Bear Creek Watershed-Scale Stormwater Plan: Existing Water Quality Conditions

April 2017

King County

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Prepared For:

King County, Snohomish County, City of Redmond, City of Woodinville, NPDES Permit requirement (Phase I- S5.C.5.c and Phase II- S5.C.4.g) and Washington State Department of Transportation in support of the Bear Creek Watershed-Scale Stormwater Management Plan

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Table of Contents

Figures

Tables

Appendices

EXECUTIVE SUMMARY

This report summarizes surface water quality data collected to support the planning effort within Bear Creek watershed study area. King County is required to develop a watershed-scale stormwater management plan under section (S5.C.5.c.ii) in the National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Stormwater Permit (permit) issued by the Washington State Department of Ecology (Ecology), effective August 1, 2013, modified January 16, 2015, and expires July 31, 2018.

Characterization of existing water quality conditions in the basin was based on sampling of storm events and base flow conditions between March 2015 and January 2016. The primary goals were to characterize existing water quality during storm events and base flows throughout the year to support calibration of a watershed model. Thirteen sites were sampled during six baseflow and six storm events. Additionally, continuous flow and temperature gages were used to calculate instantaneous loading and temperature water quality standard exceedances.

In agreement with historic data for Bear Creek (King County, 2017), temperature, dissolved oxygen, and fecal coliform bacteria were identified as water quality concerns due to exceedances of the state water quality standards. Adding to these concerns, this study identified exceedance of the state criteria for copper in Mackey and Cold creeks during wet-weather flow.

Genetic analysis of water samples indicated the presence of human gut-associated bacteria in wet-weather samples from Lower Bear Creek, Mackey Creek, and South Seidel Creek. The levels of the genetic marker in Lower Bear Creek provides compelling evidence of the presence of human feces, but the levels found in Mackey and South Seidel creeks are intriguing but less compelling. Therefore, microbial source tracking at a finer scale is recommended to determine the sources of human feces in Lower Bear Creek and confirm whether there is a concern in Mackey and South Seidel creeks. Potential sources include illicit sewage connections, failing septic systems, leaking sewer pipes, homeless encampments without access to sanitary facilities, or human feces otherwise not deposited in a functioning sanitary system.

As part of the overall Bear Creek watershed planning effort, the data collected during baseflow and storm events described in this report will be used in the calibration of a hydrologic model (HSPF) for the Bear Creek basin. The hydrologic model will be used to assess the impacts of different stormwater management strategies on the hydrology and water quality in Bear Creek.

1.0 INTRODUCTION

King County is required to develop a watershed-scale stormwater management plan under section (S5.C.5.c.ii) in the National Pollutant Discharge Elimination System (NPDES) Phase I Municipal Stormwater Permit (permit) issued by the Washington State Department of Ecology (Ecology), effective August 1, 2013, modified January 16, 2015, and expires July 31, 2018. This report summarizes surface water quality data collected to support the planning effort within Bear Creek watershed study area.

1.1 Bear Creek Watershed

King County selected the Bear Creek watershed for the watershed-scale stormwater planning effort. For this work, the Bear Creek watershed is defined as including Bear Creek and lands that drain to Bear Creek, with the following exclusions (Figure 1):

- The Evans Creek basin (a tributary to Bear Creek) is not included in King County's selection
- The reach of Bear Creek downstream of the confluence to Evans Creek, along with small direct drainages and tributaries to this reach of Bear Creek, is not included in King County's selection
- Cottage Lake and the area that drains to Cottage Lake are not included in King County's selection.[1]

King County's selection of the Bear Creek watershed, as defined above, was approved by Ecology (NPDES Phase I Municipal Stormwater Permit, August 1, 2013, Modified January 16, 2015, S5.C.5.c.i.). This planning area approximately totals 26 square miles and includes area within four other jurisdictions in addition to unincorporated King County (18.9 square miles):

- City of Redmond (2.4 square miles);
- City of Woodinville (1.1 square miles);
- Washington State Department of Transportation (0.003 square miles); and
- Snohomish County (3.7 square miles);

The majority of the unincorporated King County area is designated rural except for about 1.9 square miles residing on the urban side of the Urban Growth Boundary .A large portion of the study area, including 39% of unincorporated areas, has existing parcel densities greater than rural zoning RA 2.5.

[1] Drainages upstream of Cottage Lake are not included in the project area because Cottage Lake serves to substantially mitigate the effects of land use change upstream of the lake. The drainage area feeding to Cottage Lake is approximately 4300 acres, with over 100 acres comprised of lakes (Cottage, Crystal, and Little) and about 100 acres of wetlands.

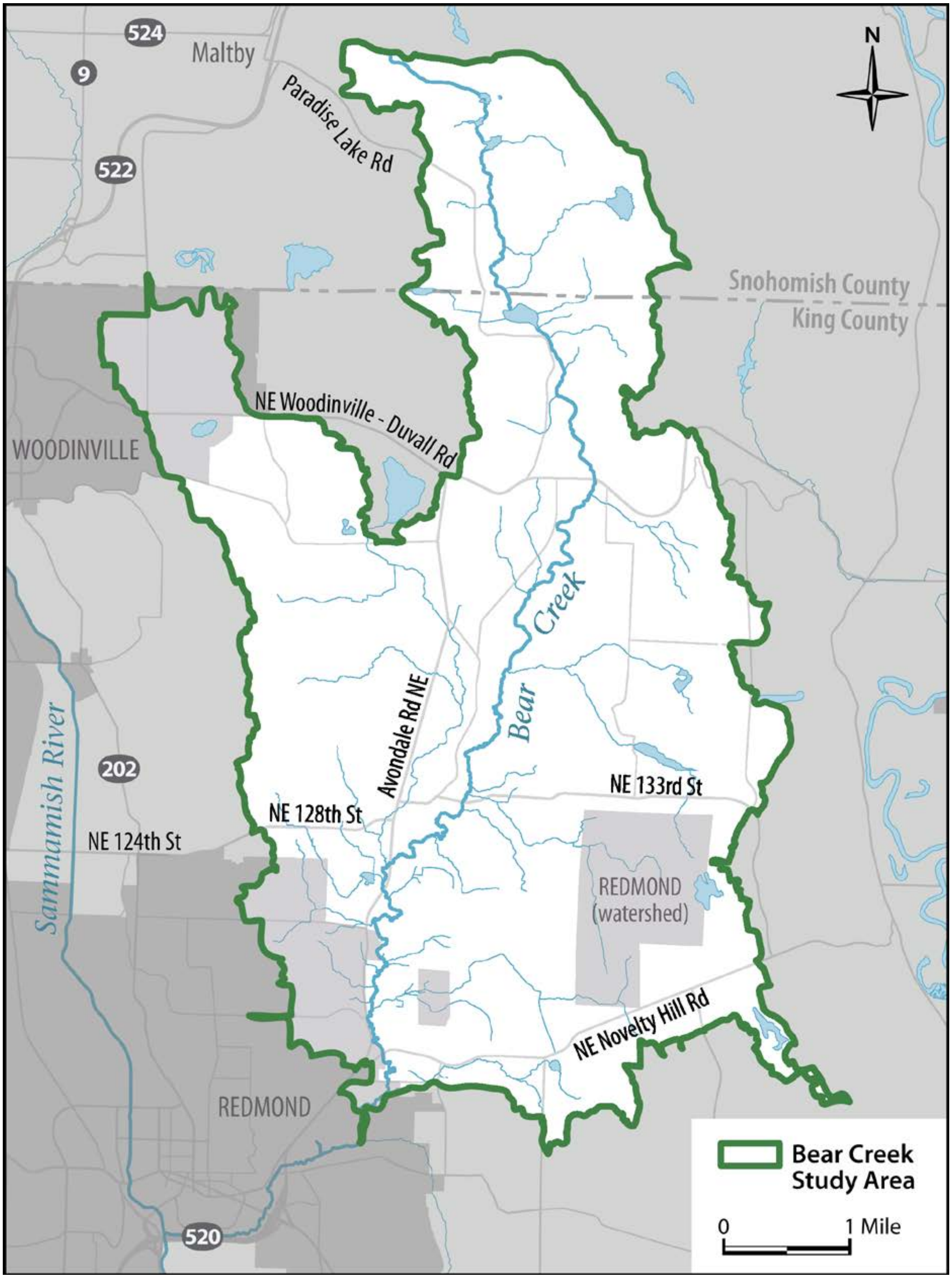

Figure 1. Bear Creek Study Area. Jurisdictions (Redmond, Woodinville, and Snohomish County) are shaded within the study area.

1.2 Project Description

This watershed-scale planning effort is intended to identify stormwater management strategies that would result in hydrologic and water quality conditions that fully support *existing* and *designated* uses as defined in the Washington Administrative Code (WAC 173-201A-020).

King County leads this planning process and coordinates with the other jurisdictions and partners to allow for their input during the project. The watershed-scale plan includes assessments of the landscape based on historic, existing, and projected future conditions. Stormwater management strategies are evaluated, using these landscape baselines, for stream health based on stream hydrology, water quality, and aquatic biota (life forms). The evaluations are informed by:

- previous study results;
- interpretations of existing and newly collected data; and
- development of computer models that project historic and future conditions and characterize the effectiveness of stormwater management strategies.

The implementation plan includes stormwater management strategies, estimated costs, and potential funding mechanisms.

1.3 Existing Conditions Assessment

King County, City of Redmond, City of Woodinville, Snohomish County, and Washington State Department of Transportation have entered into a partnership to evaluate existing conditions of Bear Creek Basin. This assessment includes extensive gaging and water quality testing (King County, 2015a). This report summarizes the results of the existing water quality conditions assessment.

Water quality is influenced by a variety of changes in environmental conditions, both natural and human-caused. Consequently, designs of this study plan include taking measurements multiple times during storm events and base flow conditions.

Objectives for this existing conditions assessment are described in the following list:

- Characterize existing conditions for the study area including baseflow and storm event situations.
- Compare existing conditions to relevant water quality standards.
- Support development and calibration of a watershed model(s).

Parameters targeted for analysis include conventionals, field parameters, nitrogen, pathogen indicators, and trace metals. Conventional parameters include: total suspended solids, particle size distribution, and turbidity. Nitrogen parameters include ammonia-N, nitrate+nitrite, and total nitrogen. Field parameters measured were: continuous water level, temperature, dissolved oxygen (DO), conductance, and pH. Fecal coliform bacteria were analyzed as an indicator of fecal pollution. A subset of samples were analyzed for Hu-

2 Bacteroidales (HF183), a genetic indicator of human gut-associated bacteria. Metals analyzed include copper and zinc, and to calculate hardness: calcium and magnesium. Particle size distribution was analyzed on suspended solids in the water-column and sediment samples taken from the streambed.

2.0 WATER QUALITY STUDY DESIGN

Water quality in the project area was characterized between March 2015 and January 2016. The goal was to capture water quality conditions throughout the year and not just during extreme conditions. Primary goals were to characterize effects of existing water conditions during wet-weather and base flow sampling to support calibration of a watershed model.

This section summarizes the study designed described in the Monitoring Quality Assurance Project Plan (QAPP) for Bear Creek Watershed-Scale Stormwater Plan (King County, 2015b). Important deviations from the QAPP are noted in this section.

2.1 Sampling Locations

Locations of sample collections were located near the boundary of existing jurisdictional areas (i.e., Woodinville, Snohomish County, and Redmond) as well as on most major tributaries to Bear Creek mainstem—generally near confluences. In total, 13 sites were sampled (Figure 2). Priority was placed on more accurately capturing as much of the drainage area as possible prior to entering into the mainstem of the creek.

Table 1 provides a summary of stations monitored by locator names, State Plane coordinates, and function of site as water quality samples or gage sites for flow or weather. Several of the gages were installed as part of a separate project, the Redmond Paired Watershed study, in Water Year (WY) 2016; the site IDs are preceded with RPWS. Further, this report summarizes temperature gage data from 2016 in addition to 2015 to better characterize temperatures in the study area. The analysis of 2016 data is a deviation from the QAPP. Figure 2 displays the station locations on a map.

Instantaneous contaminant loads were calculated at nine of the 13 water quality sites that had stream flow gage nearby. The data are presented in Section 4 and sites are listed below:

- **Lower Bear Creek** – Site: C484; Gage: (02R – BC0114)
- **Middle Bear Creek** – Site: J484; Gage: 02e
- **Upper Bear Creek** – Site: BCP01; Gage: 02f2
- **Cottage Lake Creek** – Site: N484; Gage: 02g
- **Stensland Creek** – Site: BCP09; Gage: BC0114
- **Mackey Creek** – Site: ET484; Gage: 02Q
- **Monticello Creek** – Site: BCP08; Gage: BC0119
- **South Fork Seidel Creek** – Site: SOUTH SEIDEL_YSI; Gage: 02p
- **North Fork Struve Creek** – Site: BCP04; Gage: 02M2

Note that to calculate the discharge at site C484 (Lower Bear Creek), the flow at Stensland Creek (BC0114) was subtracted from the flow at 02R (Bear Creek – RM2.1 below Stensland).

2.2 Sampling Conditions and Frequency

2.2.1 Storm Events

The goal for storm event sampling was to target six storms. Three sets of grab samples were collected at each station approximately 12 hours apart for each storm event. All 13 sites were typically sampled within a two to three hour window for each set.

Weather forecasts were monitored for the duration of the study plan. The required conditions for a storm event were defined as predicted precipitation of greater than 0.30-inches to occur in a 24-hour period, or greater than and/or equal to 0.50 inches in a 48-hour period. The target 24-hour precipitation amount antecedent to the storm was less than 0.05 inches.

2.2.2 Base Flow Events

Base flow events were scheduled events that could be delayed if defined antecedent conditions changed. Antecedent requirements are defined as less than 0.05 inches of precipitation within a 24-hour period. These sampling events were planned throughout the year: fall, winter, spring and summer. Base flow samples were originally planned to be collected twice in one day at the various sites with a sample frequency will be done every 8 to 12 hours to obtain 2 samples per base flow event. As outlined in the QAPP, it was decided that only one sample set was required per event because little diurnal variation was observed.

2.2.3 Stream Sediment Event

One stream sediment event was planned at or near each of the 13 sampling sites. Stream sediment samples were taken to assess the streambed substrate on August 27, 2015. Sediment sampling occurred when mobility of bed was minimal. Particle size analysis was done to determine the physical makeup of sediments by determining the portion of fine silt, clay, sand, or gravel present within a sediment sample. This was done to support the water quality model development. Sediments were not sampled in Cold Creek due to low flow, which is a deviation from the QAPP. No sediment chemistry analysis was completed.

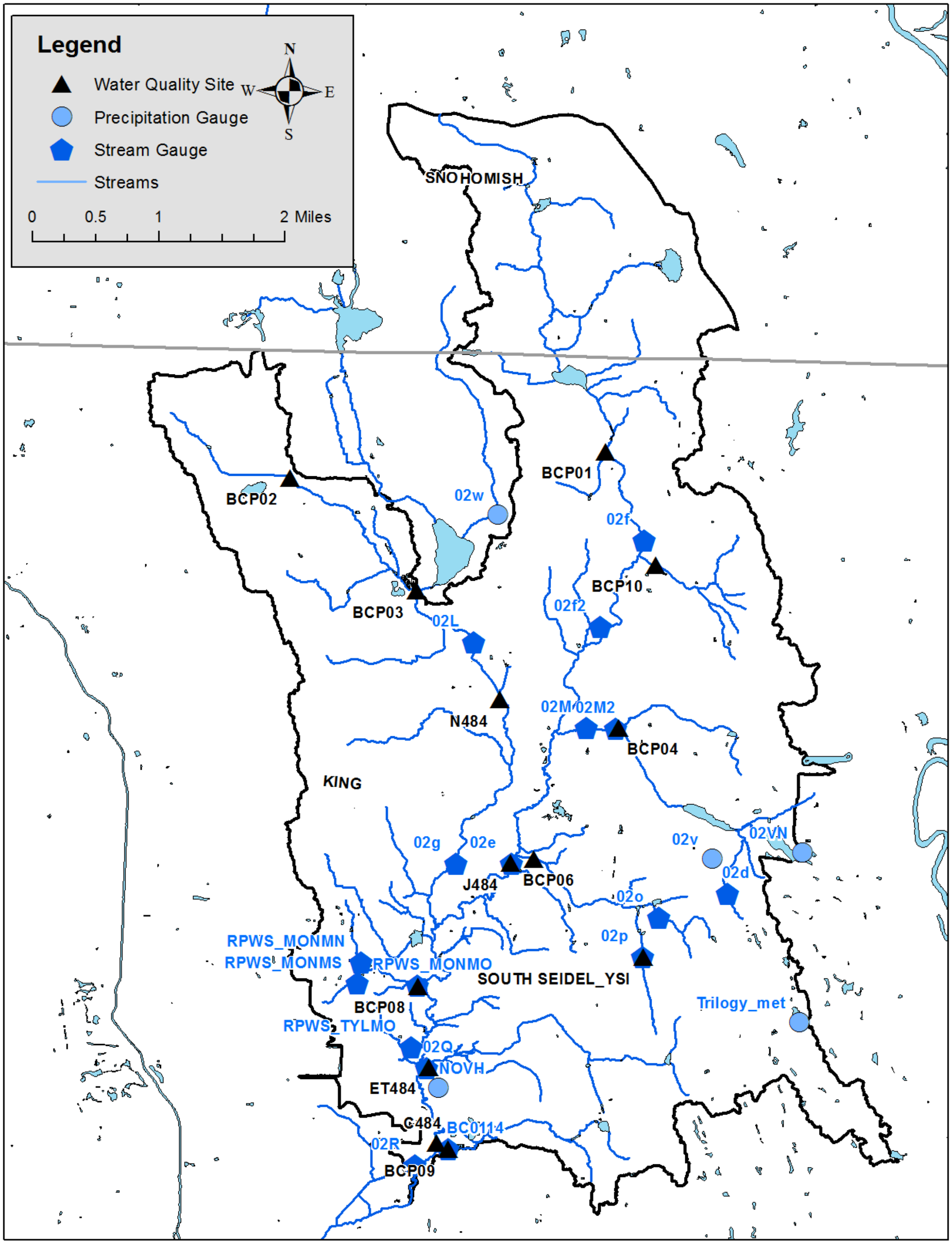

Figure 2. **Existing conditions monitoring locations. Water quality sites (13) are shown in black triangles. Stream gage sites (17) are shown with blue pentagon shapes. Precipitation gage locations (5) are shown in blue circles.**

Table 1. Station summary of monitoring locations within the study area. Thirty-five sites were monitored: 13 water quality; 17 stream flow; 5 weather / precipitation.

Type	Station		Coordinates^	
	ID	Name	Northing	Easting
Water Quality	C484*	Bear Creek - Lower	252592	1331167
	ET484	Mackey Creek	255754	1330832
	J484	Bear Creek - Middle	264277	1334271
	N484*	Cottage Lake Creek	271114	1333821
	BCP01	Bear Creek - Upper	281470	1338207
	BCP02	Cold Creek - Woodinville Limit	280362	1325067
	BCP03	Cottage Lake Outlet	275650	1330330
	BCP04	Struve Creek - East	269924	1338755
	BCP06	Seidel Creek	264453	1335222
	South Seidel_YSI	South Seidel Creek	260343	1339785
	BCP08	Monticello Creek	259136	1330378
	BCP09	Stensland Creek	252324	1331639
	BCP10	Upper Bear Trib	276729	1340305
Gage – weather station and precipitation	02V	Blakely Ridge	264452	1342677
	02Vn	Trilogy North	264691	1346448
	Trilogy_met	Trilogy weather station	257614	1346305
	NOVH	Novelty Hill	254885	1331217
	02w	Cottage Lake station	278826	1333725
Gage – stream flow and water temperature	02R	Bear Creek – Friendly Village	251651	1330256
	02d	Colin Creek	263005	1343305
	02e	Bear Creek – 133rd St NE	264261	1334284
	02f	Bear Creek – Woodinville-Duvall Rd	277752	1339828
	02f2	Bear Creek – NE 162nd	277752	1339828
	02M	Struve Creek	269915	1337424
	02M2	Struve Creek - East	269903	1338628
	02o	East Fork Seidel Creek	261985	1340446
	02P	South Fork Seidel Creek	260337	1339783
	BC0119 (RPWS_MONMO)	Monticello Creek	259154	1330344
	RPWS_MONMS	Monticello Creek – South	259293	1327858
	RPWS_MONMN	Monticello Creek - North	260122	1328000
	BC0114	Stensland Creek	252324	1331654
	RPWS_TYLMO	Tyler Creek	256570	1330101
	02Q	Mackey Creek	255723	1330752
	02G	Cottage Lake Creek – Avondale Rd	264259	1331965
	02L	Cottage Lake - NE 159th St.	273497	1332720

^ = Coordinates are presented as Washington State Plane Feet North
* refers to active long-term water quality sites in King County Streams program.

2.3 Parameters Analyzed and Summary of Sampling Events

During each round of sampling the following parameters were collected and analyzed:

- **Conventionals** (temperature, conductance, dissolved oxygen, pH, total suspended solids, turbidity),
- **nitrogen** (ammonia, nitrate+nitrite, total),
- **copper and zinc** (dissolved and total),
- **hardness** (magnesium + calcium), and
- **fecal coliform bacteria.**

Table 2 presents the date, time, and flow type for each of the sampling events and the parameters analyzed. See Appendix A for a more detailed breakdown of the sampling times. Suspended solid particle size distribution was analyzed in the first two events of baseflow and storm event flow (base: 3/4/2015 and 4/28/2015; storm: 8/29/2015 and 10/10/2015). A subset of samples were analyzed for Hu-2 Bacteroidales (HF183), a genetic indicator of human gut-associated bacteria, during the 6/25/2015, 8/29/2015, 10/15/2015, and 10/30-31/2015 events. Stream sediment samples were taken to assess the streambed particle size distribution on August 27, 2015.

Table 2. Water quality sampling schedule and parameters analyzed.

Sample Date	Time(s) Sampled	Flow Event	Number of Sample Sets[1]	Hu-2 Bacteriodales[2]	Suspended Particle Size Distribution
3/4/2015	AM & PM	Base 1	26		X
4/28/2015	AM & PM	Base 2	26		X
6/25/2015	AM*	Base 3	12*	X	
8/27/2015	PM*	Base 4	12*		
8/29-30/2015	AM,PM*,AM	Storm 1	38*	X (8/29 AM & PM)	X
10/10-11/2016	AM,PM,AM*	Storm 2	38*		X
10/15/2015	AM	Base 5	12*	X-selected sites	
10/30-31/2015	AM,PM,AM	Storm 3	39	X- selected sites	
12/3-4/2015	AM,PM,AM	Storm 4	39		
12/17-18/2015	AM,PM,AM	Storm 6	39		
12/28/2015	AM	Base 6	13		
1/13-14/2016	AM,PM,AM	Storm 6	39		

1. Conventionals (temperature, conductance, dissolved oxygen, pH, total suspended solids, turbidity), nitrogen (ammonia, nitrate+nitrite, total), copper and zinc (dissolved and total), hardness (magnesium + calcium), fecal coliform
2. Subset of sites was analyzed.
*Cold Creek (BCP02) not sampled on 6/25/2015,8/27/2015,8/29/2015 PM, 10/11/2015 AM, 10/15/2015 – due to the lack of flow.

2.4 Instantaneous Loading Estimation

Loadings of nutrients, fecal coliform bacteria, and other parameters were estimated from the gaged streams. This is useful to evaluate the relative importance of the tributaries and total load from the study. Loadings can approximate how much is leaving the study area to below the confluence with Evans Creek and eventually into the Sammamish River. Where water quality and water quantity data are available, instantaneous loads were calculated by multiplying the parameter concentration by the flow measured at the respective gage. Because flow was measured at 15-minute intervals, the flow at the time of sample collection was determined by linearly interpolating between the two adjacent flow measurements.

2.5 Comparison to Water Quality Standards

The Washington State water quality standards consist of designated uses, numeric and narrative criteria, and an antidegradation policy. Levels of fecal coliform, temperature, dissolved oxygen, pH, ammonia, metals, and organic chemicals in the samples collected were compared to respective Washington State water quality numeric criteria as outlined in WAC 173-201A-200 and 240. Bear Creek and its tributaries are designated for extraordinary primary contact recreation and have designated aquatic life uses for core summer salmonid habitat and salmonid spawning, rearing, and migration.

2.5.1 Fecal coliform bacteria

Bear Creek and its tributaries are designated for extraordinary primary contact recreation. The fecal coliform water quality numeric criteria for Bear Creek are:

> Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.

2.5.2 Temperature and Dissolved Oxygen

Temperature and dissolved oxygen (DO) levels fluctuate over the day and night in response to changes in climatic conditions and river flows. DO is additionally impacted by the respiratory requirements of aquatic plants and algae. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures and of daily minimum oxygen concentrations, the numeric criteria are expressed as the highest 7-day average of the daily maximum temperatures (7-DADMax) and 1-day minimum oxygen concentrations occurring in a water body. The beneficial uses to be protected within the Bear-Evans watershed include (1) Core Summer Salmonid Habitat and (2) Salmonid Spawning, Rearing, and Migration. The applicable temperature numeric criteria for these designated uses are contained in WAC 173-201A-200(c) as:

- To protect the designated aquatic life uses of "Core Summer Salmonid Habitat," the highest 7-DADMax temperature must not exceed 16°C (60.8°F) and 1-day minimum

DO must not fall below 9.5 mg/L at a probability frequency of more than once every ten years on average. Summer is defined as June 15 to September 15.

- To protect the designated aquatic life uses of "Salmonid Spawning, Rearing, and Migration, and Salmonid Rearing and Migration Only," the highest 7-DADMax temperature must not exceed 17.5°C (63.5°F) and 1-day minimum DO must not fall below 8.0 mg/L at a probability frequency of more than once every ten years on average.

In addition, all portions of the Bear and Cottage Lake Creeks have Supplemental Temperature Criteria and must not exceed 13°C between September 15 and May 15 (Ecology, 2011a).

Therefore to adhere to water quality standards, mainstem monitoring stations on Bear and Cottage Lake creeks have the following water quality standards in regards to temperature and dissolved oxygen:

- **May 16 – September 14**: highest 7-DADMax temperature must not exceed **16 °C** more than once every ten years on average and 1-day minimum DO must not fall below **9.5 mg/L**.
- **September 15 – May 15**: highest 7-DADMax temperature must not exceed **13 °C** more than once every ten years on average and 1-day minimum DO must not fall below **9.5 mg/L**.

All tributaries to Bear and Cottage Lake creeks have the following water quality standards in regards to temperature and dissolved oxygen:

- highest 7-DADMax temperature must not exceed **16 °C** more than once every ten years on average and 1-day minimum DO must not fall below **9.5 mg/L**.

2.5.3 pH

The Washington State water quality standards state that pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units.

2.5.4 Toxic Substances (Un-ionized Ammonia, Metals, and Organics)

Washington state has promulgated numeric water quality criteria for toxic substances "which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent upon those waters, or adversely affect public health" (WAC 173-201A-240).

The Washington State aquatic life criteria contain both acute and chronic criteria. Acute criteria may represent either an instantaneous concentration not to be exceeded at any time or a 1-hour average concentration not to be exceeded more than once every three years. Chronic criteria may represent either a 24-hour average not to be exceeded or a 4-day average not to be exceeded more than once every three years. The criteria for copper and zinc are calculated based on water hardness. To compare metals concentrations to the criteria, criteria values were calculated using the hardness value for the corresponding metal sample. The criteria for un-ionized ammonia are based on pH and temperature, and the level of un-ionized ammonia in the sample is estimated based on the total ammonia nitrogen concentration, pH, and temperature.

2.5.5 Turbidity

Turbidity is measured in "nephelometric turbidity units" or "NTUs." To meet water quality standards in Bear Creek, the maximum turbidity shall not exceed 5 NTU over background when the background is 50 NTU or less; or a 10 percent increase in turbidity when the background turbidity is more than 50 NTU.

3.0 RESULTS

The results of the existing conditions assessment are presented in this section broken up by parameter. Where applicable, a comparison to water quality standards is provided.

Water quality data are summarized in this report using Tukey boxplots. In Tukey boxplots, the thick black line represents the median, the rectangle displays the interquartile range (IQR), the whiskers represent the minimum/maximum value within 1.5*IQR of the first and third quartiles, and the points are outliers.

3.1 Discharge and Rainfall

This subsection presents discharge and rainfall data during the study period, with focus on hydrology and rainfall before and during sampling events.

In the spring and early summer of 2015 during the sampling period, flows in the Bear Creek watershed were low relative to previous years (Figure 3). Summer of 2015 was declared a statewide drought by Governor Inslee due to record low snowpack.[2] Bear Creek had periods of record low flows during this time. Fall and winter flows were similar to historic observed flows (1988-2014) with several high peak flows following intense rain events (Figures 3 and 4).

[2] http://www.governor.wa.gov/news-media/governor-declares-statewide-drought-emergency

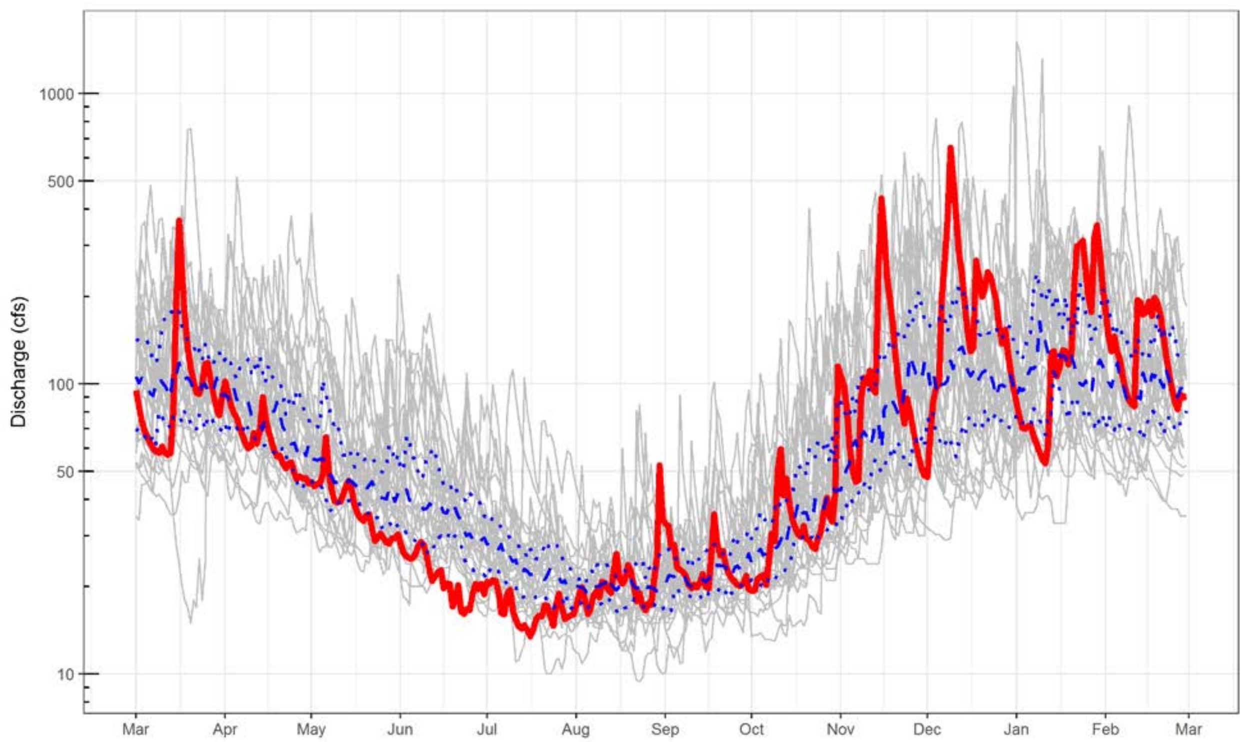

Figure 3. Daily discharge at Bear Creek below Evans Creek for March through February. 2015-2016 flow (daily discharge) data is shown in the dark red line.The grey lines are all flow regimes from 1988 to 2014. Median and 25th and 75th percentile daily flows shown in in blue lines.

