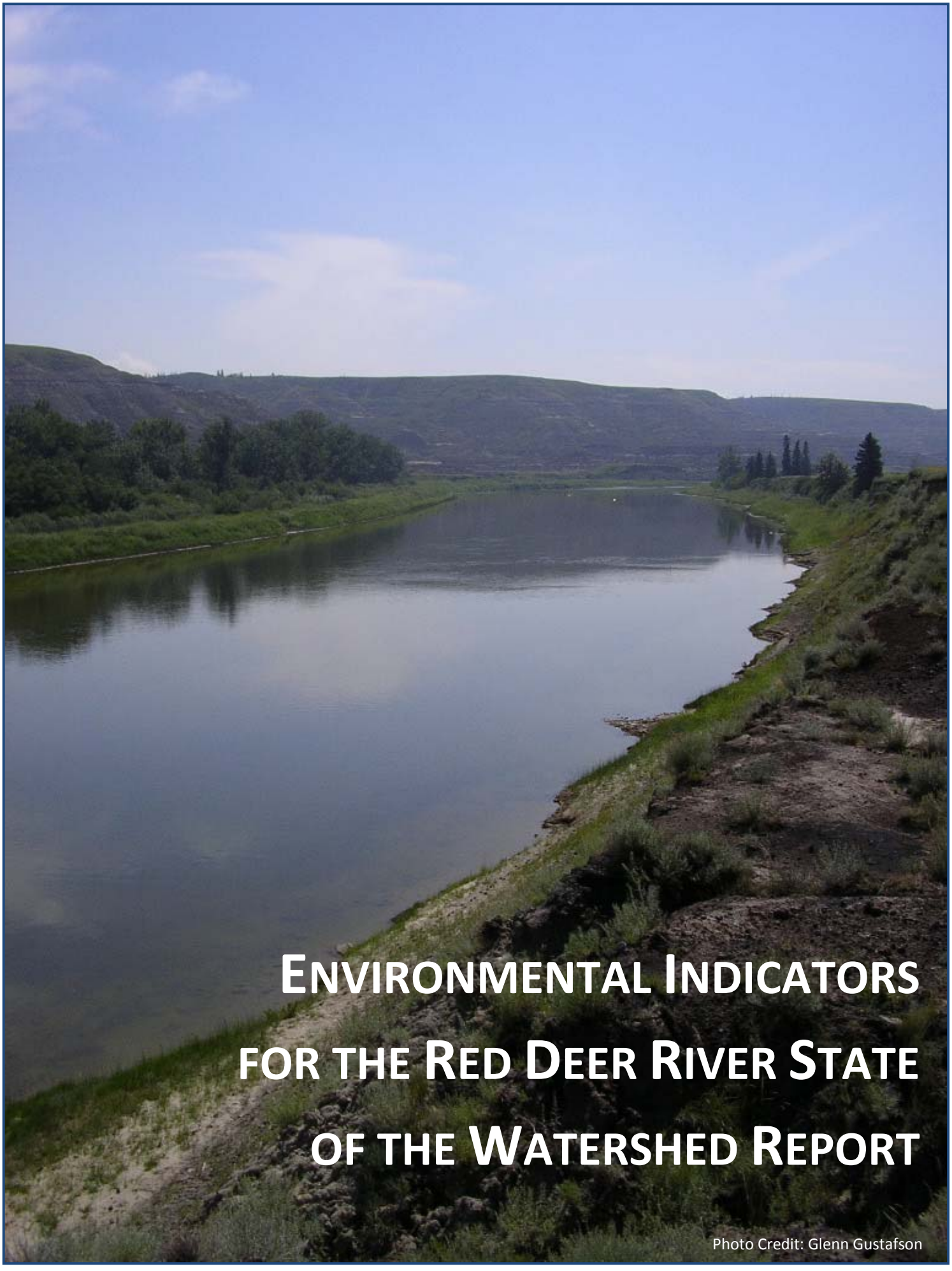

Environmental Indicators for the Red Deer River State of the Watershed Report

Photo Credit: Glenn Gustafson

Environmental Indicators for the Red Deer River State of the Watershed Report

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1.0 Introduction

The Red Deer River Watershed Alliance (RDRWA) is currently completing a State of the Watershed report for the Red Deer River from the headwaters to the Saskatchewan border. Before baseline data collection commences, the RDRWA has identified a suite of biological, chemical and physical indicators to focus data collection efforts. The indicators and their metrics will be used in the future to assess the cumulative impacts of land use on water quality, quantity and biodiversity within the watershed.

