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PRAIRIE PROVINCES WATER BOARD

Report #180

Quantifying Non-Point and Point Nutrient Sources in the Carrot and Red Deer Watersheds

Prepared for the PPWB Committee on Water Quality
By Golder Associates

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REPORT

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PRAIRIE PROVINCES WATER BOARD

Quantifying Non-Point and Point Nutrient Sources in the Carrot and Red Deer River Watersheds

Submitted to:
Joanne Sketchell, PhD
Senior Water Quality Advisor
Prairie Provinces Water Board, Committee on Water Quality
330, 2365 Albert Street
Regina, Saskatchewan

Report Number: 1527191

Distribution:
e-copy Prairie Provinces Water Board

Golder Associates

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Abbreviations and Acronyms

Abbreviation	Item
<	less than
>	greater than
±	plus or minus
≥	greater than or equal to
≤	less than or equal to
AAFC	Agriculture and Agri-Food Canada
ADF	average daily flow
AENV	Alberta Environment[1]
AEP	Alberta Environment and Parks
BC	British Columbia
EDA	effective drainage area
GDA	gross drainage area
GIS	Geographic Information Systems
Golder	Golder Associates Ltd.
Max	maximum
Min	minimum
MOE	Saskatchewan Ministry of Environment
n	number of samples
NA	not applicable
O_2	O2 Planning + Design Inc.
PFRA	Prairie Farm Rehabilitation Administration
PPWB	Prairie Provinces Water Board
R^2	coefficient of determination
RMSE	root mean square error
RPD	relative percent difference
SD	standard deviation
SWA	Saskatchewan Watershed Authority
TN	total nitrogen
TP	total phosphorus
USGS	United States Geological Survey
WSA	Water Security Agency
WSC	Water Survey of Canada
WWTP	wastewater treatment plant

[1] Now Alberta Environment and Parks (AEP).

Units

Unit Abbreviation	Units
%	percent
dam^3	cubic decametres
Ha	hectares
kg/d	kilograms per day
kg/ha/yr	kilograms per hectare per year
kg/season	kilograms per season
kg/yr	kilograms per year
Km	kilometres
km^2	square kilometres
L/d	litres per day
m^3/d	cubic metres per day
m^3/person/d	cubic metres per person per day
m^3/s	cubic metres per second
masl	metres above sea level
mg/L	milligrams per litre

1.0 INTRODUCTION

1.1 Background

The Prairie Provinces Water Board (PPWB) is an inter-jurisdictional board with representatives from:

- Alberta Environment and Parks (AEP)
- the Water Security Agency of Saskatchewan (WSA)
- Manitoba Sustainable Development
- Environment and Climate Change Canada
- Agriculture and Agri-Food Canada (AAFC)

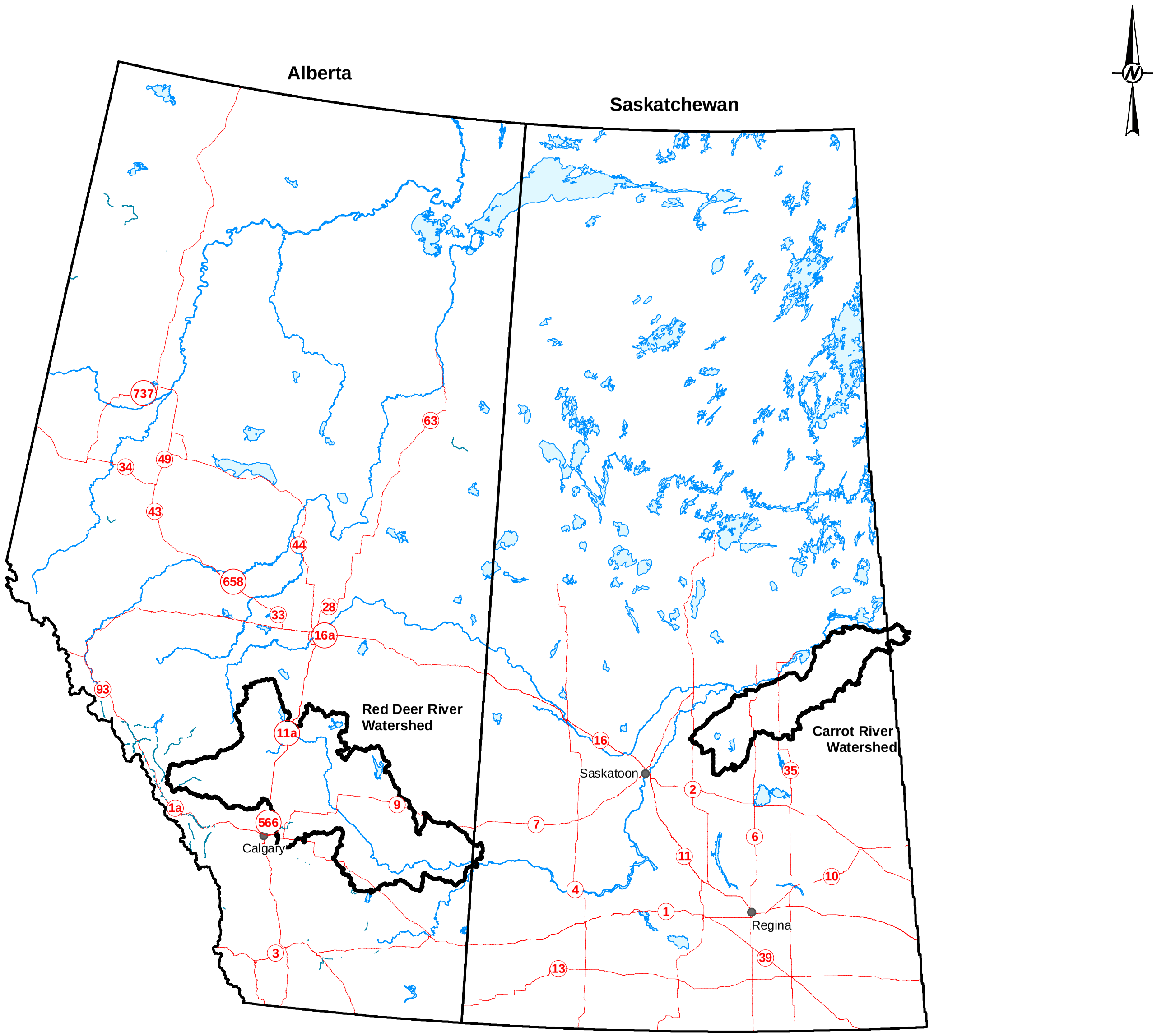
The PPWB oversees the administration of the Master Agreement on Apportionment that was introduced in 1969 and later amended in 1984, 1992, 1999 and 2015 (PPWB 2015). The Master Agreement on Apportionment represents an agreement among Canada and the provinces of Alberta, Saskatchewan, and Manitoba for the sharing of water resources and management of water quality in eastward flowing, interprovincial rivers.

The PPWB's Committee on Water Quality (COWQ) oversees the water quality aspect of the Master Agreement on Apportionment, and has identified nutrient enrichment as a priority issue. Golder Associates Ltd. (Golder) was retained to evaluate nutrient levels and loading sources in two prairie watersheds, both of which are contained within the Saskatchewan River Basin (Figure 1.1-1):

- Red Deer River watershed in Alberta
- Carrot River watershed in Saskatchewan

The two watersheds have experienced different levels of development. The Red Deer River watershed contains more urban development, whereas the Carrot River watershed is dominated by forested areas and farmland. The two watersheds also differ in terms of data availability. The Red Deer River watershed contains multiple monitoring stations, both along the river mainstem and at the mouths of several tributaries. Seasonal samples for nutrients and other water quality parameters have been collected consistently from the terminal station positioned near the river mouth at Bindloss, with additional sampling having been done at the other stations. In contrast, the Carrot River watershed contains only one sampling station on the river mainstem, with several other sampling stations situated on three tributaries in the upper watershed. Only the terminal station at Turnberry has been consistently sampled seasonally for nutrients.

Both the Red Deer and Carrot rivers contain elevated nutrient concentrations (Aquality 2009; Saskatchewan Watershed Authority [SWA] 2011). Trend analyses conducted by the COWQ using data available to the end of 2008 suggest that total phosphorus (TP) and total nitrogen (TN) levels in the Carrot River are increasing. In contrast, those in the Red Deer River appear to be either decreasing (TP) or staying relatively consistent over time (TN) (PPWB 2016). Quantification of point and non-point nutrient sources in both watersheds may provide a means to better understand these patterns and inform potential management action. Further detail on the bulk characteristics of both watersheds is described below, followed by the study objectives.



LEGEND

HIGHWAY

WATERBODY / MAJOR WATERCOURSE

PROJECT AREA WATERSHED BOUNDARY

REFERENCE(S)
1. NATIONAL TOPOGRAPHIC DATA BASE (NTDB) DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2007.
2. CANVEC BASE DATA © DEPARTMENT OF NATURAL RESOURCES CANADA, 2012. ALL RIGHTS RESERVED.
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CLIENT
PRAIRIE PROVINCE WATER BOARD

PROJECT
QUANTIFICATION OF NUTRIENT SOURCES
IN PRAIRIE RIVERS

TITLE
LOCATIONS OF THE RED DEER RIVER
AND CARROT RIVER WATERSHEDS

CONSULTANT

Golder Associates

YYYY-MM-DD	2019-05-10
DESIGNED	AW
PREPARED	SBM
REVIEWED	CP
APPROVED	JP

PROJECT NO.	PHASE	REV.	FIGURE
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1.2 Study Area

1.2.1 Red Deer River Watershed

The Red Deer River flows from its headwaters in the Rocky Mountains to its confluence with the South Saskatchewan River, approximately 21 kilometres (km) east of the Alberta-Saskatchewan border. The watershed ranges in elevation from over 3,000 metres above sea level (masl) in the alpine headwaters in the Rocky Mountains to less than 610 masl on the prairies. It has a total area of approximately 47,991 square kilometre (km^2). Although glaciers exist in the headwaters of the Red Deer River, most of the spring runoff occurs as a result of snowmelt across the watershed. Consequently, the timing of peak flows usually occurs in April for sub-basins in the lower watershed and in June in the upper watershed near the mountains.

Tributaries to the Red Deer River consist of (Red Deer River Watershed Alliance [RDWA] 2009):

- Alkali, Berry, Blood Indian, Bullpound, Fallentimber, Kneehills, Matzhiwin, Michichi, and Threehills creeks
- Blindman, James, Little Red Deer, Medicine, Panther, Raven, and Rosebud rivers

Most of the flow volume in the Red Deer River originates from areas upstream of the City of Red Deer, which represents approximately one third of the watershed (Kerr and Cooke, 2017; O2 et al. 2013). This water originates primarily from glacial melt water, snow melt and precipitation in the mountains and foothills in the upper watershed (AMEC et al. 2009).

As the river flows from the mountains and foothills to its confluence with the South Saskatchewan River, it receives runoff from forests, rangeland, cropland, parks, and urban and industrial areas (Aquality 2009). The volume of water that is accumulated through the remaining two thirds of the watershed, between the City of Red Deer and the Water Survey of Canada (WSC) monitoring station at Bindloss at the Alberta-Saskatchewan border, represents only about 20 percent (%) of the total flow volume (O2 et al. 2013). Of this 20%, only about 2% of the flow originates from the Alberta badlands region, with approximately 9% coming from the Kneehills Creek, Michichi Creek, Threehills Creek, and Rosebud River sub-watersheds (Kerr and Cooke 2017). The disparity between the size of the lower watershed area and its relatively small contributions to in-stream river flow is attributed to flatter slopes, poor drainage, and lower precipitation and runoff yields, relative to those in the upper watershed (AMEC et al. 2009).

The dominant land use within the watershed is agricultural, and approximately one-third of the watershed's population lives in rural areas (AMEC et al. 2009). Larger urban centres include the cities or towns of Sundre, Sylvan Lake, Red Deer, and Drumheller (Aquality 2009).

1.2.2 Carrot River Watershed

The Carrot River extends from the outflow of Wakaw Lake, Saskatchewan to its confluence with the Saskatchewan River approximately 30 km east of the Saskatchewan-Manitoba border (SWA 2011). About 90% of the 17,500 km^2 watershed area is located within Saskatchewan (SWA 2011). The Carrot River ranges in elevation from around 550 masl in its headwaters near Lenore Lake and the Pasquia Hills to less than 265 masl at the mouth of the river. Most of the runoff each year comes from snowmelt, and peak flows usually occur in April.

Although the Lenore Lake drainage area is within the Carrot River watershed, it is an endorheic basin and does not contribute flow to the Carrot River, except under prolonged periods of extremely wet conditions. Tributaries to the Carrot River consist of (SWA 2012):

- Burntout Brook
- Coldwell, Emmons, Goosehunting, Little Bridge, McCloy, Melfort, Sandhill, and Sweetwater creeks
- Cracking, Crooked, Dead, Doghide, Jordan, Leather, Man, Papikwan, Presbyterian, and Rice rivers

More than half of the land within the watershed is used for crop production or other agricultural purposes (Saskatchewan Ministry of Agriculture 2008; SWA 2011). Rich organic soils in the southernmost portion of the watershed are used to grow crops, and many of the tributaries to the Carrot River have been channelized, diverted, or diked to control the amount of high-quality agricultural land available in the watershed (SWA 2011).

Urban centres and rural residences are primarily concentrated in the south-central region; however, the population within the watershed fluctuates seasonally due to the presence of a number of resort communities and recreational areas (SWA 2011).

1.3 Study Objectives

Two study objectives were defined by the COWQ (Environment Canada 2015):

Objective 1 *is determining a comprehensive state of knowledge on the major sources of nutrients including point and non-point sources in the Red Deer … and Carrot River … watersheds.*

Point sources should be identified. However, the specific focus is on non-point sources of both human and natural origin (for example, increased loading due to various land uses, natural loading from different soil types or surficial geology, in-stream processes such as sediment resuspension/bank erosion and the influence of variable effective drainage areas and variable precipitation). Note the following:

- *Quantitative information on the sources should be included, where possible, to allow an assessment of the relative importance of individual sources and spatial and temporal variability.*
- *Information on the sources should be used to identify sub-watersheds at higher risk from human-derived nutrient sources.*
- *Critical gaps in knowledge about nutrient sources in these two watersheds should be identified.*

Objective 2 *is determining a current understanding of the major influences to, and causes of, current nutrient concentrations and trends in the Red Deer and Carrot River watersheds.*

Objective 2 is directly related to knowledge gained from objective 1 but requires analyses to determine how the sources identified in objective 1 including natural and anthropogenic factors relate to nutrient concentrations and trends in the rivers. These factors, in particular, should include the influences of climate, precipitation, land use, soils and drainage. Within this context it is important to identify and understand the extent of any areas with a disproportionately high contribution of nutrients to the river ecosystems, or the so called nutrient hotspots.

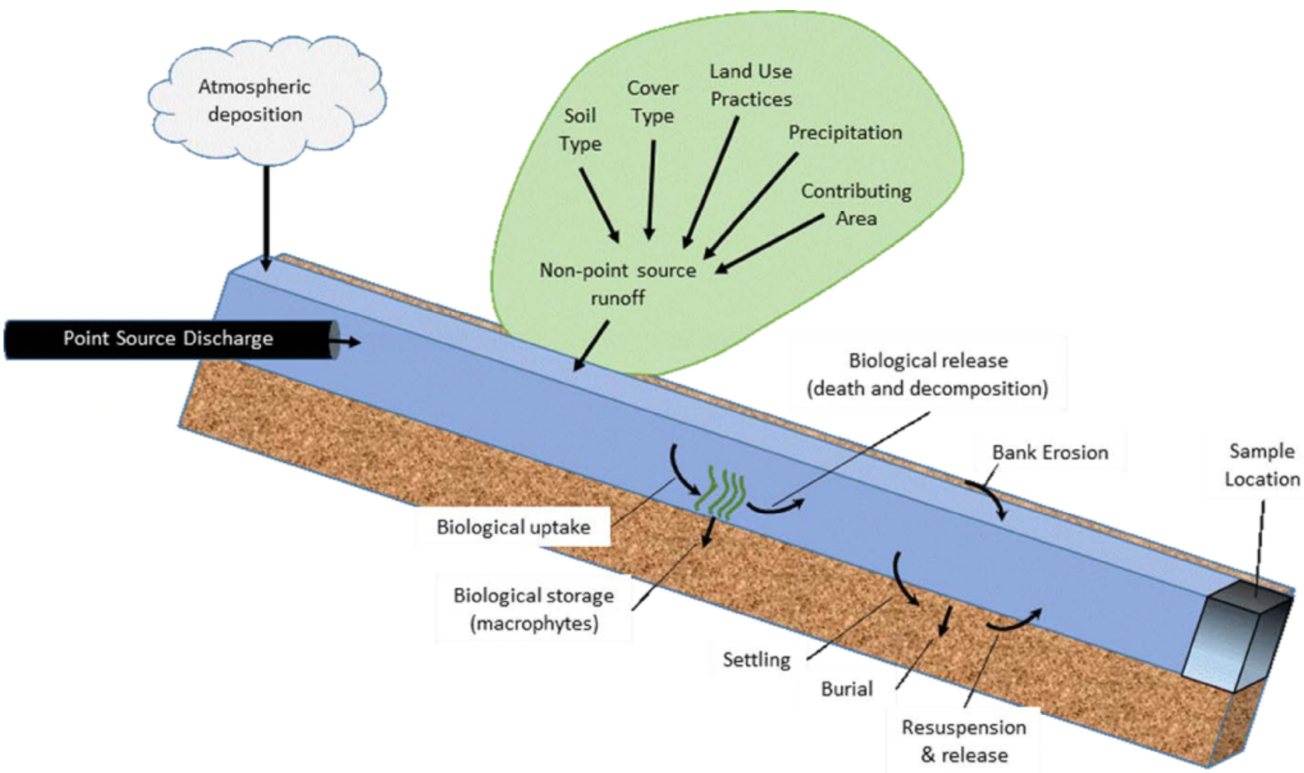
…

A key question is whether there is sufficient information and understanding to differentiate natural from anthropogenic sources to answer questions such as "What factors are influencing trends in nutrient concentrations observed in prairie interprovincial rivers?" If information is insufficient to separate natural from anthropogenic sources, recommendations should be provided on what are the most efficient approaches, within a prairie context, to gather such information.

1.4 Conceptual Model

As outlined, for example, by Bourne et al (2002), nutrient mass measured at a given monitoring station will reflect the influence of direct atmospheric deposition, point source loading, non-point source loading, and in-stream processes. A simple conceptual model of this dynamic is shown in Figure 1.4-1.

Figure 1.4-1: Conceptual Model of Factors Influencing Nutrient Mass Measured at a Given Location in a River



Loading that occurs via atmospheric deposition is a function of deposition rate and water surface area. However, in river systems, atmospheric deposition tends to be a minor nutrient source, relative to point and non-point sources; consequently, it is not often explicitly considered when developing riverine nutrient models (e.g., Collins and Wlosinski 1989; Chapra 1997; Shanahan and Alam 2003).

Point sources to a river system or waterbody can include, but are not limited to:

- municipal wastewater treatment plants
- manufacturing facilities

- industrial processing plants
- settling ponds
- tributary inputs
- municipal runoff released through storm sewers

Loading that occurs via point sources is a function of water release rate and release concentration, both of which are readily measurable.

In broad terms, point source loading associated with municipal wastewater treatment plants, manufacturing facilities, and industrial processing plants tend to be relatively consistent between wet and dry climatic conditions (Lehman 2016); water release rates are driven primarily by water use, rather than water availability. Loading via other point sources, such as tributary inputs, settling ponds and the like, are more variable, typically being higher during wet conditions than in dry conditions.

Non-point source loading, by definition, occurs over a diffuse area, rather than through a designated outfall or input location. Non-point sources include runoff from agricultural and undisturbed areas, forested lands and runoff from roads and other disturbed surfaces.

Non-point source loading is primarily a function of soil type, cover type, land use management practices, drainage area, and precipitation (Johnes et al. 1996, Jeje 2006, Donahue 2013). It can also be influenced by other factors, such as the time period between runoff events. Direct measurement of non-point source loading is difficult, as it occurs over a large, unconstrained area, is intermittent and variable (Bourne et al. 2002). Non-point source loading can be estimated using simulation models or through the application of export coefficients that describe the mass of nutrient released per unit area per unit time (e.g., kg/ha/yr) (Burke 2016). With either approach, some level of generalization and simplification is required, particularly when estimating non-point source loading from large areas. To do otherwise requires a large amount of site-specific data that are typically not available, due to the effort and expense involved in their collection (Donahue 2013).

Non-point source loading is temporally variable. It is commonly associated with runoff, and is typically higher under wet climatic conditions than under dry conditions.

In-stream processes, as illustrated in Figure 1.4-1, can consist of:

- biological uptake through growth of aquatic vegetation (Collins and Wlosinski 1989; Sosiak 2002; Golder 2004)
- biologically-induced storage in macrophyte root systems (Carrigan 1982; Golder 2004)
- biological release through death and decomposition of aquatic biota (Collins and Wlosinski 1989; Golder 2004)
- settling (Chapra 1997; Shanahan and Alam 2003)
- burial (Chapra 1997; Shanahan and Alam 2003)
- resuspension (Chapra 1997; Shanahan and Alam 2003)

- bank erosion (Chapra 1997; Shanahan and Alam 2003)

In-stream processes that act as nutrient sources consist of biological release, resuspension and bank erosion. In contrast, biological uptake, storage, settling and burial act as nutrient sinks, removing nutrient mass from the water column.

Similar to non-point source loading, in-stream processes are variable, with bank erosion and resuspension exerting a stronger influence on in-stream nutrient levels during wet climatic conditions. Conversely, under drier conditions, in-stream nutrient sinks exert a strong influence on in-stream nutrient levels than they would under wetter conditions, because decreased water velocity and improved water clarity allows for greater levels of settling and biological uptake.

Identifying the dominate factors that influence nutrient levels in prairie thus requires an examination of the relative importance of point sources and non-point sources, as well as in-stream processes, under both wet and dry conditions.

1.5 Scope and Report Organization

The study objectives defined by the COWQ were translated into the following key questions:

1) What are existing nutrient levels in the Red Deer and Carrot rivers?
2) How do they vary down the length of each river, and are they increasing over time?
3) Where are the nutrients coming from (point sources, non-point sources, in-stream processes)?
4) Which sources are the largest, and how do they compare to one another?
5) How does the relative importance of these sources change between wet and dry conditions?
6) Where are areas of risk / hotspots within each watershed?
7) Are there sufficient data available to separate anthropogenic influences from natural sources?

These key questions were used to guide the scope and format of the analysis.

The nutrients considered were TN and TP, consistent with Golder's approved scope of work. Data from 1995 to 2014[2] were used to describe existing conditions and to evaluate and identify key loading sources. Point sources considered in the assessment were municipal and industrial facilities with approvals to discharge to either river. Non-point sources were defined based on land use. The geographic scope consisted of the entire watershed area associated with each river, although efforts were focused on understanding and describing conditions in the river mainstems. The analysis was tailored to reflect data availability, with a consequential effect of looking at each river as a whole. The influence of climate was evaluated by looking at how identified nutrient sources changed between wet and dry years.

The objectives defined by COWQ specified a desire to tease apart the influence of the individual elements contributing to non-point source loading, such as the influence of soil type relative to that of the overlying cover type, underlying geology and precipitation. The data required for such an analysis were not available. Instead,

[2] The end date of 2014 reflects the time at which this study was initiated (i.e., in 2015).

non-point source loading was examined with reference to land cover type and through the use of export coefficients, comparable to the methods used by Bourne et al. (2002) and Burke (2016).

The study was conducted in a stepwise manner. First, as outlined in Section 2, measured in-stream concentrations and flows were compiled, in-stream loads were calculated and trend analyses were completed. The resulting dataset was used to answer Key Questions 1 (define existing nutrient levels) and 2 (identify spatial and temporal variability); it was also used to inform Key Question 6 (identification of hotspots or areas of risk).

Next, as outlined in Section 3, information about point sources in each watershed was compiled and used to estimate total point source loading to the Carrot and Red Deer rivers. These values were compared to calculated in-stream loads from Section 2 to identify the relative influence of point source loading on the overall nutrient load moving through each river, thereby helping to answer Key Question 3 (where are nutrients coming from) and Key Question 4 (which sources are the largest).

Following the point source evaluation, land use information was collated, as detailed in Section 4. The collated information was used to define current land use in each watershed, and to describe how land use has changed over time from 1995 to 2014.

A watershed analysis was then completed, as outlined in Section 5, wherein non-point source loading from different land uses was estimated under average, wet and dry climatic conditions. These values were used in combination with the total in-stream loads and point source loads detailed in Sections 2 and 3, respectively, to identify and, where possible, quantify in-stream sources and sinks. The combined dataset was used to answer Key Questions 3 through 7.

Key study findings and their implications for nutrient management were summarized (Section 6), uncertainties and limitations of the analysis were identified (Section 7), and, finally, study recommendations were developed (Section 8).

2.0 IN-STREAM CONDITIONS

The methods used to describe in-stream conditions, including watershed and sub-watershed boundaries, nutrient concentrations, and loads, are described in Section 2.1. In-stream conditions are described in Section 2.2. Conclusions that can be drawn from the analysis are outlined in Section 2.3. Limitations and sources of uncertainty associated with the in-stream flow and nutrient data are discussed in Section 2.4.

2.1 Methods

2.1.1 Red Deer River

2.1.1.1 Watershed Delineation

The Red Deer River watershed has been described in previous studies as a system of 15 sub-watersheds (Aquality 2009) and six reaches (Anderson 2012). For purposes of this study, the Red Deer River watershed was divided into nine sub-watershed areas to reflect data availability (Figure 2.1-1). The nine sub-watershed areas were:

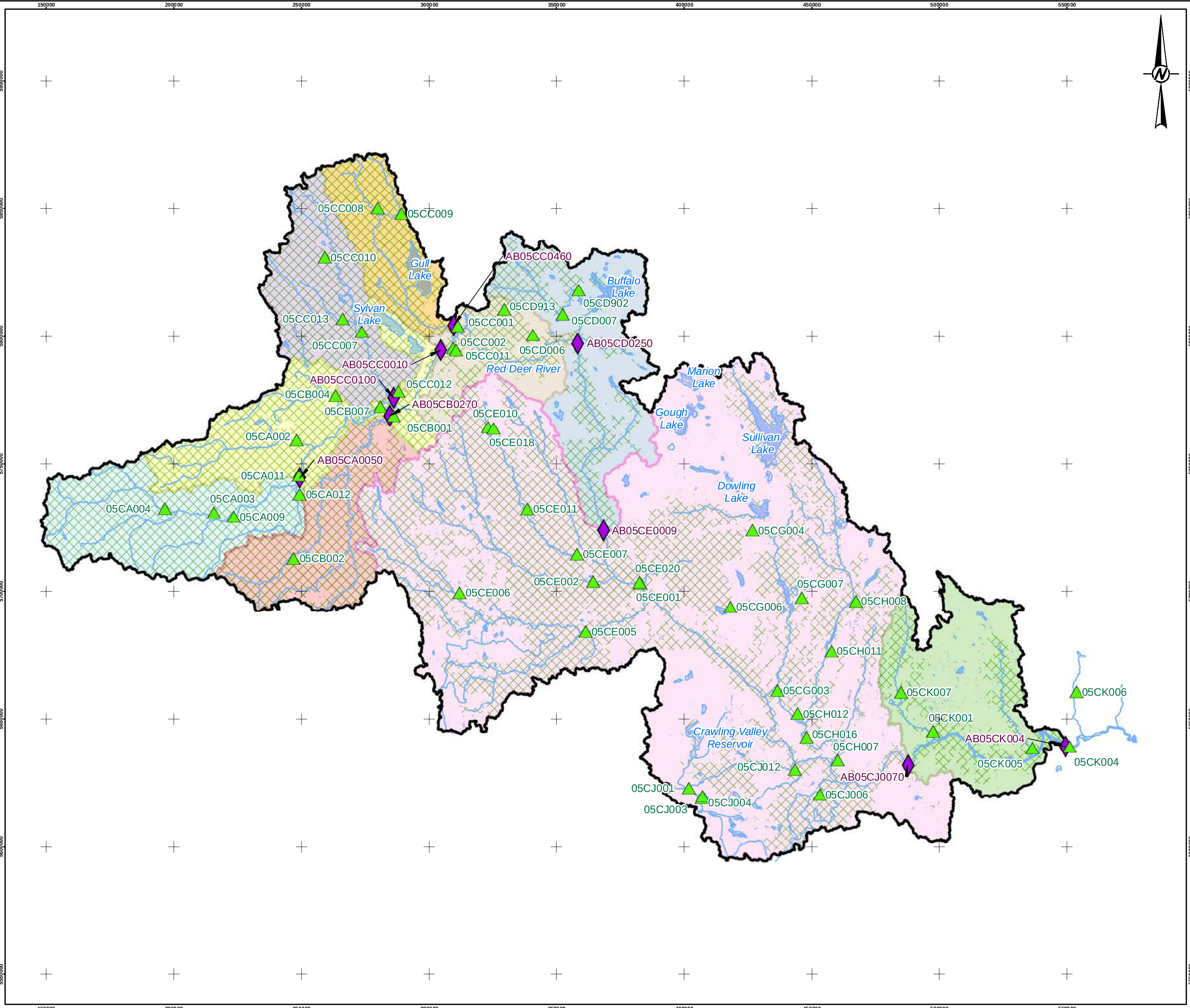
- Red Deer River upstream of Sundre
- Little Red Deer River
- Medicine River

- Red Deer River between Sundre and the City of Red Deer
- Blindman River
- Red Deer River between the City of Red Deer and Nevis
- Red Deer River between Nevis and Morrin
- Red Deer River between Morrin and Jenner
- Red Deer River between Jenner and Bindloss

The size of each sub-watershed and its associated gross drainage area (GDA) and effective drainage area (EDA) were estimated using data obtained from the WSC (Government of Canada 2016a) and AAFC (Government of Canada 2016b). The GDA represents total watershed area upstream of a given flow monitoring station; the EDA is defined as the area within the GDA that is expected to contribute runoff based on a one-in-two year return period. The EDA excludes internal drainages to marshes, sloughs, or isolated lakes (Cole 2013).

The sub-watershed boundary information obtained from WSC and AAFC was cross-referenced against hydrological datasets compiled for the Prairie Farm Rehabilitation Administration (PFRA) (Government of Canada 2016c). They were also checked against stream network and topographical features, and adjusted as appropriate.

The final watershed and sub-watershed boundaries, along with the associated nutrient and flow monitoring stations used in this study, are illustrated in Figure 2.1-1. The GDA for the area of the Red Deer River located upstream of the terminal monitoring station near Bindloss is approximately 48,000 km^2; the EDA is approximately 30,000 km^2, or approximately 63% of the GDA.



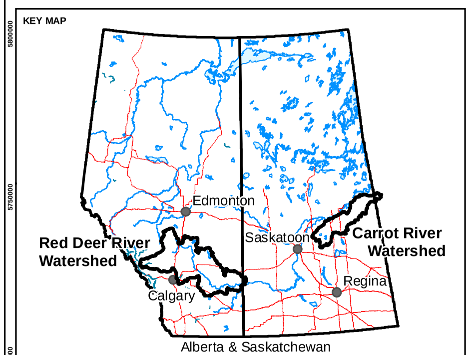
LEGEND

WATER QUALITY STATION	
FLOW STATION LOCATION	
STREAM NETWORK	
WATERBODY	
RED DEER RIVER WATERSHED	
EFFECTIVE DRAINAGE AREA	

SUB-WATERSHED BOUNDARY BY WATER QUALITY STATION

- AB05CA0050
- AB05CB0270
- AB05CC0010
- AB05CC0100
- AB05CC0460
- AB05CD0250
- AB05CE0009
- AB05CJ0070
- AB05CK004

KEY MAP



0 25 50
KILOMETRES

REFERENCE(S)
1. CROP INVENTORY 2013, AGRICULTURE AND AGRI-FOOD CANADA; CANADA OPEN DATA 2015
2. PFRA-BASED WATERSHEDS 2013, AGRICULTURE AND AGRI-FOOD CANADA; CANADA OPEN DATA 2015
3. NATIONAL TOPOGRAPHIC DATA BASE (NTDB) DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2007.
4. CANVEC BASE DATA © DEPARTMENT OF NATURAL RESOURCES CANADA, 2012. ALL RIGHTS RESERVED.
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CLIENT
PRAIRIE PROVINCE WATER BOARD

PROJECT
QUANTIFICATION OF NUTRIENT SOURCES
IN PRAIRIE WATER RIVERS

TITLE
SUB-WATERSHED BOUNDARIES AND MONITORING STATIONS IN THE RED DEER RIVER WATERSHED

CONSULTANT
Golder Associates

YYYY-MM-DD	2019-05-10
DESIGNED	AW
PREPARED	SBM/AA
REVIEWED	CP
APPROVED	JP

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2.1.1.2 Water Flow

Historical discharge data recorded at hydrometric stations in the Red Deer River watershed were obtained from WSC (Government of Canada 2016a) and are summarized in Appendix A, Figure A1 and Table A1. Individual WSC stream flow monitoring stations were preferentially selected for inclusion in the assessment based on their proximity to water quality stations of interest (Section 2.1.1.3), completeness of the available datasets, and the period over which data were recorded.

Locations of hydrometric stations that were used to estimate in-stream flows at water quality stations in the Red Deer River watershed are shown in Figure 2.1-1, with station details provided in Table 2.1-1. The number of stream flow measurements recorded at the selected stations for each season and year between 1995 and 2014 are summarized in Appendix A, Table A2.

The time-series of daily flow data from the terminal station near Bindloss was complete for 1995 through 2014. Gaps were present in the datasets obtained from the other flow monitoring stations described in Table 2.1-1. Gaps in the available records were filled by:

- substituting discharge data for comparable stations (e.g., drainage area of a similar size and topography) located nearby
- pro-rating flows according to watershed area
- linear interpolation between adjacent data points (Longabucco and Rafferty 1998)

For example, flows in the Medicine River were estimated by pro-rating flows recorded at station 05CC002 on the Red Deer River mainstem near the City of Red Deer. Calculations were based on the relative sizes of the drainage areas for the nutrient station near the mouth of the Medicine River and the drainage area for station 05CC002.

The available data were then used to estimate seasonal flows based on the following time periods:

- Winter (season 1): January through March
- Spring (season 2): April through June
- Summer (season 3): July through September
- Fall (season 4): October through December

Daily flows were used to estimate in-stream loads, as described below. Seasonal flows were used to describe annual patterns in the flow record, and annual flow volumes at the terminal station near Bindloss were calculated to characterize general flow condition by year, from 1995 to 2014.

Table 2.1–1: Hydrometric Stations used to Estimate Flows at Water Quality Stations in the Red Deer River Watershed

Location[a]	Station Code	Station Name[b]	Latitude, Longitude	Period of Record[c]	Cumulative GDA (km^2)[d]	Cumulative EDA (km^2)[d]	
						Absolute (km^2)	Relative to GDA
Tributaries[e]							
James River	05CA002	James River Near Sundre[f]	51°55'36" N, 114°41'7" W	1966-2013	817	816	100%
Little Red Deer River	05CB001	Little Red Deer River Near The Mouth	52°1'41" N, 114°8'25" W	1960-2014	2,578	2,439	95%
Blindman River	05CC001	Blindman River Near Blackfalds	52°21'14" N, 113°47'40" W	1916-2013	1,786	1,725	97%
Mainstem							
Red Deer River	05CC002	Red Deer River At Red Deer	52°16'34" N, 113°49'2" W	1912-2015	11,636 (8,241)	11,293 (8,038)	97% (98%)
	05CE001	Red Deer River At Drumheller	51°28'2" N, 112°42'41" W	1915-2015	24,972 (11,550)	20,479 (7,461)	82% (65%)
	05CK004	Red Deer River Near Bindloss[g]	50°54'10" N, 110°17'58" W	1961-2015	47,991 (23,019)	30,448 (9,969)	63% (43%)

(a) Stations are listed in order, from upstream to downstream along the Red Deer River mainstem; tributaries are included in the list, based on the location of their confluence with the Red Deer River.

(b) Station name as recorded in the Water Survey of Canada (WSC) database (Government of Canada 2016a). The stations in the table are regulated, with the exception of the James, Little Red Deer, and Blindman River stations.

(c) The "Period of Record" corresponds to flow records available as of December 2015.

(d) Cumulative GDAs and EDAs include all upstream areas that may contribute runoff to a given station. The GDAs and EDAs for individual sub-watersheds (i.e., the areas that may contribute runoff to a given station, excluding runoff to other upstream stations) are provided in brackets, as applicable.

(e) Flows in the Medicine River were pro-rated based on watershed area and flow data for nearby station 05CC002 on the Red Deer River mainstem.

(f) Flow and level are monitored year-round at most stations, with the exception of the James River station, which monitors during the open-water season. Flows in the Red Deer River upstream of Sundre were pro-rated based on watershed area and flow data for the nearby James River station.

(g) Prairie Provinces Water Board (PPWB) station; stream flow and nutrient data are recorded at this station.

GDA = gross drainage area; EDA = effective drainage area; km^2 = square kilometres; % = percent.

2.1.1.3 Nutrient Concentrations

Data Compilation and Availability

Nutrient data for the Red Deer River watershed were obtained from AEP (online data request) and PPWB (Klawunn, pers. comm 2015). A list of nutrient stations considered for inclusion in the study is included in Appendix A, Table A3. Data were collated and screened to reduce the size of the water quality dataset and focus the assessment on data collected from 1995 onward. The rationale for excluding data for years prior to 1995 was that the analytical method for measuring dissolved nitrogen (i.e., nitrogen associated with dissolved ammonia, nitrate and organic sources) in PPWB samples changed in 1994 (Bourne et al. 2002). This change was expected to have implications for calculations of total nitrogen, which are based on measurements of dissolved nitrogen and particulate nitrogen in a sample.

Once the AEP and PPWB datasets were screened to remove pre-1995 data, water quality data were classified by season, using the same temporal boundaries outlined above in Section 2.1.1.2. Additional screening steps were then completed to identify a manageable, but suitably extensive, dataset. The goal of the screening was to identify stations that met the following screening criteria:

- Total nitrogen and TP data were available for the station.
- Reported TN and TP concentrations were recorded concurrently (e.g., both TN and TP data were available for spring 2013, summer 2013, and fall 2013).
- At least five TN and five TP samples were available within a given year at a particular station.

TN concentrations were used as reported; the AEP / PPWB datasets consisted primarily of measured values, with occasional calculated results. No attempts were made to calculate TN from other nitrogen species if TN was not reported.

A total of nine stations, including the terminal station near Bindloss, were identified for inclusion in the dataset for the Red Deer River watershed, based on the screening criteria. Six of the nine stations are located on the mainstem of the Red Deer River (Table 2.1-2; Figure 2.1-1). The other three stations are located near the mouths of the following three tributaries (one station per tributary):

- Little Red Deer River
- Blindman River
- Medicine River

The availability of TN and TP data for these stations is summarized in Table 2.1-2 for the years 1995 through 2014. More detail, including numbers of samples collected at each station during each season (i.e., winter, spring, summer, and fall) and year, is provided in Appendix A, Table A2.

Table 2.1–2: Summary of Information Available at Selected Nutrient Stations in the Red Deer River Watershed

Location[a]	Station Code	Station Name[b]	Latitude, Longitude	Year																			
				1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Tributaries																							
Little Red Deer River	AB05CB0270	Red Deer River West of Innisfail	52°01'40"N, 114°08'20"W	-	-	TP	-	TP	TP	-	TN[c], TP[c]	-	TN[c], TP[c]	-	TN[c], TP[c]	-	TN[d], TP[d]	-	-	TN[c], TP[c]	-	TN[c], TP[c]	-
Medicine River	AB05CC0100	Medicine River at Hwy 54	52°05'30"N, 114°07'20"W	-	-	TP[c]	-	TP	TP	-	TN[c], TP[c]	-	TN[c], TP[c]	-	TN[c], TP[c]	-	TN[d], TP[d]	-	-	TN[c], TP[c]	-	TN[c], TP[c]	-
Blindman River	AB05CC0460	Blindman Near the Mouth, at Hwy 2A Bridge South of Blackfalds	52°21'20"N, 113°47'40"W	TP[e]	TP[f]	-	-	-	-	-	TN[c], TP[c]	-	TN[c], TP[c]	-	TN[c], TP[c]	-	TN[d], TP[d]	-	-	TN[c], TP[c]	-	TN[c], TP[c]	-
Mainstem																							
Red Deer River	AB05CA0050	Red Deer River at Sundre	51°47'45"N, 114°38'06"W	-	-	TP[c]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	TN[g], TP[g]	TN, TP	TN[f], TP[f]
	AB05CC0010	Red Deer 1 km u/s Hwy 2 Bridge	52°16'02"N, 113°51'49"W	TP	TP	TP	TP	TN[c], TP	TN, TP	TN, TP	TN[f], TP	TP	TP	TP	TP	TP	TP	TP	TP	TN[c], TP	TN, TP	TN, TP	TN[f], TP[f]
	AB05CD0250	Red Deer River at Nevis Bridge-Right Bank	52°18'23"N, 113°04'45"W	-	TP[h]	-	-	TN[c], TP[c]	TN, TP	TN, TP	TN, TP	TP	TP	TP	TP	TP	TP	TP	TP	TN[c], TP	TN, TP	TN, TP	TN[f], TP[f]
	AB05CE0009	Red Deer River at Morrin Bridge-Right Bank	51°39'02"N, 112°54'11"W	-	TP[h]	-	-	-	-	-	TN[c], TP[c]	-	-	-	-	TP[g]	TP	TP	TP	TN[c], TP	TN, TP	TN, TP	TN[f], TP[f]
	AB05CJ0070	Red Deer River d/s Dinosaur Prov Park at Hwy 884 near Jenner-Right Bank	52°05'30"N, 114°07'20"W	-	TP[h]	-	TP[h]	-	-	-	-	-	-	-	TP[i]	TP[c]	TP	TP	TP	TN[c], TP	TN, TP	TN, TP	TN[f], TP[f]
	AB05CK004	Red Deer River near Bindloss[j,k]	50°54'10" N, 110°17'58" W	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN[k], TP	TN[i,k], TP	TN, TP	TN, TP	TN, TP	TN, TP[l]	TN, TP	TN, TP	TN, TP

(a) (he)
(b) Station name as recorded in the provincial database.
(c) No data were reported for winter.
(d) No data were reported for winter and fall.
(e) No data were reported for spring and fall.
(f) No data were reported for spring, summer, and fall.
(g) No data were reported for winter, spring, and summer.
(h) No data were reported for winter, spring, and fall.
(i) No data were reported for winter and spring.
(j) Prairie Provinces Water Board (PPWB) station; stream flow and nutrient data are recorded at this station.
(k) Only one sample was collected in fall.
(l) Only two samples were collected in winter.
- = no TN or TP data were available; TN = at least one total nitrogen measurement was available; TP = at least one total phosphorus measurement was available.

TN concentrations were not available for the AEP stations on the Little Red Deer River, Medicine River, and Blindman River for the years 1995 through 2001; TP data were collected sporadically over the same period. TN and TP concentrations were measured at least once per season during spring, summer, and fall of 2002, 2004, 2006, 2011, and 2013 and during spring and summer 2008 (Table 2.1-2; Appendix A, Table A2). Nutrient concentrations representative of winter conditions were not available for any of the three tributaries.

On the river mainstem, upstream of the terminal station, TN data were only available for the years between 1999 to 2002 and 2011 to 2014; 2013 was the only year in which all stations had complete datasets with TN concentrations reported for all four seasons (Table 2.1-2; Appendix A, Table A2). Prior to 2007, TP data were typically collected seasonally, with efforts focussed on stations near the City of Red Deer and Nevis (Table 2.1-2; Appendix A, Table A2). Between 2007 to winter 2014, TP concentrations were typically measured on a monthly basis at most stations on the Red Deer River mainstem upstream of Bindloss.

The long-term water quality and flow station near Bindloss is maintained by the PPWB and was included as a primary station of interest for this study. This station has long-term data records that include the years 1995 through 2014 and align with the available land cover data (Section 4.0). Water quality samples were collected on a near monthly schedule, and flows were recorded daily (Table 2.1-2; Appendix A, Table A2).

Once the available data were compiled and screened, additional steps were taken to fill in data gaps and prepare the concentration data for use. Any TN or TP concentrations that were below the limits of detection were set equal to the detection limit. At the AEP monitoring stations, missing concentrations for winter were substituted with concentrations measured in fall at the same location. The 1995 to 2014 dataset for the terminal station near Bindloss was missing TN data for October and November 2006, and January to May, October and December 2007; TP data were missing for March 2011 from this same location. The data gaps were filled in using a multiple regression approach similar to that of the LOADEST program from the United States Geological Survey (USGS; Runkel et al. 2004). Terms in the equation included flow and date. The data gaps occurred primarily in fall and winter when nutrient concentrations were low and associated loading estimates would similarly be low (due to low flow conditions at this time of year). As a result, uncertainty or error associated with the infilling approach should have limited consequence on study findings.

Finally, TN and TP concentrations measured in samples taken from the Red Deer mainstem at Bindloss in August 2009 were identified as suspicious, because they were an order of magnitude higher than other concentrations reported for the same month in the dataset for 1995 to 2014. Further investigation indicated metal concentrations were also higher than expected in the samples. It is possible that the elevated TN and TP concentrations were the result of a sampling error or a rare, extreme event. To account for this findings, concentrations for that month were replaced with the average of the concentrations reported in July and September 2009.

Temporal Patterns

Intra-annual, seasonal patterns in TN and TP concentrations were assessed based on measurements collected during 2013, the year with the most complete dataset. Summary statistics (i.e., mean and standard deviation) were calculated by season for each station; data were also plotted by season and then assessed visually. Observed patterns were then checked against 2012 information (i.e., the next most complete dataset), where possible, for the river mainstem. This step was completed to identify whether seasonal patterns observed in 2013 were unique or similar to patterns observed in other years.

Longer-term temporal patterns in TN and TP concentrations over the period of 1995 to 2014 were examined using a modified Mann-Kendall trend analysis accounting for seasonality (Systat 2009). The trend analysis was completed based on measurements reported for the terminal station near Bindloss, the monitoring station with the longest and most consistent data record for both TN and TP. Prior to the analyses, data were tested for normality. Both TN and TP data in the Red Deer River were found to be not normally distributed ($p < 0.001$). Therefore, non-parametric Mann-Kendall, Seasonal Mann-Kendall and modified Mann-Kendall tests (Gilbert 1987) were considered. Both data sets were tested for autocorrelation, and were found to be auto-correlated. As a result, the statistical trend analyses were completed using the modified Mann-Kendall test, instead of a seasonal Mann-Kendall test (as was done by PPWB [2016]). This approach was used to account for autocorrelation without any loss of power (Hamed and Rao 1998).

Because water chemistry can be affected by river discharge or flow, flow adjustment techniques are often used in trend assessments to remove its influence on the water chemistry (PPWB 2016). Linear regression analyses were performed (Systat 2007) on log-transformed flow and log-transformed TN and TP concentration data, respectively. Subsequently, flow-adjusted trend analyses were performed using the modified Mann-Kendall tests with residuals obtained from the linear regression analyses, as per the approaches used by USEPA (2011) and PPWB (2016).

Spatial Patterns

Nutrient concentrations were examined to identify spatial patterns along the Red Deer River mainstem, as well as differences among concentrations in the Red Deer River and the assessed tributaries. Spatial patterns in the TN and TP concentrations were evaluated by plotting the data in an upstream-to-downstream orientation and visually examining the data. The assessment focussed on the year of interest that had the most complete TN and TP datasets (i.e., 2013; Table 2.1-2), with a cross-reference to information from other years, where possible. Cross-referencing the information available from other years was done to identify if the patterns observed in 2013 were consistent over time or unique to that year.

2.1.1.4 Nutrient Loads

Estimating In-Stream Loads

In-stream nutrient loads in tributary streams and at locations along the river mainstem were estimated from the flow (Section 2.1.1.2) and concentration (Section 2.1.1.3) data. The following steps were completed at each water quality station of interest:

- Discharge data (cubic metres per second [m^3/s]) were converted to units of cubic metres per day (m^3/d), and then summed to generate an estimate of total monthly flow (cubic metres per month [$m^3/month$]).
- Water quality data were simplified to single monthly values; in virtually all cases, only a single sample result was available per month, so no simplification was necessary.
- Monthly concentrations (milligrams per litre [mg/L]) were multiplied by their corresponding monthly flows to estimate monthly loads in units of kilograms per month (kg/month).
- Monthly loads were summed to estimate seasonal loads (kilograms per season [kg/season]).
- Seasonal loads were summed to estimate annual TN or TP loads, in kilograms per year (kg/yr) (Bourne et al. 2002).

If flow was not measured at the water quality station in question, flow was pro-rated from the closest WSC stream flow monitoring station, based on the ratio between the EDA for the water quality station of interest and that of its paired stream flow station (Cole 2013). This step was not necessary for the terminal station near Bindloss, because stream flow and water quality monitoring stations were co-located.

The method used to estimate in-stream load was consistent with that used by Burke (2016), and was selected in place of LOADEST (Runkel et al. 2004) to maintain simplicity. In addition, load estimates from LOADEST tend to be biased (Hirsch 2014; Jha and Jha 2013). For example, Jha and Jha (2013) found that LOADEST tended to overestimate TN and TP loads; the degree of overestimation was variable and dependent on the selected model within the LOADEST framework that was used. Other potential issues identified for LOADEST include poor model fit and heteroscedastic residuals (Hirsch 2014). Finally, Park and Engel (2014) found that the results from LOADEST were no more accurate or precise than loads estimated simply from flow and concentration data.

In acknowledgement of the uncertainty inherent in data measurement, the loading calculations were repeated using monthly water quality values ±20%. The value of ±20% was selected, because it corresponds to the criterion often used by commercial laboratories to identify notable results among split or duplicate samples. Differences less than 20% are not flagged as quality control issues that require attention, and are reflective of acceptable levels of variability in reported measurements.

Temporal Patterns

Intra-annual, seasonal patterns in TN and TP loads were assessed in a similar manner to concentrations. Summary statistics (i.e., mean and standard deviation) were calculated by season for each station in 2013, the year with the most complete dataset; data were also plotted by season and then assessed visually. Observed patterns were then checked against seasonal patterns observed in the TN and TP concentration data, to determine if seasonality in nutrient concentrations were reflected in the loads. Loads for 2013 were compared against 2012 information (i.e., the next most complete dataset), where possible, for the river mainstem. This step was completed to identify whether seasonal patterns observed in 2013 were unique or similar to patterns observed in other years.

Longer-term temporal patterns in TN and TP loads over the period of 1995 to 2014 were evaluated using a modified Mann-Kendall trend analysis accounting for seasonality (Systat 2009). The trend analysis was completed based on measurements reported for the terminal station near Bindloss. Reflective of the TP and TN water quality data, TN and TP load data in the Red Deer River were found to be not normally distributed ($p < 0.001$). Therefore, non-parametric Mann-Kendall, Seasonal Mann-Kendall, and modified Mann-Kendall tests (Gilbert 1987) were considered appropriate. Data were tested for autocorrelation. Because both TN and TP load data were found to be auto-correlated, the modified Mann-Kendall test was used to account for autocorrelation without any loss of power (Hamed and Rao 1998).

Spatial Patterns

The examination of spatial patterns focussed on the year of interest that had the most complete TN and TP datasets (i.e., 2013; Table 2.1-2). Results of the in-stream load calculations were tabularized, and annual loads (kg/yr) were plotted for each station along the Red Deer River mainstem (i.e., data were evaluated from upstream to downstream). Contributions from the various tributary streams to the river mainstem were also evaluated. This information was then used to characterize the loadings attributable to the various sub-basins within the Red Deer River watershed, to the extent possible.

2.1.2 Carrot River

2.1.2.1 Watershed Delineation

The Carrot River watershed has been described as a system of three sub-watersheds (SWA 2011). Two of these sub-watersheds, namely Carrot River East and Carrot River West, were represented in this study. The Lenore Lake sub-watershed was excluded from the study, because it is considered a non-contributing area (SWA 2011).

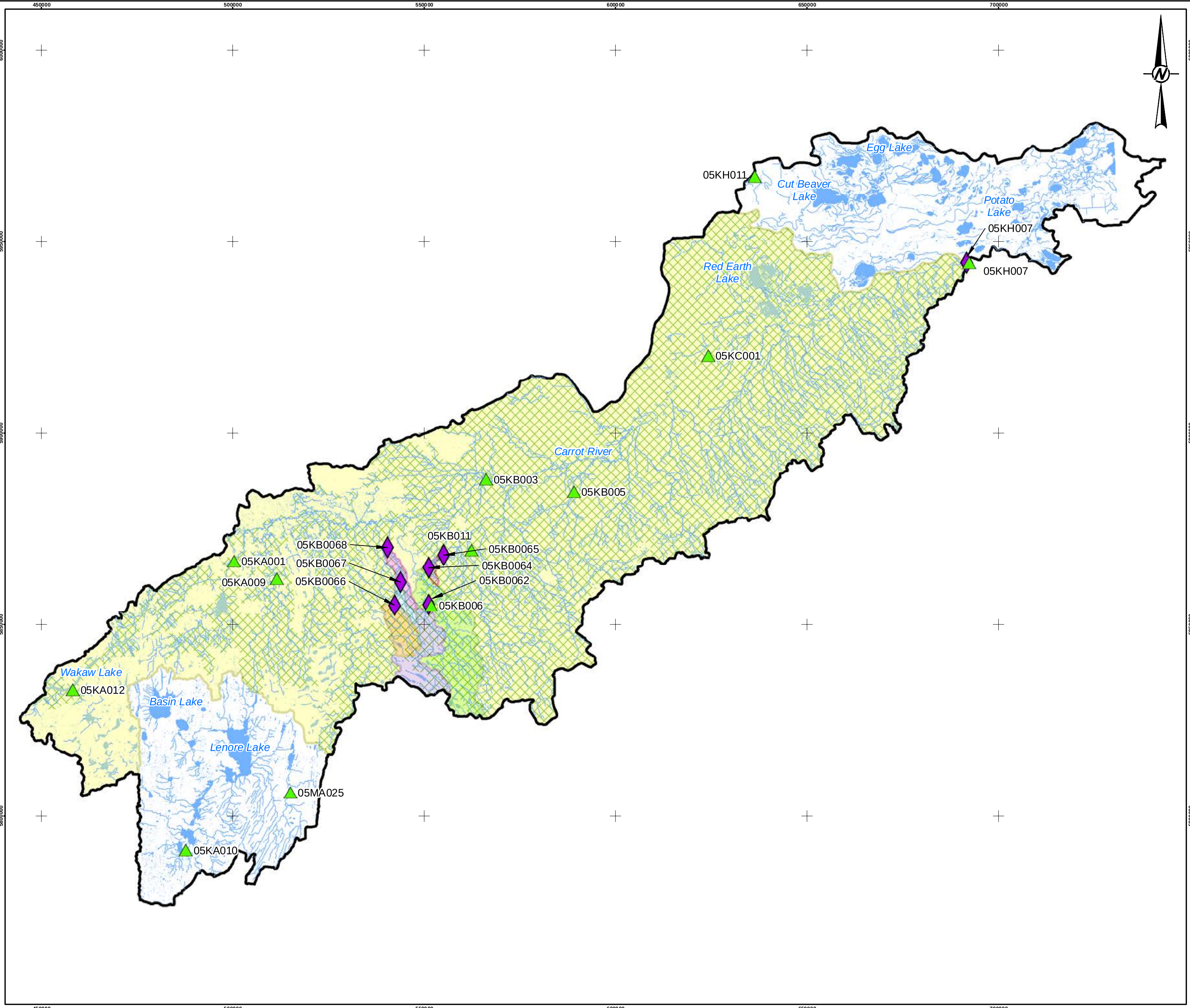
Based on the availability of nutrient data, the contributing areas associated with Carrot River East and Carrot River West were delineated into three sub-watershed:

- the Sweetwater Creek sub-watershed area
- the Leather River sub-watershed area
- other contributing areas

Nutrient data for Sweetwater Creek and the Leather River sub-watersheds were available as a result of sampling completed in support of the Saskatchewan Ministry of Agriculture and Saskatchewan Ministry of Environment (MOE) Intensive Livestock Operations' Monitoring Program (Davies and Hanley 2010). Sparse amounts of information were available from the remaining areas of the watershed, with the exception of the terminal station near Turnberry.

The size of each sub-watershed and its associated GDA and EDA were estimated using data obtained from the WSC (Government of Canada 2016a) and AAFC (Government of Canada 2016b). The data from the WSC and AAFC were used to estimate sub-watershed areas draining to each of the WSC stream flow monitoring stations (Section 2.1.2.2) and water quality monitoring stations (Section 2.1.2.3). Data compiled for the PFRA (Government of Canada 2016c) and stream network and topographical features were used to confirm or refine the GDAs and EDAs for the various sub-watersheds, as appropriate.

The final sub-watershed and watershed boundaries, along with associated nutrient and flow monitoring stations, are illustrated in Figure 2.1-2. The GDA for the area of the Carrot River located upstream of the terminal station near Turnberry is approximately 13,000 km^2; the EDA is approximately 11,000 km^2, which is equivalent to approximately 85% of the GDA.



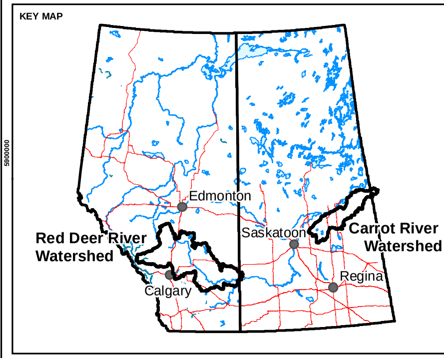
LEGEND

- WATER QUALITY STATION
- FLOW STATION LOCATION
- STREAM NETWORK
- WATERBODY
- CARROT RIVER WATERSHED
- EFFECTIVE DRAINAGE AREA

SUB-WATERSHED BOUNDARY BY WATER QUALITY STATION

- SK05KB0062
- SK05KB0064
- SK05KB0065
- SK05KB0066
- SK05KB0067
- SK05KB0068
- SK05KH007

KEY MAP



0 25 50

KILOMETRES

REFERENCE(S)

1. CROP INVENTORY 2013, AGRICULTURE AND AGRI-FOOD CANADA; CANADA OPEN DATA 2015
2. PFRA-BASED WATERSHEDS 2013, AGRICULTURE AND AGRI-FOOD CANADA; CANADA OPEN DATA 2015
3. NATIONAL TOPOGRAPHIC DATA BASE (NTDB) DATA: © DEPARTMENT OF NATURAL RESOURCES CANADA, 2007.
4. CANVEC BASE DATA © DEPARTMENT OF NATURAL RESOURCES CANADA, 2012. ALL RIGHTS RESERVED.

NAD 83 UTM ZONE 13

CLIENT

PRAIRIE PROVINCE WATER BOARD

PROJECT

QUANTIFICATION OF NUTRIENT SOURCES IN PRAIRIE RIVERS

TITLE

SUB-WATERSHED BOUNDARIES AND MONITORING STATIONS IN THE CARROT RIVER WATERSHED

CONSULTANT

Golder Associates

YYYY-MM-DD	2019-05-10
DESIGNED	AW
PREPARED	SG/AA
REVIEWED	CP
APPROVED	JP

PROJECT NO.	PHASE	REV.	FIGURE
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2.1.2.2 Water Flow

Historical discharge data recorded at hydrometric stations in the Carrot River watershed were obtained from WSC (Government of Canada 2016a) and are summarized in Appendix A, Figure A2 and Table A4. Individual WSC stations were preferentially selected for inclusion in the assessment based on their proximity to water quality stations of interest (Section 2.1.2.3), completeness of the available datasets, and the period over which data were recorded.

Locations of hydrometric stations that were used to estimate monthly flows at water quality stations in the Carrot River watershed are shown in Figure 2.1-2, with station details provided in Table 2.1-3. The numbers of stream flow measurements recorded at the selected stations for each season and year between 1995 and 2014 are summarized in Appendix A, Table A5.

Table 2.1–3: Hydrometric Stations used to Estimate Flows at Water Quality Stations in the Carrot River Watershed

Location[a]	Station Code	Station Name[b]	Latitude, Longitude	Period of Record[c]	Gross Drainage Area (km^2)	Effective Drainage Area (km^2)	
						Absolute (km^2)	Relative to GDA (%)
Leather River	05KB006	Leather River Near Star City	52°50'32" N, 104°14'24" W	1967-2015	162	121	75%
Carrot River	05KH007	Carrot River Near Turnberry[d]	53°36'49" N, 102°6'13" W	1966-2015	13,072	10,833	83%

(a) The Leather River flows into the Carrot River mainstem at a location upstream of the stream flow station near Turnberry.

(b) Station name as recorded in the Water Survey of Canada (WSC) database (Government of Canada 2016a). These stations are not regulated and currently monitor flow and level seasonally (Leather River) or year-round (Carrot River).

(c) The Period of Record corresponds to flow records available as of December 2015.

(d) Prairie Provinces Water Board (PPWB) station; stream flow and nutrient data are recorded at this station.

GDA = gross drainage area; EDA = effective drainage area; km^2 = square kilometres.

Daily mean discharges recorded at the hydrometric station on the Leather River (Table 2.1-3) were used to calculate monthly discharges for Sweetwater Creek and the Leather River. Peak flows in the Carrot River watershed typically occur during spring freshet in April, as a result of snowmelt. Winter flows (i.e., December through March) recede relative to flow conditions during the preceding fall, and are often negligible (Saskatchewan Ministry of Agriculture 2008). Consequently, most hydrometric stations in the Carrot River watershed, including at Station 05KB006 on the Leather River, do not record discharges in winter (i.e., January and February) or fall (i.e., as early as October or November and in December) (Government of Canada 2016a). To the extent possible, gaps in the available records were filled by:

- substituting discharge data for comparable stations (e.g., drainage area of a similar size and topography) located nearby;
- pro-rating flows according to watershed area; and
- linear interpolation between adjacent data points (Longabucco and Rafferty 1998).

Due to a paucity of sufficient, appropriate flow data, on the Leather River or nearby locations, missing years of data between 1998 and 2009, inclusive, could not be filled. Consequently, monthly flows could not be calculated for those years (Appendix A, Table A5).

The 1995 to 2014 time-series of daily flow data for the terminal station on the Carrot River near Turnberry was incomplete. Daily flow measurements were missing from April 2004, April 2005, part of June/July 2008, and part of April 2010. The missing daily flow values were interpolated using a one dimensional optimal interpolation (kriging) algorithm. Optimal interpolation is a weighted average; weights are applied to existing measurements at known times to predict an unknown value. The weights are derived from the timing between samples, and some measure of the correlation among the existing data.

A 6th-order polynomial was used to reflect the decrease in correlation between adjacent datapoints that occurs as time increases. Overfitting was not a concern as the regression results were not being used to extrapolate outside the range of the data, and were being applied to the same dataset the regression was being fit to.

The times between samples were calculated between all pairs of samples within one year (before and after) of the missing measurement, and those times used as predictors in the regression equation to derive the correlation coefficient for any given difference in sample time. The times between samples within one year of the missing measurement and the missing measurement itself were also determined. These two sets of times were used to calculate the weighting matrix, which was applied to the measured flow data within one year of the missing value to create the prediction for the missing flow value.

After performing the interpolation, a 100-sample, single replacement cross-validation was performed to estimate the accuracy of the interpolation. The cross-validation results for Carrot River included a coefficient of determination (R^2) of >0.99 and a root mean square error (RMSE) of 0.58 m^3/s. These predictions were due to the high cross-correlations between adjacent flow measurements.

Once the flow datasets were compiled, monthly flows were calculated for use in estimating in-stream loads. Seasonal flows were also estimated, using the same seasonal descriptions defined for the Red Deer River in Section 2.1.1.2. The seasons were organized to align with the annual spring sampling completed at the Saskatchewan Agriculture stations located on Sweetwater Creek and the Leather River (Section 2.1.2.3). Finally, annual flow volumes were calculated to characterize general flow condition by year, from 1995 to 2014.

2.1.2.3 Nutrient Concentrations

Data Compilation and Availability

Nutrient data for the Carrot River watershed were obtained from WSA (online data request) and PPWB (Klawunn, pers. comm 2015). A list of nutrient stations considered for inclusion in the study is included in Appendix A, Table A6. Data were collated and screened to focus the dataset on years between 1995 and 2014, following the approach used on the Red Deer River.

Once the WSA and PPWB datasets were screened to remove pre-1995 data, water quality were classified into seasons, as described previously for the Red Deer River (Section 2.1.1.3). Additional screening steps were then completed to identify stations for which both TN and TP data were reported, and to the extent possible, measured concurrently. Stations with at least five TN and five TP samples available within a given year were also flagged for further consideration as potential stations of interest for the detailed loading assessment. Reported TN concentrations were occasionally calculated, rather than measured; these values were retained in the dataset. However, no attempts were made to calculate TN from other nitrogen species if TN was not reported.

A total of seven stations were identified for inclusion of the dataset for the Carrot River watershed (Table 2.1-4). These include three stations on Sweetwater Creek, three stations on the Leather River, and the terminal station on the Carrot River mainstem near Turnberry (Figure 2.1-2). The nutrient sampling stations on Sweetwater Creek and the Leather River were included, because they had the most complete TN and TP datasets of those available. As previously noted, these dataset were developed in support of the Saskatchewan Ministry of Agriculture and MOE Intensive Livestock Operations' Monitoring Program (Davies and Hanley 2010).

The availability of TN and TP data for the selected stations is summarized in Table 2.1-4 for the years 1995 through 2014. Numbers of samples collected at each station during each season (i.e., winter, spring, summer, and fall) and year are provided in Appendix A, Table A5.

Table 2.1–4: Summary of Information Available at Selected Nutrient Stations in the Carrot River Watershed

Location[a]	Station Code	Station Name[b]	Latitude, Longitude	Year																			
				1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Tributaries																							
Sweetwater Creek	SK05KB0066	Sweetwater Ck.- Stn LRSC-5	52°57'37"N, 104°10'50"W	-	-	-	TP[c]	TP[d]	TP[d]	-	-	-	-	TP[c]	TP[c]	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-
	SK05KB0067	Sweetwater Ck.- Stn LRSC-6	52°53'50"N, 104°20'55"W	-	-	-	-	TP[d]	TP[d]	-	-	-	-	TP[c]	TP[c]	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-
	SK05KB0068	Sweetwater Ck.- Stn LRSC-7	52°58'44"N, 104°23'53"W	-	-	-	TP[c]	TP[d]	TP[d]	-	-	-	TP[c]	TP[c]	TP[c]	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-
Leather River	SK05KB0062	Leather R.-Stn LRSC-1 7.5 mi W. of Tisdale on Hwy#3	52°50'39"N, 104°14'27"W	-	-	-	TP[c]	TP[d]	TP[d]	-	-	-	TP[c]	TP[c]	TP[c]	TP[c]	TN[c], TP[c]	TN[c], TP[c]	-	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-
	SK05KB0064	Leather R-Stn LRSC-3 5mi W.6mi N.&2.6mi W. Tisdale	52°55'52"N, 104°14'21"W	-	-	-	TP[c]	TP[d]	TP[d]	-	-	-	TP[c]	TP[c]	TP[c]	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-
	SK05KB0065	Leather R.-Stn LRSC-4 5mi W. & 8mi N. of Tisdale	52°57'37"N, 104°10'50"W	-	-	-	TP[c]	TP[d]	TP[d]	-	-	-	TP[c]	TP[c]	TP[c]	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-	TN[c], TP[c]	TN[c], TP[c]	TN[c], TP[c]	-
Mainstem																							
Carrot River	SK05KH007	Carrot River near Turnberry	53°36'49" N, 102°6'13" W	TN, TP	TN, TP	TN[e], TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN[e], TP	TN[e], TP[e]	TN, TP	TN, TP	TN, TP	TN, TP	TN, TP	TN[e], TP[e]	TN, TP

(a) Tributaries are listed based on the location of their confluence with the Carrot River; mainstem stations are listed in order, from upstream to downstream along the Carrot River.

(b) Station name as recorded in the provincial database.

(c) No data were reported for winter, summer, and fall.

(d) No data were reported for spring, summer, and fall.

(e) At least one measurement was missing in the winter data.

- = no TN or TP data were available; TN = total nitrogen data were available; TP = total phosphorus data were available.

TN concentration data were not available for Sweetwater Creek and the Leather River for the years 1995 through 2006 and in 2010 and 2014. Total phosphorus concentrations were reported more frequently over the same time period; however, TP data were unavailable for the years 1995 through 1997, 2001 through 2003, 2010, and 2014. In these two tributaries, nutrient data were generally limited to one sample per year, with the exception of TN at Station SK05KB0064 (Leather River) in 2007 (2 samples) and TP at the same location in 1998 (2 samples) (Appendix A, Table A5). Because sampling was completed annually, the collected data only represent one season, typically spring.

The long-term water quality and flow station near Turnberry is maintained by the PPWB and was included as a primary station of interest for this study. This station has long-term data records that include the years 1995 through 2014 and align with the available land cover data (Section 4.0). Water samples were collected on a near monthly schedule and flows were recorded daily (Table 2.1-4; Appendix A, Table A5).

Once the available data were compiled and screened, TN or TP concentrations that were below the limits of detection were set equal to the detection limit. In Sweetwater Creek and the Leather River, nutrient data were so sparse that missing data could not be reliably estimated or substituted.

At the terminal station, at least one monthly TN measurement was missing for the winters of 1997, 2006, 2007, and 2013; some TP data were missing for the winters of 1997 and 2013. As in the Red Deer River, these gaps were filled using a multiple regression approach. The same multiple regression predictors were used (i.e., flow and date).

Temporal and Spatial Patterns

Seasonal and longer-term temporal patterns in TN and TP concentrations were assessed using data reported for the terminal station near Turnberry. The methods used were similar to those used on the Red Deer River. Seasonal patterns were assessed based on measurements collected during 2013, the year with the most complete dataset. Summary statistics (i.e., mean and standard deviation) were calculated, data were plotted and observed patterns were checked against information from other years, where possible, to identify if seasonal patterns observed in 2013 were unique or similar to those in other years.

Longer-term temporal patterns in TN and TP concentrations between 1995 and 2014 were evaluated using a modified Mann-Kendall trend analysis accounting for seasonality (Systat 2009). Because water chemistry can be affected by river discharge, linear regression analyses were performed (Systat 2007) on log-transformed flow and log-transformed TN and TP concentration data, respectively. Subsequently, flow-adjusted trend analyses were performed using the modified Mann-Kendall tests with residuals obtained from the linear regression analyses in a similar fashion to the approach used by USEPA (2011) and PPWB (2016).

The examination of spatial patterns focussed on data from 2013, consistent with the approach used in the Red Deer River. However, because tributary data were only available for one season per year and there was limited information available along the length of the Carrot River, the examination of potential spatial patterns in the TN and TP concentrations was constrained. Available data were plotted in an upstream-to-downstream orientation and visually examined.

2.1.2.4 Nutrient Loads

Estimating In-Stream Loads

At the terminal station near Turnberry, discharge and nutrient concentration data were used to calculate daily, seasonal and annual TN and TP loads following the approach outlined above in Section 2.1.1.4.

At other locations of interest, a different approach was used. Loads in winter, summer, and fall could not be calculated, because concentration data were not available. TN and TP loads in spring were calculated as follows:

- Discharge data (m^3/s) were converted to units of cubic metres per day (m^3/d), and then summed to estimate monthly (m^3/month) and seasonal (m^3/season) flows.
- Spring concentration values (mg/L) were multiplied by the corresponding spring flows to estimate spring loads in units of kilograms per season (kg/season).

If flow was not measured at the water quality station in question, flow was pro-rated from the closest WSC stream flow monitoring station, based on the ratio between the EDA for the water quality station of interest and that of its paired stream flow station (Cole 2013). This step was not necessary for the terminal station near Turnberry, because stream flow and water quality monitoring stations were co-located.

The approach of calculating a seasonal load estimate based on seasonal flows multiplied by a single concentration measurement results in the production of loading estimates with greater levels of uncertainty, in comparison to those generated using multiple water quality values. Data were interpreted with this limitation in mind.

As in the Red Deer River, TN and TP loading calculations were repeated using monthly water quality values ±20% in acknowledgment of the uncertainty inherent in data measurement.

Temporal and Spatial Patterns

As with concentrations, seasonal and longer-term patterns in loads were assessed using data from the terminal station near Turnberry. Data for the terminal station were plotted and qualitative intra-annual comparisons were made based on visual examination of the data. Longer-term temporal trends were assessed using a modified Mann-Kendall trend analysis accounting for seasonality (Systat 2009).

The examination of spatial patterns focussed on conditions in spring 2013. Calculated loads were plotted in an upstream-to-downstream orientation and visually examined to identify the relative contributions of Sweetwater Creek and the Leather River to the Carrot River mainstem.

2.2 Results and Discussion

2.2.1 Red Deer River

2.2.1.1 Water Flow

Total annual flow volumes (cubic decametres; dam^3) recorded at the terminal station on the Red Deer River near Bindloss between 1995 and 2014 are shown in Table 2.2-1 and in Figure 2.2-1. If the annual flow volume reaching the terminal PPWB station exceeded the 75th percentile over the historical flow record (i.e., 1961 to 2014), it was considered a high flow year. If the annual flow volume was less than the 25th percentile over the historical record, it was considered a low flow year.

Table 2.2–1: Total Annual Flow Volumes for the Terminal Stream Flow Station on the Red Deer River near Bindloss

Year	Total annual flow volume (dam^3)	Classification[(a)]	Rank[(b)]
1995	2,030,426	moderate	9
1996	1,929,191	moderate	10
1997	2,486,102	moderate	6
1998	1,886,642	moderate	12
1999	2,272,510	moderate	7
2000	1,211,138	<25th percentile	17[(d)]
2001	914,350	<25th percentile	19
2002	903,079	<25th percentile	20
2003	1,666,598	moderate	13
2004	1,241,170	<25th percentile	16
2005	3,025,668	>75th percentile	1
2006	1,605,070	moderate	15
2007	2,876,265	>75th percentile	2
2008	2,100,860	moderate	8
2009	1,066,952	<25th percentile	18[(c)]
2010	1,626,886	moderate	14[(d)]
2011	2,844,668	>75th percentile	3[(d)]
2012	1,907,349	moderate	11[(c)]
2013	2,560,404	>75th percentile	5[(c)]
2014	2,609,971	>75th percentile	4

(a) Indicates whether a flow volume was below the 25th percentile (i.e., low), between the 25th and 75th percentiles (i.e., moderate) or higher than the 75th percentile (high), as calculated using the 1961 to 2014 flow record.

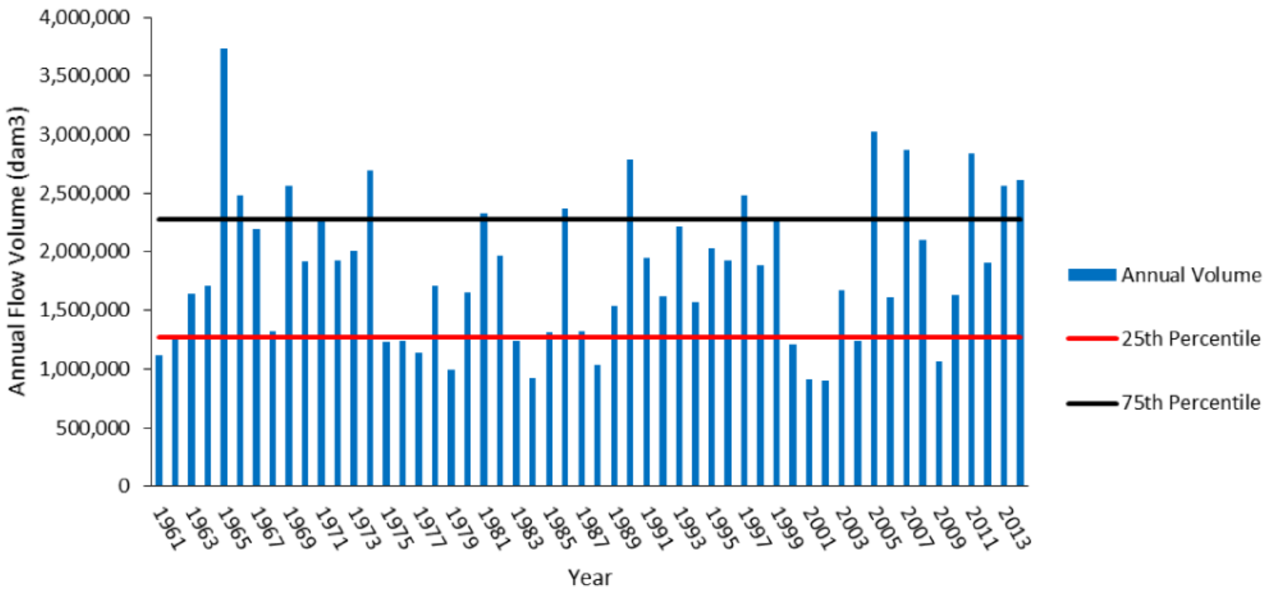
(b) Years were ranked from highest to lowest flow volume.

(c) Indicates years of data used for calibration in watershed loading analysis.

(d) Indicates years of data used for validation in watershed loading analysis.

dam^3 = cubic decametres; >= greater than; <= less than.

Figure 2.2-1: Historical Annual Flow Volumes Used to Estimate the 25th and 75th Percentile Flows for the Red Deer River at Bindloss



dam^3 = cubic decametres.

