2021–2022 Status of surface water quality, South Saskatchewan Region, Alberta

Reporting on the South Saskatchewan Region Surface Water Quality Management Framework for April 2021– March 2022

2021-2022 Status of Surface Water Quality, South Saskatchewan Region, Alberta

J.Patrick Laceby, Nadine Taube, and Jason G. Kerr

Comments or questions regarding the content of this document may be directed to:

Airshed and Watershed Stewardship Branch, Resource Stewardship Division, Environment and Protected Areas

9th Floor, 9888 Jasper Avenue NW, Edmonton, Alberta, T5J 5C6

Email: aep.info-centre@gov.ab.ca

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Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

EPA	Alberta Environment and Protected Areas
EQGASW	Environmental Quality Guidelines for Alberta Surface Waters
GOA	Government of Alberta
LTRN	Long Term River Network
LUF	Land Use Framework
SSR	South Saskatchewan Region
SSRP	South Saskatchewan Regional Plan
SSR SWQMF	South Saskatchewan Region Surface Water Quality Management Framework

Executive Summary

Background

This report was prepared by Alberta Environment and Protected Areas (EPA) to fulfill reporting requirements mandated by the South Saskatchewan Region Surface Water Quality Management Framework (SSR SWQMF; GOA 2014b), which supports the South Saskatchewan Regional Plan (SSRP; GOA 2014a).

The 2021-2022 report is the eighth annual report for the South Saskatchewan Region. Previous annual reports for the status of ambient environmental condition in the South Saskatchewan Region are accessible at: alberta.ca/south-saskatchewan-regional-planning.aspx. The Government of Alberta (GOA) determines reporting requirements for the SSRP and has a responsibility for monitoring, evaluation and reporting under the Environmental Management Frameworks, including the SSR SWQMF. This report communicates any water quality triggers or limits that were exceeded in the South Saskatchewan Region from April 1, 2021 to March 31, 2022.

Methodology

The SSR SWQMF includes 15 primary indicators and six secondary indicators. In 2021-2022 (April 1 to March 31 inclusive), these water quality indicators were measured monthly at nine water quality monitoring stations. Using methodology described in the SSR SWQMF, the annual data for the 15 primary indicators were compared to the historical record (GOA 2014b) to determine if the median and 90th percentile (peak) concentrations deviated in an undesirable direction from the historical median or peak trigger values. 2021-2022 data for each primary and secondary indicator at each station were compared to historical data for the open water (April to October) and/or winter (November to March) seasons. Values for primary indicators that deviated from historical triggers in an undesirable direction were statistically assessed for changes in the central tendency or peak concentration as per the SSR SWQMF: Statistical Methods Final Report (HDR 2011). In addition, the 2021-2022 medians for primary indicators were compared to water quality limits as defined in the SSR SWQMF, and the 2021-2022 values for secondary indicators were compared to provincial or federal water quality guidelines where available (GOA 2014b, GOA 2018).

2021-2022 (April 1 – March 31) Result Summary

For the following, exceedances were in both open water and winter seasons unless noted otherwise.

A statistically significant exceedance of the median trigger value was observed for:

- nitrate-N at Bow River at Cluny.

A statistically significant exceedance of the peak trigger values was observed for:

- chloride at Bow River at Carseland, Bow River at Cluny, and Bow River at Ronalane;
- sulphate at Bow River at Cochrane and Bow River at Carseland; and
- *Escherichia coli* at Oldman River at Hwy 3 in Lethbridge (winter only).

There were no other median or peak trigger exceedances observed for any other stations or indicators.

Median total dissolved solids concentrations (winter only) for the Milk River at SH 880 site exceeded water quality limits (as defined in the SSR SWQMF). There were no other exceedances of surface water quality limits for primary indicators.

For the secondary indicators, total mercury exceeded the chronic guideline for one sample taken in the open water season at each of the following sites: Milk River at SH 880, Bow River at Cluny, Bow River at Ronalane and South Saskatchewan River at Medicine Hat at Hwy 1. None of the remaining secondary indicators exceeded existing guideline values (GOA 2018). Three secondary indicators had detection frequencies, over the last three years (April 1, 2019 to March 31 2022), that were greater than detection frequencies in the historical dataset for the open water season, including 2,4-D (Bow River at Cochrane, Bow River at Carseland, Bow River at Cluny), Dicamba (Bow River at Cochrane, Bow River at Carseland, Bow River at Cluny, South Saskatchewan River at Medicine Hat) and Mecoprop (Bow River at Cochrane). No other secondary indicator had a detection frequency over the last three years that exceeded their detection frequency in the historical dataset.

South Saskatchewan Regional Plan

The South Saskatchewan Regional plan (SSRP) was developed by the Government of Alberta under the Land Use Framework (LUF; GOA 2008). The plan sets outcomes that describe what the Government of Alberta wants to accomplish at a regional level and is given legislative authority under the *Alberta Land Stewardship Act* (GOA 2009). The SSRP applies to the South Saskatchewan region (SSR), an area of approximately 83,764 square kilometers in size located in southern Alberta (Figure 1). For more information, see the SSRP report (GOA 2014a).

Alberta Environment and Protected Areas (EPA) is responsible for monitoring, evaluation and reporting on the condition of the environment in the SSR. The 2021-2022 Status of Surface Water Quality for the South Saskatchewan Region report fulfills the annual reporting requirements mandated by the South Saskatchewan Region Surface Water Quality Management Framework for the mainstem Bow, Milk, Oldman and South Saskatchewan Rivers (SSR SWQMF; GOA 2014b), in support of the SSRP.

Methodology

Monitoring Stations

Water quality in the SSR is assessed based on data derived from monthly water quality sampling at nine Long-Term River Network (LTRN) stations within the SSR (Figure 2). The nine LTRN stations are located within four major river systems:

- **The Oldman River:** Oldman River at Brocket, Oldman River at Hwy 3 in Lethbridge and Oldman River at Hwy 36.
- **The Bow River:** Bow River at Cochrane, Bow River at Carseland, Bow River at Cluny and Bow River at Ronalane.
- **The South Saskatchewan River:** South Saskatchewan River at Medicine Hat at Hwy 1.
- **The Milk River:** Milk River at SH 880.

Additional details on the four major river basins and the nine LTRN stations are given in the SSR SWQMF (GOA 2014b).

Figure 1. Location of the seven Land-Use Framework Regions in Alberta.The South Saskatchewan Region is shaded green.

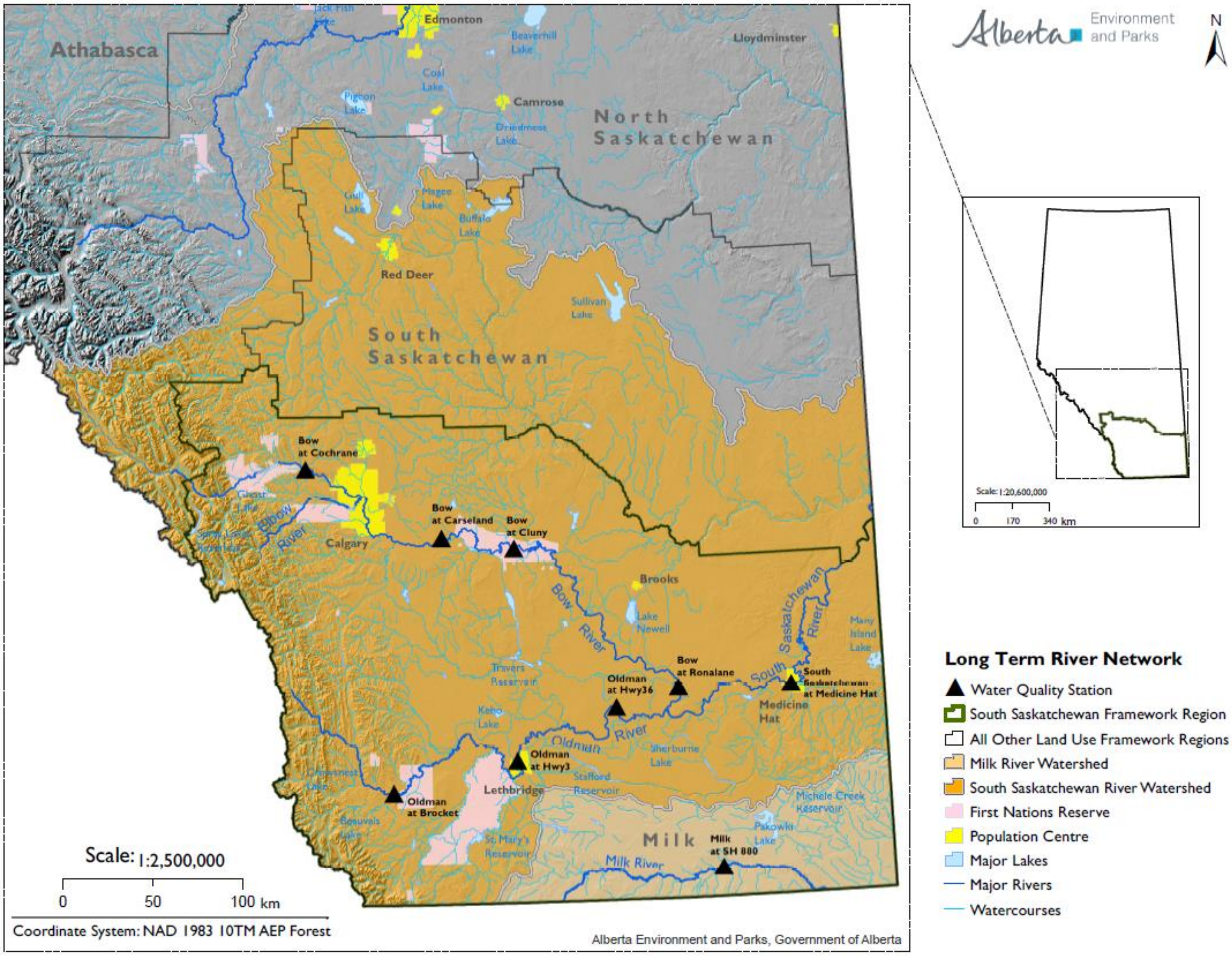

Figure 2. Location of Long Term River Network water quality stations used in the SSR SWQMF.

Monitoring Parameters

Annual data used in the 2021-2022 report were taken from monthly water quality samples at the nine LTRN stations within the SSR, taken between April 1, 2021 and March 31, 2022. Twenty-one water quality parameters, including 15 primary indicators (Table 1) and six secondary indicators (Table 2), were chosen as indicators in the framework. Rationale for indicator selection is provided in the SSR SWQMF (GOA 2014b). Sample collection, data verification and analyses follow recognized standards and protocols established by EPA for consistent sample collection and processing across the Province (AENV 2006).

Table 1. List of primary indicators for the SSR SWQMF.

Total Ammonia (NH_{3+4}-N)	Specific Conductance (Sp. Cond.)
Chloride (Cl^-)	Total Dissolved Solids (TDS)
Nitrate-N (NO_3-N)	Total Organic Carbon (TOC)
Total Nitrogen (TN)	Total Suspended Solids (TSS)
Total Dissolved Phosphorus (TDP)	Turbidity
Total Phosphorus (TP)	pH
Sulphate (SO_4)	*Escherichia coli* (*E. coli*)
Sodium Adsorption Ratio (SAR)	

Table 2. List of secondary indicators for the SSR SWQMF.

Mercury	Dicamba
Selenium	Methylchlorophenoxyacetic acid (MCPA)
2,4-Dichlorophenoxyacetic acid (2,4-D)	Mecoprop (MCPP)

Statistical Analysis

Median (50th percentile) and peak (90th percentile) triggers were calculated from historical datasets (1999-2009, with some exceptions; see GOA 2014b), and separately for two different seasons: the open water season (April to October) and the winter season (November to March). This seasonal split is to address the difference in seasonal temperature, river discharge and precipitation patterns as they affect water quality measurements. For primary indicators, seasonal median and peak concentrations calculated from the 2021-2022 data were first compared to these historical triggers to determine if there was deviation in an undesirable direction from the historical trigger values. With the exception of pH, an undesirable direction is a value greater than the trigger. For pH, values below or above the trigger could be potentially impactful (i.e., increased acidity or increased alkalinity). Seasonal median or peak concentrations (calculated from 2021-2022 data) that crossed their respective historical trigger values in an undesirable direction were assessed for statistical significance to determine if there was a (median or peak) trigger exceedance.

A median trigger exceedance is defined as a statistically significant shift in the central tendency of the 2021-2022 data for open water and/or winter seasons, relative to a corresponding upper prediction limit (UPL) calculated from the historical record following HDR (2011). A peak trigger exceedance was reported when the frequency of observations in the 2021-2022 data exceeding an UPL calculated from the historical record was higher than an expected frequency. A peak trigger exceedance also represents a statistically significant shift in the frequency of extreme values in the 2021-2022 data. Details of the statistical analyses used to determine a median or peak trigger exceedance are outlined in Appendix A. Identification of median and peak exceedances are intended to act as an early warning system of potential changes in surface water quality and a signal to do further analyses (preliminary assessment) to determine the need for further investigation.

Water quality limits for primary and secondary indicators were derived from provincial and federal water quality guidelines (GOA 2014b). A surface water quality limit is exceeded if the seasonal 2021-2022 median for a primary indicator exceeded the surface water quality limit for that indicator. For water quality indicators that are affected by toxicity modifying factors (i.e., total ammonia-N and sulphate), individual limits were calculated for each sample in the compliance year using guideline equations (GOA 2018). Individual concentrations from the compliance data were then compared against corresponding calculated limits. If greater than 50% of all months exceeded their calculated limits for a specific parameter at a specific site within a season, this was identified as a limit exceedance. For secondary indicators, any exceedances of existing guidelines values are reported. In addition, increasing trends in detections are reported for secondary indicators where the detection frequency for the last 3 years (i.e., April 1, 2019 to March 31 2022) exceeds the detection frequency of these secondary indicators in the historical dataset (1999-2009).