The use of indicators and their metrics has become a useful regulatory tool, and much data exists on the use of indicators; however, indicators may be region-specific, system-specific or seasonal. For example, stream-based metrics are not suitable for detection of habitat degradation in wetlands, and sampling dates should be arranged into seasonal groupings. Some measures are meaningless unless or until presented in a time series – is the situation improving or deteriorating with time?

Due to the large size of the Red Deer River watershed, the challenge will be to find relevant indicators that occur along the entire length of the watershed, or to choose those indicators that have a significant impact on some portion of the watershed (e.g., *E. coli* concentrations in areas of higher human or livestock populations). Where possible, measures are presented on a sub basin scale to assist in future land management decisions.

It is important to realize that any group of indicators can be used. It all depends on the desired outcome and why the indicators are being selected. Our selection of indicators is

premised on the expectation that they will be useful in the next stage of the project – an integrated watershed management plan – and because they will indicate issues to be addressed within the watershed. Water quality, quantity and riparian health are measures which can be affected by land use changes or changes in management practices.

1.1 What are indicators?

Indicators are measures of environmental quality that are used to assess the status and trends of the physical condition of the watershed. Their purpose is to show how well a system is functioning. If there is a concern, an indicator can help determine what direction to take to address the issue. To be effective, an indicator must be:

- Relevant, able to show you something about the system that you need to know.
- Easy to understand, even by people who aren't experts.
- Reliable, so the information the indicator provides is trustworthy.
- Timely, so the information is available while there is still time to act.

In addition, a good environmental indicator will simplify large amounts of complex information into a concise, easily understood format such as the Alberta Surface Water Quality Index (Alberta Environmental Protection, 1996).

1.2 RDRWA indicator selection process

On March 05, 2008, an Indicator Workshop was held in Red Deer, AB. Attendees included representatives from the RDRWA, Alberta Environment, Ducks Unlimited Canada, Alberta Sustainable Resource Development, Alberta Agriculture, Food and Rural Development, Prairie Farm Rehabilitation Administration, David Thompson Health Region, the City of Red Deer, Sundre Forest Products and the University of Lethbridge. Presentations on the following topics were made to help the RDRWA and its stakeholders to understand and select the indicators that are important to their watershed:

- water quality
- wetlands
- riparian areas and fish
- natural flow study of the Red Deer River.

After group consideration and a ranking exercise by workshop attendees, a list of indicators was chosen and ranked on priority, based on both the group consideration and by the professional experience and judgment of those involved. There are a total of 20 indicators, which are presented below.

2.0 Indicator Details

2.1 Land Use Indicators

Changes in land use patterns reflect major development trends, such as forested lands converted to agriculture and agricultural lands developed and lost to urban sprawl. Land use changes and the subsequent changes in management practices impact both the quantity and quality of water within the Red Deer River watershed. The following land use indicators and metrics have been selected (see Table 1 for a summary of land use indicators and metrics).

A. Wetland Inventory

Wetlands serve many functions in the natural landscape including water storage, flood attenuation, wildlife habitat, groundwater recharge and general water quality improvements (e.g., nutrient uptake, degradation of pesticides, and retention of sediments). Additionally, wetlands provide a cost effective and sustainable alternative to engineered treatment options. The loss of wetlands to development and/or agriculture can be deleterious to both water quantity and quality.

Wetland inventories are completed by aerial examination and enumeration of wetlands

across an area. This provides a benchmark for comparison for future inventories to monitor the percentage lost, restored or maintained. Comparisons can also be made to historical inventories to determine critical areas in need of restoration, and areas in need of protection and conservation. A percentage of loss can be determined as well. Wetland inventories are currently being completed across the province by Alberta Environment.

Performance measures can include no net loss of wetlands (i.e. no change in current number of wetlands from the benchmark set at the time of assessment), increases in net wetland area, increases in the number of sites under protection, restoration of critical wetland areas and increases in numbers of waterfowl.