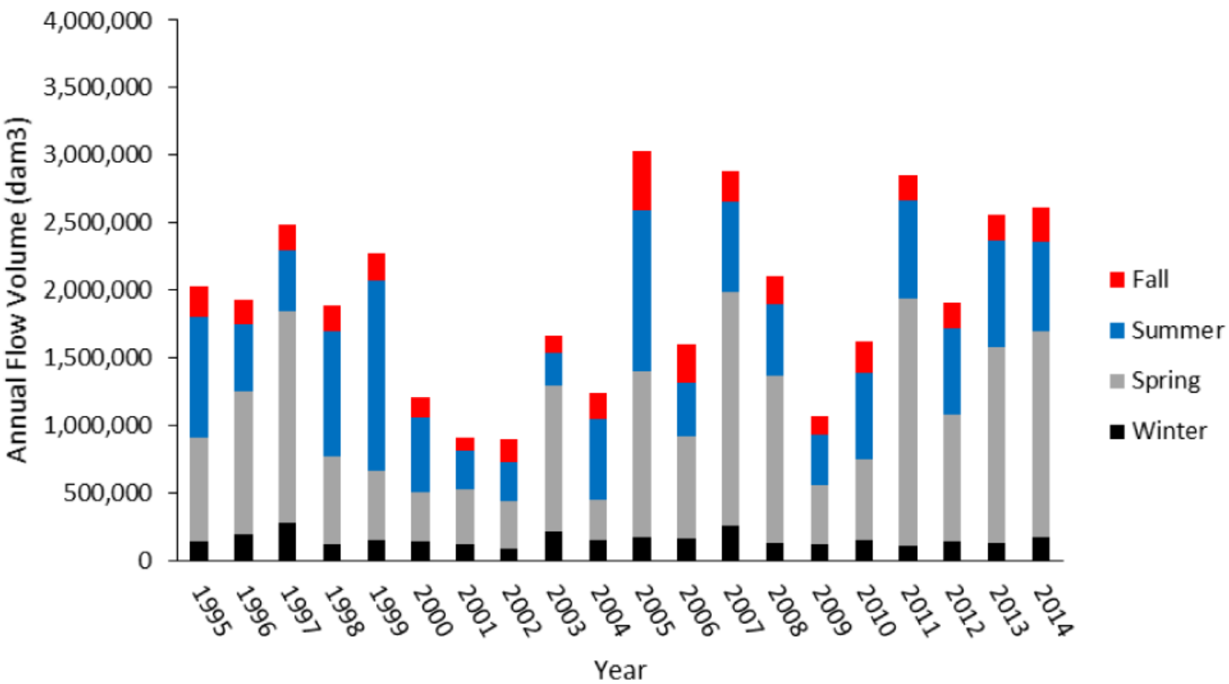
The year 2002 (903,079 dam^3) was the lowest flow year on record between 1961 and 2014; the total annual flow volume in 2002 was equal to roughly one quarter (i.e., 24%) of the annual flow volume in 1965 (3,737,322 dam^3), the highest flow year on record (Figure 2.2-1). The highest annual flow volume recorded between 1995 and 2014 occurred in 2005 (3,025,668 dam^3). It was approximately three times higher than the volume recorded in 2002 (Table 2.2-1). In the past 10 years, only one year (2009) was identified as being in the lower 25th percentile of recorded flows. Other years between 2005 and 2014 were either moderate or high flow years, relative to the entire period of record.

Despite differences in annual flow volumes, seasonal flow patterns were similar among years, as observed at the terminal station near Bindloss (Figure 2.2-2). Flows were typically greatest during spring, followed by summer. Flows in fall and winter were generally comparable (i.e., changed relatively little over time from fall to the end of winter), and were much lower compared to spring and summer.

Similar seasonal flow patterns occurred elsewhere in the watershed, as illustrated in Figure 2.2-3. Flow volumes in tributaries and along the river mainstem were largest in spring, followed by summer; flow volumes were comparable in fall and winter, albeit lower than in spring and summer.

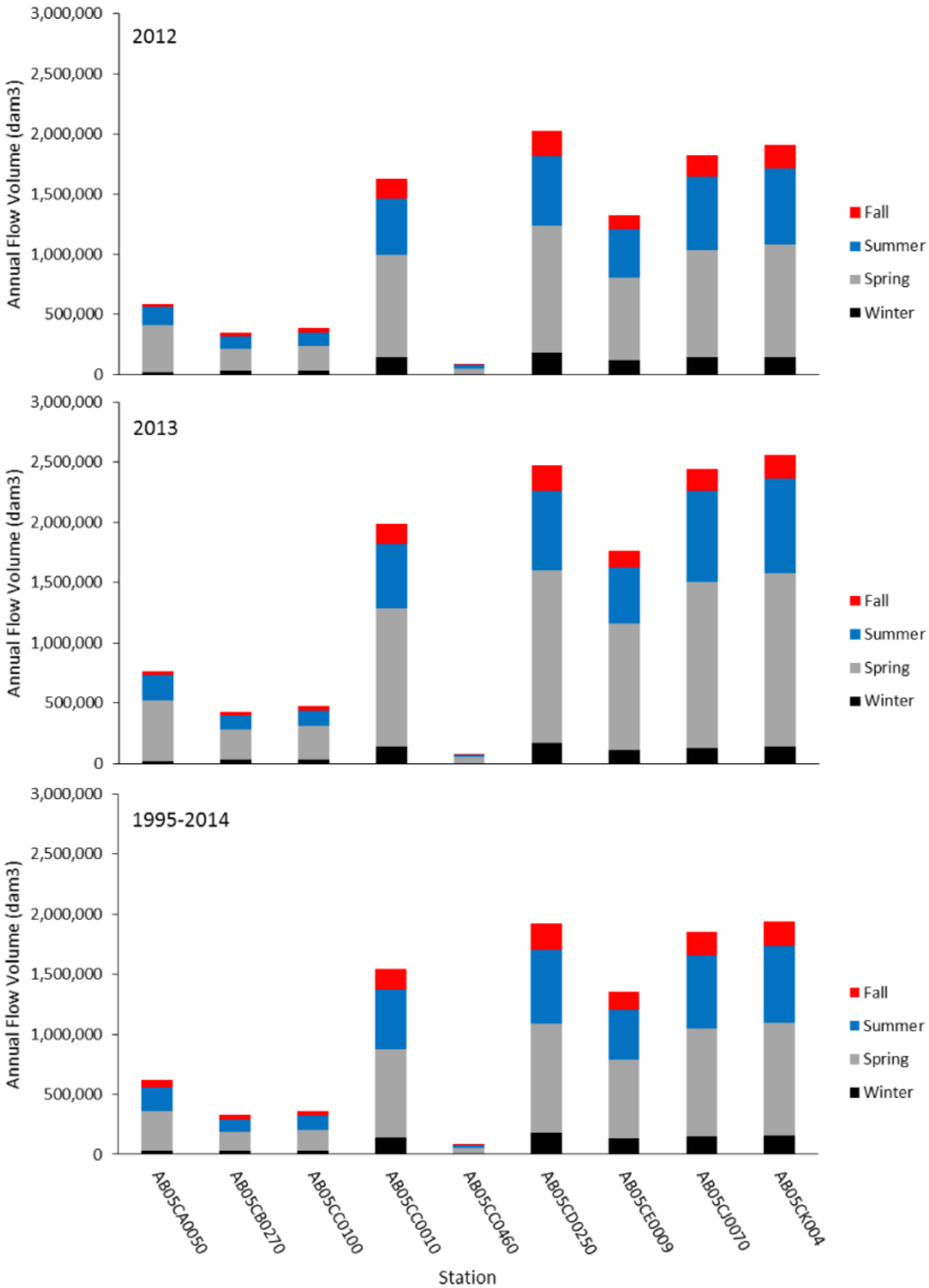
Flows from the Little Red Deer and Medicine rivers were similar, representing approximately 17 to 18% and 18 to 20%, respectively, of the in-stream flows arriving at Bindloss (Table 2.2-2). Flows in these two tributaries were larger than those in the Blindman River, which contributed, on average, approximately 4% of the flow volume reaching Bindloss (Table 2.2-2).

Figure 2.2-2: Annual Flow Volumes by Season for the Red Deer River at Bindloss, 1995 through 2014



dam^3 = cubic decametres.

Figure 2.2-3: Annual Flow Volumes by Season for Selected Nutrient Stations in the Red Deer River Watershed, 2012, 2013 and Annual Average Flow Volumes from 1995-2014



dam^3 = cubic decametres.

Most of the water flowing through the Red Deer River mainstem originates from the upper watershed, entering the mainstem between Sundre (AB05CA0050) and the City of Red Deer (AB05CC0010) (Table 2.2-2). The volume of water that is accumulated through the remaining two thirds of the watershed, between the City of Red Deer and the Water Survey of Canada (WSC) monitoring station at Bindloss at the Alberta-Saskatchewan border, represents only about 20 percent (%) of the total flow volume (O2 et al. 2013).

Flows through the Red Deer River mainstem are affected by the following activities, particularly downstream of the City of Red Deer:

- transfer of water among waterbodies and watercourses (i.e., for the maintenance of water levels)
- licenced agricultural (e.g., irrigation), municipal, and commercial withdrawals
- discharge of return flows from licenced users

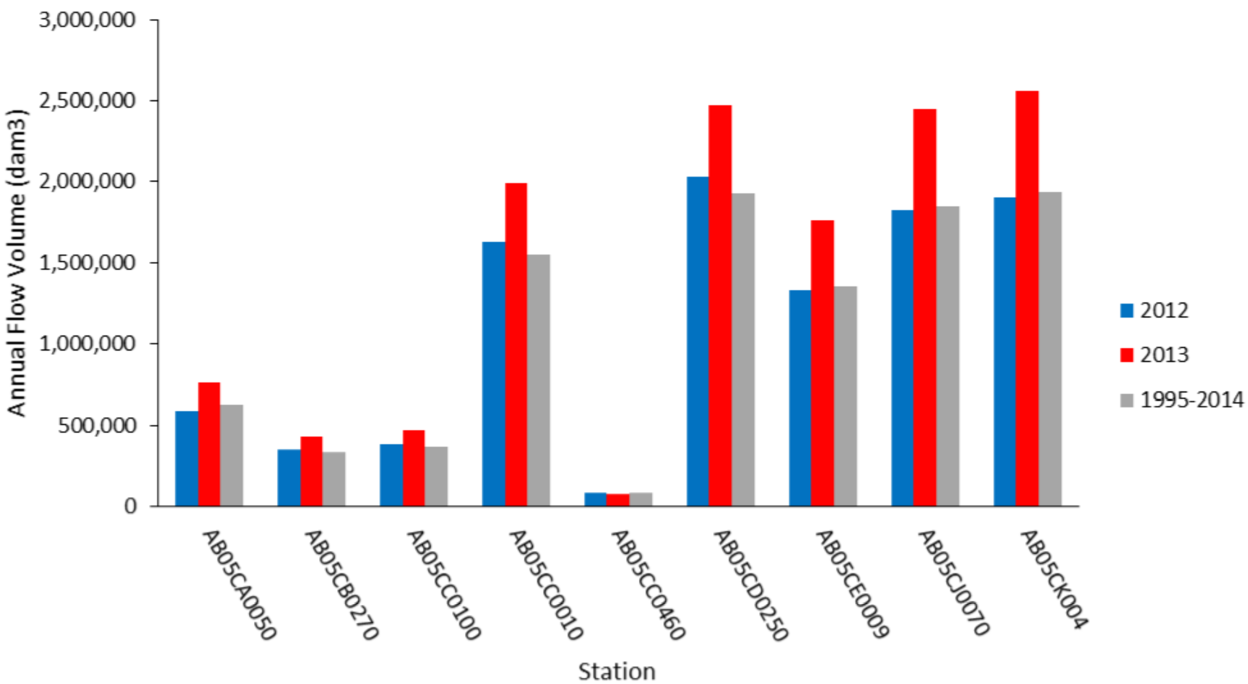
For example, water is pumped from the Red Deer River mainstem to stabilize water levels in Buffalo Lake (O2 et al. 2013). Water for Buffalo Lake is withdrawn from the Red Deer River just upstream of Nevis (AB05CD0250) (Buffalo Lake Management Team 2010). Water returns to the Red Deer River via Tail Creek, which flows into the Red Deer River immediately downstream of Nevis. In the past (i.e., as recently as 2011), water has also been pumped from the Blindman River to maintain water levels in Gull Lake (O2 et al. 2013).

The amount of water allocated to licenced users in the Red Deer River watershed is reported to be 335,000 dam^3 per year, of which only about 60,000 dam^3 (or ~20%) is returned to the river (O2 et al. 2013). Water withdrawn from the river is used for irrigation, other agricultural purposes, and commercial use; these withdrawals represented approximately 20%, 15%, and 14%, respectively, of the water allocation budget for the Red Deer River watershed in 2000 (RDRWA 2007).

Water diversions and return flows estimated by AMEC (2014) for private irrigation systems, municipal users, and other purposes indicate that approximately 150,710 dam^3 is diverted from the river mainstem and tributaries upstream of Delburne, which is approximately 22 km upstream of Nevis (AB05CD0250). Most of the water is diverted for “other” uses (i.e., approximately 62%), followed by municipal uses (36%) and irrigation (2%). Return flows for this section of the river are estimated at 37,876 dam^3, based on the data from AMEC (2014), and are comprised primarily of wastewater discharges.

The long-term (i.e., 20 year) dataset indicates a consistent decrease in annual flow volumes between Nevis (AB05CD0250) and Morrin (AB05CE0009), with a subsequent return near Jenner (Figures 2.2-3, 2.2-4). The decrease between Nevis and Morrin occurs despite an increase in drainage area with increasing distance downstream (Table 2.2-3) and the presence of point sources within the immediate sub-watershed. Publicly-available water allocation and use data were unavailable to fully explain the apparent loss of water. Available information between Delburne and Drumheller, which are 22 km upstream of Nevis and 25 km downstream of Morrin, respectively, indicate the presence of withdrawals in the order of 100,000 dam^3 with no return flow, at least to this section of the river mainstem (Alberta Environment 2003; AMEC 2014). However, the long-term flow record suggests the removal of upwards of 500,000 dam^3 of water, with the majority of the water returning to the Red Deer River between Morrin and Jenner. Given the arid nature of the immediate sub-watershed, the diversion is most likely associated with agricultural activity, with both the Eastern and Western Irrigation Districts returning flow to the river between Morrin and Jenner (RDRWA 2016).

Figure 2.2-4: Annual Flow Volumes for Selected Nutrient Stations in the Red Deer River Watershed, 2012, 2013, and 1995-2014



dam^3 = cubic decametres.

Table 2.2–2: Total Annual Flow Volumes at Selected Nutrient Stations in the Red Deer River Watershed

Location[a]	Station Code	2012		2013		1995-2014	
		Total Annual Flow Volume (dam^3)	Total Relative to Terminal Station (%)[b]	Total Annual Flow Volume (dam^3)	Total Relative to Terminal Station (%)[b]	Total Annual Flow Volume (dam^3)	Total Relative to Terminal Station (%)[b]
Tributaries							
Little Red Deer River	AB05CB0270	350,891	18	428,479	17	333,189	17
Medicine River	AB05CC0100	385,780	20	471,083	18	366,318	19
Blindman River	AB05CC0460	84,774	4	76,840	3	85,132	4
Mainstem							
Red Deer River	AB05CA0050	589,391	31	763,040	30	624,259	32
	AB05CC0010	1,629,505	85	1,989,819	78	1,547,300	80
	AB05CD0250	2,027,522	106	2,475,845	97	1,925,238	99
	AB05CE0009	1,328,854	70	1,762,977	69	1,352,016	70
	AB05CJ0070	1,821,876	96	2,445,665	96	1,851,406	96
	AB05CK004	1,907,548	100	2,560,404	100	1,938,467	100

(a) Stations are listed in order, from upstream to downstream along the Red Deer River mainstem; tributaries are included in the list.

(b) Flows are cumulative along the length of the Red Deer River mainstem.

dam^3 = cubic decametres;% = percent.

Table 2.2–3: Gross and Effective Drainage Areas for Selected Nutrient Stations in the Red Deer River Watershed

Location[(a)]	Station Code	Gross Drainage Area (ha)		Effective Drainage Area (ha)	
		Cumulative[(b)]	Sub-watershed[(c)]	Cumulative[(b)]	Sub-watershed[(c)]
Tributaries					
Little Red Deer River	AB05CB0270	257,007	257,007	242,777	242,777
Medicine River	AB05CC0100	276,279	276,279	266,917	266,917
Blindman River	AB05CC0460	178,641	178,641	172,494	172,494
Mainstem					
Red Deer River	AB05CA0050	321,545	321,545	321,545	321,545
	AB05CC0010	1,161,789	306,958	1,127,435	296,196
	AB05CD0250	1,515,596	175,166	1,402,819	102,890
	AB05CE0009	1,885,840	370,244	1,576,808	173,989
	AB05CJ0070	4,424,223	2,538,383	2,908,354	1,331,546
	AB05CK004	4,799,134	374,912	3,045,118	136,764

(a) Stations are listed in order, from upstream to downstream along the Red Deer River mainstem; tributaries are included in the list.

(b) Areas are cumulative along the length of the Red Deer River mainstem.

(c) Areas are for the immediate sub-watershed only (i.e., are not cumulative).

ha = hectares.

2.2.1.2 Nutrient Concentrations

Temporal Patterns

Based on data from 2013, TN concentrations tend to peak in the Red Deer River watershed in spring, in both tributaries and in the river mainstem (Tables 2.2-4 and 2.2-5). In the Little Red Deer, Medicine, and Blindman rivers, summer TN concentrations were higher than those observed in winter and fall, although data for these latter two periods were limited. A similar pattern was not observed in the river mainstem; summer concentrations were lower than those in winter or fall at some locations in some years, but the reverse was also observed (Table 2.2-5).

Table 2.2–4: Total Nitrogen and Total Phosphorus Concentrations at Water Quality Stations on Tributaries to the Red Deer River, 2013

Location	Station	Average Concentration ± SD (mg/L)			
		Winter[(a)]	Spring	Summer	Fall
Total Nitrogen (TN)					
Little Red Deer River	AB05CB0270	0.12 (n=1)	1.2 ± 0.39 (n=7)	0.33 ± 0.08 (n=3)	0.12 (n=1)
Medicine River	AB05CC0100	0.54 (n=1)	1.6 ± 0.23 (n=5)	0.80 ± 0.17 (n=3)	0.54 (n=1)
Blindman River	AB05CC0460	0.61 (n=1)	1.7 ± 0.55 (n=6)	1.2 ± 0.56 (n=3)	0.61 (n=1)
Total Phosphorus (TP)					
Little Red Deer River	AB05CB0270	0.004 (n=1)	0.25 ± 0.17 (n=7)	0.02 ± 0.01 (n=3)	0.004 (n=1)
Medicine River	AB05CC0100	0.06 (n=1)	0.14 ± 0.04 (n=5)	0.05 ± 0.02 (n=3)	0.06 (n=1)
Blindman River	AB05CC0460	0.02 (n=1)	0.21 ± 0.10 (n=6)	0.16 ± 0.08 (n=3)	0.02 (n=1)

(a) No data were available for winter 2013; therefore, fall data were used to simulate winter concentrations.

± = plus or minus; SD = standard deviation; mg/L = milligrams per litre; n = number of samples.

Table 2.2–5: Total Nitrogen and Total Phosphorus Concentrations at Water Quality Stations on the Mainstem of the Red Deer River, 2012 and 2013

Station	Average Concentration ± SD (mg/L)[a]							
	2012				2013			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Total Nitrogen (TN)								
AB05CA0050	-	-	-	0.23 ± 0.10	0.22 ± 0.03	0.49 ± 0.27	0.19 ± 0.05	0.26 ± 0.11
AB05CC0010	0.24 ± 0.43	0.89 ± 0.53	0.21 ± 0.07	0.16 ± 0.02	0.21 ± 0.04	0.91 ± 0.77	0.26 ± 0.13	0.15 ± 0.10
AB05CD0250	0.63 ± 0.03	1.3 ± 0.85	0.36 ± 0.18	0.67 ± 0.23	0.70 ± 0.10	1.0 ± 0.86	0.34 ± 0.18	0.57 ± 0.23
AB05CE0009	0.75 ± 0.12	1.5 ± 0.95	0.88 ± 1.1	0.78 ± 0.37	0.87 ± 0.20	1.2 ± 0.9	0.29 ± 0.20	0.53 ± 0.28
AB05CJ0070	0.66 ± 0.09	1.8 ± 1.1	0.35 ± 0.13	0.90 ± 0.08	0.74 ± 0.10	1.4 ± 1.1	0.56 ± 0.08	0.63 ± 0.24
AB05CK004	0.73 ± 0.20	2.5 ± 0.31	1.5 ± 1.5	0.82 ± 0.06	0.73 ± 0.04	2.2 ± 0.49	0.74 ± 0.39	0.90 ± 0.63
Total Phosphorus (TP)								
AB05CA0050	-	-	-	0.005 ± 0.002	0.003 ± 0.000	0.14 ± 0.21	0.03 ± 0.02	0.003 ± 0.0007
AB05CC0010	0.003 ± 0.0007	0.07 ± 0.06	0.01 ± 0.008	0.005 ± 0.001	0.003 ± 0.0007	0.09 ± 0.09	0.03 ± 0.03	0.005 ± 0.002
AB05CD0250	0.003 ± 0.0007	0.12 ± 0.09	0.02 ± 0.01	0.009 ± 0.003	0.009 ± 0.003	0.09 ± 0.01	0.04 ± 0.05	0.01 ± 0.01
AB05CE0009	0.004 ± 0.0007	0.13 ± 0.10	0.44 ± 0.75	0.007 ± 0.002	0.01 ± 0.009	0.14 ± 0.15	0.05 ± 0.05	0.007 ± 0.002
AB05CJ0070	0.005 ± 0.001	0.39 ± 0.53	0.07 ± 0.04	0.04 ± 0.03	0.01 ± 0.01	0.24 ± 0.20	0.21 ± 0.07	0.02 ± 0.01
AB05CK004	0.02 ± 0.02	0.30 ± 0.20	0.34 ± 0.41	0.06 ± 0.02	0.01 ± 0.001	0.31 ± 0.09	0.24 ± 0.26	0.07 ± 0.07

(a) Sample number is three for all stations, seasons, and years that have data in the table.

± = plus or minus; SD = standard deviation; mg/L = milligrams per litre; - = no data.

TP concentrations recorded at the selected stations on the Red Deer River tributaries in 2013 were highest during spring, followed by summer; concentrations were lowest in winter and fall (Table 2.2-4). The observed patterns matched those reported by Cross (1991). The only exception was the Medicine River; in 2013, TP concentrations in the Medicine River remained fairly consistent throughout summer and fall.

TP concentrations recorded along the river mainstem in 2012 and 2013 similarly peaked during spring, consistent with information reported by the RDRWA (2009). Unlike TN, TP concentrations measured along the mainstem declined through summer and fall, and were lowest in winter (Table 2.2-5).

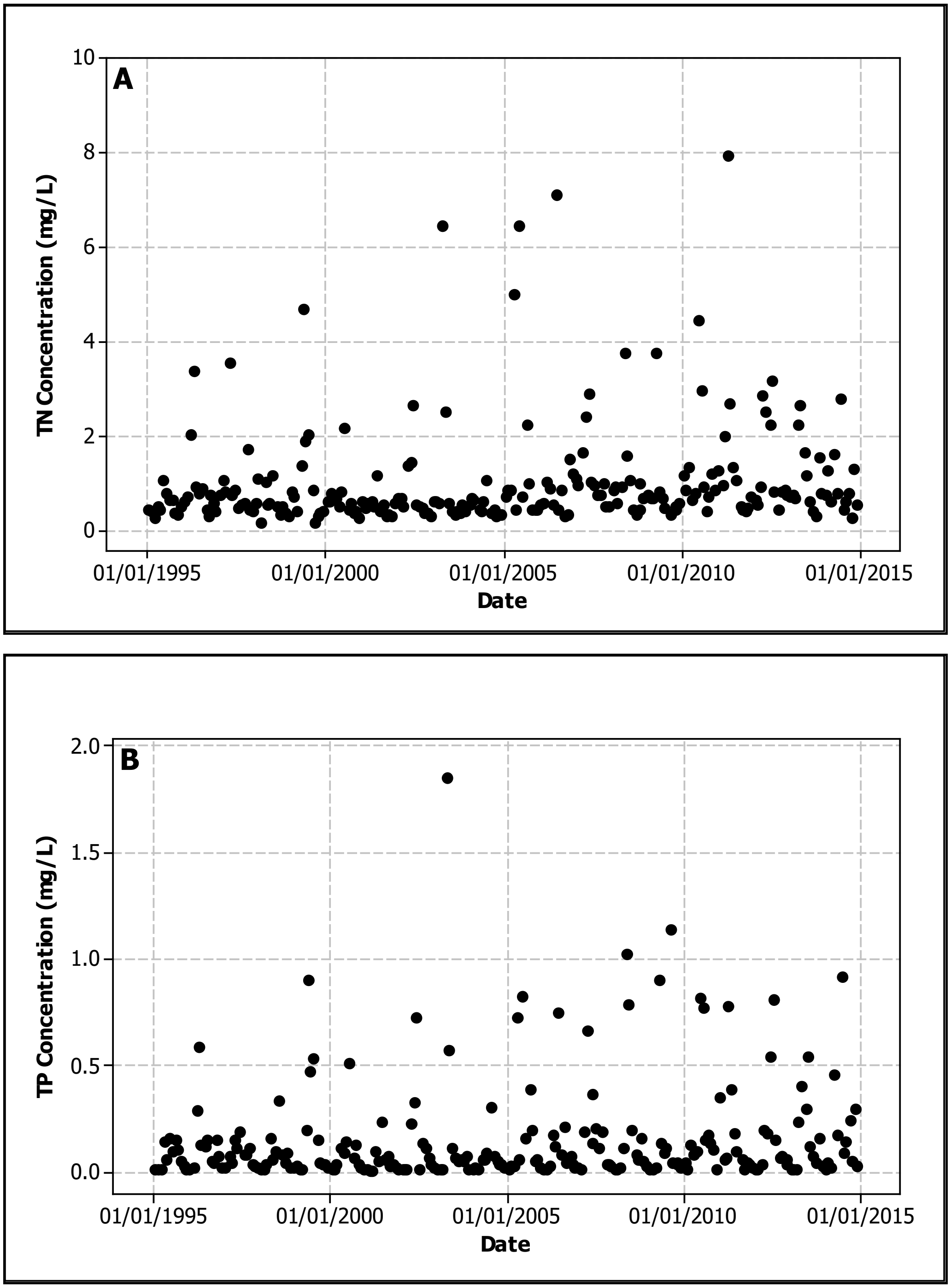
Results of the trend analysis indicate that unadjusted TN and TP concentrations have increased significantly over time between 1995 to 2014 (Figure 2.2-5, Table 2.2-6). The concentrations of both constituents were found to have significant positive relationships to flow (Figure 2.2-6), although the relationship between TP and flow was stronger that than of TN and flow (i.e., R^2 = 0.66 vs R^2 = 0.31) (Figure 2.2-6). Following application of the flow-adjustment technique described in Section 2.1.2.3, TN concentrations were still found to be increasing over time. In contrast, flow-adjusted trend analysis for TP indicated that there was no significant monotonic trend in TP concentrations over the period 1995 to 2014 (Table 2.2-6).

Table 2.2–6: Summary of Trend Analyses for Total Nitrogen and Total Phosphorus Concentrations in the Red Deer River near Bindloss, 1995 to 2014

Parameter	Test	Treatment	Sample Size	Z-Statistic	P – Value	Significant Trend[(a)]
Total Nitrogen (mg/L)	Modified Mann-Kendall	Unadjusted	240	2.77	**0.003**	↑ (0.015)
		Flow-adjusted	240	2.62	**0.004**	↑ (0.008)
Total Phosphorus (mg/L)	Modified Mann-Kendall	Unadjusted	240	2.57	**0.005**	↑ (0.001)
		Flow-adjusted	240	1.59	0.056	↔

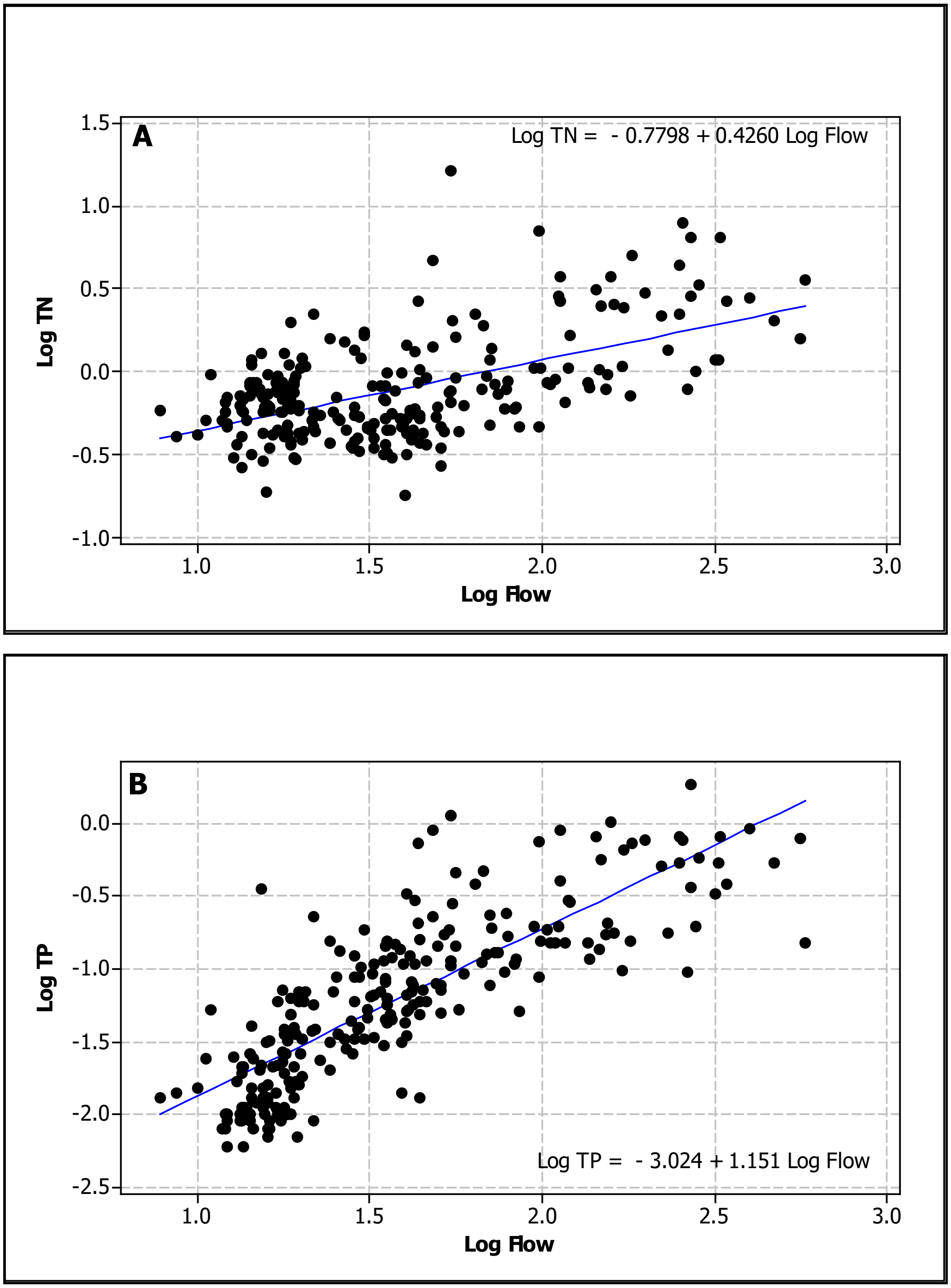
(a) ↑ = a statistically significant increasing trend, ↓ = a statistically significant decreasing trend, and ↔ = no significant trend. Slope estimate provided in parentheses when a significant trend identified; units are mg/L/yr.

Figure 2.2-5: Total Nitrogen and Total Phosphorus Concentrations in the Red Deer River near Bindloss, 1995 to 2014



Panel [A] =Total Nitrogen; Panel [B] = Total Phosphorus; mg/L = milligrams per litre. A single high total nitrogen value of 17 mg/L recorded in 2009 is not shown.

Figure 2.2-6: Linear Regression between Log-transformed Nutrient Concentrations and Log-transformed Flow in the Red Deer River near Bindloss, 1995 to 2014



Panel [A] =Total Nitrogen; Panel [B] = Total Phosphorus; mg/L = milligrams per litre.

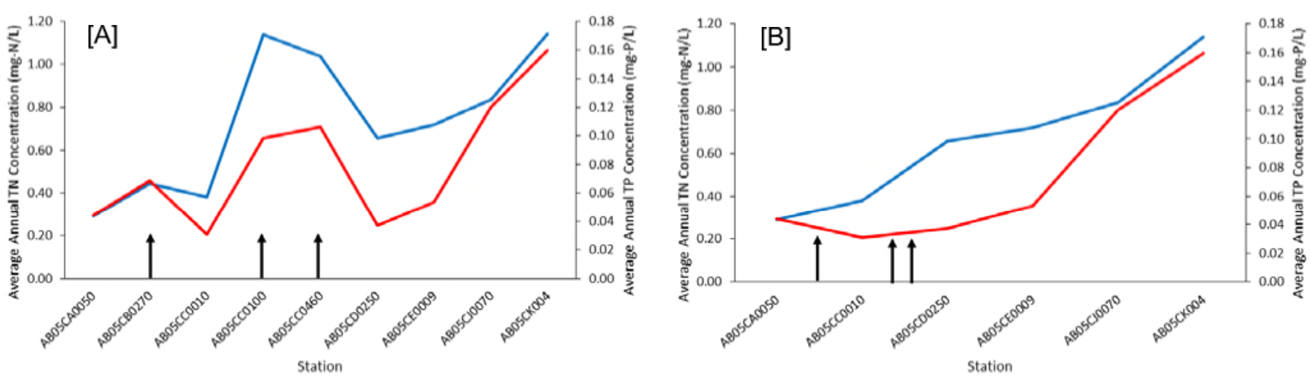
The significant increasing trends noted for unadjusted TN and TP concentrations match the findings of Burke (2016). Burke (2016) noted increasing TN and TP concentrations over time at the terminal station, although the correlation between measured values and time was considered weak. Burke's analysis was conducted on data from 1966 to 2010. No trend analyses were completed after adjusting for flow.

The results of the trend analyses completed using flow-adjusted data differ from those noted by the PPWB (2016). The PPWB (2016) found no significant trend in TN concentrations in the Red Deer River at Bindloss (when using a similar alpha value of 0.05 as used herein), along with a significant decreasing trend in TP concentrations. The PPWB conducted their analysis on TP data collected between 1967 and 2008 and TN data collected between 1993 and 2008. The analyses outlined herein were conducted on data collected between 1995 and 2014. The differences noted between the two sets of analyses may be the result of the different dataset used in each analysis.

Spatial Patterns

Among the three tributaries, nutrient concentrations were typically lowest in the Little Red Deer River, with the exception of TP concentrations in spring (Table 2.2-4). TN concentrations were highest in the Blindman River. TP concentrations were highest in the Blindman River in spring and summer, but lower in fall and winter than those in the Medicine River. All three tributaries tended to have higher nutrient concentrations than observed in the adjacent section of the Red Deer River mainstem (Figure 2.2-7).

Figure 2.2-7: Annual Average Nutrient Concentrations at Stations in the Red Deer River Watershed, 2013



Note: Arrows represent locations where the Little Red Deer, Medicine, and Blindman rivers flow into the Red Deer River mainstem.

Panel [A] = all stations; Panel [B] = stations on the Red Deer River mainstem only; TN = total nitrogen (blue line); mg-N/L = milligrams of nitrogen per litre; TP = total phosphorus (red line); mg-P/L = milligrams of phosphorus per litre

TN and TP concentrations exhibited a general upstream-to-downstream increase along the Red Deer River mainstem in 2012 and 2013 (Table 2.2-5; Figure 2.2-7). This pattern was most evident in spring. It was present, but less consistent, in other seasons, wherein concentrations at upstream stations were occasionally elevated relative to those observed further downstream in the summer, fall and/or winter (Table 2.2-5). For example, TN concentrations recorded at Sundre (AB05CA0050) were higher than those at the City of Red Deer (AB05CC0010) in fall 2012 and 2013. These variations likely reflect the effect of dilution and the presence of seasonally active in-stream sources and sinks, with the latter (i.e., sinks and sources) likely being a bigger influence than the former (i.e., dilution).

As previously noted, a large proportion of the flow in the river mainstem originates from areas upstream of the City of Red Deer, limiting the potential for dilution to occur downstream of this point. In contrast, in-stream sinks, such as Gleniffer Lake, have been documented to affect in-stream nutrient concentrations. Gleniffer Lake is located on the Red Deer River mainstem between Sundre and the City of Red Deer. The lake hold approximately 202,900 dam^3 of water, and its outflow is controlled by the Dickson Dam (O2 et al. 2013). As flows pass through the lake, nutrients and metals associated with suspended particulate matter settle out, resulting in lower nutrient concentrations in the Red Deer River downstream of the dam (Cross 1991; RDRWA 2009; Riemersma et al. 2006). The effect is more consistent and pronounced for TP than TN. For example, when looking at information collected from September 2008 to August 2011, Donald et al. (2015) identified an annual average loss of approximately 54% of the incoming TP mass as waters passed through Gleniffer Lake; in contrast, TN losses were smaller and more variable (i.e., net sequestration observed in some years but not others). The removal of nutrients (both TP and TN) through sedimentation has been noted in other reservoirs, such as Lake Diefenbaker (WSA 2012; Donald et al. 2015; North et al. 2015).

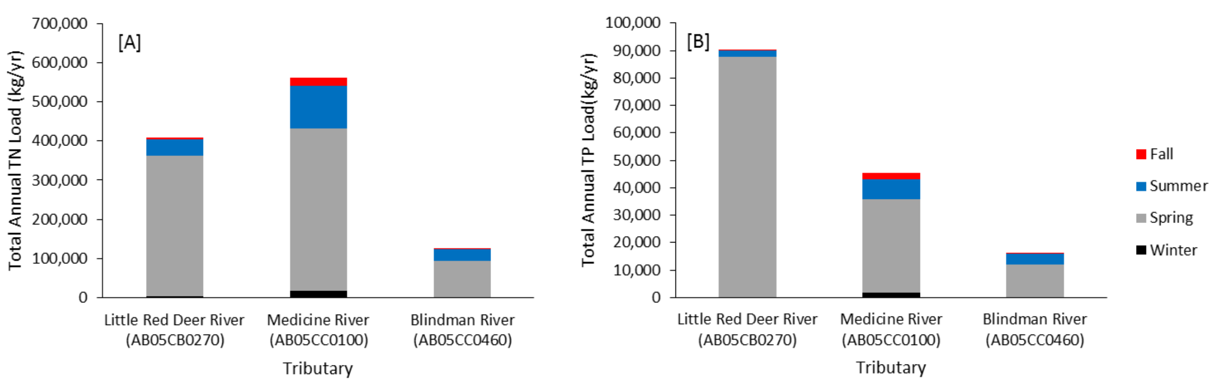
Planned releases from Gleniffer Lake can result in scouring and associated increases in turbidity and nutrient concentrations downstream in the Red Deer River (RDRWA 2009). Releases are often timed to coincide with periods of low flow to meet in-stream flow needs and the requirements of downstream licensed users (O2 et al. 2013). These types of seasonal in-stream sinks and sources contribute to the lack of a consistent increasing trend in nutrient concentrations with distance downstream across seasons.

2.2.1.3 Nutrient Loads

Temporal Patterns

Based on data from 2013, nutrient loads in the Little Red Deer, Medicine, and Blindman rivers followed a seasonal pattern similar to nutrient concentrations. Nutrient loads were highest in spring, then decreased through summer and into fall and remained comparatively low in winter (Figure 2.2-8).

Figure 2.2-8: Total Annual Nitrogen and Phosphorus Loads on Tributaries to the Red Deer River, 2013

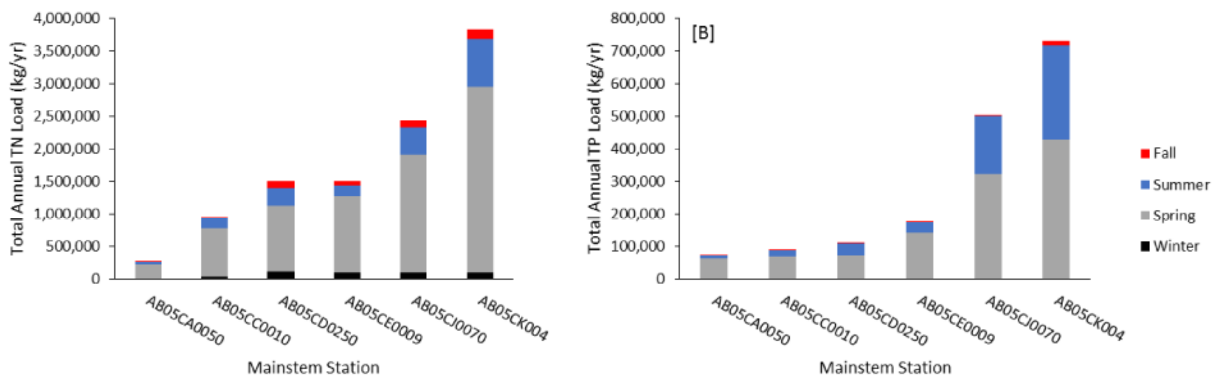


Panel [A] =Total Nitrogen (TN), Panel [B] = Total Phosphorus (TP); kg/yr = kilograms per year.

Similar to the tributaries, TP loads in the Red Deer River mainstem were highest in spring, followed by summer and then fall and winter (Figure 2.2-9). This differs from the seasonal pattern identified for TP concentrations (i.e., concentrations were generally highest in spring, followed by fall/winter and then summer). At any given station on the river mainstem in 2013, TP loading during spring and summer represented from 96 to over 99% of the total annual load. Comparatively, flow volumes in spring and summer 2013 represented between 84 and 94% of total annual flow volumes, depending on the station.

Similar to TP loads, TN loads at stations along the river mainstem were highest in spring 2013, followed by summer (Figure 2.2-9). Loads in fall and winter 2013 were comparable, but represented only a fraction of the total annual load compared to spring and summer. Again, spring and summer flows represented 84 to 94% of total annual flow volumes for stations along the river's mainstem in 2013; 85 to 96% of annual TN loads also occurred during spring and summer.

Figure 2.2-9: Seasonal Total Nitrogen and Total Phosphorus Loads at Water Quality Stations on the Red Deer River Mainstem, 2013



Note: Nutrient loads are cumulative along the length of the Red Deer River.
Panel [A] =Total Nitrogen (TN), Panel [B] = Total Phosphorus (TP); kg/yr = kilograms per year.

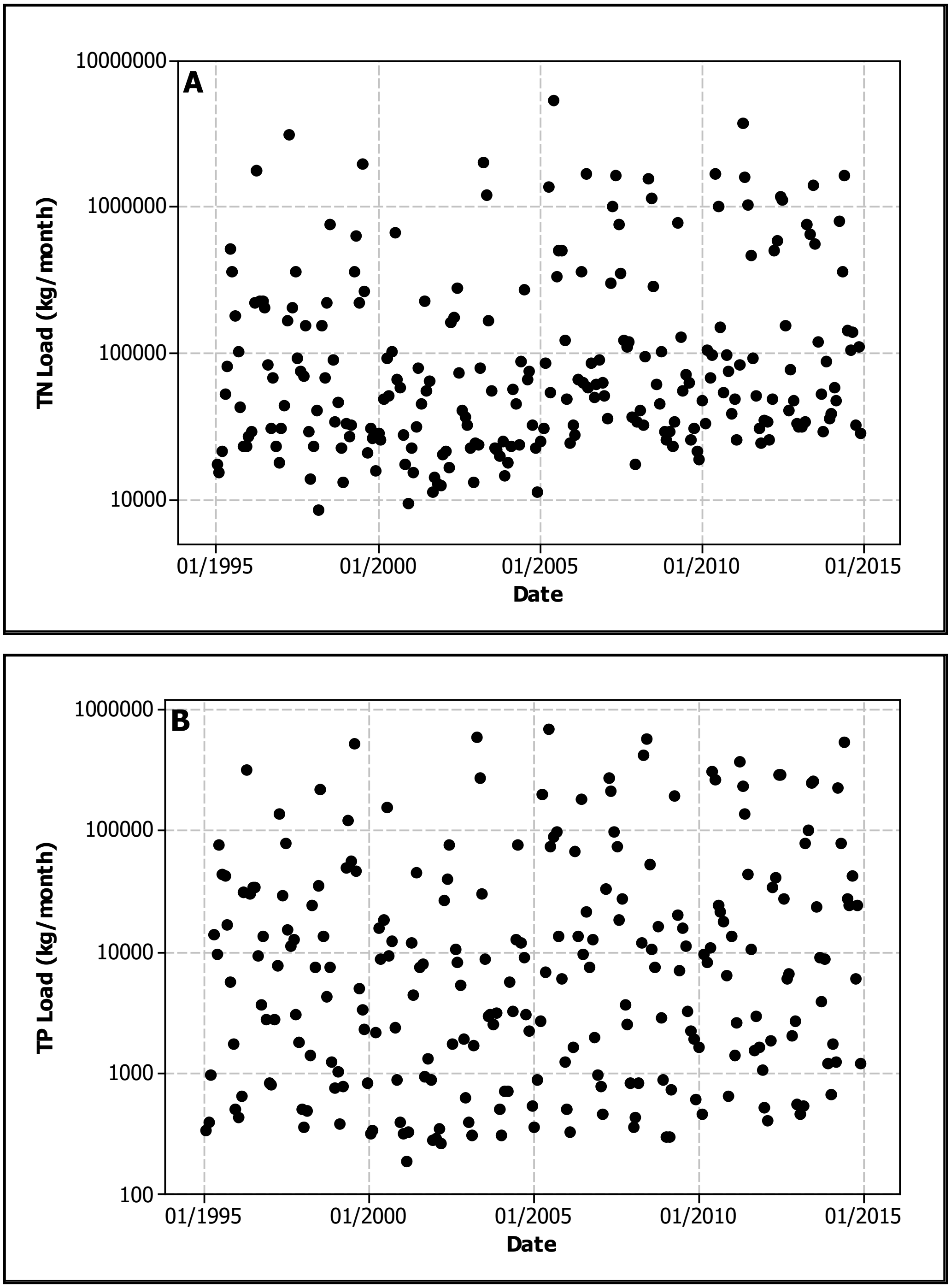
Results of the trend analysis indicate that TN loads at the terminal station near Bindloss have increased significantly between 1995 and 2014 (Table 2.2-7; Figure 2.2-10). The same is true of TP loads over the same period.

Table 2.2-7: Summary of Trend Analyses for Total Nitrogen and Total Phosphorus Loads in the Red Deer River near Bindloss, 1995 to 2014

Parameter	Units	Test	Sample Number	Z-Statistic	P-Value	Significant Trend[(a)]
Total Nitrogen	kg/month	Modified Mann-Kendall	240	1.98	**0.024**	↑ (1125)
Total Phosphorus	kg/month	Modified Mann-Kendall	240	1.87	**0.031**	↑ (46)

(a) ↑ = a statistically significant increasing trend, ↓ = a statistically significant decreasing trend, and ↔ = no significant trend.
kg/month = kilograms per month. Slope estimate provided in parentheses when a significant trend identified; units are kg/month/yr.

Figure 2.2-10: Total Nitrogen and Total Phosphorus Loads in the Red Deer River near Bindloss, 1995 to 2014



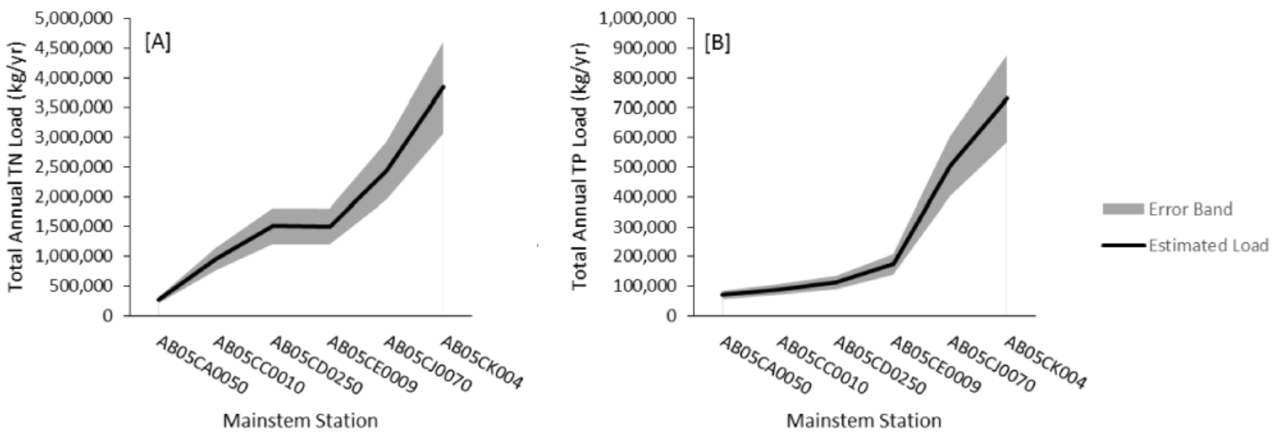
Panel [A] =Total Nitrogen (TN); Panel [B] = Total Phosphorus (TP); kg/month = kilograms per month

The increasing trend in the loads of both TN and TP likely reflects the effect of increased flow. As previously noted, recently recorded flows have been higher than historically observed (see Section 2.2.1.1). In the case of TN, the increasing trend in load also reflects the effect of significantly increasing concentrations of TN, as noted in Section 2.2.1.2.

Spatial Patterns

Similar to nutrient concentrations, nutrient loads in 2013 increased in a downstream direction along the Red Deer River mainstem (Figure 2.2-11). For TN, the increase was more gradual, whereas TP loads increased relatively sharply toward the downstream end of the river.

Figure 2.2-11: Annual Total Nitrogen and Total Phosphorus Loads at Water Quality Stations on the Red Deer River Mainstem, 2013



Note: Nutrient loads are cumulative along the length of the Red Deer River Mainstem. Error band based on variability of ±20% in reported water quality measurements.

Panel [A] =Total Nitrogen (TN), Panel [B] = Total Phosphorus (TP); kg/yr = kilograms per year.

Nutrient loads in the Little Red Deer, Blindman and Medicine rivers did not follow the same patterns as concentrations. Although TN and TP concentrations were generally highest in the Blindman River (Table 2.2-4), it delivered the smallest nutrient loads to the Red Deer River mainstem in 2013 relative to the other two tributaries (Figure 2.2-8). The Medicine River was the largest source of TN, and the Little Red Deer River was the largest source of TP, despite having the lowest concentrations of the three tributaries (Table 2.2-4). Flows in the Little Red Deer (approximately 428,479 dam^3) and Medicine (approximately 471,083 dam^3) rivers were much larger than those from the Blindman River (i.e., approximately 76,840 dam^3/yr); hence, the contrast in the observed patterns between nutrient concentrations versus loads amongst the three tributaries.

An annual TN and TP load balance for the Red Deer River is summarized in Table 2.2-9, based on data collected from 2013. The “input” loads represent loads entering a given reach of the river mainstem, either from upstream watersheds and sources draining directly to the reach in question. The “output” load represents the load leaving the reach in question, as estimated using in-stream water quality and flow measurements collected at the downstream end of the reach in question. The difference between “input” and “output” loads represents the net change in load that occurs within the reach. The calculations were conducted with the water quality concentrations as reported, and with an associated variability of ±20% (as per the methods outlined in Section 2.1.1.3).

The total incoming TN load reporting to the river mainstem between Sundre and the City of Red Deer was estimated to be approximately 1,234,200 kg/yr (Table 2.2-9). The outgoing load was estimated at approximately 955,800 kg/yr, resulting in a difference in the order of -278,400 kg/yr. The negative difference suggests the presence of in-stream sinks or withdrawals that do not return flow to the same section of the mainstem.

Most of the incoming TN load entering the river mainstem upstream of the City of Red Deer originated from the Little Red Deer and Medicine River sub-watersheds (i.e., accounted for 79% of total TN inputs); most (i.e., 78%) of the incoming TP load originated from areas upstream of Sundre and in the Little Red Deer River sub-watershed. As noted above, incoming TN and TP loads were larger than the outgoing load estimated at the City of Red Deer (Station AB05CC0010). This difference likely reflects the influence of Glennifer Lake, which is located within the immediate sub-watershed of Station AB05CC0010.

Gleniffer Lake, which has an average retention time of 70 days, is a noted nutrient sink related to the loss of nutrients through sedimentation (Cross 1991; Mitchell and Prepas 1990; O2 et al. 2013; RDRWA 2009). Scouring that occurs immediately downstream of the lake may mediate the effect to some extent, but does not negate or compensate for the overall loss. In addition to Gleniffer Lake, water withdrawals for irrigation and other purposes may contribute to the net reduction in TN and TP loads in the immediate sub-watershed for Station AB05CC0010. Water licence allocations between Dickson Dam and the City of Red Deer (Station AB05CC0010) are on the order of 5% and 7% of median river flows, respectively (Alberta Environment 2003).

The outgoing TN and TP loads estimated at the City of Red Deer in 2013 (Table 2.2-9) were comparable to those reported by Burke (2016) for the period between 2006 and 2014, which were annual average values of 887,000 kg/yr and 143,000 kg/yr, respectively.

Table 2.2–8: Estimated Total Nitrogen Load Balance at Water Quality Stations on the Mainstem of the Red Deer River, 2013

Location	Source	Input (kg/yr)[a]			Output (kg/yr)[a]		
		Best Estimate	Uncertainty Band Around Estimate[b]		Best Estimate	Uncertainty Band Around Estimate[b]	
Headwater to City of Red Deer	Upstream of Sundre (AB05CA0050)	264,147	211,317	316,976	-	-	-
	Little Red Deer River (tributary)	407,873	326,299	489,448	-	-	-
	Medicine River (tributary)	562,178	449,743	674,614	-	-	-
	Total upstream load	1,234,198	987,359	1,481,038	-	-	-
	In-stream total at Station AB05CC0010	-	-	-	955,756	764,605	1,146,907
				Difference	**-278,442**	**-222,754**	**-334,131**
City of Red Deer to Nevis	Upstream of City of Red Deer (AB05CC0010)	955,756	764,605	1,146,907	-	-	-
	Blindman River (tributary)	127,193	101,755	152,632	-	-	-
	Total upstream load	1,082,949	866,360	1,299,539	-	-	-
	In-stream total at Station AB05CD0250	-	-	-	1,510,063	1,208,050	1,812,075
				Difference	**427,113**	**341,691**	**512,536**
Nevis to Morrin	Upstream of Nevis (AB05CD0250)	1,510,063	1,208,050	1,812,075	-	-	-
	In-stream total at Station AB05CE0009	-	-	-	1,505,072	1,204,057	1,806,086
				Difference	**-4,991**	**-3,993**	**-5,989**
Morrin to Jenner	Upstream of Morrin (AB05CE0009)	1,505,072	1,204,057	1,806,086	-	-	-
	In-stream total at Station AB05CJ0070	-	-	-	2,438,900	1,951,120	2,926,680
				Difference	**933,828**	**747,062**	**1,120,593**
Jenner to Bindloss	Upstream of Jenner (AB05CJ0070)	2,438,900	1,951,120	2,926,680	-	-	-
	In-stream total at Station AB05CK004	-	-	-	3,837,204	3,069,763	4,604,645
				Difference	**1,398,304**	**1,118,644**	**1,677,965**

(a) Negative values indicate that the output load was smaller than the estimated input load arriving at a given station; Differences reflect influence of in-stream sources and sinks.

(b) Calculated based on reported water quality concentrations ±20%.

kg/yr = kilograms per year; = not applicable.

Table 2.2-9: Estimated Total Phosphorus Load Balance at Water Quality Stations on the Mainstem of the Red Deer River, 2013

Location	Source	Input (kg/yr)[a]			Output (kg/yr)[a]		
		Best Estimate	Uncertainty Band Around Estimate[b]		Best Estimate	Uncertainty Band Around Estimate[b]	
Headwater to City of Red Deer	Upstream of Sundre (AB05CA0050)	70,340	56,272	84,408	-	-	-
	Little Red Deer River (tributary)	90,074	72,059	108,089	-	-	-
	Medicine River (tributary)	45,461	36,369	54,553	-	-	-
	Total upstream load	205,876	164,700	211,836	-	-	-
	In-stream total at Station AB05CC0010	-	-	-	89,298	71,438	107,157
				Difference	**-116,578**	**-93,262**	**-139,894**
City of Red Deer to Nevis	Upstream of City of Red Deer (AB05CC0010)	89,298	71,438	107,157	-	-	-
	Blindman River (tributary)	16,115	12,892	19,338	-	-	-
	Total upstream load	105,413	84,330	126,495	-	-	-
	In-stream total at Station AB05CD0250	-	-	-	112,683	90,146	135,219
				Difference	**7,270**	**5,816**	**8,724**
Nevis to Morrin	Upstream of Nevis (AB05CD0250)	112,683	90,146	135,219	-	-	-
	In-stream total at Station AB05CE0009	-	-	-	173,578	138,863	208,294
				Difference	**60,895**	**48,716**	**73,074**
Morrin to Jenner	Upstream of Morrin (AB05CE0009)	173,578	138,863	208,294	-	-	-
	In-stream total at Station AB05CJ0070	-	-	-	503,802	403,042	604,563
				Difference	**330,224**	**264,179**	**396,269**
Jenner to Bindloss	Upstream of Jenner (AB05CJ0070)	503,802	403,042	604,563	-	-	-
	In-stream total at Station AB05CK004	-	-	-	730,573	584,458	876,687
				Difference	**226,770**	**181,416**	**272,124**

(a) Negative values indicate that the output load was smaller than the estimated input load arriving at a given station; Differences reflect influence of in-stream sources and sinks.

(b) Calculated based on reported water quality concentrations ±20%.

kg/yr = kilograms per year; = not applicable.

Moving downstream, the bulk of the incoming TN load reporting to Station AB05CD0250 near Nevis was attributed to areas upstream of the City of Red Deer, namely the Little Red Deer and Medicine River sub-watersheds (Table 2.2-8). TN loads from the immediate sub-watershed area represented about 28% of the total load passing Nevis; only 8% of the load was attributed to the Blindman River sub-watershed.

For TP, about 14% of the outgoing load at Nevis was attributed to the Blindman River, and a smaller percentage (i.e., approximately 6%) was attributed to the immediate sub-watershed (Table 2.2-9). The difference in the relative contributions of TN and TP from the immediate sub-watershed likely reflects the influence of the wastewater treatment plant at the City of Red Deer, which includes phosphorus removal but not denitrification in the treatment process. As with TN, most (94%) of the TP load originated from areas upstream of the City of Red Deer, particularly the Little Red Deer sub-watershed.

No major sinks were identified between the City of Red Deer and Nevis. Water licence allocations for the immediate sub-watershed area are expected to divert approximately 12,107 dam^3 of water and associated nutrient loads from the Red Deer River, based on data from Alberta Environment (2003). As described in Section 2.2.1.1, water is also pumped from the Red Deer River mainstem upstream AB05CD0250 to Buffalo Lake; diverted water returns to the Red Deer River via Tail Creek, which flows into the Red Deer River immediately downstream of AB05CD0250 (Buffalo Lake Management Team 2010).

At Station AB05CE0009 near Morrin, TN inputs from upstream sub-watersheds were roughly equivalent to the estimated output load in 2013 (Table 2.2-8), suggesting a negligible net input of TN through the immediate sub-watershed draining to Station AB05CE0009. In contrast, TP inputs from upstream sub-watersheds accounted for approximately 64% of the outgoing load, suggesting that the remaining 36% of the outgoing load originated from the immediate sub-watershed (Table 2.2-9).

Although estimates of in-stream TN loads could not be identified from the literature for Station AB05CE0009, data were available for Drumheller (AB05CE0010), 25 km downstream from Morrin. Burke (2016) reported average annual TN and TP loads of 1,075,000 and 127,000 kg/yr, respectively, for AB05CE0010 based on data from 2006 to 2014, values in the same order as those listed in Tables 2.2-8 and 2.2-9.

These findings indicate that a net TN sink exists in the immediate sub-watershed upstream of Morrin. A potential sink may be the 34% decrease in annual flow volumes between Nevis and Morrin (Figure 2.2-3), which includes water lost to irrigation and other licenced uses (Section 2.2.1.1). However, changes to water flow volumes would have affected calculated in-stream TN and TP loads equally; this suggest that there are other factors within the immediate sub-watershed that are influencing nutrient loads. For example, at least 70% of the sediment load in the Red Deer River arrives from the Alberta badlands, which are located downstream of Nevis (Kerr and Cooke 2017). Although this input would likely affect the levels of both TN and TP in the Red Deer River, TP loadings are expected to be greater than those of TN due to the stronger association between phosphorus and clay particles originating from the badlands (Donahue et al. 2013; Espinoza et al. 2005; Stone 2000). Consequently, the differences noted in the load balance likely reflect a common TN and TP sink (flow loss) with a compensatory increase in TP load through sediment addition. Further sampling and analysis of data from this sub-watershed is required to further understand the observed patterns.

Downstream of Morrin, TN and TP loads from the immediate sub-watershed area made up much larger proportions of the output loads estimated for Station AB05CJ0070 near Jenner than for other stations on the Red Deer River mainstem (Tables 2.2-8 and 2.2-9). Nutrient loads from the immediate sub-watershed area draining to the section of river between Morrin and Jenner represented 38% and 66% of the TN and TP loads, respectively, estimated at Jenner. No tributaries were examined in this section of the river; however, this sub-watershed is relatively large (see Figure 2.1-1 and Table 2.2-3) and includes a number of larger tributaries (e.g., Kneehills and Threehills creeks) that would contribute nutrient loads. Flows in the river mainstem increase by approximately 26% within this reach (Table 2.2-2). Part of the observed increase in flows is attributed to return flows from the Eastern and Western Irrigation Districts, which enter the Red Deer River between Morrin and Jenner (RDRWA 2016).

Most of the flows and nutrient loads reaching the terminal station on the Red Deer River mainstem near Bindloss in 2013 originated from upstream of Jenner. Approximately 4.5% of the annual flow and 36% and 31% of the TN and TP loads, respectively, were attributed to the immediate sub-watershed area between Jenner and Bindloss (Table 2.2-5). The larger nutrient loads in relation to the relatively small flow contribution indicates high concentration runoff in this area. Detailed water allocation and use data were not available for the sub-watershed between Jenner and Bindloss. However, withdrawals for the section of river between the mouth of Berry Creek and Bindloss are expected to be approximately 37,561 dam^3, based on data from AMEC (2014); no return flows were reported.

The cumulative TN and TP loads estimated for the terminal station in 2013 were approximately 3,837,200 kg/yr and 730,600 kg/yr, respectively (Tables 2.2-8 and 2.2-9). These values differ from those of Burke (2016); however, the values listed by Burke (2016) may be in error, as they are inconsistent with other values listed therein.

2.2.2 Carrot River

2.2.2.1 Water Flow

Total annual flow volumes (dam^3) for the terminal station on the Carrot River near Turnberry are shown in Table 2.2-10 for the period between 1995 and 2014, and in Figure 2.2-12 for the entire period of record (i.e., 1966 to 2014). If the annual flow volume reaching the terminal station exceeded the 75th percentile over the historical flow record, it was considered a high flow year. If the annual flow volume was less than the 25th percentile over the historical record, it was considered a low flow year.

Table 2.2–10: Total Annual Flow Volumes for the Terminal Stream Flow Station on the Carrot River near Turnberry

Year	Total annual flow volume (dam^3)	Classification[a]	Rank[b]
1995	726,303	moderate	11
1996	797,830	moderate	10
1997	837,886	moderate	9
1998	271,938	<25th percentile	17
1999	322,461	<25th percentile	16
2000	353,855	Moderate	15[d]
2001	87,249	<25th percentile	19
2002	82,510	<25th percentile	20
2003	254,456	<25th percentile	18
2004	457,293	moderate	13
2005	1,160,914	>75th percentile	6
2006	1,399,461	>75th percentile	2
2007	1,335,395	>75th percentile	3
2008	528,905	moderate	12
2009	403,671	moderate	14[c]
2010	1,589,230	>75th percentile	1[c]
2011	1,243,759	>75th percentile	5[d]
2012	868,101	>75th percentile	8[d]
2013	930,919	>75th percentile	7[c]
2014	1,263,842	>75th percentile	4

(a) Indicates whether a flow volume was below the 25th percentile (i.e., low), between the 25th and 75th percentiles (i.e., moderate) or higher than the 75th percentile (high).

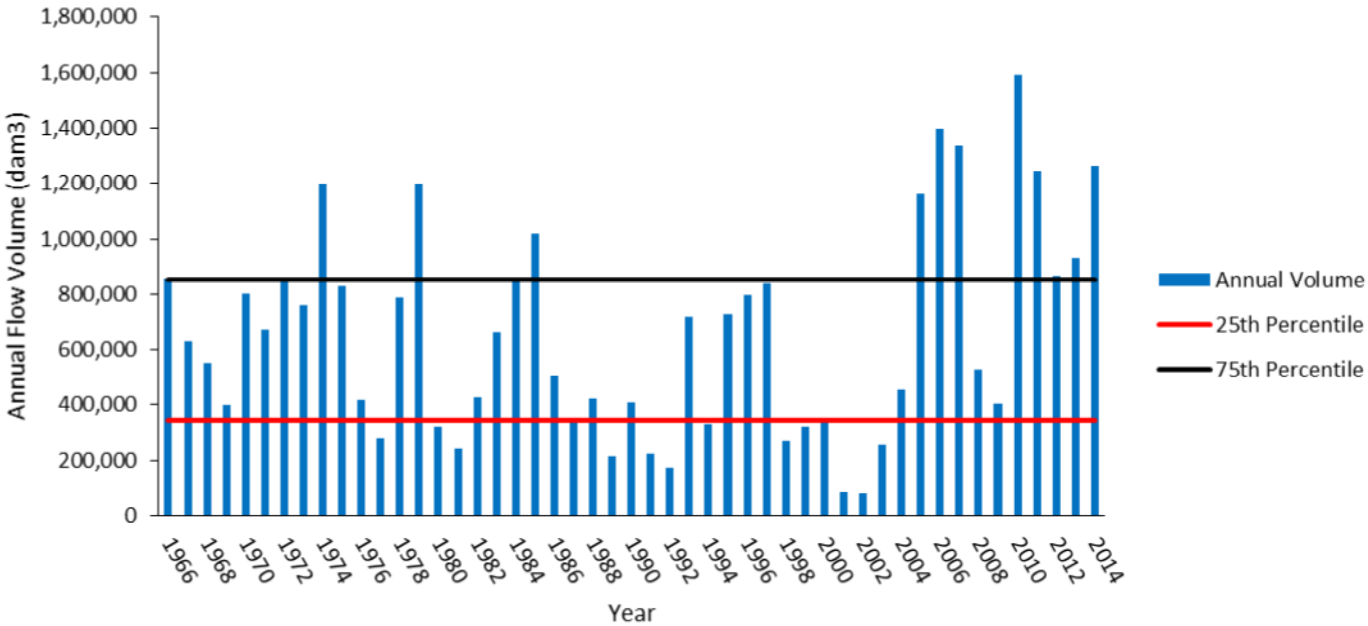
(b) Years were ranked from highest to lowest flow volume.

(c) Indicates primary years of interest for the watershed loading analyses.

(d) Indicates years of data used to validate watershed loading analyses (Sections 5.1.2.2 and 5.2.2.1).

dam^3 = cubic decametres; >= greater than; <= less than.

Figure 2.2-12: Historical Annual Flow Volumes Used to Estimate the 25th and 75th Percentile Flows for the Carrot River at Turnberry



dam^3 = cubic decametres.

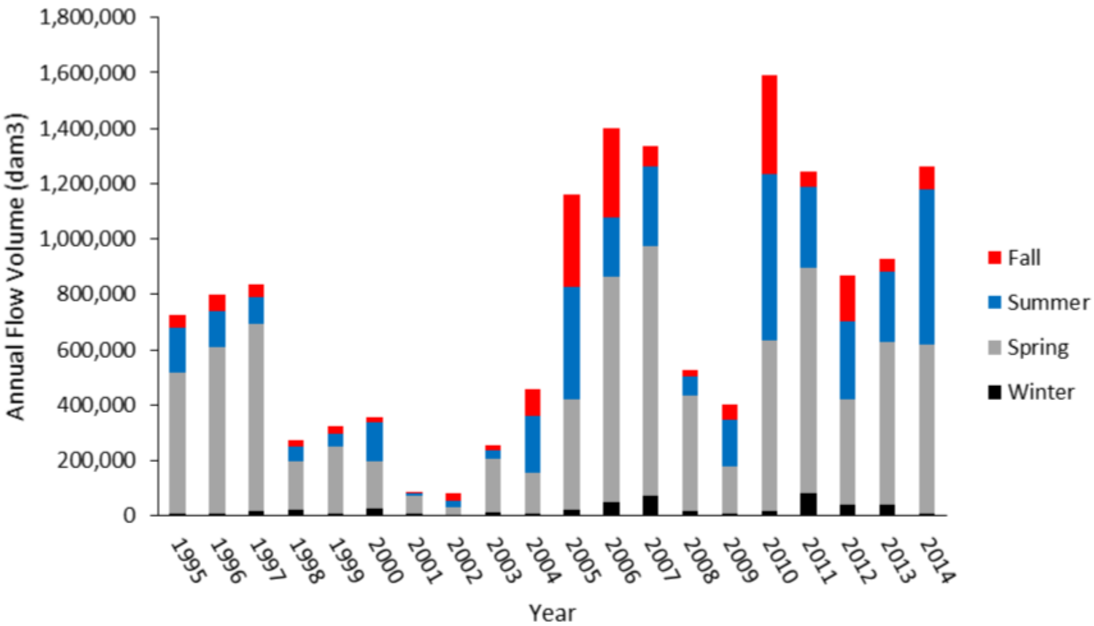
Similar to the Red Deer River, the year 2002 (82,510 dam^3) was the lowest flow year on record between 1966 and 2014. The total annual flow volume in 2002 was equal to approximately 5% of the annual flow in 2010 (1,589,230 dam^3), the highest flow year between 1966 and 2014 (Table 2.2-10). During the latter half of the assessment period (i.e., 2005 to 2014), none of the years were identified as being in the lower 25th percentile of recorded flows, and eight of the 10 years were considered high flow years.

Despite the wide range in annual flow volumes, seasonal flow patterns at the terminal station near Turnberry were similar among years (Figure 2.2-13). Flows were typically greatest in the spring and then summer. Flows in fall were higher than or comparable to those in winter, with both fall and winter flows typically being smaller than those in spring and summer.

Similar seasonal flow patterns occurred in Sweetwater Creek and the Leather River. Most of the flow occurred in spring, followed by summer and then fall and winter. At times, flows in winter and fall (e.g., in 2013) were not measurably different from 0 m^3/s.

Flows from the Leather River were larger than those from Sweetwater Creek. However, combined flows from both tributaries represent only a small fraction of the total flow reaching the terminal station at Turnberry; collectively, flows from the two tributaries in 2012 and 2013 represented only approximately 4% and 7%, respectively, of the total annual flow reaching the terminal station (Table 2.2-11, Figure 2.2-14). These values are reflective of the small size of the Sweetwater Creek and Leather River sub-watersheds relative to the remainder of the Carrot River watershed upstream of Turnberry (Table 2.2-12).

Figure 2.2-13: Annual Flow Volumes by Season for the Carrot River at Turnberry, 1995 through 2014



dam^3 = cubic decametres.

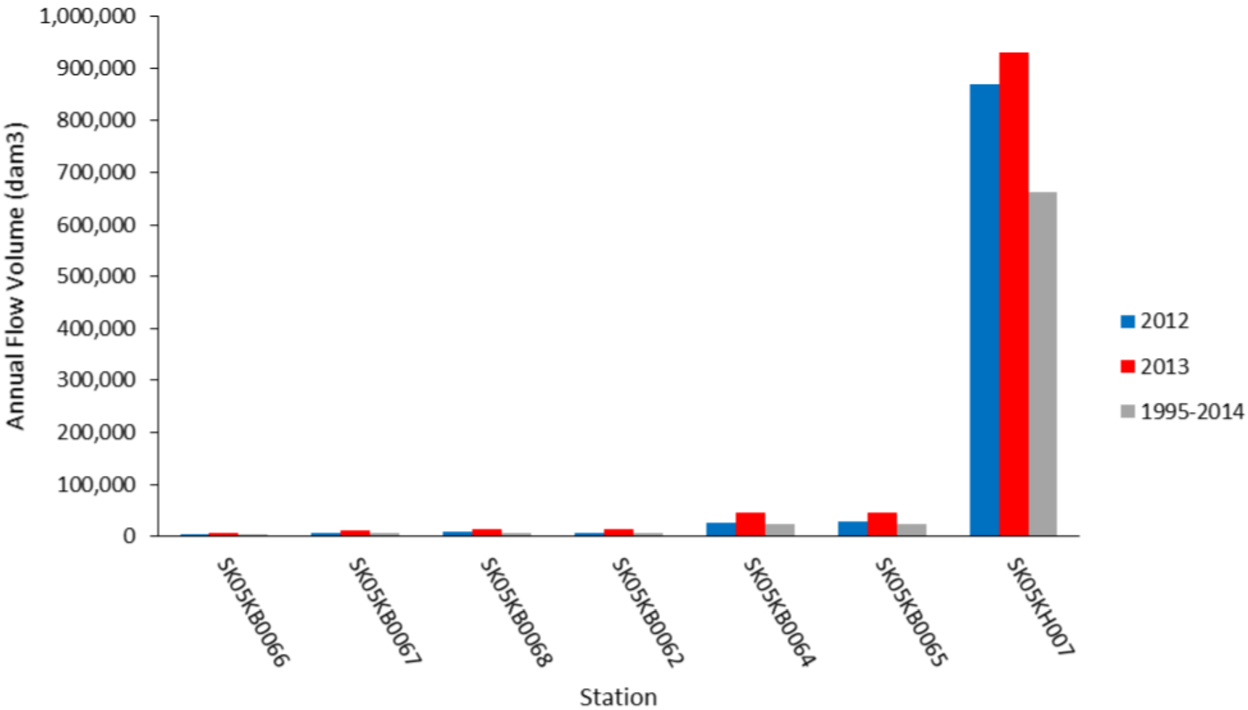
In-stream flow volumes in the Carrot River are influenced by the following:

- drainage networks and channels constructed in support of agricultural activities
- control structures, including the Star City Dam, Melfort Dam, Arborfield Dam, and Waterhen Marsh (SWA 2011)

The Star City Dam is located in the immediate sub-watershed of Station SK05KB0067 on Sweetwater Creek and is designed to hold 2,541 dam^3 of water (SWA 2011). Water is withdrawn from the reservoir and used to irrigate the golf course at Melfort Golf and Country Club. The Melfort Dam and Waterhen Marsh are located upstream of where Sweetwater Creek and the Leather River flow into the Carrot River mainstem; the Arborfield Dam is located on Burntout Brook, and is the farthest downstream control structure in the watershed (SWA 2011).

Withdrawals for irrigation and other licenses uses, such as drinking water and industrial uses, are lower than for the Red Deer River. As of 2011, total annual water licence allocations for agricultural uses, namely irrigation and livestock watering, were equal to 1,993 dam^3. SWA (2011) indicates that less than 4% of flows in the watershed are associated with return flows from wastewater treatment plants.

Figure 2.2-14: Annual Flow Volumes for Selected Nutrient Stations in the Carrot River Watershed, 2012, 2013 and 1995-2014



dam^3 = cubic decametres.

Table 2.2–11: Total Annual Flow Volumes for Selected Water Quality Stations in the Carrot River Watershed

Location[a]	Station Code	2012		2013		1995-2014	
		Total Annual Flow Volume (dam^3)	Total Relative to Terminal Station (%)	Total Annual Flow Volume (dam^3)	Total Relative to Terminal Station (%)	Total Annual Flow Volume (dam^3)	Total Relative to Terminal Station (%)
Tributaries							
Sweetwater Creek	SK05KB0066	4,572	0.5	7,665	0.8	4,099	0.6
	SK05KB0067	6,182	0.7	10,363	1.1	5,542	0.8
	SK05KB0068	8,565	1.0	14,357	1.5	7,678	1.2
Leather River	SK05KB0062	7,792	0.9	13,062	1.4	6,985	1.1
	SK05KB0064	26,983	3.1	45,231	4.9	24,188	3.7
	SK05KB0065	27,885	3.2	46,743	5.0	24,996	3.8
Mainstem							
Carrot River	SK05KH007	868,101	100	930,919	100	662,074	100

(a) Stations are listed in order, from upstream to downstream along the tributaries.

dam^3 = cubic decametres;% = percent.

Table 2.2–12: Gross and Effective Drainage Areas for Selected Nutrient Stations in the Carrot River Watershed

Location[(a)]	Station Code	Gross Drainage Area (ha)		Effective Drainage Area (ha)	
		Cumulative	Sub-watershed[(b)]	Cumulative	Sub-watershed[(b)]
Tributaries					
Sweetwater Creek	SK05KB0066	81	81	71	71
	SK05KB0067	107	26	96	25
	SK05KB0068	144	118	133	108
Leather River	SK05KB0062	162	162	121	121
	SK05KB0064	513	351	419	298
	SK05KB0065	527	176	433	135
Mainstem					
Carrot River	SK05KH007	13,072	12,401	10,833	10,267

(a) Stations are listed in order, from upstream to downstream along the Carrot River mainstem.

(b) Areas are for the immediate sub-watershed only (i.e., are not cumulative).

ha = hectares.

2.2.2.2 Nutrient Concentrations

Temporal Patterns

No seasonal patterns in TN and TP concentrations could be identified for Sweetwater Creek or the Leather River, due to the absence of concentration data for winter, summer, and fall (Table 2.2-13).

In the Carrot River mainstem, TN concentrations measured at the terminal station in 2012 and 2013 exhibited little seasonal variability; TP concentrations were also consistent regardless of season, and exhibited little within-season variability (i.e., standard deviations were low among samples within a season) (Table 2.2-13). The only exception was the slightly lower TP concentration observed at the terminal station in winter 2012. The seasonal patterns identified for the Carrot River in 2012 and 2013 differed from those of the Red Deer River, where nutrient concentrations in 2012 and 2013 typically peaked during spring and then remained relatively low in summer (TN) and fall and winter (TP).

Nutrient concentrations in the Carrot River were typically equivalent to the seasonal spring peaks observed in the Red Deer River. Of the monthly TN measurements collected at the terminal station near Turnberry in 2012 (n = 12) and 2013 (n = 12), 22 of 24 measurements were in excess of the 1 mg/L objective noted by SWA (2011). Most of the measured TP concentrations (n = 7) were above the maximum objective of 0.1 mg/L noted by SWA (2011).

Table 2.2–13: Total Nitrogen and Total Phosphorus Concentrations at Water Quality Stations in the Carrot River Watershed, 2012 and 2013

Location	Station	Average Concentration ± SD (mg/L)[a]							
		2012				2013			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Total Nitrogen (TN)									
Sweetwater Creek	SK05KB0066	-	1.6	-	-	-	3.7	-	-
	SK05KB0067	-	1.4	-	-	-	2.9	-	-
	SK05KB0068	-	1.3	-	-	-	2.6	-	-
Leather River	SK05KB0062	-	1.3	-	-	-	2.1	-	-
	SK05KB0064	-	1.3	-	-	-	2.2	-	-
	SK05KB0065	-	1.2	-	-	-	2.1	-	-
Carrot River Mainstem	SK05KH007	1.2 ± 0.06	1.5 ± 0.59	1.1 ± 0.64	1.5 ± 0.15	1.8 ± 0.07	1.5 ± 0.38	1.7 ± 0.31	1.5 ± 0.04
Total Phosphorus (TP)									
Sweetwater Creek	SK05KB0066	-	0.13	-	-	-	0.24	-	-
	SK05KB0067	-	0.06	-	-	-	0.23	-	-
	SK05KB0068	-	0.06	-	-	-	0.32	-	-
Leather River	SK05KB0062	-	0.07	-	-	-	0.28	-	-
	SK05KB0064	-	0.07	-	-	-	0.26	-	-
	SK05KB0065	-	0.07	-	-	-	0.53	-	-
Carrot River Mainstem	SK05KH007	0.06 ± 0.01	0.18 ± 0.10	0.10 ± 0.07	0.13 ± 0.04	0.14 ± 0.001	0.13 ± 0.04	0.14 ± 0.04	0.11 ± 0.02

(a) For each season, the sample number is one (n = 1) for all tributary stations and three (n = 3) for the terminal station on the Carrot River mainstem.

