Regional District of Nanaimo Biosolids Management Program

TimberWest Properties Surface Water Quality Report 2019

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Prepared for:

Regional District of Nanaimo
6300 Hammond Bay Road
Nanaimo, BC V9T 6N2

Prepared by:

SYLVIS Environmental
427 Seventh Street
New Westminster, BC
Canada, V3M 3L2
Phone: 1.800.778.1377
Fax: 604.777.9791
www.SYLVIS.com

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LIST OF ABBREVIATIONS

General abbreviations used in this document:

BC – British Columbia
CCME – Canadian Council of Ministers of the Environment
CSR – Contaminated Sites Regulation
EC – electrical conductivity
OMRR – British Columbia Organic Matter Recycling Regulation
N – nitrogen
NO_3 – nitrate
RDN – Regional District of Nanaimo
TP – total phosphorus
VIU – Vancouver Island University
WQG – British Columbia Approved Water Quality Guidelines

Unit abbreviations used in this document:

cm – centimetre
L – litre
m – metre
mg – milligram
mL – millilitres
mm – millimetres
MPN – most probable number
µg – microgram
µS – microSiemens

EXECUTIVE SUMMARY

This report summarizes the surface water monitoring program in 2019 at privately owned forest lands located along Weigles Road in Nanaimo, BC (the TimberWest Properties), where Regional District of Nanaimo biosolids are managed in a forest fertilization program. This monitoring program is carried out as part of overall biosolids management services provided by SYLVIS Environmental. Surface water quality is monitored in order to confirm the suitability and effectiveness of application rates, setback distances, and other site management requirements in mitigating potential adverse effects on water quality from biosolids management.

Surface water samples were collected biannually in the spring and fall of 2019 from the following sampling locations at upstream and downstream locations:

- Flynfall Creek;
- Caillet Creek;
- Bonnell Creek;
- W1500 Creek; and
- Benson Creek (located outside the Biosolids Area).

Surface water samples were analyzed for a full suite of parameters including the following:

1. Nutrients (nitrogen and phosphorus);
2. Chloride;
3. Electrical conductivity;
4. Trace elements regulated by the British Columbia (BC) *Organic Matter Recycling Regulation*; and,
5. Fecal coliforms.

For higher-resolution data collection, samples collected from Caillet and Benson creeks were collected on a monthly basis and analyzed a key set parameters (highly soluble species, conductivity, and microbiological parameters) which are especially relevant to characterizing water quality.

Parameter values were compared to BC *Contaminated Sites Regulation* water quality limits and BC *Approved Water Quality Guidelines*, as well as available regional reference values.

Biosolids management practices (e.g., setback distances from surface water), site characteristics (e.g., vegetated buffers to streams), and monitoring data support the assertion that biosolids are not introduced into surface water directly or indirectly. While the concentration of some parameters (e.g., nitrate, chloride) in Biosolids Area creeks (both upstream and downstream) is elevated compared to Benson Creek, concentrations tend to decrease at downstream locations, suggesting that biosolids fertilization is not having an additive impact on these parameters along the length of these creeks. This difference between Biosolids Area creeks and Benson Creek may be due to the different nature of the creeks (i.e., intermittent versus perennial creeks).

Overall, the monitoring data suggest water quality within the Biosolids Area is reflective of expectations for an intensively fertilized coastal site and does not present a risk to aquatic life or recreational use.

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1 INTRODUCTION

Biosolids from the Regional District of Nanaimo (RDN) have been managed in a forest fertilization program at privately owned forested lands owned by TimberWest Forest Corporation (the TimberWest Properties) located along Weigles Road in Nanaimo, BC since 2003.

The *Organic Matter Recycling Regulation* (OMRR), the regulation governing biosolids management in British Columbia (BC), specifies setback distances for biosolids applications from surface water bodies and groundwater wells. These setbacks are required in order to ensure that regulated biosolids constituents (nutrients, pathogens, trace elements) are not able to travel overland or through groundwater to water bodies. The forest fertilization program meets or exceeds these setback distance requirements to surface water throughout the beneficial use site. The program goes beyond OMRR requirements for protection of water resources and conducts a surface water monitoring program in order to confirm the suitability and effectiveness of application rates, setback distances, and other site management requirements in mitigating potential adverse effects on water quality from biosolids management.

This report summarizes surface water quality sampling at the TimberWest Properties in 2019 based on sampling conducted by SYLVIS.

2 BIOSOLIDS MANAGEMENT AND WATER QUALITY

Biosolids are an organic fertilizer not unlike animal manures and thus have the potential to cause pollution of water bodies if not managed appropriately. Some biosolids constituents, such as nitrogen, are mobile and may contribute to adverse environmental impacts (e.g., eutrophication). The OMRR requires specific management techniques which are designed to protect surface and groundwater quality. These requirements are:

1. A setback distance of 30 metres (m) for biosolids applications from potable water sources, irrigation wells, lakes, rivers, and streams (OMRR Schedule 8(1)d(i));
2. A requirement to apply only when groundwater is more than 1 m below the soil surface (OMRR Schedule 8(1)b));
3. A requirement to locate biosolids storage facilities 15 m from any watercourse (OMRR Division 1, Section 18-19); and,
4. A requirement to cover stored biosolids from October 1st to March 31st in regions of the province where annual precipitation exceeds 600 millimetres (mm) (OMRR Division 1, Section 20).

In addition to these regulatory requirements, the best management practice of applying biosolids at an agronomic rate (i.e., supplying only as much nutrient as the site vegetation can take up) also reduces the risk of leaching of excess nutrients and other biosolids constituents.

3 WATER SAMPLING METHODOLOGY

Throughout 2019 SYLVIS conducted surface water sampling at the same locations as were used in previous years (Figure 1). Surface water sampling locations are presented in Table 1, Appendix One.

Samples are collected from four creeks within the Biosolids Area at upstream and downstream locations (Flynfall Creek, Caillet Creek, Bonnell Creek, and W1500 Creek), plus at a single sampling location in an adjacent watershed (Benson Creek) upstream of its confluence with Flynfall Creek. Surface water samples for full suite analysis were collected in these five creeks at nine locations in the spring and fall when water flow was sufficient for sampling. Reduced suite samples were collected from Benson Creek and Caillet Creek on a monthly basis when water flow was sufficient for sampling. A summary of parameters analyzed in full and reduced suite analyses is presented in Table 2, Appendix One.

Upstream sampling locations were initially designed to be free of potential impacts from biosolids fertilization; however, biosolids fertilization unit establishment in 2019 has nullified the "upstream" status of some of these sampling locations (e.g., Upper Flynfall). In this report, comparisons between upstream and downstream sampling locations are made based on the assumption that biosolids impacts are additive along the length of the creek, but with this caveat. In addition, unpredictable flow at the upstream locations, which for every creek are the headwaters of the creek, can result in insufficient flow and an inability to collect a sample at certain times of the year. Sampling locations will be reviewed in 2020 to confirm if upstream locations need to be relocated or classified as downstream.

Samples were collected at a higher resolution from Benson Creek and Caillet Creek (downstream). These two streams were selected for additional sampling in order to understand changes in water quality throughout the year in a drainage without biosolids fertilization (Benson Creek) and a drainage with biosolids fertilization over more than a 15-year period (Caillet Creek). Benson Creek is a perennial creek which flows throughout the year, while Caillet Creek is an intermittent creek which does not flow in the summer. Caillet Creek, as an intermittent creek, is supplied predominantly by surface water (e.g., precipitation runoff and infiltration), while Benson Creek, as a perennial creek, is supplied both by surface water (predominant in winter) and groundwater (predominant in summer). Because contributions from groundwater may be of different quality than contributions from surface water, direct comparisons between Benson Creek and biosolids Area creeks are not possible. As such, the intent is not to present Benson Creek as background quality for Caillet Creek or for other Biosolids Area creeks.

Samples were collected as grab samples in sampling bottles. A summary of sampling frequency at each location is given in Table 3, Appendix One.

4 WATER QUALITY CRITERIA

As detailed in Section 2, the OMRR contains various requirements to protect water resources and thus does not contain or make reference to any water quality criteria. In BC both regulatory criteria as well as guidelines are available for water quality interpretation. Data presented in this report are compared to criteria from the following sources:

- The BC *Contaminated Sites Regulation* (CSR); and
- The BC Approved Water Quality Guidelines (WQG).

As per section 4 of the OMRR, a biosolids application site managed according to the OMRR is not a contaminated site – a condition which holds true at the TimberWest Properties. Despite this, CSR limits are used as a reference point for surface water quality at this site, along with BC Approved WQGs which are typically lower(generally on the order of 10 times).

The BC Approved WGQs provide a basis for water quality assessments and inform decision-making in the natural resource sector. Exceeding a guideline does not imply that unacceptable risk exists, but rather that the potential for adverse effects may be increased and additional investigation may be required. WQGs are available for “chronic” water quality (i.e., criteria for longer-term averages) and for “acute” water quality (i.e., maximum criteria for single point-in-time measurements). Chronic WQGs are intended to protect the most sensitive species and are recommended to be measured though five sampling events in 30 days, while acute WQGs are intended to assess risks associated with infrequent exposure events such as spills. Chronic WQGs are always lower than acute WQGs.

The sampling frequency in this water sampling program does not meet the minimum requirements for use of chronic WQGs. As per guidance, all water quality data must nonetheless meet long-term chronic WQGs, with exceedances of chronic WQGs indicating the need to increase sampling frequency to meet averaging requirements (BC Ministry of Environment and Climate Change Strategy, 2016).

In addition to WGGs and CSR limits, several reference values for ambient surface water quality are presented in tables and figures in this report. These additional criteria are presented to aid with data analysis, as WQGs and CSR limits are not available for all parameters of interest (e.g., Electrical Conductivity). These additional criteria are also presented for select parameters (e.g., nitrates) for which additional references are required in order to adequately assess potential water quality impacts, as an impacted waterway does not always exceed criteria.

5 WATER QUALITY PARAMETERS

Parameters monitored in this program help to determine potential impacts of biosolids fertilization on surface water. Parameters include soluble nutrients, other soluble species linked to anthropogenic influence, microbiology associated with biosolids, and trace elements regulated in biosolids under the OMRR.

5.1 Nitrogen

Forms of nitrogen in surface water are typical indicator analytes used to assess surface water impacts following fertilization from chemical fertilizers, animal manures, or biosolids. Nitrate is an oxidized form of nitrogen which is water soluble and, along with ammonia, is the form in which nitrogen is taken up by plants and microbes. As a mobile (water-soluble) constituent, it is also a potential indicator of excess nutrient at fertilization sites. Nitrate runoff from agricultural land is a long-standing issue which has generated a requirement for nutrient management planning at these sites; SYLVIS's planning approach represents a nutrient management plan for biosolids management.

