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Abbreviations

2D	two dimensional
3D	three dimensional
AEP	Alberta Environment and Parks
BOD	biochemical oxygen demand
CCME	Canadian Council of Ministers of the Environment
CH_3Hg^+	methylmercury
DEM	digital elevation model
Hg [II]	inorganic mercury
PDA	project development area
RAA	regional assessment area
SOD	sediment oxygen demand
TDR	technical data report
the City	City of Calgary
the Project	Springbank Off-stream Reservoir Project
TSS	total suspended sediment

7.0 ASSESSMENT OF POTENTIAL EFFECTS ON SURFACE WATER QUALITY

7.1 SCOPE OF THE ASSESSMENT

Engagement and key concerns, spatial boundaries, effects characterization and significance definition for the assessment of the flood and post-flood effects on surface water quality are presented in Volume 3A, Section 7. The temporal boundary for the flood and post-flood operations is indefinite, since the Project is a permanent installation.

7.1.1 Project Pathway

The main effect on water quality is related to suspended sediment. The Project is intended to reduce Elbow River flood water flow by retention of water temporarily in an off-stream reservoir. This means that, by design, the Project affects flows in the Elbow River and flow is the driving force behind suspended sediment concentration. The complex dynamics between flow and sediment movement during floods in the Elbow River are assessed in Section 6 (Hydrology). Water temperature, dissolved oxygen, and metal methylation conditions change similarly in response to the diversion of flood water and retention in the reservoir prior to release back into Elbow River.

This section provides an assessment of suspended sediment, temperature, dissolved oxygen, and metal methylation. These parameters have complex relationships with the other water quality parameters that are included in the CEAA EIS guidelines (i.e., turbidity, oxygen levels, pH, nutrients, dissolved/total organic carbon, biological oxygen demand, carbonaceous biochemical oxygen demand, pesticides, and aquatic indicators). Where applicable, parameters have been grouped together for assessment (Sections 7.1.1.1), used in conjunction with other parameters to complete an assessment (Section 7.1.1.2), explicitly modelled (Section 7.1.1.3), or have been removed from the assessment due to a lack of an effect pathway (Section 7.1.1.4).

The EIS guidelines also include ice regime, and sediment quality. Ice regime effects are assessed in Volume 3B, Section 6 (Hydrology). Sediment distribution, and transport effects are assessed in Volume 3B, Section 6 (Hydrology), whereas sediment quality within the off-stream reservoir (soils) is assessed in Volume 3B, Section 9 (Terrain and Soils).

7.1.1.1 Suspended Sediment and Associated Parameters

Many water quality parameters behave similarly to suspended sediment. They are either directly associated with suspended sediment transport (e.g., Foster and Charlesworth 1996) or indirectly associated with suspended sediment (e.g., Han et al. 2006). Direct associations are when suspended sediment is at least partially composed of a parameter (e.g., a nutrient or metal). In this case, the parameter suspends and settles with suspended sediment because it is a part of that sediment. Indirect associations are when suspended sediment is not composed of a parameter (e.g., a nutrient or metal), but the parameter behaves in a manner similar to suspended sediment (e.g., settling in low velocity water and suspending in high velocity water). The following parameters are often associated with suspended sediment concentrations:

- nutrients (including dissolved and total organic carbon, phosphorus, and nitrogen species; Owens and Walling 2002, Walling et al. 2005, López-Tarazón et al. 2016
- metals; Meybeck et al. 2004, Horowitz 2008, Beck and Birch 2012
- coliforms; Crane et al. 1983, Tyrrel and Quinton 2003

The quantitative assessment of suspended sediment was therefore used as a surrogate to qualitatively examine the effects of the Project on parameters where the spatial and temporal patterns were like those of TSS. For water quality parameters that could be influenced by the Project, this approach reduces duplicative efforts and addresses the core processes that produce water quality patterns in Elbow River.

7.1.1.2 Dissolved Oxygen and Temperature

Water temperatures during flood operations could increase during the retention of water in the off-stream reservoir. This could occur because the waterbody surface area to volume ratio of water in Elbow River is much greater than water retained in the off-stream reservoir. The surface area to volume ratio is significant because thermal energy is lost from waterbodies through the surface, and so water with small surface area to volume ratios are subject to losing less thermal energy (Wetzel 1975).

Dissolved oxygen concentrations during flood operations would be the result of a complex interaction between atmospheric conditions, temperature, and biological processes (such as respiration). Oxygen is introduced into aquatic systems through surface interactions with the atmosphere, and biological processes (i.e., photosynthesis). The retention of water can lower aeration and reduce oxygen input (Wetzel 1975). Oxygen is also lost from aquatic systems through different biological processes (i.e., respiration). Temperature influences the rate of biological processes and controls the maximum concentration of oxygen that can be dissolved in a water sample (oxygen saturation). Temperature also largely controls the rate of biological processes and the materials available to fuel those processes. This is measured by biological oxygen demand (BOD), BOD can also be measured in sediment where it is referred to as sediment oxygen demand (SOD).

BOD is the amount of oxygen consumed by microorganisms breaking down material in a water sample of a given temperature and over a given time. BOD measurements include oxygen consumed by nitrifying bacteria, which oxidize inorganic ammonia and nitrite to produce energy. Carbonaceous biochemical oxygen demand (CBOD), measures oxygen consumption in water samples in the same manner as BOD, but suppresses nitrification; it only indicates the respiration from the breakdown of organic compounds.

There is no project pathway where the proportion of carbon, or nitrogen materials consumed changes the potential effects of the Project on DO. BOD encompasses all respiration activities and, therefore, addresses the reason for examining oxygen demand, which is to understand oxygen depletion caused by respiration. CBOD is, therefore, not differentiated from BOD in the dissolved oxygen and temperature pathway assessment.

The qualitative assessment of BOD, oxygen, and temperature is used as a single effects pathway because these parameters are closely associated.

7.1.1.3 Metal Methylation

The Terms of Reference include a requirement to assess potential implications of lead, arsenic, cadmium, and mercury methylation in the off-stream reservoir. Literature review has indicated that only mercury methylation is considered a potential effect from operation of the Project during floods. Organic forms of lead, arsenic, and cadmium are generally not associated with reservoir operations. The main source of organic forms of lead in the environment is the industrial synthesis of additives, and their distribution in the environment is generally limited (e.g., Neves et al. 1990; Prosi 1989; CCME 1999). Arsenic is oxidized, reduced, and methylated by microbes. However, arsenic is generally an environmental issue related to smelting and gold mining (e.g., Eider 1988; CCME 2001), not reservoirs. Cadmium methylation is not identified as an environmental concern in reviewed literature (e.g., Wright and Welbourne 1994; CCME 2014).

Mercury methylation is a chemical process that occurs in soil that is inundated by water, such as in the off-stream reservoir. Because vegetation and soil would be inundated, a potential exists for methylmercury release into reservoir water and into Elbow River (upon release of the retained water).

Methylmercury is a toxic form of mercury and it bioaccumulates in aquatic food webs (e.g., Ullrich et al. 2001; Hall et al. 2005; Montgomery et al. 2000). Both mercury methylation and demethylation occur in concert in aquatic environments, with an equilibrium being established within days to weeks (Ullrich et al. 2001). Net mercury methylation, the difference between these two phenomena, is evaluated in this assessment.

7.1.1.4 Other Parameters

No effect pathways pertaining to pH were identified; pH values in Glenmore Reservoir are very similar to those observed in Elbow River (Volume 4, Appendix K, Surface Water Quality Technical Data Report). Under design conditions, the off-stream reservoir will be inundated for a maximum of approximately 40 days; therefore, given the short retention time, large changes in pH are not anticipated. The effects on pH in the permanently inundated Glenmore Reservoir are negligible, and so project effects to pH are not anticipated; pH is, therefore, not included in the assessment.

The Surface Water Quality Technical Data Report (Volume 4, Appendix K) evaluated 63 pesticides, by referring to water quality records from 2005 to 2010. Of these pesticides, two were found above detection limits, on two occasions, all of which were downstream of the Project. Due to the lack of pesticide contamination around the Project, and the fact that Project will not use pesticides during operations, pesticides are not included as an effect pathway and are not assessed.

7.1.1.5 Potential Effects

Potential effects and effect pathways of the Project on surface water quality during the flood and post-flood phases are summarized in Table 7-1.

Table 7-1 Potential Effects, Pathways, and Measurable Parameters for Surface Water Quality

Potential Environmental Effect	Effect Pathway	Measurable Parameter(s) and Units of Measurement
Change in surface water quality	• Change in suspended sediment and suspended sediment associated parameter concentrations (TSS, turbidity, metals, nutrients, dissolved/total organic carbon, and aquatic indicators). • Change in temperature, dissolved oxygen concentrations, and BOD • Change in methylmercury concentrations	• Relevant water quality and sediment quality parameters, such as: – TSS in mg/L in water – Nutrient parameters (e.g. total/dissolved phosphorus, dissolved nitrogen species, total/dissolved organic carbon) in µg/L or mg/L in water – TSS in mg/L in water – Metal parameters in mg/L in water – Total coliforms in CFU/100 mL in water – Fecal coliforms in CFU/100 mL in water • Temperature in ˚C in water • Dissolved oxygen in mg/L • BOD in mg/L in water • SOD in mg/L in sediment • methylmercury as µg/L in water and ng/g in soil and sediment

7.2 EXISTING CONDITIONS FOR SURFACE WATER AND SEDIMENT QUALITY

7.2.1 Methods

Surface water quality data for the upper Elbow River mainstem and Glenmore Reservoir were analyzed to identify seasonal and spatial patterns. Existing conditions surface water quality data were sourced from Alberta Environment and Parks (AEP) water quality database, and the City of Calgary (the City). In addition, surface water quality samples were collected in Elbow River at Highway 22 and at the proposed location of the low-level outlet, in 2016. Relevant surface water quality sites in the RAA are shown in Figure 7-1. To support the surface water quality assessment, soil chemistry and sediment data were collected in 2016 from the PDA, upper Elbow River, and Glenmore Reservoir.

For water and sediment quality data processing methods and full data analysis results, see Volume 4, Appendix K, Surface Water Technical Data Report (TDR).