± = plus or minus; SD = standard deviation; mg/L = milligrams per litre; - = no data.

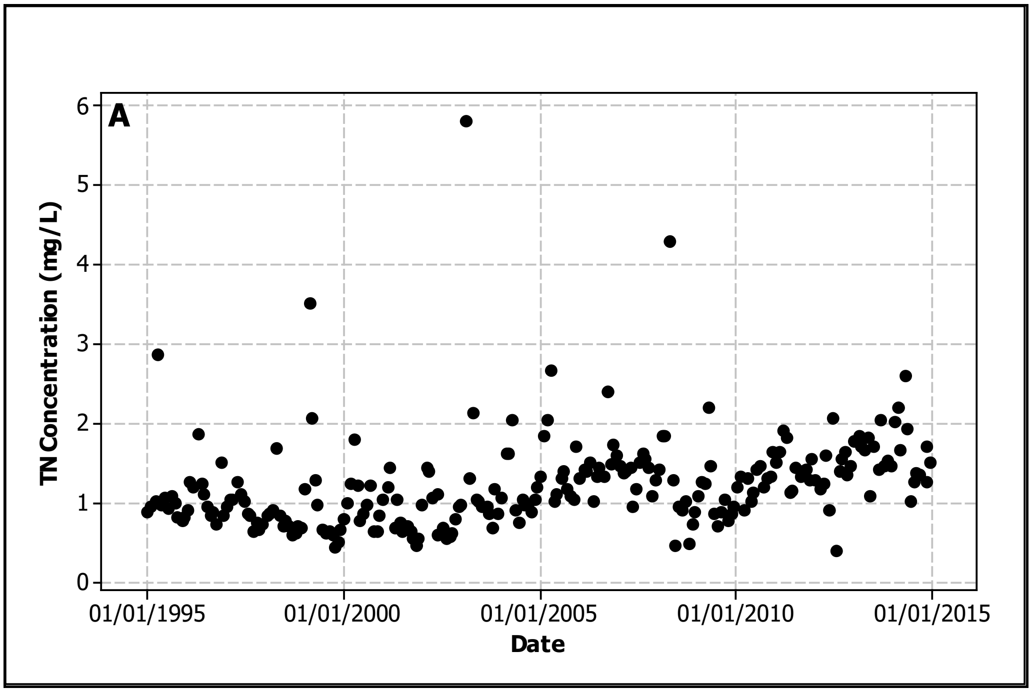
Results of the trend analysis indicate that unadjusted TN and TP concentrations in the Carrot River at Turnberry have increased significantly over time between 1995 to 2014 (Figure 2.2-14, Table 2.2-15). The concentrations of both constituents were found to have significant positive relationships to flow (Figure 2.2-16). However, neither relationship explained a large amount of the observed variability (i.e., R^2 = 0.05 and R^2 = 0.19 for TN and TP, respectively) (Figure 2.2-16). Correcting for the relationship to flow did not alter the result of the trend analysis. The concentrations of both TN and TP were found to be increasing over time between 1995 and 2014 (Table 2.2-15). These findings are consistent with the recent analyses completed by PPWB (2016).

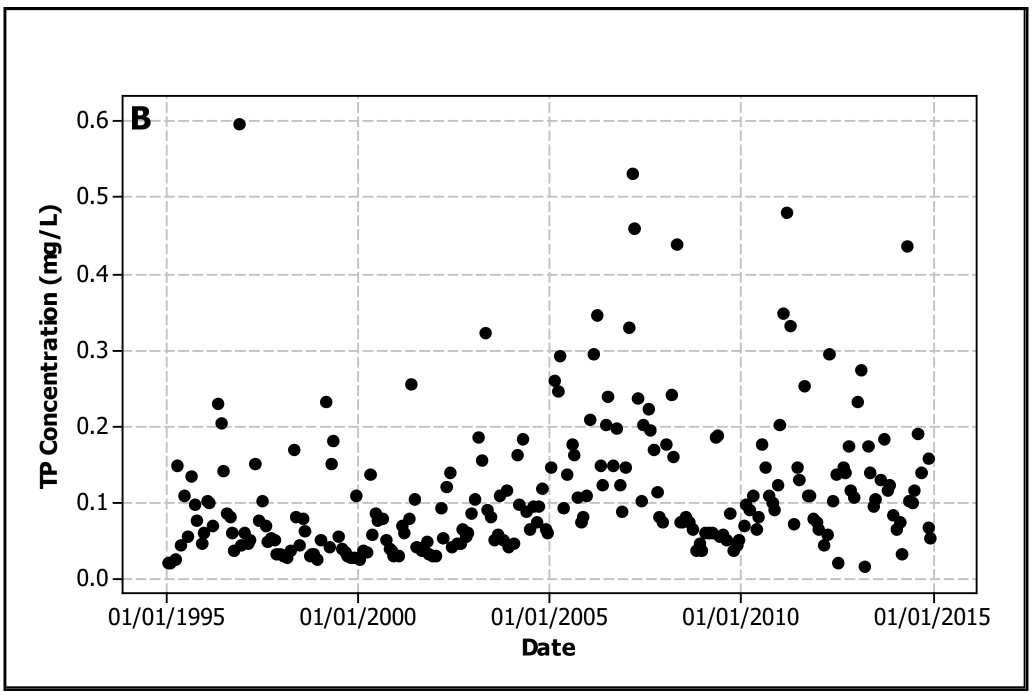
Table 2.2–14: Summary of Trend Analyses for Total Nitrogen and Total Phosphorus Concentrations in the Carrot River near Turnberry, 1995 to 2014

Parameter	Test	Treatment	Sample Size	Z-Statistic	P – Value	Significant Trend[a]
Total Nitrogen (mg/L)	Modified Mann-Kendall	Unadjusted	240	3.46	**<0.001**	↑ (0.035)
		Flow-adjusted	240	3.48	**<0.001**	↑ (0.012)
Total Phosphorus (mg/L)	Modified Mann-Kendall	Unadjusted	240	2.82	**0.002**	↑ (0.004)
		Flow-adjusted	240	2.46	**0.007**	↑ (0.013)

(a) ↑ = a statistically significant increasing trend, ↓ = a statistically significant decreasing trend, and ↔ = no significant trend. Slope estimate provided in parentheses when a significant trend identified; units are mg/L/yr.

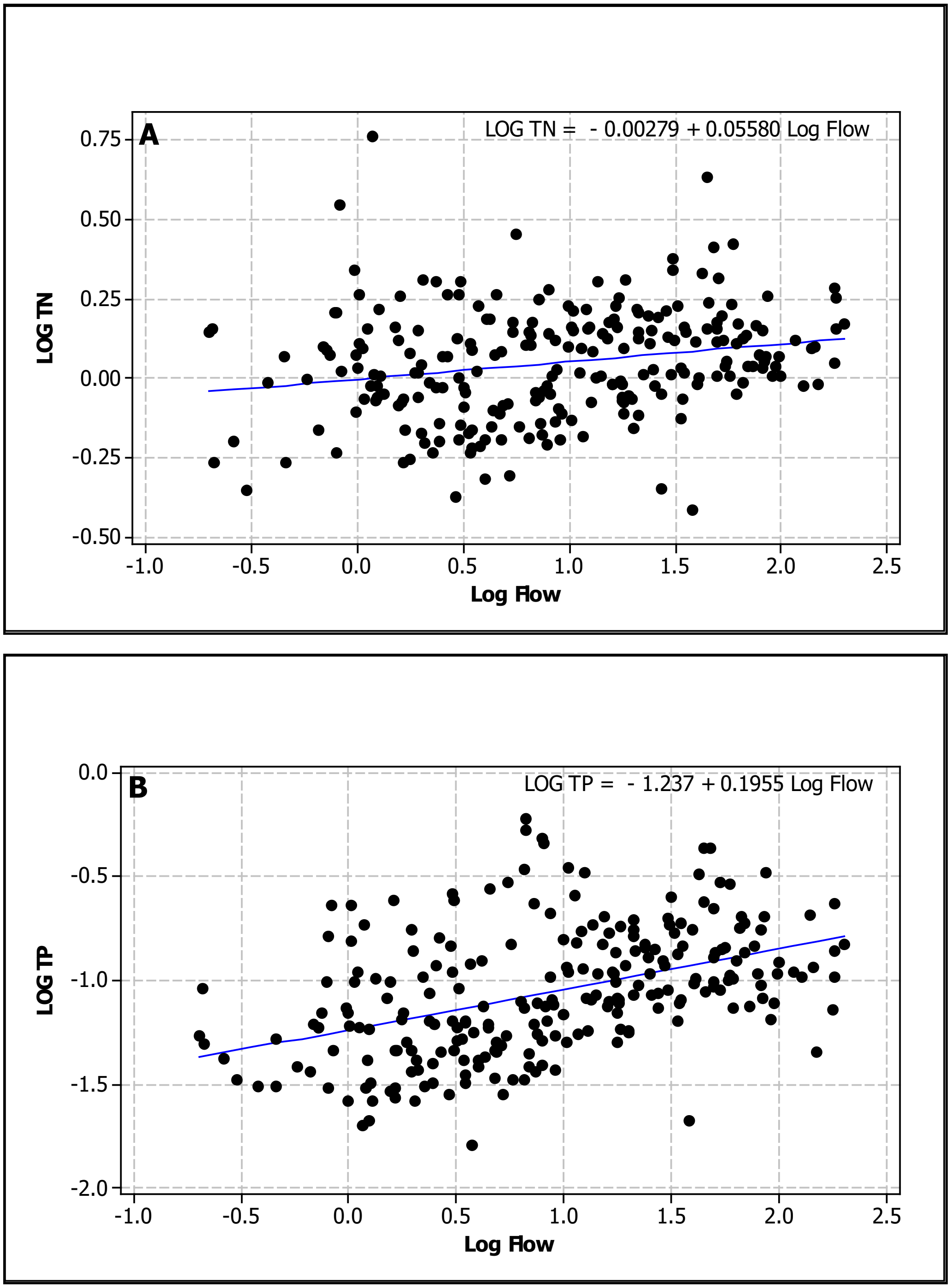
Figure 2.2-15: Time-series of Nutrient Concentrations in the Carrot River near Turnberry, 1995 to 2014





Panel [A] =Total Nitrogen; Panel [B] = Total Phosphorus; mg/L = milligrams per litre.

Figure 2.2-16: Linear Regression between Log-transformed Nutrient Concentrations and Log-transformed Flow in the Carrot River Near Turnberry, 1995 to 2014



Panel [A] =Total Nitrogen; Panel [B] = Total Phosphorus; mg/L = milligrams per litre.

Spatial Patterns

In 2012 and 2013, TN concentrations measured in individual samples collected from Sweetwater Creek and the Leather River exhibited little within-year variability, regardless of location; the same was also true of reported TP concentrations (Table 2.2-13).

In 2013, TN and TP concentrations in Sweetwater Creek and the Leather River in spring were higher than those in the Carrot River at Turnberry, suggesting that nutrients originating from the Sweetwater Creek and Leather River sub-watersheds were likely diluted as water flowed downstream to the terminal station. TN and TP concentrations may also have been influenced by marshes and wetlands along the travel path, such as the 1,530 ha Waterhen Marsh located south of Kinistino. These areas can promote removal of nitrogen and phosphorus from water that flows into the Carrot River mainstem (Hines and Mitchell 1983; Riemersma et al. 2006; WSA 2012). Data from SWA (2011) indicate that retention rates for nitrate and ammonia in wetlands may be as high as 87% and 76%, respectively; retention rates for TP may be up to 84%.

In freshet 2012, TN concentrations among the two tributaries and the river mainstem were more comparable, whereas TP levels in the river mainstem were higher than those in the two tributaries. Additional information would be required to identify if the divergence observed between 2012 and 2013 resulted from different loading dynamics or is reflective of natural variability in the tributaries that is not adequately described in the small available dataset.

2.2.2.3 Nutrient Loads

Temporal Patterns

In 2013, nutrient loads at the terminal station on the Carrot River mainstem near Turnberry showed more seasonal variation than TN or TP concentrations (Tables 2.2-13 and 2.2-15), reflective of seasonal changes in flow. Nutrient loads were highest in spring, as they were in the Red Deer River, followed by summer, winter, and then fall. The difference between spring and summer versus fall and winter nutrient loads was approximately one order of magnitude. Together, loads in spring and summer accounted for 91% and 89% of the total annual TN and TP loads, respectively, reaching the terminal station.

Table 2.2–15: Estimated Total Nitrogen and Phosphorus Loads at Water Quality Stations in the Carrot River Watershed, 2013

Location	Station	Estimated Annual Load (kg/yr)[(a)]				Estimated Annual Load (kg/yr)
		Winter	Spring	Summer	Fall	
Total Nitrogen (TN)						
Sweetwater Creek	SK05KB0066	-	26,724 (21,379-32,069)	-	-	nc
	SK05KB0067	-	28,321 (22,657-33,985)	-	-	nc
	SK05KB0068	-	35,177 (28,142-42,213)	-	-	nc
Leather River	SK05KB0062	-	25,849 (20,679-31,019)	-	-	nc
	SK05KB0064	-	93,773 (75,018-112,527)	-	-	nc
	SK05KB0065	-	92,501 (74,001-111,001)	-	-	nc
Carrot River Mainstem	SK05KH007	70,117 (56,093-84,140)	914,011 (731,209-1,096,813)	425,621 (340,496-510,745)	68,030 (54,424-81,637)	1,477,779 (1,182,223-1,773,335)
						Total Phosphorus (TP)
Sweetwater Creek	SK05KB0066	-	1,733 (1,387-2,080)	-	-	nc
	SK05KB0067	-	2,246 (1,797-2,695)	-	-	nc
	SK05KB0068	-	4,330 (3,464-5,195)	-	-	nc
Leather River	SK05KB0062	-	3,447 (2,757-4,136)	-	-	nc
	SK05KB0064	-	11,082 (8,866-13,299)	-	-	nc
	SK05KB0065	-	23,346 (18,676-28,015)	-	-	nc
Carrot River Mainstem	SK05KH007	7,468 (5,974-8,962)	74,014 (59,211-88,817)	31,629 (25,303-37,954)	5,263 (4,211-6,316)	118,374 (94,699-142,049)

(a) Error bands are provided in brackets, based on variability of ± 20% in reported TN and TP concentrations.
kg/yr = kilograms per year; - = no data; nc = cannot be calculated.

The total annual TN load (i.e., 1,477,779 kg/yr) reaching the terminal station in 2013 was higher than annual TN loads reported by Bourne et al. (2002) for the same location over the years 1994 to 2001 (mean load of 520,000 kg/yr). The same was true of the total annual TP load (i.e., 118,374 vs 51,000 kg/yr). These differences are attributed to differences in flows. As outlined in Table 2.2-10, 2013 was a much wetter year than those between 1995 and 2001.

Total annual TN loads estimated for 1995 (i.e., 803,656 kg/yr) and 2000 (i.e., 379,266 kg/yr) approximate the loads reported by Bourne et al. (2002) for the same years (i.e., 804,00 kg/yr and 379,000 kg/yr, respectively). Similarly, the TP loads estimated for the years 1995 (i.e., 54,803 kg/yr) and 2000 (i.e., 28,334 kg/yr) are comparable to the loads calculated by Bourne et al. (2002) for the same location and years (i.e., 1995: 55,000 kg/yr; 2000: 28,000 kg/yr).

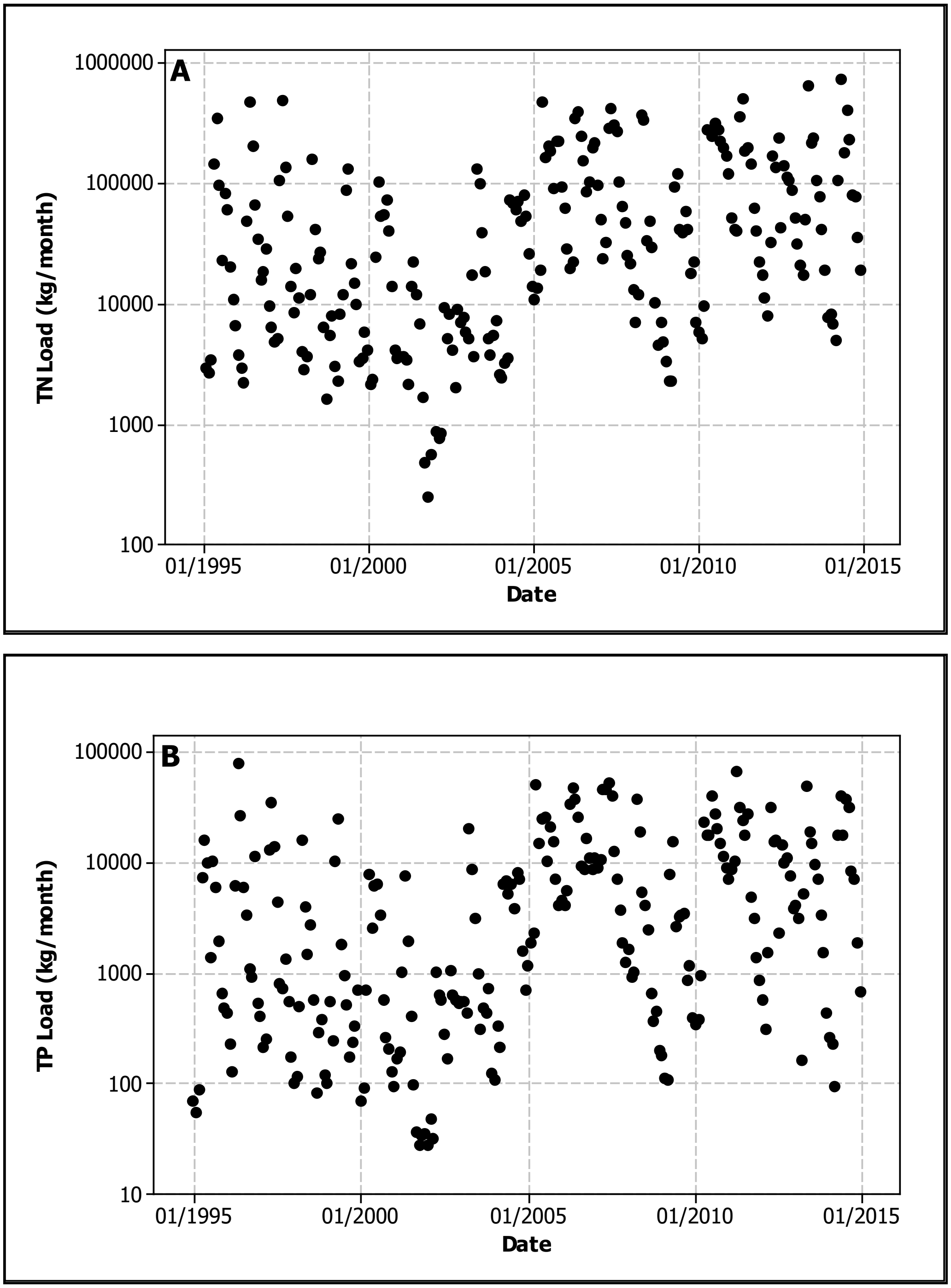
TN and TP loads at the terminal station have increased significantly over the period of 1995 to 2014 (Table 2.2-16; Figure 2.2-17). The higher loads observed at the terminal station reflect the effects of both increased flow and concentration; measured and flow-adjusted TN and TP concentrations exhibited significant temporal increases over time during the period of 1995 to 2014 (Section 2.2.2.2).

Table 2.2-16: Summary of Trend Analyses for Total Nitrogen and Total Phosphorus Loads in the Carrot River near Turnberry, 1995 to 2014

Parameter	Units	Test	Sample Number	Z-Statistic	P-Value	Significant Trend[(a)]
Total Nitrogen	kg/month	Modified Mann-Kendall	240	2.56	**0.005**	↑ (1846)
Total Phosphorus	kg/month	Modified Mann-Kendall	240	2.45	**0.007**	↑ (143)

(a) ↑ = a statistically significant increasing trend, ↓ = a statistically significant decreasing trend, and ↔ = no significant trend.
kg/month = kilograms per month. Slope estimate provided in parentheses when a significant trend identified; units are kg/month/yr.

Figure 2.2-17 Total Nitrogen and Total Phosphorus Loads in the Carrot River Near Turnberry, 1995 to 2014



Panel [A] =Total Nitrogen (TN); Panel [B] = Total Phosphorus (TP); kg/month = kilograms per month.

* Value of 0 for December of 2001 is not shown in [A].

Spatial Patterns

During spring 2013, nutrient loads in Sweetwater Creek and the Leather River increased with increasing distance downstream (Table 2.2-15). Estimated TN and TP loads reaching the mouth of the Leather River were three to five times larger than loads reaching the mouth of Sweetwater Creek. Approximately 4% and 10% of the TN loads reaching the terminal station during spring of 2013 were attributed to Sweetwater Creek and the Leather River, respectively. For TP, approximately 6% of the loads reaching the terminal station were attributed to Sweetwater Creek and 32% were attributed to the Leather River, despite only representing approximately 1% (Sweetwater Creek) and 4% (Leather River) of the total land area.

Based on the results from 2013, the Leather River is a potential nutrient hotspot, and further evaluation of this watershed should be considered. Loads from this watershed were disproportionately high, relative to its size. Nutrient loads from Sweetwater Creek were also higher than expected based on the small size of the watershed; however, the total contribution was much smaller than that of the Leather River and represented a smaller proportion of the total annual load in the Carrot River.

Due to data limitation, the potential influence of in-stream structures, such as Star City Dam, Melfort Dam, Arborfield Dam, and Waterhen Marsh, on nutrient levels could not be evaluation. The same was true of water withdrawals for irrigation and other uses.

2.3 Conclusions

2.3.1 Red Deer River

TN concentrations on the Red Deer River mainstem typically peak in spring, and decrease to annual minimums in summer. TN loads similarly peak in spring, but reach annual minimums in winter (reflecting the relative change in flow among seasons).

TP concentrations and loads in the Red Deer River mainstem typically peak during spring, and decrease to annual minimums in fall and winter. The same is true for nutrient concentrations and loads in the Little Red Deer, Medicine, and Blindman rivers.

TN and TP concentrations and loads at the terminal station at Bindloss have been increasing over time since 1995, mostly in response to increasing flows. Flow-adjusted TP concentrations remain relatively consistent, whereas flow-adjusted TN concentrations between 1995 and 2014 have increased. These trends differ from those identified by PPWB (2016). In their examination of TP and TN data collected between 1967 and 2008 and between 1993 and 2008, respectively, flow-adjusted TN and TP concentrations at Bindloss were found to be consistent (TN) or decreasing (TP) over time. The time scale considered in the two sets of analyses may be a factor contributing to the different findings.

The seasonal pattern in loading and the influence of flow on observed concentrations suggest that non-point sources likely dominate within the Red Deer River watershed, in comparison to point sources associated with municipal wastewater treatment or industrial use. Loading from these latter point sources tends to be more consistent over time, and would not produce peak in-stream loads under spring conditions.

Key spatial patterns noted in the analysis include the following:

- Concentrations and loads of both nutrients tend to increase with increasing distance downstream along the river mainstem.

- Nutrient concentrations are lower in the Little Red Deer River versus the Medicine (highest TN) and Blindman (highest TP) rivers; however, the Little Red Deer is the largest loading source of TP among the three tributaries. The Medicine River is the largest loading source of TN among them. These divergent patterns reflect the relative flow volumes of the tributaries (i.e., flow in the Blindman River is much smaller than in either of the other two tributaries).
- Most of the TN and TP load in the river mainstem upstream of the City of Red Deer originates from the Little Red Deer and Medicine rivers. These statements are also true for loads reaching downstream stations at Nevis and Morrin. Consequently, nutrient management activities focused on the Little Red Deer and Medicine rivers could have a notable effect on nutrient conditions in the river mainstem.
- Gleniffer Lake, which is located on the Red Deer River mainstem and controlled by the Dickson Dam, is considered a consistent TP sink and a potential TN sink within the immediate sub-watershed area that terminates at station AB05CC0010 upstream of the City of Red Deer.
- A nutrient sink appears to be present between Nevis and Morrin; this sink likely affects both TN and TP, with effects to TP damped through a compensatory input of sediment and associated phosphorus from the Alberta badlands.
- Most of the nutrient loads in the Red Deer River near Jenner can be attributed to the immediate sub-watershed area, which is much larger than the other sub-watersheds and contains a number of larger tributaries; this sub-watershed also receives return flows from the Eastern and Western Irrigation Districts.
- Although nutrient loads reaching the terminal station near Bindloss originate primarily from areas upstream of Jenner, the small immediate sub-watershed draining to this station produces a disproportionately high areal load, suggesting further investigation of nutrient sources in this area is warranted. That said, nutrient management activities focused within the immediate sub-watershed, should they occur, will need to occur in concert with others farther upstream (i.e., between Morrin and Jenner) to have a notable effect on in-stream nutrient conditions at the mouth of the Red Deer River.

2.3.2 Carrot River

Nutrient concentrations at the terminal station on the Carrot River near Turnberry exhibit little seasonal variability, unlike concentrations in the Red Deer River. In contrast, nutrient loads in the Carrot River vary seasonally, reflective of changes in flow. As in the Red Deer River, most loading occurs in spring and summer.

Nutrient concentrations and loads at the terminal station near Turnberry have been increasing over time, based on information collected between 1995 and 2014. These findings are in agreement with the results of trend analyses completed by the PPWB (2016) using TP data collected between 1974 and 2008 and TN data collected between 1993 and 2008.

Spatial patterns identified from the available dataset include the following:

- Nutrient concentrations are similar among stations in Sweetwater Creek and the Leather River.
- Nutrient loads in Sweetwater Creek and the Leather River increase with increasing distance downstream.
- Both TN and TP loads are much higher in the Leather River versus Sweetwater Creek.

- The Leather River may be a hotspot for TN and, to a greater extent, TP. In 2013, 32% of the TP load and 10% of the TN load arriving at the terminal station near Turnberry in spring was attributed to the Leather River, despite the fact the watershed contributed only 7% of the spring flows reaching the terminal station and represents less than (<) 5% of the total land area.

Spatial patterns were identified based on the available data; however, due to a paucity of information, it is unclear whether these patterns are unique to time period considered, or if they are applicable at broader time and spatial scales.

2.4 Limitations and Uncertainty

Limitations and uncertainty associated with the assessments of in-stream conditions in the Red Deer and Carrot rivers and their tributaries are largely attributed to data availability and the consequential effect on the spatial and temporal scope of the evaluation.

For the Red Deer River, the assessment of in-stream concentrations and calculations of nutrient loads in tributary streams was restricted to the Little Red Deer, Medicine, and Blindman rivers, because they had the largest available datasets of all the tributaries. It is possible that the exclusion of other relatively large sub-watersheds (e.g., the Threehills/Kneehills sub-watersheds) precluded the identification of other nutrient hotspots or potential sinks along the lower reaches of the river mainstem.

One approach to reducing uncertainty in the identification of in-stream sources or sinks is to conduct seasonal synoptic sampling, wherein water samples are collected at time intervals that reflect travel time down the river mainstem. Flow and nutrient concentrations are measured concurrently at the mouths of major tributaries, as well as at locations down the length of the river mainstem. The resulting load balance should provide a more precise estimate of mass gain or loss through the system.

Most sub-watersheds in the Carrot River did not have suitable datasets available to provide a more detailed spatial analysis. The lack of seasonal nutrient data for locations upstream of Turnberry also prevented an examination of seasonal trends in nutrient loads in the upper watershed, and results in uncertainty in the loading estimates generated for Sweetwater Creek and the Leather River, given that they are based on single TN and TP measurements.

Patterns noted above in Sections 2.2 and 2.3 must be interpreted appropriately in a manner that reflects the dataset on which they were based. More specifically, the spatial patterns identified using the 2012 / 2013 datasets may apply more broadly, but additional seasonal sampling at several representative locations (i.e., on major tributaries and along river mainstems) within each watershed and subsequent analysis would be required to confirm that hypothesis.

3.0 POINT SOURCES

As per the conceptual model described in Section 1.4, the in-stream TN and TP loads identified in Section 2.0 originate, in part, from point sources located within each watershed. A point source evaluation was completed to better understand these point sources. The goals of the point source evaluation were to:

- Estimate the number and location of point sources within each watershed (e.g., how many municipal point sources are in the Red Deer River watershed, and where are they located?).

- Estimate how the point sources break-down by type (e.g., are more than half of the point sources in the Red Deer River watershed municipal wastewater lagoons?).
- Determine the relative contribution of all point sources to in-stream TN and TP loads (e.g., do point sources in the Red Deer River watershed account for over half of the total in-stream load at Bindloss?).

The methods used to characterize TN and TP loads from point sources are described in Section 3.1; results are described in Section 3.2.1 for the Red Deer River and Section 3.2.2 for the Carrot River. Conclusions are outlined in Section 3.3. Limitations and sources of uncertainty associated with the point source loading estimates are discussed in Section 3.4.

3.1 Methods

3.1.1 Point Source Distribution

Point sources with approvals to discharge to the Red Deer River and Carrot River watersheds were identified and summarized by sub-watershed, with the sub-watershed boundaries defined as per Table 2.1-2 and Table 2.1-4. Available data for these point sources were obtained through online data searches and data requests. The final, compiled dataset was comprised of information from:

- AEP (AEP 2011, with updates; Li 2015, pers. comm.);
- Alberta Municipal Affairs (2017);
- SWA (2011);
- the SaskH2O website (Government of Saskatchewan 2009, with updates); and
- the regional WSA Environmental Protection Officer for Prince Albert East (Wright, pers. comm. 2016a,b,c,d).

Once the available data were compiled, point sources were labeled as being of one of the following types:

- municipal wastewater
- stormwater management
- industrial

Industrial facilities were then further delineated by sector:

- Chemical
- Food Production
- Fuel
- Manufacturing
- Mining
- Oil and Gas
- Power Generation

- Sour Gas
- Waste

Once labelled, point sources were divided into the following categories, based on data availability and receiving environment:

- **Indirect discharge facilities:** Due to their design, size, or location, these facilities do not contribute directly to nutrient loads in the tributaries or the mainstems of the Red Deer and Carrot rivers. For this reason, they were not considered further in the analysis. This category included the following:
  - facilities with overland or field discharges (e.g., sewage treatment mound, tile field) that do not drain directly into a waterbody or watercourse
  - facilities producing wastewater that is used solely for irrigation
  - exfiltration systems
  - facilities using evaporation to reduce discharge volumes to negligible levels
  - facilities that are considered over-sized for the service population and have not discharged in recent years
  - facilities that discharge to an internal drainage basin (e.g., the Lenore Lake internal basin) that does not typically flow into the Red Deer River or Carrot River
- **Direct discharge facilities:** Facilities in this category directly contribute TN and TP loads to tributaries or the mainstems of the Red Deer and Carrot rivers. These facilities consist of municipal wastewater lagoons and mechanical treatment systems that discharge to a watercourse or waterbody that ultimately flows into the Red Deer or Carrot river. Loading rates from these facilities were estimated as outlined in Section 3.1.2.
- **Other:** Little to no data were available to describe these facilities, preventing their classification as either indirect or direct discharge facilities and inhibiting the calculation of TN and TP loads. Data requirements that were unavailable included:
  - the type of treatment used, if any
  - a description of the receiving environment
  - the timing and frequency of the discharge
  - the volume of water typically discharged or the service population size, which could be used to estimate discharge volumes
  - nutrient concentrations measured in the discharge, or prescribed nutrient discharge limits that could be used as a surrogate for measured concentrations

3.1.2 Load Estimation

Nutrient loads were estimated for point sources identified as direct discharge facilities. Loads associated with indirect discharge facilities would arrive as part of non-point input, if at all, and were accounted for through the non-point source assessment in Section 5.0.

As outlined in Appendix B, Tables B1 and B2, direct discharge facilities were comprised solely of municipal wastewater facilities, which consisted of:

- stabilization ponds
- lagoons and aerated lagoons
- mechanical wastewater treatment plants (WWTPs)

For direct discharge facilities that dispose of some of their effluent through irrigation and some through direct discharged to a watercourse or waterbody, it was assumed that all of the effluent was discharged to the receiving environment, and none was used for irrigation. This approach was selected, because no data were available to calculate the proportions of wastewater effluent discharged directly to the aquatic environment. Because this approach assumes that 100% of the wastewater will enter the receiving environment, rather than X% being discharged and Y% being used for irrigation, this approach will likely over-estimate point source contributions from these facilities to some extent.

Detailed wastewater effluent data, including daily discharges (cubic metres per day [m^3/d]) and TP concentration data, for the City of Red Deer were obtained from AEP (Li 2015, pers. comm.). Less detailed data for most other direct discharge facilities in the Red Deer watershed were available from AEP (2011, with updates). Service population information was current to at least 2007; where possible, census data from Alberta Municipal Affairs (2017) were used to update the service population sizes, as appropriate, for other years of interest (i.e., 1995 to 2006 and 2008 to 2014). The final, collated dataset for direct discharge facilities in the Red Deer River watershed contained the following information:

- facility type
- frequency, timing, and duration of discharge
- discharge volume (City of Red Deer only)
- TP concentrations in the discharge (City of Red Deer only)
- receiving environment
- service population size

Data for the direct discharge facilities in the Carrot River watershed were available from the SaskH2O website (Government of Saskatchewan 2009, with updates) and the regional WSA Environmental Protection Officer for Prince Albert East (Wright, pers. comm. 2016a,b,c,d). The final, collated dataset contained the following information:

- facility type
- frequency and timing of discharge
- TN and TP concentrations in the discharge
- receiving environment
- service population size

Complete concentration and discharge datasets were required to calculate TN and TP loads (kg/d) for each of the direct discharge facilities for 2013 and other years of interest used in the watershed analysis outlined in Section 5.0. However, in the Red Deer River watershed, discharge volumes and TP concentration data were only available for the City of Red Deer WWTP; TN data were not available for any of the facilities. Data regarding the duration of effluent discharge events were obtained from AEP (2011, with updates) and consisted of reported discharge dates or discharge duration limits set as part of facilities' approvals to discharge. No volume or discharge duration data were available for municipal wastewater facilities discharging to the Carrot River. Gaps in the TN and TP concentration data were also identified.

To address these data gaps, the following assumptions were made:

- Each facility in the Carrot River watershed discharged over a one-day period per discharge event.
- Effluent discharge rates (i.e., average daily flows [ADF]; m^3/d) could be calculated based on the service population and a per capita flow of 0.4 cubic metres per person per day (m^3/person/d), as per AECOM (2009).
- TN and TP concentrations in the effluent were equivalent to typical discharge concentrations described by AECOM (2009), with some calibration to local conditions as outlined below.

TP loads originating from the City of Red Deer were calculated by multiplying the reported daily TP concentrations by the daily flow. TN loads were estimated based on the discharge volume information provided by AEP (Li 2015, pers. comm.) and a TN concentration of 20 mg/L, as prescribed by AECOM (2009) for mechanical WWTPs with unknown concentrations or discharge limits. Daily loads were summarized seasonally and annually.

To assess the representativeness of the values available from AECOM (2009) for estimating TP loads from mechanical WWTPs, a comparison of loads estimated based on measured TP concentrations versus loads estimated from the 3.5 mg/L concentration recommended by AECOM (2009) was performed. The results of the comparison suggested that the concentration from AECOM over-estimated the TP loads for the City of Red Deer WWTP by a factor of 10, when compared to loads estimated from the measured concentrations. Consequently, TP loads for the seven remaining mechanical WWTPs in the Red Deer River watershed (i.e., those at Olds, Gleniffer Lake Resort, Innisfail, Drumheller, Langdon, East Coulee, and Dinosaur Provincial Park) were estimated based on an assumed TP concentration of 0.35 mg/L, rather than 3.5 mg/L.

The assumed effluent TP concentration of 0.35 mg/L is consistent with that achieved at other tertiary WWTPs in Saskatchewan and Alberta (Table 3.1-1), and the WWTP at Drumheller is a tertiary facility (Burke 2016). Data confirming the level of treatment for the remaining facilities could not be located. However, they are all associated with small population centres, and have small effluent discharge rates in comparison to the City of Red Deer. Consequently, variability in the assumed effluent TP concentration is unlikely to alter the conclusions drawn from the analysis.

Table 3.1–1: Total Phosphorus Concentrations in Effluent from Mechanical Wastewater Treatment Plants Located Outside the Red Deer River Watershed

Plant	Treatment Level	Average TP Concentration ± SD (mg/L)	Number of Samples	Sample Date Range	Source
Saskatoon	Tertiary	0.32 ± 0.51	28	2007-2010, 2015	Government of Saskatchewan 2009, with updates
Regina	Tertiary	0.89 ± 0.60	1,323	2007-2017	
Swift Current	Tertiary	0.34 ± 0.35	29	2012-2015	
Lethbridge	Tertiary	0.38	1	2007	AEP 2001, with updates
Nanton	Tertiary	0.35	1	2006	

TP = total phosphorus; SD = standard deviation; mg/L = milligrams per litre; ± = plus or minus; AEP = Alberta Environment and Parks.

Because TN and TP data were available for wastewater lagoons in the Carrot River watershed, a similar comparison was done to evaluate the representativeness of the TN (i.e., 3 mg/L) and TP (i.e., 2.5 mg/L) concentrations available from AECOM (2009) for estimating nutrient loads from lagoon stabilization ponds that conform to AEP standards. The discharge component of the load estimates was based on the above assumption (i.e., ADFs estimated based on service population and a standard per capita flow rate of 0.4 m^3/person/d). The concentration component was defined using either measured concentrations or the concentrations from AECOM (2009). A comparison of the resulting load estimates indicated that the 3 mg-N/L concentration from AECOM (2009) underestimated measured TN loads by 82 to 127% across the six lagoons for which measured effluent concentrations were available. Increasing the TN effluent concentration from 3 to 9 mg/L reduced the average difference to within 11%; consequently, a TN concentration of 9 mg/L was used for estimating TN loads from other lagoon stabilization ponds that conformed to AEP standards but for which no TN data were available.

The average difference for TP loads estimated from measured and prescribed TP concentrations was 12%, based on the facilities in the Carrot River watershed. Therefore, the use of 2.5 mg-P/L suggested by AECOM (2009) was considered acceptable for estimating TP loads for this facility type, where measured TP data were unavailable.

The final values used to calculate TN or TP loads for the various direct discharge facility types in the Red Deer and Carrot Rivers are summarized in Table 3.1-2. Values are listed in their order of preference for each facility type.

Table 3.1–2: Values used to Estimate Total Nitrogen and Total Phosphorus Loads from Direct Discharge Municipal Wastewater Facilities in the Red Deer and Carrot River Watersheds

Facility Type	Facility Sub-type	Order of Preference	Discharge Volume (m^3/d)	TN Concentration (mg/L)	TP Concentration (mg/L)
Lagoon stabilization pond	Compliant with design standards	1	Measured data	Measured data	Measured data
		2	ADF estimated from service population size and per capita flow of 0.4 m^3/person/d	9[(a)]	2.5[(b)]
Lagoon stabilization pond	Not compliant with design standards	1	Measured data	Measured data	Measured data
		2	ADF estimated from service population size and per capita flow of 0.4 m^3/person/d	15[(b)]	2.5[(b)]
Lagoon and aerated lagoon	-	1	Measured data	Measured data	Measured data
		2	ADF estimated from service population size and per capita flow of 0.4 m^3/person/d	9[(a)]	2.5[(b)]
Mechanical aerated lagoon	-	1	Measured data	Measured data	Measured data
		2	ADF estimated from service population size and per capita flow of 0.4 m^3/person/d	30[(b)]	3.7[(b)]
Mechanical WWTP	-	1	Measured data	Measured data	Measured data
		2	ADF estimated from service population size and per capita flow of 0.4 m^3/person/d	20[(b)]	0.35[(a)]

(a) Modified from AECOM (2009)

(b) Taken directly from AECOM (2009)

m^3/d = cubic metres per day; TN = total nitrogen; mg/L = milligrams per litre; TP = total phosphorus; ADF = average daily flow; m^3/person/d = cubic metres per person per day; - = not applicable; WWTP = wastewater treatment plant.

Daily nutrient loads for each facility were summarized seasonally based on the duration and timing of discharge events (see Appendix B, Tables B3 and B4). For example, a facility that discharges continuously would have a discharge duration of 365 days per year and an estimated nutrient load for each of the four seasons. Alternatively, a facility that only discharges for three weeks each fall would have a discharge duration of 21 days and an estimated nutrient load for only one season (i.e., fall). In this case, the annual load would be equal to the load in fall, as the loads for winter, spring, and summer would be zero.

TN and TP loads from point source facilities were summed along the length of tributary streams and the mainstem of the Red Deer and Carrot rivers. Consequently, all point source facilities located upstream of a given water quality station were expected to contribute to the point source loads at that station and the stations below it. In addition to these spatial summaries, loads were summarized by facility type to identify if the type of wastewater management had an influence on estimated loads. It was expected that by analyzing the data based on treatment type and location, it would be possible to identify any point sources that are likely to be major contributors to in-stream loads.

3.2 Results and Discussion

3.2.1 Red Deer River

3.2.1.1 Point Source Distribution

A total of 154 approvals to discharge were identified for 146 point sources in the Red Deer River watershed upstream of Bindloss. Point sources identified in the Red Deer River watershed included municipal wastewater facilities, stormwater management facilities, and industrial facilities (e.g., sour gas plants, mines); the distribution of these point-sources is outlined in Table 3.2-1. A full list of point sources is provided in Appendix B, Table B1.

Table 3.2–1: Summary of Point Source Facility Types in the Red Deer River Watershed

Sub-watershed[(a)]	Closest Downstream Water Quality Station[(a)]	Facility Type	Facility Sub-Type	Number of Facilities	Proportion of Whole-Watershed Total (%)
Headwater to Sundre	AB05CA0050	Municipal Wastewater	-	2	4
		Stormwater Management	-	1	
		Industrial	Fuel	1	
			Sour Gas	1	
			Wood	1	
Little Red Deer River	AB05CB270	Municipal Wastewater	-	5	7
		Industrial	Chemical	1	
			Sour Gas	4	
Medicine River	AB05CC0100	Municipal Wastewater	-	6	8
		Stormwater Management	-	2	
		Industrial	Sour Gas	3	
Sundre to City of Red Deer	AB05CC0010	Municipal Wastewater	-	9	13
		Stormwater Management	-	4	
		Industrial	Fuel	1	
			Manufacturing	1	
			Oil and Gas	2	
			Sour Gas	2	
Blindman River	AB05CC0460	Municipal Wastewater	-	3	6
		Stormwater Management	-	2	
		Industrial	Sour Gas	4	

Table 3.2–1: Summary of Point Source Facility Types in the Red Deer River Watershed

Sub-watershed[(a)]	Closest Downstream Water Quality Station[(a)]	Facility Type	Facility Sub-Type	Number of Facilities	Proportion of Whole-Watershed Total (%)
City of Red Deer to Nevis	AB05CD0250	Municipal Wastewater	-	4	7
		Industrial	Chemical	4	
			Food Production	1	
			Sour Gas	1	
Nevis to Morrin	AB05CE0009	Municipal Wastewater	-	5	4
		Industrial	Food Production	1	
Morrin to Jenner	AB05CJ0070	Municipal Wastewater	-	40	51
		Stormwater Management	-	6	
		Industrial	Chemical	3	
			Food Production	1	
			Fuel	1	
			Manufacturing	1	
			Mine	4	
			Oil and Gas	1	
			Power Generation	1	
			Sour Gas	15	
			Waste	2	
Watershed Total				**146**	**100**

(a) No point sources were identified in the sub-watershed area between Jenner and the terminal station on the Red Deer River mainstem near Bindloss.

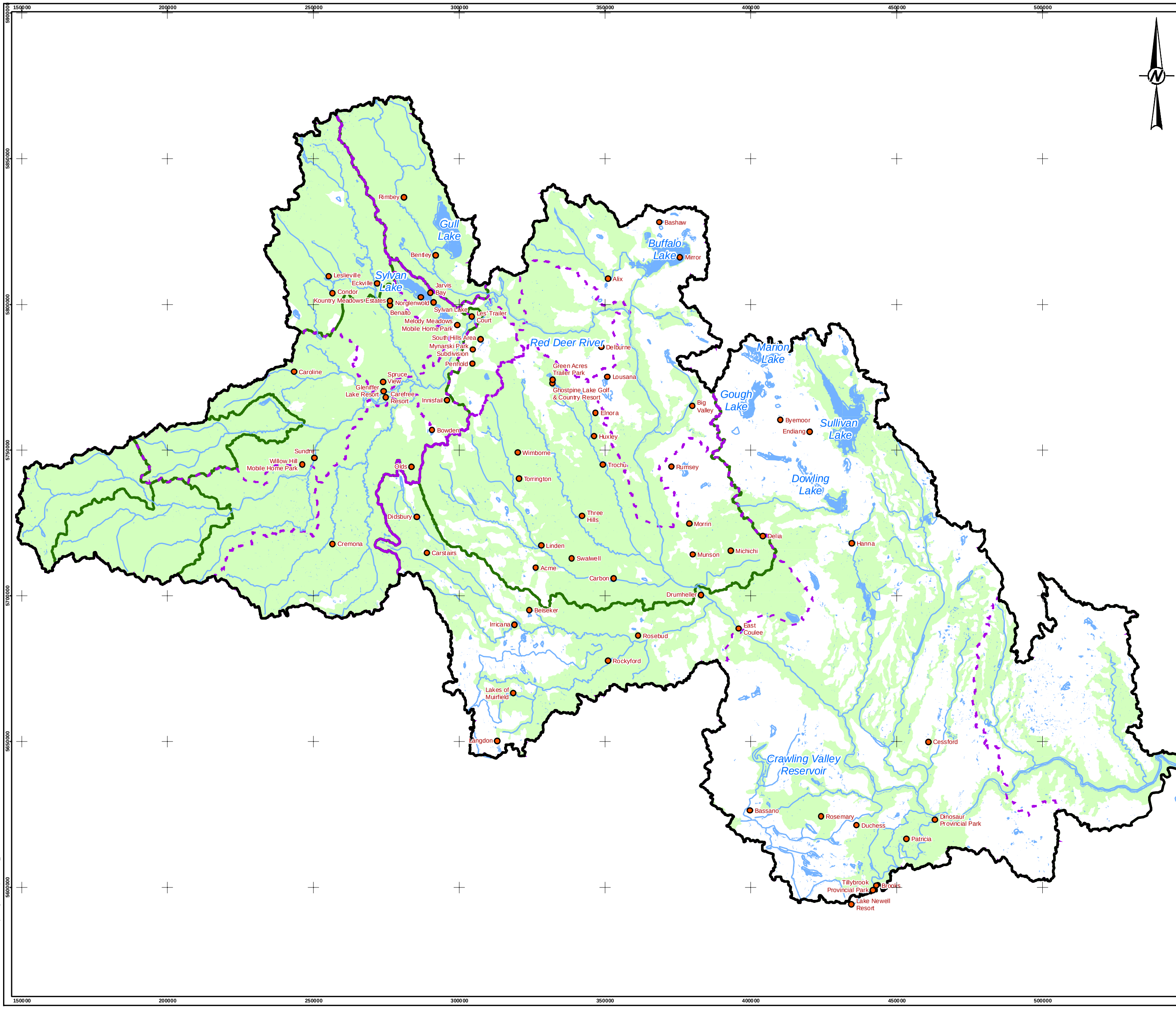
% = percent.

The total number of point sources in the Little Red Deer, Medicine, and Blindman River sub-watersheds were fairly similar, but differed by type. Unlike the Medicine and Blindman river sub-watersheds, the Little Red Deer River sub-watershed did not contain stormwater management facilities (Table 3.2-1). The Little Red Deer and Blindman river sub-watersheds had the most sour gas plants, and the Medicine River sub-watershed had the most municipal wastewater facilities.

The sub-watershed area for Station AB05CJ0070 on the Red Deer River mainstem near Jenner contained the largest total number of point sources, which is not surprising given its relatively large area compared to the other sub-watersheds. No point sources were identified in the sub-watershed downstream of AB05CJ0070 and the terminal station near Bindloss.

Overall, just over half (i.e., 51%) of the point sources in the Red Deer River watershed were municipal wastewater treatment plants; another 10% were stormwater management facilities. Collectively, industrial facilities represented 39% of the total number of point source facilities. The majority of these industrial facilities were sour gas plants, which represented 21% of the total number of point source facilities in the watershed, or 54% of all industrial facilities. None of the stormwater management or industrial facilities had sufficient data to classify them as direct or indirect discharge facilities.

Of the 74 municipal facilities with approvals to discharge to the Red Deer River or its tributaries, 72 had sufficient information to classify them as direct or indirect discharge facilities. Their locations are shown in Figure 3.2-1; details for each facility are also provided in Table 3.2-2 and Appendix B, Table B3. The Dickson Dam Administration Facility (Little Red Deer River sub-watershed) and the Meridian Beach/Raymond Shores RV Park (Blindman River sub-watershed) were the only municipal wastewater facilities which were classified as “other”, due to insufficient information.



NOTE(S)
POINT SOURCES SHOWN IN THE FIGURE ARE LIMITED TO MUNICIPAL WASTEWATER FACILITES WITH SUFFICIENT DATA FOR INCLUSION IN THE ASSESSMENT. STORMWATER MANAGEMENT AND THE INDUSTRIAL FACILITIES WERE EXCLUDED FROM THE MAP.

REFERENCE(S)
1. CROP INVENTORY 2013, AGRICULTURE AND AGRI-FOOD CANADA; CANADA OPEN DATA 2015
2. PFRA-BASED WATERSHEDS 2013, AGRICULTURE AND AGRI-FOOD CANADA; CANADA OPEN DATA 2015
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CLIENT
PRAIRIE PROVINCE WATER BOARD

PROJECT
QUANTIFICATION OF NUTRIENT SOURCES IN PRAIRIE WATER RIVERS

TITLE
POINT SOURCE FACILITIES IN THE RED DEER RIVER WATERSHED

CONSULTANT
Golder Associates

YYYY-MM-DD	2019-05-10
DESIGNED	AW
PREPARED	SBM
REVIEWED	CP
APPROVED	JP

PROJECT NO.	PHASE	REV.	FIGURE
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PATH: G:\2015\1527191 PPWB Project\Figures\Report\FIG 3_2-1 Point Source Facilities in the Red Deer River Watershed.mxd

Table 3.2–2: Summary of Municipal Wastewater Treatment Facility Types in the Red Deer River Watershed

Facility Classification	Facility Type	Facility Sub-type	Number of Facilities by Classification	Number of Facilities by Type
Direct Discharge	Lagoon stabilization pond	Compliant with design standards	24	46
	Lagoon stabilization pond	Not compliant with design standards	10	
	Lagoon and aerated lagoon	-	1	
	Mechanical aerated lagoon	-	4	
	Mechanical WWTP	-	7	
Indirect Discharge	Lagoon stabilization pond	Compliant with design standards	7	18
	Lagoon stabilization pond	Not compliant with design standards	1	
	Collection system	-	8	
	Sewage treatment mound	-	1	
	Septic tank and tile field	-	1	
Indirect Discharge - Irrigation[(a)]	Lagoon stabilization pond	Compliant with design standards	5	8
	Lagoon stabilization pond and tile field	-	1	
	Mechanical aerated lagoon and lagoon stabilization pond	-	1	
	Mechanical WWTP	-	1	
Unknown			2	2
Total			**74**	**74**

(a) Nutrient loads associated with irrigation are included in the assessment of land use and non-point sources (Section 4.0)

- = not applicable; WWTP = wastewater treatment plant.

Twenty six of the 74 municipal point sources were identified as indirect discharge facilities, based on the data available from AEP (2011, with updates). They include eight facilities that produce water that is used solely for irrigating crop land. Direct discharge facilities that are expected to contribute to TN and TP loads in the Red Deer River included 39 wastewater lagoons and seven mechanical WWTPs (Table 3.2-2).

3.2.1.2 Load Estimation

Based on an examination of point source loading for the years 2000 and 2009 to 2013 (i.e., the years of interest in the watershed analysis discussed in Section 5.0), point sources represented from 4.8 to 32% of the cumulative in-stream TN load and 1.4% to 4.9% of the cumulative in-stream TP load calculated at the terminal Red Deer River station near Bindloss (Table 3.2-3).

No longer-term temporal patterns were observed in the point source loads released from direct discharge facilities (Table 3.2-3). Therefore, variability in the proportions of the total in-stream loads attributed to point sources was reflective of changes to in-stream flows and non-point source loading during wet versus dry conditions. Cumulative point source loads tended to account for largest proportion of the total cumulative in-stream load during low flow years and the smallest proportions during higher flow years.

Additionally, TN and TP loads originating from point sources showed little seasonal variability during the years 2000 and 2009 through 2013 (Appendix B, Tables B5 and B6), apart from slight increases during spring and in the fall. This pattern is reflective of the fact that the largest point source contributors discharge year round, and are not coupled to flow availability but are instead driven by water use.

Table 3.2–3: Cumulative Total Nitrogen and Total Phosphorus Loads from Direct Discharge Facilities in the Red Deer River Watershed Upstream of Bindloss, 2000 and 2009 to 2013

Year	Total Nitrogen (TN)			Total Phosphorus (TP)		
	Point Source Load (kg/yr)	In-stream Load at Bindloss (kg/yr)	% of In-stream Load Attributable to Point Sources	Point Source Load (kg/yr)	In-stream Load at Bindloss (kg/yr)	% of In-Stream Attributable to Point Sources
2000	387,147	1,198,664	32	10,759	226,523	4.7
2009	332,406	1,292,818	26	12,398	252,953	4.9
2010	336,793	3,461,768	9.7	12,521	673,098	1.9
2011	346,985	7,300,750	4.8	12,141	815,099	1.5
2012	343,893	3,870,978	8.9	9,420	696,261	1.4
2013	351,465	3,837,204	9.2	11,512	730,573	1.6

kg/yr = kilograms per year;% = percent.

As outlined in Table 3.2-3, cumulative TN and TP loads from point sources in 2011 were 346,985 and 12,141 kg/yr, respectively. The TN estimate is lower than that generated by Burke (2016) for the same location and year (i.e., approximately 458,300 kg/yr), whereas the TP estimate is higher than that reported by Burke (2016) (i.e., 9,710 kg/yr). These differences can be attributed to the methods used to calculate the point source loading estimates. For example, Burke (2016) assumed a consistent mass loading of 10 grams of TN per person per day (g-TN/person/d) for all facilities, regardless of treatment type. In the present analysis, daily mass loading of TN varied by treatment type, and ranged from 3.6 to 12 g-TN/person/d. Similarly, although Burke (2016) used a variable TP loading rate reflective of treatment, fewer municipal facilities were considered than in the present analysis.

In 2000 and 2009 to 2013, the City of Red Deer WWTP was the single largest contributor to point source nutrient loads (Appendix B, Tables B5 and B6). Nutrient loads from this point source represented 77 to 81% of the total TN load and 42 to 57% of the total TP load originating from point sources, depending on year. This finding mirrors that of Burke (2016), who identified the City of Red Deer WWTP as the largest point source contributor of nutrient loads to the Red Deer River watershed in 2011.

Elsewhere in the watershed, point source loads represented between <1% and 6.5% of the in-stream load within the sub-watershed in which they were located (Table 3.2-4). Point sources had the smallest influence on in-stream loads in the Little Red Deer, Medicine, and Blindman river sub-watersheds, where discharges were often only seasonal or annual and service populations sizes were small. Point sources had a stronger influence in the sub-watersheds upstream of Sundre and between Morrin and Jenner. These areas were characterized as having larger population sizes, higher prevalence of continuous discharge facilities, and, for the sub-watershed near Jenner in particular, a larger number of contributing facilities. Notable contributors downstream of Morrin but upstream of Jenner included municipal wastewater treatment facilities associated with Drumheller, Langdon, Bassano, Brooks, and Dinosaur Provincial Park.

Table 3.2–4: Total Nitrogen and Total Phosphorus Loads Originating from Direct Discharge Facilities in Individual Red Deer River Sub-Watersheds, 2013

Location	Station	Total Nitrogen (TN)						Total Phosphorus (TP)					
		Point Source Load (kg/yr)		In-stream Load (kg/yr)		% of In-stream Load Attributable to Point Sources		Point Source Load (kg/yr)		In-stream Load (kg/yr)		% of In-stream Load Attributable to Point Sources	
		Watershed Specific	Cumulative	Watershed Specific[(a)]	Cumulative	Watershed Specific	Cumulative	Watershed Specific	Cumulative	Watershed Specific[(a)]	Cumulative	Watershed Specific	Cumulative
Tributaries													
Little Red Deer River	AB05CB0270	2,543	-	407,873	-	0.62	-	86	-	90,074	-	0.10	-
Medicine River	AB05CC0100	609	-	562,178	-	0.11	-	82	-	45,461	-	0.18	-
Blindman River	AB05CC0460	466	-	127,193	-	0.37	-	129	-	16,115	-	0.80	-
Mainstem													
Red Deer River	AB05CA0050	17,205	17,205	264,147	-	6.5	-	2,122	2,122	70,340	-	3.0	-
	AB05CC0010	9,782	30,138	-278,442	955,756	nc	3.2	394	2,684	-116,578	89,298	nc	3.0
	AB05CD0250	275,686	306,290	427,113	1,510,063	65	20	5,979	8,793	7,270	112,683	82	7.8
	AB05CE0009	38	306,328	-4,991	1,505,072	nc	20	439	9,232	60,895	173,578	0.7	5.3
	AB05CJ0070	45,137	351,465	933,828	2,438,900	4.8	14	2,280	11,512	330,224	503,802	0.7	2.3
	AB05CK004	0	351,465	1,398,304	3,837,204	0	9.2	0	11,512	226,770	730,573	0	1.6

(a) Values are taken from Table 2.2-6.

Watershed Specific = load attributable to activity in the immediate sub-watershed reporting to the noted monitoring station; Cumulative = cumulative load reporting to the noted monitoring station, including from the immediate sub-watershed draining to the station in question and those farther upstream.

kg/yr = kilograms per year;% = percent; nc = could not be calculated, because the in-stream load for the individual sub-watershed was negative.

3.2.2 Carrot River

3.2.2.1 Point Source Distribution

Twenty-four point sources were identified in the Carrot River watershed upstream of Turnberry. Twenty-three of the point sources identified in the watershed were municipal wastewater facilities and one was an industrial facility that manufactures farming equipment. A full list of point sources is provided in Appendix B, Table B2; Table 3.2-5 summarizes the number and type of point sources located within each sub-watershed area.

Table 3.2–5: Summary of Point Source Facility Types in the Carrot River Watershed

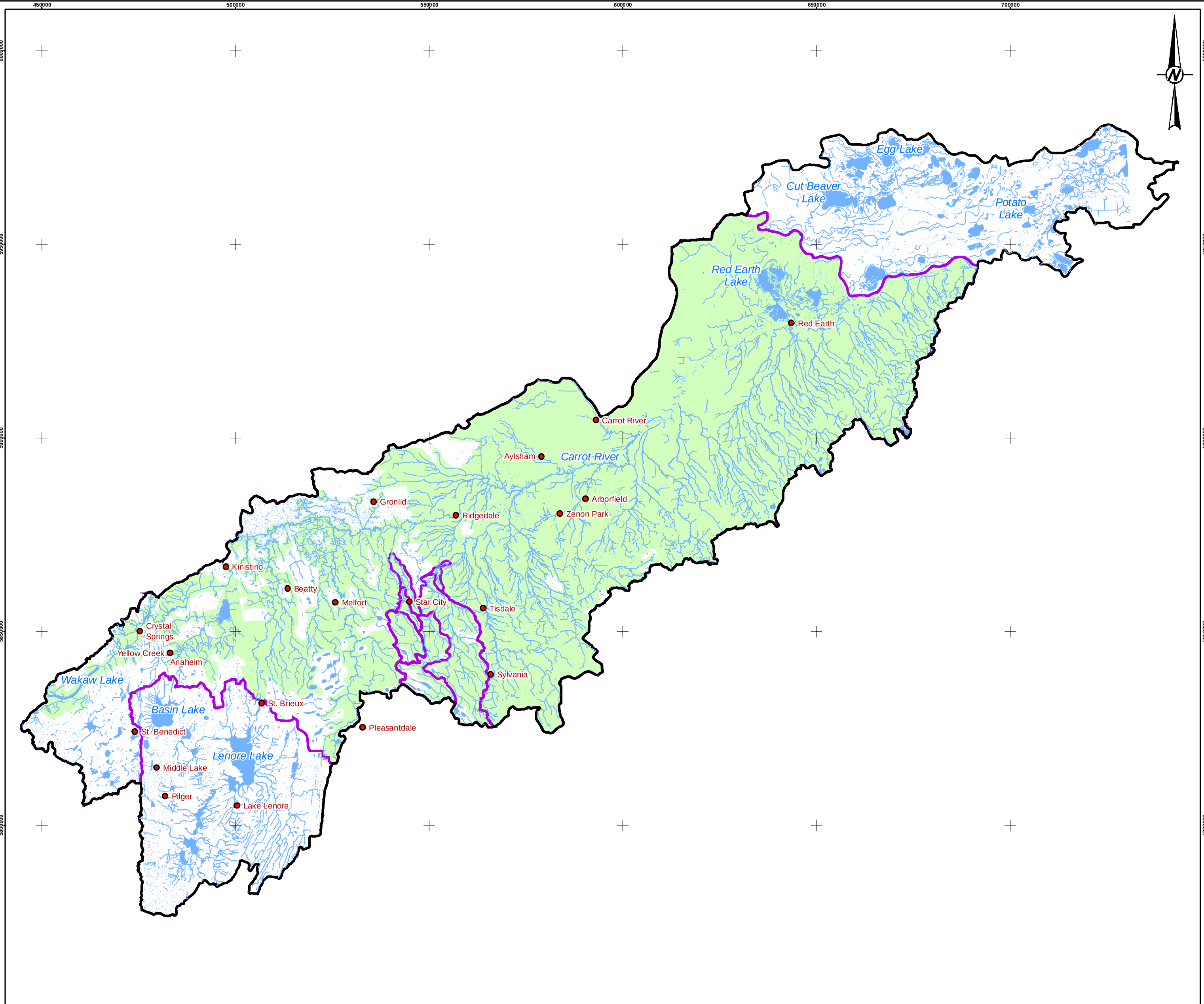
Sub-watershed	Closest Downstream Water Quality Station	Facility Type	Facility Sub-Type	Number of Facilities	Proportion of Whole-Watershed Total (%)
Sweetwater Creek	SK05KB0067	Municipal Wastewater	-	1	4
Carrot River[(a)]	SK05KH007	Municipal Wastewater	-	16	67
Lenore Lake	NA[(b)]	Municipal Wastewater	-	6	29
		Industrial	Manufacturing	1	
Watershed Total				24	100

(a) Includes all areas outside the Sweetwater Creek, Leather River, and Lenore Lake sub-watersheds; no point source facilities were identified in the Leather River sub-watershed.

(b) The Lenore Lake basin is a closed sub-watershed that does not contribute flows or nutrients to the Carrot River or its tributaries.

NA = not applicable.

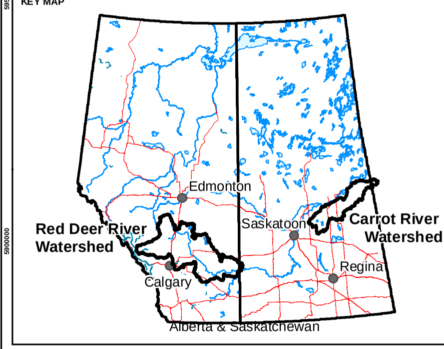
The largest numbers of point sources (i.e., 67% of all point sources) were identified in the sub-watershed area that receives flows and nutrients from areas outside the Lenore Lake, Sweetwater Creek, and Leather River sub-watersheds. This result is to be expected, given the relatively large size of this area (Figure 3.2-2).



LEGEND

- POINT SOURCE FACILITIES
- STREAM NETWORK
- WATERBODY
- CARROT RIVER WATERSHED
- SUB-WATERSHED BOUNDARY BY WATER QUALITY STATION
- EFFECTIVE DRAINAGER AREA

KEY MAP



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NOTE(S)

POINT SOURCES SHOWN IN THE FIGURE ARE LIMITED TO MUNICIPAL WASTEWATER FACILITES WITH SUFFICIENT DATA FOR INCLUSION IN THE ASSESSMENT. STORMWATER MANAGEMENT AND THE INDUSTRIAL FACILITIES WERE EXCLUDED FROM THE MAP.

REFERENCE(S)

1. CROP INVENTORY 2013, AGRICULTURE AND AGRI-FOOD CANADA; CANADA OPEN DATA 2015
2. PFRA-BASED WATERSHEDS 2013, AGRICULTURE AND AGRI-FOOD CANADA; CANADA OPEN DATA 2015
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CLIENT

PRAIRIE PROVINCE WATER BOARD

PROJECT

QUANTIFICATION OF NUTRIENT SOURCES IN PRAIRIE RIVERS

TITLE

POINT SOURCE FACILITIES IN THE CARROT RIVER WATERSHED

CONSULTANT

Golder Associates

YYYY-MM-DD	2019-05-10
DESIGNED	AW
PREPARED	SBM/LMS
REVIEWED	CP
APPROVED	JP

PROJECT NO.	PHASE	REV.	FIGURE
1527191	6000	0	3.2-2

Six municipal wastewater facilities and the single industrial facility were ultimately excluded from the analysis, because effluent is discharged to the Lenore Lake internal sub-basin, which does not typically contribute flows to the Carrot River mainstem or its tributaries. Of the remaining 17 municipal wastewater facilities, all but one had sufficient information to classify them as direct or indirect discharge facilities. No data were available for the Red Earth First Nation, so it was not considered further in the analysis (Appendix B, Table B4)..

All 16 of the remaining facilities are municipal wastewater lagoons (Appendix B, Table B4). However, nine were identified as indirect discharge facilities, based on their size (i.e., are over-sized for the communities they serve) or their receiving environment. For example, the wastewater lagoon for the Town of St. Benedict was classified as an indirect discharge facility, because the receiving environment, Sayer’s Lake, has no outflow (Hammer 1994). Consequently, there were only seven direct discharge facilities identified for the Carrot River watershed, all of which were associated with municipal wastewater treatment.

3.2.2.2 Load Estimation

Based on an examination of point source loads for the years 2000 and 2009 to 2013 (i.e., the years of interest in the watershed analysis discussed in Section 5.0), point sources are expected to represent <1% of the total cumulative in-stream TN and TP loads calculated at the terminal Carrot River station near Turnberry under wet and dry climatic conditions (Table 3.2-6).

No longer-term temporal patterns in point source loads were identified; however, loads were seasonal, occurring primarily in spring and fall (Appendix B, Tables B7 and B8). This pattern results from the municipal wastewater facilities in the Carrot River watershed typically discharging during spring and/or fall only (Appendix B, Table B4).

Table 3.2–6: Total Nitrogen and Total Phosphorus Loads Originating from Direct Discharge Facilities in the Carrot River Watershed upstream of Turnberry, 2000 and 2009 to 2013

Year	Total Nitrogen (TN)			Total Phosphorus (TP)		
	Point Source Load (kg/yr)	In-stream Load near Turnberry (kg/yr)	% of In-stream Load Attributable to Point Sources	Point Source Load (kg/yr)	In-stream Load near Turnberry (kg/yr)	% of In-stream Load Attributable to Point Sources
2000	136	379,266	0.04	37	28,334	0.13
2009	137	452,611	0.03	37	39,337	0.09
2010	115	2,133,387	0.01	37	184,544	0.02
2011	155	1,671,929	0.01	40	204,240	0.02
2012	154	1,143,626	0.01	37	115,436	0.03
2013	96	1,477,779	0.01	33	118,374	0.03

kg/yr = kilograms per year;% = percent.

During the years 2000 and 2009 through 2013, the direct discharge facilities with the largest nutrient loads were the City of Melfort, followed by Tisdale (Appendix B, Tables B7 and B8). TN loads from the Melfort wastewater treatment facility represented 27 to 71% of the cumulative point source TN loads; 16 to 50% of the total cumulative point source TN loads originated from the lagoon in Tisdale. For TP, 45 to 79% of point source loads originated at the Melfort wastewater treatment facility, and 5 to 39% came from Tisdale. However, as previously noted, point source loading, including from these two facilities, represented less than 1% of the total in-stream nutrient loads calculated at the terminal station near Turnberry.

The results for 2013 suggest that 97 to 98% of the nutrient loads from direct discharge facilities originate from the immediate sub-watershed area for the terminal station near Turnberry, reflective of the fact that the wastewater lagoons for Melfort and Tisdale discharge to this sub-watershed. Point source nutrient loads from Sweetwater Creek were negligible, and no point source loads originated from the Leather River.

3.3 Conclusions

3.3.1 Red Deer River

Point sources in the Red Deer River watershed include a total of 146 municipal wastewater, stormwater management, and industrial facilities. Just over half (i.e., 51%) of those point sources are related to municipal wastewater treatment, with another 10% associated with stormwater management. Industrial facilities represented the remaining 39%, with sour gas plants representing the majority of those industrial facilities.

Point source loading tends to be consistent over the year, with inter-annual variation largely being reflective of changing population size within the watershed. The proportions of total in-stream nutrient load attributable to point sources range from 4.8 to 32% for TN and 1.4 to 4.9% for TP. The proportional contribution is smallest during wetter, high flow years and larger in low flow years.

The City of Red Deer WWTP is the single largest contributor to point source nutrient loads. It accounts for 77 to 81% and 42 to 57% of total TN and TP point source loads, respectively. Other notable point sources include the Sundre WWTP and facilities associated with Drumheller, Langdon, Bassano, Brooks, and Dinosaur Provincial Park.

The TN loads outlined herein for the City of Red Deer WWTP were derived using an assumed effluent concentration. Given the relative size of this one point source, direct measurement of effluent TN concentrations should be considered.

Nutrient loads from direct discharge facilities in the Little Red Deer, Medicine, and Blindman River sub-watersheds are negligible relative to total in-stream loads at the individual sub-watershed level and cumulatively along the length of the Red Deer River.

Because nutrient loads from direct discharge facilities in the Red Deer River are relatively stable, it is considered unlikely that discharges from these facilities are primary drivers for either the observed increases in flow-normalized TN concentrations or the observed increases in TN and TP loads noted in Section 2.0.

3.3.2 Carrot River

Point sources in the Carrot River watershed include municipal wastewater facilities and one industrial facility. The municipal wastewater facilities typically discharge to the Carrot River in the spring and in the fall. Loads from direct discharge facilities do not appear to be increasing over time, and cumulative TN and TP loads from point sources in the Carrot River watershed represent a negligible (i.e., <1%) proportion of the total in-stream nutrient load calculated at the terminal station near Turnberry. Consequently, it would appear that non-point source loading is the primary driver controlling in-stream nutrient conditions in the Carrot River.

3.4 Limitations and Uncertainty

Limitations and uncertainty associated with the assessments of nutrient loads from point sources in the Red Deer and Carrot rivers and their tributaries are largely attributed to data availability and the use of literature values as substitutes for missing effluent data.

For both watersheds, the numbers and spatial arrangement of point sources were well defined. However, an absence of effluent flow and concentration data precluded the estimation of nutrient loads from stormwater management and industrial point sources in the Red Deer River watershed, as well as one municipal facility and the single industrial point source in the Carrot River watershed.

In the Red Deer River watershed, areas serviced by stormwater management facilities and occupied by industrial facilities are small, relative to the remaining watershed area. Additionally, only a relatively small number of facilities in the Red Deer River watershed have approvals to discharge stormwater, and discharges are expected to be of relatively short duration and initiated in response to heavy precipitation. Similarly, industrial discharges would likely be continuous inputs over the course of the year, and in-stream data indicate that nutrient concentrations and loads are highest during spring. This pattern would suggest that continuous inputs from industrial point sources cannot be substantial; otherwise, they would result in less seasonal variability in in-stream concentrations (i.e., would serve to increase winter and fall concentrations when the assimilative capacity of the Red Deer River is lower due to reduced seasonal flows). Additionally, most industrial facilities in the Red Deer River watershed are sour gas plants and other facilities related to oil and gas. Many of these facilities reuse process water or wastewater (British Columbia [BC] Oil and Gas Commission 2010; Government of Canada 2017a). That said, it is recognized that their exclusion from the analysis will likely lead to an underestimation of nutrient loads from point sources in the Red Deer River watershed. This uncertainty can be reduced through implementation of a sampling program targeted at monitoring nutrient levels in discharges from a selection of industrial dischargers.

The exclusion of industrial facilities is expected to have no impact on load estimates for the Carrot River, because the sole industrial facility does not discharge to the Carrot River or its tributaries. It discharges to Lenore Lake, a non-contributing area.

Uncertainty in the point source loading estimates is expected to arise from the use of literature values to fill in data gaps. In instances where measured discharge and/or concentration data were available, assessments were completed to help validate literature values. In two of three cases where this assessment could be completed, it was determined that load estimates based on literature values did not consistently align with estimates based on the measured data. For these cases, the literature values were adjusted or “calibrated” to the measured data. Comparing the adjusted values to nutrient concentrations in effluent discharges from other facilities and loading rates reported for other studies provides direction evidence that the adjusted values apply more broadly to similar facilities in each watershed, as was done in the analysis. Additionally, differences between the adjusted values and those from the literature are unlikely to be of major consequence to the final interpretation of the load estimates, because the largest point sources in either watershed were those on which the calibration was focused.

A lack of information prevented the adjustment or calibration of the TN effluent concentration applied to the City of Red Deer WWTP. As a result, there is uncertainty associated with the conclusion that this WWTP is the largest TN point source in the watershed, an uncertainty that can be resolved through direct measurement of TN concentrations in the effluent.

4.0 LAND COVER

As per the conceptual model outlined in Section 1.4, non-point source loading will be influenced by land cover type. Land cover includes natural areas (e.g., forests, wetlands) and areas modified by anthropogenic land uses (e.g., crops, urban areas). To understand how land cover has changed over time in both the Red Deer and Carrot River watersheds, land cover and associated land use information were gathered, synthesized, and used to:

- describe current land cover / land use within each watershed
- describe how land cover has changed over time in each watershed

Efforts were also expended to determine whether available land cover information and in-stream load data (as summarized in Section 2) could be used to identify a relationship (i.e., a correlation) between changes to patterns of land cover and in-stream nutrient loads. This exercise focussed on data for the terminal stations on the Red Deer and Carrot rivers.

The methods used to characterize patterns of land cover and examine their potential relationship with in-stream loads are described in Section 4.1; results are described in Section 4.2.1 for the Red Deer River and Section 4.2.2 for the Carrot River. Conclusions are outlined in Section 4.3, and limitations and sources of uncertainty associated with the land cover analysis are discussed in Section 4.4.

4.1 Methods

4.1.1 Land Cover Distribution

Land cover datasets from the AAFC Annual Crop Inventory listings (Government of Canada 2016d) were used to describe land cover distributions in the Red Deer and Carrot river watersheds because they provided complete spatial coverage for most years, are open-source, and contain data for a number of years between 1995 and 2014. The datasets compiled starting in 2009 have an accuracy of at least 85%, and a spatial resolution or pixel size of 30 to 56 m (Government of Canada 2017b,c,d), which was considered sufficient for use in a Geographic Information Systems (GIS)-based approach to quantifying land cover areas.

The data from AAFC were imported into a GIS platform, and land cover data were extracted for the Red Deer and Carrot River watershed areas based on the boundaries described in Section 2.1.1.1 and Section 2.1.2.1, respectively. The spatial datasets were delimited based on the EDA, rather than the GDA, for each watershed. As previously noted, the EDA is defined as the area within the GDA that is expected to contribute runoff based on a one-in-two year return period, and excludes internal drainages to marshes, sloughs, or isolated lakes (Cole 2013). The EDA was used in the land cover analyses in an effort to better understand the nature of the areas contributing runoff to each river system under the most common conditions, rather than characterizing each watershed as a whole irrespective of whether a given area contributed runoff or not. Additionally, using a common base area facilitated the identification of changes to land use over time.

Once the spatial data were delimited to the appropriate watershed boundaries, the information was converted from raster grid formats to vector polygon features. The resulting features were grouped according to their associated land cover type. Because the land cover classifications used by AAFC varied among years, a simple land cover reclassification was implemented to promote consistency among years and between the Red Deer and Carrot River watersheds (Table 4.1-1). A total of 17 land classification categories were used (Table 4.1-1); these 17 classifications represent all land cover and land use types identified in the 1995, 2000 and 2009 to 2014 datasets. Similar land cover types (e.g., grains, like barley and wheat) were grouped within a single category.

Table 4.1–1: Land Cover Classifications

Land Cover Category	Sub-classes Included in Each Category
Too wet for seeding	-
Exposed land	mud, sand, glaciers, rock, barren land, mines
Water	lakes, rivers, ponds, dugouts, reservoirs, canals
Trees/forest	coniferous, deciduous, or mixed forests
Hay/pasture	grazed grassland or pasture land, forage, alfalfa
Developed	urban areas, roadways, commercial and industrial land, golf courses
Grain/seed crops	barley, canary seeds, canola, flaxseed, hemp, mustard, oats, rye, triticale, wheat, and other similar crop types
Herbs	-
Pulses/specialty crops	beans, borage (starflower), lentils, peas, potatoes, sugar beets, sunflowers
Agriculture (undifferentiated)	livestock operations, manure storage, mixed farming
Corn crops	-
Fallow	-
Grassland/prairie	native grasses, potentially mixed with other natural vegetation types
Shrubland	mixed shrubs and native grass on marginal land
Soybean Crops	-
Wetland	-
Unclassified	Unknown[(a)]

(a) A portion of the land area in the 1995 land use datasets could not be classified by Agriculture and Agri-food Canada.

\- = no sub-classes defined for the land use classification category.

Once the land cover data were reclassified, total area (ha) of each land cover type was calculated for each year, and inter-annual differences were evaluated.

Compared to the datasets for 2009 to 2014, agricultural land types in the 1995 and 2000 datasets were not well differentiated, although the overall proportions of agricultural lands identified in 1995 and 2000 were similar to those identified within the EDA for years 2009 to 2014. To provide comparable levels of differentiation, it was assumed that agricultural diversity in 1995 and 2000 mirrored that observed in later years. More specifically, in 1995 and 2000, the total land area identified as agricultural was subdivided into categories, such as grain, hay and corn, based on the median proportions observed between 2009 and 2014. For example, between 2009 and 2014, grain/seed crops represented approximately 97% (range = 95% to 98%) of agricultural lands in the Red Deer River watershed; it was therefore assumed that grain/seed crops would represent 97% of the total agricultural land area in 1995 and 2000. This approach was used, because the proportions represented by each agricultural land type (i.e., too wet for seeding, grain/seed crops, herbs, pulses/specialty crops, undifferentiated agriculture, corn crops, fallow, and soybean crops) were consistent from 2009 through 2014, with a range spanning no more than 2 to 3%.