Recommended ambient surface water concentrations vary according to the reference. For nitrate, the chronic WQG for protection of aquatic life is 3 milligrams per litre (mg/L) nitrate-nitrogen (NO_3-N) (BC Ministry of Environment, 2009), but references for ambient concentration values of 0.3 mg/L NO_3-N (BC Ministry of Environment, 1998), 1 mg/L NO_3-N (BC Ministry of Environment, 1986), and 2 mg/L NO_3-N (Vancouver Island Health Authority, personal communication, February 15, 2018) have been suggested. Increases in surface water nitrate concentrations are expected to occur following fertilization activities in forests. Binkley (1999) summarizes studies on surface water nitrate concentrations following forest fertilization with chemical fertilizer on Vancouver Island with nitrate concentrations ranging between 0.1 and 9.3 mg/L NO_3-N. This study references 4 mg/L NO_3-N as an upper limit for annual average nitrate concentration in surface water at fertilized forest sites. These reference values are presented alongside water quality data in Appendix One.

5.2 Phosphorus

Phosphorus, along with nitrogen, is often implicated in water quality issues such as eutrophication. Phosphorus is a plant macronutrient which comprises ~2.5% of biosolids by dry weight. It sorbs strongly to soil particles, is relatively insoluble, and is not as mobile as nitrate. It typically moves into waterways attached to soil as part of an erosion event.

Due to the fact that phosphorus itself is non-toxic to aquatic organisms (i.e., rather, its side-effects such as eutrophication are harmful) and that aquatic ecosystems can adapt to different ambient phosphorus concentrations (Canadian Council of Ministers of the Environment, 2004), there is no "one-size-fits-all" phosphorus WQG for surface water, nor is there a CSR limit. There is no WQG for streams but there is for protection of aquatic life in lakes which recommends a limit of 0.005 – 0.015 mg/L total phosphorus (TP) (BC Ministry of Environment, 2001). A BC Ministry of Environment and Climate Change Strategy publication sets water quality objectives for the protection of Vancouver Island streams of 0.005 mg/L TP (average) and 0.010 mg/L TP (maximum) (BC Ministry of Environment, 2014), although this applies only to samples collected monthly between May and September. The WQG for lakes is presented alongside water quality data in Appendix One.

5.3 Electrical Conductivity

Electrical conductivity (EC) in biosolids is typically much higher than in natural soils or water. Movement of biosolids constituents which contribute to EC into surface water bodies could potentially be indicated by increases in surface water EC. There is no limit or guideline for EC but the ambient coastal stream reference value is < 100 microSiemens per centimetre (µS/cm) (BC Ministry of Environment, 1998). This reference value for EC is presented alongside water quality data in Appendix One.

5.4 Chloride

The chloride ion is highly mobile and concentrations in water are not affected by chemical reactions; chloride does not biodegrade, readily precipitate, adsorb readily onto mineral surfaces, volatilize, or bio-accumulate, making it a good indicator of anthropogenic influence. The Canadian Council of Ministers of the Environment (CCME), in the development of its water quality guidelines, identified that ambient chloride concentrations in un-impacted water bodies in the Pacific Region are < 5 mg/L, with potentially higher values in water bodies located close to the ocean (CCME, 2011). The chronic WQG for protection of aquatic life (150 mg/L) is well above this reference value. This reference value is presented alongside water quality data in Appendix One.

5.5 OMRR-Regulated Trace Elements

The mobility of most OMRR-regulated trace elements is highly dependent on soil pH, or may occur through biosolids movement into water. The pH of TimberWest Properties soils (pH 5 – 5.5), while low, does not represent an elevated potential for movement for most of these trace elements due to their tendency to become more soluble at pH < 5. As such, trace-element impact on surface water would be considered as a potential sign of biosolids runoff as opposed to trace element leaching from the soils. CSR limits or WQGs exist for all OMRR-regulated trace elements.

5.6 Fecal coliforms

Although biosolids are treated to reduce pathogen levels, they are not sterilized. Fecal coliform bacteria, which are used as an indicator for the potential presence of pathogenic microbiology in biosolids as well as in water, can be used to determine potential biosolids ingress into water bodies. Fecal coliforms in water bodies can also originate from wildlife.

For microbiological parameters, WQGs exist for the protection of drinking water and recreational use but not for protection of freshwater aquatic life. As there are no known drinking water systems downstream from the TimberWest Properties, and because recreational activities (e.g., mountain biking, hiking) do occur on the property, the recreational use WQGs are used for microbiological parameters.

6 RESULTS AND DISCUSSION

Data are presented for two separate sampling initiatives in 2019: full suite monitoring at five sampling locations in spring and winter (Section 6.1) and monthly reduced suite monitoring of parameters of interest at two sampling locations (Section 6.2). Data tables, along with relevant guidelines, limits, and reference values, can be found in Table 4 through Table 9, Appendix One. Data is presented graphically in Figure 2 through Figure 9, Appendix Two.

6.1 Full Suite Monitoring

Full suite monitoring was carried out at upstream and downstream sampling locations at four sites within the TimberWest Properties and at another site in May and November of 2019. Data for these parameters is presented in Table 4 through Table 8, and data is presented graphically in Figure 6 through Figure 9, Appendix Two.

6.1.1 Benson Creek

Benson Creek flows north along the eastern edge of the TimberWest Properties. Benson Creek is monitored to provide a local reference value for water quality. As such, samples are only collected at a single location upstream of the confluence with Flynfall Creek. Biosolids fertilization does not occur upstream from the sampling location, although some logging activity does. Benson Creek is a perennial creek with a flow that exceeds by multiple orders of magnitude the flow of creeks monitored within the Biosolids Area.

Benson Creek was initially included in the monitoring program to serve as a comparative water course without biosolids applications. As detailed in section 3, Benson Creek, as a perennial creek, cannot be compared to Biosolids Area creeks due to its different hydrology, and water quality in Benson Creek should not be interpreted as the water quality which would be observable at the TimberWest Properties absent the biosolids program.

Benson Creek and its sampling point are depicted in Figure 1, Appendix Two, and Photograph 1, Appendix Three. All water quality data for Benson Creek were below CSR limits, WQGs, and reference values. Nitrogen forms, phosphorus forms, and chloride were well below guidelines and in some cases below analytical detection limits. All analytical data for Benson Creek are presented in Table 4, Appendix One.

6.1.2 Flynfall Creek

Flynfall Creek is a major drainage at the TimberWest Properties. The creek originates from an area of high elevation which serves as the headwaters to Flynfall and Bonnell Creeks and generally flows eastward roughly parallel to Weigles Road. Upstream samples were taken at the outflow of the headwaters and downstream samples were taken at a bridge crossing over the creek outside the property boundary and roughly due south of the MotoCross track. Flynfall Creek flows into Benson Creek before draining into Brannen Lake. No surface water diversion permits are in effect along Flynfall or Benson Creeks. Flynfall Creek and its sampling points are depicted in Figure 1, Appendix Two, and Photograph 2 and Photograph 3, Appendix Three.

All water quality data for Flynfall Creek were below CSR limits. All data were below WQGs with the following exceptions.

- pH at the Upper Flynfall sampling location in winter 2019 was 6.4 (guideline range is 6.5 – 9.0). Surface water in this pH range is common on Vancouver Island in forest environments due to high precipitation and the acidic nature of forest soils and the use of biosolids at this site is not considered to be a factor for this finding. While the WQG for pH recommends 6.5 – 9.0 as a range over which unrestricted change in pH is permitted without risking harm to aquatic freshwater life, it also recognizes that many areas of Coastal BC have naturally occurring pH below this range.

Nitrate, total phosphorus, EC, and chloride were below the range of reference values. For these and other parameters of interest (fecal coliforms), no downstream values in winter 2019 (the upstream location was dry in the spring) were higher than upstream values. An increase in nutrients in downstream samples when compared to upstream samples can be an indication of nutrient runoff from the Biosolids Area. The data suggests no adverse impact on water quality from biosolids applications within the Flynfall Creek drainage.

All analytical data for Flynfall Creek are presented in Table 5, Appendix One.

6.1.3 Caillet Creek

Caillet Creek drains the northern portion of the TimberWest Properties. The creek originates from roughly the center of the northern third of the TimberWest Properties and generally flows eastward parallel to Weigles Road. Upstream samples were taken at the location of suitable flow nearest to the headwaters and downstream samples were taken downstream of the entire biosolids application area. Caillet Creek flows into Brannen Lake. No surface water diversion permits are in effect along the length of the creek. Caillet Creek and its sampling points are depicted in Figure 1, Appendix Two, and Photograph 4 and Photograph 5, Appendix Three.

All water quality data for Caillet Creek were below CSR limits, WQGs, and reference value ranges.

For parameters of interest (nitrogen, phosphorus, chloride, EC, OMRR trace elements, and fecal coliforms), no downstream values in winter 2019 (both upstream and downstream sampling locations were dry in the spring) were meaningfully higher than upstream values. The data suggests no adverse impact on water quality from biosolids applications within the Caillet Creek drainage.

All analytical data for Caillet Creek are presented in Table 6, Appendix One.

6.1.4 Bonnell Creek

Bonnell Creek drains a small portion of the TimberWest Properties to the west. The creek originates from an area of high elevation which serves as the headwaters to Bonnell and Flynfall Creeks and generally flows westward out of the TimberWest Properties. Upstream samples were taken at the outflow of the headwaters and downstream samples were taken before the next tributary flows into the creek. Bonnell Creek flows off the TimberWest Properties and then turns north, eventually draining into Nanoose Bay; no known surface water diversion permits are in effect along the creek. Bonnell Creek and its sampling points are depicted in Figure 1, Appendix Two, and Photograph 6 and Photograph 7, Appendix Three.

This sampling location (upstream and downstream) was dry during the spring 2019 sampling event. All winter 2019 water quality data for Bonnell Creek were below CSR limits. All data were below WQGs with several exceptions.

- Total aluminum upstream (290 µg/L) and downstream (230 µg/L) was approximately 6 times higher than the chronic guideline (41 µg/L) and was higher than the acute guideline (~50-100 µg/L) as well. This parameter has been high in upstream samples in this creek since 2013 which indicates elevated background concentrations.

- Total copper at the upstream sampling location was at the WQG; however, this WQG has been discontinued in favour of a WQG for dissolved copper, which was not measured in 2019. In the future, dissolved copper will be measured in surface water and compared to the new WQG.
- Total mercury at the upstream sampling location (0.02 µg/L) was also at the WQG, the highest measurement recorded in this creek since 2013. Total mercury has been 0.01 µg/L or lower prior to 2019.
- Total silver value at both sampling locations was reported as below the analytical detection limit, which is also the WQG.
- Total zinc at both the upstream and downstream sampling location was above the WQG, which indicates elevated background concentrations.
- Water pH at the upstream location was below the WQG range, but surface water in this pH range is common on Vancouver Island in forest environments due to high precipitation and the acidic nature of forest soils.

Nitrate was below the WQG and the reference value range. Total phosphorus was above the reference value at both upstream and downstream sampling locations, suggesting high background levels. EC and chloride were below CSR limits, WGQs, and reference values. For these parameters of interest and fecal coliforms, no downstream values in winter 2019 (the creek was dry in the spring) were meaningfully higher than upstream values. These data suggests that there is no negative effect on water quality from biosolids applications within the Bonnell Creek drainage. Several parameters were noted as elevated in this creek, however there is no indication that downstream samples were of lesser quality than upstream samples.