Historically, EPA replaced any censored data of a given parameter (i.e., observations measured below the method detection limit) with one-half of the detection limit value. This practice was adopted for this report with the calculation of the historical triggers, as well as with the annual compliance dataset. Statistical methods used in this report are described in the SSR SWQMF: Statistical Methods Final Report (HDR 2011), *Unified Guidance* (USEPA 2009) and Smith et al. (2001). Additional details on the analytical and statistical methods are provided in Appendix A and the SSR SWQMF (GOA 2014b). All statistical assessments were performed using R statistical software (Millard 2013, R Development Core Team 2020).

Results

Exceedances of Water Quality Triggers

In 2021-2022, statistically significant median and peak trigger exceedances were observed at five stations for four primary indicators. Unless otherwise noted, these exceedances are for combined open water and winter season datasets.

A statistically significant exceedance of the median trigger value was observed for:

- nitrate-N at Bow River at Cluny.

A statistically significant exceedance of the peak trigger values was observed for:

- chloride at Bow River at Carseland, Bow River at Cluny, and Bow River at Ronalane;
- sulphate at Bow River at Cochrane and Bow River at Carseland; and
- *Escherichia coli* at Oldman River at Hwy 3 in Lethbridge (winter only).

There were no other median or peak trigger exceedances observed for primary indicators. Summary statistics, including the annual and historical medians (50^{th} percentile) and peaks (90^{th} percentile) are presented in Appendix B.

Table 3. Median and peak (90th percentile) values for primary indicators exhibiting a statistically significant trigger exceedance (shaded in blue) in the SSR during 2021-2022. Calculation results leading to identification of the statistically significant trigger exceedances are listed in Table 4. An asterisk for the compliance period indicates that the statistically significant exceedances were calculated with aggregate (open + winter) data.

Indicator	Period	Season	Median	90th Percentile	n
BOW RIVER AT COCHRANE					
Sulphate (mg/L)	1999-2009 (trigger)	open	33.6	40.4	70
		winter	42.2	45.8	50
	2021-2022*	open	37	48.2	7
		winter	51	53.2	5
BOW RIVER AT CARSELAND					
Chloride (mg/L)	1999-2009 (trigger)	open	7.6	13.1	70
		winter	12.7	20.4	50
	2021-2022*	open	13	17.4	7
		winter	20	27.8	5
Sulphate (mg/L)	1999-2009 (trigger)	open	42.8	51.5	70
		winter	53.9	58	50
	2021-2022*	open	49	59.6	7
		winter	64	70.4	5
BOW RIVER AT CLUNY					
Chloride (mg/L)	1999-2009 (trigger)	open	0.52	0.837	59
		winter	1.195	1.455	40
	2021-2022*	open	14	18.8	7
		winter	25	31.6	5
Nitrate-N (mg/L)	1999-2009 (trigger)	open	0.52	0.837	59
		winter	1.195	1.455	40
	2021-2022*	open	0.55	0.702	7
		winter	1.4	1.76	5
BOW RIVER AT RONALANE					
Chloride (mg/L)	1999-2009 (trigger)	open	8.4	12	70
		winter	13	19.7	49
	2021-2022*	open	14	21	7
		winter	24	34.8	5
OLDMAN RIVER AT HWY 3 IN LETHBRIDGE					
***Escherichia coli* (cfu/100ml)**	1999-2009 (trigger)	open	13	99	68
		winter	1	7	48
	2021-2022	open	11	20	7
		winter	32	89	5

Table 4. Central tendency (mean/median) UPL and peak UPL results for primary indicators exhibiting a statistically significant trigger exceedance in the SSR. Failures (shaded in blue) indicate where a significant trigger exceedance occurred.

Indicator	Units	Season (O=open; W=winter)	Central Tendency Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
BOW RIVER AT COCHRANE								
Sulphate	mg/L	O/W	45.28	48.7	PASS	41.77	5	FAIL
BOW RIVER AT CARSELAND								
Chloride	mg/L	O/W	18.33	28.94	PASS	16.79	4	FAIL
Sulphate	mg/L	O/W	59.08	62.87	PASS	55.93	5	FAIL
BOW RIVER AT CLUNY								
Chloride	mg/L	O/W	22.65	47.81	PASS	19.77	4	FAIL
Nitrate-N	mg/L	O/W	0.91	0.9	FAIL	1.38	0	PASS
BOW RIVER AT RONALANE								
Chloride	mg/L	O/W	19.76	24.56	PASS	17.26	6	FAIL
OLDMAN RIVER AT HWY 3 IN LETHBRIDGE								
E. coli	cfu/100ml	W	109.45	148.45	PASS	129.11	3	FAIL

Exceedances of Water Quality Limits

Median total dissolved solids concentrations (winter only; 630 mg/L) at Milk River at SH 880 exceeded water quality limits (500 mg/L – Table 5). There were no other exceedances of surface water quality limits for primary indicators.

Table 5. List of surface water quality limits for primary indicators. Limit values were taken from the SSR SWQMF (GOA 2014b).

Primary Indicator	Units	Surface Water Quality Limit
Total Ammonia-N	mg/L	Varies with pH and temperature[A]
Chloride	mg/L	100
Nitrate-N	mg/L	3.0
Sulphate	mg/L	Varies with hardness[A]
Sodium Adsorption Ratio (SAR)	rel units	5
Specific Conductance	µS/cm	1000
Total Dissolved Solids	mg/L	500
pH	pH units	<6.5 or >9.0
Escherichia coli	cfu per 100 mL	100

[A] Calculations are given in Environmental Quality Guidelines for Alberta Surface Waters (GOA 2014c).

Exceedances of Secondary Indicators

There were chronic guideline exceedances for total mercury concentrations with one exceedance reported in the open water season at Milk River at SH 880, Bow River at Cluny, Bow River at Ronalane and South Saskatchewan River at Medicine Hat at Hwy 1. None of the remaining secondary indicators exceeded existing guideline values (GOA 2018). Summary statistics for all secondary indicators are provided in Appendix B. Note that summary statistics shown for secondary indicators are for information purposes only as there are no triggers or limits assigned to these indicators.

Table 6. List of guideline values for secondary indicators. Guideline values were taken from the Environmental Quality Guidelines for Alberta Surface Waters (GOA 2018).

Secondary Indicator	Unit	Protection of Aquatic Life	Protection of Agricultural Water Use (Irrigation)	Protection of Agricultural Water Use (Livestock Water)
Total Mercury	ug/L	(chronic) 0.005 (acute) 0.013	---	3
Total Selenium	ug/L	(guideline) 2 (alert) 1	---	50
2,4-Dichlorophenoxyacetic acid (2,4-D)	ug/L	(chronic) 4	---	See Phenoxy herbicides below in this table
Dicamba	ug/L	(chronic) 10	0.008	122
Methylchlorophenoxyacetic acid (MCPA)	ug/L	(chronic) 2.6	(continuous use) 20 (intermittent use) 50	See Phenoxy herbicides below in this table
Mecoprop (MCPP)	ug/L	(chronic) 13 (acute) 10,000	---	See Phenoxy herbicides below in this table
Phenoxy herbicides (sum of all phenoxy herbicides including 2,4-D, MCPP, MCPA)	ug/L	See individual indicators above	See individual indicators above	100

Increasing Trends in Sample Detection for Secondary Indicators

There were increasing trends in sample detection reported for three secondary indicators at four sites in the SSR. The detection frequency of 2,4-D over the last 3 years was greater than the detection frequency in the historical dataset at Bow River at Cochrane, Bow River at Carseland, and Bow River at Cluny. Dicamba had a detection frequency that was greater than the detection frequency in the historical dataset over the last 3 years at Bow River at Cochrane, Bow River at Carseland, Bow River at Cluny, and South Saskatchewan River at Medicine Hat. Mecoprop had a detection frequency that was greater than the detection frequency in the historical dataset over the last 3 years at Bow River at Cochrane. None of the other secondary indicators had sample detection frequencies over the last three years that exceeded their detection frequency in the historical dataset. Detection frequencies for the historical dataset and the three year reporting dataset (April 1, 2019 to March 31, 2022) for all secondary indicators is provided in Appendix C.

Table 7. Secondary indicators with detection frequencies in the reporting data that were greater than their detection frequencies in the historical dataset, including the number of samples, the number of detects and the detection frequency (DF) in both the historical dataset and the three year reporting dataset (April 1, 2019 to March 31, 2022).

		Historical Dataset			Reporting Dataset (2019-2022)		
Secondary Indicator	**Season**	**Samples**	**Detects**	**DF**	**Samples**	**Detects**	**DF**
BOW RIVER AT COCHRANE							
2,4-D	Open	44	3	7%	11	1	9%
Dicamba	Open	44	0	0%	11	1	9%
Mecoprop	Open	44	2	5%	11	1	9%
BOW RIVER AT CARSELAND							
2,4-D	Open	44	33	75%	11	9	82%
Dicamba	Open	44	2	5%	11	1	9%
BOW RIVER AT CLUNY							
2,4-D	Open	32	23	72%	10	8	80%
Dicamba	Open	32	2	6%	10	1	10%
SOUTH SASKATCHEWAN RIVER AT MEDICINE HAT							
Dicamba	Open	44	15	34%	10	5	50%

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Appendix A

Analytical and Statistical Methods Used to Assess Trigger and Limit Exceedances

The South Saskatchewan Region Surface Water Quality Management Framework (SSR SWQMF) established median and 90th percentile triggers for 15 primary indicators and identifies six secondary indicators, for which there were not enough data of sufficient length and/or level of analytical detection to facilitate the quantification of robust trigger values (GOA 2014b). Water samples for general parameters were analyzed by Bureau Veritas. *Escherichia coli* was analysed by ProvLab Alberta. Mercury was analysed by University of Alberta Biogeochemical Analytical Service Laboratory. Selenium and pesticides were analysed by InnoTech Alberta. All statistical analyses and plots were conducted using packages *EnvStats* (v2.3.1; Millard 2013), *lawstat* (v3.4; Gastwirth et al. 2020), *lmtest* (v0.9.37; Zeileis and Hothorn 2002), *MASS* (v7.3.51.5; Venables and Ripley 2002), and *outliers* (v0.14; Komsta 2011) in R version 4.0.0. (R Development Core Team 2020). Analyses used were based on recommendations made in the *South Saskatchewan Regional Plan Surface Water Quality Management Framework: Statistical Methods Final Report* (HDR 2011).

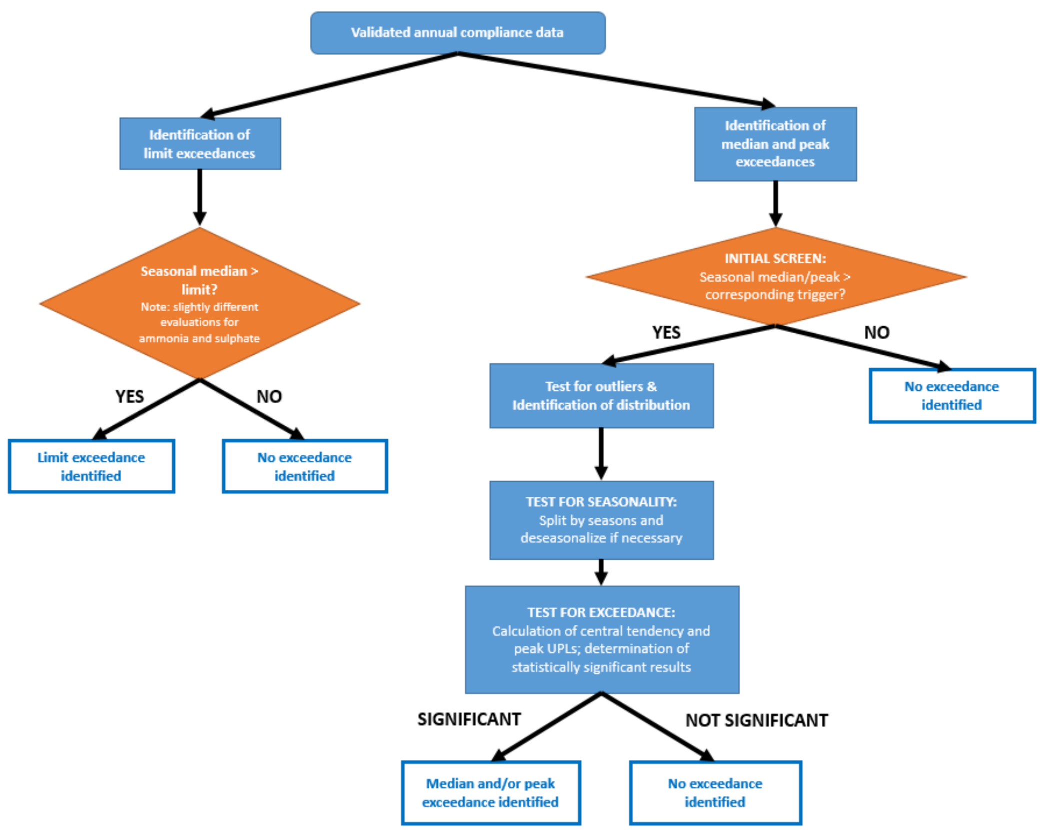

Figure A-1. Flowchart of statistical approach

Preliminary Data Screening

All water quality data used in the assessment were from the Long-Term River Network (LTRN) stations in the South Saskatchewan River Basin. The historical dataset (used for trigger development and comparisons against annual compliance data) included data from April 1999 to March 2009 (actual time range dependent on parameter; see GOA 2014b).The annual compliance data for a given year (e.g., 2021-2022) includes data from the beginning of April to the end of next March (e.g., April 1, 2021 to March 31, 2022). Any data points below the method detection limit (MDL) were substituted with a value of ½ the MDL.

Each year is divided into two seasons: open water (April to October) and winter (November to March). Seasonal median and 90th percentile (peak) triggers were calculated for each water quality indicator using the historical dataset, to reproduce values listed in the SSR SWQMF (GOA 2014b). Seasonal median and 90th percentile concentrations are then calculated for each indicator in the annual compliance dataset. For each indicator and season at each station, the compliance median and peak value were compared to its respective historical trigger. If the compliance value exceeded the trigger value, the indicator was flagged for further statistical analyses to determine if there was a significant deviation from historical triggers in an undesired direction. Note that for pH, when compliance data were either above or below the trigger values at a given site, further statistical analyses were undertaken. This was to account for the fact that both lower than historic or higher than historic pH values could be considered undesirable. Seasonal median compliance values were also compared to surface water quality limits (based on provincial and federal guidelines and defined in SSR SWQMF; GOA 2014b), and any exceedances of the limits by the calculated medians were reported (Figure A-1 and A-2).