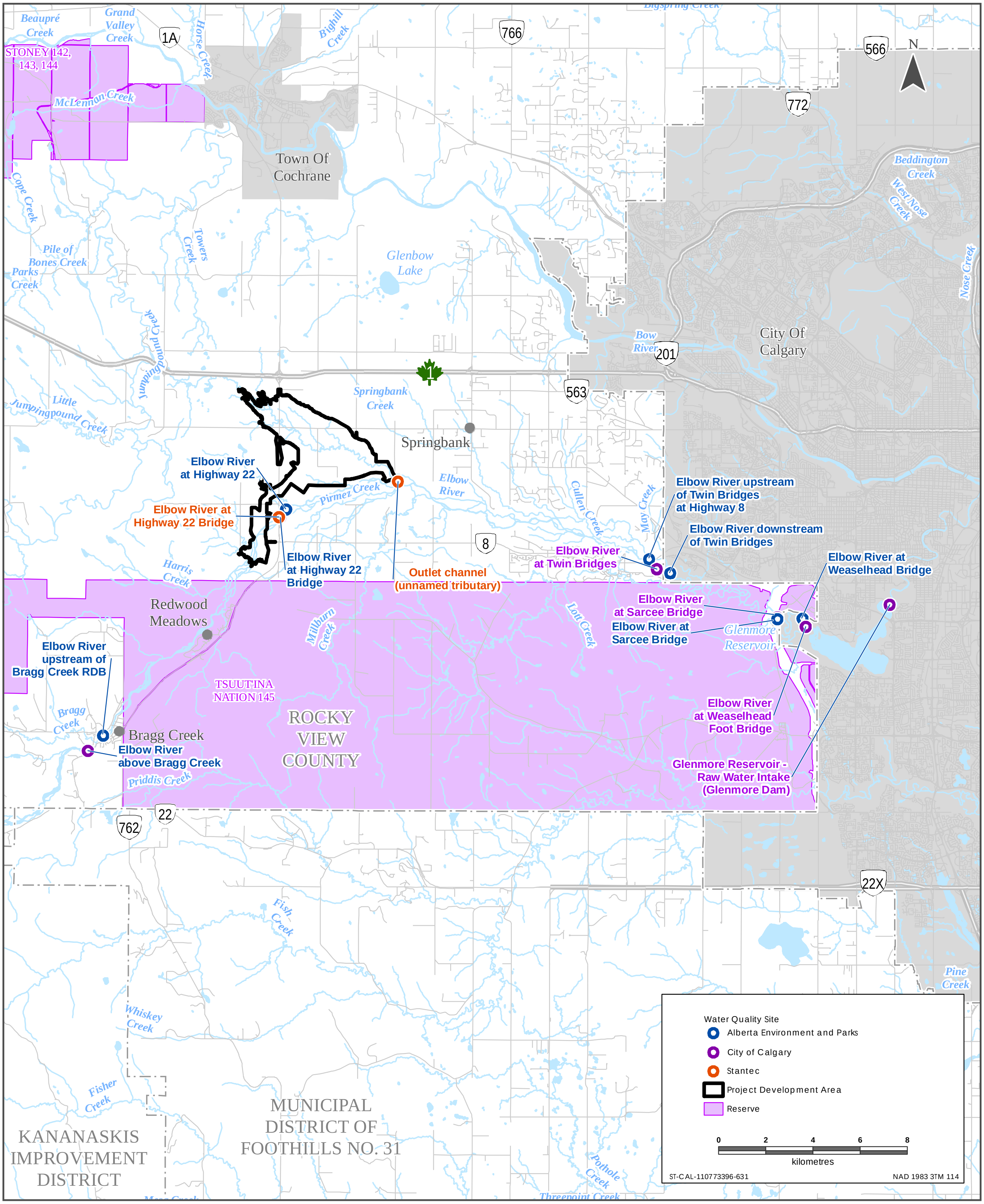
7.2.2 Overview

Water quality of upper Elbow River reflects lithology and geochemistry in the watershed, with major sources of nutrients and suspended sediment located within the City of Calgary limits (see Volume 4, Appendix K; Sosiak and Dixon 2004).

Water quality in Elbow River upstream of Glenmore Reservoir has been reported as good in relation to aquatic ecosystem and human uses of water from the river (Sosiak and Dixon 2004). However, concentrations of some parameters increased between 1979 and 1997 in the Elbow River upstream of Glenmore Reservoir within the city limits at Highway 8, including dissolved phosphorus, turbidity, and bacteria (Sosiak 1999). These changes were potentially related to runoff from livestock wintering areas and seepage from septic fields (Sosiak 1999).

Sosiak and Dixon (2004) identified two major processes that influence water quality in the watershed:

- non-point source runoff from agriculture, recreation, and residential development upstream of the City of Calgary. There are no approved wastewater discharges to the Elbow River upstream of Glenmore Reservoir.
- urban runoff from Calgary that is conveyed to Elbow River and Glenmore Reservoir



Sources: Base Data - ESRI, Natural Earth, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Relevant Upper Elbow River Water Quality Sites in the Regional Assessment Area

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 7-1

7.2.2.1 Suspended Sediment and Suspended Sediment Associated Parameters

The main project effect on water quality is anticipated to be related to the settling of suspended sediment. The processes that effect suspended sediment patterns can also effect other water quality parameters (e.g., Foster and Charlesworth 1996), and so parameters associated with suspended sediment could be directly linked to the main Project effect on water quality. The results discussion therefore focuses on identifying data patterns in suspended sediment and sediment-associated parameters. A summary of the suspended sediment associated parameter data analysis results are provided; see Volume 4, Appendix K Surface Water Quality TDR for complete data analysis results.

Between 1979 and 2016, suspended sediment concentrations in the upper Elbow River mainstem were greatest during the summer season, lowest during the fall and winter, and intermediate in the spring (see Figure 7-2).

The concentrations of suspended sediment increased from upstream to downstream in the upper Elbow River between Bragg Creek and Weaselhead Bridge. The increase in concentration from upstream to downstream was particularly distinct during the spring and summer. During fall and winter this spatial pattern were less pronounced, but still present. Suspended sediment concentrations were lower at Glenmore Dam than at the upper Elbow River mainstem sites upstream of Glenmore Reservoir, indicating that suspended sediment is stored prior to, or after it enters Glenmore Reservoir. Despite storage, the seasonal pattern, although dampened, was still apparent at Glenmore Dam. The highest measured concentration of suspended sediment observed in the upper Elbow River was 3,570 mg/L at the Highway 22 bridge on June 16, 2002.

Several nutrient parameters, total coliforms, and several metals had similar seasonal patterns as suspended sediment in the upper Elbow River mainstem. Similar seasonal patterns indicated that these parameters are particle-associated or vary as a response to similar conditions as suspended sediment. These parameter concentrations were greatest during the spring and/or summer, and were also most variable during this period. Like suspended sediment concentrations, the spatial patterns of these parameters were positive, meaning that these parameter concentrations increased in the upper Elbow River from Bragg Creek to Weaselhead Bridge.

Based on a quantitative analysis, the following parameters were very similar to suspended sediment in data patterns: total phosphorus (see Figure 7-3), total coliforms, dissolved phosphorus, total dissolved phosphorous, and total organic carbon. These parameters had highest concentrations observed during the spring and summer. Total Kjeldahl nitrogen (see Figure 7-4), fecal coliforms, and conductivity were moderately similar to suspended sediment. These parameter concentrations were greatest during the spring and summer, following the same pattern as suspended sediment. All except dissolved phosphorus also increased in concentration from upstream to downstream in Elbow River. Nitrate and nitrite (see Figure 7-5), and total nitrogen concentrations were greatest in the winter and spring, and had variation patterns that were not comparable to total suspended sediment (TSS). Total ammonia had very similar variation patterns to TSS, however, no apparent seasonal pattern was identified.

Based on visual assessment of seasonal patterns, total aluminum (see Figure 7-6), arsenic, boron, chromium, cobalt, iron, manganese, nickel, titanium, and vanadium had similar seasonal patterns as suspended sediment. Dissolved boron and arsenic concentrations were also greatest during the spring and summer. These metals also increased in from upstream to downstream, except for dissolved arsenic.

7.2.2.2 Temperature and Dissolved Oxygen

The upper Elbow River water temperature existing conditions data varied both seasonally and spatially (see Figure 7-7 and Figure 7-8). Temperatures were greatest during the summer, were lowest during the winter, and generally increased from upstream to downstream locations during all seasons. Water temperatures were higher during all seasons at Glenmore Dam compared to the upper Elbow River mainstem sites upstream of the Glenmore Reservoir.

Upper Elbow River dissolved oxygen concentrations varied seasonally, but were not associated with any apparent spatial pattern (see Figure 7-9). Dissolved oxygen concentrations were greatest during the winter, lowest during the summer, and intermediate during the spring and fall. This seasonal pattern likely reflects the water saturation of dissolved oxygen, which decreases with increasing temperature.

7.2.2.3 Total and Dissolved Mercury

Available total and dissolved mercury data for th upper Elbow River from 1979 to 2016 is summarized in Table 7-3. Total mercury detection limits ranged from 0.04 to 1 µg/L and dissolved mercury detection limits ranged from 0.005 to 0.025 µg/L. The one detected total mercury concentration of 0.1 µg/L is from the provincial monitoring dataset and was measured on April 27, 1988.

In addition to total and dissolved mercury data, some extractable mercury data are also available for upper Elbow River. Total metal analysis measures all forms of an individual element in a sample, whereas dissolved metals are in solution and not associated with particles or colloids. Extractable metal analysis refers to the concentration of metals after acidification of an unfiltered sample and is used primarily to estimate drinking water exposures rather than aquatic life exposures (US EPA 2016). A total of 22 samples of extractable mercury are available between 1982 and 2015 at Glenmore Dam, with maximum concentration of 0.09 µg/L and minimum 0.001 µg/L.

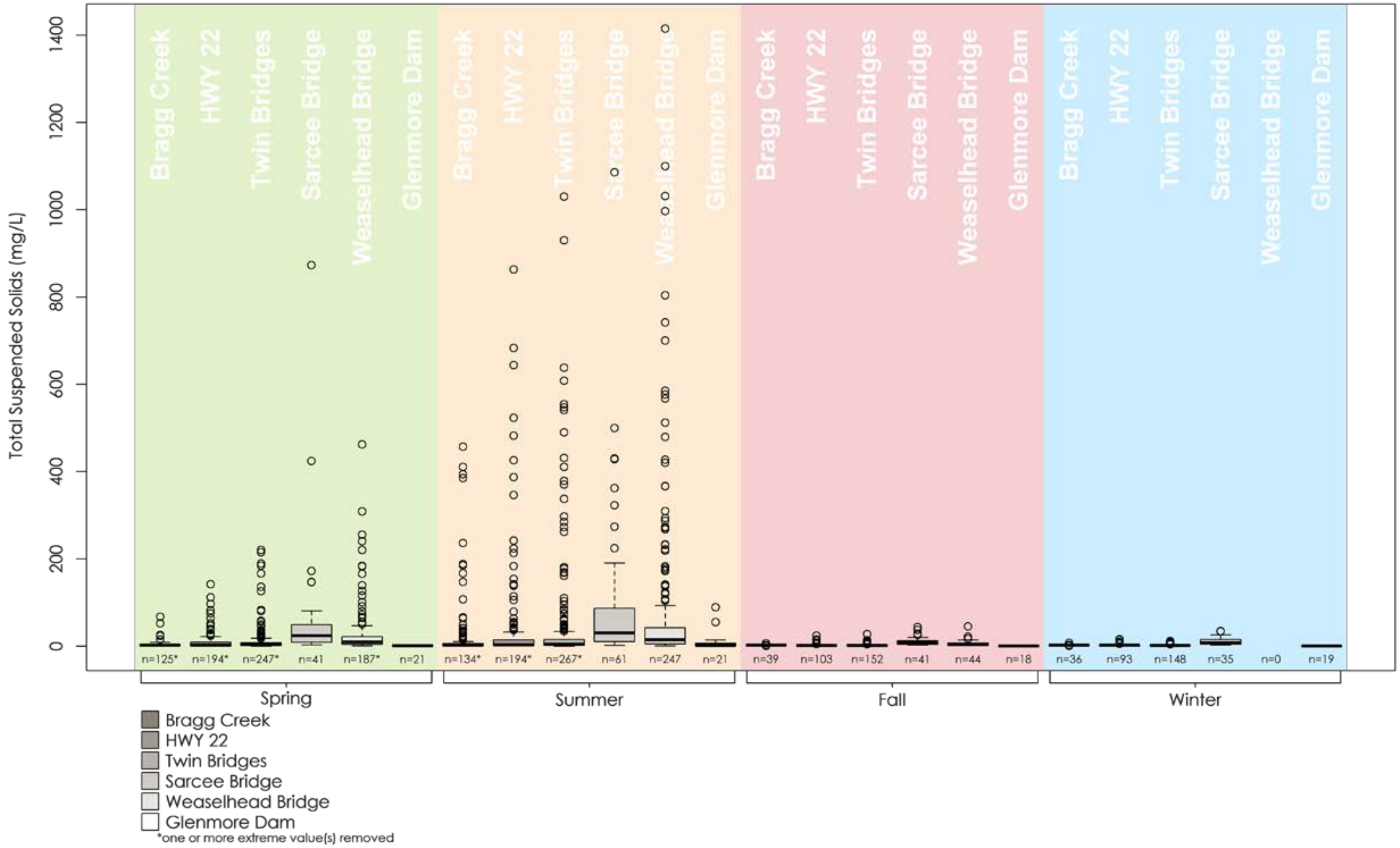


Figure 7-2 Total Suspended Solid Concentrations in the Regional Assessment Area, 1979 to 2016

