric from the perspective of habitat management and conservation. However assessing functional biodiversity requires a dedicated long-term analysis that often precludes its use in broad-scale planning efforts.

COMPONENT/ATTRIBUTE	COMPOSITION	STRUCTURE	FUNCTION
Ecosystem	Ecosystems in an area	Patch size	Connectivity
Species	Species richness in an area	Abundance	Predator/prey dynamics
Genetic	Number of unique genes in a population	Relative abundance of each unique gene in a population	Adaptation

Figure 3. Examples of Biodiversity Components and Attributes (Vold & Buffet, 2008)

3.2 Ecosystem Services

Societies gain a multitude of values, benefits, goods and services from ecosystems. Collectively, these benefits are known as ecosystem services. The Millennium Ecosystem Assessment report (Millennium Ecosystem Assessment, 2003, 2005) defines ecosystem services as the “benefits people obtain from ecosystems” and distinguishes four categories of ecosystem services (Figure 4:

- Provisioning services
- Regulating services
- Cultural services
- Supporting services

Supporting services differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over a very long time period, whereas changes in the other categories have relatively direct and short-term impacts on people (Millennium Ecosystem Assessment, 2003). For

[1] Metapopulation is a population in which individuals are spatially distributed in a habitat in two or more subpopulations. Populations of mountain sheep and coral-reef fishes are good examples of metapopulations. Human activities and natural disasters are the main causes of metapopulation and increase the population that occurs as metapopulations. Such factors cause the fragmentation of a large habitat into patches.

example, humans do not directly use soil formation services, although changes in this would indirectly affect people through the impact on provisioning services, such as food production.

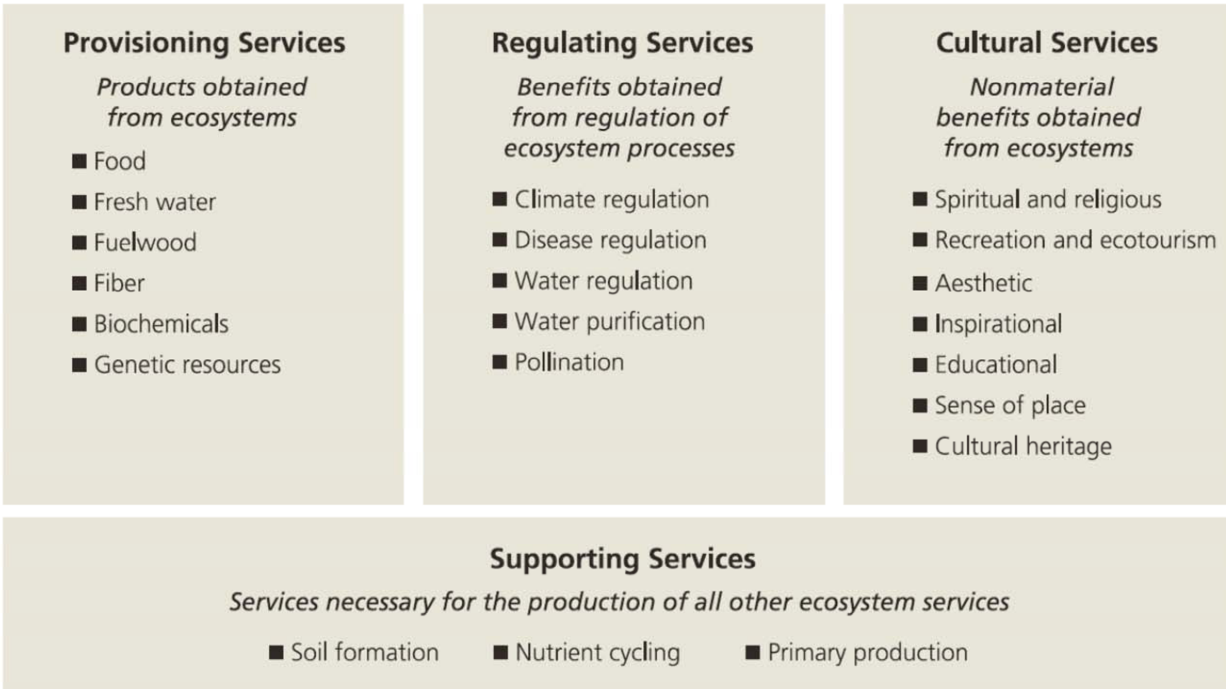

Figure 4. The Four Categories of Ecosystems Services - Millennium Ecosystem Assessment Report (2005).

At present, there are few studies that link changes in biodiversity with changes in ecosystem functioning and human well-being. Societies have benefited economically over the last century from the conversion of natural ecosystems to anthropogenically influenced systems. The losses of biodiversity and associated changes in ecosystem services have resulted in the decline of well-being, resulting in the impoverishment of certain social groups who depend on the land for their livelihood (Millennium Ecosystem Assessment, 2003, 2005).

Local or functional extinction, or the reduction of populations to the point that they no longer contribute to ecosystem functioning, can have dramatic impacts on ecosystem services. Changes in biotic interactions between species (i.e., predation, parasitism, competition, and facilitation) can lead to disproportionately large, irreversible, and often negative alterations of ecosystem processes. Many changes in ecosystem services are brought about by the removal or introduction of organisms in ecosystems that disrupt biotic interactions or ecosystem processes. Based on the Millennium Ecosystem Assessment (2005), some critical links on the importance of biodiversity to ecosystem services are:

- Biodiversity affects key ecosystem processes in terrestrial ecosystems such as biomass production, nutrient and water cycling, and soil formation and retention (all of which govern and ensure supporting services).
- The preservation of the number, types, and relative abundance of resident species can enhance invasion resistance in a wide range of natural and semi-natural ecosystems.
- Biodiversity influences climate at local, regional, and global scales. Therefore, changes in land use and land cover that affect biodiversity can affect climate. In addition to biodiversity within habitats, the diversity of habitats in a landscape exerts additional impacts on climate across multiple scales.

- Some components of biodiversity affect carbon sequestration and are therefore important in the context of carbon-based climate change mitigation when afforestation[2], reforestation, reduced deforestation, and biofuel plantations are involved.
- The maintenance of natural pest control services, which benefits food security, rural household incomes, and national incomes of many countries, is strongly dependent on biodiversity.

Ecosystem	Ecosystem Function	Ecosystem Service Value Assessed	Annual Non-Market Flow Value Estimates (millions, 2002$)
Forests	Atmospheric and climate stabilization	Annual net carbon sequestration (excludes peatlands); carbon storage (i.e., stock value) is an estimated $849.2 billion	$1,852
	Water stabilization and water supply	Watershed service: municipal water use (cubic metres/year [database incomplete])	$18
	Raw materials	• Subsistence value for Aboriginal communities and households • Non-timber forest products (mushrooms, berries, and wild rice)	$575 $79
	Genetic resources	• Biodiversity: value of pest control by birds • Biodiversity: passive value—willingness to pay (WTP) for conservation	$5,401 $12
	Recreation	Economic value to Canadians from recreation-related activities	$4,484
	Cultural	Included in subsistence values for Aboriginal communities and households	*
Wetlands and peatlands	Atmospheric and climate stabilization (peatlands)	Annual carbon sequestration; carbon storage (i.e., stock value) is an estimated $349.1 billion	$383
	Disturbance avoidance (peatlands)	Flood control and water filtering	$76,998
	Disturbance avoidance (non-peatland wetlands)	Flood control, water filtering, and biodiversity value	$3,372
	Water stabilization and water supply		**
	Erosion control and sediment retention		**
	Raw materials	Included in subsistence values for Aboriginal communities and households	*
	Genetic resources	Included in flood control, water filtering, and biodiversity value	**
	Recreation	Included in the economic value to Canadians from recreation-related activities	***
	Cultural	Part of subsistence values for Aboriginal communities and households	*
Lakes, rivers, riparian zones	Raw materials	Included in subsistence values for Aboriginal communities and households	*
	Recreation	Included in the economic value to Canadians from recreation-related activities	***
	Cultural	Included in subsistence values for Aboriginal communities and households	*
Undeveloped lands	Cultural	Included in the economic value to Canadians from recreation-related activities	*
TOTAL Non-Market Value of Boreal Ecosystem Services (flow values only)			$93,174 million; $159.52/hectare/year

Note: * included in subsistence values for Aboriginal households of $575.1 million; ** included in flood control, water filtering, and biodiversity value; *** included in the forest ecosystem, recreation ecosystem function economic value estimate.

Figure 5. Boreal Ecosystem Services Value Accounts (Anielski & Wilson, 2005).

[2] Afforestation refers to the establishment of a forest or stand of trees in an area where there was no forest

3.3 Status of Biodiversity

In addressing the complex topic of biological diversity, it has become conventional to think in hierarchical terms: from the genetic material within individual cells, to individual organisms, populations, species, communities of species, and the entire biosphere (Noss, 1990). The diversity of species, however, is the most accepted measure of the biodiversity of an area.

For all aspects of biodiversity, the current pace of loss is gaining momentum and shows no indication of slowing down. Species extinction does happen naturally, but there is mounting evidence that humans have increased the extinction rate by a factor of 100 times the natural rate over the past 100 years (United Nations Environment Programme, 2014). Since the current extinction rate is much greater than the rate at which new species arise, there is a net loss of biodiversity.

Virtually all Earth's ecosystems have been somehow influenced by human actions, especially through agricultural practices and river damming (Millennium Ecosystem Assessment, 2005). Although the most rapid changes in ecosystems are now taking place in developing countries, industrial countries historically experienced comparable changes. Figure 6 demonstrates the loss in each biome type prior to 1950 and between 1950 and 1990. While cultivated lands provide many provisioning services (such as grains, fruits, and meat), habitat conversion to agriculture typically leads to reductions in local native biodiversity (Millennium Ecosystem Assessment, 2005).

The following sections describe the status of biodiversity from the global scale to our region of interest.

3.3.1 Global

Much of the emphasis in biodiversity studies is on mammals, birds, and insects, all of which are relatively large and relatively easy to observe. However, it is also important to consider the diversity of smaller organisms such as invertebrates, fungi, or bacteria in soils and freshwater or marine environments. Globally, around 1.75 million species have been described and formally named to date, and there are grounds for believing that several million more species exist but remain undiscovered (Convention on Biological Diversity, 1993). Eight million of the approximate10 million animal species estimated to exist are insects. Almost 10,000 bird species and 4,640 mammals are recognized, and it is believed that very few of either group remain to be discovered. Approximately 71% of the Earth's surface is covered by marine waters, yet this is the most unexplored ecosystem type in the world (Convention on Biological Diversity, 1993).

Water

Only 2-3% percent of the total world’s water volume is non-saline. Approximately two-thirds of this quantity is locked away as ice, and around one-third is stored as groundwater in the upper layers of the Earth's crust. Surface freshwater, i.e., the world's lakes, rivers and wetlands, hold only a small volume of the remaining water, but these waterbodies support a considerable portion of the world’s biodiversity. For example, about 40% of the more than 25,000 fish species known in the world occur in freshwater, and many isolated water systems, particularly large old lakes, contain a vast number of species found nowhere else on Earth. Freshwater ecosystems, even more than terrestrial and marine environments, are highly threatened and have suffered significant losses of biodiversity (Puckett, Jelks, Burkhead, & Walsh, 2008).

Land

Land, bearing the wide diversity of terrestrial ecosystems that humans are most familiar with, as well as surface freshwaters, covers less than one-third (29%) of the Earth's surface. Although the information available on the distribution of the world's species is uneven and incomplete, the single most obvious pattern in global biodiversity is that overall species richness tends to increase toward the equator. In the simplest terms, this means that there are more species in total and per unit area in the tropics than in temperate regions and more in temperate regions than in polar regions. This variation in species number is strongly correlated with global variation in incident energy and water availability, which may potentially lead to increased net primary production by photosynthetic organisms. A possible explanation for variation in species number is that this broader resource base may allow more species to coexist (Convention on Biological Diversity, 1993).

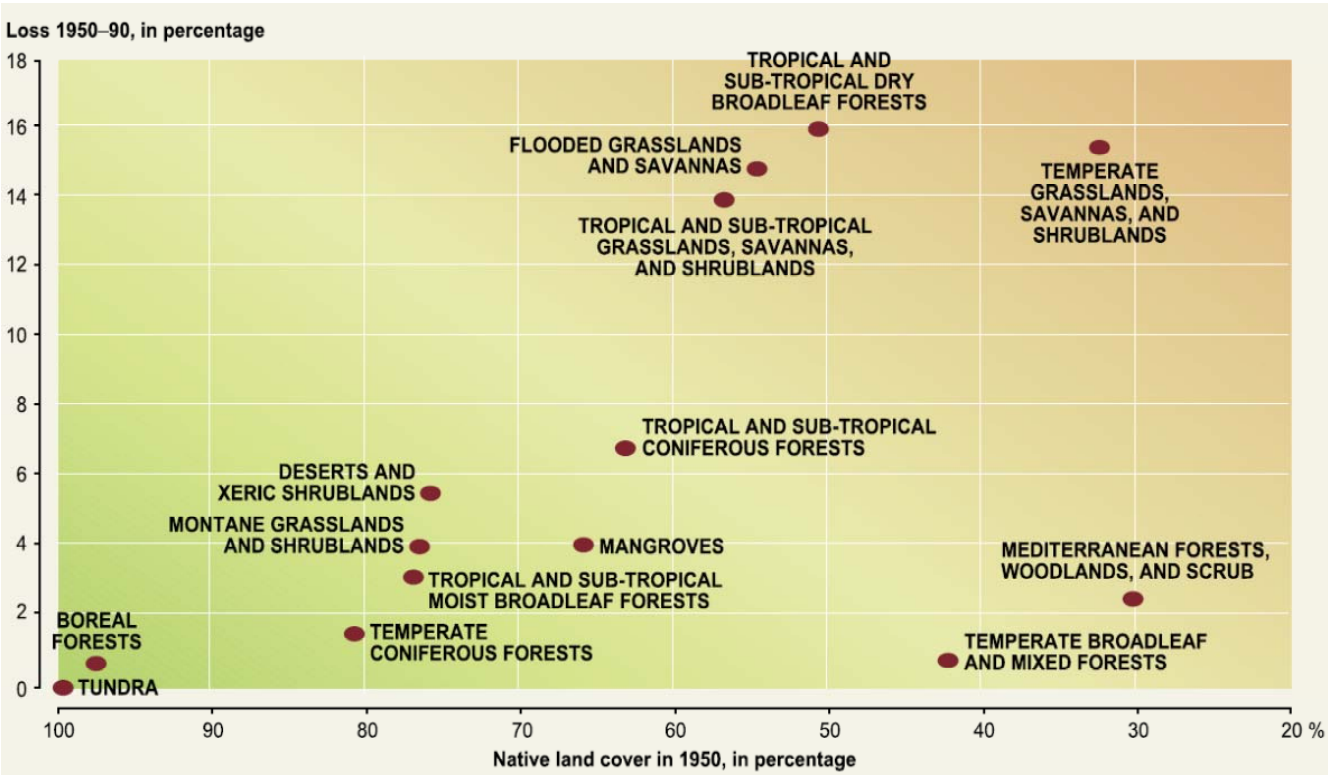

Figure 6. Relationship Between Native Habitat Loss to Agriculture by 1950 and Losses Between 1950 and 1990 (Millennium Ecosystem Assessment, 2005).

3.3.2 Canada

Canada has identified over 70,000 species, approximately half of which are terrestrial, a quarter freshwater, and the other quarter marine. The marine environment has fewer species than expected, while freshwater has more. This trend reverses itself at higher levels of classification, where two-thirds of biological phyla are mostly, or exclusively marine, while only a third is primarily terrestrial or freshwater. The patterns of Canadian biodiversity follow a definite declining trend towards less biodiverse environments, largely following the increasingly hostile environment as one heads north. This gradient pattern has been taken into account in the borders and definitions of Canada's ecozones (The Redpath Museum, 2014).

Canadian Biodiversity: Ecosystem Status and Trends (2010) was the first assessment of Canada's biodiversity from an ecosystem perspective. Some findings reveal that much of Canada's natural endowment remains healthy, including large tracts of undisturbed wilderness, internationally significant wetlands, and thriving estuaries, particularly in sparsely populated or less accessible areas. Over half of Canada's landscape remains intact and relatively free from human infrastructure. Much of this undisturbed landscape is in the far and remote north, the northern boreal forest and the coastal temperate rainforest.

The report highlights that the government of Canada recognizes freshwater fisheries for their significant economic and cultural importance (Federal Provincial and Territorial Governments of Canada, 2010). For example, significant policy interventions have allowed fish populations to recover from past overharvesting. Also, contaminants such as DDT and PCBs, which caused a profound decrease in wildlife populations, are no longer used. Federal, provincial, and territorial governments have protected many ecologically significant areas in the last 15 years. Canadians have demonstrated their commitment to biodiversity conservation through the growing number of individuals, groups, and businesses involved in stewardship initiatives.

Conservation Priorities

While progress has been made, the Canadian working group on biodiversity suggests that action is still needed to maintain important ecosystems (Federal Provincial and Territorial Governments of Canada, 2010). The following trends were identified as requiring action for reversal:

- Loss of old growth forests
- Changes in river flows at critical times of the year
- Loss of wildlife habitat in agricultural landscapes
- Declines in certain bird populations
- Contaminants recently detected in the environment are known to be impacting wildlife populations increases in wildfire
- Significant shifts in marine, freshwater, and terrestrial food webs

Temperature increases, shifting seasons, and changes in precipitation, ice cover, snowpack, and frozen ground are indicators of climate change that have the capacity to alter ecosystems in unpredictable ways.

Following the mentioned trends, examples of ecosystems elements or natural processes that are compromised or are reaching critical thresholds include (Federal Provincial and Territorial Governments of Canada, 2010):

- Fish populations that have not recovered despite the removal of fishing pressure
- Declines in the area and condition of grasslands, where grassland bird populations are dropping sharply
- Fragmented forests that place forest-dwelling caribou at risk
- Dramatic loss of sea ice in the Arctic, which is currently causing a multitude of ecosystem impacts and is expected to trigger declines in ice-associated species such as polar bears
- Nutrient loading is on the rise again in over 20% of the water bodies sampled, including some of the Great Lakes where, 20 years ago regulations successfully reduced nutrient inputs
- Lakes affected by acid deposition have been slow to recover despite reductions in acidifying air emissions
- Invasive non-native species have reached critical levels in the Great Lakes and elsewhere

Detecting changes in ecosystems early-on, and acting before thresholds are crossed, has the greatest likelihood of preventing biodiversity loss. Restoration, although more costly and time-consuming than prevention, has also proven to be successful.

Monitoring

Canada's long-term climate and hydrological monitoring programs are comprehensive, but Canada has not put equivalent effort into monitoring biodiversity and ecosystems. Information collected on local and regional scales cannot be extrapolated to a broader scale. Appropriate ecosystem-level information is less available than decision makers may realize, which is impacting the ability to develop relevant land use policies (Federal Provincial and Territorial Governments of Canada, 2010).

3.3.3 Alberta

Alberta's diverse landscape and aquatic ecosystems support a wide variety of plants and animals. However, Alberta's growing human population and economy, along with associated factors, can impact native plants and animals. In 2010, it was determined that 21 of 584 vertebrate species (i.e., 3.6%) are at risk of disappearing from the province. This is an increase from the 2.2% of species at risk reported in 2005. The calculation uses the number of vertebrates (584) rather than the full range of species (5,235) to make long-term comparisons more meaningful. The percentage of species at risk in Alberta was most recently reported in the 2010-11 Annual Report of Alberta's Ministry of Environment and Sustainable Resource Development (2011a). The *2010 General Status of Alberta Wild Species* report (2011b) showed that most populations of plants and animals are healthy and secure. Of the 5,235 species assessed in the province, as of June 2011 there are:

- 16 endangered species (face imminent extinction or elimination from Alberta)
- 13 threatened species (likely to become endangered if limiting factors are not reversed)
- 15 species of special concern (characteristics that make them particularly sensitive to human activities or natural events)

Alberta compares favourably on a national basis, where the percentage of species at risk is 2.7% (Alberta ESRD, 2005).The most recent Alberta results report on 5,235 species, including hundreds of vertebrate animals and thousands of plants and invertebrates (Alberta ESRD, 2011b). The general status ranking for each wild species in Alberta is based on population size, population dispersion, population distribution, trend in population, trend in distribution, threats to populations, and threats to habitat. The ranks are *At Risk, May be at Risk, Sensitive, Secure, Not Assessed, Exotic/Alien, Extirpated/Extinct, and Accidental/Vagrant*. The percentage of species at risk increased in 2010 relative to 2005, primarily because the measure changed from all species at risk to vertebrate species at risk to provide a more stable long-term measure. The next analysis will be conducted in 2015 (Alberta ESRD, 2012a).

Status of Alberta Species

Figure 7 shows the proportion of Alberta's wild species in several general status categories, including comparisons between 2000, 2005 and 2010 (Alberta ESRD, 2012b). Data for this indicator is taken from the General Status of Alberta Wild Species 2000, 2005 and 2010. These rankings were prepared over a five-year period by species experts across Canada and represent the most up-to-date inventory of provincial biodiversity at the species level.

Nationally, a greater proportion of species from the reptiles and amphibians groups are classified as "secure" than in Alberta. However, these statistics are influenced by a relatively small number of species from each group represented in Alberta (Alberta ESRD, 2012b). In the remaining groups that have larger population sizes (mammals and birds), the national status classifications are comparable to Alberta's. Changes in national status between 2005 and 2010 are limited in most groups; however, more reptiles have been classified as At Risk (Figures 7 and 8). Freshwater fish were not assessed in Canada in 2010, so this group was not included in the Alberta comparisons.

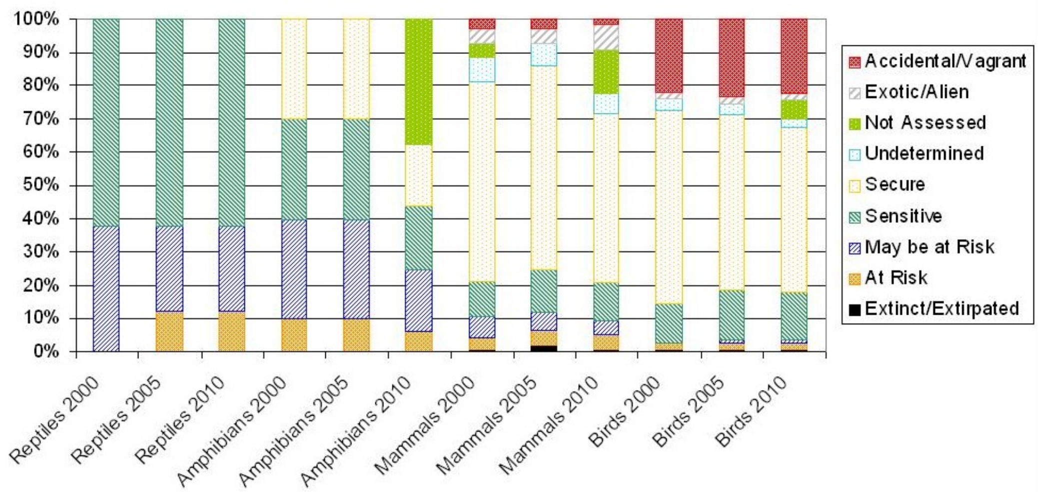

Figure 7. Comparison of 2000, 2005 and 2010 General Status of Alberta Wild Species (Alberta ESRD, 2011b).

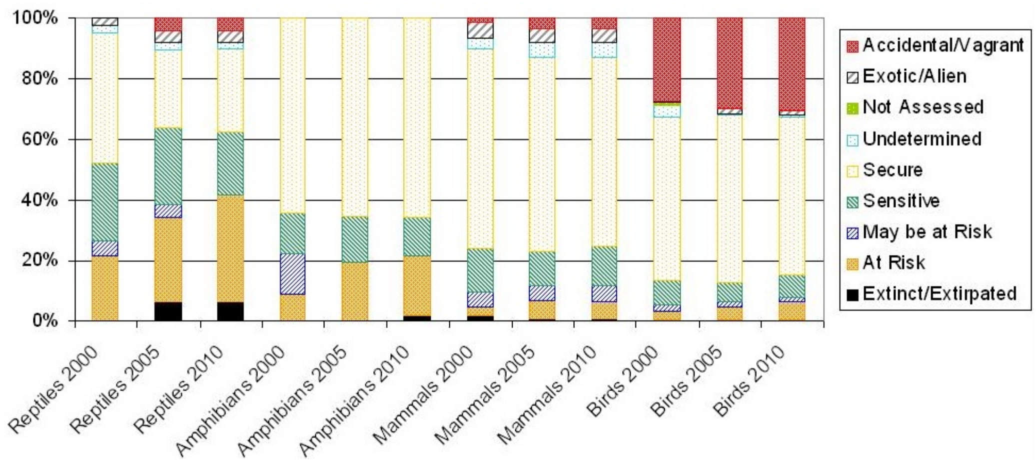

Figure 8. Comparison of 2000, 2005 and 2010 General Status of Canada's Wild Species (Alberta ESRD, 2011b).

3.3.4 Red Deer River Watershed

The majority of the land base in the Red Deer River watershed is covered by annual croplands, grasslands and perennial cropland/pastures (35%, 23%, and 20% respectively). Coniferous forests cover about 7% of the land base, while the remaining land covers represent <2.5% each and are uncommon at the watershed scale (Aquality Environmental Consulting Ltd., 2009).

The watershed has a clear west-east gradient, where percentage cover of the treed and forested land base ranges from 40-70% in the western sub-watersheds to 10-15% in the eastern sub-watersheds (Aquality Environmental Consulting Ltd., 2009). Conversely, the grassland and forage (i.e., perennial pasture) land cover has a percentage cover increase that trends upwards from west (~35%) to east (~65%). Annual croplands and developed lands are most prominent in the central region, particularly the Waskasoo Creek, Threehills Creek, Kneehills Creek, and Rosebud River sub-watersheds.

3.4 Monitoring of Aquatic and Terrestrial Biodiversity

3.4.1 Canada

Canadians recognize the need to maintain a healthy environment and are concerned about the degradation of ecosystems and the loss of species and genetic diversity that results from human activities. The Government of Canada, with support from provincial and territorial governments, signed and ratified the United Nations Convention on Biological Diversity in 1992. The Convention was believed to be a very important global and national instrument for promoting and guiding efforts to conserve biodiversity and the sustainable use of biological resources (Minister of Supply and Services, 1995).

As soon as the Convention came into force in 1993, work on a Canadian Biodiversity Strategy began to determine the measures required to meet the obligations of the Convention and to enhance coordination of national efforts aimed at the conservation of biodiversity and the sustainable use of biological resources. The centrepiece of the framework is a suite of four national outcomes:

- Healthy and diverse ecosystems
- Viable populations of species
- Genetic resources and adaptive potential
- Sustainable use of biological resources

Following the adoption of the Biodiversity Outcomes Framework in 2006, the Canadian Councils of Resource Ministers mandated the development of an Ecosystem Status and Trends Report for Canada as a first deliverable in 2007 (Federal Provincial and Territorial Governments of Canada, 2010).

Provincial and territorial governments have integrated biodiversity into government initiatives, using a variety of policies, strategies, legislation and voluntary approaches. Canadian initiatives regarding biodiversity issues deal with key sectors such as federal, provincial and territorial government, urban areas, Aboriginal peoples, academic and scientific institutions, environmental non-governmental organizations, industry and business, and stewardship. As part of Canada's Species at Risk Act (Minister of Justice, 2002), the federal government established the Habitat Stewardship Program, which allocates up to $13 million per year for projects that conserve and protect species at risk and their habitats, and engage citizens in conservation projects. In 2007, the Government of Canada announced the Natural Areas Conservation Program (2013) to help non-profit, non-government organizations secure ecologically sensitive lands and ensure the protection of ecosystems, wildlife and habitat. Through a federal contribution of $225 million to the program, 336 properties, totalling more than 103,600 hectares, have been acquired, resulting in population increases of 74 species at risk.

Reports on the general status of more than 1,600 Canadian wild species are meant to be updated every five years, with the first released in 2000 (National Status Working Group, 2011). In addition, Parks Canada (2009) has a comprehensive science-based monitoring system in place to assess ecological integrity. For each major park ecosystem, a set of monitoring measures is chosen based on an understanding of ecosystem structure, ecological function, and the stressors impacting the ecosystem. Monitoring results are recorded in an information system that provides regular updates of each park's ecological condition. Results are reported to the public in a State of Parks report. Canada is also monitoring Arctic biodiversity through its participation in the Circumpolar Biodiversity Monitoring Program (CBMP), an initiative of the Arctic Council's Conservation of Arctic Flora and Fauna Working Group (2004). The CBMP is a mechanism for harmonizing and enhancing long-term biodiversity monitoring efforts across the Arctic in order to improve the detection of, and reporting on, significant trends and pressures.

3.4.2 Alberta

Environment and Sustainable Resource Development (ESRD) is the designated ministry steward of air, land, water and biodiversity in the province of Alberta. Alberta ESRD's vision aims to achieve desired environmental outcomes and sustainable development of natural resources for Albertans. In late 1995, the Government of Alberta committed to using the Canadian Biodiversity Strategy (Minister of Supply and Services, 1995) as a guide for conserving biodiversity and ensuring the sustainable use of biological resources. Currently, Alberta ESRD provides two condition indicators (i.e., susceptibility of biodiversity to change) with regards to biodiversity: percentage of species at risk and status of Alberta species. Another important source of biodiversity information in the province is the Alberta Biodiversity Monitoring Institute (ABMI). The ABMI program encompasses more than 20 scientists and surveys a broad range of biodiversity components such as diversity of living organisms, habitat structures, vegetation communities and landscape patterns (Alberta Biodiversity Monitoring Institute, 2003). Other important sources of biodiversity information in Alberta are grouped in Table 2.

Table 2. Main Provincial Sources of Biodiversity Data Grouped by Biodiversity Indicator.

Type of indicator	Metric	Source[3]	Spatial
All	Biodiversity on Alberta's species	ABMI	Mix
All	Biodiversity on Alberta's species	ACIMS	Mix
Structure	Stands physical attributes	AVI	Yes
Structure	Terrain features	AltaLis	Yes
Composition	Land Cover	CPVI	Yes
Composition	Percentage of native Land Cover	NPVI	Yes
Composition	Percentage of native Land Cover	GVI	Yes
Composition	Fish and wildlife inventory data	FWMIS	Yes
Function	General water quality of lakes and large rivers	Alberta ESRD	No
Function	ID of species at risk	Species at Risk program	No
Composition	Biological monitoring of lakes and rivers	Alberta ESRD	No

3.4.3 Red Deer River Watershed

In 2008, the RDRWA developed a State of the Watershed report (Aquality Environmental Consulting Ltd., 2009). The purpose of the report was to summarize the current knowledge, comment on the environmental integrity of the Red Deer River watershed, and provide the basis for a future Integrated Watershed Management Plan. The report focuses on 20 indicators, including biological indicators, which provide the background information required for improved watershed management decisions by regulators, policy makers, landowners and industrial users. Table 3 summarizes biological indicators (derived from plant and animal data) from which various aspects of ecosystem health can be determined or inferred, and ultimately linked to the overall health of the watershed (Aquality Environmental Consulting Ltd., 2008).

[3] Acronyms are: Alberta Monitoring Institute (ABMI), Alberta Conservation Information Management System (ACIMS), Alberta Vegetation Inventory (AVI), Central Parkland Vegetation Inventory (CPVI), Native Prairie Vegetation Inventory (NPVI), Grassland Vegetation Inventory (GVI), Fisheries & Wildlife Management Information System (FWMIS), Alberta Environment and Sustainable Resource Development (Alberta ESRD). The Column Type of Indicator Refers to Biodiversity Attributes Covered (i.e., Structure, Composition, And Function). The Column Spatial Refers to Information Conducive of Spatial Analysis.

Table 3. Summary of Biological indicators and Metrics for the Red Deer River Watershed (Aquality Environmental Consulting Ltd., 2008).

Indicator	Metric (s)	Performance Measures
Biodiversity (terrestrial and aquatic)	Species richness and abundance	Changes in species richness and abundance, protection of habitat areas
Fish	Index of Biological Integrity (IBI)	Maintenance and/or improvement in riparian area health, preservation of fish habitat
Land Cover	Percentage of land cover	Increase in percentage cover of native vegetation
Species at risk	Number of species at risk within watershed and their distribution	No addition of species at risk

3.5 Indicators of Biodiversity

3.5.1 Importance

Biodiversity indicators are measurable surrogates for environmental end points that are of value to the public. Stakeholders often require biodiversity monitoring programs to track the impact of changes in human land use activities so that potential mitigation strategies can be evaluated (Forester & Machlis, 1996). Species monitoring has additional importance to stakeholders because species are independent, self-replicating units that cannot be re-created (Bunnell, 1998). As such, a biodiversity indicator should be sufficiently sensitive to provide an early warning of change, be widely applicable, easy and cost effective to measure and calculate, and relevant to ecologically significant phenomena (Noss, 1990). Landres et al.(1988) recommend using indicators as part of a comprehensive risk analysis strategy that focuses on key habitats (including corridors, mosaics, and other landscape structures) as well as species. Such a strategy might include monitoring indicators of compositional, structural, and functional biodiversity at multiple levels of organization. The Alberta Biodiversity Monitoring Institute (2014) suggests using an organizational structure for biodiversity indicators in monitoring programs that takes into account the amounts and patterns of various landscape types. Remote sensing can be a feasible way to monitor these landscape attributes while linking regional patterns to ecosystem integrity (Franklin, 1993). However, landscape metrics are not sufficiently detailed to document changes in local habitat structure (Hunter, 2005; Lindenmayer, Margules, & Botkin, 2000). Thus, it is necessary to monitor structures within vegetation types using ground methods (Hunter, 2005). Finally, since species may not be tightly linked to a particular landscape or habitat characteristics, some species should be monitored to ensure that biota are responding as predicted (Franklin, 1993; Hunter, 2005).