B. Riparian Health

Riparian areas are an important transition zone between uplands and water. They act as buffer zones, protecting water quality and attenuating floods. Contaminants are adsorbed onto sediments, assimilated by vegetation and transformed by soil microbes into less harmful forms (Klapproth and Johnson, 2000). They have long been proven effective in reducing nutrients, sediments and other anthropogenic pollutants that enter surface waters via overland and subsurface flow (Klapproth and Johnson, 2000; Lee and Smyth, 2003; Mayer et al., 2006). While this indicator does not examine water quality specifically, certain suppositions can be drawn regarding the potential impacts to the receiving waterbody once the health and functionality of the riparian area has been assessed.

Riparian health can be determined using techniques such as aerial videography and on-the-ground assessments. Aerial videography involves a fly-over of a water body and the entire shoreline is recorded using a video camera. GPS points are taken at regular intervals. A specialist who is trained in interpretation of these videos can then assign a score to sections of the shoreline, and an overall score to the entire water body. This score is based on parameters such as current riparian vegetation cover, land use, riparian area width or absence, and many others. Riparian health assessments have been completed on many major water bodies within the province, such as Moose Lake and Lac la Biche by the Alberta Conservation Association.

On-the-ground assessments are completed by trained professionals from the Alberta Riparian Management Association (Cows and Fish). The entire shoreline of a water body is assessed on foot at certain predetermined intervals. A score of health is assigned based on presence or absence of invasive species, percent cover, presence or absence of bare ground and compaction, and many other parameters. These assessments are time consuming and can only be accurately completed by individuals trained in the Cows and Fish method. Riparian assessments have been completed on a by-request basis across the province.

Performance measures for riparian areas include increases or maintenance of current riparian health scores, increases in restored riparian areas, improvements in water quality and fish numbers, and preservation of riparian buffers.

C. Livestock and Grazing Leases

A component of the agricultural sector's indicators will be the category of livestock

density. Areas of higher livestock density within a sub-watershed are expected to have greater impacts on downstream water quality. Results from an Alberta Environment study have shown that streams that drain land with high intensity livestock operations have higher nutrient concentrations, dissolved nutrients, mass loads, fecal bacteria and exports of total dissolved phosphorus than streams with medium or low intensity livestock operations (Anderson et al., 1998). This indicator will help identify areas in need of manure best management practices (BMP's). For the purposes of the State of the Watershed report, 'grazing leases' will be a measure of livestock density within the green zone, whereas 'livestock' will be a measure of livestock density from within the white zone.

Livestock and grazing lease density is typically measured using the Agricultural Census data from Statistics Canada. This data can then be mapped to show areas of high to low livestock density. This can be cross-referenced with wetland and riparian data to identify surface water and groundwater areas at risk of contamination due to livestock fecal input. Water quality data can also be used to show areas of high nutrient loading and fecal bacteria counts.

Performance measures include improvements in water quality parameters (particularly nutrients, fecal bacteria and solids), decreases in livestock numbers in areas sensitive to surface or groundwater contamination, and increases and improvements in manure best management practices.

D. Urban, Rural and Recreational Development

Urban sprawl, rural and recreational development is the expansion of urban areas, rural subdivisions and recreational areas into surrounding landscape. The measurement of this indicator determines the area of watershed lost to development. This expansion can have many negative effects on the environment. These effects can include (but are not limited to) the loss of wetlands, riparian areas, intermittent streams, and wildlife habitat, as well as increased surface runoff (stormwater) into neighbouring creeks, rivers and lakes. Stormwater is generally higher in nutrients, bacteria, salts than surface waters and can also contain hydrocarbons and pesticides, all of which can be harmful to aquatic life.

The current developed area is determined using aerial photographs and satellite imagery. This information can be compared to historical photos to determine increases or decreases in developed area. This data can also be correlated with the wetland and riparian data, which will give an indication of the amounts of wetland and riparian area lost over a certain time period due to development. Increases in the amount of impermeable (paved) surfaces can also be measured and estimations of storm water volumes into local waterbodies can be determined.

Performance measures can include improvements in water quality (particularly in total solids, nutrients, bacteria, pesticides and hydrocarbons), decreases or maintenance of current amounts of impermeable areas, increases in usage of low impact development techniques (such as green roofs, permeable pavement, swales etc.), increases in urban densities vs. sprawl (building "up" instead of "out"), and decreases in the amount of rural acreage homes.