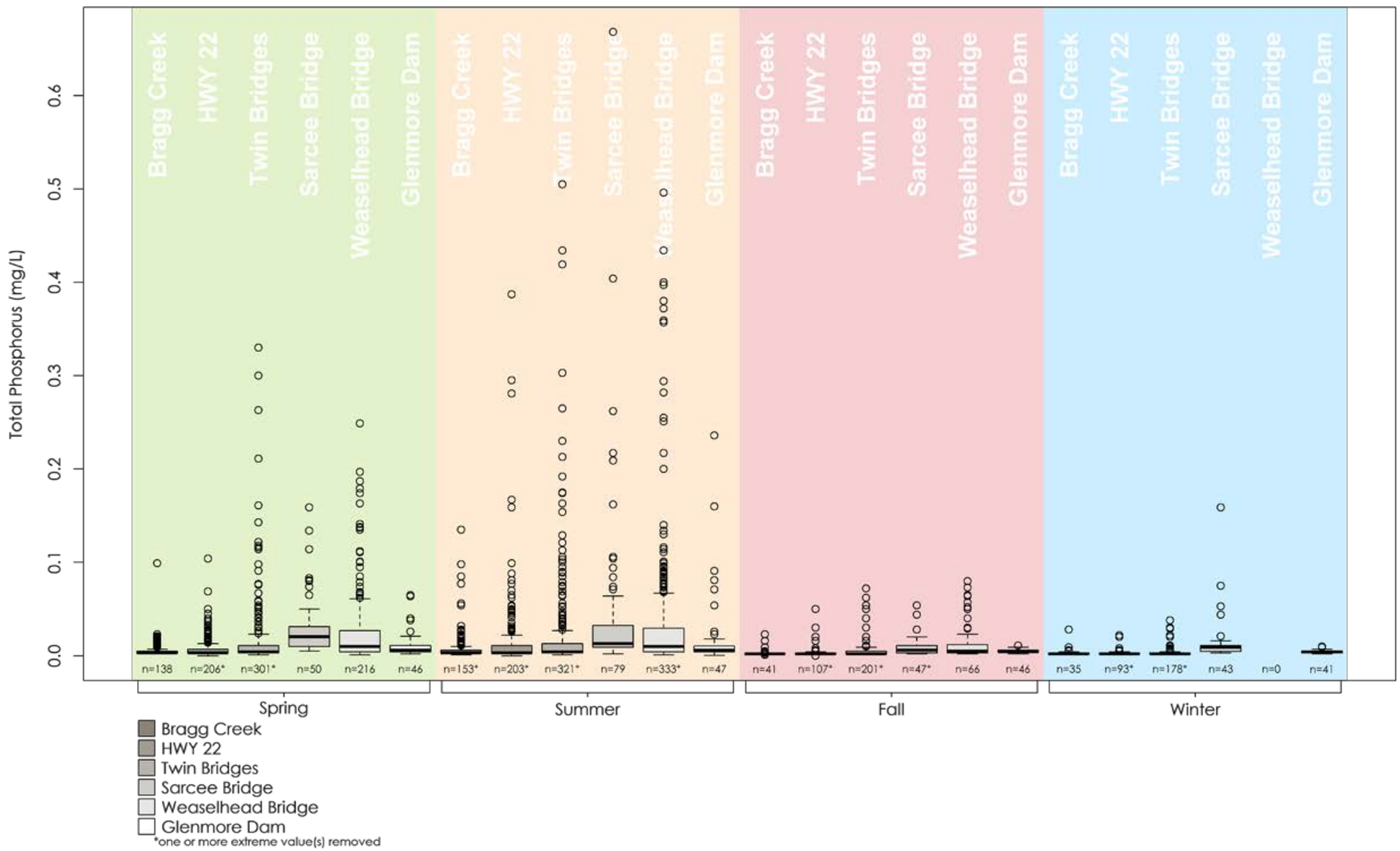


Figure 7-3 Total Phosphorus Concentration in the Upper Elbow River Mainstem Sites and at Glenmore Dam, 1979 to 2016

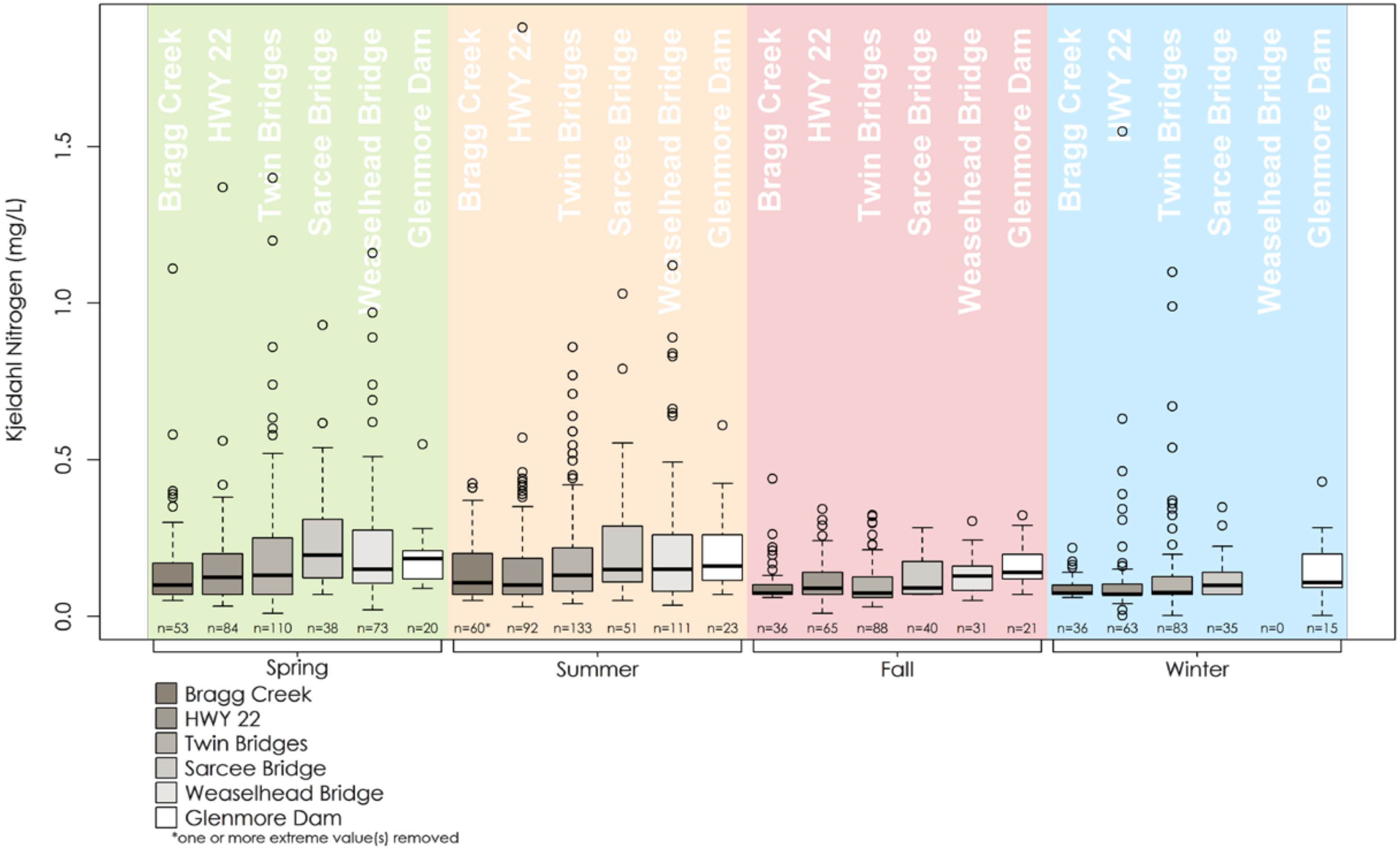


Figure 7-4 Total Kjeldahl Nitrogen Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam, 1979 to 2016

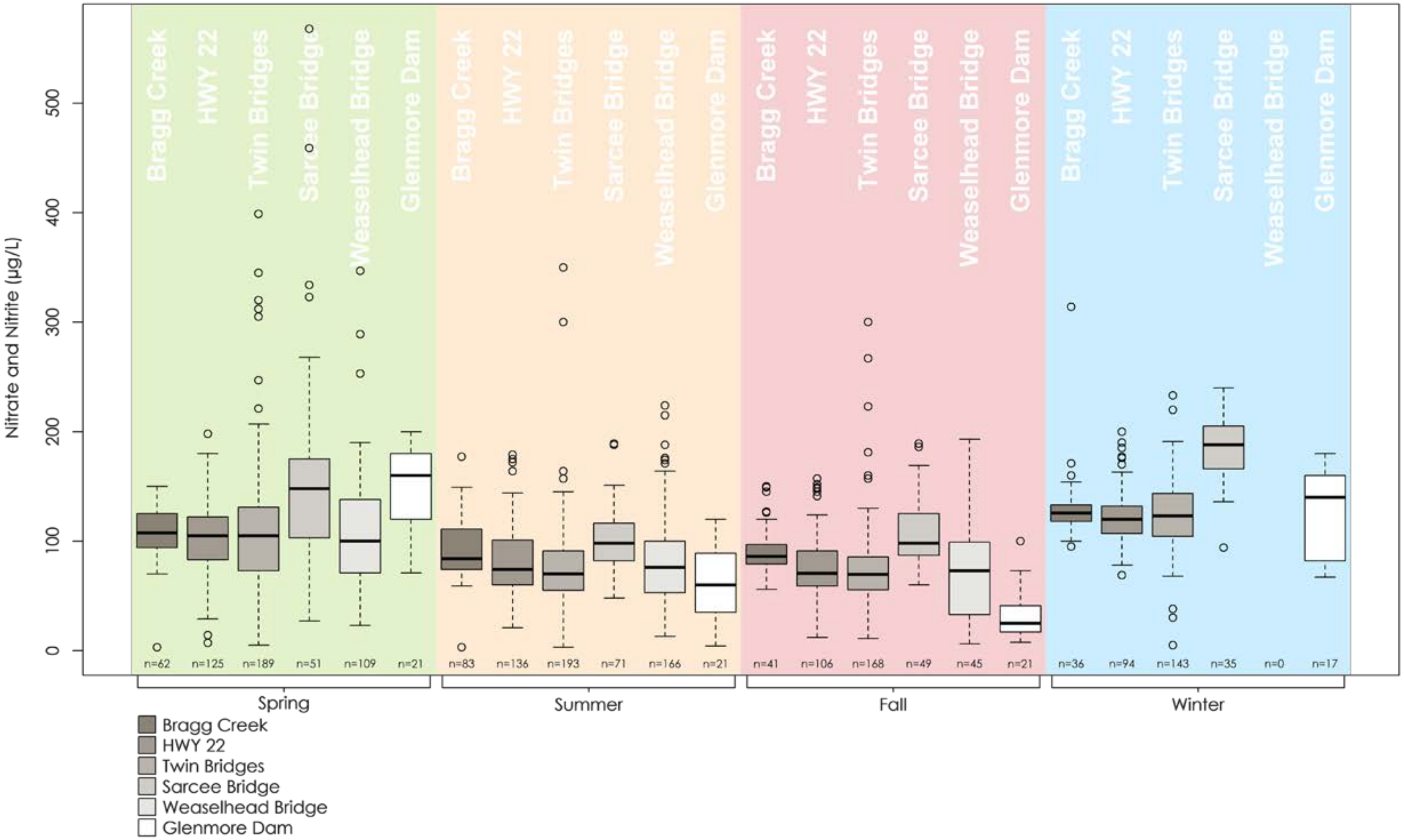


Figure 7-5 Total Nitrate and Nitrite Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam, 1979 to 2016