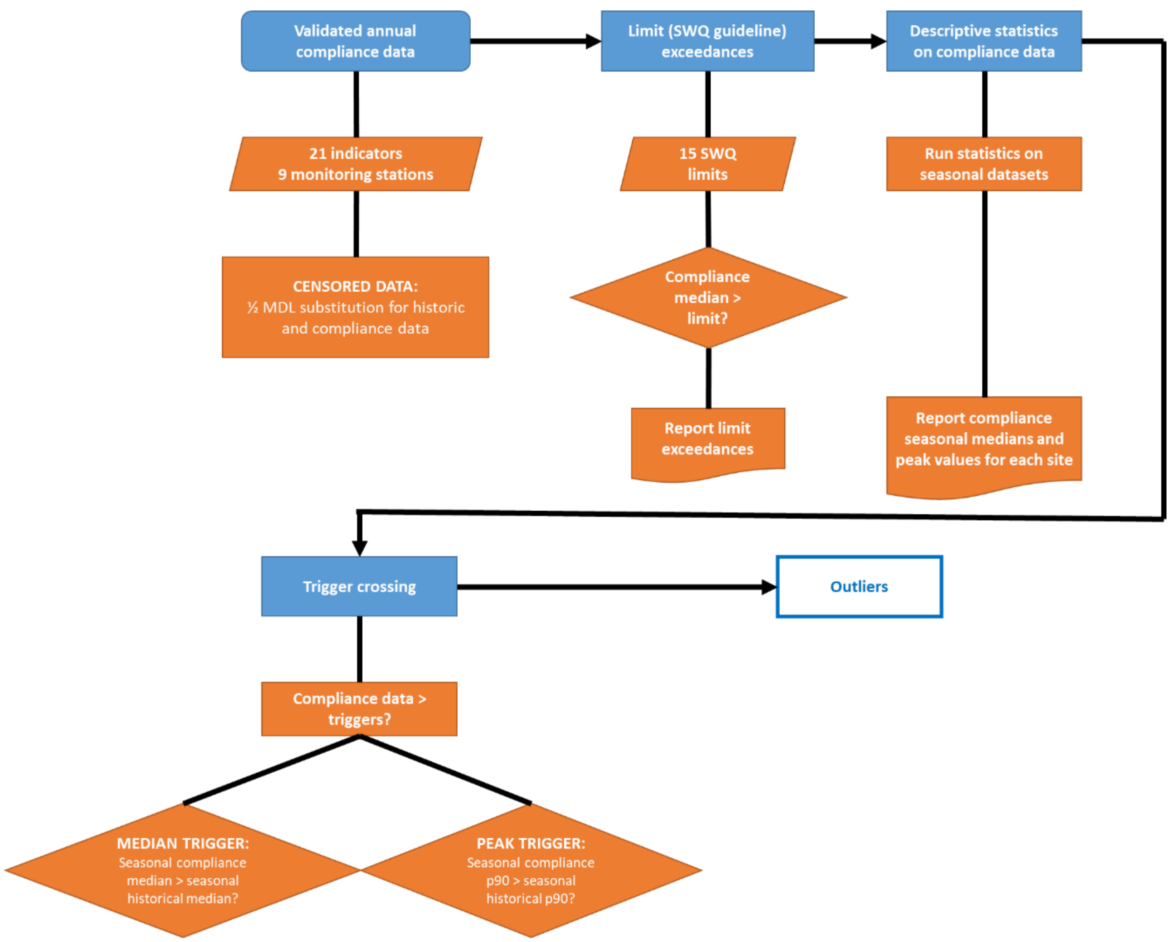

Figure A-2. Flowchart of preliminary data screening steps.

Outlier and Distribution Testing

Regardless of whether the open water season or the winter season trigger was exceeded in a particular parameter, a seasonal aggregate (open water and winter combined) dataset was first statistically analysed for significance. Outliers were detected using Rosner's outlier test. Distribution of the temporal aggregate data (historical and annual compliance data combined) was preliminarily assessed using Q-Q plots and goodness-of-fit (GoF) tests based on a ProUCL algorithm, which uses the Lilliefors test for datasets with n>50 (function *EnvStats::distChoose()*) Figure A-3. A value of 0.001 was added to individual concentrations to account for cases of 0 CFU/100 mL for *Escherichia coli* concentrations, which may generate issues with the GoF procedure. This addition was done for all runs for consistency. For these tests, significance level was set at $\alpha = 0.01$.

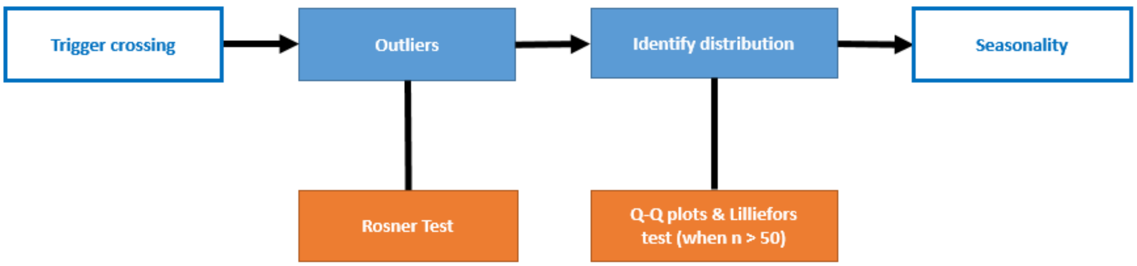

Figure A-3. Flowchart of outlier and distribution testing steps.

Seasonality

HDR (2011) recommended testing the seasonal aggregate data (historical and annual compliance data) for seasonality, and if detected, the data was deseasonalized with a simple correction method. With this approach, for each month, the monthly mean was subtracted from all values in that month and then the overall mean across all months was added back to each individual value. Residuals were calculated using the function *stats::lm()* to fit a regression line. Distribution of residuals between months was evaluated using the Shapiro-Wilk test ($\alpha = 0.01$), and variances analysed with Levene's test ($\alpha = 0.01$). Differences between months were evaluated using a one-way ANOVA ($\alpha = 0.05$) if residuals were normal or log-normal, and the monthly data showed equal variance. Otherwise, it was evaluated using the non-parametric Kruskal-Wallis test ($\alpha = 0.05$). If seasonality was significant, the dataset was deseasonalized.

In addition to temporal correlation between monthly data, some values may exhibit a dependence on the season (open water vs. winter). As such, HDR (2011) recommends a final preprocessing check to determine if the difference between the two groups is statistically significant. If the results indicate that there is no significant seasonality in the data, the analysis proceeds with the combined dataset (open water and winter data). In the event that the seasonality is significant, the data are split into their respective groups (i.e., open water and winter data) and exceedance tests are conducted on the separate groups. The distribution of residuals between subgroups was evaluated using the Shapiro-Wilk test ($\alpha = 0.01$).Then differences between subgroups were evaluated using a one-way ANOVA ($\alpha = 0.05$; if residuals were normal or log-normal and variance was equal) or a Kruskal-Wallis rank sum test ($\alpha = 0.05$). If a significant difference between subgroups is indicated, then data grouping is required, the dataset is separated into open water and winter data, and each group re-assessed for outliers, distribution and seasonality (Figure A-4).

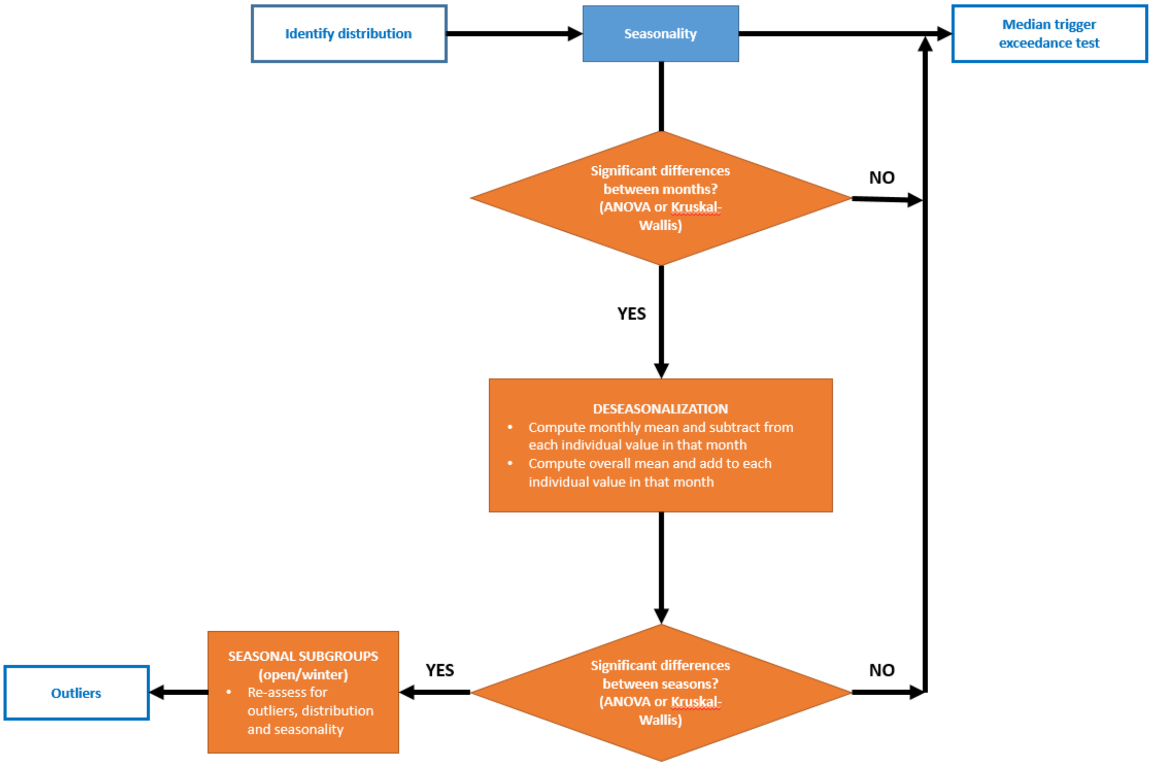

Figure A-4. Flowchart of seasonality testing steps.

Trigger Exceedances

HDR (2011) recommends the use of upper prediction limits (UPLs) over the use of median, 90th/95th percentiles or upper confidence limits for establishing baseline limits against which future observations would be tested. UPLs are not directly comparable to empirical percentile values; the 90th percentile UPL represents "the value above which there is only a [10]% likelihood that new or future observations will occur" (HDR 2011, p. 31).

To test whether the historical data and compliance data are from the same distribution, a Kolmogorov-Smirnov test was used. If both datasets were from a normal or log-normal distribution, the parametric UPL calculations were used; if both datasets were from a non-normal distribution, the non-parametric UPL calculations were used. If the two datasets did not come from the same distribution, the non-parametric UPL calculations were used. Only historical data was used in the calculation of UPLs (Figure A-5).

Median Trigger Exceedances

To evaluate exceedances of the median trigger, an UPL was calculated from the historic dataset using *EnvStats::predIntNorm()*, *EnvStats::predIntLNorm()* or *EnvStats::predIntNpar()*, for normal, log-normal and non-parametric distributions respectively. The UPL was compared to the compliance mean (mean of compliance data) if the normal or log-normal UPL was used. If the non-parametric UPL was used, however, the median of the three most recent compliance observations was used instead (HDR 2011, USEPA 2009). If the compliance mean/median (dependent on distribution) was greater than the UPL limit, a compliance median trigger exceedance occurred.

Peak Trigger Exceedances

For evaluating peak trigger exceedances in normally or log-normally distributed data, a UPL was calculated as the prediction interval for the next 12 observations using the historic dataset. This UPL was compared to each individual compliance data point. For normal data, *EnvStats::predIntNorm()* and *EnvStats::predIntLNorm()* was used for this calculation. For non-normal data, the *EnvStats::predIntNpar()* calculation, which corresponds to a percentile limit, was used to calculate an UPL for comparison against individual compliance data points in non-parametric data.

The percentage of compliance data points that exceed the UPL was recorded, and a binomial test was applied to the number of exceedances. If the number of individual exceedances was greater than the acceptable number of violations (10% natural violations), a compliance peak trigger exceedance has occurred.

Limit Exceedances

Limit exceedances were determined by comparing the seasonal compliance median concentrations to the limit values defined in SSR SWQMF (GOA 2014b). If the seasonal median concentration calculated from the current year exceeded the limit value for a specific primary parameter at a specific site, this was identified as a limit exceedance. For primary indicators that are affected by toxicity modifying factors (i.e., total ammonia-N and sulphate), individual limits were calculated for each sample in the compliance year using guideline equations (GOA 2018). Individual concentrations from the compliance data were then compared against corresponding calculated limits. If greater than 50% of all months exceeded their calculated limits for a primary parameter at a specific site within a season, this was identified as a limit exceedance.

Secondary Indicators

Secondary indicators are other indicators of interest that did not have sufficient length nor level of analytical detection to calculate robust triggers (GOA 2014b). In total there were six secondary indicators identified, including total mercury, total recoverable selenium, 2,4-Dichlorophenoxyacetic acid (2,4-D), Dicamba, Methylchlorophenoxyacetic acid (MCPA) and Mecoprop (MCPP). Although there were no limits defined for the secondary indicators, any exceedances of existing guideline values are reported (GOA 2014b).

Increasing trends in sample detections are also reported for secondary indicators where the detection frequency over the last three years (e.g. April 1, 2019 to March 31, 2022) was greater than the detection frequency in the historical dataset (1999-2009). Three years of reporting data are used to reduce the potential bias from analysis of samples near the limits of detection on the trends in detection frequencies and small sample sizes. Mercury data after April 1, 2008 was used in this analysis of detection frequency owing to a significant change in the analytical method. Results for all secondary indicators are provided in Appendix C - Table C4.