3.5.2 Hierarchical Framework

Noss (1990) emphasizes four points to consider when choosing biodiversity indicators:

1. Conduct a comprehensive assessment of biodiversity as an end point in itself, rather than as an index of air quality, water quality, or some other anthropocentric measure of environmental health.
2. Selection of indicators depends on formulating specific questions relevant to management or policy that are to be answered through the monitoring process.
3. Indicators for the level of organization one wishes to monitor can be selected from levels at, above, or below that level. Thus, if one is monitoring a population, indicators might be selected from the landscape level (e.g., habitat corridors that are necessary to allow dispersal), the

population level (e.g., population size, fecundity, survivorship, age and sex ratios), the individual level (e.g., physiological parameters), and the genetic level (e.g., heterozygosity).

4. The indicators developed by Noss (1990) in Table 4 are general categories, most of which cut across ecosystem types. In application, many indicators will be specific to ecosystems. Coarse woody debris, for example, is a structural element critical to biodiversity in many old-growth forests, such as in the Pacific Northwest (Franklin et al., 1981), but may not be important in more open-structured habitats, including forest types subject to frequent fire.

Table 4. Indicator Variables for Inventorying, Monitoring, and Assessing Terrestrial Biodiversity at Three Levels of Organization: Compositional, Structural, and Functional Attributes (Noss, 1990).

	Indicators			
	Composition	**Structure**	**Function**	**Inventory and monitoring tools**
Regional Landscape	Habitat or land-cover types; patterns of species distributions	Patchiness; fragmentation; pattern of habitat distribution	Disturbance processes; nutrient cycling rates; energy flow rates; connectivity; hydrologic processes; human land-use trends	Aerial photographs; Geographic Information System (GIS) technology; time series analysis; spatial statistics; mathematical indices
Community-Ecosystem	Abundance, richness, evenness, rarity, and diversity of species and guilds; proportions of endemic, exotic, threatened, and endangered species	Substrate and soil variables; slope and aspect; vegetation biomass and physiognomy	Nutrient cycling rates; herbivory, parasitism, and predation rates; colonization and local extinction rates; fine-scale disturbance processes, including human intrusion	Same as for Regional Landscape; resource inventories; habitat suitability indices; observations, censuses and inventories, captures, and other sampling methodologies
Population-Species	Abundance; frequency; importance or cover value; biomass; density	Population structure (sex ratio, age ratio); morphological variability	Demographic processes; metapopulation dynamics; phenology	Censuses; remote sensing; habitat suitability index; species-habitat modelling; population viability analysis

3.5.2.1 Planning for Biodiversity Management: the Notion of Patterns and Scale in Biodiversity

Biodiversity occurs at multiple spatial scales and levels of biological organization (Schwartz, 1999). A greater emphasis on conservation and management of diversity must occur at all appropriate levels and scales (Poiani et al., 1998). Figure 9 illustrates a hierarchical framework used to classify and analyze aquatic biodiversity at multiple scales within a watershed. At a regional scale, the primary purpose of biodiversity planning is to identify a set of reporting units that best represents the native species and ecosystems of the region and the underlying ecological processes that sustain them. Planning at the scale of reporting units aims to maintain or improve the ecological condition of targeted biological or environmental features of these areas (Poiani et al., 1998). Reporting units incorporate a broad set of biodiversity indicators at a variety of levels of biological organization and spatial scales. Carefully derived planning units must adequately represent the patterns of biodiversity in a region in order to accurately achieve the target-based goals of environmental management plans (Groves et al., 2002).

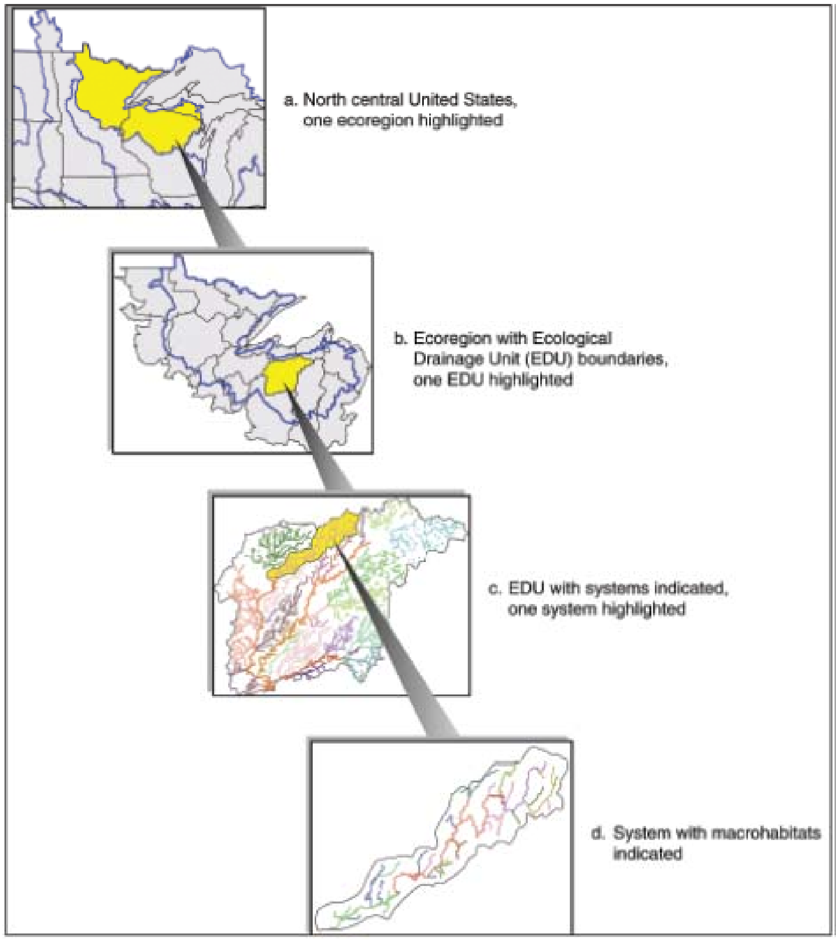

Figure 9. Hierarchical Framework Used to Classify Aquatic Biodiversity (Groves et al., 2002).

3.6 Metrics of Diversity

Complete and systematic knowledge of the watershed is a desired outcome of sound regional planning for biodiversity. While a great deal of information exists for small areas of the watershed, as well as a wealth of personal knowledge harbored by those who live and work in the region, comprehensive spatially-explicit information is not available. With this in mind, only a limited set of metrics can be produced, based on the data at hand.

The following section outlines the metrics chosen for this analysis to summarize the diversity found in the Red Deer River watershed. These metrics are intended to reflect a hierarchical framework of biodiversity indicators (Table 4), and was strongly dependent on data availability. A more thorough data collection and analysis effort, which is beyond the scope of this document, will undoubtedly produce more realistic and nuanced assessments of biodiversity across the watershed. The metrics employed in this analysis represent a a first pass in describing and inferring biodiversity values to inform current practices, and guide more rigorous and systematic data collection and sampling efforts.

3.6.1 Land Cover Diversity

Land cover in the RDRW was compiled using the best land cover information available. The ABMI human footprint dataset provides detailed spatial information on developed areas in the watershed. To fill in the gaps between these features, a combination of the Central Parkland Vegetation Inventory, the Grassland Vegetation Inventory, and the ABMI Wall-to-Wall land cover datasets were used. A crosswalk was devised to combine the varied land cover categories of each data layer into an appropriate and consistent set of classes used in this analysis (Table 5).

Table 5. Land Cover Crosswalk Between Original Cover Classes.

Agriculture
landcov = 'Agricultural'
landcov = 'AnnualCropland'
landcov = 'PerennialCroplandandPasture'
landcov = 'Human Modified'
FP_NAME = 'Cultivation (Crop/Pasture/Bare Ground)'

Forest
landcov = 'broadleafForest-dense'
landcov = 'ConiferousForest'
landcov = 'ConiferousForest_Dense'
landcov = 'ConiferousForest_Open'
landcov = 'DeciduousForest'
landcov = 'mixedwood-dense'
landcov = 'N_Conif'
landcov = 'N_Decid'

water
landcov = 'water'
FP_NAME = 'Canals'
FP_NAME = 'Reservoirs'

Wetland
landcov = 'Wetland'
landcov = 'Wetland_Shrub'
landcov = 'Wetland_treed'

Vegetated
landcov = 'herb'
landcov = 'shrub_tall'
landcov = 'shrubland'
landcov = 'Upland'
FP_NAME = 'Seismic line'
FP_NAME = 'Cut Blocks'

grassland
landcov = 'Grassland'
landcov = 'N_Grass'

unvegetated
landcov = 'barren'
landcov = 'shadow'
landcov = 'snow'
landcov = 'rock'
landcov = 'exposed land'
FP_NAME = 'Borrow-Pits/Dugouts/Sumps'

developed
landcov = 'developed'
landcov = 'Industrial'
landcov = 'Settled'
FP_NAME = 'Well Site'
FP_NAME = 'Urban'
FP_NAME = 'Rural (Residential/Industrial)'
FP_NAME = 'Road – Hard Surface'
FP_NAME = 'Rail – Hard Surface'
FP_NAME = 'Municipal (Water and Sewage)'
FP_NAME = 'Mine Site'
FP_NAME = 'Industrial Site Rural'
FP_NAME = 'High Density Livestock Operation'

After compilation and reclassification of this data, the resulting shapefile was dissolved to remove boundaries between polygons that shared the same land cover class, to produce polygons whose boundaries match observed changes in land cover. This land cover dataset serves as an important component of subsequent analyses on the composition and configuration of natural and anthropogenic cover. However, the anthropogenic footprint data is available at a very fine resolution, the natural cover classes are less refined, and would undoubtedly benefit from comprehensive field validation, which remains outside the scope of this report. It should serve as a general assessment at the watershed scale, but would not be sufficient for fine-scale planning exercises.

3.6.2 Wetland Complexes

Wetlands play an important role in the maintenance of biodiversity, providing diverse habitats and serving as stepping stones for movement across the landscape. However, all wetlands are not equal. ; Proximity to other wetlands and the nature of the land cover separating wetlands contributes to a wetland's value in the context of a particular area. Wetlands influence the ecological function of their surroundings. Small wetlands that make up part of a large wetland complex may be more valuable than isolated wetlands of equivalent size.

Wetland complexes have been referred to as the functional ecological unit of the prairie pothole region of central North America (Johnson et al. 2010). To identify these complexes, a "buffer" based spatial analysis may be used to identify wetlands that neighbour other wetlands. All wetland cover polygons in the compiled land cover dataset were selected, and buffered outwards by 100 m. Overlapping buffers were merged, and any wetlands occupying the same merged buffer were considered to be in the same "wetland complex". A total wetland area was calculated for each complex. The ratio of the number of wetlands to the number of complexes was calculated for each reporting unit, as this ratio increases, more wetlands make up part of the same complex. This provides a rough metric for the comparison of overall distribution of wetlands between areas.

3.6.3 Species Richness

Species richness is a commonly used metric used to assess and compare the diversity of organisms in an area. This is a fundamental metric, but one that is fraught with misconceptions. Species richness does not incorporate any information as to the ecological role served by individual species, nor does it speak to the distribution of those species across the reporting unit. Indeed, richness does not itself identify which species are commonly found elsewhere, and which are endemic to the local region. More fundamentally, the richness of an area has been shown to be proportional to the area in question (MacArthur and Wilson, 1967). This makes comparisons between regions of different areas problematic. However, historically observed species richness is an appropriate baseline value to compile when beginning a longer-term monitoring program in a region. This can serve to identify hotspots of diversity, and notable gaps in observation records.

A point count dataset was constructed from the provincial Alberta Conservation Information Management System (ACIMS) and Fisheries and Wildlife Management Information System (FWMIS) datasets. These provincial datasets compile species observations from a wide variety of sources, over a broad time period, and are not the result of a concerted and systematic survey of biodiversity. That being said, they contain a great wealth of information regarding the occurrence of species across the province. The ACIMS data focuses on rare plant and arthropod observations, and generally does not list common and broadly distributed species. The FWMIS dataset compiles terrestrial and aquatic vertebrate species observations, and is more inclusive, containing examples of common wildlife such as deer. In total, 123,891 observations are found in the Red Deer River watershed. ACIMS data are comprised of polygon observations (sensitive species found in the ACIMS database are reported only at the township scale). This data was reduced to centroid points, so that a single point layer could be analyzed. The species were summarized into broader taxonomic groupings (birds, mammals, fish, arthropods, reptiles, graminoids, forbs, lichens, mosses, sedges, and liverworts) and compiled by reporting units.

3.6.4 Slope

Terrain complexity has profound effects on the local functioning of ecological processes. As slope increases, incoming solar radiation has a more heterogeneous effect on the land, causing small scale local differences in energy availability and microclimate. At the same time, steeper slopes tend to be more sensitive to disturbances from human activities, as plants found in these areas often occur at the edge of their ranges, and soils are more sensitive to erosion.

A 25 m Digital Elevation Model was used to produce slope values across the entire watershed. This slope value was classified into discrete classes (Less than 5 % slope, 5-10% 10-15%, and greater than 15% slope), and the fraction of each class found in each reporting unit was summarized. Although 25 m pixels are undoubtedly too coarse to allow for identification of fine scale terrain features, this analysis is sufficient to allow for differentiation of terrain across the entire watershed.

A terrain ruggedness index model provides a more powerful tool for assessing terrain complexity (often used in species-specific habitat suitability index models), however the calculation is rather more involved, requiring a pixel-by-pixel moving window assessment of the surrounding area, and is beyond the current scope of this report.

3.6.5 Land Cover Change

The MODIS land cover product is designed to support scientific investigations that require information related to the current state and seasonal-to-decadal scale dynamics in global land cover properties (https://lpdaac.usgs.gov/products/modis_products_table). MODIS Land Cover Type (MCD12Q1) includes five main layers in which land cover is mapped using different classification systems (Friedl et al., 2002). The MCD12Q1 product consists of five different land cover classifications that are produced for each calendar year at 500 m resolution. The 8-Biome classification proposed by Running et al. (1994) was employed to investigate land cover changes in the RDRW from 2001 to 2011 (Table 6).

Table 6. Land Cover Types Description.

Class	8-Biome classification
0	Water
1	Evergreen needleleaf vegetation
2	Evergreen broadleaf vegetation
3	Deciduous needleleaf vegetation
4	Deciduous Broadleaf vegetation
5	Annual broadleaf vegetation
6	Annual grass vegetation
7	Non-vegetated land
8	Urban

3.6.6 Riparian Disturbance

Natural riparian vegetation acts to stabilize banks during flooding events, preventing erosion. At the same time, the complex habitats provided by riparian vegetation make them important sources of biodiversity. Riparian areas function as important corridors for wildlife movement through the landscape. Disturbed riparian areas are associated with reduced bank stability, as the absence of natural riparian vegetation results in increased bank erosion. Disturbed riparian areas are more prone to flood-related damage, and are less likely to serve as habitat for species naturally adapted to riparian conditions.

Site-level Riparian Health Assessments are frequently used throughout the province to assess the condition of riparian areas. However, these assessments require detailed site visits and are simply beyond the capacity of watershed-wide planning. On the other hand, a GIS-derived assessment of riparian potential provides a useful tool for identifying areas with the potential to harbour riparian vegetation (due to their proximity to water bodies, adjusted by the effects of local terrain conditions). The Caslys variable width riparian model (Caslys Consulting Ltd., 2010) makes use of a digital elevation model to estimate potential riparian areas across the province using a cost-distance approach. By intersecting the Caslys polygons with non-natural land cover polygons, an estimate of the total disturbed riparian area can be constructed and summarized for each reporting unit.

3.6.7 Landscape Intactness

The degree of human disturbance in a landscape is a strong predictor for the habitat quality of that landscape. Many approaches to measuring human disturbance and habitat fragmentation have been proposed and implemented over the years, but few metrics respond in a consistent and intuitive fashion to changes in the amount and configuration of disturbance. Jaeger's (2000) Effective Mesh Size metric is a very useful tool for quantifying not only the amount, but the configuration, of such disturbances. It is calculated using a “habitat patch” layer (in this case, all natural land cover classes) and a continuous “planning unit” layer.

Effective Mesh Size can best be described as the effective area of continuous natural cover in a particular area, or the probability that any two points selected randomly within a given unit will be part of the same connected patch. The greater the value, the more likely that any two points placed at random in an area will fall within the same connected natural area. That is, the greater the human footprint, the lower the effective mesh size. This analysis is conducted using 1 km^2 hexagon unit areas to summarize the distribution of natural land cover types. A “cross-boundary” procedure (Girvetz, Thorne, Berry, & Jaeger, 2008; Moser, Jaeger, Tappeiner, Tasser, & Eiselt, 2006) prevents these hexagon units from artificially fragmenting the landscape, looking outside the bounds of the individual hexagons to assess whether natural cover is connected. Areas with larger mesh sizes contain larger and more connected natural cover, areas with smaller mesh sizes contain less and more fragmented natural cover. Areas with zero mesh size contain no natural cover within that 1 km^2 hexagon.

4. Terrestrial Biodiversity

4.1 Natural Regions and Sub-Regions

In Alberta, the Natural Regions landscape classification describes environmental diversity (Natural Regions Committee & NRC, 2006). This land classification system provides the basis for representing important biodiversity elements at a landscape or regional scale, and emphasizes overall spatial patterns reflecting climate, geological and soil factors. The Red Deer River watershed covers five natural regions and 13 natural sub-regions (Table 7), which are defined below.

Table 7. Percentage of Coverage of Natural Sub-Regions per Reporting Unit.

	Reporting Unit				
Natural Sub-region	**1**	**2**	**3**	**4**	**5**
Northern Fescue	0%	0%	0%	35%	10%
Dry Mixedgrass	0%	0%	0%	0%	81%
Mixedgrass	0%	0%	0%	0%	9%
Central Parkland	0%	23%	46%	47%	0%
Foothills Fescue	0%	0%	0%	18%	0%
Lower Foothills	17%	21%	5%	0%	0%
Dry Mixedwood	7%	43%	34%	0%	0%
Central Mixedwood	0%	0%	15%	0%	0%
Sub-Alpine	23%	0%	0%	0%	0%
Upper Foothills	25%	7%	0%	0%	0%
Alpine	26%	0%	0%	0%	0%
Montane	1%	0%	0%	0%	0%
Foothills Parkland	0%	5%	0%	0%	0%

4.1.1 Rocky Mountain Natural Region

This region is part of a major uplift that trends along the western part of Alberta forming the Continental Divide. The Rocky Mountain Natural Region is underlain primarily by upthrust and folded carbonate and quartzitic bedrock. This region is the most topographically rugged region in Alberta, and ranges in width from only 10 kilometres in the Waterton Lakes National Park area to more than 100 kilometres in the central portion. Elevations rise from east to west, from major river valleys at 1,000 to 1,500 metres, to 3,700 metres along the Continental Divide (Natural Regions Committee & NRC, 2006). Many of Alberta's largest rivers originate in this region and subsequently drain into the Saskatchewan and Mackenzie River systems. The highest mountains occur in the central part of the region with the lower mountains in the far north and far south. Within the Rocky Mountain Natural Region, three natural sub-regions have been identified; reflecting changes in environmental conditions related to altitude and aspect. These natural sub-regions are the Alpine Sub-region, the Subalpine Sub-region, and the Montane Sub-region, which are described below.

4.1.1.1 Alpine Sub-region

This region includes all areas above the tree line, including vegetated areas, rockland, snowfield and glaciers. Materials are generally residual bedrock and colluvium often on steep slopes. Extensive areas of unvegetated bedrock occur. Rock glaciers occur from Kananaskis Country north to Jasper National Park. Neoglacial landforms are especially prevalent in the Main Ranges of Banff and Jasper National Parks. The mean temperature from May to September is about 6^0C, and frost-free periods are rare.

Mean annual precipitation is highly variable and ranges from 420 – 850 mm. Alpine vegetation typically forms a complex mosaic, in which microclimatic variations are reflected in marked changes in dominant species.

4.1.1.2 Subalpine Sub-region

The Subalpine Sub-region occupies a band between the Montane and Alpine Sub-regions in the south and between the Upper Foothills and Alpine Sub-regions in the north. The boundary between the Subalpine and the Upper Foothills is based partly on the changes from Foothills bedrock to Rocky Mountain strata, although portions of the Foothills Geological Belt are included in the Subalpine Sub-region in the Kakwa area. The upper limit of the Subalpine Sub-region ranges from about 2,300 metres in southern Alberta to 2,000 metres in northern Alberta. Lower elevation limits are around 1,600 metres in the south and 1,350 metres in the north. Morainal materials occupy much of the Subalpine Sub-region with colluvial and residual bedrock materials frequent at higher elevations. Fluvial and glaciofluvial deposits are common along stream valleys, with lesser amounts of glaciolacustrine and aeolian materials. The mean annual temperature ranges from -1^{0}C – 3^{0}C, with a mean July temperature of about 15^{0}C. Total annual precipitation is highly variable and ranges from 460 – 1400 mm. Winter precipitation is higher in this Sub-region than in any other, with often more than 200 cm of snowfall. Soils vary widely, reflecting the great diversity in parent materials and ecological conditions. The Sub-region is often divided into a Lower Subalpine characterized by closed forest of lodgepole pine (*Pinus contorta* Douglas ex Louden) and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt) and an Upper Subalpine with spruce-fir closed forests and open forests near the tree line. At lower elevations, lodgepole pine forests cover extensive areas following fire. Engelmann spruce and subalpine fir forests typically occur on higher, moister sites that have not been subject to fire. Open forests in the Upper Subalpine are transitional to the treeless Alpine Sub-region above. Dominant trees include Engelman spruce, subalpine fire and whitebark pine (*Pinus albicaulis* Engelm.).

4.1.1.3 Montane Sub-region

Much of the southerly portion of the Montane Sub-region occurs on east-west trending ridges that extend out from the Foothills Belt from the United States border to the Porcupine Hills. The Porcupine Hills are underlain by relatively flat-lying sedimentary rocks. To the north, the Montane Sub-region occurs mostly along major river valleys. Along the Bow River, it extends from the lower reaches of the Ghost River to about Castle Junction and, along the North Saskatchewan River from Kootenay Plains to Saskatchewan Crossing. The most northerly outlier is along the Athabasca River and adjacent valleys from Yellowhead Pass to Brule Lake. A small, disjunct area is the Ya-Ha-Tinda along the Red Deer River west of Sundre. Portions of the Cypress Hills are also included here. Sandstone outcrops are typical of the main, southerly portion. The Cypress Hills are capped by Tertiary gravels and were unglaciated during the last glaciation. The landforms of the major valleys are primarily fluvial and glaciofluvial terraces and fans with smaller areas of glaciolacustrine, Aeolian and moranial deposits. Elevations range from 1000 – 1350 metres in Jasper National Park, to 1,350 – 1,600 metres in Banff National Park, to more than 1,600 along the Eastern Slopes south of Calgary.

4.1.2 Foothills Natural Region

The Foothills Natural Region is transitional zone situated between the Rocky Mountain Natural Region and the Boreal Forest Natural Region. It consists of two sub-regions, the Lower Foothills and the Upper Foothills. This natural region occurs from Turner Valley in the south, north along the eastern edge of the Rocky Mountains in a gradually widening belt, and also includes several outlying hill masses such as the Swan Hills, Pelican Mountain, and the Naylor Hills.

4.1.2.1 Upper Foothills Sub-region

This Sub-region occurs on strongly rolling topography along the eastern edge of the Rocky Mountains from about the Bow River north to the Grande Cache area, with disjunct occurrences in the Swan Hills and Clear Hills. The sub-region is generally between the Lower Foothills and Subalpine sub-regions with an upper elevation limit of about 1,500 metres in the south to 1,000 metres in the north. Bedrock outcrops of marine shales and non-marine sandstones are frequent. Morainal deposits are common over bedrock throughout much of the area, although colluvium and residuum occur on steeper terrain. The Sub-region has a mean annual precipitation of about 540 mm, with about 340 mm occurring from May-September. The mean May-September temperature is 10 – 12^{0}C. Upland forests are nearly all coniferous and dominated by white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) Britton, Sterns & Poggenb.). Lodgepole pine forests occupy large portions of upland sites and black spruce dominates wet sites.

4.1.2.2 Lower Foothills Sub-region

The Lower Foothills Sub-region occurs on rolling topography created by the deformed bedrock along edge of the Rocky Mountains. Lower elevations range from about 1,250 metres in the south, to about 700 metres near Lesser Slave Lake, and to about 350 metres at the northern end near Rainbow Lake. Upper elevation limits range from about 1,450 metres in the south to 1,000 metres in the north. The sub-region also includes several flat-topped erosional remnants with flat-lying bedrock that are partially capped with Tertiary gravels, such as Swan Hills, Pelican Mountain, and Clear Hills. Surficial materials are commonly a moranial veneer or blanket over bedrock. Extensive organic deposits occur in valleys and wet depressions, especially in eastern portions. Along the mountains, bedrock outcrops of marine shales and non-marine sandstones occur often in valleys. Fluvial and glaciofluvial deposits occur along major stream valleys. Mean annual precipitation averages 465 mm, of which two-thirds falls from May-September. The mean May-September temperature is 11 – 13 ^{0}C. The forests reflect the transitional nature of the Sub-region, in which mixed forests of white spruce, black spruce, lodgepole pine, balsam fir (*Abies balsamea* (L.) Mill.), aspen (*Populus* spp.), balsam poplar (*Populus balsamifera* L.) and paper birch (*Betula papyrifera* Marsh.) occur. Lodgepole pine forests are perhaps the best indication of the lower boundary of the Sub-region. The upper boundary is marked by the occurrence of nearly pure coniferous forest cover. Black spruce forests occur on moist upland sites, and fens are common in much of the Sub-region.

4.1.3 Boreal Forest

This region is the largest in Alberta most of it however, occurs north of the Red Deer River watershed. The landscape in this particular region is covered almost entirely by trees, with aspen and balsam poplar dominating the evergreens. In the northernmost areas evergreens form a seemingly endless carpet, broken only by water in the form of fens, bogs, lakes and rivers. Inside the Boreal Forest of Alberta are extensive expanses of aspen parkland in the Grande Prairie, Peace River and Fort Vermilion areas. There are also four major river systems that drain most of Alberta's north country. The presence of extensive wetlands is a major characteristic of the Boreal Forest Natural Region as well. The Boreal Forest Natural Region is very diverse topographically, climatically and biologically. Many of the changes are gradual and subtle which makes division into sub-regions difficult and seemingly arbitrary. The Boreal Forest may be divided into six sub-regions, two of which cover part of the Red Deer River watershed. These are the Dry Mixedwood Sub-region and the Central Mixedwood Sub-region, which are described below.

4.1.3.1 Dry Mixedwood Sub-region

This Sub-region is characterized by low relief and level to undulating terrain. Surficial materials are mostly till as ground morain and hummocky moraine landforms with some areas of Aeolian dunes and sandy outwash plain. The climate of the Sub-region is subhumid continental with short, cool summers and long, cold winters. The mean May-September temperature is about 13^{0}C, and the growing season is about 90 days. Annual precipitation averages 350 mm, with June and July being the wettest months. Winters are relatively dry, with about 60 mm of precipitation. Aspen is an important tree species, occurring in both pure and mixed stands. Balsam poplar frequently occurs with aspen on the moister sites. Over time, white spruce and, in some areas, balsam fir can be expected to increase or replace aspen and balsam poplar as the dominant species; however, frequent fire seldom permits this to occur, and pure deciduous stands are common in the southern part of the Sub-region.

4.1.3.2 Central Mixedwood Sub-region

Surficial materials in the Central Mixedwood Sub-region are predominantly till as ground moraine and hummocky moraine landforms with some areas of Aeolian dunes, sandy outwash plain, and glaciolacustrine plain. The terrain has low relief and a level to undulating surface. The climate is subhumid and continental with short, cool summers and long, cold winters. While the average temperature from May-September is about 12^0C, the frost-free period is about 85 days. Annual precipitation averages about 380 mm, with June and July being the wettest months. Winters tend to be relatively dry however, overall, moister and cooler than the Dry Mixedwood Sub-region. The vegetation is similar to that of the Dry Mixedwood Sub-region. The differences are largely in the proportion of various vegetation types and other landscape features. Aspen is the characteristic forest species occurring in both pure and mixed stands, while balsam poplar frequently occurs with aspen, especially on moister sites in depressions and along streams. Mixedwood forests, which are characterized by a mosaic of deciduous and coniferous patches, are widespread throughout the Sub-region and characteristic of upland sites. Jack pine forests typically occupy dry, sandy upland sites which may be quite open and have prominent ground cover of lichens. Peatlands are also common in this Sub-region.

4.1.4 Parkland Natural Region

This region comprises approximately 12 per cent, or 37,000 square kilometres, of Alberta. As such, it is considered to be an ecotone, or area of transition between the aspen groves and the grasslands. The legacy of the Ice Age is evident in the form of a gently rolling blanket of moraines that overlay parts of this region. This is the most densely populated region in Alberta, with the greatest density in the Central Parkland Sub-region. It is a rich ecosystem, full of various types of vegetation and species that are not limited to any one particular area. Development and farming have drastically altered the vegetation, particularly in the central parkland region. Land use has changed much of the native vegetation. Two Sub-regions are represented in the Red Deer River watershed: the Central Parkland Sub-region and the Foothills Parkland Sub-region, which are described below.

4.1.4.1 Central Parkland Sub-region

Within this sub-region, there is a gradual transition from grassland with groves of aspen in the south to closed aspen forest in the north. Native vegetation is scarce because most land has been cultivated to grow agricultural crops. The majority of the remaining natural land is on rougher terrain or poorer soils.

Surficial deposits range from intermediate-textured hummocky and ground moraines to fine-textured glaciolacustrine deposits and coarse outwash, kame moraine, and dune field materials. Moraines are most widespread, with kame moraines located throughout eastern portions of the sub-region. The Neutral Hills are an excellent example of ice-thrust bedrock ridges. The mean annual temperature is 2^0C, with a May-September average of 13^0C. The frost-free period averages 95 days. The mean annual precipitation ranges from 350 – 450 mm, with May-September averaging 300 mm. Aspen and balsam poplar forests are two major forest types that occur in the Central Parkland. Both are characterized by a lush, species rich understory. Shrub communities of snowberry, rose, choke cherry and Saskatoon are more extensive in the northern portion of the Central Parkland Sub-region. Elevations range from just over 500 metres where the Battle River enters Saskatchewan to around 1,100 metres in western portions. Numerous permanent streams, all part of the Saskatchewan River system, cut across the sub-region. Numerous lakes are scattered throughout the sub-region as well as a wide variety of permanent wetlands. Many of the lakes and wetlands are slightly to strongly saline.

In Alberta, the Central Parkland Sub-region is one of the most productive waterfowl areas. Nonetheless, only about 2% of this area is formally protected in parks or other conservation areas. With only about 5% remaining in its natural state (most deep and rich soils with reliable moisture have largely been converted to productive farmland), the Parkland Sub-region is the most heavily human-impacted and fragmented sub-region in Alberta (Van Tighem, 1993).

4.1.4.2 Foothills Parkland Sub-region

The Foothills Parkland Sub-region occupies a narrow band along eastern edge of the geological foothills from Calgary south to the Porcupine Hills, and from Pincher Creek south to the American border in the Waterton Lakes National Park area. The topography is rougher than that of the Central Parkland sub-region, and elevations are higher, ranging to over 1300 metres near Paine Lake. There are also a number of permanent streams that drain into the Saskatchewan River system. Surficial deposits include extensive areas of hummocky and ground moraines, as well as more restricted areas of outwash and glaciolacustre deposits along the valleys. Extensive river terraces also occur in some areas. Mean annual precipitation ranges from 500 – 650 mm, with a mean May-September volume of 290 mm. The mean May-September temperature ranges from 12 – 3^0C, while the region experiences about 90 frost-free days each year. Aspen is generally dominant in the upland forests, with balsam poplar occurring on moister sites. Willow groveland dominated by Bebb willow occurs extensively on fine-textured glaciolacustrine material and on imperfectly to poorly-drained morainal sites. The understory in all forest stands is lush and dominated by a variety of herbaceous plants.

4.1.5 Grassland Natural Region

The Grassland Natural Region is located in the southeastern corner of the province and comprises approximately 14% of Alberta's total natural landscape. Alberta's grasslands are part of the Great Plains that stretch from the Gulf of Mexico, through the United States, and into Canada's prairie provinces. The region is a flat to gently rolling plain with a few major hill systems. Most of the bedrock is covered with extensive, thick glacial till deposits. The diversity of the uplands is increased by numerous areas of fine-textured materials laid down in proglacial lakes and coarse-textured deposits in dune fields and outwash plains, both of which are associated with proglacial lake basins. Rivers in the Grassland Natural Region are part of either the Saskatchewan River or Missouri River systems. Numerous coulees and ravines are associated with these river valley systems. With the exception of isolated igneous outcrops, bedrock exposures are all of sedimentary origin and commonly occur along stream valleys. There are four sub-regions within the Grassland Natural Region, which are separated primarily by different climates, soils and vegetation. They are the Northern Fescue Sub-region, the Foothills Fescue Sub-region, the Dry Mixedgrass Sub-region, and the Mixedgrass Sub-region, all of which are described below.