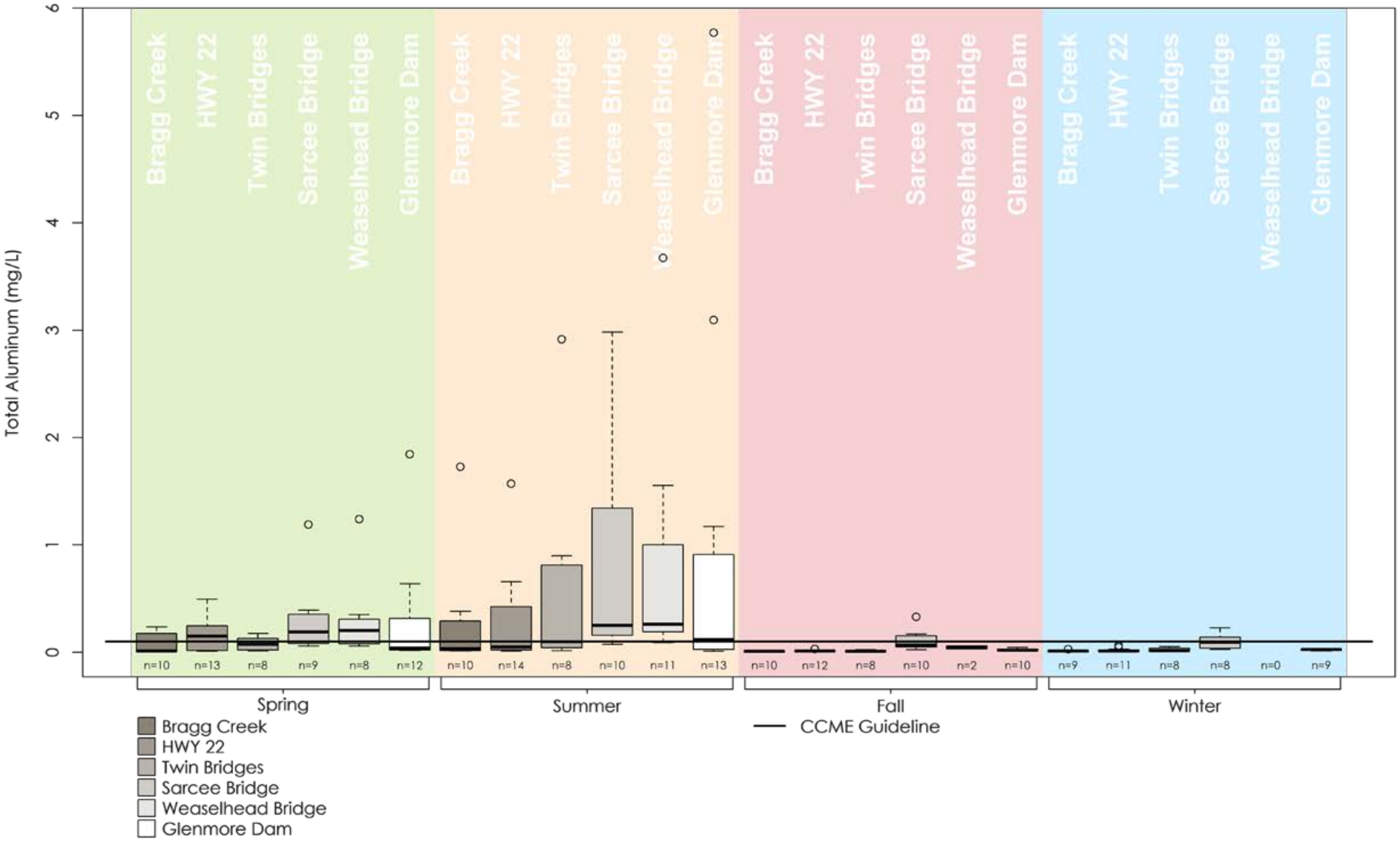


Figure 7-6 Total Aluminum Concentrations in the Upper Elbow River Mainstem Sites and at Glenmore Dam, 2006 to 2016

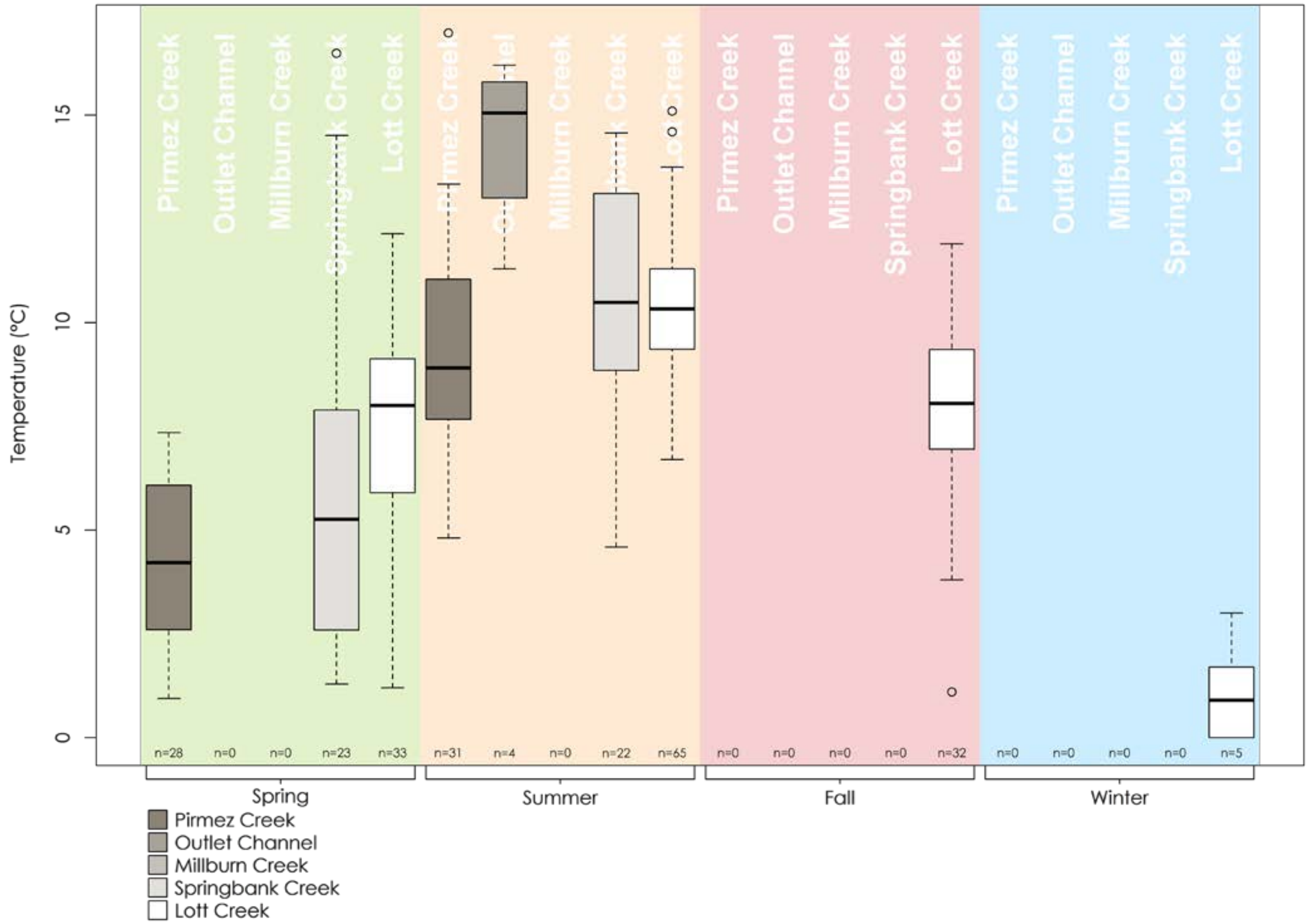


Figure 7-7 Temperature in the Elbow River Mainstem Sites and at Glenmore Dam, 1979 to 2016

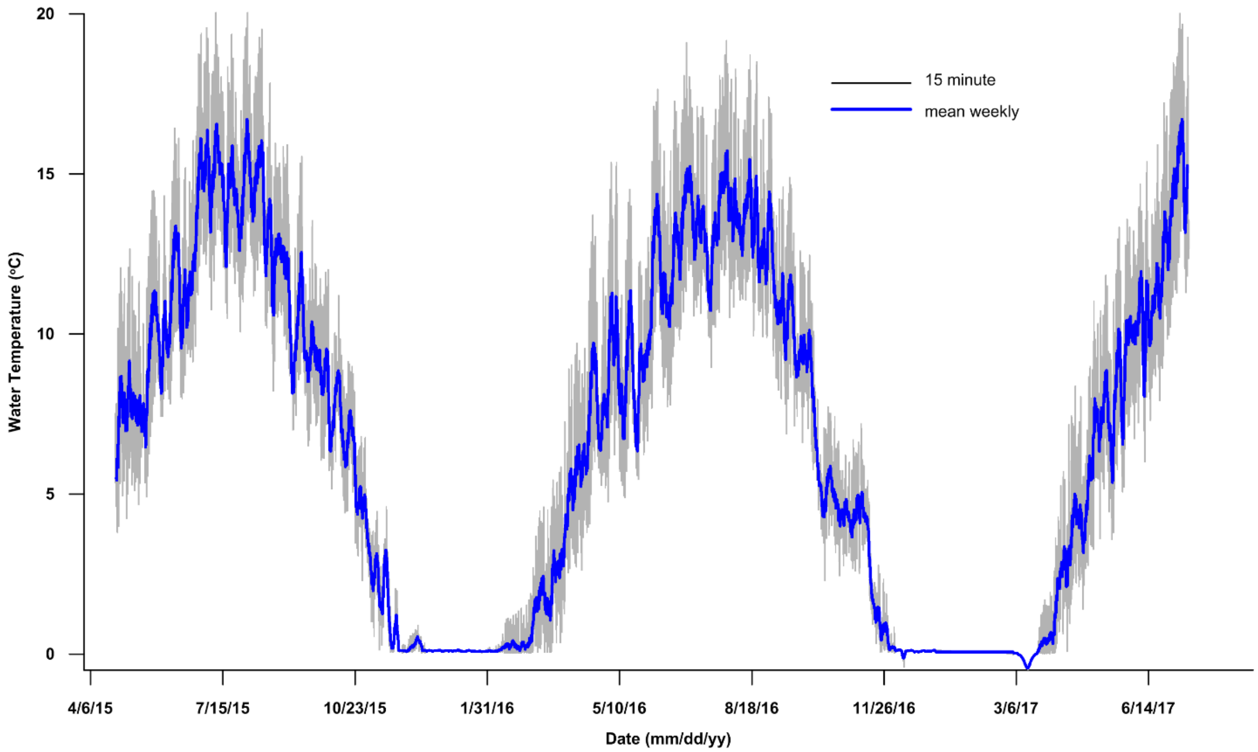


Figure 7-8 Continuously Measured Temperature in Elbow River at Highway 22 Bridge, 2015 to 2017