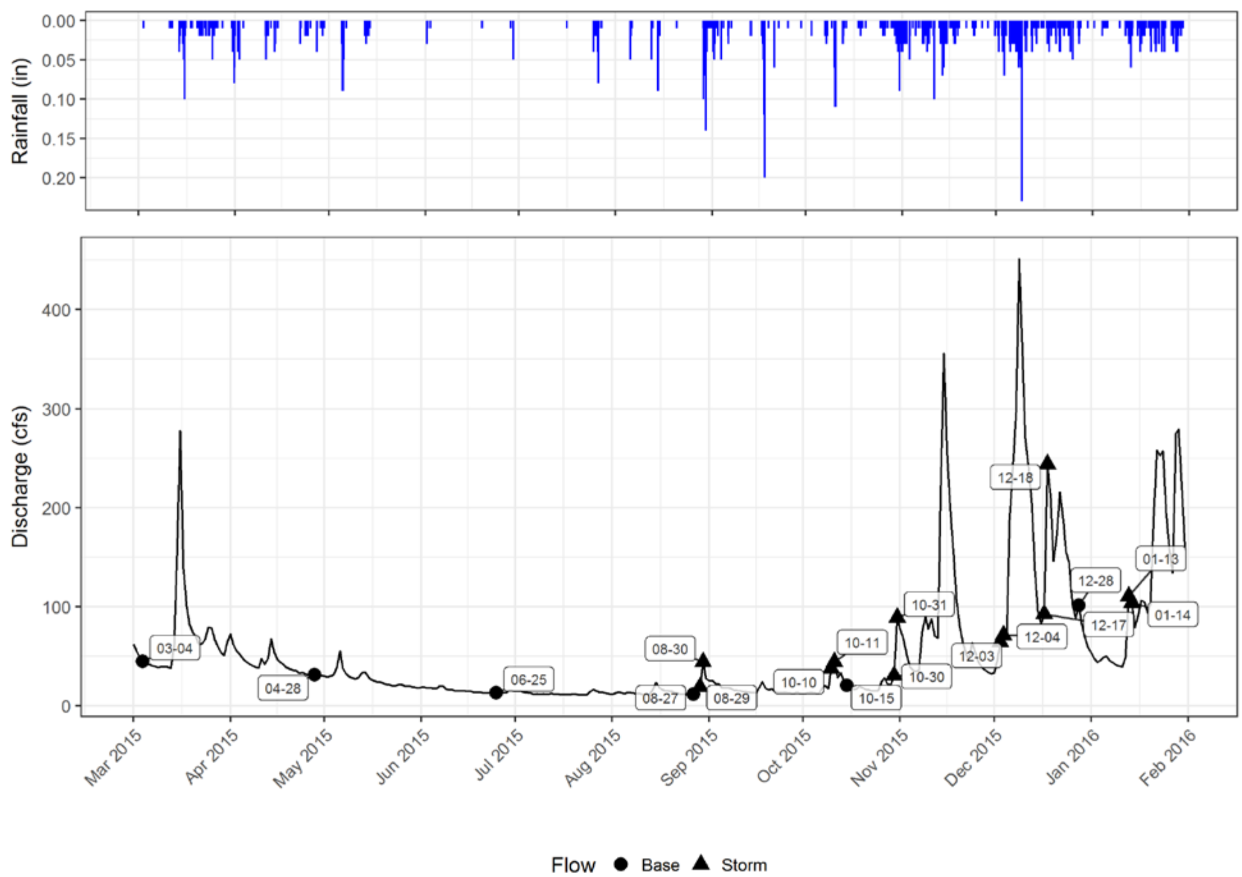

Figure 4. Rainfall at Novelty Hill rain gage and discharge at Bear Creek – Friendly Village. Sampling events and flow type shown.

Table 3 presents the 24-hour antecedent rainfall and total rainfall for each event at the Novelty Hill rain gage. Importantly, the Dec. 28 base flow event had notable levels of antecedent rainfall (0.46 in over the preceding 24 hours) and the storm sample on Dec. 17 morning had little antecedent rainfall (0.01 in over the preceding 24 hours). The hydrographs from these dates indicate that the Dec. 17 morning sample is more representative of baseflow. The Dec. 17 afternoon and Dec. 18 samples better represent wet-weather flow. The Dec. 28 sample is representative of the falling limb following a storm event.

Figure 5 provides an overview for gaged streams during the sampling period. Appendix A presents the hydrographs for nine gaged streams where water quality sampling occurring during each of the sampling events.

Table 3. Twenty-four antecedent and total rainfall for sampling events at Novelty Hill rain gage.

Date	Flow Type	24-hour antecedent Precipitation (in)	Event total (in)
03/04/2015	Base 1	0.00	0.00
04/28/2015	Base 2	0.00	0.04
3/4/2015	Base 3	0.00	0.00
08/27/2015	Base 4	0.00	0.00
08/29-30/2015	Storm 1	0.47	1.07
10/10-11/2015	Storm 2	0.32	0.61
10/15/2015	Base 5	0.00	0.00
10/30-31/2015	Storm 3	0.47	1.01
12/3-4/2015	Storm 4	0.37	0.26
12/17-18/2015	Storm 5	0.01	1.04
12/28/2015	Base 6	0.46	0.00
1/13-14/2016	Storm 6	0.62	0.29

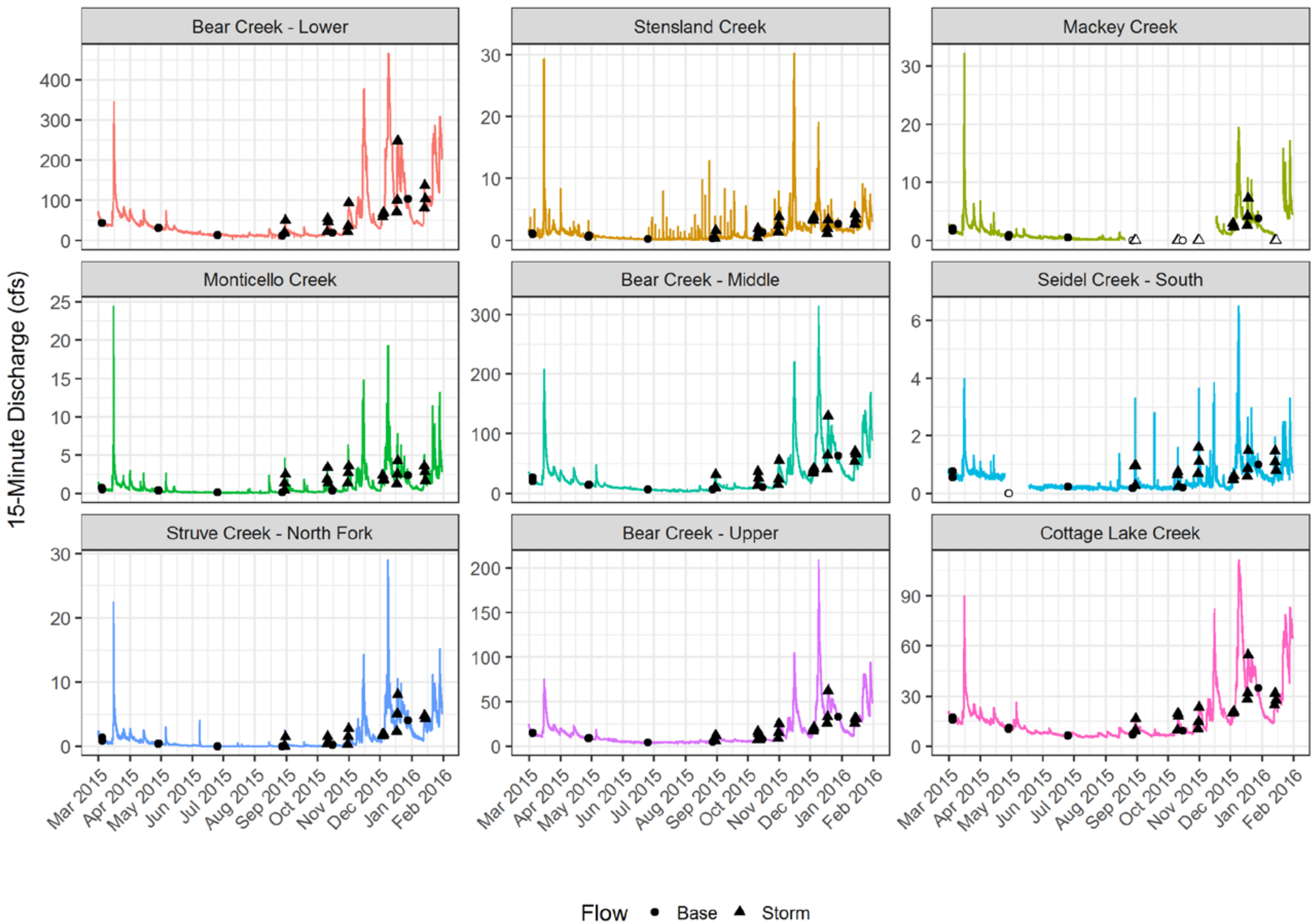

Figure 5. Hydrograph of gaged streams and sample times. Periods of no flow data indicated with no line and hollow points.

3.2 Temperature

Temperature is an important physical parameter for aquatic systems as it influences many of the chemical processes in water (e.g., dissolved oxygen concentration). Temperature also exerts a major influence on biological activity, growth, and therefore ultimately the survival of aquatic organisms.

3.2.1 Water Quality Summary

During the study period, water temperature followed the expected seasonal trend (Figure 6). Generally, wet-weather flow water temperatures were warmer than base flow samples collected around the same time. The warmest temperatures were observed at Stensland Creek (max: 20.7 °C), Upper Bear Creek (20.8 °C) and Cottage Lake outlet (20.9 °C) (Table 4). Each of these sites are shortly downstream of large areas of unshaded open water: Lower Stensland Wetland Mitigation site, Paradise Lake, and Cottage Lake, respectively.

Monitoring at the continuous water temperature sites indicate that temperatures were greater in July 2015 than July 2016 throughout the study area (Figure 7). Temperatures between the two years were otherwise similar. Temperatures were greatest furthest upstream on Bear Creek at Woodinville-Duvall Rd. (02f – maximum 26.2 °C on July 3, 2015), with downstream sites slightly cooler. The warming of Paradise Lake's open waters and the low velocity flows moving through the wetland downstream are the major factor contributing to the elevated temepratrure. The stream is likely cooled by interaction with groundwater and inputs of cooler waters (Upper Bear Trib, Struve Creek, Seidel Creek) as it travels downstream.

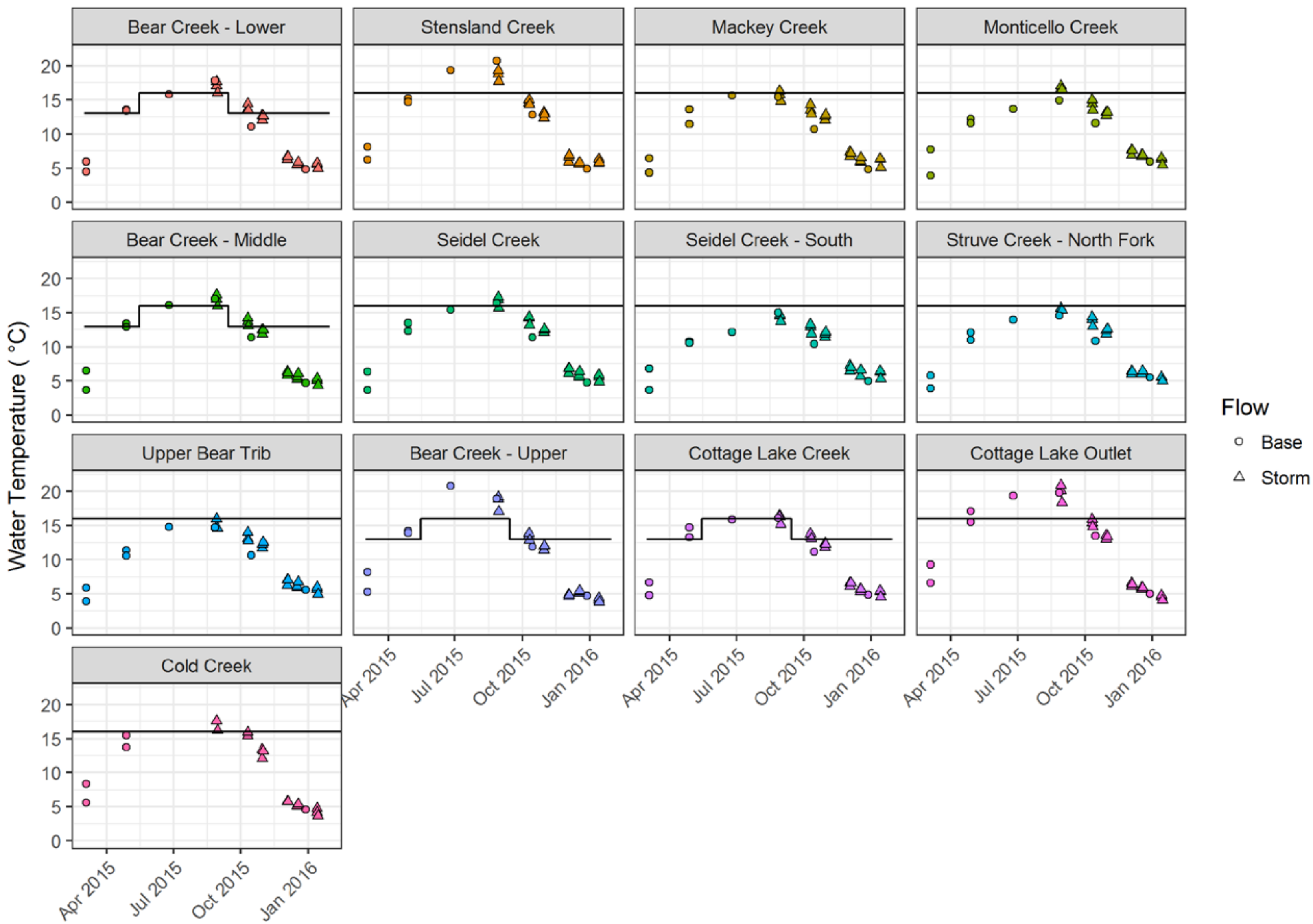

Figure 6. Water temperature in grab samples collected March 2015 to January 2016. State temperature standards shown as solid line.

Table 4. Summary statistics for water temperature grab samples taken March 2015 to January 2016. All values in degrees Celcius.

Site	ID	Flow	Samples	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	8	10.9	11.1	4.5	17.8
		Storm	18	10.1	6.7	4.9	17.7
Stensland Creek	BCP09	Base	8	12.7	12.8	4.9	20.7
		Storm	18	10.7	6.9	5.6	19.3
Mackey Creek	ET484	Base	8	10.3	10.7	4.3	15.6
		Storm	18	10.1	7.4	5.1	16.3
Monticello Creek	BCP08	Base	8	10.2	11.6	3.9	14.9
		Storm	18	10.7	7.7	5.4	17
Bear Creek - Middle	J484	Base	8	10.7	11.4	3.7	17.0
		Storm	18	9.93	6.4	4.4	17.6
Seidel Creek	BCP06	Base	8	10.5	11.4	3.7	16.4
		Storm	18	10.2	6.8	4.9	17.3
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8	9.31	10.4	3.7	15
		Storm	18	9.63	7.3	5.3	14.7
Struve Creek	BCP04	Base	8	9.72	10.9	3.9	14.6
		Storm	18	9.92	6.5	5.0	15.7
Upper Bear Trib	BCP10	Base	8	9.7	10.6	3.9	14.8
		Storm	18	9.88	7.1	5.0	16.0
Bear Creek - Upper	BCP01	Base	8	12.2	11.9	4.7	20.8
		Storm	18	9.64	5.5	3.8	19.2
Cottage Lake Creek	N484	Base	8	11	11.2	4.8	16.1
		Storm	18	9.78	6.6	4.5	16.5
Cottage Lake Outlet	BCP03	Base	8	13.3	13.5	5.0	19.8
		Storm	18	10.9	6.6	4.1	20.9
Cold Creek	BCP02	Base	5	9.56	8.4	4.6	15.5
		Storm	16	9.35	5.8	3.7	17.6

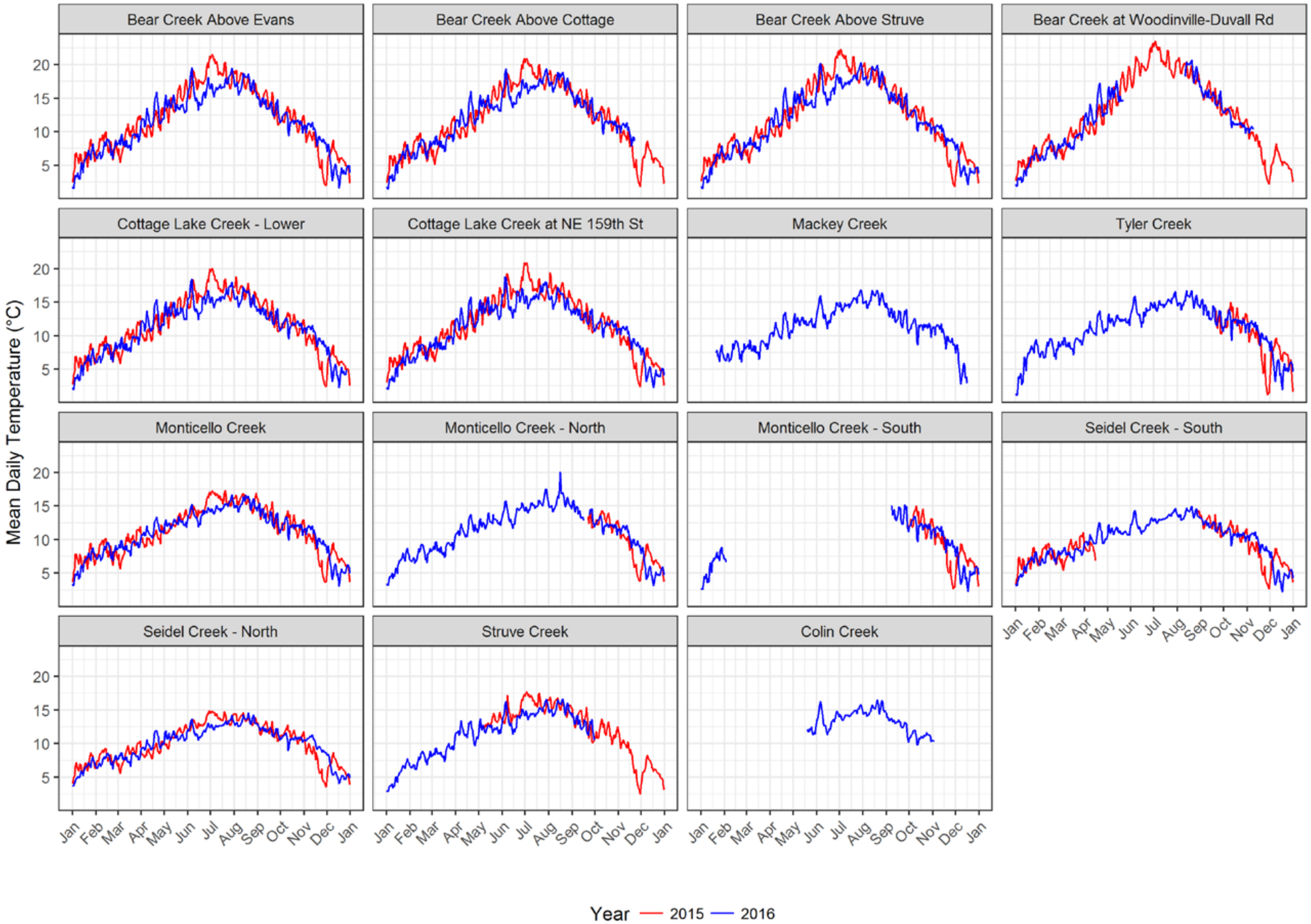

Figure 7. Mean daily temperature at continuous temperature monitoring stations in 2015 (red line) and 2016 (blue line).

3.2.2 Comparison to Water Quality Standards

At all sites except South Seidel Creek and Struve Creek East, grab sample temperatures collected in the summer were observed above 16 °C. Grab samples are not sufficient to compare to the state 7-DADMax criteria. Continuous temperature data from King County gages were used to calculate the 7-DADMax to compare to the Washington state water quality standards. In some cases, gages did not collect data throughout the entirety of the summer period (Jun. 15 – Sept. 15) or only were collected in 2015 or 2016.

Exceedances of the 16 °C water quality criterion were common throughout the study area during the summer (Table 5; Figure 8). Only the south fork of Seidel Creek was observed to have no exceedances in the summers of 2015 and 2016. Upper Bear Creek was above the standard nearly every day of the 2015 and 2016 summer periods. Cottage Lake Creek, Middle and Lower Bear Creek, and Stensland Creek, and Struve Creek were above the criterion more than 50 percent of the period(s). Mackey, Tyler's, and Monticello creeks also exceeded the standard.

Data from Water Year (WY) 2016, including that from the Redmond Paired watershed study, help support the conclusion that water temperature is a chronic concern, and not isolated to drought years, like 2015. Also data exceedances were observed for Mackey, Tyler's, Colin, and south Monticello sites that started monitoring temperature in 2016 (Table 5).

Table 5. Number of days with 7-DADMax exceedances during the summer periods (June 15 – Sept. 15) in 2015 and 2016.

Site	Gage ID	2015			2016		
		Days Monitored	Days Above 16 °C	Fraction Above	Days Monitored	Days Above 16 °C	Fraction Above
Bear Creek Above Evans	02R	93	**87**	0.94	93	**72**	0.77
Mackey Creek	02Q	Started in WY2016			93	**37**	0.40
Tyler's Creek	RPWS_ TYLMO	Started in WY2016			93	**30**	0.32
Monticello Creek – Mouth	BC0119	93	**68**	0.73	93	**32**	0.34
Monticello Creek – North	RPWS_ MONMN	Started in WY2016			93	**34**	0.37
Monticello Creek – South	RPWS_ MONMS	Started in WY2016			8	**1**	0.12
Bear Creek Above Cottage Creek	02e	93	**87**	0.94	93	**74**	0.80
Seidel Creek – North	02o	93	0	0.00	93	0	000
Seidel Creek – South	02p	21	0	0.00	93	0	0.00
Struve Creek	02M	93	**60**	0.65	93	**30**	0.32
Colin Creek	RPWS_	Started in WY2016			93	**14**	0.15

Site	Gage ID	2015			2016		
		Days Monitored	**Days Above 16 °C**	**Fraction Above**	**Days Monitored**	**Days Above 16 °C**	**Fraction Above**
	COLM						
Bear Creek Above Struve	02f2	93	**93**	1.00	93	**88**	0.95
Bear Creek at Woodinville-Duvall Rd	02f	93	**93**	1.00	36	**36**	1.00
Cottage Lake Creek – Lower	02g	93	**80**	0.86	93	**53**	0.57
Cottage Lake Creek at NE 159th St	02L	93	**82**	0.88	93	**66**	0.71

Due to high water temperatures throughout Bear Creek, Ecology established a Total Maximum Daily Load (TMDL) in 2011 for Bear and Cottage Lake creeks, which "prescribes restoring system potential mature riparian shade, increasing infiltration of stormwater, and reducing the amount of effective impervious surface in the watershed" (Ecology, 2011). The continuous temperature data in 2015 and 2016 in Bear Creek confirms that temperature continues to be a widespread water quality issue in the basin.

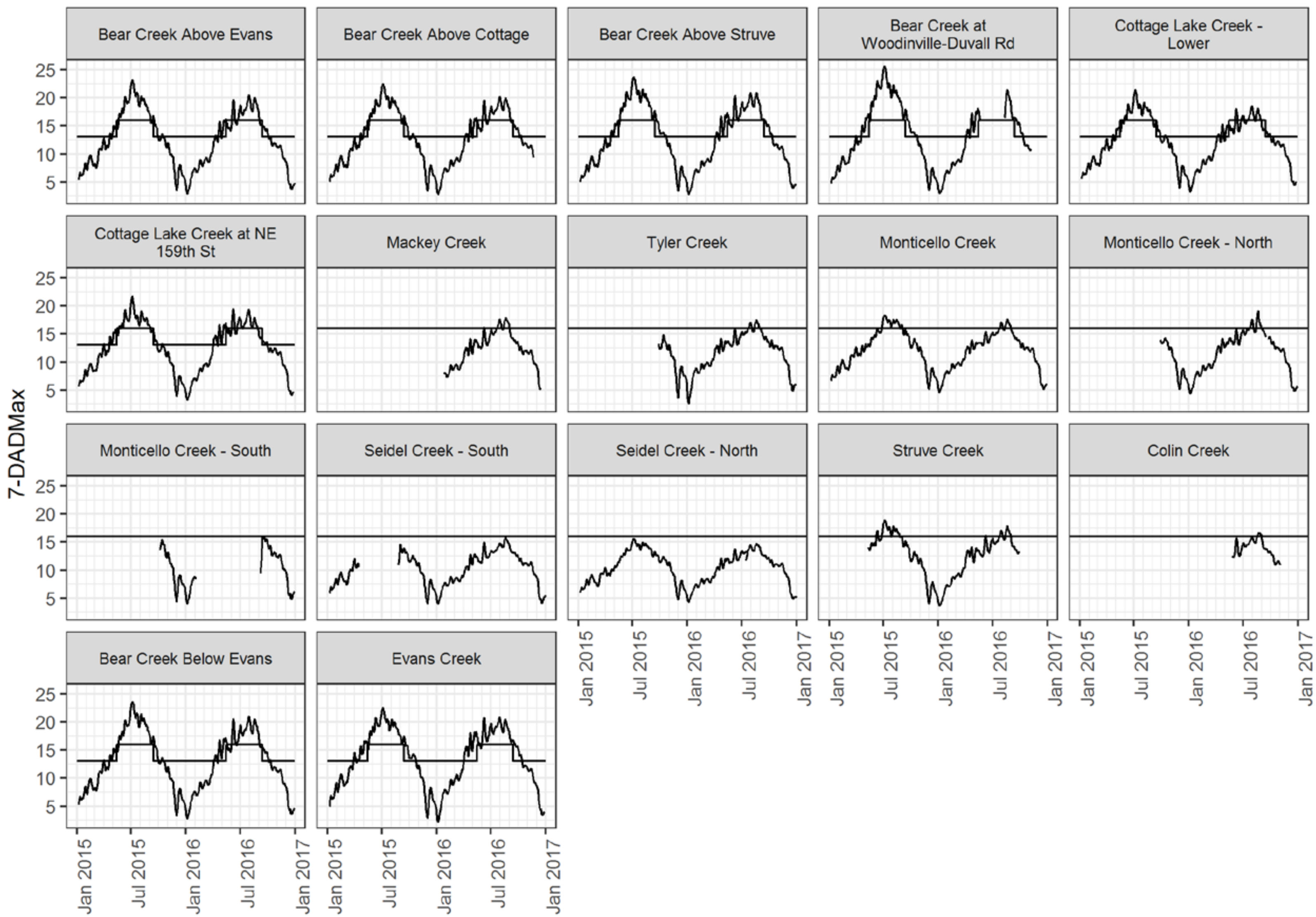

Figure 8. Seven-day average daily maximum temperature at continuous temperature gages in study area. State temperature standards shown as solid line.

3.3 Dissolved Oxygen

Dissolved oxygen is important to many of the chemical processes that are important in the aquatic environment. The concentration of dissolved oxygen is also important in determining the amount of habitat available for different types of aquatic organisms.

3.3.1 Water Quality Summary

Generally, dissolved oxygen concentrations did not differ greatly during baseflow and storm event flow. Storm dissolved oxygen levels were lower than base flow in Stensland Creek and Upper Bear Creek. However, Stensland Creek had supersaturated base flow dissolved oxygen concentrations that were higher than the other sites. These high levels were likely driven by photosynthetic activity in upstream Stensland Creek wetlands. Large mats of algae have been observed in the Stensland Creek wetlands (UW Green Futures Lab, 2013). Sampling did not capture the expected oxygen minimum during nighttime respiration or from the decomposition of the algae (Odum, 1956).

Dissolved oxygen at Upper Bear Creek and the Cottage Lake outlet appear lower compared to the other sites in the study area (Figure 9; Table 6). The low oxygen levels at the Cottage Lake outlet and upper Bear Creek were likely influenced by the upstream lakes (Cottage and Paradise), whose large unshaded surface area are exposed to greater radiative warming and therefore more likely to have lower dissolved oxygen. Additionally, detritus from the lakes and the nearby wetlands may contribute additional biological oxygen demand.

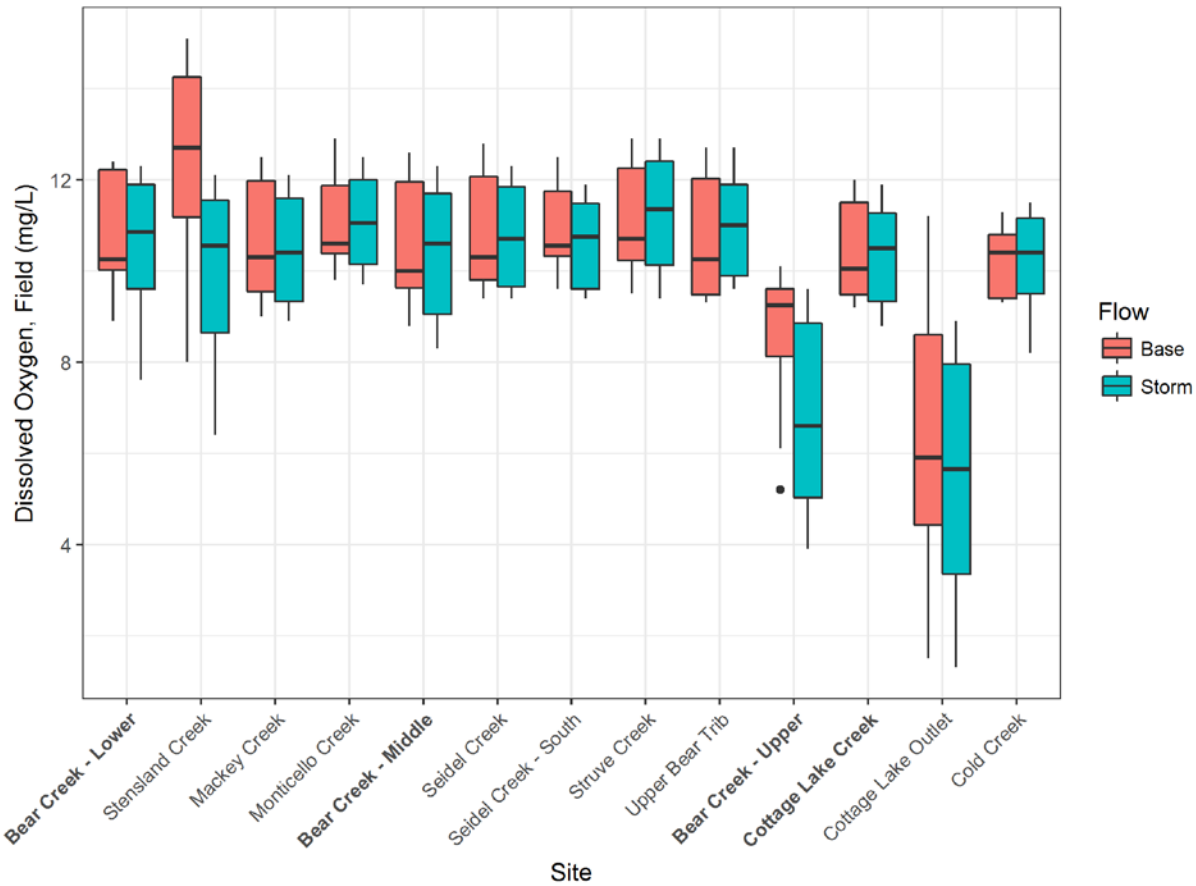

Figure 9. Dissolved oxygen concentrations grab samples taken March 2015 to January 2016. Mainstem Bear and Cottage sites shown in bold.

