Bighill Creek Water Quality Sampling
Baseline Study

By

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EXECUTIVE SUMMARY

This report documents current surface water and sediment quality conditions in Bighill Creek. This study was conducted from June 2017 to July 2018. Surface water samples were collected at five locations along the creek (Sites 1 to 5) in June, August, and October 2017 and in January and April 2018. Sediment and local spring water samples (Spr1 and Spr2) were collected in June and October 2017. Water quality indicators were measured in the field and in the laboratory. Data were compared to the Canadian Council of Ministers of the Environment (CCME) (2003), Alberta Environment and Sustainable Resource Development (AESRD) (2014), and Government of Alberta (2018) guidelines for the protection of aquatic life, for livestock watering, and for irrigation use.

The surface water data showed the following results:

- Flow rates reached a mean of 0.195 m^3/s and a median of 0.134 m^3/s. The mean is the sum of the values divided by the number of measurements. The median is the central or middle value. These are two representations of the centre of a dataset and reporting both provides more information on the dataset analyzed.
- pH ranged from 8.05 to 8.61.
- Day time water temperatures reached a mean of 7.4^{o}C and a median of 4.7^{o}C.
- Day time dissolved oxygen concentrations reached a mean of 13.6 mg/L and a median of 13.8 mg/L.
- Biochemical oxygen demand concentrations were generally below detection limit (2.0 mg/L) except in October at Site 1 (4.7 mg/L) and in April at all sites.
- Total organic carbon concentrations reached a mean of 4.9 mg/L and a median of 2.6 mg/L.
- Total dissolved solid concentrations reached a mean of 350 mg/L and a median of 365 mg/L.
- Total suspended solid concentrations reached a mean of 12.7 mg/L and a median of 4.7 mg/L.
- Electrical conductivity reached a mean of 0.640 mS/cm and a median of 0.639 mS/cm.
- True colour reached a mean of 24.8 PtCo units and a median of 9.0 PtCo units.
- Chlorophyll concentrations reached a mean of 6.5 µg/L and a median of 4.7 µg/L.
- Fecal coliform counts reached a mean of 168.5 MPN/100 mL and a median of 13.0 MPN/100 mL.
- Total phosphorus concentrations reached a mean of 0.0505 mg/L and a median of 0.0170 mg/L.
- Dissolved phosphorus concentrations reached a mean of 0.019 mg/L and a median of 0.0047 mg/L.
- Total Kjeldahl nitrogen concentrations reached a mean of 0.53 mg/L and a median of 0.39 mg/L.
- Nitrate + nitrite nitrogen concentrations reached a mean of 1.36 mg/L and a median of 1.2 mg/L.

- Total ammonia nitrogen concentrations reached a mean of 0.056 mg/L and a median of 0.042 mg/L.
- Metal results showed that total selenium exceeded the guideline at Site 5 in January and at Spr2 in June. The exceedance at Spr2 indicates this metal is naturally occurring in groundwater. Total chromium concentration at Site 1 in October also exceeded the guideline. The reason for this exceedance is unclear.
- Phenol concentrations reached a mean of 0.0033 mg/L and a median of 0.0019 mg/L. All phenol concentrations measured in June – January were below guidelines. However, concentrations measured in April were all above guideline. Spring snowmelt runoff may have brought phenol-containing natural, residential or industrial effluents into Bighill Creek.

The sediment data showed the following results:

- Sediment texture was loam to sandy loam.
- Sediment salinity concentrations showed that soluble chloride concentration exceeded the guideline at Site 1 in October.
- Available nitrogen concentrations were below detection limits.
- Available phosphorus concentrations reached a mean of 1.5 mg/kg and a median of 1.2 mg/kg.
- Available potassium concentrations reached a mean of 105 mg/kg and a median of 109 mg/kg.
- Total metal concentrations did not exceed guidelines.
- Concentrations of polycyclic aromatic hydrocarbons showed that in June at Site 5 Pyrene concentration exceeded the guideline. In October at Site 1 Dibenz(a,h)anthracene concentration may have exceeded the guideline (detection limit was higher than the guideline). In October at Site 5, Benzo(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Phenanthrene, and Pyrene exceeded their respective guidelines. Site 5 is located downstream of the Town of Cochrane where residential and industrial activities take place. Effluents from these activities may have contributed to these exceedances.
- Phenol sediment concentrations were below guidelines.

The results of this study show that the water quality of Bighill Creek is comparable to that of similar water ways near Cochrane and west of the City of Calgary. These results can act as a benchmark for assessing changes in water quality in the future.

Being a one-year study with five sampling points in time, this study is limited with regard to making conclusive statements or recommendations. In order to better understand the Bighill Creek watershed and land use interactions, further water and sediment sampling is recommended upstream of Site 1, along the valley, and in the Town of Cochrane.

It would be useful to repeat this study in the future in order to look for changes. This would allow comparisons over time and space as well as correlations with land uses affecting water quality. The area around the Town of Cochrane is undergoing changes such as increased human population, land development, more industrial activities, increased gravel operations, and potential relocation of agricultural practices. Thus, an increase in monitoring at regular intervals is recommended.

This baseline study is designed to provide the information necessary to help protect the aquatic and riparian environments, the downstream receiving waters, as well as to support reclaiming the watershed as a recreational zone and for the reintroduction of a sport fishery. It is complemented by a fish inventory conducted by Trout Unlimited in June 2018, a riparian assessment conducted by the Alberta Habitat Management Society in summer 2018, and stewardship efforts of the Bighill Creek Preservation Society to improve the trail system in the provincial and county reserve areas along the Creek.

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1.0 INTRODUCTION

The Bighill Creek (also known as Bighill Springs Creek) watershed is naturally, historically, and regionally significant. Its main source is in the Bighill Springs Provincial Park, and the valley it pours into is a unique U-shaped 15 km valley that reaches the Bow River in the Town of Cochrane. The tufa formations, ancient buffalo jumps, ecological quality and diversity of the creek and riparian zone, and cool water temperatures in summer and fall render this watershed a significantly valuable habitat and wildlife corridor.

The Bighill Creek Preservation Society (BCPS) was formed in 2015 and has been concerned about the general health of the Bighill Creek Valley as it adapts to increasing development and population pressure around the valley.

Water quality is an important indicator of the health of a watershed. Historical data show a lack of information regarding water quality of Bighill Creek along the valley and into the Town of Cochrane. The purpose of this study was to report the current surface water and sediment quality conditions.

2.0 METHODS

2.1 Sampling Location

Five surface water samples were collected in Bighill Creek between Highway 567, furthest upstream location – Site 1, and near the confluence with the Bow River, furthest downstream location – Site 5 (Table 1). Sites 2-4 were located in the Bighill Valley between Bighill Springs Provincial Park and the Town of Cochrane (Figure 1). In addition, two spring water samples were collected at Spr1 and Spr2 (Figure 1 and Table 1). These sampling sites were selected in agreement with the Bighill Creek Preservation Society to assess the impacts of different land uses on surface water and sediment quality.

Surface water samples were collected on the following dates: 22 June 2017, 28 August 2017, 22 October 2017, 23 January 2018, and 24 April 2018. Sediment samples were collected on 22 June and 22 October 2017 at Site 1 and Site 5. Spring water was also sampled on these two dates.

2.2 Analyses

2.2.1 Field Data

Surface water velocity was measured at each site using a digital handheld velocity meter for measuring flow in open channels. It consists of a turbo propeller with a positive displacement sensor which is placed in a stream or on the bottom of a streambed and a digital display (Global Water, FP111). Flow rates were obtained by multiplying the average velocity with the cross-sectional area of the channel.

In situ water quality data were collected using a handheld multimeter (YSI Environmental, 556 Multiparameter System). This multiprobe system takes simultaneous measurements of pH, temperature, electrical conductivity (EC), and dissolved oxygen (DO).

Sediments were sampled at Site 1 and Site 5 twice during this sampling program: in June 2017 and October 2017. The following parameters were analysed: soil texture, salinity, available nitrogen, available phosphorus, available potassium, metals, polycyclic aromatic hydrocarbons (PAH), and phenols.

Grab water samples were collected with bottles supplied by Maxxam Analytics Inc. They were kept on ice in coolers and transported to the accredited laboratory.

2.2.2 Laboratory Analyses

Maxxam Analytics Inc. (4000 – 19 Street NE, Calgary, AB T2E 6P8, Tel: (403) 291-3077, Toll free: (800) 386-7247, Fax: (403) 735-2240) provided physical, chemical, and biological analyses including fecal coliforms, biochemical oxygen demand (BOD), chlorophyll a, true colour, total phosphorus (TP), dissolved phosphorus (DP), total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), total organic carbon (TOC), total suspended solids (TSS), routine analysis (anions and cations), total metals, and phenols. A more limited analysis was performed on the spring water samples (fecal coliforms, TP, DP, TKN, TAN, and routine analyses. Data were compared to the Alberta Surface Water Quality Guidelines and the current Canadian Water Quality Guidelines (CCME, 2003; AESRD, 2014 and Government of Alberta, 2018).

To ensure accuracy and precision within the sampling program, duplicate samples and field blank samples were taken to assess cross-contamination potential and sample precision. The internal laboratory quality control consists of method blanks, matrix spikes, calibration checks and relative percent difference between internally split samples.

2.2.3 Statistics

Both the mean and median of each dataset were calculated and reported. The mean is the sum of the values divided by the number of measurements. The median is the central or middle value. These are two representations of the centre of a dataset and reporting both provides more information on the dataset analyzed.

Where replicated measurements were conducted, the standard error of the mean was calculated and plotted on the figures. It represents the standard deviation of the sample distribution and shows the level of fluctuation around the mean.

3.0 RESULTS AND DISCUSSION

3.1 Water

3.1.1 Water Flow

Surface water flow measured in Bighill Creek ranged from 0.0 m^3/s (Site 1 in August) to 0.672 m^3/s (Site 3 in April), with a mean of 0.195 m^3/s and a median of 0.134 m^3/s (Figure 2).

Flows at Bighill Creek were comparable to those measured in Grand Valley Creek in 2005 (Sosiak, 2006) and in springs at Glenbow Ranch Provincial Park (Hayachi and Morgan, 2015) but were lower than those measured at Nose Creek in 2013 (Palliser Environmental, 2014). They were also lower than those measured at a long-term gauging station located near Site 4 (Hayachi, 2018). The highest flows were in April across locations, likely due to snowmelt runoff.

Spring water flow ranged from 0.001 m^3/s (Spr2 in October) to 0.184 m^3/s (Spr1 in June). Spr1 is located at the headwaters of the springs within the Provincial Park and is the sum of several springs upstream. Spr2, however, is a unique spring with a smaller channel located on the north side of the valley between Site 2 and Site 3 (Figure 2). This explains the higher flows measured at Spr1 compared to Spr2.

3.1.2 pH

The pH of water represents the balance between acids and bases and describes the activity of hydrogen ions in solution. It influences the availability of nutrients, concentrations of total ammonia, the relative toxicity of many trace elements, and can affect the general composition of an aquatic environment.

The pH measured in Bighill Creek ranged from 8.05 (Site 1 in April) to 8.61 (Site 5 in August) with a mean of 8.33 and a median of 8.38 (Figure 3 and Table 2). These values were comparable to pH obtained near Site 5 by the City of Calgary (2013). The pH was within the CCME water quality guideline of 6.5 to 9.0 (CCME, 1999a).

3.1.3 Water Temperature

Water temperature is important as it strongly influences chemical and biological processes in surface water bodies. A change in the temperature of a surface water system can affect plant photosynthesis, fish communities, as well as algal and benthic communities, diversity, and productivity. Higher water temperatures decrease oxygen solubility and decrease the availability of dissolved oxygen to fish. Temperature also affects total ammonia concentrations in water.

Day time surface water temperatures measured in Bighill Creek ranged from -0.2 C (Site 5 in January) to 17.3 C (Site 4 in June) with a mean of 7.4 C and a median of 4.7 C (Figure 4). The City of Calgary found a temperature median of 10.70 C near Site 5 during their sampling program from 2000 to 2013 (City of Calgary, 2013).

The water temperature was highest in June and April and lowest in January. In January, all temperatures were at or below freezing except at Site 2 where the temperature was 1.7 C. Site 2 is downstream of Spr1 which is at the main headwaters for Bighill Springs. The spring water at Spr1 likely contributed to this increase in water temperature. Similarly, Spr1 likely contributed to the temperature increase at Site 2 in October.