E. Linear Development

In Alberta, landscape disturbances from linear development can be very high. Linear developments include seismic activity, pipelines, roads, railways and utility right of ways. Quantifying linear development will help us understand potential changes in water quality and fish and wildlife populations. For example, wildlife corridors can be interrupted by roads, and watersheds can have their drainage patterns permanently altered by increases in impervious or compacted surfaces.

Linear disturbances are mapped using aerial photos and satellite imagery. Comparisons can be made to historical data to estimate the increase in disturbed areas, and current levels will serve as a benchmark for future comparison.

Performance measures can include a maintenance or decrease in the amount of linearly disturbed areas, preservation of wildlife corridors, preservation or restoration of natural drainage patterns and improvements in water quality, particularly nutrient loads and solids.

F. Oil and Gas Activity

Oil and gas activity is very common throughout the province of Alberta. With oil and gas development there can be a number of associated impacts, including loss of wetlands, habitat fragmentation and surface water and groundwater contamination. This Indicator will show areas with high drilling density and help to identify areas at high risk of groundwater and surface water contamination from hydrocarbons or salinity. This indicator includes an inventory of coalbed methane activity within the watershed.

Current oil and gas density is determined using aerial photos, drilling logs, satellite imagery and data from the Energy and Utilities Board (EUB). This data can be correlated with proximity to wetland, riparian and shallow groundwater areas to determine areas at high risk of contamination due to hydrocarbons and salinity.

Performance measures can include sensitive areas protected from drilling, maintenance in the amount of current wells in an area (i.e. no new wells from benchmark date), improvements in water quality data, increases in the monitoring programs implemented in drilling areas, increases in the amounts of certified reclaimed sites, and improvements in drilling and drilling waste management practices.

2.2 Water Quality

Changes in water quality indicate either a deterioration or improvement in the condition of the watershed and demonstrate specific areas that require further attention or protection. Changes in water quality are

brought about by changes in land use or land management practices, landscape disturbance, and natural events. The major anthropogenic impacts on water quality result from logging, mining (including oil and gas), wetland drainage, dredging, dam construction, agricultural runoff, industrial wastes, municipal wastes, land erosion, road construction and land development. The following water quality indicators and metrics have been selected (see Table 2 for a summary).

A. Nutrient Levels

Nitrogen and phosphorus are essential nutrients to most aquatic plants; in Alberta, phosphorus is typically the limiting agent in aquatic systems. Excess nutrients can lead to eutrophication. Eutrophication is an excessive amount of aquatic plant (macrophyte) and phytoplankton growth resulting from the presence of excess nutrients, which can lead to decreased oxygen levels within the water column, potentially leading to suffocation of fish and other aquatic organisms (Brönmark and Hansson, 2005). In addition, excessive phytoplankton growth (a bloom), particularly of cyanobacteria, can lead to the release of toxins into the water column. These toxins can be harmful to aquatic organisms, waterfowl, livestock and humans alike. Environmental quality guidelines exist for nitrogen and phosphorus to protect aquatic life, recreation and livestock drinking water (CCME, 1999). Changes in nutrient concentrations in aquatic systems can be linked to changes in land use, and can come from point and non-point sources within the landscape.

B. Bacteria

Coliforms are a broad class of bacteria found in human and animal wastes. Total coliforms include *Escherichia coli*, fecal bacteria and other coliforms that occur naturally in warm blooded animals. *E. coli* and other fecal bacteria are capable of causing human illness if ingested. *E. coli* is one of three bacteria commonly used to measure the direct contamination of water by human or other mammal wastes. Environmental quality guidelines exist for *E. coli* for drinking water, agricultural (irrigation) and recreational water. Due to the short survival time of these organisms outside of animals, the impacts of these coliforms can be short-lived or episodic following larger precipitation events. Sources of this type of bacteria include agricultural and municipal runoff, wildlife, faulty septic systems and septic fields.