4.1.5.1 Northern Fescue Sub-region

The Northern Fescue Sub-region is characterized by gently rolling terrain. Stream drainage is part of the Saskatchewan River system except for a large area of internal drainage in the Sounding Creek basin. Few stream valleys dissect the sub-region, but those with permanent flow are usually well-incised. The mean May-September temperature is 14^0C, and the frost-free period is about 90 days. Mean annual precipitation is 400 mm, with a mean May-September precipitation of 280 mm. The vegetation is dominated by rough fescue (*Festuca campestris* Rybd.).

4.1.5.2 Foothills Fescue Sub-region

This sub-region occurs largely on morainal, glaciolacustrine and outwash deposits along the lower flanks of the Foothills Geologic Belt, the Porcupine Hills and onto the adjacent plains area. Elevations in this sub-region are higher than in the Northern Fescue sub-region. The climate also differs, with greater frequency of Chinooks and thus, a milder winter climate. The majority of precipitation falls during the growing season, with a mean annual precipitation of 500 mm and 290 mm falling from May-September.

The mean May-September temperature is 11 – 13 ^{0}C, and the mean annual temperature is 3^{0}C. The average frost-free period is 90 days. Grasslands are dominated by rough fescue, Idaho fescue (*Festuca idahoensis* Elmer) and oat grass (*Trisetum* spp.).

4.1.5.3 Dry Mixedgrass Sub-region

The Dry Mixedgrass Sub-region is the warmest and driest Sub-region in Alberta. The name "Mixedgrass" comes from the predominance of both short and mid-height grasses. The most widespread are the mid-grasses such as spear grass (Piptochaetium spp.) and the short-grasses such as blue grama (*Bouteloua gracilis* (Willd.ex Griffiths), with northern wheat grass (*E. lanceolatus*) and western wheat grass (*P. smithii*) also being important in hummocky areas. Of the four grassland sub-regions, the Mixedgrass Sub-region also contains the highest diversity of animal species. Many of the species in this region occur nowhere else in the province, particularly those of sand dune areas and the extreme southeast part of Alberta. A few species are absent from the rest of Canada or occur in only local areas. The topography of the Dry Mixedgrass Sub-region is generally subdued with only a few minor uplands. The predominant landform is a low-relief ground moraine but there are significant areas of hummocky moraine, glaciofluvial outwash, glaciolacustrine sand plains, fine-textured glaciolacustrine lake deposits, and eroded plains. Elevations range from 600 – 1300 m. The average summer temperature is 16^{0}C, and the total annual precipitation ranges from 260 – 280 mm. Summer precipitation in this sub-region is the lowest of any sub-region in Alberta. Although much of the natural vegetation in the sub-region has been replaced by agricultural crops, extensive areas of native rangeland remain, which are primarily managed for grazing by domestic livestock.

4.1.5.4 Mixedgrass Sub-region

This sub-region typically includes gently undulating to rolling morainal and glacial lake deposits. Slightly cooler and moister conditions prevail in this sub-region relative to the Dry Mixedgrass Sub-region, and soils are primarily Dark Brown Chernozems. The Mixedgrass Sub-region is similar to the Dry Mixedgrass Sub-region in many features. The topography is generally subdued with a few minor uplands. The mean annual temperature is 5^{0}C, with a mean summer temperature of 15^{0}C. Winter temperatures are a few degrees warmer than in the Dry Mixedgrass Sub-region, with a greater frequency and Chinook days (20 – 30 more days). Native grasslands in the Mixedgrass Sub-region are dominated by needle grasses and wheat grasses, with many of the same forbs and dwarf shrubs that occur in grasslands of the Dry Mixedgrass Sub-region. In contrast to the Dry Mixedgrass Sub-region, the vegetation is characterized by a both greater biomass production and abundance of species that end to favor cooler and moister sites. Much of the natural vegetation of the sub-region has been replaced by agricultural crops. The moister, cooler conditions are reflected in the greater productivity of rangelands, which typically produce 25% more biomass than the Dry Mixedgrass Sub-region

4.2 Land Cover

4.2.1 Compiled Land Cover

Agriculture and grassland are the dominant land cover classes in the Red Deer River watershed (Figure 10 and Table 8). Land cover types with limitations in biodiversity are developed and unvegetated, and to a certain extent include disturbed vegetation. Developed and disturbed vegetation and agriculture land cover types combined, represent 56 % of the RDRW total area (Table 8). Natural vegetation (forest, grassland, vegetated and wetland classes) make up 40% of the total area, with the remainder comprised of naturally unvegetated mountainous terrain (2%) and water (2%). Landscape unit 1 is comprised predominantly of forest cover and natural unvegetated terrain (indeed the bulk of these classes occur in unit 1, with some spill-over into unit 2). Moving from west to east, the general trend is one of decreasing forest cover, and increasing wetland and grassland cover. Extensive agriculture is found throughout all but unit 1, coupled with extensive developed areas throughout (although the highest proportion of developed area is found in the urbanized unit 3, focused on Red Deer itself). The largest fraction of water is found in unit 3 (Figure 11).

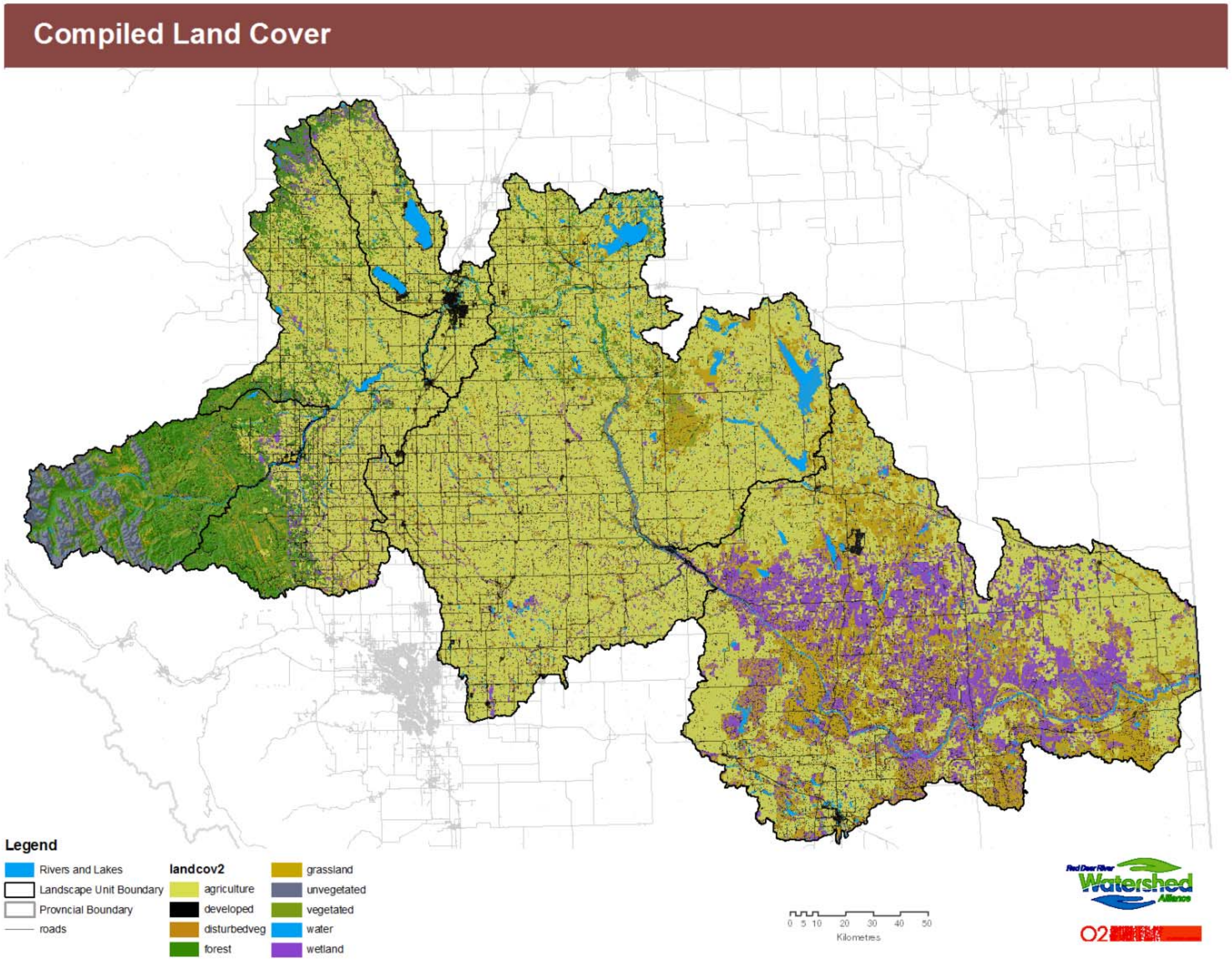

Figure 10. Land cover in the Red Deer River Watershed Compiled from Central Parkland Vegetation Inventory, Grasslands Inventory, Geobase Land cover and ABMI Wall to Wall Land Cover Data.

Table 8. Distribution of Land Cover Classes Across the Red Deer River Watershed. Land Cover Stratified per Terrestrial Reporting Unit.

Land Cover	Area (Km ^{2})	Area (%)
Agriculture	30889.45	48%
Developed	3243.99	5%
Disturbed vegetation	1693.85	3%
Forest	5573.43	9%
Grassland	11861.93	19%
Unvegetated	1469.06	2%
Vegetated	1658.45	3%
Water	1418.41	2%
Wetland	5967.19	9%
Total	63775.76	100%

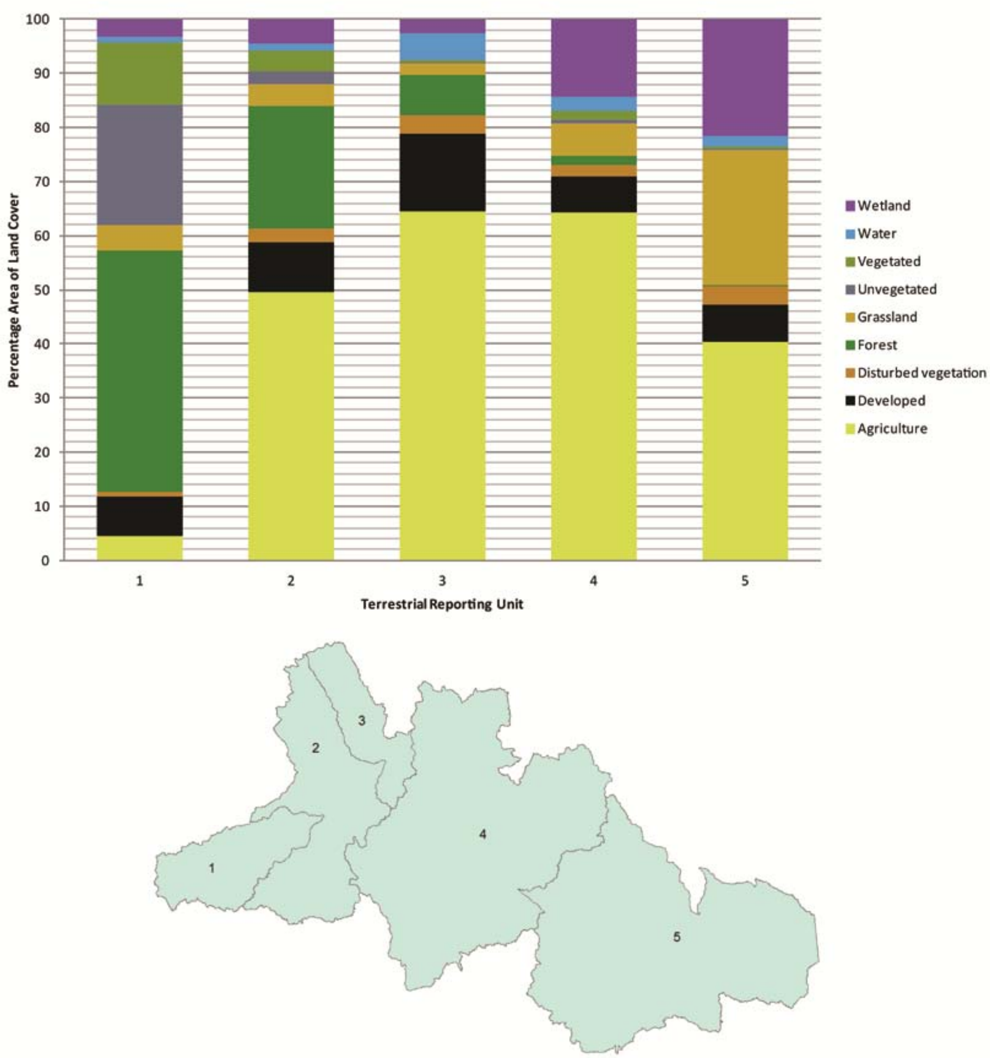

Figure 11. Land Cover Classes Across Terrestrial Reporting Units.

4.3 Wetland Complexes

Wetlands are found throughout the watershed, but predominantly in unit 5, where they make up about 21% of the area. The wetland complex analysis identifies a single large complex in the centre of unit 5, spreading westwards into unit 4 (Figure 12, Table 9). This wetland complex contains over 200 km^2 of wetlands in total, all within 200 m of other wetlands. At the same time, there remain many outlying wetlands that are further removed from this main complex, comprising about two-thirds of all wetlands in unit 5. Wetlands in other units are scarcer, and tend to be found in clusters surrounding streams. Units

2 and 3 are particularly aggregated, forming a series of complexes in the northern portion of the watershed.

Table 9. Number of Wetlands and Associated Complexes on Each Terrestrial Reporting Unit in the Red Deer River Watershed. The Ratio Indicates the Total Number of Wetlands (per Reporting Unit) Divided by the Total Number of Wetland Complexes; The Larger the Ratio the More Spatially Sparse the Wetlands.

Terrestrial Reporting Unit	# Wetlands	# Wetland Complexes	Ratio
1	1995	1169	1.17
2	5867	2819	2.08
3	1331	509	2.61
4	3987	2877	1.39
5	9290	3852	2.41

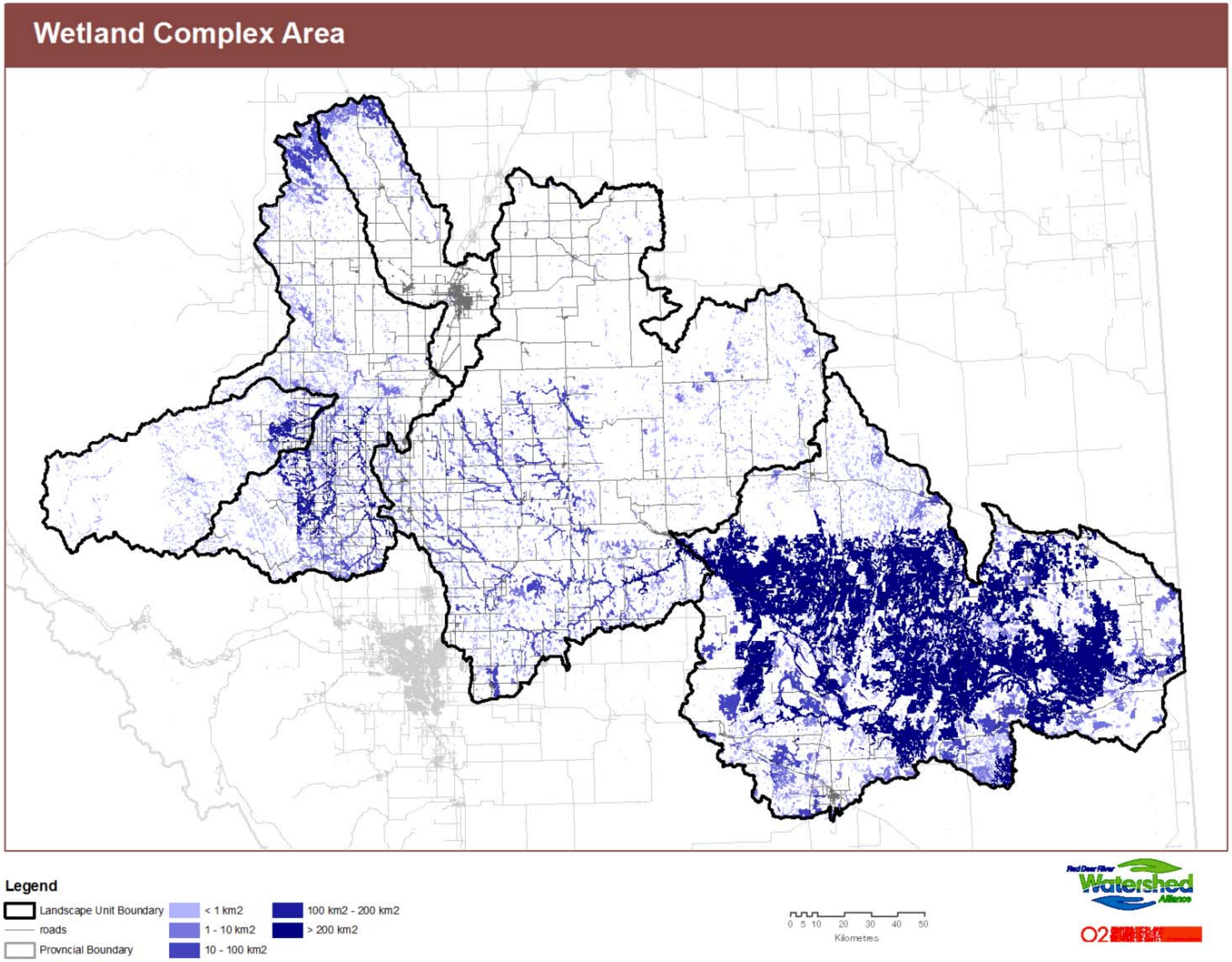

Figure 12. Wetland Complex Area (km²) in the Red Deer River Watershed.

4.4 Species

The ACIMS and FWMIS datasets comprise a large collection of species occurrence records, collected over a broad range of time (Figure 13, white points indicate species occurrence records). As these collections are not the result of a single concerted sampling regime, it is problematic to draw strong inferences about the distribution of biodiversity in the watershed. Different sampling intensities and approaches, coupled with an uncalibrated detection probability mean that the absence of information does not necessarily indicate an absence of diversity. The second confounding factor is the species-area effect, whereby species richness tends to increase with the size of the sample area. As units 4 and 5 comprise much larger areas than units 1 through 3, the expectation is that greater richness will be observed in those areas. Those concerns aside, the data provide a strong basis for the exploration of species richness in the watershed, and highlight the range of diversity found in and around the Red Deer River.

4.4.1 Species Richness

Unit 5 contains the richest collection of observed species diversity in the watershed, including the greatest number of mammals, reptiles, forbs and arthropods (Figure 13, Table 10). Unit 4 is close behind, and contains the greatest number of bird species observed. Fish richness is high throughout the watershed, but lowest in the upper headwaters in unit 1. Lichen diversity is bimodal, completely absent from units 2 and 3, but prevalent elsewhere, with the greatest diversity found in unit 1. Tree and shrub species observation records have only been recorded in unit 1. Moss diversity is highest in unit 1, but mosses are found throughout the area.

Table 10. Taxonomic Richness by Terrestrial Reporting Unit.

Landscape Units	richness	bird	mammal	amphibian	fish	reptile	forb	graminoid	arthropod	lichen	liverwort	moss	sedge	Tree shrub
1. Upper Headwaters	187	70	19	5	23	0	18	1	3	30	1	9	5	3
2. Lower Headwaters	264	179	37	6	30	1	4	1	1	0	0	4	1	0
3. Central Urbanized	208	132	25	7	27	1	5	1	6	0	1	2	1	0
4. Central Agriculture	368	226	48	6	30	5	16	3	10	16	1	6	1	0
5. Dry Grasslands	388	219	49	6	30	7	43	5	13	7	1	7	1	0

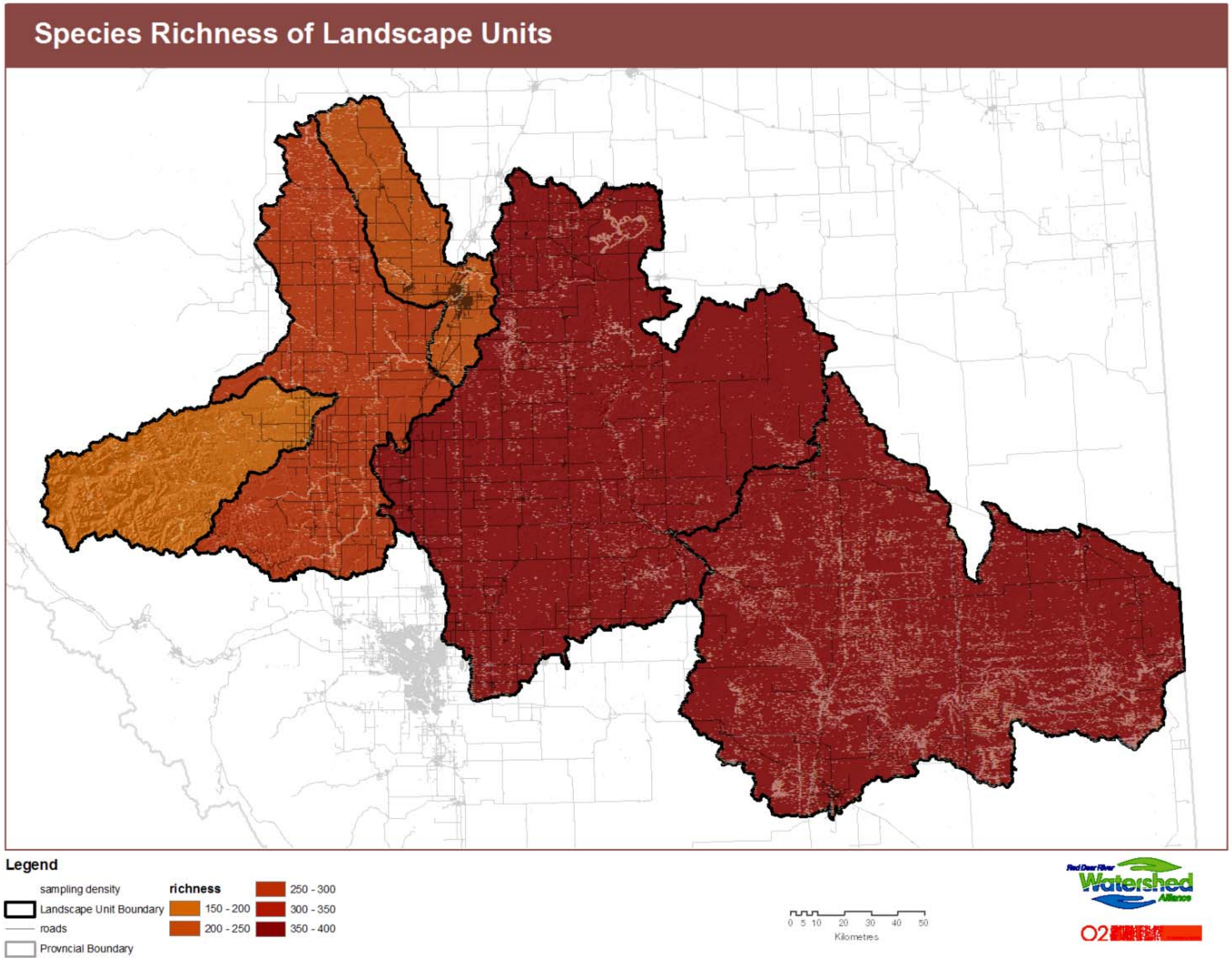

Figure 13. Species Richness Across Terrestrial Reporting Units in the Red Deer River Watershed[4]

[4] White Points Indicate Species Occurrence Records

4.4.2 Species at Risk

Twenty nationally or provincially listed Species At Risk have been observed and recorded in the Red Deer River watershed. These species include eight birds, four plants, one mammal, three amphibians, three fish, and one insect species. (see Appendix 1-3 for species-specific occurrences per unit).

Mammals:

- Swift Fox (Endangered)

Birds:

- Loggerhead shrike (Threatened)
- Sprague pipit (Threatened)
- Peregrine falcon *anatum* subspecies (Threatened)
- Piping plover (Endangered)
- Sage thrasher (Endangered)
- Burrowing owl (Endangered)
- Long-billed curlew (Special Concern)
- Yellow Rail (Special Concern)

Amphibians:

- Great plains toad (Special Concern)
- Western toad (Sensitive)
- Northern Leopard Frog (At Risk)

Insects:

- Monarch butterfly (Special Concern)

Plants:

- Slender mouse-ear-cress (Threatened)
- Tiny cryptanthe (Endangered)
- Whitebark Pine (Endangered)
- Limber Pine (Endangered)

Fish:

- Bull Trout (Special Concern)
- Lake Sturgeon (Threatened)
- Mountain Sucker (Threatened)

4.5 Terrain conditions

Steep slopes are found predominantly in the mountainous terrain of unit 1, and along the incised edges of the Red Deer River in units 4 and 5. Shallow slopes are found throughout the agriculturally dominated areas of units 2, 3, and 4, and in the grassland and wetland dominated areas of unit 5. Unit 4 contains many examples of rolling hills between 5 – 10 degree slopes, likely providing small scale habitat opportunities and microclimates throughout that area (Figure 14, Figure 15).

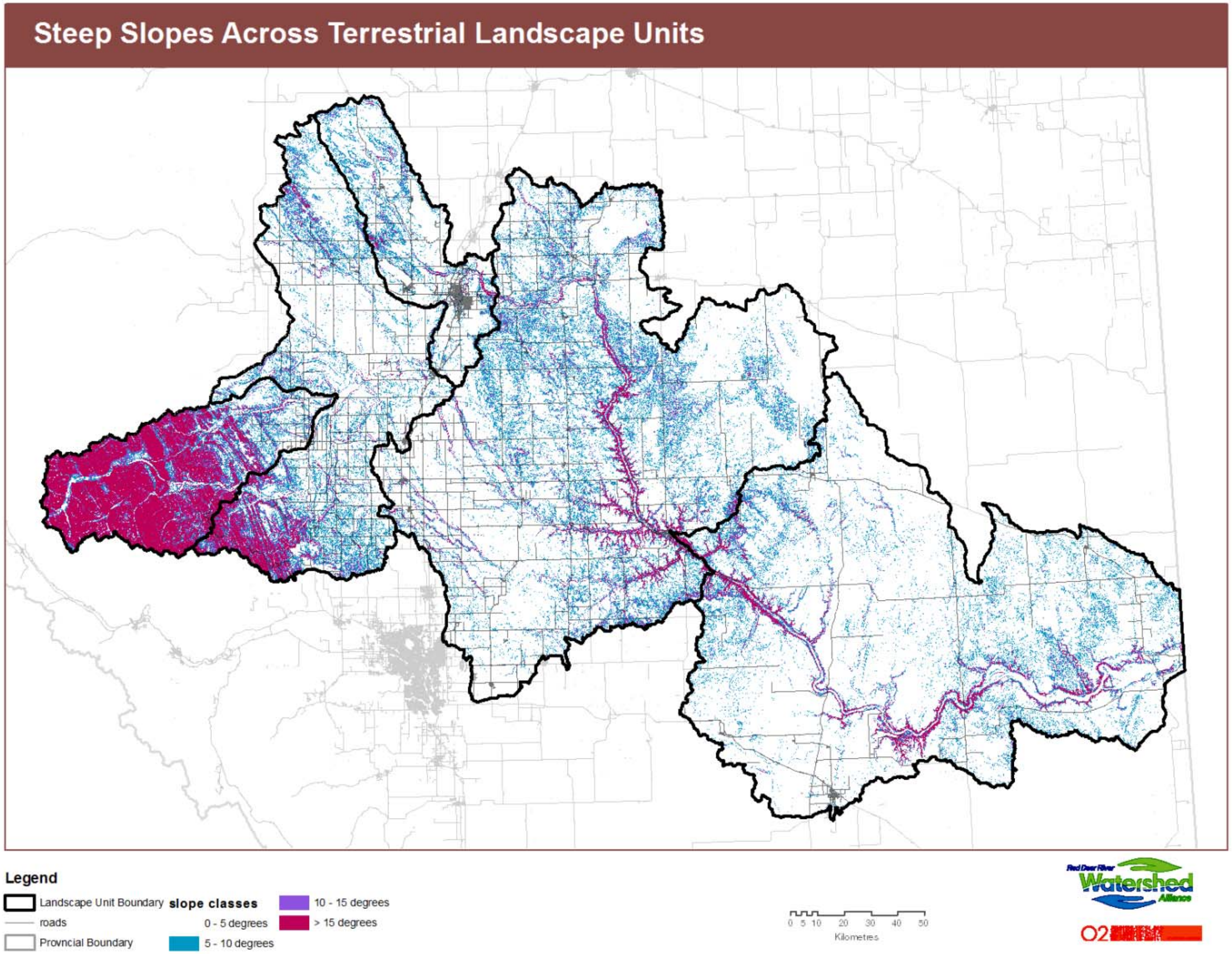

Figure 14. Map of Steep Slopes Across Terrestrial Reporting Units in the Red Deer River Watershed.

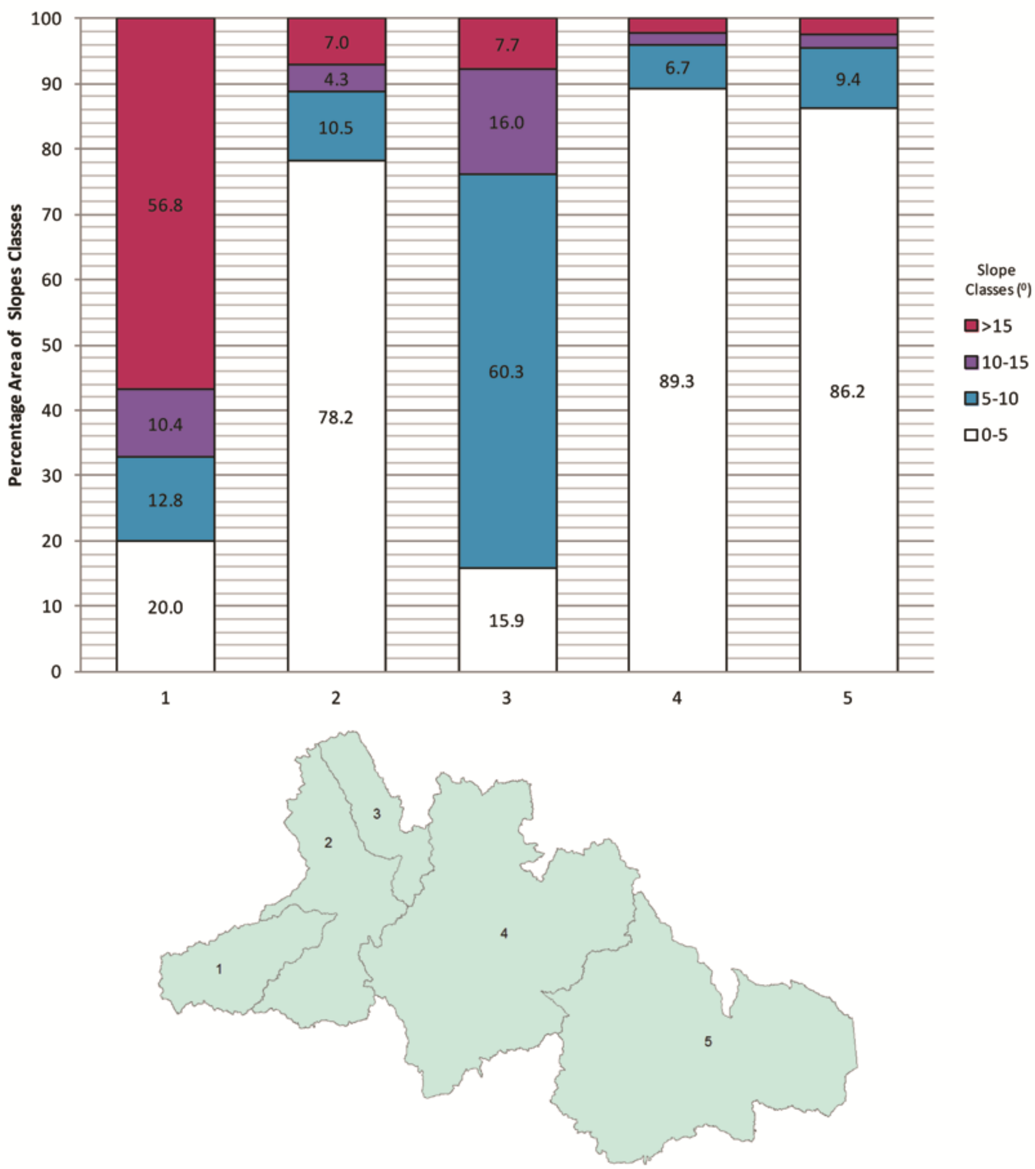

Figure 15. Percentage Area of Slope Classes Across Terrestrial Reporting Units in the Red Deer River Watershed.

4.6 Recent Change in Land Cover

Analysis of the MODIS time series reveals some of the limitations of the coarse imagery, as little change in the "urban" class could be detected, despite extensive development over this time period (Figure 16). The extensive nature of the "grassland" class indicates that MODIS cannot distinguish between natural grassland and agriculture. Most observed fluctuations are between broadleaf and conifer (in units 1 and 2) and between broadleaf, conifer and water classes in unit 3 and 4. This may be an indication of variations in moisture availability between years. The greatest degree of change was detected in units 1 and 2, and portions of unit 3 (Figure 17).