3.1.4 Dissolved Oxygen

The most fundamental parameter in water, DO is essential for aquatic life and for the metabolism of all aerobic aquatic organisms. Its levels can decrease with excessive organic matter decomposition, plant and animal respiration, excessive growth of aquatic plants, and an

increase in water temperatures can reduce its solubility in water. Sources of DO are from the atmosphere and from plant photosynthesis.
Day time DO in Bighill Creek ranged from 9.6 mg/L (Site 5 in April) to 20.5 mg/L (Site 1 in April), with a mean of 13.6 mg/L and a median of 13.8 mg/L (Figure 5). These are comparable to values measured at West Nose Creek at Big Hill Springs Rd in 2013 (Palliser Environmental, 2014). The City of Calgary found a median of 9.70 mg/L near Site 5 in their sampling program between 2000 and 2013 (City of Calgary, 2013).

All DO measurements were above the Alberta acute (5.0 mg/L) and chronic (6.5 mg/L) guidelines as well as CCME cold water guidelines (9.5 mg/L for early life stages and 6.5 mg/L for other life stages) (CCME, 1999b).

3.1.5 Biochemical Oxygen Demand

Water bodies produce and consume oxygen. They gain oxygen from the atmosphere and from plant photosynthesis. Respiration by aquatic organisms and decomposition consume oxygen. The BOD of a water body is the amount of DO consumed by microorganisms to metabolize organic matter. Sources of high BOD potentially include sewage treatment plant effluent, farmland runoff, feedlots, urban storm water runoff, failed septic tanks, among others. Pristine rivers generally have a 5-day BOD below 1 mg/L and moderately polluted rivers may have a BOD ranging from 2 to 8 mg/L (Connor, 2016). Treated municipal sewage would have a BOD below 20 mg/L whereas untreated sewage BOD could range between 200 mg/L (USA) and 600 mg/L (Europe) (Sawyer et al., 2003).

Most BOD concentrations measured in Bighill Creek were below detection limit (2.0 mg/L), which accounts for the uniform levels seen on Figure 6, except in October at Site 1 (4.7 mg/L) and in April at all sites (Figure 6). In April, BOD ranged from 2.7 mg/L at Site 3 to 5.9 mg/L at Site 1. These concentration increases were also measured for total organic carbon and TP. The increase in April is likely due to the addition of organic matter from spring snowmelt runoff into the Creek.

Concentrations of BOD at Site 1 were higher than at other sites in October and April. This is likely due to an increase in activities releasing organic matter upstream of Site 1 in fall and spring. There is a peak in total Kjeldahl nitrogen at Site 1 in October and April, and a peak in dissolved phosphorus in April, indicating that the likely source of organic matter is animal manure including cattle, wildlife, birds, wildlife, and domestic animals.

3.1.6 Total Organic Carbon

Total Organic Carbon is an important parameter used to monitor overall levels of organic compounds present in surface water. Concentrations of TOC measured in Bighill Creek ranged from 0.5 mg/L (January at Site 2 and Site 4) to 13.0 mg/L (April at Site 1, Site 3, and Site 4), with a mean of 4.9 mg/L and a median of 2.6 mg/L (Figure 7). These are lower than the mean (6.04 mg/L) and median (5.9 mg/L) measured by the City of Calgary near Site 5 between 2000 and 2013 (City of Calgary, 2013).

Concentrations of TOC were higher in April than on other sampling dates. As with the BOD, TSS concentrations, this is likely an increase in organic particle movement from spring snowmelt runoff. Concentrations of TOC were higher at Site 1 than other sites for all sampling dates except in April when Site 3 and Site 4 were equally high. As with the BOD, TSS and nutrient results, elevated TOC concentrations originated upstream of Site 1 and were likely due to an increase in organics and nutrient runoff from animal manure including cattle, wildlife, birds, wildlife, and domestic animals.

3.1.7 Total Dissolved Solids

Total dissolved solids are a measure of inorganic salts and organic matter dissolved in water. They usually originate from natural sources, sewage, urban and agricultural runoff, and industrial waste water. Depending on rock formations, the concentration of TDS in water can vary depending on the presence of carbonates, chlorides, calcium, magnesium, and sulphates. Values of TDS were obtained from a conversion of conductivity calculated by the equipment. The guideline for livestock water is 3,000 mg/L and for irrigation water between 500 and 3,500 mg/L (AESRD, 2014).

All sites had similar values of TDS concentrations ranging from 253 mg/L (Site 1 in April) to 498 mg/L (Site 1 in January) with a mean of 350 mg/L and a median of 365 mg/L (Figure 8). All TDS measurements were below both irrigation and livestock water guidelines. The TDS values at Bighill Creek are comparable to those measured at springs along the northern bank of the Bow River Valley at Glenbow Ranch Provincial Park (Hayashi and Morgan, 2015).

Values of TDS in January exceeded those during all other sampling events. During winter months, the main source of TDS is groundwater as snowmelt and rainfall runoff are generally insignificant. This indicates that in January the springs likely contributed to TDS concentrations. In contrast, the relatively high TDS concentrations in June and August were likely a combination of minerals originating from groundwater as well as from rainfall and snowmelt (June) runoff events.

3.1.8 Total Suspended Solids

Total suspended solids indicate the concentration of suspended particles in water such as fine silt and clay soil particles, organic matter, and micro-organisms. Suspended solids often carry nutrients and contaminants and in excess can be detrimental to aquatic life.

Concentrations of TSS in Bighill Creek ranged from 0.9 mg/L (Spr1 and Spr2 in June 2017, and Site 5 in October 2017) to 61.0 mg/L (Site 4 in April 2018), with a mean of 12.7 mg/L and a median of 4.7 mg/L (Figure 9). These values are comparable to those measured by the City of Calgary (2013). Sosiak (2006) found a median TSS concentration of 6.8 mg/L in 2004 and 9.6 mg/L in 2005 in Grand Valley Creek located west of Cochrane.

Concentrations of TSS measured in April were higher than during all previous sampling events, especially at Sites 2-5. Spring snowmelt runoff likely contributed to this increase. The leap from

Site 1 (12 mg/L) to Site 2 (36 mg/L) in April may illustrate the effect of an increased use of the Provincial Park located between these sampling locations.

Concentrations of TSS measured at Site 1 in June and October were higher than at other sampling locations during those two sampling dates. This indicates a potential source of TSS located upstream of Site 1. Organic indicators such as BOD and nutrients indicate the likely source of TSS upstream of Site 1 is animal manure including cattle, wildlife, birds, wildlife, and domestic animals.

3.1.9 Electrical Conductivity

Electrical Conductivity is a measure of the ability of water to conduct an electric current. It is an indication of total dissolved solids and the sum of anions and cations as they conduct an electrical current.

Electrical conductivity is dependent on temperature and was standardized to 25^{o}C using the equation in Mutual and Hayashi (2014). Electrical conductivity at Bighill Creek ranged from 0.391 mS/cm (Site 1 in April) to 0.889 mS/cm (Spr1 in June) with a mean of 0.640 mS/cm and a median of 0.639 mS/cm (Figure 10). All EC measurements were below the irrigation guideline of 1.0 mS/cm (AESRD, 2014). Mutual and Hayashi (2014) reported EC values of 0.426 – 1.313 mS/cm at springs in Glenbow Ranch Provincial Park. Sosiak (2006) reported comparable EC values in Grand Valley Creek, Alberta.

Water EC was lower in April than all previous sampling dates. Spring snowmelt runoff likely diluted the groundwater rich in minerals and lowered their concentrations. Values were relatively comparable during summer, fall and winter. Higher EC at Spr1 and Spr2 in June may be a combination of groundwater minerals as well as salts originating from spring snowmelt and rainfall runoff. High EC at Site 1 indicate a source of minerals upstream of this sampling location.

3.1.10 True Colour

The colour of water can be used as an indicator for environmental impacts such as changes in physical, chemical, and biological characteristics of a watercourse arising from anthropogenic activities. Studies have shown a positive correlation between water colour and primary production in freshwater (Del Giogio and Peters, 1994). The colour of light and turbidity of water determine the depth of penetration of light in water. True colour depends on the dissolved fraction of water which can include natural minerals and dissolved organic substances. Colour also depends on factors affecting the solubility and stability of the dissolved and particulate fractions of water such as pH and temperature.

True colour measured in Bighill Creek ranged from below detection (<2.0 PtCo units) at Site 2 in January to 97.0 PtCo units at Site 1 in April, with a mean of 24.8 PtCo units and a median of 9.0 PtCo units (Figure 11). The City of Calgary (2013) found a mean of 20.1 PtCo units near Site 5 over the years 2000-2013. The median in April 2018 (90 PtCo units) was higher than the median across all measurements, indicating higher turbidity which is likely a result of increased flows from snowmelt runoff.

3.1.11 Chlorophyll a

Chlorophyll a is an estimate of phytoplankton biomass in freshwater. It estimates the amount of algae floating in the water column and indicates whether nutrients such as phosphorus (P) and nitrogen (N) may be in excess. According to AESRD (2013), chlorophyll concentrations above 25 µg/L indicate a hypereutrophic environment with very high productivity, 8-25 µg/L indicate a eutrophic environment that is highly productive, 2.5-8 µg/L indicate a mesotrophic environment that is moderately productive, and below 2.5 µg/L indicate an oligotrophic environment that has low productivity.

Chlorophyll concentrations in Bighill Creek ranged from 0.7 µg/L (Site 2 in January) to 34.8 µg/L (Site 1 in October) with a mean of 6.5 µg/L and a median of 4.7 µg/L (Figure 12).

Most values measured were in the mesotrophic zone except one hypereutrophic sample found at Site 1 in October indicating an excess in nutrient concentrations. Nutrient (Total Kjeldahl Nitrogen and Total Ammonia Nitrogen) concentrations were also elevated at Site 1 in October, resulting in elevated chlorophyll concentrations. Chlorophyll median concentration in April (10.9 µg/L) was higher than the total median, indicating eutrophic environment. Higher runoff and an increase in nutrients and organic matter from snowmelt in April likely resulted in this increase.

3.1.12 Fecal Coliforms

Fecal coliforms are bacteria that generally originate in the intestines of warm-blooded animals. Their presence in an aquatic environment indicates that the water has been contaminated with fecal material of man or other animals. They are an indicator that a potential health risk exists for individuals exposed to this water. Fecal coliform bacteria may occur in ambient water as a result of the overflow of domestic sewage or nonpoint sources of human and animal waste. In drinking water, the minimum acceptable concentration is 0 organisms detected in 100 mL of sample. For irrigation and contact recreation uses, the guidelines are 100 and 200 organisms in 100 mL, respectively.

Fecal coliform counts in Bighill Creek ranged from 0.9 MPN/100 mL (Site 2 in January) to 2401 MPN/100 mL (Site 1 in June) with a mean of 168.5 MPN /100 mL and a median of 13.0 MPN /100 mL (Figure 13). The City of Calgary (2013) measured total coliforms and found a median of 1251.5 MPN /100 mL during its sampling program near Site 5. Sosiak (2006) reported fecal coliform counts in Grand Valley Creek reaching 10,000 and 22,000 in spring 2004 which likely reflected spring runoff from agricultural sites.

Counts in August were higher than other sampling dates, especially at Site 1 (980 MPN/100 mL) and Site 2 (690 MPN /100 mL). Land uses upstream of Site 1 increased fecal coliform levels in Bighill Creek in spring and summer, likely through the movement of runoff from animal manure including cattle, wildlife, birds, and domestic animals. This is reflected by high nitrogen concentrations at Site 1 described below.

The fecal coliform counts in April were below 10 MPN/100 mL despite higher April concentrations of phosphorus and nitrogen. These parameters are usually positively correlated, and it is unclear why fecal coliform counts are lowest in April.

3.1.13 Nutrients

3.1.13.1 Total Phosphorus

An essential nutrient for all living organisms, P plays a major role in biological metabolism. Compared to other macronutrients, it is the least abundant in water bodies (Wetzel, 2001). Water bodies containing low P concentrations can support relatively diverse and abundant aquatic life. However, elevated P concentrations can adversely affect aquatic ecosystems (Chambers et al., 2001). Sources include P in soils and sediments, atmospheric deposition, animal manures, inorganic fertilizers, failed septic systems, sewage treatment plants, urban runoff.