C. Parasites

Waters that are polluted may contain several different disease-causing organisms, commonly called pathogens. Enteric pathogens, those that live in the intestine of warm blooded animals, can carry or cause a number of infectious diseases. *Cryptosporidium* and *Giardia* species are two such pathogens. *Cryptosporidium* and *Giardia* are aquatic parasites found in almost all environments including lakes, rivers, reservoirs and groundwater. They come from the feces of rodents, birds, cows, pigs and humans. They are a highly infectious parasite responsible for gastrointestinal conditions known as cryptosporidiosis and giardiasis.

Table 1. Summary of land use indicators and metrics for the Red Deer River watershed.

Land Use Indicator	Metric(s)	What Indicator Means	Performance Measures
Wetland Inventory	- Area (ha) of intact natural wetlands - Area (ha) of reclaimed/restored wetlands - Area(ha) of drained wetlands	Provides an idea of wetlands lost and wetlands remaining. May indicate critical areas in need of restoration.	Preservation of current wetland cover, restoration of critical drained areas
Riparian Health	- Aerial Videography - Cows and Fish Riparian Health Assessment	Areas with impacted riparian health can experience poorer water quality due to the loss of filtering and protection from the riparian vegetation. Will show areas in need of restoration or preservation.	Improvement in riparian health, restoration of degraded areas
Livestock and Grazing Leases (White and Green Zones)	- No. head per hectare - Manure production (tonnes)	Will indicate extent of livestock production in the watershed (white and green zones) and amount of manure present, may indicate need for manure management BMPs.	Decrease or maintenance of current livestock counts and manure production, manure best management practices
Urban, Rural and Recreational Development	- Urban versus rural population - % or hectares of watershed/sub-watershed developed as urban area, rural subdivision or for recreational purposes	Indicates area of watershed lost to development and increase in impermeable area	Increases in high density developments, decrease in land lost to urban and rural developments, limits to recreational activities in ecologically sensitive areas
Linear Development/ Habitat Fragmentation	- No. of road crossings in given area - % of watershed that has linear development (i.e. % covered by roads, pipelines, cut lines, etc.)	Indicates amount of land lost to linear disturbance and subsequent disruption and fragmentation of wildlife habitat and corridors	Maintenance or decrease of current amount of linear disturbance

Oil and Gas Activity	- # of wells (active, decommissioned and abandoned) per given area. Includes natural gas, oil and coalbed methane - Carbon, hydrogen and nitrogen isotope fingerprinting.	Identifies risks to groundwater and surface water from hydrocarbons or salinity, will show areas of high drilling density. Will help identify areas needing protection/restrictions/monitoring.	Maintenance or decrease in the number of oil wells, increased numbers of certified reclaimed oil wells

D. Pesticides

Pesticides are a group of chemicals, including herbicides, insecticides, rodenticides and fungicides, used for many purposes, including pest control and aesthetics in urban areas, golf courses and in forestry and agricultural production. Pesticides are a common contaminant of streams and dugouts in the high intensity agricultural areas of Alberta (Anderson et al., 1998). Herbicides were detected in 54 of 112 dugouts (48%) sampled in 1994 and in 10 of 14 dugouts (71%) sampled in 1996 during the CAESA program (Anderson et al., 1998).

E. Point Source Inputs

Point source inputs include effluents from waste water treatment plants (WWTP), stormwater outfalls and industry. Effluent from WWTP's, although regulated, generally has higher concentrations of certain compounds (e.g., nutrients, solids, pharmaceuticals, metals, etc.) than the receiving environment. For example, a study of ten WWTP's in the United States found that concentrations of the majority of the variables tested were either below detection or at trace levels in the upstream samples, while the same variables were found at their maximum allowable concentrations in the wastewater effluent samples (USGS, 2008). Like municipal wastewater effluents, stormwater outfalls contain elevated levels of nutrients, salts and solids compared to the receiving environment (Gray et al., 2008). Industrial effluents can also contribute elevated levels of different contaminants, such as metals, solids, hydrocarbons and/or salts, as well as other chemicals used in processing or manufacturing.

Photo Credit: Bill Shaw

Benchmark water quality is determined using existing water quality data provided from government agencies (federal and provincial), private citizens, health authorities and watershed groups. This is compiled using field survey measures, including long term monitoring stations and annual water sample collection. These samples are then analyzed by certified environmental laboratories. This data is summarized and trends can be determined by graphing certain parameters of interest. This can indicate what parameters are of particular concern and are in need of long term monitoring. These parameters can also be linked to certain land use practices, which will show where outreach and education is needed in order to improve current conditions and prevent further degradation.