After the land use data from 1995, 2000, and 2009 to 2014 were assigned to their appropriate land cover descriptions and agricultural land areas were further sub-divided for the years 1995 and 2000, summary tables and maps were developed. For 2013, the areas (ha) associated with each of the land use classifications were determined for the Red Deer and Carrot River tributaries and the remaining sub-watershed areas along the river mainstems, including the terminal stations. Maps of the spatial distributions of the various land cover types within the Red Deer and Carrot river sub-watersheds were produced. For the years 1995, 2000, 2009 through 2012, and 2014, areas associated with each of the land cover classifications were determined across each watershed, and maps depicting the locations of each land cover type were developed. Pie charts and stacked bar graphs showing the proportions of the different land cover types by year were prepared and used to characterize land cover changes over time.

4.1.2 Data Review in Support of a Potential Examination of Correlations Between Land Use and Nutrient Loads

Once land cover areas (ha) and their relative contributions to total watershed areas (i.e.,% contribution) were identified for the various land cover types, the data for the terminal stations on the Red Deer and Carrot rivers were reviewed to identify if variations over time among the different land types were sufficiently large to support an examination of potential correlations between land use and in-stream nutrient loads.

First, land cover types representing less than 3% of the total watershed area across multiple years were excluded from consideration, because loading from these land cover types would likely be insufficient to materially affect in-stream loads (McFarland and Hauck 2001). This step resulted in the exclusion of 12 of the 17 identified land types in the Red Deer River watershed. The five remaining land types consisted of:

- Exposed land
- Grain / seed crop
- Grassland / prairie
- Hay / pasture
- Trees / forest

In the Carrot River watershed, this first step resulted in the exclusion of 13 of the 17 identified land types, with the remaining land types consisting of:

- Grain / seed crop
- Hay / pasture
- Trees / forest
- Wetland

Next, the degree of variation among years for each of the remaining land types was examined, and the potential to detect statistically significant correlations was evaluated. The evaluation considered the number of data points available for the analysis (i.e., 8) and the multiple comparisons involved (e.g., five for the Red Deer River; one per land type), along with the guidance provided by Lazzeroni and Ray (2012), Diez et al. (2012), Wilson VanVoorhis and Morgan (2007).

For all five land types in the Red Deer River watershed and the four remaining land types in the Carrot River watershed, the degree of variation among years was small, typically in the order of 5 to 10%. Given the small number of data points available and this small degree of annual variation, the analysis was discontinued, as there would be insufficient statistical power available to detect meaningful correlations between land type and in-stream load.

4.2 Results and Discussion

4.2.1 Land Cover Distribution in the Red Deer River Watershed

In 2013, the dominant land cover types in the Little Red Deer, Medicine, and Blindman River sub-watersheds were (Table 4.2-1):

- grain/seed crops (34 to 36% of the EDA)
- trees/forest (17 to 31% of the EDA)
- hay/pasture (17 to 30 of the EDA)

Together, these three land types represented between 81 and 86% of the EDA in each tributary sub-watershed. The remaining areas were primarily a mix of developed land, grassland/prairie, pulses/specialty crops, shrubland, water, and wetlands (Appendix C, Figure C1). Land cover types that were absent from the three tributary sub-watersheds in 2013 consisted of: too wet for seeding, herbs, agriculture (undifferentiated), fallow, and soybean crops.

Table 4.2–1: Total Area of Various Land Cover Types Identified within the Little Red Deer, Medicine, and Blindman River Sub-watersheds, 2013

Land Cover Type	Area (ha) by Station(a)					
	Little Red Deer River		Medicine River		Blindman River	
	AB05CB0270		AB05CC0100		AB05CC0460	
	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)
Agriculture (undifferentiated)	0	0	0	0	0	0
Corn crops	11	<0.01	0	0	178	0.10
Developed	3,313	1.4	1,791	0.67	2,828	1.6
Exposed land	206	0.08	198	0.07	529	0.31
Fallow	0	0	0	0	0	0
Grain/seed crops	87,153	36	92,810	35	58,341	34
Grassland/prairie	24,599	10	1,940	0.73	80	0.05
Hay/pasture	41,749	17	76,655	29	52,194	30
Herbs	0	0	0	0	0	0
Pulses/specialty crops	1,195	0.49	1,779	0.67	1,818	1.1
Shrubland	6,531	2.7	18,921	7.1	11,778	6.8
Soybean Crops	0	0	0	0	0	0
Too wet for seeding	0	0	0	0	0	0
Trees/forest	75,488	31	58,840	22	29,003	17
Water	313	0.13	899	0.34	8,671	5.0
Wetland	2,219	0.91	13,084	4.9	7,074	4.1
Total Sub-watershed Area (ha)(b)	**242,777**	**100**	**266,917**	**100**	**172,494**	**100**

(a) The tributaries are listed in order from upstream to downstream, based on where they flow into the Red Deer River.

(b) Refers to the total effective drainage area (EDA) for each station listed in the table.

ha = hectares;% = percent; <= less than.

The cumulative total areas (ha) of each land cover type upstream of the water quality stations on the Red Deer River mainstem are summarized in Table 4.2-2; areas reported for each station include the areas for all upstream sub-watersheds that contribute to the station of interest. Total areas (ha) for individual sub-watersheds (i.e., non-cumulative areas) are summarized in Table 4.2-3.

Table 4.2–2: Cumulative Total Areas (Hectares [ha]) of Various Land Cover Types Identified within Sub-watersheds that Terminate at Water Quality Stations on the Red Deer River Mainstem, 2013

Land Cover Type	Cumulative Area (ha) by Station[a]											
	AB05CA0050		AB05CC0010		AB05CD0250		AB05CE0009		AB05CJ0070		AB05CK004	
	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)
Agriculture (undifferentiated)	0	0	0	0	0	0	0	0	0	0	0	0
Corn crops	0	0	55	<0.01	304	0	628	0.04	3,304	0.11	3,306	0.11
Developed	1,709	0.53	11,819	1.0	21,456	1.5	23,388	1.5	36,023	1.2	36,367	1.2
Exposed land	78,529	24	82,375	7.3	83,250	5.9	92,154	5.8	137,162	4.7	140,225	4.6
Fallow	0	0	0	0	0	0	0	0	1,051	0.04	5,495	0.18
Grain/seed crops	2,872	0.89	243,440	22	363,246	26	438,380	28	1,094,353	38	1,105,631	36
Grassland/prairie	28,459	8.9	71,410	6.3	72,788	5.2	78,092	5.0	398,398	14	491,962	16
Hay/pasture	6,085	1.9	166,764	15	236,025	17	269,268	17	430,745	15	446,038	15
Herbs	0	0	0	0	0	0	0	0	24	<0.01	24.4	<0.01
Pulses/specialty crops	9	<0.01	3,657	0.32	6,374	0.45	7,994	0.51	35,300	1.2	36,509	1.2
Shrubland	17,709	5.5	57,735	5.1	75,045	5.3	92,018	5.8	111,813	3.8	112,118	3.7
Soybean Crops	0	0	0	0	0	0	0	0	96	<0.01	96	<0.01
Too wet for seeding	0	0	0	0	0	0	0	0	0.34	<0.01	0.34	<0.01
Trees/forest	185,411	58	461,583	41	497,501	35	510,000	32	522,669	18	524,473	17
Water	258	0.08	8,732	0.77	18,651	1.3	30,053	1.9	52,788	1.8	54,928	1.8
Wetland	505	0	19,865	1.8	28,179	2.0	34,835	2.2	84,627	2.9	87,943	2.9
Total Sub-watershed Area (ha)[b]	**321,545**	**100**	**1,127,435**	**100**	**1,402,819**	**100**	**1,576,808**	**100**	**2,908,354**	**100**	**3,045,118**	**100**

(a) Stations are listed in order from upstream to downstream along the Red Deer River mainstem. The land cover area for a given station includes upstream sub-watersheds that would contribute to the loads passing the station of interest (e.g., the land cover areas for station AB05CC0010 include areas in the Little Red Deer River and Medicine River sub-watersheds because these tributaries flow into the mainstem upstream of AB05CC0010).

(b) Refers to the total effective drainage area (EDA) for each station listed in the table.

ha = hectares;% = percent; <= less than.

Table 4.2–3: Total Areas (Hectares [ha]) of Various Land Cover Types Identified within Individual Sub-watersheds that Terminate at Water Quality Stations on the Red Deer River Mainstem, 2013

Land Cover Type	Individual Sub-watershed Areas (ha) by Station[a]											
	AB05CA0050		AB05CC0010		AB05CD0250		AB05CE0009		AB05CJ0070		AB05CK004	
	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)
Agriculture (undifferentiated)	0	0	0	0	0	0	0	0	0	0	0	0
Corn crops	0	0	44	0.01	71	0.07	324	0.19	2,677	0.20	1	<0.01
Developed	1,709	0.53	5,006	1.7	6,809	6.6	1,932	1.1	12,635	0.95	344	0.25
Exposed land	78,529	24	3,443	1.2	345	0.34	8,904	5.1	45,009	3.4	3,063	2.2
Fallow	0	0	0	0	0	0	0	0	1,051	0.08	4,444	3.2
Grain/seed crops	2,872	0.89	60,605	20	61,464	60	75,134	43	655,974	49	11,278	8.2
Grassland/prairie	28,459	8.9	16,412	5.5	1,298	1.3	5,303	3.0	320,307	24	93,564	68
Hay/pasture	6,085	1.9	42,275	14	17,067	17	33,243	19	161,477	12	15,293	11
Herbs	0	0	0	0	0	0	0	0	24	<0.01	0	0
Pulses/specialty crops	9	<0.01	674	0.23	900	0.87	1,619	0.93	27,306	2.1	1,209	0.88
Shrubland	17,709	5.5	14,574	4.9	5,533	5.4	16,973	9.8	19,796	1.5	305	0.22
Soybean Crops	0	0	0	0	0	0	0	0	96	0.01	0	0
Too wet for seeding	0	0	0	0	0	0	0	0	0.34	<0.01	0	0
Trees/forest	185,411	58	141,845	48	6,915	6.7	12,499	7.2	12,669	0.95	1,805	1.3
Water	258	0.08	7,262	2.5	1,248	1.2	11,403	6.6	22,734	1.7	2,140	1.6
Wetland	505	0.16	4,057	1.4	1,240	1.2	6,656	3.8	49,792	3.7	3,317	2.4
Total Sub-watershed Area (ha)[b]	**321,545**	**100**	**296,197**	**100**	**102,890**	**100**	**173,989**	**100**	**1,331,546**	**100**	**136,764**	**100**

(a) Stations are listed in order from upstream to downstream along the Red Deer River mainstem. The land cover area for a given station does not include upstream sub-watersheds that would contribute to the loads passing the station of interest (e.g., the land cover areas for station AB05CC0010 only include the immediate sub-watershed area, and not areas in the Little Red Deer River and Medicine River sub-watersheds.

(b) Refers to the total effective drainage area (EDA) for each station listed in the table.

ha = hectares;% = percent; = less than.

The drainage area associated with the furthest upstream sub-watershed (i.e., that associated with water quality Station AB05CA0050 near Sundre; Figure 2.1-1), which represented approximately one-tenth of the total EDA, was dominated by (Table 4.2-2 and Table 4.2-3):

- trees/forest (58%)
- exposed land (24%)
- grassland/prairie (9%)

The treed/forested and exposed land area in this sub-watershed represented approximately one-third and one-half of the treed/forested and exposed land areas, respectively, across the entire Red Deer River watershed in 2013 (Table 4.2-2). Agricultural activity was virtually absent from this sub-watershed (i.e., land cover types associated with crop production represented <1% of the sub-watershed EDA).

The next downstream water quality station on the Red Deer River mainstem is Station AB05CC0010, which is located immediately upstream of the City of Red Deer (Figure 2.1-1). In 2013, the cumulative EDA (i.e., all contributing areas for AB05CC0010) was dominated by (Table 4.2-2; Appendix C, Figure C1):

- trees/forest (41%)
- grain/seed crops (22%)
- hay/pasture (15%)

These land cover types were also identified as the dominant land cover types by Burke (2016) for the same region in 2000.

Treed/forested areas represented roughly half of the land cover in the immediate sub-watershed. Most of the grain/seed crops and hay/pasture land were concentrated along the Little Red Deer and Medicine rivers, which drain into the Red Deer River mainstem upstream of the station, and along the river mainstem itself between Sundre and the City of Red Deer.

In the sub-watershed area on the Red Deer River mainstem between the City of Red Deer and the next downstream water quality station near Nevis (AB05CD0250), land cover in 2013 transitioned from largely forested/treed areas to more agricultural land. Dominant land cover types in this sub-watershed were grain/seed crops (60%) and hay/pasture (17%) (Table 4.2-3). However, trees/forest remained the dominant land cover type in the cumulative EDA, being concentrated, as previously noted, upstream of the City of Red Deer (Table 4.2-2; Appendix C, Figure C1).

Agricultural land uses continued to dominate with increasing distance downstream; the immediate sub-watershed area for AB05CE0009 near Morrin was dominated by:

- grain/seed crops (43%)
- hay/pasture (19%)
- shrubland (10%)

The dominant land cover types in the cumulative sub-watershed area for AB05CE0009 were primarily dictated by land cover and land use practices upstream of station AB05CD0250, and therefore included trees/forest.

The sub-watershed between Morrin and Jenner contained large areas of agricultural land. Grain/seed crops represented 49% of the individual sub-watershed EDA in 2013 (Table 4.2-3). Cumulatively, the EDA for this station was dominated by:

- grain/seed crops (38%)
- trees/forest (18%)
- hay/pasture (15%)
- grassland/prairie (14%)

At the downstream end of the watershed, grassland/prairie was the dominant land cover type, covering approximately 68% of the sub-watershed EDA between Jenner and Bindloss (Table 4.2-3). Overall, in 2013, the dominant land cover types upstream of the terminal station on the Red Deer River mainstem near Bindloss were grain/seed crops, trees/forest, grassland/prairie, and hay/pasture (Table 4.2-2). Agricultural lands (i.e., croplands and hay/pasture) represented 52% of the total EDA.

The same land cover types tended to dominate the Red Deer River during years 1995, 2000, 2009, and 2011 through 2014 (Table 4.2-4; Figure 4.2-1; Appendix C, Figures C2 through C9). Trees/forest represented between 10% and 17% of total land cover across the watershed; grain/seed crops and hay/pasture represented 32% to 43% and 10% to 21% of the total EDA, respectively. Total land area associated with agricultural uses varied between 44% and 56%. Shrubland, wetland, and developed areas exhibited general increases over time, but represented only small portions of the overall watershed.

Table 4.2–4: Total Areas (Hectares [ha]) of Various Land Cover Types Identified within the Red Deer River Watershed, 2000 and 2009-2014

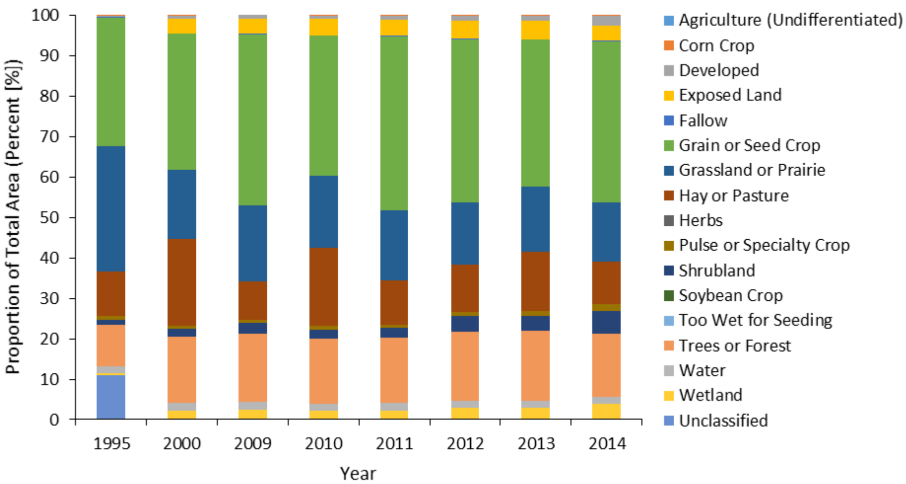
Land Cover Type	1995		2000		2009		2010		2011		2012		2013		2014	
	Area (ha)	Proportion of Total Area (%)[(a)]	Area (ha)	Proportion of Total Area (%)[(a)]	Area (ha)	Proportion of Total Area (%)[(a)]	Area (ha)	Proportion of Total Area (%)[(a)]	Area (ha)	Proportion of Total Area (%)[(a)]	Area (ha)	Proportion of Total Area (%)[(a)]	Area (ha)	Proportion of Total Area (%)[(a)]	Area (ha)	Proportion of Total Area (%)[(a)]
Agriculture (Undifferentiated)	0	0	0	0	0	0	0	0	19	<0.01	0.27	<0.01	0	0	0	0
Corn Crop	1,814	0.06	1,917	0.06	0	0	2,051	0.07	2,320	0.08	1,997	0.07	3,306	0.11	5,033	0.17
Developed	11,261	0.37	27,634	0.91	27,234	0.89	25,221	0.83	31,886	1.0	35,931	1.2	36,367	1.2	76,738	2.5
Exposed Land	0	0	106,651	3.5	114,365	3.8	123,945	4.1	120,540	4.0	139,274	4.6	140,225	4.6	112,088	3.7
Fallow	3,757	0.12	3,970	0.13	825	0.03	4,548	0.15	8,281	0.27	4,204	0.14	5,495	0.18	3,419	0.11
Grain or Seed Crop	971,291	32	1,026,321	34	1,286,984	42	1,054,955	35	1,306,250	43	1,226,902	40	1,105,631	36	1,209,457	40
Grassland or Prairie	939,931	31	520,393	17	574,563	19	538,070	18	526,442	17	469,379	15	491,962	16	449,223	15
Hay or Pasture	339,663	11	649,766	21	291,492	9.6	590,790	19	336,684	11	356,089	12	446,038	15	319,412	10
Herbs	9.1	<0.01	9.6	<0.01	0	0	0	0	0	0	118	<0.01	24	<0.01	23	<0.01
Pulse or Specialty Crop	24,267	0.80	25,642	0.84	23,212	0.76	26,123	0.86	17,629	0.58	30,924	1.0	36,509	1.2	53,023	1.7
Shrubland	40,097	1.3	57,536	1.9	80,682	2.7	70,936	2.3	79,525	2.6	118,436	3.9	112,118	3.7	172,821	5.7
Soybean Crop	0	0	0	0	0	0	0	0	0	0	0	0	96	<0.01	203	0.01
Too Wet for Seeding	0.15	<0.01	0.16	<0.01	0	0	711	0.02	0	0	1.9	<0.01	0.34	<0.01	0	0
Trees or Forest	310,738	10	501,606	16	514,040	17	487,699	16	492,877	16	518,514	17	524,473	17	471,271	15
Water	51,625	1.7	56,675	1.9	57,444	1.9	51,095	1.7	53,326	1.8	55,378	1.8	54,928	1.8	54,970	1.8
Wetland	13,718	0.5	66,592	2.2	73,722	2.4	68,983	2.3	69,344	2.3	87,974	2.9	87,943	2.9	117,424	3.9
Unclassified	337,485	11.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Watershed Area (ha)[(b)]	**3,045,657**	**100**	**3,044,714**	**100**	**3,044,562**	**100**	**3,045,128**	**100**	**3,045,122**	**100**	**3,045,122**	**100**	**3,045,118**	**100**	**3,045,106**	**100**

(a) Refers to the proportion of the total watershed area (ha) that is represented by a particular land cover type.

(b) Refers to the total area (ha) of the effective drainage area (EDA) identified for the terminal Prairie Provinces Water Board (PPWB) station (AB05CK004).

ha = hectares;% = percent.

Figure 4.2-1: Proportions (%) of Land Cover Types in the Red Deer River Watershed by Year, 1995, 2000, and 2009-2014



The land cover areas in Table 4.2-4 for the year 2000 were compared to those identified by Burke (2016) for the same year and location (i.e., at the PPWB station near Bindloss). In general, land areas classified into the largest groups were in agreement. The largest discrepancy involved the amount of treed/forested area present (i.e., 16% trees/forest in the present study versus 9.3% of "productive woodland"); this discrepancy remains reasonably small (thereby indicating consistency between the two studies), and may be related to the methods used to identify and classify forested areas.

4.2.2 Land Cover Distribution in the Carrot River Watershed

For Sweetwater Creek, grain/seed crops were by far the most dominant land cover type in 2013. This land cover type occupied 86% of the total tributary sub-watershed (Table 4.2-5; Appendix C, Figure C10). Much of the remaining area was associated with hay/pasture, exposed land, and trees/forest. None of the land within the Sweetwater Creek sub-watershed was classified as herbs, agriculture (undifferentiated), corn crops, grassland/prairie, or soybean crops.

Table 4.2–5: Cumulative Total Areas (Hectares [ha]) of Various Land Cover Types Identified within Sub-watersheds that Terminate at Water Quality Stations in the Carrot River Watershed, 2013

Land Cover Type	Area (ha) by Station[(a)]													
	Sweetwater Creek						Leather River						Carrot River	
	SK05KB0066		SK05KB0067		SK05KB0068		SK05KB0062		SK05KB0064		SK05KB0065		SK05KH007	
	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)
Agriculture (undifferentiated)	0	0	0	0	0	0	0	0	10	0.02	10	0.02	246	0.02
Corn crops	0	0	0	0	0	0	0	0	0.8	<0.01	1	<0.01	6	<0.01
Developed	44	0.62	102	1.1	166	1.2	24	0.19	131	0.31	131	0.30	4,734	0.44
Exposed land	283	4.0	322	3.4	338	2.5	735	6.1	1,280	3.1	1,285	3.0	14,848	1.4
Fallow	27	0.39	27	0.29	27	0.21	53	0.44	94	0.22	94	0.22	3,734	0.34
Grain/seed crops	5,841	82	7,844	82	11,428	86	7,605	63	31,374	75	32,588	75	513,635	47
Grassland/prairie	0	0	0	0	0	0	10	0.09	73	0.17	73	0.17	432	0.04
Hay/pasture	350	4.9	517	5.4	531	4.0	1,346	11	3,503	8.4	3,513	8.1	48,196	4.4
Herbs	0	0	0	0	0	0	0	0	0	0	0	0	126	0.01
Pulses/specialty crops	0	0	92	0.96	92	0.69	69	0.57	81	0.19	81	0.19	8,614	0.80
Shrubland	205	2.9	283	3.0	312	2.3	794	6.5	1,639	3.9	1,654	3.8	44,006	4.1
Soybean Crops	0	0	0	0	0	0	0	0	0	0	0	0	16	<0.01
Too wet for seeding	32	0.45	32	0.34	32	0.24	73	0.60	96	0.23	96	0.22	2,723	0.25
Trees/forest	211	3.0	254	2.7	265	2.0	1,115	9.2	3,124	7.4	3,263	7.5	334,184	31
Water	21	0.29	21	0.22	21	0.16	62	0.51	70	0.17	70	0.16	16,287	1.5
Wetland	84	1.2	94	0.98	96	0.72	235	1.9	456	1.1	456	1.1	91,503	8.4
Total Sub-watershed Area (ha)[(b)]	**7,099**	**100**	**9,588**	**100**	**13,309**	**100**	**12,122**	**100**	**41,932**	**100**	**43,315**	**100**	**1,083,291**	**100**

(a) Stations are listed in order from upstream to downstream. The land cover area for a given station includes upstream sub-watersheds that would contribute to the loads passing the station of interest (e.g., the land cover areas for station SK05KB0067 include areas in the upstream of SK05KB0066).

(b) Refers to the total effective drainage area (EDA) for each station listed in the table.

ha = hectares;% = percent.

Table 4.2–6: Total Areas (Hectares [ha]) of Various Land Cover Types Identified within Individual Sub-watersheds that Terminate at Water Quality Stations in the Carrot River Watershed, 2013

Land Cover Type	Area (ha) by Station[(a)]													
	Sweetwater Creek						Leather River						Carrot River	
	SK05KB0066		SK05KB0067		SK05KB0068		SK05KB0062		SK05KB0064		SK05KB0065		SK05KH007	
	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)	Area (ha)	Proportion of Total Area (%)
Agriculture (undifferentiated)	0	0	0	0	0	0	0	0	10	0.03	0	0	235	0.02
Corn crops	0	0	0	0	0	0	0	0	1	<0.01	0	0	5	<0.01
Developed	44	0.62	58	2.3	64	1.7	24	0.19	107	0.36	0	0	4,437	0.43
Exposed land	283	4.0	38	1.5	16	0.43	735	6.1	545	1.8	5	0.33	13,226	1.3
Fallow	27	0.39	0	0	0	0	53	0.44	41	0.14	0	0	3,613	0.35
Grain/seed crops	5,841	82	2,003	80	3,584	96	7,605	63	23,768	80	1,214	88	469,620	46
Grassland/prairie	0	0	0	0	0	0	10	0.09	62	0.21	0	0	359	0.03
Hay/pasture	350	4.9	166	6.7	14	0.38	1,346	11	2,157	7.2	10	0.74	44,152	4.3
Herbs	0	0	0	0	0	0	0	0	0	0	0	0	126	0.01
Pulses/specialty crops	0	0	92	3.7	0	0	69	0.57	11	0.04	0	0	8,442	0.82
Shrubland	205	2.9	78	3.1	29	0.78	794	6.5	846	2.8	15	1.1	42,040	4.1
Soybean Crops	0	0	0	0	0	0	0	0	0	0	0	0	16	<0.01
Too wet for seeding	32	0.45	0	0	0	0	73	0.60	23	0.08	0	0	2,595	0.25
Trees/forest	211	3.0	43	1.7	11	0.29	1,115	9.2	2,009	6.7	140	10	330,655	32
Water	21	0.29	0	0	1	0.02	62	0.51	9	0.03	0	0	16,195	1.6
Wetland	84	1.2	10	0.41	3	0.07	235	1.9	220	0.74	0	0	90,951	8.9
Total Sub-watershed Area (ha)(b)	**7,099**	**100**	**2,489**	**100**	**3,721**	**100**	**12,122**	**100**	**29,810**	**100**	**1,384**	**100**	**1,026,667**	**100**

(a) Stations are listed in order from upstream to downstream. The land cover area for a given station does not include upstream sub-watersheds that would contribute to the loads passing the station of interest (e.g., the land cover areas for station SK05KB0067 only include the immediate sub-watershed area, and not areas in the SK05KB0066 sub-watershed.

(b) Refers to the total effective drainage area (EDA) for each station listed in the table.

ha = hectares;% = percent.

Approximately half (i.e., 51%) of the grains/seed crops land cover type was located in the most up-stream sub-watershed (i.e., upstream of SK05KB0066) (Tables 4.2-5 and 4.2-6). All or nearly all of the land areas within the Sweetwater Creek EDA that were classified as too wet for seeding, exposed land, water, trees/forest, fallow, and wetland were located in this same zone. Between stations SK05KB0066 and SK05KB0067, areas of hay/pasture, developed land, and grains/seed crops increased; pulses and specialty crops were also noted. Land cover types were fairly similar among the sub-watershed areas for station SK05KB0067 and the farthest downstream station at SK05KB0068, although areas represented by grains/seed crops and developed land increased (Table 4.2-6).

Similar to Sweetwater Creek, the Leather River sub-watershed was dominated by grain/seed crops, which made up 75% of cumulative EDA (Table 4.2-5; Appendix C, Figure C10). On a smaller, individual catchment scale, grain/seed crops represented anywhere from 63% to 88% of the drainage area (Table 4.2-6). Trees/forest and hay/pasture were sub-dominant land cover types; however, the areas associated with these classifications were only equivalent to between 10% and 15% of the areas assigned to grains/seed crops. None of the land within the Leather River sub-watersheds was classified as herbs or soybean crops in 2013; only one hectare of land was classified as corn crops.

The most upstream sub-watershed on the Leather River (SK05KB0062) is 12,123 km^2, or approximately 28% of the total cumulative sub-watershed area for the Leather River (Figure 2.1-2). This same area represented 23% of the land in the Leather Creek sub-watershed assigned to the grains/seeds category in 2013. Most of the lands within the Leather River sub-watersheds that were classified as too wet for seeding, water, and pulses/specialty crops categories in 2013 were also located within this upstream sub-watershed.

The areas upstream of SK05KB0064 represented approximately 97% of the total drainage area that was assessed for the Leather River (Figure 2.1-2). Nearly all (i.e., 96%) of the land within the Leather River drainage area that was classified as grains/seed crops in 2013 was located upstream of the SK05KB0064 station. The bulk of the lands associated with grains/seeds was located within the SK05KB0064 EDA, rather than the most upstream sub-watershed. Each of the remaining land cover types that were identified in this sub-watershed represented less than 10% of the total drainage area.

The most downstream sub-watershed on the Leather River is the smallest of the three that were included in the assessment; only small increases in the total areas attributed to the various land cover types were observed based on the inclusion of this sub-watershed area (Table 4.2-6). The relative contributions of the various land cover types to the total sub-watershed area were essentially the same as those observed for the cumulative sub-watershed area at SK05KB0064.

In 2013, the individual sub-watershed area upstream of the terminal station on the Carrot River near Turnberry represented 95% of the whole-watershed EDA, and was dominated by grain/seed crops (46%) and trees/forest (32%) (Table 4.2-6). The EDA for the whole Carrot River watershed upstream of Turnberry was primarily comprised of (Table 4.2-5):

- grain/seed crops (47%)
- trees/forest (31%)
- wetland (8%)

Collectively, only about 13% of the land cover in the Carrot River watershed in 2013 was assigned to the remaining land cover types (Appendix C, Figure C11).

The relative proportions of the most land cover types in the Carrot River watershed varied, if only a little, among the years 1995, 2000, and 2009 to 2014 (Table 4.2-7; Figure 4.2-2; Appendix C, Figures C11 through C18). The year 2010 differed from all other years in that the “too wet to be seeded” category represented a much higher proportion of the overall land cover (i.e., 23% versus <1% in the other years that were assessed). This spike in the total land areas that were too wet for seeding is corroborated by the flow volume data for that same year (Table 2.2-10). The excess moisture that would have existed in the watershed is likely to have hampered crop production for that year.

In the years other than 2010, some of the land classification types consistently represented large proportions of the EDAs and others were typically absent or only present in small quantities (Figure 4.2-2; Appendix C, Figures C11 through C18). Grain/seed crops were the dominant land cover type, representing between 44 to 48% of the total EDA. Trees/forest was the sub-dominant land cover type each year, and covered anywhere from 23 to 31% of the EDA (Table 4.2-7; Figure 4.2-2). Each of the other land cover types typically represented less than 10% of the EDA, with the exception of wetlands, which represented 11% of the Carrot River EDA in 2014. Undifferentiated agriculture, corn crops, herbs, and soybean crops consistently represented <1% of the land cover for all years.

Table 4.2–7: Total Areas (Hectares [ha]) of Various Land Cover Types Identified within the Carrot River Watershed, 2000 and 2009-2014

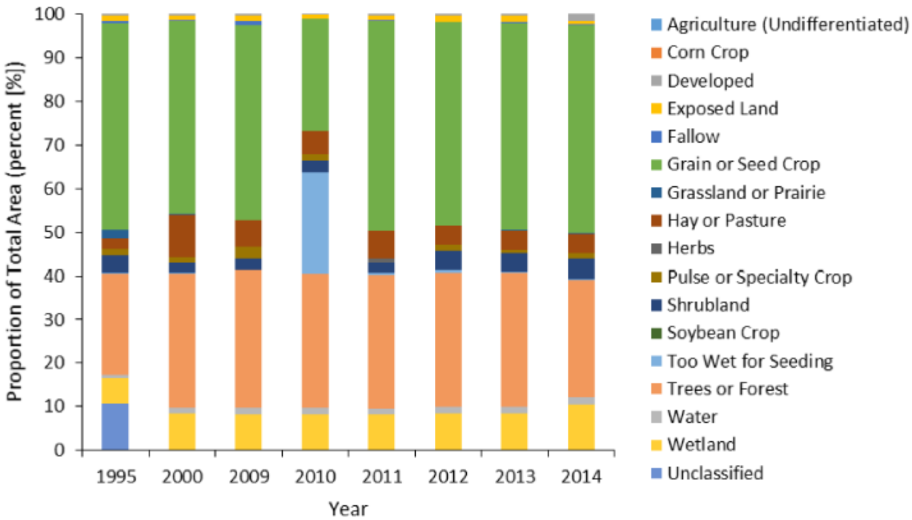
Land Cover Type	1995		2000		2009		2010		2011		2012		2013		2014	
	Area (ha)	Proportion of Total Area (%)[a]	Area (ha)	Proportion of Total Area (%)[a]	Area (ha)	Proportion of Total Area (%)[a]	Area (ha)	Proportion of Total Area (%)[a]	Area (ha)	Proportion of Total Area (%)[a]	Area (ha)	Proportion of Total Area (%)[a]	Area (ha)	Proportion of Total Area (%)[a]	Area (ha)	Proportion of Total Area (%)[a]
Agriculture (Undifferentiated)	0	0	0	0	0	0	0	0	0	0	0.00	0	246	0.02	0	0
Corn Crop	0.67	<0.01	0.63	<0.01	0	0	0	0	0	0	2.2	<0.01	5.6	<0.01	1.4	<0.01
Developed	5,227	0.48	3,842	0.35	4,589	0.42	2,771	0.26	4,272	0.39	4,487	0.41	4,734	0.44	18,943	1.7
Exposed Land	13,800	1.3	11,756	1.1	12,758	1.2	8,489	0.78	10,466	0.97	15,434	1.4	14,848	1.4	5,953	0.55
Fallow	2,999	0.28	2,790	0.26	12,087	1.1	866	0.08	2,821	0.26	1,237	0.11	3,734	0.34	4,533	0.42
Grain or Seed Crop	514,608	47	478,630	44	483,001	45	278,569	26	522,597	48	504,196	47	513,635	47	515,723	48
Grassland or Prairie	20,238	1.9	3,123	0.29	455	0.04	241	0.02	19	<0.01	601	0.06	432	0.04	448	0.04
Hay or Pasture	27,366	2.5	104,390	9.6	65,132	6.0	58,442	5.4	66,877	6.2	47,733	4.4	48,196	4.4	48,735	4.5
Herbs	86	0.01	80	0.01	0	0	130	0.01	10,152	0.94	62	0.01	126	0.01	0	0
Pulse or Specialty Crop	14,180	1.3	13,189	1.2	29,077	2.7	14,104	1.3	0	0	16,382	1.5	8,614	0.80	14,426	1.3
Shrubland	44,100	4.1	22,777	2.1	29,301	2.7	30,173	2.8	24,335	2.2	46,901	4.3	44,006	4.1	48,894	4.5
Soybean Crop	0	0	0	0	0	0	0	0	0	0	0	0	16	<0.01	248	0.02
Too Wet for Seeding	3,424	0.32	3,185	0.29	0	0	249,692	23	4,548	0.42	5,235	0.48	2,723	0.25	1,711	0.16
Trees or Forest	248,950	23	334,473	31	342,062	32	334,897	31	333,709	31	333,151	31	334,184	31	291,632	27
Water	10,034	0.93	13,787	1.3	13,994	1.3	15,370	1.4	13,522	1.2	16,636	1.5	16,287	1.5	17,649	1.6
Wetland	62,005	5.7	91,031	8.4	90,419	8.3	89,566	8.3	89,985	8.3	91,244	8.4	91,503	8.4	114,177	11
Unclassified	116,419	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Watershed Area (ha)[b]	**1,083,436**	**100**	**1,083,053**	**100**	**1,082,875**	**100**	**1,083,310**	**100**	**1,083,303**	**100**	**1,083,302**	**100**	**1,083,291**	**100**	**1,083,073**	**100**

(a) Refers to the proportion of the total watershed area (ha) that is represented by a particular land cover type.

(b) Refers to the total area (ha) of the effective drainage area (EDA) identified for the terminal Prairie Provinces Water Board (PPWB) station (SK05KH007).

ha = hectares;% = percent.

Figure 4.2-2: Proportions (%) of Land Cover Types in the Carrot River Watershed by Year, 1995, 2000, and 2009-2014



4.3 Conclusions

4.3.1 Red Deer River

Trees/forest, grain/seed crops, and hay/pasture are the dominant land cover types in the Red Deer River watershed. Trees/forest, and to a lesser extent, exposed land and grassland/prairie, are the dominant land cover types near the Red Deer River headwaters, upstream of Sundre. Areas of grain/seed crops and hay/pasture are more prevalent between Sundre and the City of Red Deer. Cumulative areas designated to agricultural land uses tend to increase with distance downstream, and represent more than half of the land cover upstream of Jenner. The area between Jenner and Bindloss is largely classified as grassland/prairie.

Similar to the case for the whole-watershed, grain/seed crops, trees/forest and hay/pasture represent the largest proportions of the land cover in the Little Red Deer, Medicine, and Blindman river sub-watersheds. Much of the remaining area is comprised of developed land, grassland/prairie, pulses/specialty crops, shrubland, water, and wetlands.

4.3.2 Carrot River

Similar to the Red Deer River, most of the land in the Carrot River watershed is dominated by grain/seed crops and trees/forest; however, a larger proportion of the remaining area is attributed to wetlands, rather than hay/pasture. Nearly all of the land in the Sweetwater Creek and Leather River sub-watersheds are classified as grain/seed crops. In the remainder of the EDA upstream of Turnberry, grain/seed crops are primarily concentrated in the southwest (upstream) portion of the watershed; the northeast (downstream) portion of the watershed is dominated by large plots of forested land interspersed with wetlands.

4.4 Limitations and Uncertainty

Limitations and uncertainty associated with the assessments of land cover in the Red Deer and Carrot rivers and their tributaries are largely attributed to data availability and differences in classification schemes used by AAFC over the 20 year period of record.

For the year 1995, approximately 11% of the total area in each of the Red Deer and Carrot River watersheds could not be classified. This was attributed to poor quality imagery and conditions at the time of data collection (e.g., shadows, obscured by clouds). Proportions of the various land cover types within each watershed were calculated based on the total area of land that could be classified in 1995; the areas of land that could not be classified were left out of the analysis.

In the Red Deer River, the affected area is located in the upstream sub-watersheds, where trees/forest are expected to dominate (Appendix C, Figure C3). In the Carrot River, data were unavailable for the furthest downstream regions of the watershed, which were similarly dominated by trees/forest and wetlands. Although it is impossible to provide an accurate, quantitative estimation of the land cover types in the missing areas, it is reasonable to assume that much of the unclassified land will be trees/forest in the Red Deer River watershed and trees/forest/wetland in the Carrot River watershed. Areas of these land cover types are expected to remain more consistent over time, relative to an agricultural areas that may, for example, be used for hay one year, and then tilled and seeded to a grain/seed or corn crop in subsequent years. For this reason, the missing data are not expected to alter the conclusions outlined above.

The minimum accuracy of the land cover classifications in the AAFC datasets is 85% (Government of Canada 2017b,c,d), meaning that approximately 15% of the land may have been misclassified by the AAFC as a result of imagery quality, existence of areas with mixed cover or other similar factors. For example, the shrubland classification may include areas that are in reality wetlands with woody vegetation (Government of Canada 2016d). The AAFC also indicated that winter wheat, grasslands, and shrublands may be erroneously assigned to the category associated with hay/pasture (Government of Canada 2016d). These misclassifications may be relatively minor on a whole-watershed scale, but could have implications for trying to identify nutrient hotspots at a sub-watershed scale. Ground-truthing exercises could be used to verify the rate at which these types of errors are made and to confirm the classifications in the AAFC dataset (McFarland and Hauck 2001).

Another area of uncertainty involves the consistent application of the EDA from year to year. As climate conditions vary from year to year, so to will the land area contributing runoff. However, as noted by Burke (2016), it is challenging to capture and adequately describe this type of variability in land use analyses, given the required spatial and temporal information that are not often readily available. The EDA was used in this assessment to maintain consistency with the in-stream information presented in Section 2.0, since the in-stream and land cover data were used together in the watershed loading analysis described in Section 5.0. The EDA was also used, because it describes the land area contributing flow under commonly observed conditions, and provides a common base area upon which to identify changes to land use over time. It is anticipated that error introduced into the analysis through this approach would be lowest under average flow conditions, increasing under low and high flow conditions where it may result in an overestimation and underestimation, respectively, of contributing areas.

The land use analysis described herein could likely be improved by combining the AAFC datasets with other sources of information for the purposes of providing a combined description of cover type and land use intensity over time. Information of interest would include:

- livestock presence, density and type (e.g., cattle, poultry, sheep) across the watershed over time
- number, size and geographic spread of farms across the watershed over time
- inputs related to crop production over time and space, such as pesticide and fertilizer application rates

- human population density and presence across the watershed over time

The combined dataset could then be compared to observed in-stream loads to identify potential correlations.

There are obvious cost implications to moving forward with such an endeavor, related to the effort required to locate, procure, compile and analyze the noted information. Challenges to an efficient integration of the information into a single dataset could include data quality, spatial discrepancies and changes to census boundaries or the existence of census boundaries that do not align with watershed or sub-watershed boundaries (Burke 2016). Consequently, it would be prudent to proceed with such an endeavour in a stepwise manner, building gradually in terms of the different types of data that are considered in the analysis and the spatial scale over which the exercise is undertaken. Once an effective methodology has been developed, the scope of the analysis could be expanded.

5.0 WATERSHED LOADING ANALYSIS

A watershed loading analysis was undertaken to estimate non-point source loading from different land uses under average, wet, and dry climatic conditions. The analysis was completed using point source data from Section 3, land cover data from Section 4, and the total in-stream loads detailed in Section 2. More specifically, export coefficients were applied to estimate nutrient loads from the various land cover types detailed in Section 3 (Burke 2016; Donahue 2013; Johnes 1996); the resulting values were summed together with the point source loading estimates from Section 3 and compared to the in-stream loads from Section 2. Results of the comparison were used to refine the export coefficients and add to the identification of potential in-stream sources and sinks discussed in Section 2. The overall purpose of the analysis was to help answer Key Questions 3 through 7.

An export coefficient-based approach was selected for this study, because the required land cover information could be easily obtained from AAFC, export coefficients are readily available from the literature for most land cover types, the analyses can be completed without the use of sophisticated or expensive software, and the method can be used when few measured data are available (Johnes 1996; Matias and Johnes 2012).

Sensitivity and scenario analyses were conducted to determine how the results of the watershed analysis may change in relation to changes to input parameters, namely the export coefficients and patterns of land cover and land use, respectively (Ciavola et al. 2014; Johnes 1996; Matias and Johnes 2012). The objectives of this exercise were to identify:

- which export coefficients had the largest influence on the results
- how model outputs would respond to changes in land cover and land use (e.g., if developed land increased by 20%, how might non-point source TN or TP loading change)

The watershed analysis and associated sensitivity/scenario analyses were conducted using an Excel-based, mass balance model, similar to the approach used by Johnes (1996) and Johnes et al. (2007). Details of the model setup are described below in Section 5.1. The analysis focused on the years 2000 and 2009 through 2013, based on:

- the availability of concurrent nutrient and land cover data
- the requirement to assess conditions representative of dry, moderate, and wet years

Model calibration, validation, and interpretation steps for the Red Deer River watershed are described in Sections 5.1.1.3 and 5.1.1.4; Sections 5.1.2.3 and 5.1.2.4 describe these steps for the Carrot River. Results of the analysis are discussed in Section 5.2, and conclusions are outlined in Section 5.3. Limitations and sources of uncertainty associated with the land cover analyses are discussed in Section 5.4.

5.1 Methods

5.1.1 Red Deer River

5.1.1.1 General Approach

Non-point source loading is primarily a function of soil and cover type, land use practices, drainage area, and precipitation. To simplify the analysis, the influence of soil type, cover type and land use practices were considered in combination through the use of export coefficients, which describe the mass of TP or TN released per unit area. Export coefficients were combined with the land area information identified in Section 4.0 to estimate non-point source loading.

As outlined in more detail below, the export coefficients were calibrated such that predicted non-point source loads for a given year, when added to the point source loads estimated for that same year (as per Section 3.0), produced a total in-stream estimate that was similar to that estimated from corresponding in-stream flow and concentration data (Johnes 1996; McFarland and Hauck 2001). The calibrated rates were then validated by applying them, unchanged, to another year and comparing predicted loads to those calculated from in-stream data (Matias and Johnes 2012). Once validated, the resulting dataset was used to identify which land cover types were responsible for the production of the majority of the non-point source load reporting to the river mainstem.

Focus was placed on land types that represented more than 3% of the total watershed area. Cover types that consistently represented less than 3% of the area were excluded, because they exert little influence on total non-point source loading estimates; thus, export coefficients assigned to these small areas are difficult to calibrate with precision (McFarland and Hauck 2001).

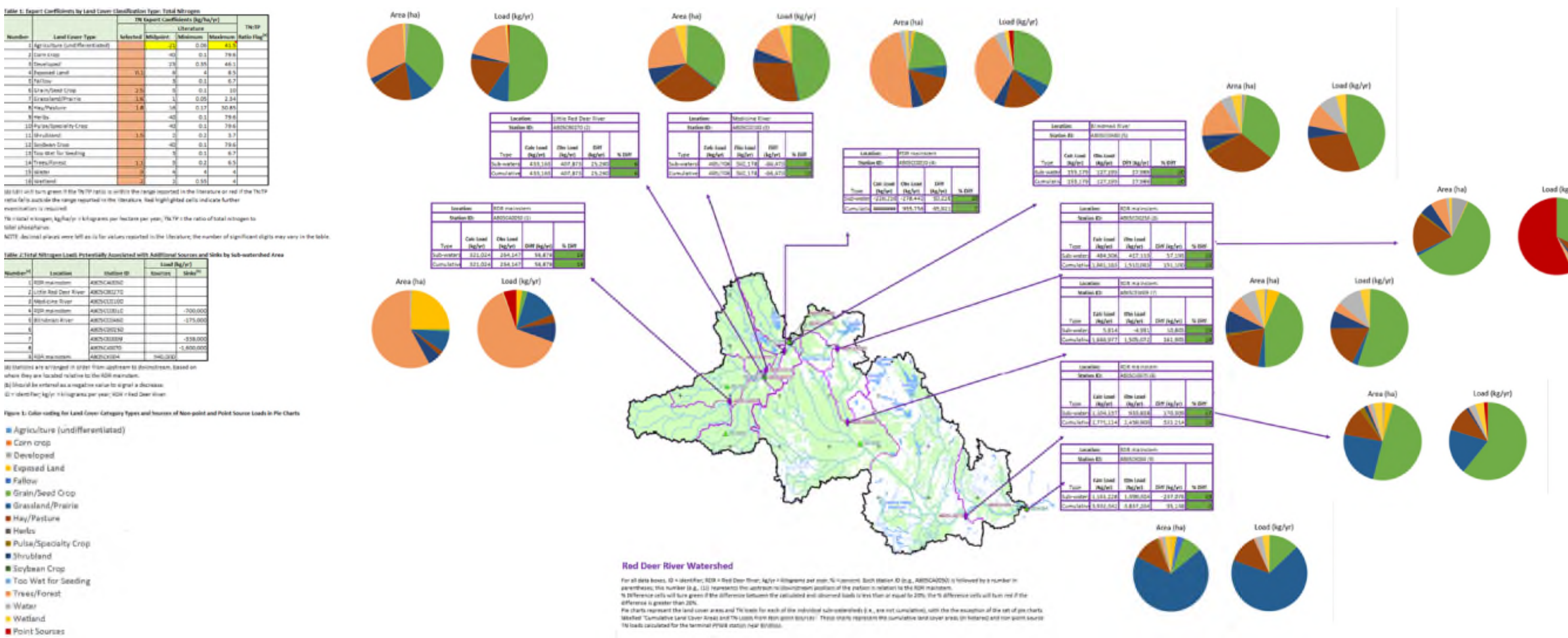
For the Red Deer River, the key years of inquiry were 2009 (low flow), 2012 (moderate flow) and 2013 (high flow); the years 2000 (low flow), 2010 (moderate flow) and 2011 (high flow) were selected to validate the results generated from 2009, 2012 and 2013, respectively. The 2013 evaluation included an explicit examination of spatial variation across the watershed, as was done in the in-stream analysis outlined in Section 2.0. For all other years, the watershed analysis focussed on patterns across the entire watershed and estimating cumulative non-point source loading reporting to the river mainstem near Bindloss.

5.1.1.2 Model Set-up

Model Platform and General Configuration

The mass-balance model for the Red Deer River was developed in Microsoft Excel, and employed a dashboard-style configuration. This model configuration was selected to promote ease-of-use and efficiency by minimizing data-input times for each model run, and to allow for easy viewing and interpretation of the model results. A snap-shot of the model interface is shown in Figure 5.1-1. The different components of the model are described in Table 5.1-1.

Figure 5.1-1: Model Interface for the 2013 Mass-Balance Watershed Loading Model Developed for the Red Deer River



The model configuration includes data entry and output fields for TN and TP loads, as well as the export coefficients and TN:TP export ratios identified for the various land cover types (Figure 5.1-1 and Table 5.1-1). The TN:TP export ratio for a given land cover type is the ratio between the export coefficient for TN and the export coefficient for TP. Export ratios were included in the model output as a check on the calibration; the goal was to maintain the ratio of TN to TP within the range reported in the literature. Export coefficients are a measure of the efficiency of TN or TP export from a particular land cover type, and are expressed in units of kilograms per hectare per year (kg/ha/yr). Export coefficients reflect land use practices (e.g., fertilizer use, manure application practices, establishment and use of buffer zones), vegetation types (e.g., forest, grassland), soil type, and climate. The greater the potential for TN or TP runoff, the greater the export coefficient.

Table 5.1–1: Summary of Model Configuration Details

Parameter	Tab	Model Component	Description
TN or TP	Dashboard	watershed map	■ shows locations of in-stream water quality monitoring stations
		call-out boxes	■ one per monitoring station ■ each box summarizes: ▪ the station ID (e.g., AB05CA0050) and location (e.g., mainstem) ▪ observed nutrient load (kg/yr) for the immediate and cumulative sub-watershed(s)[(a)] ▪ nutrient load calculated for the immediate and cumulative sub-watershed(s)[(b)] ▪ absolute and percent difference between calculated and observed nutrient loads[(c)] ■ pie charts showing land cover types (% of total) and loads attributed to point and non-point sources ■ load pie chart changes in response to changing export coefficients
		export coefficients table	■ summarizes the range of export coefficients (kg/ha/yr) identified in the literature for the land cover types of interest ■ user specified value for export coefficients applied to Red Deer River watershed ▪ only one TN and one TP export coefficient can be selected per land cover type ▪ the same set of export coefficients is applied to all sub-watersheds ■ includes a warning system to alert the user if the TN:TP ratio is outside the range reported in the literature[(d)]
		sources and sinks table	■ table for adding sources and sinks ▪ opportunity to account for missing point source information and known or suggested in-stream sources or sinks ▪ used in the calculation of nutrient loads for the immediate and cumulative sub-watershed(s)[(b)]

Table 5.1–1: Summary of Model Configuration Details

Parameter	Tab	Model Component	Description

	Load Calculations	station summary tables	■ one for each monitoring station
			■ each table includes:
			  ▪ observed nutrient load for the immediate and cumulative sub-watershed(s)[(a)]
			  ▪ estimated nutrient loads from point sources
			  ▪ summary of land cover areas (ha)
			  ▪ export coefficients pulled in from the export coefficients table in the Dashboard tab
			  ▪ calculation of non-point source loads[(e)]
			  ▪ nutrient load calculated for the immediate and cumulative sub-watershed(s)[(b)]
			  ▪ calculate absolute and percent difference between calculated and observed nutrient loads[(c)]
			■ results are summarized in the call-out boxes in the Dashboard tab

TN:TP	TN:TP Ratios	TN:TP summary table	■ summarizes the range (min-max) of TN:TP ratios in the literature for each of the land cover types ■ calculates the TN:TP ratio for the selected export coefficients, which are pulled from the export coefficients table in the Dashboard tab ▪ includes a warning system to alert the user if the TN:TP ratio is outside the range reported in the literature[(d)]

(a) Refers to in-stream TN or TP loads (kg/yr) from Section 2.0.

(b) Nutrient loads are calculated based on the combined loads from point sources, non-point sources, and sources and sinks.

(c) Conditional formatting is used to alert the user to large (i.e., >20%) or acceptable (i.e., ≤20%) differences between calculated and observed loads.

(d) One of the acceptability criteria for the model runs is that the TN:TP export ratio must fall within the range of TN:TP ratios reported in the literature.

(e) Non-point source loads (kg/yr) were calculated by multiplying the area (ha) of a given land cover type by its selected export coefficient (kg/ha/yr). Loads from the individual land cover types were summed to estimate the total annual TN or TP load from non-point sources.

TN = total nitrogen; TP = total phosphorus; ID = identifier; kg/yr = kilograms per year; kg/ha/yr = kilograms per hectare per year;% = percent; TN:TP = the ratio of the TN export coefficient to the TP export coefficient; ha = hectares.

Export Coefficients

A literature review was completed to identify export coefficients that could be used to help quantify nutrient loads from the land cover types in the Red Deer and Carrot River watersheds. Data sources specific to these watersheds or nearby watersheds that were considered similar in terms of land use/land cover, geology, climate and runoff were examined (Table 5.1-2).

Table 5.1–2: Literature Sources Reviewed for Export Coefficient Information

Alberta Water Council 2013	Han et al. 2011	Morales-Marin et al. 2015
Anderson 1999	Jedrych 2008	O2 et al. 2013
Anderson 2012	Jedrych et al. 2014	Pilechi et al. 2012
Beaulac and Reckhow 1982	Jeje 2006	Reckhow et al. 1980
Bourne et al. 2002	Johnes and Heathwaite 1997	RDRWA 2009
Carrot River Valley Watershed Association 2014	Jones and Armstrong 2001	Riemersma et al. 2006
Charette and Trites 2011	Lin 2004	Saskatchewan Ministry of Agriculture 2008
Cooke and Prepas 1998	Little et al. 2006	SWA 2011
Donahue 2013	McDonald 2011	SWA 2012
Green Planet Communications 2012	McDonald 2013	Timmins et al. 1977

O2 = O2 Planning + Design Inc.; RDRWA = Red Deer River Watershed Alliance; SWA = Saskatchewan Watershed Authority.

5.1.1.3 Model Calibration

To calibrate the export coefficients, the following information was entered into the model and remained fixed:

- the “observed” in-stream loads (Section 2.0);
- estimated loads from point sources (Section 3.0); and
- land cover areas (ha) from Section 4.0.

Initial values were assigned to the export coefficients based on the minimum, midpoint, and maximum values from the literature. Of these three sets of values, the minimums provided the closest approximation of observed in-stream loads, and, as a result, were used as a starting point for the calibration. As previously noted, the export coefficient assigned to each land type was the same for the whole watershed; this assumes that the export coefficient for a given land cover type represents average conditions of soil type and land use practices, such as fertilizer application rates and the timing of planting and harvesting, across the watershed (McFarland and Hauck 2001).

The export coefficients were then adjusted, as were the values of potential sources and sinks, until nutrient loads from point sources, non-point sources, and in-stream processes approximated the observed in-stream loads. Increasing one or more export coefficient increased the nutrient load arriving at each station; decreasing export coefficients decreased loads. The magnitude of change for each watershed was dependent on its land cover composition.

The calibration was considered complete when the relative percent difference (RPD) between the calculated and observed TN and TP loads were less than or equal to (≤) 20%. The acceptability criteria was applied to both cumulative loads and loads originating from individual sub-watershed areas. An RPD of ≤20% was selected based on standard criteria for duplicate measurements of water quality parameters (e.g., AENV 2006) and acceptability criteria used in similar comparisons among estimated and measured loads (e.g., McFarland and Hauck 2001; Ruzycki et al. 2014).

For the year 2013, the calibration was completed in a step-wise fashion, by station, moving from upstream to downstream through the Red Deer River watershed. The basic steps were carried out as follows:

- **Step 1:** The minimum, mid-point, and maximum export coefficients from the literature (Table 5.1-2) were entered into the export coefficient table to identify the most appropriate starting point for the calibration.
- **Step 2:** An initial value equal to the minimum reported in the literature was assigned to each export coefficient. The minimum value was chosen, because it provided the closest approximation of observed in-stream loads. This finding matched that of Mattson and Isaac (1999) and McFarland and Hauck (2001), who found that export coefficients from the upper ranges of literature values often resulted in inflated nutrient loading estimates.
- **Step 3**: Starting at farthest upstream sub-watershed (AB05CA0050), the minimum export coefficients from Step 2 were adjusted until the calculated loads and observed loads arriving at Station AB05CA0050 differed by ≤20% and all TN:TP ratios were maintained within the range of literature values. The adjustment process involved initially adjusting all of the export coefficients by the same relative amount (e.g., consistent percent increase) and then adjusting individual export coefficients to “fine tune” the model, focusing on the dominant contributors first.
- **Step 4:** Step 3 was repeated, but for AB05CB0270 on the Little Red Deer River. This step was constrained by the fact that adjusting the export coefficients to align the calculated and observed loads for the Little Red Deer River would affect the calibration for AB05CA0050. The calibration was considered successful if the RPDs between calculated and observed TN and TP loads were ≤20% for both AB05CA0050 and AB05CB0270.
- **Step 5:** Step 4 was repeated for each consecutive tributary and mainstem station along the length of the Red Deer River, until the terminal station was reached. For some stations, an RPD ≤20% could not be achieved while maintaining the RPDs at ≤20% for upstream stations (i.e., calibrating the next downstream station would force the RPD for an already-calibrated station outside the 20% range). In this case, a source or sink was added to the immediate sub-watershed to bring all RPDs back to within 20%. Sinks were also added at locations where the observed load was higher upstream than it was further downstream. Within the model framework, sources and sinks represent a bulk mechanism for describing the potential influence of in-stream processes and/or variations in nutrient export rates for the same land type across the watershed, be that from, for example, differences in underlying soil types or land management practises.
- **Step 6:** A sensitivity analysis was undertaken to identify how model outputs were influenced by the selected export coefficients and whether model improvements were warranted (Johnes 1996; Winter 1998).
- **Step 7:** Results of the sensitivity analysis were used to refine the calibrated values as outlined below.

For the year 2013, the sensitivity analysis for the Red Deer River focussed on each of the nine sub-watersheds identified in Section 2.2.1. It was conducted in two stages.

First, the export coefficient for one of the land cover types was reduced by 10% relative to the “baseline” value set during the calibration process (Johnes 1996; Matias and Johnes 2012). Export coefficients for all other land cover types were held constant at their respective “baseline” values (Winter 1998). The non-point source load for each sub-watershed was recalculated based on the shift in this one export coefficient. The resulting load for each sub-watershed was then compared to the non-point source loads calculated based on the calibrated model (i.e., “baseline” with no ±10% shifts) (Johnes 1996). Comparisons were based on percent change in TN or TP load

(Kothandaraman 1968). This process was repeated for each land cover type considered in the watershed loading analysis.

The second stage of the analysis was completed in a similar fashion; however, individual export coefficients were increased, rather than decreased, by 10% relative to the “baseline” values.

The baseline values assigned to the export coefficients were considered acceptable if a 10% shift in any one export coefficient resulted in a <10% shift in the resulting TN or TP loads. If changing an individual export coefficient by 10% resulted in a >10% change in loads, it was assumed that the model outputs were particularly sensitive to the export coefficient in question (i.e., the export coefficient was likely a source of variance in the model outputs), and that refinement was possible. In this case, the calibration process was completed again, but the export coefficient in question was calibrated first, before the remaining export coefficients, sources, or sinks were manipulated (Winter 1998).

The model was considered successfully calibrated when the RPDs between calculated and observed loads were ≤20% for both TN and TP at all stations, no TN:TP ratio warnings were issued by the model, and the sensitivity analysis indicated that the final results were relatively insensitive to possible errors in the selected export coefficients (Matias and Johnes 2012; Winter 1998).

For 2009 and 2012, the above calibration and sensitivity analysis procedures were repeated with a focus on the terminal station, in light of the scope and budget of the project and the availability (or lack thereof) of in-stream sub-watershed data. Consequently, a source or sink included in the 2009 or 2012 scenario would be representative of a net effect across the watershed (e.g., a bulk loss or gain of nutrient load across the watershed), and could be compared to the sum total of the individual sources and sinks included in the 2013 scenario to identify if and how the net effect varied with flow condition.

5.1.1.4 Model Validation

Model validation assumed export coefficients used to calibrate the model for one year should provide a similarly acceptable estimation of observed loads when applied to another year with similar volumes of run-off and in-stream flow (e.g., Matias and Johnes 2012; Vanni et al. 2001). Model validation may also be achieved by applying export coefficients for one watershed to other, nearby watersheds with similar soil, topography, and climate (Johnes 1996; McFarland and Hauck 2001).

In this study, data for the years 2000 (low flow), 2010 (moderate flow) and 2011 (high flow) were used to validate the models for 2009 (low flow), 2012 (moderate flow) and 2013 (high flow), respectively.

Validation procedures focussed on the terminal station near Bindloss, and consisted of the following steps, using the years 2013 (calibration) and 2011 (validation) as an example:

- **Step 1:** The observed in-stream loads, estimated loads from point sources, and land cover areas were entered into the station summary tables for 2011.
- **Step 2:** The TN and TP export coefficients selected for 2013 were entered, un-altered, into the export coefficients tables for 2011. This approach generated estimates of nutrient loads for the terminal station near Bindloss, based on the point sources and land cover present in 2011. Calculations of RPDs and the “Load” pie charts updated automatically to reflect the addition of the export coefficients.

- **Step 3:** The RPDs between calculated and observed loads for 2011 were checked to determine whether they were ≤20% for TN and TP.
- **Step 4:** The “Area” and “Load” pie charts for 2011 were examined to identify land cover types that represented small areas, but disproportionately large fractions of the TN or TP loads, or vice versa, based on the use of the export coefficients from 2013.
- **Step 5:** A sensitivity analysis was completed to identify how model outputs were influenced by the selected export coefficients (Johnes 1996; Winter 1998).
- **Step 6:** If the RPDs between calculated and observed loads at the terminal PPWB station were ≤20% for TN and TP in 2011, no land cover types appeared to represent a disproportionate amount of the load, and the error introduced by each of the export coefficients was considered acceptable (i.e., a 10% increase or decrease in one export coefficient did not change the resulting load by more than 10%), the model for 2013 was considered validated.

  If these criteria were not met, particularly if the RPDs between calculated and observed loads were >20% for 2011, the model for 2013 was considered invalid. Potential causes for invalidation were investigated, including:

  - differences in the diversity or proportions of land cover types present in 2013 versus 2011
  - differences in the timing, frequency, duration, and magnitude of nutrient loads from point sources in 2013 versus 2011
  - differences in the observed loading estimates between 2011 and 2013, as calculated from in-stream concentration and flow data
  - the presence of a potential source or sink that was not accounted for in either 2013 or 2011
  - the use of export coefficients that are ultimately inappropriate and not transferable from 2013 to 2011

Completing the validation with a focus on the terminal station means that the model was validated at a watershed scale. Thus, components of the validated model, such as the export coefficients, are representative of general characteristics across the watershed, notwithstanding that they may still vary from sub-watershed to sub-watershed.

5.1.1.5 Model Interpretation

Once the models were calibrated and validated, model outputs were examined to identify:

- the amount of the in-stream TN and TP loads attributed to point sources, non-point sources, and, potentially, in-stream sources and sinks
- which land cover types appear to be the largest contributors to nutrient loads, and where are they located
- the locations and potential sizes of any sources and sinks that may be present in the watershed
- the influence of climate (wet versus dry years) on loads from non-point sources

Model information was also used to help inform the identification of nutrient-loading hotspots, to the extent possible.

Scenario analyses were also completed to determine how nutrient loads would respond to changes to land cover and land use; this information was expected to inform recommendations associated with land use and management (Jones et al. 2008; Matias and Johnes 2012; Soranno et al. 1996) (as outlined in Section 8). The analyses focussed on conditions in 2009, 2012, and 2013 at the terminal station near Bindloss, and was conducted in two stages, similar to the sensitivity analyses outlined above.

In the first stage, 10% of the area associated with land cover type “x” (e.g., trees/forest) was re-assigned to land cover type “y” (e.g., hay/pasture). Areas assigned to the remaining land cover types were left unchanged, and the export coefficients selected in the model calibration were used unaltered. Nutrient loads were then recalculated and compared to the loads predicted in the model calibration; comparisons were expressed in terms of percent change (Winter 1998). This process was repeated for each combination of land cover types.

The second stage of the scenario analysis was similar to the first, except land cover type “x” (e.g., trees/forest) was assumed to expand by 10%, with all of the added area being removed from land cover type “y” (e.g., hay/pasture).

Stages 1 and 2 were repeated for land cover changes on the order of 20%, 30%, 40%, and 50% (e.g., if 50% of exposed land is converted to shrubland, how much does the TN load change?).

5.1.2 Carrot River

5.1.2.1 General Approach

The same general approach as outlined above for the Red Deer River was applied to the Carrot River. The key years of inquiry were 2009 (drier flow), 2010 (high flow) and 2013 (moderate / high flow), with validation using 2000 (drier flow), 2011 (high flow) and 2012 (moderate / high flow). Although 2000 and 2009 had recorded flows above the 25th percentile of those recorded over the period of record (Table 2.2-10), they were used, because nutrient and/or land cover data were unavailable for lower flow years (Sections 2.1.2 and 4.0).

5.1.2.2 Model Set-up

The mass balance model set-up for the Carrot River was simpler than that of the Red Deer River, and was comprised of the following components:

- a watershed map showing the location of the terminal station on the Carrot River mainstem
- one export coefficients table each for TN and TP
- one call-out box each for TN and TP loads arriving at the terminal station
- one sources and sinks table for TN, and another for TP
- one station summary table for TN, and other for TP
- one TN:TP ratio summary table

Although there are fewer components to the Carrot River model, each existing component has the same features as those described in Table 5.1-1 for the Red Deer River. Sources of information reviewed to identify export coefficients appropriate to the Carrot River watershed are summarized Table 5.1-2.

5.1.2.3 Model Calibration and Validation

Model calibration for the Carrot River followed the same general steps as the Red Deer River:

- **Step 1:** Observed in-stream loads and estimated loads from point sources and land cover were entered into the station summary table for station SK05KH007 on the Carrot River mainstem near Turnberry.
- **Step 2:** The minimum, mid-point, and maximum export coefficients from the literature were entered into the export coefficient table to identify the most appropriate starting point for the calibration.
- **Step 3:** An initial value equal to the minimum reported in the literature was assigned to each export coefficient. Similar to the case of the Red Deer River and other studies (Mattson and Isaac 1999; McFarland and Hauck 2001), the mid-point and maximum literature values overestimated TN and TP loads.
- **Step 4:** Export coefficients, sources, and sinks were adjusted until the calculated and observed loads differed by ≤20% for both TN and TP and all TN:TP ratios were within range of literature values.
- **Step 5:** A sensitivity analysis was completed to identify how the model outputs were influenced by the selected export coefficients and whether model improvements were warranted (Johnes 1996; Winter 1998).

The model was considered successfully calibrated when the RPDs between calculated and observed loads were ≤20% for both TN and TP, no TN:TP ratio warnings were issued by the model, and the results of the sensitivity analysis indicated that the final model results were relatively insensitive to possible errors in the selected export coefficients (Matias and Johnes 2012; Winter 1998).

Model validation procedures for the Carrot River watershed were the same as those described in Section 5.1.1.4 for the Red Deer River.

5.1.2.4 Model Interpretation

Once the models were calibrated and successfully validated, model outputs for each year were examined to identify:

- the amount of the in-stream TN and TP loads attributed to point sources, non-point sources, and, potentially, in-stream sources and sinks
- which land cover types appear to be the largest contributors to nutrient loads
- the potential size of sources or sinks that may be present in the watershed
- the influence of climate (wet versus dry years) on loads from non-point sources

Due to a lack of yearly in-stream data at Saskatchewan Agriculture water quality monitoring stations positioned within the watershed, a spatial analysis could not be conducted, and the locations of any potential sources, sinks, or nutrient hotspots could not be identified directly from the model outputs. Instead, predictions of nutrient loading hotspots were based on the following:

- the proportion of the total calculated TN and TP loads attributed to point sources each year and the distribution of key direct discharge facilities in the watershed (as determined in Section 3.0); and
- an examination of the land cover maps in Appendix C to identify areas that contain obvious, concentrated pockets or tracts of land cover types that are predicted to be among the largest contributors to nutrient loads.

Because predictions of nutrient hotspots in the Carrot River are inferred from a limited dataset, it is recommended that these predictions be confirmed through monitoring.

Scenario analyses were conducted to determine how nutrient loads at the terminal station near Turnberry would change in response to changes in land cover and land use. The analysis focussed on conditions in 2009, 2010, and 2013, and was expected to inform recommendations associated with land use and management (Jones et al. 2008; Matias and Johnes 2012; Soranno et al. 1996) (as outlined in Section 8). The same process described in Section 5.1.1.5 for the Red Deer River was used to complete the scenario analysis. Land cover changes on the order of 10%, 20%, 30%, 40%, and 50% were examined.

5.2 Results and Discussion

5.2.1 Red Deer River

5.2.1.1 Model Calibration and Validation

The model calibration was successful for 2013. Cumulative TN and TP loads calculated for each of tributary and mainstem station in the Red Deer River watershed calibrated to within 20% of observed loads (Table 5.2-1), based on the selected export coefficients (Table 5.2-2) and the addition of sources and sinks, as required (Table 5.2-3). Nutrient loads for individual sub-watersheds (i.e., non-cumulative loads) also calibrated to within 20% of the observed loads (Table 5.2-1).

Table 5.2–1: Model Calibration Results for Calculated Nutrient Loads Arriving at Water Quality Stations in the Red Deer River Watershed, 2013

Location[a]	Station Code	Total Nitrogen						Total Phosphorus					
		Cumulative Loads (kg/yr)[b]			Loads (kg/yr) by Sub-watershed[c]			Cumulative Loads (kg/yr)[b]			Loads (kg/yr) by Sub-watershed[c]		
		Observed	Calculated	% Difference	Observed	Calculated	% Difference	Observed	Calculated	% Difference	Observed	Calculated	% Difference
Tributaries													
Little Red Deer River	AB05CB0270	407,873	433,163	6	407,873	433,163	6	90,074	74,608	19	90,074	74,608	19
Medicine River	AB05CC0100	562,178	495,706	13	562,178	495,706	13	45,461	55,469	20	45,461	55,469	20
Blindman River	AB05CC0460	127,193	155,179	20	127,193	155,179	20	16,115	19,383	18	16,115	19,383	18
Mainstem													
Red Deer River	AB05CA0050	264,147	321,024	19	264,147	321,024	19	70,340	60,128	16	70,340	60,128	16
	AB05CC0010	1,021,677	955,756	7	-278,442	-228,216	20	89,298	92,288	3	-116,578	-97,917	17
	AB05CD0250	1,510,063	1,661,163	10	427,113	484,306	13	112,683	119,688	6	7,270	8,017	10
	AB05CE0009	1,505,072	1,666,977	10	-4,991	5,814	15	173,578	170,201	2	60,895	50,513	19
	AB05CJ0070	2,438,900	2,771,114	13	933,828	1,104,137	17	503,802	483,303	4	330,224	313,102	5
	AB05CK004	3,837,204	3,932,342	2	1,398,304	1,161,228	19	730,573	669,547	9	226,770	186,244	20

(a) Stations are listed in order, from upstream to downstream along the Red Deer River mainstem; tributaries are included in the list, based on the location of their confluence with the Red Deer River.

(b) Loads are cumulative along the length of the Red Deer River; the estimated TN or TP load for each station includes loads from all upstream sub-watersheds.

(c) Loads are not cumulative along the length of the Red Deer River; the estimated TN or TP load for each station represents the load originating from the immediate sub-watershed only (i.e., loads reaching upstream stations are excluded).

kg/r = kilograms per year;% = percent.

Table 5.2–2: Export Coefficients Used to Describe Nutrient Loading from Various Land Cover Types in the Red Deer River Watershed, 2000 and 2009-2013

Land Cover Type	Export Coefficients (kg/ha/yr)								
	Literature Values			Selected Values					
	Min	Mid-point	Max	Wet Years (2013, 2011)	Change from Min Literature Value[(a)]	Moderate Years (2012, 2010)	Change from Min Literature Value[(a)]	Dry Years (2009, 2000)	Change from Min Literature Value[(a)]
Total Nitrogen (TN)									
Exposed Land	4.0	6.3	8.5	*0.1*	decreased	*0.07*	decreased	*0.02*	decreased
Grain/Seed Crop	0.10	5.1	10	2.5	increased	1.8	increased	0.50	increased
Grassland/Prairie	0.05	1.2	2.3	1.6	increased	1.1	increased	0.30	increased
Hay/Pasture	0.17	16	31	1.8	increased	1.3	increased	0.30	increased
Shrubland	0.20	2.0	3.7	1.5	increased	1.1	increased	-	-
Trees/Forest	0.20	3.4	6.5	1.1	increased	0.80	increased	0.20	no change
Water	4.0	4.0	4.0	*3*	decreased	-	-	-	-
Wetland	0.55	2.3	4.0	2	increased	-	-	-	-
Total Phosphorus (TP)									
Exposed Land	0.20	0.85	1.5	*0.01*	decreased	*0.01*	decreased	*0.003*	decreased
Grain/Seed Crop	0.01	19	38	0.25	increased	0.25	increased	0.08	increased
Grassland/Prairie	0.0085	4.7	9.4	0.31	increased	0.31	increased	0.09	increased
Hay/Pasture	0.02	2.5	4.9	0.22	increased	0.20	increased	0.04	increased
Shrubland	0.0085	0.34	0.666	0.1	increased	0.2	increased	-	-
Trees/Forest	0.0075	73	145	0.24	increased	0.24	increased	0.07	increased
Water	0.20	4.0	7.7	0.20	no change	-	-	-	-
Wetland	0.01	0.36	0.70	0.04	increased	-	-	-	-

(a) The minimum export coefficients from the literature were used as a starting point for calibrating the calculated TN and TP loads to the observed loads in the Red Deer River watershed. Values that fall outside the range of export coefficients reported in the literature are *italicized.*

kg/ha/yr = kilograms per hectare per year; Min = minimum; Max = maximum; - = export coefficient was not determined, because the land cover type represented <3% of the EDA for the calibration year; < = less than; % = percent; EDA = effective drainage area.

Table 5.2–3: Sources and Sinks Used in the Mass-Balance Model for the Red Deer River Sub-Watersheds, 2013

Location	Station ID	TN Load (kg/yr)		TP Load (kg/yr)	
		Sources	Sinks	Sources	Sinks
Little Red Deer River	AB05CB0270	-	-	17,000	-
Medicine River	AB05CC0100	-	-	-	2,000
Blindman River	AB05CC0460	-	175,000	-	17,000
Red Deer River Mainstem	AB05CA0050	-	-	-	-
	AB05CC0010	-	700,000	-	165,000
	AB05CD0250	-	-	-	20,000
	AB05CE0009	-	338,000	15,000	-
	AB05CJ0070	-	1,600,000	-	-
	AB05CK004	940,000	-	150,000	-

ID = identifier; TN = total nitrogen; kg/yr = kilograms per year; TP = total phosphorus.

Results of the sensitivity analysis for 2013 indicated that, in general, variations in export coefficients associated with the most prevalent land cover types had the largest influence on model outputs. In a number of sub-watersheds, grain/seed crop export coefficients had the largest influence. Upstream of Sundre (AB05CA0050) and along the Red Deer River mainstem between Sundre and the City of Red Deer (AB05CC0010), nutrient loads were sensitive to changes to the export coefficients for trees/forest. At the farthest downstream sub-watershed, loading estimates were sensitive to changes to the export coefficients for grassland/prairie.

Based on these results, refinement of the model focussed on adjusting the export coefficients for grain/crops first, followed by trees/forest and grassland/prairie. Export coefficients for the remaining land cover types, as well as sources and sinks required to balance the model, were adjusted last. The final export coefficients used in the model (i.e., those listed in Table 5.2-2) resulted in a <10% shift in the resulting non-point source TN and TP loads (Table 5.2-4).

Table 5.2–4: Percent Change in Calculated Nutrient Loads, Based on a 10 Percent (%) Increase or Decrease in Export Coefficients for Land Cover Types Included in the Watershed Loading Analysis, 2013

Location[a]	Station Code	% Change in Non-point Source Loads (kg/yr) Based on ± 10% Change in Export Coefficient Assigned to:[b]							
		Exposed Land	Grain/Seed Crops	Grassland/ Prairie	Hay/Pasture	Shrubland	Trees/Forest	Water	Wetland
Total Nitrogen									
Tributaries									
Little Red Deer River	AB05CB0270	0.0	5.1	0.9	1.7	0.2	1.9	0.0	0.1
Medicine River	AB05CC0100	0.0	4.7	0.1	2.8	0.6	1.3	0.1	0.5
Blindman River	AB05CC0460	0.0	4.4	0.0	2.8	0.5	1.0	0.8	0.4
Mainstem									
Red Deer River	AB05CA0050	0.3	0.2	1.5	0.4	0.9	6.7	0.0	0.0
	AB05CC0010	0.0	3.3	0.6	1.6	0.5	3.4	0.5	0.2
	AB05CD0250	0.0	7.4	0.1	1.5	0.4	0.4	0.2	0.1
	AB05CE0009	0.0	5.5	0.2	1.7	0.7	0.4	1.0	0.4
	AB05CJ0070	0.0	6.2	1.9	1.1	0.1	0.1	0.3	0.4
	AB05CK004	0.0	1.3	6.8	1.2	0.0	0.1	0.3	0.3
Total Phosphorus									
Tributaries									
Little Red Deer River	AB05CB0270	0.0	3.8	1.3	1.6	0.1	3.1	0.0	0.0
Medicine River	AB05CC0100	0.0	4.0	0.1	2.9	0.3	2.5	0.0	0.1
Blindman River	AB05CC0460	0.0	4.0	0.0	3.2	0.3	1.9	0.5	0.1
Mainstem									
Red Deer River	AB05CA0050	0.1	0.1	1.5	0.2	0.3	7.7	0.0	0.0
	AB05CC0010	0.0	2.3	0.8	1.4	0.2	5.1	0.2	0.0
	AB05CD0250	0.0	7.0	0.2	1.7	0.3	0.8	0.1	0.0
	AB05CE0009	0.0	5.4	0.5	2.1	0.5	0.9	0.7	0.1
	AB05CJ0070	0.0	5.3	3.2	1.1	0.1	0.1	0.1	0.1
	AB05CK004	0.0	0.8	8.0	0.9	0.0	0.1	0.1	0.0

(a) Stations are listed in order, from upstream to downstream along the Red Deer River mainstem; tributaries are included in the list, based on the location of their confluence with the Red Deer River.