All analytical data for Bonnell Creek are presented in Table 7, Appendix One.

6.1.5 W1500 Creek

W1500 Creek drains a small portion of the TimberWest Properties to the north of the Caillet drainage. The creek generally flows eastward out of the TimberWest Properties. Upstream samples were taken at the nearest location of suitable flow to the headwaters and downstream samples were taken before the next tributary flows into the creek. There are no known surface water diversion permits in effect along this portion of the creek. W1500 Creek and its sampling points are depicted in Figure 1, Appendix Two, and Photograph 8 and Photograph 9, Appendix Three.

The upstream sampling location was dry during the spring 2019 sampling event. All winter 2019 water quality data for W1500 Creek were below CSR limits. Most data were below WQGs with several exceptions.

- Nitrate at both upstream and downstream locations in winter 2019 was above the WQG, suggesting a high background concentration.
- In winter total aluminum exceeded its WQG, although it did not in the spring. This parameter has been high in this creek during past sampling events.

- Total copper at the downstream sampling location in winter was at the WQG; however, this WQG has been discontinued in favour of a WQG for dissolved copper, which was not measured in 2019 but will be in the future.
- Total zinc at the downstream sampling location in winter was above the WQG.
- Water pH in 2019 samples was on occasion below the WQG range, but surface water in this pH range is common on Vancouver Island in forest environments due to high precipitation and the acidic nature of forest soils.

For these parameters of interest and fecal coliforms, no downstream values in winter 2019 (the upstream location was dry in the spring) were meaningfully higher than upstream values, with the exception of zinc. The winter sample indicated a value of 15.0 µg/L downstream, whereas the WQG was calculated at 7.5 µg/L. The concentration measured is similar to the upstream value measured in Bonnel Creek on the same date (17.0 µg/L), and as such not an unusual background value. This increase in itself does not represent an indication of biosolids runoff, as several other mobile parameters would show an increase in the case of such an event.

Nitrate levels in the upstream and downstream samples exceeded the chronic WQG in the November sample, with no significant increase between the upstream and downstream samples. No exceedance of the WGQ was noted in the downstream spring sample (no upstream sample collected). Because there was no significant increase in the November downstream sample, it can be assumed that high levels of nitrates were present in this creek in November due to circumstances unrelated to biosolids fertilization. These samples did not exceed the acute WQG of 32.8 mg/L.

These data suggests that there is no negative effect on water quality from biosolids applications within the W1500 Creek drainage. Although several parameters were noted as elevated in this creek, there is no indication that downstream samples were of lesser quality than upstream samples.

All analytical data for W1500 Creek are presented in Table 8, Appendix One.

6.2 Monthly Monitoring

Parameters of interest (nitrate, total phosphorus, chloride, EC, *E. Coli* and fecal coliforms) were measured monthly in Benson Creek and Caillet Creek (downstream) on the TimberWest Properties. The Caillet Creek drainage hosts numerous historical and current biosolids fertilization sites. All monthly data for these parameters is presented in Table 9, and data is presented graphically in Figure 2 through Figure 5, Appendix Two.

Benson Creek was initially included in the monitoring program to serve as a comparative watershed without biosolids applications. However, as detailed in Section 3, it is not advisable to compare water quality in these two creeks as Benson Creek is a higher-volume perennial creek which flows throughout the year, while Caillet Creek is a lower volume intermittent creek which does not flow in the summer. Due to lack of flow in Caillet Creek from July - September, there are no sample pairs for comparison during this period.

6.2.1 Nitrate

Monthly monitoring of Benson and Caillet Creeks revealed that nitrate concentrations were on average 30 times lower in Benson Creek (Figure 2, Appendix Two). Benson Creek nitrate concentrations were similar to regional reference values for background surface water nitrate (BC Ministry of Environment, 1986, 1998). Benson Creek nitrate concentrations were below the chronic WQG (3 mg/L) as well as below the regional reference value for fertilized forest sites (4 mg/L) (Binkley et al., 1999).

Nitrate levels in Caillet Creek remain below the chronic WQG but are indicative and expected of a fertilized forest site. Historically, biosolids have been managed in this drainage for at least fifteen years. Currently, biosolids are land-applied on an annual basis at the TimberWest Properties, and so there is a constant supply of organic nitrogen which persists throughout the non-growing season while continuing to release some amount of soluble nitrogen.

6.2.2 Phosphorus

Phosphorus in Caillet Creek was consistently lower than in Benson Creek (Figure 3, Appendix Two). Values in both creeks fall below the WQG of 0.015 mg/L for lakes (BC Ministry of Environment, 2001) as well as the regional objective for stream protection of 0.010 mg/L (BC Ministry of Environment, 2014).

6.2.3 Electrical Conductivity

EC was higher throughout the year in Caillet Creek compared to Benson Creek (Figure 4, Appendix Two), though all measured values were below the ambient coastal stream reference value of 100 µS/cm (BC Ministry of Environment, 1998).

6.2.4 Chloride

Chloride was marginally higher in Caillet Creek compared to Benson Creek (Figure 5, Appendix Two). All measured values were below the chronic WQG of 150 mg/L and the CCME reference value of 5 mg/L for un-impacted water bodies.

7 DISCUSSION SUMMARY

Biosolids can have effects on surface water quality through one of the following:

- Introduction of biosolids into surface water;
- Movement of biosolids into surface water; or
- Movement of soluble biosolids constituents into surface water.

Biosolids are never applied into standing water and setback distances from surface water features are employed; nor has there been any accidental introduction of biosolids into water bodies at this site. Therefore, there has been no introduction of biosolids into surface water. The movement of soluble biosolids constituents into surface water can be assessed through the monitoring of surface water quality on site, as completed through this monitoring program. Several parameters would need to exhibit an increase in concentration from upstream to downstream locations in order to determine an impact on surface water from biosolids fertilization activities. Our monitoring program did not find such an impact, as described below.

While biosolids are surface-applied and are commonly exposed to precipitation after being land-applied, the land is vegetated (moss, salal, etc.) and overland flow is constrained by this vegetation. While 30 m is the minimum setback distance from surface water, most fertilization occurs at greater setback distances. As such, the physical movement of biosolids into surface water is very unlikely. Biosolids microbiological constituents (*E. coli* and fecal coliforms) are largely filtered by the soil matrix and thus would be more likely to be introduced to surface water via overland flow. Microbiological constituents in surface water in 2019 were generally low and did not exceed the WQG for recreational use.

The intermittent creeks at the TimberWest Properties are supplied exclusively by surface runoff and infiltration throughout the rainy portions of the year. As such, any soluble and mobile biosolids constituents may be introduced into surface water if their movement is not constrained in some way by soil and vegetation. Biosolids trace element movement is unlikely given the soil and water pH, and data from surface water monitoring in 2019 support this: there are only 3 exceedances of chronic WQGs of trace elements associated with biosolids (e.g., total zinc in Bonnell and W1500 Creeks), and the data suggest that in Bonnell Creek this may be a background concentration. Phosphorus is higher in Benson Creek than in any creek within the TimberWest Properties with the exception of Bonnell Creek in November (Figure 3 and Figure 6, Appendix Two). EC (Figure 4 and Figure 7, Appendix Two) is consistently higher in biosolids area creeks than in Benson Creek, but is below the reference value of 100 µS/cm with the exception of Bonnell Creek in November. Chloride (Figure 5 and Figure 8, Appendix Two) is consistently higher in biosolids area creeks than in Benson Creek, but is below chronic WQG and the reference value of 5 mg/L.

Benson Creek is not a true control sample location due to different stream hydrological characteristics (i.e., perennial versus intermittent flow). With this caveat in mind, it is observed that nitrate is significantly higher in Biosolids Area creeks than in Benson Creek (Table 9, Appendix One and Figure 2 and Figure 9, Appendix Two). Nitrate values in Biosolids Area creeks, including the maximum nitrate measurement of 4.6 mg/L, are within the expected range of fertilized forest sites on Vancouver Island (Binkley et al., 1999) and are generally below the chronic WQG of 3 mg/L. As a highly mobile constituent, nitrate is expected to be higher at fertilized sites. However, it is important to note that for every pair of upstream/downstream values reported in 2019, nitrate is lower at downstream locations. As it is expected that biosolids impacts are additive along the length of a creek, it is unclear what the conflicting signals of elevated nitrate and lower downstream concentrations are indicating. In previous years, downstream samples have indicated higher nitrate downstream (e.g., Caillet and W1500 creeks).

Overall, water quality at the TimberWest Property is well below CSR limits and meets water quality standards for the protection of aquatic life in BC. While in previous years in some creeks nitrate was elevated in comparison with Benson Creek as well as increasing downstream, in 2019 nitrate concentrations decreased in downstream samples. Water quality on site is reflective of expectations for an intensively fertilized coastal site and does not present a risk to aquatic life or recreational use.

8 DATA QUALITY CONTROL

The collected samples were analyzed by accredited third party laboratories. All sample containers used to collect the sample were supplied by the laboratory that conducting the analysis. The accredited laboratories use appropriate test method validation, traceable calibrations, apply quality control samples, and conduct statistical techniques to monitor performance and the ability to identify non-conformance.

Analysis of relative percent difference (RPD) was performed on a pair of duplicate samples from Caillet Creek in November 2019. RPD values were not able to be calculated for most parameters of interest (RPD should not be calculated where one value is less than five times the laboratory detection limit) (BC Ministry of Environment and Climate Change Strategy, 2013). All available RPD values were below 20% with the exception of total iron (27%). RPD values > 50% indicate a potential problem with the sampling approach. These results suggest that the current approach to collecting grab samples from the same location is appropriate and can continue to be used in the future.

9 OTHER REPORTS

Assessments of potential effects of biosolids on groundwater quality have been made twice in the past, in 2003 and 2012 (Dakin, 2003; Cleary and Tiplady, 2012). Both reports concluded that application of biosolids had low potential for impact on groundwater wells located in the vicinity of the TimberWest Properties.

In 2014, SYLVIS completed an enhanced surface water quality monitoring project in response to a concern from a property owner directly east (downhill) from the TimberWest Properties. Water quality in Caillet Creek and in a ditch on the neighboring property were sampled over a five-month period to investigate whether there were any effects from biosolids stockpiles and applications. Similar to results presented in this report, all parameters investigated (nutrients, chloride, caffeine) were below relevant guidelines while some parameters (nitrate, chloride) showed small increases in downstream samples when compared to upstream (SYLVIS Environmental, 2014).

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APPENDIX ONE – TABLES

Table 1: Surface water sampling locations at the TimberWest Properties.