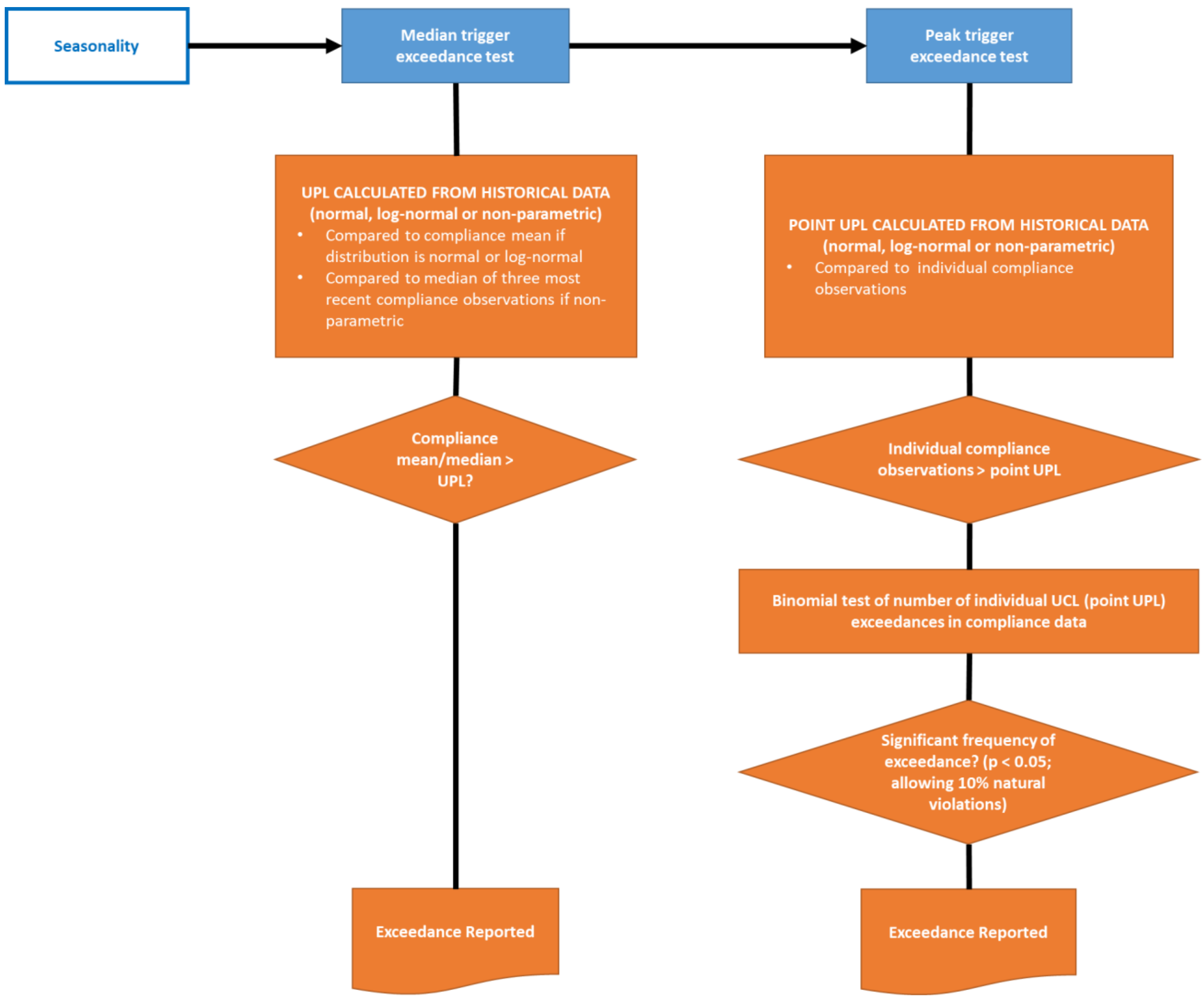

Figure A-5. Flowchart of exceedance testing steps.

Appendix B

Descriptive Statistics for the Nine Long Term River Network Stations

Table B-1. Median and 90th percentile values for primary indicators in the Oldman River at Brocket.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**1999-2009** (trigger)	open	0.01	0.06	91
		winter	0.01	0.039	52
	2021-2022	open	0.015	0.019	7
		winter	0.015	0.015	5
Chloride (mg/L)	**1999-2009** (trigger)	open	0.9	1.8	70
		winter	1.2	1.9	50
	2021-2022	open	1.7	2.5	7
		winter	1	1.7	5
Nitrate-N (mg/L)	**1999-2009** (trigger)	open	0.078	0.128	91
		winter	0.092	0.132	52
	2021-2022	open	0.046	0.053	7
		winter	0.037	0.05	5
Total Nitrogen (mg/L)	**1999-2009** (trigger)	open	0.23	0.35	70
		winter	0.19	0.32	50
	2021-2022	open	0.14	0.2	7
		winter	0.18	0.2	5
Total Dissolved Phosphorus (mg/L)	**1999-2009** (trigger)	open	0.003	0.006	91
		winter	0.003	0.005	52
	2021-2022	open	0.003	0.003	7
		winter	0.003	0.003	5
Total Phosphorus (mg/L)	**1999-2009** (trigger)	open	0.007	0.018	91
		winter	0.005	0.01	52
	2021-2022	open	0.003	0.005	7
		winter	0.005	0.008	5
Sulphate (mg/L)	**1999-2009** (trigger)	open	22.1	29.4	70
		winter	29.6	36	50
	2021-2022	open	22	30.4	7
		winter	26	29.8	5
Sodium Adsorption Ratio	**1999-2009** (trigger)	open	0.16	0.22	70
		winter	0.18	0.2	50
	2021-2022	open	0.14	0.17	7
		winter	0.15	0.16	5
Specific Conductance (μS/cm)	**1999-2009** (trigger)	open	276	313	91
		winter	308	342	52
	2021-2022	open	280	324	7

		winter	310	322	5
Total Dissolved Solids (mg/L)	**1999-2009** (trigger)	open	156	181	70
		winter	179	202	50
	2021-2022	open	150	180	7
		winter	170	182	5
Total Organic Carbon (mg/L)	**1999-2009** (trigger)	open	2	3.7	70
		winter	1.6	2.2	50
	2021-2022	open	1.7	2.5	7
		winter	1.6	1.9	5
Total Suspended Solids (mg/L)	**1999-2009** (trigger)	open	3	10	84
		winter	1	6	47
	2021-2022	open	2	3	7
		winter	2	6	5
Turbidity (NTU)	**1999-2009** (trigger)	open	4.5	18.8	91
		winter	2.3	8.5	52
	2021-2022	open	2.8	5.1	7
		winter	4.5	11	5
pH	**1999-2009** (trigger)	open	8.26	8.35	91
		winter	8.25	8.34	52
	2021-2022	open	8.19	8.31	7
		winter	8.3	8.38	5
***Escherichia coli* (cfu/100ml)**	**1999-2009** (trigger)	open	3	14	70
		winter	2	27	49
	2021-2022	open	2	9	7
		winter	4	6	5

Table B-2. Median and 90th percentile values for secondary indicators in the Oldman River at Brocket.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**1999-2009**	open	0.0025	0.0032	39
		winter	0.0025	0.0025	4
	2021-2022	open	0.005	0.005	4
		winter			0
Dicamba (µg/L)	**1999-2009**	open	0.0025	0.0068	39
		winter	0.0025	0.0025	4
	2021-2022	open	0.008	0.008	4
		winter			0
MCPA (µg/L)	**1999-2009**	open	0.0025	0.0025	39
		winter	0.0025	0.0025	4
	2021-2022	open	0.003	0.003	4
		winter			0
Mecoprop (µg/L)	**1999-2009**	open	0.0025	0.0025	39
		winter	0.0025	0.0025	4
	2021-2022	open	0.004	0.004	4
		winter			0
Total Mercury (ng/L)	**1999-2009**	open	0.3	1.395	18
		winter	0.325	0.615	8
	2021-2022	open	1.18	1.526	7
		winter	1.25	1.45	5
Total Recoverable Selenium (µg/L)	**1999-2009**	open	0.5245	0.7633	14
		winter	0.734	0.8508	7
	2021-2022	open	0.5	0.6	7
		winter	0.5	0.72	5

Table B-3. Median and 90th percentile values for primary indicators in the Oldman River at Hwy 3 in Lethbridge.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**1999-2009** (trigger)	open	0.02	0.07	94
		winter	0.02	0.059	52
	2021-2022	open	0.015	0.015	7
		winter	0.02	0.04	5
Chloride (mg/L)	**1999-2009** (trigger)	open	1.5	3.2	70
		winter	2.1	3	50
	2021-2022	open	2.7	2.9	7
		winter	1.9	2.6	5
Nitrate-N (mg/L)	**1999-2009** (trigger)	open	0.022	0.138	94
		winter	0.219	0.348	52
	2021-2022	open	0.007	0.022	7
		winter	0.15	0.156	5
Total Nitrogen (mg/L)	**1999-2009** (trigger)	open	0.25	0.64	72
		winter	0.4	0.59	50
	2021-2022	open	0.16	0.26	7
		winter	0.31	0.37	5
Total Dissolved Phosphorus (mg/L)	**1999-2009** (trigger)	open	0.003	0.009	93
		winter	0.003	0.006	52
	2021-2022	open	0.003	0.004	7
		winter	0.003	0.008	5
Total Phosphorus (mg/L)	**1999-2009** (trigger)	open	0.012	0.151	94
		winter	0.008	0.022	52
	2021-2022	open	0.007	0.011	7
		winter	0.008	0.035	5
Sulphate (mg/L)	**1999-2009** (trigger)	open	35.8	52.1	70
		winter	45	58	50
	2021-2022	open	35	53.2	7
		winter	38	41.4	5
Sodium Adsorption Ratio	**1999-2009** (trigger)	open	0.42	0.59	70
		winter	0.46	0.6	50
	2021-2022	open	0.37	0.46	7
		winter	0.34	0.39	5
Specific Conductance (µS/cm)	**1999-2009** (trigger)	open	323	397	91
		winter	358	437	52
	2021-2022	open	320	384	7
		winter	330	364	5
Total Dissolved Solids (mg/L)	**1999-2009** (trigger)	open	182	224	69
		winter	217	256	50
	2021-2022	open	200	214	7
		winter	170	202	5
Total Organic Carbon (mg/L)	**1999-2009** (trigger)	open	2.4	3.9	70
		winter	1.7	2.5	50
	2021-2022	open	1.8	2.7	7

		winter	1.4	1.6	5
Total Suspended Solids (mg/L)	**1999-2009** (trigger)	open	9	189	93
		winter	7	34	52
	2021-2022	open	7	10	7
		winter	11	37	5
Turbidity (NTU)	**1999-2009** (trigger)	open	10	153	91
		winter	6.3	27.5	52
	2021-2022	open	5.5	7	7
		winter	11	29.8	5
pH	**1999-2009** (trigger)	open	8.34	8.57	91
		winter	8.2	8.28	52
	2021-2022	open	8.34	8.43	7
		winter	8.11	8.28	5
***Escherichia coli* (cfu/100ml)**	**1999-2009** (trigger)	open	13	71	72
		winter	2	13	48
	2021-2022	open	11	20	7
		winter	32	89	5

Table B-4. Median and 90th percentile values for secondary indicators in the Oldman River at Hwy 3 in Lethbridge.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**1999-2009**	open	0.006	0.031	46
		winter	0.0025	0.0025	4
	2021-2022	open	0.0065	0.0091	4
		winter			0
Dicamba (µg/L)	**1999-2009**	open	0.0025	0.01	46
		winter	0.0025	0.0025	4
	2021-2022	open	0.008	0.008	4
		winter			0
MCPA (µg/L)	**1999-2009**	open	0.0025	0.01	46
		winter	0.0025	0.0025	4
	2021-2022	open	0.003	0.0058	4
		winter			0
Mecoprop (µg/L)	**1999-2009**	open	0.0025	0.0027	46
		winter	0.0025	0.0025	4
	2021-2022	open	0.004	0.004	4
		winter			0
Total Mercury (ng/L)	**1999-2009**	open	0.3	2.056	18
		winter	0.3	1.352	8
	2021-2022	open	1.11	1.304	7
		winter	1.02	1.932	5
Total Recoverable Selenium (µg/L)	**1999-2009**	open	0.605	0.8464	14
		winter	0.895	1.2	7
	2021-2022	open	0.6	0.7	7
		winter	0.6	0.76	5

Table B-5. Median and 90th percentile values for primary indicators in the Oldman River at Hwy 36.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**1999-2009** (trigger)	open	0.02	0.11	91
		winter	0.03	0.134	57
	2021-2022	open	0.015	0.028	7
		winter	0.11	0.156	5
Chloride (mg/L)	**1999-2009** (trigger)	open	4	6.1	70
		winter	6	8.1	50
	2021-2022	open	5.9	6.3	7
		winter	4.7	5.5	5
Nitrate-N (mg/L)	**1999-2009** (trigger)	open	0.006	0.14	91
		winter	0.317	0.495	57
	2021-2022	open	0.009	0.043	7
		winter	0.18	0.262	5
Total Nitrogen (mg/L)	**1999-2009** (trigger)	open	0.31	0.75	70
		winter	0.59	0.96	55
	2021-2022	open	0.27	0.39	7
		winter	0.51	0.67	5
Total Dissolved Phosphorus (mg/L)	**1999-2009** (trigger)	open	0.003	0.01	91
		winter	0.003	0.007	57
	2021-2022	open	0.003	0.003	7
		winter	0.003	0.012	5
Total Phosphorus (mg/L)	**1999-2009** (trigger)	open	0.015	0.173	91
		winter	0.009	0.019	57
	2021-2022	open	0.014	0.036	7
		winter	0.026	0.035	5
Sulphate (mg/L)	**1999-2009** (trigger)	open	44.8	61.4	70
		winter	58.1	77.4	50
	2021-2022	open	52	63.6	7
		winter	53	53	5
Sodium Adsorption Ratio	**1999-2009** (trigger)	open	0.56	0.78	70
		winter	0.65	0.8	50
	2021-2022	open	0.58	0.64	7
		winter	0.5	0.55	5
Specific Conductance (µS/cm)	**1999-2009** (trigger)	open	357	425	91
		winter	414	502	52
	2021-2022	open	380	420	7
		winter	360	394	5
Total Dissolved Solids (mg/L)	**1999-2009** (trigger)	open	200	243	70
		winter	246	296	50
	2021-2022	open	210	234	7
		winter	210	226	5
Total Organic Carbon (mg/L)	**1999-2009** (trigger)	open	2.9	4.4	70
		winter	2.2	3	55
	2021-2022	open	2.4	3	7

		winter	1.7	2.1	5
Total Suspended Solids (mg/L)	**1999-2009** (trigger)	open	11	200	90
		winter	3	17	57
	2021-2022	open	5	17	7
		winter	30	41	5
Turbidity (NTU)	**1999-2009** (trigger)	open	9.9	180	91
		winter	4.9	19.9	52
	2021-2022	open	2.7	7.7	7
		winter	19	29.8	5
pH	**1999-2009** (trigger)	open	8.37	8.52	91
		winter	8.21	8.33	57
	2021-2022	open	8.35	8.42	7
		winter	8.19	8.35	5
***Escherichia coli* (cfu/100ml)**	**1999-2009** (trigger)	open	14	151	70
		winter	3	17	53
	2021-2022	open	9	66	7
		winter	5	16	5