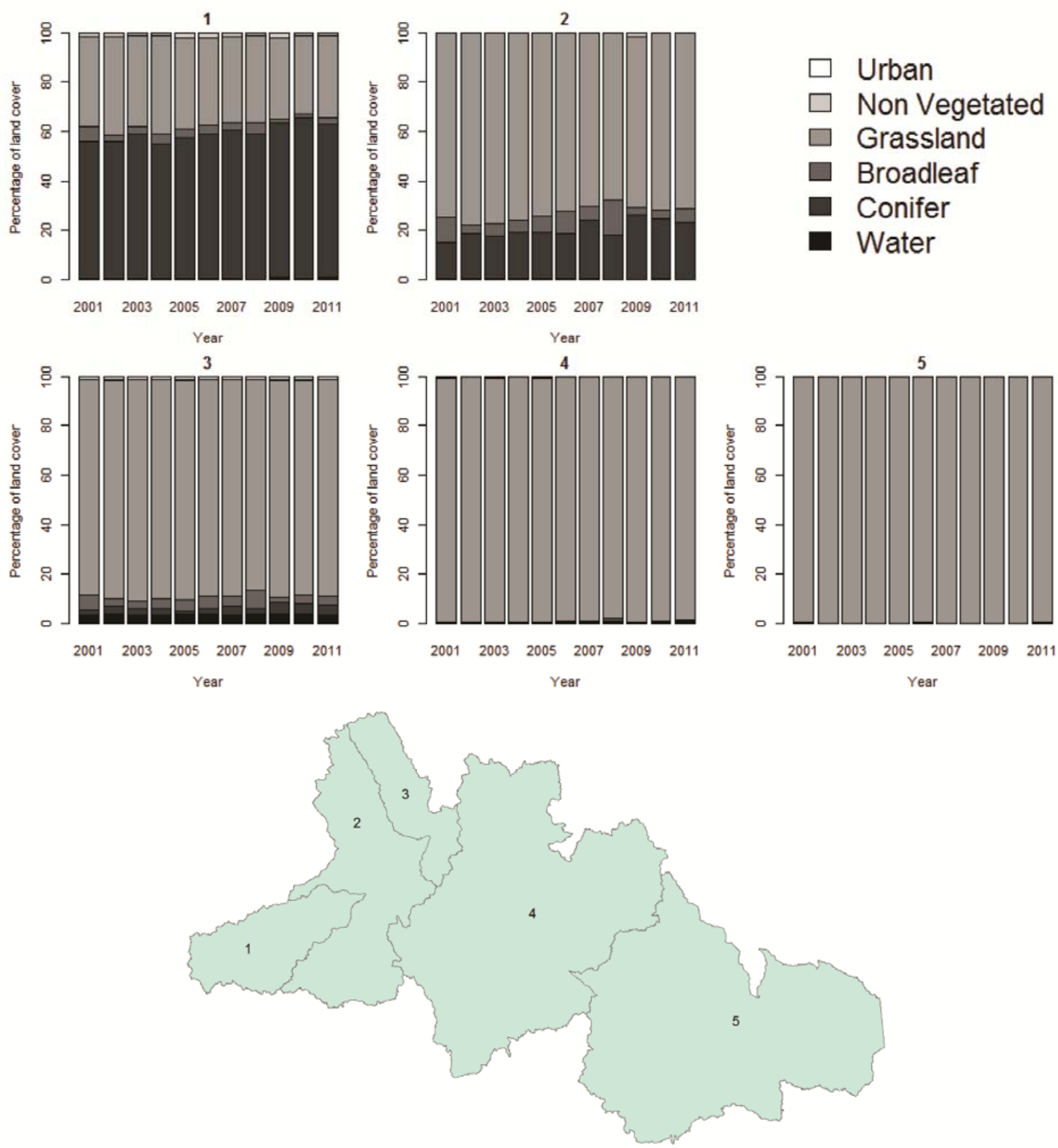

Figure 16. Time Series of Land Cover Change Using MODIS 12Q1 Products. Each Panel Number Refers to a Terrestrial Reporting Unit.

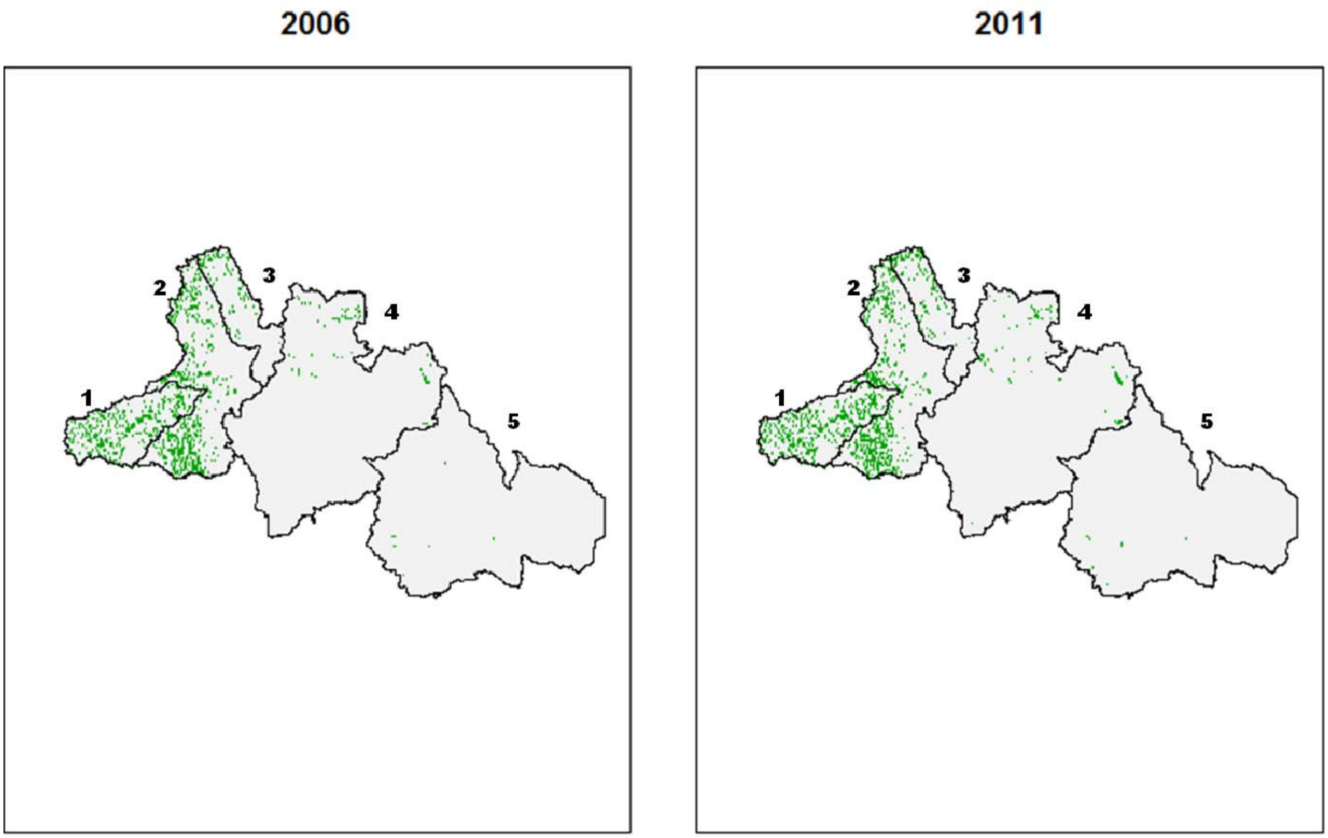

Figure 17. Distribution of Change in Land Cover Classes in the Red Deer River Watershed for the Years 2006 and 2011. The Reference Year was the 2001 MODIS 12Q1 Land Cover Tiles. Numbers Refer to Terrestrial Reporting Units.

4.7 Riparian Disturbance

Developed land cover was observed in riparian areas throughout the watershed (Figure 18), with the least disturbance occurring in unit 1 (approximately 12% of riparian extents), and the greatest proportion in unit 3 (70% of riparian extents). Unit 4 contained the greatest total amount of disturbance (Figure 19). In general, the more rugged terrain in units 1 and 2 is free from disturbance, as well as the more wetland dominated areas in unit 5.

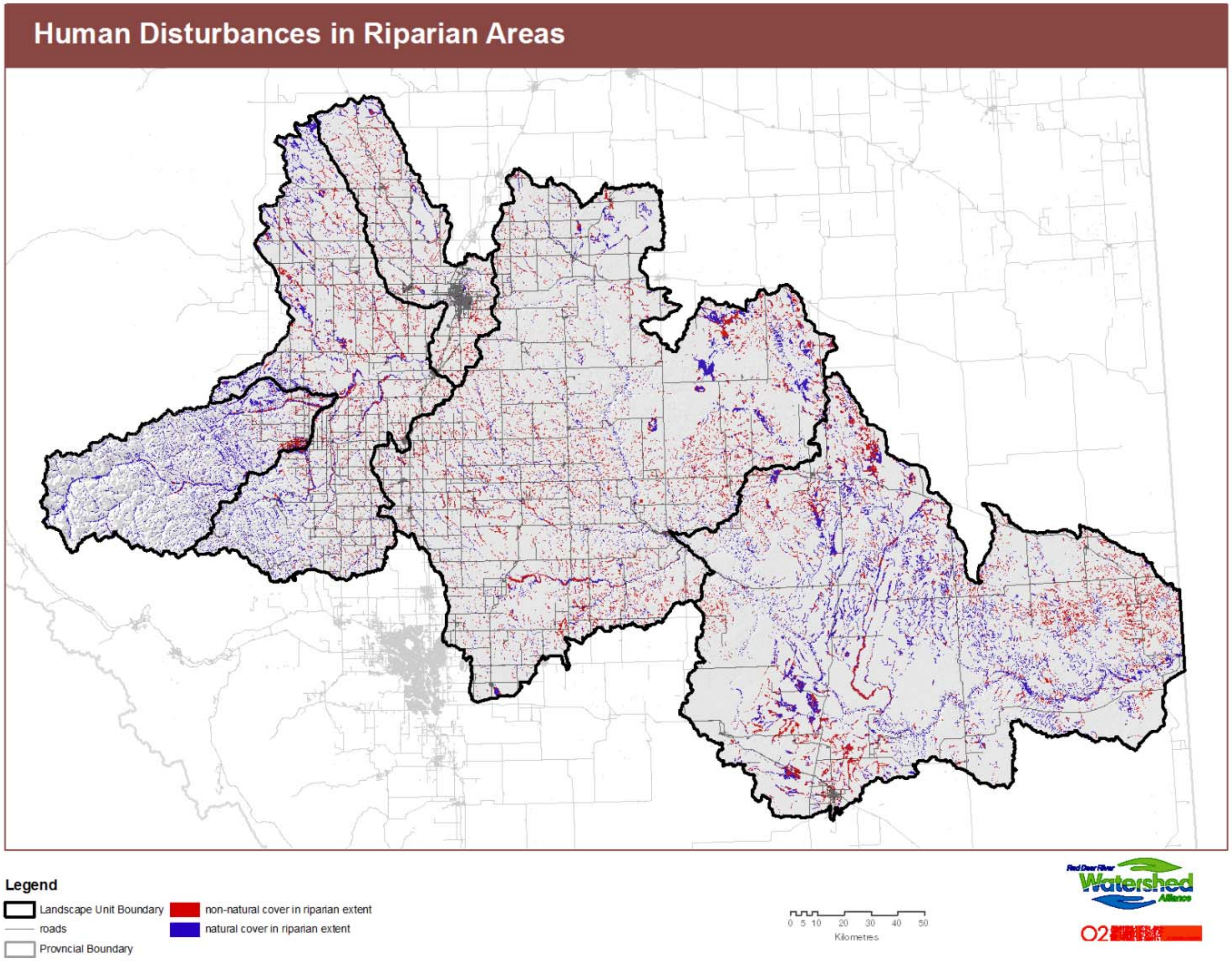

Figure 18. Map of Human Disturbed Riparian Areas Across Terrestrial Reporting Units in the Red Deer River Watershed.

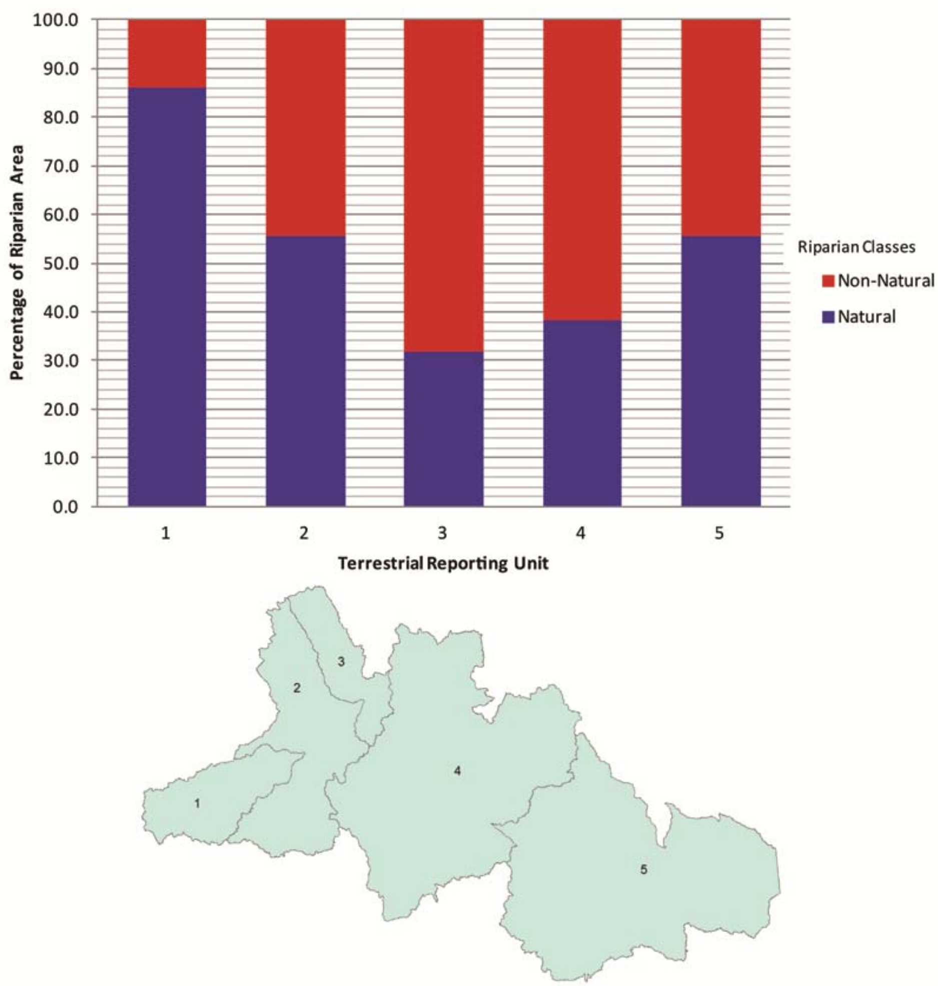

Figure 19. Percentage of Natural and Non-natural Riparian Area Across Terrestrial Reporting Units.

4.8 Landscape Intactness

The effective mesh size analysis provides a useful assessment of landscape intactness across the watershed (Figure 20). Most of unit 1 remains fundamentally intact (Table 11), as are the peripheral regions to the north and south of unit 2 (Figure 21). Only the very northern tip of unit 3 contains any large patches of contiguous natural vegetation. Unit 4 retains an intact corridor associated with the Red Deer River, as well as a largely intact area in the central-east of the unit. Scattered intact areas are found throughout unit 5, concentrated in the north and east of the unit. However, many examples of areas with little to no natural cover are found throughout unit 4, to the west and far east of unit 5, and to the southwest of Red Deer itself, in unit 2 (Figure 20).

Table 11. Relative Percentage of Intact Area in The Landscape per Reporting Unit, Based on the ABMI Human Footprint Layer. RDRW = Red Deer River Watershed.

	Area of Landscape Intactness (Km^2)				
Reporting Unit	**0**	**0-0.1**	**0.1-1**	**1-10**	**>10**
RDRW	9.2%	38.9%	22.9%	18.6%	10.4%
1	0.15%	5.2%	12.2%	20.5%	62.0%
2	5.6%	49.2%	20.9%	15.6%	8.7%
3	12.6%	67.4%	13.5%	5.3%	1.3%
4	14.6%	59.7%	19.2%	5.5%	1.0%
5	7.7%	18.1%	31.3%	34.8%	8.2%

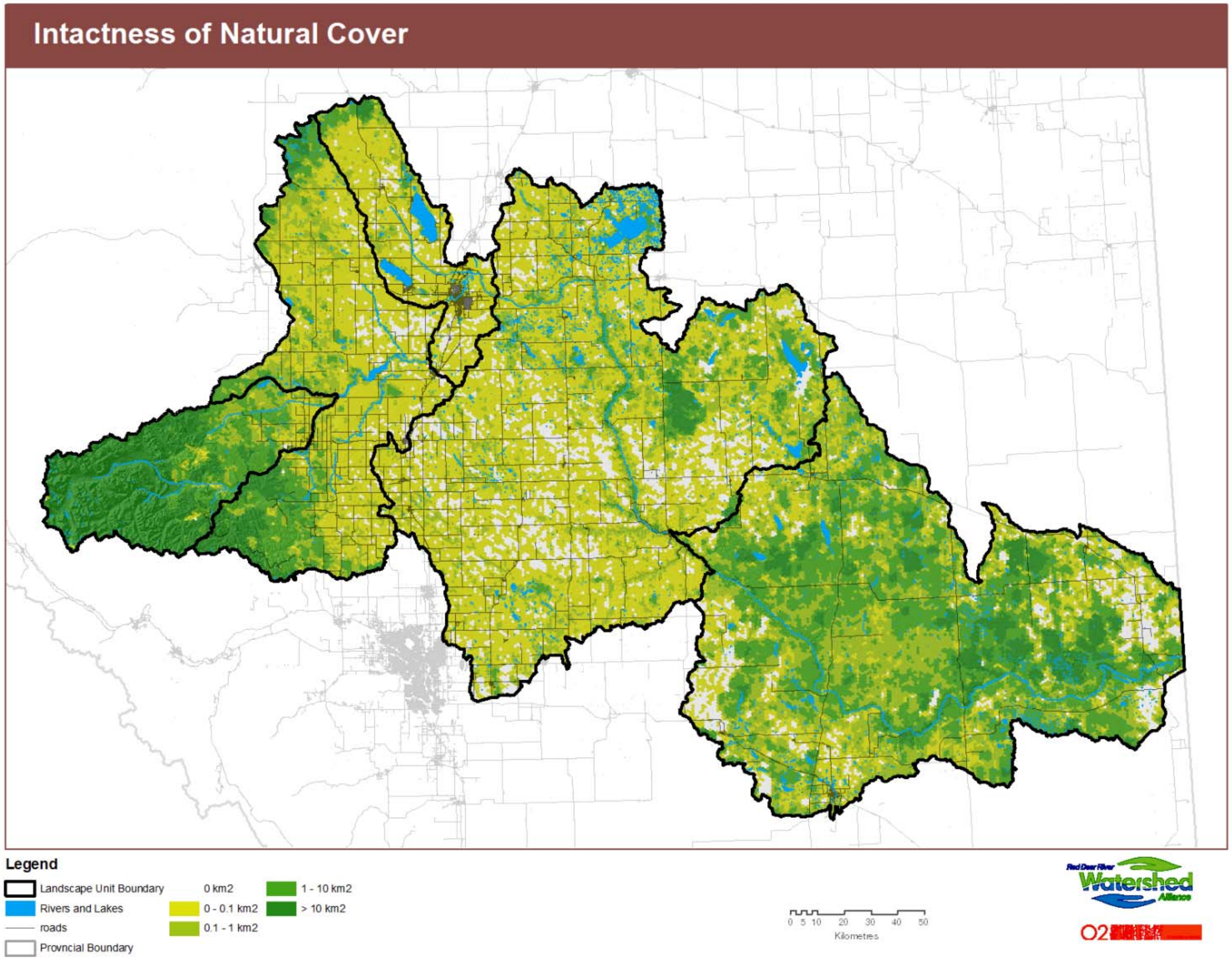

Figure 20. Map Intactness of Natural Cover in the Red Deer River Watershed.

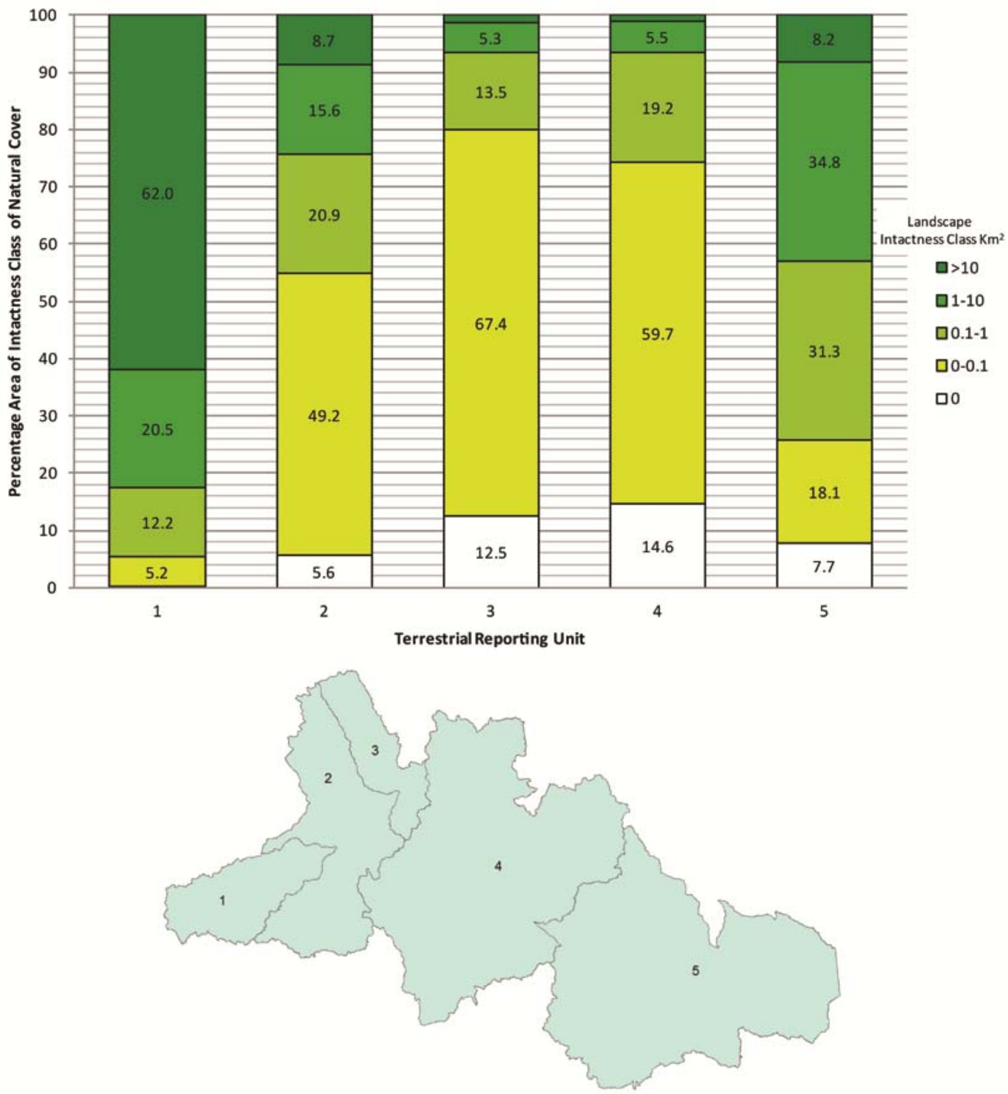

Figure 21. Percentage of Landscape Intactness Classes (km²) Across Terrestrial Reporting Units.

5. AQUATIC BIODIVERSITY

5.1 Fish

Thirty-two different fish species have been observed and recorded in the Red Deer River. The most predominant species are mountain whitefish, longnose dace, and longnose sucker, whose population numbers seemed to have significantly stabilized over time (Aquality Environmental Consulting Ltd., 2009). Changes in the backwater areas of stream systems in the watershed have led to declines in northern pike, while walleye populations have seen an increase in numbers in the area below the dam towards Blindloss (Michael Sullivan Personal communication, 2014).

5.2 Benthic invertebrates

Although extensive research and documentation exists for benthic invertebrates in the Red Deer River watershed, the information has not yet been compiled into a single spatial dataset. The invertebrate community of the Red Deer River has been called the most diverse and abundant benthic invertebrate community when compared to the Bow, Oldman, South Saskatchewan, North Saskatchewan, Athabasca, and Beaver Rivers (Anderson, 1991). However, Cross (1991) indicated that the longitudinal zonation of benthic invertebrate communities in spring was similar to that seen in other rivers across different ecoregions in Alberta. However, these reports are based on invertebrate sampling efforts conducted in the late 1980s, and therefore may not represent the current conditions in the watershed.

Smith (2003) reported that the communities of benthic invertebrates found in the Red Deer River watershed were indicative of good water quality. Historically, the Red Deer River has maintained its benthic community composition and diversity throughout its length (Aquality Environmental Consulting Ltd., 2009). Those communities are mainly represented by the taxa Ephemeroptera, Plecoptera, and Trichoptera and Chironomidae (mayflies, stoneflies, caddisflies, and midges, respectively). Nutrient enrichment, especially from municipal wastewater discharges, has induced measurable changes in invertebrate community composition below the discharge points (Cross, 1991; Shaw & Anderson, 1994). However, no current information is available to describe community responses since major upgrades took place at the City of Red Deer's treatment plant, which now also treats wastewater from a number of adjacent municipalities. Longitudinal patterns in benthic invertebrate communities were altered by the Dickson Dam, as indicated by data collected from 1983-1987 (Anderson, 1991; Cross, 1991; Shaw & Anderson, 1994).

Golder Associates (Golder Associates Ltd., 2001, 2005) examined benthic invertebrate communities in the Red Deer River in Reach 3 (Red Deer to Drumheller) (Figure 10), as part of monitoring programs for chemical processing facilities effluent that discharge into the river. Overall, the studies indicated that the common invertebrates were similar to those of other large rivers in southern Alberta. Furthermore, the invertebrate community was indicative of a nutrient-enriched aquatic ecosystem on the basis of the dominance of taxa that are tolerant of mild enrichment and the very low abundance of more sensitive taxa such as Plecoptera (stoneflies). Golder (2001a) concluded that there was a small localized effect of the effluent from Red Deer to Drumheller on the benthic invertebrate community in the Red Deer River.

Effects of the NOVA effluent on benthic invertebrates were reportedly more notable; increasing abundance of Oligochaeta (worms), reductions in pollution-sensitive taxa, and a small reduction in taxonomic richness of the community were observed up to approximately 600 m downstream of the outfall (Golder 2001b). These effects were attributed to organic enrichment. The *Ephemeroptera*, *Plecoptera*, and *Trichoptera* orders accounted for approximately 50% of the mean number of taxa. In general, there is insufficient data on benthic invertebrates for the Red Deer River (North/South Consultants Inc., 2007). Available information suggested that communities may be affected by point sources in some areas and that spatial differences along the length of the river may also reflect varying "natural" conditions (i.e., different ecoregions). Data were more numerous, however, for primary producers, most notably pigment levels of algae attached to rocks (epilithic algae). Epilithic chlorophyll-*a* levels indicate eutrophic conditions in the Red Deer River. Based on this information, conditions in the Red Deer River are "fair"(North/South Consultants Inc., 2007).

5.3 Lake Status

All lake units are surrounded by significant amounts of agricultural land cover near the lake shore, which may influence water quality and impact the aquatic biodiversity of the lake itself. Sylvan Lake is the notable outlier of the five lakes, surrounded by substantial amounts of development and disturbed vegetation, as well as a large amount of forested cover. Other lakes include a substantial amount of grassland cover, especially Gough Lake. Sullivan Lake has the least amount of development in its surrounding watershed (Figure 22).

General descriptions of lake reporting units, including hydrological, water quality, limnological, and fisheries information, were primarily obtained from the Atlas of Alberta Lakes (Mitchell & Prepas, 1990).

5.3.1 Sylvan Lake

The Sylvan Lake lies in a preglacial valley. The dominant soils in the watershed are Orthic Gray Luvisols developed on weakly calcareous glacial till. Most of the Sylvan Lake area was originally mixedwood forest dominated by trembling aspen, but approximately 90% of the forest has been cleared for agriculture. Cereal grain, canola production, and mixed farming are the main land uses.

5.3.1.1 Hydrology and Chemistry

Sylvan Lake is generally flat, with a small area at the centre declining to the lake's maximum depth of 18.3 m. At an elevation of 936.5 m, 20% of the lake is occupied by the littoral zone, which is less than 3.5 m deep. The inflowing streams flow only intermittently, with an outlet stream that enters the Cygnet Lake at the southeast, and then flows to the Red Deer River.

Sylvan Lake is a well-buffered freshwater lake. Its dominant ions are bicarbonate, sodium and magnesium. The lake's high sodium and magnesium concentrations suggest a significant amount of groundwater inflow. Sylvan Lake is mesotrophic, where changes in phosphorus and chlorophyll *a* concentrations over the summer are similar to those in other well-mixed lakes in Alberta. While the phosphorus concentration peaks in August, the chlorophyll *a* concentration peaks in late August or September.

5.3.1.2 Aquatic Biology

The lake has little algal growth and few areas of dense aquatic macrophytes. Surveys conducted in 1976 (Jones, Beste, & Tsui, 1976) and 2004 (AXYS Environmental Consulting Ltd., 2005) indicated that the phytoplankton community was dominated by golden-brown algae (Chyrysophyta). In late August, blue-green algae (Cyanophyta), particularly Aphanizomenon flos-aquae, were very abundant. Macrophytes occurred in patches in sheltered areas around the lake and grew densely in the northwest end. The most common emergent species were bulrush (Scirpus sp.) and common cattail (Typha latifolia). Submergent macrophytes included pondweeds (Potamogeton spp.), water buttercup (Ranunculus circinata), Canada waterweed (Elodea canadensis) and the macroalga stonewort (Chara sp.).
As of the 1976 survey (Jones et al., 1976), the dominant organism in the littoral zone was the amphipod Hyalella azteca, representing 92% of the invertebrate community. The dominant invertebrate in the profundal zone were midge larvae (Chironomidae), which made up over half of the community. Sphaeriid clams (Pelecypoda) were abundant in both the profundal and littoral regions.

5.3.1.3 Fish and Wildlife

Fish populations in the lake are thought to be limited by a shortage of weed beds, a lack of cover and shortage of spawning grounds. At least seven species of fish have been reported in Sylvan Lake: northern pike, yellow perch, walleye, burbout, lake trout, spottail shiners, and lake whitefish. The lake has few areas that are suitable for breeding or nesting waterfowl or for other aquatic wildlife. In most areas the shore is too steep or has been altered by human use, making it inconducive to supporting wildlife habitat.

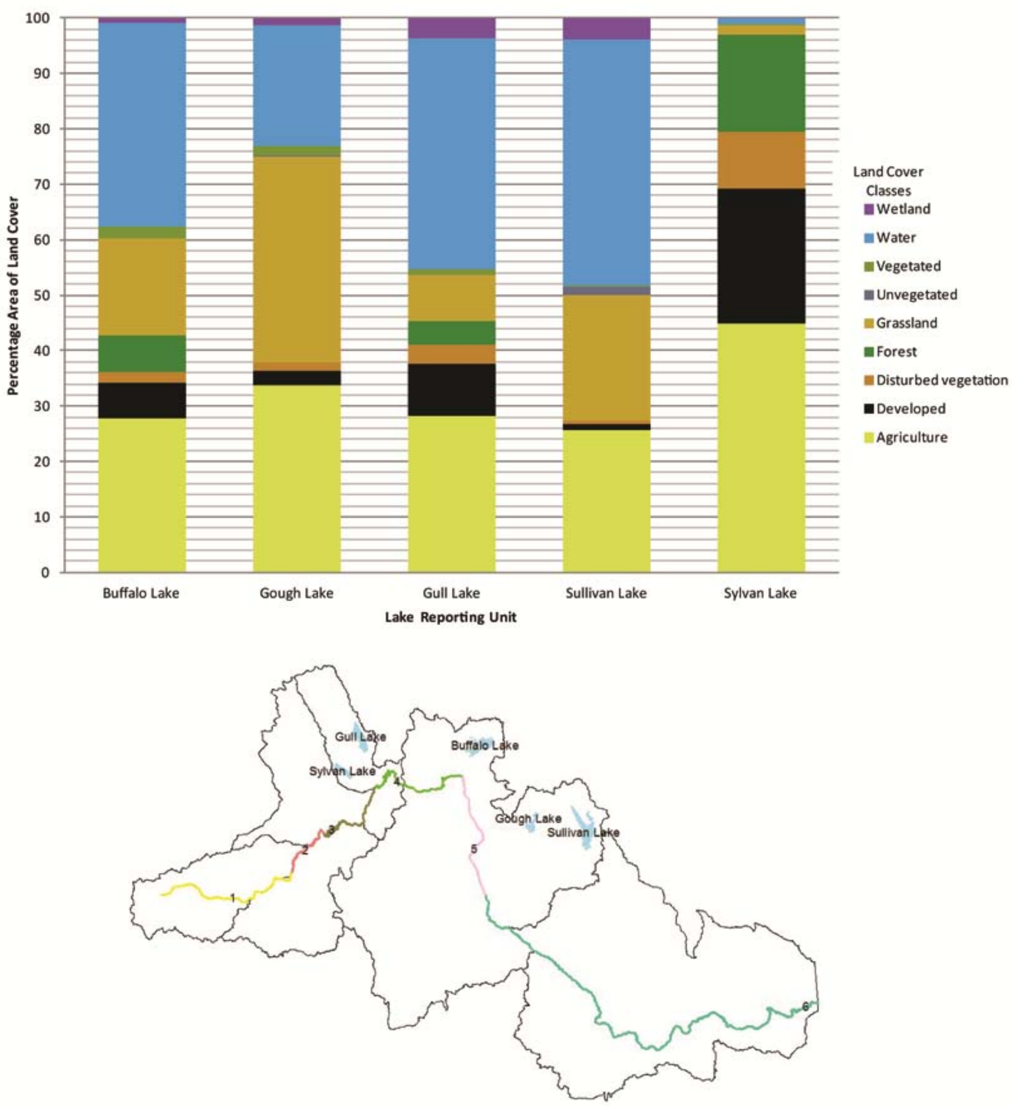

Figure 22. Percentage of Land Cover Classes Across Lake Reporting Units With a 1 km Buffer.