Creek	Location	Coordinates	In Biosolids Area
Flynfall Creek	Upstream	49°11'50.24"N, 124° 7'8.61"W	Yes
	Downstream	49°11'30.86"N, 124° 6'13.96"W	Yes
Caillet Creek	Upstream	49°12'25.57"N, 124° 6'27.87"W	Yes
	Downstream	49°12'23.80"N, 124° 5'22.96"W	Yes
Bonnell Creek	Upstream	49°11'54.26"N, 124° 7'40.79"W	Yes
	Downstream	49°11'57.46"N, 124° 7'51.20"W	Yes
W1500 Creek	Upstream	49°12'22.78"N, 124° 7'13.78"W	Yes
	Downstream	49°12'39.87"N, 124° 6'34.74"W	Yes
Benson Creek	Upstream	49°11'15.34"N, 124° 4'47.58"W	No

Table 2: Parameters analysed in full and reduced suite analysis.

Parameter Group	Full Suite	Reduced Suite	Rationale
Inorganic Non-metallic Parameters			
Total Kjeldahl Nitrogen	✓		General water quality
Carbon - total organic	✓		General water quality
Nitrogen - ammonium-N	✓		General water quality
Nitrogen – nitrate + nitrite-N	✓	✓	Most mobile N form
Phosphorus - orthophosphate	✓		General water quality
Phosphorus - total	✓	✓	Form for which local reference value exists
Phosphorus - dissolved	✓		General water quality
Trace Elements			
BCCSR - Metals (Total)	✓		General water quality
Microbiological Analysis			
Total and E. Coli	✓	✓	Highly variable parameter
Fecal Coliforms	✓	✓	Highly variable parameter
Routine Water			
Electrical Conductivity	✓	✓	Represents many soluble parameters
Chloride	✓	✓	Highly soluble parameter
Acidity			
pH	✓	✓	Important variable - measured in field

Table 3: Frequency of sampling at TimberWest Properties surface water sampling points, 2019.

Location	2019											
	January	February	March	April	May	June	July	August	September	October	November	December
	Monthly reduced suite				Semi-annual full suite	Monthly reduced suite					Semi-annual full suite	Monthly reduced suite
Caillet Creek Upper					dry						✓	
Caillet Creek Lower	✓	✓	✓	✓	✓	dry	dry	dry	dry	✓	✓	✓
Flynfall Creek Upper					dry						✓	
Flynfall Creek Lower					✓					✓	✓	
Bonnell Creek Upper					dry						✓	
Bonnell Creek Lower					dry						✓	
W1500 Creek Upper					dry						✓	
W1500 Creek Lower					✓						✓	
Benson Creek	✓	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	✓

Table 4: Surface water quality data from Benson Creek, 2019.

Date	Units	29-May-19	18-Nov-19	Water Quality Guidelines[a]	CSR Limits[b]	Other Reference Criteria
Sample Location		**Benson Creek**	**Benson Creek**			
Inorganic Non-metallic Parameters						
Total Kjeldahl Nitrogen	mg/L	0.20	0.24	-	-	
Total Organic Carbon	mg/L	2.0	6.2	-	-	
Ammonia + Ammonium - N	mg/L	< 0.01 (1.8)	< 0.01 (1.9)	calculated[c]	18.4	
Nitrate - N	mg/L	0.1	0.1	3	40[d]	0.3 – 2[e]
Nitrite - N	mg/L	< 0.003 (0.02)	< 0.003 (0.02)	calculated[c]	0.2	
Orthophosphate-P (dissolved)	mg/L	< 0.002	0.008	-	-	
Phosphorus (total dissolved)	mg/L	< 0.003	< 0.003	-	-	
Phosphorus (total)	mg/L	0.006	0.006	-	-	0.015[f]
Trace Elements Total						
Aluminum Al - total	µg/L	21 (385)	91 (385)	calculated[c]	-	
Arsenic As - total	µg/L	0.10	< 0.1	NS[g]	50	
Cadmium Cd - total	µg/L	< 0.01	< 0.01	-	-	
Chromium Cr - total	µg/L	0.1	0.2	NS	10	
Cobalt Co - total	µg/L	< 0.02	0.15	4	40	
Copper Cu - total	µg/L	0.7 (2.0)	0.9 (2.0)	calculated[c]	20	
Iron Fe - total	µg/L	6	39	NS	NS	
Lead Pb - total	µg/L	0.01 (3.6)	0.01 (3.5)	calculated[c]	40	
Manganese Mn - total	µg/L	< 1 (671)	1 (650)	calculated[c]	NS	
Mercury Hg - total	µg/L	< 0.01	< 0.01	0.02	0.25	
Molybdenum Mo - total	µg/L	0.04	< 0.02	1,000	10,000	
Nickel Ni - total	µg/L	< 0.2	< 0.2	NS	250	
Selenium Se - total	µg/L	< 0.2	< 0.2	2	20	
Silver Ag - total	µg/L	< 0.01 (0.05)	< 0.01 (0.05)	calculated[c]	0.5	
Zinc Zn - total	µg/L	0.9 (7.5)	3.0 (7.5)	calculated[c]	75	
Routine Water						
pH - field	pH units	7.1	7.0	6.5 - 9.0	-	
Electrical Conductivity	µS/cm at 25° C	42	29	-	-	100[h]
Chloride (dissolved)	mg/L	1.00	1.47	150	1,500	5[i]
Hardness (total)	mg $CaCO_3$/L	15	10	-	-	
Microbiological Analysis						
Escherichia coli	MPN/100 ml	< 1.0	2	77[j]	-	
Fecal Coliforms	MPN/100 ml	3	3	200[j]	-	

Note: Exceedances of guidelines are shown in bold type. Exceedances of regulatory limits shown in bold red type.
Note: NS = "no standard available".
a - Unless otherwise noted, these are chronic (30-day) WQG for total species for protection of freshwater aquatic life.
b - CSR limits for protection of freshwater aquatic life, Schedule 3.2. Criteria include static and calculated limits.
c - Calculated guidelines are shown in brackets next to individual parameter values.
d - CSR limit represents a 10:1 dilution from original value of 400 mg/L as per CSR guidance.
e - As per BC Ministry of Environment (1998), BC Ministry of Environment (1986), Vancouver Island Health Authority, personal communication (February 15, 2018), and Binkley (1999).
f - BC Approved Water Quality Guideline for protection of freshwater aquatic life in lakes.
g - No standard exists for this protection factor for this parameter.
h - As per Canadian Council of the Ministers of Environment, 2011.
i - As per BC Ministry of Environment, 1998.
j - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 5: Surface water quality data from Flynfall Creek, 2019.

Date	Units	29-May-19	29-May-19	18-Nov-19	18-Nov-19	Water Quality Guidelines[a]	CSR Limits[b]	Other Reference Criteria
Sample Location		Upper Flynfall	Lower Flynfall	Upper Flynfall	Lower Flynfall			
Inorganic Non-metallic Parameters								
Total Kjeldahl Nitrogen	mg/L	-	0.10	0.28	0.09	-	-	
Total Organic Carbon	mg/L	-	0.8	4.2	2.3	-	-	
Ammonia + Ammonium - N	mg/L	-	< 0.01 (1.8)	0.01 (1.9)	< 0.01 (1.9)	calculated[c]	18.4	
Nitrate - N	mg/L	-	0.3	1.3	0.8	3	40[d]	0.3 – 2[e]
Nitrite - N	mg/L	-	< 0.003 (0.02)	< 0.003 (0.04)	< 0.003 (0.04)	calculated[c]	0.2 - 0.4	
Orthophosphate-P (dissolved)	mg/L	-	< 0.002	0.007	0.003	-	-	
Phosphorus (total dissolved)	mg/L	-	< 0.003	< 0.003	< 0.003	-	-	
Phosphorus (total)	mg/L	-	0.003	0.008	0.004	-	-	0.015[f]
Trace Elements Total								
Aluminum Al - total	µg/L	-	32 (100)	52 (100)	33 (100)	calculated[c]	-	
Arsenic As - total	µg/L	-	< 0.1	< 0.1	< 0.1	NS[g]	50	
Cadmium Cd - total	µg/L	-	< 0.01	0.02	< 0.01	-	-	
Chromium Cr - total	µg/L	-	0.1	0.1	0.1	NS	10	
Cobalt Co - total	µg/L	-	0.03	0.08	0.04	4	40	
Copper Cu - total	µg/L	-	0.2 (2.0)	0.6 (2.0)	0.4 (2.0)	calculated[c]	20	
Iron Fe - total	µg/L	-	33	28	21	NS	NS	
Lead Pb - total	µg/L	-	0.03 (3.8)	0.03 (3.9)	< 0.01 (3.8)	calculated[c]	40	
Manganese Mn - total	µg/L	-	4 (702)	< 1 (715)	< 1 (706)	calculated[c]	NS	
Mercury Hg - total	µg/L	-	< 0.01	< 0.01	< 0.01	0.02	0.25	
Molybdenum Mo - total	µg/L	-	< 0.02	< 0.02	< 0.02	1,000	10,000	
Nickel Ni - total	µg/L	-	0.3	0.6	0.3	NS	250	
Selenium Se - total	µg/L	-	< 0.2	< 0.2	< 0.2	2	20	
Silver Ag - total	µg/L	-	< 0.01 (0.05)	0.02 (0.05)	< 0.01 (0.05)	calculated[c]	0.5	
Zinc Zn - total	µg/L	-	< 0.5 (7.5)	3.9 (7.5)	3.0 (7.5)	calculated[c]	75	
Routine Water								
pH - field	pH units	-	6.9	**6.2**	6.9	6.5 - 9.0	-	
Electrical Conductivity	µS/cm at 25° C	-	62	73	66	-	-	100[h]
Chloride (dissolved)	mg/L	-	1.25	2.98	2.05	150	1,500	5[i]
Hardness (total)	mg $CaCO_3$/L	-	22	25	23	-	-	
Microbiological Analysis								
Escherichia coli	MPN/100 ml	-	1	20	1	77[j]	-	
Fecal Coliforms	MPN/100 ml	-	1	36	2	200[j]	-	

Note: Exceedances of guidelines are shown in bold type. Exceedances of regulatory limits shown in bold red type.
Note: NS = "no standard available".
a - Unless otherwise noted, these are chronic (30-day) WQG for total species for protection of freshwater aquatic life.
b - CSR limits for protection of freshwater aquatic life, Schedule 3.2. Criteria include static and calculated limits.
c - Calculated guidelines are shown in brackets next to individual parameter values.
d - CSR limit represents a 10:1 dilution from original value of 400 mg/L as per CSR guidance.
e - As per BC Ministry of Environment (1998), BC Ministry of Environment (1986), Vancouver Island Health Authority, personal communication (February 15, 2018), and Binkley (1999).
f - BC Approved Water Quality Guideline for protection of freshwater aquatic life in lakes.
g - No standard exists for this protection factor for this parameter.
h - As per Canadian Council of the Ministers of Environment, 2011.
i - As per BC Ministry of Environment, 1998.
j - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 6: Surface water quality data from Caillet Creek, 2019.