Total phosphorus includes particulate and dissolved forms of P, both organic and inorganic. The previous guideline for TP (0.05 mg/L) has been withdrawn and narrative statements have been developed based on a use-protection approach to protect aquatic life (AESRD, 2014). Concentrations “should be maintained so as to prevent detrimental changes to algal and aquatic plant communities, aquatic biodiversity, oxygen levels, and recreational quality. Where priorities warrant, develop site-specific nutrient objectives and management plans” (AESRD, 2014).

Concentrations of TP at Bighill Creek ranged from 0.0029 mg/L (Spr1 in June) to 0.2100 mg/L (Site 1 in April) with a mean of 0.0505 mg/L and a median of 0.0170 mg/L (Figure 14). The City of Calgary (2013) found a mean and a median of 0.04 mg/L near Site 5.

Concentrations measured in April were higher than other sampling dates. Concentrations of TP were likely abundant in snowmelt runoff, resulting in higher values in April. In addition, TP was higher at Site 1 in both June and October, indicating a source of TP upstream of Site 1. Concentrations at Bighill Creek were comparable to those measured in Grand Valley Creek in 2004 and 2005 (Sosiak, 2006).

3.1.13.2 Dissolved Phosphorus

Dissolved phosphorus is a highly reactive form of P that is quickly absorbed by aquatic plants and algae. It is therefore a better measure of P available for plant and algal growth compared to TP.

Concentrations of DP in Bighill Creek ranged from below detection (<0.0030 mg/L) (at Spr1 in June, Site 5 in August, Spr1 and Spr2 in October, and Site 2 in January) to 0.12 mg/L (Site 1 in April), with a mean of 0.019 mg/L and a median of 0.0047 mg/L (Figure 15). These are comparable to measurements (median 0.02 mg/L) near Site 5 (City of Calgary, 2013).

The highest concentrations were measured in April, likely as a result of an increase in flow due to spring snowmelt runoff. The median concentration was comparable to those measured in Grand Valley Creek in 2004 (Sosiak, 2006)

3.1.13.3 Total Kjeldahl Nitrogen

Nitrogen is another essential nutrient for all forms of life including aquatic plants. Elevated N concentrations can result in eutrophication and excessive growth of algae and aquatic plants. Sources of N include atmospheric deposition, municipal and industrial wastewater, septic tanks and runoff from agricultural practices. The Kjeldahl procedure is a digestion that releases N from all N containing compounds in the sample and is essentially an indicator of total N present.

Concentrations of TKN in Bighill Creek ranged from 0.049 mg/L (Spr1 in June and October) to 1.7 mg/L (Site 1 in October and April), with a mean of 0.53 mg/L and a median of 0.39 mg/L (Figure 16). Sosiak (2006) measured TKN concentrations in Grand Valley Creek and found a median of 0.3-0.7 mg/L in 2004 and 2005. The City of Calgary (2013) found a median and mean of 0.25 mg/L near Site 5.

As with TP, DP, TOC, colour, and TSS, concentrations of TKN were highest in April, likely as a result of increased flow from snowmelt runoff and the accumulation of organic matter from upstream and surrounding land uses. Concentrations of TKN were higher at Site 1 for most sampling dates, and this was also found for TP and TOC. The likely source of organic matter upstream of Site 1 is runoff from animal manure including cattle, wildlife, birds, and domestic animals.

3.1.13.4 Nitrate + Nitrite Nitrogen

Nitrate and nitrite N are often measured together due to the instability of nitrite in the presence of oxygen and its low concentrations. Although nitrate is required for plant growth, elevated concentrations can result in detrimental eutrophication of the aquatic system.

Nitrate + nitrite concentrations in Bighill Creek ranged from 0.045 mg/L (Site 1 in April) to 2.9 mg/L (Site 2 in January, Spr1 in June and October) with a mean of 1.36 mg/L and a median of 1.2 mg/L (Table 2). These are higher than the mean (0.30 mg/L) and median (0.25 mg/L) found by the City of Calgary (2013) near Site 5. The elevated concentrations at Spr1 and in January indicate a groundwater contribution of nitrate + nitrite to the Creek.

3.1.13.5 Total Ammonia Nitrogen

Known for its suffocating odour at ambient temperature and pressure, ammonia is an important source of available N in the environment because it is oxidized by microorganisms during nitrification (Weil and Brady, 2017). Ammonia is therefore produced by the decomposition of organic matter. It comes in two forms: ammonium is the cation and ionized form NH_4^+ whereas ammonia is the non-ionized form NH_3. The latter is the toxic form of ammonia N. Total ammonia N is found mainly in municipal and industrial wastewater effluent and in runoff downstream of intense manure or mineral fertilizer use. The guideline varies with pH and temperature (CCME, 2010).

Concentrations of TAN in Bighill Creek ranged from 0.014 mg/L (Spr2 in June, Site 2, Site 4, Site 5, Spr1 and Spr2 in October, and Site 2 in January) to 0.23 mg/L (Site 1 in April) with a mean of 0.056 mg/L and a median of 0.042 mg/L (Figure 17). All concentrations were below CCME guidelines. These values are slightly higher than those measured by the City of Calgary (2013) near Site 5 (mean 0.03 mg/L and median 0.02 mg/L).

Concentrations of TAN in April at sites 1-4 were higher than the mean, illustrating the impact of spring snowmelt runoff on organic matter levels and its decomposition in Bighill Creek in the springtime. Concentrations at Site 1 were higher than other sampling locations for most sampling dates except August and January when concentrations at Site 3 were higher. The decrease in concentrations from Site 1 to Site 2 indicates that the source of ammonia is upstream of Site 1. Concentrations of TAN increased from Site 2 to Site 3 in June, August, October and January, indicating a potential source of TAN between these two locations. The land uses in this area that may be contributing to this increase are agricultural and recreational. Wildlife are common in the Bighill Creek Valley and may also be contributing to the nutrient concentrations.

3.1.14 Total Metals

Metals occur naturally in aquatic systems as a result of soil and rock weathering, and volcanic eruptions. Anthropogenic sources include mining and metal processing. Acid mine drainage releases metals from bedrock and the acid solution is dispersed into the environment. In a low pH environment, metals are more soluble and mobile and toxicity levels increase (Simate and Ndlovu, 2014).

Metal concentrations in Bighill Creek water are shown in Table 3. Total selenium exceeded the guideline at Site 5 in January and at Spr 2 in June (Table 3). The exceedance at Spr2 indicates this metal is naturally occurring in groundwater. According to AESRD (2014), total metal concentrations can exceed guidelines under natural conditions particularly in certain seasons due to their strong association with suspended solids in water. Total chromium concentration at Site 1 in October exceeded the guideline. The reason for this exceedance is unclear.

3.1.15 Phenols

Phenols are chemicals that consist of a hydroxyl group bonded directly to an aromatic hydrocarbon group. They occur naturally in amino acids, hormones, serotonin, in plants and end up in aquatic environments as a result of the decomposition of aquatic vegetation. Major anthropogenic sources include domestic sewage and industrial effluents such as the pulp, paper and wood industry (Environment Canada, 1997). The guideline for the protection of aquatic life is 0.004 mg/L (CCME, 1999c).

Concentrations of phenols in Bighill Creek ranged from below detection limit (<0.0020 mg/L) at all sampling locations in June, October, January, and most sampling locations in August, to

0.0087 mg/L at Site 2 in April, with a mean of 0.0033 mg/L and a median of 0.0019 mg/L (Figure 18).

All phenol concentrations measured in June – January were below guidelines. However, concentrations measured in April were all above guideline. Spring snowmelt runoff may have brought phenol-containing residential or industrial effluents as well as naturally occurring phenols into Bighill Creek.

3.2 Sediment

Sediments are organic and inorganic materials that constitute the bed of a stream or river. They originate from erosion of minerals surrounding the stream and are deposited through sedimentation. They include mineral matter such fine clay, silt, and sand, coarse materials such as gravel, cobbles and boulders, and bedrock. They also include organic matter such as aquatic plants, animal matter, pieces of vegetation such as leaves and branches. Large material can affect flow patterns and microhabitats. Their degradation results in the formation of organic particles and the release of dissolved nutrients and organic matter. They may act as a source of chemicals (nutrients and potential contaminants) to aquatic organisms. Sediment diversity of shapes and sizes can provide a range of surfaces available for colonization, habitat formation, and flow patterns, resulting in a diverse and abundant aquatic life.

3.2.1 Texture

Aquatic plants and microorganisms depend on carbon and mineral nutrients for their sustenance. These nutrients are often adsorbed to sediment surface areas. Clay particles have a higher surface area than silt or sand particles and higher clay content generally means more organic matter and nutrients can be adsorbed and available for freshwater life. Sediment texture was measured in June and October at Site 1 and Site 5 and was classified as loam and sandy loam (Table 4).

3.2.2 Salinity

Alberta is known for its marine evaporite salt deposits (Dumont, 2008). The southern portion of the prairie provinces has naturally elevated salinity and high TDS (CEPA, 1999) due to high concentrations of sodium, bicarbonate, sulphate, and chloride (Last and Ginn, 2005).
As with water salinity, sediment salinity can affect aquatic plant growth. The concentrations of salts were measured for Bighill Creek sediments and are presented in Table 5.

Soluble chloride concentration (140 mg/L) exceeded the guideline (120 mg/L) at Site 1 in October (Table 5). Chloride occurs naturally in saline groundwater discharges from saline aquifers. In addition, above background concentrations are common in densely populated areas with dense roadways, and chloride concentrations are a common indicator of increasing urbanization.

3.2.3 Nutrients

The concentration of nutrients in aquatic sediments plays an important role in aquatic plant growth. Rattray et al. (1991) found that where nutrients in water were limited (oligotrophic conditions) plants turned to sediments to find their nutrients, and where the water was rich in nutrients (eutrophic conditions) plants did not take up sediment nutrients.

Available nutrient concentrations in Bighill Creek sediments were measured in June and October 2017 at Site 1 and Site 5.

3.2.3.1 Available Nitrogen

All available N concentrations in Bighill Creek Sediments were below detection limits (<2.0 mg/kg) (Figure 19).

3.2.3.2 Available Phosphorus

Available P concentrations measured in Bighill Creek sediments ranged from 1.0 mg/kg (Site 5 in June) to 2.5 mg/kg (Site 1 in June) with a mean of 1.5 mg/kg and a median of 1.2 mg/kg (Figure 20).

3.2.3.3 Available Potassium

Available potassium concentrations measured in Bighill Creek sediments ranged from 52 mg/kg (Site 5 in June) to 150 mg/kg (Site 1 in October) with a mean of 105 mg/kg and a median of 109 mg/kg (Figure 21).

3.2.4 Total Metals

Metals can find their way to aquatic sediments naturally or anthropogenically, via point and nonpoint sources. Guidelines vary depending on the metal and we have compared total metal concentrations to the Interim Sediment Quality Guidelines (CCME, 2003 and AESRD, 2014). Concentrations of total metals measured in Bighill Creek sediments are shown in Table 6, and none exceeded these guidelines.

3.2.5 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons are organic compounds that are present in coal, crude oil, and gasoline They are also present in the environment as a result of incomplete combustion of forest fires, coal cooking, oil, gas, wood stoves, etc. Major sources of PAH contamination of freshwater include oil spills and refinery effluents, domestic sewage, landfills, storm water runoff, and wood preservatives. The fate of PAHs in the environment is determined by the following processes: volatilization, photolysis, hydrolysis, microbial degradation, adsorption and sedimentation (Southworth, 1979). Guidelines vary depending on the PAH and we have compared PAH concentrations to the Interim Sediment Quality Guideline (CCME, 1999 and AESRD, 2014).

Concentrations of PAH measured in Bighill Creek sediments are presented in Table 7. In June at Site 5, Pyrene concentration (0.059 mg/kg) exceeded the guideline (0.0530 mg/kg). In October at Site 1, Dibenz(a,h)anthracene concentration (<0.0090 mg/kg) may have exceeded the guideline (0.00622 mg/kg). In October at Site 5, Benzo(a)anthracene, Benzo(a)pyrene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Phenanthrene, and Pyrene exceeded their respective guidelines (Table 7). Site 5 is located downstream of the Town of Cochrane where residential and industrial activities take place. Effluents from these activities may have contributed to these PAH exceedances.