Table B-6. Median and 90th percentile values for secondary indicators in the Oldman River at Hwy 36.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**1999-2009**	open	0.0135	0.0802	44
		winter	0.0025	0.0025	4
	2021-2022	open	0.0145	0.0215	4
		winter			0
Dicamba (µg/L)	**1999-2009**	open	0.0025	0.0117	44
		winter	0.0025	0.0025	4
	2021-2022	open	0.008	0.008	4
		winter			0
MCPA (µg/L)	**1999-2009**	open	0.0025	0.0184	44
		winter	0.0025	0.0025	4
	2021-2022	open	0.003	0.0065	4
		winter			0
Mecoprop (µg/L)	**1999-2009**	open	0.0025	0.007	44
		winter	0.0025	0.0025	4
	2021-2022	open	0.004	0.004	4
		winter			0
Total Mercury (ng/L)	**1999-2009**	open	0.425	2.367	18
		winter	0.795	1.731	8
	2021-2022	open	1.06	1.494	4
		winter	1.74	2.274	0
Total Recoverable Selenium (µg/L)	**1999-2009**	open	0.591	0.9972	14
		winter	1.12	1.254	7
	2021-2022	open	0.6	0.7	4
		winter	0.7	0.76	0

Table B-7. Median and 90th percentile values for primary indicators in the Bow River at Cochrane.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**1999-2009** (trigger)	open	0.005	0.041	70
		winter	0.007	0.025	50
	2021-2022	open	0.015	0.015	7
		winter	0.015	0.015	5
Chloride (mg/L)	**1999-2009** (trigger)	open	1.9	2.9	70
		winter	2	2.6	50
	2021-2022	open	2.1	2.5	7
		winter	2	5.6	5
Nitrate-N (mg/L)	**1999-2009** (trigger)	open	0.074	0.108	69
		winter	0.109	0.13	50
	2021-2022	open	0.076	0.099	7
		winter	0.13	0.13	5
Total Nitrogen (mg/L)	**1999-2009** (trigger)	open	0.18	0.4	70
		winter	0.17	0.23	50
	2021-2022	open	0.16	0.22	7
		winter	0.13	0.19	5
Total Dissolved Phosphorus (mg/L)	**2004-2009** (trigger)	open	0.002	0.004	35
		winter	0.002	0.004	25
	2021-2022	open	0.003	0.003	7
		winter	0.003	0.003	5
Total Phosphorus (mg/L)	**2004-2009** (trigger)	open	0.005	0.009	35
		winter	0.003	0.006	25
	2021-2022	open	0.003	0.014	7
		winter	0.003	0.003	5
Sulphate (mg/L)	**1999-2009** (trigger)	open	33.6	40.4	70
		winter	42.2	45.8	50
	2021-2022	open	37	48.2	7
		winter	51	53.2	5
Sodium Adsorption Ratio	**1999-2009** (trigger)	open	0.07	0.12	70
		winter	0.07	0.1	50
	2021-2022	open	0.07	0.08	7
		winter	0.08	0.08	5
Specific Conductance (µS/cm)	**1999-2009** (trigger)	open	289	317	70
		winter	330	349	50
	2021-2022	open	290	344	7
		winter	340	350	5
Total Dissolved Solids (mg/L)	**1999-2009** (trigger)	open	165	190	70
		winter	190	200	50
	2021-2022	open	170	190	7
		winter	200	206	5
Total Organic Carbon (mg/L)	**1999-2009** (trigger)	open	1	1.6	34
		winter	0.8	0.9	14
	2021-2022	open	0.7	3.5	7

		winter	0.7	0.8	5
Total Suspended Solids (mg/L)	**1999-2009** (trigger)	open	2	8	70
		winter	1	2	50
	2021-2022	open	2	16	7
		winter	1	2	5
Turbidity (NTU)	**1999-2009** (trigger)	open	1.8	10.1	70
		winter	0.8	1.7	50
	2021-2022	open	0.8	14	7
		winter	0.9	2.5	5
pH	**1999-2009** (trigger)	open	8.23	8.38	70
		winter	8.17	8.3	50
	2021-2022	open	7.88	8.22	7
		winter	7.8	8.2	5
***Escherichia coli* (cfu/100ml)**	**1999-2009** (trigger)	open	2	13	70
		winter	1	2	49
	2021-2022	open	3	10	7
		winter	1	1	5

Table B-8. Median and 90th percentile values for secondary indicators in the Bow River at Cochrane.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**1999-2009**	open	0.0025	0.0025	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.005	0.005	4
		winter			0
Dicamba (µg/L)	**1999-2009**	open	0.0025	0.01	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.008	0.008	4
		winter			0
MCPA (µg/L)	**1999-2009**	open	0.0025	0.0025	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.003	0.003	4
		winter			0
Mecoprop (µg/L)	**1999-2009**	open	0.0025	0.0025	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.004	0.004	4
		winter			0
Total Mercury (ng/L)	**1999-2009**	open	0.3	0.918	22
		winter	0.335	0.497	10
	2021-2022	open	0.39	1.476	7
		winter	0.39	0.72	5
Total Recoverable Selenium (µg/L)	**1999-2009**	open	0.5005	0.5933	18
		winter	0.612	0.801	9
	2021-2022	open	0.5	0.64	7
		winter	0.6	0.7	5

Table B-9. Median and 90th percentile values for primary indicators in the Bow River at Carseland.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**1999-2009** (trigger)	open	0.045	0.16	70
		winter	0.25	0.472	50
	2021-2022	open	0.025	0.074	7
		winter	0.087	0.174	5
Chloride (mg/L)	**1999-2009** (trigger)	open	7.6	13.1	70
		winter	12.7	20.4	50
	2021-2022	open	13	17.4	7
		winter	20	27.8	5
Nitrate-N (mg/L)	**1999-2009** (trigger)	open	0.601	0.99	69
		winter	1.13	1.403	50
	2021-2022	open	0.67	0.892	7
		winter	1.1	1.36	5
Total Nitrogen (mg/L)	**1999-2009** (trigger)	open	1.02	1.72	70
		winter	1.67	2.17	50
	2021-2022	open	0.94	1.38	7
		winter	1.4	1.76	5
Total Dissolved Phosphorus (mg/L)	**2004-2009** (trigger)	open	0.007	0.016	35
		winter	0.017	0.028	25
	2021-2022	open	0.003	0.009	7
		winter	0.013	0.032	5
Total Phosphorus (mg/L)	**2004-2009** (trigger)	open	0.021	0.083	35
		winter	0.03	0.062	25
	2021-2022	open	0.023	0.04	7
		winter	0.02	0.045	5
Sulphate (mg/L)	**1999-2009** (trigger)	open	42.8	51.5	70
		winter	53.9	58	50
	2021-2022	open	49	59.6	7
		winter	64	70.4	5
Sodium Adsorption Ratio	**1999-2009** (trigger)	open	0.3	0.45	70
		winter	0.39	0.58	50
	2021-2022	open	0.36	0.43	7
		winter	0.51	0.56	5
Specific Conductance (μS/cm)	**1999-2009** (trigger)	open	346	398	69
		winter	422	443	50
	2021-2022	open	380	434	7
		winter	450	490	5
Total Dissolved Solids (mg/L)	**1999-2009** (trigger)	open	201	232	70
		winter	246	260	50
	2021-2022	open	210	250	7
		winter	270	286	5
Total Organic Carbon (mg/L)	**1999-2009** (trigger)	open	2	3.6	34
		winter	1.5	1.9	14
	2021-2022	open	1.7	2.1	7

		winter	1.2	1.4	5
Total Suspended Solids (mg/L)	**1999-2009** (trigger)	open	6	64	70
		winter	5	14	50
	2021-2022	open	4	27	7
		winter	4	9	5
Turbidity (NTU)	**1999-2009** (trigger)	open	4	48.4	70
		winter	2.6	9.3	50
	2021-2022	open	1.2	16	7
		winter	2.2	3.9	5
pH	**1999-2009** (trigger)	open	8.2	8.39	70
		winter	8.06	8.2	50
	2021-2022	open	8.01	8.22	7
		winter	7.8	8.12	5
Escherichia coli **(cfu/100ml)**	**1999-2009** (trigger)	open	28	144	67
		winter	10	25	47
	2021-2022	open	22	43	7
		winter	4	5	5

Table B-10. Median and 90th percentile values for secondary indicators in the Bow River at Carseland.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**1999-2009**	open	0.0075	0.026	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.0065	0.007	4
		winter			0
Dicamba (µg/L)	**1999-2009**	open	0.0025	0.01	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.008	0.008	4
		winter			0
MCPA (µg/L)	**1999-2009**	open	0.0025	0.0071	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.003	0.003	4
		winter			0
Mecoprop (µg/L)	**1999-2009**	open	0.005	0.0167	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.004	0.004	4
		winter			0
Total Mercury (ng/L)	**1999-2009**	open	0.3	4.807	22
		winter	0.345	0.685	10
	2021-2022	open	0.73	2.136	7
		winter	0.59	1.262	5
Total Recoverable Selenium (µg/L)	**1999-2009**	open	0.585	0.8819	18
		winter	0.825	0.9796	9
	2021-2022	open	0.6	0.7	7
		winter	0.7	0.8	5

Table B-11. Median and 90th percentile values for primary indicators in the Bow River at Cluny.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**1999-2009** (trigger)	open	0.025	0.12	71
		winter	0.195	0.372	48
	2021-2022	open	0.015	0.033	7
		winter	0.13	0.16	5
Chloride (mg/L)	**1999-2009** (trigger)	open	8	13	71
		winter	13	20.9	43
	2021-2022	open	14	18.8	7
		winter	25	31.6	5
Nitrate-N (mg/L)	**1999-2009** (trigger)	open	0.52	0.837	59
		winter	1.195	1.455	40
	2021-2022	open	0.55	0.702	7
		winter	1.4	1.76	5
Total Nitrogen (mg/L)	**1999-2009** (trigger)	open	0.94	1.52	71
		winter	1.68	2.07	48
	2021-2022	open	0.79	1.02	7
		winter	1.8	2.22	5
Total Dissolved Phosphorus (mg/L)	**2004-2009** (trigger)	open	0.005	0.014	35
		winter	0.012	0.02	22
	2021-2022	open	0.003	0.009	7
		winter	0.007	0.021	5
Total Phosphorus (mg/L)	**2004-2009** (trigger)	open	0.017	0.128	35
		winter	0.016	0.025	22
	2021-2022	open	0.012	0.077	7
		winter	0.019	0.034	5
Sulphate (mg/L)	**1999-2009** (trigger)	open	47.8	58.1	48
		winter	57.2	63.1	32
	2021-2022	open	53	60.2	7
		winter	65	68.6	5
Sodium Adsorption Ratio	**1999-2009** (trigger)	open	0.35	0.58	48
		winter	0.42	0.72	32
	2021-2022	open	0.37	0.49	7
		winter	0.59	0.67	5
Specific Conductance (µS/cm)	**1999-2009** (trigger)	open	360	425	47
		winter	441	490	32
	2021-2022	open	370	434	7
		winter	480	502	5
Total Dissolved Solids (mg/L)	**1999-2009** (trigger)	open	211	245	48
		winter	257	290	32
	2021-2022	open	210	248	7
		winter	280	286	5
Total Organic Carbon (mg/L)	**1999-2009** (trigger)	open	2.2	4.3	23
		winter	1.3	1.8	16
	2021-2022	open	1.5	2	7

		winter	1.2	1.2	5
Total Suspended Solids (mg/L)	**1999-2009** (trigger)	open	11	80	71
		winter	4	9	48
	2021-2022	open	6	85	7
		winter	8	15	5
Turbidity (NTU)	**1999-2009** (trigger)	open	8.5	62.7	48
		winter	2.8	7.1	32
	2021-2022	open	1.7	15.4	7
		winter	3.8	7.6	5
pH	**1999-2009** (trigger)	open	8.3	8.46	48
		winter	8	8.23	37
	2021-2022	open	8.26	8.35	7
		winter	8.02	8.19	5
***Escherichia coli* (cfu/100ml)**	**1999-2009** (trigger)	open	8	56	67
		winter	1	6	48
	2021-2022	open	10	41	7
		winter	1	3	5

Table B-12. Median and 90th percentile values for secondary indicators in the Bow River at Cluny.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**1999-2009**	open	0.0065	0.0384	32
		winter	0.0025	0.0025	3
	2021-2022	open	0.0065	0.0094	4
		winter			0
Dicamba (µg/L)	**1999-2009**	open	0.0025	0.01	32
		winter	0.0025	0.0025	3
	2021-2022	open	0.008	0.008	4
		winter			0
MCPA (µg/L)	**1999-2009**	open	0.0025	0.0097	32
		winter	0.0025	0.0025	3
	2021-2022	open	0.003	0.003	4
		winter			0
Mecoprop (µg/L)	**1999-2009**	open	0.0055	0.0209	32
		winter	0.0025	0.0025	3
	2021-2022	open	0.004	0.004	4
		winter			0
Total Mercury (ng/L)	**1999-2009**	open	0.3	2.526	17
		winter	0.3	0.372	5
	2021-2022	open	0.94	4.358	7
		winter	0.96	1.71	5
Total Recoverable Selenium (µg/L)	**1999-2009**	open	0.698	0.9347	10
		winter	0.789	0.824	4
	2021-2022	open	0.5	0.68	7
		winter	0.8	0.8	5