Table 6. Summary statistics for dissolved oxygen grab samples taken March 2015 to January 2016. All values in mg/L.

Site	Locator	Flow	Samples	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	8	10.8	10.2	8.9	12.4
		Storm	18	10.6	10	7.6	12.3
Stensland Creek	BCP09	Base	8	12.3	12	8	15.1
		Storm	18	9.99	10.2	6.4	12.1
Mackey Creek	ET484	Base	8	10.6	10.1	9	12.5
		Storm	18	10.5	9.7	8.9	12.1
Monticello Creek	BCP08	Base	8	11.1	10.5	9.8	12.9
		Storm	18	11.1	10.4	9.7	12.5
Bear Creek - Middle	J484	Base	8	10.6	9.9	8.8	12.6
		Storm	18	10.4	9.7	8.3	12.3
Seidel Creek	BCP06	Base	8	10.8	10.3	9.4	12.8
		Storm	18	10.8	10	9.4	12.3
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8	10.9	10.5	9.6	12.5
		Storm	18	10.6	10.2	9.4	11.9

Site	Locator	Flow	Samples	Mean	Median	Min	Max
Struve Creek	BCP04	Base	8	11.1	10.7	9.5	12.9
		Storm	18	11.3	10.6	9.4	12.9
Upper Bear Trib	BCP10	Base	8	10.7	10.2	9.3	12.7
		Storm	18	11	10.2	9.6	12.7
Bear Creek - Upper	BCP01	Base	8	8.49	9.2	5.2	10.1
		Storm	18	6.71	5.8	3.9	9.6
Cottage Lake Creek	N484	Base	8	10.4	9.9	9.2	12
		Storm	18	10.4	9.9	8.8	11.9
Cottage Lake Outlet	BCP03	Base	8	6.3	5.5	1.5	11.2
		Storm	18	5.46	5.6	1.3	8.9
Cold Creek	BCP02	Base	5	10.2	10.4	9.3	11.3
		Storm	16	10.3	10.4	8.2	11.5

3.3.2 Comparison to Water Quality Standards

Continuous dissolved oxygen data was not available to calculate the daily minimum dissolved oxygen concentration. Generally, diurnal dissolved oxygen minima occur in the mid-morning and levels increase through mid-afternoon (Ecology, 2011). It is therefore likely that the morning sampling as part of this study is approximate to the daily minima.

Dissolved oxygen levels below the state criterion were detected at all sites except Monticello Creek (Table 7; Figure 10). Upper Bear Creek and Cottage Lake outlet had the greatest frequency of not meeting the standard. When multiple samples were collected on the same day, the lowest value was compared to the standards.

Due to low dissolved oxygen throughout Bear Creek, Ecology has established a Total Maximum Daily Load (TMDL) in 2001 for Bear and Cottage Lake creeks, which “prescribes restoring system potential mature riparian shade, increasing infiltration of stormwater, and reducing the amount of effective impervious surface in the watershed” (Ecology, 2011). Ecology (2011) determined that the warm surface water temperature was the principal driver of low dissolved oxygen and decreasing surface temperatures would improve dissolved oxygen levels. Monitoring data confirms that low dissolved oxygen is a concern in the basin.

Table 7. Number of days with dissolved oxygen standard violations during the summer standard period (Jun. 15 – Sept. 15). When multiple samples were collected on the same day, the lowest value was compared to the standards.

Site	Locator	Summer (Jun. 15 – Sept. 15)			Non-Summer		
		Days Monitored	Number of Days <9.5 mg/L	Fraction	Days Monitored	Number of Days <9.5 mg/L	Fraction
Bear Creek - Lower	C484	3	2	0.67	9	1	0.11
Stensland Creek	BCP09	3	2	0.67	9	3	0.33
Mackey Creek	ET484	3	3	1.00	9	2	0.22
Monticello Creek	BCP08	3	0	0.00	9	0	0.00
Bear Creek - Middle	J484	3	3	1.00	9	2	0.22
Seidel Creek	BCP06	3	2	0.67	9	0	0.00
Seidel Creek - South	SOUTH SEIDEL_YSI	3	1	0.33	9	1	0.11
Struve Creek	BCP04	3	1	0.33	9	0	0.00
Upper Bear Trib	BCP10	3	1	0.33	9	1	0.11
Bear Creek - Upper	BCP01	3	3	1.00	9	8	0.89
Cottage Lake Creek	N484	3	2	0.67	9	3	0.33
Cottage Lake Outlet	BCP03	3	3	1.00	9	8	0.89
Cold Creek	BCP02	1	1	1.00	8	2	0.22

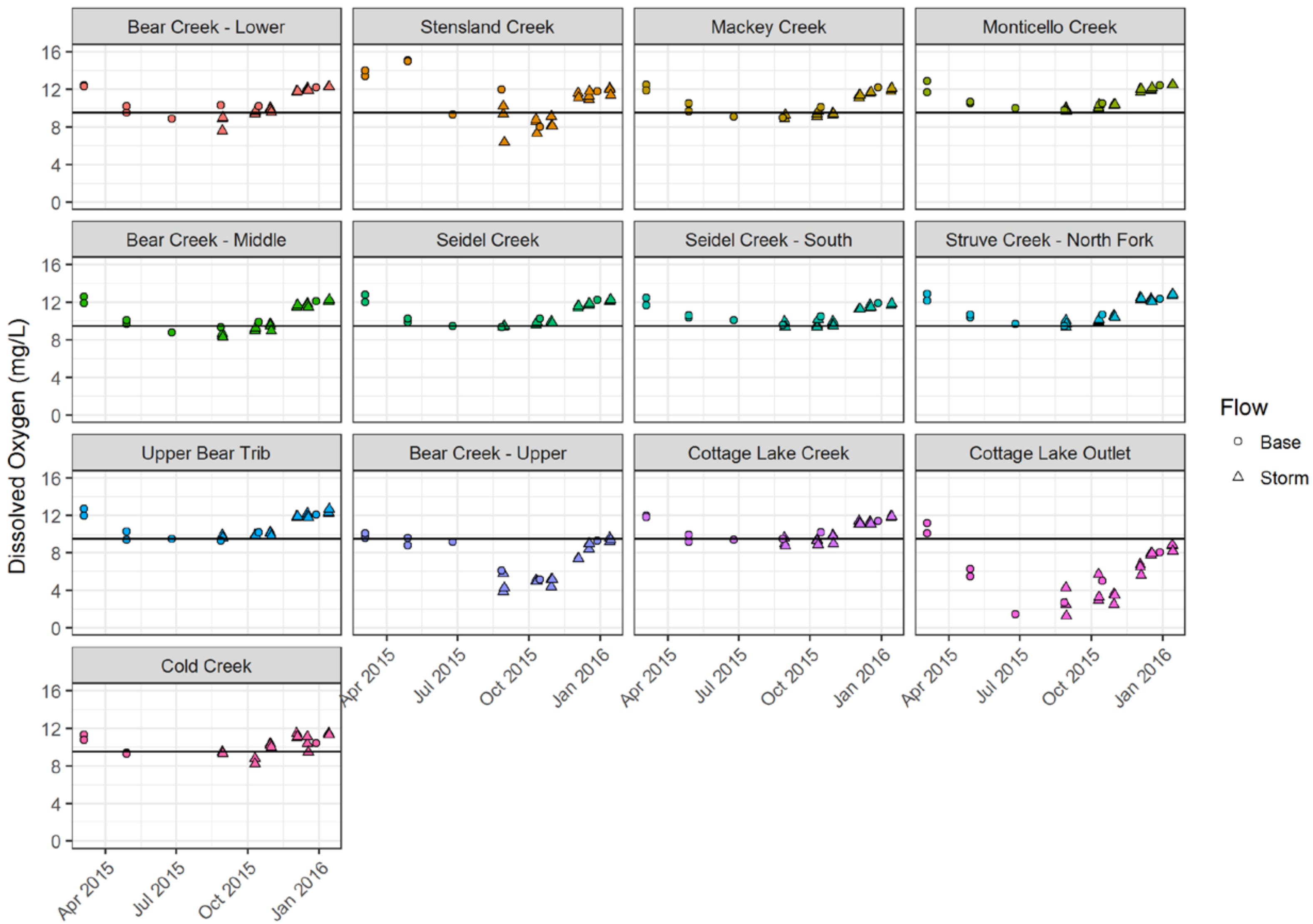

Figure 10. Dissolved oxygen in grab samples at study area sample sites. State DO standard of 9.5 mg/L shown as solid horizontal line. See Table 8 for number of days state standards were not met.

3.4 Fecal Coliform

The surface Water Quality Standards for the State of Washington (WAC 173-201A) contain bacteria criteria designed to reduce the chance of people becoming ill from eating shellfish, swimming, or wading in the waters of the state. The current criterion for bacterial pollution is based on using fecal coliform as an indicator of public health risk to swimmers.

While specific indicator bacteria may not be pathogenic to humans, their presence indicates the potential presence of pathogenic bacteria and viruses that occur in conjunction with the indicator bacteria. Most fecal coliform bacteria do not cause disease, but co-exist in the intestines with disease-carrying pathogens that pose a public health risk. The higher the fecal bacteria counts, the higher the probability of pathogenic bacteria pollution. A problem with the fecal coliform tests is that they also enumerate the non-fecal *Klebsiella* bacteria. These bacteria are non-pathogenic, and their enumeration can result in overstating health risks, particularly in bathing waters with a high wood waste component.

3.4.1 Water Quality Summary

Concentrations of fecal coliform bacteria were generally higher during wet-weather flow than baseflow by (Figure 11; Table 8). Concentrations ranged from 1 to 46, 000 CFU/100 mL. The greatest concentration was observed at Mackey Creek on Aug. 29, 2015 during the morning. 14,000 CFU/100 mL was observed at South Seidel Creek on the morning of the same date. These maxima follow a 2-week dry period ending with a 1.7 inch rain event (0.4 inches of which fell in the morning prior to sampling the study area. Elevated values were seen throughout the study area that morning, indicating this was a first-flush event.

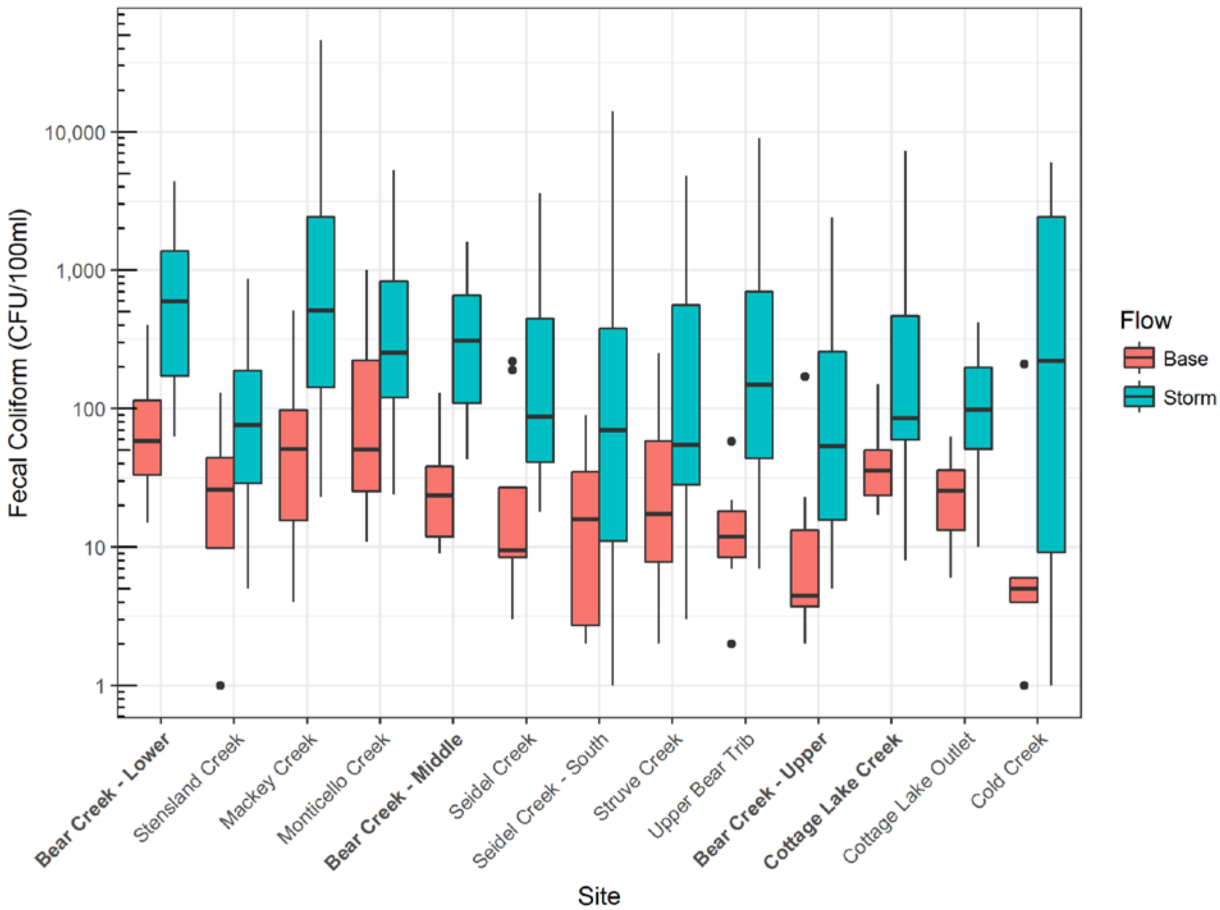

Figure 11. Fecal coliform concentrations were greater during storms than baseflow in grab samples taken March 2015 to January 2016. Mainstem Bear and Cottage sites shown in bold. Note log-scale.

Table 8. Summary statistics for fecal coliform grab samples taken March 2015 to January 2016. All values in CFU/100 mL.

Site	ID	Flow	Detections	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	8/8	114	51	15	400
		Storm	18/18	1160	520	63	4400
Stensland Creek	BCP09	Base	7/8	38	25	<1	130
		Storm	18/18	190	72	5	870
Mackey Creek	ET484	Base	8/8	122	50	4	510
		Storm	18/18	3560	510	23	46,000
Monticello Creek	BCP08	Base	8/8	241	34	11	1000
		Storm	18/18	887	200	24	5300
Bear Creek - Middle	J484	Base	8/8	36.9	19	9	130
		Storm	18/18	522	300	43	1600
Seidel Creek	BCP06	Base	8/8	57.8	9	3	220
		Storm	18/18	424	59	18	3600

Site	ID	Flow	Detections	Mean	Median	Min	Max
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8/8	26.4	9	2	90
		Storm	18/18	1280	41	1	14,000
Struve Creek	BCP04	Base	8/8	52.4	15	2	250
		Storm	18/18	549	51	3	4800
Upper Bear Trib	BCP10	Base	8/8	17.4	10	2	58
		Storm	18/18	908	140	7	9000
Bear Creek - Upper	BCP01	Base	8/8	27.8	4	2	170
		Storm	18/18	290	51	5	2400
Cottage Lake Creek	N484	Base	8/8	48.4	27	17	150
		Storm	18/18	715	81	8	7300
Cottage Lake Outlet	BCP03	Base	8/8	28.1	21	6	63
		Storm	18/18	134	88	10	420
Cold Creek	BCP02	Base	5/5	45.2	5	1	210
		Storm	16/16	1360	96	1	6000

Hu-2 Bacteroidales

In addition to fecal coliform bacteria, a subset of samples were analyzed for the Hu-2 Bacteroidales genetic marker (Hu-2). Hu-2 provides evidences for the presence of fecal bacteria associated with the human gut. Elevated levels can indicate human fecal contamination due to failing septic systems, illicit sewer connections or discharges, or human feces otherwise entering surface waters.

For this work, a subset of the total samples collected was analyzed for Hu-2. Fifty-seven of 333 samples were analyzed for the genetic marker. All sites were analyzed for base flow event 3 and storm event 1, rounds 1 and 2. Five sites had additional analyses done for base flow event 5 and storm event 3 all rounds. Appendix B presents the fecal coliform bacteria and Hu-2 levels for each sample analyzed.

A significant positive relationship between fecal coliforms and the genetic tracer was found (Kendall's tau: 0.37; p=0.0001). However, high fecal coliforms do not necessitate high Hu-2 levels. For example, 46,000 CFU/100 mL fecal coliforms were detected at Mackey Creek on Aug. 29, 2015 AM and 0.66 copies/mL Hu-2 were detected, but on the same day 1,400 CFU/100 mL fecal coliforms were detected in Lower Bear Creek and 840 copies/mL Hu-2 were detected. While related, fecal coliform is not a good predictor of Hu-2.

At this time, there is no explicit threshold for the genetic tracer that reliably indicates significant contamination or unacceptable public health risk. Converse et al. (2009) proposed an action value of 50 copies/mL to initiate additional source tracking. A more conservative threshold of 10 copies/mL has been used by King County during its microbial source tracking work (D. Bouchard, pers. comm., 11/10/2016). Lower Bear Creek, Mackey Creek, and South Seidel Creek were the sites where values above 10 copies/mL were detected. These detections were during two of the five storm events sampled:

- Aug. 29, 2015 at Lower Bear Creek (840 copies/mL) and South Seidel Creek (16 copies/mL); and
- Oct. 30, 2015 at Lower Bear Creek (170 and 84 copies/mL) and Mackey Creek (28 and 15 copies/mL).

No base flow event had Hu-2 values above 10 copies/mL (Table 9).

These findings indicate compelling evidence of human fecal material entering Lower Bear Creek and the possible presence of human fecal material entering Mackey Creek and South Seidel Creek. The area draining to South Seidel Creek is primarily forested with a system of hiking trails, and the likely sources would be defecation associated with homeless encampments or hikers. Mackey Creek drains low-density residential development in its lower reaches and forested land further upland; illicit connections and leaking septic systems would be likely sources of contamination. Because Lower Bear Creek drains a large area, it is difficult to determine sources of contamination; illicit connections or leaking septic systems near the mainstem or its tributaries are likely contributors. Further sampling is required to confirm these sources. Middle Bear Creek and Cottage Lake Creek do not appear to have substantial levels of human feces-associated bacteria and therefore are not likely contributing to the levels seen in Lower Bear Creek.

Table 9. Summary statistics for Hu-2-Bacteriodales grab samples taken June 2015 to October 2015. All values in copies/mL.

Site	ID	Flow	Detections	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	2/2	1.38	–	0.47	2.3
		Storm	5/5	220	84	1	840
Stensland Creek	BCP09	Base	0/1	ND	ND	<0.01	<0.01
		Storm	0/2	ND	ND	<0.01	<0.01
Mackey Creek	ET484	Base	2/2	1.43	NA	0.66	2.2
		Storm	5/5	10.1	5.4	0.66	28
Monticello Creek	BCP08	Base	1/2	0.19	–	<0.01	0.19
		Storm	5/5	3.59	1.2	0.28	9.1
Bear Creek - Middle	J484	Base	0/2	ND	ND	<0.01	<0.01
		Storm	4/5	1.3	1.3	0.66	2.3
Seidel Creek	BCP06	Base	1/1	0.95	–	0.95	0.95
		Storm	2/2	0.805	–	0.76	0.85
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	0/1	ND	ND	<0.01	<0.01
		Storm	2/2	8.1	–	0.19	16
Struve Creek	BCP04	Base	1/1	1	–	1	1
		Storm	1/2	2.3	NA	<0.01	2.3
Upper Bear Trib	BCP10	Base	0/1	ND	ND	<0.01	<0.01
		Storm	2/2	0.975	–	0.95	1
Bear Creek - Upper	BCP01	Base	0/1	ND	ND	ND	ND
		Storm	1/2	0.19	–	<0.01	0.19
Cottage Lake Creek	N484	Base	1/2	0.66	–	0.66	0.66

Site	ID	Flow	Detections	Mean	Median	Min	Max
		Storm	3/5	1.03	0.47	<0.01	3.1
Cottage Lake Outlet	BCP03	Base	0/1	ND	ND	<0.01	<0.01
		Storm	0/2	ND	ND	<0.01	<0.01
Cold Creek	BCP02	Storm	0/1	ND	ND	<0.01	<0.01

ND - non-detect
* - refers to sites with additional analyses

3.4.2 Comparison to Water Quality Standards

All 13 monitored sites exceeded the fecal coliform 90th percentile criterion (100 CFU/100 mL), and 10 of 13 monitored sites exceeded the geometric mean criterion (50 CFU/100 mL). Stensland Creek, South Seidel Creek, and Upper Bear Creek had geometric means below the numeric criterion (Table 10).

Due to bacteria issues throughout Bear Creek, Ecology has established a Total Maximum Daily Load (TMDL) for fecal coliform bacteria. The TMDL set bacteria reduction goals relative to 2007 loadings of six stream sites (three are outside the study area) to meet the extraordinary primary contact standard by December, 2015 (Ecology, 2011). There are:

- 76% reduction for Cottage Lake Creek (N484)
- 57% reduction for Middle Bear Creek (J484)
- 78% reduction for Lower Bear Creek (C484)
- *91% reduction for Upper Evans Creek (outside study area)*
- *63% reduction for Lower Evans Creek (outside study area)*
- *88% reduction for Bear Creek below Evans (outside study area)*

Table 10. Comparison to state geometric and 90th percentile fecal coliform standards. Bold values are greater than state standard. All values in CFU/100 mL.

Site	ID	Geometric Mean[1]	90th Percentile[2]
Bear Creek - Lower	C484	**280**	**2850**
Stensland Creek	BCP09	48	**465**
Mackey Creek	ET484	**250**	**3250**
Monticello Creek	BCP08	**193**	**1400**
Bear Creek - Middle	J484	**134**	**1400**
Seidel Creek	BCP06	**72**	**640**
Seidel Creek - South	SOUTH SEIDEL_YSI	46	**2050**
Struve Creek – North Fork	BCP04	**61**	**800**
Upper Bear Trib	BCP10	**78**	**1050**
Bear Creek - Upper	BCP01	35	**410**
Cottage Lake Creek	N484	**101**	**1050**
Cottage Lake Outlet	BCP03	**57**	**220**
Cold Creek	BCP02	**68**	**3300**

1. Washington state geometric mean standard: 50 CFU/100 mL
2. Washington state 90th percentile standard: 100 CFU/100 mL

3.4.3 Instantaneous Loading

Fecal coliform loading during storms was greater than that of base flow in all gaged streams by one to two orders of magnitude (Figure 12). Results indicate that Middle Bear and Cottage Lake creeks are important pathways of fecal coliforms to Lower Bear Creek (Table 11). There are several additional pathways not accounted for: chiefly, the stormwater discharge and runoff of pasture into lower Bear Creek, in some cases, exceeds the loading from the gaged streams.

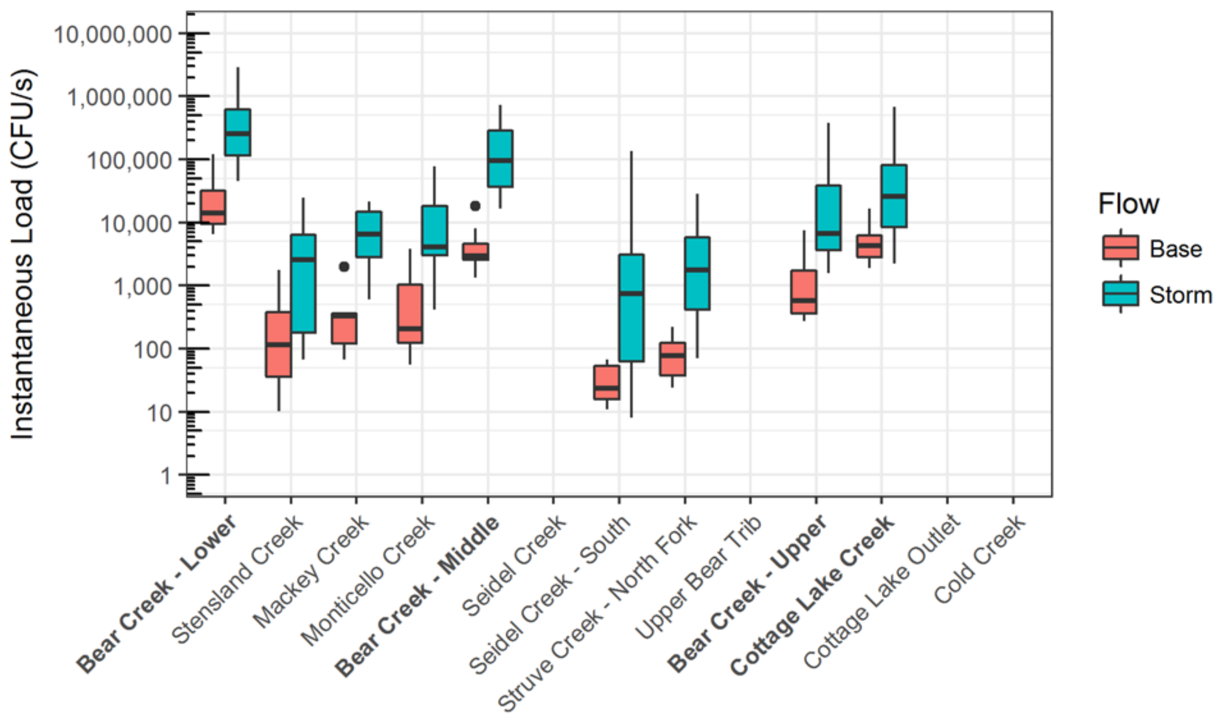

Figure 12. Instantaneous loadings of fecal coliform bacteria from gaged streams. Mainstem Bear and Cottage sites shown in bold. Note log-scale.

Table 11. Fecal coliform load to Lower Bear Creek from gaged streams and from Lower Bear Creek per sampling event. All values in 1000s of CFU/s. Difference between load from and load into color-coded where red indicates the calculated load leaving lower Bear Creek is greater than the calculated load from the upstream gaged streams and green indicates vice versa.

Event	Date	Bear Creek – Lower Load	Sum Upstream	Difference (Bear Creek Lower – Upstream)	Bear Creek - Middle	Cottage Lake Creek	Monti-cello Creek	Mackey Creek
Base 1	3/4/2015 AM	**6.5**	**7.5**	-1	2.4	4.7	NC	0.4
	3/4/2015 PM	**6.5**	**6.9**	-0.4	2.7	3.9	NC	0.1
Base 2	4/28/2015 AM	**120**	**7.2**	113	2.6	5.3	NC	0.3
	4/28/2015 PM	**16**	**3.3**	13	1.3	1.9	NC	0.1
Base 3	6/25/2015 AM	**29**	**12**	17	8.1	3.2	NC	0.3
Base 4	8/27/2015 AM	**11**	**14**	-3	3.3	11	NC	NC
Storm 1	8/29/2015 AM	**260**	**810**	-550	140	670	NC	NC
	8/29/2015 PM	**270**	**80**	190	35	45	NC	NC
	8/30/2015 AM	**2,200**	**680**	1,500	510	170	NC	NC
Storm 2	10/10/2015 AM	**560**	**230**	330	43	110	78	NC
	10/10/2015 PM	**2,100**	**830**	1,300	510	290	31	NC
	10/11/2015 AM	**240**	**170**	70	78	85	6.7	NC
Base 5	10/15/2015 AM	**13**	**8**	5	3.8	1.9	0.3	NC
Storm 3	10/30/2015 AM	**79**	**33**	46	18	7.6	7	NC
	10/30/2015 PM	**250**	**150**	100	120	27	3.5	NC
	10/31/2015 AM	**2,900**	**500**	2,400	400	72	25	NC
Storm 4	12/03/2015 AM	**99**	**41**	58	17	7.5	2.9	15
	12/03/2015 PM	**66**	**56**	10	42	11	0.6	2.7
	12/04/2015 AM	**200**	**31**	170	18	7.3	2.2	3.1
Storm 5	12/17/2015 AM	**45**	**40**	5	33	2.2	4.4	0.6
	12/17/2015 PM	**98**	**88**	10	58	4.5	4.1	21
	12/18/2015 AM	**350**	**200**	150	140	39	3.4	14
Base 6	12/28/2015 AM	**44**	**40**	4	18	16	3.8	2
Storm 6	1/13/2016 AM	**650**	**760**	-110	730	22	7.2	NC
	1/13/2016 PM	**1,100**	**390**	700	360	26	1	NC
	1/14/2016 AM	**190**	**170**	20	150	21	0.4	NC

"NC" = Not calculated due to lack of continuous flow data at the time of water quality sampling.

3.5 Total Suspended Solids and Turbidity

Turbidity and total suspended solids (TSS) are two indicators used to estimate the amount of suspended material in the water, whether it is mineral (e.g., soil particles) or organic (e.g., algae). Particulate matter provides attachment places for pollutants such as metals or bacteria to enter the receiving water. High concentrations of particulate matter can result in increased sedimentation that can impair important habitat for fish and invertebrates. In general, human activities within the watershed usually result in higher turbidity and TSS measurements (e.g., development results in loss of vegetation, increased erosion, and runoff). High flow events can also cause soil and bank erosion.

TSS is a measure of the actual weight of material per volume of water and is reported in milligrams per liter. This measurement becomes important when trying to calculate total quantities of material in a stream, or when trying to determine the loading of particulate matter into receiving waters. Turbidity is measured as the amount of light scattered in a water sample and is reported as nephelometric turbidity units (NTU). In general, the more material in the water, the greater the light scattering and higher NTU reading.

3.5.1 Water Quality Summary

Turbidity and TSS were generally higher during wet-weather flow (Tables 12 and 13; Figures 13 and 14). The highest TSS measured was in Monticello Creek during a storm event on Oct. 30, 2015. The highest turbidity was measured in Cold and Monticello creeks during the Oct. 30, 2015 storm event. TSS ranged from less than 0.5 mg/L to 163 mg/L, and turbidity ranged from 0.6 NTU to 53 NTU.

Table 12. Summary statistics for total suspended solids grab samples taken March 2015 to January 2016. All values in mg/L.

Site	Locator	Flow	Detections	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	8/8	5.51	4.6	2	10.2
		Storm	18/18	25.3	16.3	3.5	92.4
Stensland Creek	BCP09	Base	8/8	2.22	1.54	1	3.4
		Storm	18/18	2.01	1.3	0.6	4.6
Mackey Creek	ET484	Base	8/8	4.16	2.39	0.5	12.7
		Storm	18/18	10.7	7.1	2.4	32.6
Monticello Creek	BCP08	Base	7/8	3.34	1.63	<0.5	10.6
		Storm	18/18	75.9	64.4	2.5	163
Bear Creek - Middle	J484	Base	8/8	3.38	2.59	1.4	8.55
		Storm	18/18	9.51	5.16	2.8	35.3
Seidel Creek	BCP06	Base	6/8	1.19	1.16	<0.5	1.59
		Storm	18/18	9.02	4.3	0.9	27.1
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8/8	4.81	4.5	1.6	8.2
		Storm	18/18	23.1	7.2	1.6	85.1
Struve Creek	BCP04	Base	8/8	1.47	1.2	0.5	3
		Storm	18/18	9.43	4.8	1.2	48.4
Upper Bear Trib	BCP10	Base	8/8	1.44	1.3	0.9	2.63
		Storm	18/18	13	8.9	0.8	51
Bear Creek - Upper	BCP01	Base	6/8	2.5	1.67	0.9	6.9
		Storm	17/18	1.03	0.9	<0.5	2.3
Cottage Lake Creek	N484	Base	8/8	2.21	1.8	1.3	3.81
		Storm	18/18	7.81	4.9	2.3	34.9
Cottage Lake Outlet	BCP03	Base	8/8	4.75	1.7	0.5	24
		Storm	18/18	1.01	0.9	0.5	1.8
Cold Creek	BCP02	Base	4/5	28.5	1.0	<0.5	136
		Storm	16/16	17.6	12.8	1.1	48.4

Table 13. Summary statistics for turbidity grab samples taken March 2015 to January 2016. All values in NTU.