5.3.1.4 Management

The latest review of science based documents reveals that Sylvan Lake has become polluted over time (AXYS Environmental Consulting Ltd., 2005). A recreationally desirable meso-eutrophic status is shifting to an undesirable eutrophic status. Recommendations include minimizing or eliminating high risk

practices within the watershed, such as....and implementing measuring and monitoring programs to track changes in lake water quality.
The lack of a collective, modern strategic plan to guide the future development, use and conservation on Sylvan Lake is a significant concern (Planned Environmental Associates, 2006). Alberta's Land Use Policy recommends cooperative and collective planning in situations where the responsibility of managing a resource overlaps with other governing bodies. In the case of Sylvan Lake, the current land use strategies affecting the watershed have evolved from rural land uses. Such strategies typically do not contemplate natural capital development and conservation to sustain the delivery of a variety of values to communities. As a consequence, "agriculturally assessed lands" are regularly converted to residential developments when market demand exists. Red Deer County has taken leadership on this issue and has adopted policies to direct cooperative development of the Sylvan Lake Intermunicipal Development Plan with Sylvan Lake and other affected municipalities (Planned Environmental Associates, 2006).

5.3.2 Gull Lake

Gull Lake is characterized by a large, shallow basin. Much of the land in the drainage basin has been cleared for cereal crops and cattle production. The native vegetation surrounging Gull Lake is typical of the Aspen Parkland and Boreal Mixedwood ecoregions, dominated by trembling aspen, white spruce and willow. The shoreline is sandy, but soft organic sediments have accumulated in the shallow water of protected bays. The greatest depth of the lake (8 m) covers a large area of the bottom in the centre area of the basin (Mitchell & Prepas, 1990).

5.3.2.1 Hydrology and Chemistry

The water level has been declining in Gull Lake since it was first recorded in 1924 (Williams Engineering Canada Inc., 2010). Now, in some areas, up to 400 metres of former lake bottom is exposed, measured perpendicular to the present shore line. The gradient is very low, and the water table is close to the surface, making it an attractive location for waterfowl and wildlife.

Gull Lake is slightly saline. Bicarbonate, sodium and sulphate are the dominant ions. Levels of dissolved oxygen are high throughout the water column. In winter, dissolved oxygen concentrations decline gradually. The relatively low concentrations of chlorophyll *a* in Gull Lake indicate that it is mesotrophic, although the phosphorous levels suggest it is a more productive lake. It is probable that some portion of the supply of total phosphorous to the lake is derived from its bottom sediments (internal phosphorus loading), as occurs in most shallow, productive lakes in Alberta. Increases in phosphorous and chlorophyll levels in summer may be the result of such internal loading. Overall, Gull Lake is classified as an eutrophic lake based on nutrient, chlorophyll and transparency criteria (Alberta Lake Management Society, 2006). The lake experiences occasional blooms of noxious algae, low winter oxygen concentrations. There has not been a significant decline in the water quality of the lake in recent years (Mitchell & LeClair, 2003). Levels of total phosphorous and chlorophyll *a* have not increased since monitoring began and, and phosphorous levels have remained fairly consistent since the 1970s.

5.3.2.2 Aquatic Biology

A survey conducted in 1969 indicated that green and blue-green algae were most abundant in June and blue-green algae (*Anabaena flosaquae*) dominated the phytoplankton community by mid-August. The biomass of phytoplankton was low through May and June, and green algae, diatoms (Baccillariophyta) and cryptophytes (Cryptophyta) were the dominant groups. The prevalent species included *Ankyra judayii*, *Staurastrum* sp., *Rhodomonas minuta*, *Sphaerocystis schroeteri*, *Amphora ovalis* and *Asterionella formosa*. By mid-July, the total biomass had increased considerably, and the dominant species were the diatoms *Fragilaria crotonensis* and *Stephanodiscus niagarae*, the green alga *Mougeotia* sp., and the blue-green alga *Lyngbya Birgei*. *Mougeotia* sp. maintained a high population through August, but *Fragilaria crotonensis* was replaced by *F. capucina*, and *Ceratium hirundinella*, a species of Pyrrhophya, became dominant. In September and October, the species with the highest biomass was *Fragilaria crotonensis*, followed by *Closterium acutum* and *Gomphosphaeria aponina*.

Gull Lake supports extensive submergent macrophyte beds but emergent species such as common cattail, common great bulrush and sedge were found along only 30% of the shoreline in 1974. The subrmergent zone in Gull Lake was dominated by large-sheath pondweed (*Potamageton vaginatus*), and in many areas it was the sole species present. In shallow areas (less than 1 m deep) northern watermilfoil (*Myriophyllum exalbescens*) and Sago pondweed (*Potamogeton pectniatus*) were common.

A survey conducted in 1978 and 1979 indicated that large grazers, *Daphnia pulicaria* and *Diaptomus sicilis*, were abundant in the spring and early summer, but their populations were smaller through the remainder of the summer to the end of October. Large numbers of the rotifer *Conochilus* sp. were present in July. Seven other species of rotifers were observed sporadically throughout the summer. The predaceous copepod *Diacyclops bicuspidatus thomasi* was most abundant in spring and early summer, but was present throughout the entire open-water season. About 98% of the organisms collected were scuds and midge larvae.

5.3.2.3 Fish and Wildlife

The Red Deer River State of the Watershed Report identifies Gull Lake as one of the largest and most productive lakes in the Dry Mixedwood Subregion of Alberta for waterfowl and other migratory birds in need of staging grounds (Aquality Environmental Consulting Ltd., 2009). The area contains significant staging and production wetlands for waterfowl, marsh birds and shorebirds. Specifically, two large low-lying wet areas are identified directly to the north of the lake and to the east of the lake (Map 2). The Gull Lake area also contains foraging and loafing habitat for the American white pelican. The lake serves as a staging area during fall migration, and the marshy north end supports Ring-billed Gulls, Black Terns, Common Goldeneye, American Widgeons, Mallards, Blue-winged Teal, White-winged Scoters, Common Mergansers, Common Loons and Red-winged Blackbirds.

Among fish species, white suckers, northern pike, walleye, burbout, lake whitefish, spottail shiners and brook stickleback are known to inhabit Gull Lake.

5.3.2.4 Management

Gull Lake is known for its sandy beaches, a provincial park located on the southern portion of the lake, and its sport fishing. It supports many recreational activities such as boating, swimming, fishing, and sailing. The current policy document controlling land use and development is an intermunicipal development plan pertaining to the municipalities around Gull Lake (Williams Engineering Canada Inc., 2010). The plan addresses changes in development pressures, environmental issues, regulatory regimes, market demands, public attitudes and preferences around the lake. Drawing on public comments and input from stakeholders around Lacombe County, the plan recognizes that land use decisions within the watershed may adversely affect the lake. Therefore, consistency and a common vision shared by municipalities is necessary to ensure that Gull Lake remains a healthy and well-maintained asset within the Central Alberta region.

5.3.3 Buffalo Lake

Buffalo Lake is naturally divided into four areas:

1) Main Bay at the east end is the largest and deepest (maximum depth of 6.5 m) and supports most of the recreational activity on the lake;
2) Secondary Bay, to the west of Main Bay, is smaller and shallow (maximum depth of 2.5 m);
3) The Narrows is a channel west of Secondary Bay, which serves as a popular fishing area;

4) Parlby Bay is the smallest bay west of the Narrows. Due to its shallow depth (maximum depth of 1.1 m) and abundant aquatic plant populations, it provides excellent waterfowl habitat.

The drainage basin of Buffalo Lake is large (1440 km^2) and consists of a gently rolling glacial till plain that slopes from an elevation of 975 m on the western boundary to 780 m at the lake. The drainage basin lies within the Aspen Parkland Ecoregion, dominated by trembling aspen, wild rose and Saskatoon and with rough fescue grassland on drier, south facing slopes. Approximately 65% of the basin has been cleared for agriculture.

5.3.3.1 Hydrology and Chemistry

Buffalo Lake is 20.5 km long and 8.2 km wide at its widest point, with a moderately-sized surface area relative to its drainage basin. Almost all surface inflow to the lake enters at the west end of Parlby Bay through Parlby Creek. The contribution of groundwater inflow in maintaining the lake's water balance is significant. Areas of artesian upwelling of groundwater are evident at the west end of the lake and along the north shore of Secondary Bay, as well as within the lake. There has been no surface outflow from Buffalo Lake since 1929. Groundwater outflow is very likely since the salinity of the lake is not as high as would be expected if evaporation were the only route for water leaving the lake.

Buffalo Lake is a "managed lake". Its water levels and shorelands are controlled by provincial government policies that guide the operation of the Parlby Creek – Buffalo Lake Water Management System. Water from the Red Deer River is diverted to Buffalo Lake to restore historical water levels which are beneficial to shoreland and fish habitat and to support different recreational activities (Alberta Sustainable Resource Development, 2010).

Buffalo Lake is a well-buffered, moderately saline lake. Its dominant ions are sodium, sulphate and bicarbonate. The salinity and the concentrations of most ions in the lake increase along a gradient from west to east. This gradient can be attributed to the different sources of water in the lake. The water is well-mixed vertically and usually not thermally stratified in the summer. In winter, dissolved oxygen concentrations are high (over 6 mg/L) down to a depth of 4 m. Buffalo Lake is mesotrophic, although the total phosphorous concentration in the lake is moderately high. The phosphorus gradient from west to east runs opposite to the gradient for most other ions. Both total phosphorus and chlorophyll *a* concentrations increase over the summer, reaching a peak in August and September.

5.3.3.2 Aquatic Biology

Anabaena flos-aqua was the most abundant algae species sampled in several surveys; the codominant species were *Microspora tumidula*, *Synechochystis* sp., *Oocystis parva*, and *Gomphosphaeria aponina* and *G. lacustris*. There are no data for zooplankton in Buffalo Lake. Midge larvae were the dominant group of benthic invertebrates.

5.3.3.3 Fish and Wildlife

Buffalo Lake supports four species of fish: northern pike, burbot, white sucker and brook stickleback. All of these species are native to the lake and are tolerant of high salinity and alkalinity. The lake is also second only to Beaverhill Lake in its importance for waterfowl brood production, moulting and fall staging, and for nesting of colonial birds. Muskrats are plentiful in the area, especially along the north and west shores.

5.3.3.4 Management

Buffalo Lake is a popular lake under growth and development pressure from recreational users, cottage owners, and subdivision developers. If not properly managed, subdivision development and increased visitor use could adversely affect the lake by deteriorating water quality, degrading riparian areas and impacting the plants and animals that depend on the lake and its shorelands. Clear management direction is needed by government agencies and municipalities to protect the health of Buffalo Lake. In 2010, the Government of Alberta published the Buffalo Lake Integrated Shoreland Management Plan (Alberta Sustainable Resource Development, 2010) to manage current and future development pressures on Buffalo Lake and its ecology. The water level of the lake is closely tied to the Red Deer River. The water right-of-way that rings the lake reaches an elevation of 781.2 metres surrounding the lake, reflecting the 1:100 year flood zone. The resulting Crown land ranges in width from several metres to several hundred and “comprises approximately 1585 hectares” of littoral (wet) zone and riparian area. This area is advantageous to the province, as it plays a central role in helping to manage activities that are likely to undermine riparian function as well as fish and bird habitat.

5.3.4 Gough and Sullivan Lakes

There were no records or information in the Atlas of Alberta lakes pertaining to Gough and Sullivan lakes. Furthermore, there is very little information available describing the environmental conditions of the lakes. In contrast to Gough Lake and its land area, which have been cultivated, leaving little natural vegetation, the Sullivan Lake area has been designated by Ducks Unlimited Canada as a critical landscape in need of conservation and restoration. Sullivan Lake is at high risk of habitat loss from agriculture, petroleum development, road construction and rural subdivisions (Ducks Unlimited Canada, 2014).

5.4 Land Cover Surrounding River Reaches

Substantial differences in land cover are visible between the different reaches (Figure 23). Reach 1 is bordered by the largest proportion of forest cover, and small examples of all other cover types. Reach 2 is bordered by wetlands, forest, developed areas and agriculture. Reach 3 is primarily bordered by agriculture. Reach 4 neighbours the greatest amount of developed area of all reaches, as well as some forest cover and a substantial amount of agricultural cover. Reach 5 is bordered by a substantial amount of unvegetated terrain, as well as grassland, forest and agriculture. Reach 6 borders the largest proportion of wetland and grassland cover of all the reaches, and the least amount of forest cover overall.

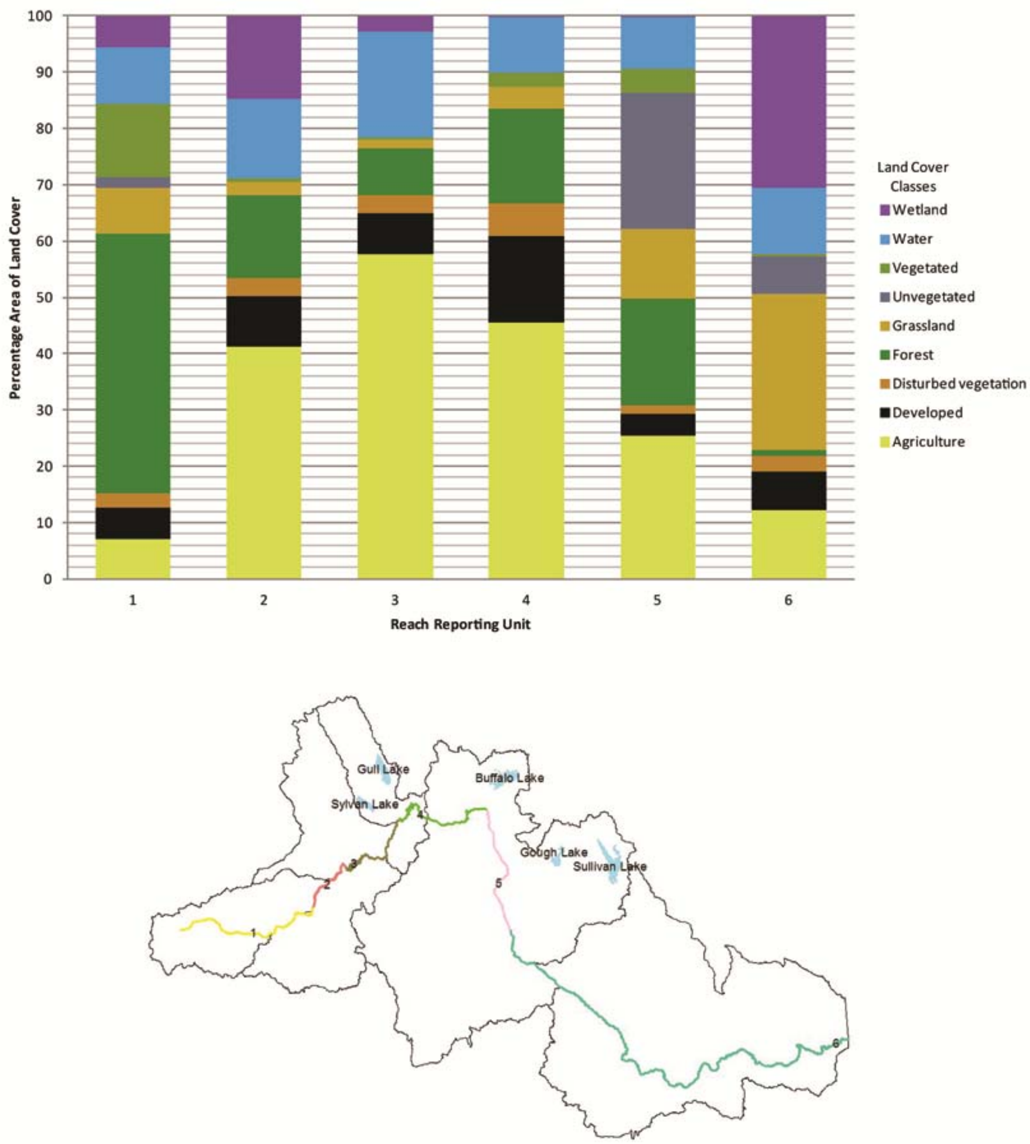

Figure 23. Percentage of Land Cover Classes Across Reach Reporting Units With a 1 km Buffer.

5.5 Species

5.5.1 Species Richness

In general, and based on the ACIMS and FWMIS datasets, lake species diversity is low, with the notable exception of Buffalo Lake, where a large number of bird species have been recorded, as well as fish, amphibian and forb species (Figure 24, Table 12). Sullivan Lake has no records of fish species, and

Gough Lake has no recorded species at all — undoubtedly a function of low sampling effort. Information on macrophytes, phytoplankton and zooplankton in this lake has not been collated to date, and represents a substantial data gap in assessing present lake biodiversity.

Table 12. Species Richness of Major Lakes.

Name	richness	bird	fish	amphibian	forb
Sullivan Lake	3	3	0	0	0
Sylvan Lake	9	1	7	1	0
Buffalo Lake	123	113	6	2	2
Gull Lake	17	8	9	0	0
Gough Lake	0	0	0	0	0

With regard to the Red Deer River, the highest species richness has been observed in Reach 6, with Reach 3 a close second place. Reach 6 is dominated by fish species records, while Reach 3 contains more bird species (Figure 25, Table 13).

Table 13. Species Richness of River Reaches.

Name	richness	mammal	fish	arthropod	bird	amphibian	reptile	lichen	sedge
Reach 1 - Headwaters to Hwy 22	14	0	10	0	0	0	0	3	1
Reach 2 - Hwy 22 - Gleniffer Lake	19	4	11	0	4	0	0	0	0
Reach 3 - Gleniffer Lake to Hwy 2	47	0	19	0	25	2	1	0	0
Reach 4 - Hwy 2 to Nevis	35	0	21	0	13	0	1	0	0
Reach 5 - Nevis to Morrin	23	1	18	0	4	0	0	0	0
Reach 6 - Morrin to Bindloss	50	11	24	2	8	3	2	0	0

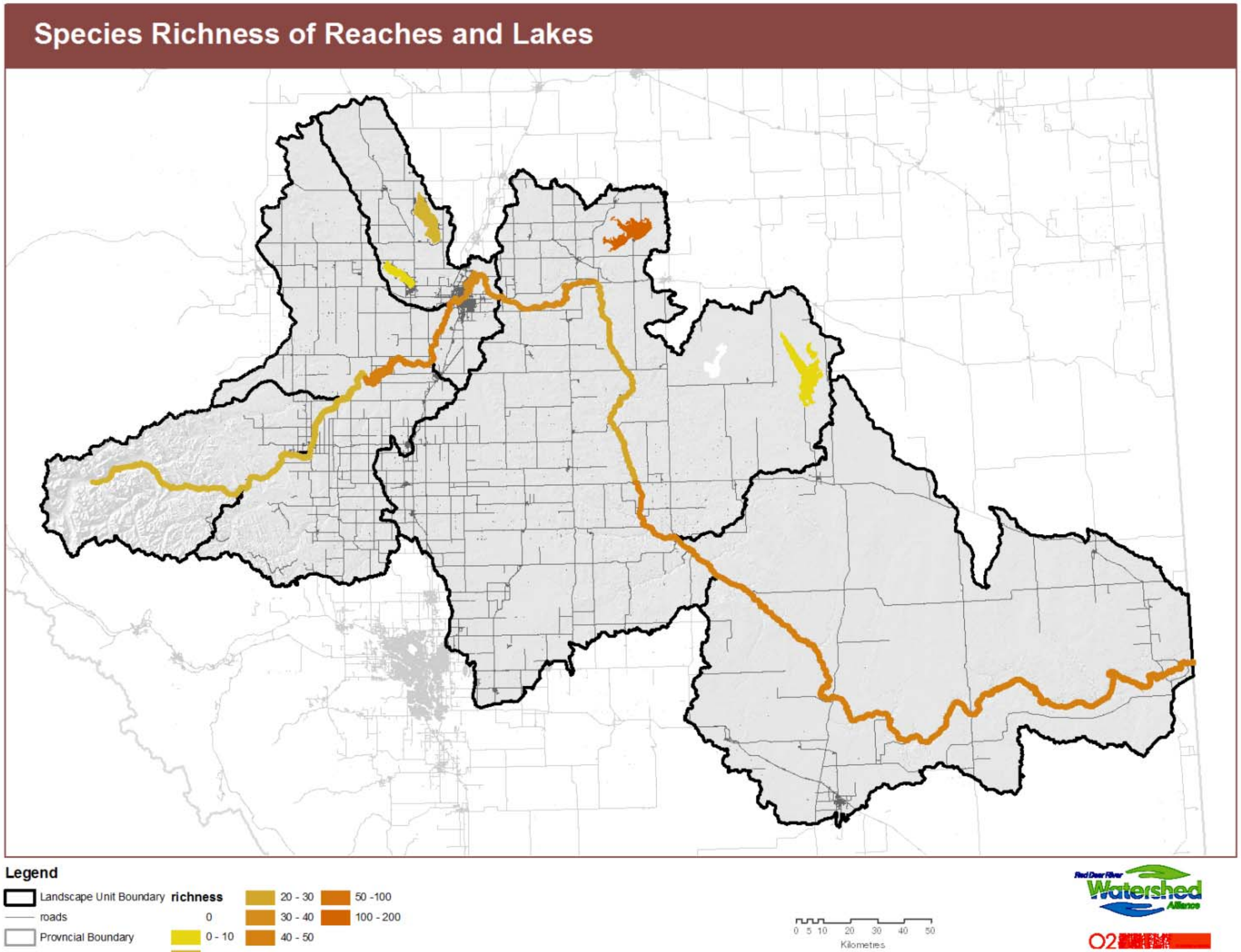

Figure 24. Map of Species Richness Across Aquatic Units (i.e., Reaches and Lakes) in the Red Deer River Watershed.

5.5.2 *Species At Risk*

Sullivan Lake contains observations of Burrowing Owls and Loggerhead Shrike. At Buffalo Lake, there have been observations of Northern Leopard Frog, Sprague's Pipit and Piping Plover. Gull Lake also contains observations of Piping Plover (Table 14; Appendix 2).

Bull Trout and Mountain Sucker are found in Reaches 1 and 2, Mountain Sucker in Reach 3, Lake Sturgeon and Peregrine Falcons have been observed in Reach 4, Peregrine Falcon in Reach 5, and Lake Sturgeon, Loggerhead Shrike and the Great Plains Toad have been observed in and around Reach 6 (Appendix 3).

Table 14. Species At Risk By Lake and River Reach Units.

Name	Species At Risk
Sullivan Lake	Burrowing Owl, Loggerhead Shrike
Sylvan Lake	-
Buffalo Lake	Northern Leopard Frog, Sprague's Pipit, Piping Plover
Gull Lake	Piping Plover
Gough Lake	-
Reach 1 - Headwaters to Hwy 22	Bull Trout, Mountain Sucker
Reach 2 - Hwy 22 - Gleniffer Lake	Bull Trout, Mountain Sucker
Reach 3 - Gleniffer Lake to Hwy 2	Mountain Sucker
Reach 4 - Hwy 2 to Nevis	Lake Sturgeon, Peregrine Falcon
Reach 5 - Nevis to Morrin	Peregrine Falcon
Reach 6 - Morrin to Bindloss	Lake Sturgeon, Loggerhead Shrike, Great Plains Toad

5.6 Terrain Conditions

Sylvan Lake contains the most complex surrounding terrain, and its terrestrial biodiversity is likely to be the most sensitive to development disturbances. Buffalo Lake contains a number of steep slopes, but for the most part, the terrain surrounding these lakes is relatively flat (Figure 25).

Reaches 4 and 5 are surrounded by the most complex terrain, while the areas surrounding Reach 2 and 3 are comparatively flat (Figure 26). The upper portions of Reach 1 are also quite steep, but become less so as the area opens up into the foothills.

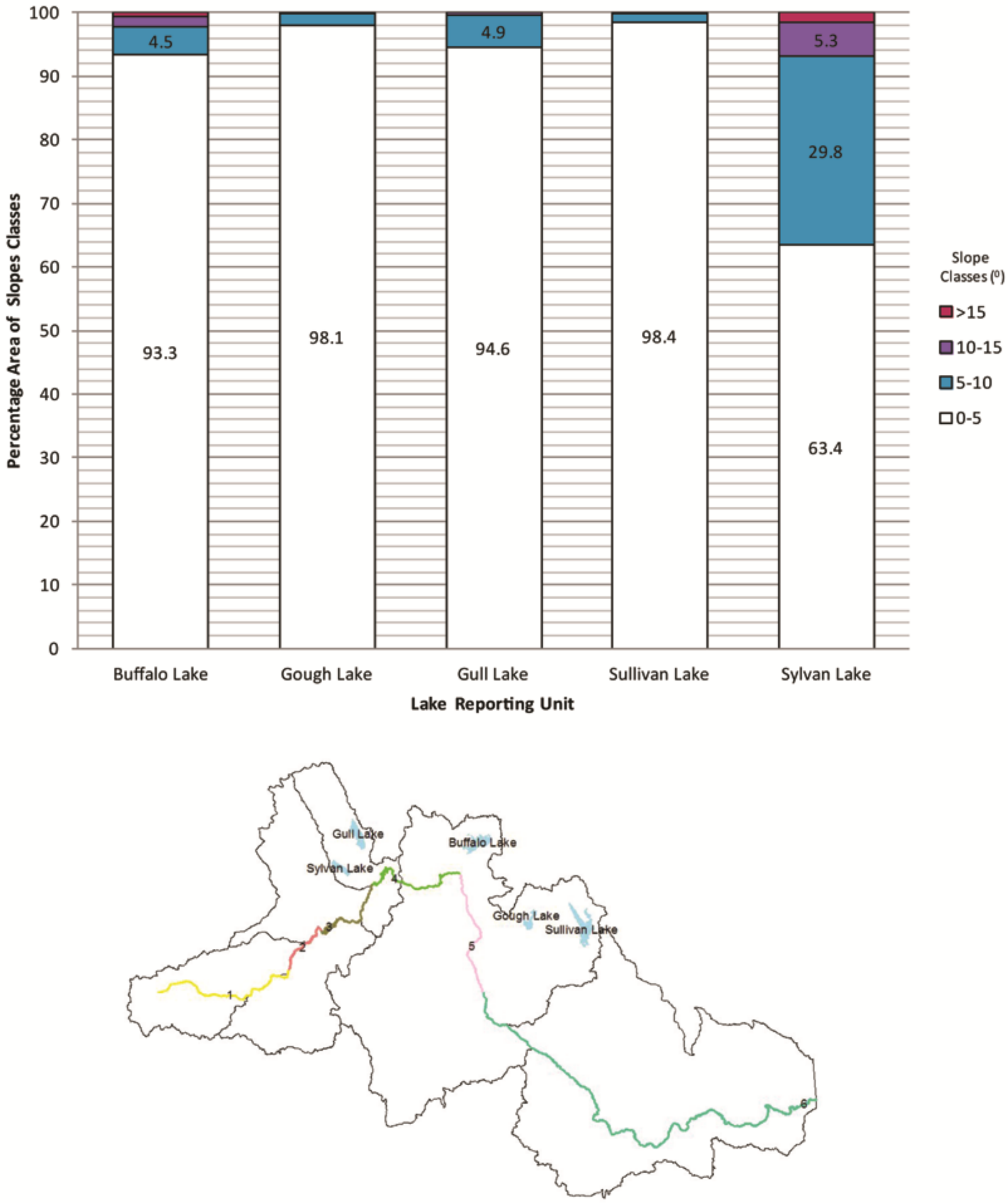

Figure 25. Percentage Area of Slope Classes Across Lake Reporting Units in the Red Deer River Watershed.

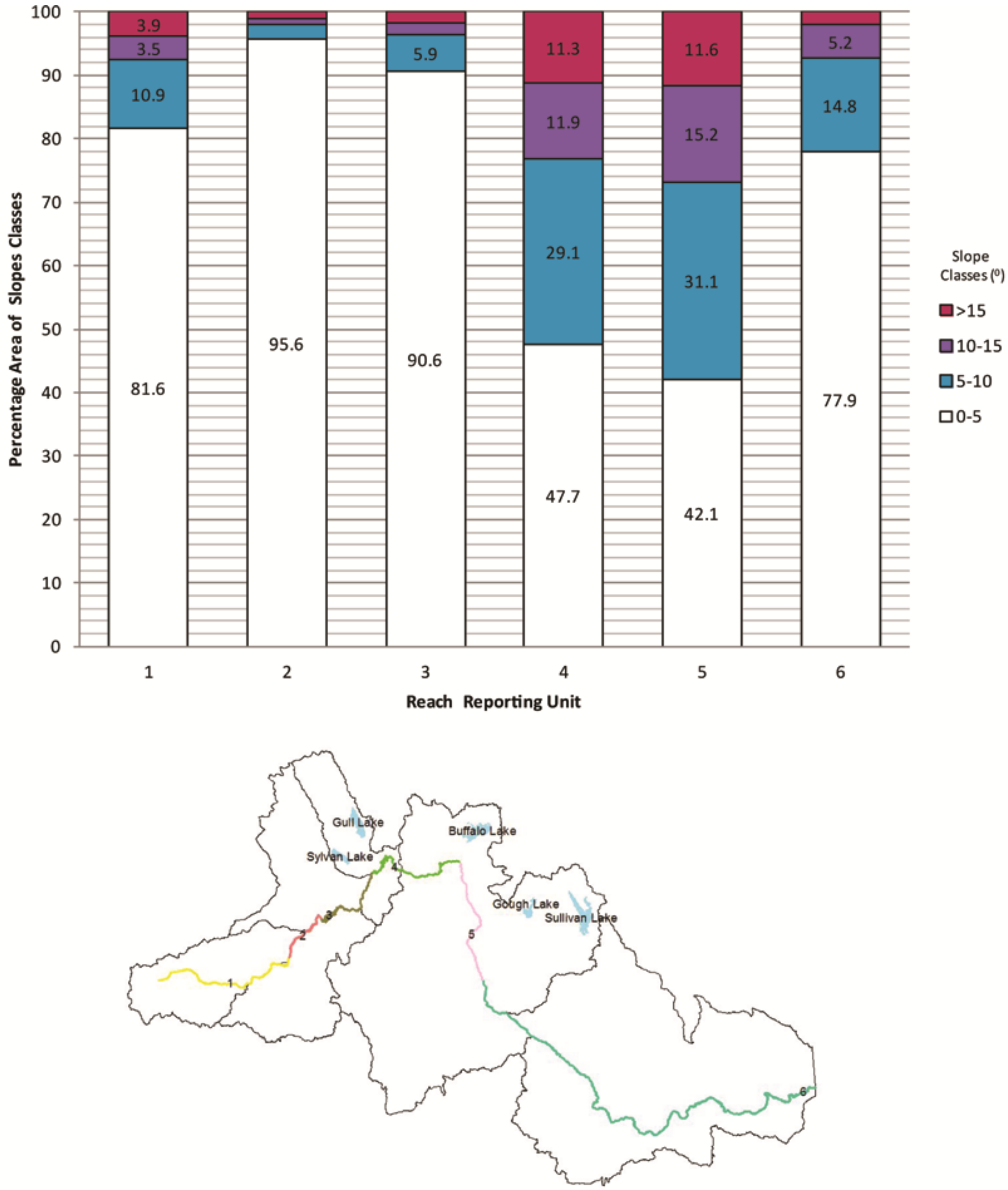

Figure 26. Percentage Area of Slope Classes Across Reach Reporting Units in the Red Deer River Watershed.

5.7 Landscape Intactness

Buffalo Lake, Gough Lake and Sullivan Lake all contain large areas of intact natural cover (Figure 27), although no natural patches over 10 km^2 currently occur in the area. Sylvan Lake in particular, contains no patches over 1 km^2, while Gull Lake and Sullivan Lake contain regions that are completely dominated by human footprint.

Reach 1 contains the most intact natural cover surrounding it (Figure 28). Only Reach 1 and 6 have neighbouring natural patches greater than 10 km^2, while Reach 3 and 4 have few patches greater than 1 km^2. Only Reach 3 contains areas with complete human footprint cover (in and around the city of Red Deer).