3.2.6 Phenols

Phenol sediment concentrations are shown in Figure 22. All phenol concentrations in Bighill Creek sediments were below guidelines.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The results of this study show that the water quality of Bighill Creek is comparable to that of similar water ways near Cochrane and west of the City of Calgary. These results can act as a benchmark for assessing changes in water quality in the future.

Being a one-year study with five sampling points in time, this study is limited with regard to making conclusive statements or recommendations. In order to better understand the Bighill Creek watershed and land use interactions, further water and sediment sampling is recommended upstream of Site 1, along the valley, and in the Town of Cochrane.

It would be useful to repeat this study in the future in order to look for changes. This would allow comparisons over time and space as well as correlations with land uses affecting water quality. The area around the Town of Cochrane is undergoing changes such as increased human population, land development, more industrial activities, increased gravel operations, and potential relocation of agricultural practices. Thus, an increase in monitoring at regular intervals is recommended.

This baseline study is designed to provide the information necessary to help protect the aquatic and riparian environments, the downstream receiving waters, as well as to support reclaiming the watershed as a recreational zone and for the reintroduction of a sport fishery. It is complemented by a fish inventory conducted by Trout Unlimited in June 2018, a riparian assessment conducted by the Alberta Habitat Management Society in summer 2018, and stewardship efforts of the Bighill Creek Preservation Society to improve the trail system in the provincial and county reserve areas along the Creek.

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FIGURES

Figure 1. Sampling Locations in Bighill Creek in 2017 and 2018. Yellow and red pins indicate surface and spring water samples, respectively.

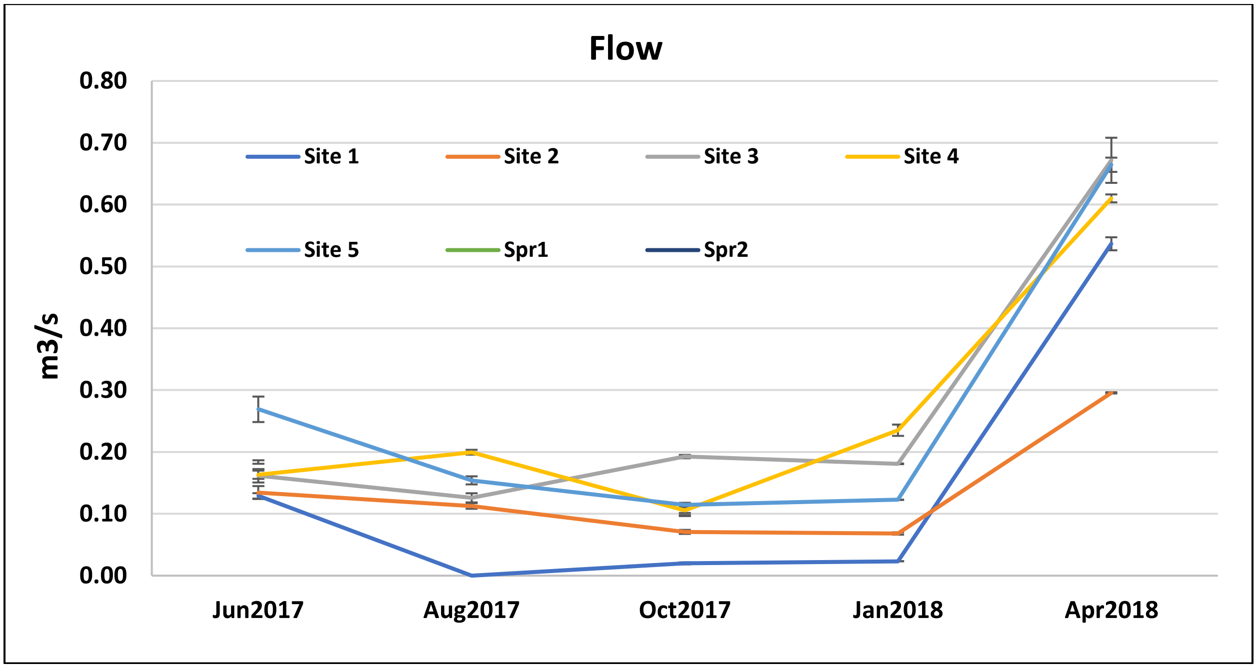

Figure 2. Flow (m^3/s) in June, August, October 2017 and January and April 2018 at Sites 1-5 and Spr1-2.

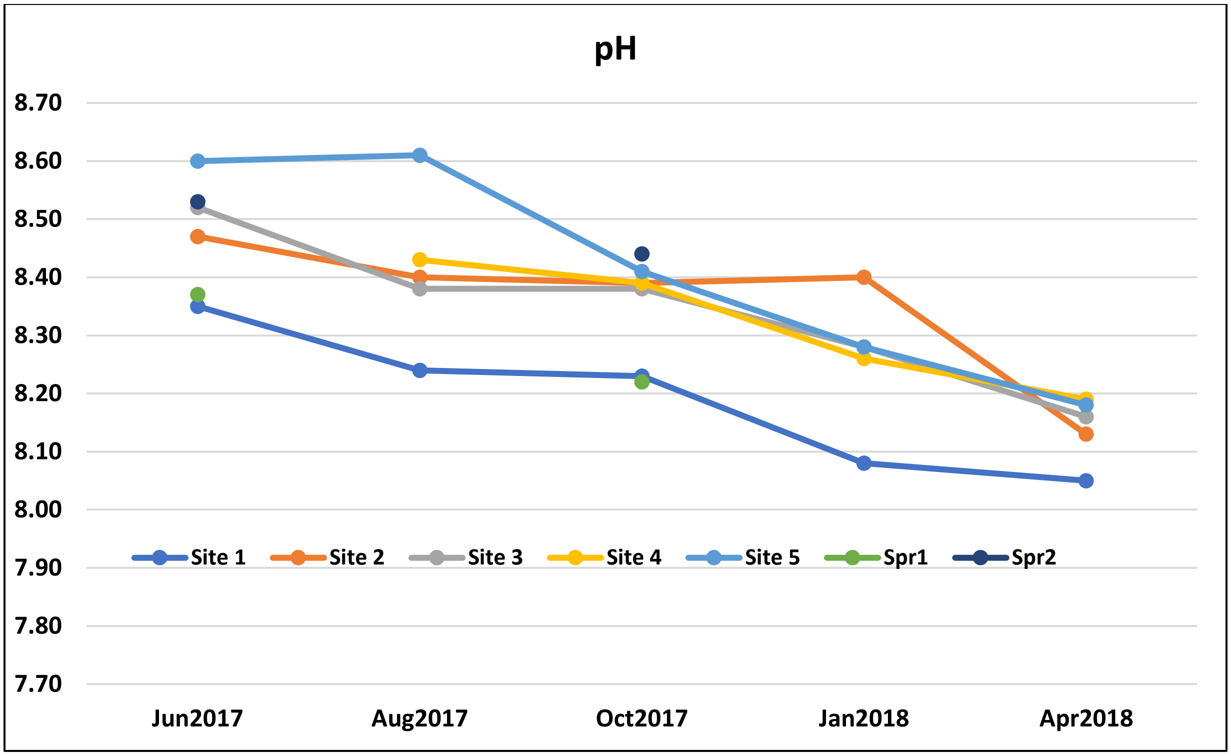

Figure 3. pH in Bighill Creek.

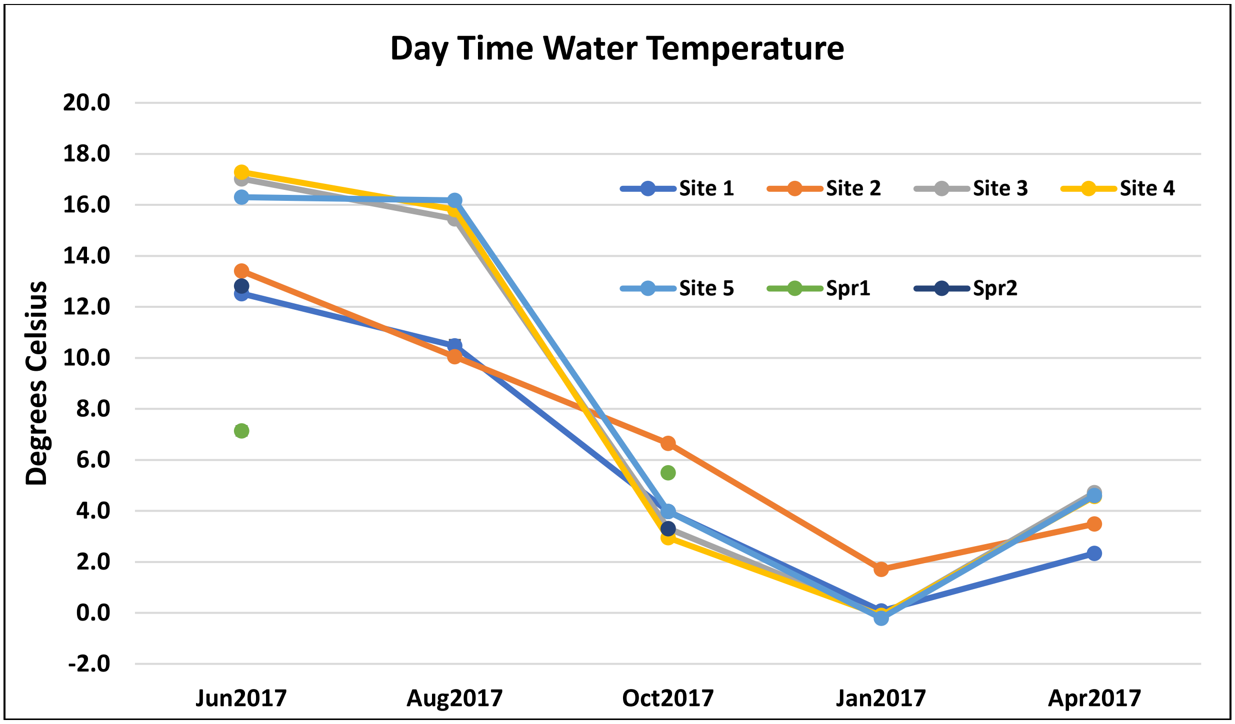

Figure 4. Day time water temperature (ºC) in Bighill Creek in June, August and October 2017, January and April 2018 at Sites 1-5 and Spr1-2.

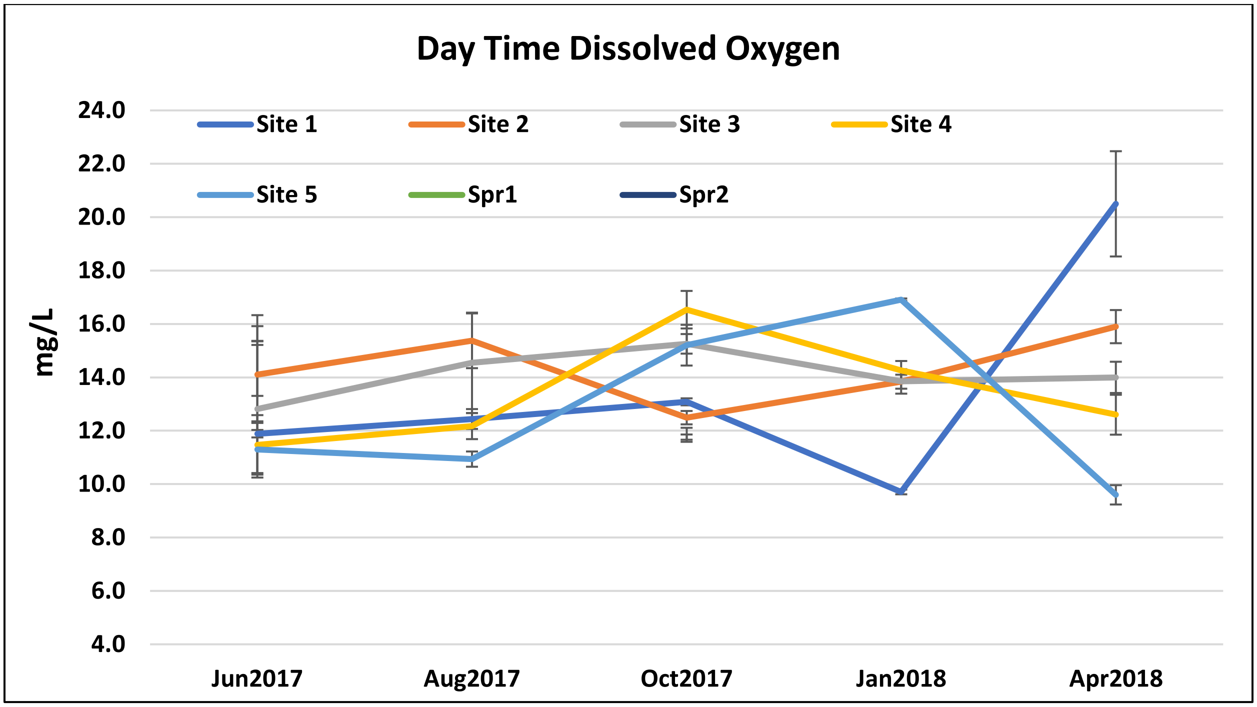

Figure 5. Day time dissolved oxygen (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr1-2.