Site	ID	Flow	Detections	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	8/8	3.14	2.46	1.31	5.72
		Storm	18/18	11.1	7.46	2.14	33.8
Stensland Creek	BCP09	Base	8/8	1.84	1.72	1.11	2.71
		Storm	18/18	2.48	2	0.984	6.62
Mackey Creek	ET484	Base	8/8	2.28	1.8	0.683	4.91
		Storm	18/18	8.07	5.98	1.58	22.9
Monticello Creek	BCP08	Base	8/8	2.36	1.44	0.859	6.83
		Storm	18/18	20.1	15.9	1.74	53.2
Bear Creek - Middle	J484	Base	8/8	1.88	1.61	1.01	3.04
		Storm	18/18	4.11	2.89	2.17	9.21
Seidel Creek	BCP06	Base	8/8	1.6	1.34	1.08	2.6
		Storm	18/18	6.44	4.01	2.1	18.6
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8/8	2.95	2.76	1.35	5.44
		Storm	18/18	11	4.13	2.21	38.3
Struve Creek	BCP04	Base	8/8	0.993	0.92	0.63	1.29
		Storm	18/18	5.08	2.84	1.29	20.4
Upper Bear Trib	BCP10	Base	8/8	1.28	1.26	0.698	1.89
		Storm	18/18	6.99	3.46	1.68	29.1
Bear Creek - Upper	BCP01	Base	8/8	1.26	0.931	0.572	3.65
		Storm	18/18	0.948	0.919	0.608	1.31
Cottage Lake Creek	N484	Base	8/8	1.26	1.02	0.835	1.95
		Storm	18/18	3.71	2.94	1.7	10.2
Cottage Lake Outlet	BCP03	Base	8/8	2.7	1.52	1.11	10.9
		Storm	18/18	1.39	1.35	0.778	2.62
Cold Creek	BCP02	Base	5/5	1.73	1.16	0.822	4.47
		Storm	16/16	18.7	11.4	0.897	53.3

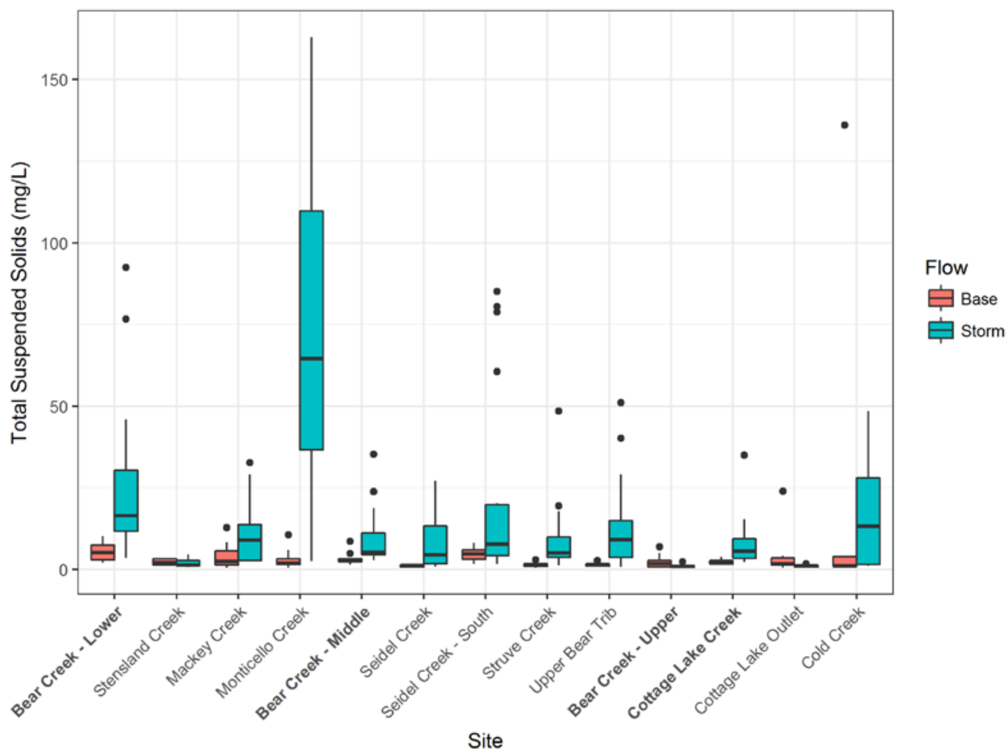

Figure 13. Total suspended solid concentrations during baseflow and storm event flow grab samples taken March 2015 to January 2016. Mainstem Bear and Cottage sites shown in bold.

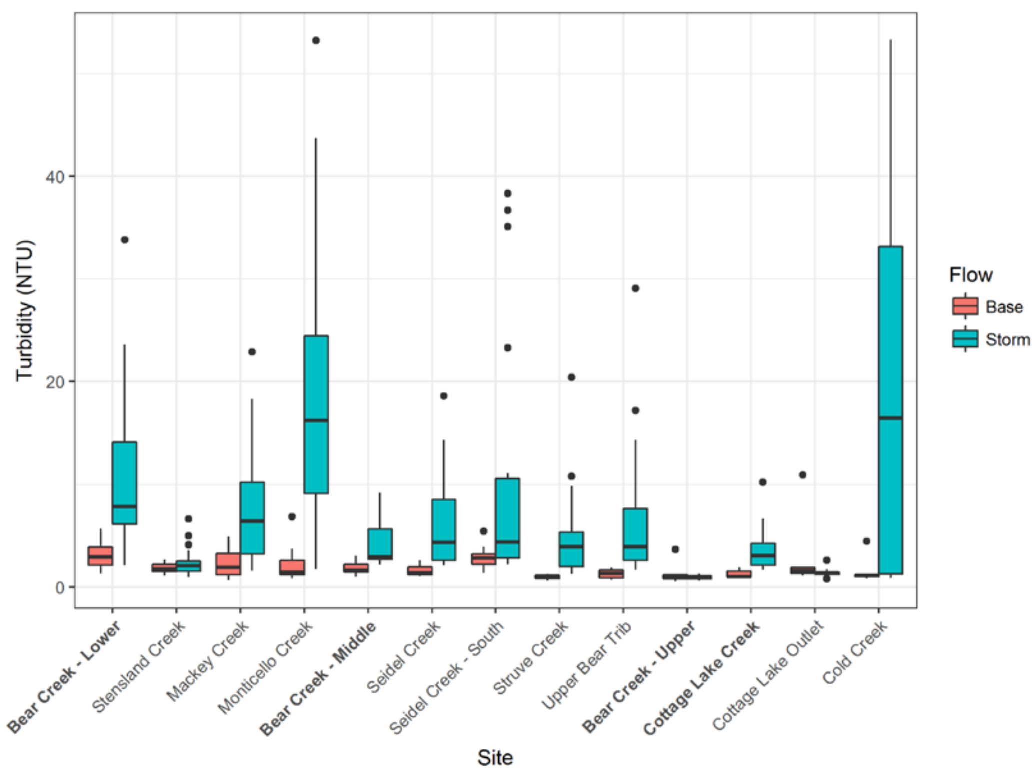

Figure 14. Turbidity during baseflow and storm event flow grab samples taken March 2015 to January 2016. Mainstem Bear and Cottage sites shown in bold.

Particle Size Distribution

Particle size distribution (PSD) was analyzed on all samples from the first two baseflow events and the first two storm events. The particle sizes are broken into three groups:

- Clay (less than 3.9 microns)
- Silt (3.9 to <62.5 microns)
- Sand (62.5 to <500 microns)

Particles greater than or equal to 500 microns were removed by filtration prior to measuring PSD. The percentages of the three particle size classification for each sample are presented in Appendix E. Some of the PSD analyses suffered quality control issues where the detector-corrected values had poor fit or the sum of the PSD was less than 100 percent.

Figure 15 summarizes the average PSD for each site based on baseflow and storm event flow. Samples where the sum of the PSD was less than 80 percent were removed from the summary analysis. The remaining samples were weighted to be based on the reported sum PSD in order to allow comparability between samples. For example, if a sample was reported as 40 percent clay, 20 percent sand, and 20 percent silt, the value were revised based on the 80 percent total to 50 percent clay, 25 percent sand, and 25 percent silt. Generally, wet-weather flows contained larger particles; exceptions were for most samples in Upper Bear Creek and the Cottage Lake outlet where the fraction of clay, the finest particles, increased relative to base flow.

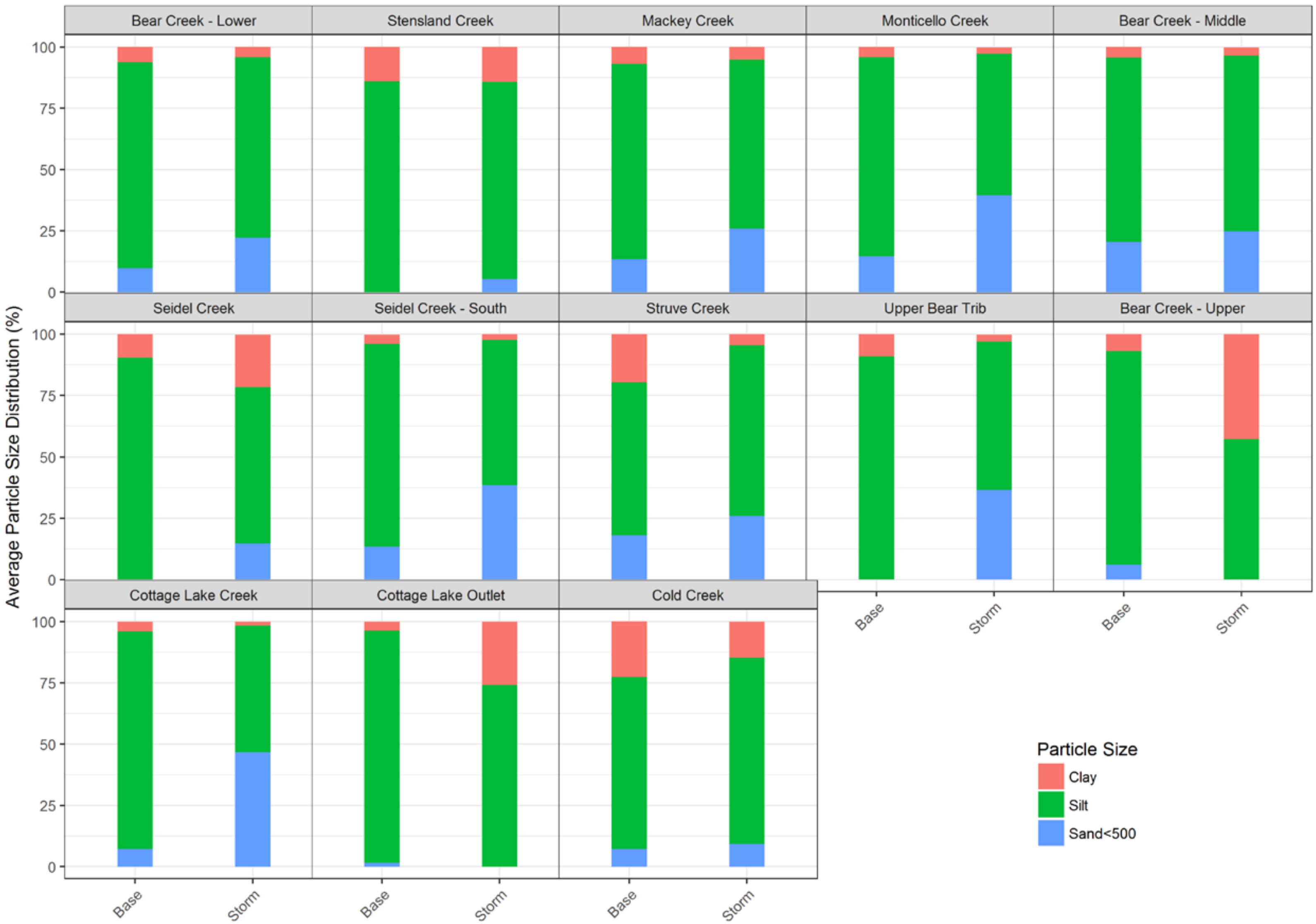

Figure 15. Adjusted average particle size distribution of clay, silt, and sand in suspended solids by site and flow type from the two baseflow and two storm events sampled.

3.5.2 Instantaneous Loading

Suspended solid loading during storms was greater than that of base flow in nearly all gaged streams (Figure 16). Upper Bear Creek did not have substantial differences in loading between storm event flow and baseflow at between 10 and 30 mg/s.

The interquartile range of the total load leaving the study area (Lower Bear Creek + Stensland Creek) was between 50 and 200 mg/s during baseflow and 700 to 2,000 mg/s during storm event flow.

The loading of suspended solids from Monticello Creek during storm event flow was the largest of all tributaries (interquartile range: 100 to 350 mg/s). Despite Monticello Creek's smaller flows, its storm event flow loading was approximately equivalent to that of Middle Bear Creek (100 to 500 mg/s) and Cottage Lake Creek (70 to 200 mg/s) and greater than all other gaged Bear Creek tributaries (Figure 16).

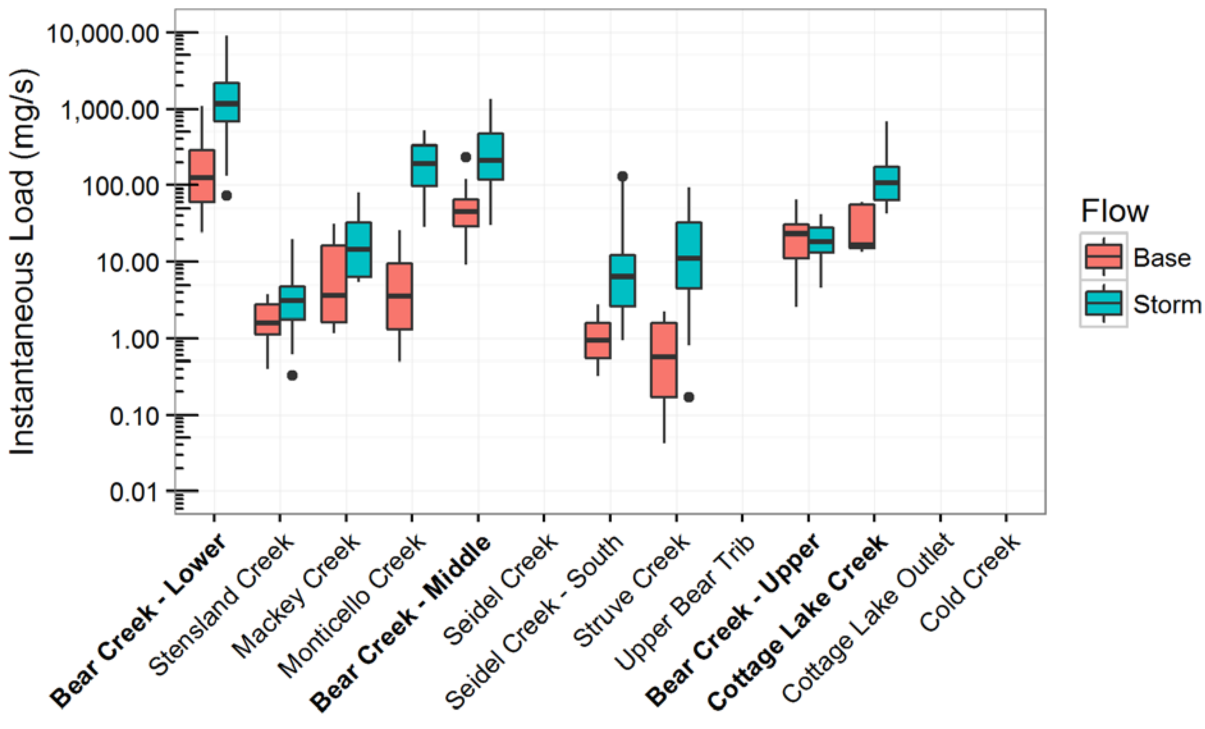

Figure 16. Instantaneous loadings of suspended solids from gaged streams. Mainstem Bear and Cottage sites shown in bold.

The load from Lower Bear Creek was typically greater than the sum of loads from Middle Bear Creek, Cottage Lake Creek, Mackey Creek, and Monticello Creek during both storm event flow and baseflow (Table 15). While the difference may be attributed in part to transport time, there is additional loading from Tyler Creek, small unnamed tributaries, bank erosion, sediment resuspension, and the stormwater system occurring in lower Bear Creek that may, in some cases, exceed the loading from the gaged streams.

Table 14. Suspended solid load to Lower Bear Creek from gaged streams and from Lower Bear Creek per sampling event. All values in mg/s. Difference between load from and load into color-coded where red indicates the calculated load leaving lower Bear Creek is greater than the calculated load from the upstream gaged streams and green indicates vice versa.

Event	Date	Bear Creek – Lower Load	Sum Upstream	Difference (Bear Creek Lower – Upstream)	Bear Creek - Middle	Cottage Lake Creek	Monti-cello Creek	Mackey Creek
Base 1	3/4/2015 AM	**400**	**322**	+78	230	60	2	30
	3/4/2015 PM	**250**	**115**	+135	50	60	0.8	4
Base 2	4/28/2015 AM	**210**	**54**	+156	30	20	0.7	3
	4/28/2015 PM	**70**	**52**	+18	40	10	0.8	1
Base 3	6/25/2015 AM	**57**	**34**	+23	16	16	0.9	1
Base 4	8/27/2015 AM	**23**	**22**	+1	9	13	0.1	NC
Storm 1	8/29/2015 AM	**200**	**194**	+6	83	110	1	NC
	8/29/2015 PM	**72**	**127**	-55	30	48	49	NC
	8/30/2015 AM	**2,300**	**525**	+1,800	380	120	25	NC
Storm 2	10/10/2015 AM	**200**	**360**	-160	94	62	200	NC
	10/10/2015 PM	**4,200**	**2,500**	+1,700	1,300	680	500	NC
	10/11/2015 AM	**840**	**380**	+460	130	160	85	NC
Base 5	10/15/2015 AM	**58**	**71**	-13	53	17	0.5	NC
Storm 3	10/30/2015 AM	**120**	**170**	-50	67	42	56	NC
	10/30/2015 PM	**610**	**1,000**	-390	430	140	440	NC
	10/31/2015 AM	**8,600**	**1,900**	**+6,700**	1,300	360	190	NC
Storm 4	12/03/2015 AM	**1,300**	**450**	+850	180	77	160	34
	12/03/2015 PM	**760**	**330**	+430	170	46	110	5
	12/04/2015 AM	**900**	**470**	+430	120	50	290	6
Storm 5	12/17/2015 AM	**890**	**230**	+660	120	69	35	7
	12/17/2015 PM	**1,600**	**450**	+1,150	300	93	28	30
	12/18/2015 AM	**8,600**	**1,200**	**+7,400**	600	180	340	81
Base 6	12/28/2015 AM	**1,100**	**235**	+900	120	59	25	31
Storm 6	1/13/2016 AM	**1,500**	**1,760**	-260	980	260	520	NC
	1/13/2016 PM	**4,500**	**1,000**	+3,500	490	190	320	NC
	1/14/2016 AM	**1,600**	**490**	+1,100	240	100	150	NC

"NC" = Not calculated due to lack of continuous flow data at the time of water quality sampling.

3.6 Nitrogen

Total nitrogen includes inorganic and organic nitrogen. The two forms of inorganic nitrogen (ammonia-nitrogen and nitrate+nitrite-nitrogen) are highly soluble in water and are components of fertilizers, sewage effluents, and manure.

Under natural conditions, a major source of NO_3^- in streams is terrestrial decomposition of organic materials. In soils, the regeneration of NO_3^- from organic nitrogen occurs through the activities of bacteria and fungi. These organisms convert organic nitrogen forms to ammonia, and then nitrite bacteria partially oxidize ammonia (NH_4^+) to nitrite (NO2-). Under aerobic conditions, another group of bacteria converts nitrite to nitrate. In addition, some plants fix atmospheric nitrogen. Bacteria on the roots fix the nitrogen in the soil by combining it with oxygen to form nitrate (NO_3^-). Alder trees (Alnus sp.), which are prevalent along many of the streams, are the primary source of the nitrogen-fixing bacteria in forested areas and wetlands. Nitrogen fixation by dense stands of alder can be as high as 22,500 mg/m^2/year, most of which enters the stream as leachate from direct leaf-fall or release during decomposition of foliage (Wetzel, 1975).

Ammonia-nitrogen is generated by heterotrophic bacteria as the primary end product of decomposition of organic matter. Although intermediate nitrogen compounds are formed in the progressive degradation of organic material, these rarely accumulate and are deaminated rapidly by bacterial utilization. Ammonia is a major excretory product of aquatic and terrestrial animals, but in the normal aquatic environment, the majority of ammonia-nitrogen is formed through decomposition.

Ammonia in water is present primarily as NH_4^+ and as un-ionized NH_4OH, the latter being highly toxic to many organisms, especially fish. The proportions of NH_4^+ to NH_4OH are dependent on pH and, to a lesser extent temperature.

3.6.1 Water Quality Summary

Generally, total nitrogen concentrations were greater during storm events than baseflow (Figure 17; Table 16). However, Cold Creek had higher total nitrogen concentration during baseflow than during storm events. Concentrations ranged from 0.25 to 2.5 mg/L. In general, total nitrogen was primarily composed of nitrate+nitrite and particulate nitrogen. Nitrate+nitrite concentrations ranged from less than 0.01 to 2.2 mg/L (Figure 18; Table 17), and ammonia ranged from less than 0.002 to 0.222 mg/L (Figure 19; Table 18).

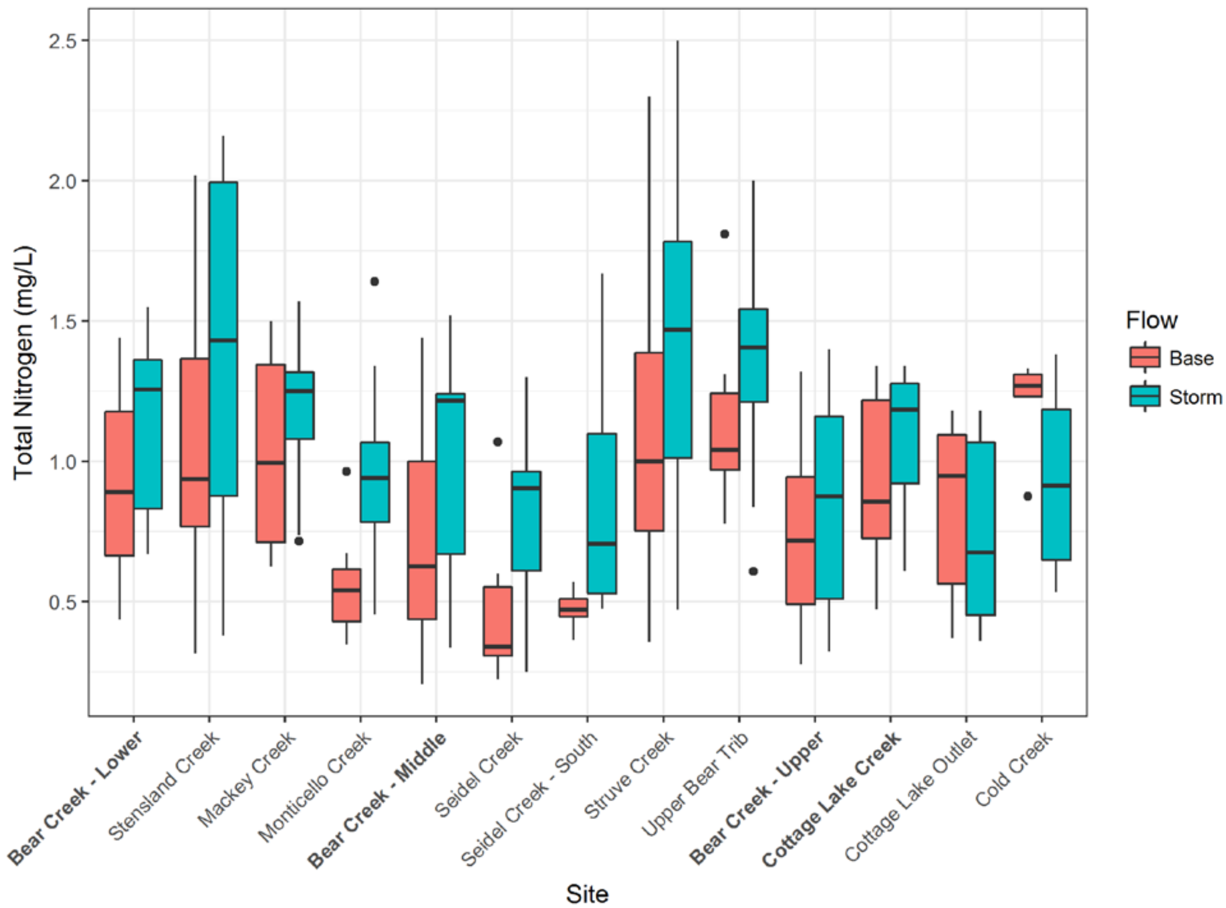

Figure 17. Total nitrogen concentrations during baseflow and storm event flow grab samples taken March 2015 to January 2016. Mainstem Bear and Cottage sites shown in bold.

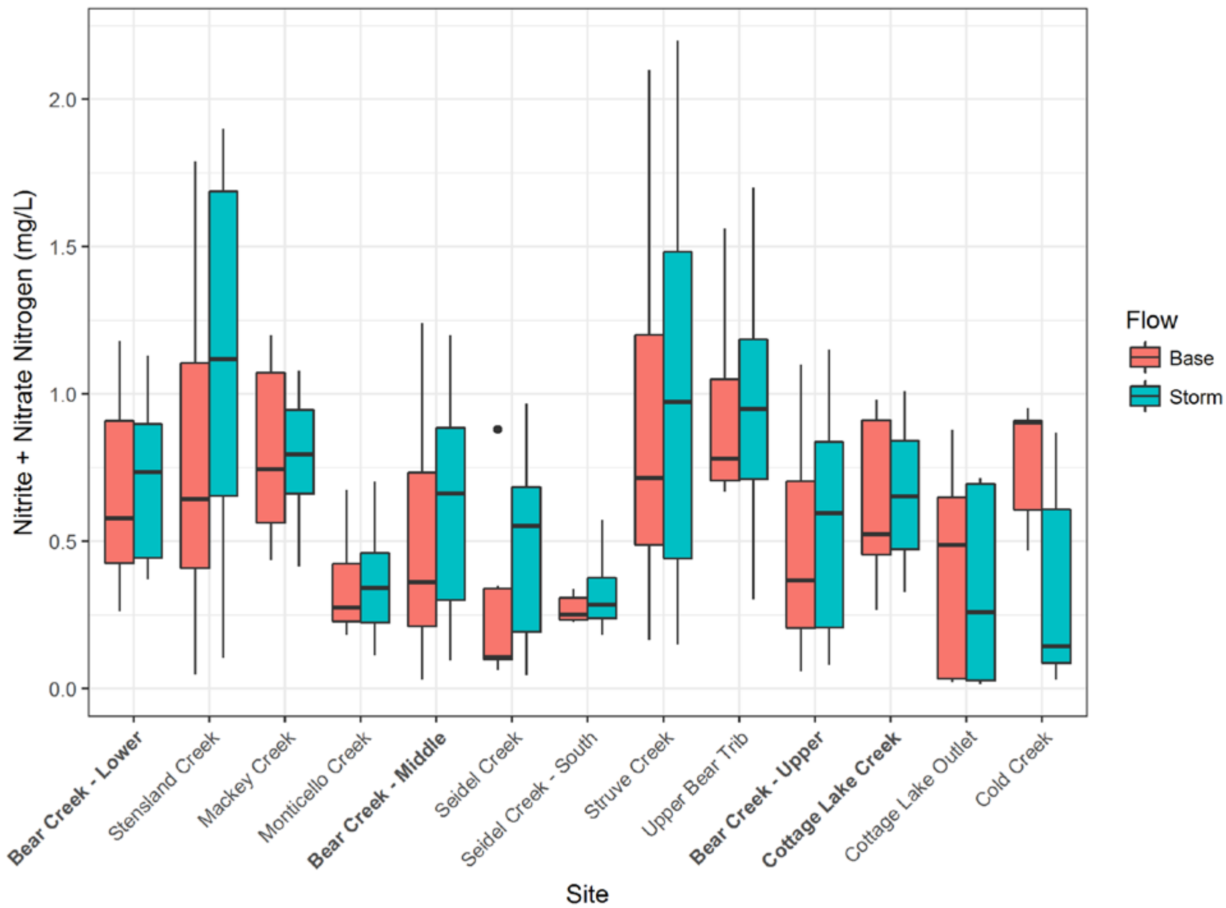

Figure 18. Nitrite+nitrate nitrogen concentrations during baseflow and storm event flow grab samples taken March 2015 to January 2016. Mainstem Bear and Cottage sites shown in bold.

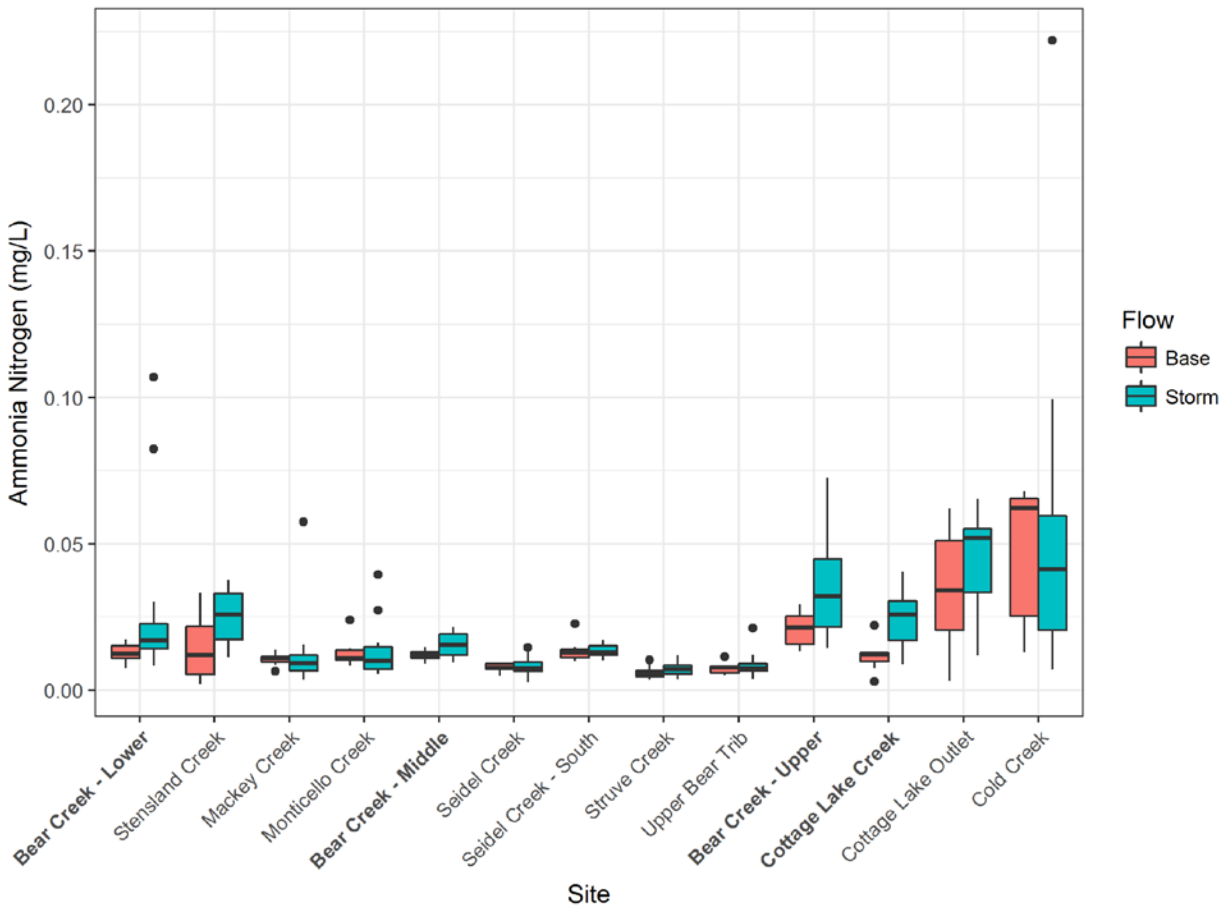

Figure 19. Ammonia nitrogen concentrations during baseflow and storm event flow grab samples taken March 2015 to January 2016. Mainstem Bear and Cottage sites shown in bold.