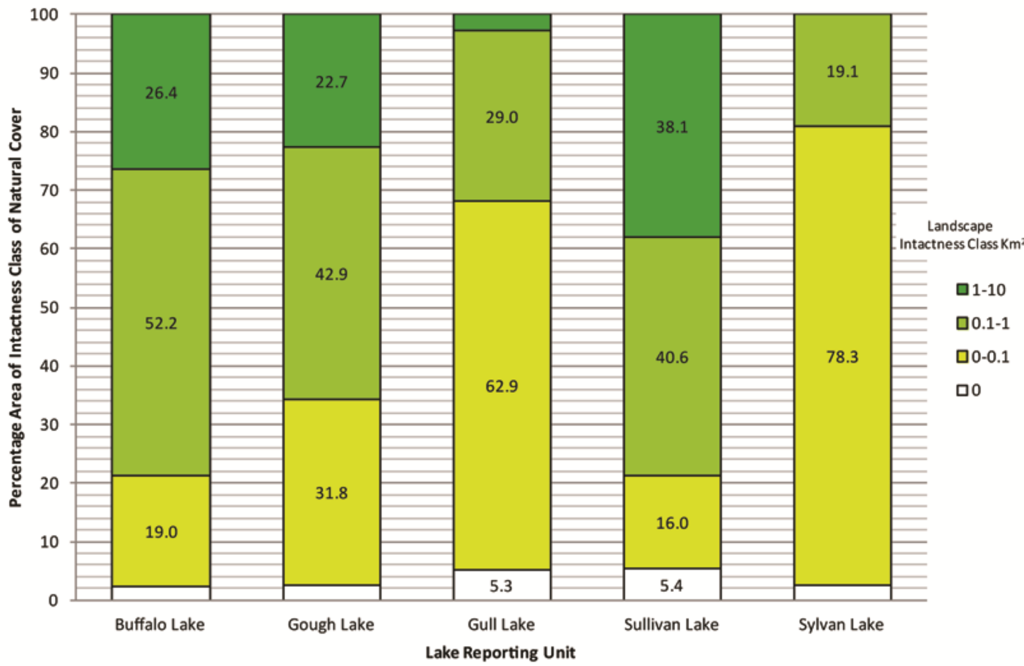

Figure 27. Percentage of Landscape Intactness Classes (Km2) Across Lake Reporting Units With a 1 km Buffer.

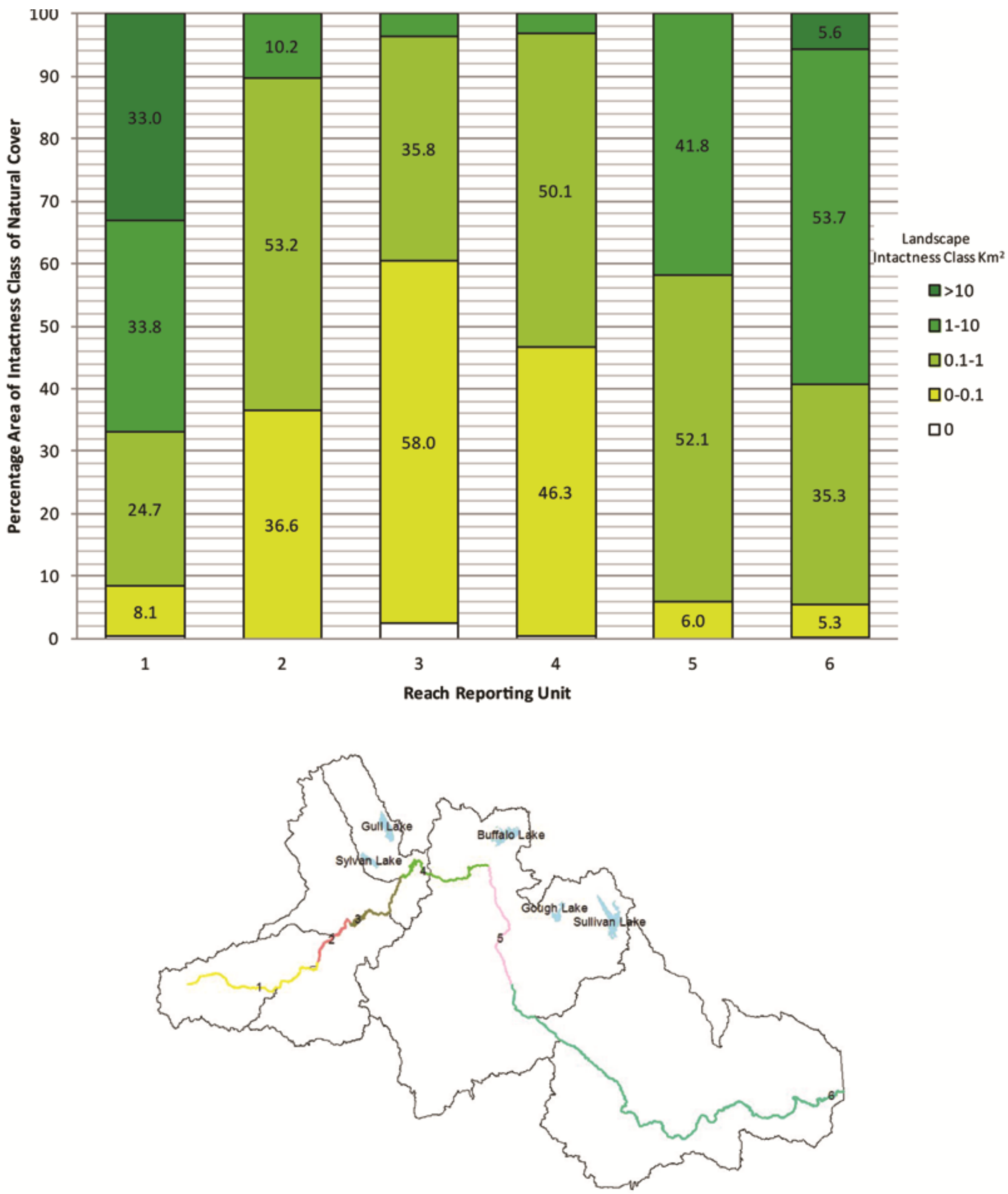

Figure 28. Percentage of Landscape Intactness Classes (km^2) Across Reach Reporting Units with a 1 km Buffer.

6. TOOLS AND CHALLENGES FOR BIODIVERSITY MANAGEMENT

6.1 Synthesis of Current Policy and Management Issues

Key pieces of Alberta's current legislation related to biodiversity management include (Alberta ESRD, 2014c):

- ***Public Lands Act* and Public Lands Administration Regulation.** Provides for the setting of land disturbance standards and land conservation tools in support of biodiversity management
- ***Provincial Parks Act.*** Plays an important role in protecting natural diversity and intact habitat for supporting biodiversity, in addition to ensuring a wide range of recreation opportunities and tourism experiences
- ***Water Act.*** Provides for the allocation and use of Alberta's water resources and the protection of rivers, streams, lakes and wetlands
- ***Wildlife Act.*** Provides for harvesting limits and designation and recovery of species at risk
- ***Environmental Protection and Enhancement Act.*** Provides for the assessment and regulation of activities to minimize their environmental impacts, based on principles including continuous improvement and pollution prevention
- ***Climate Change and Emissions Management Act.*** Provides for the management and reporting of emissions of carbon dioxide, methane and other specified gases, and requires measurable reductions in greenhouse gas emissions for specified activities
- ***Forests Act.*** Provides for the sustainable management of Alberta's forests, including a legislated requirement for reforestation

In addition to legislation, a number of strategies — such as the Clean Air Strategy, Water for Life, Gene Conservation Plan for Native Trees of Alberta, Alberta's Plan for Parks and the Land-use Framework — provide high-level goals for air, water, land and biodiversity management and specify how Alberta will achieve these goals.

6.1.1 Parks/Protected Areas

Approximately 3.1% of the RDRW consist of parks and protected areas. Banff National Park covers over 1,027 km^2 in the Upper Headwaters. There are 57 provincial parks and protected areas in the watershed, including 10 Provincial Parks, 1 Wildland Provincial Park, 26 Natural Areas, 17 Public Recreational Areas, 2 Ecological Reserves, and 1 Wilderness Area (O2 Planning + Design Inc., 2013b). A portion of the lower Red Deer River valley including Dinosaur Provincial Park and some limited surrounding areas is designated as a UNESCO World Heritage Site.

6.1.1.1 Prescribed Burns in Protected Areas

Fire has shaped Alberta's forests for generations. Fires recycle nutrients, help plants reproduce, create a mosaic of vegetation types, and provide habitat for a variety of wildlife species. The exclusion of fire from the landscape by people has contributed to an increase in the overall age of forests, which has contributed to a decrease in biodiversity and forest health. For instance, the absence of natural fires has paved the way for insect outbreaks (e.g., mountain pine beetle) and large-scale uncontrollable wildfires (Parks Canada, 2012).

A prescribed burnis an intentional fire planned and managed by fire specialists. Parks Canada conducts prescribed burns in the uppermost portions of the RDRW to restore ecological integrity and natural processes in Banff National Park. The province has also conducted prescribed burns. Although these activities are planned and conducted carefully, it is possible that they may generate risks to watershed values downstream.

6.1.2 Local policies

A search for the word “biodiversity” was conducted among the eight largest municipalities in the RDRW. While the inclusion of environment and protection of natural resources was clear in all jurisdictions, the Counties of Red Deer and Mountain View, City of Brooks, and Towns of Strathmore and Blackfalds did not mention the word biodiversity in their municipal development plans.

In contrast, the County of Rocky View cites biodiversity as part of the benefits of wetland and riparian areas conservation (Rocky View County, 2013). The Town of Sylvan Lake 2013 draft Municipal Development Plan includes biodiversity as one of the key points of community concern under the Natural Environment Section (Parkland Cummunity Planning Services, 2013). The City of Red Deer is the only municipality that includes the concept of biodiversity at a policy level: policy 9.11 (from the Environmental and Ecological Management section) indicates that the City of Red Deer should establish a stewardship program with residents that would include biodiversity (The City of Red Deer, 2008).

6.1.3 Regional Planning

Alberta’s Land-Use Framework (LUF) calls for the development of regional plans for seven new land use regions, the Red Deer River Region included. The seven regions are congruent with the province's major watersheds and align with municipal boundaries. The government plans to create Biodiversity Management Frameworks for each of the seven planning regions under the *Alberta Land Stewardship Act*. The government will likely release the first Biodiversity Management Framework for the Lower Athabasca Region (slated for release by end of year 2013), as well as the second for the South Saskatchewan Region in 2014. Each region is expected to have its own biodiversity priorities and indicators, although some indicators will be province-wide.

In the current draft of the SSRP, biodiversity takes the top of eight Strategic Directions for the Region that comprise the Strategic Plan section: *Conserving and Maintaining the Benefits of Biodiversity*. Under the Implementation Plan section, biodiversity is included as the second outcome of *Strategies and Outcomes: Biodiversity*. Appendix F of the Plan corresponds to an overview of the biodiversity management framework, which includes regional objectives, indicators and targets, methodologies to establish targets for biodiversity indicators, management approaches, and a monitoring approach. Development of the SSRP and content related to biodiversity is particularly relevant to the RDRW, given the proximity of the area and similarities in terms of environment and socioeconomics.

Contrasting with the draft of the SSRP, the approved Lower Athabasca Regional Plan (GOA, 2012) places biodiversity, together with air, water and land disturbance, in the strategic portion of the plan. The implementation portion of the plan positions biodiversity along with ecosystems function.

The Red Deer Region is bordered by the Alberta-Saskatchewan border to the east, goes to the westerly edge of Mountain View County, south of Iddesleigh and to the most northerly boundary of Ponoka County. Red Deer is the region’s largest city. This region is about 5,033,751 hectares in total. The plan for the Red Deer Region has yet to commence.

6.1.4 White and Green Areas

Land-use decisions made in Alberta today are shaped by the government’s 1948 initiative to divide the province into the white and green areas. The white area covers about 39% of the province. It is largely comprised of land owned by individuals and groups (homeowners, farmers, companies, organizations, etc.). Generally, ownership rights are limited to the land surface and do not include subsurface, non-renewable natural resources. While private landowners can make decisions about how to use and manage their land, they must follow laws, bylaws and regulations set out by municipal and provincial governments (GOA, 2008a).

The green area covers about 61 per cent of the province, mainly in the north and along the Eastern Slopes. It is largely owned by the provincial Crown and is referred to as public land. It is set aside primarily for renewable and non-renewable resource development, limited grazing, conservation, and recreational use. The provincial government is mandated to manage public land use (GOA, 2008a).

The green area (unsettled) and the white area (settled) regions in Alberta differ significantly by extent, land ownership, population, land use type, authority to set regulations, and ecosystem types (Table 15). Because the areas are based on settlement and land use patterns, the boundaries will likely change over time. Management and conservation strategies would need to follow suit and hence, the use of natural boundaries (based on Alberta Natural Regions and Sub-regions), rather than the green and white areas, may be more appropriate for biodiversity assessment, monitoring, and management (Locky, 2011).

Table 15. Key Aspects of White and Green Areas in Alberta (GOA, 2008a).

White Area	Green Area
• Settled lands	• Forested lands
• Covers about 39 per cent of Alberta	• Covers about 61 per cent of Alberta
• Three-quarters privately owned by more than 1.7 million individual title holders (50,000 own or use most of the land for agriculture)	• Nearly all publicly owned
• Primarily in the populated central, southern and Peace River areas	• Primarily in northern Alberta, some in the mountains and foothills
• Main land uses: settlements, agriculture, oil and gas development, tourism and recreation, conservation of natural spaces, and fish and wildlife habitat	• Main land uses: timber production and other wood products, oil and gas development, tourism and recreation, conservation of natural spaces, watershed protection, and fish and wildlife habitat
• Authority to set regulations and make decisions is primarily with municipal governments on private land and with the provincial government on public land	• Authority to set regulations and make decisions is primarily with the provincial government

6.1.5 East Slope policy

The Eastern Slopes of Alberta's Rocky Mountains cover an area of approximately 90,000 km^2 of mainly forest-covered mountains and foothills. Since the late 1970s, the impacts of land use change and pressures for resource extraction were identified as significant to the environmental quality and management of this region (GOA, 1984). The upper watersheds of the Eastern Slopes are the source of water for a number of downstream needs including agricultural, municipal, and aquatic ecosystem needs. Protecting watersheds in the Eastern Slopes is especially important for downstream water users. In 1977, a Policy for Resource Management of the Eastern Slopes (the Eastern Slopes Policy) was approved. It was revised in 1984 (GOA, 1984). The revised Eastern Slopes Policy included the following objectives for the region:

- Ensure that wildlife populations are protected from severe decline and viable populations are maintained;
- Maintain wildlife on the basis of fundamental ecological principles;
- Maintain areas of wilderness or primitive character.

The policy is intended to guide public lands and resource management within the eastern slopes region. The policy describes the concept of land use zonation and compatible uses which should be implemented in the development of Sub-Regional Integrated Resource Plans.

6.1.6 Wetlands

On September 10, 2013, the Government of Alberta released the *Alberta Wetland Policy*, which considers the core principles of Alberta's *Water for Life: Alberta's Strategy for Sustainability* (released in 2003 and renewed in 2008). The implementation plan for the new policy will be released for the White Zone (settled and agricultural areas) by August 2014 and for the Green Zone (primarily Crown-owned land in the northern part of the province) by August 2015.

The goals of the Wetland Policy will be integrated into the Government of Alberta's policies, programs, initiatives, and directives, to ensure a coordinated approach to wetland management across the province. The policy, especially the Wetland Mitigation Decision Framework, will be incorporated into the Government's regulatory process to ensure compliance, and will be incorporated into local government (municipalities, First Nations', and Métis Settlements) processes to ensure integration across all levels of government with respect to regional variations in impacts, needs, and local environments.

The new, comprehensive policy abandoned previous "no-net loss" provisions, and moved from an area-based compensation to a function-based replacement (biodiversity being one of the functions assessed). This replacement approach will no longer be based on a 3:1 ratio for restoration. Instead, it will follow a sliding scale from a ratio of 8:1 to 0.125:1 based on functionality. Non-restorative replacement is also an option.

To ensure strategic alignment of *The Alberta Wetland Policy*, the Alberta Urban Municipalities Association (AUMA) has advocated that municipalities should take strong a leadership role in water management and water management principles used to guide environmental policy development in Alberta. For example, some of the roles municipalities would like to play, assuming appropriate resources and support are available include:

- Leading in responsible water management — water conservation, efficiency and productivity, and maintaining healthy aquatic ecosystems
- Engaging in shaping water policies and legislation, and having the authority and resources for effective monitoring, reporting and enforcement in conjunction with other orders of government
- Partnering in the implementation of provincial and regional land and watershed management plans that reduce the cumulative effects of development on aquatic ecosystems (AUMA, 2013)

Currently, several Alberta municipalities have developed their own wetland conservation strategies and policies. Novel wetland development and mitigation projects initiated by municipalities exemplify the importance of a distinct wetlands policy in areas where wetland losses have been historically high.

6.1.7 Actual Presence of Biodiversity in Current Policies or Management Plans

In late 1995, the Government of Alberta committed to using the Canadian Biodiversity Strategy as a guide for conserving biodiversity and ensuring the sustainable use of biological resources. The province uses four indicator themes to evaluate and manage the status of biodiversity in Alberta:

- Condition
- Pressure
- Response
- Performance

With the exception of the condition theme, the latter three themes still lack specific indicators (Alberta ESRD, 2014a).

Condition indicators reflect the susceptibility of biodiversity to change in the presence of various pressures (Alberta ESRD, 2014a). Condition indicators may illustrate changes in biological productivity, species richness, or Species at Risk (Alberta ESRD, 2014b). Changes in condition may be independent of local pressures, or highly dependent on management practices.

Pressure indicators are related to industrial and residential development, habitat fragmentation, population growth, or consumption. Environmental and other monitoring databases are used to derive pressure indicators such as invasive species, habitat loss and fragmentation. To date, no pressure indicators have been developed by the province (Alberta ESRD, 2014e).

Response indicators are related to the actions taken to mitigate loss of, or protect biodiversity. Such actions might be related to land use (e.g., wetland or habitat restoration), species protection via management plans, or habitat protection via preservation mechanisms (e.g., protected areas, invasive species management plans). Responses should be designed to act on the pressures that have been identified in a particular region. To date, no response indicators have been developed for the province (Alberta ESRD, 2014f).

Performance indicators measure the success of management actions on enhancing biodiversity. Such management actions might include endangered species action plans, species at risk recovery plans, biodiversity stewardship initiatives, or conservation programs and policies. No performance indicators have been developed to date (Alberta ESRD, 2014d).

The condition indicators of biodiversity in Alberta are related to species at risk. This indicator includes eight groups of organisms:

- Amphibians
- Freshwater fish
- Orchids
- Ferns
- Mammals
- Butterflies
- Reptiles
- Birds

The Accord for the Protection of Species at Risk (Species at Risk Public Registry, 2006) is an agreement by provincial, territorial, and federal ministers responsible for wildlife. The Accord requires parties to "monitor, assess, and report regularly on the status of all wild species." Alberta works with other Canadian jurisdictions through two national committees: the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Recovery of Nationally Endangered Wildlife (RENEW). Positive gains have been made in the conservation and recovery of species at risk in Alberta; however, continued emphasis is needed to prevent more species from becoming at risk. Some successes include:

- Western blue flag removed from threatened list
- Peregrine falcon moved from endangered to threatened
- Reduction of piping plover mortality with predator closures on nests
- Re-introduction of swift fox, which was thought to have disappeared from Alberta

6.1.8 Navigation Protection Act (Formerly Navigable Waters Protection Act)

In 2002, The Navigable Waters Protection Act (NWPA) was described as a "federal statute designed to protect the public's right to navigation and marine safety in the navigable waters of Canada." The Act was administered by the Navigable Waters Protection Program (NWPP) under the Canadian Coast Guard (CCG) of the Department of Fisheries and Oceans. In 2006, the Department of Fisheries and Oceans (DFO) became responsible for the *Navigable Waters Protection Act* and the *Fisheries Act*. Prior to the amendments in 2009, the NWPA considered impacts on navigation and the environment. Those who wanted to build in, on or over Canadian waterways triggered an environmental assessment approval process under the Act. Under the 2009 amendments, the word 'waters' was removed from the title of the Act and the legislation was renamed as the Navigation Protection Act (NPA). The amendment also has no mention of environment as such but several sections address environmental protection. As a consequence, the *Minor Works and Waters Order* was passed to provide for exempting minor works and waters from the Act's application. In 2012, the Act was amended by the *Jobs and Growth Act, 2012* to provide for:

- Limitation of the Act's application to works in certain navigable waters that are set out in its schedule
- Application to certain works in other navigable waters, with the approval of the Minister of Transport
- Assessment process for certain works and to provide that works that are assessed as likely to substantially interfere with navigation require the Minister's approval
- Administrative monetary penalties and additional offences

The amendments came into effect in April 2014 (Minister of Transport, 2014).

6.1.9 Fisheries Act

As part of its Omnibus Budget Bill in 2012, the federal government passed significant changes to the Fisheries Act that came into effect November 25 (Jobs Growth and Long-Term Prosperity Act, 2013). The changes marked the end of the prohibition against the harmful alteration, disruption or destruction of fish habitat (the HADD Provision). Previously, the Fisheries Act applied to all fish bearing waters in Canada. Now, protection is limited to only commercial, recreational or Aboriginal fisheries. This suggests that the government has overlooked the fact that a fishery can be valuable for ecological reasons (without having value as a commercial, recreational or Aboriginal fishery). In addition, under the new provision, the permissible degree of harm is much higher (Heelan, 2013).The Fisheries Act now prohibits fish deaths or the permanent alteration or destruction of habitat (as opposed to harmful alteration, disruption or destruction of fish habitat).

The Department of Fisheries and Oceans has published several supplements and supporting documents following the changes to the Fisheries Act:

- Fisheries Protection Policy Statement
- Operational approach for implementing the changes
- Guidance for existing and new authorizations from the department
- Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting

6.2 Key Biodiversity Issues

The following primary issues present key challenges in the maintenance of biodiversity in the Red Deer River Watershed.

6.2.1 Habitat Loss and Connectivity Issues

Estimates of landscape connectivity are derived from the analysis of the spatial arrangement of habitat availability and fragmentation. As such, the notion of biodiversity as inversely related to habitat fragmentation and human-built infrastructure is widely recognized (Forman, 1995; Franklin, 1993; Theobald et al., 2012). In this particular case, the management of biodiversity and connectivity across the landscape in the RDRW could benefit from a non-species specific approach to depict critical arrangements of biodiversity. A map of landscape intactness (or integrity as an inverse of human-influenced landscape) is a useful first step (Figure 21) to understand connectivity issues in the RDRW. However, an assessment of landscape connectivity, including critical patterns, issues and potential directions to management, would require further modelling. Hence, landscape connectivity is included as part of the follow-up recommendations in this report (Table 19).

6.2.2 Invasive Alien Species

In the community workshops held in 2011, members of the public listed invasive plants as a significant area of concern in the watershed (RDRWA, 2011). This indicates a growing recognition that invasive species have a global and local impact on the economy, social values, and the natural environment. However, there are still gaps in our knowledge of invasive species and their impacts on Alberta's economy. The Alberta government is following a collaborative approach to invasive species management. Specific actions from the Alberta government include the Alberta Invasive Alien Species Management Framework Assessment Tool (GOA, 2010a), and provincial legislation to weed control such as the *Weed Control Act* (GOA, 2011). The Alberta Invasive Alien Species Management Framework Assessment Tool aims to facilitate management of the risks of invasive alien species by focusing on provincial initiatives, which include most Government of Alberta ministries involved in land or resource management.

Despite its importance, the management of invasive alien species in Alberta is not as comprehensive or well developed as it should be given the potential adverse impacts of invasive species on biodiversity. Current records of invasive alien species are sparse, weighted towards plant/weed control, and lack information on distribution or abundance of invasive species. Relevant resources for invasive alien species management are the Alberta Invasive Plant Identification Guide (Wheatland County, 2012), and the Alberta Invasive Species Council website (https://www.abinvasives.ca/).

Currently, the province is in the process of developing an Aquatic Invasive Species Prevention Program. Priority areas include: early detection, monitoring, inspections (boats), education and outreach, and collaboration (particularly between the US and adjacent provinces). Of particular concern are Zebra and Quagga mussels, Eurasian Watermilfoil (Alberta Tourism Parks and Recreation, 2014), and Lyngbye cyanobacteria (Kirkwood, Shea, Jackson, & McCauley, 2007). Current policies in place that address aquatic invasive species include:

- The Alberta Weed Control Act
  - Schedule 1: Eurasian watermilfoil, purple loosestrife, flowering rush, Himalayan balsam
- The Alberta Fisheries Act
  - 42: Restricted possession: zebra mussels and sea lamprey
  - 32(2): Threats to fish health: Ministerial Order, quagga mussels, authority to Fishery Officers

Additional provincial legislation related to aquatic invasive species include:

- Agricultural Pests Act (allows the minister to declare animals, plants, birds, insects or diseases to be "pests" and to eradicate them or prevent their establishment)
- Code of Practice for Pesticides (details the safe handling, use and application of pesticides to ensure environmental protection. Section 11 deals with Forest Management Pesticide use and Section 12 involves Industrial Vegetation Management)
- Fisheries (Alberta) Act, Regulation (controls the import of fish eggs and live fish)
- Forest and Prairie Protection Act (section 28 regulates forest pest control)
- Forest Act, Timber Management Regulation (sections 164.1 (1) (2) and (3) describe importation of logs or other forest products into Alberta that may carry insects and disease)
- Public Lands Act (lists the duties of the land-holder with regard to seed and weeds)
- Wildlife Act (controls the possession, import and export of wildlife. The Wildlife Regulation prohibits import, export and possession of wildlife without a permit)

6.2.3 Land Cover Health

The forest health program under Alberta ESRD is responsible for monitoring and managing the biological, physiological, and environmental factors that may have an adverse effect on the health of the forest, which can include:

- Insects
- Nematodes
- Microorganisms (viruses, bacteria, fungi)
- Parasitic plants
- Mammals
- Birds
- Noxious and restricted weeds
- Non-infectious disorders caused by climate, soil, applied chemicals, air pollutants and other physiographic conditions

Alberta ESRD provides Spatial Wildfire Data and Forest Pest Survey Data as ESRI® ArcGIS shapefiles. Information relevant to the RDRW includes six wildfires that took place since 2010, as well as general forest health, which indicates a series of blowdowns that took place in 2010.

There are no reports addressing grasslands or wetlands health in the RDRW. Although grasslands health assessments are well standardized (e.g., Rangeland Health Assessment for Grassland, Forest and Tame Pasture, Government of Alberta, revised in 2009) CPAWS (2011) suggest that a new rangeland assessment protocol that includes biodiversity (and ecosystem services) would more accurately depict the role of grazing in the health of the ecosystems by not simply considering the capacity of the land to be used for grazing. A revised protocol that includes such components would help to guide better sustainable rangeland management.

6.2.4 Climate Change and Extreme Events

In recent years, the occurrences of extreme events such as ice storms, droughts and floods have been on the rise worldwide and have been recorded recently in Alberta as well. Information available does not allow direct links between biodiversity in the RDRW and extreme events. However, sources relevant to biodiversity such as past and future weather trends, along with land cover functional responses (e.g., evapotranspiration, primary production and leaf area index) in the RDRW could be incorporated and modelled by employing satellite image inventories and climate databases.

Recently, Schneider (2013) developed a report on Alberta's Natural Sub-regions under climate change projections with the following highlights that relate to the RDRW current land cover types. It is important to clarify that although overall precipitation is projected to increase, most climate models predict that Alberta will become substantially drier in coming decades and hence, the scenarios presented are characterized by a an overall drying trend in the future:

- ***Grassland and Parkland.*** Under a cool model scenario, representing the least amount of predicted climate change, the Grassland and Parkland shift roughly one Sub-region northward by the 2050s. Communities representing the warm and dry end of the environmental spectrum within a given Sub-region will increase, at the expense of communities on the cool and wet end of the spectrum. The mechanism underlying these changes is mainly competition. Under a hot model, the Parkland will experience the climate of the Dry Mixedgrass by the 2080s. The Dry Mixedgrass in turn will become similar to the driest parts of Wyoming and southern Idaho, where the vegetation is dominated by sage-brush species that are adapted to extreme aridity. This suggests that immigration of species exotic to Alberta will become an important factor under a Hot scenario. What is unclear is whether the rate of species adaptation or migration will be able to keep up with the rate of climate change. Another issue to consider is species dissociation, which refers to potential for processes desynchronization such as presence of pollinators when blooms occur. Under a warmer climate, prairie wetlands will experience reduced runoff and groundwater flows because of regional drying due to increased evapotranspiration. They will also experience increased losses to evaporation, caused by earlier spring melt and higher summer temperatures. As a result, it is expected that the average water level of wetlands will decline and the amount of time that seasonal wetlands are dry will increase.

- ***Dry mixedwood.*** Under a Cool model the Dry Mixedwood region will experience a Parkland climate by mid-century. This will cause an expansion of the small grasslands that already exist along the Peace River lowlands, as well as the appearance of scattered grassy openings elsewhere in the aspen forest. Under a Hot model, the aspen would have limited capacity for regeneration. Therefore, widespread transitions to grass are possible after mid-century, at a rate largely determined by the rate of disturbance. Drought, insects, and possibly fire, will be the leading agents of disturbance, opening and expanding gaps in the aspen forest.
- ***Central Mixedwood.*** The pattern of change in the Central Mixedwood will be strongly influenced by elevation. Lower elevation areas are warmer and will become moisture limited first, beginning with the lowlands along the Peace and Athabasca Rivers. Higher elevation areas will follow. Under a Cool model, the Dry Mixedwood appears in low elevation regions along the Peace and Athabasca Rivers by the 2020s and extends across most of the Sub-region by the 2050s. Under a Hot model, almost the entire Central Mixedwood will experience a Grassland climate envelope by the 2050s. Successional transitions will mainly manifest after the mature trees have been killed by fire or other disturbance. In stands that have been killed by fire, successional patterns are expected to be complex. There is likely to be some influx of pioneer species and those adapted to dry conditions, but also some regeneration back to spruce and aspen. Peatlands occupy 45% of the Central Mixed-wood but only 15% of the Dry Mixedwood. Therefore, a transition to the warmer and drier climate of the Dry Mixedwood, as expected under a Cool model, implies that approximately two-thirds of the peatlands in the Central Mixedwood will dry out and undergo succession to a wooded ecosystem. Given the large extent of the Central Mixed-wood (about 25% of Alberta), this translates into more than 50,000 km^2 of new terrestrial habitat. It is unclear how quickly the drying will occur — a time lag can be expected because of the ability of peat to absorb and store water during wet periods. As the drying progresses, succession to shrubs and then black spruce forest will follow rapidly.
- ***Foothills.*** The main change that can be expected in the Lower Foothills by the 2080s, is a general increase in ecological diversity, as species from the Central Mixedwood, Montane, and the Foothills Fescue (to a limited degree) increase in abundance while a legacy of existing Foothills species (especially lodgepole pine) remains intact in favourable sites and in areas that have escaped disturbance. Fire and mountain pine beetle are both important agents of change. Under a Hot model, the southern part of the Lower Foothills becomes moisture limited as a result of increased evapotranspiration by the 2050s, and the entire Sub-region is moisture limited by the 2080s. Because successional transitions are limited by the rate of disturbance, it is unlikely that widespread changes (or loss of initial forest conditions) will occur by the end of the century.
- ***Montane.*** With climate warming, the grasslands found at lower elevations and dry sites within the Montane will expand into higher elevations. Under a Cool model, at least some parts of the Sub-region should remain forested by the 2080s. But under a Hot model, it is likely that most of the Sub-region will transition to grasslands.
- ***Rocky Mountains.*** Vegetative communities in the Rocky Mountains will generally shift to higher elevations as the climate warms. However, species do not all move at the same rate, and local site conditions, snow pack, and disturbance history affect patterns of advance, both at treeline and at lower elevations. Therefore, the Alpine, Subalpine, and Upper Foothills will not move upslope as intact units. Instead, the vegetative patterns of the Sub-regions will blend as the climate warms, increasing ecological diversity (though not permanently).

6.2.5 Wetlands health

A variety of wetland inventories have been completed in Alberta. High resolution wetland inventory was undertaken primarily in the white zone (settled and agricultural areas) in the southern part of the province (GOA, 2010b). In the green zone, which falls primarily in the boreal forest and northern part of the province, wetland inventories are focused on classifying the different types of wetlands. This inventory identifies wetlands to a minimum of five different types based on the Canadian Wetland Classification System including bog, fen, swamp, marsh, and shallow open water wetlands. In southern Alberta (GeoDiscover Alberta, 2012), approximately 64% of wetlands have disappeared since settlement, which translates in loses of approximately 0.3-0.5% of wetlands each year. The causes for wetland loss include: drought, population growth, industrial development, land use changes, and management practices and policies (GOA, 2010b). Despite the lack of information targeting the health of wetlands in Alberta or the RDRW, wetland characterization and protection is a key theme in the province. The Bow River Basin Watershed Management Plan includes wetland health inventory and classification as one of the stepping stones for wetlands protection (BRBC, 2008).

6.2.6 Water Quality

6.2.6.1 Reaches

Based on the report on an initial assessment of aquatic health in the Red Deer River watershed (North/South Consultants Inc., 2007), water quality was rated “good” in their first monitored three reaches, deteriorating slightly to a rank of “fair” in the most downstream reach. The Red Deer River is oligotrophic, based on nutrient concentrations, near its headwaters but becomes more nutrient-rich as the river moves downstream.

Total phosphorus and nitrogen levels increase notably with increasing distance downstream, although data from 1999 to 2003 indicate that total phosphorus remains fairly constant in the middle reaches but increases significantly closer to the provincial border (Cross, 1991; North/South Consultants Inc., 2007).