Date / Sample Location	Units	29-May-19 Upper Caillet	29-May-19 Lower Caillet	18-Nov-19 Upper Caillet	18-Nov-19 Lower Caillet	Water Quality Guidelines[a]	CSR Limits[b]	Other Reference Criteria
Inorganic Non-metallic Parameters								
Total Kjeldahl Nitrogen	mg/L	-	-	0.28	0.07	-	-	
Total Organic Carbon	mg/L	-	-	4.7	1.8	-	-	
Ammonia + Ammonium - N	mg/L	-	-	0.01 (1.86)	0.01 (1.86)	calculated[c]	18.4	
Nitrate - N	mg/L	-	-	1.9	1.6	3	40[d]	0.3 – 2[e]
Nitrite - N	mg/L	-	-	0.003 (0.04)	0.003 (0.04)	calculated[c]	0.4	
Orthophosphate-P (dissolved)	mg/L	-	-	0.005	0.002	-	-	
Phosphorus (total dissolved)	mg/L	-	-	0.003	0.003	-	-	
Phosphorus (total)	mg/L	-	-	0.007	0.003	-	-	0.015[f]
Trace Elements Total								
Aluminum Al - total	µg/L	-	-	71 (722)	14 (722)	calculated[c]	-	
Arsenic As - total	µg/L	-	-	0.10	0.10	NS[g]	50	
Cadmium Cd - total	µg/L	-	-	0.01	0.01	-	-	
Chromium Cr - total	µg/L	-	-	0.3	0.1	NS	10	
Cobalt Co - total	µg/L	-	-	0.05	0.03	4	40	
Copper Cu - total	µg/L	-	-	0.5 (2.0)	0.4 (2.0)	calculated[c]	20	
Iron Fe - total	µg/L	-	-	70	13	NS	NS	
Lead Pb - total	µg/L	-	-	0.03 (4.1)	0.01 (3.9)	calculated[c]	40	
Manganese Mn - total	µg/L	-	-	2 (750)	1 (728)	calculated[c]	NS	
Mercury Hg - total	µg/L	-	-	0.01	0.01	0.02	0.25	
Molybdenum Mo - total	µg/L	-	-	0.02	0.02	1,000	10,000	
Nickel Ni - total	µg/L	-	-	1.7	0.4	NS	250	
Selenium Se - total	µg/L	-	-	0.2	0.2	2	20	
Silver Ag - total	µg/L	-	-	0.01 (0.05)	0.01 (0.05)	calculated[c]	0.5	
Zinc Zn - total	µg/L	-	-	4.0 (7.5)	3.5 (7.5)	calculated[c]	75	
Routine Water								
pH - field	pH units	-	-	6.6	6.7	6.5 - 9.0	-	
Electrical Conductivity	µS/cm at 25° C	-	-	94	82	-	-	100[h]
Chloride (dissolved)	mg/L	-	-	2.23	2.30	150	1,500	5[i]
Hardness (total)	mg $CaCO_3$/L	-	-	33	28	-	-	
Microbiological Analysis								
Escherichia coli	MPN/100 ml	-	-	5	1	77[j]	-	
Fecal Coliforms	MPN/100 ml	-	-	3	2	200[j]	-	

Note: Exceedances of guidelines are shown in bold type. Exceedances of regulatory limits shown in bold red type.
Note: NS = "no standard available".
a - Unless otherwise noted, these are chronic (30-day) WQG for total species for protection of freshwater aquatic life.
b - CSR limits for protection of freshwater aquatic life, Schedule 3.2. Criteria include static and calculated limits.
c - Calculated guidelines are shown in brackets next to individual parameter values.
d - CSR limit represents a 10:1 dilution from original value of 400 mg/L as per CSR guidance.
e - As per BC Ministry of Environment (1998), BC Ministry of Environment (1986), Vancouver Island Health Authority, personal communication (February 15, 2018), and Binkley (1999).
f - BC Approved Water Quality Guideline for protection of freshwater aquatic life in lakes.
g - No standard exists for this protection factor for this parameter.
h - As per Canadian Council of the Ministers of Environment, 2011.
i - As per BC Ministry of Environment, 1998.
j - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 7: Surface water quality data from Bonnell Creek, 2019.

Date	Units	29-May-19	29-May-19	18-Nov-19	18-Nov-19	Water Quality Guidelines[a]	CSR Limits[b]	Other Reference Criteria
Sample Location		Upper Bonnell	Lower Bonnell	Upper Bonnell	Lower Bonnell			
Inorganic Non-metallic Parameters								
Total Kjeldahl Nitrogen	mg/L	-	-	0.68	< 0.07	-	-	
Total Organic Carbon	mg/L	-	-	22.0	15.0	-	-	
Ammonia + Ammonium - N	mg/L	-	-	0.02 (1.9)	0.03 (1.9)	calculated[c]	18.4	
Nitrate - N	mg/L	-	-	1.0	0.5	3	40[d]	0.3 – 2[e]
Nitrite - N	mg/L	-	-	< 0.003 (0.04)	< 0.003 (0.04)	calculated[c]	0.4	
Orthophosphate-P (dissolved)	mg/L	-	-	0.012	0.004	-	-	
Phosphorus (total dissolved)	mg/L	-	-	0.026	0.012	-	-	
Phosphorus (total)	mg/L	-	-	0.033	0.018	-	-	0.015[f]
Trace Elements Total								
Aluminum Al - total	µg/L	-	-	**290 (27)**	**230 (27)**	calculated[c]	-	
Arsenic As - total	µg/L	-	-	< 0.5	< 0.5	NS[g]	50	
Cadmium Cd - total	µg/L	-	-	< 0.05	< 0.05	-	-	
Chromium Cr - total	µg/L	-	-	0.3	0.4	NS	10	
Cobalt Co - total	µg/L	-	-	0.30	0.10	4	40	
Copper Cu - total	µg/L	-	-	2 (2.0)	1 (2.0)	calculated[c]	20	
Iron Fe - total	µg/L	-	-	360	190	NS	NS	
Lead Pb - total	µg/L	-	-	0.5 (4.0)	0.1 (3.9)	calculated[c]	40	
Manganese Mn - total	µg/L	-	-	30 (733)	5 (715)	calculated[c]	NS	
Mercury Hg - total	µg/L	-	-	0.02	0.01	0.02	0.25	
Molybdenum Mo - total	µg/L	-	-	< 0.1	< 0.1	1,000	10,000	
Nickel Ni - total	µg/L	-	-	1	< 1	NS	250	
Selenium Se - total	µg/L	-	-	< 1	< 1	2	20	
Silver Ag - total	µg/L	-	-	< 0.05 (0.05)	< 0.05 (0.05)	calculated[c]	0.5	
Zinc Zn - total	µg/L	-	-	**17.0 (7.5)**	**7.9 (7.5)**	calculated[c]	75	
Routine Water								
pH - field	pH units	-	-	**6.0**	6.6	6.5 - 9.0	-	
Electrical Conductivity	µS/cm at 25° C	-	-	65	58	-	-	100[h]
Chloride (dissolved)	mg/L	-	-	2.21	2.45	150	1,500	5[i]
Hardness (total)	mg $CaCO_3$/L	-	-	29	25	-	-	
Microbiological Analysis								
Escherichia coli	MPN/100 ml	-	-	3	< 1.0	77[j]	-	
Fecal Coliforms	MPN/100 ml	-	-	10	5	200[j]	-	

Note: Exceedances of guidelines are shown in bold type. Exceedances of regulatory limits shown in bold red type.
Note: NS = "no standard available".
a - Unless otherwise noted, these are chronic (30-day) WQG for total species for protection of freshwater aquatic life.
b - CSR limits for protection of freshwater aquatic life, Schedule 3.2. Criteria include static and calculated limits.
c - Calculated guidelines are shown in brackets next to individual parameter values.
d - CSR limit represents a 10:1 dilution from original value of 400 mg/L as per CSR guidance.
e - As per BC Ministry of Environment (1998), BC Ministry of Environment (1986), Vancouver Island Health Authority, personal communication (February 15, 2018), and Binkley (1999).
f - BC Approved Water Quality Guideline for protection of freshwater aquatic life in lakes.
g - No standard exists for this protection factor for this parameter.
h - As per Canadian Council of the Ministers of Environment, 2011.
i - As per BC Ministry of Environment, 1998.
j - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 8: Surface water quality data from W1500 Creek, 2019.

Date	Units	29-May-19	29-May-19	18-Nov-19	18-Nov-19	Water Quality Guidelines[a]	CSR Limits[b]	Other Reference Criteria
Sample Location		Upper W1500	Lower W1500	Upper W1500	Lower W1500			
Inorganic Non-metallic Parameters								
Total Kjeldahl Nitrogen	mg/L	-	0.10	0.51	0.26	-	-	
Total Organic Carbon	mg/L	-	1.3	4.6	2.1	-	-	
Ammonia + Ammonium - N	mg/L	-	0.01 (1.8)	< 0.01 (1.9)	0.02 (1.9)	calculated[c]	18.4	
Nitrate - N	mg/L	-	1.7	**4.5**	**4.6**	3	40[d]	0.3 – 2[e]
Nitrite - N	mg/L	-	< 0.003 (0.02)	0.004 (0.04)	0.003 (0.04)	calculated[c]	0.2 - 0.4	
Orthophosphate-P (dissolved)	mg/L	-	< 0.002	0.005	< 0.002	-	-	
Phosphorus (total dissolved)	mg/L	-	< 0.003	0.007	0.004	-	-	
Phosphorus (total)	mg/L	-	0.004	0.009	0.004	-	-	0.015[f]
Trace Elements Total								
Aluminum Al - total	µg/L	-	15 (28)	**55 (28)**	**92 (28)**	calculated[c]	-	
Arsenic As - total	µg/L	-	< 0.1	< 0.1	< 0.5	NS[g]	50	
Cadmium Cd - total	µg/L	-	< 0.01	< 0.01	< 0.05	-	-	
Chromium Cr - total	µg/L	-	0.1	0.1	0.4	NS	10	
Cobalt Co - total	µg/L	-	0.03	0.05	0.10	4	40	
Copper Cu - total	µg/L	-	0.6 (2.0)	0.7 (2.0)	2 (2.0)	calculated[c]	20	
Iron Fe - total	µg/L	-	5	20	40	NS	NS	
Lead Pb - total	µg/L	-	0.02 (4.3)	0.01 (4.1)	< 0.05 (4.3)	calculated[c]	40	
Manganese Mn - total	µg/L	-	< 1 (781)	2 (755)	< 5 (777)	calculated[c]	NS	
Mercury Hg - total	µg/L	-	< 0.01	< 0.01	< 0.01	0.02	0.25	
Molybdenum Mo - total	µg/L	-	< 0.02	< 0.02	< 0.1	1,000	10,000	
Nickel Ni - total	µg/L	-	0.3	0.4	< 1	NS	250	
Selenium Se - total	µg/L	-	< 0.2	< 0.2	< 1	2	20	
Silver Ag - total	µg/L	-	< 0.01 (0.05)	< 0.01 (0.05)	< 0.05 (0.05)	calculated[c]	0.5	
Zinc Zn - total	µg/L	-	4.1 (7.5)	1.8 (7.5)	**15.0 (7.5)**	calculated[c]	75	
Routine Water								
pH - field	pH units	-	**6.2**	**6.1**	6.8	6.5 - 9.0	-	
Electrical Conductivity	µS/cm at 25° C	-	100	99	110	-	-	100[h]
Chloride (dissolved)	mg/L	-	1.44	2.38	2.18	150	1,500	5[i]
Hardness (total)	mg $CaCO_3$/L	-	40	34	39	-	-	
Microbiological Analysis								
Escherichia coli	MPN/100 ml	-	< 1.0	16	6	77[j]	-	
Fecal Coliforms	MPN/100 ml	-	< 1.0	7	2	200[j]	-	