Table B-13. Median and 90th percentile values for primary indicators in the Bow River at Ronalane.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**1999-2009** (trigger)	open	0.02	0.081	70
		winter	0.13	0.292	49
	2021-2022	open	0.016	0.046	7
		winter	0.018	0.123	5
Chloride (mg/L)	**1999-2009** (trigger)	open	8.4	12	70
		winter	13	19.7	49
	2021-2022	open	14	21	7
		winter	24	34.8	5
Nitrate-N (mg/L)	**1999-2009** (trigger)	open	0.302	0.747	69
		winter	1.19	1.44	49
	2021-2022	open	0.23	0.506	7
		winter	1.4	1.66	5
Total Nitrogen (mg/L)	**1999-2009** (trigger)	open	0.68	1.26	70
		winter	1.58	1.91	49
	2021-2022	open	0.63	1.03	7
		winter	1.9	2	5
Total Dissolved Phosphorus (mg/L)	**2004-2009** (trigger)	open	0.005	0.01	35
		winter	0.005	0.017	24
	2021-2022	open	0.003	0.005	7
		winter	0.004	0.013	5
Total Phosphorus (mg/L)	**2004-2009** (trigger)	open	0.025	0.138	35
		winter	0.012	0.027	24
	2021-2022	open	0.017	0.08	7
		winter	0.009	0.018	5
Sulphate (mg/L)	**1999-2009** (trigger)	open	62.2	78.1	70
		winter	60.9	70.5	49
	2021-2022	open	70	80.8	7
		winter	77	87.6	5
Sodium Adsorption Ratio	**1999-2009** (trigger)	open	0.55	0.8	70
		winter	0.48	0.67	49
	2021-2022	open	0.55	0.68	7
		winter	0.61	0.89	5
Specific Conductance (μS/cm)	**1999-2009** (trigger)	open	386	431	70
		winter	448	499	49
	2021-2022	open	400	480	7
		winter	510	540	5
Total Dissolved Solids (mg/L)	**1999-2009** (trigger)	open	228	260	70
		winter	263	291	49
	2021-2022	open	240	272	7
		winter	300	312	5
Total Organic Carbon (mg/L)	**1999-2009** (trigger)	open	3	4.8	34
		winter	1.5	2.5	14
	2021-2022	open	2	2.6	7

		winter	1.4	1.9	5
Total Suspended Solids (mg/L)	**1999-2009** (trigger)	open	12	72	70
		winter	6	18	49
	2021-2022	open	6	99	7
		winter	7	15	5
Turbidity (NTU)	**1999-2009** (trigger)	open	10.4	73.3	70
		winter	3.8	17.4	49
	2021-2022	open	2.9	41.8	7
		winter	6.2	10.1	5
pH	**1999-2009** (trigger)	open	8.32	8.58	70
		winter	8.06	8.3	49
	2021-2022	open	8.21	8.37	7
		winter	8.1	8.33	5
***Escherichia coli* (cfu/100ml)**	**1999-2009** (trigger)	open	14	77	69
		winter	1	6	49
	2021-2022	open	22	269	7
		winter	4	6	5

Table B-14. Median and 90th percentile values for secondary indicators in the Bow River at Ronalane.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**1999-2009**	open	0.0325	0.1443	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.02	0.0358	4
		winter			0
Dicamba (µg/L)	**1999-2009**	open	0.0095	0.0354	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.008	0.008	4
		winter			0
MCPA (µg/L)	**1999-2009**	open	0.0025	0.0629	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.004	0.0057	4
		winter			0
Mecoprop (µg/L)	**1999-2009**	open	0.0055	0.016	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.0065	0.0097	4
		winter			0
Total Mercury (ng/L)	**1999-2009**	open	0.9	4.236	18
		winter	0.3	0.51	6
	2021-2022	open	0.86	4.056	7
		winter	1.23	1.392	5
Total Recoverable Selenium (µg/L)	**1999-2009**	open	0.69	0.9378	14
		winter	0.831	1.0012	5
	2021-2022	open	0.6	0.74	7
		winter	0.9	1.24	5

Table B-15. Median and 90th percentile values for primary indicators in the South Saskatchewan River at Medicine Hat at Hwy 1.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**1999-2009** (trigger)	open	0.02	0.06	70
		winter	0.09	0.253	48
	2021-2022	open	0.019	0.069	7
		winter	0.05	0.16	5
Chloride (mg/L)	**1999-2009** (trigger)	open	6.4	9.8	70
		winter	12.6	19.9	48
	2021-2022	open	9.5	14.4	7
		winter	16	26.2	5
Nitrate-N (mg/L)	**1999-2009** (trigger)	open	0.103	0.497	69
		winter	1.015	1.258	48
	2021-2022	open	0.25	0.404	7
		winter	0.91	0.996	5
Total Nitrogen (mg/L)	**1999-2009** (trigger)	open	0.55	1.01	70
		winter	1.33	1.72	48
	2021-2022	open	0.65	0.96	7
		winter	1.3	1.36	5
Total Dissolved Phosphorus (mg/L)	**1999-2009** (trigger)	open	0.004	0.009	70
		winter	0.004	0.01	48
	2021-2022	open	0.003	0.004	7
		winter	0.003	0.005	5
Total Phosphorus (mg/L)	**1999-2009** (trigger)	open	0.022	0.098	70
		winter	0.01	0.042	48
	2021-2022	open	0.01	0.084	7
		winter	0.01	0.013	5
Sulphate (mg/L)	**1999-2009** (trigger)	open	56.5	76.9	70
		winter	62.4	77.6	48
	2021-2022	open	54	77.6	7
		winter	58	63.4	5
Sodium Adsorption Ratio	**1999-2009** (trigger)	open	0.6	0.79	70
		winter	0.59	0.88	48
	2021-2022	open	0.6	0.72	7
		winter	0.57	0.81	5
Specific Conductance (µS/cm)	**1999-2009** (trigger)	open	369	436	68
		winter	462	519	48
	2021-2022	open	370	474	7
		winter	440	462	5
Total Dissolved Solids (mg/L)	**1999-2009** (trigger)	open	221	252	70
		winter	268	316	48
	2021-2022	open	240	270	7
		winter	260	266	5
Total Organic Carbon (mg/L)	**1999-2009** (trigger)	open	2.7	4	34
		winter	1.7	3	13

	2021-2022	open	1.9	2.6	7
		winter	1.8	2	5
Total Suspended Solids (mg/L)	**1999-2009** (trigger)	open	19	105	70
		winter	5	32	48
	2021-2022	open	10	148	7
		winter	12	15	5
Turbidity (NTU)	**1999-2009** (trigger)	open	16.4	80.5	70
		winter	4	28.3	48
	2021-2022	open	3.9	23	7
		winter	8.5	12.5	5
pH	**1999-2009** (trigger)	open	8.32	8.47	70
		winter	8.14	8.27	48
	2021-2022	open	8.06	8.38	7
		winter	8.21	8.36	5
***Escherichia coli* (cfu/100ml)**	**1999-2009** (trigger)	open	13	99	68
		winter	1	7	48
	2021-2022	open	30	72	7
		winter	1	20	5

Table B-16. Median and 90th percentile values for secondary indicators in the South Saskatchewan River at Medicine Hat at Hwy 1.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**1999-2009**	open	0.0245	0.1049	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.0175	0.0326	4
		winter			0
Dicamba (µg/L)	**1999-2009**	open	0.0025	0.017	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.008	0.008	4
		winter			0
MCPA (µg/L)	**1999-2009**	open	0.0025	0.0168	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.004	0.0057	4
		winter			0
Mecoprop (µg/L)	**1999-2009**	open	0.0025	0.0132	44
		winter	0.0025	0.0025	3
	2021-2022	open	0.004	0.0089	4
		winter			0
Total Mercury (ng/L)	**1999-2009**	open	0.55	2.609	18
		winter	0.3	0.408	5
	2021-2022	open	1.17	5.692	7
		winter	1.16	1.49	5
Total Recoverable Selenium (µg/L)	**1999-2009**	open	0.573	0.847	14
		winter	0.9995	1.071	4
	2021-2022	open	0.6	0.78	7
		winter	0.8	0.8	5

Table B-17. Median and 90th percentile values for primary indicators in the Milk River at SH 880.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
Total Ammonia-N (mg/L)	**2003-2009** (trigger)	open	0.025	0.07	81
		winter	0.04	0.13	31
	2021-2022	open	0.015	0.023	7
		winter	0.025	0.089	5
Chloride (mg/L)	**2003-2009** (trigger)	open	1.3	6.2	81
		winter	8	14.3	31
	2021-2022	open	1.2	4.3	7
		winter	7.1	10.2	5
Nitrate-N (mg/L)	**2003-2009** (trigger)	open	0.031	0.123	81
		winter	0.382	0.807	31
	2021-2022	open	0.007	0.014	7
		winter	0.15	0.268	5
Total Nitrogen (mg/L)	**2003-2009** (trigger)	open	0.32	0.59	78
		winter	0.82	1.22	31
	2021-2022	open	0.23	0.44	7
		winter	0.49	0.65	5
Total Dissolved Phosphorus (mg/L)	**2003-2009** (trigger)	open	0.003	0.006	81
		winter	0.003	0.01	31
	2021-2022	open	0.003	0.003	7
		winter	0.003	0.003	5
Total Phosphorus (mg/L)	**2003-2009** (trigger)	open	0.079	0.193	81
		winter	0.007	0.039	31
	2021-2022	open	0.06	0.103	7
		winter	0.007	0.012	5
Sulphate (mg/L)	**2003-2009** (trigger)	open	22.3	170	81
		winter	197	316	31
	2021-2022	open	21	90.4	7
		winter	210	302	5
Sodium Adsorption Ratio	**2003-2009** (trigger)	open	0.43	2.26	81
		winter	2.54	3.8	31
	2021-2022	open	0.4	1.44	7
		winter	2.95	4.19	5
Specific Conductance (µS/cm)	**2003-2009** (trigger)	open	248	733	81
		winter	916	1380	31
	2021-2022	open	240	490	7
		winter	970	1120	5
Total Dissolved Solids (mg/L)	**2003-2009** (trigger)	open	140	488	81
		winter	606	900	31
	2021-2022	open	130	292	7
		winter	630	748	5
Total Organic Carbon (mg/L)	**2003-2009** (trigger)	open	2.1	4.2	39
		winter	3.7	4.8	26
	2021-2022	open	1.3	2.6	7

		winter	2.8	3.5	5
Total Suspended Solids (mg/L)	**2003-2009** (trigger)	open	107	304	81
		winter	3	12	31
	2021-2022	open	90	152	7
		winter	4	6	5
Turbidity (NTU)	**2003-2009** (trigger)	open	60	170	81
		winter	3.7	17.5	31
	2021-2022	open	33	51.8	7
		winter	4.2	7	5
pH	**2003-2009** (trigger)	open	8.23	8.43	81
		winter	8.3	8.41	31
	2021-2022	open	8.11	8.26	7
		winter	8.23	8.36	5
***Escherichia coli* (cfu/100ml)**	**2003-2009** (trigger)	open	57	230	79
		winter	1	9	30
	2021-2022	open	24	200	7
		winter	3	32	5

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Table B-18. Median and 90th percentile values for secondary indicators in the Milk River at SH 880.

INDICATOR	TIME PERIOD	SEASON	MEDIAN	90TH PERCENTILE	*n*
2,4-D (µg/L)	**2003-2009**	open	0.0025	0.0114	24
		winter			0
	2021-2022	open	0.005	0.0071	4
		winter			0
Dicamba (µg/L)	**2003-2009**	open	0.0025	0.0025	24
		winter			0
	2021-2022	open	0.008	0.0087	4
		winter			0
MCPA (µg/L)	**2003-2009**	open	0.0025	0.003	24
		winter			0
	2021-2022	open	0.003	0.003	4
		winter			0
Mecoprop (µg/L)	**2003-2009**	open	0.0025	0.0025	24
		winter			0
	2021-2022	open	0.004	0.004	4
		winter			0
Total Mercury (ng/L)	**2003-2009**	open	2.15	9.5	18
		winter	0.3	0.695	6
	2021-2022	open	3.25	4.842	7
		winter	0.92	1.53	5
Total Recoverable Selenium (µg/L)	**2003-2009**	open	0.354	0.887	14
		winter	1.2	1.506	5
	2021-2022	open	0.2	0.38	7
		winter	0.7	1.06	5

Appendix C

Statistical Summary, LTRN Station Information and Boxplots

Table C-1. Results of the statistical assessment of the 2021-2022 compliance values against the Framework triggers for sites on the Oldman River. The surface water quality parameters with concentrations that had statistically significant test results are highlighted. Normal and log-normal distributions used parametric UPL calculations, while non-normal distributions used non-parametric UPL calculations. Central tendency UPL trigger exceedances were reported (e.g. FAIL) when the compliance mean/median values exceeded the central tendency UPL. Peak UPL trigger exceedances (e.g. FAIL) were reported when there was a significant number of individual values exceeding the peak UPL determined with the binomial test.