Table 15. Summary statistics for total nitrogen concentrations in grab samples taken March 2015 to January 2016. All values in mg/L.

Site	ID	Flow	Detections	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	8/8	0.922	0.889	0.436	1.44
		Storm	18/18	1.16	1.25	0.67	1.55
Stensland Creek	BCP09	Base	8/8	1.05	0.878	0.315	2.02
		Storm	18/18	1.38	1.06	0.379	2.16
Mackey Creek	ET484	Base	8/8	1.04	0.85	0.625	1.5
		Storm	18/18	1.16	1.23	0.715	1.57
Monticello Creek	BCP08	Base	8/8	0.559	0.487	0.347	0.963
		Storm	18/18	0.966	0.93	0.455	1.64
Bear Creek - Middle	J484	Base	8/8	0.721	0.622	0.206	1.44
		Storm	18/18	1.02	1.21	0.337	1.52
Seidel Creek	BCP06	Base	8/8	0.464	0.333	0.224	1.07
		Storm	18/18	0.792	0.879	0.25	1.3

Site	ID	Flow	Detections	Mean	Median	Min	Max
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8/8	0.473	0.467	0.364	0.572
		Storm	18/18	0.851	0.689	0.476	1.67
Struve Creek – North Fork	BCP04	Base	8/8	1.1	0.931	0.357	2.3
		Storm	18/18	1.42	1.33	0.471	2.5
Upper Bear Trib	BCP10	Base	8/8	1.13	1.02	0.777	1.81
		Storm	18/18	1.37	1.4	0.608	2.0
Bear Creek - Upper	BCP01	Base	8/8	0.742	0.642	0.277	1.32
		Storm	18/18	0.854	0.671	0.321	1.4
Cottage Lake Creek	N484	Base	8/8	0.926	0.852	0.474	1.34
		Storm	18/18	1.1	1.17	0.61	1.34
Cottage Lake Outlet	BCP03	Base	8/8	0.843	0.922	0.37	1.18
		Storm	18/18	0.735	0.487	0.36	1.18
Cold Creek	BCP02	Base	5/5	1.2	1.27	0.875	1.33
		Storm	16/16	0.918	0.844	0.535	1.38

Table 16. Summary statistics for nitrate+nitrite nitrogen concentrations in grab samples taken March 2015 to January 2016. All values in mg/L.

Site	ID	Flow	Detections	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	8/8	0.656	0.572	0.263	1.18
		Storm	18/18	0.714	0.617	0.371	1.13
Stensland Creek	BCP09	Base	8/8	0.741	0.634	0.0489	1.79
		Storm	18/18	1.09	0.825	0.105	1.9
Mackey Creek	ET484	Base	8/8	0.8	0.586	0.437	1.2
		Storm	18/18	0.785	0.794	0.415	1.08
Monticello Creek	BCP08	Base	8/8	0.338	0.249	0.181	0.675
		Storm	18/18	0.362	0.311	0.112	0.701
Bear Creek - Middle	J484	Base	8/8	0.483	0.361	0.03	1.24
		Storm	18/18	0.627	0.515	0.0948	1.2
Seidel Creek	BCP06	Base	8/8	0.254	0.104	0.0621	0.88
		Storm	18/18	0.459	0.492	0.0469	0.968
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8/8	0.269	0.235	0.226	0.338
		Storm	18/18	0.321	0.277	0.182	0.572
Struve Creek – North Fork	BCP04	Base	8/8	0.857	0.647	0.165	2.1
		Storm	18/18	1.04	0.727	0.149	2.2
Upper Bear Trib	BCP10	Base	8/8	0.911	0.742	0.668	1.56
		Storm	18/18	0.969	0.923	0.302	1.7
Bear Creek - Upper	BCP01	Base	8/8	0.455	0.365	0.0595	1.1
		Storm	18/18	0.573	0.415	0.081	1.15
Cottage Lake Creek	N484	Base	8/8	0.618	0.519	0.266	0.981
		Storm	18/18	0.654	0.542	0.329	1.01

Site	ID	Flow	Detections	Mean	Median	Min	Max
Cottage Lake Outlet	BCP03	Base	8/8	0.408	0.467	0.023	0.877
		Storm	17/18	0.327	0.0549	0.015	0.715
Cold Creek	BCP02	Base	5/5	0.768	0.904	0.469	0.768
		Storm	15/16	0.337	0.142	0.0559	0.337

Table 17. Summary statistics for ammonia nitrogen concentrations in grab samples taken March 2015 to January 2016. All values in mg/L.

Site	ID	Flow	Detections	Mean	Median	Min	Max
Bear Creek - Lower	C484	Base	8/8	0.0127	0.0117	0.0076	0.0173
		Storm	17/18	0.0252	0.0166	0.0083	0.107
Stensland Creek	BCP09	Base	7/8	0.0146	0.0072	<0.002	0.0332
		Storm	17/18	0.0248	0.0244	0.0112	0.0376
Mackey Creek	ET484	Base	8/8	0.0104	0.0105	0.0064	0.0138
		Storm	17/18	0.0116	0.0092	0.0035	0.0575
Monticello Creek	BCP08	Base	8/8	0.0127	0.0108	0.0083	0.0239
		Storm	17/18	0.0125	0.0096	0.0055	0.0394
Bear Creek - Middle	J484	Base	8/8	0.0119	0.0117	0.009	0.0147
		Storm	17/18	0.0152	0.015	0.0094	0.0216
Seidel Creek	BCP06	Base	8/8	0.0077	0.0075	0.0048	0.0094
		Storm	17/18	0.00813	0.007	0.0028	0.0146
Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8/8	0.0136	0.0127	0.0099	0.0227
		Storm	17/18	0.0133	0.0128	0.0102	0.0171
Struve Creek – North Fork	BCP04	Base	8/8	0.00609	0.0055	0.0035	0.0103
		Storm	16/18	0.0071	0.007	0.0036	0.0119
Upper Bear Trib	BCP10	Base	8/8	0.00758	0.0077	0.0052	0.0115
		Storm	16/18	0.00818	0.0069	0.0038	0.0211
Bear Creek - Upper	BCP01	Base	8/8	0.0211	0.0187	0.0133	0.0293
		Storm	17/18	0.0345	0.0301	0.0144	0.0727
Cottage Lake Creek	N484	Base	8/8	0.0116	0.0118	0.0029	0.0221
		Storm	17/18	0.0234	0.0249	0.0088	0.0404
Cottage Lake Outlet	BCP03	Base	8/8	0.0336	0.0334	0.0032	0.0621
		Storm	18/18	0.0452	0.0519	0.0118	0.0653
Cold Creek	BCP02	Base	5/5	0.0468	0.0622	0.0129	0.0681
		Storm	14/16	0.0512	0.0359	0.0069	0.222

3.6.2 Comparison to Water Quality Criteria

The water quality standards numeric criteria for un-ionized ammonia are based on pH and temperature. The criteria were calculated based on the equations provided in WAC 173-201A-240 Table 240 Notes f and g. The amount of un-ionized ammonia was estimated based on the ammonia concentration and on the sample pH and temperature.[3] The water quality standards were not exceeded in any sample at any monitoring site (Figure 20).

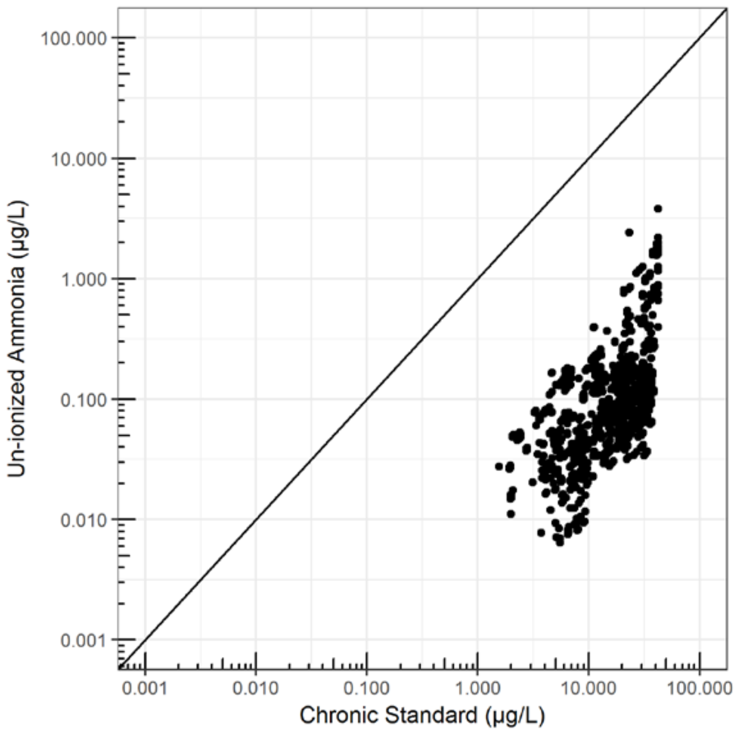

Figure 20. Estimated un-ionized ammonia versus chronic criterion. Values below diagonal lines are below the water quality standard.

3.6.3 Instantaneous Loading

Total nitrogen, nitrate+nitrite, and ammonia loading during storms was greater than that of base flow in all gaged streams (Figures 21, 22 and 23). Upper Bear Creek and Cottage Lake Creek appear to be primary pathways during baseflow and storm event flow to Lower Bear Creek – Upper Bear and Middle Bear Creek loads are similar, suggesting little additional loading between the two monitoring sites.

[3] Fraction un-ionized = $\frac{1}{1+10^{pka-pH}}$ $where\ pka = 0.0901821 + \frac{2729.92}{T}$ $where\ T = temperature\ in\ Kelvin.$

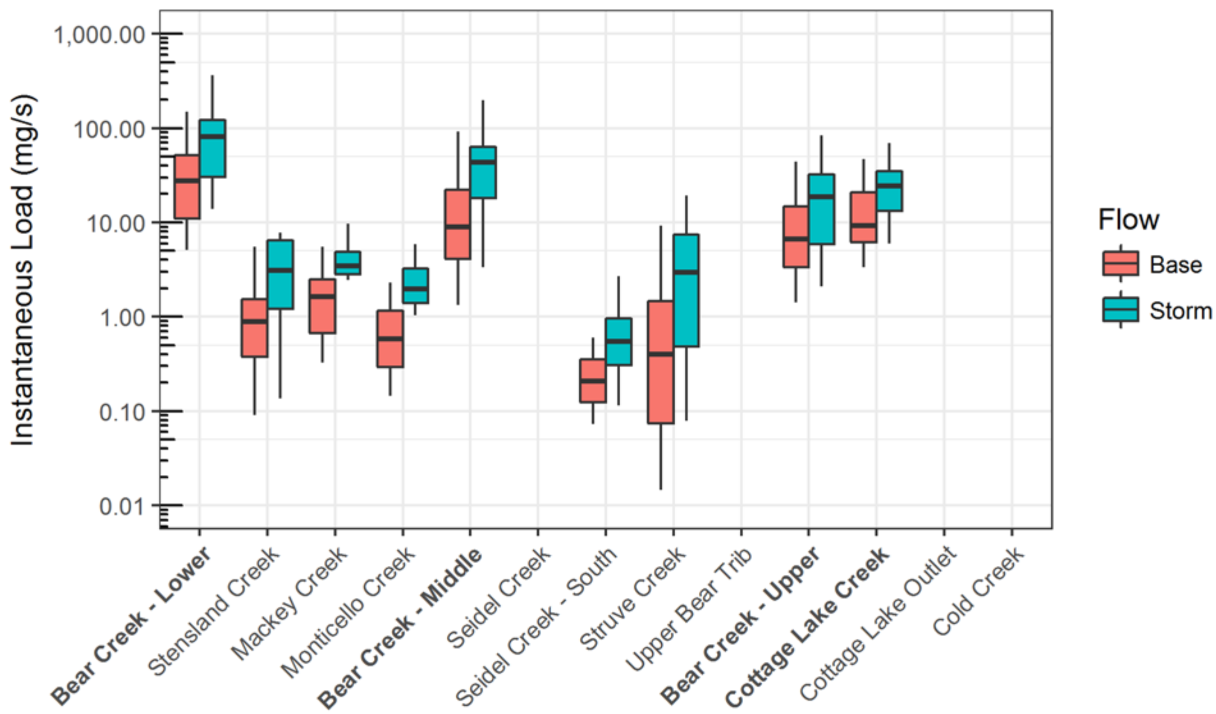

Figure 21. Instantaneous loadings of total nitrogen from gaged streams. Mainstem Bear and Cottage sites shown in bold.

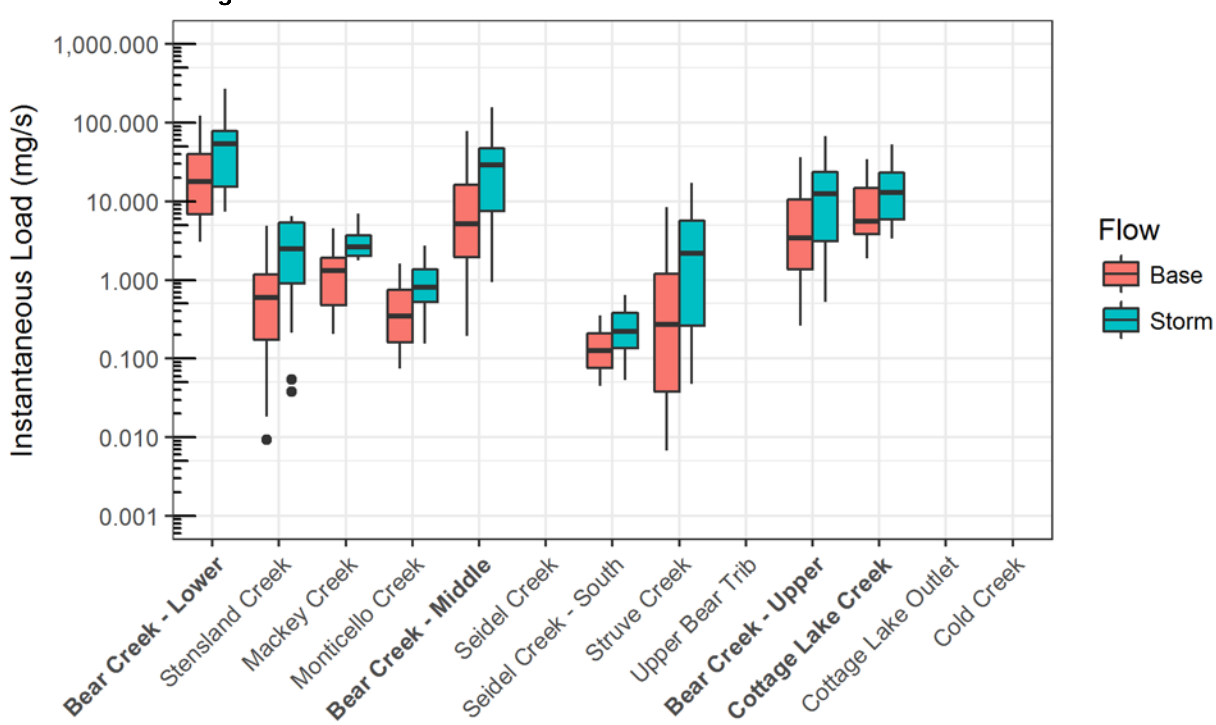

Figure 22. Instantaneous loadings of nitrate+nitrite nitrogen from gaged streams. Mainstem Bear and Cottage sites shown in bold.

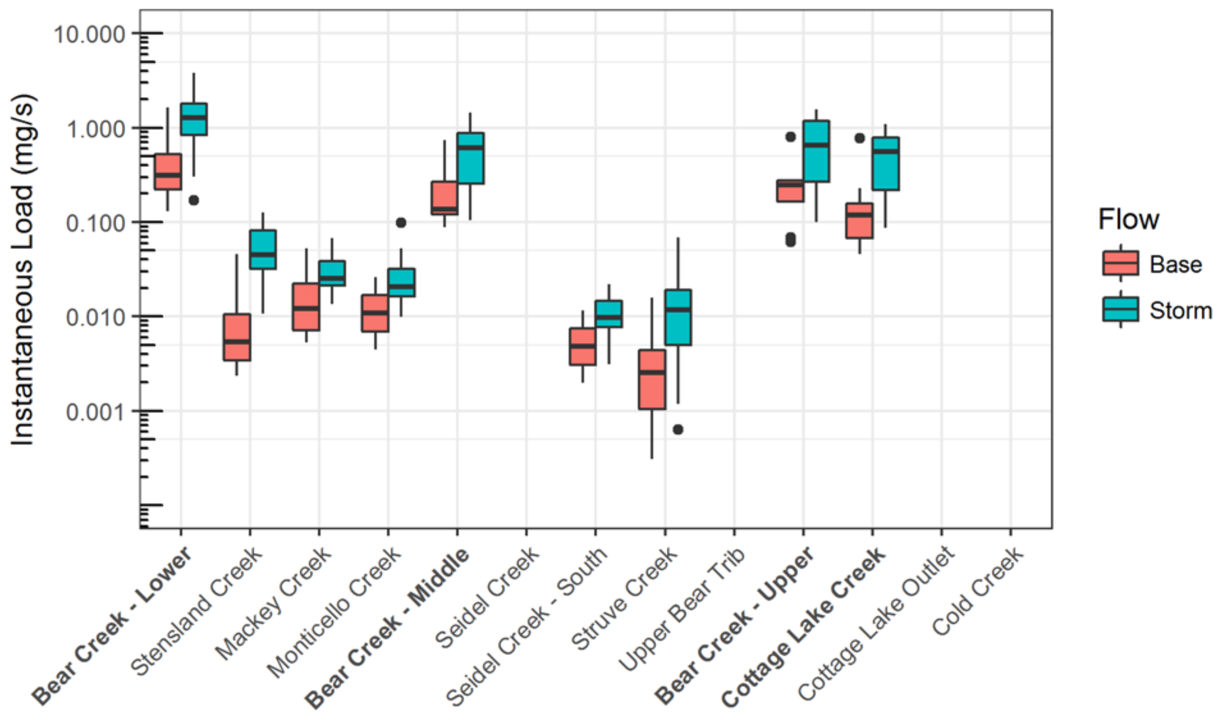

Figure 23. Instantaneous loadings of ammonia nitrogen from gaged streams. Mainstem Bear and Cottage sites shown in bold.

3.7 Copper and Zinc

Copper and zinc are abundant trace elements that occur naturally in the earth's crust and can be found in surface waters. A major natural source of copper and zinc is the weathering and erosion of rocks and soils. Anthropogenic sources of copper include pesticide use, piping, and automobile brake pads. Anthropogenic sources of zinc include tire weathering, galvanized surfaces (e.g., roofs, gutters), and fertilizers. Both copper and zinc are toxic to fish and other aquatic organisms at high levels.

3.7.1 Water Quality Summary

Copper and zinc (both dissolved and total) concentrations were greater during sampled storm events than baseflow events (Figures 24, 25, 26, and 27; Tables 19 and 20). Copper concentrations were generally greatest at Cold Creek, but Mackey Creek had a dissolved copper sample (10 µg/L) nearly twice that of Cold Creek's maximum (6 µg/L). Dissolved copper concentrations ranged from less than 0.2 to 10 µg/L, and total copper ranged from less than 0.2 to 16 µg/L. Zinc concentrations were greatest at Monticello and Cold creeks. Dissolved zinc concentrations ranged from less than 0.5 to 18.9 µg/L, and total zinc ranged from less than 0.5 to 59.6 µg/L.

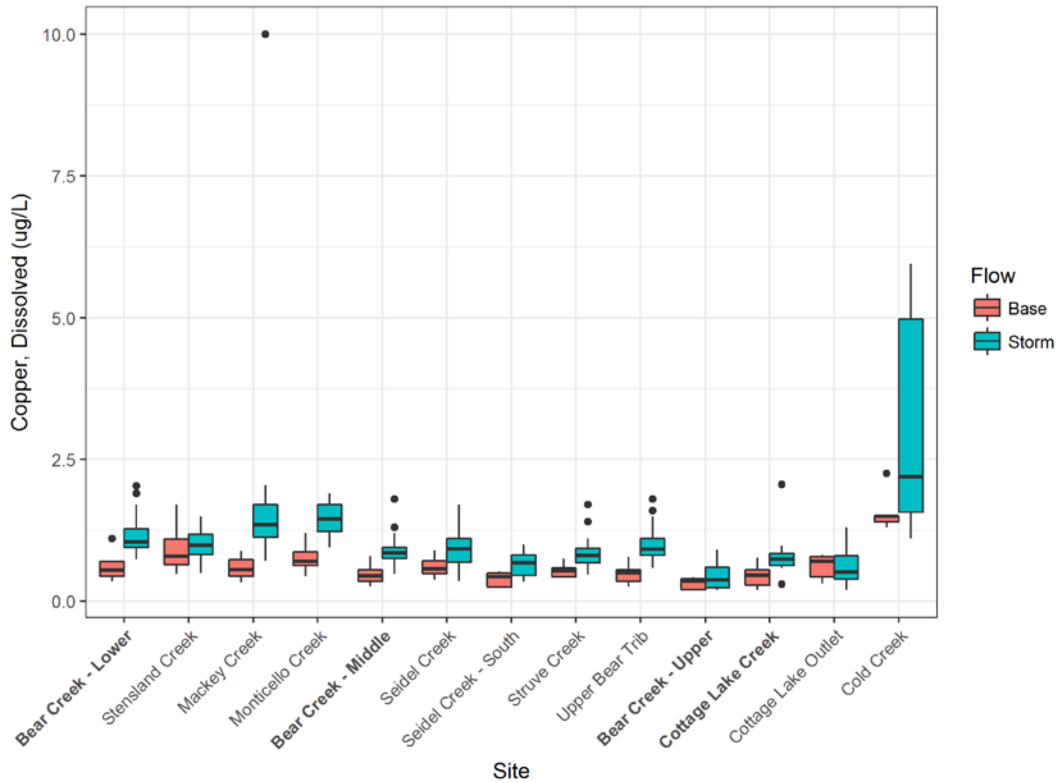

Figure 24. Concentrations of dissolved copper during baseflow and storm event flow. Mainstem Bear and Cottage sites shown in bold.

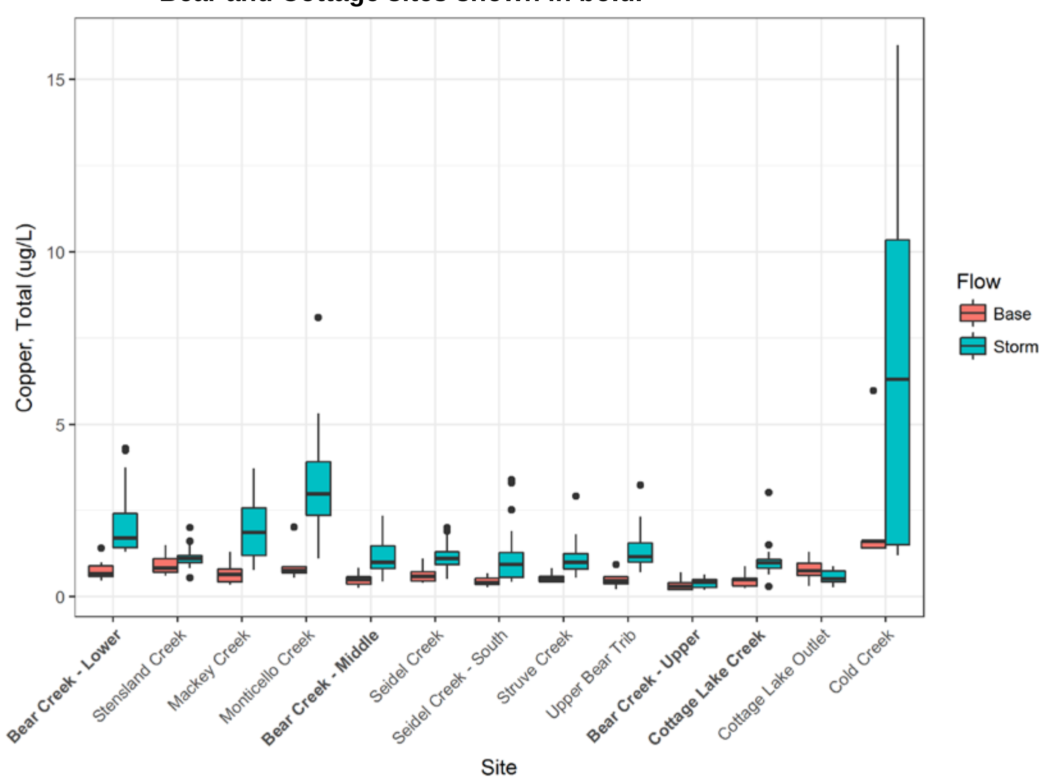

Figure 25. Concentrations of total copper during baseflow and storm event flow. Mainstem Bear and Cottage sites shown in bold.

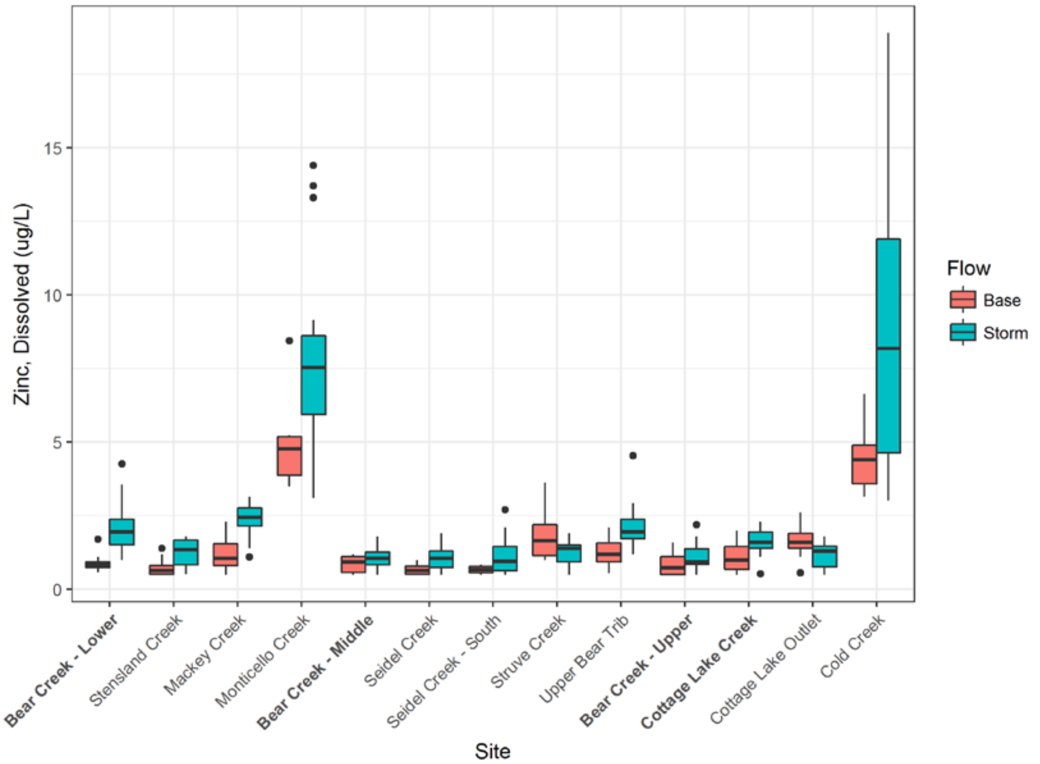

Figure 26. Concentrations of dissolved zinc during baseflow and storm event flow. Mainstem Bear and Cottage sites shown in bold.

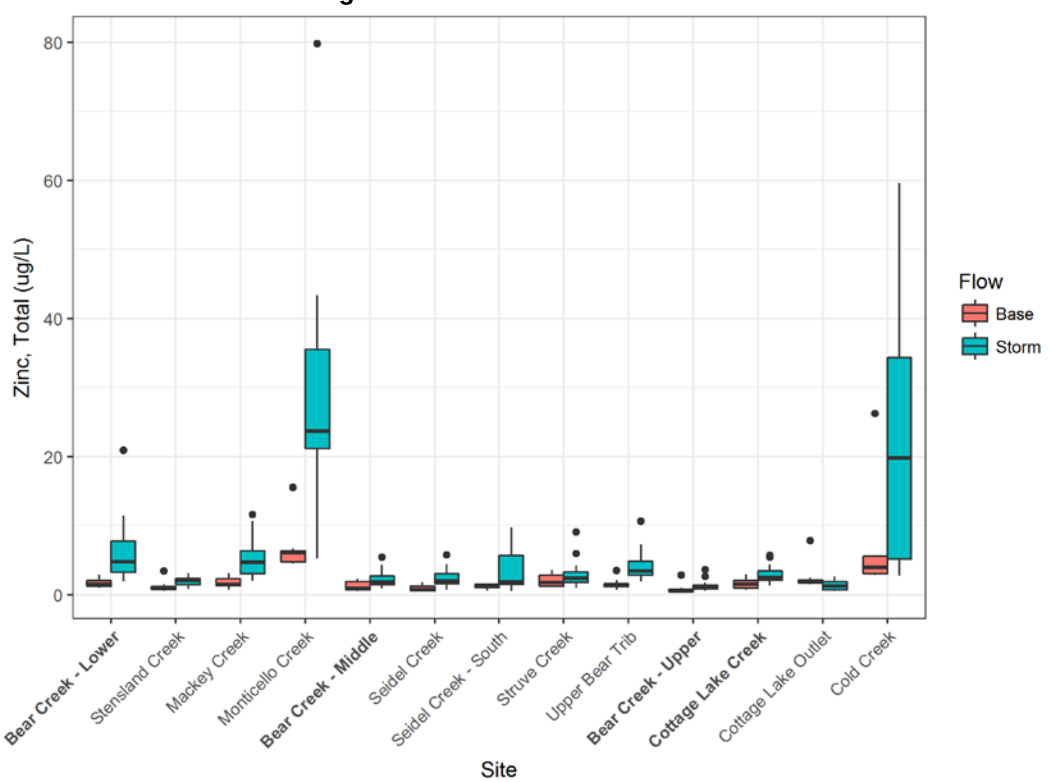

Figure 27. Concentrations of total zinc during baseflow and storm event flow. Mainstem Bear and Cottage sites shown in bold.

Table 18. Summary statistics for dissolved and total copper in grab samples collected March 2015 to January 2016. All values in µg/L.