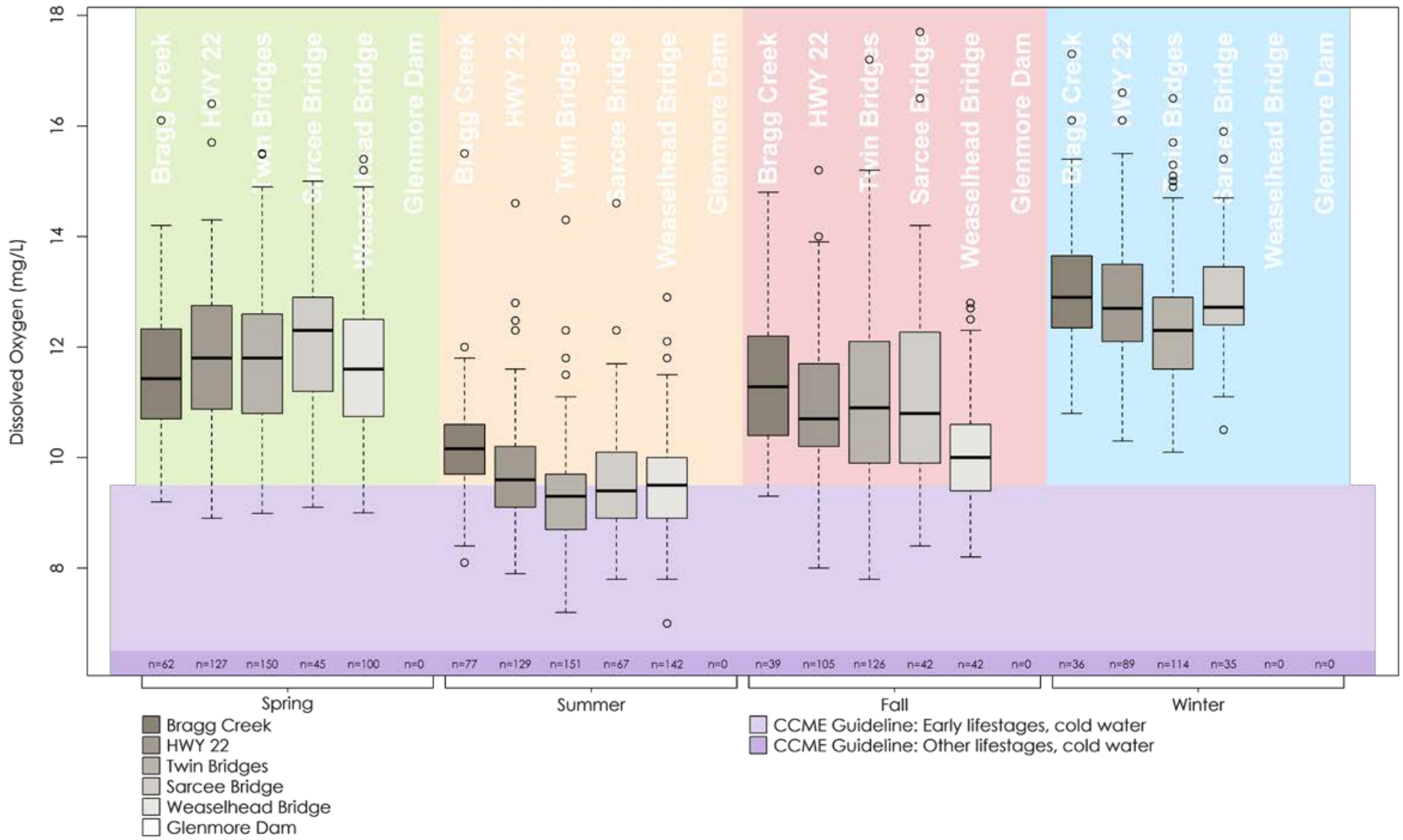


Figure 7-9 Dissolved Oxygen Concentration in the Elbow River Mainstem Sites and at the Glenmore Dam from 1979 to 2016

Table 7-2 Total and Dissolved Mercury Data for Upper Elbow River

Site	n above Detection Limit	Less than Detection Limit	Above Guideline	Mean (µg/L)	Median (µg/L)	Maximum (µg/L)	Minimum (µg/L)
Total Mercury							
Bragg Creek	0	0	0	-	-	-	-
Highway 22	1	9	1	-	-	0.1	0.1
Twin Bridges	0	10	0	-	-	-	-
Sarcee Bridge	0	0	0	-	-	-	-
Weaselhead Bridge	0	0	0	-	-	-	-
Glenmore Dam	0	0	0	-	-	-	-
Dissolved Mercury							
Bragg Creek	0	0	-	-	-	-	-
Highway 22	0	4	-	-	-	-	-
Twin Bridges	0	0	-	-	-	-	-
Sarcee Bridge	0	0	-	-	-	-	-
Weaselhead Bridge	0	0	-	-	-	-	-
Glenmore Dam	0	10	-	-	-	-	-

NOTE:
n = total number of samples

7.2.3 Comparison With Guidelines

Of the 39 parameters analyzed that were associated with either Alberta or CCME Water Quality Guidelines, 15 had observations outside of their respective guidelines (see Volume 4, Appendix K, Surface Water Quality Technical Data Report, Table 3 2).

The percentage of observations outside of guidelines increased in the upper Elbow River mainstem from upstream (Bragg Creek) to downstream sites (Weaselhead Bridge) for dissolved oxygen, total aluminum, and total iron.

7.3 PROJECT INTERACTIONS WITH SURFACE WATER QUALITY

Table 7-3 identifies the physical activities that might interact with water quality during the flood and post-flood operation phases of the Project.

Table 7-3 Project-Environment Interactions with Surface Water Quality

Project Components and Physical Activities	Environmental Effect Change in surface water quality
Flood and Post-flood Operations	
Reservoir filling	✓
Reservoir draining	✓
Reservoir sediment partial clean up	✓
Channel maintenance	✓
Road and bridge maintenance	✓
NOTES: ✓ = Potential interaction – = No interaction	

During flood operation, water quality in the low-level outlet would be affected by draining of retained water in the off-stream reservoir. Surface water quality in Elbow River would be affected by both reservoir filling and draining, primarily by settled suspended sediment that is mobilized during high flows in the off-stream reservoir and the low-level outlet. Surface water quality can be also affected by methylation of metals in the reservoir during reservoir filling and retention. Surface water quality in Elbow River would be affected by released water from the reservoir that contains methylmercury as a result of organic matter decomposition (in the reservoir) in inundated soil by microbes.

During post-flood operations, sediment clean up, channel maintenance, and road and bridge maintenance can introduce sediment to the low-level outlet and into Elbow River.

7.4 ASSESSMENT OF RESIDUAL ENVIRONMENTAL EFFECTS ON SURFACE WATER QUALITY

7.4.1 Analytical Assessment Techniques

Three floods are assessed: the design flood, 1:100 year flood, and 1:10 year flood. The design flood has a less than 0.5% probability of occurring in any given year. The probability of a 1:100 year flood and a 1:10 year flood occurring in any given year is 1% and 10%, respectively.

7.4.1.1 Suspended Sediment and Suspended Sediment Associated Parameters

DHI Water and Environment's software, MIKE21™, a two dimensional (2D) hydrodynamic numerical model that simulates vertically homogenous flow and sediment transport was used to assess the potential changes in flow and sediment transport due to the Project operation. For details on predicted changes to suspended sediment concentration for the three assessed floods, see Section 6 and Volume 4, Appendix J Hydrology TDR.

The assessment of change in suspended sediment associated parameter concentrations is based on existing conditions data analysis on which parameters behave like suspended sediment (see Volume 4, Appendix K Water Quality TDR) and the sediment transport modelling results (see Section 6 and Volume 4, Appendix J Hydrology TDR).

7.4.1.2 Temperature and Dissolved Oxygen

There are no analogous measurements or surrogate parameters in the area of the Project for evaluating the effects of short-term water retention in a relatively low organic carbon environment (pasture land). Therefore, there are no available parameters to calibrate and validate a model.

The method used in the assessment considers the factors that affect dissolved oxygen and/or temperature in reservoirs and compares these factors in the project context to other reservoirs. The Glenmore Reservoir is not ideal for comparison with the off-stream reservoir because Glenmore it is a wet reservoir. However, the comparison between the two is used to understand the direction and magnitude of potential changes in these parameters.

7.4.1.3 Methylmercury

Change in water methylmercury concentration are calculated by using a high and low methylmercury yield rates reported in literature for experimentally filled reservoir areas. In three short-term (3-year) experimental reservoirs created in the Experimental Lakes Area of Ontario in upland forests, the flux of methylmercury from flooded soils into water ranged from 27–122 $ng/m^2/day$ (Hall et al. 2005; Bodaly et al. 2004). Methylmercury flux varied by type of soil flooded (low, moderate and high carbon content), with greatest flux observed in the reservoir that flooded moderate carbon soils. Another experimental reservoir had an overall average mercury methylation rate in the first year of 5 to 15 ng/m^2/d (St. Louis et al. 2004). Out of the reported release rates in literature, 27 ng/m^2/day is selected as the low release rate estimate and 122 ng/m^2/day as the high release rate estimate for this assessment.

Methylmercury concentration in diverted water into the reservoir is assumed to be zero because methylmercury concentrations during a flood are not known and existing conditions data indicates that total and dissolved mercury concentrations in the river are low (see Section 7.2.2.3).

The area in the reservoir filled by a flood is calculated from estimated flood water volumes as well as water surface elevation values for the reservoir. The approximate elevation values are used to approximate the spatial extent of the flood surface and calculate the area of terrain covered. A 1-metre digital elevation model (DEM) is used for to calculate the spatial extent of the reservoir. The DEM dataset used was a mosaic of various LiDAR datasets. Approximate terrain surface (3D) areas were generated for each cell in the DEM dataset. The slope of each cell was calculated and then used to create the 3D surface area for that cell. These 3D surface areas were summed up for each of the depths under each of the surface water elevations.

The following formula is used for 3D area per cell generation:

3D area = float(cellSize) * (float(cellSize) / Cos(Slope(dem, "DEGREE") / (180.0 / pi)))

7.4.2 Change in Surface Water Quality: Suspended Sediment and Suspended Sediment Associated Parameters

The primary purpose of the Project is to mitigate downstream flood hazard to the City of Calgary by modifying the hydrology of the Elbow River during high flows by temporarily diverting water. However, because the Project is a mitigation, this hydrological interaction is intentional and expected. The complex dynamics between flow and sediment movement in Elbow River are discussed in Section 6.0.

The main effect on water quality is related to suspended sediment, which comprises organic and inorganic matter that is held in water by turbulence (Bilotta and Brazier 2008). The silt and clay fractions of suspended sediment comprise clay minerals, iron hydroxides, manganese oxides and organic matter (Foster and Charlesworth 1996). Ion exchange processes occur between positively charged matter (such as metals and nutrients) and negatively charged particle surfaces, binding positively charged matter to particle surfaces.

Project Residual Effect

Suspended Sediment on Change in Surface Water Quality

Suspended sediment modelling results are presented in full in Section 6.4.3 and summarized below. Peak suspended sediment concentrations in the Elbow River upstream of the diversion structure are estimated as (see Section 6, Table 6-6):

- 139,682 mg/L (design flood)
- 77,649 mg/L (1:100 year flood)
- 4,818 mg/L (1:10 year flood)

These peak concentrations are estimated to decrease slightly in the Elbow River downstream of the diversion structure because flow in Elbow River is sufficiently large during the floods to maintain suspended sediment in the water downstream of the diversion structure.

Suspended sediment concentration in the diverted water decreases rapidly, and most suspended sediment would remain in the reservoir after discharge back to Elbow River during a design flood and 1:100 year flood. During a 1:10 year flood, most suspended sediment that is diverted into the reservoir would return to Elbow River.

Suspended sediment concentration is predicted to increase during the last few days of discharge because of sediment re-mobilization in the reservoir and sediment mobilization in the low-level outlet. Peak concentrations of suspended sediment exiting from the low-level outlet at the Elbow River confluence are estimated as (see Section 6.4.3):

- 17,955 mg/L (design flood)
- 20,692 mg/L (1:100 year flood)
- 1,798 mg/L (1:10 year flood)

It is anticipated that these suspended sediment concentrations during the last few days of the discharge can be controlled with the low-level outlet gate operation (i.e., reducing flow rate) and, possibly, also with sediment and silt fences. Without further mitigation, the resulting increase in the Elbow River of suspended sediment concentrations is likely to exceed the Canadian Water Quality Guideline (CCME 2016):

- clear flow—maximum increase of 25 mg/L from background levels for any short-term exposure (e.g., 24-h period). Maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 h and 30 d).
- high flow—maximum increase of 25 mg/L from background levels at any time when background levels are between 25 mg/L and 250 mg/L. Should not increase more than 10% of background levels when background is greater than or equal to 250 mg/L.

The estimated concentrations during the modelled floods are high for the design flood and the 1:100 year flood. These concentrations occur as a response to naturally-occurring floods. Even though the total load of sediment in Elbow River is greatly reduced by the Project, flood operation is not predicted to substantially affect the Elbow River suspended sediment concentrations during active diversion. The Project does increase suspended sediment concentrations for a short duration (days) at the end of water release back into Elbow River. However, it is anticipated that this increase in suspended sediment concentration can be mitigated with the operation of the low-level outlet and with physical sediment barriers. The effect of water release from the reservoir on water quality in Elbow River is of high magnitude, short term, timing is seasonal (due to typical flood occurrences), and reversible.