Indicator	Units	Distribution	Deseasonal-ized? (i.e., difference between months)	Separated by Seasons	Season (O=open; W=winter)	Compliance Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
OLDMAN RIVER AT BROCKET											
Ammonia-N	mg/L	Non-Normal	No	No	O/W	0.01	0.15	PASS	0.08	0	PASS
Chloride	mg/L	Non-Normal	Yes	No	O/W	0.44	4.23	PASS	2.23	1	PASS
E. coli	cfu/100ml	Non-Normal	Yes	No	O/W	16.28	783.41	PASS	58.78	0	PASS
Nitrate-N	mg/L	Non-Normal	Yes	No	O/W	0.02	0.2	PASS	0.15	0	PASS
pH	pH units	Non-Normal	No	No	O/W	8.37	8.49	PASS	8.38	1	PASS
SAR	rel units	Non-Normal	Yes	No	O/W	0.13	0.34	PASS	0.24	0	PASS
Sp. Cond.	µS/cm	Normal	Yes	No	O/W	292.4	299.87	PASS	347.52	0	PASS
Sulphate	mg/L	Non-Normal	Yes	No	O/W	20.69	34.58	PASS	30.57	0	PASS
TDP	mg/L	Non-Normal	No	No	O/W	0	0.03	PASS	0.01	0	PASS
TDS	mg/L	Non-Normal	Yes	No	O/W	147.44	198.71	PASS	186.83	0	PASS
TN	mg/L	Non-Normal	Yes	No	O/W	0.12	1.82	PASS	0.4	0	PASS
TOC	mg/L	Non-Normal	Yes	No	O/W	2.05	4.77	PASS	3.56	0	PASS
TP	mg/L	Non-Normal	Yes	Yes	O	0	0.07	PASS	0.03	0	PASS
TP	mg/L	Normal	Yes	Yes	W	0.01	0.01	PASS	0.02	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	O	1.58	55.26	PASS	22.11	0	PASS
TSS	mg/L	Lognormal	Yes	Yes	W	2.4	2.43	PASS	15.26	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	O	4.37	59.92	PASS	33.36	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	W	7.34	23.46	PASS	15.84	0	PASS
OLDMAN RIVER AT HWY 3											
Ammonia-N	mg/L	Non-Normal	No	No	O/W	0.02	0.27	PASS	0.1	0	PASS
Chloride	mg/L	Non-Normal	Yes	No	O/W	1.44	26.54	PASS	4.7	0	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	O	93.87	5477.05	PASS	394	0	PASS

Indicator	Units	Distribution	Deseasonal-ized? (i.e., difference between months)	Separated by Seasons	Season (O=open; W=winter)	Compliance Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
E. coli	cfu/100ml	Non-Normal	Yes	Yes	W	109.45	148.45	PASS	129.11	3	FAIL
Nitrate-N	mg/L	Non-Normal	Yes	No	O/W	-0.01	0.92	PASS	0.25	0	PASS
pH	pH units	Non-Normal	Yes	No	O/W	8.2	8.56	PASS	8.46	1	PASS
SAR	rel units	Non-Normal	Yes	No	O/W	0.34	0.76	PASS	0.7	0	PASS
Sp. Cond.	µS/cm	Lognormal	Yes	No	O/W	5.81	5.9	PASS	483.98	0	PASS
Sulphate	mg/L	Lognormal	Yes	No	O/W	3.62	3.81	PASS	77.92	0	PASS
TDP	mg/L	Non-Normal	No	No	O/W	0	0.08	PASS	0.01	0	PASS
TDS	mg/L	Non-Normal	Yes	No	O/W	157.03	292.03	PASS	248.85	0	PASS
TN	mg/L	Non-Normal	Yes	No	O/W	0.3	5.62	PASS	0.86	0	PASS
TOC	mg/L	Non-Normal	Yes	No	O/W	2.03	16.7	PASS	4.81	0	PASS
TP	mg/L	Non-Normal	Yes	Yes	O	0.05	2.08	PASS	0.43	0	PASS
TP	mg/L	Non-Normal	Yes	Yes	W	0.05	0.17	PASS	0.08	1	PASS
TSS	mg/L	Non-Normal	Yes	Yes	O	68.7	3260.21	PASS	517.11	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	W	70.3	202.33	PASS	109.21	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	O	42.64	1994.36	PASS	348.46	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	W	42.92	173.27	PASS	84.9	0	PASS
OLDMAN RIVER AT HWY 36											
Ammonia-N	mg/L	Non-Normal	Yes	No	O/W	0.09	0.23	PASS	0.16	1	PASS
Chloride	mg/L	Normal	Yes	No	O/W	4.72	5.85	PASS	10.07	0	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	O	106.6	9207.15	PASS	726.91	0	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	W	134.6	187.67	PASS	162.96	0	PASS
Nitrate-N	mg/L	Non-Normal	Yes	No	O/W	0.01	1.09	PASS	0.39	0	PASS
pH	pH units	Normal	Yes	No	O/W	8.29	8.36	PASS	8.67	0	PASS
SAR	rel units	Normal	Yes	No	O/W	0.52	0.67	PASS	1.01	0	PASS
Sp. Cond.	µS/cm	Normal	Yes	No	O/W	366.51	406.26	PASS	521.52	0	PASS
Sulphate	mg/L	Normal	Yes	No	O/W	50.25	58.94	PASS	89.34	0	PASS
TDP	mg/L	Non-Normal	No	No	O/W	0.01	0.13	PASS	0.02	0	PASS
TDS	mg/L	Normal	Yes	No	O/W	211.67	239.87	PASS	310.77	0	PASS

Indicator	Units	Distribution	Deseasonal-ized? (i.e., difference between months)	Separated by Seasons	Season (O=open; W=winter)	Compliance Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
TN	mg/L	Non-Normal	Yes	No	O/W	0.41	6.6	PASS	1.01	0	PASS
TOC	mg/L	Non-Normal	Yes	No	O/W	2.26	16.74	PASS	4.52	0	PASS
TP	mg/L	Non-Normal	Yes	Yes	O	0.06	2.09	PASS	0.47	0	PASS
TP	mg/L	Non-Normal	Yes	Yes	W	0.06	0.1	PASS	0.09	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	O	63.07	3254.16	PASS	560.86	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	W	74.74	119.34	PASS	93.99	1	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	O	37.55	1353.89	PASS	401.15	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	W	47.79	88.08	PASS	78.86	0	PASS

Table C-2. Results of the statistical assessment of the 2021-2022 compliance values against the Framework triggers for sites on the Bow River. The surface water quality parameters with concentrations that had statistically significant test results are highlighted. Normal and log-normal distributions used parametric UPL calculations, while non-normal distributions used non-parametric UPL calculations. Central tendency UPL trigger exceedances were reported (e.g. FAIL) when the compliance mean/median values exceeded the central tendency UPL. Peak UPL trigger exceedances (e.g. FAIL) were reported when there was a significant number of individual values exceeding the peak UPL determined with the binomial test.

Indicator	Units	Distribution	Deseasonal-ized? (i.e., difference between months)	Separated by Seasons	Season (O=open; W=winter)	Compliance Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
BOW RIVER AT COCHRANE											
Ammonia-N	mg/L	Non-Normal	No	No	O/W	0.01	0.38	PASS	0.06	0	PASS
Chloride	mg/L	Non-Normal	No	No	O/W	2	9.3	PASS	3.78	1	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	O	17.93	1200.39	PASS	61.57	0	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	W	19.43	33.88	PASS	27.38	0	PASS
Nitrate-N	mg/L	Non-Normal	Yes	Yes	O	0.11	3.29	PASS	0.17	0	PASS
Nitrate-N	mg/L	Non-Normal	Yes	Yes	W	0.13	0.15	PASS	0.14	1	PASS
pH	pH units	Non-Normal	No	No	O/W	7.8	8.46	PASS	8.4	0	PASS
SAR	rel units	Non-Normal	Yes	No	O/W	0.08	0.17	PASS	0.12	0	PASS
Sp. Cond.	µS/cm	Non-Normal	Yes	No	O/W	314.36	391.36	PASS	328.62	2	PASS
Sulphate	mg/L	Non-Normal	Yes	No	O/W	45.28	48.7	PASS	41.77	5	FAIL
TDP	mg/L	Non-Normal	No	No	O/W	0	0	PASS	0	0	PASS
TDS	mg/L	Normal	Yes	No	O/W	180	180.49	PASS	202.58	0	PASS
TN	mg/L	Non-Normal	Yes	Yes	O	0.22	5.58	PASS	0.56	0	PASS
TN	mg/L	Normal	Yes	Yes	W	0.24	0.3	PASS	0.4	0	PASS
TOC	mg/L	Non-Normal	Yes	No	O/W	0.97	2.73	PASS	1.94	1	PASS
TP	mg/L	Non-Normal	Yes	No	O/W	0	0.07	PASS	0.01	0	PASS
TSS	mg/L	Non-Normal	Yes	No	O/W	4.97	136.15	PASS	10.34	1	PASS
Turbidity	NTU	Non-Normal	Yes	No	O/W	4.51	110.13	PASS	8.11	0	PASS
BOW RIVER AT CARSELAND											
Ammonia-N	mg/L	Non-Normal	Yes	No	O/W	-0.01	0.5	PASS	0.37	0	PASS
Chloride	mg/L	Non-Normal	Yes	No	O/W	18.33	28.94	PASS	16.79	4	FAIL
E. coli	cfu/100ml	Non-Normal	Yes	No	O/W	52.42	2601.33	PASS	195.82	0	PASS
Nitrate-N	mg/L	Normal	Yes	No	O/W	0.81	0.96	PASS	1.44	0	PASS
pH	pH units	Non-Normal	Yes	No	O/W	7.76	8.6	PASS	8.36	0	PASS

Indicator	Units	Distribution	Deseasonal-ized? (i.e., difference between months)	Separated by Seasons	Season (O=open; W=winter)	Compliance Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
SAR	rel units	Non-Normal	Yes	No	O/W	0.47	0.98	PASS	0.54	0	PASS
Sp. Cond.	µS/cm	Non-Normal	Yes	No	O/W	433.68	457.69	PASS	434.14	2	PASS
Sulphate	mg/L	Non-Normal	Yes	No	O/W	59.08	62.87	PASS	55.93	5	FAIL
TDP	mg/L	Lognormal	Yes	No	O/W	-4.52	-3.95	PASS	0.07	0	PASS
TDS	mg/L	Non-Normal	Yes	No	O/W	255.15	267.79	PASS	254.68	3	PASS
TN	mg/L	Lognormal	Yes	No	O/W	0.11	0.4	PASS	2.67	0	PASS
TOC	mg/L	Normal	Yes	No	O/W	1.56	2.34	PASS	3.82	0	PASS
TP	mg/L	Non-Normal	Yes	No	O/W	0.06	1.13	PASS	0.1	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	O	26.98	1488.53	PASS	89.2	0	PASS
TSS	mg/L	Lognormal	Yes	Yes	W	5.25	5.29	PASS	209.25	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	O	19.01	973.31	PASS	114.55	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	W	18.71	43.98	PASS	33.24	0	PASS
BOW RIVER AT CLUNY											
Ammonia-N	mg/L	Non-Normal	Yes	No	O/W	0	0.57	PASS	0.26	0	PASS
Chloride	mg/L	Non-Normal	Yes	No	O/W	22.65	47.81	PASS	19.77	4	FAIL
E. coli	cfu/100ml	Non-Normal	Yes	No	O/W	17.82	476.55	PASS	79.01	0	PASS
Nitrate-N	mg/L	Normal	Yes	No	O/W	0.91	0.9	FAIL	1.38	0	PASS
pH	pH units	Normal	Yes	No	O/W	8.04	8.26	PASS	8.6	0	PASS
SAR	rel units	Lognormal	Yes	No	O/W	-0.8	-0.7	PASS	1.05	0	PASS
Sp. Cond.	µS/cm	Normal	Yes	No	O/W	415.05	418.13	PASS	512.07	0	PASS
Sulphate	mg/L	Non-Normal	Yes	No	O/W	56.13	99.59	PASS	66.89	0	PASS
TDP	mg/L	Non-Normal	Yes	No	O/W	0.01	0.08	PASS	0.02	0	PASS
TDS	mg/L	Non-Normal	Yes	No	O/W	253.27	329.15	PASS	273.38	0	PASS
TN	mg/L	Non-Normal	Yes	No	O/W	1.59	4.1	PASS	1.76	1	PASS
TOC	mg/L	Non-Normal	Yes	No	O/W	1.8	3.43	PASS	3.36	0	PASS
TP	mg/L	Non-Normal	Yes	No	O/W	0.06	1.17	PASS	0.11	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	O	28.79	1624.02	PASS	96.47	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	W	36.8	74.5	PASS	39.42	1	PASS
Turbidity	NTU	Non-Normal	Yes	No	O/W	11.89	95.7	PASS	50.54	0	PASS

Indicator	Units	Distribution	Deseasonal-ized? (i.e., difference between months)	Separated by Seasons	Season (O=open; W=winter)	Compliance Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
BOW RIVER AT RONALANE											
Ammonia-N	mg/L	Non-Normal	Yes	No	O/W	-0.03	0.36	PASS	0.25	0	PASS
Chloride	mg/L	Non-Normal	Yes	No	O/W	19.76	24.56	PASS	17.26	6	FAIL
E. coli	cfu/100ml	Non-Normal	Yes	Yes	O	32.58	737.14	PASS	161.66	1	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	W	32.1	40.03	PASS	36.42	0	PASS
Nitrate-N	mg/L	Normal	Yes	No	O/W	0.76	0.77	PASS	1.22	0	PASS
pH	pH units	Non-Normal	Yes	No	O/W	8.3	8.7	PASS	8.48	0	PASS
SAR	rel units	Lognormal	Yes	No	O/W	-0.56	-0.51	PASS	1.07	0	PASS
Sp. Cond.	µS/cm	Non-Normal	Yes	No	O/W	480.64	537.55	PASS	473.28	2	PASS
Sulphate	mg/L	Non-Normal	Yes	No	O/W	79.38	106.19	PASS	85.17	1	PASS
TDP	mg/L	Non-Normal	Yes	No	O/W	0	0.1	PASS	0.02	0	PASS
TDS	mg/L	Non-Normal	Yes	No	O/W	284.26	332.17	PASS	282.76	2	PASS
TN	mg/L	Normal	Yes	No	O/W	1.13	1.21	PASS	1.82	0	PASS
TOC	mg/L	Non-Normal	Yes	No	O/W	2.03	6.58	PASS	4.78	0	PASS
TP	mg/L	Non-Normal	Yes	No	O/W	0.02	0.25	PASS	0.15	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	O	19.48	281.76	PASS	117.43	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	W	26.84	55.64	PASS	46.38	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	O	13.19	193.14	PASS	126.71	0	PASS
Turbidity	NTU	Non-Normal	Yes	Yes	W	20.74	57.74	PASS	36.59	0	PASS

Table C-3. Results of the statistical assessment of the 2021-2022 compliance values against the Framework triggers for sites on the South Saskatchewan River. The surface water quality parameters with concentrations that had statistically significant test results are highlighted. Normal and log-normal distributions used parametric UPL calculations, while non-normal distributions used non-parametric UPL calculations. Central tendency UPL trigger exceedances were reported (e.g. FAIL) when the compliance mean/median values exceeded the central tendency UPL. Peak UPL trigger exceedances (e.g. FAIL) were reported when there was a significant number of individual values exceeding the peak UPL determined with the binomial test.