(b) Only one export coefficient was changed at a time; all other export coefficients were held constant.

% = percent; TP = total phosphorus; kg/yr = kilograms per year; ± = plus or minus.

The 2013 export coefficients were applied directly to 2011 to validate the model. The use of the final selected export coefficients from 2013 resulted in calculated nutrient loads that differed from observed in-stream TN and TP loads at the terminal station near Bindloss by 19% and 13%, respectively (Table 5.2-5). Consequently, the model was considered to be successfully validated.

Table 5.2–5: Model Calibration and Validation Results for Calculated Nutrient Loads Arriving at the Terminal Prairie Provinces Water Board Station on the Red Deer River Near Bindloss, 2000 and 2009 through 2013

Year Type	Year	TN Load (kg/yr)			TP Load (kg/yr)		
		Observed	Calculated	% Difference	Observed	Calculated	% Difference
Wet	2013[(a)]	3,837,204	3,932,342	2	730,573	669,547	9
	2011[(b)]	7,300,750	6,033,121	19	815,099	716,859	13
Moderate	2012[(a)]	3,870,978	4,086,389	5	696,261	670,550	4
	2010[(b)]	3,461,768	4,072,481	16	673,098	686,601	2
Dry	2009[(a)]	1,292,818	1,340,809	4	252,953	215,053	16
	2000[(b)]	1,198,664	1,353,809	12	201,123	226,523	12

(a) Model calibration year.
(b) Model validation year
TN = total nitrogen; kg/r = kilograms per year; TP = total phosphorus;% = percent.

No sources or sinks were required to validate the model based on the 2011 data, which suggests that the 2013 export coefficients are representative of average conditions across the Red Deer River watershed, but that export rates likely differ by sub-watershed; hence, the requirement for internal sources and sinks in 2013.

The export coefficients developed for 2013 were applied to 2012 and 2009. They were then adjusted to calibrate the model to moderate and dry conditions, respectively. Similar to the approach used for 2013, refinement of the model focussed on adjusting the export coefficients for grain/crops first, followed by grassland/prairie and trees/forest. Export coefficients for the remaining land cover types were adjusted last. Sensitivity analysis indicated that changes in the order of 10% to the final export coefficients (i.e., those listed in Table 5.2-2) resulted in shifts of <10% in the resulting non-point source TN and TP loading estimates (Table 5.2-6).

Table 5.2–6: Percent Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10 Percent (%) Increase or Decrease in Export Coefficients, 2009 and 2012

Year	% Change in Non-point Source Loads (kg/yr) Based on ± 10% Change in Export Coefficients[a]					
	Exposed Land	Grain/Seed Crops	Grassland/ Prairie	Hay/Pasture	Shrubland	Trees/Forest
Total Nitrogen (TN)						
2009	0.0	6.4	1.7	0.9	- [b]	1.0
2012	0.0	5.9	1.4	1.2	0.3	1.1
Total Phosphorus (TP)						
2009	0.0	5.1	2.6	0.6	-[b]	1.8
2012	0.0	4.6	2.2	1.1	0.2	1.9

(a) Only one export coefficient was changed at a time; all other export coefficients were held constant.

(b) Not included in the watershed loading analysis, because the land cover type represented <3% of the EDA.

% = percent; kg/yr = kilograms per year; ± = plus or minus; < = less than; EDA = effective drainage area.

The models developed for moderate (2012) and dry (2009) flow years were validated successfully (Table 5.2-5). No sources or sinks were required to calibrate or validate either model.

For each land cover type, the TN:TP export ratio was successfully maintained within the range of values reported in the literature, wherein the range was defined as follows:

- minimum TN:TP ratio = minimum TN export coefficient reported in the literature divided by minimum TP export coefficient reported in the literature for the land type in question
- maximum TN:TP ratio = maximum TN export coefficient reported in the literature divided by maximum TP export coefficient reported in the literature for the land type in question

For wet, moderate, and dry years, TN and TP export coefficients generally fell within the range of values reported in the literature (Table 5.2-2).The only exceptions were the export coefficients for exposed land and water. TN and TP export coefficients selected for exposed land were consistently below the lowest value reported in the literature. For water, which was only included in the 2013 calibration and the 2011 validation, the export coefficient for TN was below the minimum value from the literature.

The successful calibration and validation of the models developed for 2013, 2012, and 2009 suggests that the export coefficients used in each model are likely transferrable, at a watershed scale, to other years that are representative of wet, moderate, and dry conditions, respectively.

5.2.1.2 Model Interpretation

Distribution of Non-Point Source Loads

In 2013, the dominant land cover types in the Little Red Deer, Medicine, and Blindman river sub-watersheds were the main contributors to non-point source nutrient loads in these tributary rivers (Appendix D, Table D1 and Figures D1 through D3):

- Grain/seed crops: 44 to 51% and 38 to 40% of non-point source TN and TP loads, respectively.
- Hay/pasture: 17 to 28% and 16 to 32% of non-point source TN and TP loads, respectively.
- Trees/forest**:** 10 to 19% and 19 to 31% of non-point source TN and TP loads, respectively.

Consistent with Table 3.2-4, <1% of the calculated in-stream loads were attributed to point sources in the three tributaries; as a result, point source loads are not considered major drivers of nutrient loading in and from the Little Red Deer, Medicine, and Blindman River sub-watersheds.

No TN sources or sinks were required to calibrate the model for the Little Deer or Medicine rivers. TN loading from these sub-watersheds is, therefore, primarily attributed to non-point source loads from grain/seed crops, hay/pasture, and trees/forest. Approximately 23% (17,000 kg/yr) the TP load originating from the Little Red Deer River could not be attributed to point or non-point sources, and was identified as originating from an in-stream source in the model (Table 5.2-3). Similarly, a small TP sink equivalent to 3% (2,000 kg/yr) of the total TP load was identified in the Medicine River. Given their relative magnitude, both items likely reflect uncertainty in the export coefficients and land cover classifications, rather than actual in-stream TP sources or sinks.

In contrast, in the Blindman River, a sink equivalent to approximately 53% (175,000 kg/yr) of the total estimated TN load was identified, as was a sink equivalent to 47% (17,000 kg/yr) of the TP load (Table 5.2-3). Consistency in the relative size of the sink between the two constituents and its magnitude suggest that the sink exists. It may be related to water withdrawals, although more investigation is required to identify the mechanism(s) responsible for the apparent sink.

Of the tributaries, the Little Red Deer (TN and TP) and Medicine (TN) rivers were the largest contributors to nutrient loads (Table 5.2-1); nutrient loads from the Blindman River were approximately one-third of those originating from the Medicine River. The model outputs are in agreement with the in-stream data, given that in-stream loads in the Medicine and Little Red Deer rivers had higher in-stream nutrient loads than the Blindman River in 2013. Because the proportions of the land cover types were similar among watersheds, differences in non-point source loading among the watersheds are attributed to watershed size (i.e., area) and differences in net export after consideration of potential sources and sinks.

In 2013, 95% of the TN loads and 96% of the TP loads reaching station AB05CA0050 near Sundre were attributed to non-point sources; most of this material (i.e., TN - 67%; TP - 77%) originated from trees/forest areas, which covered most of the sub-watershed EDA (Section 4.2.1.1; Appendix D, Table D2, Figure D4). Fifteen percent of non-point source TN and TP loads were attributed grain/seed crops. Loads from other land cover types each represented <10% of the total non-point source loads.

For Station AB05CC0010 near the City of Red Deer, >98% of the incoming loads from non-point and point sources were attribute to non-point sources in 2013. Burke (2016) similarly found that point source loads represented only a fraction of the nutrient loads in the Red Deer River at AB05CC0010, relative to loads from non-point sources. The dominant land cover types in the cumulative EDA for AB05CC0010 were the main contributors to non-point source loads (Appendix D, Table D2 and Figure D5):

- Grain/seed crops: 36 and 25% of non-point source TN and TP loads, respectively.
- Trees/forest: 30 and 46% of non-point source TN and TP loads, respectively.
- Hay/pasture: 18 and 15% of non-point source TN and TP loads, respectively.

The same land cover types also dominated the EDA for the immediate sub-watershed (Appendix D, Table D3); however, most of the nutrient loads from trees/forest came from areas upstream of Sundre, and most of the loads from grain/seed crops and hay/pasture originated in the downstream reaches of the Little Red Deer and Medicine River sub-watersheds.

As discussed in Section 2.2.1.3, the sub-watershed for Station AB05CC0010 near the City of Red Deer differs from other sub-watersheds in that in-stream data suggest a decline in TN and TP loads within the sub-watershed, in contrast to the pattern of increasing loads with increasing distance downstream identified elsewhere. This decline is attributed, in part, to Glennifer Lake, which has been identified by others as a consistent TP sink (Cross 1991; Donald et al. 2015). Water withdrawals for irrigation and other licenced uses also contribute to the removal of nutrient loads from this section of the Red Deer River (Alberta Environment 2003). As such, the requirement for relatively large TN and TP sinks in the calibrated model for 2013 is not unexpected. The model results suggest that in the order of 41% of TN loads and 64% of TP loads originating from upstream of AB05CC0010 are sequestered in Glennifer Lake or lost as a result of water withdrawals.

Further downstream, the dominant land cover types in the immediate sub-watershed area for Station AB05CD0250 near Nevis were also the dominant contributors to non-point source loads:

- Grain/seed crops: 74% for TN and 70% for TP.
- Hay/pasture: 15% for TN and 17% for TP.

Each of the remaining land cover types contributed <10% of the total non-point source nutrient loads for this station (Appendix D, Figure D6). However, cumulatively, nutrient loads were attributed to:

- Grain/seed crops: 41 and 30% of non-point source TN and TP loads, respectively.
- Trees/forest: 25 and 40% of non-point source TN and TP loads, respectively.
- Hay/pasture: 19 and 17% of non-point source TN and TP loads, respectively.

Approximately two-thirds of the cumulative TN load at Station AB05CD0250 was attributed to land use upstream of the City of Red Deer. The remainder divided almost equally between point sources and non-point sources in the immediate sub-watershed. The dominate point source was the City of Red Deer WWTP (Table 3.2-4). Although water is withdrawn from this section of the river to fulfill water licence allocations and maintain Buffalo Lake, model outputs for 2013 indicate that this activity is not a large or notable TN sink.

For TP, loads at AB05CD0250 were governed primarily by land cover upstream of the City of Red Deer. The TP sink modelled for the immediate sub-watershed was roughly equivalent to the TP loads from land cover in the immediate sub-watershed (i.e., ~20,000 kg/yr; Table 5.2-3). The presence of a TP sink in the absence of a comparable TN sink may be explain by one of the following hypotheses:

- The TP export coefficients in this area may be smaller than those that apply to other parts of the watershed, which is resulting in an over-estimation of in-stream TP loads that is balanced in the model through the inclusion of an in-stream sink.
- TN inputs from the City of Red Deer WWTP have been over-estimated, relative to the TP input, and this over-estimation is masking the effect of the aforementioned water withdrawals on in-stream TN levels.

The collection of effluent TN concentration data from the City of Red Deer WWTP would be required to evaluate this issue further.

Mirroring trends observed farther upstream, the dominant land cover types in the cumulative EDA for station AB05CE0009 near Morrin were the main contributors to nutrient loads from non-point sources (Appendix D, Figure D7):

- Grain/seed crops: 43 and 33% of non-point source TN and TP loads, respectively.
- Trees/forest: 22 and 37% of non-point source TN and TP loads, respectively.
- Hay/pasture: 19 and 18% of non-point source TN and TP loads, respectively.

Most of the TN and TP loads in the immediate sub-watershed area for AB05CE0009 were attributed to grain/seed crops, followed by hay/pasture; however, water (10% of TN loads) was a greater contributor to in-stream loads than trees/forest (Appendix D, Figure D7).

A TN sink was required in the AB05CE0009 sub-watershed to calibrate the model (Table 5.2-3). The need for a sink was not unexpected, considering there is a net loss of water from the river mainstem as it moves through this sub-watershed (Figure 2.2-3). A TP source, rather than sink, was required for model calibration. This contrast suggests that local TP inputs are sufficiently high that they mask the effect of water withdrawal. It also suggests that TP export coefficients in this area may be higher than those that apply to other parts of the watershed.

As observed in upstream sub-watersheds, the largest cover types by area were typically the largest non-point contributors to in-stream loads in the two remaining reaches of the Red Deer River. Non-point sources also tended to dominate, relative to point source loads (Appendix D, Figures D8 and D9).

To calibrate the model, a large TN sink was added to the sub-watershed area between Morrin and Jenner; no TP source or sink was required (Table 5.2-3). The TN sink required to calibrate model was equivalent to approximately 60% of the non-point source load originating from within the immediate sub-watershed. The need for a TN sink in the absence of a TP sink suggests that TN export coefficients in this area are lower than those that apply elsewhere in the watershed, particularly those applied to grasslands / prairie and grain/seed crops (which represent 73% of the immediate contributing area).

In the final sub-watershed, between Jenner and the terminal station at Bindloss, both TN and TP sources were required to calibrate the model (Table 5.2-3). Both sources were relatively large and represent approximately 45% of the incoming, non-point source load from the immediate sub-watershed. Consistency in the magnitude of each required source suggests that the EDA for this sub-watershed may have been under-estimated, and that more land area was contributing runoff and load to the river mainstem in 2013 than accounted for in the model. Alternatively, nutrient export rates may be higher in this area than elsewhere in the watershed for similar land types.

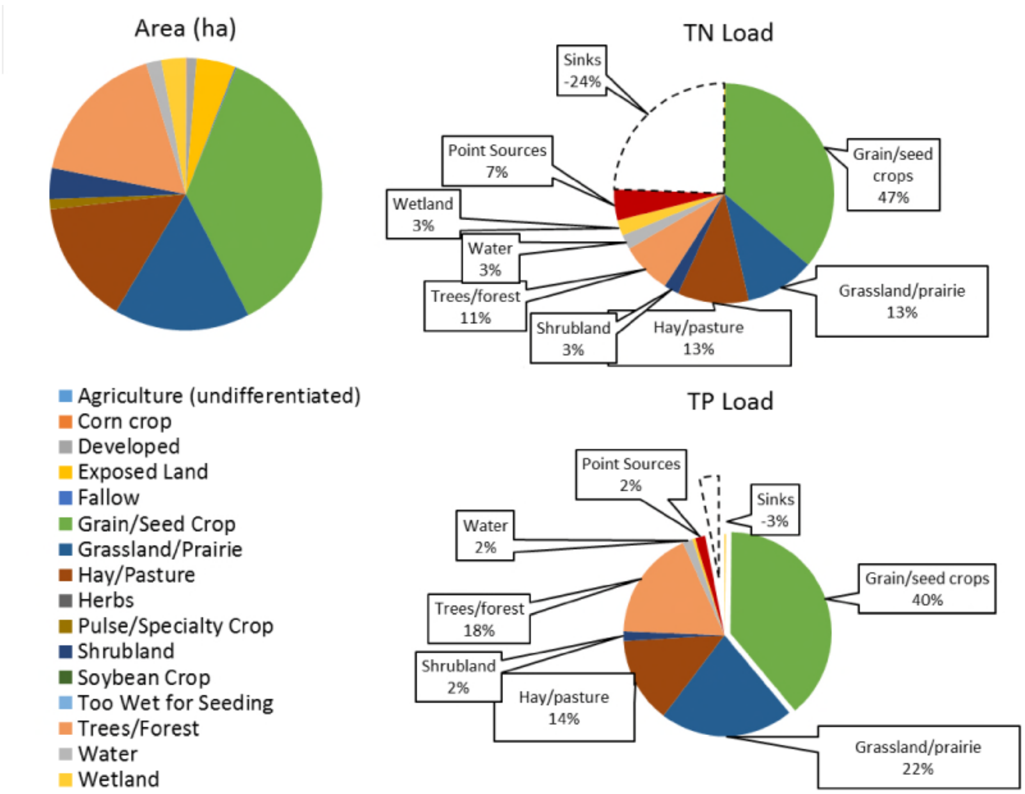
Looking at the watershed as a whole, the land cover types identified as the largest contributors to cumulative non-point source TN and TP loads to the Red Deer River mainstem in 2013 included (Figure 5.2-1):

- Grain/seed crops: 47 and 40% of non-point source TN and TP loads, respectively.
- Grassland/prairie: 13 and 22% of non-point source TN and TP loads, respectively.
- Hay/pasture: 13 and 14% of non-point source TN and TP loads, respectively.
- Trees/forest: 11 and 18% of non-point source TN and TP loads, respectively.

These land cover types represented 90% of the cumulative non-point source TN loads and 96% of the cumulative non-point source TP loads. Loads from the agricultural categories of grain/seed crops and hay/pasture were compared to TN and TP loads estimated by Burke (2016) for the same location (i.e., AB05CK004). In 2013, TN loads from grain/seed crops and hay/pasture were approximately 3,566,946 kg/yr and TP loads were approximately 374,536 kg/yr. These values are above the average estimates (TN: 1,178,000 kg/yr; TP: 210,000 kg/yr) but well below the maximum estimates (TN: 16,760,000 kg/yr; TP: 2,548,000 kg/yr) from Burke (2016).

After accounting for cumulative effects of in-stream sinks, non-point source loads represented 93% of the remaining TN load and 98% of the remaining TP load; point sources represented about 7% and 2% of the remaining TN and TP loads, respectively. Given the non-point source loading distribution, agricultural land practices (TN and TP) and management of forested lands upstream of Sundre (TP) are considered key drivers in controlling nutrient levels in the Red Deer River.

Figure 5.2-1: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads Reporting to the Red Deer River Mainstem, 2013



Notes: Areas are presented as proportions (%) of the total cumulative effective drainage area for the watershed. Loads are expressed as proportions of the total cumulative load from all sources, minus any sinks.

TN = total nitrogen; TP = total phosphorus.

Scenario Analysis

Results of the scenario analysis indicate that calculated TN and TP loads are relatively insensitive to changes in land cover (Table 5.2-7; Appendix E, Tables E1 through E10). A 10% or 20% change in land cover type changed TN and TP loads by less than 10%, regardless of which land cover types were changed. Similarly, increasing or decreasing the area by 30% changed the calculated TN and TP loads relatively little for most land cover types (i.e., by less than 10%). Grain/seed crops were the only exception. If 30% of grain/seed crops were converted to exposed land, a 15% decrease in TN loads and a 12% decrease in TP loads was observed, based on conditions at Bindloss. Converting 30% of the area devoted to grain/seed crops in 2013 to wetlands also resulted in a 10% decrease in TP loads, but only a 3.0% decrease in TN loads (Appendix E, Table E5).

Table 5.2–7: Maximum Percent Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10, 20, 30, 40, or 50 Percent (%) Change in Land Cover Types, 2013

Parameter	Maximum % Change in Non-point Source Loads (kg/yr) Based on a Change in Land Cover[(a)]									
	10%		20%		30%		40%		50%	
	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
TN	4.9	4.9	6.2	9.7	8.5	15	11	20	14	24
TP	3.9	3.9	4.9	7.8	6.2	12	6.2	16	6.2	20

[(a)] The area (ha) of land cover type "A" was either decreased by 10% and the difference assigned to land cover type "B", or land cover type "A" was increased by 10% at the expense of land cover type "B". Areas of all other land cover types were held constant.

% = percent; kg/yr = kilograms per year; TN = total nitrogen; TP = total phosphorus; ha = hectares.

Changing areas of grain/seed crops by 40% had the largest effect on calculated nutrient loads, relative to the other land cover types (Appendix E, Tables E7 and E8):

- TN and TP loads decreased by 20% and 16%, respectively, when 40% of the area associated with grain/seed crops was converted to exposed land.
- TN loads decreased by 11% when 40% of the land was converted from grain/seed crops to trees/forest.
- TP loads decreased by 14% when 40% of the land was converted from grain/seed crops to wetlands.
- TN loads increased by 11% when areas of grain/seed crops were increased by 40% at the expense of trees/forest.

Scenarios focussed on increasing or decreasing areas of exposed land, grassland/prairie, hay/pasture, shrubland, trees/forest, water, and wetland by 40% resulted in relatively small (i.e., <10%) changes in TN and TP loads. The same was true for changes on the order of 50% (Appendix E, Tables E9 and E10). Percent changes in nutrient loads were generally less than 10%, with the exception of the following scenarios:

- TN and TP loads decreased by 24% and 19%, respectively, when 50% of the land was converted from grain/seed crops to exposed land.
- TN and TP loads decreased by 10% and 12%, respectively, when 50% of the land was converted from grain/seed crops to shrubland.
- TN loads decreased by 14% when 50% of the land was converted from grain/seed crops to trees/forest.
- TN loads increased by 14% when 50% of the land was converted to grain/seed crops at the expense of trees/forest.
- TP loads decreased by 17% when 50% of the land was converted from grain/seed crops to wetland.
- TP loads decreased by 11% if 50% of grassland/prairie was converted to exposed land.

These results suggest, at a high level, that conversion of land to accommodate additional cropland would have the largest negative effect on nutrient loads, if done at a sufficiently large scale. The opposite would also appear to be true. These results mirror those reported by others. For example, Jones et al. (2008) reported that a 30% reduction in cropland was only expected to result in an approximately 20% decrease in TN and TP concentrations in reservoirs on the Missouri Plains. Johnes (1996) indicated that changes in land cover were likely to have only minor effects to nutrient concentrations in rivers.

The information outlined above was generated assuming that nutrient export rates from converted areas would be the same as those assigned to existing areas of the same land type. That may not be true, depending on the nature of the land conversion (e.g., where and how it occurs). For example, changing from grain/seed crops to exposed land could result in a much different effect than outlined above if the newly exposed land is easily erodible and results in higher nutrient export rates than existing areas of exposed land in the Red Deer watershed. The information outlined above should be interpreted with this understanding in mind.

Influence of Climate on Non-Point Source Loading

Typically, TN and TP export coefficients were found to be highest under wet conditions, followed by moderate, and then dry conditions (Table 5.2-2), consistent with Donahue (2013). Exceptions consisted of TP export coefficients for grain/seed crops, grassland/prairie, shrubland, and trees/forest, which were similar among wet and moderate conditions.

In all six years (i.e., 2000 and 2009 to 2013), the following land cover types consistently represented the largest proportions of the EDA for the Red Deer River and were the largest contributors to non-point source TN and TP loads reaching the terminal station near Bindloss (Appendix D, Table D4):

- Grain/seed crops: 51 to 64% of TN loads and 39 to 51% of TP loads.
- Grassland/prairie: 14 to 17% of TN loads and 22 to 26% of TP loads.
- Hay/pasture: 11 to 21% of TN loads and 5.8 to 18% of TP loads.
- Trees/forest: 10 to 11% of TN loads and 17 to 19% of TP loads.

For wet and moderate years, nutrient loads from agricultural land cover types (i.e., grain/seed crops and hay/pasture) were marginally higher than those predicted by Burke (2016) for 2001. Agricultural loads predicted by Burke (2016) were between 729,000 and 16,760,000 kg/yr for TN (average = 1,178,000 kg/yr) and between 77,000 and 2,548,000 kg/yr for TP (average = 210,000 kg/yr). Modelled non-point source TN loads for dry years (i.e., 2000 and 2009) were roughly equal to the minimum loads estimated by Burke (2016). TP loads for dry years were between the minimum and average values.

Results of scenario analyses completed for 2009 (dry year) and 2012 (moderate year) were similar to those reported above for 2013. TN and TP loads from non-point sources were found to be relatively insensitive to small-scale land cover conversions (Table 5.2-8; Appendix E, Tables E11 through 30). A 10% or 20% change in land cover type changed TN and TP loads by less than 10% for most scenarios. The only exception was the conversion of grain/seed crops to exposed land; this conversion decreased the TN loads by about 13% in 2009 and 11% in 2012.

Under the wetter conditions observed in 2013, converting 30% of the area devoted to grain/seed crops to exposed land reduced modelled TN and TP loads by 15% and 12% respectively. Under the moderate conditions observed in 2012, this same conversion resulted in a 17% reduction in TN loads and a 13% reduction in TP loads. Under dry conditions (2009), the TN and TP loads were reduced by 18% and 15%, respectively.

Table 5.2–8: Maximum Percent Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10, 20, 30, 40, or 50 Percent (%) Change in Land Cover Types, 2009 and 2012

Parameter	Maximum % Change in Non-point Source Loads (kg/yr) Based on a Change in Land Cover[(a)]									
	10%		20%		30%		40%		50%	
	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
2009										
TN	5.4	6.1	7.7	13	12	18	15	25	15	31
TP	4.3	4.9	5.1	9.8	5.8	15	5.8	20	5.8	24
2012										
TN	5.7	5.7	6.6	11	9.8	17	13	23	14	28
TP	4.5	4.5	5.1	8.9	6.4	13	6.3	18	6.3	22

[(a)] The area (ha) of land cover type "A" was either decreased by 10% and the difference assigned to land cover type "B", or land cover type "A" was increased by 10% at the expense of land cover type "B". Areas of all other land cover types were held constant.

% = percent; kg/yr = kilograms per year; TN = total nitrogen; TP = total phosphorus; hectares.

Of the scenarios modelled based on 40% land cover conversions, changes to grain/seed crops had the largest influence on nutrient loads in both 2009 and 2012 (Appendix E). For example, under the drier conditions observed in 2009:

- TN and TP loads decreased by 25% and 20%, respectively, if grain/seed crop areas were converted to exposed land.
- Nutrient loads decreased by 10% if grain/seed crop areas were converted to grassland/prairie (TN only) or hay/pasture (TN and TP).

Similarly, under the moderate conditions observed in 2012, TN and TP loads decreased by 23% and 18%, respectively, if grain/seed crop areas were converted to exposed land.

The same was true for the 50% land cover conversation (see Appendix E); changes focussed on grain/seed crops had the largest influence on modelled nutrient loads.

These results, like those reported for 2013, suggest that conversion of land to accommodate additional cropland would have the largest negative effect on nutrient loads, if done at a sufficiently large scale. The opposite would also appear to be true. The results would also suggest that how the land is managed may be as important to nutrient loading as what the land is used for; for example, Donahue (2013) and Jeje (2006) note that factors such as tillage practices, fertilizer application rates, manure usage and degree of vegetative cover crop affect nutrient export rates from agricultural lands.

As previously noted, the information outlined above was generated assuming that nutrient export rates from converted areas would be the same as those assigned to existing areas of the same land type. That may not be true, depending on the nature of the land conversion (e.g., where and how it occurs). For example, changing from grain/seed crops to exposed land could result in a much different effect than outlined above if the newly exposed land is easily erodible and results in higher nutrient export rates than existing areas of exposed land in the Red Deer watershed. The information outlined above should be interpreted with this understanding in mind.

5.2.2 Carrot River

5.2.2.1 Model Calibration and Validation

The model calibration was successful for 2013. Cumulative nutrient loads calculated for the terminal station on the Carrot River mainstem near Turnberry calibrated to within 20% of observed loads (Table 5.2-9), based on the selected export coefficients (Table 5.2-10). No sources and sinks were added to the model. For each land cover type, the TN:TP export ratio was successfully maintained within the range of values reported in the literature.

Table 5.2–9: Model Calibration and Validation Results for Calculated Nutrient Loads Arriving at the Terminal Prairie Provinces Water Board Station on the Carrot River Near Turnberry, 2000 and 2009 through 2013

Year Type	Year	TN Load (kg/yr)			TP Load (kg/yr)		
		Observed	Calculated	% Difference	Observed	Calculated	% Difference
Wet	2010[(a)]	2,133,387	1,747,428	20	184,544	214,159	15
	2011[(b)]	1,671,929	1,690,924	1	204,240	211,610	4
Moderate	2013[(a)]	1,477,779	1,345,514	9	118,374	125,572	6
	2012[(b)]	1,143,626	1,335,624	15	115,436	124,402	7
Dry	2009[(a)]	452,611	377,722	18	39,337	32,437	19
	2000[(b)]	379,266	393,431	4	28,334	34,429	19

(a) Model calibration year.

(b) Model validation year.

TN = total nitrogen; kg/r = kilograms per year; TP = total phosphorus;% = percent.

Table 5.2–10: Export Coefficients Used to Describe Nutrient Loading from Various Land Cover Types in the Carrot River Watershed, 2000 and 2009-2013

Land Cover Type	Export Coefficients (kg/ha/yr)								
	Literature Values			Selected Values					
	Min	Mid-point	Max	Wet Years (2010, 2011)	Change from Min Literature Value[(a)]	Moderate Years (2013, 2012)	Change from Min Literature Value[(a)]	Drier Years (2009, 2000)	Change from Min Literature Value[(a)]
Total Nitrogen (TN)									
Grain/Seed Crop	0.1	5.1	10	1.6	increased	1.25	increased	0.30	increased
Hay/Pasture	0.17	16	31	2.3	increased	1.8	increased	0.50	increased
Shrubland	0.20	2.0	3.7	-	-	1.5	increased	-	-
Too Wet for Seeding	0.10	3.4	6.7	1.9	increased	-	-	-	-
Trees/Forest	0.20	3.4	6.5	1.4	increased	1.1	increased	0.40	increased
Wetland	0.55	2.3	4.0	2.5	increased	2.0	increased	0.70	increased
Total Phosphorus (TP)									
Grain/Seed Crop	0.01	19	38	0.23	increased	0.13	increased	0.034	increased
Hay/Pasture	0.02	2.5	4.9	0.33	increased	0.22	increased	0.06	increased
Shrubland	0.0085	0.34	0.666	-	-	0.10	increased	-	-
Too Wet for Seeding	0.01	19	38	0.25	increased	-	-	-	-
Trees/Forest	0.0075	73	145	0.18	increased	0.12	increased	0.03	increased
Wetland	0.01	0.36	0.70	0.09	increased	0.04	increased	0.02	increased

(a) The minimum export coefficients from the literature were used as a starting point for calibrating the calculated TN and TP loads to the observed loads in the Carrot River watershed. None of the selected values fell outside the range of export coefficients reported in the literature.

kg/ha/yr = kilograms per hectare per year; Min = minimum; Max = maximum; - = export coefficient was not determined because the land cover type represented <3% of the EDA for the calibration year; < = less than; % = percent; EDA = effective drainage area.

Results of the sensitivity analysis completed for the Carrot River, based on TN and TP data for 2013, indicated that calculated loads from non-point sources were most sensitive to the grain/seed crop export coefficients. Consequently, refinement of the model and improvements to the calibration focussed on adjusting the export coefficients for grain/seed crops first, followed by the other land cover types. The final export coefficients used in the model (i.e., those listed in Table 5.2-10) resulted in a <10% shift in the resulting non-point source TN and TP loads (Table 5.2-11).

Table 5.2–11: Percent Change in Calculated Nutrient Loads, Based on a 10 Percent (%) Increase or Decrease in Export Coefficients for Land Cover Types Included in the Watershed Loading Analysis, 2013

Location	Station Code	Parameter	% Change in Non-point Source Loads (kg/yr) Based on ± 10% Change in Export Coefficient Assigned to:[a]				
			Grain/Seed Crops	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Carrot River	05KH007	TN	4.6	0.62	0.49	2.9	1.4
		TP	5.2	0.82	0.36	3.4	0.31

(a) Only one export coefficient was changed at a time; all other export coefficients were held constant.

% = percent; TN = total nitrogen; TP = total phosphorus; kg/yr = kilograms per year; ± = plus or minus.

The 2013 export coefficients were applied directly to 2012 to validate the model. The use of the unaltered export coefficients from 2013 resulted in calculated nutrient loads that differed from observed in-stream TN and TP loads by 15% and 7%, respectively (Table 5.2-12). Consequently, the model was considered to be successfully validated, without the use of sources or sinks.

The export coefficients developed for 2013 were applied to 2009 and 2010. They were then adjusted to calibrate the model to dry and wet conditions, respectively. Similar to the approach used for 2013, refinement of the model focussed on adjusting the export coefficients for grain/crops first, followed by the remaining land cover types. Sensitivity analysis indicated that changes in the order of 10% to the final export coefficients (i.e., those listed in Table 5.2-10) resulted in shifts of <10% in the resulting non-point source TN and TP loading estimates (Table 5.2-12).

The models developed for wet (2010) and dry (2009) flow years were calibrated and validated successfully (Table 5.2-9). No sources or sinks were required to calibrate or validate the models.

Table 5.2–12: Percent Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 10 Percent (%) Increase or Decrease in Export Coefficients, 2009 and 2010

Year	% Change in Non-point Source Loads (kg/yr) Based on ± 10% Change in Export Coefficients[a]				
	Grain/Seed Crops	Hay/Pasture	Too Wet for Seeing	Trees/Forest	Wetland
Total Nitrogen (TN)					
2009	3.8	0.86	-[b]	3.6	1.7
2010	2.6	0.77	2.7	2.7	1.3
Total Phosphorus (TP)					
2009	5.1	1.2	- [b]	3.2	0.56
2010	3.0	0.90	2.9	2.8	0.38

(a) Only one export coefficient was changed at a time; all other export coefficients were held constant.

(b) Not included in watershed loading analysis, because the land cover type represented <3% of the EDA.

% = percent; kg/yr = kilograms per year; ± = plus or minus; < = less than; EDA = effective drainage area.

The successful calibration and validation of the models developed for 2013, 2010, and 2009 suggests that the export coefficients used in each model are likely transferrable, at a watershed scale, to other years that are representative of moderate, wet, and dry conditions, respectively.

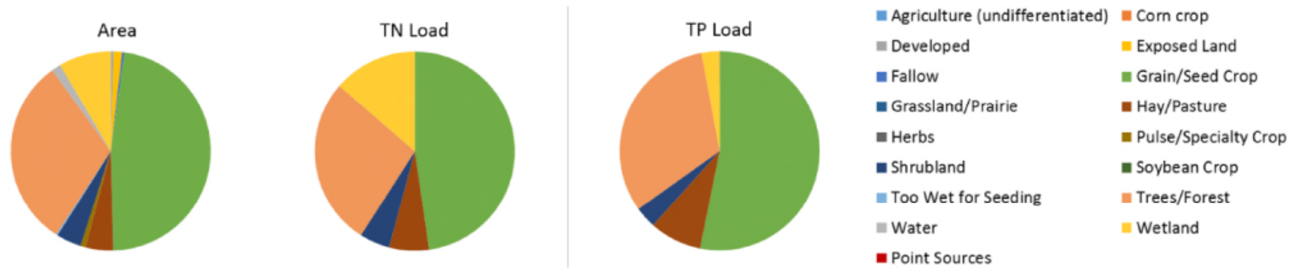
5.2.2.2 Model Interpretation

In 2013, the dominant land cover types in the Carrot River watershed were the main contributors to non-point source nutrient loads at the terminal station near Turnberry (Appendix D, Table D5):

- Grain/seed crops: 48% and 53% of non-point source TN and TP loads, respectively.
- Trees/forest: 27% and 32% of non-point source TN and TP loads, respectively.
- Wetlands: 14% of non-point source TN loads, but only 2.9% of TP loads.

Collectively, 89% and 88% of non-point source TN and TP loads, respectively, were attributed to these land cover types, based on conditions in 2013. All other land cover types represented relatively small (i.e., <10%) fractions of the total loads (Figure 5.2-2). Overall, loads from point sources were negligible compared to non-point source loads; <1% of the calculated in-stream loads were attributed to point sources, which is consistent with Table 3.2-6. As a result, point source loads are not considered major drivers of nutrient loads in the Carrot River upstream of Turnberry.

Figure 5.2-2: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads Reporting to the Carrot River Mainstem, 2013



Notes: Areas are presented as proportions (%) of the total cumulative effective drainage area for the watershed. Loads are expressed as proportions of the total cumulative load from all sources.

TN = total nitrogen; TP = total phosphorus.

Insufficient in-stream data were available to estimate observed loads and support calibration of calculated loads for the Carrot River sub-watersheds. That said, due to the high degree of grain/seed crop coverage in the Leather River sub-watershed, it is recommended that the Leather River be investigated in more detail, to confirm whether it is a nutrient hotspot, as suggested by the in-stream analysis outlined in Section 2. Runoff and nutrient loading from the forested/treed land in the downstream section of the watershed may also be worthy of further consideration.

Scenario Analysis

As in the Red Deer River, results of the scenario analysis indicate that calculated TN and TP loads are relatively insensitive to changes in land cover (Table 5.2-13; Appendix E, Tables E31 through E40). A 10% or 20% change in land cover type changed TN and TP loads by less than 10%, regardless of which land cover types were changed. Similarly, increasing or decreasing the area by 30% changed the calculated TN and TP loads relatively little for most land cover types (i.e., by less than 10%). Grain/seed crops were the only exception. Changes of 30% to the land area covered by grain/seed crops resulted in changes of greater than 10% to TP loads.

Table 5.2–13: Maximum Percent Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 10, 20, 30, 40, or 50 Percent (%) Change in Land Cover Types, 2013

Parameter	Maximum % Change in Non-point Source Loads (kg/yr) Based on a Change in Land Cover[(a)]									
	10%		20%		30%		40%		50%	
	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
TN	2.9	2.9	5.7	5.1	8.6	6.1	11	6.1	14	6.1
TP	3.7	3.7	7.4	7.4	11	11	15	15	18	18

[(a)] The area (ha) of land cover type "A" was either decreased by 10% and the difference assigned to land cover type "B", or land cover type "A" was increased by 10% at the expense of land cover type "B". Areas of all other land cover types were held constant.

% = percent; kg/yr = kilograms per year; TN = total nitrogen; TP = total phosphorus; ha = hectares.

Of the scenarios based on 40% changes to land cover, changes to nutrient loads in excess of 10% included the following (Appendix E, Tables E37 and E38):

- TN loads increased by 11% when grain/seed crops were converted to wetland.
- TP loads decreased by 15% when grain/seed crops were converted to wetlands.
- TP loads increased by 15% when grain/seed crops were converted to hay/pasture.
- TP loads increased by 11% when trees/forest were converted to hay/pasture.

When land cover was changed by 50%, changes to nutrient loads in excess of 10% included the following (Appendix E, Tables E39 and E40):

- TN and TP loads increased by 11% and 18%, respectively, when grain/seed crops were converted to hay/pasture.
- TN loads increased by 14% and TP loads decreased by 18% when grain/seed crops were converted to wetland.
- TN loads increased by 11% and TP loads decreased by 11% when trees/forest were converted to wetland.
- TP loads increased by 13% when trees/forest were converted to hay/pasture.

These results suggest that large changes to land cover would be required before an appreciable change to nutrient loading occurred, consistent with the results of the scenario analysis conducted on the Red Deer River.

As previously noted, the information outlined above was generated assuming that nutrient export rates from converted areas would be the same as those assigned to existing areas of the same land type. That may not be true, and the information outlined above should be interpreted with this understanding in mind.

Influence of Climate on Non-point Source Loading

TN and TP export coefficients were consistently highest under wet conditions, followed by moderate, and then dry conditions (Table 5.2-10).

In all six years (i.e., 2000 and 2009 to 2013), the following land cover types represented the largest proportions of the EDA for the Carrot River and were the largest contributors to non-point source TN and TP loads reaching the terminal station near Turnberry (Appendix D, Table D5):

- Grain/seed crops: 26 to 49% of non-point source TN loads and 30 to 57% of non-point source TP loads.
- Too wet for seeding: 27% of non-point source TN loads and 29% of non-point source TP loads (2010 only).
- Trees/forest: 27 to 36% of non-point source TN loads and 28 to 32% of non-point source TP loads.
- Wetland: 13 to 17% of non-point source TN loads, with TP loads consistently being <6% of modelled in-stream loads.

Similar to 2013, the scenario analyses conducted for 2009 (dry year) and 2010 (wet year) indicate that TN and TP loads from non-point sources are relatively insensitive to small-scale land cover conversions (Table 5.2-14; Appendix E, Tables E41 through E60). A 10% or 20% change in land cover type changed TN and TP loads by less than 10% for all scenarios and both years, with the exception of one scenario in 2009. Converting 20% of grain/seed crops to wetlands resulted in a 10% increase in TN loads.

For 2010, land cover conversions in the order of 30% and 40% changed the TN and TP loads in the Carrot River by <10% (Table 5.2-14). Even when the 50% land cover change scenarios were considered, only two resulted in TN and TP loads that differed from the modelled or calibrated loads by more than 10% (Appendix E, Tables E59 and E60):

- TN and loads increased by 11% if 50% of trees/forest were converted to wetlands.
- TP loads increased by 12% if 50% of trees/forest were converted to hay/pasture.

Table 5.2–14: Maximum Percent Change in Calculated Nutrient Loads in Carrot River Near Turnberry, Based on a 10, 20, 30, 40, or 50 Percent (%) Change in Land Cover Types, 2009 and 2010

Parameter	Maximum % Change in Non-point Source Loads (kg/yr) Based on a Change in Land Cover[(a)]									
	10%		20%		30%		40%		50%	
	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
2009										
TN	5.1	5.1	10	9.6	15	9.6	20	9.6	26	9.6
TP	3.9	3.9	7.8	5.2	12	6.3	16	8.4	19	10
2010										
TN	2.1	1.4	4.2	2.9	6.3	5.6	8.4	5.6	11	5.6
TP	2.4	1.8	4.7	3.7	7.0	5.5	9.4	7.5	12	9.3

(a) The area (ha) of land cover type “A” was either decreased by 10% and the difference assigned to land cover type “B”, or land cover type “A” was increased by 10% at the expense of land cover type “B”. Areas of all other land cover types were held constant.

% = percent; kg/yr = kilograms per year; TN = total nitrogen; TP = total phosphorus; hectares.

Under drier conditions (2009), only two of the 30% land cover conversion scenarios resulted in changes of more than 10% to estimated nutrient loads (Appendix E, Tables E45 and E46):

- TN loads increased by 15% when areas of grain/seed crop were converted to wetland.
- TP loads increased by 12% when areas of grain/seed crop were converted to hay/pasture.

Of the scenarios based on 40% and 50% changes to land cover, changes to nutrient loads remained below 30% (Appendix E, Tables E47 to E50).

Consistent with 2013, results of 2009 and 2010 scenario analyses suggest that large changes to land cover would be required before an appreciable change to nutrient loading to the Carrot River occurred.

As previously noted, the information outlined above was generated assuming that nutrient export rates from converted areas would be the same as those assigned to existing areas of the same land type. That may not be true, and the information outlined above should be interpreted with this understanding in mind.

5.3 Conclusions

5.3.1 Red Deer River

Export coefficient-based watershed loading models were successfully calibrated and validated for wet, moderate and dry conditions. The export coefficients used in each model were generally within the ranges of values reported in the literature, as were TN:TP runoff ratios. The calibrated coefficients are likely transferrable, at a watershed scale, to other years of data.

Of the Red Deer River tributaries that were assessed, the Little Red Deer (TN and TP) and Medicine (TN) rivers were the largest contributors to nutrient loads in 2013, due in part to their size relative to the Blindman River. The Blindman River is the smallest of the three sub-watersheds, and contains TN and TP sinks. These sinks may be related to water withdrawals, although more investigation is required to identify the mechanism(s) responsible for the apparent loss of TN and TP from this sub-watershed.

Most of the TN and TP loads reaching the Red Deer River mainstem at Sundre originate from treed/forested areas and, to a lesser extent, areas of grain/seed crops. Consistent with the findings of Burke (2016), >98% of the incoming loads to the next downstream station near the City of Red Deer originate from non-point rather than point sources. Glennifer Reservoir appears to act as a notable TP sink between Sundre and the City of Red Deer, based both on the analysis of in-stream data (Section 2) and the watershed model analysis for 2013 outlined herein. It may also be a TN sink, although the results of Donald et al. (2015) would suggest that its effect on TN loads may be limited; thus, TN losses through this reach may be due to water withdrawals or other processes.

Cumulative TN and TP loads at Nevis are primarily driven by non-point sources. However, more than half of the TN load and one-fifth of the TP load from the immediate sub-watershed were attributed to the City of Red Deer WWTP in 2013.

Farther downstream (Nevis to Morrin), withdrawals upwards of 500,000 dam^3 of water result in a net loss of water from the river mainstem, which act as a nutrient sink. However, this sink appears to act more strongly on TN loads than TP loads, which suggest that local TP inputs are sufficiently high that they mask the effect of water withdrawal. It also suggests that TP export coefficients in this area may be higher than those that apply to other parts of the watershed.

Land cover, primarily grain/seed crops, grassland/prairie and hay/pasture, appear to be the largest contributors to nutrient loads between Morrin and Jenner; however, results of the watershed analysis completed for 2013 suggests that TN export coefficients in this area are lower than those that apply elsewhere in the watershed, particularly in relation to grasslands / prairie and grain/seed crops. Return flows from the Eastern and Western Irrigation Districts enter the mainstem in this reach, and monitoring of these return flows should be considered.

In the final sub-watershed, between Jenner and the terminal station at Bindloss, grassland/prairie is the largest contributor to loads entering the Red Deer River. The need for large, similarly sized TN and TP sources to calibrate the 2013 watershed model suggests that the EDA for this sub-watershed may have been under-estimated, and that more land area was contributing runoff and load to the river mainstem in 2013 than accounted for in the model. Nutrient export coefficients in this sub-watershed may also be higher than those that apply elsewhere in the watershed, as suggested by the results of the in-stream loading analysis outlined in Section 2.2.

Looking at the watershed as a whole, non-point source loads account for more than 90% of the in-stream TN and TP loads. The predominant land cover types in the Red Deer River watershed are the largest contributors to nutrient loads measured at the terminal near Bindloss; they include:

- grain/seed crops;
- hay/pasture;
- trees/forest; and
- grassland/prairie.

Overall, TN loads measured at the terminal station on the Red Deer River originate primarily from:

- agricultural lands (i.e., grain/seed crops and hay/pasture);
- grassland and prairie areas downstream of the City of Red Deer;
- areas of trees/forest upstream of Sundre and in tributary watersheds; and
- the City of Red Deer WWTP (particularly in drier years).

TP loads measured at the terminal station from point sources are small in comparison to those from non-point sources. Overall, the largest contributors to TP loads in the Red Deer River are:

- agricultural lands (i.e., grain/seed crops and hay/pasture);
- grassland and prairie areas downstream of the City of Red Deer; and
- areas of trees/forest upstream of Sundre and in tributary watersheds.

Nutrient loads from non-point sources in the Red Deer River watershed are highest during wet years and lowest during dry years. Consequently, most of the nutrient load measured at the terminal station comes from non-point sources, rather than point sources, during wetter years. Conversely, because nutrient loads from point sources remain relatively consistent from year to year regardless of climatic conditions, the proportion of the in-stream load attributed to point sources is larger during dry years than in wet years.

The scenario analyses completed for 2009 (dry), 2012 (moderate), and 2013 (wet) indicated that, in general, non-point source TN and TP loads are relatively insensitive to changes in land cover. In general, land cover conversions on the order of 10 to 20% resulted in a <10% change in nutrient loads. These results suggest that how the land is managed (e.g., fertilizer application rates, manure usage, tillage practices) may be as important to nutrient loading as what the land is used for.

5.3.2 Carrot River

Similar to the Red Deer River, export coefficient-based watershed loading models were successfully calibrated and validated for wet, moderate and dry conditions. The export coefficients used in each model were generally within the ranges of values reported in the literature, as were TN:TP runoff ratios. The calibrated coefficients are likely transferrable, at a watershed scale, to other years of data.

In the Carrot River watershed, the predominant land cover types are the largest contributors to nutrient loads reaching the terminal station on the Carrot River mainstem near Turnberry; they include:

- grain/seed crops;
- trees/forest; and
- wetlands (TN only).

Nutrient loads from point sources are considered negligible in the Carrot River, regardless of climatic conditions (i.e., represent <1% of in-stream loads).

Insufficient in-stream data were available to conduct a sub-watershed loading analysis analogous to that completed in the Red Deer River. That said, due to the high degree of grain/seed crop coverage in the Leather River sub-watershed, it is recommended that the Leather River be investigated in more detail, to confirm whether it is a nutrient hotspot, as suggested by the in-stream analysis outlined in Section 2. Results also indicate that future nutrient studies in this watershed should examine the role of wetlands in nutrient loading and sequestration.

Results of the scenario analyses for 2009, 2010, and 2013 were similar to those conducted in the Red Deer River; non-point source TN and TP loads were found to be relatively insensitive to changes to land cover.

5.4 Limitations and Uncertainty

Because the mass-balance models rely on in-stream data from Section 2.0, estimates of point source loads from Section 3.0, and land cover data from Section 4.0, limitations and sources of uncertainty associated with these data types are applicable to the watershed loading analysis. Other areas of uncertainty associated with the watershed loading analysis are outlined below.

Mass Balance Approach

The mass-balance models used in the watershed loading analysis are similar to those used in other studies in that they assume in-stream loads should be approximate the sum total of point source loads, non-point source loads, and in-stream sources and sinks (Johnes 1996; McFarland and Hauck 2001; Winter 1998). Similar to other studies, the models used here were also validated against data from other years with experiencing similar flow conditions (i.e., wet, dry, or moderate) (Johnes 1996; Matias and Johnes 2012). The use of un-calibrated and un-validated export coefficients directly from the literature often leads to overestimates of nutrient loads (e.g., Reckhow et al. 1980) or loading estimates with extremely large error terms (e.g., Burke 2016). Although there is some uncertainty associated with the use of export coefficients (see below), one of the drawbacks of the approach used here is that it does not distinguish natural loading from a given parcel of land from that attributable to human activity, an undertaking that requires a large amount of site-specific data.

Other analytical approaches that could be employed include multiple regression analysis (Mattson and Isaac 1999; McFarland and Hauck 2001) and co-location analyses (Burke 2016). With the multiple regression approach, the standard deviation around each export coefficient can be estimated; however, required sample sizes are larger than those afforded by the datasets available for the Red Deer and Carrot River watersheds (McFarland and Hauck 2001). The co-location analyses completed by Burke (2016) involved assigning qualitative risk ratings to water quality stations based on the probability that a measurement from that location would exceed applicable water quality guidelines. This approach requires that in-stream data have sufficient spatial coverage, and samples sizes per station are large enough to provide confidence in the assigned risk ratings.

Overall, the export coefficient-based approach to identifying the main contributors to non-point source loads and to align point source and non-point source estimates with in-stream loads provides an overall characterization of the system in question and can be used as a screening tool to identify where more detailed follow-up study may be warranted or required. This statement aligns with findings of other researchers (e.g., Longabucco and Rafferty 1998).

It is anticipated that collection and inclusion of additional watershed information in the watershed loading models could improve their utility as a management tool. In addition to improved spatial coverage and sampling frequency associated with in-stream data (Section 2.4), additional data types that could be collected and reflected in the model include:

- types, numbers, and densities of livestock (Matias and Johnes 2012)
- rates and spatial distributions of manure fertilizer application (Matias and Johnes 2012)
- densities and distributions of human populations and farming operations (Burke 2016)
- water volume and quality data for irrigation return flows (Section 5.5.2.1)

Consideration of this type of information, as well as the sub-category information underlying each broad land use category, could be used to modify or adjust the export coefficients assigned to the same land type in different areas of the watershed. For example, the export coefficients for agricultural lands could be set higher in parts of the watershed where manure application rates are typically higher than in areas where they are lower. Similarly, export coefficients assigned to, for example, exposed land could be set higher in parts of the watershed where the exposed land consists of barren land or more easily erodible soils and lower in areas when the exposed land consists largely of rock. Such differentiation would help to better delineate the watershed and identify key loading sources; supporting this type of approach with additional in-stream information would also allow model calibration and validation steps to be conducted at watershed and sub-watershed scales, rather than just at a watershed scale (as done herein with the exception of 2013).

In-stream Data

For the Carrot River watershed, the lack of observed in-stream data upstream of Turnberry imposed a notable limitation on the watershed loading analysis. Calibration targets (i.e., observed in-stream loads) could not be included in the analysis for the Carrot River sub-watersheds. As a result, model calibration was restricted to the terminal station, despite the availability of point source and land cover data for all areas of the watershed. This lack of spatial coverage restricted and largely precluded the identification of nutrient hotspots within the watershed.

Small Land Areas

The export coefficient selection and model calibration process focussed on land cover types that represented large proportions of the individual sub-watersheds. Land cover types representing less than 3% of the total watershed area were excluded from the exercise for the reasons outlined herein. Although they are likely to be minor contributors, loading rates from these areas remains uncharacterized.

Spatial Variations in Export

Because the same export coefficients were applied to all sub-watersheds, differences in nutrient export rates among the different sub-watersheds were not directly considered in the model. It is likely that localized differences in factors such as slope, soil type, precipitation and land practices result in different nutrient export rates from the same land type in different parts of the watershed. As noted above, these differences likely contributed to the need to add sources and sinks to the 2013 Red Deer River watershed model. The absence of sources and sinks from the other watershed models (i.e., those developed without consideration of sub-watershed performance) indicate that, while they may differ by sub-watershed, the selected export coefficients adequately represent average nutrient export rates across the watershed as a whole.

6.0 KEY FINDINGS AND IMPLICATIONS FOR NUTRIENT MANAGEMENT

6.1 Key Findings

6.1.1 Red Deer River

What are existing nutrient levels, how do they vary down the length of each river, and are they increasing over time?

At the terminal station near Bindloss, TN concentrations range from 0.73 to 2.5 mg/L, based on information collected in 2012 and 2013. Information from the same dataset suggests that TP concentrations range from 0.01 to 0.34 mg/L. In general, TP concentrations and loads peak during spring, and then decline to annual minimums in winter. The same is true for TN loads, although TN concentrations in the river mainstem typically declined to annual minimums in summer, rather than winter.

TN and TP concentrations and loads at the terminal station near Bindloss have been increasing over time since 1995, mostly in response to increasing flows. Flow-adjusted TP concentrations remain relatively consistent, whereas flow-adjusted TN concentrations between 1995 and 2014 have increased. These trends differ from those identified by PPWB (2016). In their examination of TP data collected from 1967 to 2008 and TN data from 1993 to 2008, flow-adjusted concentrations at Bindloss were found to be consistent (TN) or decreasing (TP) over time. The time scale considered in the two sets of analyses may be a factor contributing to the different findings.

Key spatial patterns include the following:

- Concentrations and loads of both nutrients tend to increase with increasing distance downstream along the river mainstem.
- In the three tributaries examined, nutrient concentrations tend to be higher in the Blindman River, but loads are highest in the Little Red Deer (TP) and Medicine (TN) rivers, reflecting the larger size of these two watersheds and greater in-stream flows.

- Most of the TN and TP load in the river mainstem upstream of the City of Red Deer originates from the Little Red Deer and Medicine rivers. These statements are also true for loads measured at downstream stations at Nevis and Morrin.
- Gleniffer Lake, which is located on the Red Deer River mainstem and controlled by the Dickson Dam, is a sink for TP within the immediate sub-watershed area that terminates at station AB05CC0010 upstream of the City of Red Deer. It may also be a sink for TN, although the results of Donald et al. (2015) would suggest that its effect on TN loads may be limited; thus, TN losses through this reach may be due to water withdrawals or other processes.
- A nutrient sink appears to be present between Nevis and Morrin; this sink likely affects both TN and TP, with effects to TP damped through a compensatory input of sediment and associated phosphorus from the Alberta badlands.
- Most of the nutrient loads in the Red Deer River near Jenner can be attributed to the immediate sub-watershed area, which is much larger than the other sub-watersheds and contains a number of larger tributaries; this sub-watershed also receives return flows from the Eastern and Western Irrigation Districts.
- Although nutrient loads reaching the terminal station near Bindloss originate primarily from areas upstream of Jenner, the small immediate sub-watershed draining to this station produces a disproportionately high areal load.

Where are the nutrients coming from (point sources, non-point sources, in-stream processes)?

Collectively, non-point sources are the largest contributor to nutrient loads in the Red Deer River. However, during dry years, TN loads from point sources exert a notable influence (i.e., representing up to 32% of the total in-stream load); the largest point source is the City of Red Deer WWTP. Even in dry years, non-point sources are the dominant source of TP loading to the Red Deer River.

Which sources are the largest, and how do they compare to one another?

Looking at the watershed as a whole, non-point source loads typically account for more than 90% of the in-stream TN and TP loads in the Red Deer River, except under dry conditions when TN loads from point sources become more notable (i.e., represent a greater proportion of the total in-stream load). The predominant land cover types in the watershed are the largest contributors to nutrient loads reaching the terminal station near Bindloss. More specifically, TN loads reaching the terminal station on the Red Deer River originate primarily from (listed in order of relative contribution):

- agricultural lands (i.e., grain/seed crops and hay/pasture);
- grassland and prairie areas downstream of the City of Red Deer;
- areas of trees/forest upstream of Sundre and in tributary watersheds; and
- the City of Red Deer WWTP.

TP loads reaching the terminal station from point sources are small in comparison to those from non-point sources. Overall, the largest contributors to TP loads in the Red Deer River are similar to those for TN and consist of (listed in order of relative contribution):

- agricultural lands (i.e., grain/seed crops and hay/pasture);
- grassland and prairie areas downstream of the City of Red Deer; and
- areas of trees/forest upstream of Sundre and in tributary watersheds.

How does the relative importance of these sources change between wet and dry conditions?

Nutrient loads from non-point sources in the Red Deer River watershed are higher during wet years and lower during dry years. However, for TP, non-point source loading continues to be the dominant loading source even under dry conditions. For TN, contributions from point sources become more influential under drier conditions.

Where are areas of risk / hotspots within the watershed?

As noted in Section 2, the small immediate sub-watershed draining to the terminal station at Bindloss produces a disproportionately high areal load, suggesting further investigation of nutrient sources in this area is warranted.

Are there sufficient data available to separate anthropogenic influences from natural sources?

The answer to this question depends on the scale at which is it considered or applied.

The information presented herein identifies how anthropogenic point sources, such as the discharge of municipal effluent, compare to non-point source loading from more natural forested areas. Similarly, the calibrated export coefficients outlined herein provide an indication of how loading from areas where human influence is typically higher (i.e., agricultural areas) differs from that where human influence / activity is typically less (i.e., more natural forested areas). It also identifies how human activities involving the creation of on-stream reservoirs and/or water withdrawals can influence in-stream nutrient conditions.

There are insufficient data available to identify how much of the total non-point source load released from a given parcel of land is related to the make-up of the underlying soil, in comparison to the overlying cover type, local geology or local land use practice. In other words, there are insufficient data available to divide the load from individual areas into what may be considered to be naturally occurring, because of soil type, aspect and geology, and that which may be considered to be of anthropogenic origin, because of cover type and land use practice.

6.1.2 Carrot River

What are existing nutrient levels, how do they vary down the length of each river, and are they increasing over time?

TN and TP concentrations at the terminal station on the Carrot River near Turnberry range from 1.1 to 1.8 mg/L and 0.06 and 0.18 mg/L, respectively, based on information collected in 2012 and 2013. In general, they exhibit little seasonal variability, unlike concentrations in the Red Deer River. Nutrient loads in the Carrot River, however, vary seasonally, reflective of changes in flow. As in the Red Deer River, most loading occurs in spring and summer.

Nutrient concentrations and loads at the terminal station near Turnberry have been increasing over time, based on information collected between 1995 and 2014. These findings are in agreement with the results of trend analyses completed by the PPWB (2016) using TP data collected between 1974 and 2008 and TN data collected between 1993 and 2008.

Spatial patterns identified from the available dataset include the following:

- Nutrient concentrations are similar among stations in Sweetwater Creek and the Leather River.
- Nutrient loads in Sweetwater Creek and the Leather River increase with increasing distance downstream.
- Both TN and TP loads are much higher in the Leather River versus Sweetwater Creek.

Where are the nutrients coming from (point sources, non-point sources, in-stream processes)?

Collectively, non-point sources are the largest contributor to nutrient loads in the Carrot River. Point sources represent a negligible fraction (i.e., <1%) of total in-stream loads.

Which sources are the largest, and how do they compare to one another?

In the Carrot River watershed, the predominant land cover types are the largest contributors to nutrient loads reaching the terminal station near Turnberry; they include:

- grain/seed crops;
- trees/forest; and
- wetlands (TN only).

Nearly all of the land in the upper half of the watershed, including in the Sweetwater Creek and Leather River sub-watersheds, is classified as grain/seed crops (i.e., unless the ground was too wet for seeding). Farther downstream, the watershed is dominated by large plots of forested land interspersed with wetlands.

How does the relative importance of these sources change between wet and dry conditions?

More than 99% of the nutrient loads reaching the terminal station at Turnberry are attributed to non-point source loads, regardless of climatic conditions. Similar to the Red Deer River, nutrient loads in the Carrot River are lowest during dry years, and highest during wet years.

Where are areas of risk / hotspots within the watershed?

The Leather River may be a hotspot for TN and, to a greater extent, TP. In 2013, 32% of the TP load and 10% of the TN load measured at the terminal station near Turnberry in spring may be attributable to the Leather River, despite the fact the watershed contributed only 7% of the spring flows reaching the terminal station and represents < 5% of the total land area.

Are there sufficient data available to separate anthropogenic influences from natural sources?

The answer to this question is similar to outlined above for Red Deer River. The information presented herein identifies how anthropogenic point sources appear to have a negligible influence on nutrient conditions in the

Carrot River. Similarly, the analysis indicates that the Leather River, where anthropogenic activity occurs, may be a nutrient hotspot. However, there are insufficient data available to divide a non-point source load from an individual parcel of land into what may be considered to be naturally occurring and that which may be considered to be of anthropogenic origin.

6.2 Implications for Nutrient Management

6.2.1 Red Deer River

As noted in Section 6.1.1, most of the TN and TP load in the river mainstem upstream of the City of Red Deer originates from the Little Red Deer and Medicine rivers. Consequently, nutrient management activities focused on the Little Red Deer and Medicine rivers could have a notable effect on nutrient conditions in the river mainstem, although ease of implementation would need to be further evaluated as would potential benefit relative to effort involved and desired endpoint. Similarly, although nutrient loads reaching the terminal station near Bindloss originate primarily from areas upstream of Jenner, the small immediate sub-watershed draining to this station produces a disproportionately high areal load, suggesting further investigation of nutrient sources in this area is warranted. That said, nutrient management activities focused within the immediate sub-watershed, should they occur, will need to occur in concert with others farther upstream (i.e., between Morrin and Jenner) to have a notable effect on in-stream nutrient conditions at the mouth of the Red Deer River.

TN loads from point sources can exert a notable influence on conditions in the river mainstem (i.e., representing up to 32% of the total in-stream load), with the City of Red Deer WWTP being the largest point source. The TN loads outlined herein for the City of Red Deer WWTP were derived using an assumed effluent concentration. Given the relative size of this one point source, direct measurement of effluent TN concentrations should be considered. Potential management actions can then be assessed, if and as warranted, with due consideration to cost and benefits associated with any change.

Finally, the results of the scenario analyses indicated that, in general, non-point source TN and TP loads appear to be relatively insensitive to changes in land cover. These results suggest that how the land is managed may be as important to nutrient loading as what the land is used for; for example, Donahue (2013) and Jeje (2006) note that factors such as tillage practices, fertilizer application rates, manure usage and degree of vegetative cover crop affect nutrient export rates from agricultural lands.

6.2.2 Carrot River

Nutrient conditions in the Carrot River are driven by non-point source inputs. Consequently, management efforts in this watershed should focus on non-point source control, particularly in agricultural areas in the upper portion of the watershed (which represented the largest loading source). Although data are limited, the Leather River would appear to be an area worthy of further investigation, given that a notable proportion of the nutrient load arriving at the terminal station near Turnberry during runoff conditions was attributed to outputs from this watershed, despite its relatively small size.

7.0 AREAS OF UNCERTAINTY

Areas of uncertainty or limitations in this study relate primarily to the following:

- data availability;
- accuracy of measured data; and
- application of consistent export coefficients across each watershed.

7.1 Data Availability

In the Red Deer River watershed, the assessment of in-stream concentrations and calculations of nutrient loads in tributary streams was restricted to the Little Red Deer, Medicine, and Blindman rivers, because of data availability. The exclusion of other relatively large sub-watersheds (e.g., the Threehills/Kneehills sub-watersheds) may have precluded the identification of other nutrient hotspots or potential sinks along the lower reaches of the river mainstem. Similarly, a lack of information prevented the adjustment or calibration of the TN effluent concentration applied to the City of Red Deer WWTP. As a result, there is uncertainty associated with the conclusion that this WWTP is the largest TN point source in the watershed.

Most sub-watersheds in the Carrot River did not have suitable datasets available to provide a more detailed spatial analysis. The lack of seasonal nutrient data for locations upstream of Turnberry also prevented an examination of seasonal trends in nutrient loads in the upper watershed, and results in uncertainty in the loading estimates generated for Sweetwater Creek and the Leather River.

The spatial patterns identified herein for both the Red Deer River and the Carrot River were developed with a focus on conditions in selected years. While the patterns described likely apply more broadly, this hypothesis would need to be confirmed with additional seasonal sampling at several representative locations (i.e., on major tributaries and along river mainstems) within each watershed and subsequent analysis.

7.2 Accuracy of Measured Data

Any measurement is subject to some uncertainty, related to the accuracy and precision of the instruments and methods used to collect the data point in question. For example, the minimum accuracy of the land cover classifications in the AAFC datasets is 85% (Government of Canada 2017b,c,d), meaning that approximately 15% of the land may have been misclassified by the AAFC as a result of imagery quality, existence of areas with mixed cover or other similar factors. The AAFC also indicated that winter wheat, grasslands, and shrublands may be erroneously assigned to the category associated with hay/pasture (Government of Canada 2016d). In a similar manner, water quality sample results typically include some level of uncertainty, with 20% being a comment standard used by commercial laboratories to identify notable results among split or duplicate samples.

While this level of accuracy is acceptable, it can limit the degree to which nutrient hotspots and/or in-stream sources and sinks can be detected. In other words, to be identifiable, sources, sinks or hotspots need to be of sufficient size to separate their influence on in-stream conditions from those potentially attributable to measurement error.

7.3 Consistent Export Coefficients

As noted in Section 5.0, the same export coefficients were applied to all sub-watersheds across each basin. It is known that localized differences in factors such as slope, soil type, precipitation and land practices result in different nutrient export rates from the same land type in different parts of the watershed. As noted in Section 5.0, these differences likely contributed to the need to add sources and sinks to the 2013 Red Deer River watershed model. The absence of sources and sinks from the other watershed models (i.e., those developed without consideration of sub-watershed performance) indicate that, while they may differ by sub-watershed, the selected export coefficients adequately represent average nutrient export rates across the watershed as a whole.

8.0 RECOMMENDATIONS

8.1 Addressing Uncertainties

An approach that could be used to reduce uncertainty in the identification of in-stream sources and sinks in the Red Deer and Carrot River watersheds would be to conduct seasonal synoptic sampling, wherein water samples are collected at time intervals that reflect travel time down the river mainstem. Flow and nutrient concentrations would be measured concurrently at the mouths of major tributaries, as well as at locations down the length of the river mainstem. The resulting load balance should provide a more precise estimate of mass gain or loss through the system.

More uniform and frequent collection of nutrient concentration data (e.g., monthly sampling at water quality stations of interest) would allow for better characterization of seasonal and annual variability, which, in turn, would help to identify nutrient hotspots or areas requiring more detailed investigation.

The previously noted uncertainty related to the influence of the City of Red Deer WWTP on in-stream TN levels could be resolved through direct measurement of TN concentrations in the treated effluent released from the facility.

The watershed analysis described herein could be improved by combining the AAFC datasets with other sources of information for the purposes of providing a combined description of cover type and land use intensity over time. Information of interest would include:

- livestock presence, density and type (e.g., cattle, poultry, sheep);
- densities and distributions of human populations and farming operations; and
- inputs related to crop production over time and space, such as pesticide and fertilizer application rates.

The combined dataset could be used to modify or adjust the export coefficients assigned to the same land type in different areas of the watershed. For example, the export coefficients for agricultural lands could be set higher in parts of the watershed where manure application rates are typically higher than in areas where they are lower. Such differentiation would help to better delineate the watershed and identify key loading sources.

There are obvious cost implications to moving forward with such an endeavor, related to the effort required to locate, procure, compile and analyze the noted information. Challenges to an efficient integration of the information into a single dataset could include data quality, spatial discrepancies and changes to census boundaries or the existence of census boundaries that do not align with watershed or sub-watershed boundaries (Burke 2016). Consequently, it would be prudent to proceed with such an endeavour in a stepwise manner, building gradually in terms of the different types of data that are considered in the analysis and the spatial scale over which the exercise is undertaken. Once an effective methodology has been developed, the scope of the analysis could be expanded.

8.2 Applying Methods to Other Watersheds

The methods described herein are applicable to other watersheds. However, sufficient data are required to support the evaluation, and the following recommendations should be considered prior to initiation of such studies:

- Major tributaries and sub-watershed areas should be identified, along with large point sources.
- Existing flow and water quality data for the watershed should be collated, including that available at in-stream flow and water quality monitoring stations and at large effluent discharge points.
- The assembled dataset should be reviewed to identify if spatial and temporal coverage is sufficient to support the desired level of analysis.
- Additional data collection should be considered to fill key gaps, if and as appropriate.

8.3 Separation of Non-Point Source Loading into Natural and Anthropogenic Components

Study Objective 2 outlined a desire to separate natural influences to in-stream nutrient conditions from those of anthropogenic origin; if data were insufficient to achieve that objective, then recommendations on how such data could be collected were requested (see Section 1.3). It is understood that the desire to differentiate anthropogenic loading from that which may be more natural in origin stems, at least in part, from Section 4 of the MAA, which states (PPWB 2015):

> *If the concentration of a chemical, physical or biological variable in a river reach, as a result of human activities, is not within the acceptable limit or limits when compared to the agreed objective for that chemical, physical or biological variable, reasonable and practical measures will be taken by the party in whose jurisdiction the chemical, physical or biological variable originates so that the quality of the water in the river reach is within the acceptable limit or limits.*

As discussed in Section 6.1, the information presented herein identifies the relative influence of anthropogenic point sources on in-stream conditions, in comparison to that related to non-point source loading from more natural forested areas. Similarly, the calibrated export coefficients outlined herein provide an indication of how loading from areas where human influence is typically higher (i.e., agricultural areas) differs from that where human influence / activity is typically less (i.e., more natural forested areas). It also identifies how human activities involving the creation of on-stream reservoirs and/or water withdrawals can influence in-stream nutrient conditions.

There are insufficient data available to divide the load from individual areas into what may be considered to be naturally occurring, because of soil type, aspect and geology, and that which may be considered to be of anthropogenic origin, because of cover type and land use practice. As noted by Donahue (2013), this type of characterization of non-point source loading requires a great deal of site-specific data, which are time consuming and expensive to collect. It is not a recommended approach for application at a watershed scale.

In addition, such an undertaking is unlikely to be completely successful, given the pervasiveness of human activity and the link of human activity to climate change, the latter of which can result in changes to runoff flows. Runoff flows are a key driver to non-point source loading, including those from natural, undisturbed areas. Consequently, it may be difficult to conclusively identify, particularly moving forward, which loading components are strictly natural in origin and which reflect anthropogenic influence. In light of these considerations, the PPWB may wish to move away from, to the extent possible, a strict delineation of loading sources into natural and anthropogenic “bins”, at least at a watershed scale.

It would likely be more effective to characterize existing loading patterns and identify the relative influence of different sources and potential sinks without compartmentalization following a tiered approach. Initially, studies can be conducted at a watershed scale, as done herein, with a focus on identifying broad patterns, general characteristics, trends and potential hotspots. They can then be refined through more detailed studies on selected aspects of the watershed to prove out hotspots, address uncertainties and, once proven out, better characterize the components of key sources (e.g., identify if nutrient export rates from a given hotspot are driven by erosion, tillage practices, agricultural intensity or some other factors, working in isolation or in combination). Using this information, nutrient management strategies could be developed, as required, with a focus on the biggest contributing sources most amenable to modification, regardless of the degree to which the source in question is natural or anthropogenic in origin. They could be then tested and trialed to see if they are reasonable and practical for larger-scale implementation. Following this type of tiered approach is expected to be more effective overall, compared to broader watershed-scale delineation of nutrient inputs into natural and anthropogenic categories, because efforts are more closely linked to the ultimate goal of the maintaining nutrient levels in prairie rivers at or below the objectives outlined in the MAA using reasonable and practical strategies.

Finally, the nutrient objectives outlined in the MAA were defined using existing in-stream data following a reference condition-type approach. They should, as a result, reflect a baseline of natural input, and deviation from the objectives should be driven primarily by human activity, which potentially lessens the need to explicitly identify incoming loads as being strictly natural or anthropogenic in origin.

9.0 CLOSURE

The work outlined herein was completed Amy Wiebe, Collen Prather, Jaewoo Kim and J.P. Bechtold. We trust this report meets your needs. Should you have any questions or comment, please contact the undersigned.

GOLDER ASSOCIATES LTD.