Sediment will be removed from project infrastructure where there is a risk it could impede water flow during future floods. Sediment inputs into the low-level outlet channel can be managed using sediment and erosion control measures, if required. The effect of the remaining sediment in the low-level outlet on water quality in the low-level outlet and Elbow River is anticipated to be negligible to low in magnitude.

Suspended Sediment Associated Parameters

Water quality parameters that follow similar seasonal patterns as suspended sediment were identified based on existing conditions water quality data in Elbow River (Volume 4, Appendix K, Surface Water Qulaity Technical Data Report).

Existing Elbow River water quality data reflect less than bankfull flow conditions in the river (i.e., much lower flows than the assessed floods). However, it is assumed the parameters likely behave similarly to suspended sediment during a flood because the physical mechanism of negatively charged suspended sediment particles attracting positively charged matter remains the same during flood conditions.

Nutrients, some ions, total coliform bacteria, and organic carbon had a similar seasonal pattern as suspended sediment in the existing conditions dataset. Out of nutrients, both total and dissolved phosphorus and ammonia followed the suspended sediment seasonal pattern closely. Out of ions, magnesium, calcium, and sulphate did the same. Metals (total aluminum, arsenic, boron, chromium, cobalt, iron, manganese, nickel, titanium, and vanadium) also had similar seasonal patterns as suspended sediment, although the data did not lend itself to a quantitative seasonal pattern analysis.

The majority (over 70%) of aluminum, arsenic, barium, chromium, copper, iron, manganese, nickel, zinc, and phosphorus have been found to be associated with suspended sediment particles in major US rivers (Horowitz 2004). In contrast, strontium was generally found in the dissolved phase, whereas lithium as divided equally between both phases (Horowitz 2004). In urban runoff, 70-80% of phosphorus and 50-80% of nitrogen have been reported to be particle-bound, with higher adherence to smaller particles (Vaze and Chiew 2004).

The load of particles associated water quality parameter concentrations are expected to be high during a flood and settle out of the water during retention in the reservoir. Most of the settled sediment would remain in the reservoir during discharge back into the Elbow River. For the design flood, 1.8% of suspended sediment load and associated matter in the retained water exits the reservoir, with 98.2% remaining at the bottom of the reservoir after it is drained. For the 1:10 year flood, 4.6% of the suspended sediment exits the reservoir when it is drained. For the 1:100 year flood, 11.7% of suspended sediment exits the reservoir.

Metals and nutrients that are associated with particles through ion exchange are less available to biota than dissolved forms, and the dissolved concentrations of metals are generally much lower than the sediment-bound phase (Foster and Charlesworth 1996; Vaze and Chiew 2004).

Generally, reservoirs act as nutrient sinks with sedimentation and sediment-water processes regulating the nutrient status of a reservoir (Alexander et al. 2002; Bosch 2008; Kennedy and Walker 1990). Nutrient availability for phytoplankton production is generally reduced by sedimentation losses in reservoirs (Kennedy and Walker 1990). While river-borne nutrient influx and sedimentation is the dominate process regulating nutrients in a reservoir, internal nutrient loading also plays a role (Kennedy and Walker 1990). Inundated organic matter decomposition consumes oxygen and can create anoxic conditions at the sediment water boundary, which are suitable for chemical processes that release nutrients into water from sediment (Kennedy and Walker 1990). The extent of nutrient release from the reservoir is dependent on water residence time (i.e., the speed of microbial decomposition processes beginning) and dissolved oxygen conditions. See following section on a discussion on dissolved oxygen.

Metals and nutrients occur in either in solid or dissolved form. The solid form acts similar to suspended solids because these particles remain suspended with high water velocity and will settle with the lower velocities that will occur in the reservoir. The reservoir is expected to have no effect on dissolved parameters. The overall effect of the reservoir will reduce or not change the total load of parameters that are associated with suspended solids. No increase in loads are expected.

In summary, parameters that are associated with suspended sediment are expected to be deposited in the reservoir, reducing loads downstream in the Elbow River and in Glenmore Reservoir. As with suspended sediment, there will a small, short-term increase in concentration and load when water in released back into Elbow River. These changes will be small compared to the concentrations and loads transported during a flood in the absence of the Project. The operation of the reservoir will occur infrequently, so the nature of the change is not anticipated to change the water quality of Elbow River or Glenmore Reservoir.

7.4.3 Change in Surface Water Quality: Water Temperature and Dissolved Oxygen

Project Residual Effect

Water temperature can increase during water retention (loss of water velocity) in the reservoir, if air temperature is sufficiently warm.

Loss of water velocity can also reduce oxygen mixing into the reservoir water compared to river conditions. However, wind mixing in the relatively shallow reservoir is anticipated to replenish dissolved oxygen in the retained water.

Dissolved oxygen can be consumed by retained water because of organic matter decomposition, if the residence time and weather conditions create suitable conditions for decomposition to occur. Decomposition of organic matter involves both chemical oxidation and biological respiration in the water column (BOD) and in sediment (SOD; Terry et al. 2017).

BOD and CBOD data were not available or collected from the Elbow River. However, total organic carbon (TOC) is low in the Elbow River (generally less than 5 mg/L) indicating that CBOD is likely low. Nitrogenous BOD components (ammonia and nitrate) are also low in the Elbow River. This indicates that BOD values will likely be at a low level at the beginning of flood operations. During the water retention period, organic carbon and nitrogenous nutrients will be deposited in the off-stream with suspended sediment and, thereby, removing the means for increased BOD.

Sediment oxygen demand is dependent on temperature, water flow and mixing, residence time and sediment composition. The modelling of SOD in aquatic systems is challenging because of these dependencies (Akomeah and Lindenschmidt 2017). The amount of organic material available for decomposition is lower than in many studied permanent reservoirs and shallow lakes (e.g., Terry et al. 2017; Akomeah and Lindenschmidt 2017) and temperature of water entering the reservoir would be relatively cold. The current plan is for the reservoir to be fenced, which minimizes organic matter originating from livestock manure. Therefore, SOD is anticipated to be higher in the reservoir compared to the Elbow River but similar to the Elbow River floodplain. Compared to Glenmore Reservoir, the off-stream reservoir is anticipated to have similar BOD and with similarly low SOD. The off-stream reservoir would likely have a higher rate of wind mixing compared to Glenmore Reservoir. Changes to dissolved oxygen in the off-stream reservoir are expected to be smaller than those that are currently observed in the Glenmore Reservoir.

As the water from the reservoir is released, it will mix with Elbow River water. Generally, temperature in the river could increase as a result of the retained water being released back into the river. If a change in temperature did occur it would be temporary and localized due to the rapid mixing with Elbow River water. The dissolved oxygen concentration in the low-level outlet channel should increase due to increased water velocity that causes increased mixing and re-aeration of water. If the dissolved oxygen in the low-level outlet remains below the saturation point, the effect on dissolved oxygen in Elbow River is expected to be localized and temporary because of rapid aeration of water in the river.

For the design flood, the release of retained water from the reservoir would contribute 29% to 59% (Figure 7-10) of total flow in Elbow River downstream of the low-level outlet. For the 1:100 year flood, the release of retained water from the reservoir would contribute 5% to 34% (Figure 7-11) of total flow in Elbow River downstream of the low-level outlet. For the 1:10 year flood, the released water would contribute less than 5% of the total flow in the Elbow River (Figure 7-12). Dilution of retained water back into Elbow River is higher in the more likely floods and smaller in the unlikely design flood.

During an Elbow River flood without the Project in place, water temperatures are expected to increase and dissolved oxygen concentrations decrease as floodwaters reach Elbow River floodplains or the Glenmore Reservoir. Compared to these conditions, the effect of the Project during a flood is anticipated to be of low magnitude, temporary and localized to the area where the outlet channel meets the Elbow River. The Project is not anticipated to affect temperature and dissolved oxygen in the Elbow River.

The area of the off-stream reservoir south of Springbank road will have no public access. This area will be owned and operated by AEP, left fallow, and not involve any agricultural activity. The area of the off-stream reservoir north of Springbank Road will be publicly owned and privately stewarded, and have grazing options through public leases. Therefore, during most instances when the off-stream reservoir is operated, the flooded area will primarily be over fallow land, and be free of livestock waste, or fertilizers that may be associated with agricultural activities. The organic material in the off-stream reservoir during flood operations will be primarily comprised of fallow vegetation (Table 7.4-1). This is anticipated to limit the off-stream reservoir's contribution of bioavailable organic materials that could reduce dissolved oxygen during flood operations.

Table 7.4-1 Predicted Off-stream Reservoir Flooded Areas

Flood Scenario	Off-stream Reservoir Flooded Area (ha)	Percent of Flooded Area (%)	
		South of Spring Bank Road	North of Spring Bank Road
1:10		100.0	0.0
1:100	62.26	95.1	4.9
Design	251.62	75.2	24.8

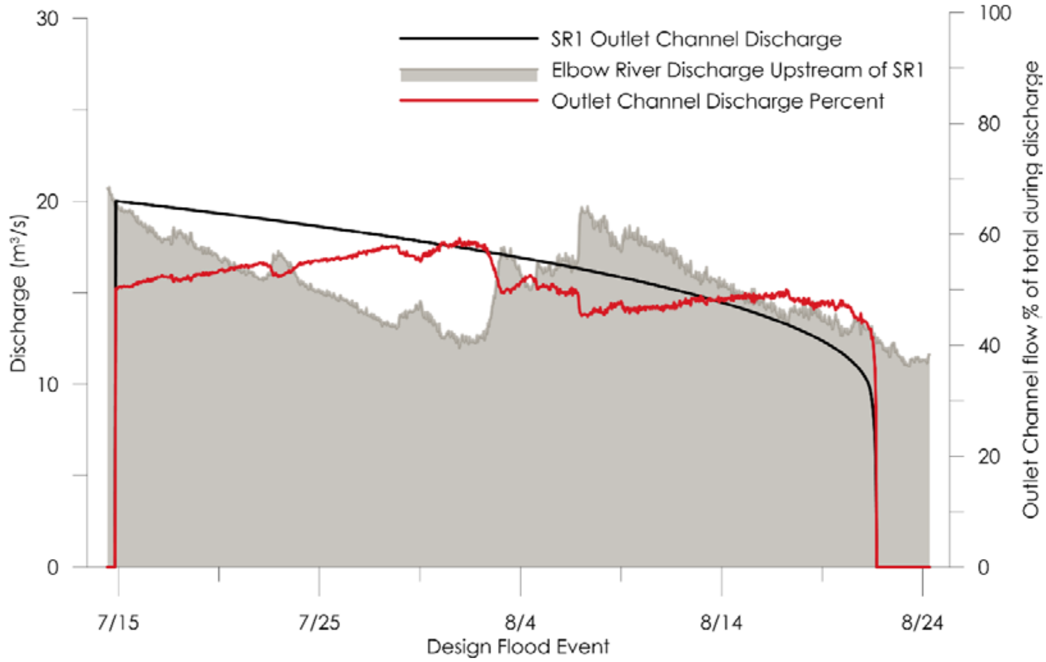


Figure 7-10 Dilution in Elbow River During Water Release from the Reservoir (Discharge) for the Design Flood