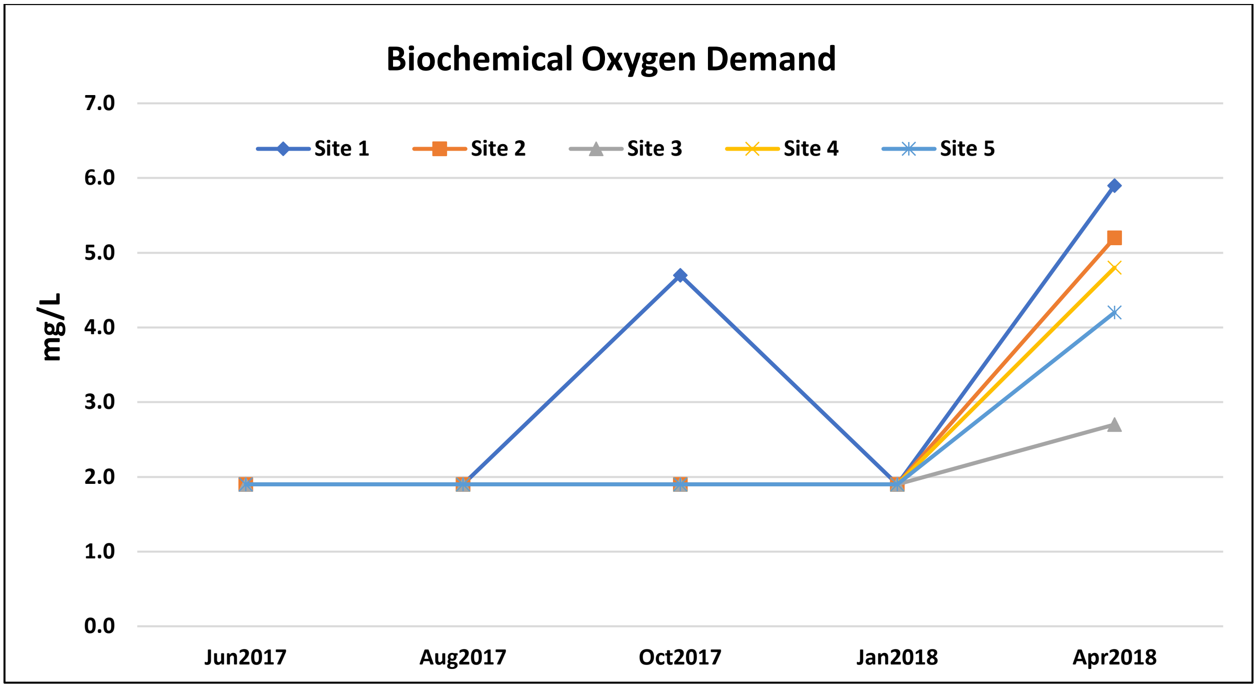

Figure 6. Biochemical oxygen demand (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5. Detection limit is 2 mg/L.

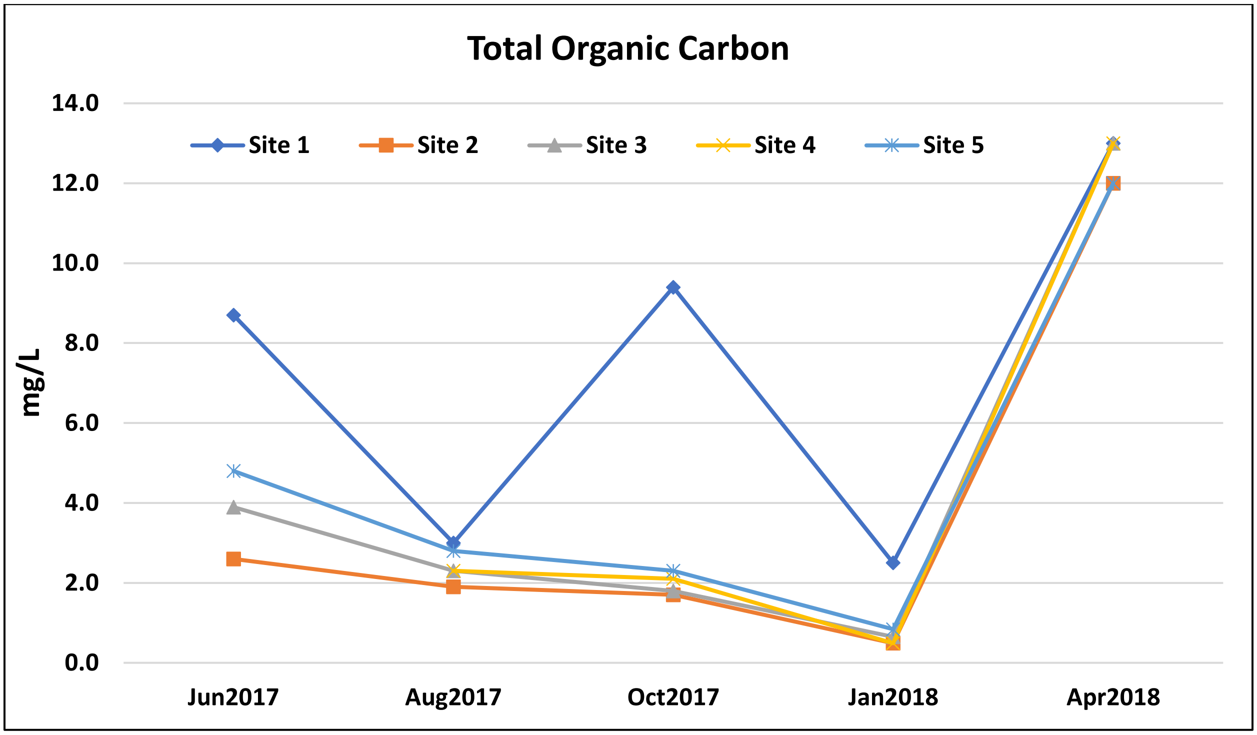

Figure 7. Total organic carbon (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5.

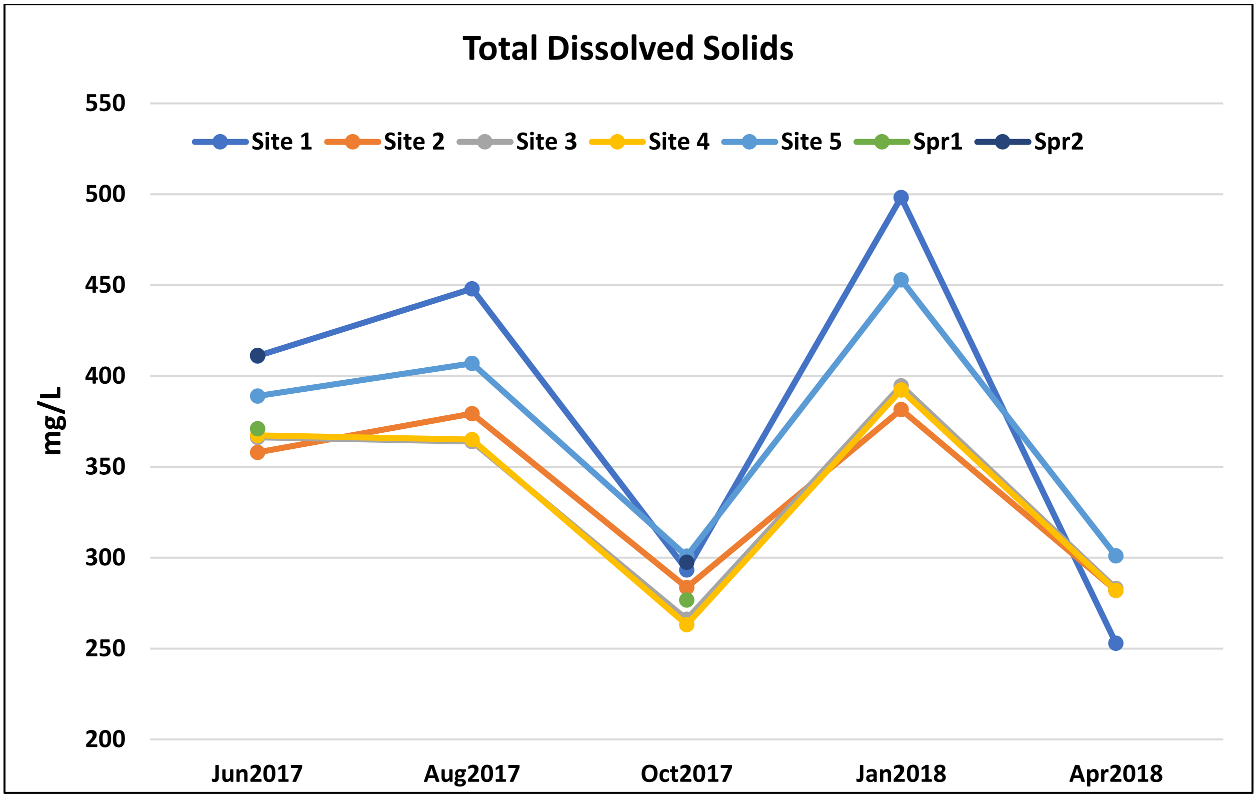

Figure 8. Total dissolved solids (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr1-2.

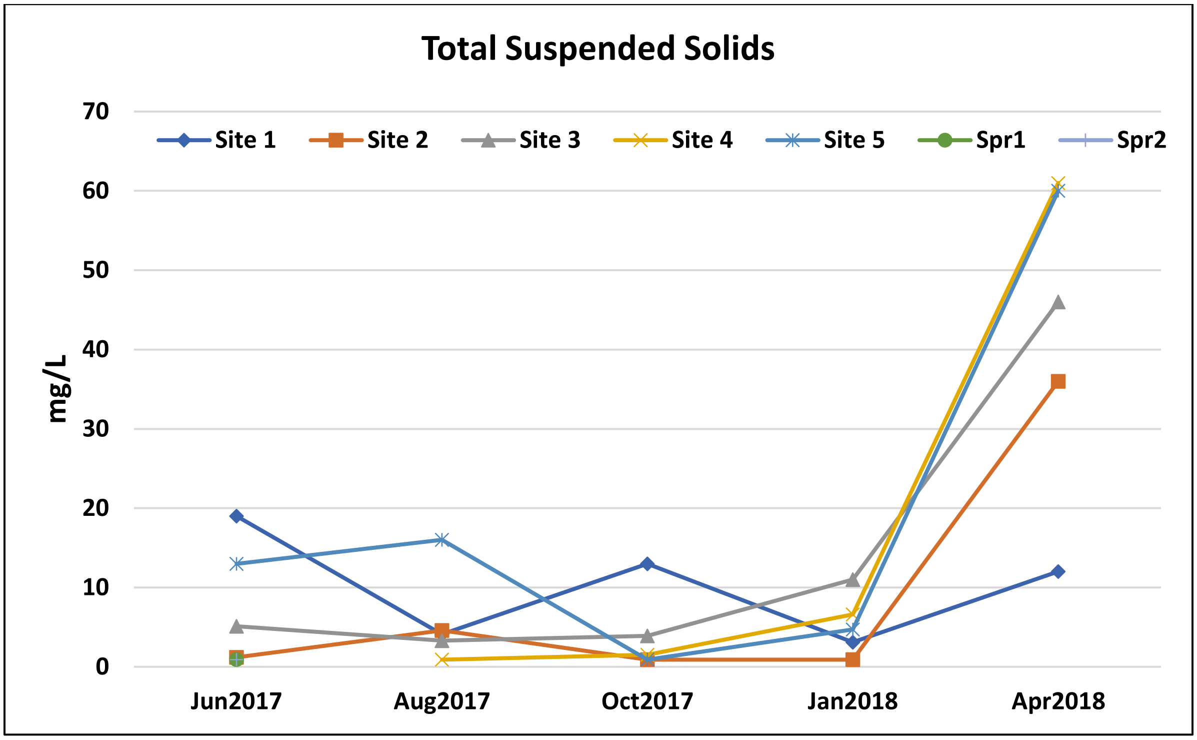

Figure 9. Total suspended solids (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr1-2.