J.P. Bechtold, MASc, PBiol
Principal, Senior Water Quality Specialist

AFW/JPB/rp/jlb

https://capws.golder.com/sites/environmentcanadaquantifyingnonpointandpointnutrientsourcesalberta/p4000_final report/1527191_final.docx

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APPENDIX A

Available In-stream Measurements, 1995 to 2014

Table A1: Hydrometric Stations In the Red Deer River Watershed, Upstream of Bindloss

Station Code	Station Name	Date Range	
		Start	End
05CA002	JAMES RIVER NEAR SUNDRE	1966	2012
05CA003	DEER CREEK (MAIN STEM) NEAR SUNDRE	1966	1995
05CA004	RED DEER RIVER ABOVE PANTHER RIVER	1967	2012
05CA009	RED DEER RIVER BELOW BURNT TIMBER CREEK	1973	2012
05CA011	BEARBERRY CREEK NEAR SUNDRE	1978	2013
05CA012	FALLENTIMBER CREEK NEAR SUNDRE	1978	2013
05CB001	LITTLE RED DEER RIVER NEAR THE MOUTH	1960	2013
05CB002	LITTLE RED DEER RIVER NEAR WATER VALLEY	1961	2013
05CB004	RAVEN RIVER NEAR RAVEN	1971	2012
05CB007	DICKSON DAM TUNNEL OUTLET	1983	2012
05CC001	BLINDMAN RIVER NEAR BLACKFALDS	1916	2012
05CC002	RED DEER RIVER AT RED DEER	1912	2014
05CC007	MEDICINE RIVER NEAR ECKVILLE	1962	2012
05CC008	BLINDMAN RIVER NEAR BLUFFTON	1965	2012
05CC009	LLOYD CREEK NEAR BLUFFTON	1965	2012
05CC010	BLOCK CREEK NEAR LEEDALE	1976	2012
05CC011	WASKASOO CREEK AT RED DEER	1984	2012
05CC012	TINDASTOLL CREEK NEAR MARKERVILLE	1986	1995
05CC013	LASTHILL CREEK NEAR ECKVILLE	2006	2012
05CD006	HAYNES CREEK NEAR HAYNES	1978	2012
05CD007	PARLBY CREEK AT ALIX	1983	2012
05CD902	PARLBY CREEK NEAR MIRROR	1981	2013
05CD913	HAYNES CREEK (M1) NEAR JOFFRE	1999	2009
05CE001	RED DEER RIVER AT DRUMHELLER	1915	2014
05CE002	KNEEHILLS CREEK NEAR DRUMHELLER	1921	2012
05CE005	ROSEBUD RIVER AT REDLAND	1951	2014
05CE006	ROSEBUD RIVER BELOW CARSTAIRS CREEK	1957	2012
05CE007	THREEHILLS CREEK NEAR CARBON	1965	2012
05CE010	RAY CREEK NEAR INNISFAIL	1967	2012
05CE011	RENWICK CREEK NEAR THREEHILLS	1967	2012
05CE018	THREEHILLS CREEK BELOW RAY CREEK	1971	2012
05CE020	MICHICHI CREEK AT DRUMHELLER	1979	2012
05CG003	BULLPOUND CREEK NEAR THE MOUTH	1964	1995

Table A1: Hydrometric Stations In the Red Deer River Watershed, Upstream of Bindloss

Station Code	Station Name	Date Range	
		Start	End
05CG004	BULLPOUND CREEK NEAR WATTS	1980	2013
05CG006	FISH CREEK ABOVE LITTLE FISH LAKE	1984	2012
05CG007	ALBERTA POWER LIMITED COOLING POND OUTLET	1985	2013
05CH007	BERRY CREEK NEAR THE MOUTH	1964	2012
05CH008	BERRY CREEK NEAR ROSE LYNN	1967	2012
05CH011	BERRY CREEK RESERVOIR OUTLET	1983	2012
05CH012	DEADFISH INFLOW CANAL NEAR CESSFORD	1983	1995
05CH016	BERRY CREEK BELOW DEADFISH CREEK	1984	1995
05CJ001	EASTERN IRRIGATION DISTRICT NORTH BRANCH CANAL NEAR BASSANO	1914	2000
05CJ003	EASTERN IRRIGATION DISTRICT EAST BRANCH CANAL NEAR LATHOM	1917	2000
05CJ004	EASTERN IRRIGATION DISTRICT SPRINGHILL CANAL NEAR LATHOM	1917	2000
05CJ006	ONETREE CREEK NEAR PATRICIA	1951	2014
05CJ012	MATZHIWIN CREEK BELOW WARE COULEE	1989	2014
05CK001	BLOOD INDIAN CREEK NEAR THE MOUTH	1911	2011
05CK004	RED DEER RIVER NEAR BINDLOSS	1960	2014
05CK005	ALKALI CREEK NEAR THE MOUTH	1962	2012
05CK007	BLOOD INDIAN CREEK NEAR CABIN LAKE	1983	2009

Table A2: Number of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Red Deer River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season[a]											
	Discharge (m^3/s)[b]				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
AB05CA0050[c]												
1995	44	91	92	31	-	-	-	-	-	-	-	-
1996	41	91	92	35	-	-	-	-	-	-	-	-
1997	31	91	92	31	-	-	-	-	-	2	3	1
1998	37	91	92	31	-	-	-	-	-	-	-	-
1999	31	91	92	31	-	-	-	-	-	-	-	-
2000[e]	31	91	92	31	-	-	-	-	-	-	-	-
2001	31	91	92	31	-	-	-	-	-	-	-	-
2002	31	91	92	31	-	-	-	-	-	-	-	-
2003	31	91	92	31	-	-	-	-	-	-	-	-
2004	31	91	92	31	-	-	-	-	-	-	-	-
2005	31	91	92	31	-	-	-	-	-	-	-	-
2006	31	91	92	31	-	-	-	-	-	-	-	-
2007	31	91	92	31	-	-	-	-	-	-	-	-
2008	31	91	92	31	-	-	-	-	-	-	-	-
2009[d]	31	91	92	31	-	-	-	-	-	-	-	-
2010[e]	31	91	92	31	-	-	-	-	-	-	-	-
2011[e]	31	91	92	31	-	-	-	-	-	-	-	-
2012[d]	31	91	92	31	-	-	-	3	-	-	-	3
2013[d]	31	91	92	31	3	3	3	3	3	3	3	3
2014	-	-	-	-	3	-	-	-	3	-	-	-
AB05CB0270												
1995	90	91	92	92	-	-	-	-	-	-	-	-
1996	91	91	92	92	-	-	-	-	-	-	-	-
1997	90	91	92	92	-	-	-	-	1	16	3	1
1998	90	91	92	92	-	-	-	-	-	-	-	-
1999	90	91	92	92	-	-	-	-	3	9	10	1
2000[e]	91	91	92	92	-	-	-	-	2	8	4	1
2001	90	91	92	92	-	-	-	-	-	-	-	-
2002	90	91	92	92	-	10	3	1	-	10	3	1
2003	90	91	92	92	-	-	-	-	-	-	-	-
2004	91	91	92	92	-	4	3	1	-	4	3	1
2005	90	91	92	92	-	-	-	-	-	-	-	-
2006	90	91	92	92	-	2	4	1	-	2	4	1
2007	90	91	92	92	-	-	-	-	-	-	-	-
2008	91	91	92	92	-	6	3	-	-	6	3	-
2009[d]	90	91	92	92	-	-	-	-	-	-	-	-
2010[e]	90	91	92	92	-	-	-	-	-	-	-	-
2011[e]	90	91	92	92	-	7	3	1	-	7	3	1
2012[d]	91	91	92	92	-	-	-	-	-	-	-	-
2013[d]	90	91	92	92	-	7	3	1	-	7	3	1
2014	90	91	92	92	-	-	-	-	-	-	-	-

Table A2: Number of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Red Deer River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season[a]											
	Discharge (m^3/s)[b]				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
AB05CC0100												
1995	90	91	92	92	-	-	-	-	-	-	-	-
1996	91	91	92	92	-	-	-	-	-	-	-	-
1997	90	91	92	92	-	-	-	-	-	11	3	1
1998	90	91	92	92	-	-	-	-	-	-	-	-
1999	90	91	92	92	-	-	-	-	2	9	10	1
2000[e]	91	91	92	92	-	-	-	-	2	9	5	1
2001	90	91	92	92	-	-	-	-	-	-	-	-
2002	90	91	92	92	-	9	3	1	-	9	3	1
2003	90	91	92	92	-	-	-	-	-	-	-	-
2004	91	91	92	92	-	4	3	1	-	4	3	1
2005	90	91	92	92	-	-	-	-	-	-	-	-
2006	90	91	92	92	-	2	4	1	-	2	4	1
2007	90	91	92	92	-	-	-	-	-	-	-	-
2008	91	91	92	92	-	5	3	-	-	5	3	-
2009[d]	90	91	92	92	-	-	-	-	-	-	-	-
2010[e]	90	91	92	92	-	-	-	-	-	-	-	-
2011[e]	90	91	92	92	-	6	3	1	-	6	3	1
2012[d]	91	91	92	92	-	-	-	-	-	-	-	-
2013[d]	90	91	92	92	-	5	3	1	-	5	3	1
2014	90	91	92	92	-	-	-	-	-	-	-	-
AB05CC0010												
1995	90	91	92	92	-	-	-	-	4	3	3	3
1996	91	91	92	92	-	-	-	-	3	3	3	3
1997	90	91	92	92	-	-	-	-	2	4	3	3
1998	90	91	92	92	-	-	-	-	3	3	3	3
1999	90	91	92	92	-	2	2	2	3	3	3	3
2000[e]	91	91	92	92	2	1	2	2	3	3	3	3
2001	90	91	92	92	2	2	2	2	3	3	3	3
2002	90	91	92	92	2	-	-	-	3	3	3	4
2003	90	91	92	92	-	-	-	-	5	3	3	3
2004	91	91	92	92	-	-	-	-	3	3	3	3
2005	90	91	92	92	-	-	-	-	3	3	3	3
2006	90	91	92	92	-	-	-	-	3	3	3	3
2007	90	91	92	92	-	-	-	-	3	3	3	3
2008	91	91	92	92	-	-	-	-	3	3	3	3
2009[d]	90	91	92	92	-	-	-	-	3	3	3	3
2010[e]	90	91	92	92	-	-	-	-	3	3	3	3
2011[e]	90	91	92	92	-	3	3	3	3	3	3	3
2012[d]	91	91	92	92	3	3	3	3	3	3	3	3
2013[d]	90	91	92	92	3	3	3	3	3	3	3	3
2014	90	91	92	92	3	-	-	-	3	-	-	-

Table A2: Number of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Red Deer River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season[a]											
	Discharge (m^3/s)[b]				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
AB05CC0460												
1995	90	91	92	92	-	-	-	-	1	-	4	-
1996	91	91	92	92	-	-	-	-	2	-	-	-
1997	90	91	92	92	-	-	-	-	-	-	-	-
1998	90	91	92	92	-	-	-	-	-	-	-	-
1999	90	91	92	92	-	-	-	-	-	-	-	-
2000[e]	91	91	92	92	-	-	-	-	-	-	-	-
2001	90	91	92	92	-	-	-	-	-	-	-	-
2002	90	91	92	92	-	10	3	1	-	10	3	1
2003	90	91	92	92	-	-	-	-	-	-	-	-
2004	91	91	92	92	-	4	3	1	-	4	3	1
2005	90	91	92	92	-	-	-	-	-	-	-	-
2006	90	91	92	92	-	2	4	1	-	2	4	1
2007	90	91	92	92	-	-	-	-	-	-	-	-
2008	91	91	92	92	-	5	3	-	-	5	3	-
2009[d]	90	91	92	92	-	-	-	-	-	-	-	-
2010[e]	90	91	92	92	-	-	-	-	-	-	-	-
2011[e]	90	91	92	92	-	7	3	1	-	7	3	1
2012[d]	91	91	92	92	-	-	-	-	-	-	-	-
2013[d]	90	91	92	92	-	6	3	1	-	6	3	1
2014	-	-	-	-	-	-	-	-	-	-	-	-
AB05CD0250												
1995	90	91	92	92	-	-	-	-	-	-	-	-
1996	91	91	92	92	-	-	-	-	-	-	2	-
1997	90	91	92	92	-	-	-	-	-	-	-	-
1998	90	91	92	92	-	-	-	-	-	-	-	-
1999	90	91	92	92	-	1	2	2	-	1	3	3
2000[e]	91	91	92	92	2	1	2	2	3	3	3	3
2001	90	91	92	92	2	2	2	2	3	3	3	3
2002	90	91	92	92	7	1	3	1	8	4	6	5
2003	90	91	92	92	-	-	-	-	5	3	3	3
2004	91	91	92	92	-	-	-	-	3	3	3	3
2005	90	91	92	92	-	-	-	-	3	3	3	3
2006	90	91	92	92	-	-	-	-	3	3	3	3
2007	90	91	92	92	-	-	-	-	3	3	3	3
2008	91	91	92	92	-	-	-	-	3	3	3	3
2009[d]	90	91	92	92	-	-	-	-	3	3	3	3
2010[e]	90	91	92	92	-	-	-	-	3	3	3	3
2011[e]	90	91	92	92	-	3	3	3	3	3	3	3
2012[d]	91	91	92	92	3	3	3	3	3	3	3	3
2013[d]	90	91	92	92	3	3	3	3	3	3	3	3
2014	90	91	92	92	3	-	-	-	3	-	-	-

Table A2: Number of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Red Deer River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season(a)											
	Discharge (m^3/s)(b)				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
AB05CE0009												
1995	90	91	92	92	-	-	-	-	-	-	-	-
1996	91	91	92	92	-	-	-	-	-	-	4	-
1997	90	91	92	92	-	-	-	-	-	-	-	-
1998	90	91	92	92	-	-	-	-	-	-	-	-
1999	90	91	92	92	-	-	-	-	-	-	-	-
2000(e)	91	91	92	92	-	-	-	-	-	-	-	-
2001	90	91	92	92	-	-	-	-	-	-	-	-
2002	90	91	92	92	-	1	2	2	-	1	2	2
2003	90	91	92	92	-	-	-	-	-	-	-	-
2004	91	91	92	92	-	-	-	-	-	-	-	-
2005	90	91	92	92	-	-	-	-	-	-	-	-
2006	90	91	92	92	-	-	-	-	-	-	-	-
2007	90	91	92	92	-	-	-	-	-	-	-	2
2008	91	91	92	92	-	-	-	-	3	3	3	3
2009(d)	90	91	92	92	-	-	-	-	3	3	3	3
2010(e)	90	91	92	92	-	-	-	-	3	3	3	3
2011(e)	90	91	92	92	-	3	3	4	3	3	3	4
2012(d)	91	91	92	92	3	3	3	3	3	3	3	3
2013(d)	90	91	92	92	3	3	3	3	3	3	3	3
2014	90	91	92	92	3	-	-	-	3	-	-	-
AB05CJ0070												
1995	90	91	92	92	-	-	-	-	-	-	-	-
1996	91	91	92	92	-	-	-	-	-	-	2	-
1997	90	91	92	92	-	-	-	-	-	-	-	-
1998	90	91	92	92	-	-	-	-	-	-	2	-
1999	90	91	92	92	-	-	-	-	-	-	-	-
2000(e)	91	91	92	92	-	-	-	-	-	-	-	-
2001	90	91	92	92	-	-	-	-	-	-	-	-
2002	90	91	92	92	-	-	-	-	-	-	-	-
2003	90	91	92	92	-	-	-	-	-	-	-	-
2004	91	91	92	92	-	-	-	-	-	-	-	-
2005	90	91	92	92	-	-	-	-	-	-	-	-
2006	90	91	92	92	-	-	-	-	-	-	3	3
2007	90	91	92	92	-	-	-	-	-	3	3	3
2008	91	91	92	92	-	-	-	-	3	3	3	3
2009(d)	90	91	92	92	-	-	-	-	3	3	3	3
2010(e)	90	91	92	92	-	-	-	-	3	3	3	3
2011(e)	90	91	92	92	-	3	3	3	3	3	3	3
2012(d)	91	91	92	92	3	3	3	3	3	3	3	3
2013(d)	90	91	92	92	3	3	3	3	3	3	3	3
2014	90	91	92	92	3	-	-	-	3	-	-	-

Table A2: Number of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Red Deer River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season(a)											
	Discharge (m^3/s)(b)				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
AB05CK004												
1995	90	91	92	92	3	3	3	3	3	3	3	3
1996	91	91	92	92	3	3	3	3	3	3	3	3
1997	90	91	92	92	3	3	3	3	3	3	3	3
1998	90	91	92	92	3	3	3	3	3	3	3	3
1999	90	91	92	92	3	3	3	3	3	3	3	3
2000(e)	91	91	92	92	3	3	3	3	3	3	3	3
2001	90	91	92	92	3	3	3	3	3	3	3	3
2002	90	91	92	92	3	3	3	3	3	3	3	3
2003	90	91	92	92	3	3	3	3	3	3	3	3
2004	91	91	92	92	3	3	3	3	3	3	3	3
2005	90	91	92	92	3	3	3	3	3	3	3	3
2006	90	91	92	92	3	3	3	3	3	3	3	3
2007	90	91	92	92	3	3	3	3	3	3	3	3
2008	91	91	92	92	3	3	3	3	3	3	3	3
2009(d)	90	91	92	92	3	3	3	3	3	3	3	3
2010(e)	90	91	92	92	3	3	3	3	3	3	3	3
2011(e)	90	91	92	92	3	3	3	3	3	3	3	3
2012(d)	91	91	92	92	3	3	3	3	3	3	3	3
2013(d)	90	91	92	92	3	3	3	3	3	3	3	3
2014	90	91	92	92	3	3	3	3	3	3	3	3

(a) Winter = January-March; spring = April-June; summer = July-September; fall = October-December.

(b) Discharges (m^3/s) at the water quality sampling stations listed in the table were calculated based on measurements taken at the nearest stream flow monitoring station.

(c) Discharge data originated from stations 05CA002 and 05CB001 located on the James River and Little Red Deer River, respectively.

(d) 2009, 2012, and 2013 were the years selected for the model calibration component of the watershed loading analysis.

(e) 2000, 2010, and 2011 were the years selected for the model validation component of the watershed loading analysis.

m^3/s = cubic metres per second; TN = total nitrogen; mg/L = milligrams per litre; TP = total phosphorus; - no measurements reported; WSC = Water Survey of Canada.

Table A3: Water Quality (Nutrient) Stations In the Red Deer River Watershed

Station Code	Station Name	Total Nitrogen			Total Phosphorus		
		Start	End	Sample Count	Start	End	Sample Count
05CA0050	AT SUNDRE	2012	2014	18	1997	2014	24
05CB0270	WEST OF INNISFAIL	2002	2013	60	1997	2013	119
05CC0010	1 KM U/S HWY 2 BRIDGE	1999	2014	59	1995	2014	235
05CC0100	AT HWY 54	2002	2013	55	1997	2013	109
05CC0310	D/S OF RED DEER STP EFFLUENT,U/S OF THE BLINDMAN RIVER-RIGHT BANK	2002	2002	7	1997	2002	8
05CC0360	TRANSECT - D/S OF RED DEER STP EFFL, U/S OF BLINDMAN RIVER	2002	2002	11	1995	2002	29
05CC0460	NEAR THE MOUTH, AT HWY 2A BRIDGE SOUTH OF BLACKFALDS	2002	2013	58	1995	2013	65
05CD0120	AT JOFFRE BRIDGE-RIGHT BANK	2002	2002	11	1996	2002	13
05CD0150	AT JOFFRE BRIDGE-CENTRE	2002	2002	7	1996	2002	11
05CD0250	AT NEVIS BRIDGE-RIGHT BANK	1999	2014	68	1996	2014	193
05CE0009	AT MORRIN BRIDGE-RIGHT BANK	2002	2014	42	1996	2014	87
05CE0010	AT MORRIN BRIDGE - CENTRE	1999	2002	29	1995	2007	171
05CE0109	BELOW DRUMHELLER NEAR EAST COULEE AT HWY 10-RIGHT BANK	2002	2002	9	1996	2002	11
05CE0110	BELOW DRUMHELLER NEAR EAST COULEE AT HWY 10-CENTRE	2002	2002	8	1996	2002	12
05CJ0070	D/S DINOSAUR PROV PARK AT HWY 884 NEAR JENNER-RIGHT BANK	2011	2014	36	1996	2014	94
05CJ0071	NEAR JENNER AT HWY 884 D/S DINOSAUR PROVINCIAL PARK - CENTRE	2002	2002	17	1996	2002	23
05CK004	RED DEER RIVER NEAR BINDLOSS	1990	2014	290	1990	2014	300

Table A4: Hydrometric Stations In the Carrot River Watershed, Upstream of Turnberry.

Station Code	Station Name	Period of Record	
		Start	End
05KA001	CARROT RIVER NEAR KINISTINO	1919	2014
05KA009	GOOSEHUNTING CREEK NEAR BEATTY	1958	2014
05KA010	WALDSEA LAKE NEAR HUMBOLDT	1964	2010
05KA012	WAKAW LAKE NEAR WAKAW	1974	2014
05KB003	CARROT RIVER NEAR ARMLEY	1955	2014
05KB005	BURNTOUT BROOK NEAR ARBORFIELD	1955	2014
05KB006	LEATHER RIVER NEAR STAR CITY	1967	2014
05KB011	DOGHIDE RIVER NEAR RUNCIMAN	1977	2014
05KC001	CARROT RIVER NEAR SMOKY BURN	1955	2014
05KH007	CARROT RIVER NEAR TURNBERRY[(a)]	1966	2014
05MA025	RANCH CREEK ABOVE RANCH LAKE	1986	2014

(a) Terminal Prairie Provinces Water Board (PPWB) station on the Carrot River mainstem near Turnberry.

Table A5: Numbers of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Carrot River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season[a]											
	Discharge (m^3/s)[b]				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
SK05KB0066[c]												
1995	31	91	92	31	-	-	-	-	-	-	-	-
1996	31	91	92	31	-	-	-	-	-	-	-	-
1997	31	91	92	31	-	-	-	-	-	-	-	-
1998	31	91	92	31	-	-	-	-	-	1	-	-
1999	31	91	63	-	-	-	-	-	1	-	-	-
2000[e]	31	91	69	-	-	-	-	-	1	-	-	-
2001	31	91	67	-	-	-	-	-	-	-	-	-
2002	31	91	67	-	-	-	-	-	-	-	-	-
2003	31	91	64	-	-	-	-	-	-	-	-	-
2004	31	91	62	-	-	-	-	-	-	-	-	-
2005	31	91	92	31	-	-	-	-	-	1	-	-
2006	31	91	92	19	-	-	-	-	-	1	-	-
2007	31	91	92	10	-	1	-	-	-	1	-	-
2008	31	91	92	31	-	1	-	-	-	1	-	-
2009[d]	31	91	92	31	-	1	-	-	-	1	-	-
2010[d]	31	91	92	40	-	-	-	-	-	-	-	-
2011[e]	31	91	92	31	-	1	-	-	-	1	-	-
2012[e]	31	91	92	31	-	1	-	-	-	1	-	-
2013[d]	31	91	92	29	-	1	-	-	-	1	-	-
2014	58	182	184	70	-	-	-	-	-	-	-	-
SK05KB0067[c]												
1995	31	91	92	31	-	-	-	-	-	-	-	-
1996	31	91	92	31	-	-	-	-	-	-	-	-
1997	31	91	92	31	-	-	-	-	-	-	-	-
1998	31	91	92	31	-	-	-	-	-	-	-	-
1999	31	91	63	-	-	-	-	-	1	-	-	-
2000[e]	31	91	69	-	-	-	-	-	1	-	-	-
2001	31	91	67	-	-	-	-	-	-	-	-	-
2002	31	91	67	-	-	-	-	-	-	-	-	-
2003	31	91	64	-	-	-	-	-	-	-	-	-
2004	31	91	62	-	-	-	-	-	-	-	-	-
2005	31	91	92	31	-	-	-	-	-	1	-	-
2006	31	91	92	19	-	-	-	-	-	1	-	-
2007	31	91	92	10	-	1	-	-	-	1	-	-
2008	31	91	92	31	-	1	-	-	-	1	-	-
2009[d]	31	91	92	31	-	1	-	-	-	1	-	-
2010[d]	31	91	92	40	-	-	-	-	-	-	-	-
2011[e]	31	91	92	31	-	1	-	-	-	1	-	-
2012[e]	31	91	92	31	-	1	-	-	-	1	-	-
2013[d]	31	91	92	29	-	1	-	-	-	1	-	-
2014	58	182	184	70	-	-	-	-	-	-	-	-

Table A5: Numbers of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Carrot River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season[a]											
	Discharge (m^3/s)[b]				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
SK05KB0068[c]												
1995	31	91	92	31	-	-	-	-	-	-	-	-
1996	31	91	92	31	-	-	-	-	-	-	-	-
1997	31	91	92	31	-	-	-	-	-	-	-	-
1998	31	91	92	31	-	-	-	-	-	1	-	-
1999	31	91	63	-	-	-	-	-	1	-	-	-
2000[e]	31	91	69	-	-	-	-	-	1	-	-	-
2001	31	91	67	-	-	-	-	-	-	-	-	-
2002	31	91	67	-	-	-	-	-	-	-	-	-
2003	31	91	64	-	-	-	-	-	-	-	-	-
2004	31	91	62	-	-	-	-	-	-	1	-	-
2005	31	91	92	31	-	-	-	-	-	1	-	-
2006	31	91	92	19	-	-	-	-	-	1	-	-
2007	31	91	92	10	-	1	-	-	-	1	-	-
2008	31	91	92	31	-	1	-	-	-	1	-	-
2009[d]	31	91	92	31	-	1	-	-	-	1	-	-
2010[d]	31	91	92	40	-	-	-	-	-	-	-	-
2011[e]	31	91	92	31	-	1	-	-	-	1	-	-
2012[e]	31	91	92	31	-	1	-	-	-	1	-	-
2013[d]	31	91	92	29	-	1	-	-	-	1	-	-
2014	58	182	184	70	-	-	-	-	-	-	-	-
SK05KB0062[c]												
1995	31	91	92	31	-	-	-	-	-	-	-	-
1996	31	91	92	31	-	-	-	-	-	-	-	-
1997	31	91	92	31	-	-	-	-	-	-	-	-
1998	31	91	92	31	-	-	-	-	-	1	-	-
1999	31	91	63	-	-	-	-	-	1	-	-	-
2000[e]	31	91	69	-	-	-	-	-	1	-	-	-
2001	31	91	67	-	-	-	-	-	-	-	-	-
2002	31	91	67	-	-	-	-	-	-	-	-	-
2003	31	91	64	-	-	-	-	-	-	-	-	-
2004	31	91	62	-	-	-	-	-	-	1	-	-
2005	31	91	92	31	-	-	-	-	-	1	-	-
2006	31	91	92	19	-	-	-	-	-	1	-	-
2007	31	91	92	10	-	-	-	-	-	1	-	-
2008	31	91	92	31	-	1	-	-	-	1	-	-
2009[d]	31	91	92	31	-	1	-	-	-	1	-	-
2010[d]	31	91	92	40	-	-	-	-	-	-	-	-
2011[e]	31	91	92	31	-	1	-	-	-	1	-	-
2012[e]	31	91	92	31	-	1	-	-	-	1	-	-
2013[d]	31	91	92	29	-	1	-	-	-	1	-	-
2014	58	182	184	70	-	-	-	-	-	-	-	-

Table A5: Numbers of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Carrot River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season[a]											
	Discharge (m^3/s)[b]				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
SK05KB0064[c]												
1995	31	91	92	31	-	-	-	-	-	-	-	-
1996	31	91	92	31	-	-	-	-	-	-	-	-
1997	31	91	92	31	-	-	-	-	-	-	-	-
1998	31	91	92	31	-	-	-	-	-	2	-	-
1999	31	91	63	-	-	-	-	-	1	-	-	-
2000[e]	31	91	69	-	-	-	-	-	1	-	-	-
2001	31	91	67	-	-	-	-	-	-	-	-	-
2002	31	91	67	-	-	-	-	-	-	-	-	-
2003	31	91	64	-	-	-	-	-	-	-	-	-
2004	31	91	62	-	-	-	-	-	-	1	-	-
2005	31	91	92	31	-	-	-	-	-	1	-	-
2006	31	91	92	19	-	-	-	-	-	1	-	-
2007	31	91	92	10	-	2	-	-	-	2	-	-
2008	31	91	92	31	-	1	-	-	-	1	-	-
2009[d]	31	91	92	31	-	1	-	-	-	1	-	-
2010[d]	31	91	92	40	-	-	-	-	-	-	-	-
2011[e]	31	91	92	31	-	1	-	-	-	1	-	-
2012[e]	31	91	92	31	-	1	-	-	-	1	-	-
2013[d]	31	91	92	29	-	1	-	-	-	1	-	-
2014	58	182	184	70	-	-	-	-	-	-	-	-
SK05KB0065[c]												
1995	31	91	92	31	-	-	-	-	-	-	-	-
1996	31	91	92	31	-	-	-	-	-	-	-	-
1997	31	91	92	31	-	-	-	-	-	-	-	-
1998	31	91	92	31	-	-	-	-	-	1	-	-
1999	31	91	63	-	-	-	-	-	1	-	-	-
2000[e]	31	91	69	-	-	-	-	-	1	-	-	-
2001	31	91	67	-	-	-	-	-	-	-	-	-
2002	31	91	67	-	-	-	-	-	-	-	-	-
2003	31	91	64	-	-	-	-	-	-	-	-	-
2004	31	91	62	-	-	-	-	-	-	1	-	-
2005	31	91	92	31	-	-	-	-	-	1	-	-
2006	31	91	92	19	-	-	-	-	-	1	-	-
2007	31	91	92	10	-	1	-	-	-	1	-	-
2008	31	91	92	31	-	1	-	-	-	1	-	-
2009[d]	31	91	92	31	-	1	-	-	-	1	-	-
2010[d]	31	91	92	40	-	-	-	-	-	-	-	-
2011[e]	31	91	92	31	-	1	-	-	-	1	-	-
2012[e]	31	91	92	31	-	1	-	-	-	1	-	-
2013[d]	31	91	92	29	-	1	-	-	-	1	-	-
2014	58	182	184	70	-	-	-	-	-	-	-	-

Table A5: Numbers of Discharge, Total Nitrogen and Total Phosphorus Measurements Reported at Selected Stations in the Carrot River Watershed from 1995 to 2014

Year	Number of Measurements / Samples per Season[a]											
	Discharge (m^3/s)[b]				Total Nitrogen (TN)				Total Phosphorus (TP)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
SK05KH007												
1995	90	91	92	92	3	3	3	3	3	3	3	3
1996	91	91	92	92	3	3	3	3	3	3	3	3
1997	90	91	92	92	3	3	3	3	3	3	3	3
1998	90	91	92	92	3	3	3	3	3	3	3	3
1999	90	91	92	92	3	3	3	3	3	3	3	3
2000[e]	91	91	92	92	3	3	3	3	3	3	3	3
2001	90	91	92	92	3	3	3	3	3	3	3	3
2002	90	91	92	92	3	3	3	3	3	3	3	3
2003	90	91	92	92	3	3	3	3	3	3	3	3
2004	91	58	92	92	3	3	3	3	3	3	3	3
2005	90	66	92	92	3	3	3	3	3	3	3	3
2006	90	91	92	92	3	3	3	3	3	3	3	3
2007	90	91	92	92	3	3	3	3	3	3	3	3
2008	91	86	77	92	3	3	3	3	3	3	3	3
2009[d]	90	91	92	92	3	3	3	3	3	3	3	3
2010[d]	90	77	92	92	3	3	3	3	3	3	3	3
2011[e]	90	91	92	92	3	3	3	3	3	3	3	3
2012[e]	91	91	92	92	3	3	3	3	3	3	3	3
2013[d]	90	91	92	92	3	3	3	3	3	3	3	3
2014	90	91	92	92	3	3	3	3	3	3	3	3

(a) Winter = January-March; spring = April-June; summer = July-September; fall = October-December.

(b) Discharges (m^3/s) at the water quality sampling stations listed in the table were estimated based on measurements taken at the nearest stream flow monitoring station; however, refer to (c)

(c) Discharges at water quality stations on Sweetwater Creek were pro-rated based on flows in the Leather River; insufficient discharge data were available for Sweetwater Creek. Data that were missing for the Leather River hydrometric station were filled in using the methods described in Section 2.1.2.2.

(d) 2009, 2010, and 2013 were the years selected for the model calibration component of the watershed loading analysis.

(e) 2000, 2011, and 2012 were the years selected for the model validation component of the watershed loading analysis.

m^3/s = cubic metres per second; TN = total nitrogen; mg/L = milligrams per litre; TP = total phosphorus; - no measurements reported.

Table A6: Water Quality (Nutrient) Stations In the Carrot River Watershed

Station Code	Station Name	Total Nitrogen			Total Phosphorus		
		Date Range		Sample Count	Date Range		Sample Count
05KB0062	LEATHER R.-STN LRSC-1 7.5 mi W. of Tisdale on Hwy#3	2008	2013	5	1998	2013	12
05KB0063	LEATHER R-STN LRSC-2 5MI W.4MI N.&3MI W.OF TISDALE	2010	2010	1	2010	2010	10
05KB0064	LEATHER R-STN LRSC-3 5mi W.6mi N.&2.6mi W. Tisdale	2007	2013	7	1998	2013	14
05KB0065	LEATHER R.-STN LRSC-4 5mi W. & 8mi N. of Tisdale	2007	2013	6	1998	2013	12
05KB0066	SWEETWATER CK.-STN LRSC-5	2007	2013	6	1998	2013	11
05KB0067	SWEETWATER CK.-STN LRSC-6	2007	2013	6	1999	2013	10
05KB0068	SWEETWATER CK.-STN LRSC-7	2007	2013	6	1998	2013	12
05KB0080	BURNOUT BK.-STN #2 NE10-46-12W2 SASK AG & FOOD	2008	2013	5	1998	2013	12
05KB0083	CARROT R.-HWY #23 X-ING	2007	2013	7	1998	2013	14
05KB0084	LEATHER R.-HWY #335 X-ING WEST OF ARBORFIELD	2007	2013	6	1998	2013	12
05KB0085	CARROT R.-HWY #35 X-ING NORTH OF NICKLEN	2007	2013	6	1998	2013	11
05KB0110	DOGHIDE R.-5MI N. OF TISDALE ON HWY #35 & 1MI W.	2007	2013	6	1999	2013	10
05KC0031	CARROT R.-3.5 MI. NORTH #55-NORTH OF SMOKEY BURN	2007	2013	6	1998	2013	12
05KH007	CARROT RIVER NEAR TURNBERRY	1990	2014	267	1990	2014	275

APPENDIX B

Specifications for Point Sources Identified in the Red Deer and Carrot River Watersheds

Table B1: Municipal Wastewater, Stormwater Management, and Industrial Facilities with Approvals to Discharge to the Red Deer River Watershed

Receiving Sub-basin	Nearest Downstream Water Quality Station	Facility Type	Name of Community/Industrial Site	Category[a]
Upper Red Deer River	AB05CA0050	Industrial - Fuel	Sundre Alternate Fuel Production	Other
		Industrial - Sour Gas	Burnt Timber Sour Gas Plant	Other
		Industrial - Wood	Sundre Wood Processing Plant	Other
		Municipal Wastewater	Sundre	Direct Discharge
		Municipal Wastewater	Willow Hill Mobile Home Park	Indirect Discharge
		Stormwater Management	Sundre	Other
	AB05CC0010	Industrial - Oil and Gas	Sundre Pump Station and Tank Storage Facility	Other
		Industrial - Sour Gas	Sundre Sour Gas Plant	Other
Raven River	AB05CC0010	Municipal Wastewater	Caroline	Direct Discharge
Little Red Deer River	AB05CB0270	Industrial - Chemical	Shantz Sulphur Forming and Handling Facility	Other
		Industrial - Sour Gas	Crossfield Sour Gas Plant	Other
		Industrial - Sour Gas	Harmattan Sour Gas Plant	Other
		Industrial - Sour Gas	North Caroline Sour Gas Plant	Other
		Industrial - Sour Gas	South Elkton Sour Gas Plant	Other
		Municipal Wastewater	Bowden	Direct Discharge
		Municipal Wastewater	Cremona	Direct Discharge
		Municipal Wastewater	Olds	Direct Discharge
		Municipal Wastewater	Carefree Resort	Indirect Discharge
		Municipal Wastewater	Dickson Dam Administration Facility	Other
	AB05CC0010	Industrial - Sour Gas	Caroline Sour Gas Plant	Other
Medicine/ Blindman Rivers	AB05CC0010	Industrial - Fuel	Innisfail Biodiesel Plant	Other
		Industrial - Manufacturing	Innisfail Insulation Manufacturing Plant	Other
		Industrial - Oil and Gas	Bowden Refinery	Other
		Municipal Wastewater	Innisfail	Direct Discharge
		Municipal Wastewater	Melody Meadows Mobile Home Park	Direct Discharge
		Municipal Wastewater	Sylvan Lake	Direct Discharge
		Municipal Wastewater	Gleniffer Lake Resort	Indirect Discharge
		Municipal Wastewater	Jarvis Bay	Indirect Discharge
		Municipal Wastewater	Norglenwold	Indirect Discharge
		Municipal Wastewater	Penhold	Indirect Discharge
		Municipal Wastewater	South Hills Area	Indirect Discharge
		Stormwater Management	Innisfail/Napolean Meadows Subdivision	Other
		Stormwater Management	Penhold	Other
		Stormwater Management	Red Deer County	Other
		Stormwater Management	Sylvan Lake	Other
	AB05CC0100	Industrial - Sour Gas	Medicine River Sour Gas Plant	Other
		Industrial - Sour Gas	Sylvan Lake Sour Gas Plant[b]	Other
		Industrial - Sour Gas	Wilson Creek Sour Gas Plant[b]	Other
		Municipal Wastewater	Benalto	Direct Discharge
		Municipal Wastewater	Condor	Direct Discharge
		Municipal Wastewater	Eckville	Direct Discharge
		Municipal Wastewater	Kountry Meadows Estates	Direct Discharge

Table B1: Municipal Wastewater, Stormwater Management, and Industrial Facilities with Approvals to Discharge to the Red Deer River Watershed

Receiving Sub-basin	Nearest Downstream Water Quality Station	Facility Type	Name of Community/Industrial Site	Category[a]
Medicine/ Blindman Rivers (con't)	AB05CC0100 (con't)	Municipal Wastewater	Leslieville	Direct Discharge
		Municipal Wastewater	Spruce View	Direct Discharge
		Stormwater Management	Benalto	Other
		Stormwater Management	Eckville	Other
	AB05CC0460	Industrial - Sour Gas	East Gilby Sour Gas Plant	Other
		Industrial - Sour Gas	Gilby Sour Gas Plants[b]	Other
		Industrial - Sour Gas	West Gilby Sour Gas Plant	Other
		Industrial - Sour Gas	Rimbey Sour Gas Plant	Other
		Municipal Wastewater	Bentley	Direct Discharge
		Municipal Wastewater	Rimbey	Direct Discharge
		Municipal Wastewater	Meridian Beach/Raymond Shores RV Park	Other
		Stormwater Management	Bentley	Other
		Stormwater Management	Rimbey	Other
	AB05CD0250	Industrial - Food Production	Red Deer Distillery	Other
		Municipal Wastewater	City of Red Deer	Direct Discharge
		Municipal Wastewater	Les' Trailer Court	Indirect Discharge
		Municipal Wastewater	Mynarski Park Subdivision	Indirect Discharge
Red Deer River below Red Deer/ Buffalo Lake	AB05CD0250	Industrial - Chemical	Joffre Anhydrous Ammonia Manufacturing Plants[b]	Other
		Industrial - Chemical	Joffre Chemical Manufacturing Plant	Other
		Industrial - Chemical	Joffre Prairie Rose Linear Alpha Olefins Plant	Other
		Industrial - Chemical	Prentiss Chemical and Petrochemical Manufacturing Plant	Other
		Industrial - Sour Gas	Nevis Sour Gas Plant	Other
		Municipal Wastewater	Delburne	Indirect Discharge
	AB05CE0009	Industrial - Food Production	Alix Malt Production Plant	Other
		Municipal Wastewater	Bashaw	Direct Discharge
		Municipal Wastewater	Big Valley	Direct Discharge
		Municipal Wastewater	Mirror	Direct Discharge
		Municipal Wastewater	Alix	Indirect Discharge
		Municipal Wastewater	Lousana	Indirect Discharge
	AB05CJ0070	Municipal Wastewater	Rumsey	Indirect Discharge
Threehills Creek/Kneehills Creek/Rosebud River	AB05CJ0070	Municipal Wastewater	Acme	Direct Discharge
		Municipal Wastewater	Beiseker	Direct Discharge
		Municipal Wastewater	Carbon	Direct Discharge
		Municipal Wastewater	Carstairs	Direct Discharge
		Municipal Wastewater	Delia	Direct Discharge
		Municipal Wastewater	Didsbury	Direct Discharge
		Municipal Wastewater	Drumheller	Direct Discharge
		Municipal Wastewater	Elnora	Direct Discharge
		Municipal Wastewater	Huxley	Direct Discharge
		Municipal Wastewater	Irricana	Direct Discharge
		Municipal Wastewater	Langdon	Direct Discharge

Table B1: Municipal Wastewater, Stormwater Management, and Industrial Facilities with Approvals to Discharge to the Red Deer River Watershed

Receiving Sub-basin	Nearest Downstream Water Quality Station	Facility Type	Name of Community/Industrial Site	Category[a]
Threehills Creek/Kneehills Creek/Rosebud River (con't)	AB05CJ0070 (con't)	Municipal Wastewater	Linden	Direct Discharge
		Municipal Wastewater	Michichi	Direct Discharge
		Municipal Wastewater	Morrin	Direct Discharge
		Municipal Wastewater	Rockyford	Direct Discharge
		Municipal Wastewater	Swalwell	Direct Discharge
		Municipal Wastewater	Three Hills	Direct Discharge
		Municipal Wastewater	Torrington	Direct Discharge
		Municipal Wastewater	Trochu	Direct Discharge
		Municipal Wastewater	Wimborne	Direct Discharge
		Municipal Wastewater	Ghostpine Lake Golf & Country Resort	Indirect Discharge
		Municipal Wastewater	Green Acres Trailer Park	Indirect Discharge
		Municipal Wastewater	Lakes of Muirfield	Indirect Discharge
		Municipal Wastewater	Munson	Indirect Discharge
		Municipal Wastewater	Rosebud	Indirect Discharge
		Stormwater Management	Carbon	Other
		Stormwater Management	Didsbury	Other
		Stormwater Management	Drumheller	Other
		Stormwater Management	Irricana	Other
		Stormwater Management	Lakes of Muirfield	Other
		Stormwater Management	Langdon	Other
		Industrial - Chemical	Standard Fertilizer Manufacturing Plant	Other
		Industrial - Fuel	Olds Biodiesel Plant	Other
		Industrial - Manufacturing	Rockyford Explosives Manufacturing Plant	Other
		Industrial - Power Generation	Strathmore Power Plant	Other
		Industrial - Sour Gas	Carstairs Sour Gas Plant	Other
		Industrial - Sour Gas	Lone Pine Creek Sour Gas Plants[b]	Other
		Industrial - Sour Gas	Olds Sour Gas Plant	Other
		Industrial - Sour Gas	Swalwell Sour Gas Plant	Other
		Industrial - Sour Gas	Twining Sour Gas Plant	Other
		Industrial - Sour Gas	Wayne-Rosedale Sour Gas Plant	Other
		Industrial - Sour Gas	West Drumheller Sour Gas Plant	Other
		Industrial - Sour Gas	Wimborne Sour Gas Plant	Other
		Industrial - Waste	Beiseker Biomedical Waste Incinerator	Other
		Industrial - Waste	Drumheller Regional Landfill	Other
Middle Red Deer River/Bullpound Creek	AB05CJ0070	Municipal Wastewater	East Coulee	Direct Discharge
		Municipal Wastewater	Hanna	Direct Discharge
		Industrial - Chemical	Brooks Calcium Chloride Recovery and Storage Plant	Other
		Industrial - Chemical	Brooks Solvent Recycling Facility	Other
		Industrial - Food Production	Brooks Meat Packing Plant	Other
		Industrial - Mine	Sheerness Coal Mine	Other
		Industrial - Sour Gas	Alderson West Sour Gas Plant	Other
		Industrial - Sour Gas	Bantry North Sour Gas Plant	Other

Table B1: Municipal Wastewater, Stormwater Management, and Industrial Facilities with Approvals to Discharge to the Red Deer River Watershed

Receiving Sub-basin	Nearest Downstream Water Quality Station	Facility Type	Name of Community/Industrial Site	Category[a]
Middle Red Deer River/Bullpound Creek (con't)	AB05CJ0070	Industrial - Sour Gas	Bantry Sour Gas Plant	Other
		Industrial - Sour Gas	Princess Sour Gas Plant	Other
		Industrial - Sour Gas	Rosemary Sour Gas Plant	Other
		Industrial - Sour Gas	Suffield A2 Sour Gas Plant	Other
Dowling Lake/Sullivan Lake	AB05CJ0070	Municipal Wastewater	Byemoor	Indirect Discharge
		Municipal Wastewater	Endiang	Indirect Discharge
		Industrial - Sour Gas	Halkirk Sour Gas Plant	Other
Middle Red Deer River/Matzhiwin Creek	AB05CJ0070	Municipal Wastewater	Bassano	Direct Discharge
		Municipal Wastewater	Brooks	Direct Discharge
		Municipal Wastewater	Dinosaur Provincial Park	Direct Discharge
		Municipal Wastewater	Patricia	Direct Discharge
		Municipal Wastewater	Rosemary	Direct Discharge
		Municipal Wastewater	Duchess	Indirect Discharge
		Municipal Wastewater	Lake McGregor Country Estates	Indirect Discharge
		Municipal Wastewater	Lake Newell Resort	Indirect Discharge
		Municipal Wastewater	Tillybrook Provincial Park	Indirect Discharge
Berry Creek/Carolside Reservoir	AB05CJ0070	Municipal Wastewater	Cessford	Indirect Discharge
		Industrial - Mine	Montgomery Coal Mine	Other
		Industrial - Mine	Sheerness Coal Mine	Other
		Industrial - Mine	Sheerness Coal Mine Wastewater Drainage	Other
		Industrial - Oil and Gas	Sunnynook Brine Storage Pond	Other

(a) Point source facilities are categorized as "direct discharge" facilities if they discharge into tributaries or the mainstem of the Red Deer River, "indirect discharge" facilities if they do not discharge into watercourses or waterbodies that ultimately flow into the Red Deer River or its tributaries, or "other" facilities if insufficient data were available to categorize them as "direct discharge" or "indirect discharge" facilities.

(b) Multiple approvals to discharge were issued to these facilities.

Table B2: Municipal Wastewater, Stormwater Management, and Industrial Facilities with Approvals to Discharge to the Carrot River Watershed

Receiving Sub-basin	Nearest Downstream Water Quality Station	Facility Type	Name of Community/Industrial Site	Category[a]
Carrot River East	SK05KH007	Municipal Wastewater	Arborfield	Direct
		Municipal Wastewater	Aylsham	Indirect
		Municipal Wastewater	Bjorkdale	Indirect
		Municipal Wastewater	Carrot River	Direct
		Municipal Wastewater	Sylvania	Indirect
		Municipal Wastewater	Red Earth First Nation	Other
		Municipal Wastewater	Tisdale	Direct
		Municipal Wastewater	Zenon Park	Direct
Carrot River West	SK05KH007	Municipal Wastewater	Beatty	Indirect
		Municipal Wastewater	Crystal Springs	Indirect
		Municipal Wastewater	Kinistino	Direct
		Municipal Wastewater	Melfort	Direct
		Municipal Wastewater	Pleasantdale	Indirect
		Municipal Wastewater	Ridgedale	Indirect
		Municipal Wastewater	St. Benedict	Indirect
		Municipal Wastewater	Yellow Creek	Indirect
	SK05KB0067	Municipal Wastewater	Star City	Direct
	NA[b]	Municipal Wastewater	Gronlid	Indirect
Lenore Lake	NA[b]	Municipal Wastewater	Anaheim	Indirect
		Municipal Wastewater	Lake Lenore	Indirect
		Municipal Wastewater	Middle Lake	Indirect
		Municipal Wastewater	Pilger	Indirect
		Municipal Wastewater	St. Brieux	Indirect
		Industrial - Manufacturing	Bourgault Industries	Indirect

(a) Point source facilities are categorized as "direct discharge" facilities if they discharge into tributaries or the mainstem of the Carrot River, "indirect discharge" facilities if they do not discharge into watercourses or waterbodies that ultimately flow into the Carrot River or its tributaries, or "other" facilities if insufficient data were available to categorize them as "direct discharge" or "indirect discharge" facilities.

(b) The Lenore Lake basin is a closed sub-watershed that does not contribute flows or nutrients to the Carrot River or its tributaries.

Table 3: Details for Municipal Point Sources that Discharge to Receiving Environments within the Red Deer River Watershed, Based on Available Data

Receiving Sub-basin	Community	Facility Type	Receiving Environment	Service Population	Schedule of Release[a]	Notes
Upper Red Deer River	Sundre	mechanical aerated lagoon	Red Deer River	3,928[b]	continuously	-
	Willow Hill Mobile Home Park	sewage treatment mound	NA	100[b]	considered an indirect discharge facility	indirect discharge facility; excluded
Raven River	Caroline	mechanical aerated lagoon	Raven River	472-515[c]	continuously	-
Little Red Deer River	Bowden	lagoon stabilization pond	Bowden Creek	1,014-1,241[c]	once per year	-
	Carefree Resort	collection system	NA	100[b]	considered an indirect discharge facility	indirect discharge facility; excluded
	Cremona	lagoon stabilization pond	drainage course to Little Red Deer River	380-463[c]	once per year	-
	Olds	mechanical WWTP	Olds Creek	6,230-8,511[c]	twice per year	-
Medicine/Blindman Rivers	Benalto	lagoon stabilization pond[d]	Medicine River	129[b]	once per year	-
	Bentley	lagoon stabilization pond	Blindman River	1,800[b]	once per year	-
	Condor	lagoon stabilization pond[d]	Lasthill Creek	132[b]	once per year	-
	Eckville	mechanical aerated lagoon	Medicine River	914-1,125[c]	twice per year	-
	Gleniffer Lake Resort	mechanical WWTP	irrigation	2000[b]	-	irrigated land is included in the assessment of non-point sources; excluded
	Innisfail	mechanical WWTP	Little Buffalo Creek/irrigation	12,245[b]	twice per year	because only some of the wastewater is used for golf course irrigation, this facility was retained in the assessment of point sources
	Jarvis Bay	collection system	NA	83-203[c]	considered an indirect discharge facility	indirect discharge facility; excluded
	Kountry Meadows Estates	lagoon stabilization pond[d]	Medicine River	321[b]	once per year	-

Table 3: Details for Municipal Point Sources that Discharge to Receiving Environments within the Red Deer River Watershed, Based on Available Data

Receiving Sub-basin	Community	Facility Type	Receiving Environment	Service Population	Schedule of Release[(a)]	Notes
Medicine/Blindman Rivers (con't)	Les' Trailer Court	lagoon stabilization pond and tile field	irrigation	100[(b)]	-	irrigated land is included in the assessment of non-point sources; excluded
	Leslieville	lagoon stabilization pond[(d)]	Lobstick Creek	232[(b)]	once per year	-
	Melody Meadows Mobile Home Park	lagoon stabilization pond	Signat Creek	102[(b)]	once per year	-
	Mynarski Park Subdivision	collection system	NA	1,426[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded
	Norglenwold	collection system	NA	100[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded
	Penhold	collection system	NA	1,625-2,476[(c)]	considered an indirect discharge facility	indirect discharge facility; excluded
	Red Deer	mechanical WWTP	Red Deer River	106,705[(b)]	continuously	-
	Rimbey	lagoon and aerated lagoon	Blindman River	2,106-2,496[(c)]	twice per year	-
	South Hills Area	collection system	NA	2,566[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded
	Spruce View	lagoon stabilization pond	Dickson Creek	308[(b)]	once per year	-
	Sylvan Lake	mechanical aerated lagoon	Sylvan Creek	7,008-13,015[(c)]	twice per year	-

Table 3: Details for Municipal Point Sources that Discharge to Receiving Environments within the Red Deer River Watershed, Based on Available Data

Receiving Sub-basin	Community	Facility Type	Receiving Environment	Service Population	Schedule of Release[(a)]	Notes
Red Deer River below Red Deer/ Buffalo Lake	Alix	mechanical aerated lagoon and lagoon stabilization pond	Westcan Malting ponds/irrigation	775-851[(c)]	-	irrigated land is included in the assessment of non-point sources; excluded
	Bashaw	lagoon stabilization pond	Slingstone Lake	980[(b)]	once per year	-
	Big Valley	lagoon stabilization pond	Big Valley Creek	363[(b)]	twice per year	-
	Delburne	lagoon stabilization pond	Delburne Lake/irrigation	800[(b)]	once per year	irrigated land is included in the assessment of non-point sources; Delburne Lake is not expected to contribute to the Red Deer River under most flow conditions; excluded
	Lousana	lagoon stabilization pond	Mikwan Lake	50[(b)]	once per year	Mikwan Lake is not expected to contribute to the Red Deer River under most flow conditions; excluded
	Mirror	lagoon stabilization pond	Parlby Creek	595[(b)]	considered an indirect discharge facility	discharge is allowed to evaporate; excluded
	Rumsey	lagoon stabilization pond	NA	80[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded
Threehills Creek/Kneehills Creek/Rosebud River	Acme	lagoon stabilization pond	Kneehill Creek	653-730[(c)]	twice per year	-
	Beiseker	lagoon stabilization pond	Rosebud River	785-837[(c)]	once per year	-
	Carbon	lagoon stabilization pond	Kneehill Creek	570[(b)]	twice per year	-
	Carstairs	lagoon stabilization pond	Rosebud River	5,020[(b)]	once per year	-
	Delia	lagoon stabilization pond[(d)]	Michichi Creek	214[(b)]	twice per year	-
	Didsbury	lagoon stabilization pond	Rosebud River	3,782-4,957[(c)]	once per year	-

Table 3: Details for Municipal Point Sources that Discharge to Receiving Environments within the Red Deer River Watershed, Based on Available Data

Receiving Sub-basin	Community	Facility Type	Receiving Environment	Service Population	Schedule of Release[(a)]	Notes
Threehills Creek/Kneehills Creek/Rosebud River (con't)	Drumheller	mechanical WWTP	Red Deer River	9,000[(b)]	continuously	-
	Elnora	lagoon stabilization pond	Ghost Pine Creek	388[(b)]	once per year	-
	Ghostpine Lake Golf & Country Resort	lagoon stabilization pond	irrigation	100[(b)]	-	irrigated land is included in the assessment of non-point sources; excluded
	Green Acres Trailer Park	lagoon stabilization pond	irrigation	100[(b)]	-	irrigated land is included in the assessment of non-point sources; excluded
	Huxley	lagoon stabilization pond[(d)]	Ghost Pine Creek	90[(b)]	once per year	-
	Irricana	lagoon stabilization pond	Crossfield Creek	1,016-1,243[(c)]	once per year	-
	Lakes of Muirfield	collection system	NA	100[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded
	Langdon	mechanical WWTP	Weed Lake to Hartell Coulee to Serviceberry Creek	3,500[(b)]	continuously	-
	Linden	lagoon stabilization pond	Kneehill Creek	630-741[(c)]	once per year	-
	Michichi	lagoon stabilization pond	Michichi Creek	56[(b)]	once per year	-
	Morrin	lagoon stabilization pond	West Michichi Creek via Michichi Creek	245-275[(c)]	once per year	-
	Munson	lagoon stabilization pond	NA	217[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded
	Rockyford	lagoon stabilization pond	Serviceberry Creek	361[(b)]	once per year	-
	Rosebud	septic tank and tile field	NA	98[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded
	Swalwell	lagoon stabilization pond[(d)]	Kneehill Creek	117[(b)]	once per year	-

Table 3: Details for Municipal Point Sources that Discharge to Receiving Environments within the Red Deer River Watershed, Based on Available Data

Receiving Sub-basin	Community	Facility Type	Receiving Environment	Service Population	Schedule of Release[(a)]	Notes
Threehills Creek/Kneehills Creek/Rosebud River (con't)	Three Hills	lagoon stabilization pond	Three Hills Creek/irrigation	3,230-3,375[(c)]	once per year	because only some of the wastewater is used for golf course irrigation, this facility was retained in the assessment of point sources
	Torrington	lagoon stabilization pond	Kneehill Creek	217[(b)]	once per year	-
	Trochu	lagoon stabilization pond	Ghost Pine Creek	958-1,113[(c)]	once per year	-
	Wimbourne	lagoon stabilization pond[(d)]	Kneehill Creek	48[(b)]	once per year	-
Middle Red Deer River/Bullpound Creek	East Coulee	mechanical WWTP	Red Deer River	279[(b)]	continuously	-
	Hanna	lagoon stabilization pond	Bull Pound Creek	3,000[(b)]	twice per year	-
Dowling Lake/Sullivan Lake	Byemoor	lagoon stabilization pond[(d)]	unnamed slough	45[(b)]	once per year	discharge is allowed to evaporate once it enters the slough; excluded
	Endiang	lagoon stabilization pond	NA	39[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded
Middle Red Deer River/Matzhiwin Creek	Bassano	lagoon stabilization pond[(d)]	unnamed wetland to Red Deer River	1,390[(b)]	continuously	-
	Brooks	lagoon stabilization pond	One Tree Creek	15,982[(b)]	twice per year	-
	Dinosaur Provincial Park	mechanical WWTP	Red Deer River	350[(b)]	continuously	-
	Duchess	lagoon stabilization pond	Eastern Irrigation District canal (for irrigation)	1,098[(b)]	once per year	irrigated land is included in the assessment of non-point sources; excluded
	Lake McGregor Country Estates	lagoon stabilization pond	irrigation	200[(b)]	-	irrigated land is included in the assessment of non-point sources; excluded
	Lake Newell Resort	collection system	NA	400[(b)]	considered an indirect discharge facility	indirect discharge facility; excluded

Table 3: Details for Municipal Point Sources that Discharge to Receiving Environments within the Red Deer River Watershed, Based on Available Data

Receiving Sub-basin	Community	Facility Type	Receiving Environment	Service Population	Schedule of Release[a]	Notes
Middle Red Deer River/Matzhiwin Creek (con't)	Patricia	lagoon stabilization pond[d]	Little Sandhill Creek	164[b]	once per year	-
	Rosemary	lagoon stabilization pond	Matziwan Creek	485[b]	once per year	-
	Tillybrook Provincial Park	lagoon stabilization pond	NA	100[b]	considered an indirect discharge facility	indirect discharge facility; excluded
Berry Creek/Carolside Reservoir	Cessford	lagoon stabilization pond	NA	41[b]	considered an indirect discharge facility	indirect discharge facility; excluded

(a) If the timing of the discharges (e.g., winter, freshet, summer and/or fall) were not specified in the data, it was assumed that discharges occurred during freshet for facilities that discharged once per year, and during freshet and fall for facilities that discharged twice per year. This assumption was based on patterns in the discharge schedules for the Carrot River watershed.

(b) Based on the reported 2007 service population (AEP 2011, with updates).

(c) Based on the census population data reported for 2000 and 2009 through 2013 (Alberta Municipal Affairs 2017).

(d) As of 2007, the facility was non-compliant with 1997 design standards.

NA = not applicable; WWTP = wastewater treatment plant; - = no data.

Table B4: Details for Municipal Point Sources that Discharge to Receiving Environments within the Carrot River Watershed, Including the Lenore Lake Internal Sub-Basin, Based on Available Data

Receiving Sub-basin	Community	Facility Type	Receiving Environment	Population	Schedule of Release	Notes
Carrot River East	Arborfield	wastewater lagoons	Burntout Brook	326	twice per year (freshet and fall)	-
	Aylsham	wastewater lagoons	field	NA	NA	indirect discharge; excluded
	Bjorkdale	wastewater lagoons	NA	NA	considered an "indirect discharge" facility	indirect discharge; excluded
	Carrot River	wastewater lagoons	Emmons Creek	1,000	twice per year (freshet and fall)	-
	Sylvania	wastewater lagoons	field	NA	considered an "indirect discharge" facility	indirect discharge; excluded
	Red Earth First Nation	other[a]	unknown	1,300	unknown	no data; excluded
	Tisdale	wastewater lagoons	Doghide River	3,180	twice per year (freshet and fall)	-
	Zenon Park	wastewater lagoons	natural run to Burntout Brook	187	twice per year (freshet and fall)	-
Carrot River West	Beatty	wastewater lagoons	field	55	considered an "indirect discharge" facility	indirect discharge and lagoon is oversized for population; excluded
	Crystal Springs	wastewater lagoons	exfiltration	17	considered an "indirect discharge" facility	indirect discharge and lagoon is oversized for population; excluded
	Gronlid	wastewater lagoons	field	NA	considered an "indirect discharge" facility	discharge to Lenore Lake watershed (indirect discharge); excluded
	Kinistino	wastewater lagoons	Carrot River	743	twice per year	discharged three times per year in 2012 and 2013
	Melfort	multi-celled lagoon	Melfort Creek	6,500	twice per year (freshet and fall)	release is intermittent/infrequent
	Pleasantdale	wastewater lagoons	field	NA	considered an "indirect discharge" facility	indirect discharge; excluded
	Ridgedale	wastewater lagoons	field	-	-	indirect discharge; excluded
	St. Benedict	wastewater lagoons	Sayer's Lake	78	-	Sayer’s Lake is a closed saline lake (indirect discharge); excluded[b]
	Star City	wastewater lagoons	Sweetwater Creek	460	twice per year (freshet and fall)	-
	Yellow Creek	wastewater lagoons	exfiltration/McLoy Creek	37	considered an "indirect discharge" facility	indirect discharge; excluded

Table B4: Details for Municipal Point Sources that Discharge to Receiving Environments within the Carrot River Watershed, Including the Lenore Lake Internal Sub-Basin, Based on Available Data

Receiving Sub-basin	Community	Facility Type	Receiving Environment	Population	Schedule of Release	Notes
Lenore Lake	Anaheim	wastewater lagoons	NA	NA	NA	discharge to Lenore Lake watershed (indirect discharge); excluded
	Lake Lenore	wastewater lagoons	NA	NA	NA	discharge to Lenore Lake watershed (indirect discharge); excluded
	Middle Lake	wastewater lagoons	unnamed creek to Lucian Lake	242	twice per year	discharge to Lenore Lake watershed (indirect discharge); excluded
	Pilger	wastewater lagoons	field	74	twice per year	discharge to Lenore Lake watershed (indirect discharge); excluded
	St. Brieux	wastewater lagoons	St. Brieux Lake	690	twice per year	discharge to Lenore Lake watershed (indirect discharge); excluded
		Bourgault Industries (industrial discharge)	unnamed slough	NA	-	discharge to Lenore Lake watershed (indirect discharge); excluded

(a) Point source facilities are categorized as "other" facilities if insufficient data were available to categorize them as "direct discharge" or "indirect discharge" facilities and complete loading analyses.

(b) Hammer (1994)

- = no data; NA = not applicable.

Table B5: Total Nitrogen Concentrations and Loads at Direct Discharge Facilities in the Red Deer River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	Year/Season[c]																							
					2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Upper Red Deer River	Sundre	3,928[d]	1,571[d]	TN Concentration (mg/L)[e]	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
				Daily TN Load (kg/d)[f]	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47
				Seasonal TN Load (kg/season)[g]	4,289	4,289	4,337	4,337	4,242	4,289	4,337	4,337	4,242	4,289	4,337	4,337	4,242	4,289	4,337	4,337	4,289	4,289	4,337	4,337	4,242	4,289	4,337	4,337
				Annual TN Load (kg/yr)[h]	17,252				17,205				17,205				17,205				17,252				17,205			
Raven River	Caroline	472-515[i]	189-206[i]	TN Concentration (mg/L)[e]	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
				Daily TN Load (kg/d)[f]	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
				Seasonal TN Load (kg/season)[g]	515	515	521	521	556	562	569	569	556	562	569	569	556	562	569	569	547	547	553	553	541	547	553	553
				Annual TN Load (kg/yr)[h]	2,073				2,256				2,256				2,256				2,200				2,194			
Little Red Deer River	Cremona	380-463[i]	152-185[i]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	1.4	-	-	-	1.7	-	-	-	1.7	-	-	-	1.7				1.6				1.6		
				Seasonal TN Load (kg/season)[g]	-	29	-	-	-	35	-	-	-	35	-	-	-	35				35				35		
				Annual TN Load (kg/yr)[h]	29				35				35				35				35				35			
	Olds	6,230-8,511[i]	2,492-3,404[i]	TN Concentration (mg/L)[e]	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20
				Daily TN Load (kg/d)[f]	-	50	-	50	-	58	-	58	-	58	-	58	-	58	-	58	-	66	-	66	-	68	-	68
				Seasonal TN Load (kg/season)[g]	-	872	-	872	-	1,015	-	1,015	-	1,015	-	1,015	-	1,015	-	1,015	-	1,153	-	1,153	-	1,192	-	1,192
				Annual TN Load (kg/yr)[h]	1,744				2,029				2,029				2,029				2,306				2,383			
	Bowden	1,014-1,241[i]	406-496[i]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	3.7	-	-	-	4.4	-	-	-	4.4	-	-	-	4.4	-	-	-	4.5	-	-	-	4.5	-	-
				Seasonal TN Load (kg/season)[g]	-	102	-	-	-	125	-	-	-	125	-	-	-	125	-	-	-	125	-	-	-	125	-	-
				Annual TN Load (kg/yr)[h]	102				125				125				125				125				125			
Medicine/Blindman Rivers	Eckville	914-1,125[i]	366-450[i]	TN Concentration (mg/L)[e]	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30
				Daily TN Load (kg/d)[f]	-	11.0	-	11.0	-	12	-	12	-	12	-	12	-	12	-	12	-	14	-	14	-	14	-	14
				Seasonal TN Load (kg/season)[g]	-	208	-	208	-	228	-	228	-	228	-	228	-	228	-	228	-	257	-	257	-	257	-	257
				Annual TN Load (kg/yr)[h]	417				457				457				457				513				513			
	Leslieville	232[d]	93[d]	TN Concentration (mg/L)[e]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Daily TN Load (kg/d)[f]	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-
				Seasonal TN Load (kg/season)[g]	-	8.4	-	-	-	8.4	-	-	-	8.4	-	-	-	8.4	-	-	-	8.4	-	-	-	8.4	-	-
				Annual TN Load (kg/yr)[h]	8.4				8.4				8.4				8.4				8.4				8.4			
	Condor	132[d]	53[d]	TN Concentration (mg/L)[e]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Daily TN Load (kg/d)[f]	-	0.8	-	-	-	0.8	-	-	-	0.8	-	-	-	0.8	-	-	-	0.8	-	-	-	0.8	-	-
				Seasonal TN Load (kg/season)[g]	-	6.3	-	-	-	6.3	-	-	-	6.3	-	-	-	6.3	-	-	-	6.3	-	-	-	6.3	-	-
				Annual TN Load (kg/yr)[h]	6.3				6.3				6.3				6.3				6.3				6.3			
	Benalto	129[d]	52[d]	TN Concentration (mg/L)[e]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Daily TN Load (kg/d)[f]	-	0.77	-	-	-	0.77	-	-	-	0.77	-	-	-	0.77	-	-	-	0.77	-	-	-	0.77	-	-
				Seasonal TN Load (kg/season)[g]	-	16	-	-	-	16	-	-	-	16	-	-	-	16	-	-	-	16	-	-	-	16	-	-
				Annual TN Load (kg/yr)[h]	16				16				16				16				16				16			
	Kountry Meadows Estates	321[d]	128[d]	TN Concentration (mg/L)[e]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Daily TN Load (kg/d)[f]	-	1.9	-	-	-	1.9	-	-	-	1.9	-	-	-	1.9	-	-	-	1.9	-	-	-	1.9	-	-
				Seasonal TN Load (kg/season)[g]	-	40	-	-	-	40	-	-	-	40	-	-	-	40	-	-	-	40	-	-	-	40	-	-
				Annual TN Load (kg/yr)[h]	40				40				40				40				40				40			
	Spruce View	308[d]	123[d]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	1.1	-	-	-	1.1	-	-	-	1.1	-	-	-	1.1	-	-	-	1.1	-	-	-	1.1	-	-
				Seasonal TN Load (kg/season)[g]	-	24	-	-	-	24	-	-	-	24	-	-	-	24	-	-	-	24	-	-	-	24	-	-
				Annual TN Load (kg/yr)[h]	24				24				24				24				24				24			
	Innisfail	12,245[d]	4,898[d]	TN Concentration (mg/L)[e]	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20	-	20
				Daily TN Load (kg/d)[f]	-	98	-	98	-	98	-	98	-	98	-	98	-	98	-	98	-	98	-	98	-	98	-	98
				Seasonal TN Load (kg/season)[g]	-	3,478	-	3,478	-	3,478	-	3,478	-	3,478	-	3,478	-	3,478	-	3,478	-	3,478	-	3,478	-	3,478	-	3,478
				Annual TN Load (kg/yr)[h]	6,955				6,955				6,955				6,955				6,955				6,955			

Table B5: Total Nitrogen Concentrations and Loads at Direct Discharge Facilities in the Red Deer River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	Year/Season[c] 2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Medicine/Blindman Rivers (con't)	Sylvan Lake	7,008-13,015[i]	2,803-5,206[i]	TN Concentration (mg/L)[e]	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30	-	30
				Daily TN Load (kg/d)[f]	-	84	-	84	-	133	-	133	-	133	-	133	-	133	-	133	-	148	-	148	-	156	-	156
				Seasonal TN Load (kg/season)[g]	-	168	-	168	-	267	-	267	-	267	-	267	-	267	-	267	-	296	-	296	-	312	-	312
				Annual TN Load (kg/yr)[h]	336				534				534				534				592				625			
	Melody Meadows Mobile Home Park	102[d]	41[d]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	0.4	-	-	-	0.4	-	-	-	0.4	-	-	-	0.4	-	-	-	0.4	-	-	-	0.4	-	-
				Seasonal TN Load (kg/season)[g]	-	7.7	-	-	-	7.7	-	-	-	7.7	-	-	-	7.7	-	-	-	7.7	-	-	-	7.7	-	-
				Annual TN Load (kg/yr)[h]	7.7				7.7				7.7				7.7				7.7				7.7			
	Red Deer	106,705[d]	42,682[d]	TN Concentration (mg/L)[e]	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
				Daily TN Load (kg/d)[f]	854	854	854	854	683	746	719	669	641	737	854	631	627	811	825	712	677	758	776	718	700	792	786	742
				Seasonal TN Load (kg/season)[g]	77,681	77,681	78,535	78,535	61,434	67,927	66,145	61,522	57,687	67,110	78,600	58,017	56,391	73,844	75,855	65,517	61,583	69,004	71,373	66,097	63,041	72,044	72,297	68,304
				Annual TN Load (kg/yr)[h]	312,432				257,028				261,414				271,605				268,058				275,686			
	Rimbey	2,106-2,496[i]	842-998[i]	TN Concentration (mg/L)[e]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[f]	-	7.6	-	7.6	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0		8.6		8.56		8.6		8.6
				Seasonal TN Load (kg/season)[g]	-	136	-	167	-	162	-	198	-	162	-	198	-	162	-	198		154		188		154		188
				Annual TN Load (kg/yr)[h]	303				359				359				359				342				342			
	Bentley	1,800[d]	720[d]	TN Concentration (mg/L)[e]	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0
				Daily TN Load (kg/d)[f]	-	-	-	6.5	-	-	-	6.5	-	-	-	6.5	-	-	-	6.5	-	-	-	6.5	-	-	-	6.5
				Seasonal TN Load (kg/season)[g]	-	-	-	123	-	-	-	123	-	-	-	123	-	-	-	123	-	-	-	123	-	-	-	123
				Annual TN Load (kg/yr)[h]	123				123				123				123				123				123			
Red Deer River below Red Deer/Buffalo Lake	Bashaw	980[d]	392[d]	TN Concentration (mg/L)[e]	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0
				Daily TN Load (kg/d)[f]	-	-	-	3.5	-	-	-	3.5	-	-	-	3.5	-	-	-	3.5	-	-	-	3.5	-	-	-	3.5
				Seasonal TN Load (kg/season)[g]	-	-	-	11	-	-	-	11	-	-	-	11	-	-	-	11	-	-	-	11	-	-	-	11
				Annual TN Load (kg/yr)[h]	11				11				11				11				11				11			
	Big Valley	363[d]	145[d]	TN Concentration (mg/L)[e]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[f]	-	1.3	-	1.3	-	1.3	-	1.3	-	1.3	-	1.3	-	1.3	-	1.3	-	1.3	-	1.3	-	1.3	-	1.3
				Seasonal TN Load (kg/season)[g]	-	14	-	14	-	14	-	14	-	14	-	14	-	14	-	14	-	14	-	14	-	14	-	14
				Annual TN Load (kg/yr)[h]	27				27				27				27				27				27			
Threehills Creek/Kneehills Creek/Rosebud River	Three Hills	3,230-3,375[i]	1,292-1,350[i]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	12	-	-	-	12	-	-	-	12	-	-	-	12	-	-	-	12	-	-	-	12	-	-
				Seasonal TN Load (kg/season)[g]	-	255	-	-	-	251	-	-	-	251	-	-	-	251	-	-	-	244	-	-	-	244	-	-
				Annual TN Load (kg/yr)[h]	255				251				251				251				244				244			
	Elnora	388[d]	155[d]	TN Concentration (mg/L)[e]	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0
				Daily TN Load (kg/d)[f]	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4
				Seasonal TN Load (kg/season)[g]	-	-	-	29	-	-	-	29	-	-	-	29	-	-	-	29	-	-	-	29	-	-	-	29
				Annual TN Load (kg/yr)[h]	29				29				29				29				29				29			
	Huxley	90[d]	36[d]	TN Concentration (mg/L)[e]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Daily TN Load (kg/d)[f]	-	0.54	-	-	-	0.54	-	-	-	0.54	-	-	-	0.54	-	-	-	0.54	-	-	-	0.54	-	-
				Seasonal TN Load (kg/season)[g]	-	11	-	-	-	11	-	-	-	11	-	-	-	11	-	-	-	11	-	-	-	11	-	-
				Annual TN Load (kg/yr)[h]	11				11				11				11				11				11			
	Trochu	958-1,113[i]	383-445[i]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	3.4	-	-	-	4.0	-	-	-	4.0	-	-	-	4.0				3.9				3.9		
				Seasonal TN Load (kg/season)[g]	-	72	-	-	-	84	-	-	-	84	-	-	-	84				81				81		
				Annual TN Load (kg/yr)[h]	72				84				84				84				81				81			
	Wimbourne	48[d]	19[d]	TN Concentration (mg/L)[e]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Daily TN Load (kg/d)[f]	-	0.29	-	-	-	0.29	-	-	-	0.29	-	-	-	0.29	-	-	-	0.29	-	-	-	0.29	-	-
				Seasonal TN Load (kg/season)[g]	-	6.0	-	-	-	6.0	-	-	-	6.0	-	-	-	6.0	-	-	-	6.0	-	-	-	6.0	-	-
				Annual TN Load (kg/yr)[h]	6.0				6.0				6.0				6.0				6				6.0			

Table B5: Total Nitrogen Concentrations and Loads at Direct Discharge Facilities in the Red Deer River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	Year/Season[c]																							
					2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Threehills Creek/Kneehills Creek/Rosebud River (con't)	Torrington	217[d]	87[d]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	0.78	-	-	-	0.78	-	-	-	0.78	-	-	-	0.78	-	-	-	0.78	-	-	-	0.78	-	-
				Seasonal TN Load (kg/season)[g]	-	16	-	-	-	16	-	-	-	16	-	-	-	16	-	-	-	16	-	-	-	16	-	-
				Annual TN Load (kg/yr)[h]	16				16				16				16				16				16			
	Linden	630-741[i]	252-296[i]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	2.3	-	-	-	2.7	-	-	-	2.7	-	-	-	2.7	-	-	-	2.6	-	-	-	2.6	-	-
				Seasonal TN Load (kg/season)[g]	-	48	-	-	-	56	-	-	-	56	-	-	-	56	-	-	-	55	-	-	-	55	-	-
				Annual TN Load (kg/yr)[h]	48				56				56				56				55				55			
	Acme	653-730[i]	261-292[i]	TN Concentration (mg/L)[e]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[f]	-	2.4	-	2.4	-	2.4	-	2.4	-	2.6	-	2.6	-	2.6	-	2.6	-	2.4	-	2.4	-	2.4	-	2.4
				Seasonal TN Load (kg/season)[g]		8.3	-	8.3	-	8.3	-	8.3	-	9.2	-	9.2	-	9.2	-	9.2	-	8.2	-	8.2	-	8.2	-	8.2
				Annual TN Load (kg/yr)[h]	17				17				18				18				16				16			
	Swalwell	117[d]	47[d]	TN Concentration (mg/L)[e]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Daily TN Load (kg/d)[f]	-	0.70	-	-	-	0.70	-	-	-	0.70	-	-	-	0.70	-	-	-	0.70	-	-	-	0.70	-	-
				Seasonal TN Load (kg/season)[g]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Annual TN Load (kg/yr)[h]	15				15				15				15				15				15			
	Carbon	570[d]	228[d]	TN Concentration (mg/L)[e]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[f]		2		2.1		2		2.1		2		2.1		2		2.1		2		2.1		2		2.1
				Seasonal TN Load (kg/season)[g]		23		23		23		23		23		23		23		23		23		23		23		23
				Annual TN Load (kg/yr)[h]	45				45				45				45				45				45			
	Delia	214[d]	86[d]	TN Concentration (mg/L)[e]	-	15	-	15	-	15	-	15	-	15	-	15	-	15	-	15	-	15	-	15	-	15	-	15
				Daily TN Load (kg/d)[f]		1.3		1.3		1.3		1.3		1.3		1.3		1.3		1.3		1.3		1.3		1.3		1.3
				Seasonal TN Load (kg/season)[g]		13		13		13		13		13		13		13		13		13		13		13		13
				Annual TN Load (kg/yr)[h]	27				27				27				27				27				27			
	Michichi	56[d]	22[d]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	0.20	-	-	-	0.20	-	-	-	0.20	-	-	-	0.20	-	-	-	0.20	-	-	-	0.20	-	-
				Seasonal TN Load (kg/season)[g]	-	4.2	-	-	-	4.2	-	-	-	4.2	-	-	-	4.2	-	-	-	4.2	-	-	-	4.2	-	-
				Annual TN Load (kg/yr)[h]	4.2				4.2				4.2				4.2				4.2				4.2			
	Morrin	245-275[i]	98-110[i]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	1.0	-	-	-	0.91	-	-	-	0.91	-	-	-	0.91	-	-	-	0.88	-	-	-	0.88	-	-
				Seasonal TN Load (kg/season)[g]	-	21	-	-	-	19	-	-	-	19	-	-	-	19	-	-	-	19	-	-	-	19	-	-
				Annual TN Load (kg/yr)[h]	21				19				19				19				19				19			
	Drumheller	9,000[d]	3,600[d]	TN Concentration (mg/L)[e]	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
				Daily TN Load (kg/d)[f]	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72	72
				Seasonal TN Load (kg/season)[g]	6,552	6,552	6,624	6,624	6,480	6,552	6,624	6,624	6,480	6,552	6,624	6,624	6,480	6,552	6,624	6,624	6,552	6,552	6,624	6,624	6,480	6,552	6,624	6,624
				Annual TN Load (kg/yr)[h]	26,352				26,280				26,280				26,280				26,352				26,280			
	Didsbury	3,782-4,957[i]	1,513-1,983[i]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	14	-	-	-	14	-	-	-	14	-	-	-	14	-	-	-	14	-	-	-	14	-	-
				Seasonal TN Load (kg/season)[g]	-	381	-	-	-	381	-	-	-	381	-	-	-	381	-	-	-	381	-	-	-	381	-	-
				Annual TN Load (kg/yr)[h]	381				381				381				381				381				381			
	Carstairs	5,020[d]	2,008[d]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	18	-	-	-	18	-	-	-	18	-	-	-	18	-	-	-	18	-	-	-	18	-	-
				Seasonal TN Load (kg/season)[g]	-	380	-	-	-	380	-	-	-	380	-	-	-	380	-	-	-	380	-	-	-	380	-	-
				Annual TN Load (kg/yr)[h]	380				380				380				380				380				380			
	Irricana	1,016-1,243[i]	406-497[i]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	3.7	-	-	-	4.5	-	-	-	4.5	-	-	-	4.5	-	-	-	4.2	-	-	-	4.2	-	-
				Seasonal TN Load (kg/season)[g]	-	77	-	-	-	94	-	-	-	94	-	-	-	94	-	-	-	88	-	-	-	88	-	-
				Annual TN Load (kg/yr)[h]	77				94				94				94				88				88			

Table B5: Total Nitrogen Concentrations and Loads at Direct Discharge Facilities in the Red Deer River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Threehills Creek/Kneehills Creek/Rosebud River (con't)	Beiseker	785-837[i]	314-335[i]	TN Concentration (mg/L)[e]	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0
				Daily TN Load (kg/d)[f]	-	-	-	2.9	-	-	-	3.0	-	-	-	3.0	-	-	-	3.0	-	-	-	2.8	-	-	-	2.8
				Seasonal TN Load (kg/season)[g]	-	-	-	43	-	-	-	45	-	-	-	45	-	-	-	45	-	-	-	42	-	-	-	42
				Annual TN Load (kg/yr)[h]	43				45				45				45				42				42			
	Langdon	3,500[d]	1,400[d]	TN Concentration (mg/L)[e]	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
				Daily TN Load (kg/d)[f]	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
				Seasonal TN Load (kg/season)[g]	2,548	2,548	2,576	2,576	2,520	2,548	2,576	2,576	2,520	2,548	2,576	2,576	2,520	2,548	2,576	2,576	2,548	2,548	2,576	2,576	2,520	2,548	2,576	2,576
				Annual TN Load (kg/yr)[h]	10,248				10,220				10,220				10,220				10,248				10,220			
	Rockyford	361[d]	144[d]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	1.3	-	-	-	1.3	-	-	-	1.3	-	-	-	1.3	-	-	-	1.3	-	-	-	1.3	-	-
				Seasonal TN Load (kg/season)[g]	-	27	-	-	-	27	-	-	-	27	-	-	-	27	-	-	-	27	-	-	-	27	-	-
				Annual TN Load (kg/yr)[h]	27				27				27				27				27				27			
Middle Red Deer River/Bull Pound Creek	East Coulee	279[d]	112[d]	TN Concentration (mg/L)[e]	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
				Daily TN Load (kg/d)[f]	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
				Seasonal TN Load (kg/season)[g]	203	203	205	205	201	203	205	205	201	203	205	205	201	203	205	205	203	203	205	205	201	203	205	205
				Annual TN Load (kg/yr)[h]	817				815				815				815				817				815			
	Hanna	3,000[d]	1,200[d]	TN Concentration (mg/L)[e]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[f]	-	11	-	11	-	11	-	11	-	11	-	11	-	11	-	11	-	11	-	11	-	11	-	11
				Seasonal TN Load (kg/season)[g]	-	113	-	113	-	113	-	113	-	113	-	113	-	113	-	113	-	113	-	113	-	113	-	113
				Annual TN Load (kg/yr)[h]	227				227				227				227				227				227			
Middle Red Deer River/Matzhiwin Creek	Bassano	1,390[d]	556[d]	TN Concentration (mg/L)[e]	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
				Daily TN Load (kg/d)[f]	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
				Seasonal TN Load (kg/season)[g]	759	759	767	767	751	759	767	767	751	759	767	767	751	759	767	767	759	759	767	767	751	759	767	767
				Annual TN Load (kg/yr)[h]	3,052				3,044				3,044				3,044				3,052				3,044			
	Rosemary	485[d]	194[d]	TN Concentration (mg/L)[e]	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-	-	9.0	-	-
				Daily TN Load (kg/d)[f]	-	1.7	-	-	-	1.7	-	-	-	1.7	-	-	-	1.7	-	-	-	1.7	-	-	-	1.7	-	-
				Seasonal TN Load (kg/season)[g]	-	7.0	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0	-	-
				Annual TN Load (kg/yr)[h]	7.0				7.0				7.0				7.0				7.0				7.0			
	Brooks	15,982[d]	6,396[d]	TN Concentration (mg/L)[e]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[f]	-	58	-	58	-	58	-	58	-	58	-	58	-	58	-	58	-	58	-	58	-	58	-	58
				Seasonal TN Load (kg/season)[g]	-	1,007	-	1,007	-	1,007	-	1,007	-	1,007	-	1,007	-	1,007	-	1,007	-	1,007	-	1,007	-	1,007	-	1,007
				Annual TN Load (kg/yr)[h]	2,014				2,014				2,014				2,014				2,014				2,014			
	Patricia	164[d]	66[d]	TN Concentration (mg/L)[e]	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-	-	15	-	-
				Daily TN Load (kg/d)[f]	-	1.0	-	-	-	1.0	-	-	-	1.0	-	-	-	1.0	-	-	-	1.0	-	-	-	1.0	-	-
				Seasonal TN Load (kg/season)[g]	-	22	-	-	-	22	-	-	-	22	-	-	-	22	-	-	-	22	-	-	-	22	-	-
				Annual TN Load (kg/yr)[h]	22				22				22				22				22				22			
	Dinosaur Provincial Park	350[d]	140[d]	TN Concentration (mg/L)[e]	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
				Daily TN Load (kg/d)[f]	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
				Seasonal TN Load (kg/season)[g]	255	255	258	258	252	255	258	258	252	255	258	258	252	255	258	258	255	255	258	258	252	255	258	258
				Annual TN Load (kg/yr)[h]	1,025				1,022				1,022				1,022				1,025				1,022			

Year/Season[c]

(a) Sub-basins are listed in order from upstream to downstream along the length of the Red Deer River main stem; communities are also listed in order from upstream to downstream, based on their position along tributaries to the Red Deer River main stem, or the main stem itself.