Performance measures can include improvements in water quality parameters (e.g. 25% improvement in nutrient levels from 2008 benchmark concentrations), decrease in the incidents of pesticide detections, lower fecal bacteria and parasite levels, decreases in the number of harmful algal blooms, decreases in boil water advisories, decreases in winter fish kills, and many others.

Table 2. Summary of water quality indicators and metrics for the Red Deer River watershed.

Indicator	Metric(s)	What Indicator Means	Performance Measures
Nutrient Values	- Concentrations of total phosphorus (TP), total dissolved phosphorus (TDP), total nitrogen (TN), nitrate-nitrite (NO_2-NO_3), ammonia ($NH_{3)}$	Can indicate contamination from fertilizer, manure, sewage, etc. Indicates trophic status and risk of eutrophication.	Improvements in water quality parameters (benchmarks can be set either using CCME guideline values or arbitrary values), less winter fish kills
Bacteria	-Total coliforms -*E. coli* -Cyanobacteria (lakes only)	Indicates fecal contamination, either by livestock or humans. Cyanobacteria have human health risk potential as well.	Lower fecal/coliform counts, decreases in the number of algal blooms, decreases in the number of boil water advisories
Parasites	-*Giardia spp.* -*Cryptosporidium* spp.	Parasites indicate fecal contamination and potential risks to human health. Will identify areas needing improved water treatment, water use limitations and investigation into sources of contamination.	Decreases in parasite counts
Pesticides	Frequency of pesticide(s) detections in water body(s)	Will show areas of high pesticides use that may require a change in management practices, and may indicate areas requiring special attention to water treatment.	Lower numbers of detections, lowered concentrations
Point Source Inputs	-Volume, timing and quality of water released (temperature, pH, biological oxygen demand (BOD), conductivity) -Nutrient loading rates	Indicates effects of WWTP, industrial and stormwater effluent release on receiving water bodies; will help identify total maximum daily loads (TMDLs) if required and if improvements in treatment efficacy is needed.	Improvements in treatment processes, decreases in nutrient levels and release volumes

2.3 Water Quantity

Water quantity is important for the maintenance of stream flows providing aquatic habitat (in stream flow needs), has functions related to water quality, and is essential for the treatment and production of sufficient volumes of drinking water to meet current demands. Irrigation, industry and livestock production are all highly dependent on a minimum amount of water. Water quantity is necessary for many recreational activities, and in recent years many cottagers and recreational lake users across Alberta have voiced concerns about the decreasing volumes of water seen across the province. The following water quantity indicators and metrics have been selected (see Table 3 for a summary).

A. Water Volume

Water volume is the amount of water flowing past one point over a given time, or in the case of lakes, the total amount of water present in the lake at a given time. This amount can vary seasonally and annually with shifts in weather patterns. Water withdrawals for consumptive uses have increased dramatically in recent years and have resulted in some basins within the province being closed to new water licenses.

This data is collected using long term hydrometric stations, water gauges and bathymetric mapping. Environment Canada and Alberta Environment often set up long term monitoring stations to track water levels and this information can be used to calculate water volumes.

Performance measures can include increases or maintenance of water volumes, decreases in number of water licenses issued for surface water bodies, increases in fish populations and seasonal variations remaining within historical norms.

B. Minimum Flows to Maintain Ecological Integrity

Minimum flows to maintain ecological integrity are the lowest flows or volumes (lakes) required to sustain native aquatic species and natural ecosystem functions. For example, fish require a minimum depth for easy passage and some riparian plant species require seasonal (spring) flooding for growth and/or reproduction. Minimum flows must be determined before allocation of water can safely take place, in order to preserve the ecological functionality of our aquatic ecosystems.

Minimum flows are calculated based on the species of interest, e.g. fish, invertebrates, plants, etc, and are based on preserving the health and functionality of an aquatic ecosystem. Calculating this value can include determining minimum flows required to keep ammonium concentrations below toxic levels for fish populations, or minimum flows required for successful recruitment of riparian vegetation, for example.

Performance measures for this parameter can include increases in or maintenance of fish populations, prevention of toxic levels of parameters such as ammonium, and successful growth of riparian vegetation communities.