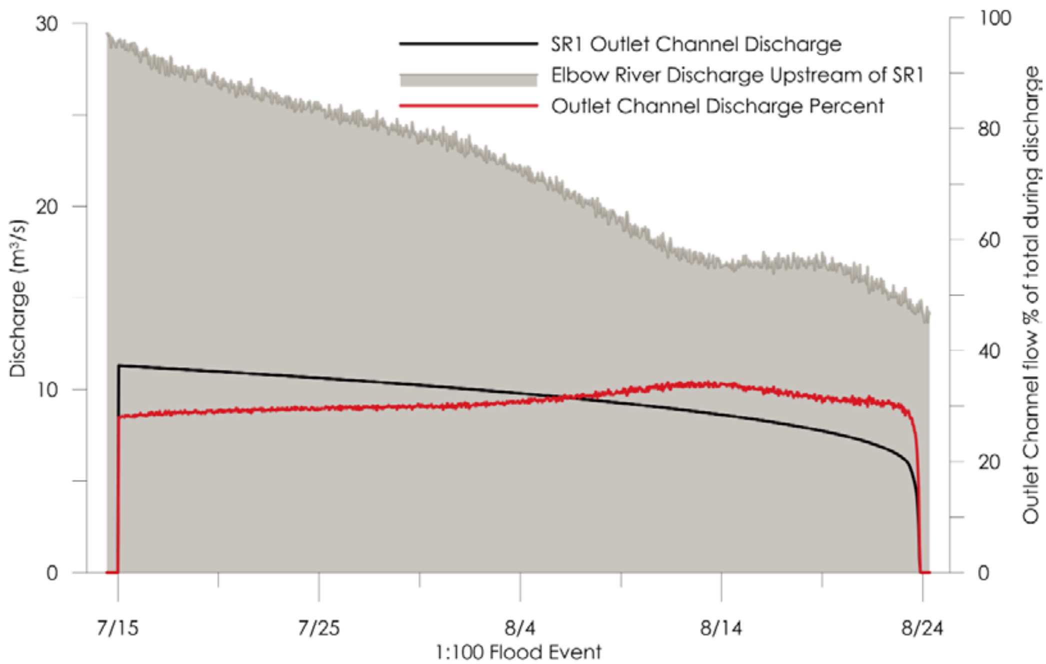


Figure 7-11 Dilution in Elbow River During Water Release from the Reservoir (Discharge) for the 1:100 Year Flood

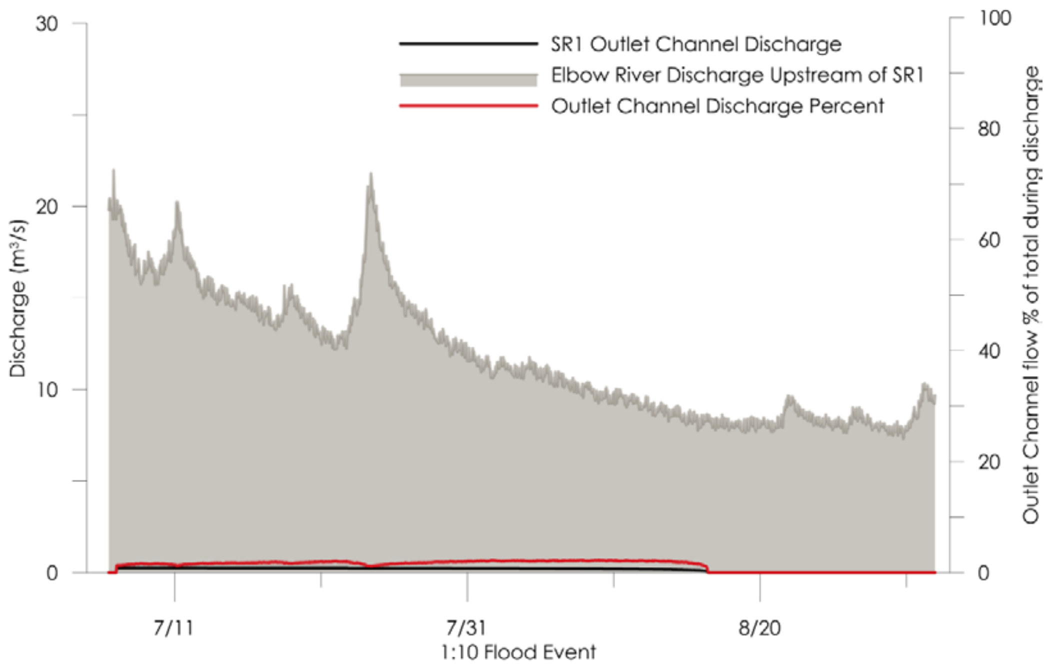


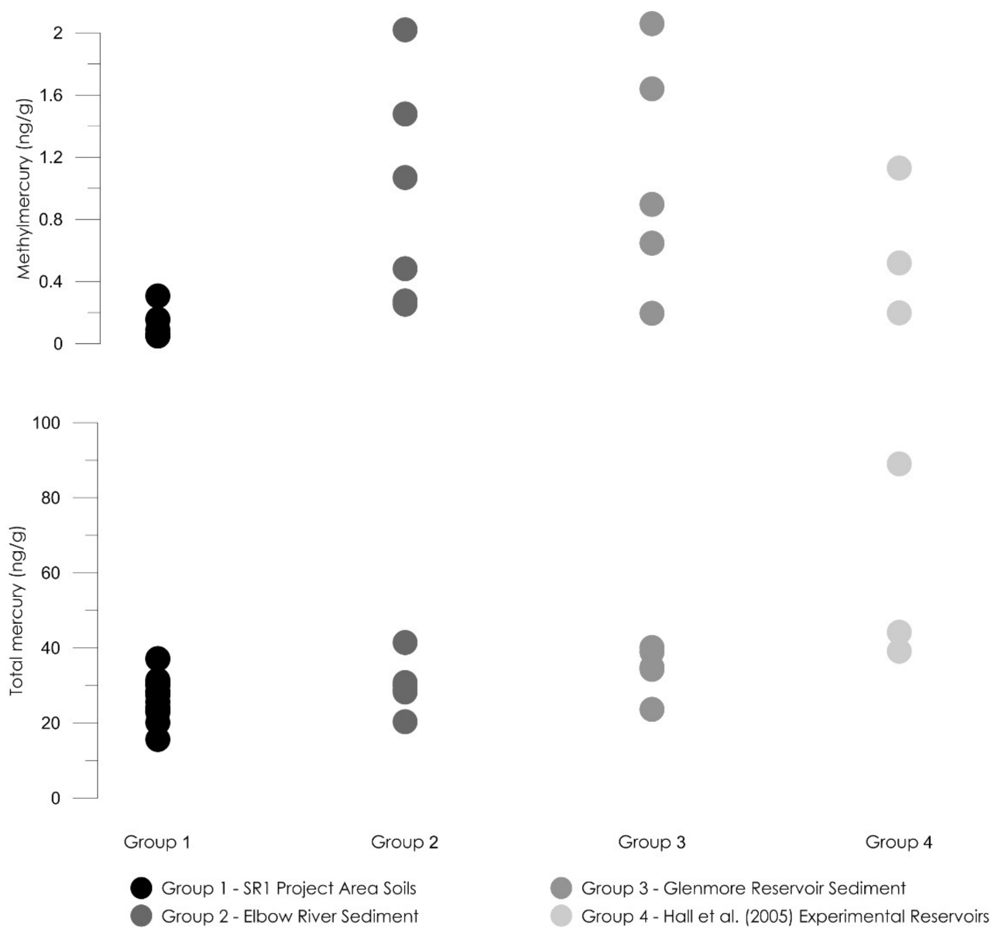
Figure 7-12 Dilution in Elbow River During Water Release from the Reservoir (Discharge) for the 1:10 Year Flood

7.4.4 Change in Surface Water Quality: Methylmercury

Mercury methylation is a chemical process that occurs in soil that is inundated by water, such as a reservoir. Flooded organic carbon in soil and vegetation decomposition results in microbial activity causing the methylation of inorganic mercury (Hg [II]) to methylmercury (CH_3Hg^+) (e.g., Bodaly et al. 2004; Hall et al. 2005; Montgomery et al. 2000; Mucci et al. 1995; St. Louis et al. 2004; Tremblay et al. 1998; Ullrich 2001). Methylmercury is a toxic form of mercury and it bioaccumulates in aquatic food webs. Both mercury methylation and demethylation occur in concert in aquatic environments, with an equilibrium being established within days to weeks (Ullrich et al. 2001). Net mercury methylation, the difference between these two phenomena, is the subject of this discussion.

Because vegetation and soil in the reservoir would be inundated during flood operation, a potential exists for methylmercury release into the reservoir water and into Elbow River. The most detailed studies in water and sediment quality following reservoir filling have been completed in the Experimental Lakes Area in Canada, where both boreal wetland (St. Louis et al. 2004) and upland forest (Hall et al. 2005; Bodaly et al. 2004) have been flooded and the methylmercury release rates calculated. In three short-term (3-year) experiments, the flux of methylmercury from flooded soils into water ranged from 27–122 ng/m^2/day (Hall et al. 2005; Bodaly et al. 2004). Methylmercury flux varied by type of soil flooded (low, moderate and high carbon content), with the greatest flux observed in a reservoir that flooded moderate carbon soils. Another experimental reservoir, created by the flooding of a wetland complex had an overall average mercury methylation rate in the first year of 5–15 ng/m²/d (St. Louis et al. 2004). Out of these reported methylmercury release rates, 27 ng/m²/day is selected as a low release estimate, and 122 ng/m²/day as a high release estimate, for this assessment.

The existing condition of the reservoir is predominantly grass-dominated pasture lands with topsoil mercury (15.6–37.2 ng/g) and methylmercury (0.05–0.31 ng/g) content. The three experimental reservoirs in the Hall et al. (2005) study had topsoil mercury of 39.2–89.1 ng/g and methylmercury of 0.20–1.13 ng/g (see Figure 7-13). The values cited for Hall et al. (2005) are for the humic/fungal layer of soil, which is comparable to the top 20 cm soil samples collected from the reservoir footprint.



SOURCE: Hall et al. (2005)

Figure 7-13 Total Mercury and Methylmercury in Existing Soil: Off-stream Reservoir, Elbow River, and Glenmore Reservoir Sediment

The amount of organic carbon is likely a factor in mercury methylation rates (Yao et al. 2011). However, the results from studies such as Hall et al. (2005) provide mixed results on the effect of carbon content on mercury methylation rates. Montgomery et al. (2000) suggested that temperature might be the main governing factor of methylmercury release into water column the short term (weeks) and the availability of organic carbon might be the governing factor in the long term (over 6 months). Existing soil organic carbon content in the reservoir ranged from 2.9% to 26.6%, with an average of 8.2%.

Mercury methylation, and mercury levels in water, would begin to increase immediately upon reservoir filling (Hall et al. 2005; St. Louis et al. 2004; Montgomery et al. 2000). Total mercury and methylmercury concentration peaks appear to be predominantly associated with temporary spikes in suspended particulate matter, to which both forms of mercury preferentially adsorb (Ullrich et al. 2001; Mucci et al. 1995; Tremblay et al. 1998).

Project Residual Effect

Methylmercury concentrations in the retained water in the reservoir are estimated from two release rate estimates: 27 ng/m^2/day was selected as the low release rate estimate and 122 ng/m^2/day as the high release rate estimate (see Section 7.4.1.3). Water would be in the reservoir from the start of diversion to the end of emptying for the following durations (see Section 6.5.2):

- 62 days (design flood)
- 84 days (1:100 year flood)
- 74 days (1:10 year flood)

Methylmercury concentration in the retained water would slowly rise and peak at concentrations from 0.00028 µg/L to 0.0013 µg/L at the end of reservoir draining during a design flood (see Figure 7-14);or the 1:100 year flood, methylmercury concentration at the end of the release period would be 0.00044 µg/L to 0.0020 µg/L (Figure 7-15); for 1:10 year flood, the methylmercury concentration is the greatest, at between 0.00045 µg/L and 0.0020 µg/L (Figure 7-16).

The estimated low and high methylmercury concentrations are below the CCME Canadian Water Quality Guideline for the Protection of Aquatic Life (0.004 µg/L, CCME 2003). Because the guideline concentration is not exceeded, no toxicological effects on aquatic life are anticipated.