(b) Represents the estimated average volume of wastewater effluent released per day when the point source facility is discharging to the environment. Unless site-specific data were available, the ADF was calculated from the estimated service population size for the facility and a per capita flow of 0.4 m^3/person/day (AECOM 2009).

(c) Seasons include winter (January-March), freshet (April-June), summer (July-September), and fall (October-December).

(d) Based on the reported 2007 service population (AEP 2011, with updates).

(e) Average estimated TN concentration. Measured TN concentration data (mg/L) were not available for the facilities listed in the table; concentrations were set based on the approach described by AECOM (2009). For lagoon stabilization ponds that conform to design standards, the TN concentration was set at 9 mg/L to align the approach described by AECOM (2009) with measured concentration data that were available for facilities in the Carrot River watershed for the years 2000 and 2009 through 2013.

(f) Represents the estimated average amount of TN (kg) released per day, when the point source facility is discharging to the environment.

(g) Represents the estimated total amount of TN (kg) released per season. Some facilities discharge wastewater effluent seasonally (e.g., freshet and fall only); therefore seasonal loads may be zero (i.e., 0 kg/season) during some seasons (e.g., winter).

(h) Represents the sum total of TN (kg) released during winter, freshet, summer, and fall.

(i) Based on the census population data reported for 2000 and 2009 through 2013 (Alberta Municipal Affairs 2017).

ADF = average daily flow; m^3/d = cubic metres per day; TN = total nitrogen; - = not applicable; mg/L = milligrams per litre; kg/d = kilograms per day; kg/season = kilograms per season; kg/yr = kilograms per year.

Table B6: Total Phosphorus Concentrations and Loads at Direct Discharge Facilities in the Red Deer River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	Year/Season[c]																							
					2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Upper Red Deer River	Sundre	3,928[d]	1,571[d]	TP Concentration (mg/L)[e]	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
				Daily TP Load (kg/d)[f]	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
				Seasonal TP Load (kg/season)[g]	529	529	535	535	523	529	535	535	523	529	535	535	523	529	535	535	529	529	535	535	523	529	535	535
				Annual TP Load (kg/yr)[h]	2,128				2,122				2,122				2,122				2,128				2,122			
Raven River	Caroline	472-515[i]	189-206[i]	TP Concentration (mg/L)[e]	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
				Daily TP Load (kg/d)[f]	0.70	0.70	0.70	0.70	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
				Seasonal TP Load (kg/season)[g]	64	64	64	64	69	69	70	70	69	69	70	70	69	69	70	70	67	67	68	68	67	67	68	68
				Annual TP Load (kg/yr)[h]	256				278				278				278				271				271			
Little Red Deer River	Cremona	380-463[i]	152-185[i]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.38	-	-	-	0.46	-	-	-	0.46	-	-	-	0.46	-	-	-	0.46	-	-	-	0.46	-	-
				Seasonal TP Load (kg/season)[g]	-	8.0	-	-	-	9.7	-	-	-	9.7	-	-	-	9.7	-	-	-	9.6	-	-	-	9.6	-	-
				Annual TP Load (kg/yr)[h]	8.0				9.7				9.7				9.7				9.6				9.6			
	Olds	6,230-8,511[i]	2,492-3,404[i]	TP Concentration (mg/L)[e]	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35
				Daily TP Load (kg/d)[f]	-	0.87	-	0.87	-	1.0	-	1.0	-	1.0	-	1.0	-	1.0	-	1.0	-	1.2	-	1.2	-	1.2	-	1.2
				Seasonal TP Load (kg/season)[g]	-	15	-	15	-	18	-	18	-	18	-	18	-	18	-	18	-	20	-	20	-	21	-	21
				Annual TP Load (kg/yr)[h]	30.5				35.5				35.5				35.5				40				41.7			
	Bowden	1,014-1,241[i]	406-496[i]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	1.0	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-
				Seasonal TP Load (kg/season)[g]	-	28	-	-	-	35	-	-	-	35	-	-	-	35	-	-	-	35	-	-	-	35	-	-
				Annual TP Load (kg/yr)[h]	28				35				35				35				35				35			
Medicine/Blindman Rivers	Eckville	914-1,125[i]	366-450[i]	TP Concentration (mg/L)[e]	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7
				Daily TP Load (kg/d)[f]	-	1.4	-	1.4	-	1.5	-	1.5	-	1.5	-	1.5	-	1.5	-	1.5	-	1.7	-	1.7	-	1.7	-	1.7
				Seasonal TP Load (kg/season)[g]	-	26	-	26	-	28	-	28	-	28	-	28	-	28	-	28	-	32	-	32	-	32	-	32
				Annual TP Load (kg/yr)[h]	51				56				56				56				63				63			
	Leslieville	232[d]	93[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.23	-	-	-	0.23	-	-	-	0.23	-	-	-	0.23	-	-	-	0.23	-	-	-	0.23	-	-
				Seasonal TP Load (kg/season)[g]	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-	-	1.4	-	-
				Annual TP Load (kg/yr)[h]	1.4				1.4				1.4				1.4				1.4				1.4			
	Condor	132[d]	53[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.13	-	-	-	0.13	-	-	-	0.13	-	-	-	0.13	-	-	-	0.13	-	-	-	0.13	-	-
				Seasonal TP Load (kg/season)[g]	-	1.1	-	-	-	1.1	-	-	-	1.1	-	-	-	1.1	-	-	-	1.1	-	-	-	1.1	-	-
				Annual TP Load (kg/yr)[h]	1.1				1.1				1.1				1.1				1.1				1.1			
	Benalto	129[d]	52[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.13	-	-	-	0.13	-	-	-	0.13	-	-	-	0.13	-	-	-	0.13	-	-	-	0.13	-	-
				Seasonal TP Load (kg/season)[g]	-	2.7	-	-	-	2.7	-	-	-	2.7	-	-	-	2.7	-	-	-	2.7	-	-	-	2.7	-	-
				Annual TP Load (kg/yr)[h]	2.7				2.7				2.7				2.7				2.7				2.7			
	Kountry Meadows Estates	321[d]	128[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.32	-	-	-	0.32	-	-	-	0.32	-	-	-	0.32	-	-	-	0.32	-	-	-	0.32	-	-
				Seasonal TP Load (kg/season)[g]	-	6.7	-	-	-	6.7	-	-	-	6.7	-	-	-	6.7	-	-	-	6.7	-	-	-	6.7	-	-
				Annual TP Load (kg/yr)[h]	6.7				6.7				6.7				6.7				6.7				6.7			
	Spruce View	308[d]	123[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.31	-	-	-	0.31	-	-	-	0.31	-	-	-	0.31	-	-	-	0.31	-	-	-	0.31	-	-
				Seasonal TP Load (kg/season)[g]	-	6.8	-	-	-	6.8	-	-	-	6.8	-	-	-	6.8	-	-	-	6.8	-	-	-	6.8	-	-
				Annual TP Load (kg/yr)[h]	6.8				6.8				6.8				6.8				6.8				6.8			
	Innisfail	12,245[d]	4,898[d]	TP Concentration (mg/L)[e]	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35	-	0.35
				Daily TP Load (kg/d)[f]	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7	-	1.7
				Seasonal TP Load (kg/season)[g]	-	61	-	61	-	61	-	61	-	61	-	61	-	61	-	61	-	61	-	61	-	61	-	61
				Annual TP Load (kg/yr)[h]	122				122				122				122				122				122			

Table B6: Total Phosphorus Concentrations and Loads at Direct Discharge Facilities in the Red Deer River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m³/d)[b]	Parameter	Year/Season[c]																							
					2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Medicine/Blindman Rivers (con't)	Sylvan Lake	7,008-13,015[i]	2,803-5,206[i]	TP Concentration (mg/L)[e]	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7	-	3.7
				Daily TP Load (kg/d)[f]	-	10	-	10	-	16	-	16	-	16	-	16	-	16	-	16	-	18	-	18	-	19	-	19
				Seasonal TP Load (kg/season)[g]	-	21	-	21	-		-		-		-		-		-		-		-		-		-	
				Annual TP Load (kg/yr)[h]	41				0.0				0.0				0.0				0.0				0.0			
	Melody Meadows Mobile Home Park	102[d]	41[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.10	-	-	-	0.10	-	-	-	0.10	-	-	-	0.10	-	-	-	0.10	-	-	-	0.10	-	-
				Seasonal TP Load (kg/season)[g]	-	2.1	-	-	-	2.1	-	-	-	2.1	-	-	-	2.1	-	-	-	2.1	-	-	-	2.1	-	-
				Annual TP Load (kg/yr)[h]	2.1				2.1				2.1				2.1				2.1				2.1			
	Red Deer	106,705[d]	42,682[d]	TP Concentration (mg/L)[e]	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
				Daily TP Load (kg/d)[f]	15	15	15	15	12	13	13	12	11	13	15	11	11	14	14	12	12	13	14	13	12	14	14	13
				Seasonal TP Load (kg/season)[g]	1,359	1,359	1,374	1,374	1,149	1,596	1,973	2,304	1,238	1,436	2,659	1,775	951	2,700	2,257	781	709	895	1,004	1,310	961	1,851	1,592	1,575
				Annual TP Load (kg/yr)[h]	5,468				7,023				7,107				6,689				3,917				5,979			
	Rimbey	2,106-2,496[i]	842-998[i]	TP Concentration (mg/L)[e]	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[f]	-	2.1	-	2.1	-	2.5	-	2.50	-	2.5	-	2.5	-	2.5	-	2.5	-	2.4	-	2.4	-	2.4	-	2.4
				Seasonal TP Load (kg/season)[g]	-	38	-	38	-	45	-	55	-	45	-	55	-	45	-	55	-	43	-	52	-	43	-	52
				Annual TP Load (kg/yr)[h]	76				100				100				100				95.1				95.1			
	Bentley	1,800[d]	720[d]	TP Concentration (mg/L)[e]	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5
				Daily TP Load (kg/d)[f]	-	-	-	1.8	-	-	-	1.8	-	-	-	1.8	-	-	-	1.8	-	-	-	1.8	-	-	-	1.8
				Seasonal TP Load (kg/season)[g]	-	-	-	34	-	-	-	34	-	-	-	34	-	-	-	34	-	-	-	34	-	-	-	34
				Annual TP Load (kg/yr)[h]	34				34				34				34				34				34			
Red Deer River below Red Deer/Buffalo Lake	Bashaw	980[d]	392[d]	TP Concentration (mg/L)[e]	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5
				Daily TP Load (kg/d)[f]	-	-	-	0.98	-	-	-	0.98	-	-	-	0.98	-	-	-	0.98	-	-	-	0.98	-	-	-	0.98
				Seasonal TP Load (kg/season)[g]	-	-	-	2.9	-	-	-	2.9	-	-	-	2.9	-	-	-	2.9	-	-	-	2.9	-	-	-	2.9
				Annual TP Load (kg/yr)[h]	2.9				2.9				2.9				2.9				2.9				2.9			
	Big Valley	363[d]	145[d]	TP Concentration (mg/L)[e]	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[f]	-	11	-	12	-	13	-	14	-	15	-	16	-	17	-	18	-	19	-	19	-	20	-	21
				Seasonal TP Load (kg/season)[g]	-	118	-	128	-	137	-	147	-	156	-	166	-	175	-	185	-	194	-	204	-	213	-	223
				Annual TP Load (kg/yr)[h]	246				284				322				360				398				436			
Threehills Creek/ Kneehills Creek/Rosebud River	Three Hills	3,230-3,375[i]	1,292-1,350[i]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	3.4	-	-	-	3.3	-	-	-	3.3	-	-	-	3.3	-	-	-	3.2	-	-	-	3.2	-	-
				Seasonal TP Load (kg/season)[g]	-	71	-	-	-	70	-	-	-	70	-	-	-	70	-	-	-	68	-	-	-	68	-	-
				Annual TP Load (kg/yr)[h]	71				70				70				70				68				68			
	Elnora	388[d]	155[d]	TP Concentration (mg/L)[e]	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5
				Daily TP Load (kg/d)[f]	-	-	-	0.39	-	-	-	0.39	-	-	-	0.39	-	-	-	0.39	-	-	-	0.39	-	-	-	0.39
				Seasonal TP Load (kg/season)[g]	-	-	-	8.1	-	-	-	8.1	-	-	-	8.1	-	-	-	8.1	-	-	-	8.1	-	-	-	8.1
				Annual TP Load (kg/yr)[h]	8.1				8.1				8.1				8.1				8.1				8.1			
	Huxley	90[d]	36[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.40	-	-	-	0.40	-	-	-	0.40	-	-	-	0.40	-	-	-	0.40	-	-	-	0.40	-	-
				Seasonal TP Load (kg/season)[g]	-	36	-	-	-	36	-	-	-	36	-	-	-	36	-	-	-	36	-	-	-	36	-	-
				Annual TP Load (kg/yr)[h]	36				36				36				36				36				36			
	Trochu	958-1,113[i]	383-445[i]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]		1.0				1.1				1.1				1.1				1.1				1.1		
				Seasonal TP Load (kg/season)[g]		20				23				23				23				23				23		
				Annual TP Load (kg/yr)[h]	20				23				23				23				23				23			
	Wimbourne	48[d]	19[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.05	-	-	-	0.05	-	-	-	0.05	-	-	-	0.05	-	-	-	0.05	-	-	-	0.05	-	-
				Seasonal TP Load (kg/season)[g]	-	1.0	-	-	-	1.0	-	-	-	1.0	-	-	-	1.0	-	-	-	1.0	-	-	-	1.0	-	-
				Annual TP Load (kg/yr)[h]	1.0				1.0				1.0				1.0				1				1.0			

Table B6: Total Phosphorus Concentrations and Loads at Direct Discharge Facilities in the Red Deer River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	Year/Season[c]																							
					2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Threehills Creek/ Kneehills Creek/Rosebud River (con't)	Torrington	217[d]	87[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.22	-	-	-	0.22	-	-	-	0.22	-	-	-	0.22	-	-	-	0.22	-	-	-	0.22	-	-
				Seasonal TP Load (kg/season)[g]	-	4.6	-	-	-	4.6	-	-	-	4.6	-	-	-	4.6	-	-	-	4.6	-	-	-	4.6	-	-
				Annual TP Load (kg/yr)[h]	4.6				4.6				4.6				4.6				4.6				4.6			
	Linden	630-741[i]	252-296[i]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.63	-	-	-	0.74	-	-	-	0.74	-	-	-	0.74	-	-	-	0.73	-	-	-	0.73	-	-
				Seasonal TP Load (kg/season)[g]	-	13	-	-	-	16	-	-	-	16	-	-	-	16	-	-	-	15	-	-	-	15	-	-
				Annual TP Load (kg/yr)[h]	13				16				16				16				15				15			
	Acme	653-730[i]	261-292[i]	TP Concentration (mg/L)[e]	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[f]	-	0.66	-	0.66	-	0.66	-	0.66	-	0.73	-	0.73	-	0.73	-	0.73	-	0.65	-	0.65	-	0.65	-	0.65
				Seasonal TP Load (kg/season)[g]	-	2.3	-	2.3	-	2.3	-	2.3	-	2.6	-	2.6	-	2.6	-	2.6	-	2.3	-	2.3	-	2.3	-	2.3
				Annual TP Load (kg/yr)[h]	4.6				4.6				5.1				5.1				4.6				4.6			
	Swalwell	117[d]	47[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.12	-	-	-	0.12	-	-	-	0.12	-	-	-	0.12	-	-	-	0.12	-	-	-	0.12	-	-
				Seasonal TP Load (kg/season)[g]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Annual TP Load (kg/yr)[h]	2.5				2.5				2.5				2.5				2.5				2.5			
	Carbon	570[d]	228[d]	TP Concentration (mg/L)[e]	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[f]	-	0.57	-	0.57	-	0.57	-	0.57	-	0.57	-	0.57	-	0.57	-	0.57	-	0.57	-	0.57	-	0.57	-	0.57
				Seasonal TP Load (kg/season)[g]	-	6.3	-	6.3	-	6.3	-	6.3	-	6.3	-	6.3	-	6.3	-	6.3	-	6.3	-	6.3	-	6.3	-	6.3
				Annual TP Load (kg/yr)[h]	13				13				13				13				13				13			
	Delia	214[d]	86[d]	TP Concentration (mg/L)[e]	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[f]	-	0.21	-	0.21	-	0.21	-	0.21	-	0.21	-	0.21	-	0.21	-	0.21	-	0.21	-	0.21	-	0.21	-	0.21
				Seasonal TP Load (kg/season)[g]	-	2.2	-	2.2	-	2.2	-	2.2	-	2.2	-	2.2	-	2.2	-	2.2	-	2.2	-	2.2	-	2.2	-	2.2
				Annual TP Load (kg/yr)[h]	4.5				4.5				4.5				4.5				4.5				4.5			
	Michichi	56[d]	22[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.06	-	-	-	0.06	-	-	-	0.06	-	-	-	0.06	-	-	-	0.06	-	-	-	0.06	-	-
				Seasonal TP Load (kg/season)[g]	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-
				Annual TP Load (kg/yr)[h]	1.2				1.2				1.2				1.2				1.2				1.2			
	Morrin	245-275[i]	98-110[i]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.28	-	-	-	0.25	-	-	-	0.25	-	-	-	0.25	-	-	-	0.25	-	-	-	0.25	-	-
				Seasonal TP Load (kg/season)[g]	-	5.8	-	-	-	5.3	-	-	-	5.3	-	-	-	5.3	-	-	-	5.1	-	-	-	5.1	-	-
				Annual TP Load (kg/yr)[h]	5.8				5.3				5.3				5.3				5.1				5.1			
	Drumheller	9,000[d]	3,600[d]	TP Concentration (mg/L)[e]	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
				Daily TP Load (kg/d)[f]	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
				Seasonal TP Load (kg/season)[g]	115	115	116	116	113	115	116	116	113	115	116	116	113	115	116	116	115	115	116	116	113	115	116	116
				Annual TP Load (kg/yr)[h]	461				460				460				460				461				460			
	Didsbury	3,782-4,957[i]	1,513-1,983[i]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	3.8	-	-	-	4.6	-	-	-	4.6	-	-	-	4.6	-	-	-	5.0	-	-	-	5.0	-	-
				Seasonal TP Load (kg/season)[g]	-	106	-	-	-	129	-	-	-	129	-	-	-	129	-	-	-	139	-	-	-	139	-	-
				Annual TP Load (kg/yr)[h]	106				129				129				129				139				139			
	Carstairs	5,020[d]	2,008[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	5.0	-	-	-	5.0	-	-	-	5.0	-	-	-	5.0	-	-	-	5.0	-	-	-	5.0	-	-
				Seasonal TP Load (kg/season)[g]	-	105	-	-	-	105	-	-	-	105	-	-	-	105	-	-	-	105	-	-	-	105	-	-
				Annual TP Load (kg/yr)[h]	105				105				105				105				105				105			
	Irricana	1,016-1,243[i]	406-497[i]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	1.0	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-	-	1.2	-	-
				Seasonal TP Load (kg/season)[g]	-	21	-	-	-	26	-	-	-	26	-	-	-	26	-	-	-	24	-	-	-	24	-	-
				Annual TP Load (kg/yr)[h]	21				26				26				26				24				24			

Table B6: Total Phosphorus Concentrations and Loads at Direct Discharge Facilities in the Red Deer River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	Year/Season[c]																							
					2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Threehills Creek/ Kneehills Creek/Rosebud River (con't)	Beiseker	785-837[i]	314-335[i]	TP Concentration (mg/L)[e]	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5
				Daily TP Load (kg/d)[f]	-	-	-	0.80	-	-	-	0.84	-	-	-	0.84	-	-	-	0.84	-	-	-	0.79	-	-	-	0.79
				Seasonal TP Load (kg/season)[g]	-	-	-	12	-	-	-	13	-	-	-	13	-	-	-	13	-	-	-	12	-	-	-	12
				Annual TP Load (kg/yr)[h]	12				13				13				13				12				11.8			
	Langdon	3,500[d]	1,400[d]	TP Concentration (mg/L)[e]	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
				Daily TP Load (kg/d)[f]	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
				Seasonal TP Load (kg/season)[g]	45	45	45	45	44	45	45	45	44	45	45	45	44	45	45	45	45	45	45	45	44	45	45	45
				Annual TP Load (kg/yr)[h]	179				179				179				179				179				179			
	Rockyford	361[d]	144[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.36	-	-	-	0.36	-	-	-	0.36	-	-	-	0.36	-	-	-	0.36	-	-	-	0.36	-	-
				Seasonal TP Load (kg/season)[g]	-	7.6	-	-	-	7.6	-	-	-	7.6	-	-	-	7.6	-	-	-	7.6	-	-	-	7.6	-	-
				Annual TP Load (kg/yr)[h]	7.6				7.6				7.6				7.6				7.6				7.6			
Middle Red Deer River/Bull Pound Creek	East Coulee	279[d]	112[d]	TP Concentration (mg/L)[e]	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
				Daily TP Load (kg/d)[f]	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
				Seasonal TP Load (kg/season)[g]	3.6	3.6	3.6	3.6	3.5	3.6	3.6	3.6	3.5	3.6	3.6	3.6	3.5	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.5	3.6	3.6	3.6
				Annual TP Load (kg/yr)[h]	14				14				14				14				14				14			
	Hanna	3,000[d]	1,200[d]	TP Concentration (mg/L)[e]	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[f]	-	3.0	-	3.0	-	3.0	-	3.0	-	3.0	-	3.0	-	3.0	-	3.0	-	3.0	-	3.0	-	3.0	-	3.0
				Seasonal TP Load (kg/season)[g]	-	32	-	32	-	32	-	32	-	32	-	32	-	32	-	32	-	32	-	32	-	32	-	32
				Annual TP Load (kg/yr)[h]	63				63				63				63				63				63			
Middle Red Deer River/ Matzhiwin Creek	Bassano	1,390[d]	556[d]	TP Concentration (mg/L)[e]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
				Daily TP Load (kg/d)[f]	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
				Seasonal TP Load (kg/season)[g]	126	126	128	128	125	126	128	128	125	126	128	128	125	126	128	128	126	126	128	128	125	126	128	128
				Annual TP Load (kg/yr)[h]	509				507				507				507				509				507			
	Rosemary	485[d]	194[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.49	-	-	-	0.49	-	-	-	0.49	-	-	-	0.49	-	-	-	0.49	-	-	-	0.49	-	-
				Seasonal TP Load (kg/season)[g]	-	1.9	-	-	-	1.9	-	-	-	1.9	-	-	-	1.9	-	-	-	1.9	-	-	-	1.9	-	-
				Annual TP Load (kg/yr)[h]	1.9				1.9				1.9				1.9				1.9				1.9			
	Brooks	15,982[d]	6,396[d]	TP Concentration (mg/L)[e]	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[f]	-	16	-	16	-	16	-	16	-	16	-	16	-	16	-	16	-	16	-	16	-	16	-	16
				Seasonal TP Load (kg/season)[g]	-	280	-	280	-	280	-	280	-	280	-	280	-	280	-	280	-	280	-	280	-	280	-	280
				Annual TP Load (kg/yr)[h]	559				559				559				559				559				559			
	Patricia	164[d]	66[d]	TP Concentration (mg/L)[e]	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-	-	2.5	-	-
				Daily TP Load (kg/d)[f]	-	0.16	-	-	-	0.16	-	-	-	0.16	-	-	-	0.16	-	-	-	0.16	-	-	-	0.16	-	-
				Seasonal TP Load (kg/season)[g]	-	3.6	-	-	-	3.6	-	-	-	3.6	-	-	-	3.6	-	-	-	3.6	-	-	-	3.6	-	-
				Annual TP Load (kg/yr)[h]	3.6				3.6				3.6				3.6				3.6				3.6			
	Dinosaur Provincial Park	350[d]	140[d]	TP Concentration (mg/L)[e]	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
				Daily TP Load (kg/d)[f]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
				Seasonal TP Load (kg/season)[g]	4.5	4.5	4.5	4.5	4.4	4.5	4.5	4.5	4.4	4.5	4.5	4.5	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.4	4.5	4.5	4.5
				Annual TP Load (kg/yr)[h]	18				18				18				18				18				18			

(a) Sub-basins are listed in order from upstream to downstream along the length of the Red Deer River main stem; communities are also listed in order from upstream to downstream, based on their position along tributaries to the Red Deer River main stem, or the main stem itself.
(b) Represents the estimated average volume of wastewater effluent released per day when the point source facility is discharging to the environment. Unless site-specific data were available, the ADF was calculated from the estimated service population size for the facility and a per capita flow of 0.4 m^3/person/day (AECOM 2009).
(c) Seasons include winter (January-March), freshet (April-June), summer (July-September), and fall (October-December).
(d) Based on the reported 2007 service population (AEP 2011, with updates).
(e) Average estimated TP concentration. Measured TP concentration data (mg/L) were not available for the facilities listed in the table, with the exception of the City of Red Deer (2009-2013 only); concentrations were set based on the approach described by AECOM (2009). For mechanical WWTPs, the TP concentration was set at 0.35 mg/L to align the approach described by AECOM (2009) with measured concentration data that were available for the City of Red Deer for the years 2000 and 2009 through 2013.
(f) Represents the estimated average amount of TP (kg) released per day, when the point source facility is discharging to the environment.
(g) Represents the estimated total amount of TP (kg) released per season. Some facilities discharge wastewater effluent seasonally (e.g., freshet and fall only); therefore seasonal loads may be zero (i.e., 0 kg/season) during some seasons (e.g., winter).
(h) Represents the sum total of TP (kg) released during winter, freshet, summer, and fall.
(i) Based on the census population data reported for 2000 and 2009 through 2013 (Alberta Municipal Affairs 2017).
ADF = average daily flow; m^3/d = cubic metres per day; TP = total phosphorus; - = not applicable; mg/L = milligrams per litre; kg/d = kilograms per day; kg/season = kilograms per season; kg/yr = kilograms per year.

Table B7: Total Nitrogen Concentrations and Loads at Direct Discharge Facilities in the Carrot River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	Year/Season[c]																							
					2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Carrot River West	Kinistino	743	297	TN Concentration (mg/L)[d]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	20.0	-	3.4	-	6.0	9.8	10.0
				Daily TN Load (kg/d)[e]	-	2.7	-	2.7	-	2.7	-	2.7	-	2.7	-	2.7	-	2.7	-	2.7	-	5.9	-	1.0	-	1.8	2.9	3.0
				Seasonal TN Load (kg/season)[f]	-	2.7	-	2.7	-	2.7	-	2.7	-	2.7	-	2.7	-	2.7	-	2.7	-	11.9	-	1.0	-	1.8	2.9	3.0
				Annual TN Load (kg/yr)[g]	5.3				5.3				5.3				5.3				12.9				7.7			
	Melfort	6500	2600	TN Concentration (mg/L)[d]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	1.5	-	19.0	-	2.3	-	15.2	-	3.9	-	6.7	-	1.7
				Daily TN Load (kg/d)[e]	-	23	-	23	-	23	-	23	-	23	-	4	-	49	-	6.0	-	40	-	10	-	17	-	4.4
				Seasonal TN Load (kg/season)[f]	-	47	-	47	-	47	-	47	-	47	-	7.5	-	99	-	12	-	79	-	20	-	17	-	8.8
				Annual TN Load (kg/yr)[g]	94				94				54				111				99				26			
	Star City	460	184	TN Concentration (mg/L)[d]	-	9.0	-	9.0	-	18.0	-	3.1	-	9.6	-	1.2	-	14.0	-	4.1	-	23.0	-	2.5	-	15.0	-	1.5
				Daily TN Load (kg/d)[e]	-	1.7	-	1.7	-	3.3	-	0.6	-	1.8	-	0.2	-	2.6	-	0.8	-	4.2	-	0.5	-	2.8	-	0.3
				Seasonal TN Load (kg/season)[f]	-	1.7	-	1.7	-	3.3	-	0.6	-	3.5	-	0.2	-	2.6	-	0.8	-	4.2	-	0.5	-	2.8	-	0.3
				Annual TN Load (kg/yr)[g]	3.3				3.9				3.8				3.3				4.7				3.0			
Carrot River East	Arborfield	326	130	TN Concentration (mg/L)[d]	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[e]	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2
				Seasonal TN Load (kg/season)[f]	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2	-	1.2
				Annual TN Load (kg/yr)[g]	2.3				2.3				2.3				2.3				2.3				2.3			
	Carrot River	1000	400	TN Concentration (mg/L)[d]	9.0	-	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[e]	3.6	-	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6
				Seasonal TN Load (kg/season)[f]	3.6	-	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6	-	3.6
				Annual TN Load (kg/yr)[g]	7.2				7.2				7.2				7.2				7.2				7.2			
	Tisdale	3180	1272	TN Concentration (mg/L)[d]	9.0	-	-	9.0	-	9.0	-	10.0	-	13.0	-	6.0	-	8.8	-	11.0	-	13.0	-	8.1	-	38.0	-	-
				Daily TN Load (kg/d)[e]	11	-	-	11	-	11	-	13	-	17	-	7.6	-	11	-	14	-	17	-	10	-	48	-	-
				Seasonal TN Load (kg/season)[f]	11	-	-	11	-	11	-	13	-	33	-	7.6	-	11	-	14	-	17	-	10	-	48	-	-
				Annual TN Load (kg/yr)[g]	23				24				41				25				27				48			
	Zenon Park	187	74.8	TN Concentration (mg/L)[d]	-	9.0	-	9.0	-	9.0	-	1.9	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0	-	9.0
				Daily TN Load (kg/d)[e]	-	0.7	-	0.7	-	0.7	-	0.1	-	0.7	-	0.7	-	0.7	-	0.7	-	0.7	-	0.7	-	0.7	-	0.7
				Seasonal TN Load (kg/season)[f]	-	0.7	-	0.7	-	0.7	-	0.1	-	0.7	-	0.7	-	0.7	-	0.7	-	0.7	-	0.7	-	0.7	-	0.7
				Annual TN Load (kg/yr)[g]	1.3				0.8				1.3				1.3				1.3				1.3			

(a) Sub-basins are listed in order from upstream to downstream along the length of the Carrot River main stem; communities are also listed in order from upstream to downstream, based on their position along tributaries to the Carrot River main stem, or the main stem itself.

(b) Represents the estimated average volume of wastewater effluent released per day when the point source facility is discharging to the environment. It is calculated from the estimated service population size for the facility and a per capita flow of 0.4 m^3/person/day (AECOM 2009).

(c) Seasons include winter (January-March), freshet (April-June), summer (July-September), and fall (October-December).

(d) Average measured or estimated TN concentration. TN concentration data (mg/L) were not available for some facilities listed in the table; concentrations were set at 9 mg/L to align the approach described by AECOM (2009) for wastewater lagoons with the measured concentration data that were available for the years 2000 and 2009 through 2013.

(e) Represents the estimated average amount of TN (kg) released per day, when the point source facility is discharging to the environment.

(f) Represents the estimated total amount of TN (kg) released per season. Some facilities discharge wastewater effluent seasonally (e.g., freshet and fall only); therefore seasonal loads may be zero (i.e., 0 kg/season) during some seasons (e.g., winter).

(g) Represents the sum total of TN (kg) released during winter, freshet, summer and fall.

ADF = average daily flow; m^3/d = cubic metres per day; TN = total nitrogen; - = not applicable; mg/L = milligrams per litre; kg/d = kilograms per day; kg/season = kilograms per season; kg/yr = kilograms per year.

Table B8: Total Phosphorus Concentrations and Loads at Direct Discharge Facilities in the Carrot River Watershed, 2000 and 2009-2013

Receiving Sub-basin[a]	Community[a]	Service Population Size	ADF (m^3/d)[b]	Parameter	Year/Season[c]																							
					2000				2009				2010				2011				2012				2013			
					Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall	Winter	Freshet	Summer	Fall
Carrot River West	Kinistino	743	297	TP Concentration (mg/L)[d]	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	3.9	-	1.4	-	1.2	3.2	0.82
				Daily TP Load (kg/d)[e]	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	1.1	-	0.42	-	0.36	1.0	0.24
				Seasonal TP Load (kg/season)[f]	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	0.74	-	2.3	-	0.42	-	0.36	0.95	0.24
				Annual TP Load (kg/yr)[g]	1.5				1.5				1.5				1.5				2.7				1.6			
	Melfort	6500	2600	TP Concentration (mg/L)[d]	-	3.9	-	1.765	-	2.5	-	2.5	-	2.5	-	1.3	-	5.0	-	1.07	-	3.5	-	1.3	-	3.2	-	1.2
				Daily TP Load (kg/d)[e]	-	10	-	4.589	-	6.5	-	6.5	-	6.5	-	3.38	-	13	-	2.782	-	9.1	-	3.4	-	8.3	-	3.2
				Seasonal TP Load (kg/season)[f]	-	20	-	9.178	-	13	-	13	-	13	-	6.76	-	26	-	5.564	-	18	-	6.7	-	8.3	-	6.5
				Annual TP Load (kg/yr)[g]	29				26				20				32				25				15			
	Star City	460	184	TP Concentration (mg/L)[d]	-	2.5	-	2.5	-	3.1	-	1.1	-	2.8	-	1.3	-	2.5	-	0.89	-	2.7	-	0.50	-	2.0	-	0.86
				Daily TP Load (kg/d)[e]	-	0.46	-	0.46	-	0.57	-	0.20	-	0.51	-	0.24	-	0.46	-	0.16	-	0.50	-	0.09	-	0.37	-	0.15824
				Seasonal TP Load (kg/season)[f]	-	0.46	-	0.46	-	0.57	-	0.20	-	1.0	-	0.24	-	0.46	-	0.16	-	0.50	-	0.09	-	0.37	-	0.15824
				Annual TP Load (kg/yr)[g]	0.92				0.77				1.3				0.62				0.59				0.53			
Carrot River East	Arborfield	326	130	TP Concentration (mg/L)[d]	-	2.5	-	1.7	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[e]	-	0.33	-	0.22	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33
				Seasonal TP Load (kg/season)[f]	-	0.33	-	0.22	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33	-	0.33
				Annual TP Load (kg/yr)[g]	0.55				0.65				0.65				0.65				0.65				0.65			
	Carrot River	1000	400	TP Concentration (mg/L)[d]	4.8	-	-	2.13	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[e]	1.9	-	-	0.85	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1
				Seasonal TP Load (kg/season)[f]	1.9	-	-	0.85	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1	-	1
				Annual TP Load (kg/yr)[g]	2.8				2.0				2.0				2.0				2.0				2.0			
	Tisdale	3180	1272	TP Concentration (mg/L)[d]	0.72	-	-	0.76	-	2.5	-	1.9	-	3.6	-	1.8	-	1.5	-	1.4	-	3.1	-	1.4	-	10	-	-
				Daily TP Load (kg/d)[e]	0.92	-	-	0.97	-	3.2	-	2.4168	-	4.6	-	2.2896	-	1.9	-	1.7808	-	3.9	-	1.8	-	13	-	-
				Seasonal TP Load (kg/season)[f]	0.92	-	-	0.97	-	3.2	-	2.4168	-	9.2	-	2.2896	-	1.9	-	1.7808	-	3.9	-	1.8	-	13	-	-
				Annual TP Load (kg/yr)[g]	1.9				5.6				11				3.7				5.7				13			
	Zenon Park	187	74.8	TP Concentration (mg/L)[d]	-	1.7	-	2.5	-	2.5	-	1.4	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5	-	2.5
				Daily TP Load (kg/d)[e]	-	0.13	-	0.19	-	0.19	-	0.10	-	0.19	-	0.19	-	0.19	-	0.19	-	0.19	-	0.19	-	0.19	-	0.187
				Seasonal TP Load (kg/season)[f]	-	0.13	-	0.19	-	0.19	-	0.10	-	0.19	-	0.19	-	0.19	-	0.19	-	0.19	-	0.19	-	0.19	-	0.187
				Annual TP Load (kg/yr)[g]	0.32				0.29				0.37				0.37				0.37				0.37			

(a) Sub-basins are listed in order from upstream to downstream along the length of the Carrot River main stem; communities are also listed in order from upstream to downstream, based on their position along tributaries to the Carrot River main stem, or the main stem itself.
(b) Represents the estimated average volume of wastewater effluent released per day when the point source facility is discharging to the environment. It is calculated from the estimated service population size for the facility and a per capita flow of 0.4 m^3/person/day (AECOM 2009).
(c) Seasons include winter (January-March), freshet (April-June), summer (July-September), and fall (October-December).
(d) TP concentration data (mg/L) were not available for some facilities listed in the table; concentrations were set at 2.5 mg/L based on the approach described by AECOM (2009) for wastewater lagoons.
(e) Represents the estimated average amount of TP (kg) released per day, when the point source facility is discharging to the environment.
(f) Represents the estimated total amount of TP (kg) released per season. Some facilities discharge wastewater effluent seasonally (e.g., freshet and fall only); therefore seasonal loads may be zero (i.e., 0 kg/season) during some seasons (e.g., winter).
(g) Represents the sum total of TP (kg) released during winter, freshet, summer and fall.
ADF = average daily flow; m^3/d = cubic metres per day; TP = total phosphorus; - = not applicable; mg/L = milligrams per litre; kg/d = kilograms per day; kg/season = kilograms per season; kg/yr = kilograms per year.

APPENDIX C

Maps of Land Cover Types Identified in the Red Deer and Carrot River Watersheds

APPENDIX D

Proportions of Land Cover Types and Nutrient Loads in the Red Deer and Carrot River Watersheds

RED DEER RIVER

Table D1 **Proportional Areas and Nutrient Loads for Various Land Cover Types Identified within the Little Red Deer, Medicine, and Blindman River Sub-watersheds, 2013[a]**

Land Cover Type	Little Red Deer River AB05CB0270			Medicine River AB05CC0100			Blindman River AB05CC0460		
	Proportion of EDA Area (%)[b,c]	Calculated Load (kg/yr)[d]	Proportion of Nutrient Load from Non-Point Sources (%)[c,d]	Proportion of EDA Area (%)[b,c]	Calculated Load (kg/yr)[d]	Proportion of Nutrient Load from Non-Point Sources (%)[c,d]	Proportion of EDA Area (%)[b,c]	Calculated Load (kg/yr)[d]	Proportion of Nutrient Load from Non-Point Sources (%)[c,d]
Total Nitrogen (TN)									
Agriculture (undifferentiated)	0	-	-	0	-	-	0	-	-
Corn crop	<0.01	-	-	0	-	-	0.10	-	-
Developed	1.4	-	-	0.67	-	-	1.6	-	-
Exposed Land	0.08	21	<0.01	0.07	20	<0.01	0.31	53	0.02
Fallow	0	-	-	0	-	-	0	-	-
Grain/Seed Crop	*36*	217,882	*51*	*35*	232,025	*47*	*34*	145,854	*44*
Grassland/Prairie	10	39,359	9.1	0.73	3,104	0.63	0.05	128	0.04
Hay/Pasture	*17*	75,148	*17*	*29*	137,979	*28*	*30*	93,949	*28*
Herbs	0	-	-	0	-	-	0	-	-
Pulse/Specialty Crop	0.49	-	-	0.67	-	-	1.1	-	-
Shrubland	2.7	9,797	2.3	7.1	28,382	5.7	6.8	17,667	5.4
Soybean Crop	0	-	-	0	-	-	0	-	-
Too Wet for Seeding	0	-	-	0	-	-	0	-	-
Trees/Forest	*31*	83,036	*19*	*22*	64,724	*13*	*17*	31,903	*10*
Water	0.13	940	0.22	0.34	2,696	0.54	5.0	26,012	7.9
Wetland	0.91	4,438	1.0	4.9	26,168	5.3	4.1	14,148	4.3
Totals	**100**	**430,621**	**100**	**100**	**495,097**	**100**	**100**	**329,714**	**100**
Total Phosphorus (TP)									
Agriculture (undifferentiated)	0	-	-	0	-	-	0	-	-
Corn crop	<0.01	-	-	0	-	-	0.10	-	-
Developed	1.4	-	-	0.67	-	-	1.6	-	-
Exposed Land	0.08	2.1	<0.01	0.07	2.0	<0.01	0.31	5.3	0.01
Fallow	0	-	-	0	-	-	0	-	-
Grain/Seed Crop	*36*	21,788	*38*	*35*	23,203	*40*	*34*	14,585	*40*
Grassland/Prairie	10	7,626	13	0.73	601	1.0	0.05	25	0.07
Hay/Pasture	*17*	9,185	*16*	*29*	16,864	*29*	*30*	11,483	*32*
Herbs	0	-	-	0	-	-	0	-	-
Pulse/Specialty Crop	0.49	-	-	0.67	-	-	1.1	-	-
Shrubland	2.7	653	1.1	7.1	1,892	3.3	6.8	1,178	3.2
Soybean Crop	0	-	-	0	-	-	0	-	-
Too Wet for Seeding	0	-	-	0	-	-	0	-	-
Trees/Forest	*31*	18,117	*31*	*22*	14,122	*25*	*17*	6,961	*19*
Water	0.13	63	0.11	0.34	180	0.31	5.0	1,734	4.8
Wetland	0.91	89	0.15	4.9	523	0.91	4.1	283	0.78
Totals	**100**	**57,522**	**100**	**100**	**57,387**	**100**	**100**	**36,254**	**100**

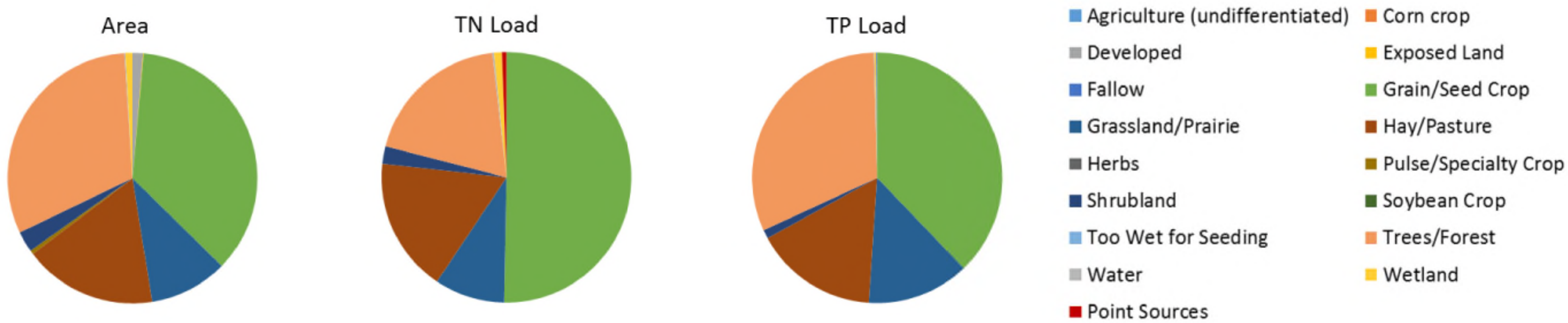
Notes: EDA = effective drainage area; % = percent; kg/yr = kilograms per year; < = less than.

(a) The tributaries are listed in order from upstream to downstream, based on where they flow into the Red Deer River.

(b) Relative to the EDA for each station listed in the table.

(c) The values corresponding to the three largest land cover areas and the three largest loads are *italicized* in the table.

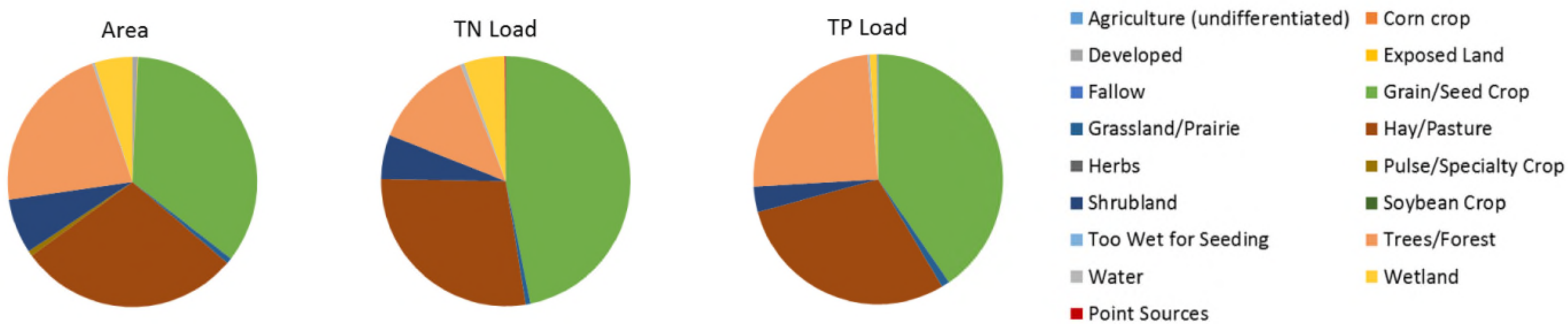
(d) Land cover types that consistently represented <3% of the EDAs for individual stations were excluded from the nutrient loading calculations (McFarland and Hauck 2001).



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

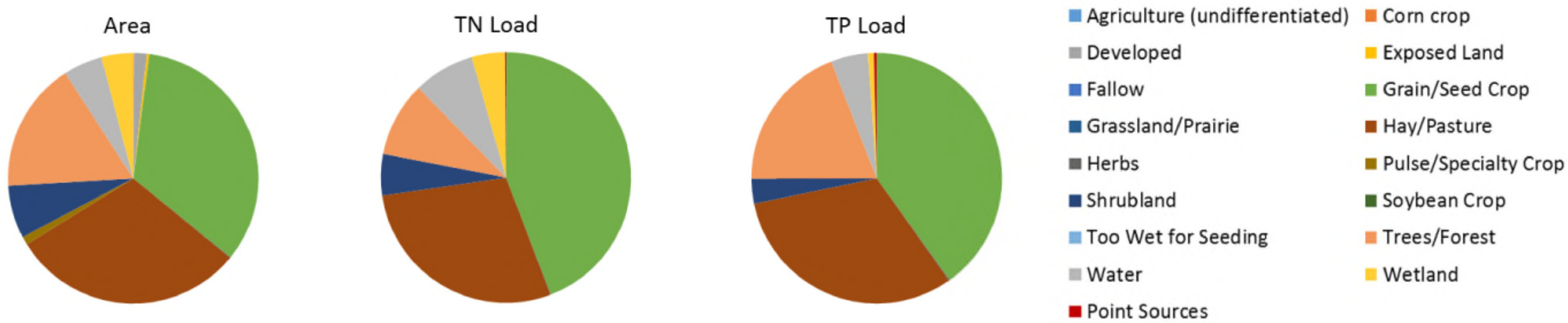
Figure D1: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CB0270 on the Little Red Deer River, 2013



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

Figure D2: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CC0100 on the Medicine River, 2013



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

Figure D3: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CC0460 on the Blindman River, 2013

Table D2 Cumulative Proportional Areas and Nutrient Loads for Various Land Cover Types Identified within Sub-watersheds that Terminate at Water Quality Stations on the Red Deer River Main Stem, 2013[(a)]

	Red Deer River Mainstem																	
	AB05CA0050			AB05CC0010			AB05CD0250			AB05CE0009			AB05CJ0070			AB05CK004		
Land Cover Type	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]
Total Nitrogen (TN)																		
Agriculture (undifferentiated)	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Corn crop	0	-	-	<0.01	-	-	0	-	-	0.04	-	-	0.11	-	-	0.11	-	-
Developed	0.53	-	-	1.0	-	-	1.5	-	-	1.5	-	-	1.2	-	-	1.2	-	-
Exposed Land	*24*	7,853	2.6	7.3	8,238	0.49	5.9	8,325	0.37	5.8	9,216	0.36	4.7	13,717	0.26	4.6	14,023	0.26
Fallow	0	-	-	0	-	-	0	-	-	0	-	-	0.04	-	-	0.18	-	-
Grain/Seed Crop	0.89	7,181	2.4	*22*	608,601	*36*	*26*	908,114	*41*	*28*	1,095,949	*43*	*38*	2,735,883	*52*	*36*	2,764,078	*51*
Grassland/Prairie	*8.9*	45,534	*15*	6.3	114,256	6.8	5.2	116,461	5.2	5.0	124,947	4.9	14	637,437	*12*	*16*	787,140	*14*
Hay/Pasture	1.9	10,953	3.6	*15*	300,175	*18*	*17*	424,844	*19*	*17*	484,682	*19*	*15*	775,340	*15*	15	802,868	*15*
Herbs	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Pulse/Specialty Crop	<0.01	-	-	0.32	-	-	0.45	-	-	0.51	-	-	1.2	-	-	1.2	-	-
Shrubland	5.5	26,563	*8.7*	5.1	86,602	5.1	5.3	112,568	5.0	5.8	138,027	5.4	3.8	167,720	3.2	3.7	168,178	3.1
Soybean Crop	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Too Wet for Seeding	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Trees/Forest	*58*	203,952	*67*	*41*	507,742	*30*	*35*	547,251	*25*	*32*	561,000	*22*	*18*	574,935	11	*17*	576,920	11
Water	0.08	774	0.25	0.77	26,196	1.5	1.3	55,952	2.5	1.9	90,160	3.5	1.8	158,363	3.0	1.8	164,784	3.0
Wetland	0.16	1,010	0.33	1.8	39,729	2.3	2.0	56,358	2.5	2.2	69,669	2.7	2.9	169,253	3.2	2.9	175,887	3.2
Totals	**100**	**303,820**	**100**	**100**	**1,691,540**	**100**	**100**	**2,229,874**	**100**	**100**	**2,573,650**	**100**	**100**	**5,232,649**	**100**	**100**	**5,453,878**	**100**
Total Phosphorus (TP)																		
Agriculture (undifferentiated)	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Corn crop	0	-	-	<0.01	-	-	0	-	-	0.04	-	-	0.11	-	-	0.110	-	-
Developed	0.53	-	-	1.0	-	-	1.5	-	-	1.5	-	-	1.2	-	-	1.20	-	-
Exposed Land	*24*	785	1.4	7.3	824	0.34	5.9	832	0.28	5.8	922	0.28	4.7	1,372	0.21	4.6	1,402	0.21
Fallow	0	-	-	0	-	-	0	-	-	0	-	-	0.04	-	-	0.2	-	-
Grain/Seed Crop	0.89	718	1.2	*22*	60,860	*25*	*26*	90,811	*30*	*28*	109,595	*33*	*38*	273,588	*42*	*36.0*	276,408	*41*
Grassland/Prairie	*8.9*	8,822	*15*	6.3	22,137	9.2	5.2	22,564	7.6	5.0	24,208	7.3	14	123,504	*19*	*16*	152,508	*22*
Hay/Pasture	1.9	1,339	2.3	*15*	36,688	*15*	*17*	51,925	*17*	*17*	59,239	*18*	*15*	94,764	15	*15*	98,128	14
Herbs	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Pulse/Specialty Crop	<0.01	-	-	0.32	-	-	0.45	-	-	0.51	-	-	1.2	-	-	1.20	-	-
Shrubland	5.5	1,771	*3.1*	5.1	5,773	2.4	5.3	7,505	2.5	5.8	9,202	2.8	3.8	11,181	1.7	3.70	11,212	1.6
Soybean Crop	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Too Wet for Seeding	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Trees/Forest	*58*	44,499	*77*	*41*	110,780	*46*	*35*	119,400	*40*	*32*	122,400	*37*	*18*	125,440	*19*	17.0	125,874	*19*
Water	0.08	52	0.09	0.77	1,746	0.73	1.3	3,730	1.3	1.9	6,011	1.8	1.8	10,558	1.6	1.8	10,986	1.6
Wetland	0.16	20	0.03	1.8	795	0.33	2.0	1,127	0.38	2.2	1,393	0.42	2.9	3,385	0.53	2.9	3,518	0.52
Totals	**100**	**58,006**	**100**	**100**	**239,604**	**100**	**100**	**297,896**	**100**	**100**	**332,970**	**100**	**100**	**643,792**	**100**	**100**	**680,035**	**100**

Notes: EDA = effective drainage area; % = percent; kg/yr = kilograms per year; < = less than.

(a) Stations are listed in order from upstream to downstream along the Red Deer River main stem. The land cover area for a given station includes upstream sub-watersheds that would contribute to the loads passing the station of interest (e.g., the land cover areas for station AB05CC0010 include areas in the Little Red Deer River and Medicine River sub-watersheds because these tributaries flow into the main stem upstream of AB05CC0010).

(b) Relative to the EDA for each station listed in the table.

(c) The values corresponding to the three largest land cover areas and the three largest loads are *italicized* in the table.

(d) Land cover types that consistently represented <3% of the EDAs for individual stations were excluded from the nutrient loading calculations (McFarland and Hauck 2001). Data values that were not calculated are denoted with a dash "-".

Table D3 Proportional Areas and Nutrient Loads for Various Land Cover Types Identified within Individual Sub-watersheds that Terminate at Water Quality Stations on the Red Deer River Main Stem, 2013 [(a)]

	Red Deer River Mainstem																	
	AB05CA0050			AB05CC0010			AB05CD0250			AB05CE0009			AB05CJ0070			AB05CK004		
Land Cover Type	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]	Proportion of EDA Area (%)[(b,c)]	Calculated Load (kg/yr)[(d)]	Proportion of Nutrient Load from Non-Point Sources (%)[(c,d)]
Total Nitrogen (TN)																		
Agriculture (undifferentiated)	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Corn crop	0	-	-	<0.01	-	-	0.02	-	-	0.04	-	-	0.11	-	-	0.11	-	-
Developed	0.53	-	-	1.0	-	-	1.5	-	-	1.5	-	-	1.2	-	-	1.2	-	-
Exposed Land	*24*	7,853	2.6	7.3	344	0.07	5.9	35	0.02	5.8	890	0.26	4.7	4,501	0.17	4.6	306	0.14
Fallow	0	-	-	0	-	-	0	-	-	0	-	-	0.04	-	-	0.18	-	-
Grain/Seed Crop	0.89	7,181	2.4	*22*	151,513	*33*	*26*	153,659	*74*	*28*	187,835	*55*	*38*	1,639,934	*62*	*36*	28,195	*13*
Grassland/Prairie	*8.9*	45,534	*15*	6.3	26,258	5.7	5.2	2,077	1.0	5.0	8,486	2.5	14	512,491	*19*	*16*	149,702	*68*
Hay/Pasture	1.9	10,953	3.6	*15*	76,095	*16*	*17*	30,721	*15*	*17*	59,837	*17*	*15*	290,659	*11*	15	27,528	*12*
Herbs	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Pulse/Specialty Crop	<0.01	-	-	0.32	-	-	0.45	-	-	0.51	-	-	1.2	-	-	1.2	-	-
Shrubland	5.5	26,563	*8.7*	5.1	21,861	4.7	5.3	8,299	*4.0*	5.8	25,459	7.4	3.8	29,693	1.1	3.7	458	0.21
Soybean Crop	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Too Wet for Seeding	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Trees/Forest	*58*	203,952	*67*	*41*	156,030	*34*	*35*	7,606	3.6	*32*	13,749	4.0	*18*	13,935	0.52	*17*	1,985	0.90
Water	0.08	774	0.25	0.77	21,787	4.7	1.3	3,744	1.8	1.9	34,208	*10*	1.8	68,203	2.6	1.8	6,420	2.9
Wetland	0.16	1,010	0.33	1.8	8,113	1.8	2.0	2,480	1.2	2.2	13,312	3.9	2.9	99,584	3.7	2.9	6,633	3.0
Totals	**100**	**303,820**	**100**	**100**	**462,002**	**100**	**100**	**208,620**	**100**	**100**	**343,776**	**100**	**100**	**2,659,000**	**100**	**100**	**221,228**	**100**
Total Phosphorus (TP)																		
Agriculture (undifferentiated)	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Corn crop	0	-	-	<0.01	-	-	0.02	-	-	0.04	-	-	0.11	-	-	0.11	-	-
Developed	0.53	-	-	1.0	-	-	1.5	-	-	1.5	-	-	1.2	-	-	1.2	-	-
Exposed Land	*24*	785	1.4	7.3	34	0.05	5.9	3.5	0.02	5.8	89	0.25	4.7	450	0.14	4.6	31	0.08
Fallow	0	-	-	0	-	-	0	-	-	0	-	-	0.04	-	-	0.18	-	-
Grain/Seed Crop	0.89	718	1.2	*22*	15,151	*23*	*26*	15,366	*70*	*28*	18,784	*54*	*38*	163,993	*53*	*36*	2,819	*7.8*
Grassland/Prairie	*8.9*	8,822	*15*	6.3	5,088	7.6	5.2	402	1.8	5.0	1,644	4.7	13.7	99,295	*32*	*16*	29,005	*80*
Hay/Pasture	1.9	1,339	2.3	*15*	9,300	*14*	*17*	3,755	*17*	*17*	7,313	*21*	*15*	35,525	*11*	15	3,365	*9.3*
Herbs	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Pulse/Specialty Crop	<0.01	-	-	0.32	-	-	0.45	-	-	0.51	-	-	1.2	-	-	1.2	-	-
Shrubland	5.5	1,771	*3.1*	5.1	1,457	2.2	5.3	553	2.5	5.8	1,697	4.8	3.8	1,980	0.6	3.7	31	0.08
Soybean Crop	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Too Wet for Seeding	0	-	-	0	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Trees/Forest	*58*	44,499	*77*	*41*	34,043	*51*	*35*	1,660	*7.5*	*32*	3,000	*8.6*	*18*	3,040	*1.0*	*17*	433	1.2
Water	0.08	52	0.09	0.77	1,452	2.2	1.3	250	1.1	1.9	2,281	6.5	1.8	4,547	1.5	1.8	428	1.2
Wetland	0.16	20	0.03	1.8	162	0.24	2.0	50	0.23	2.2	266	0.76	2.9	1,992	0.64	2.9	133	0.37
Totals	**100**	**58,006**	**100**	**100**	**66,689**	**100**	**100**	**22,039**	**100**	**100**	**35,074**	**100**	**100**	**310,822**	**100**	**100**	**36,244**	**100**

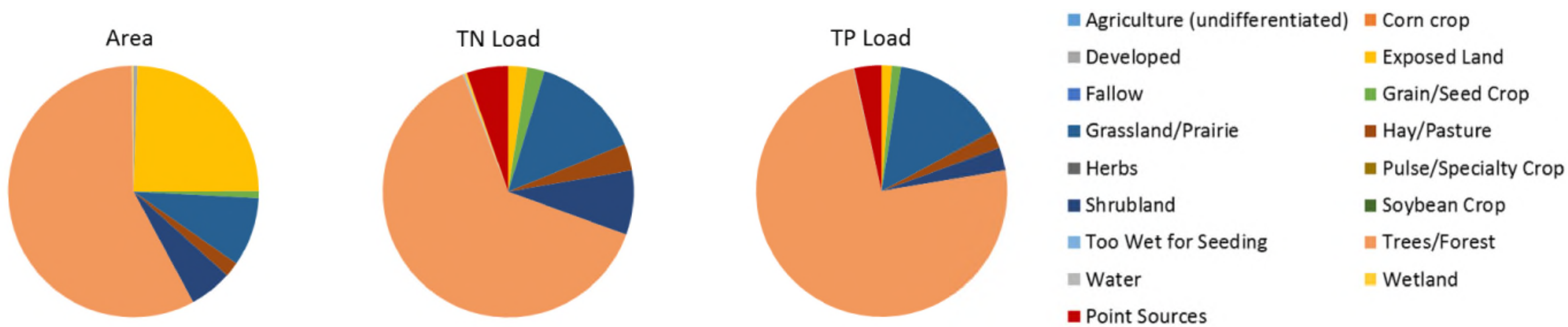
Notes: EDA = effective drainage area; % = percent; kg/yr = kilograms per year; < = less than.

(a) Stations are listed in order from upstream to downstream along the Red Deer River main stem. The land cover area for a given station does not include upstream sub-watersheds that would contribute to the loads passing the station of interest (e.g., the land cover areas for station AB05CC0010 only include the immediate sub-watershed area, and not areas in the Little Red Deer River and Medicine River sub-watersheds.

(b) Relative to the EDA for each station listed in the table.

(c) The values corresponding to the largest land cover areas and the largest loads are *italicized* in the table.

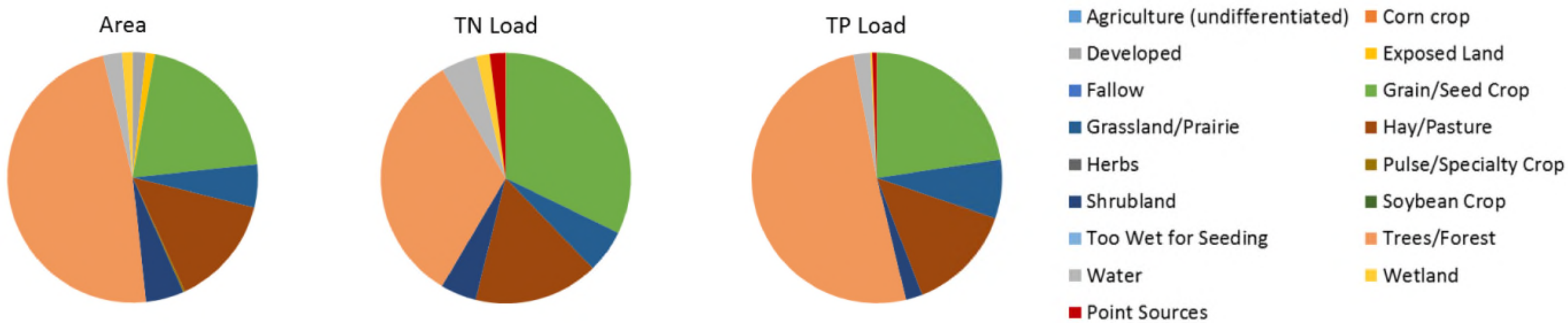
(d) Land cover types that consistently represented <3% of the EDAs for individual stations were excluded from the nutrient loading calculations (McFarland and Hauck 2001). Data values that were not calculated are denoted with a dash "-".



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

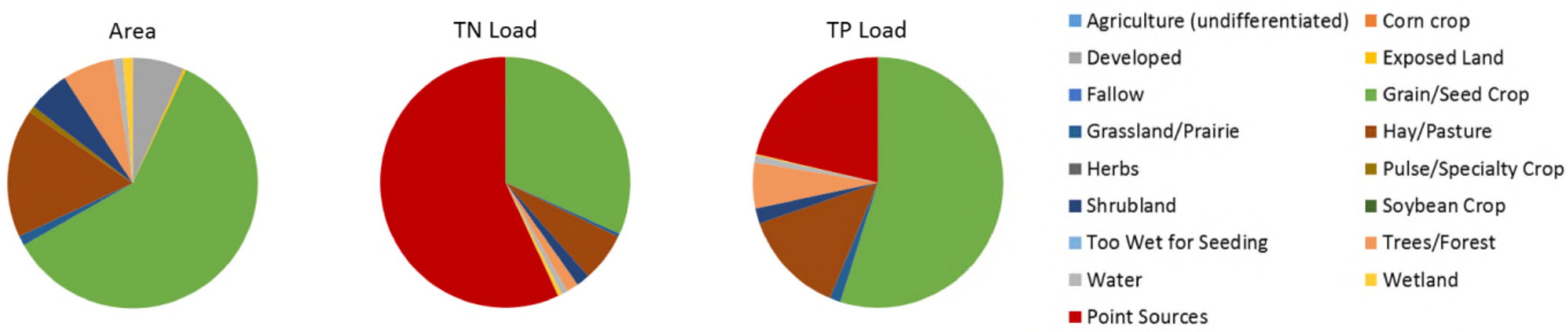
Figure D4: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CA0050 on the Red Deer River Mainstem, 2013



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

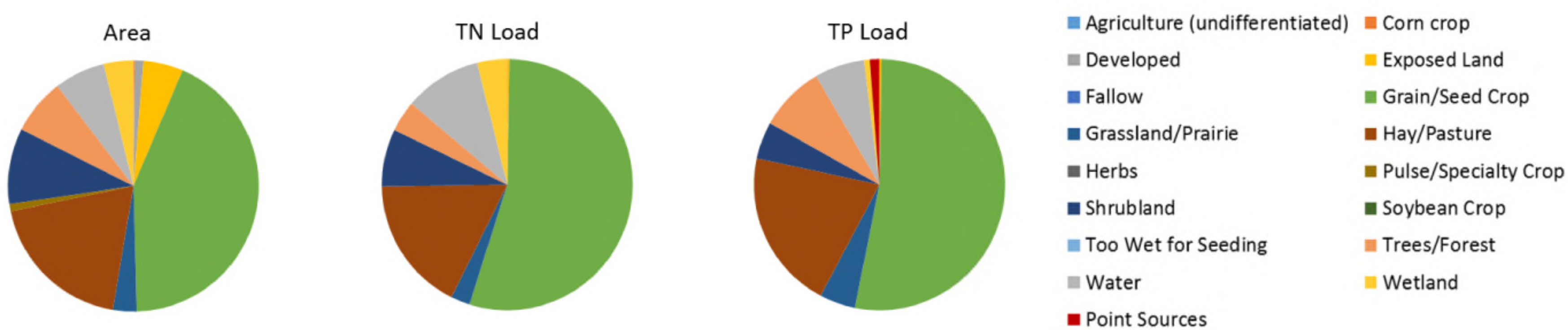
Figure D5: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CC0010 on the Red Deer River Mainstem, 2013



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

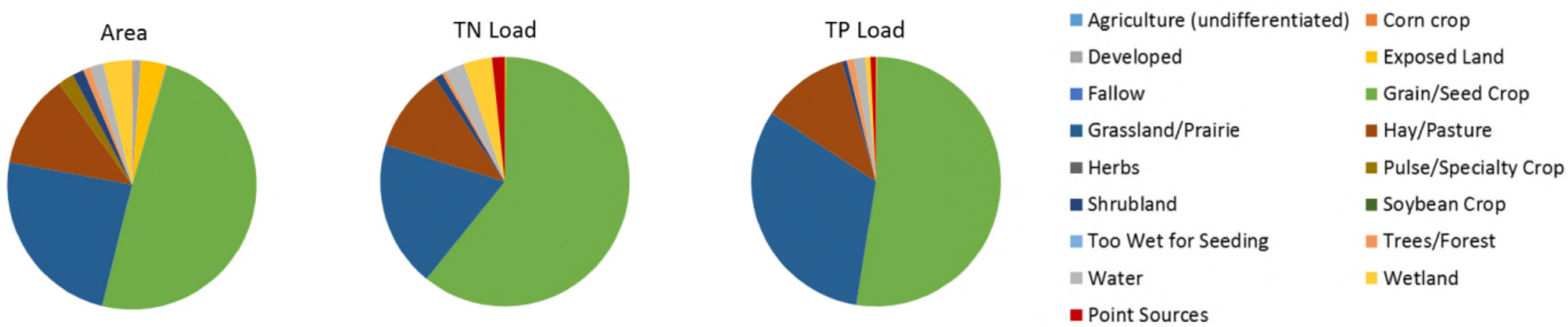
Figure D6: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CD0250 on the Red Deer River Mainstem, 2013



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

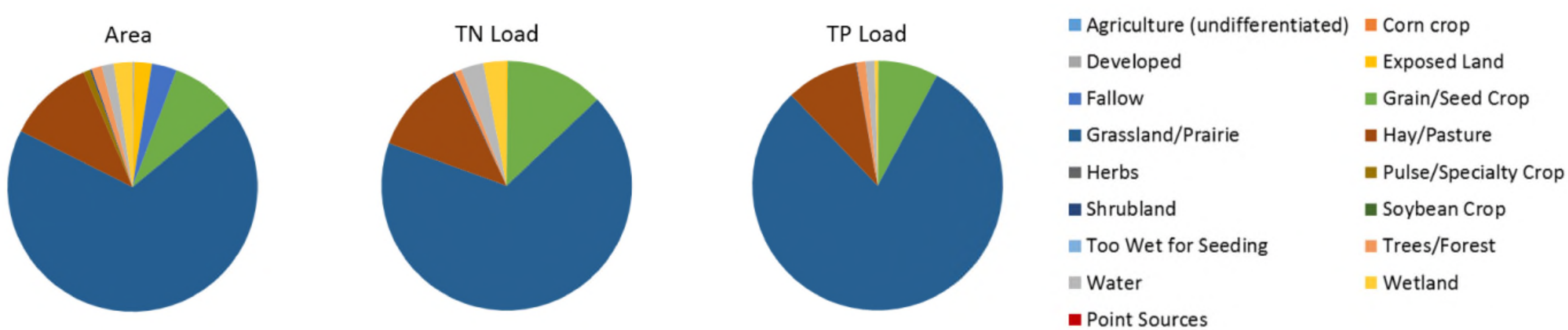
Figure D7: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CE0009 on the Red Deer River Mainstem, 2013



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

Figure D8: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CJ0070 on the Red Deer River Mainstem, 2013



Notes: Areas are presented as proportions (%) of the total effective drainage area for individual sub-watersheds (i.e., are not cumulative). Nutrient loads for each land cover type are presented as proportions (%) of the total calculated load for individual sub-watersheds (i.e., are not cumulative). Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

Figure D9: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CK004 on the Red Deer River Mainstem, 2013

Table D4 **Proportional Areas and Nutrient Loads for Various Land Cover Types Identified within the Red Deer River Watershed, 2000 and 2009-2013**

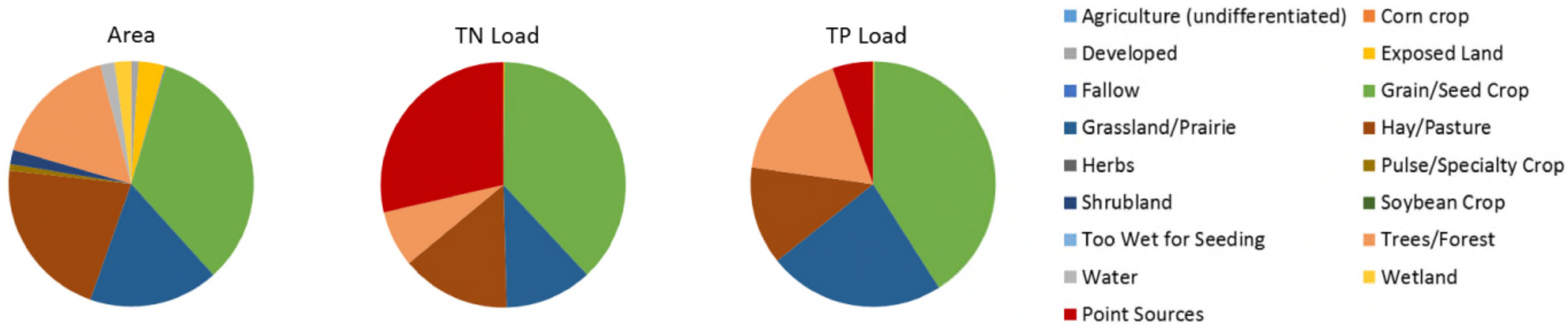
Land Cover Type	Wet						Moderate						Dry					
	2013			2011			2012			2010			2009			2000		
	Proportion of EDA Area (%)[a,b]	Calculated Load (kg/yr)[c]	Proportion of Nutrient Load from Non-Point Sources (%)[b,c]	Proportion of EDA Area (%)[a,b]	Calculated Load (kg/yr)[c]	Proportion of Nutrient Load from Non-Point Sources (%)[b,c]	Proportion of EDA Area (%)[a,b]	Calculated Load (kg/yr)[c]	Proportion of Nutrient Load from Non-Point Sources (%)[b,c]	Proportion of EDA Area (%)[a,b]	Calculated Load (kg/yr)[c]	Proportion of Nutrient Load from Non-Point Sources (%)[b,c]	Proportion of EDA Area (%)[a,b]	Calculated Load (kg/yr)[c]	Proportion of Nutrient Load from Non-Point Sources (%)[b,c]	Proportion of EDA Area (%)[a,b]	Calculated Load (kg/yr)[c]	Proportion of Nutrient Load from Non-Point Sources (%)[b,c]
Total Nitrogen (TN)																		
Agriculture (undifferentiated)	0	-	-	<0.01	-	-	<0.01	-	-	0	-	-	0	-	-	0	-	-
Corn crop	0.11	-	-	0.08	-	-	0.07	-	-	0.07	-	-	0	-	-	0.06	-	-
Developed	1.2	-	-	1.0	-	-	1.2	-	-	0.83	-	-	0.89	-	-	0.91	-	-
Exposed Land	4.6	14,023	0.26	4.0	12,054	0.21	4.6	9,749	0.26	4.1	8,676	0.23	3.8	2,287	0.23	3.5	2,133	0.22
Fallow	0.18	-	-	0.27	-	-	0.14	-	-	0.15	-	-	0.03	-	-	0.13	-	-
Grain/Seed Crop	*36*	2,764,078	*51*	*43*	3,265,625	*57*	*40*	2,208,424	*59*	*35*	1,898,919	*51*	*42*	643,492	*64*	*34*	513,161	*53*
Grassland/Prairie	*16*	787,140	14	*17*	842,307	*15*	*15*	516,317	*14*	*18*	591,877	*16*	*19*	172,369	*17*	*17*	156,118	*16*
Hay/Pasture	15	802,868	*15*	11	606,031	*11*	12	462,916	*12*	*19*	768,027	*21*	10	87,448	8.7	*21*	194,930	*20*
Herbs	<0.01	-	-	0	-	-	<0.01	-	-	0	-	-	0	-	-	<0.01	-	-
Pulse/Specialty Crop	1.2	-	-	0.58	-	-	1.0	-	-	0.86	-	-	0.76	-	-	0.84	-	-
Shrubland	3.7	168,178	3.1	2.6	119,288	2.1	3.9	130,279	3.5	2.3	78,030	2.1	2.7	-	-	1.9	-	-
Soybean Crop	<0.01	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Too Wet for Seeding	<0.01	-	-	0	-	-	<0.01	-	-	0.02	-	-	0	-	-	<0.01	-	-
Trees/Forest	*17*	576,920	*11*	*16*	542,165	10	17	414,811	11	16	390,159	10	*17*	102,808	*10*	16	100,321	10
Water	1.8	164,784	3.0	1.8	159,979	2.8	1.8	-	-	1.7	-	-	1.9	-	-	1.9	-	-
Wetland	2.9	175,887	3.2	2.3	138,689	2.4	2.9	-	-	2.3	-	-	2.4	-	-	2.2	-	-
Totals	**100**	**5,453,878**	**100**	**100**	**5,686,136**	**100**	**100**	**3,742,496**	**100**	**100**	**3,735,689**	**100**	**100**	**1,008,404**	**100**	**100**	**966,663**	**100**
Total Phosphorus (TP)																		
Agriculture (undifferentiated)	0	-	-	0	-	-	<0.01	-	-	0	-	-	0	-	-	0	-	-
Corn crop	0.11	-	-	0.08	-	-	0.07	-	-	0.07	-	-	0	-	-	0.06	-	-
Developed	1.2	-	-	1.0	-	-	1.2	-	-	0.83	-	-	0.89	-	-	0.91	-	-
Exposed Land	4.6	1,402	0.21	4.0	1,205	0.17	4.6	1,393	0.21	4.1	1,239	0.18	3.8	343	0.17	3.5	320	0.17
Fallow	0.18	-	-	0.27	-	-	0.14	-	-	0.15	-	-	0.03	-	-	0.13	-	-
Grain/Seed Crop	*36*	276,408	*41*	*43*	326,562	*46*	*40*	306,726	*46*	*35*	263,739	*39*	*42*	102,959	*51*	*34*	82,106	*43*
Grassland/Prairie	*16*	152,508	*22*	*17*	163,197	*23*	*15*	145,507	*22*	*18*	166,802	*25*	*19*	51,711	*26*	*17*	46,835	*25*
Hay/Pasture	15	98,128	14	11	74,070	11	12	71,218	11	*19*	118,158	*18*	10	11,660	5.8	*21*	25,991	14
Herbs	<0.01	-	-	0	-	-	<0.01	-	-	0	-	-	0	-	-	<0.01	-	-
Pulse/Specialty Crop	1.2	-	-	0.58	-	-	1.0	-	-	0.86	-	-	0.76	-	-	0.84	-	-
Shrubland	3.7	11,212	1.6	2.6	7,953	1.1	3.9	11,844	1.8	2.3	7,094	1.1	2.7	-	-	1.9	-	-
Soybean Crop	<0.01	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Too Wet for Seeding	<0.01	-	-	0	-	-	<0.01	-	-	0.02	-	-	0	-	-	<0.01	-	-
Trees/Forest	*17*	125,874	*19*	*16*	118,291	*17*	*17*	124,443	*19*	16	117,048	17	*17*	35,983	*18*	16	35,112	*18*
Water	1.8	10,986	1.6	1.8	10,665	1.5	1.8	-	-	1.7	-	-	1.9	-	-	1.9	-	-
Wetland	2.9	3,518	0.52	2.3	2,774	0.39	2.9	-	-	2.3	-	-	2.4	-	-	2.2	-	-
Totals	**100**	**680,035**	**100**	**100**	**704,717**	**100**	**100**	**661,130**	**100**	**100**	**674,079**	**100**	**100**	**202,655**	**100**	**100**	**190,364**	**100**

Notes: EDA = effective drainage area; % = percent; kg/yr = kilograms per year; < = less than.

(a) Refers to the proportion of the total watershed EDA that is represented by a particular land cover type.

(b) The values corresponding to the largest land cover areas and the largest loads are *italicized* in the table.

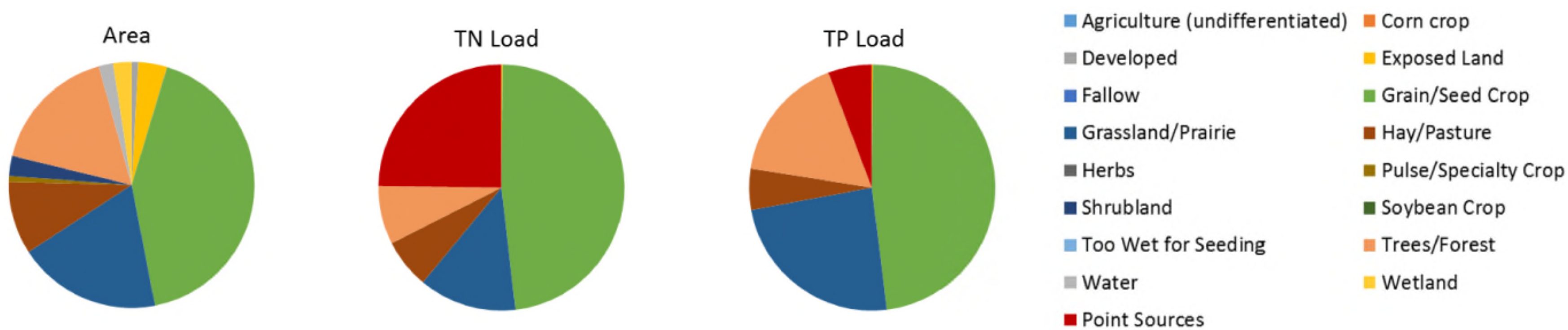
(c) Land cover types that represented <3% of the EDA during the model calibration years (i.e., 2013, 2012, and 2009) were excluded from the nutrient loading calculations (McFarland and Hauck 2001). Data values that were not calculated are denoted with a dash "-".