	Site	ID	Flow	Detections	Mean	Median	Min	Max
Copper, Dissolved	Bear Creek - Lower	C484	Base	8/8	0.604	0.51	0.35	1.1
			Storm	18/18	1.19	1	0.74	2.03
	Stensland Creek	BCP09	Base	8/8	0.929	0.65	0.48	1.7
			Storm	18/18	0.996	0.97	0.5	1.5
	Mackey Creek	ET484	Base	8/8	0.585	0.54	0.33	0.88
			Storm	18/18	1.82	1.3	0.71	10
	Monticello Creek	BCP08	Base	8/8	0.754	0.66	0.44	1.2
			Storm	18/18	1.44	1.4	0.95	1.9
	Bear Creek - Middle	J484	Base	7/8	0.45	0.37	<0.4	0.79
			Storm	18/18	0.912	0.85	0.48	1.8
	Seidel Creek	BCP06	Base	8/8	0.606	0.54	0.38	0.9
			Storm	18/18	0.902	0.86	0.36	1.7
	Seidel Creek - South	SOUTH SEIDEL_YSI	Base	7/8	0.366	0.26	<0.4	0.52
			Storm	18/18	0.655	0.67	0.34	1
	Struve Creek	BCP04	Base	8/8	0.536	0.52	0.41	0.75
			Storm	18/18	0.869	0.8	0.47	1.7
	Upper Bear Trib	BCP10	Base	8/8	0.485	0.5	0.25	0.78
			Storm	18/18	1.03	0.9	0.59	1.8
	Bear Creek - Upper	BCP01	Base	4/8	0.284	0.2	<0.2	0.42
			Storm	15/18	0.419	0.36	<0.2	0.91
	Cottage Lake Creek	N484	Base	7/8	0.458	0.44	0.26	0.77
			Storm	18/18	0.795	0.71	0.3	2.06
	Cottage Lake Outlet	BCP03	Base	8/8	0.621	0.64	0.31	0.82
			Storm	17/18	0.624	0.5	<.2	1.3
	Cold Creek	BCP02	Base	5/5	1.59	1.5	1.3	2.25
			Storm	16/16	3.11	2.17	1.1	5.95
Copper, Total	Bear Creek - Lower	C484	Base	8/8	0.779	0.63	0.47	1.4
			Storm	18/18	2.16	1.7	1.3	4.3
	Stensland Creek	BCP09	Base	8/8	0.94	0.76	0.6	1.5
			Storm	18/18	1.15	1.1	0.55	2
	Mackey Creek	ET484	Base	8/8	0.672	0.62	0.35	1.3
			Storm	18/18	1.9	1.8	0.77	3.72
	Monticello Creek	BCP08	Base	8/8	0.891	0.72	0.54	2.01
			Storm	18/18	3.31	2.78	1.1	8.09
	Bear Creek - Middle	J484	Base	8/8	0.484	0.49	0.25	0.83
			Storm	18/18	1.14	1	0.44	2.34
	Seidel Creek	BCP06	Base	8/8	0.63	0.57	0.4	1.1
			Storm	18/18	1.18	1.1	0.5	2
	Seidel Creek	SOUTH	Base	6/8	0.418	0.37	<0.4	0.68

	Site	ID	Flow	Detections	Mean	Median	Min	Max
	- South	SEIDEL_YSI	Storm	18/18	1.22	0.88	0.42	3.39
	Struve Creek	BCP04	Base	7/8	0.534	0.46	<0.4	0.82
			Storm	18/18	1.12	1	0.55	2.91
	Upper Bear Trib	BCP10	Base	8/8	0.484	0.45	0.22	0.93
			Storm	18/18	1.38	1.1	0.7	3.23
	Bear Creek - Upper	BCP01	Base	3/8	0.343	NC	<0.2	0.7
			Storm	16/18	0.401	0.4	<0.2	0.64
	Cottage Lake Creek	N484	Base	8/8	0.471	0.47	0.24	0.88
			Storm	18/18	1.06	0.98	0.29	3.02
	Cottage Lake Outlet	BCP03	Base	8/8	0.766	0.69	0.31	1.3
			Storm	18/18	0.561	0.5	0.27	0.88
	Cold Creek	BCP02	Base	5/5	2.39	1.6	1.4	5.97
			Storm	16/16	6.75	6.22	1.2	16

Table 19. Summary statistics for dissolved and total zinc in grab samples collected March 2015 to January 2016. All values in µg/L.

	Site	ID	Flow	Detections	Mean	Median	Min	Max
Zinc, Dissolved	Bear Creek - Lower	C484	Base	8/8	0.921	0.82	0.58	1.7
			Storm	18/18	2.16	1.9	1	4.27
	Stensland Creek	BCP09	Base	6/8	0.769	0.63	<0.5	1.4
			Storm	18/18	1.25	1.3	0.51	1.8
	Mackey Creek	ET484	Base	7/8	1.25	1	<0.5	2.3
			Storm	18/18	2.38	2.4	1.1	3.15
	Monticello Creek	BCP08	Base	8/8	4.93	4.4	3.49	8.44
			Storm	18/18	7.95	7.46	3.11	14.4
	Bear Creek - Middle	J484	Base	6/8	0.895	0.86	<0.5	1.2
			Storm	16/18	1.1	1	<0.5	1.8
	Seidel Creek	BCP06	Base	6/8	0.696	0.63	<0.5	1
			Storm	16/18	1.08	1	<0.5	1.9
	Seidel Creek - South	SOUTH SEIDEL_YSI	Base	7/8	0.672	0.64	<0.5	0.84
			Storm	15/18	1.1	0.89	<0.5	2.7
	Struve Creek	BCP04	Base	8/8	1.91	1.6	1	3.63
			Storm	17/18	1.21	1.4	<0.5	1.9
	Upper Bear Trib	BCP10	Base	8/8	1.26	1.1	0.54	2.1
			Storm	18/18	2.15	1.9	1.2	4.54
	Bear Creek - Upper	BCP01	Base	6/8	0.856	0.63	<0.5	1.6
			Storm	16/18	1.09	0.91	<0.5	2.2
	Cottage Lake Creek	N484	Base	7/8	1.14	0.89	<0.5	2
			Storm	18/18	1.57	1.6	0.53	2.3
	Cottage	BCP03	Base	8/8	1.6	1.6	0.56	2.61

	Site	ID	Flow	Detections	Mean	Median	Min	Max
	Lake Outlet		Storm	16/18	1.17	1.3	<0.5	1.8
	Cold Creek	BCP02	Base	5/5	4.54	4.4	3.16	6.64
			Storm	16/16	8.55	6.96	3.01	18.9
Zinc, Total	Bear Creek - Lower	C484	Base	8/8	1.7	1.5	0.99	2.87
			Storm	18/18	6.14	4.53	1.9	20.9
	Stensland Creek	BCP09	Base	7/8	1.24	0.91	<0.5	3.41
			Storm	18/18	1.91	2	0.83	3.12
	Mackey Creek	ET484	Base	8/8	1.74	1.3	0.71	3.08
			Storm	18/18	5.21	4.65	2	11.6
	Monticello Creek	BCP08	Base	8/8	6.8	6.05	4.48	15.5
			Storm	18/18	28.3	23.6	5.24	79.8
	Bear Creek - Middle	J484	Base	7/8	1.21	0.77	<0.5	2.3
			Storm	18/18	2.18	1.7	0.88	5.42
	Seidel Creek	BCP06	Base	7/8	0.919	0.63	<0.5	1.8
			Storm	18/18	2.36	1.8	0.73	5.74
	Seidel Creek - South	SOUTH SEIDEL_YSI	Base	8/8	1.21	1.2	0.55	1.6
			Storm	17/18	3.43	1.8	<0.5	9.77
	Struve Creek	BCP04	Base	8/8	2.04	1.4	1.1	3.55
			Storm	18/18	2.98	2.2	1	9.08
	Upper Bear Trib	BCP10	Base	8/8	1.6	1.4	0.68	3.49
			Storm	18/18	4.4	3.45	1.9	10.7
	Bear Creek - Upper	BCP01	Base	4/8	0.9	NC	<0.5	2.8
			Storm	18/18	1.29	1.1	0.58	3.63
	Cottage Lake Creek	N484	Base	8/8	1.58	1.2	0.71	2.96
			Storm	18/18	2.94	2.4	1.3	5.67
	Cottage Lake Outlet	BCP03	Base	8/8	2.59	1.7	1.5	7.79
			Storm	17/18	1.38	1.1	<0.5	2.61
	Cold Creek	BCP02	Base	5/5	8.3	3.93	2.84	26.2
			Storm	16/16	22.1	18.5	2.78	59.6

3.7.2 Comparison to Water Quality Standards

The Washington State water quality standards aquatic life criteria contain both acute and chronic criteria for dissolved copper and zinc. Acute criteria may represent a 1-hour average concentration not to be exceeded more than once every three years. Chronic criteria may represent a 4-day average not to be exceeded more than once every three years. The water quality criteria for copper and zinc are calculated based on hardness.

Two sites during three storm sampling events had exceedances of the dissolved copper criteria. These were:

- Mackey Creek (ET484)

    - Aug. 30, 2015 AM – 10.0 µg/L
- Cold Creek (BCP02)
    - Aug. 29, 2015 AM – 5.05 µg/L
    - Aug. 30, 2015 AM – 5.43 µg/L
    - Oct. 10, 2015 AM – 2.87 µg/L (chronic criterion violation only)
    - Oct. 10, 2015 PM – 4.95 µg/L
    - Oct. 30, 2015 AM – 4.82 µg/L (chronic criterion violation only)
    - Oct. 30, 2015 PM – 5.95 µg/L
    - Oct. 31, 2015 AM – 5.80 µg/L

The dissolved copper exceedance at Mackey Creek (10 µg/L) exceeded the total copper concentration (2.81 µg/L) (Figure 28). The total and dissolved samples were collected separately; it is likely that the copper concentrations during storms in Mackey Creek are heterogeneous and the discrepancy between the samples reflect this. It is possible that the high copper concentration in Mackey Creek reflect a discrete release of copper rather than an ongoing source, as all other dissolved copper concentration were less than 2 µg/L.

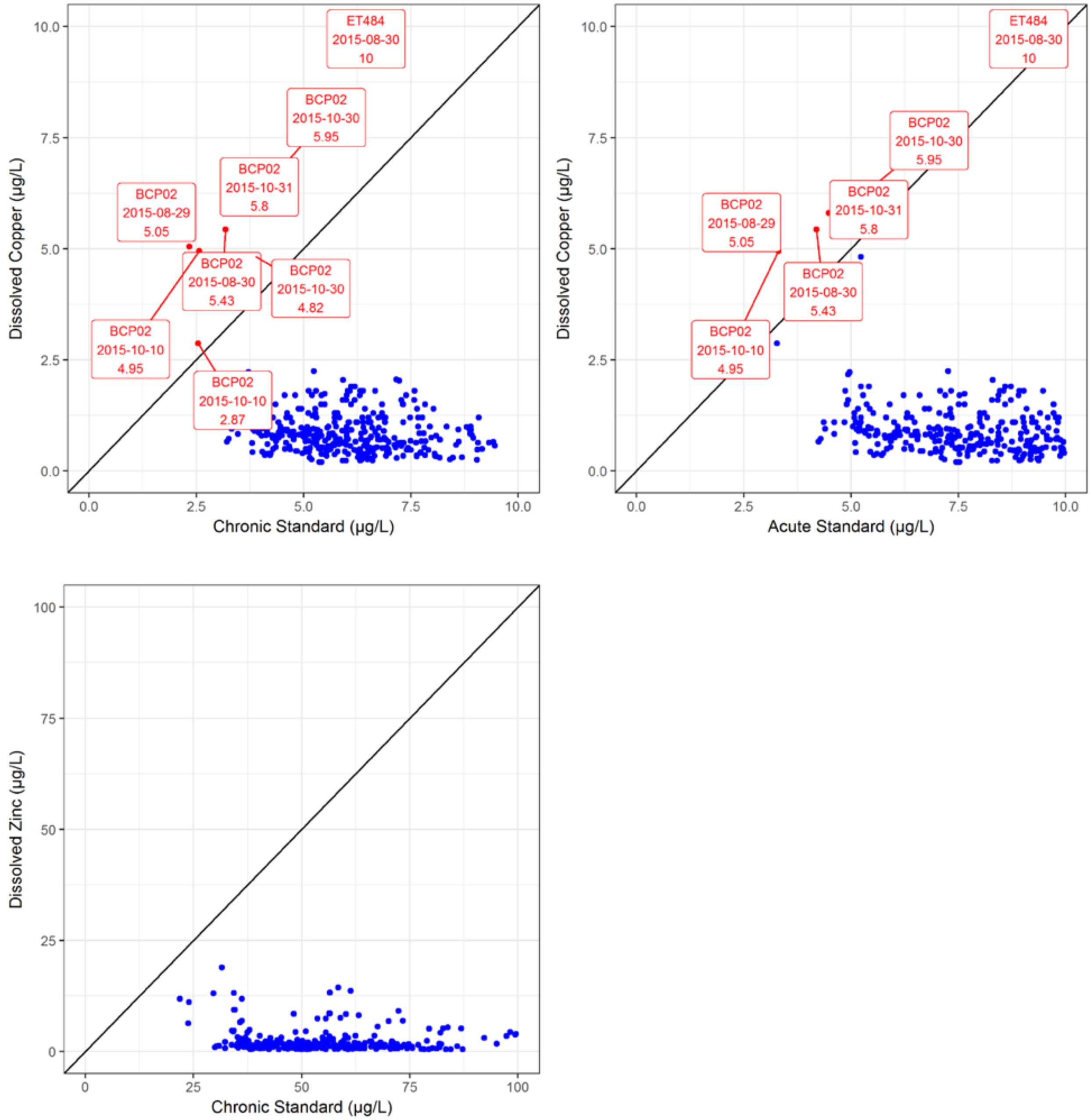

Figure 28. Dissolved copper compared to the (a) chronic and (b) acute standard, and (c) dissolved zinc compared to the chronic standard for grab sampled collected March 2015 to January 2016.

3.7.3 Instantaneous Loading

Copper and zinc loading during storms was greater than that of base flow in all gaged streams (Figures 29, 30, 31, and 32). The interquartile range of the total load of dissolve copper leaving the study area (Lower Bear Creek + Stensland Creek) was between 8 and 20 µg/s during base flow and 50 to 100 µg/s during storm event flow. The dissolved zinc load leaving the study area was 20 to 40 µg/s during base flow and 90 to 200 µg/s during storm event flow.

Middle Bear Creek, Cottage Lake Creek, and Upper Bear Creek are important pathways of copper and zinc to Lower Bear Creek. Monticello Creek is also an important pathway of zinc to the Bear Creek mainstem.

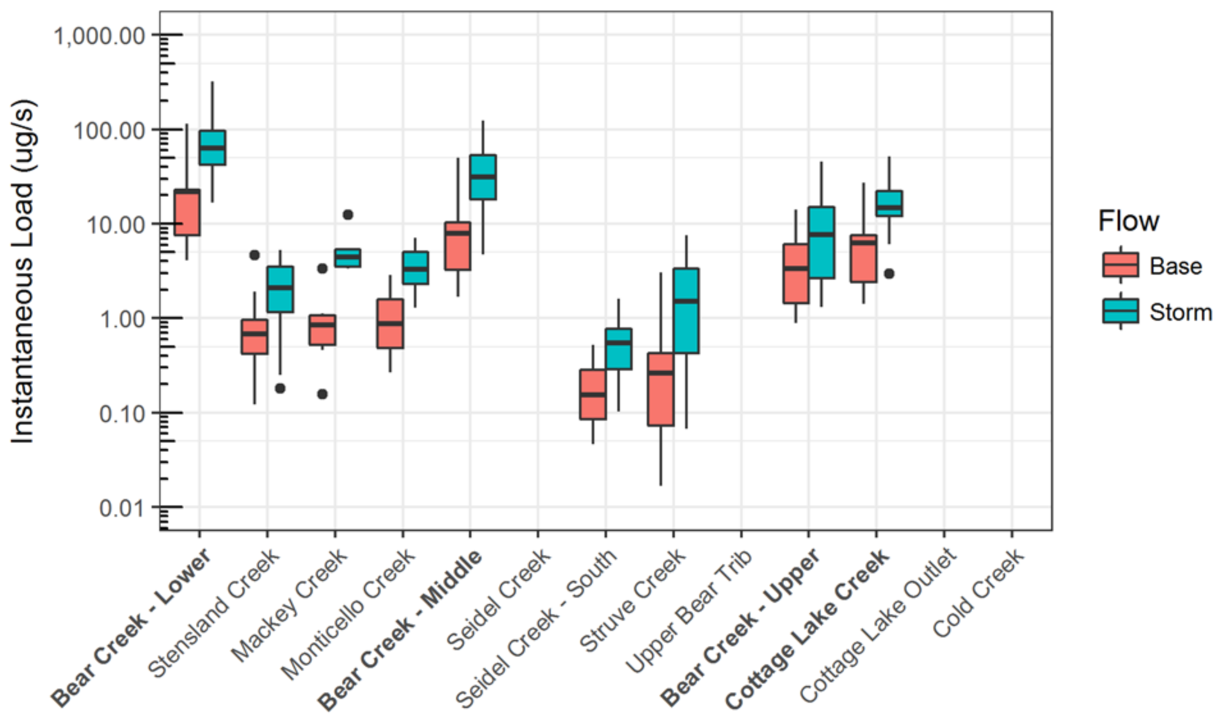

Figure 29. Instantaneous loadings of dissolved copper from gaged streams. Mainstem Bear and Cottage sites shown in bold.

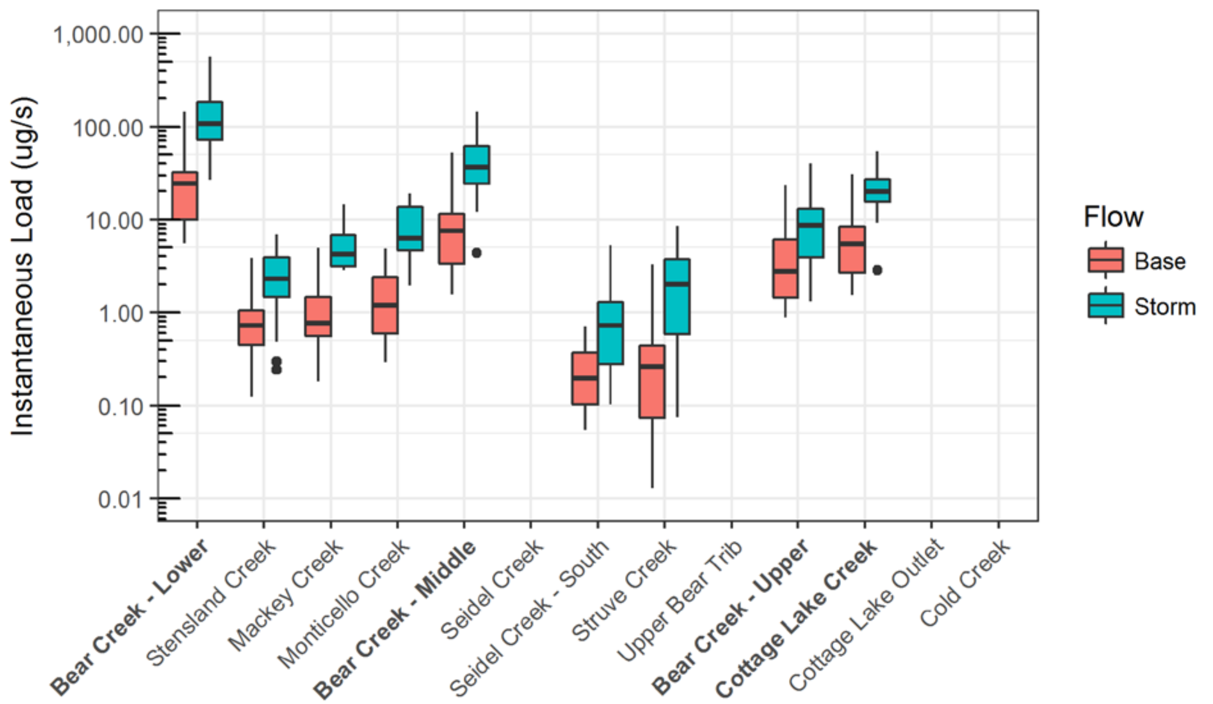

Figure 30. Instantaneous loadings of total copper from gaged streams. Mainstem Bear and Cottage sites shown in bold.

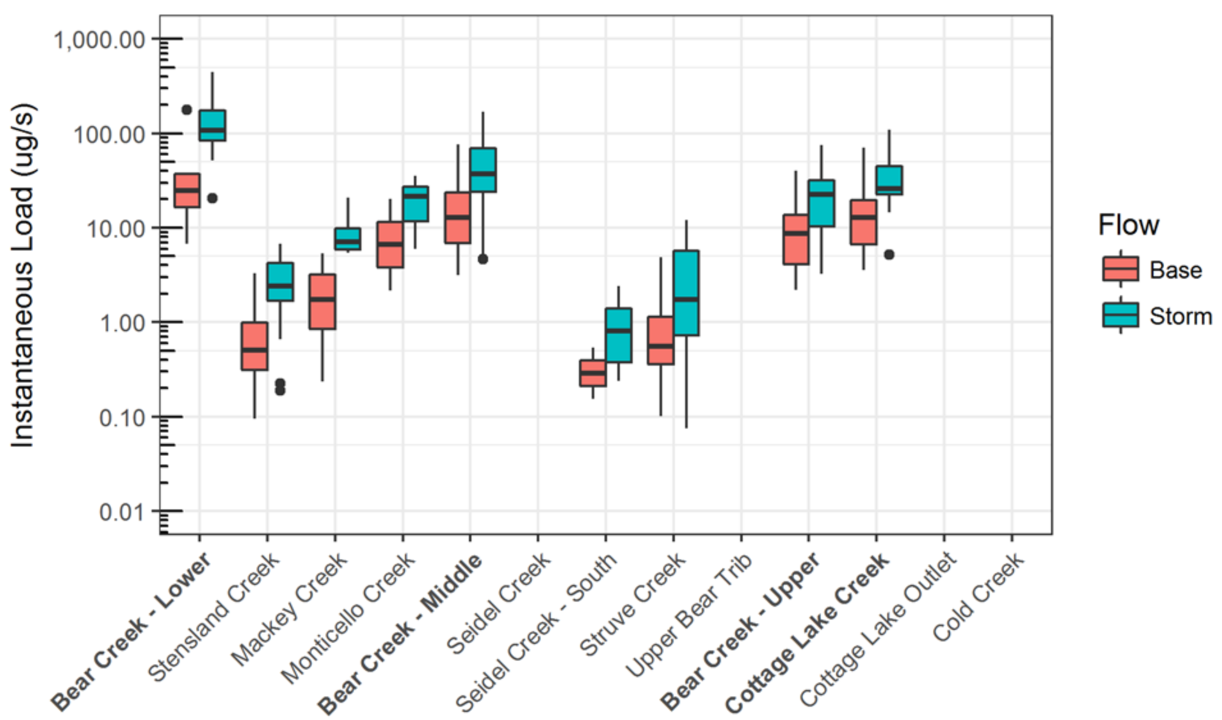

Figure 31. Instantaneous loadings of dissolved zinc from gaged streams. Mainstem Bear and Cottage sites shown in bold.

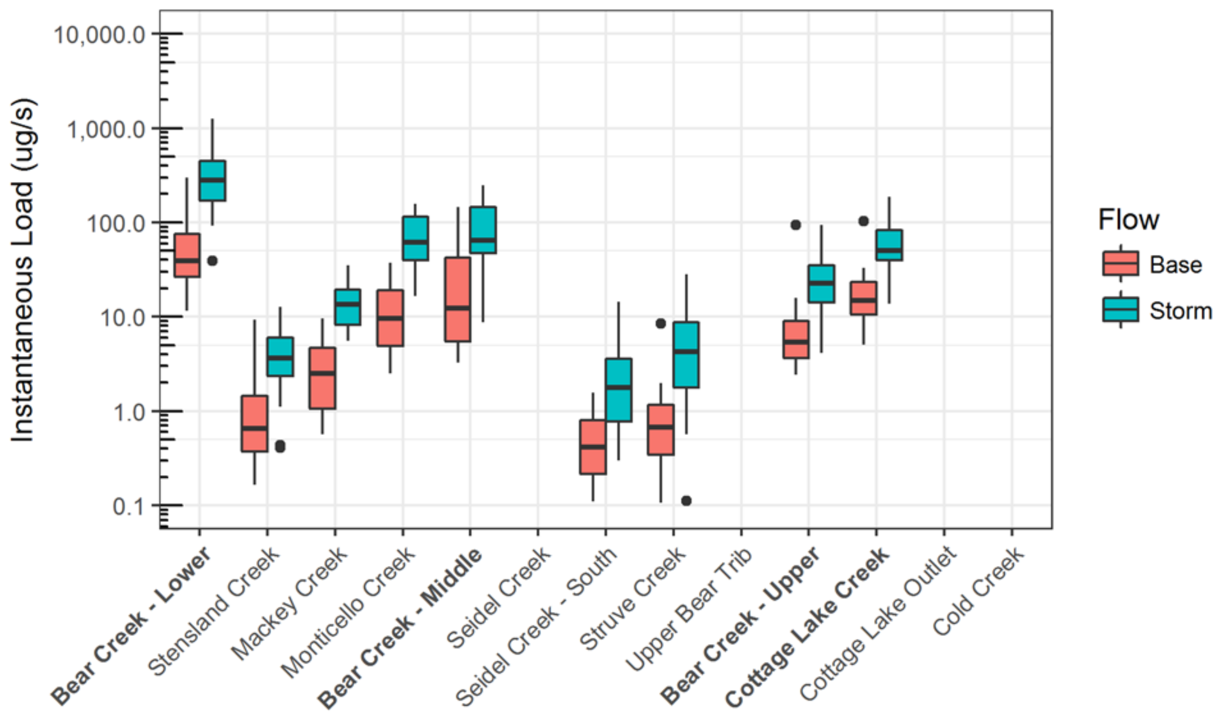

Figure 32. Instantaneous loadings of total zinc from gaged streams. Mainstem Bear and Cottage sites shown in bold.

3.8 Streambed Sediment Particle Size Distribution

Sediments were sampled on August 27, 2015 during relatively low summer flow when streambed sediment mobility is lowest. Sand and gravel were the dominant particle sizes in the Bear Creek study area (Figure 33). However, Upper Bear Creek had a substantial fraction silt (44%) and clay (14%). Gravel was the dominant substrate for Cottage Lake Creek, the Cottage Lake outlet, the north fork of Struve Creek, and Seidel Creek.

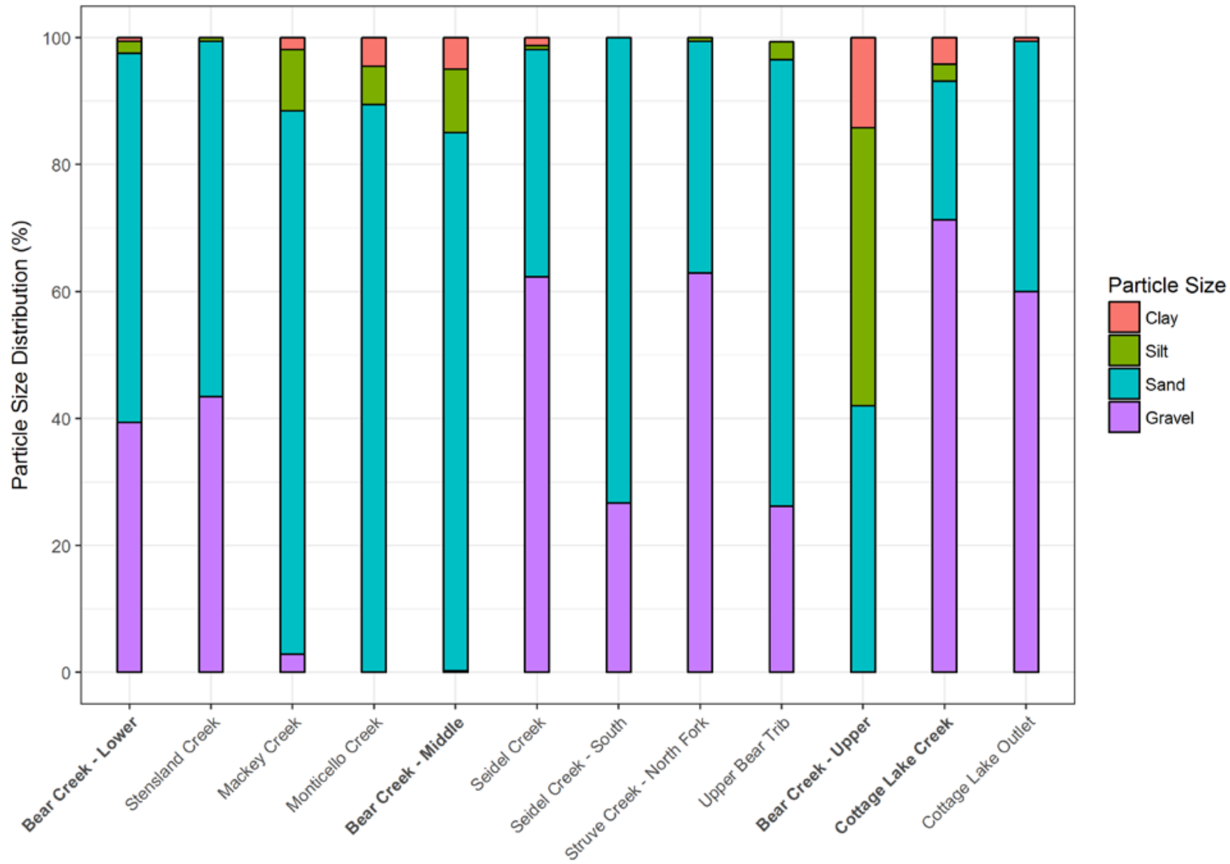

Figure 33. Particle size distribution of stream bed sediments at water quality sites sampled in August 2015. Mainstem Bear and Cottage sites shown in bold. Cold Creek was not sampled due to no water flow.

4.0 SUMMARY AND CONCLUSIONS

Characterization of existing water quality conditions in the basin was based on sampling of storm events and base flow conditions between March 2015 and January 2016. The primary goals were to characterize existing water quality during storm events and base flows throughout the year to support calibration of a watershed model. Thirteen sites were sampled during six baseflow and six storm events. Additionally, continuous flow and temperature gages were used to calculate instantaneous loading and temperature water quality standard exceedances.

In agreement with historic data for Bear Creek (King County, 2017), temperature, dissolved oxygen, and fecal coliform bacteria were identified as water quality concerns due to exceedances of the state water quality standards. Adding to these concerns, this study identified exceedance of the state criteria for dissolved copper in Mackey and Cold creeks during wet-weather.

Genetic analysis of water samples indicated the presence of human gut-associated bacteria in wet-weather samples from Lower Bear Creek, Mackey Creek, and South Seidel Creek. The levels of the genetic marker in Lower Bear Creek provides compelling evidence of the presence of human feces, but the levels found in Mackey and South Seidel creeks are intriguing but less compelling. Therefore, microbial source tracking at a finer scale is recommended to determine the sources of human feces in Lower Bear Creek and confirm whether there is a concern in Mackey and South Seidel creeks. Potential sources include illicit sewage connections, failing septic systems, leaking sewer pipes, homeless encampments without access to sanitary facilities, or human feces otherwise not deposited in a functioning sanitary system.

Monticello Creek was identified as a major pathway of suspended solids during wet-weather flow, with instantaneous loads similar to Middle Bear Creek and greater than Cottage Lake Creek. Suspended solid loading from stormwater conveyance systems, bank erosion, and un-gaged tributaries were identified as additional important pathways to Lower Bear Creek.

As part of the overall Bear Creek watershed planning effort, the data collected during baseflow and storm events described in this report will be used in the calibration of a hydrologic model (HSPF) for the Bear Creek basin. The hydrologic model will be used to assess the impacts of different stormwater management strategies on the hydrology and water quality in Bear Creek.

5.0 REFERENCES

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Appendix A: Sampling Dates, Times, and Sample Numbers

Table A-1. Sampling date/time for the six baseflow and six storm events.