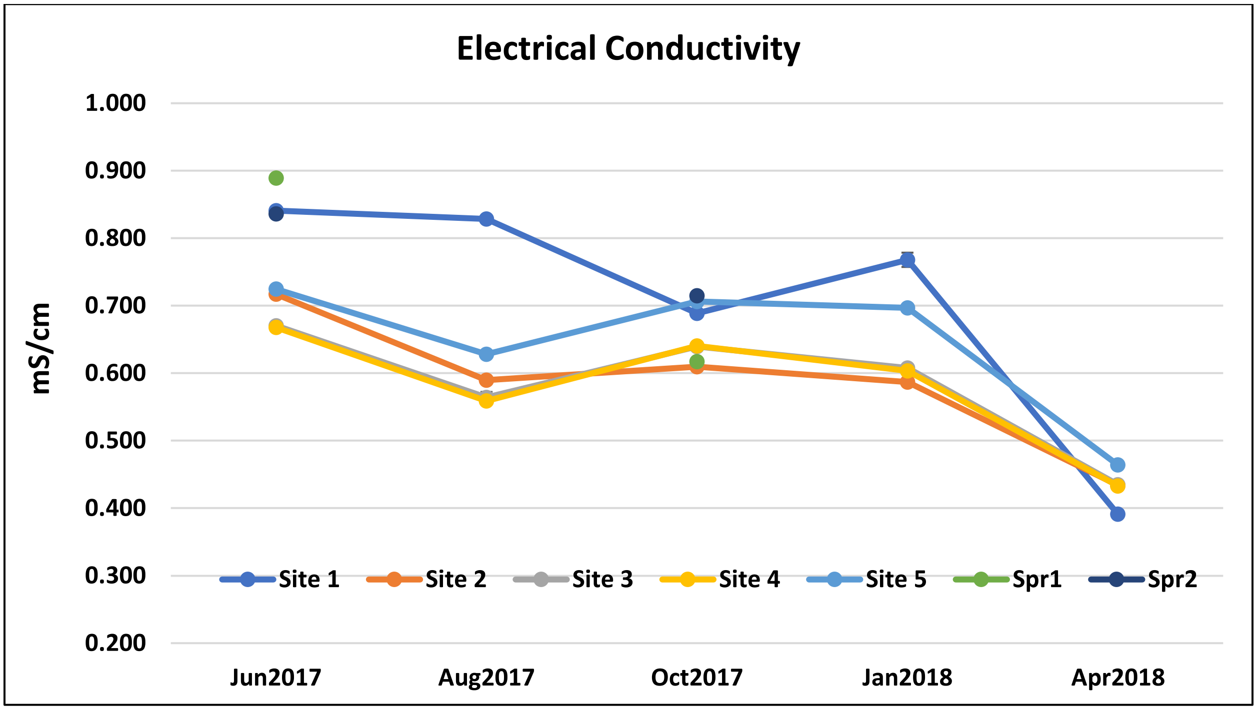

Figure 10. Electrical conductivity (mS/cm) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr1-2.

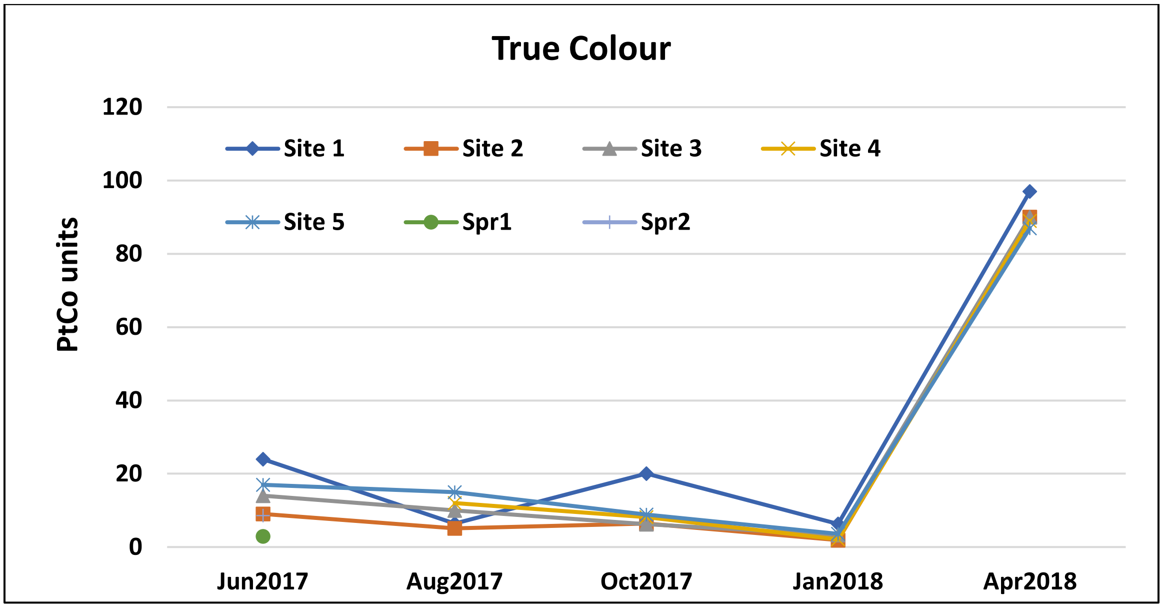

Figure 11. True colour (PtCo units) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr1-2.

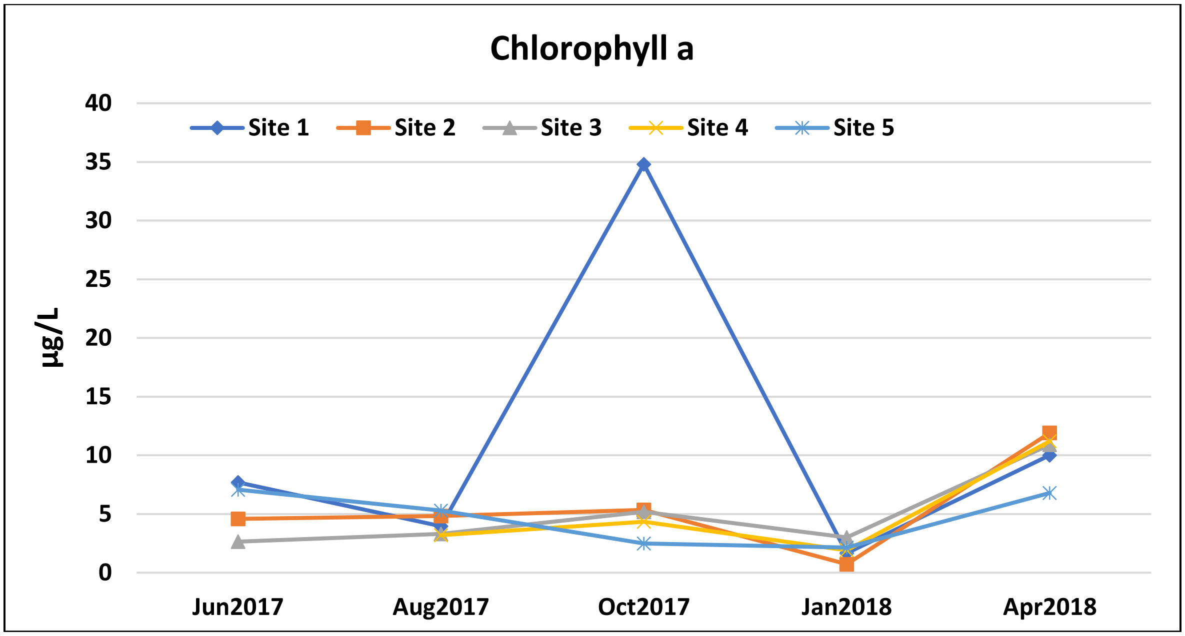

Figure 12. Chlorophyll (µg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5.

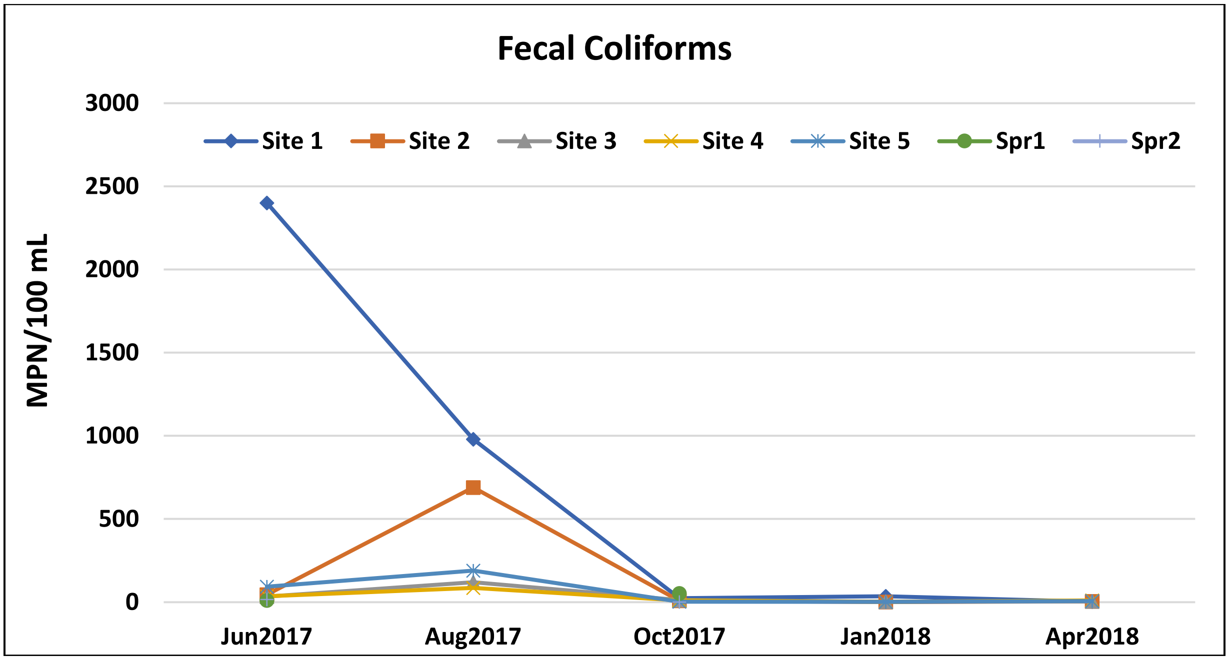

Figure 13. Fecal coliforms (MPN/100 mL) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr 1-2.

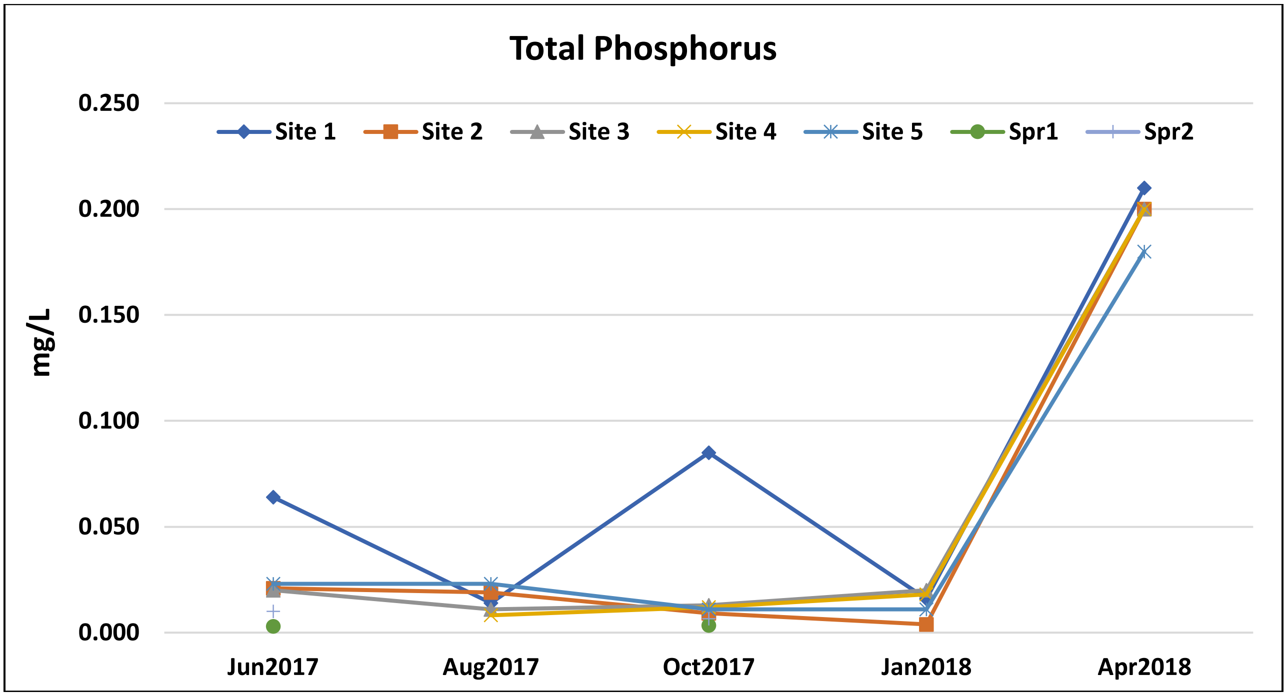

Figure 14. Total phosphorus (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr 1-2.