Increased winter flow due to the construction of the Dickson Dam has improved dissolved oxygen (DO) levels in the Red Deer River, although some low levels below the 1-day minimum guideline of 5 mg/L (Alberta Environment, 1999) were still detected even after the increased flow (Shaw & Anderson, 1994). Increased flow can augment the DO levels only to a degree, and if the point source loading continues to increase in the Red Deer River, low DO concentrations may become more frequent (Clipperton, Koning, Locke, Mahoney, & Quazi, 2003). In addition to increased winter flows due to the dam, substantial upgrading of the sewage treatment process at Red Deer municipal wastewater treatment plant has also helped reduce oxygen depletion. In general, the Red Deer River is well oxygenated. There are occasional occurences of low DO at sites located between the City of Red Deer and the eastern border (towards Nevis) but the events are restricted to winter. The river is somewhat alkaline and occasional excursions beyond the Alberta Environment water quality guideline for pH for the protection of aquatic life occurred at all long-term river monitoring sites. The lowest compliance rate occurred at Bindloss (61%) (North/South Consultants Inc., 2007).

Some water quality parameters increase notably near the border at Blindloss, including total suspended and dissolved solids, aluminum, iron, manganese, and total phosphorus and nitrogen. This is believed to reflect geology and sediment re-suspension. There was insufficient information to assess the current aquatic ecosystem health (AEH) of the Red Deer River on the basis of sediment quality. The implications of water quality objectives on the management of the RDRW (Anderson, 2012) indicate deteriorating trends for several water quality indicators: total nitrogen, (nitrite+nitrate)-nitrogen, ammonia, and total dissolved solids. Additionally, other indicators exceed the most sensitive guidelines at one or more locations with long-term monitoring data: fecal coliform bacteria, *E. Coli,* and dissolved oxygen. The latter suggests a need to better understand loading patterns in the RDRW in order to make informed decisions about selecting and implementing the most effective load reduction measures to correct deteriorating trends. A more comprehensive understanding of loading patters will also enable compliance with site-specific water quality objectives at long-term monitoring sites. Anderson (2012) suggests investigating the relative influence of loadings from natural and man-made point and non-point sources on river water quality in each reach and under a range of river flows. It is important to note that Anderson's (2012) data preceded upgrades at the Red Deer Wastewater Treatment Plant and changes in sewage handling at nearby municipalities. Therefore, current water quality conditions may differ.

Agriculture is prominent throughout the RDRW, with the exception of the upper reach in the mountain and foothills regions. Given agriculture's prominence in the region, nutrients are a particular concern. Furthermore, because the Red Deer River lacks "large" tributaries (Rood, George, & Tymensen, 2002), assessments of agricultural impacts on the Red Deer River mainstem, including Blindman River and Threehills Creek, are challenging. Major point sources (>200,000 m3/year) in the RDRW include a number of municipal wastewater plants, gas/petrochemical processing plants, water discharge cooling ponds, and irrigation return flows (North/South Consultants Inc., 2007).

6.2.7 Lakes

Water quality information related to the trophic status of lakes or general water quality of lakes and reservoirs in the RDRW is available through Alberta ESRD (data from 1978 to 2009). An in-depth analysis of trends and gaps could be performed to determine the current status, indicators, and thresholds for functional biodiversity in the RDRW. Although water quality analysis is out of the scope of the present report, valuable information could be found in Water Quality Conditions and Long-Term Trends in Alberta Lakes (Casey, 2011).

6.2.8 Water Quantity

There is agreement among scientists that the natural flow variability of a system should be maintained or replicated to protect the biodiversity and ecological services of a river system (Arthington, Bunn, Poff, & Naiman, 2006). The important hydrologic components in a system include magnitude, frequency, timing, duration, rate of change, and predictability of flow events. The natural flow regime is important for many aspects of aquatic ecological health including water quality, energy sources, physical habitat, and biotic interactions (Table 16). Not only do these facets of the natural flow regime sustain different ecological niches in a system, but each species in a riverine system evolved based on the characteristics of the naturally occurring flow regime. How each component of the natural flow regime can affect riverine ecology, and why it is important to consider flow variability in river restoration, is examined in Bunn and Arthington (2002).

Goter et al. (2007) developed six flow scenarios to analyze potential ecosystem impacts associated with alternative water-uses for the Red Deer River. With the exclusion of natural flows, the scenarios explored were: present use of existing licences, instream flow needs (based on Clipperton et al. 2003), increased use of existing licences, new licences with high water conservation objective (WCO), and new licences with proposed WCO. Present use of existing licences and the instream flow needs determination (Clipperton et al. 2003) resulted in slight impacts on the aquatic environment. The increased use of existing licences, new licences with high WCO, and new licences with proposed WCO indicated serious impacts to the aquatic ecosystem with measurable declines in the condition or abundance of stream biota.

Table 16. Instream Flow Needs to Maintain Adequate Water Quality for the Protection of Mainstem Fisheries Have Been Determined for Most of the Red Deer River (Clipperton et al., 2003).

Reach	Minimum inflow needs (m^3 sec^{-1})			
	Winter (weeks 1-11, 51-52)	Spring (weeks 12-24)	Summer (weeks 25-37)	Fall (weeks 38-50)
Dickson Dam to Medicine River	16	16-23	18-33	17-22
Medicine River to Blindman River	16	16-23	18-33	17-22
Blindman River to the Special Areas Water Supply Project	16-17	17-23	17-33	17-21
Special Areas Water Supply Project to Drumheller	16-17	12-22	18-35	18-22
Drumheller to Dinosaur Provincial Park	16-18	17-23	22-40	18-25
Dinosaur Provincial Park to Bindloss	16-18	17-22	21-39	18-25
Bindloss to Saskatchewan border	16-18	17-22	21-39	18-25

6.3 Draft Goals for Terrestrial and Aquatic Biodiversity

The conservation and sustainable use of biodiversity is an essential element in an overall environmental management approach that supports the social licence for development and management of Alberta's natural resources. Developing comprehensive plans to manage biodiversity clearly involves coordination between jurisdictions (e.g., federal, provincial, municipal). In the current draft of the South Saskatchewan Regional Plan (SSRP), one of the strategies identified for provincial and regional outcomes (i.e., biodiversity and ecosystem function are sustained with shared stewardship) involves the review and consideration (as necessary) of integrated resources plans in the region into the SSRP (GOA, 2013). For the draft of the SSRP, the section on biodiversity focuses on indicators at a regional scale that are affected by land use activity.

The governments and Canada and Alberta have made a commitment to conserving biodiversity and achieving the sustainable use of biological resources across our diverse landscapes. Today's Alberta includes working landscapes, and the Land-Use Framework policy acknowledges the need to balance environmental, social and economic considerations. The diversity of the Red Deer Watershed needs to be maintained, enabling it to contribute to national and provincial biodiversity goals.

The importance of integrated regional management is well established and a matter of provincial policy. In keeping with the need for regional integration, the proposed management goals, targets and indicators for aquatic and terrestrial biodiversity adopt the Biodiversity Management Framework proposed in the draft of the SSRP as a starting point (GOA, 2013). It is worth to mention that the biodiversity framework for the now approved SSRP is under development (GOA, 2014).

Recommended draft goals for biodiversity are provided below:

- Terrestrial and aquatic biodiversity are maintained
- Species at risk are recovered and key grasslands habitat is sustained
- Key wetland complexes are retained and land uses surrounding them are managed with best practices
- Areas important for biodiversity are identified and assessed as potential conservation areas

- Biodiversity and healthy functioning ecosystems continue to provide a range of benefits to communities in the region and to the rest of Alberta
- Long-term ecosystem health and resiliency is monitored and maintained

6.4 Draft Indicators and Targets for Terrestrial and Aquatic Biodiversity

Key recommended indicators and targets for biodiversity are grouped in environmental, programmatic and social indicators (Table 17, 18 and 19, respectively; see Sections 1.4 and 1.5 for definitions). The indicators incorporate the Overview of Biodiversity Management Framework as found in the current draft of the SSRP (GOA, 2013), and the latest draft of possible indicators for Canada's 2020 Biodiversity Targets (Federal Provincial and Territorial Biodiversity Working Group, 2013).

Key draft indicators are highlighted in orange.

Table 17. Draft Environmental Indicators (key draft indicators are highlighted in orange).

Indicator	Target	Notes
Amount of native land cover	No net loss from current amounts, implementation of rangeland assessment protocol across the watershed	Recovery of previously disturbed grasslands unlikely, making the long term preservation of remaining natural grasslands a high priority
Percentage of total territory identified for conservation through land protection and land stewardship programs	At least 17 per cent of terrestrial areas and waterways in the watershed are conserved through networks of protected areas and other area-based conservation measures	The percentages of area protected are currently reported by the Canadian Environmental Sustainability Indicators (CESI) initiative (hereafter CESI indicators)
Total wetland area	100 per cent of existing natural wetlands are conserved or enhanced to sustain their ecosystem services, total wetland area in the watershed is increased	This aligns with new provincial wetland policy, and is a change from the Background Technical Report on Riparian Areas, Wetlands, and Land Use (O2 Planning + Design Inc., 2013). Explore conservation tools such as mitigation banking
Degree of landscape connectivity	By 2020, develop a spatially explicit assessment of connectivity. Implement best practices to maintain connectivity on all private land	Requires a species specific assessment of fragmentation impacts
Nutrient concentrations of rivers, streams and lakes	By 2020, implement the narrative statements developed for nutrient levels as in Environmental Quality Guidelines for Alberta Surface Waters (Alberta ESRD, 2014). Spatially explicit data is made easily accessible to the public	This is a CESI indicator and Alberta ESRD has a comprehensive monitoring system in place. Increases in nutrient concentrations can result in increased growth of opportunistic species, lowering the diversity of communities present, and reducing the value of habitat.
Species at risk population trends	Species at risk listed under federal law meet the recovery objectives of federal and provincial strategies	Data on population trends are extracted from the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessments and the General Status of Alberta Wild Species reports
Number and location of invasive alien species in the RDRW	Development of an invasive species management program, including definition and identification of pathways of invasive alien species introductions, and a risk-based intervention plan for priority pathways and species	Requires collaboration with provincial programs such as the Alberta Invasive Species Council

Indicator	Target	Notes
Area and number of important and representative species habitats	Selection and ranking of appropriate keystone and indicator species to allow for species prioritization and spatially explicit identification of key habitat	Systematic gap analysis will be essential to target conservation effort

Table 18. Draft Programmatic Indicators (key draft indicators are highlighted in orange).

Indicator	Target	Notes
Centralized, comprehensive monitoring and inventory program	RDRW has established a comprehensive inventory of protected spaces that includes private conservation areas, and an ongoing methodology for assessing their significance and value	Mainly driven by the province, ABMI and AEMERA
Number of commercial operations that incorporate sustainable forest management practices	The suite of indicators in the Canadian Council of Forest Ministers (CCFM) Criteria and Indicators (C&I) Framework is actively used to inform management decisions	Coordination between Canadian Forest Service, Alberta ESRD, Foothills Research Institute, and the forestry industry
Number of commercial operations that incorporate sustainable rangelands management practices	Rangeland assessment protocol is implemented and grazing is actively managed across the watershed to maintain healthy grasslands	Coordination between CPAWS, private land owners, and government agencies will be required
Number of commercial operations that incorporate sustainable farmland management practices	≥ 50 percent of farms adopt sustainable farmland management practices, and provide an increased contribution to biodiversity and habitat quality	Preparation of Environmental Farm Plans does not guarantee improved practices or positive effects on biodiversity. BMPs related to biodiversity would rely on data from the province
Number of commercial operations that incorporate sustainable aquaculture management practices	≥ 50 percent of all aquaculture operations adopt best management practices to reduce impacts on aquatic biodiversity	This indicator would require baseline research to assess current conditions
Number of land use and development plans that consider climate adaptation	Frameworks for monitoring and long term trend analyses are in place, explicitly incorporating adaptive management into watershed and regional planning	Requires collaboration with broader monitoring and management groups, latitudinal coordination in response to changing growth conditions
Motorized access to public land	Existing uses are identified and compiled in a spatial inventory. Recreational activities are clustered away from sensitive areas and access restrictions are installed. Public education on potential impacts is in place	Public participation necessary to establish preferred areas for recreation
Extent and duration of linear disturbances	A comprehensive reclamation program is in place whereby existing disturbed areas, priorities, and actions are defined. Best practices for future disturbances are established	Project specific, long term assessment of impacts. Requires industry participation and project approval conditions. Best practices must be habitat specific.

Indicator	Target	Notes
Number of licenses with water conservation objectives (WCO)	Existing management plans for water licensing incorporate river flow WCO that scientifically determine sustainable natural aquatic ecosystems over the long term	Incorporate the estimated effects of river flows on the aquatic environment of the Red Deer River as developed by Goater et al. (2007)
Stream continuity	Best management practices are established for stream crossings. Multiple disturbances are concentrated to one area. High quality stream habitat is avoided	Requires assessment of stream function prior to disturbance
Natural disturbance intensity, frequency and extent	A toolbox of BMPs with disturbances that mimic natural succession regimes is developed. Areas with homogeneous age structures are identified	With reference to historic patterns of disturbance, but may be influenced by changing environmental conditions (i.e., drought cycles, etc)
Number of ecosystem goods and services that are actively monitored and valued	Implemenation of an ecosystem goods and services valuation program	Community and industry focus, cross-sector collaboration
Number of land management plans that incorporate biodiversity conservation strategies	All future land management plans explicitly incorporate biodiversity management frameworks	Municipality focus, requires cross-sector support and involvement of RDRWA. Indicators rely on the cooperation of all jurisdictions to review and report progress.
Incorporation of national and provincial biodiversity indicators with regional planning frameworks	RDRW Integrated Watershed Management Plan includes language which aligns with broader Red Deer and South Saskatchewan regional frameworks	Broad scale, community focus. Existing and proposed indicators do not address traditional or community knowledge. It is important to explore the possibility of developing an appropriate indicator for traditional knowledge, which involves discussions with Aboriginal Organizations

Table 19. Draft Social Indicators (key draft indicators are highlighted in orange).

Indicator	Target	Notes
Degree of public participation in monitoring and preservation of biodiversity	Citizen science programs are designed and implemented. Public participation in environmental monitoring activities is encouraged. Information on biodiversity is distributed	Standardized monitoring programs require sound scientific and statistical methods to ensure that observations are stratified, and that observer effort is accounted for
Number of schools that have biodiversity activities in their curricula	Biodiversity is explicitly incorporated into all elementary and secondary school curricula	Combined effort between the RDRWA and Alberta Education
Percentage of RDRW residents who report that they take action to protect their watershed	An increase in participation of watershed residents in biodiversity conservation activities. Increase in public engagement events within the watershed.	RDRW co-ordinate with surveys such as the Households and the Environment Survey
Public perception of biodiversity value	Publish and distribute educational material that results in increased public understanding of the valuation of natural capital and the economic costs of environmental degradation.	Outreach efforts must be targeted across a broad demographic range, urban rural gradient, age and education

6.5 Management Implications and Recommendations

The following recommendations relate specifically to biodiversity management in the Red Deer River Watershed. Recommendations are listed under three main categories: reporting units, future needs, and key Beneficial Management Practices (BMPs).

6.5.1 Reporting Units

There is a need to adopt an adaptive and spatially stratified management approach to ensure that planning and reporting units continue to reflect natural and functional delineations and management strategies can be directed towards the most appropriate areas. Table 20 outlines a number of the primary characteristics and challenges that each unit faces today. As these aspects change, revisions to the unit boundaries may be appropriate to ensure that management units reflect an internally uniform set of characteristics.

Table 20. Significant Characteristics and Potential Challenges for Reporting Units Used in this Report.

Landscape Units	Characteristics	Challenges
1. Upper Headwaters	Forested land cover, mountainous terrain	Pest species, forestry operations, oil and gas exploration, exurban development
2. Lower Headwaters	Wetland complexes, mammal and bird diversity	Pest species, forestry operations, development, exurban development, oil and gas exploration
3. Central Urbanized	Wetland complexes	Ongoing urban expansion, development, oil and gas exploration
4. Central Agriculture	High species richness	Areas under sampled for biodiversity, extensive existing agriculture, oil and gas exploration
5. Dry Grasslands	Species Rich grasslands, Large Wetland Complexes	Agricultural development, mining operations, oil and gas exploration
Lake Units		
Sullivan Lake	Largely intact surrounding landscape, minimal development	Presence of Burrowing Owls and Loggerhead Shrike
Sylvan Lake	Fish richness	Existing developments surrounding the lake. Steep slopes may be sensitive to disturbance
Buffalo Lake	Highest bird species richness	Presence of Piping Plover and Sprague's Pipit
Gull Lake	Fish and bird richness	Presence of Piping Plover
Gough Lake	Large amounts of grassland surrounding the lake, small development footprint	Lack of species observations, potentially due to low sampling effort
Reach Units		
Reach 1 - Headwaters to Hwy 22	Headwaters of the Red Deer River, largely intact surrounding landscapes	Erosion, steep slopes, and activity in the area may impact water quality and aquatic diversity
Reach 2 - Hwy 22 to upstream of Gleniffer Lake	Wetlands surrounding reach	Conflicted land uses may introduce issues with biodiversity management
Reach 3 – Gleniffer Lake to Hwy 2	High bird and fish richness	Urbanization and riparian disturbance
Reach 4 - Hwy 2 to Nevis	Complex terrain, high fish richness	Steep slopes, extensive agricultural activities
Reach 5 - Nevis to Morrin	Complex terrain	Steep slopes
Reach 6 - Morrin to Bindloss	Relatively intact surrounding landscape, high species richness, high wetland density	Large area may require division or refinement for practical management

6.5.2 Future Needs

Alberta Environment and Sustainable Resource Development is the designated ministry steward of air, land, water and biodiversity in the province of Alberta. In late 1995, the Government of Alberta committed to using the Canadian Biodiversity Strategy (Minister of Supply and Services, 1995) as a guide for conserving biodiversity and ensuring the sustainable use of biological resources. Currently, Alberta ESRD has developed two condition indicators (i.e., susceptibility of biodiversity to change) with regards to biodiversity: percentage of species at risk and status of Alberta species. Another important source of biodiversity information in the province is the Alberta Biodiversity Monitoring Institute (ABMI). The ABMI has a structured sampling program across the province that has been the main source of biodiversity monitoring.

In the future, the Alberta Environmental Monitoring, Evaluation and Reporting Agency (AEMERA) will coordinate most of the biodiversity monitoring work. This program will be linked to other biodiversity monitoring initiatives led by government or partners of government such as the Rangeland Health Monitoring Program, Forest Management Plan reporting, and the Species at Risk recovery plan reporting. Data also comes from existing monitoring done by ESRD (rare, hunted, fished or trapped species) or other organizations (e.g., Alberta Conservation Association), academics, and the federal government if applicable (GOA, 2013). With a formal announcement of its development in 2012, AEMERA was recently proclaimed as part of Bill 31 in April 2014 (aemera.org, 2014). Given the upcoming development of biodiversity management frameworks and associated monitoring programs, the Alberta government and the RDRWA should collaboratively establish monitoring programs for the watershed.

6.5.2.1 Environmental Impact Assessment Research Synthesis

Opportunities must be available to ensure that small-scale, project-specific site assessments are compiled into a broader regional dataset. This will aid the planning and assessment process by ensuring that new data is collected in a consistent fashion, allowing long-term, spatially explicit assessments. Collaboration with land-use planners before disturbances occur will allow more rigorous BACI (Before-After/Control-Impact) comparisons, and increase the understanding of the ecological processes at play in this watershed. While individual projects may be conducted at the local scale, and restricted in the degree of assessment and observation that is feasible, the aggregate of many local-scale assessments (if conducted in a concerted fashion with similar methodologies) can add up to a great wealth of information for the region as a whole.

6.5.2.2 Research Needs

Indicators for biodiversity in this report were deliberatively balanced to cover at least one aspect of composition, structure and function of biodiversity in the RDRW (Table 21). In this process, many research needs where recognized. While some of these research gaps require additional efforts of data filling and compilation (particularly under a spatially explicit context), some of them involve different depths of statistical modelling (Table 22). One particular gap that requires attention is the lack of temporal analysis of patterns in biodiversity across the RDRW. Properties of biodiversity are very site or locally dependant. Caution should be taken during the extrapolation (or standardization) and interpretation of quantitative indicators of biodiversity health.

Table 21. Biodiversity Parameters in the RDRW.

Indicator	Type
Land cover	Composition
Wetland Complex	Structure
Richness	Composition
Steep Slopes	Structure
Riparian Disturbance	Function
Intactness	Function

Table 22 summarizes a series of biodiversity indicators that should complement (and enhance) biodiversity management in the RDRW:

Table 22. Additional Biodiversity Indicators for the RDRW.

Indicator	Type of Indicator	Source	Benefit
Connectivity	Functional	RDRW Intactness and Land Cover	Provides comprehensive assessment of the contribution of landscape composition and configuration to the maintenance of biodiversity across the watershed
Climate	Functional	Climate WNA	Provides long-term assessment of variability challenges to changes in habitat suitability
Water Use Efficiency	Functional	MODIS satellite images	Integrates carbon yield with water usage across different land cover types
Diversity / Environmental Sampling	Resource Selection Function	ABMI Raw datasets (non spatial)	Creates spatial-explicit and species-specific valuation models
Nutrient dynamics	Functional	Alberta ESRD	Provides changing water quality and cascade effects of habitat suitability over time
Macrophyte Diversity Compilation (terrestrial and aquatic)	Composition	Various	Fills gaps in spatial biodiversity knowledge
Landsat Land Cover Time Series	Composition	Landsat	Better quantifies the historical changes in the watershed
Terrain Ruggedness Index	Composition	Digital Elevation Model	Provides a more refined assessment of environmental complexity

6.5.3 Beneficial Management Practices

Beneficial management practices (BMPs) are common-sense operating principles that are simple and economical to implement. With respect to biodiversity, the purpose of BMPs is to guide conservation efforts aimed at protecting rare species and critical habitats, while enhancing landscape connectivity across the broader region. Managing a landscape for enhanced connectivity is based on Forman’s Indispensible Landscape Patterns, which posit that if certain “indispensible patterns” are strategically protected, one can conserve the majority of important habitats and ecological functions in the landscape (Forman, 1995).

The following suggested BMPs are either documented through agencies such as the Alberta Energy Regulator, AER (formerly EUB and ERCB), AESRD, CAPP, other industry organizations, or by the authors of this document. Priority BMPs are highlighted in bold.

6.5.3.1 General BMPs

- **Consider cumulative effects and timing in development and operations**
- Maintain habitat and connectivity of habitat where possible
- Replace or restore lost habitat
- Restore connectivity by reclaiming disturbances
- Maintain stream continuity (minimizing fragmentation of watercourses resulting from barriers at stream crossings)
- Undertake pre-project planning and consultation with municipal staff to avoid environmentally sensitive areas
- Provide conservation offsets to reduce impacts to sensitive landscapes
- Minimize the duration and extent of linear disturbances
- Maintain a diverse range natural cover types (forest seral stages, wetlands, etc.)
- Include habitat and species protection in the guiding principles of new Municipal Development Plans
- Retain a qualified environmental specialist to analyze, inspect, and monitor relevant pre-development, construction, operation and reclamation activities

6.5.3.2 Urban and Country Residential BMPs

- **Cluster development in areas close to existing infrastructure**
- Redevelop brownfield and greyfield sites rather than expanding into natural areas
- Use buffers and corridors to link and protect sensitive habitats
- Maintain natural/native vegetation that contributes to wildlife corridors
- Use local native plants, trees and shrubs
- Use natural landscaping techniques to salvage at least 20 cm of topsoil
- Reduce soil compaction, stockpile natural soils during construction projects
- Create narrow roads with infiltration swales
- New residential areas should be developed using Low Impact Development (LID technologies for sustainable storm water management

6.5.3.3 Lakeshore/Lake Front Recreational and Residential Development BMPs

- **Reduce the disruption and fragmentation of natural habitats**
- Identify ecologically significant areas and propose mitigation strategies for development on lands requiring Area Structure Plans or Area Redevelopment Plans
- Address critical ecological characteristics such as steep slopes and permeable soils as part of optimal site design

- Seek to retain greater amounts of undisturbed land in designs for new communities in order to promote biodiversity and improve water quality
- Build partnerships with neighbouring municipalities to work towards an integrated regional open space system
- Identify and protect strategic parcels, blocks, and corridors that provide opportunities for source control of stormwater infiltration
- Establish and implement a Low Impact Development (LID) stormwater management initiative on all municipality-owned, day-use parking lots adjacent to lakes
- Identify in the Outline Plan stage for all future subdivision applications: environmentally sensitive areas, kettle depressions, drainage courses, wetlands, and recharge zones located in sensitive groundwater areas

6.5.3.4 Agriculture BMPs

From Beneficial Management Practices Environmental Manual for Crop Producers in Alberta (Alberta Agriculture and Rural Development, 2004)

On Cropped Land:

- Convert marginally productive lands for annual crops to long term forage production
- Provide incentives for non-cropped areas
- Add perennial or annual forages to crop rotations, and manage perennial forage stands for longer life
- Use a flushing bar when haying
- Delay haying near wetlands until at least July 1, and whenever possible delay until mid-July
- Plant fall-seeded crops
- Reduce or eliminate tillage and/or try to eliminate fall tillage to provide cover and food during winter
- Use strip cropping rather than conventional fallow
- Use integrated pest management

On Non-Cropped Land:

- **Retain existing natural areas**
- Enhance the habitat values of treed areas by adding productive trees and leaving dead trees
- Avoid over-grazing of pasture land and delay spring grazing near wet areas
- Enhance habitat value in idle areas by planting a variety of grasses, legumes and shrubs, and adding nesting boxes
- Maintain the edges between habitat types
- Store reject bales carefully to avoid deer eating crops in corridors
- Stream fencing to allow recovery of riparian zones
- Promote rotational grazing, and relocation of cow/calf wintering sites
- Implement runoff containment and management

6.5.3.5 Oil and Gas BMPs

- **Use low impact installation methods for pipelines and other infrastructure to minimize disturbance**
- Develop site designs that avoid impacting intact native vegetation communities and wetlands (i.e. use existing access roads and disturbances)
- Implement Low Impact Seismic (LIS) techniques for cut lines
- Reduce access to cut lines
- Progressively reclaim well sites by revegetating areas that are not in use
- Use low impact techniques for constructing temporary access roads and block access to recreational users
- Consider leveraging the Orphan Wells Program for contaminated sites and low production wells

6.5.3.6 Recreation BMPs

- **Avoid creating disturbances which allow access (e.g. snowmobile trails) to wintering ungulate populations and other sensitive natural areas**
- Restrict recreation access during spring thaw, breeding periods and during migration events
- Require the use of established trails and linear disturbances for “off-roading”
- Continue to restrict and enforce off-highway vehicle use in environmental reserve lots and other conservation lands
- Restore areas damaged by recreational usage (e.g., ATVs, horse trails)
- Promote and develop educational and outreach programs for co-habitation with wildlife

6.5.3.7 Education BMPs

- **Support ongoing, targeted education of public officials, civil servants, the development community, and the public to ensure proper understanding, support, and technical knowledge**
- Prioritize target audiences for BMPs adoption in order to make the best use of limited resources.

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LIST OF ACRONYMS

ABMI	Alberta Biodiversity Monitoring Institute
ACIMS	Alberta Conservation Information Management System
AEH	Aquatic Ecosystem Health
AEMERA	Alberta Environmental Monitoring, Evaluation and Reporting Agency
Alberta ESRD	Alberta Environment and Sustainable Resource Development
AUMA	Alberta Urban Municipalities Association
AVI	Alberta Vegetation Inventory
BACI	Before-After/Control-Impact
BMP	Beneficial management Practices
CBC	cross-boundary cut procedure
CBMP	Circumpolar Biodiversity Monitoring Program
CCFM	Canadian Council of Forest Ministers
CCG	Canadian Coast Guard
CESI	Canadian Environmental Sustainability Indicators
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPVI	Central Parkland Vegetation Inventory
DFO	Department of Fisheries and Oceans
DO	Dissolved Oxygen
FWMIS	Fisheries & Wildlife Management Information System
GIS	Geographic Information Systems
GVI	Grassland Vegetation Inventory
IBI	Index of Biological Integrity

IWMP	Integrated Watershed Management Plan
LIS	Low Impact Seismic
LUF	Land-use Framework
Meff	Effective Mesh Size
NPVI	Native Prairie Vegetation Inventory
NWPA	Navigable Waters Protection Act
NWPP	Navigable Waters Protection Program
O2	O2 Planning + Design Inc.
RDRW	Red Deer River Watershed
RDRWA	Red Deer River Watershed Alliance
RENEW	Recovery of Nationally Endangered Wildlife
SOW	State of the Watershed Report
SSRP	South Saskatchewan Regional Plan
TAC	Technical Advisory Committee
WCO	water conservation objective
WPAC	Watershed Planning and Advisory Council

GLOSSARY

Abiotic	Nonliving, as in abiotic factor, which is a nonliving physical and chemical attribute of a system
Abundance	Species abundance is the number of individuals per species, and relative abundance refers to the evenness of distribution of individuals among species in a community
Afforestation	Establishment of forest on land that has not supported forest under current climate conditions
Allele	A variant form of a gene
Biodiversity	The diversity, or variety, of plants and animals and other living things in a particular area or region
Biodiversity management unit	An ecosystem-based classificatory scheme for managing biodiversity
Biotic	Pertains to a living thing (such as plant, animal, fungus, etc.) as well as its products (e.g. secretions, wastes, and remains)
Connectivity	The degree to which the landscape facilitates or impedes movement between resources patches
Diversity	A measure of the diversity within an ecological community that incorporates both species richness (the number of species in a community) and the evenness of species' abundances
Ecoregion	An ecoregion is part of an ecozone characterized by distinctive ecological responses to climate as expressed by the development of vegetation, soil, water, and fauna
Ecosystem	A community of plants, animals and smaller organisms that live, feed, reproduce and interact in the same area or environment
Ecosystem services	The benefits people obtain from ecosystems
Endangered species	Any native species that faces a significant risk of extinction in the near future throughout all or a significant portion of its range
Habitat	The location or environment where an organism is most likely to be found
Indicators	Measurable surrogates for environmental end points of value to the public
Meta-population	A set of spatially separated populations, which have some form of migration or mixing behaviour between them
Outcomes	The desired future conditions that guide the development and implementation of an organization's recommendations
Phenology	The study of periodic plant and animal life cycle events and how these are influenced by seasonal and inter-annual variations in climate, as well as habitat factors (such as elevation)
Rarity	The current status of an extant organism with is restricted either in numbers or area to a level that is demonstrably less than the majority of other organisms of comparable taxonomic entities

Resilience	The ability of the system to maintain its identity in the face of internal change and external shocks and disturbances
Richness	The number of species present in a sample, community, or taxonomic group
Species of concern	Informal term that refers to those species that might be in need of concentrated conservation actions but receive no legal protection
Succession	The progressive replacement of one dominant type of species or community by another in an ecosystem
Targets	Specific, quantitative values assigned to indicators that reflect a desired outcome
Taxa	Plural from taxon
Taxonomic group	A taxon with all its subordinate taxa and their individuals, for example the taxonomic group Insectaconsists of all insects and their taxa
Threatened species	Any native species that is at risk of becoming endangered in the near future.

APPENDIX A: Terrestrial Unit Species List

The following tables summarize the species reported in the Alberta provincial ACIMS and FWMIS species observation databases. Federally and provincially designated species at risk are highlighted in orange. These lists represent only a compilation of recorded observations, and are not exhaustive. The absence of a species record does not guarantee the absence of the species.