C. Contributing Areas to Watershed

Contributing areas to the watershed are areas from which runoff flows into the lakes, creeks and rivers of the watershed. From this information, we can determine an estimated volume of water contributed to the river on an annual basis.

This parameter is determined by mapping out the watersheds of all major water bodies within the larger watershed of interest. Area is determined by calculating the area of all land contributing water directly into the water body of interest and contributing volume can be estimated using meteorological data (precipitation amounts).

Performance measures for this parameter would include no loss of annual input volumes, no water directed out of the subwatershed of interest, and subsequently maintenance of instream flow needs.

D. Allocation

Surface and groundwater water withdrawal permits for the watershed are quantified by user sector (agriculture, municipal, industrial) along with information on licenses, consumption, and return flows. This information will be used along with water flow data to show areas of potential future constraints on surface water availability, which may have implications for future development.

This parameter is measured by using the online approvals and applications viewer provided by Alberta Environment. From this website, all groundwater and surface water withdrawal permits can be seen, along with the associated approved volumes and time periods.

Performance measures will include maintenance or decrease in the amount of allocations in water stressed areas, approvals granted to a level that will preserve instream flow needs and groundwater levels, and preservation of good quality return flows.

E. Groundwater Recharge/Discharge

Areas where groundwater gets recharged or discharges to the surface indicate areas where the groundwater table is close to the surface and the soils are generally more permeable. These areas are at greater risk of becoming contaminated from development, agricultural and/or industrial activities. Knowing where groundwater recharges and discharges will help to identify areas requiring special protection and limitations to land use.

Groundwater discharge and recharge areas can be determined using historical information, aerial photos, groundwater studies and satellite imagery. These areas can be mapped and overlapped with other variables such as land use, oil and gas exploration, and other parameters of interest.

Performance indicators will include maintenance and protection of groundwater discharge and recharge areas, limitations to land use in areas of concern, improvements or maintenance of local groundwater quality and preservation of local hydrology.

2.4 Bioindicators

Bioindicators are biological (plant and animal) data from which various aspects of ecosystem health can be determined or inferred. The presence, absence and abundance of such data can be linked to water quality, quantity and ultimately to overall watershed health (see Table 4 for a summary).

Table 3. Summary of Water Quantity indicators and metrics for the Red Deer River Watershed.

Indicator	Metric(s)	What Indicator Means	Performance Measures
Water Volume	-River/creek flow volume (m^3/day, month/year) -Lake level (meters above sea level) -Lake volume (m^3)	Indicates seasonal and annual fluctuations, low volumes will increase effects of contamination due to loss of dilution factor, may indicate drought conditions.	Maintenance of current water levels or return to a chosen benchmark water level
Minimum Flows to Maintain Ecological Integrity	-Flow volume -Lake level	Used in calculation of in stream flow needs – does the ecosystem have sufficient water to function normally?	Determination of minimum flow requirements, maintenance of determined required water levels
Contributing Areas to Watershed	Area (ha, m^3 or %) of land area that contributes water to the RDR	Assists with determining annual input volumes (overland flow).	Limitations to land uses in contributing areas, implementation of best management practices
Allocations	-# of licensed withdrawals	Should any further withdrawals be granted? Are we over allocated?	Number of allocations lower than instream flow need values
Groundwater Discharge/Recharge	-Identification of areas of groundwater recharge/discharge. -Sensitivity of recharge areas to contamination	Identifies areas requiring special protection from development, agriculture, etc., due to close proximity to groundwater table.	Maintenance and protection of groundwater recharge/discharge areas

A. Wildlife Biodiversity (Terrestrial and Aquatic)

Wildlife inventories to determine the biodiversity within the watershed will help indicate changes in environmental conditions (e.g., habitat fragmentation, loss of nesting and breeding sites, nutrient enrichment, etc.). A loss of biodiversity can cause an ecosystem to become less stable and more vulnerable to environmental change (Wilsey and Potvin, 2000). A change in diversity may also affect nutrient cycling and/or energy flow through the ecosystem (Wilsey and Potvin, 2000).

Wildlife biodiversity will be determined using completed wildlife surveys and inventories from organizations such as Ducks Unlimited, Alberta Conservation Association, Sustainable Resource Development, Fish and Wildlife and others.