Note: Exceedances of guidelines are shown in bold type. Exceedances of regulatory limits shown in bold red type.
Note: NS = "no standard available".
a - Unless otherwise noted, these are chronic (30-day) WQG for total species for protection of freshwater aquatic life.
b - CSR limits for protection of freshwater aquatic life, Schedule 3.2. Criteria include static and calculated limits.
c - Calculated guidelines are shown in brackets next to individual parameter values.
d - CSR limit represents a 10:1 dilution from original value of 400 mg/L as per CSR guidance.
e - As per BC Ministry of Environment (1998), BC Ministry of Environment (1986), Vancouver Island Health Authority, personal communication (February 15, 2018), and Binkley (1999).
f - BC Approved Water Quality Guideline for protection of freshwater aquatic life in lakes.
g - No standard exists for this protection factor for this parameter.
h - As per Canadian Council of the Ministers of Environment, 2011.
i - As per BC Ministry of Environment, 1998.
j - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

Table 9: Monthly surface water quality data from Benson Creek and Caillet Creek (downstream), 2019

Parameters	**Nutrients**				**Routine Water**				**Microbiological Analysis**			
	Nitrate - N		**Phosphorus (total)**		**Electrical Conductivity**		**Chloride (dissolved)**		**Escherichia coli**		**Fecal Coliforms**	
Units	mg/L		mg/L		µS/cm at 25° C		mg/L		MPN/100 ml		MPN/100 ml	
Creek	Benson	Caillet	Benson	Caillet	Benson	Caillet	Benson	Caillet	Benson	Caillet	Benson	Caillet
10-Jan-19	0.04	2.2	0.008	0.006	20	73	0.77	1.70	2.0	4.1	< 1.0	< 1.0
20-Feb-19	0.11	2.3	0.004	0.003	27	78	0.97	1.78	2.0	< 1.0	< 1.0	< 1.0
25-Mar-19	0.11	2.1	0.005	0.004	22	74	0.86	1.68	< 1.0	< 1.0	< 1.0	< 1.0
23-Apr-19	0.04	1.7	0.004	0.003	27	79	0.91	1.57	2.0	< 1.0	< 1.0	< 1.0
29-May-19	0.11	-	0.006	-	42	-	1.00	-	< 1.0	-	3.0	-
19-Jun-19	0.20	-	0.004	-	52	-	1.43	-	< 1.0	-	1.0	-
15-Jul-19	0.20	-	0.003	-	56	-	1.21	-	**101.4**	-	71.7	-
15-Aug-20	-	-	-	-	-	-	-	-	-	-	-	-
16-Sep-19	0.46	-	0.010	-	68	-	1.38	-	36.4	-	19.9	-
23-Oct-19	0.09	2.1	0.006	0.003	28	82	1.67	2.48	3.1	41.0	< 1.0	39.3
18-Nov-19	0.10	1.6	0.006	0.003	29	82	1.47	2.30	2.0	1.0	3.1	2.0
16-Dec-19	0.10	2.7	0.004	0.003	27	86	1.40	2.43	< 1.0	< 1.0	2.0	1.0
WQG[a]	3		-		-		150		77[b]		200[b]	
CSR[c]	40[d]		-		-		1,500		-		-	
Other Reference Criteria	0.3 - 2[e]		0.015[f]		100[g]		5[h]		-		-	

Note: Exceedances of guidelines are shown in bold type. Exceedances of regulatory limits shown in bold red type.

a - Unless otherwise noted, these are chronic (30-day) British Columbia Approved Water Quality Guidelines for total species for protection of freshwater aquatic life.

b - British Columbia Approved Water Quality Guideline for recreation/aesthetics primary contact.

c - Contaminated Sites Regulation limits for protection of freshwater aquatic life, Schedule 3.2. Criteria include static and calculated limits.

d - CSR limit represents a 10:1 dilution from original value of 400 mg/L as per CSR guidance.

e - As per BC Ministry of Environment (1998), BC Ministry of Environment (1986), Vancouver Island Health Authority, personal communication (February 15, 2018), and Binkley (1999).

f - No standard exists for this protection factor for this parameter.

g - As per BC Ministry of Environment, 1998.

h - As per Canadian Council of the Ministers of Environment, 2011.

APPENDIX TWO – FIGURES

Figure 1: Overview of sampling locations at the TimberWest Properties.

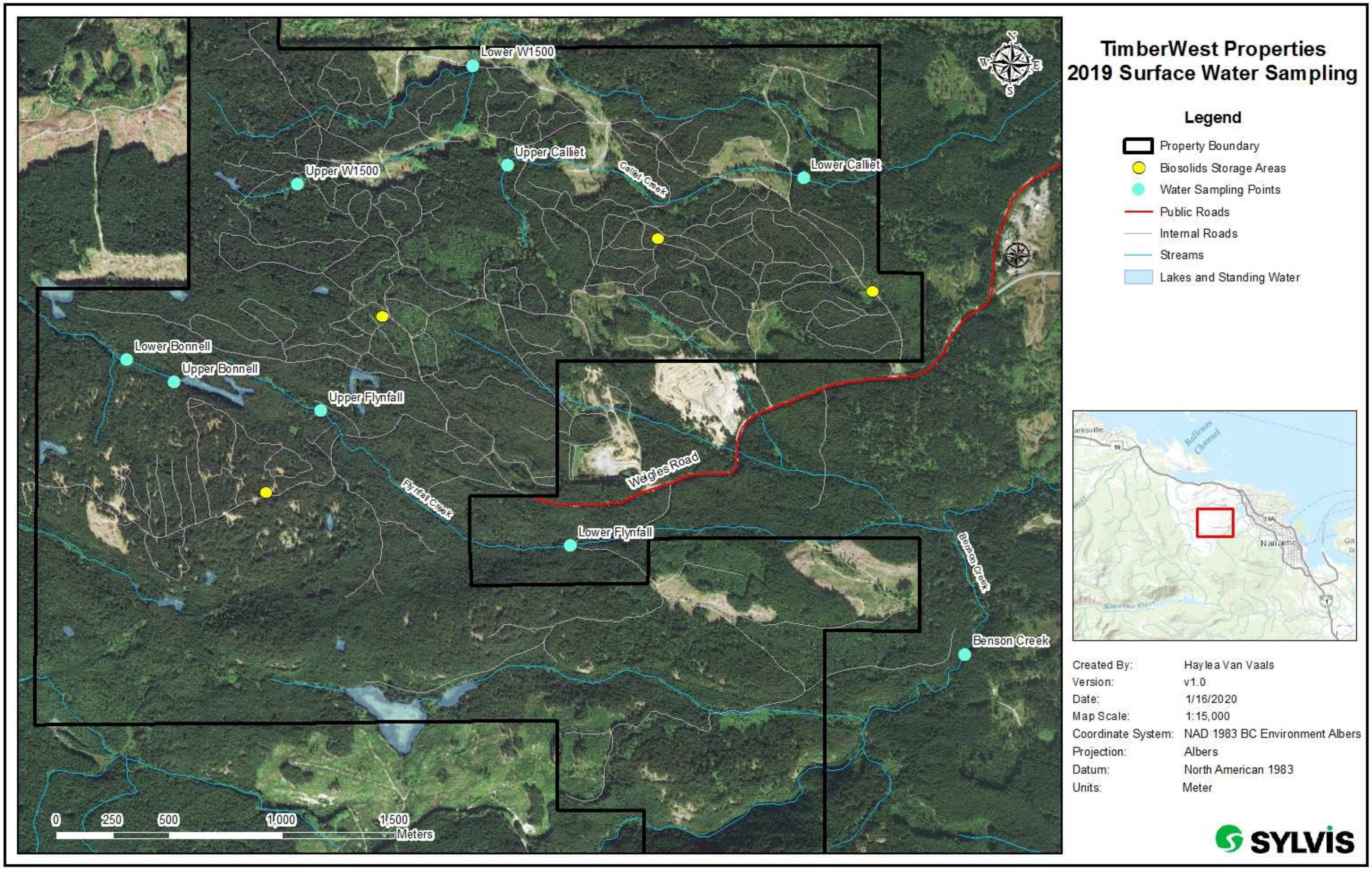


Figure 2: Monthly nitrate-N concentrations in Benson and Caillet Creeks along with the chronic (long-term) BC Approved Water Quality Guideline for protection of aquatic life, 2019.

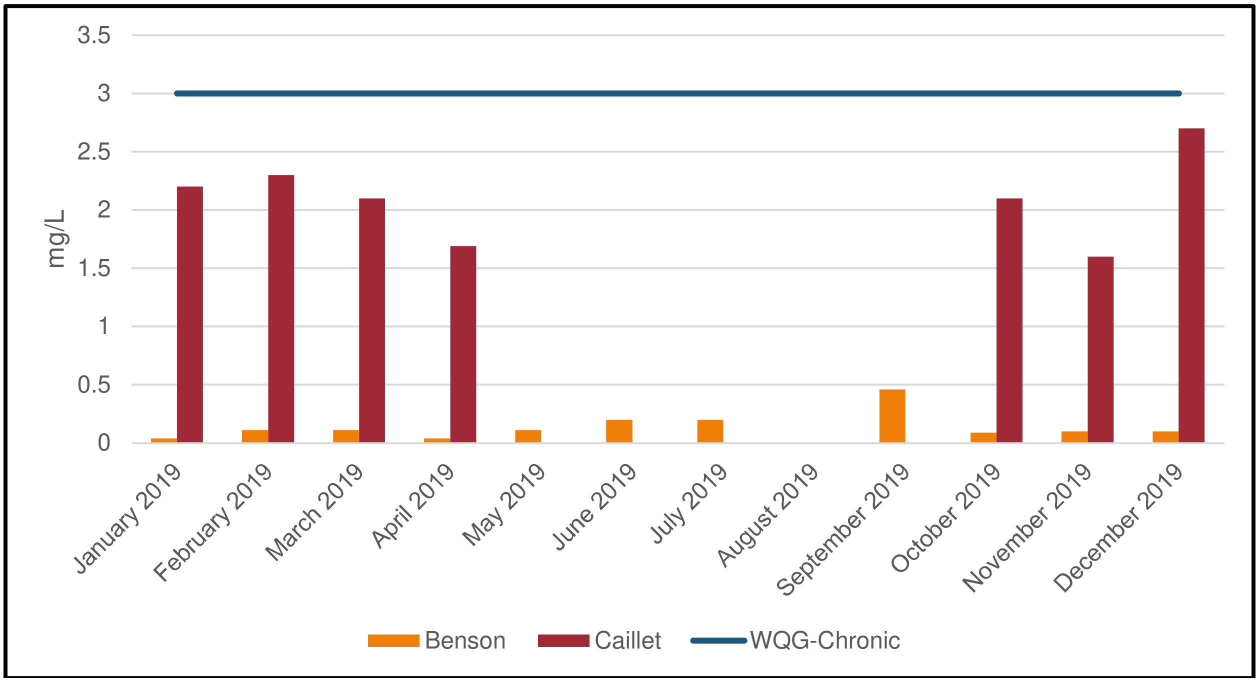


Figure 3: Monthly total phosphorus concentrations in Benson and Caillet Creeks, 2019 (no chronic long-term BC Approved Water Quality Guideline for protection of aquatic life available).