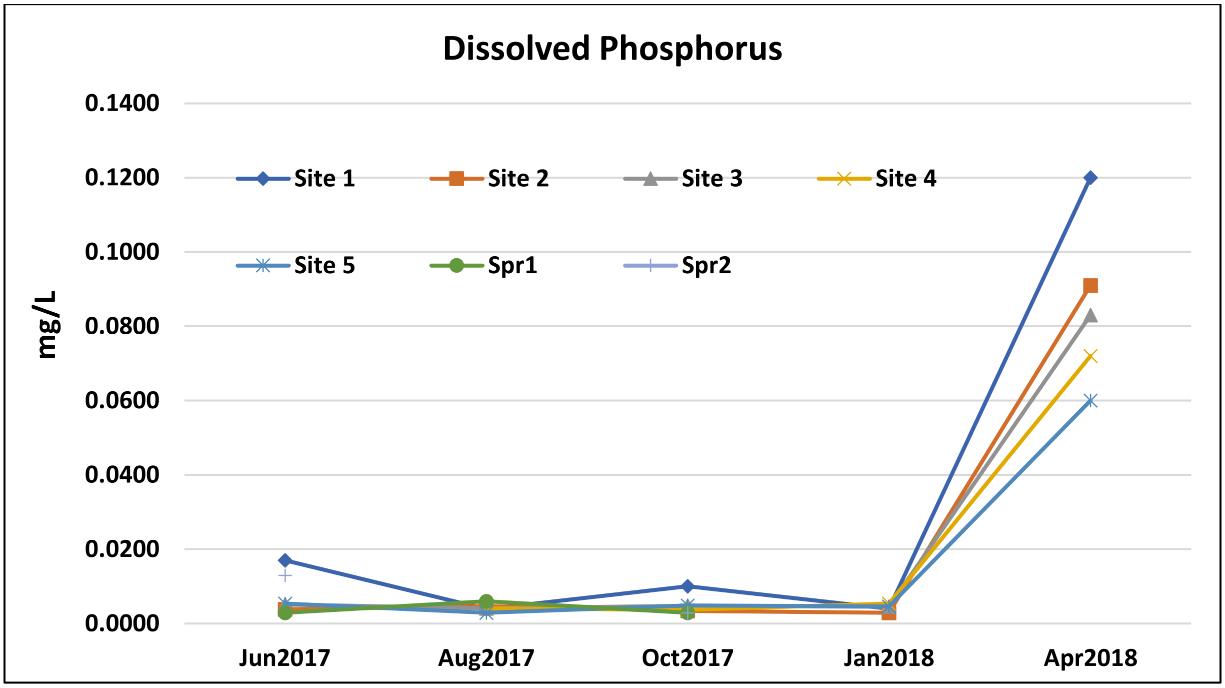

Figure 15. Dissolved phosphorus (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr 1-2.

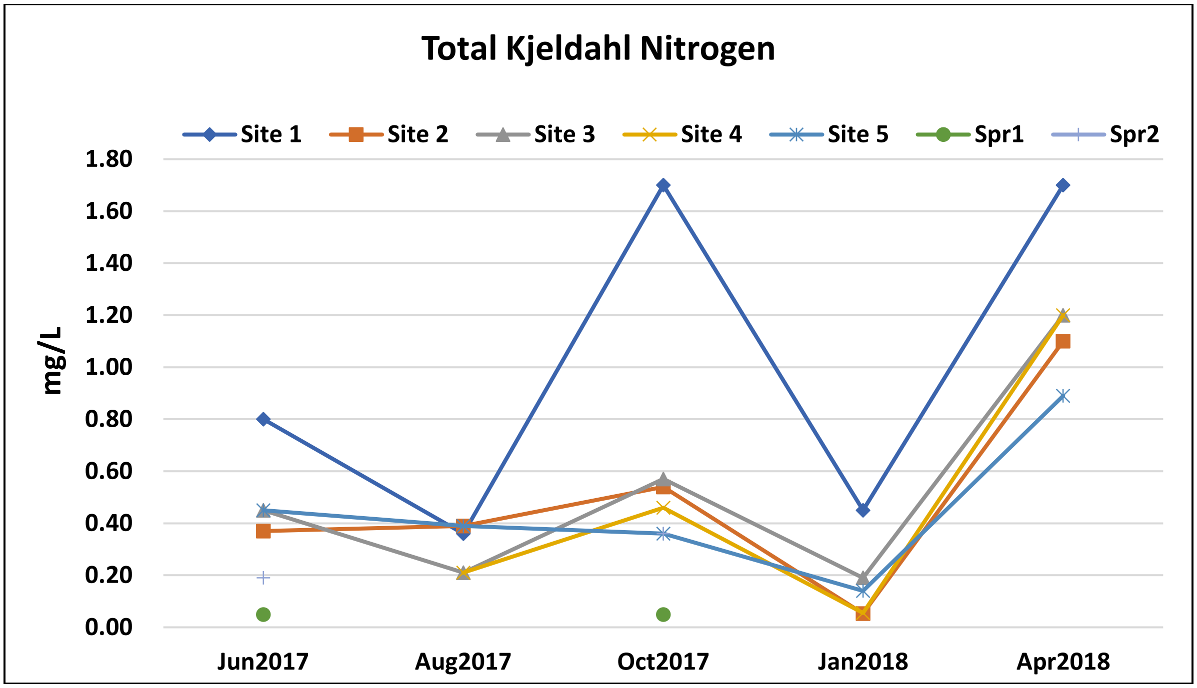

Figure 16. Total Kjeldahl nitrogen (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr 1-2.

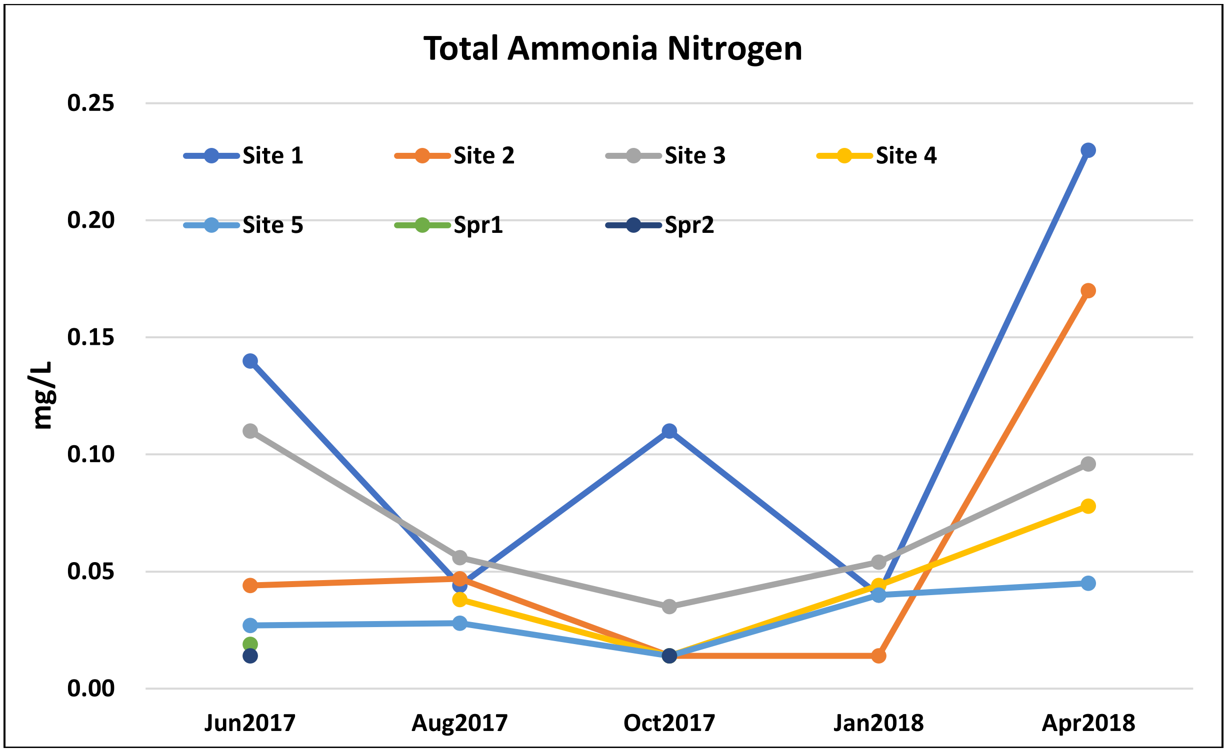

Figure 17. Total ammonia nitrogen (mg/L) in Bighill Creek in June, August, and October 2017, January and April 2018 at Sites 1-5 and Spr 1-2.

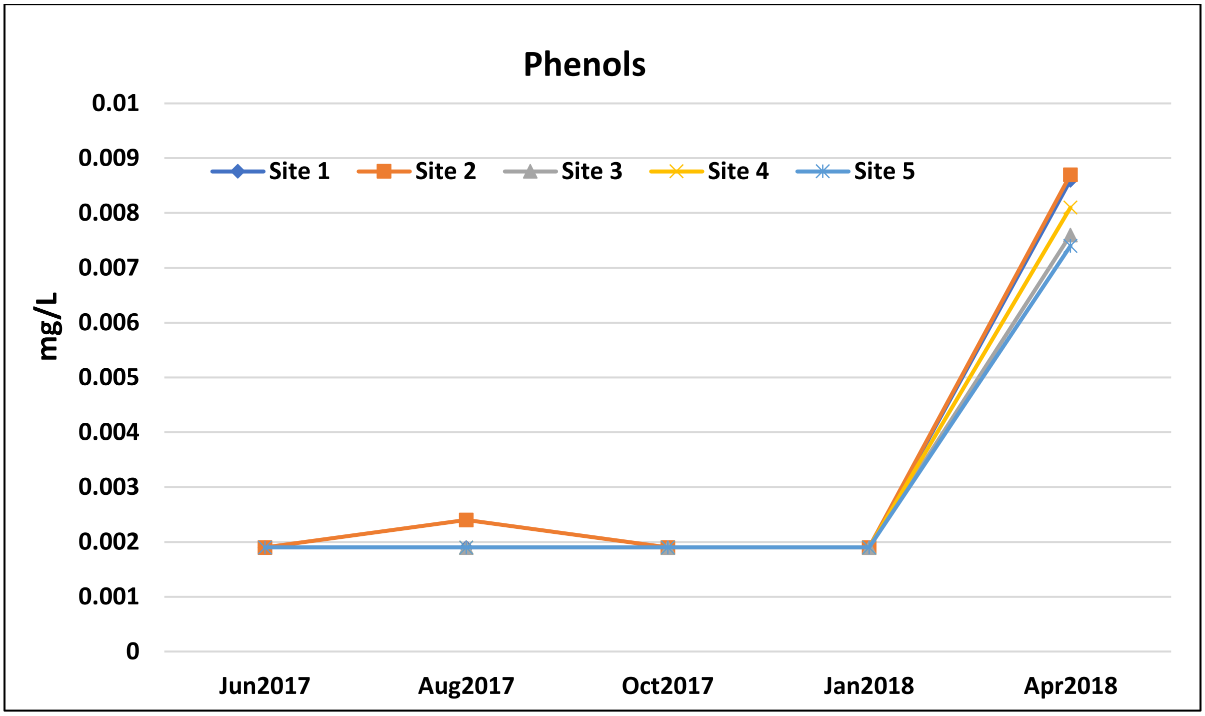

Figure 18. Phenols (mg/L) in Bighill Creek surface water in June, August, and October 2017, January and April 2018 at Sites 1-5. Detection limit was 0.002 mg/L.