Performance measures will include maintenance of current populations of species of interest, number of re-introductions, successful annual recruitment and habitat preservation.

B. Fish

Inventories of selected fish populations may show increases or declines through introductions or changes in environmental conditions. Indicator species that are sensitive (e.g., bull trout) to environmental pollution may show areas of concern with their absence, while others may show similar with their presence. Invasive species, if present, will indicate areas of concern requiring future monitoring. Trophic cascade effects may be linked with changes in water quality.

Fish data will be collected from creel (angler) surveys, biological assessments and other reports completed by Fish and Wildlife, Sustainable Resource Development, Department of Fisheries and Oceans the Alberta Conservation Association and others. The number of issued fish licenses within the watershed may also be determined.

Performance measures will include maintenance or improvement of current fish population numbers, increases in species diversity, maintenance of habitat and riparian areas, decreases in licenses issued in areas with low populations and numerous age classes of fish.

C. Land Cover

Land cover is the type of vegetation or lack thereof covering the landscape; it includes grass, trees shrubs, asphalt and bare ground. Inventory of vegetation populations may show increases or declines through introductions or changes in environmental conditions. Indicator species that are sensitive to environmental pollution may show areas of concern with their absence, while others may show areas of concern with their presence. Changes in land cover can indicate a change in land use and identify areas that need restoration, are at risk of erosion and/or areas with rare plant species that need protection. Land cover is a separate measurement from land use even though these two terms are sometimes used interchangeably.

Land cover is determined using aerial photos and satellite imagery. Photos can be compared to historical data for comparison purposes and current data can be used to set a benchmark level of cover. Rare plant species will be located using rare plant surveys and the Alberta Biodiversity Index will be utilized as well.

Performance measures will include healthy native vegetation populations, an increase in land cover over current levels, no loss of native

vegetation cover, no loss of rare plant species, decreases in number of invasive species, decreases in harmful insect and disease occurrences and preservation and conservation of sensitive areas.

D. Species at Risk

Identifying species at risk and their habitats will help to determine sensitive areas and level of protection required. Species that are at risk act as umbrella species. Protecting areas where species at risk occur, the habitats of other species are indirectly protected. The *Species at Risk Act* (SARA) was introduced in June 2003 to provide legal protection of wildlife species and conservation of biological diversity. The Act aims to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk (Government of Canada, 2008).

Species at risk data will be obtained from federal and provincial wildlife surveys and may be mapped using GIS software. Areas containing species at risk can be highlighted and protection efforts can be initiated.

Performance measures would include no further extinctions or “downgrading” of the status of any species, restoration of extirpated, endangered or threatened species to safe levels, and preservation of specialized habitat.

Table 4. Summary of bioindicators and metrics for the Red Deer River watershed.

Indicator	Metric(s)	What Indicator Means	Performance Measures
Wildlife Biodiversity (terrestrial and/or aquatic)	-Species richness -Species abundance -Simpson's Diversity Index	Identifies areas of low biodiversity which may require more protection.	Increases in species diversity and abundance, protection of habitat areas
Fishes	-Index of Biological Integrity (IBI) -Species richness/diversity	Will provide an indication of aquatic ecosystem health	Increases or maintenance of species diversity and abundance, decreased number of issued licenses for areas of concern, maintenance and/or improvement in riparian area health, preservation of fish habitat
Land Cover	- Alberta Vegetation Inventory (AVI), Native Vegetation Inventory (NVI) and Grassland Vegetation inventory (GVI) - % cover of trees, shrubs, grassland (natural and cultivated), bare soil, etc.	Identifies areas that have been cleared of vegetation and may need restoration, erosion risks and rare plant species needing protection	Protection and/or restoration of areas of concern, no loss of rare plant species, increase in % cover of native vegetation, decrease in number of invasive species
Species at Risk	-number of species at risk within watershed and their distribution. -Bull trout occurrence and habitat -Leopard Frog occurrence and habitat	To determine the species at risk in the watershed so their habitat can be protected, to provide for the recovery and encourage the management of the species and other species to prevent them from becoming at risk	No addition of species to SARA list, preservation and protection of habitat areas containing SARA species, no negative changes in species ratings

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