1. Upper Headwaters

Taxa	Species	Taxa	Species	Taxa	Species
fish	cutthroat trout	lichen	spoke pepper-spore lichen	bird	common snipe
	bull trout		cladonia bacilliformis		cliff swallow
	unknown		map lichen		red-winged blackbird
	mountain whitefish		firedot lichen		blue-winged teal
	brook trout		fan ramalina		green-winged teal
	longnose sucker		phaeophyscia nigricans		gadwall
	longnose dace		black-eyed rosette lichen		boreal chickadee
	brown trout		bare-bottomed sunburst lichen		brown-headed cowbird
	lake chub		jelly flakes		mourning warbler
	rainbow trout		kindred blood lichen		warbling vireo
	white sucker		red-fruited pox lichen		spotted sandpiper
	spoonhead sculpin		black woodscript lichen		house sparrow
	mountain sucker		cladonia lichen		macgillivray's warbler
	burbot		white-spotted woodscript lichen		cedar waxwing
	brook stickleback		rock pimples		bufflehead
	trout-perch		assimilative dot lichen		cape may warbler
	fathead minnow	bird	harlequin duck		blue-headed vireo
	emerald shiner		bay-breasted warbler		herring gull
	finescale dace		pine siskin		mourning dove
	walleye		black-capped chickadee		golden eagle
	iowa darter		gray jay		american kestrel
	northern redbelly dace		ruby-crowned kinglet		american tree sparrow
	northern pike		red-breasted nuthatch		caspian tern
mammal	bighorn sheep		hermit thrush		great blue heron
	grizzly bear		yellow-rumped warbler	moss	limprichtia cossonii
	black bear		spruce grouse		bryum algovicum
	cougar		red-naped sapsucker		brown moss
	red squirrel		northern harrier		conardia compacta
	moose		dark-eyed junco		rhizomnium andrewsianum
	mule deer		american robin		globe-fruited splachnum
	white-tailed deer		american crow		cushion moss
	horse		northern pygmy-owl		slender splachnum
	gray wolf		alder flycatcher		curl-leaved fork moss
	coyote		yellow-bellied sapsucker	forb	whitlow-grass
	wapiti		barred owl		early buttercup
	mountain goat		western tanager		flame-colored lousewort
	northern pocket gopher		willow flycatcher		alpine bladder catchfly
	pygmy shrew		barn swallow		hairy cinquefoil
	beaver		varied thrush		alpine harebell
	richardson's ground squirrel		ruffed grouse		alpine sheep sorrel
	deer		common raven		trifid-leaved fleabane
	red fox		red-breasted merganser		alpine poppy
arthropod	little copper		orange-crowned warbler		pale alpine fleabane
	astarte fritillary		rose-breasted grosbeak		pink false dandelion
	shasta blue		tennessee warbler		macoun's whitlow-grass
tree_shrub	alaska willow		lesser scaup		willowherb
	limber pine		least flycatcher		lemmon's rock cress
	whitebark pine		white-crowned sparrow		primrose
lichen	tattered jellyskin lichen		white-throated sparrow		marsh felwort
	lichen		black-billed magpie		pale blue-eyed grass
	disk lichen		clay-colored sparrow		rock arnica
	brown cobblestone lichen		northern flicker	liverwort	liverwort
	button lichen		vesper sparrow	sedge	pasture sedge
	chocolate chip lichens		red-tailed hawk		seaside sedge
	fringed chocolate chip lichen		blue jay		beautiful cotton grass
	granite firedot lichen		black-billed cuckoo		two-parted sedge
	pepper-spore lichen		savannah sparrow		lakeshore sedge
	brownish monk's-hood lichen		lincoln's sparrow	amphibian	columbia spotted frog
	slender splachnum		tree swallow		boreal toad
	jellyskin		european starling		wood frog
	brown pepper-spore lichen		canada goose		northern leopard frog
	camouflage lichen		tundra swan		boreal chorus frog
				graminoid	northern bent grass

2. Lower Headwaters

Taxa	Species	Taxa	Species
bird	great horned owl	bird	ruby-crowned kinglet
	clay-colored sparrow		cape may warbler
	sora		bay-breasted warbler
	savannah sparrow		cooper's hawk
	house wren		blue jay
	song sparrow		gray jay
	american redstart		barred owl
	american robin		northern pygmy-owl
	yellow-bellied sapsucker		cedar waxwing
	red-winged blackbird		great gray owl
	swainson's thrush		sandhill crane
	northern flicker		spotted towhee
	red-breasted nuthatch		swainson's hawk
	white-throated sparrow		ruffed grouse
	black-billed magpie		boreal owl
	killdeer		varied thrush
	common raven		dusky flycatcher
	tree swallow		western tanager
	white-breasted nuthatch		wilson's warbler
	brewer's blackbird		willow flycatcher
	brown-headed cowbird		brewer's sparrow
	western meadowlark		house sparrow
	american goldfinch		eastern kingbird
	downy woodpecker		lapland longspur
	barn swallow		olive-sided flycatcher
	american crow		virginia rail
	gray catbird		northern shoveler
	least flycatcher		gadwall
	yellow warbler		lincoln's sparrow
	baltimore oriole		hammond's flycatcher
	pileated woodpecker		mountain chickadee
	canada goose		tennessee warbler
	ring-necked duck		dark-eyed junco
	canvasback		townsend's solitaire
	ruddy duck		great blue heron
	black-capped chickadee		piping plover
	red-tailed hawk		spruce grouse
	le conte's sparrow		long-tailed vole
	chipping sparrow		short-eared owl
	rock dove		sharp-shinned hawk
	western wood-pewee		northern harrier
	red-eyed vireo		common yellowthroat
	alder flycatcher		spotted sandpiper
	common redpoll		yellow rail
	hairy woodpecker		common tern
	mountain bluebird		rose-breasted grosbeak
	white-crowned sparrow		evening grosbeak
	boreal chickadee		orange-crowned warbler
	hermit thrush		lazuli bunting
	northern hawk owl		blue-headed vireo
	solitary sandpiper		purple finch
	northern saw-whet owl		black tern
	american kestrel		horned lark
	common snipe		vesper sparrow
	pine siskin		blue-winged teal
	warbling vireo		european starling
	black-billed cuckoo		harlequin duck
	yellow-rumped warbler		gyrfalcon
	eastern phoebe		ruby-throated hummingbird
	horned grebe		rufous hummingbird
	lesser scaup		wilson's phalarope
	bufflehead		bald eagle
	cinnamon teal		american coot
	green-winged teal		northern pintail
	cliff swallow		ring-billed gull
	golden-crowned kinglet		pied-billed grebe

2. Lower Headwaters			
Taxa	Species	Taxa	Species
bird	sprague's pipit	mammal	striped skunk
	common merganser		little brown bat
	yellow-headed blackbird		muskrat
	golden eagle		marten
	western bluebird		beaver
	ovenbird		big brown bat
	pine grosbeak		red fox
	common loon		badger
	philadelphia vireo		arctic shrew
	mourning dove		deer
	snow goose		hoary bat
	western kingbird		water shrew
	black-throated green warbler		snowshoe hare
	brown creeper		gray wolf
	bank swallow		canada lynx
	redhead		fisher
	peregrine falcon		woodchuck
	northern goshawk		western jumping mouse
	snow bunting	amphibian	boreal chorus frog
	american tree sparrow		wood frog
	merlin		northern leopard frog
	common goldeneye		tiger salamander
	american wigeon		boreal toad
	american bittern		canadian toad
	red-necked grebe	fish	lake chub
	american white pelican		white sucker
	osprey		brook trout
	prairie falcon		longnose dace
	double-crested cormorant		burbot
	franklin's gull		rainbow trout
	american avocet		brook stickleback
	marbled godwit		brown trout
	rough-legged hawk		pearl dace
	red crossbill		longnose sucker
	bohemian waxwing		lake whitefish
	sharp-tailed grouse		spoonhead sculpin
	hooded merganser		mountain whitefish
	ferruginous hawk		bull trout
	willet		northern pike
	grasshopper sparrow		northern redbelly dace
	baird's sparrow		fathead minnow
	lesser yellowlegs		mountain sucker
	tundra swan		trout-perch
	white-winged crossbill		slimy sculpin
	northern shrike		bull trout x brook trout hybrid
	least sandpiper		finescale dace
	broad-winged hawk		spottail shiner
mammal	coyote		shorthead redhorse
	moose		northern redbelly dace
	wapiti		triopsidae
	white-tailed deer		walleye
	northern pocket gopher		goldeye
	porcupine		mooneye
	mule deer		yellow perch
	least weasel	forb	marsh gentian
	horse		smooth sweet cicely
	red squirrel		leafy pondweed
	franklin's ground squirrel		golden saxifrage
	cougar	moss	flagon-fruited splachnum
	grizzly bear		brachythecium rutabulum
	richardson's ground squirrel		callicladium haldanianum
	black bear		pohlia bulbifera
	deer mouse	reptile	red-sided garter snake
	prairie vole	arthropod	variegated meadowhawk
	meadow vole	sedge	hudson bay sedge
	house mouse	graminoid	slender spikerush

3. Central Urbanized

Taxa	Species	Taxa	Species
bird	cinnamon teal	bird	long-billed dowitcher
	green-winged teal		downy woodpecker
	northern shoveler		northern pintail
	american coot		rough-legged hawk
	canvasback		hairy woodpecker
	canada goose		tundra swan
	red-tailed hawk		brewer's blackbird
	black tern		ring-billed gull
	sora		western bluebird
	red-winged blackbird		bald eagle
	redhead		white-breasted nuthatch
	gadwall		northern goshawk
	northern flicker		bank swallow
	northern harrier		great horned owl
	american crow		black-necked stilt
	savannah sparrow		great blue heron
	song sparrow		willet
	black-billed magpie		marbled godwit
	american robin		gray partridge
	black-capped chickadee		ring-necked duck
	alder flycatcher		horned grebe
	clay-colored sparrow		yellow rail
	yellow warbler		virginia rail
	american goldfinch		common merganser
	house wren		forster's tern
	european starling		dark-eyed junco
	brown-headed cowbird		chipping sparrow
	vesper sparrow		yellow-rumped warbler
	least flycatcher		common yellowthroat
	tree swallow		osprey
	warbling vireo		cedar waxwing
	eastern kingbird		red-breasted nuthatch
	wilson's phalarope		peregrine falcon
	blue-winged teal		red-eyed vireo
	solitary sandpiper		white-throated sparrow
	lesser scaup		short-eared owl
	franklin's gull		cooper's hawk
	common snipe		merlin
	western grebe		ferruginous hawk
	american wigeon		double-crested cormorant
	blue jay		veery
	bufflehead		american white pelican
	ruddy duck		ruffed grouse
	common goldeneye		purple martin
	red-necked grebe		mountain bluebird
	common raven		northern saw-whet owl
	pine siskin		wandering shrew
	yellow-bellied sapsucker		sharp-tailed grouse
	barn swallow		golden eagle
	swainson's hawk		boreal chickadee
	common redpoll		white-crowned sparrow
	yellow-headed blackbird		piping plover
	killdeer		barred owl
	grasshopper sparrow		rock dove
			eastern phoebe

3. Central Urbanized			
Taxa	Species	Taxa	Species
bird	western wood-pewee	fish	fathead minnow
	pileated woodpecker		brook stickleback
	pied-billed grebe		white sucker
	western meadowlark		lake chub
	common loon		walleye
	le conte's sparrow		shorthead redhorse
	hermit thrush		mountain whitefish
	rose-breasted grosbeak		longnose sucker
	ruby-crowned kinglet		goldeye
	willow flycatcher		brown trout
	northern pygmy-owl		mooneye
	swainson's thrush		northern pike
	gray catbird		longnose dace
	gray jay		goldfish
	spotted sandpiper		spoonhead sculpin
	northern shrike		burbot
	golden-crowned kinglet		sauger
	tennessee warbler		lake whitefish
	connecticut warbler		rainbow trout
	sandhill crane		lake sturgeon
	blue-headed vireo		trout-perch
	blackpoll warbler		yellow perch
	yellow-bellied flycatcher		emerald shiner
amphibian	boreal chorus frog		spottail shiner
	wood frog		quillback
	tiger salamander		iowa darter
	canadian toad		pearl dace
	northern leopard frog	forb	marsh felwort
	long-toed salamander		marsh gentian
	boreal toad		crowfoot violet
mammal	northern pocket gopher		golden saxifrage
	richardson's ground squirrel		macloskey's violet
	moose	sedge	umbellate sedge
	little brown bat	arthropod	crimson-ringed whiteface
	coyote		dot-tailed whiteface
	white-tailed deer		variegated meadowhawk
	badger		river jewelwing
	red squirrel		hobomok skipper
	white-tailed jack rabbit		alkali bluet
	mule deer	graminoid	marsh muhly
	porcupine	reptile	red-sided garter snake
	deer mouse	moss	bryum algovicum
	meadow vole		brachythecium rutabulum
	prairie vole	liverwort	liverwort
	least weasel		
	muskrat		
	franklin's ground squirrel		
	hoary bat		
	least chipmunk		
	beaver		
	snowshoe hare		
	red fox		
	wapiti		
	deer		
	black bear		

4. Central Agriculture

Taxa	Species	Taxa	Species	Taxa	Species
bird	gadwall	bird	eared grebe	bird	least flycatcher
	upland sandpiper		greater yellowlegs		sage thrasher
	swainson's hawk		least sandpiper		snow goose
	northern shoveler		lesser yellowlegs		sharp-shinned hawk
	green-winged teal		vesper sparrow		red-breasted nuthatch
	blue-winged teal		wilson's phalarope		red-eyed vireo
	killdeer		common snipe		baltimore oriole
	gray partridge		nelson's sharp-tailed sparrow		swainson's thrush
	american robin		clay-colored sparrow		gray catbird
	european starling		barn swallow		greater white-fronted goose
	black-billed magpie		hairy woodpecker		long-billed dowitcher
	american coot		short-billed dowitcher		western wood-pewee
	lesser scaup		northern flicker		forster's tern
	canada goose		merlin		black-billed cuckoo
	american wigeon		purple finch		bay-breasted warbler
	redhead		brown-headed cowbird		northern saw-whet owl
	canvasback		bald eagle		northern goshawk
	american crow		tree swallow		mountain bluebird
	mourning dove		common tern		ovenbird
	brewer's blackbird		horned grebe		white-throated sparrow
	rock dove		black-crowned night-heron		cliff swallow
	great blue heron		rusty blackbird		yellow-bellied sapsucker
	marbled godwit		marsh wren		mccown's longspur
	american avocet		yellow rail		pine siskin
	red-winged blackbird		bank swallow		spotted sandpiper
	ring-billed gull		sprague's pipit		spotted towhee
	sora		baird's sparrow		bohemian waxwing
	northern harrier		cape may warbler		say's phoebe
	bufflehead		tundra swan		brewer's sparrow
	cinnamon teal		loggerhead shrike		blackpoll warbler
	northern pintail		piping plover		le conte's sparrow
	black-necked stilt		yellow warbler		ruby-crowned kinglet
	common yellowthroat		downy woodpecker		ruffed grouse
	peregrine falcon		eastern phoebe		white-winged crossbill
	black tern		white-crowned sparrow		hudsonian godwit
	savannah sparrow		snow bunting		alder flycatcher
	horned lark		white-breasted nuthatch		tennessee warbler
	black-capped chickadee		trumpeter swan		red-necked phalarope
	song sparrow		sharp-tailed grouse		pileated woodpecker
	white-faced ibis		pied-billed grebe		dark-eyed junco
	willet		rough-legged hawk		wood duck
	american bittern		ring-necked duck		harris's sparrow
	great horned owl		hooded merganser		surf scoter
	common raven		yellow-rumped warbler		long-eared owl
	red-tailed hawk		brown thrasher		turkey vulture
	short-eared owl		chestnut-collared longspur		purple martin
	franklin's gull		solitary sandpiper		swamp sparrow
	ruddy duck		western grebe		wilson's warbler
	western kingbird		double-crested cormorant		lincoln's sparrow
	american goldfinch		american white pelican		house finch
	cedar waxwing		california gull		northern rough-winged swallow
	yellow-headed blackbird		cooper's hawk		virginia rail
	ferruginous hawk		house wren		greater scaup
	long-billed curlew		common redpoll		semipalmated plover
	eastern kingbird		common grackle		baird's sandpiper
	burrowing owl		northern shrike		lark sparrow
	house sparrow		warbling vireo		hermit thrush
	western meadowlark		golden eagle		snowy owl
	american kestrel		prairie falcon		blue jay
	ring-necked pheasant		orange-crowned warbler		veery
	american pipit		chipping sparrow		osprey
	black-bellied plover		lapland longspur		bonaparte's gull
	common goldeneye		american tree sparrow		sandhill crane

4. Central Agriculture

Taxa	Species	Taxa	Species	Taxa	Species
bird	barred owl	mammal	striped skunk	fish	lake chub
	northern waterthrush		snowshoe hare		longnose sucker
	varied thrush		red fox		brook stickleback
	red crossbill		thirteen-lined ground squirrel		fathead minnow
	philadelphia vireo		raccoon		rainbow trout
	golden-crowned kinglet		least chipmunk		trout-perch
	red-necked grebe		long-eared bat		pearl dace
	rose-breasted grosbeak		swift fox		goldeye
	red-breasted merganser		prairie shrew		sauger
	magnolia warbler		southern red-backed vole		walleye
	eastern bluebird		pronghorn		burbot
	mountain chickadee		water shrew		shorthead redhorse
	boreal chickadee		cougar		mountain whitefish
	gray jay		hoary bat		northern pike
	wild turkey		western small-footed bat		spottail shiner
	western tanager		red bat		emerald shiner
	canada warbler		silver-haired bat		quillback
	blue-headed vireo		wapiti		mooneye
	american redstart		franklin's ground squirrel		river shiner
	yellow-bellied flycatcher		black bear		lake whitefish
	ruby-throated hummingbird		northern long-eared bat		unknown
	red-breasted sapsucker		arctic shrew		goldfish
	white-throated swift	forb	blunt-leaved yellow cress		yellow perch
	common merganser		clammy hedge-hyssop		spoonhead sculpin
	pine grosbeak		powell's saltbush		brown trout
	white-winged scoter		low townsendia		lake sturgeon
	common loon		saltbush	lichen	sulphur lichens
	great crested flycatcher		spiked lobelia		alternating dog-lichen
	olive-sided flycatcher		low cinquefoil		peltigera horizontalis
	traill's flycatcher		lance-leaved loosestrife		sulphur-firedot lichen
	nashville warbler		waterpod		cobblestone lichen
	three-toed woodpecker		few-flowered aster		lichen
	herring gull		crowfoot violet		vagabond lichen
	caspian tern		salt-marsh sand spurry		cladonia lichen
	sedge wren		widgeon-grass		disk lichen
	black-and-white warbler		marsh gentian		rock-shield lichen
	willow flycatcher		smooth sweet cicely		rim-lichen
mammal	muskrat		marsh felwort		sand-loving iceland lichen
	meadow vole	amphibian	boreal chorus frog		rock-posy lichen
	deer mouse		northern leopard frog		comma lichen
	richardson's ground squirrel		canadian toad		dot lichen
	least weasel		tiger salamander		shadow lichen
	northern grasshopper mouse		great plains toad	liverwort	liverwort
	coyote		wood frog	graminoid	prairie cord grass
	badger	reptile	plains garter snake		prairie wedge grass
	long-tailed weasel		wandering garter snake		canada brome
	moose		bull snake	moss	long-stalked beardless moss
	sagebrush vole		prairie rattlesnake		cuspidate earth moss
	white-tailed jack rabbit		red-sided garter snake		bryum marratii
	white-tailed deer	arthropod	variegated meadowhawk		desmatodon randii
	pygmy shrew		woodland skipper		fallacious screw moss
	mule deer		shasta blue		pterygoneurum subsessile
	masked shrew		acadian hairstreak	sedge	lakeshore sedge
	ermine		lorquin's admiral		
	red squirrel		silver-spotted skipper		
	beaver		dod's old world swallowtail		
	prairie vole		dun skipper		
	house mouse		hobomok skipper		
	porcupine		common green darner		
	big brown bat	fish	longnose dace		
	little brown bat		flathead chub		
	northern pocket gopher		white sucker		
	nuttall's cottontail		prussian carp		

5. Dry Grasslands

Taxa	Species	Taxa	Species	Taxa	Species
bird	willet	bird	ring-necked pheasant	bird	black-bellied plover
	western meadowlark		rough-legged hawk		goldeye
	horned lark		northern shrike		hooded merganser
	ring-billed gull		cliff swallow		warbling vireo
	northern harrier		mccown's longspur		baltimore oriole
	short-eared owl		eastern kingbird		downy woodpecker
	sprague's pipit		franklin's gull		northern goshawk
	swainson's hawk		gray partridge		turkey vulture
	western kingbird		bank swallow		brewer's sparrow
	green-winged teal		snow goose		house sparrow
	blue-winged teal		lesser yellowlegs		eastern phoebe
	bufflehead		rock dove		alder flycatcher
	gadwall		mourning dove		dark-eyed junco
	canvasback		plains spadefoot		spotted towhee
	sharp-tailed grouse		american robin		cedar waxwing
	common snipe		loggerhead shrike		common poorwill
	burrowing owl		le conte's sparrow		red-headed woodpecker
	clay-colored sparrow		nelson's sharp-tailed sparrow		black-billed cuckoo
	long-billed curlew		black-crowned night-heron		rock wren
	grasshopper sparrow		common merganser		gray catbird
	savannah sparrow		great horned owl		mountain bluebird
	herring gull		virginia rail		passerine birds
	upland sandpiper		cape may warbler		trumpeter swan
	canada goose		pied-billed grebe		olive-sided flycatcher
	brown-headed cowbird		bonaparte's gull		orange-crowned warbler
	marbled godwit		red-breasted merganser		blackpoll warbler
	common raven		song sparrow		yellow-bellied sapsucker
	vesper sparrow		harlequin duck		lincoln's sparrow
	common yellowthroat		red-necked grebe		ruby-crowned kinglet
	red-winged blackbird		bobolink		ovenbird
	killdeer		yellow rail		wilson's warbler
	yellow-headed blackbird		forster's tern		white-throated sparrow
	redhead		red-eyed vireo		western wood-pewee
	northern shoveler		northern flicker		yellow-bellied flycatcher
	wilson's phalarope		american bittern		macgillivray's warbler
	american crow		rusty blackbird		pine siskin
	baird's sparrow		piping plover		willow flycatcher
	red-tailed hawk		american goldfinch		black-and-white warbler
	ferruginous hawk		snow bunting		tennessee warbler
	american wigeon		tundra swan		connecticut warbler
	black-necked stilt		greater white-fronted goose		red-naped sapsucker
	northern pintail		snowy owl		black-capped chickadee
	spotted sandpiper		lark bunting		american redstart
	american avocet		merlin		veery
	cinnamon teal		golden eagle		pectoral sandpiper
	american coot		greater yellowlegs		cooper's hawk
	eared grebe		long-billed dowitcher		common loon
	black tern		prairie falcon		sandhill crane
	barn swallow		lapland longspur		short-billed dowitcher
	brewer's blackbird		great gray owl		least sandpiper
	ring-necked duck		yellow warbler		red-necked phalarope
	common goldeneye		european starling		semipalmated sandpiper
	lesser scaup		house wren		american tree sparrow
	chestnut-collared longspur		lark sparrow		common redpoll
	common grackle		sharp-shinned hawk		baird's sandpiper
	marsh wren		western grebe		solitary sandpiper
	common tern		horned grebe		pileated woodpecker
	double-crested cormorant		chipping sparrow		greater sage grouse
	sora		greater scaup		bay-breasted warbler
	california gull		swainson's thrush		palm warbler
	ruddy duck		great crested flycatcher		lazuli bunting
	great blue heron		brown thrasher		wild turkey
	sanderling		common nighthawk		gray jay
	black-billed magpie		yellow-rumped warbler		broad-winged hawk
	tree swallow		northern rough-winged swallow		northern saw-whet owl
	american white pelican		least flycatcher		cordilleran flycatcher
	white-crowned sparrow		bald eagle		sage thrasher
	american kestrel		say's phoebe		peregrine falcon

5. Dry Grasslands

Taxa	Species	Taxa	Species	Taxa	Species
bird	bohemian waxwing	amphibian	boreal chorus frog	forb	tiny cryptanthe
	wood duck		northern leopard frog		sand verbena
	townsend's solitaire		canadian toad		smooth sweet cicely
	gyrfalcon		tiger salamander		shrubby evening-primrose
	osprey		wood frog		kelsey's cat's eye
	golden-crowned kinglet		great plains toad		bur ragweed
	yellow-breasted chat	fish	rainbow trout		goosefoot
	black swift		yellow perch		watson's goosefoot
	brown creeper		walleye		annual skeletonweed
	white-winged scoter		white sucker		chaffweed
	american black duck		burbot		prickly milk vetch
	long-tailed duck		northern pike		few-flowered aster
	western painted turtle		longnose sucker		pale blue-eyed grass
	western sandpiper		lake whitefish		short-stalk mouse-ear chickweed
	brambling		spottail shiner		early buttercup
mammal	coyote		lake chub		crowfoot violet
	white-tailed jack rabbit		brook stickleback		waterpod
	richardson's ground squirrel		flathead chub		taraxia
	pronghorn		fathead minnow		lance-leaved loosestrife
	badger		longnose dace		alkali bluet
	white-tailed deer		sauger		spatulate-leaved heliotrope
	long-tailed weasel		shorthead redhorse		low cinquefoil
	prairie shrew		goldeye	graminoid	alkali muhly
	sagebrush vole		quillback		little-seed rice grass
	meadow vole		silver redhorse		marsh muhly
	muskrat		mooneye		prairie wedgegrass
	northern grasshopper mouse		river shiner	arthropod	brimstone clubtail
	mule deer		prussian carp		acadian hairstreak
	nuttall's cottontail		emerald shiner		sagebrush sheepmoth
	northern pocket gopher		trout-perch		ruddy copper
	wapiti		tullibee (cisco)		delaware skipper
	deer mouse		lake sturgeon		woodland skipper
	red fox		mountain whitefish		salt creek tiger beetle
	striped skunk		finescale dace		verna flower moth
	gray wolf		pearl dace		acastus checkerspot
	house mouse		goldfish		dusky dune moth
	olive-backed pocket mouse	reptile	plains garter snake		gold-edged gem
	prairie vole		prairie rattlesnake		beautiful tiger beetle
	ord's kangaroo rat		bull snake		shasta blue
	porcupine		red-sided garter snake	lichen	mountain scale
	western harvest mouse		wandering garter snake		lichen
	western small-footed bat		western hog-nosed snake		brown-eyed scale
	long-eared bat		rubber boa		button lichen
	bobcat	forb	saltmarsh sandspurry		rock pimples
	beaver		hairy pepperwort		grain-spored lichen
	moose		devil's beggarticks		common beggarticks
	big brown bat		short-stalked chickweed	liverwort	liverwort
	little brown bat		sandhills cinquefoil	moss	jaffueliobryum raui
	hoary bat		american bugleweed		aloe-like rigid screw moss
	thirteen-lined ground squirrel		poison suckleya		green-cushioned weissia
	raccoon		dwarf woollyheads		pterygoneurum subsessile
	franklin's ground squirrel		hairy water fern		hairy-leaved beardless moss
	cougar		low yellow evening-primrose		bryum amblyodon
	least chipmunk		slender mouse-ear-cress		bryum algovicum
	pygmy shrew		saltbush	sedge	awned cyperus
	swift fox		nodding umbrella-plant		
	least weasel		narrowleaf umbrella-wort		
	ermine		pennsylvania pellitory		
	river otter		powell's saltbush		
	deer		common beggarticks		
	masked shrew		clammyweed		
	dusky shrew		mouse-ear cress		
	southern red-backed vole		field toad-flax		
	arctic shrew		smooth narrow-leaved goosefoot		

APPENDIX B: Lake Unit Species List.

The following tables summarize the species reported in the Alberta provincial ACIMS and FWMIS species observation databases. Federally and provincially designated species at risk are highlighted in orange. These lists represent only a compilation of recorded observations, and are not exhaustive. The absence of a species record does not guarantee the absence of the species.

1. Sullivan Lake

Taxa	Species
bird	trumpeter swan
	burrowing owl
	loggerhead shrike

2. Sylvan Lake

Taxa	Species
fish	walleye
	lake whitefish
	northern pike
	white sucker
	burbot
	yellow perch
	emerald shiner
amphibian	boreal chorus frog
bird	wandering shrew

3. Buffalo Lake			
Taxa	Species	Taxa	Species
bird	sora	bird	northern flicker
	vesper sparrow		canvasback
	least flycatcher		bank swallow
	clay-colored sparrow		northern pintail
	savannah sparrow		canada goose
	common snipe		chipping sparrow
	le conte's sparrow		northern harrier
	yellow warbler		western grebe
	blue-winged teal		purple martin
	american robin		common loon
	nelson's sharp-tailed sparrow		black-billed magpie
	red-winged blackbird		common goldeneye
	warbling vireo		bufflehead
	ruddy duck		hooded merganser
	black tern		pileated woodpecker
	lesser scaup		barn swallow
	gray catbird		common tern
	great blue heron		rose-breasted grosbeak
	red-tailed hawk		downy woodpecker
	song sparrow		ruffed grouse
	cedar waxwing		double-crested cormorant
	redhead		eared grebe
	american bittern		cinnamon teal
	hermit thrush		pied-billed grebe
	common yellowthroat		hairy woodpecker
	tennessee warbler		house sparrow
	american coot		eastern phoebe
	brown-headed cowbird		white-faced ibis
	eastern kingbird		american redstart
	wilson's phalarope		willet
	ruby-throated hummingbird		yellow-rumped warbler
	green-winged teal		pine siskin
	house wren		western meadowlark
	forster's tern		wood duck
	american goldfinch		sandhill crane
	marsh wren		great horned owl
	northern shoveler		american avocet
	alder flycatcher		marbled godwit
	gadwall		great crested flycatcher
	brewer's blackbird		purple finch
	american crow		dark-eyed junco
	red-eyed vireo		philadelphia vireo
	tree swallow		olive-sided flycatcher
	ring-necked duck		sprague's pipit
	american white pelican		black-necked stilt
	baltimore oriole		piping plover
	european starling		herring gull
	yellow-headed blackbird		yellow-bellied sapsucker
	california gull		cliff swallow
	franklin's gull		mourning dove
	lesser yellowlegs		western wood-pewee
	american wigeon	forb	few-flowered aster
	common raven		widgeon-grass
	killdeer	fish	spottail shiner
	white-winged scoter		northern pike
	common grackle		white sucker
	ring-billed gull		burbot
	black-crowned night-heron		fathead minnow
	red-necked grebe		brook stickleback
	white-throated sparrow	amphibian	northern leopard frog
	spotted sandpiper		canadian toad
	black-capped chickadee		

4. Gull Lake	
Taxa	Species
fish	spottail shiner
	emerald shiner
	white sucker
	lake whitefish
	yellow perch
	northern pike
	walleye
	iowa darter
	burbot
bird	western grebe
	piping plover
	american coot
	red-winged blackbird
	yellow-headed blackbird
	sora
	canvasback
	red-necked grebe

APPENDIX C: Reach Unit Species List.

The following tables summarize the species reported in the Alberta provincial ACIMS and FWMIS species observation databases. Federally and provincially designated species at risk are highlighted in orange. These lists represent only a compilation of recorded observations, and are not exhaustive. The absence of a species record does not guarantee the absence of the species.

Reach 1 - Headwaters to Hwy 22

Taxa	Species
fish	mountain whitefish
	brook trout
	bull trout
	cutthroat trout
	rainbow trout
	mountain sucker
	white sucker
	longnose sucker
	longnose dace
	burbot
lichen	jellyskin
	brown pepper-spore lichen
	jelly flakes
sedge	seaside sedge

Reach 2 - Hwy 22 to upstream of Glennifer Lake

Taxa	Species
fish	mountain whitefish
	longnose dace
	longnose sucker
	mountain sucker
	bull trout
	white sucker
	brown trout
	brook trout
	burbot
	spoonhead sculpin
	brook stickleback
bird	barred owl
	northern pygmy-owl
	spotted sandpiper
	house sparrow
mammal	moose
	deer
	wapiti
	coyote

Reach 3 - Glennifer Lake to Hwy 2	
Taxa	Species
bird	blue-winged teal
	gadwall
	american coot
	ruddy duck
	red-necked grebe
	redhead
	american wigeon
	bufflehead
	canada goose
	northern pintail
	common goldeneye
	great blue heron
	cinnamon teal
	american white pelican
	common merganser
	spotted sandpiper
	double-crested cormorant
	green-winged teal
	common loon
	sandhill crane
	northern shoveler
	franklin's gull
	canvasback
	american avocet
	marbled godwit
amphibian	boreal toad
	canadian toad
fish	mountain whitefish
	walleye
	white sucker
	longnose sucker
	brown trout
	northern pike
	rainbow trout
	mountain sucker
	burbot
	lake whitefish
	goldeye
	shorthead redhorse
	brook stickleback
	longnose dace
	mooneye
	trout-perch
	spottail shiner
	spoonhead sculpin
	yellow perch
reptile	red-sided garter snake

Reach 4 - Hwy 2 to Nevis	
Taxa	Species
bird	peregrine falcon
	prairie falcon
	canada goose
	common snipe
	golden eagle
	common goldeneye
	franklin's gull
	bald eagle
	blue-winged teal
	lesser yellowlegs
	common merganser
	osprey
	bank swallow
fish	walleye
	burbot
	longnose sucker
	white sucker
	brown trout
	goldeye
	lake sturgeon
	longnose dace
	shorthead redhorse
	mountain whitefish
	mooneye
	sauger
	northern pike
	emerald shiner
	quillback
	lake whitefish
	rainbow trout
	spoonhead sculpin
	lake chub
	trout-perch
	spottail shiner
reptile	red-sided garter snake

Reach 5 - Nevis to Morrin

Taxa	Species
mammal	mule deer
fish	goldeye
	mooneye
	white sucker
	sauger
	shorthead redhorse
	walleye
	northern pike
	emerald shiner
	quillback
	longnose dace
	flathead chub
	longnose sucker
	burbot
	river shiner
	lake chub
	mountain whitefish
	lake whitefish
	spoonhead sculpin
bird	peregrine falcon
	great horned owl
	red-tailed hawk
	bald eagle

Reach 6 - Morrin to Bindloss

Taxa	Species
mammal	mule deer
	white-tailed deer
	western small-footed bat
	sagebrush vole
	northern grasshopper mouse
	nuttall's cottontail
	moose
	cougar
	white-tailed jack rabbit
	coyote
	pronghorn
fish	sauger
	shorthead redhorse
	goldeye
	northern pike
	white sucker
	longnose sucker
	quillback
	silver redhorse
	mooneye
	river shiner
	burbot
	flathead chub
	walleye
	emerald shiner
	lake chub
	spottail shiner
	brook stickleback
	longnose dace
	prussian carp
	lake sturgeon
	finescale dace
	mountain whitefish
	trout-perch
	lake whitefish
arthropod	ruddy copper
	delaware skipper
bird	gray partridge
	great blue heron
	american redstart
	black-capped chickadee
	loggerhead shrike
	sharp-tailed grouse
	western meadowlark
	savannah sparrow
amphibian	northern leopard frog
	canadian toad
	great plains toad
reptile	bull snake
	prairie rattlesnake