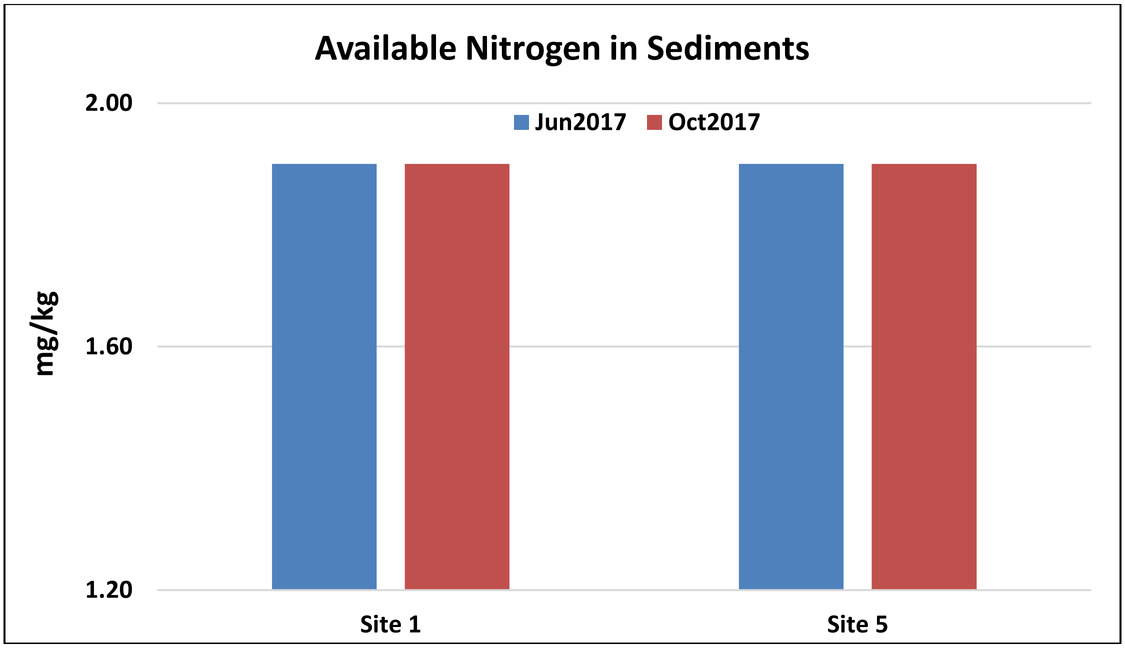

Figure 19. Available nitrogen (mg/kg) in Bighill Creek sediments in June and October 2017 at Sites 1 and 5.

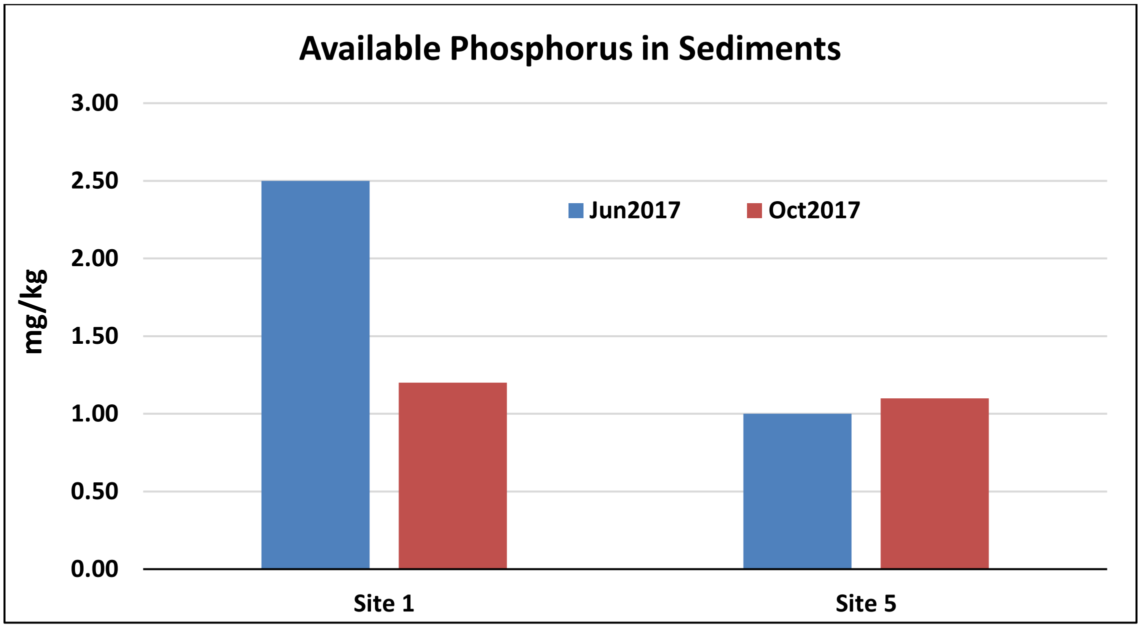

Figure 20. Available phosphorus (mg/kg) in Bighill Creek sediments in June and October 2017 at Sites 1 and 5.

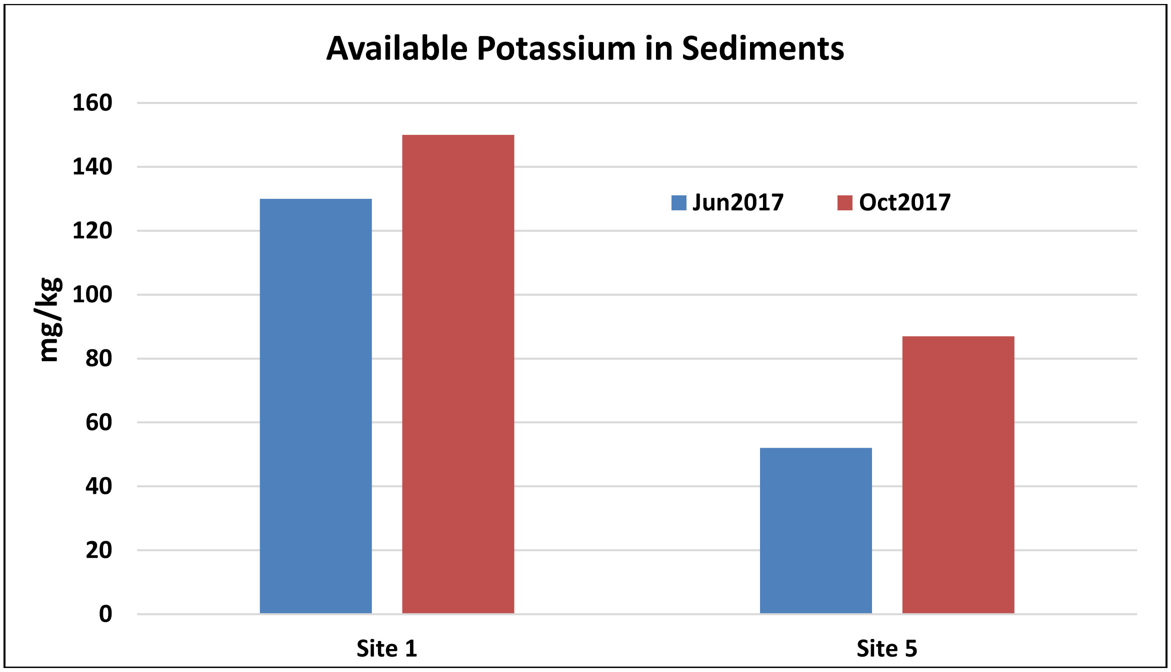

Figure 21. Available potassium (mg/kg) in Bighill Creek sediments in June and October 2017 at sites 1 and 5.

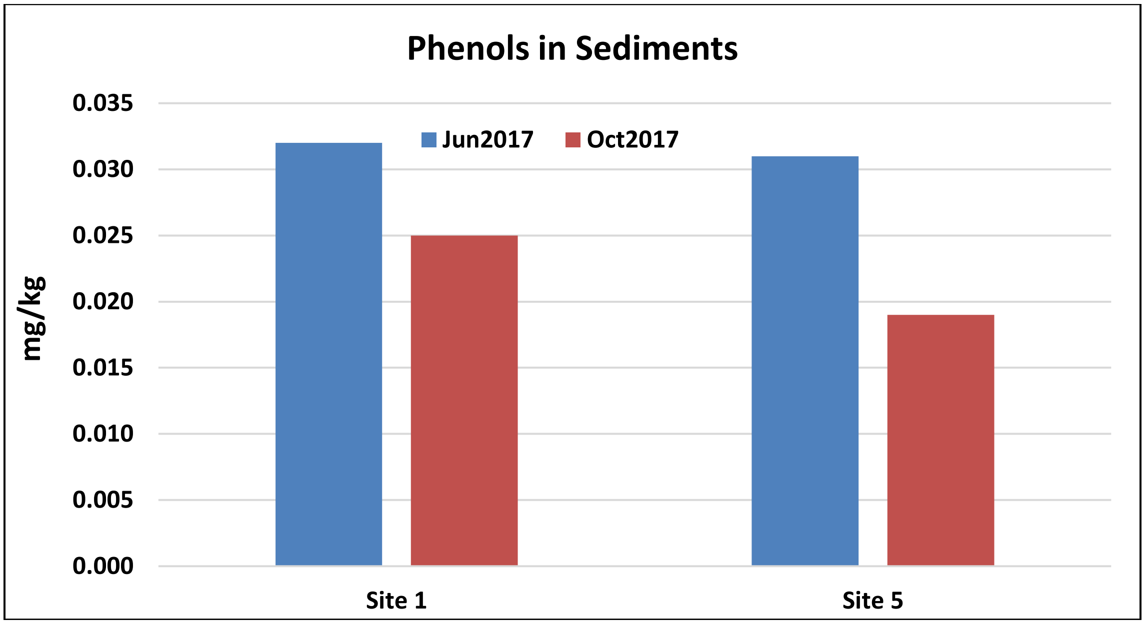

Figure 22. Phenols (mg/kg) in Bighill Creek sediments in June and October 2017 at Site 1 and Site 5.

TABLES

Table 1: Surface water and sediment sampling locations

Site #	Site Description	Substrate Sampled	GPS Coordinates (UTM - NAD 83)
Site 1	At Highway 567	Water and sediment	11U 683397mE 5683226mN
Site 2	Downstream of Bighill Springs Provincial Park	Water	11U 682754mE 5680575mN
Site 3	Access Point along the Creek	Water	11U 679479mE 5676563mN
Site 4	Off Ranche Road	Water	11U 678544mE 5676097mN
Site 5	Confluence with Bow River	Water and sediment	11U 676107mE 5672952mN
Spr1	Bighill Springs Provincial Park	Water	11U 682014mE 5681198mN
Spr2	Access Point along the Creek	Water	11U 679998mE 5677680mN

Table 2: Routine analyses of Bighill Creek surface and spring water in June, August, October 2017 and January and April 2018. (See excel sheet attached.)

Table 3: Total Metals in Bighill Creek surface and spring water in June, August, October 2017 and January and April 2018. (See excel sheet attached).

Table 4. Sediment texture in Bighill Creek in June and October 2017 at Site 1 and Site 5.

	UNITS	SITE 1		SITE 5	
		Jun	Oct	Jun	Oct
Physical Properties					
% sand by hydrometer	%	40	42	58	52
% silt by hydrometer	%	47	40	35	34
Clay Content	%	14	18	6.8	14
Texture		Loam	Loam	Sandy Loam	Loam

Table 5. Minerals in Bighill Creek sediments in June and October 2017 at Site 1 and Site 5. (See excel sheet attached).

Table 6. Total metals in Bighill Creek sediments in June and October 2017 at Site 1 and Site 5.

Table 7. Polycyclic aromatic hydrocarbons in Bighill Creek Sediments in June and October 2017 at Site 1 and Site 5. (See excel attached).