Site	Locator	Event	Sample Date and Time	Sample Number
Bear Creek - Lower	C484	Base 1	3/4/2015 7:06	L61008-1
			3/4/2015 15:00	L61009-1
		Base 2	4/28/2015 7:20	L62555-1
			4/28/2015 15:01	L62556-1
		Base 3	6/25/2015 7:45	L63051-1
		Base 4	8/27/2015 15:20	L63448-1
		Storm 1	8/29/2015 7:45	L62729-1
			8/29/2015 18:00	L62730-1
			8/30/2015 7:35	L62731-1
		Storm 2	10/10/2015 8:00	L63674-1
			10/10/2015 16:30	L63676-1
			10/11/2015 7:40	L63677-1
		Base 5	10/15/2015 9:32	L63888-1
		Storm 3	10/30/2015 8:00	L63950-1
			10/30/2015 19:05	L63951-1
			10/31/2015 8:35	L63952-1
		Storm 4	12/3/2015 6:55	L64170-1
			12/3/2015 16:30	L64171-1
			12/4/2015 7:50	L64172-1
		Storm 5	12/17/2015 7:30	L64432-1
			12/17/2015 16:40	L64433-1
			12/18/2015 8:30	L64434-1
		Base 6	12/28/2015 8:06	L64252-1
		Storm 6	1/13/2016 7:15	L64489-1
			1/13/2016 16:01	L64490-1
			1/14/2016 8:02	L64491-1
Stensland Creek	BCP09	Base 1	3/4/2015 7:19	L61008-14
			3/4/2015 15:15	L61009-14
		Base 2	4/28/2015 7:29	L62555-2
			4/28/2015 15:15	L62556-2
		Base 3	6/25/2015 7:56	L63051-2
		Base 4	8/27/2015 15:40	L63448-2
		Storm 1	8/29/2015 8:00	L62729-2
			8/29/2015 18:10	L62730-2
			8/30/2015 7:45	L62731-2
		Storm 2	10/10/2015 8:30	L63674-2
			10/10/2015 16:45	L63676-2
			10/11/2015 7:50	L63677-2
		Base 5	10/15/2015 9:49	L63888-2
		Storm 3	10/30/2015 8:25	L63950-2

Site	Locator	Event	Sample Date and Time	Sample Number
			10/30/2015 19:15	L63951-2
			10/31/2015 8:45	L63952-2
		Storm 4	12/3/2015 7:10	L64170-2
			12/3/2015 16:40	L64171-2
			12/4/2015 8:00	L64172-2
		Storm 5	12/17/2015 7:45	L64432-2
			12/17/2015 16:50	L64433-2
			12/18/2015 8:50	L64434-2
		Base 6	12/28/2015 8:19	L64252-2
		Storm 6	1/13/2016 7:35	L64489-2
			1/13/2016 16:10	L64490-2
			1/14/2016 8:14	L64491-2
Mackey Creek	ET484	Base 1	3/4/2015 7:35	L61008-2
			3/4/2015 15:35	L61009-2
		Base 2	4/28/2015 7:43	L62555-3
			4/28/2015 15:30	L62556-3
		Base 3	6/25/2015 8:11	L63051-3
		Base 4	8/27/2015 15:00	L63448-3
		Storm 1	8/29/2015 8:20	L62729-3
			8/29/2015 18:30	L62730-3
			8/30/2015 8:10	L62731-3
		Storm 2	10/10/2015 8:50	L63674-3
			10/10/2015 17:00	L63676-3
			10/11/2015 8:05	L63677-3
		Base 5	10/15/2015 10:04	L63888-3
		Storm 3	10/30/2015 8:40	L63950-3
			10/30/2015 19:30	L63951-3
			10/31/2015 9:00	L63952-3
		Storm 4	12/3/2015 7:20	L64170-3
			12/3/2015 16:55	L64171-3
			12/4/2015 8:10	L64172-3
		Storm 5	12/17/2015 7:55	L64432-3
			12/17/2015 17:00	L64433-3
			12/18/2015 9:00	L64434-3
		Base 6	12/28/2015 8:35	L64252-3
		Storm 6	1/13/2016 7:49	L64489-3
			1/13/2016 16:20	L64490-3
			1/14/2016 8:25	L64491-3
Monticello Creek	BCP08	Base 1	3/4/2015 8:32	L61008-13
			3/4/2015 16:42	L61009-13

Site	Locator	Event	Sample Date and Time	Sample Number
		Base 2	4/28/2015 8:41	L62555-5
			4/28/2015 16:38	L62556-5
		Base 3	6/25/2015 9:08	L63051-5
		Base 4	8/27/2015 14:35	L63448-5
		Storm 1	8/29/2015 9:30	L62729-5
			8/29/2015 19:25	L62730-5
			8/30/2015 9:00	L62731-5
		Storm 2	10/10/2015 9:30	L63674-5
			10/10/2015 17:45	L63676-5
			10/11/2015 8:50	L63677-5
		Base 5	10/15/2015 11:25	L63888-5
		Storm 3	10/30/2015 9:35	L63950-5
			10/30/2015 18:30	L63951-5
			10/31/2015 9:45	L63952-5
		Storm 4	12/3/2015 7:30	L64170-5
			12/3/2015 17:00	L64171-5
			12/4/2015 8:25	L64172-5
		Storm 5	12/17/2015 8:05	L64432-5
			12/17/2015 18:00	L64433-5
			12/18/2015 9:10	L64434-5
		Base 6	12/28/2015 9:47	L64252-5
		Storm 6	1/13/2016 8:01	L64489-5
			1/13/2016 17:00	L64490-5
			1/14/2016 8:34	L64491-5
Bear Creek - Middle	J484	Base 1	3/4/2015 8:47	L61008-3
			3/4/2015 16:57	L61009-3
		Base 2	4/28/2015 8:56	L62555-6
			4/28/2015 16:58	L62556-6
		Base 3	6/25/2015 9:23	L63051-6
		Base 4	8/27/2015 13:22	L63448-6
		Storm 1	8/29/2015 9:50	L62729-6
			8/29/2015 19:40	L62730-6
			8/30/2015 9:15	L62731-6
		Storm 2	10/10/2015 9:50	L63674-6
			10/10/2015 18:00	L63676-6
			10/11/2015 9:10	L63677-6
		Base 5	10/15/2015 11:40	L63888-6
		Storm 3	10/30/2015 9:45	L63950-6
			10/30/2015 18:40	L63951-6
			10/31/2015 10:00	L63952-6

Site	Locator	Event	Sample Date and Time	Sample Number
		Storm 4	12/3/2015 8:20	L64170-6
			12/3/2015 17:55	L64171-6
			12/4/2015 9:10	L64172-6
		Storm 5	12/17/2015 8:55	L64432-6
			12/17/2015 18:10	L64433-6
			12/18/2015 10:00	L64434-6
		Base 6	12/28/2015 10:03	L64252-6
		Storm 6	1/13/2016 8:50	L64489-6
			1/13/2016 17:14	L64490-6
			1/14/2016 9:15	L64491-6
Seidel Creek	BCP06	Base 1	3/4/2015 9:01	L61008-11
			3/4/2015 17:08	L61009-11
		Base 2	4/28/2015 9:05	L62555-7
			4/28/2015 17:10	L62556-7
		Base 3	6/25/2015 9:34	L63051-7
		Base 4	8/27/2015 13:35	L63448-7
		Storm 1	8/29/2015 10:00	L62729-7
			8/29/2015 20:00	L62730-7
			8/30/2015 9:30	L62731-7
		Storm 2	10/10/2015 10:00	L63674-7
			10/10/2015 18:10	L63676-7
			10/11/2015 9:15	L63677-7
		Base 5	10/15/2015 11:52	L63888-7
		Storm 3	10/30/2015 10:00	L63950-7
			10/30/2015 18:50	L63951-7
			10/31/2015 10:05	L63952-7
		Storm 4	12/3/2015 8:35	L64170-7
			12/3/2015 18:00	L64171-7
			12/4/2015 9:15	L64172-7
		Storm 5	12/17/2015 9:05	L64432-7
			12/17/2015 18:15	L64433-7
			12/18/2015 10:05	L64434-7
		Base 6	12/28/2015 10:17	L64252-7
		Storm 6	1/13/2016 9:01	L64489-7
			1/13/2016 17:24	L64490-7
			1/14/2016 9:25	L64491-7
Seidel Creek - South	SOUTH SEIDEL_YSI	Base 1	3/4/2015 8:03	L61008-5
			3/4/2015 16:05	L61009-5
		Base 2	4/28/2015 8:09	L62555-4
			4/28/2015 16:08	L62556-4

Site	Locator	Event	Sample Date and Time	Sample Number
		Base 3	6/25/2015 8:40	L63051-4
		Base 4	8/27/2015 14:05	L63448-4
		Storm 1	8/29/2015 9:00	L62729-4
			8/29/2015 19:00	L62730-4
			8/30/2015 8:35	L62731-4
		Storm 2	10/10/2015 9:15	L63674-4
			10/10/2015 17:20	L63676-4
			10/11/2015 8:30	L63677-4
		Base 5	10/15/2015 10:38	L63888-4
		Storm 3	10/30/2015 9:05	L63950-4
			10/30/2015 18:00	L63951-4
			10/31/2015 9:20	L63952-4
		Storm 4	12/3/2015 7:55	L64170-4
			12/3/2015 17:20	L64171-4
			12/4/2015 8:50	L64172-4
		Storm 5	12/17/2015 8:30	L64432-4
			12/17/2015 17:25	L64433-4
			12/18/2015 9:35	L64434-4
		Base 6	12/28/2015 9:08	L64252-4
		Storm 6	1/13/2016 8:28	L64489-4
			1/13/2016 16:39	L64490-4
			1/14/2016 8:50	L64491-4
Struve Creek - North Fork	BCP04	Base 1	3/4/2015 9:33	L61008-9
			3/4/2015 16:15	L61009-9
		Base 2	4/28/2015 8:37	L62555-12
			4/28/2015 19:15	L62556-12
		Base 3	6/25/2015 11:22	L63051-12
		Base 4	8/27/2015 12:00	L63448-12
		Storm 1	8/29/2015 10:21	L62729-12
			8/29/2015 19:10	L62730-12
			8/30/2015 8:49	L62731-12
		Storm 2	10/10/2015 9:53	L63674-12
			10/10/2015 17:58	L63676-12
			10/11/2015 8:52	L63677-12
		Base 5	10/15/2015 10:00	L63888-12
		Storm 3	10/30/2015 9:24	L63950-12
			10/30/2015 18:51	L63951-12
			10/31/2015 9:33	L63952-12
		Storm 4	12/3/2015 8:04	L64170-12
			12/3/2015 17:28	L64171-12

Site	Locator	Event	Sample Date and Time	Sample Number
			12/4/2015 8:48	L64172-12
		Storm 5	12/17/2015 8:18	L64432-12
			12/17/2015 17:58	L64433-12
			12/18/2015 9:37	L64434-12
		Base 6	12/28/2015 12:26	L64252-12
		Storm 6	1/13/2016 8:30	L64489-12
			1/13/2016 17:08	L64490-12
			1/14/2016 9:16	L64491-12
Upper Bear Trib	BCP10	Base 1	3/4/2015 9:55	L61008-10
			3/4/2015 16:30	L61009-10
		Base 2	4/28/2015 9:00	L62555-13
			4/28/2015 18:22	L62556-13
		Base 3	6/25/2015 11:46	L63051-13
		Base 4	8/27/2015 12:21	L63448-13
		Storm 1	8/29/2015 9:55	L62729-13
			8/29/2015 19:32	L62730-13
			8/30/2015 8:29	L62731-13
		Storm 2	10/10/2015 9:35	L63674-13
			10/10/2015 17:40	L63676-13
			10/11/2015 8:33	L63677-13
		Base 5	10/15/2015 10:19	L63888-13
		Storm 3	10/30/2015 9:29	L63950-13
			10/30/2015 19:09	L63951-13
			10/31/2015 9:52	L63952-13
		Storm 4	12/3/2015 8:22	L64170-13
			12/3/2015 17:46	L64171-13
			12/4/2015 9:04	L64172-13
		Storm 5	12/17/2015 8:29	L64432-13
			12/17/2015 18:15	L64433-13
			12/18/2015 9:53	L64434-13
		Base 6	12/28/2015 12:55	L64252-13
		Storm 6	1/13/2016 8:50	L64489-13
			1/13/2016 17:23	L64490-13
			1/14/2016 9:36	L64491-13
Bear Creek - Upper	BCP01	Base 1	3/4/2015 8:45	L61008-6
			3/4/2015 15:49	L61009-6
		Base 2	4/28/2015 8:12	L62555-11
			4/28/2015 17:43	L62556-11
		Base 3	6/25/2015 10:47	L63051-11
		Base 4	8/27/2015 12:42	L63448-11

Site	Locator	Event	Sample Date and Time	Sample Number
		Storm 1	8/29/2015 9:33	L62729-11
			8/29/2015 18:51	L62730-11
			8/30/2015 8:15	L62731-11
		Storm 2	10/10/2015 9:18	L63674-11
			10/10/2015 17:28	L63676-11
			10/11/2015 8:20	L63677-11
		Base 5	10/15/2015 10:33	L63888-11
		Storm 3	10/30/2015 8:59	L63950-11
			10/30/2015 18:31	L63951-11
			10/31/2015 9:13	L63952-11
		Storm 4	12/3/2015 7:43	L64170-11
			12/3/2015 17:05	L64171-11
			12/4/2015 8:25	L64172-11
		Storm 5	12/17/2015 8:42	L64432-11
			12/17/2015 17:38	L64433-11
			12/18/2015 9:15	L64434-11
		Base 6	12/28/2015 11:55	L64252-11
		Storm 6	1/13/2016 8:00	L64489-11
			1/13/2016 16:40	L64490-11
			1/14/2016 8:50	L64491-11
Cottage Lake Creek	N484	Base 1	3/4/2015 7:10	L61008-4
			3/4/2015 15:00	L61009-4
		Base 2	4/28/2015 7:13	L62555-8
			4/28/2015 15:00	L62556-8
		Base 3	6/25/2015 9:58	L63051-8
		Base 4	8/27/2015 13:03	L63448-8
		Storm 1	8/29/2015 7:35	L62729-8
			8/29/2015 18:00	L62730-8
			8/30/2015 7:27	L62731-8
		Storm 2	10/10/2015 8:04	L63674-8
			10/10/2015 16:38	L63676-8
			10/11/2015 7:40	L63677-8
		Base 5	10/15/2015 11:17	L63888-8
		Storm 3	10/30/2015 8:01	L63950-8
			10/30/2015 17:47	L63951-8
			10/31/2015 8:31	L63952-8
		Storm 4	12/3/2015 6:48	L64170-8
			12/3/2015 16:23	L64171-8
			12/4/2015 7:45	L64172-8
		Storm 5	12/17/2015 7:22	L64432-8

Site	Locator	Event	Sample Date and Time	Sample Number
			12/17/2015 16:48	L64433-8
			12/18/2015 8:32	L64434-8
		Base 6	12/28/2015 10:37	L64252-8
		Storm 6	1/13/2016 7:15	L64489-8
			1/13/2016 16:00	L64490-8
			1/14/2016 7:57	L64491-8
Cottage Lake Outlet	BCP03	Base 1	3/4/2015 7:45	L61008-8
			3/4/2015 15:15	L61009-8
		Base 2	4/28/2015 7:31	L62555-9
			4/28/2015 16:26	L62556-9
		Base 3	6/25/2015 10:13	L63051-9
		Base 4	8/27/2015 11:05	L63448-9
		Storm 1	8/29/2015 8:19	L62729-9
			8/29/2015 18:18	L62730-9
			8/30/2015 7:38	L62731-9
		Storm 2	10/10/2015 8:29	L63674-9
			10/10/2015 16:50	L63676-9
			10/11/2015 7:55	L63677-9
		Base 5	10/15/2015 10:59	L63888-9
		Storm 3	10/30/2015 8:18	L63950-9
			10/30/2015 17:58	L63951-9
			10/31/2015 8:41	L63952-9
		Storm 4	12/3/2015 7:03	L64170-9
			12/3/2015 16:45	L64171-9
			12/4/2015 7:56	L64172-9
		Storm 5	12/17/2015 7:37	L64432-9
			12/17/2015 17:00	L64433-9
			12/18/2015 8:44	L64434-9
		Base 6	12/28/2015 11:02	L64252-9
		Storm 6	1/13/2016 7:30	L64489-9
			1/13/2016 16:10	L64490-9
			1/14/2016 8:13	L64491-9
Cold Creek	BCP02	Base 1	3/4/2015 8:11	L61008-7
			3/4/2015 15:32	L61009-7
		Base 2	4/28/2015 7:50	L62555-10
			4/28/2015 16:52	L62556-10
		Base 3	*No flow – not sampled*	
		Base 4	*No flow – not sampled*	
		Storm 1	8/29/2015 8:48	L62729-10
			No flow – not sampled	

Site	Locator	Event	Sample Date and Time	Sample Number
			8/30/2015 7:53	L62731-10
		Storm 2	10/10/2015 9:00	L63674-10
			10/10/2015 17:18	L63676-10
			No flow – not sampled	
		Base 5	*No flow – not sampled*	
		Storm 3	10/30/2015 8:35	L63950-10
			10/30/2015 18:09	L63951-10
			10/31/2015 8:51	L63952-10
		Storm 4	12/3/2015 7:17	L64170-10
			12/3/2015 16:50	L64171-10
			12/4/2015 8:05	L64172-10
		Storm 5	12/17/2015 7:59	L64432-10
			12/17/2015 17:18	L64433-10
			12/18/2015 8:59	L64434-10
		Base 6	12/28/2015 11:22	L64252-10
		Storm 6	1/13/2016 7:45	L64489-10
			1/13/2016 16:25	L64490-10
			1/14/2016 8:30	L64491-10

Appendix B: Hydrographs for Each Sampling Event

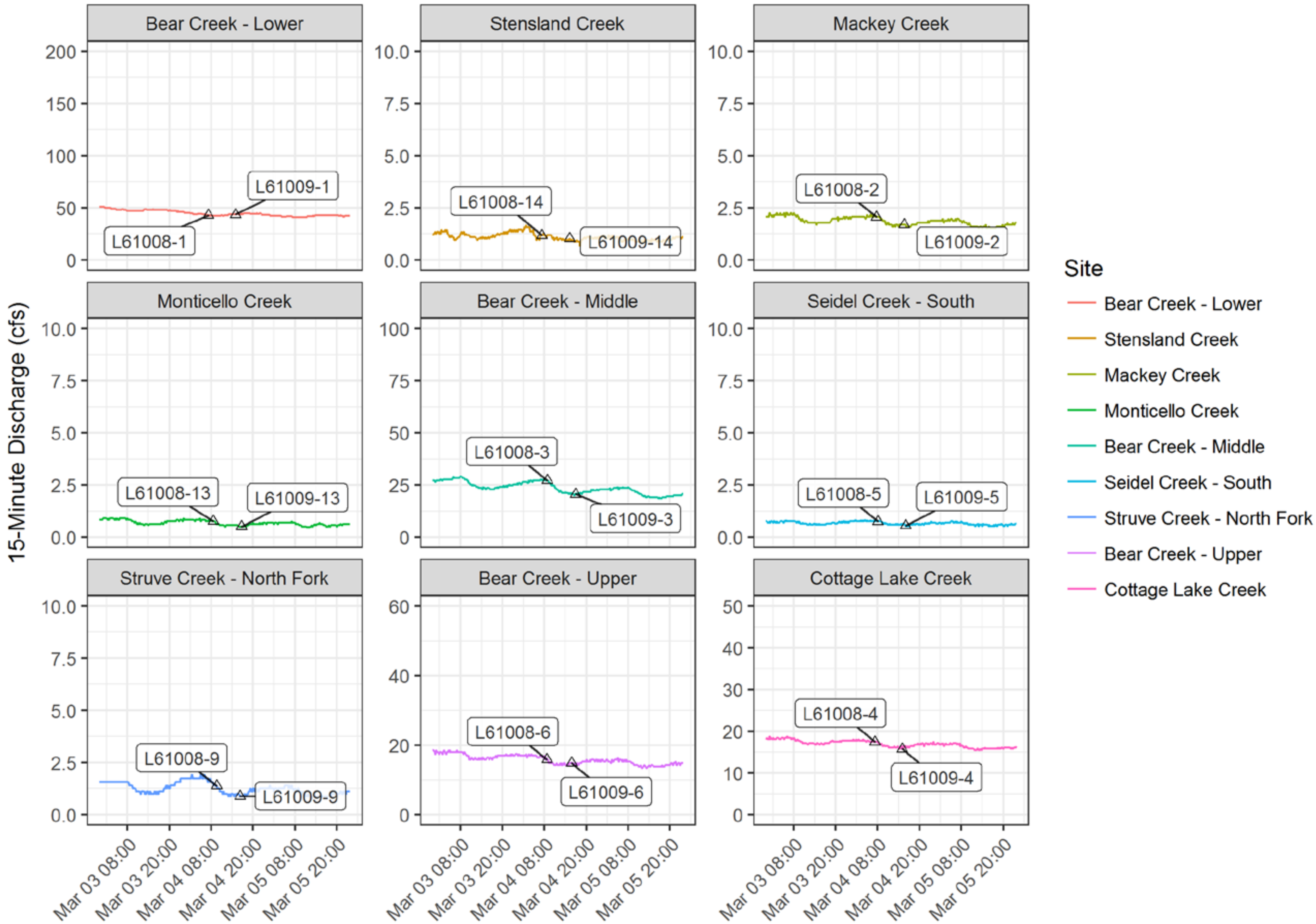

Figure B-1 Hydrographs for gaged streams during the March 3, 2015 baseflow sampling. Sampling times and sample numbers marked.

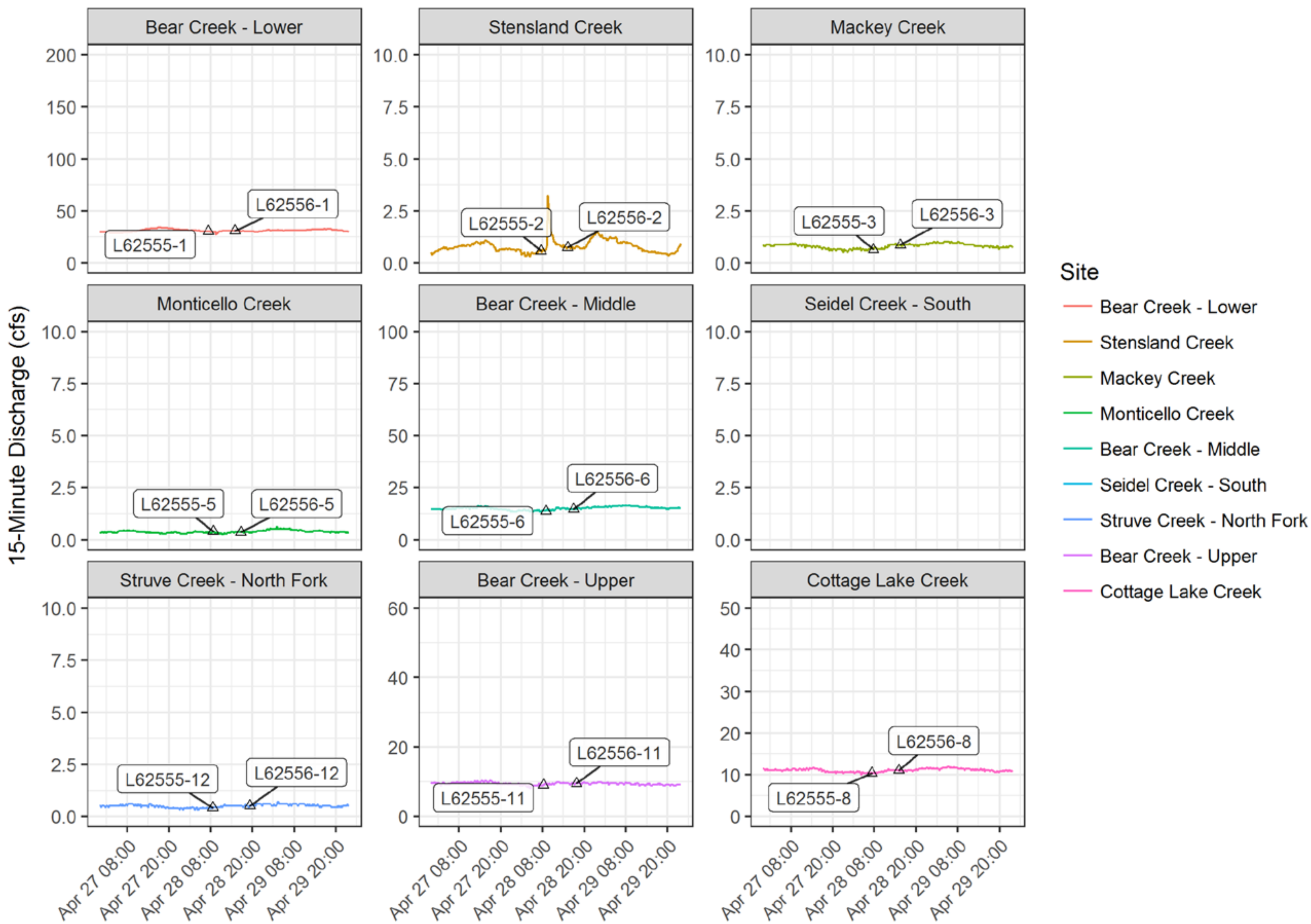

Figure B-2 Hydrographs for gaged streams during the April 28, 2015 baseflow sampling. Sampling times and sample numbers marked.

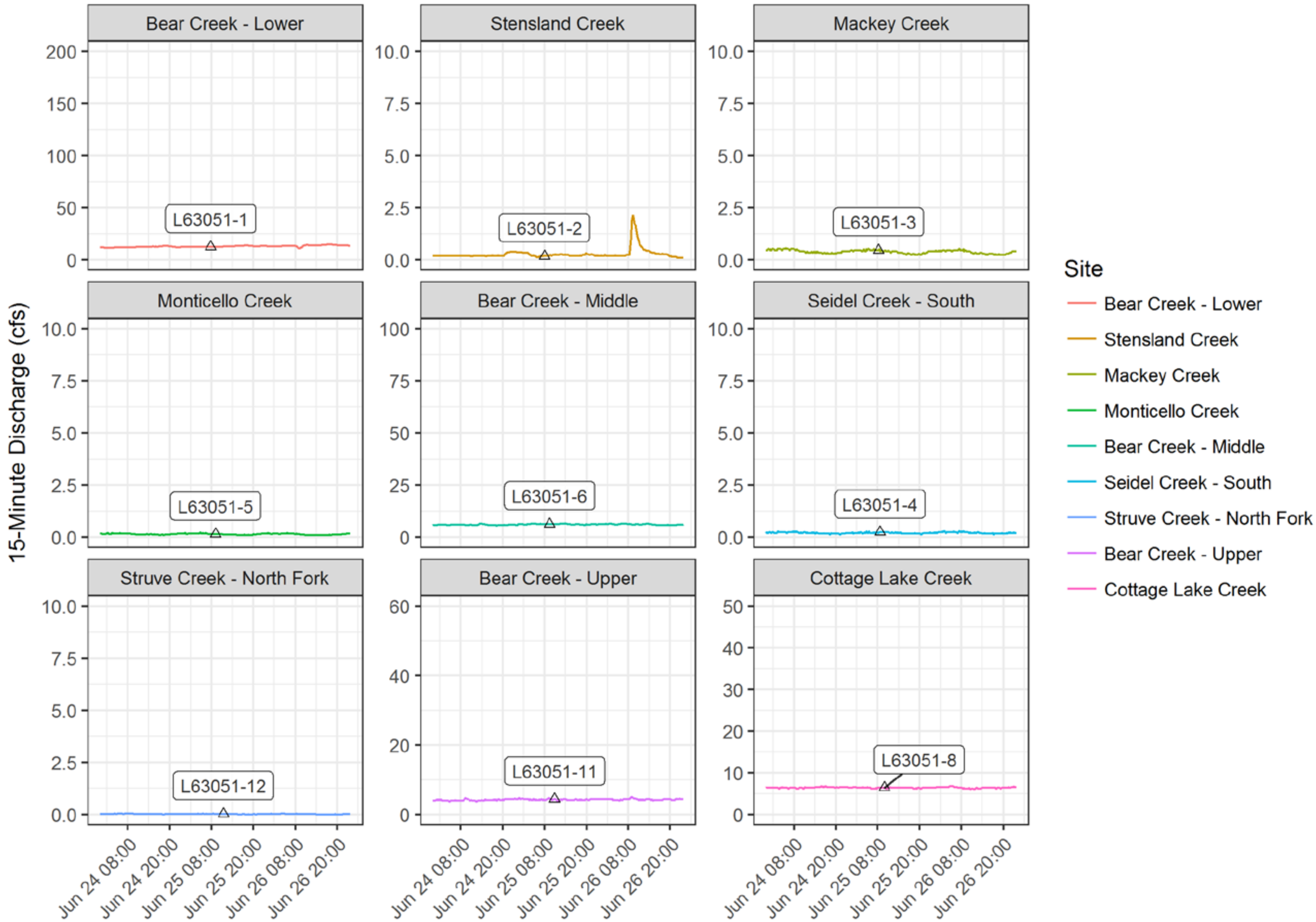

Figure B-3 Hydrographs for gaged streams during the June 25, 2015 baseflow sampling. Sampling times and sample numbers marked.

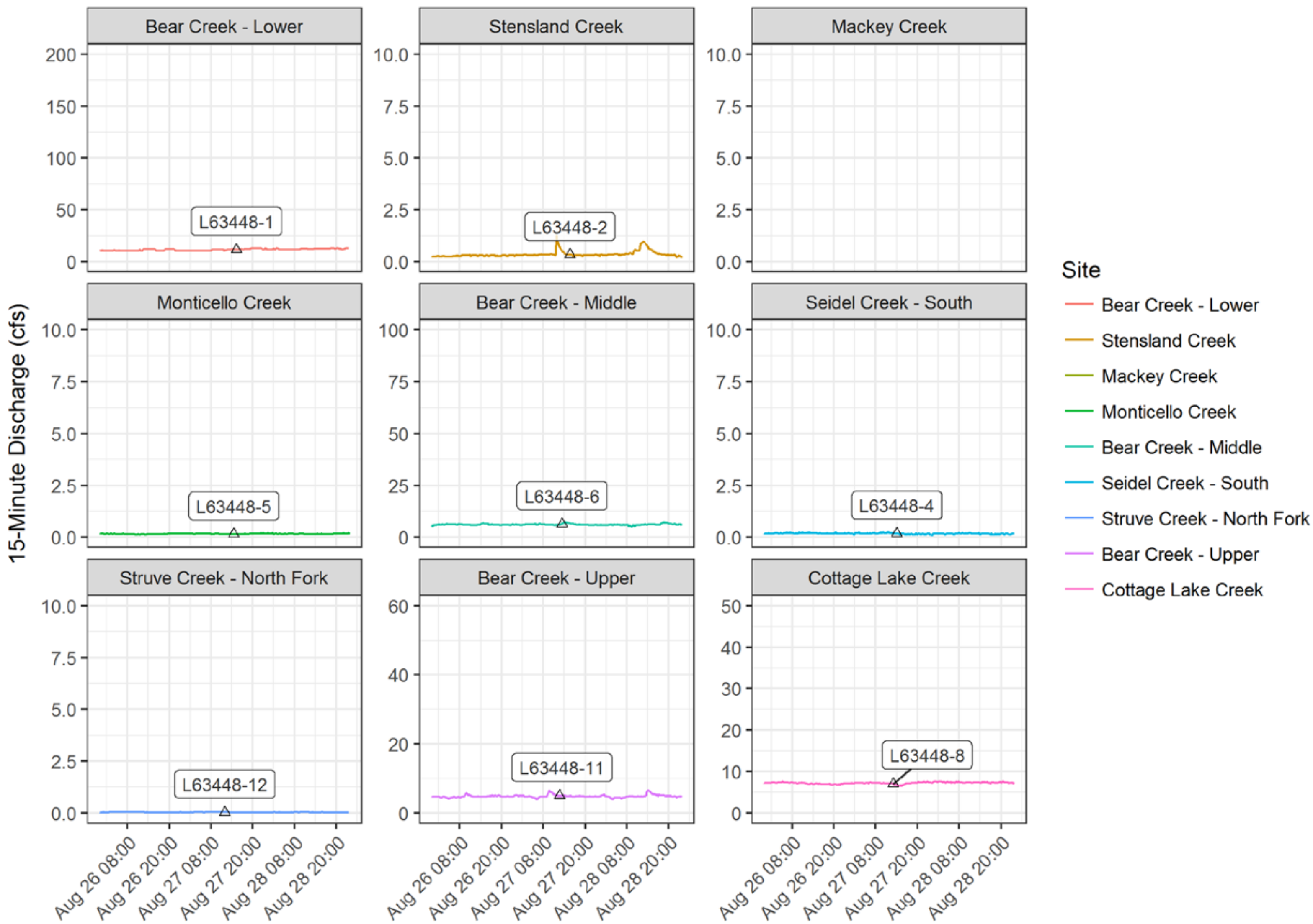

Figure B-4 Hydrographs for gaged streams during the August 27, 2015 baseflow sampling. Sampling times and sample numbers marked.