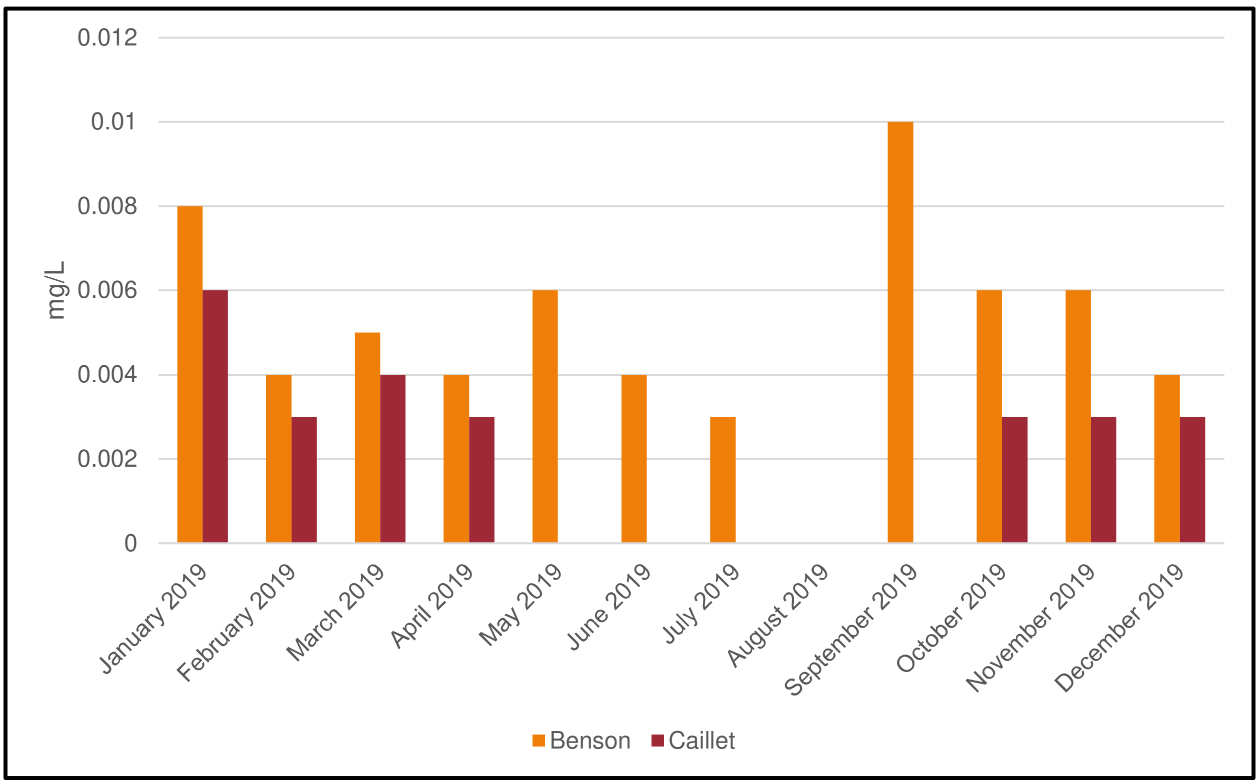


Figure 4: Monthly electrical conductivity in Benson and Caillet Creeks with reference value, 2019 (no chronic long-term BC Approved Water Quality Guideline for protection of aquatic life available).

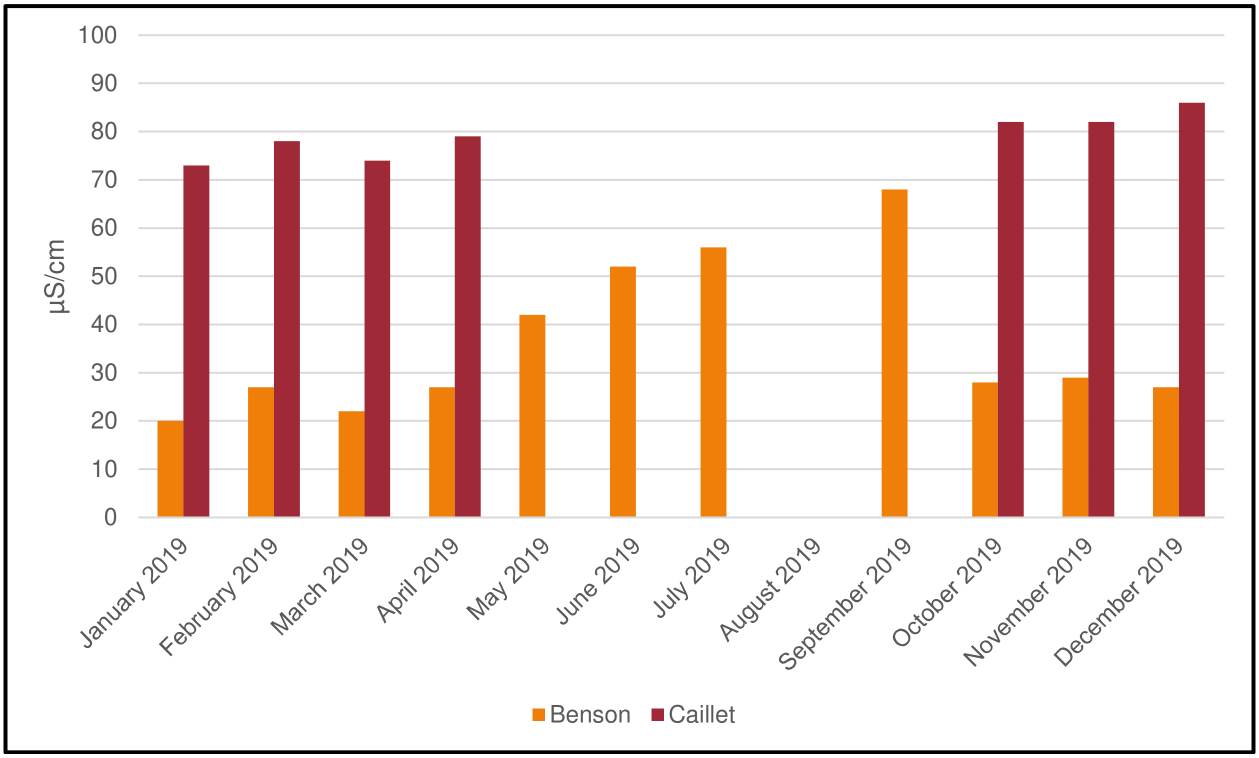


Figure 5: Monthly dissolved chloride concentration in Benson and Caillet Creeks with chronic (long-term) BC Approved Water Quality Guideline for protection of aquatic life, 2019.

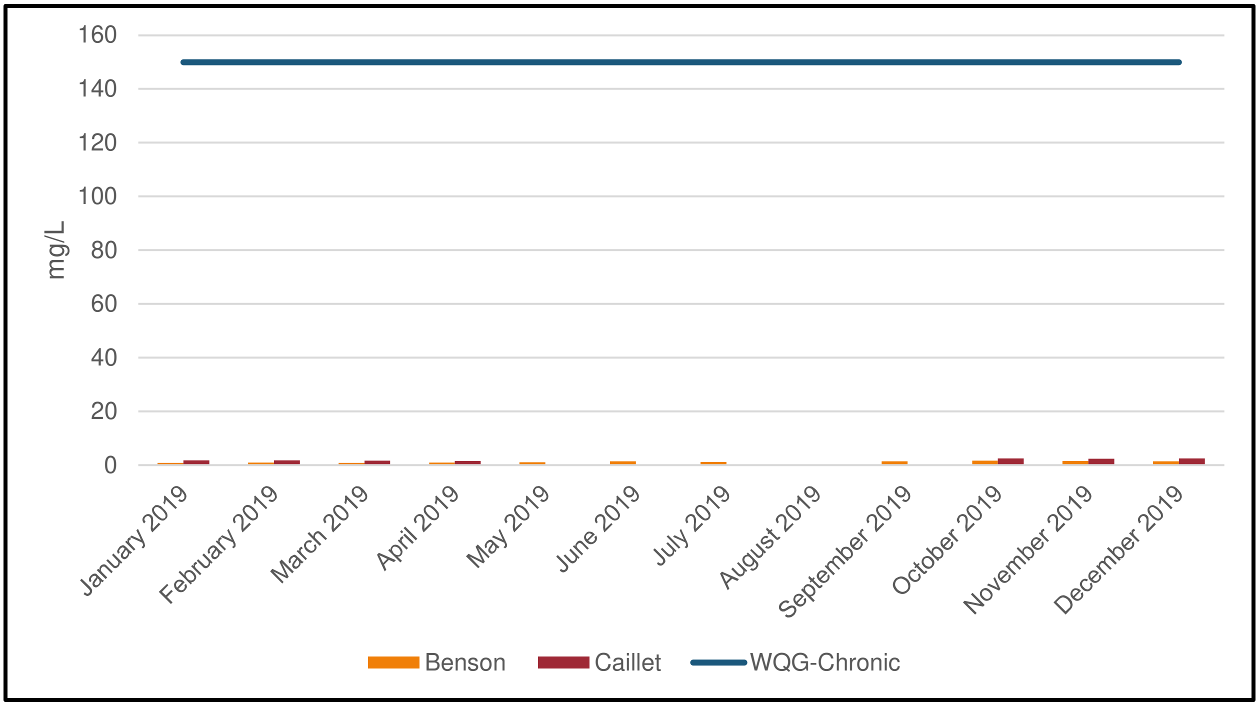


Figure 6: Total phosphorus concentrations in Biosolids Area creeks and Benson Creek, 2019 (no chronic long-term BC Approved Water Quality Guideline for protection of aquatic life available).