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

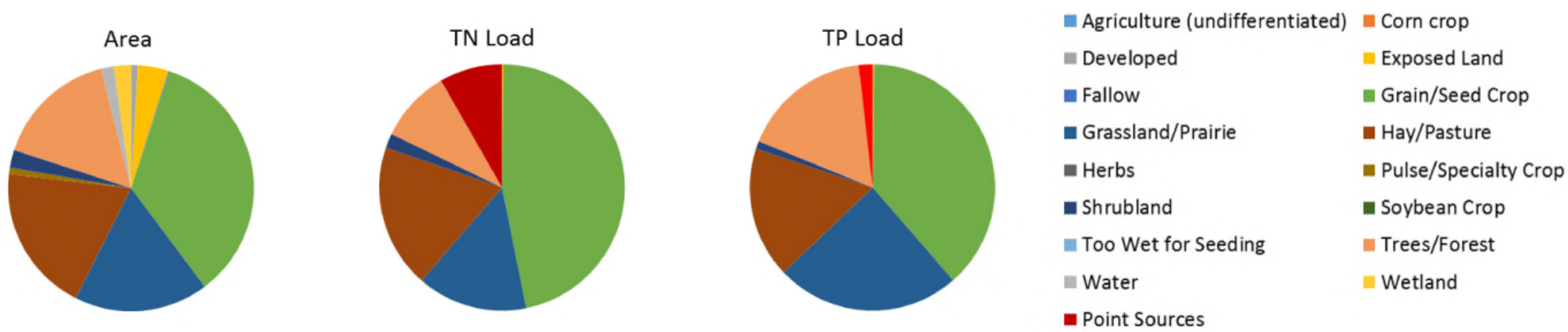
Figure D10: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CK004 on the Red Deer River Mainstem, 2000



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

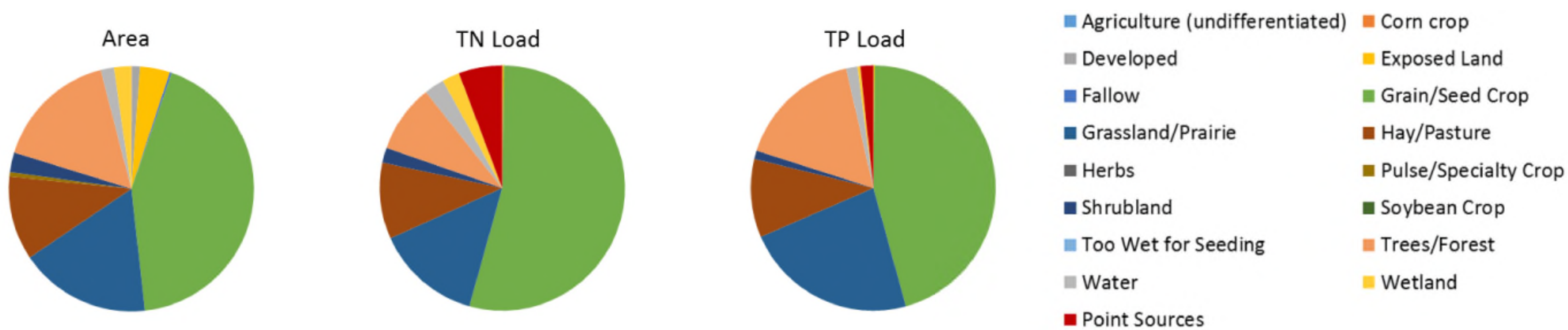
Figure D11: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CK004 on the Red Deer River Mainstem, 2009



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

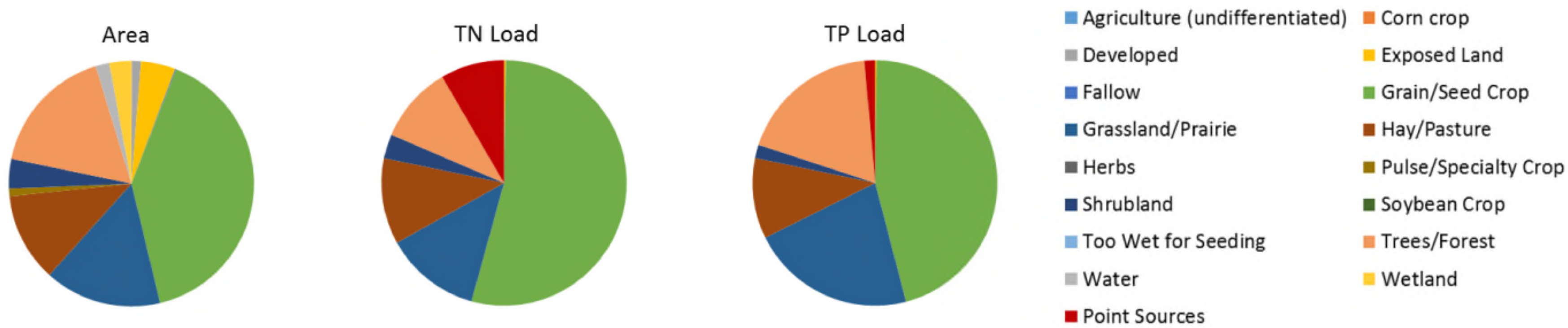
Figure D12: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CK004 on the Red Deer River Mainstem, 2010



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

Figure D13: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CK004 on the Red Deer River Mainstem, 2011



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

Figure D14: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05CK004 on the Red Deer River Mainstem, 2012

CARROT RIVER

Table D5: Proportional Areas and Nutrient Loads for Various Land Cover Types Identified within the Carrot River Watershed, 2000 and 2009-2013

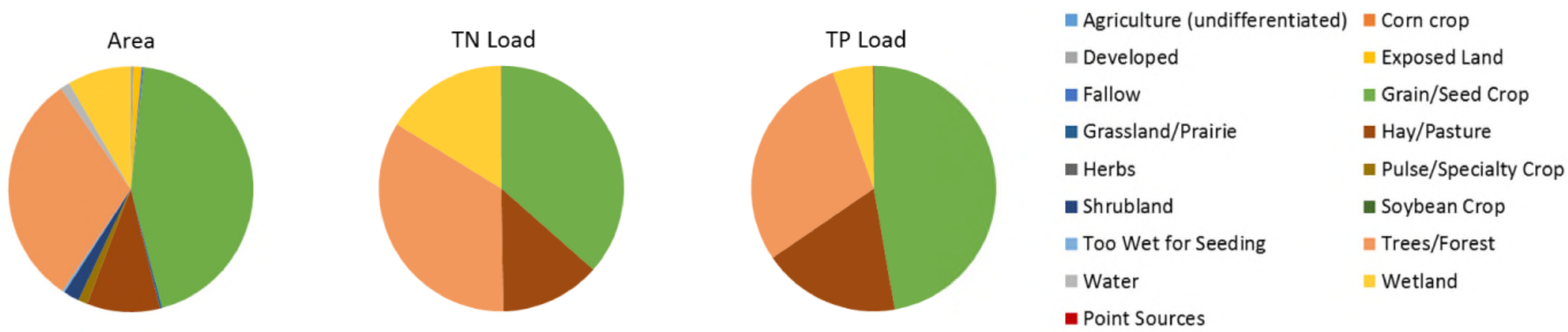
Land Cover Type	Wet						Moderate						Dry					
	2013			2012			2010			2011			2009			2000		
	Proportion of EDA Area (%)(a,b)	Calculated Load (kg/yr)(c)	Proportion of Nutrient Load from Non-Point Sources (%)(b,c)	Proportion of EDA Area (%)(a,b)	Calculated Load (kg/yr)(c)	Proportion of Nutrient Load from Non-Point Sources (%)(b,c)	Proportion of EDA Area (%)(a,b)	Calculated Load (kg/yr)(c)	Proportion of Nutrient Load from Non-Point Sources (%)(b,c)	Proportion of EDA Area (%)(a,b)	Calculated Load (kg/yr)(c)	Proportion of Nutrient Load from Non-Point Sources (%)(b,c)	Proportion of EDA Area (%)(a,b)	Calculated Load (kg/yr)(c)	Proportion of Nutrient Load from Non-Point Sources (%)(b,c)	Proportion of EDA Area (%)(a,b)	Calculated Load (kg/yr)(c)	Proportion of Nutrient Load from Non-Point Sources (%)(b,c)
Total Nitrogen (TN)																		
Agriculture (undifferentiated)	0.02	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Corn crop	<0.01	-	-	<0.01	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Developed	0.44	-	-	0.41	-	-	0.26	-	-	0.39	-	-	0.35	-	-	0.35	-	-
Exposed Land	1.4	-	-	1.4	-	-	0.78	-	-	0.97	-	-	1.1	-	-	1.1	-	-
Fallow	0.34	-	-	0.11	-	-	0.08	-	-	0.26	-	-	0.26	-	-	0.26	-	-
Grain/Seed Crop	*47*	642,044	*48*	*47*	630,245	*47*	*26*	445,710	*26*	*48*	836,155	*49*	*44*	144,900	*38*	*44*	143,589	*37*
Grassland/Prairie	0.04	-	-	0.06	-	-	0.02	-	-	<0.01	-	-	0.29	-	-	0.29	-	-
Hay/Pasture	4.4	86,753	6.4	4.4	85,919	6.4	5.4	134,417	7.7	6.2	153,817	9.1	10	32,566	8.6	9.6	52,195	13
Herbs	0.01	-	-	0.01	-	-	0.01	-	-	0.94	-	-	<0.01	-	-	0.01	-	-
Pulse/Specialty Crop	0.80	-	-	1.5	-	-	1.3	-	-	0	-	-	1.2	-	-	1.2	-	-
Shrubland	4.1	66,009	4.9	4.3	70,352	5.3	2.8	-	-	2.2	-	-	2.1	-	-	2.1	-	-
Soybean Crop	<0.01	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Too Wet for Seeding	0.25	-	-	0.48	-	-	*23*	474,415	*27*	0.42	8,641	0.51	0.29	-	-	0.29	-	-
Trees/Forest	*31*	367,602	*27*	*31*	366,466	*27*	*31*	468,856	*27*	*31*	467,193	*28*	*31*	136,825	*36*	*31*	133,789	*34*
Water	1.5	-	-	1.5	-	-	1.4	-	-	1.2	-	-	1.3	-	-	1.3	-	-
Wetland	*8.4*	183,006	*14*	*8.4*	182,488	*14*	8.3	223,915	13	*8.3*	224,963	*13*	*8.4*	63,293	*17*	*8.4*	63,722	*16*
Totals	**100**	**1,345,415**	**100**	**100**	**1,335,470**	**100**	**100**	**1,747,313**	**100**	**100**	**1,690,769**	**100**	**100**	**377,584**	**100**	**100**	**393,295**	**100**
Total Phosphorus (TP)																		
Agriculture (undifferentiated)	0.02	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Corn crop	<0.01	-	-	<0.01	-	-	0	-	-	0	-	-	<0.01	-	-	<0.01	-	-
Developed	0.44	-	-	0.41	-	-	0.26	-	-	0.39	-	-	0.35	-	-	0.35	-	-
Exposed Land	1.4	-	-	1.4	-	-	0.78	-	-	0.97	-	-	1.1	-	-	1.1	-	-
Fallow	0.34	-	-	0.11	-	-	0.08	-	-	0.26	-	-	0.26	-	-	0.26	-	-
Grain/Seed Crop	*47*	66,773	*53*	*47*	65,545	*53*	*26*	64,071	*30*	*48*	120,197	*57*	*44*	16,422	*51*	*44*	16,273	*47*
Grassland/Prairie	0.04	-	-	0.06	-	-	0.02	-	-	<0.01	-	-	0.29	-	-	0.29	-	-
Hay/Pasture	4.4	10,603	*8.4*	4.4	10,501	*8.4*	5.4	19,286	9.0	6.2	22,069	*10*	*10*	3,908	*12*	*9.6*	6,263	*18*
Herbs	0.01	-	-	0.01	-	-	0.01	-	-	0.94	-	-	<0.01	-	-	0.01	-	-
Pulse/Specialty Crop	0.8	-	-	1.5	-	-	1.3	-	-	0	-	-	1.2	-	-	1.2	-	-
Shrubland	4.1	4,401	3.5	4.3	4,690	3.8	2.8	-	-	2.2	-	-	2.1	-	-	2.1	-	-
Soybean Crop	<0.01	-	-	0	-	-	0	-	-	0	-	-	0	-	-	0	-	-
Too Wet for Seeding	0.25	-	-	0.48	-	-	*23*	62,423	*29*	0.42	1,137	0.54	0.29	-	-	0.29	-	-
Trees/Forest	*31*	40,102	*32*	*31*	39,978	*32*	*31*	60,281	*28*	*31*	60,068	*28*	*31*	10,262	*32*	*31*	10,034	*29*
Water	1.5	-	-	1.5	-	-	1.4	-	-	1.2	-	-	1.3	-	-	1.3	-	-
Wetland	*8.4*	3,660	2.9	*8.4*	3,650	2.9	8.3	8,061	3.8	*8.3*	8,099	3.8	8.4	1,808	5.6	8.4	1,821	5.3
Totals	**100**	**125,539**	**100**	**100**	**124,365**	**100**	**100**	**214,122**	**100**	**100**	**211,570**	**100**	**100**	**32,400**	**100**	**100**	**34,392**	**100**

Notes: EDA = effective drainage area; % = percent; kg/yr = kilograms per year; < = less than.

(a) Refers to the proportion of the total watershed EDA that is represented by a particular land cover type.

(b) The values corresponding to the largest land cover areas and the largest loads are *italicized* in the table.

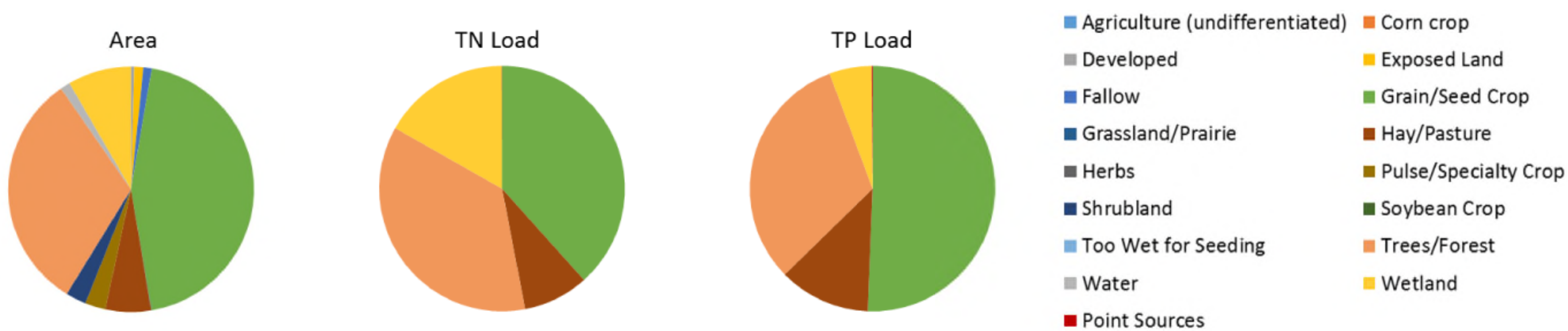
(c) Land cover types that represented <3% of the EDA during the model calibration years (i.e., 2013, 2012, and 2009) were excluded from the nutrient loading calculations (McFarland and Hauck 2001). Data values that were not calculated are denoted with a dash "-".



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

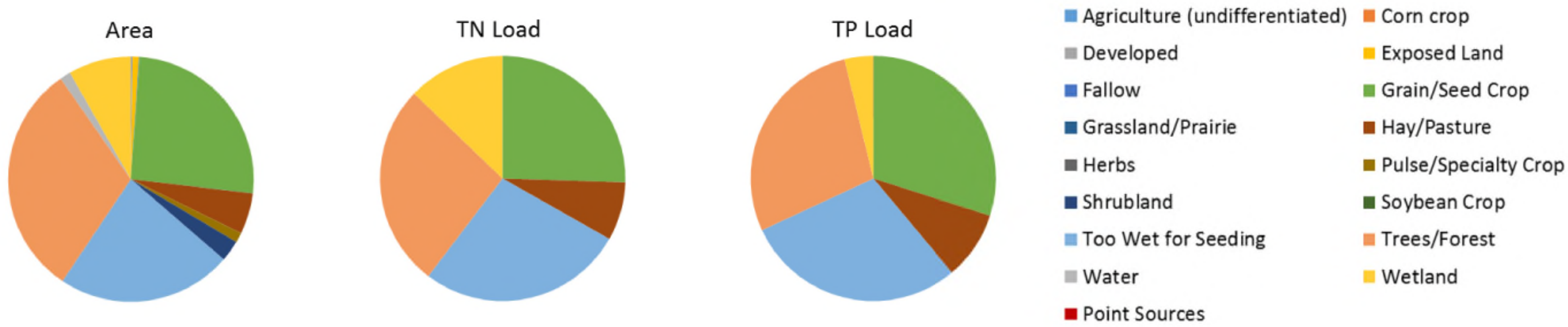
Figure D15: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05KH007 on the Carrot River Mainstem, 2000



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

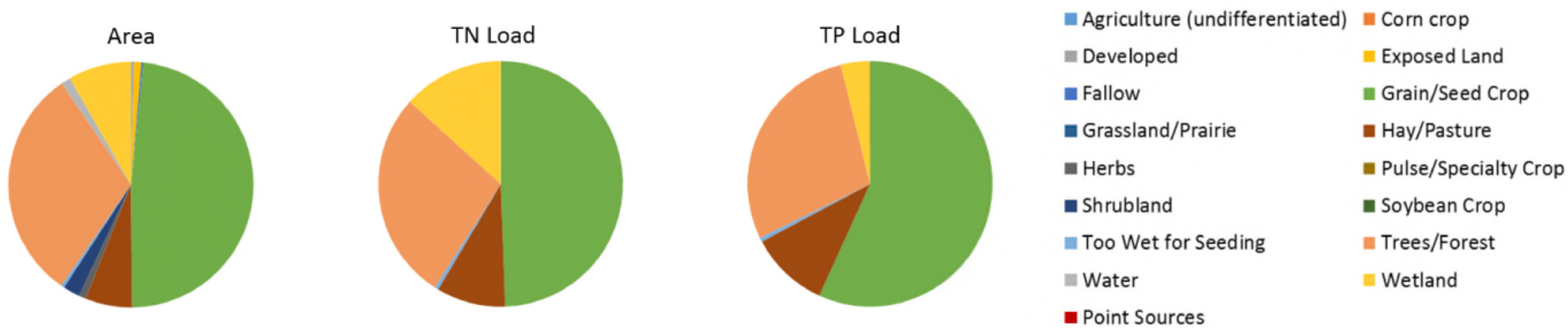
Figure D16: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05KH007 on the Carrot River Mainstem, 2009



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

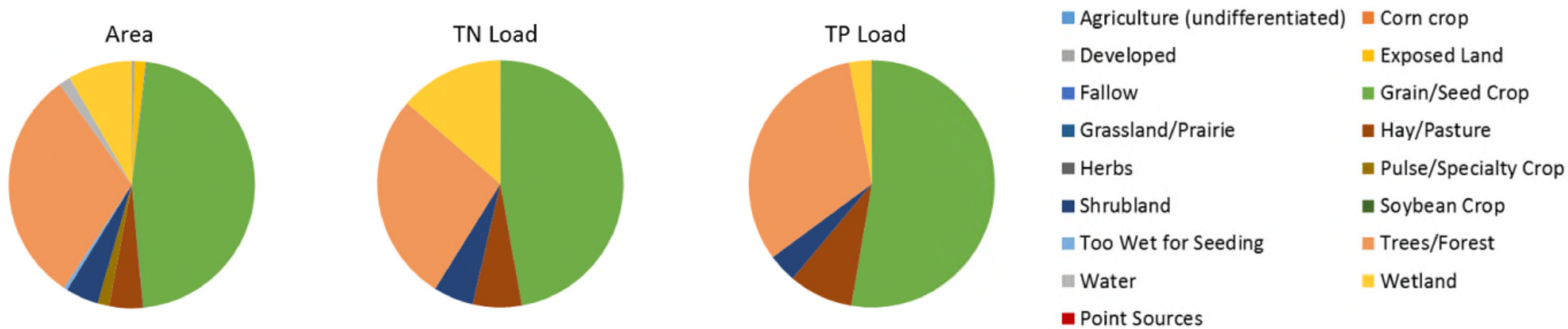
Figure D17: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05KH007 on the Carrot River Mainstem, 2010



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

Figure D18: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05KH007 on the Carrot River Mainstem, 2011



Notes: Areas and nutrient loads are presented as proportions (%) of the total effective drainage area and the total calculated load, respectively, for the watershed. Loads from point sources are included in the load pie charts.

TN = total nitrogen; TP = total phosphorus.

Figure D19: Land Cover Areas and Calculated Annual Total Nitrogen and Total Phosphorus Loads at Station AB05KH007 on the Carrot River Mainstem, 2012

APPENDIX E

Scenario Analysis Results for Land Cover Types and Nutrient Loads in the Red Deer and Carrot River Watersheds

RED DEER RIVER

Table E1: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (10% Decrease):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		-4.9	-1.4	-1.4	-0.29	-1.0	-0.29	-0.31
Grain/Seed Crop	0.62		0.81	0.57	0.21	1.3	-0.05	0.08
Grassland/Prairie	0.39	-1.8		-0.16	0.02	0.48	-0.14	-0.06
Hay/Pasture	0.44	-1.4	0.18		0.06	0.67	-0.12	-0.03
Shrubland	0.36	-2.0	-0.09	-0.25		0.38	-0.15	-0.08
Trees/Forest	0.26	-2.8	-0.45	-0.57	-0.08		-0.19	-0.15
Water	0.75	1.0	1.3	0.98	0.31	1.8		0.16
Wetland	0.49	-1.0	0.36	0.16	0.10	0.87	-0.10	
Total Phosphorus (TP)								
Exposed Land		-3.9	-2.2	-1.4	-0.15	-1.8	-0.15	-0.04
Grain/Seed Crop	0.49		-0.43	0.20	0.25	0.08	0.04	0.27
Grassland/Prairie	0.62	0.98		0.59	0.35	0.54	0.09	0.35
Hay/Pasture	0.43	-0.49	-0.65		0.20	-0.15	0.02	0.23
Shrubland	0.19	-2.4	-1.5	-0.79		-1.1	-0.08	0.08
Trees/Forest	0.47	-0.16	-0.51	0.13	0.23		0.03	0.26
Water	0.39	-0.81	-0.80	-0.13	0.16	-0.31		0.21
Wetland	0.06	-3.4	-2.0	-1.2	-0.10	-1.5	-0.13	

% = percent.

Table E2: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (10% Increase):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		4.9	1.4	1.4	0.29	0.96	0.29	0.31
Grain/Seed Crop	-0.62		-0.81	-0.57	-0.21	-1.4	0.05	-0.08
Grassland/Prairie	-0.39	1.8		0.16	-0.02	-0.48	0.14	0.06
Hay/Pasture	-0.44	1.4	-0.18		-0.06	-0.67	0.12	0.03
Shrubland	-0.36	2.0	0.09	0.25		-0.38	0.15	0.08
Trees/Forest	-0.26	2.8	0.45	0.57	0.08		0.19	0.15
Water	-0.75	-0.50	-1.3	-0.98	-0.31	-1.8		-0.16
Wetland	-0.49	0.81	-0.36	-0.16	-0.10	-0.87	0.10	
Total Phosphorus (TP)								
Exposed Land		3.9	2.2	1.4	0.15	1.8	0.15	0.04
Grain/Seed Crop	-0.49		0.43	-0.20	-0.25	-0.08	-0.04	-0.27
Grassland/Prairie	-0.62	-0.98		-0.59	-0.35	-0.54	-0.09	-0.35
Hay/Pasture	-0.43	0.49	0.65		-0.20	0.15	-0.02	-0.23
Shrubland	-0.19	2.4	1.5	0.79		1.1	0.08	-0.08
Trees/Forest	-0.47	0.16	0.51	-0.13	-0.23		-0.03	-0.26
Water	-0.39	0.40	0.80	0.13	-0.16	0.31		-0.21
Wetland	-0.06	2.7	2.0	1.2	0.10	1.5	0.13	

% = percent.

Table E3: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 20% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (20% Decrease):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		-9.7	-2.7	-2.8	-0.58	-1.9	-0.58	-0.61
Grain/Seed Crop	1.2		1.6	1.1	0.41	2.7	-0.10	0.16
Grassland/Prairie	0.77	-3.7		-0.33	0.04	0.96	-0.28	-0.13
Hay/Pasture	0.87	-2.8	0.36		0.12	1.4	-0.24	-0.06
Shrubland	0.72	-4.1	-0.18	-0.49		0.77	-0.30	-0.16
Trees/Forest	0.51	-5.7	-0.90	-1.1	-0.16		-0.38	-0.29
Water	1.5	2.0	2.5	2.0	0.62	3.7		0.32
Wetland	0.98	-2.0	0.72	0.33	0.21	1.7	-0.20	
Total Phosphorus (TP)								
Exposed Land		-7.8	-4.3	-2.8	-0.30	-3.6	-0.31	-0.08
Grain/Seed Crop	0.99		-0.87	0.39	0.49	0.15	0.08	0.54
Grassland/Prairie	1.2	2.0		1.2	0.69	1.1	0.18	0.70
Hay/Pasture	0.87	-0.98	-1.3		0.40	-0.31	0.03	0.47
Shrubland	0.37	-4.9	-3.0	-1.6		-2.2	-0.16	0.16
Trees/Forest	0.95	-0.33	-1.0	0.26	0.46		0.06	0.52
Water	0.78	-1.6	-1.6	-0.26	0.33	-0.62		0.41
Wetland	0.12	-6.8	-3.9	-2.4	-0.20	-3.1	-0.26	

% = percent.

Table E4: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 20% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (20% Increase):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		6.2	2.7	2.8	0.58	1.9	0.58	0.61
Grain/Seed Crop	-1.2		-1.6	-1.1	-0.41	-2.7	0.10	-0.16
Grassland/Prairie	-0.77	3.7		0.33	-0.04	-0.96	0.28	0.13
Hay/Pasture	-0.87	2.8	-0.36		-0.12	-1.4	0.24	0.06
Shrubland	-0.72	2.1	0.18	0.49		-0.77	0.30	0.16
Trees/Forest	-0.51	5.7	0.90	1.1	0.16		0.38	0.29
Water	-1.5	-0.50	-1.4	-1.2	-0.62	-1.9		-0.32
Wetland	-0.98	0.81	-0.64	-0.32	-0.21	-1.5	0.20	
Total Phosphorus (TP)								
Exposed Land		5.0	4.34	2.8	0.30	3.6	0.31	0.08
Grain/Seed Crop	-0.99		0.87	-0.39	-0.49	-0.15	-0.08	-0.54
Grassland/Prairie	-1.2	-2.0		-1.2	-0.69	-1.1	-0.18	-0.70
Hay/Pasture	-0.87	0.98	1.30		-0.40	0.31	-0.03	-0.47
Shrubland	-0.37	2.5	3.04	1.6		2.2	0.16	-0.16
Trees/Forest	-0.95	0.33	1.01	-0.26	-0.46		-0.06	-0.52
Water	-0.78	0.40	0.89	0.16	-0.33	0.32		-0.41
Wetland	-0.12	2.7	3.49	2.3	0.20	2.6	0.26	

% = percent.

Table E5: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 30% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (30% Decrease):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		-15	-4.1	-4.2	-0.86	-2.9	-0.88	-0.92
Grain/Seed Crop	1.9		2.4	1.7	0.62	4.0	-0.15	0.24
Grassland/Prairie	1.2	-5.5		-0.49	0.06	1.4	-0.42	-0.19
Hay/Pasture	1.3	-4.3	0.54		0.19	2.0	-0.36	-0.10
Shrubland	1.1	-6.1	-0.27	-0.74		1.2	-0.45	-0.24
Trees/Forest	0.77	-8.5	-1.4	-1.7	-0.25		-0.57	-0.44
Water	2.2	3.0	3.8	2.9	0.93	5.5		0.48
Wetland	1.5	-3.0	1.1	0.49	0.31	2.6	-0.30	
Total Phosphorus (TP)								
Exposed Land		-12	-6.5	-4.1	-0.45	-5.3	-0.46	-0.12
Grain/Seed Crop	1.5		-1.3	0.59	0.74	0.23	0.12	0.81
Grassland/Prairie	1.9	2.9		1.8	1.04	1.6	0.27	1.1
Hay/Pasture	1.3	-1.5	-2.0		0.59	-0.46	0.05	0.70
Shrubland	0.56	-7.3	-4.6	-2.4		-3.2	-0.24	0.23
Trees/Forest	1.4	-0.49	-1.5	0.39	0.69		0.10	0.78
Water	1.2	-2.4	-2.4	-0.39	0.49	-0.93		0.62
Wetland	0.19	-10	-5.9	-3.5	-0.30	-4.6	-0.39	

% = percent.

Table E6: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 30% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (30% Increase):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		6.2	3.9	4.2	0.86	2.6	0.88	0.92
Grain/Seed Crop	-1.9		-2.4	-1.7	-0.62	-4.0	0.15	-0.24
Grassland/Prairie	-1.2	5.5		0.49	-0.06	-1.4	0.42	0.19
Hay/Pasture	-1.3	4.3	-0.54		-0.19	-2.0	0.36	0.10
Shrubland	-1.1	2.1	0.21	0.62		-0.82	0.45	0.24
Trees/Forest	-0.77	8.5	1.4	1.7	0.25		0.57	0.44
Water	-2.2	-0.50	-1.4	-1.2	-0.93	-1.9		-0.48
Wetland	-1.5	0.81	-0.64	-0.32	-0.31	-1.5	0.30	
Total Phosphorus (TP)								
Exposed Land		4.9	6.2	4.1	0.45	4.7	0.46	0.12
Grain/Seed Crop	-1.5		1.3	-0.59	-0.74	-0.23	-0.12	-0.81
Grassland/Prairie	-1.9	-2.9		-1.8	-1.0	-1.6	-0.27	-1.1
Hay/Pasture	-1.3	1.5	2.0		-0.59	0.46	-0.05	-0.70
Shrubland	-0.56	2.5	3.5	2.0		2.3	0.24	-0.23
Trees/Forest	-1.4	0.49	1.5	-0.39	-0.69		-0.10	-0.78
Water	-1.2	0.40	0.89	0.16	-0.49	0.3		-0.62
Wetland	-0.19	2.7	3.5	2.3	0.30	2.6	0.39	

% = percent.

Table E7: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 40% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (40% Decrease):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		-20	-5.4	-5.6	-1.2	-3.8	-1.2	-1.2
Grain/Seed Crop	2.5		3.2	2.3	0.82	5.4	-0.20	0.32
Grassland/Prairie	1.5	-7.3		-0.65	0.08	1.9	-0.56	-0.26
Hay/Pasture	1.7	-5.7	0.72		0.25	2.7	-0.48	-0.13
Shrubland	1.4	-8.1	-0.36	-1.0		1.5	-0.60	-0.32
Trees/Forest	1.0	-11	-1.8	-2.3	-0.33		-0.77	-0.58
Water	3.0	4.1	5.1	3.9	1.2	7.3		0.64
Wetland	2.0	-4.1	1.4	0.65	0.41	3.5	-0.40	
Total Phosphorus (TP)								
Exposed Land		-16	-8.7	-5.5	-0.59	-7.1	-0.61	-0.16
Grain/Seed Crop	2.0		-1.7	0.79	1.0	0.31	0.16	1.1
Grassland/Prairie	2.5	3.9		2.4	1.4	2.2	0.36	1.4
Hay/Pasture	1.7	-2.0	-2.6		0.79	-0.62	0.06	0.93
Shrubland	0.7	-9.8	-6.1	-3.1		-4.3	-0.32	0.31
Trees/Forest	1.9	-0.65	-2.0	0.52	0.92		0.13	1.0
Water	1.6	-3.3	-3.2	-0.52	0.66	-1.2		0.83
Wetland	0.25	-14	-7.8	-4.7	-0.40	-6.2	-0.52	

% = percent.

Table E8: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 40% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (40% Increase):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		6.2	3.9	4.4	1.2	2.6	1.2	1.2
Grain/Seed Crop	-2.5		-3.2	-2.3	-0.82	-5.4	0.20	-0.32
Grassland/Prairie	-1.5	7.3		0.65	-0.08	-1.9	0.56	0.26
Hay/Pasture	-1.7	5.7	-0.72		-0.25	-2.7	0.48	0.13
Shrubland	-1.4	2.1	0.21	0.62		-0.82	0.60	0.32
Trees/Forest	-1.0	11	1.8	2.3	0.33		0.77	0.58
Water	-2.9	-0.50	-1.4	-1.2	-1.2	-1.9		-0.64
Wetland	-2.0	0.81	-0.65	-0.32	-0.41	-1.5	0.40	
Total Phosphorus (TP)								
Exposed Land		4.9	6.2	4.3	0.59	4.7	0.61	0.16
Grain/Seed Crop	-2.0		1.7	-0.79	-1.0	-0.31	-0.16	-1.1
Grassland/Prairie	-2.5	-3.9		-2.4	-1.4	-2.2	-0.36	-1.4
Hay/Pasture	-1.7	2.0	2.6		-0.79	0.62	-0.06	-0.93
Shrubland	-0.74	2.5	3.5	2.0		2.3	0.32	-0.31
Trees/Forest	-1.9	0.65	2.0	-0.52	-0.92		-0.13	-1.0
Water	-1.5	0.40	0.89	0.16	-0.66	0.32		-0.83
Wetland	-0.25	2.7	3.5	2.3	0.40	2.6	0.52	

% = percent.

Table E9: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 50% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (50% Decrease):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		-24	-6.8	-7.0	-1.4	-4.8	-1.5	-1.5
Grain/Seed Crop	3.1		4.1	2.9	1.0	6.7	-0.25	0.40
Grassland/Prairie	1.9	-9.1		-0.82	0.10	2.4	-0.70	-0.32
Hay/Pasture	2.2	-7.1	0.90		0.31	3.4	-0.60	-0.16
Shrubland	1.8	-10	-0.45	-1.2		1.9	-0.76	-0.40
Trees/Forest	1.3	-14	-2.3	-2.9	-0.41		-1.0	-0.73
Water	3.7	5.1	6.3	4.9	1.5	9.1		0.81
Wetland	2.4	-5.1	1.8	0.82	0.51	4.3	-0.50	
Total Phosphorus (TP)								
Exposed Land		-20	-11	-6.9	-0.74	-8.9	-0.77	-0.19
Grain/Seed Crop	2.5		-2.2	1.0	1.2	0.39	0.20	1.4
Grassland/Prairie	3.1	4.9		3.0	1.7	2.7	0.44	1.7
Hay/Pasture	2.2	-2.4	-3.3		1.0	-0.77	0.08	1.2
Shrubland	0.93	-12	-7.6	-3.9		-5.4	-0.40	0.39
Trees/Forest	2.4	-0.81	-2.5	0.66	1.2		0.16	1.3
Water	2.0	-4.1	-4.0	-0.66	0.82	-1.5		1.0
Wetland	0.31	-17	-9.8	-5.9	-0.49	-7.7	-0.65	

% = percent.

Table E10: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 50% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (50% Increase):							
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest	Water	Wetland
Total Nitrogen (TN)								
Exposed Land		6.2	3.9	4.4	1.4	2.6	1.5	1.5
Grain/Seed Crop	-3.1		-4.1	-2.9	-1.0	-6.7	0.25	-0.40
Grassland/Prairie	-1.9	8.1		0.82	-0.10	-2.4	0.70	0.32
Hay/Pasture	-2.2	5.7	-0.90		-0.31	-3.4	0.60	0.16
Shrubland	-1.8	2.1	0.21	0.62		-0.82	0.76	0.40
Trees/Forest	-1.3	14	2.3	2.9	0.41		1.0	0.73
Water	-2.9	-0.50	-1.4	-1.2	-1.5	-1.9		-0.81
Wetland	-2.4	0.81	-0.65	-0.32	-0.51	-1.5	0.50	
Total Phosphorus (TP)								
Exposed Land		4.9	6.2	4.3	0.74	4.7	0.77	0.19
Grain/Seed Crop	-2.5		2.2	-1.0	-1.2	-0.39	-0.20	-1.4
Grassland/Prairie	-3.1	-4.3		-3.0	-1.7	-2.7	-0.44	-1.7
Hay/Pasture	-2.2	2.0	3.3		-1.0	0.77	-0.08	-1.2
Shrubland	-0.93	2.5	3.5	2.0		3.9	0.40	-0.39
Trees/Forest	-2.4	0.77	2.5	-0.66	-1.2		-0.16	-1.3
Water	-1.5	0.40	0.89	0.16	-0.81	0.32		-1.0
Wetland	-0.31	2.7	3.5	2.3	0.49	2.6	0.65	

% = percent.

Table E11: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (10% Decrease):				
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Trees/ Forest
Total Nitrogen (TN)					
Exposed Land		-6.1	-1.6	-0.81	-0.92
Grain/Seed Crop	0.54		1.1	0.58	1.5
Grassland/Prairie	0.32	-2.6		0	0.51
Hay/Pasture	0.32	-2.6	0		0.51
Trees/Forest	0.20	-3.8	-0.57	-0.29	
Total Phosphorus (TP)					
Exposed Land		-4.9	-2.5	-0.53	-1.7
Grain/Seed Crop	0.43		-0.28	0.58	0.25
Grassland/Prairie	0.49	0.64		0.72	0.51
Hay/Pasture	0.21	-2.5	-1.4		-0.76
Trees/Forest	0.38	-0.64	-0.57	0.43	

% = percent.

Table E12: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (10% Increase):				
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Trees/ Forest
Total Nitrogen (TN)					
Exposed Land		5.4	1.6	0.81	0.92
Grain/Seed Crop	-0.54		-1.1	-0.58	-1.5
Grassland/Prairie	-0.32	2.6		0	-0.51
Hay/Pasture	-0.32	2.6	0		-0.51
Trees/Forest	-0.20	3.8	0.57	0.29	
Total Phosphorus (TP)					
Exposed Land		4.4	2.5	0.53	1.7
Grain/Seed Crop	-0.43		0.28	-0.58	-0.25
Grassland/Prairie	-0.49	-0.64		-0.72	-0.51
Hay/Pasture	-0.21	2.5	1.4		0.76
Trees/Forest	-0.38	0.64	0.57	-0.43	

% = percent.

Table E13: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 20% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (20% Decrease):				
	Exposed Land	**Grain/ Seed Crop**	**Grassland/ Prairie**	**Hay/ Pasture**	**Trees/ Forest**
Total Nitrogen (TN)					
Exposed Land		-12	-3.2	-1.6	-1.8
Grain/Seed Crop	1.1		2.3	1.2	3.1
Grassland/Prairie	0.64	-5.1		0.	1.0
Hay/Pasture	0.64	-5.1	0		1.0
Trees/Forest	0.41	-7.7	-1.1	-0.58	
Total Phosphorus (TP)					
Exposed Land		-9.8	-4.9	-1.1	-3.4
Grain/Seed Crop	0.87		-0.57	1.2	0.51
Grassland/Prairie	0.98	1.3		1.4	1.0
Hay/Pasture	0.42	-5.1	-2.8		-1.5
Trees/Forest	0.76	-1.3	-1.1	0.86	

% = percent.

Table E14: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 20% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (20% Increase):				
	Exposed Land	**Grain/ Seed Crop**	**Grassland/ Prairie**	**Hay/ Pasture**	**Trees/ Forest**
Total Nitrogen (TN)					
Exposed Land		5.4	3.2	1.6	1.8
Grain/Seed Crop	-1.1		-2.3	-1.2	-3.1
Grassland/Prairie	-0.64	5.1		0	-1.0
Hay/Pasture	-0.64	5.1	0		-1.0
Trees/Forest	-0.41	7.7	1.1	0.58	
Total Phosphorus (TP)					
Exposed Land		4.4	4.9	1.1	3.4
Grain/Seed Crop	-0.87		0.57	-1.2	-0.51
Grassland/Prairie	-0.98	-1.3		-1.4	-1.0
Hay/Pasture	-0.42	5.1	2.8		1.5
Trees/Forest	-0.76	1.3	1.1	-0.86	

% = percent.

Table E15: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 30% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (30% Decrease):				
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Trees/ Forest
Total Nitrogen (TN)					
Exposed Land		-18	-4.8	-2.4	-2.8
Grain/Seed Crop	1.6		3.4	1.7	4.6
Grassland/Prairie	0.95	-7.7		0	1.5
Hay/Pasture	0.95	-7.7	0		1.5
Trees/Forest	0.61	-11	-1.7	-0.87	
Total Phosphorus (TP)					
Exposed Land		-15	-7.4	-1.6	-5.1
Grain/Seed Crop	1.3		-0.85	1.7	0.76
Grassland/Prairie	1.5	1.9		2.2	1.5
Hay/Pasture	0.63	-7.6	-4.3		-2.3
Trees/Forest	1.1	-1.9	-1.7	1.3	

% = percent.

Table E16: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 30% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (30% Increase):				
	Exposed Land	**Grain/ Seed Crop**	**Grassland/ Prairie**	**Hay/ Pasture**	**Trees/ Forest**
Total Nitrogen (TN)					
Exposed Land		5.4	3.2	2.4	2.0
Grain/Seed Crop	-1.6		-3.4	-1.7	-4.6
Grassland/Prairie	-0.95	7.7		0	-1.5
Hay/Pasture	-0.95	5.8	0		-1.5
Trees/Forest	-0.61	11	1.7	0.87	
Total Phosphorus (TP)					
Exposed Land		4.4	4.9	1.6	3.8
Grain/Seed Crop	-1.3		0.85	-1.7	-0.76
Grassland/Prairie	-1.5	-1.9		-2.2	-1.5
Hay/Pasture	-0.63	5.8	4.3		2.3
Trees/Forest	-1.1	1.9	1.7	-1.3	

% = percent.

Table E17: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 40% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (40% Decrease):				
	Exposed Land	**Grain/ Seed Crop**	**Grassland/ Prairie**	**Hay/ Pasture**	**Trees/ Forest**
Total Nitrogen (TN)					
Exposed Land		-25	-6.4	-3.2	-3.7
Grain/Seed Crop	2.2		4.6	2.3	6.1
Grassland/Prairie	1.3	-10		0	2.0
Hay/Pasture	1.3	-10	0		2.0
Trees/Forest	0.82	-15	-2.3	-1.2	
Total Phosphorus (TP)					
Exposed Land		-20	-9.9	-2.1	-6.8
Grain/Seed Crop	1.7		-1.1	2.3	1.0
Grassland/Prairie	2.0	2.5		2.9	2.0
Hay/Pasture	0.84	-10	-5.7		-3.0
Trees/Forest	1.5	-2.5	-2.3	1.7	

% = percent.

Table E18: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 40% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (40% Increase):				
	Exposed Land	**Grain/ Seed Crop**	**Grassland/ Prairie**	**Hay/ Pasture**	**Trees/ Forest**
Total Nitrogen (TN)					
Exposed Land		5.4	3.2	3.2	2.0
Grain/Seed Crop	-2.2		-4.6	-2.3	-6.1
Grassland/Prairie	-1.3	10		0	-2.0
Hay/Pasture	-1.3	5.8	0		-2.0
Trees/Forest	-0.82	15	2.3	1.2	
Total Phosphorus (TP)					
Exposed Land		4.4	4.9	2.1	3.8
Grain/Seed Crop	-1.7		1.1	-2.3	-1.0
Grassland/Prairie	-2.0	-2.5		-2.9	-2.0
Hay/Pasture	-0.84	5.8	5.7		3.0
Trees/Forest	-1.5	2.5	2.3	-1.7	

% = percent.

Table E19: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 50% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (50% Decrease):				
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Trees/ Forest
Total Nitrogen (TN)					
Exposed Land		-31	-8.0	-4.1	-4.6
Grain/Seed Crop	2.7		5.7	2.9	7.7
Grassland/Prairie	1.6	-13		0	2.6
Hay/Pasture	1.6	-13	0		2.6
Trees/Forest	1.0	-19	-2.9	-1.5	
Total Phosphorus (TP)					
Exposed Land		-24	-12	-2.7	-8.5
Grain/Seed Crop	2.2		-1.4	2.9	1.3
Grassland/Prairie	2.5	3.2		3.6	2.5
Hay/Pasture	1.0	-13	-7.1		-3.8
Trees/Forest	1.9	-3.2	-2.8	2.2	

% = percent.

Table E20: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 50% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (50% Increase):				
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Trees/ Forest
Total Nitrogen (TN)					
Exposed Land		5.4	4.9	4.0	3.1
Grain/Seed Crop	-2.7		-5.7	-2.9	-7.7
Grassland/Prairie	-1.6	11		0	-2.6
Hay/Pasture	-1.6	5.8	0		-2.6
Trees/Forest	-1.0	15	2.9	1.5	
Total Phosphorus (TP)					
Exposed Land		4.5	4.9	2.1	3.8
Grain/Seed Crop	-2.2		1.4	-2.9	-1.3
Grassland/Prairie	-2.5	-2.8		-3.6	-2.5
Hay/Pasture	-1.0	5.8	7.1		3.8
Trees/Forest	-1.9	2.5	2.8	-2.2	

% = percent.

Table E21: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10% Decrease in Individual Land Cover Types, 2012

Converted to:	Converted from (10% Decrease):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		-5.7	-1.3	-1.2	-0.33	-1.0
Grain/Seed Crop	0.64		0.88	0.48	0.22	1.4
Grassland/Prairie	0.38	-2.3		-0.19	0	0.42
Hay/Pasture	0.46	-1.6	0.25		0.06	0.69
Shrubland	0.38	-2.3	0	-0.19		0.42
Trees/Forest	0.27	-3.3	-0.38	-0.48	-0.09	
Total Phosphorus (TP)						
Exposed Land		-4.5	-2.1	-1.0	-0.16	-1.8
Grain/Seed Crop	0.51		-0.43	0.27	0.27	0.08
Grassland/Prairie	0.63	1.1		0.59	0.38	0.55
Hay/Pasture	0.40	-0.93	-0.78		0.18	-0.31
Shrubland	0.19	-2.8	-1.5	-0.54		-1.1
Trees/Forest	0.48	-0.19	-0.50	0.22	0.25	

% = percent.

Table E22: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 10% Increase in Individual Land Cover Types, 2012

Converted from:	Converted to (10% Increase):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		5.7	1.3	1.2	0.33	1.0
Grain/Seed Crop	-0.64		-0.88	-0.48	-0.22	-1.4
Grassland/Prairie	-0.38	2.3		0.19	0	-0.42
Hay/Pasture	-0.46	1.6	-0.25		-0.06	-0.69
Shrubland	-0.38	2.2	0	0.19		-0.42
Trees/Forest	-0.27	3.3	0.38	0.48	0.09	
Total Phosphorus (TP)						
Exposed Land		4.5	2.1	1.0	0.16	1.8
Grain/Seed Crop	-0.51		0.43	-0.27	-0.27	-0.08
Grassland/Prairie	-0.63	-1.1		-0.59	-0.38	-0.55
Hay/Pasture	-0.40	0.93	0.78		-0.18	0.31
Shrubland	-0.19	2.69	1.49	0.54		1.1
Trees/Forest	-0.48	0.19	0.50	-0.22	-0.25	

% = percent.

Table E23: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 20% Decrease in Individual Land Cover Types, 2012

Converted to:	Converted from (20% Decrease):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		-11	-2.6	-2.3	-0.65	-2.0
Grain/Seed Crop	1.3		1.8	0.95	0.44	2.8
Grassland/Prairie	0.77	-4.6		-0.38	0	0.83
Hay/Pasture	0.92	-3.3	0.50		0.13	1.4
Shrubland	0.77	-4.6	0	-0.38		0.83
Trees/Forest	0.54	-6.6	-0.75	-0.95	-0.19	
Total Phosphorus (TP)						
Exposed Land		-8.9	-4.3	-2.0	-0.32	-3.6
Grain/Seed Crop	1.0		-0.85	0.54	0.54	0.16
Grassland/Prairie	1.3	2.2		1.2	0.75	1.1
Hay/Pasture	0.80	-1.9	-1.6		0.36	-0.63
Shrubland	0.38	-5.6	-3.0	-1.1		-2.2
Trees/Forest	0.97	-0.37	-0.99	0.43	0.50	

% = percent.

Table E24: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 20% Increase in Individual Land Cover Types, 2012

Converted from:	Converted to (20% Increase):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		6.4	2.6	2.3	0.65	2.0
Grain/Seed Crop	-1.3		-1.8	-0.95	-0.44	-2.8
Grassland/Prairie	-0.77	4.6		0.38	0	-0.83
Hay/Pasture	-0.92	3.3	-0.50		-0.13	-1.4
Shrubland	-0.77	2.2	0	0.38		-0.83
Trees/Forest	-0.54	6.6	0.75	0.95	0.19	
Total Phosphorus (TP)						
Exposed Land		5.1	4.3	2.1	0.32	3.6
Grain/Seed Crop	-1.0		0.85	-0.54	-0.54	-0.16
Grassland/Prairie	-1.3	-2.2		-1.2	-0.75	-1.1
Hay/Pasture	-0.80	1.9	1.6		-0.36	0.63
Shrubland	-0.38	2.7	3.0	1.1		2.2
Trees/Forest	-0.97	0.37	0.99	-0.43	-0.50	

% = percent.

Table E25: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 30% Decrease in Individual Land Cover Types, 2012

Converted to:	Converted from (30% Decrease):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		-17	-3.9	-3.5	-0.98	-3.0
Grain/Seed Crop	1.9		2.6	1.4	0.66	4.2
Grassland/Prairie	1.2	-6.9		-0.57	0	1.3
Hay/Pasture	1.4	-4.9	0.75		0.19	2.1
Shrubland	1.2	-6.9	0	-0.57		1.3
Trees/Forest	0.81	-9.8	-1.1	-1.4	-0.28	
Total Phosphorus (TP)						
Exposed Land		-13	-6.4	-3.1	-0.48	-5.4
Grain/Seed Crop	1.5		-1.3	0.81	0.81	0.24
Grassland/Prairie	1.9	3.3		1.8	1.1	1.7
Hay/Pasture	1.2	-2.8	-2.3		0.54	-0.94
Shrubland	0.57	-8.4	-4.5	-1.6		-3.3
Trees/Forest	1.5	-0.56	-1.5	0.65	0.75	

% = percent.

Table E26: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 30% Increase in Individual Land Cover Types, 2012

Converted from:	Converted to (30% Increase):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		6.4	3.8	3.5	0.98	2.7
Grain/Seed Crop	-1.9		-2.6	-1.4	-0.66	-4.2
Grassland/Prairie	-1.2	6.9		0.57	0	-1.3
Hay/Pasture	-1.4	4.8	-0.75		-0.19	-2.1
Shrubland	-1.2	2.2	0	0.57		-0.95
Trees/Forest	-0.81	9.8	1.1	1.4	0.28	
Total Phosphorus (TP)						
Exposed Land		5.1	6.4	3.1	0.48	4.9
Grain/Seed Crop	-1.5		1.3	-0.81	-0.81	-0.24
Grassland/Prairie	-1.9	-3.3		-1.8	-1.1	-1.7
Hay/Pasture	-1.2	2.7	2.3		-0.54	0.94
Shrubland	-0.57	2.7	3.8	1.6		2.51
Trees/Forest	-1.5	0.56	1.5	-0.65	-0.75	

% = percent.

Table E27: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 40% Decrease in Individual Land Cover Types, 2012

Converted to:	Converted from (40% Decrease):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		-23	-5.2	-4.7	-1.3	-4.1
Grain/Seed Crop	2.6		3.5	1.9	0.89	5.5
Grassland/Prairie	1.5	-9.2		-0.76	0	1.7
Hay/Pasture	1.8	-6.6	1.0		0.25	2.8
Shrubland	1.5	-9.2	0	-0.76		1.7
Trees/Forest	1.1	-13	-1.5	-1.9	-0.38	
Total Phosphorus (TP)						
Exposed Land		-18	-8.5	-4.1	-0.64	-7.2
Grain/Seed Crop	2.0		-1.7	1.1	1.1	0.31
Grassland/Prairie	2.5	4.5		2.4	1.50	2.2
Hay/Pasture	1.6	-3.7	-3.1		0.72	-1.3
Shrubland	0.76	-11	-6.0	-2.2		-4.4
Trees/Forest	1.9	-0.74	-2.0	0.86	1.0	

% = percent.

Table E28: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 40% Increase in Individual Land Cover Types, 2012

Converted from:	Converted to (40% Increase):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		6.4	3.8	4.6	1.3	2.7
Grain/Seed Crop	-2.6		-3.5	-1.9	-0.89	-5.5
Grassland/Prairie	-1.5	8.8		0.76	0	-1.7
Hay/Pasture	-1.8	4.8	-1.0		-0.25	-2.8
Shrubland	-1.5	2.2	0	0.63		-0.95
Trees/Forest	-1.09	13	1.5	1.9	0.38	
Total Phosphorus (TP)						
Exposed Land		5.1	6.3	4.0	0.64	4.9
Grain/Seed Crop	-2.0		1.7	-1.1	-1.1	-0.31
Grassland/Prairie	-2.5	-4.3		-2.4	-1.5	-2.2
Hay/Pasture	-1.6	2.7	3.1		-0.72	1.3
Shrubland	-0.76	2.7	3.7	1.8		2.5
Trees/Forest	-1.9	0.74	2.0	-0.86	-1.0	

% = percent

Table E29: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 50% Decrease in Individual Land Cover Types, 2012

Converted to:	Converted from (50% Decrease):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		-28	-6.5	-5.9	-1.6	-5.1
Grain/Seed Crop	3.2		4.4	2.4	1.1	6.9
Grassland/Prairie	1.9	-11		-0.95	0	2.1
Hay/Pasture	2.3	-8.2	1.3		0.32	3.5
Shrubland	1.9	-11	0	-0.95		2.1
Trees/Forest	1.4	-16	-1.9	-2.4	-0.47	
Total Phosphorus (TP)						
Exposed Land		-22	-11	-5.1	-0.81	-9.0
Grain/Seed Crop	2.5		-2.1	1.4	1.3	0.39
Grassland/Prairie	3.2	5.6		3.0	1.9	2.7
Hay/Pasture	2.0	-4.6	-3.9		0.90	-1.6
Shrubland	0.95	-14	-7.5	-2.7		-5.5
Trees/Forest	2.4	-0.93	-2.5	1.1	1.3	

% = percent.

Table E30: Percent (%) Change in Calculated Nutrient Loads in the Red Deer River Near Bindloss, Based on a 50% Increase in Individual Land Cover Types, 2012

Converted from:	Converted to (50% Increase):					
	Exposed Land	Grain/ Seed Crop	Grassland/ Prairie	Hay/ Pasture	Shrubland	Trees/ Forest
Total Nitrogen (TN)						
Exposed Land		6.4	3.8	4.6	1.6	2.7
Grain/Seed Crop	-3.2		-4.4	-2.4	-1.1	-6.9
Grassland/Prairie	-1.9	8.8		0.95	0	-2.1
Hay/Pasture	-2.3	4.8	-1.3		-0.32	-3.5
Shrubland	-1.9	2.2	0	0.63		-0.95
Trees/Forest	-1.4	14	1.9	2.4	0.47	
Total Phosphorus (TP)						
Exposed Land		5.1	6.3	4.0	0.81	4.9
Grain/Seed Crop	-2.5		2.1	-1.4	-1.3	-0.39
Grassland/Prairie	-3.2	-4.3		-3.0	-1.9	-2.7
Hay/Pasture	-2.0	2.7	3.9		-0.90	1.6
Shrubland	-0.95	2.7	3.8	1.8		2.5
Trees/Forest	-2.4	0.78	2.5	-1.1	-1.3	

% = percent

CARROT RIVER

Table E31: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 10% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (10% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.20	-0.08	0.37	-0.51
Hay/Pasture	2.1		0.10	1.7	-0.14
Shrubland	0.95	-0.11		0.99	-0.34
Trees/Forest	-0.57	-0.25	-0.13		-0.61
Wetland	2.9	0.07	0.16	2.2	
Total Phosphorus (TP)					
Grain/Seed Crop		-0.35	0.11	0.27	0.66
Hay/Pasture	3.7		0.42	2.66	1.3
Shrubland	-1.2	-0.46		-0.53	0.44
Trees/Forest	-0.41	-0.38	0.07		0.58
Wetland	-3.7	-0.69	-0.21	-2.1	

% = percent.

Table E32: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 10% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (10% Increase):				
	Grain/Seed Crop	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		0.20	0.08	-0.37	0.51
Hay/Pasture	-2.0		-0.10	-1.7	0.14
Shrubland	-0.82	0.11		-0.99	0.34
Trees/Forest	0.57	0.25	0.13		0.61
Wetland	-2.9	-0.07	-0.16	-2.2	
Total Phosphorus (TP)					
Grain/Seed Crop		0.35	-0.11	-0.27	-0.66
Hay/Pasture	-3.5		-0.42	-2.7	-1.3
Shrubland	1.1	0.46		0.53	-0.44
Trees/Forest	0.41	0.38	-0.07		-0.58
Wetland	3.7	0.69	0.21	2.1	

% = percent.

Table E33: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 20% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (20% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.39	-0.16	0.75	-1.0
Hay/Pasture	4.2		0.20	3.48	-0.27
Shrubland	1.9	-0.21		2.0	-0.68
Trees/Forest	-1.2	-0.50	-0.26		-1.2
Wetland	5.7	0.14	0.33	4.5	
Total Phosphorus (TP)					
Grain/Seed Crop		-0.69	0.21	0.53	1.3
Hay/Pasture	7.4		0.84	5.32	2.6
Shrubland	-2.5	-0.92		-1.1	0.87
Trees/Forest	-0.82	-0.77	0.14		1.2
Wetland	-7.4	-1.4	-0.42	-4.3	

% = percent.

Table E34: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 20% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (20% Increase):				
	Grain/Seed Crop	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		0.39	0.16	-0.75	1.0
Hay/Pasture	-2.0		-0.20	-2.51	0.27
Shrubland	-0.82	0.21		-1.3	0.68
Trees/Forest	1.2	0.50	0.26		1.2
Wetland	-5.1	-0.14	-0.33	-4.5	
Total Phosphorus (TP)					
Grain/Seed Crop		0.69	-0.21	-0.53	-1.3
Hay/Pasture	-3.5		-0.84	-3.84	-2.6
Shrubland	1.1	0.92		0.70	-0.87
Trees/Forest	0.82	0.77	-0.14		-1.2
Wetland	6.6	1.4	0.42	4.3	

% = percent.

Table E35: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 30% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (30% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.59	-0.25	1.1	-1.5
Hay/Pasture	6.3		0.29	5.2	-0.41
Shrubland	2.9	-0.32		3.0	-1.0
Trees/Forest	-1.7	-0.75	-0.39		-1.8
Wetland	8.6	0.21	0.49	6.7	
Total Phosphorus (TP)					
Grain/Seed Crop		-1.0	0.32	0.80	2.0
Hay/Pasture	11		1.3	8.0	3.9
Shrubland	-3.7	-1.4		-1.6	1.3
Trees/Forest	-1.2	-1.2	0.21		1.8
Wetland	-11	-2.1	-0.63	-6.4	

% = percent.

Table E36: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 30% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (30% Increase):				
	Grain/Seed Crop	**Hay/Pasture**	**Shrubland**	**Trees/Forest**	**Wetland**
Total Nitrogen (TN)					
Grain/Seed Crop		0.59	0.25	-1.1	1.5
Hay/Pasture	-2.0		-0.29	-2.5	0.41
Shrubland	-0.82	0.32		-1.3	1.0
Trees/Forest	1.7	0.75	0.39		1.8
Wetland	-5.1	-0.21	-0.49	-6.1	
Total Phosphorus (TP)					
Grain/Seed Crop		1.0	-0.32	-0.80	-2.0
Hay/Pasture	-3.5		-1.3	-3.84	-3.9
Shrubland	1.1	1.4		0.70	-1.3
Trees/Forest	1.2	1.2	-0.21		-1.8
Wetland	6.6	2.1	0.63	5.8	

% = percent.

Table E37: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 40% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (40% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.79	-0.33	1.5	-2.0
Hay/Pasture	8.4		0.39	7.0	-0.54
Shrubland	3.8	-0.43		4.0	-1.4
Trees/Forest	-2.3	-1.0	-0.52		-2.5
Wetland	11	0.29	0.65	8.9	
Total Phosphorus (TP)					
Grain/Seed Crop		-1.4	0.42	1.1	2.6
Hay/Pasture	15		1.7	11	5.3
Shrubland	-4.9	-1.8		-2.1	1.8
Trees/Forest	-1.6	-1.5	0.28		2.3
Wetland	-15	-2.8	-0.84	-8.5	

% = percent.

Table E38: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 40% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (40% Increase):				
	Grain/Seed Crop	**Hay/Pasture**	**Shrubland**	**Trees/Forest**	**Wetland**
Total Nitrogen (TN)					
Grain/Seed Crop		0.79	0.33	-1.5	2.0
Hay/Pasture	-2.0		-0.39	-2.5	0.54
Shrubland	-0.82	0.43		-1.3	1.4
Trees/Forest	2.3	1.0	0.52		2.5
Wetland	-5.1	-0.29	-0.65	-6.1	
Total Phosphorus (TP)					
Grain/Seed Crop		1.4	-0.42	-1.1	-2.6
Hay/Pasture	-3.5		-1.7	-3.8	-5.3
Shrubland	1.1	1.8		0.70	-1.8
Trees/Forest	1.6	1.5	-0.28		-2.3
Wetland	6.6	2.8	0.84	5.8	

% = percent.

Table E39: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 50% Decrease in Individual Land Cover Types, 2013

Converted to:	Converted from (50% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.99	-0.41	1.9	-2.6
Hay/Pasture	11		0.49	8.7	-0.68
Shrubland	4.8	-0.54		5.0	-1.7
Trees/Forest	-2.9	-1.3	-0.65		-3.1
Wetland	14	0.36	0.82	11	
Total Phosphorus (TP)					
Grain/Seed Crop		-1.7	0.53	1.3	3.3
Hay/Pasture	18		2.1	13	6.6
Shrubland	-6.1	-2.3		-2.7	2.2
Trees/Forest	-2.1	-1.9	0.35		2.9
Wetland	-18	-3.5	-1.1	-11	

% = percent.

Table E40: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 50% Increase in Individual Land Cover Types, 2013

Converted from:	Converted to (50% Increase):				
	Grain/Seed Crop	Hay/Pasture	Shrubland	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		0.99	0.41	-1.9	2.6
Hay/Pasture	-2.0		-0.49	-2.5	0.68
Shrubland	-0.82	0.54		-1.3	1.6
Trees/Forest	2.9	1.3	0.65		3.1
Wetland	-5.1	-0.36	-0.82	-6.1	
Total Phosphorus (TP)					
Grain/Seed Crop		1.7	-0.53	-1.3	-3.3
Hay/Pasture	-3.5		-2.1	-3.8	-6.6
Shrubland	1.1	2.3		0.70	-2.1
Trees/Forest	2.1	1.9	-0.35		-2.9
Wetland	6.6	3.5	1.1	5.8	

% = percent.

Table E41: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 10% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (10% Decrease):			
	Grain/Seed Crop	Hay/Pasture	Trees/Forest	Wetland
Total Nitrogen (TN)				
Grain/Seed Crop		1.9	-0.91	-0.96
Hay/Pasture	2.6		0.91	-0.48
Trees/Forest	1.3	-0.17		-0.72
Wetland	5.1	0.34	2.7	
Total Phosphorus (TP)				
Grain/Seed Crop		-0.52	0.42	0.39
Hay/Pasture	3.9		3.2	1.1
Trees/Forest	-0.60	-0.60		0.28
Wetland	-2.1	-0.80	-1.1	

% = percent.

Table E42: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 10% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (10% Increase):			
	Grain/Seed Crop	Hay/Pasture	Trees/Forest	Wetland
Total Nitrogen (TN)				
Grain/Seed Crop		0.34	0.91	0.96
Hay/Pasture	-2.6		2.4	0.48
Trees/Forest	-1.3	0.17		0.72
Wetland	-5.1	-0.34	-2.7	
Total Phosphorus (TP)				
Grain/Seed Crop		0.52	-0.42	-0.39
Hay/Pasture	-3.9		1.5	-1.1
Trees/Forest	0.60	0.60		-0.28
Wetland	2.1	0.80	1.1	

% = percent.

Table E43: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 20% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (20% Decrease):			
	Grain/Seed Crop	Hay/Pasture	Trees/Forest	Wetland
Total Nitrogen (TN)				
Grain/Seed Crop		3.7	-1.8	-1.9
Hay/Pasture	5.1		1.8	-0.96
Trees/Forest	2.6	-0.34		-1.4
Wetland	10	0.69	5.4	
Total Phosphorus (TP)				
Grain/Seed Crop		-1.1	0.84	0.78
Hay/Pasture	7.8		6.3	2.2
Trees/Forest	-1.2	-1.2		0.56
Wetland	-4.2	-1.6	-2.1	

% = percent.

Table E44: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 20% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (20% Increase):			
	Grain/Seed Crop	**Hay/Pasture**	**Trees/Forest**	**Wetland**
Total Nitrogen (TN)				
Grain/Seed Crop		0.69	1.8	1.9
Hay/Pasture	-3.5		4.9	0.96
Trees/Forest	-2.6	0.34		1.4
Wetland	-9.6	-0.69	-5.4	
Total Phosphorus (TP)				
Grain/Seed Crop		1.1	-0.84	-0.78
Hay/Pasture	-5.2		3.0	-2.2
Trees/Forest	1.2	1.2		-0.56
Wetland	3.9	1.6	2.1	

% = percent.

Table E45: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 30% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (30% Decrease):			
	Grain/Seed Crop	Hay/Pasture	Trees/Forest	Wetland
Total Nitrogen (TN)				
Grain/Seed Crop		5.6	-2.7	-2.9
Hay/Pasture	7.7		2.7	-1.4
Trees/Forest	3.8	-0.52		-2.2
Wetland	15	1.0	8.2	
Total Phosphorus (TP)				
Grain/Seed Crop		-1.6	1.3	1.2
Hay/Pasture	12		9.5	3.4
Trees/Forest	-1.8	-1.8		0.84
Wetland	-6.3	-2.4	-3.0	

% = percent.

Table E46: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 2030% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (30% Increase):			
	Grain/Seed Crop	**Hay/Pasture**	**Trees/Forest**	**Wetland**
Total Nitrogen (TN)				
Grain/Seed Crop		1.0	2.7	2.9
Hay/Pasture	-3.5		7.3	1.4
Trees/Forest	-3.8	0.52		2.2
Wetland	-9.6	-1.0	-7.2	
Total Phosphorus (TP)				
Grain/Seed Crop		1.6	-1.3	-1.2
Hay/Pasture	-5.2		4.5	-3.4
Trees/Forest	1.8	1.8		-0.84
Wetland	3.9	2.4	2.8	

% = percent.

Table E47: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 40% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (40% Decrease):			
	Grain/Seed Crop	Hay/Pasture	Trees/Forest	Wetland
Total Nitrogen (TN)				
Grain/Seed Crop		7.4	-3.6	-3.8
Hay/Pasture	10		3.6	-1.9
Trees/Forest	5.1	-0.69		-2.9
Wetland	20	1.4	11	
Total Phosphorus (TP)				
Grain/Seed Crop		-2.1	1.7	1.6
Hay/Pasture	16		13	4.5
Trees/Forest	-2.4	-2.4		1.1
Wetland	-8.4	-3.2	-4.2	

% = percent.

Table E48: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 40% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (40% Increase):			
	Grain/Seed Crop	Hay/Pasture	Trees/Forest	Wetland
Total Nitrogen (TN)				
Grain/Seed Crop		1.4	3.6	3.8
Hay/Pasture	-3.5		9.7	1.9
Trees/Forest	-5.1	0.69		2.9
Wetland	-9.6	-1.4	-7.2	
Total Phosphorus (TP)				
Grain/Seed Crop		2.1	-1.7	-1.6
Hay/Pasture	-5.2		6.0	-4.5
Trees/Forest	2.4	2.4		-1.1
Wetland	3.9	3.2	2.8	

% = percent.

Table E49: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 50% Decrease in Individual Land Cover Types, 2009

Converted to:	Converted from (50% Decrease):			
	Grain/Seed Crop	Hay/Pasture	Trees/Forest	Wetland
Total Nitrogen (TN)				
Grain/Seed Crop		9.3	-4.5	-4.8
Hay/Pasture	13		4.5	-2.4
Trees/Forest	6.4	-0.86		-3.6
Wetland	26	1.7	14	
Total Phosphorus (TP)				
Grain/Seed Crop		-2.6	2.1	2.0
Hay/Pasture	19		16	5.6
Trees/Forest	-3.0	-3.0		1.4
Wetland	-10	-4.0	-5.3	

% = percent.

Table E50: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 50% Increase in Individual Land Cover Types, 2009

Converted from:	Converted to (50% Increase):			
	Grain/Seed Crop	Hay/Pasture	Trees/Forest	Wetland
Total Nitrogen (TN)				
Grain/Seed Crop		1.7	4.5	4.8
Hay/Pasture	-3.5		12	2.4
Trees/Forest	-6.4	0.86		3.6
Wetland	-9.6	-1.7	-7.2	
Total Phosphorus (TP)				
Grain/Seed Crop		2.6	-2.1	-2.0
Hay/Pasture	-5.2		7.5	-5.6
Trees/Forest	3.0	3.0		-1.4
Wetland	3.9	4.0	2.8	

% = percent.

Table E51: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 10% Decrease in Individual Land Cover Types, 2010

Converted to:	Converted from (10% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.23	-0.43	0.38	-0.46
Hay/Pasture	1.1		0.57	1.7	-0.10
Too Wet for Seeding	0.48	-0.13		0.96	-0.31
Trees/Forest	-0.32	-0.30	-0.71		-0.56
Wetland	1.4	0.07	0.86	2.1	
Total Phosphorus (TP)					
Grain/Seed Crop		-0.27	-0.23	0.78	0.59
Hay/Pasture	1.3		0.93	2.4	1.0
Too Wet for Seeding	0.26	-0.22		1.1	0.67
Trees/Forest	-0.65	-0.41	-0.82		0.38
Wetland	-1.8	-0.66	-1.9	-1.4	

% = percent.

Table E52: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 10% Increase in Individual Land Cover Types, 2010

Converted from:	Converted to (10% Increase):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		0.23	0.43	-0.38	0.46
Hay/Pasture	-1.1		-0.57	1.5	0.10
Too Wet for Seeding	-0.48	0.13		-0.96	0.31
Trees/Forest	0.32	0.30	0.71		0.56
Wetland	-1.4	-0.07	-0.86	-2.1	
Total Phosphorus (TP)					
Grain/Seed Crop		0.27	0.23	-0.78	-0.59
Hay/Pasture	-1.3		-0.93	1.4	-1.0
Too Wet for Seeding	-0.26	0.22		-1.1	-0.67
Trees/Forest	0.65	0.41	0.82		-0.38
Wetland	1.8	0.66	1.9	1.4	

% = percent.

Table E53: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 20% Decrease in Individual Land Cover Types, 2010

Converted to:	Converted from (20% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.47	-0.86	0.77	-0.92
Hay/Pasture	2.2		1.1	3.5	-0.21
Too Wet for Seeding	0.96	-0.27		1.9	-0.62
Trees/Forest	-0.64	-0.60	-1.4		-1.1
Wetland	2.9	0.13	1.7	4.2	
Total Phosphorus (TP)					
Grain/Seed Crop		-0.55	-0.47	1.6	1.2
Hay/Pasture	2.6		1.9	4.7	2.0
Too Wet for Seeding	0.52	-0.44		2.2	1.3
Trees/Forest	-1.3	-0.82	-1.6		0.75
Wetland	-3.6	-1.3	-3.7	-2.8	

% = percent.

Table E54: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 20% Increase in Individual Land Cover Types, 2010

Converted from:	Converted to (20% Increase):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		0.47	0.86	-0.77	0.92
Hay/Pasture	-2.2		-1.1	3.0	0.21
Too Wet for Seeding	-0.96	0.27		-1.9	0.62
Trees/Forest	0.64	0.60	1.4		1.1
Wetland	-2.9	-0.13	-1.7	-4.2	
Total Phosphorus (TP)					
Grain/Seed Crop		0.55	0.47	-1.6	-1.2
Hay/Pasture	-2.6		-1.9	2.9	-2.0
Too Wet for Seeding	-0.52	0.44		-2.2	-1.3
Trees/Forest	1.3	0.82	1.6		-0.75
Wetland	3.6	1.3	3.7	2.8	

% = percent.

Table E55: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 30% Decrease in Individual Land Cover Types, 2010

Converted to:	Converted from (30% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.70	-1.3	1.2	-1.4
Hay/Pasture	3.4		1.7	5.2	-0.31
Too Wet for Seeding	1.4	-0.40		2.9	-0.92
Trees/Forest	-0.96	-0.90	-2.1		-1.7
Wetland	4.3	0.20	2.6	6.3	
Total Phosphorus (TP)					
Grain/Seed Crop		-0.82	-0.70	2.4	1.8
Hay/Pasture	3.9		2.8	7.0	3.0
Too Wet for Seeding	0.78	-0.66		3.3	2.0
Trees/Forest	-2.0	-1.2	-2.5		1.1
Wetland	-5.5	-2.0	-5.6	-4.2	

% = percent.

Table E56: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 30% Increase in Individual Land Cover Types, 2010

Converted from:	Converted to (30% Increase):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		0.70	1.3	-1.2	1.4
Hay/Pasture	-2.3		-1.3	4.5	0.31
Too Wet for Seeding	-1.4	0.40		-2.9	0.92
Trees/Forest	0.96	0.90	2.1		1.7
Wetland	-4.3	-0.20	-2.6	-5.6	
Total Phosphorus (TP)					
Grain/Seed Crop		0.82	0.70	-2.4	-1.8
Hay/Pasture	-2.7		-2.2	4.3	-3.0
Too Wet for Seeding	-0.78	0.66		-3.3	-2.0
Trees/Forest	2.0	1.2	2.5		-1.1
Wetland	5.5	2.0	5.6	3.8	

% = percent.

Table E57: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 40% Decrease in Individual Land Cover Types, 2010

Converted to:	Converted from (40% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-0.94	-1.7	1.5	-1.9
Hay/Pasture	4.5		2.3	6.9	-0.41
Too Wet for Seeding	1.9	-0.54		3.8	-1.2
Trees/Forest	-1.3	-1.2	-2.9		-2.3
Wetland	5.7	0.27	3.4	8.4	
Total Phosphorus (TP)					
Grain/Seed Crop		-1.1	-0.93	3.1	2.3
Hay/Pasture	5.2		3.7	9.4	4.0
Too Wet for Seeding	1.0	-0.87		4.4	2.7
Trees/Forest	-2.6	-1.6	-3.3		1.5
Wetland	-7.3	-2.6	-7.5	-5.6	

% = percent.

Table E58: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 40% Increase in Individual Land Cover Types, 2010

Converted from:	Converted to (40% Increase):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		0.94	1.7	-1.5	1.9
Hay/Pasture	-2.3		-1.3	6.0	0.41
Too Wet for Seeding	-1.9	0.54		-3.8	1.2
Trees/Forest	1.3	1.2	2.9		2.3
Wetland	-4.6	-0.27	-3.1	-5.6	
Total Phosphorus (TP)					
Grain/Seed Crop		1.1	0.93	-3.1	-2.3
Hay/Pasture	-2.7		-2.2	5.7	-4.0
Too Wet for Seeding	-1.0	0.87		-4.4	-2.7
Trees/Forest	2.6	1.6	3.3		-1.5
Wetland	5.9	2.6	6.7	3.8	

% = percent.

Table E59: Percent (%) Change in Calculated Nutrient Loads in the Carrot River near Turnberry, Based on a 50% Decrease in Individual Land Cover Types, 2010

Converted to:	Converted from (50% Decrease):				
	Grain/Seed Crop	Hay/Pasture	Too Wet for Seeding	Trees/Forest	Wetland
Total Nitrogen (TN)					
Grain/Seed Crop		-1.2	-2.1	1.9	-2.3
Hay/Pasture	5.6		2.9	8.6	-0.51
Too Wet for Seeding	2.4	-0.67		4.8	-1.5
Trees/Forest	-1.6	-1.5	-3.6		-2.8
Wetland	7.2	0.33	4.3	11	
Total Phosphorus (TP)					
Grain/Seed Crop		-1.4	-1.2	3.9	2.9
Hay/Pasture	6.5		4.7	12	5.0
Too Wet for Seeding	1.3	-1.1		5.5	3.4
Trees/Forest	-3.3	-2.1	-4.1		1.9
Wetland	-9.1	-3.3	-9.3	-7.0	

% = percent.

Table E60: Percent (%) Change in Calculated Nutrient Loads in the Carrot River Near Turnberry, Based on a 50% Increase in Individual Land Cover Types, 2010

Converted from:	Converted to (50% Increase):				
	Grain/Seed Crop	**Hay/Pasture**	**Too Wet for Seeding**	**Trees/Forest**	**Wetland**
Total Nitrogen (TN)					
Grain/Seed Crop		1.2	2.1	-1.9	2.3
Hay/Pasture	-2.3		-1.3	7.5	0.51
Too Wet for Seeding	-2.4	0.67		-4.8	1.5
Trees/Forest	1.6	1.5	3.6		2.8
Wetland	-4.6	-0.33	-3.1	-5.6	
Total Phosphorus (TP)					
Grain/Seed Crop		1.4	1.2	-3.9	-2.9
Hay/Pasture	-2.7		-2.2	7.2	-5.0
Too Wet for Seeding	-1.3	1.1		-5.5	-3.4
Trees/Forest	3.3	2.1	4.1		-1.9
Wetland	5.9	3.3	6.7	3.8	

% = percent.

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For more information, visit golder.com

Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1721 8th Street East
Saskatoon, Saskatchewan, S7H 0T4
Canada
T: +1 (306) 665 7989

Golder Associates

Prairie Provinces Water Board
Suite 1001 - 10th Floor, Alvin Hamilton Building
1783 Hamilton Street
Regina, SK S4P 2B6
www.ppwb.ca