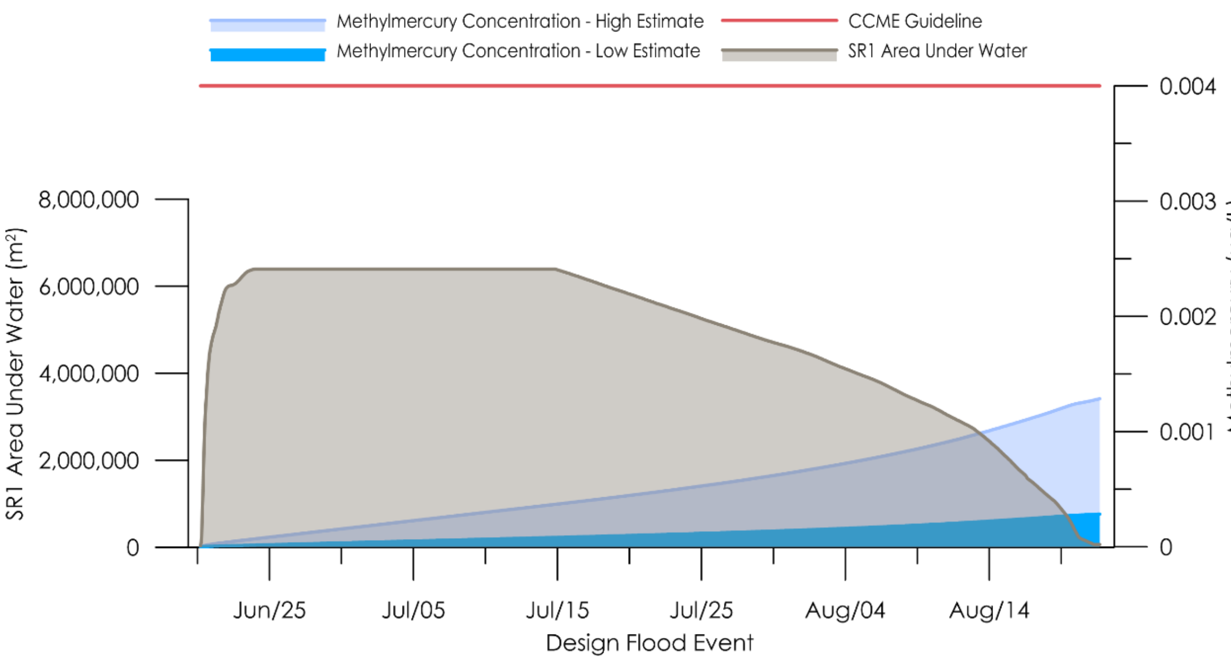


Figure 7-14 Estimated Reservoir Water Methylmercury Concentration and Reservoir Area Under Water During the Design Flood

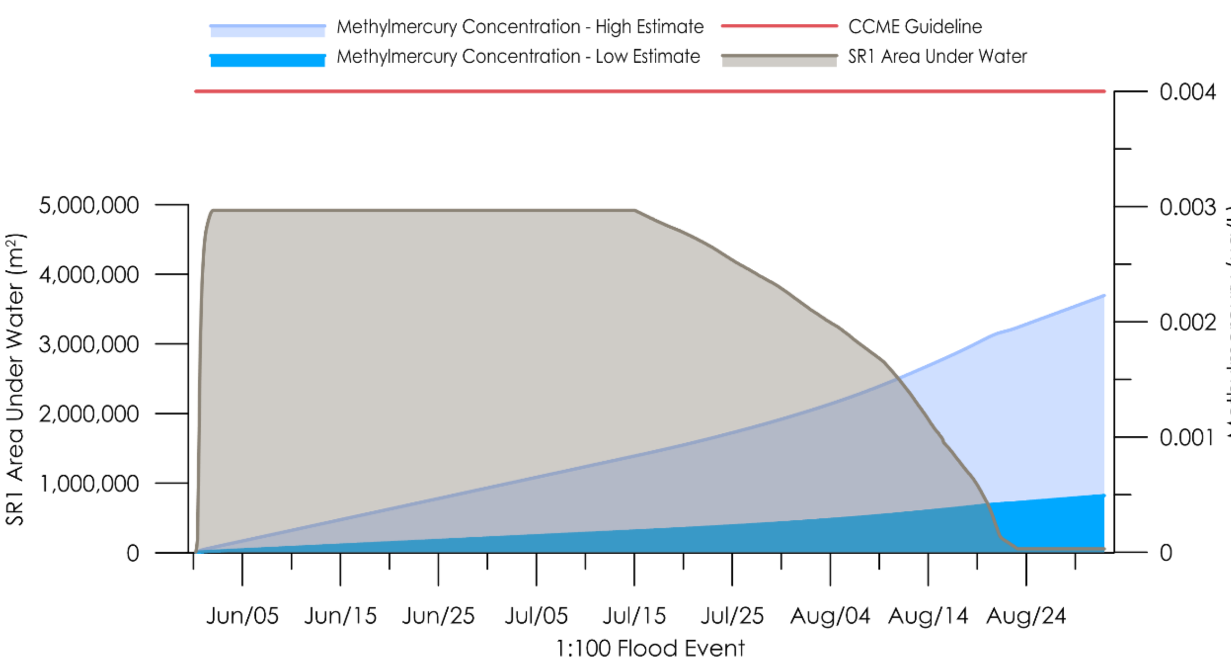


Figure 7-15 Estimated Reservoir Water Methylmercury Concentration and Reservoir Area Under Water During the 1:100 Year Flood

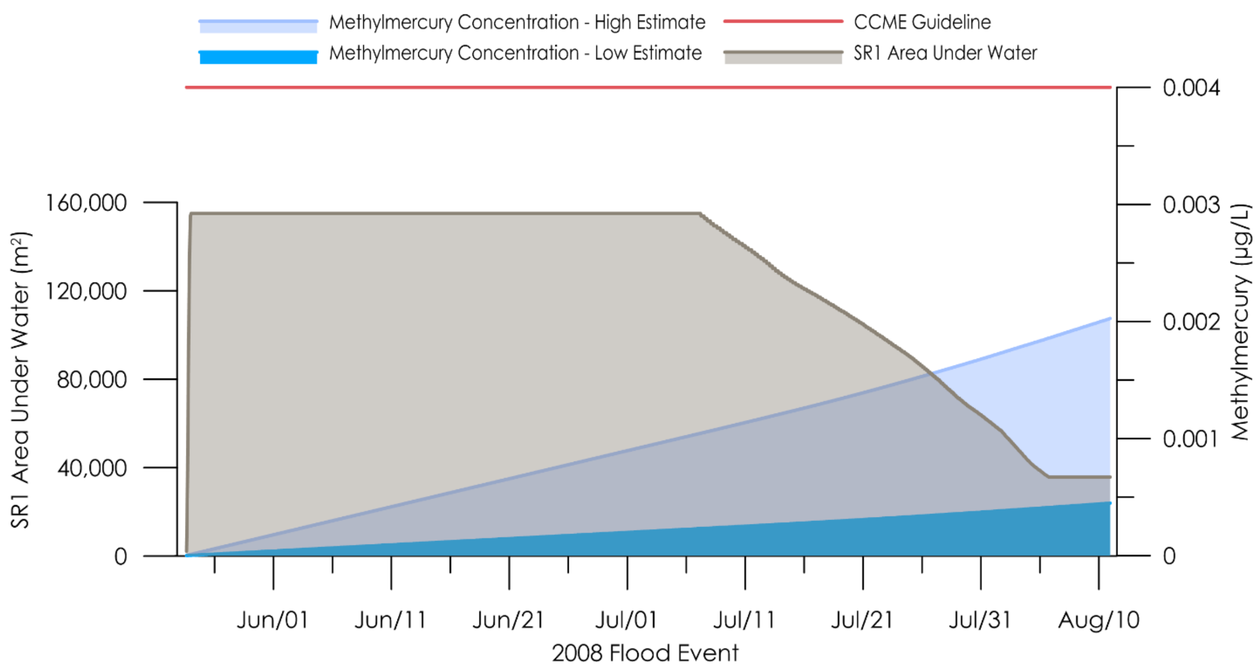


Figure 7-16 Estimated Reservoir Water Methylmercury Concentration and Reservoir Area Under Water During the 1:10 Year Flood

Mercury methylation occurs during floods on the Elbow River without the presence of the Project. This is evident in the higher methylmercury concentrations in the Elbow River sediment and Glenmore Reservoir sediment compared to the existing condition of soils in the off-stream reservoir. However, the total mercury concentrations are similar between all three (Figure 7-13). Therefore, the methylation of mercury in the reservoir would not introduce a new environmental effect to the watershed. However, the shallowness of the reservoir and the residence time in the off-stream reservoir can result in a higher mercury methylation rate compared to existing conditions.

After release of water into the Elbow River, the reservoir area would not contribute methylmercury; microbial decomposition processes would cease in the reservoir. It is possible that decomposition processes continue in relatively small areas near the low-level outlet. However, these processes are not expected to affect water quality measurably in the Elbow River downstream of the Project.

7.4.5 Summary of Project Residual Effects

During flood operation, the Project is expected to have a reversible, short-term adverse effect on water quality. Operation will be an irregular and infrequent event. The magnitude of the effect is anticipated to be from low to high and timing is seasonal. The high magnitude effect is related to suspended sediment concentrations in the Elbow River at the end water release. This effect can be managed with the operation of the low-level outlet gate and, possibly, also by using erosion and sediment control measures in the reservoir once it is almost empty.

Even though the concentration of sediment will be higher for a short time in the Elbow River following a flood, the Project reduces the total load of suspended sediment and associated parameters (e.g., metals, nutrients) to the Glenmore Reservoir thus improving source water for the City of Calgary's water supply.

During cleanup, it is not anticipated that the Project would measurably affect water quality in Elbow River or Glenmore Reservoir. Sediment would be removed from project infrastructure where there is a risk that water flow could be impeded in future flood diversions.

Table 7-4 summarizes the residual effects on water quality.

Table 7-4 Project Residual Effects on Water Quality during Flood and Post-Flood Operations

Environmental Effect	Residual Effects Characterization								
	Project Phase	Timing	Direction	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological and Socio-economic Context
Change in Water Quality	F	S	A	L-H	LAA	ST	IR	R	D
Change in Water Quality	PF	S	A	N-L	PDA	MT	IR	R	D

KEY

See Volume 3A, Table 7-2 for detailed definitions

Project Phase
F: Flood Operations
PF: Post-Flood Operations

Timing Consideration
S: Seasonality
T: Time of day
R: Regulatory

Direction:
P: Positive
A: Adverse
N: Neutral

Magnitude:
N: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Duration:
ST: Short-term;
MT: Medium-term
LT: Long-term

N/A: Not applicable

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Ecological/Socio-Economic Context:
D: Disturbed
U: Undisturbed

7.5 DETERMINATION OF SIGNIFICANCE

The effect of the Project on water quality is not significant because the change in water quality is not anticipated to cause acute or chronic toxicity or change the trophic status of the Elbow River or Glenmore Reservoir. Even though the total load of sediment in the Elbow River is reduced by the project, flood operation is not predicted to substantially affect the Elbow River suspended sediment concentrations during diversion. The Project does increase suspended sediment concentrations for a short duration (days) at the end of release of water back into Elbow River.

7.6 PREDICTION CONFIDENCE

Effects of the Project on water temperature and dissolved oxygen are evaluated qualitatively. Prediction confidence of the qualitative assessment on water temperature and dissolved oxygen is moderate, given weather effects on water quality during water retention in the reservoir.

Prediction confidence in methylmercury concentrations is moderate. A thorough literature review provided a range of methylmercury release rates from environments with higher organic carbon content than existing condition of soils in the reservoir. These release rates are a theoretical maximum of release from the reservoir area that would be inundated. However, given the complex dynamics between methylation and demethylation and environmental factor such as pH, temperature and available carbon, the overall prediction confidence is moderate.

7.7 CONCLUSIONS

Flood-operations would occur when suspended sediment concentrations in the Elbow River are already high. The Project would not substantially change these high concentrations during diversion. During the last few days of water release back into Elbow River, suspended sediment concentrations are predicted to increase in the low-level outlet and cause a short-term peak.

Suspended sediment concentrations are expected to be high during Elbow River floods and settle out of the water when the water is retained in the reservoir. Most of the settled sediment would stay in reservoir during water release.

Because vegetation and soil would be inundated, there is a potential for methylmercury to be retained in water as it is released back into Elbow River. The estimated low and high methylmercury concentrations in all floods are below the CCME Canadian Water Quality Guideline for the Protection of Aquatic Life. The reservoir area is not expected to continue to contribute methylmercury after it is drained.

See Volume 3C for follow-up and monitoring recommendations for water quality during Project flood operation.

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