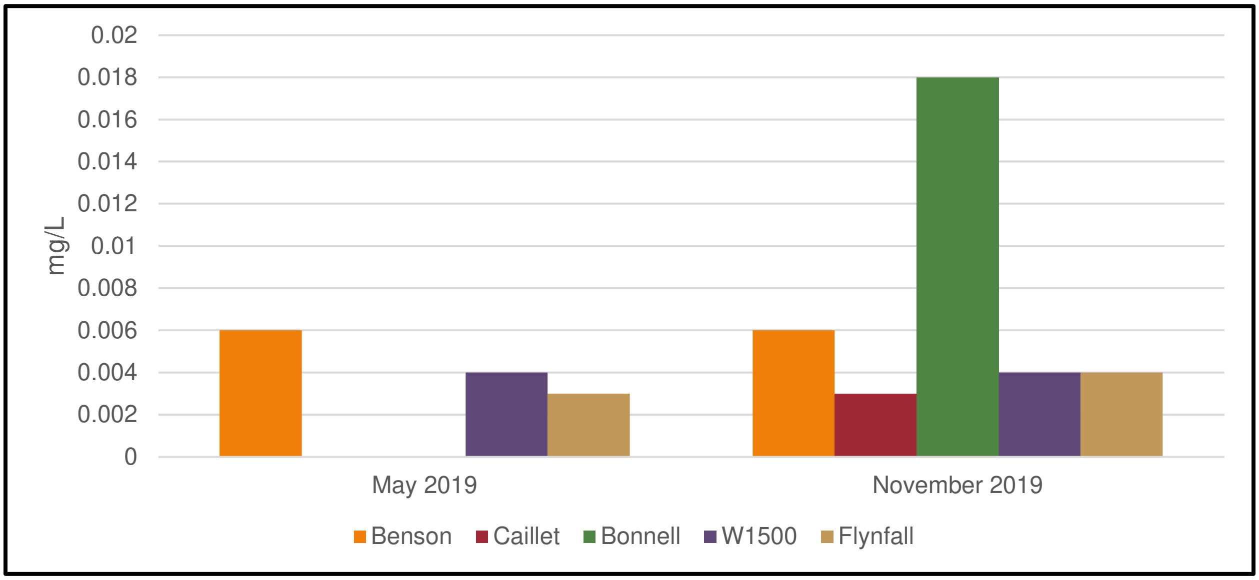


Figure 7: Electrical conductivity in Biosolids Area creeks and Benson Creek with reference value, 2019 (no chronic long-term BC Approved Water Quality Guideline for protection of aquatic life available).

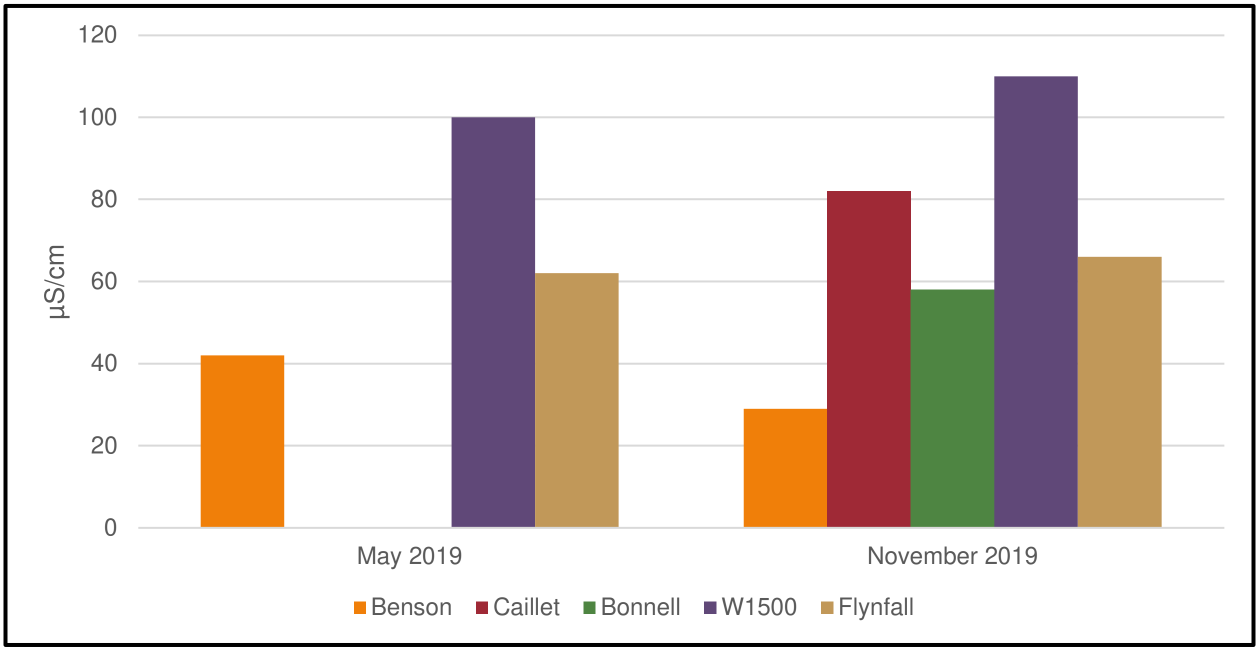


Figure 8: Dissolved chloride concentrations in Biosolids Area creeks and Benson Creek with chronic (long-term) BC Approved Water Quality Guideline for protection of aquatic life, 2019.

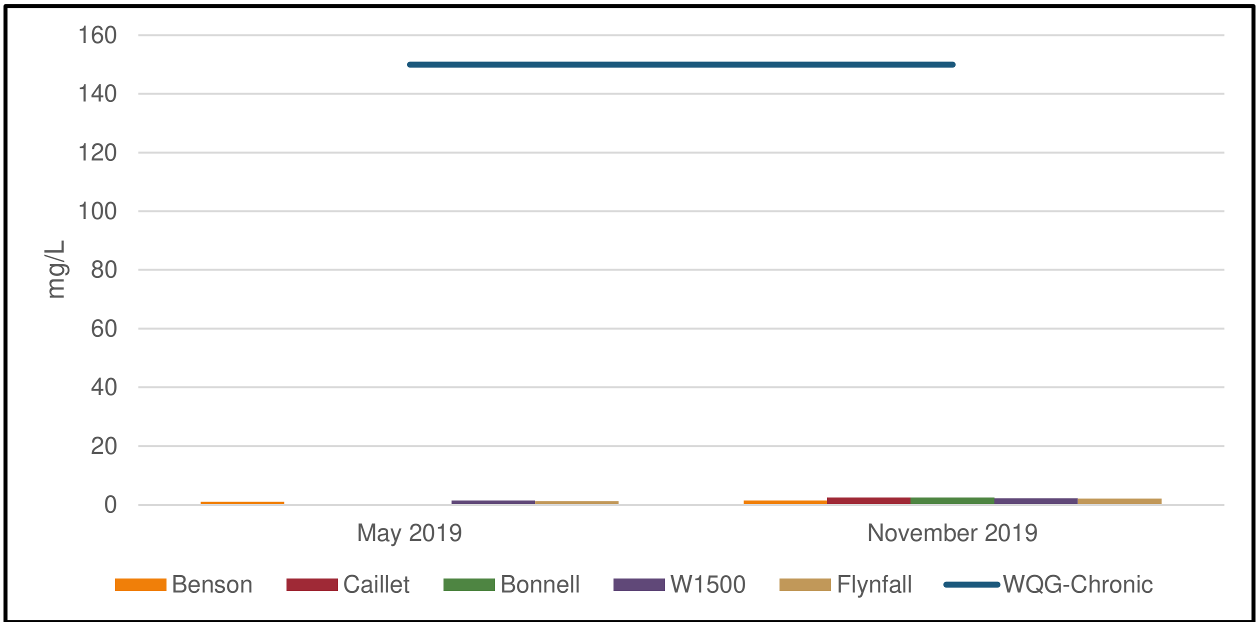
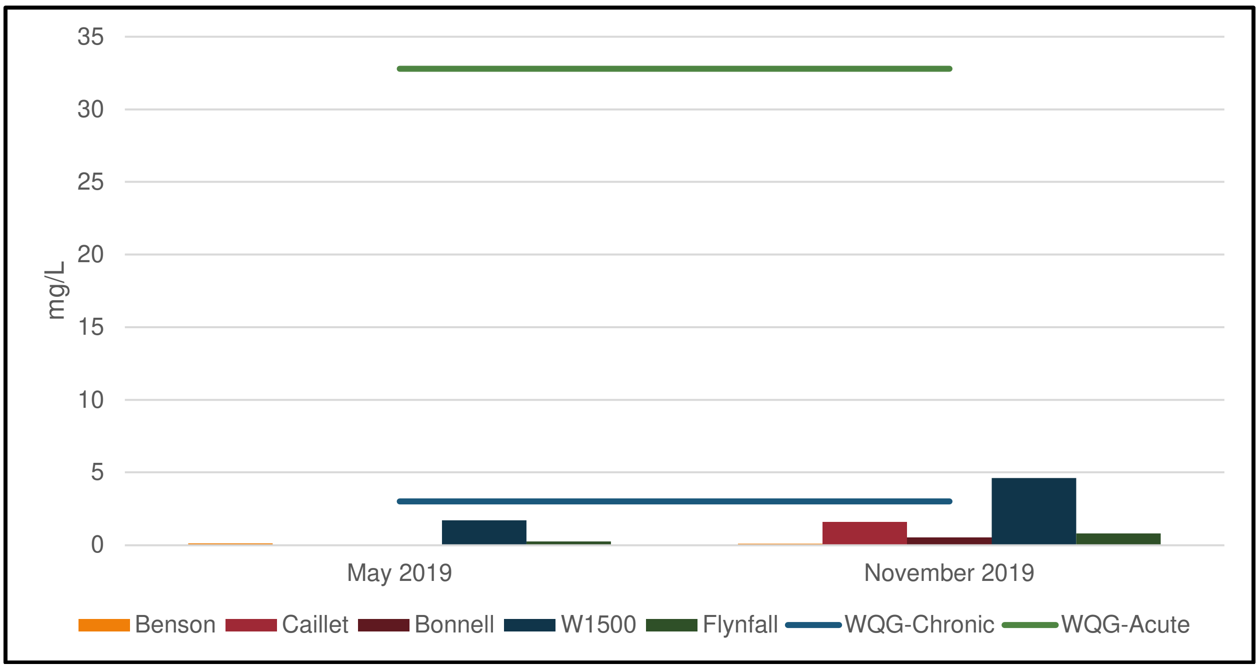


Figure 9: Nitrate concentration in Biosolids Area creeks and Benson Creek with chronic (long-term) and acute (short-term) BC Approved Water Quality Guidelines for protection of aquatic life, 2019.



APPENDIX THREE – PHOTOGRAPHS

Photograph 1: Benson Creek sampling location. (November 2019)

Photograph 2: Upper Flynfall Creek sampling location. (November 2019)

Photograph 3: Lower Flynfall Creek sampling location. (November 2019)

Photograph 4: Upper Caillet Creek sampling location. (November 2019)

Photograph 5: Lower Caillet Creek sampling location. (November 2019)

Photograph 6: Upper Bonnell Creek sampling location. (November 2019)

Photograph 7: Lower Bonnell Creek sampling location. (November 2019)

Photograph 8: Upper W1500 Creek sampling location. (November 2019)

Photograph 9: Lower W1500 Creek sampling location.(November 2019)