Indicator	Units	Distribution	Deseasonalized? (i.e., difference between months)	Separated by Seasons	Season (O=open; W=winter)	Compliance Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
SOUTH SASKATCHEWAN RIVER AT MEDICINE HAT											
Ammonia-N	mg/L	Non-Normal	Yes	No	O/W	0.05	0.26	PASS	0.16	0	PASS
Chloride	mg/L	Non-Normal	Yes	No	O/W	13.96	19.94	PASS	15.83	2	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	O	16.93	628.02	PASS	214.7	0	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	W	24.83	34.83	PASS	32.14	2	PASS
Nitrate-N	mg/L	Non-Normal	Yes	No	O/W	0.42	3.98	PASS	0.88	0	PASS
pH	pH units	Non-Normal	Yes	No	O/W	8.33	8.78	PASS	8.48	0	PASS
SAR	rel units	Lognormal	Yes	No	O/W	-0.55	-0.4	PASS	1.19	0	PASS
Sp. Cond.	µS/cm	Normal	Yes	No	O/W	409.88	438.05	PASS	562.82	0	PASS
Sulphate	mg/L	Lognormal	Yes	No	O/W	4.05	4.21	PASS	111.5	0	PASS
TDP	mg/L	Non-Normal	No	No	O/W	0	0.06	PASS	0.01	0	PASS
TDS	mg/L	Lognormal	Yes	No	O/W	5.48	5.55	PASS	343.99	0	PASS
TN	mg/L	Non-Normal	Yes	No	O/W	0.81	4.29	PASS	1.41	0	PASS
TOC	mg/L	Non-Normal	Yes	No	O/W	2.07	4.89	PASS	4.24	0	PASS
TP	mg/L	Non-Normal	Yes	No	O/W	0.03	0.37	PASS	0.12	0	PASS
TSS	mg/L	Non-Normal	Yes	No	O/W	40.85	539.1	PASS	122.74	1	PASS
Turbidity	NTU	Non-Normal	Yes	No	O/W	28.93	442.23	PASS	87.34	0	PASS
MILK RIVER AT SH 880											
Ammonia-N	mg/L	Non-Normal	Yes	No	O/W	0.02	0.38	PASS	0.13	0	PASS
Chloride	mg/L	Non-Normal	Yes	No	O/W	2.39	15.96	PASS	8.19	0	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	O	67.53	4347.47	PASS	297.53	0	PASS
E. coli	cfu/100ml	Non-Normal	Yes	Yes	W	104.67	128.67	PASS	119	2	PASS
Nitrate-N	mg/L	Non-Normal	Yes	No	O/W	-0.09	0.75	PASS	0.37	0	PASS
pH	pH units	Non-Normal	Yes	No	O/W	8.21	8.54	PASS	8.43	0	PASS
SAR	rel units	Non-Normal	Yes	No	O/W	1.37	3.28	PASS	2.36	1	PASS

Indicator	Units	Distribution	Deseasonalized? (i.e., difference between months)	Separated by Seasons	Season (O=open; W=winter)	Compliance Mean/ Median	Central Tendency UPL	Central Tendency UPL Pass/Fail	Peak UPL	No. of Individual Exceedance	Peak UPL Pass/Fail
Sp. Cond.	µS/cm	Non-Normal	Yes	No	O/W	450.56	1150.56	PASS	817.12	0	PASS
Sulphate	mg/L	Non-Normal	Yes	No	O/W	77.98	302.84	PASS	156.54	0	PASS
TDP	mg/L	Non-Normal	No	No	O/W	0	0.25	PASS	0.02	0	PASS
TDS	mg/L	Non-Normal	Yes	No	O/W	253.83	773.83	PASS	482.28	0	PASS
TN	mg/L	Non-Normal	Yes	No	O/W	0.25	3.51	PASS	1.08	0	PASS
TOC	mg/L	Non-Normal	Yes	No	O/W	2.93	14.75	PASS	9.54	0	PASS
TP	mg/L	Non-Normal	Yes	No	O/W	0.08	1.69	PASS	0.2	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	O	106.02	2441.42	PASS	370.09	0	PASS
TSS	mg/L	Non-Normal	Yes	Yes	W	125.77	656.36	PASS	352	0	PASS
Turbidity	NTU	Non-Normal	Yes	No	O/W	73.91	1842.05	PASS	184.06	0	PASS

Table C-4. Secondary indicators' detection frequencies in the historical and reporting dataset (April 1, 2019 to March 31, 2022) including the number of samples, the number of detects, and the detection frequency (DF).

		Historical Dataset			Reporting Dataset (2019-2022)		
Secondary Indicator	**Season**	**Samples**	**Detects**	**DF**	**Samples**	**Detects**	**DF**
BOW RIVER AT COCHRANE							
2,4-D	open	44	3	7%	11	1	9%
Dicamba	open	44	0	0%	11	1	9%
MCPA	open	44	0	0%	11	0	0%
Mecoprop	open	44	2	5%	11	1	9%
T-Hg	ice	5	5	100%	15	15	100%
T-Hg	open	7	7	100%	19	18	95%
TR-Se	ice	9	9	100%	15	15	100%
TR-Se	open	18	18	100%	19	19	100%
BOW RIVER AT CARSELAND							
2,4-D	open	44	33	75%	11	9	82%
Dicamba	open	44	2	5%	11	1	9%
MCPA	open	44	8	18%	11	0	0%
Mecoprop	open	44	26	59%	11	2	18%
T-Hg	ice	5	5	100%	14	14	100%
T-Hg	open	7	7	100%	19	19	100%
TR-Se	ice	9	9	100%	15	15	100%
TR-Se	open	18	18	100%	19	19	100%
BOW RIVER AT CLUNY							
2,4-D	open	32	23	72%	10	8	80%
Dicamba	open	32	2	6%	10	1	10%
MCPA	open	32	8	25%	10	0	0%
Mecoprop	open	32	22	69%	10	3	30%
T-Hg	ice	1	1	100%	14	14	100%
T-Hg	open	3	3	100%	19	19	100%
TR-Se	ice	4	4	100%	15	15	100%
TR-Se	open	10	10	100%	19	19	100%
2,4-D	open	32	23	72%	10	8	80%
BOW RIVER AT RONALANE							
2,4-D	open	44	41	93%	11	9	82%
Dicamba	open	44	22	50%	11	3	27%
MCPA	open	44	19	43%	11	2	18%
Mecoprop	open	44	35	80%	11	2	18%
T-Hg	ice	1	1	100%	15	15	100%
T-Hg	open	3	3	100%	19	19	100%
TR-Se	ice	5	5	100%	14	14	100%
TR-Se	open	14	14	100%	19	19	100%
2,4-D	open	44	41	93%	11	9	82%
OLDMAN RIVER AT BROCKET							
2,4-D	open	39	4	10%	11	0	0%
Dicamba	open	39	2	5%	11	0	0%
MCPA	open	39	2	5%	11	0	0%
Mecoprop	open	39	0	0%	11	0	0%
T-Hg	ice	3	3	100%	14	14	100%
T-Hg	open	3	3	100%	19	19	100%

		Historical Dataset			Reporting Dataset (2019-2022)		
Secondary Indicator	Season	Samples	Detects	DF	Samples	Detects	DF
TR-Se	ice	7	7	100%	14	14	100%
TR-Se	open	14	14	100%	19	19	100%
OLDMAN RIVER AT HWY 3							
2,4-D	open	46	29	63%	11	5	45%
Dicamba	open	46	6	13%	11	0	0%
MCPA	open	46	14	30%	11	1	9%
Mecoprop	open	46	7	15%	11	0	0%
T-Hg	ice	3	3	100%	14	13	93%
T-Hg	open	3	3	100%	19	19	100%
TR-Se	ice	7	7	100%	14	14	100%
TR-Se	open	14	14	100%	19	19	100%
OLDMAN RIVER AT HWY 36							
2,4-D	open	44	40	91%	11	8	73%
Dicamba	open	44	11	25%	11	1	9%
MCPA	open	44	18	41%	11	1	9%
Mecoprop	open	44	8	18%	11	0	0%
T-Hg	ice	3	3	100%	14	14	100%
T-Hg	open	3	3	100%	19	19	100%
TR-Se	ice	7	7	100%	14	14	100%
TR-Se	open	14	14	100%	19	19	100%
SOUTH SASKATCHEWAN RIVER AT MEDICINE HAT							
2,4-D	open	44	40	91%	10	9	90%
Dicamba	open	44	15	34%	10	5	50%
MCPA	open	44	19	43%	10	3	30%
Mecoprop	open	44	23	52%	10	1	10%
T-Hg	ice	1	1	100%	15	15	100%
T-Hg	open	3	3	100%	19	19	100%
TR-Se	ice	4	4	100%	15	15	100%
TR-Se	open	14	14	100%	19	19	100%
MILK RIVER AT SH 880							
2,4-D	open	24	9	38%	11	4	36%
Dicamba	open	24	1	4%	11	0	0%
MCPA	open	24	4	17%	11	1	9%
Mecoprop	open	24	1	4%	11	0	0%
T-Hg	ice	1	1	100%	14	14	100%
T-Hg	open	3	3	100%	20	20	100%
TR-Se	ice	5	5	100%	14	14	100%
TR-Se	open	14	13	93%	20	14	70%

Table C-5. Monitoring station numbers and corresponding station names.

STATION NUMBER	STATION NAME	ABBREVIATED STATION NAME (For Figure C-1)
AB05AB0070	Oldman River at Brocket	OMR BROCKET
AB05AD0010	Oldman River at Hwy 3	OMR HWY 3
AB05AG0010	Oldman River at Hwy 36	OMR HWY 36
AB05BH0010	Bow River at Cochrane	BR COCHRANE
AB05BM0590	Bow River at Cluny	BR CARSELAND
AB05BM0010	Bow River at Carseland	BR CLUNY
AB05BN0010	Bow River at Ronalane	BR RONALANE
AB05AK0020	South Saskatchewan River at Medicine Hat	SSR MH
AB11AA0070	Milk River at SH 880	MLK SH 880

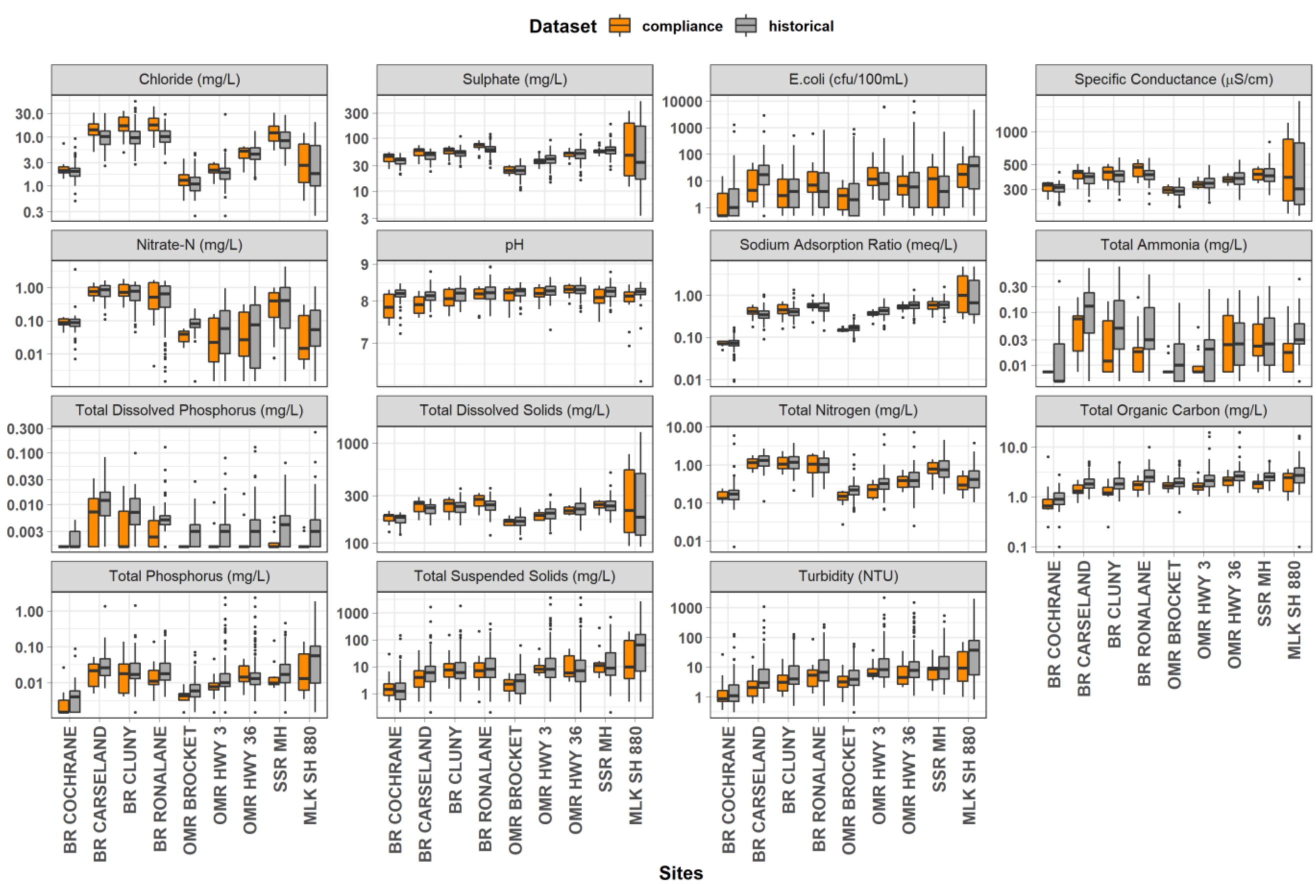

Figure C-1. Graphical presentations of the historical data (1999 – 2009), and the compliance data (2021-2022) for water quality parameters (all primary indicators) measured at the sites in the SSRB.Note the log scale. Full station names are listed in Table C-4 above.