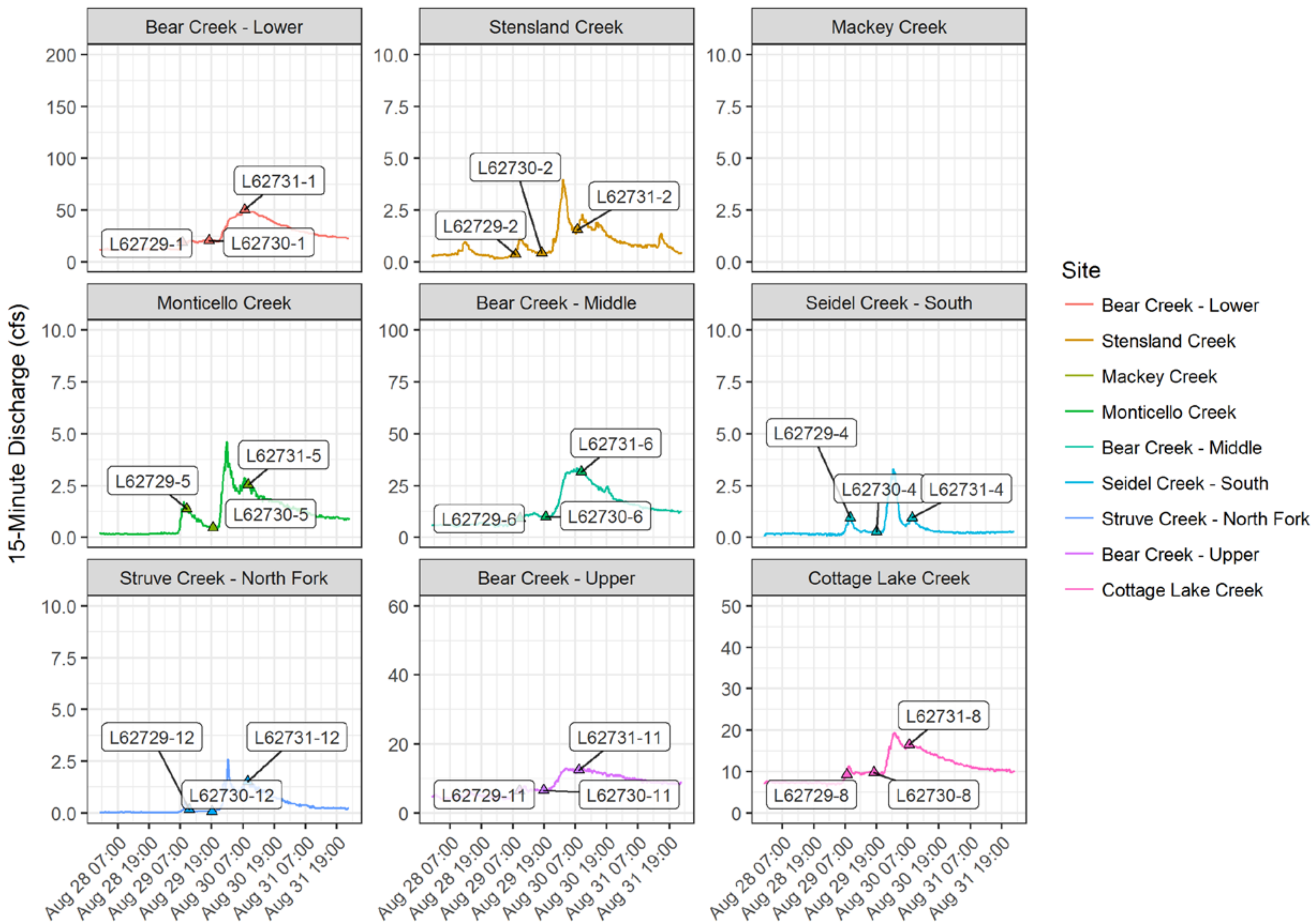

Figure B-5 Hydrographs for gaged streams during the August 29-30, 2015 storm event sampling. Sampling times and sample numbers marked.

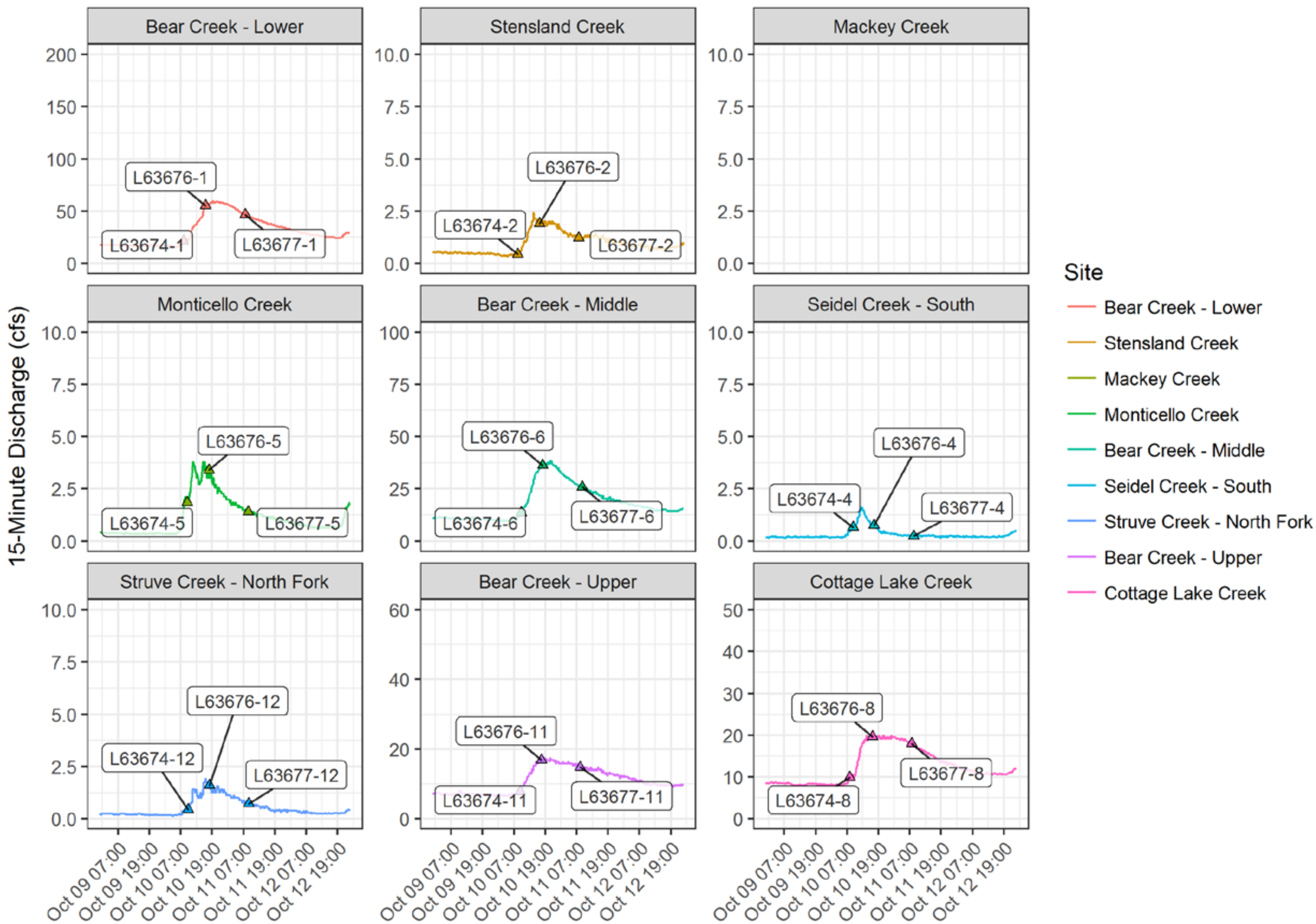

Figure B-6 Hydrographs for gaged streams during the October 10-11, 2015 storm event sampling. Sampling times and sample numbers marked.

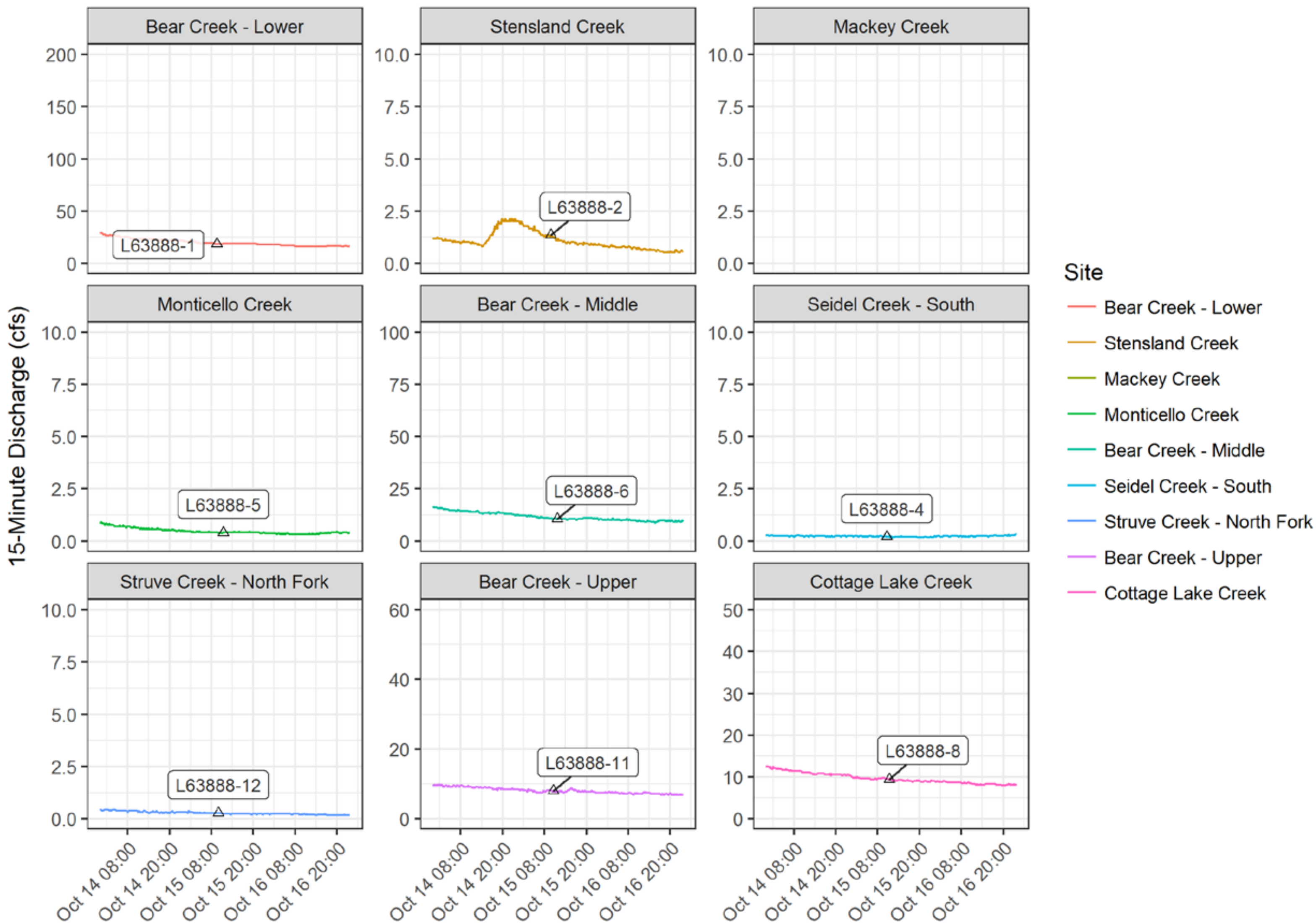

Figure B-7 Hydrographs for gaged streams during the October 15, 2015 baseflow sampling. Sampling times and sample numbers marked.

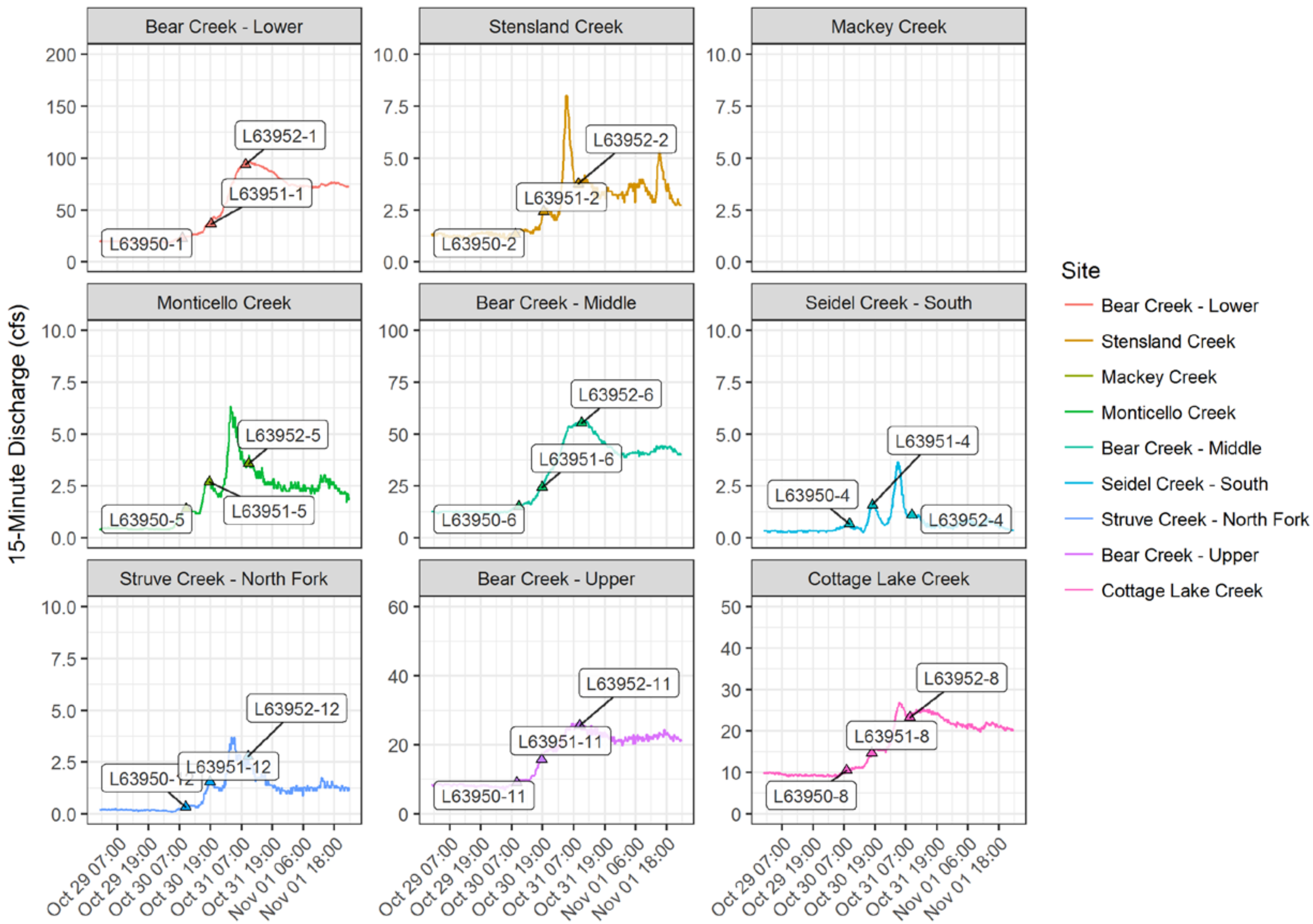

Figure B-8 Hydrographs for gaged streams during the October 30-31, 2015 storm event sampling. Sampling times and sample numbers marked.

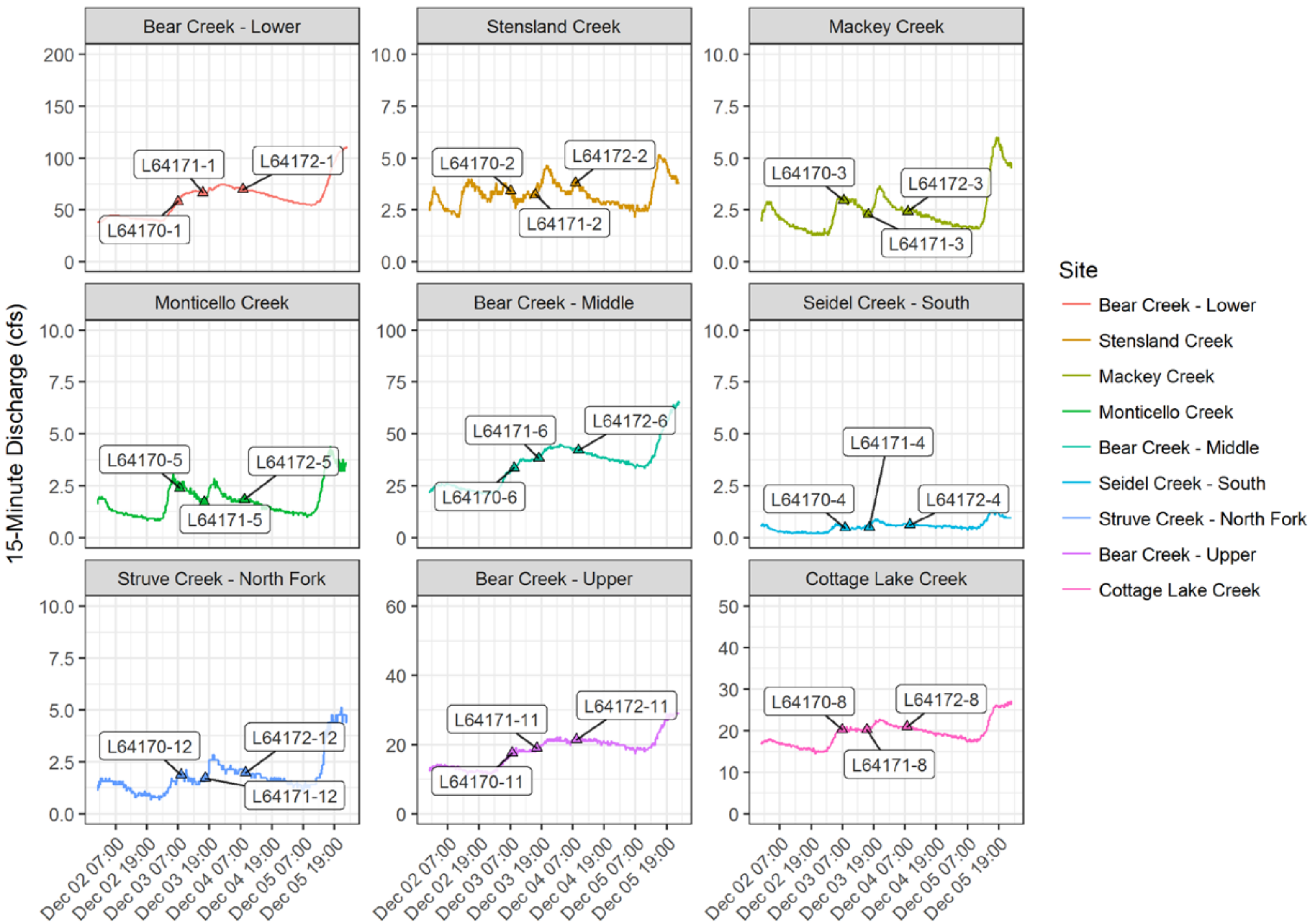

Figure B-9 Hydrographs for gaged streams during the December 3-4, 2015 storm event sampling. Sampling times and sample numbers marked.

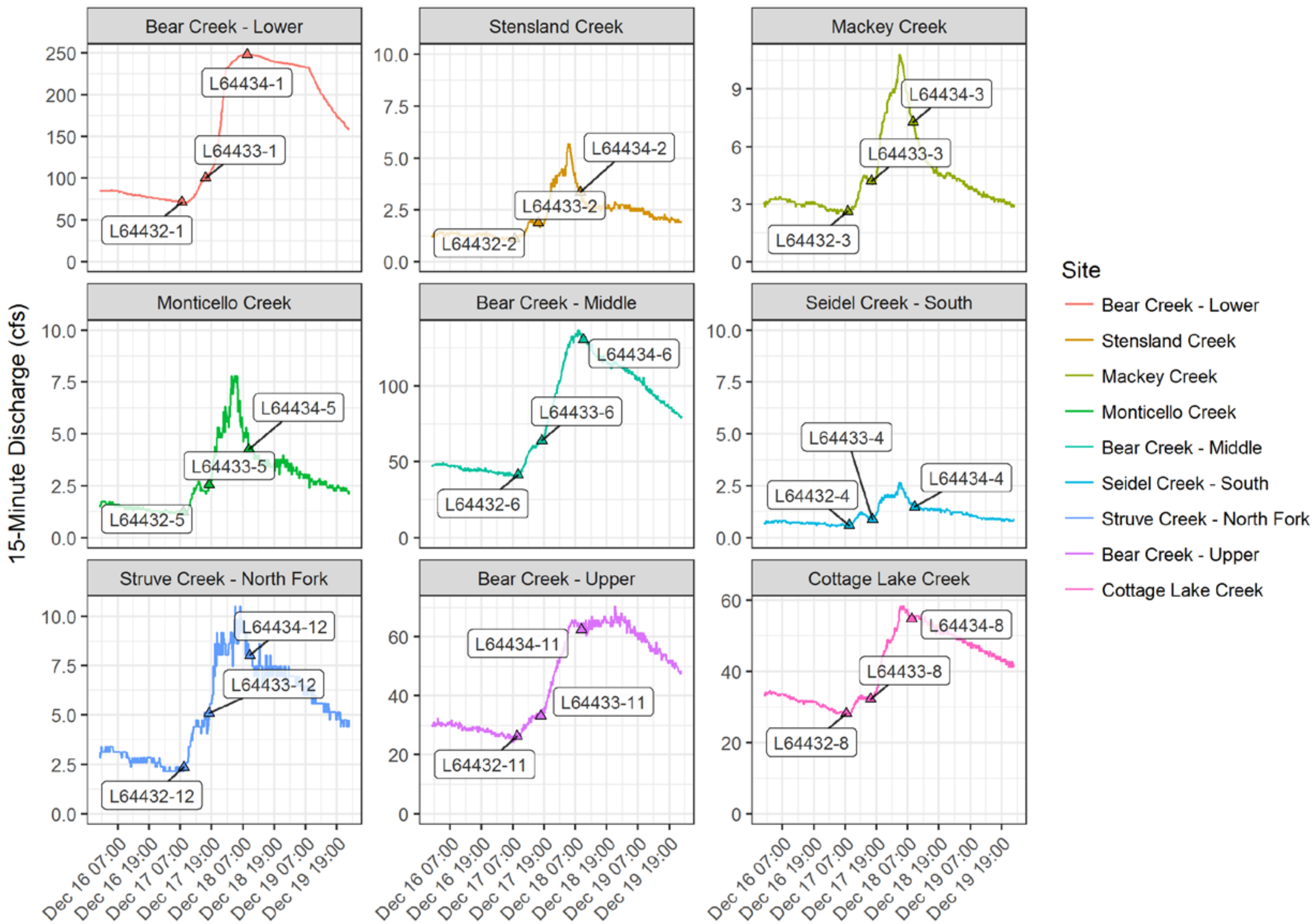

Figure B-10 Hydrographs for gaged streams during the December 17-18, 2015 storm event sampling. Sampling times and sample numbers marked.

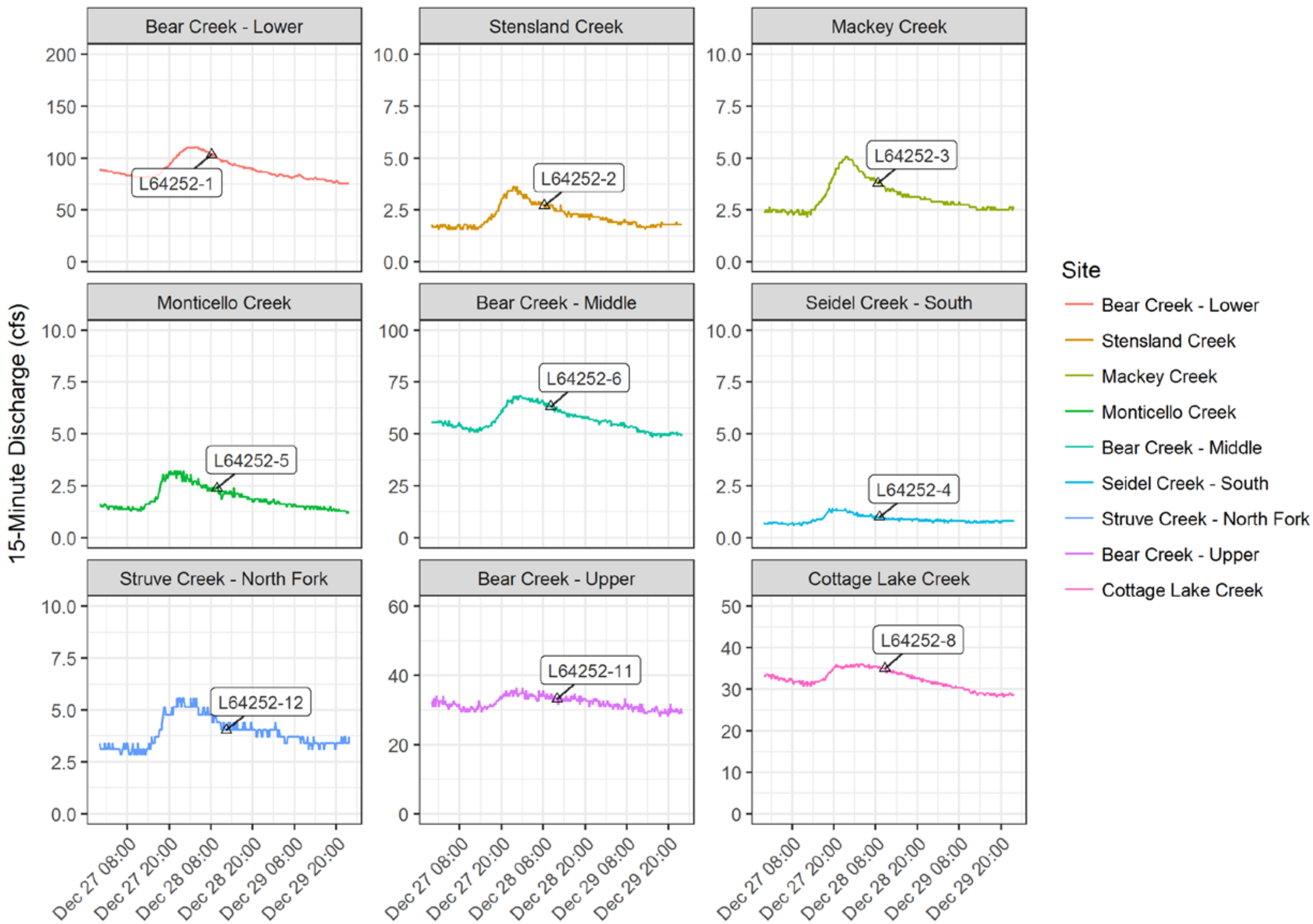

Figure B-11 Hydrographs for gaged streams during the December 28, 2015 baseflow sampling. Sampling times and sample numbers marked.

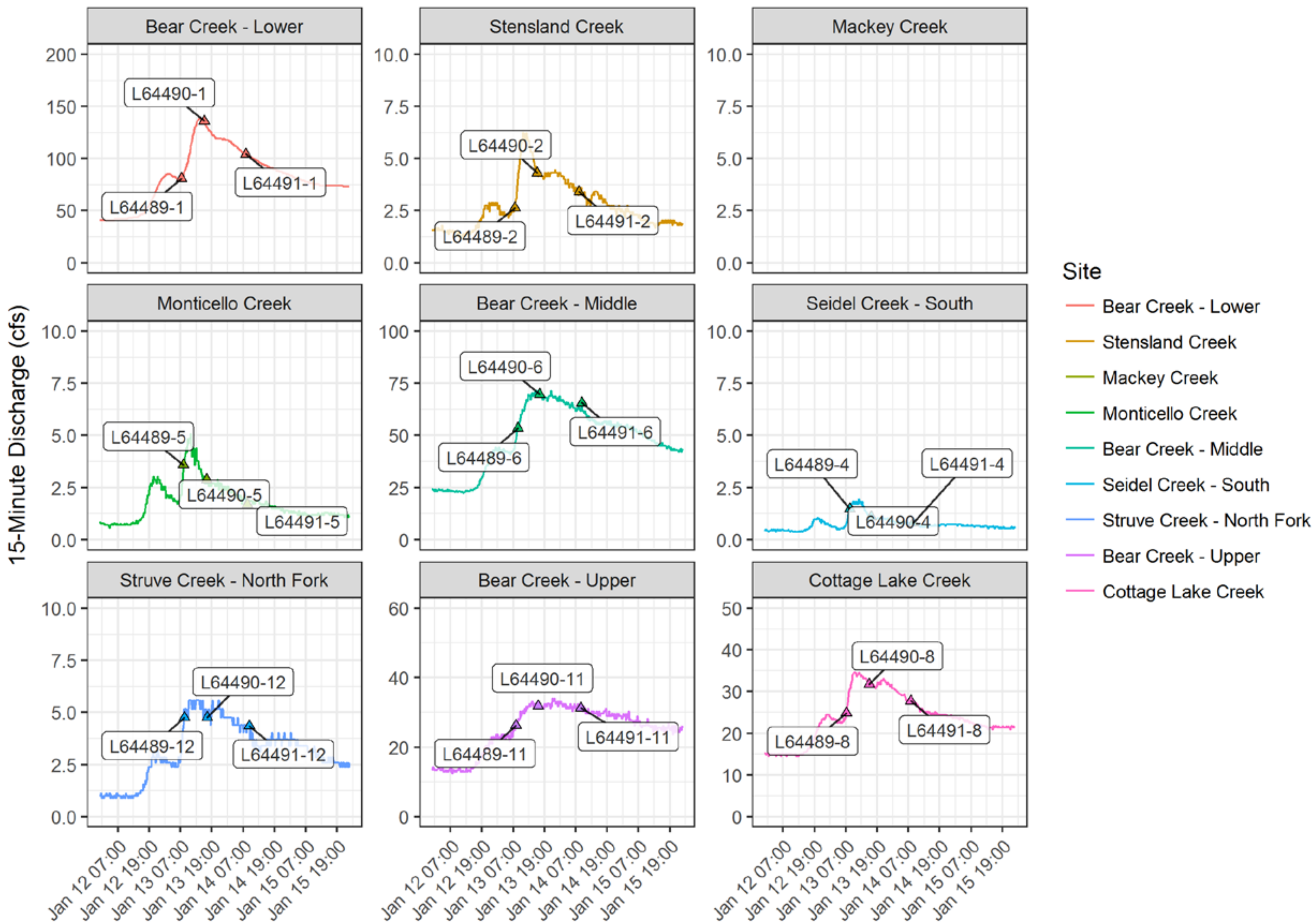

Figure B-12 Hydrographs for gaged streams during the January 13-14, 2016 storm event sampling. Sampling times and sample numbers marked.

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Appendix C: Fecal Coliform and Hu-2 Bacteriodales Concentrations

Table C-1. Fecal coliform and Hu-2 Bacteroidales concentrations in samples analyzed for Hu-2 Bacteroidales.

Locator	Site Name	Flow	Sample Date and Time	Sample Number	Fecal Coliform (CFU/100 mL)	Hu-2-Bacteroidales (copies/mL)	Hu-2 Flag
BCP01	Bear Creek - Upper	Base 3	6/25/2015 10:47	L63051-11	170	0.01	<MDL
		Storm 1 – Round 1	8/29/2015 9:33	L62729-11	99	0.19	JU
		Storm 1 – Round 2	8/29/2015 18:51	L62730-11	81	0.01	<MDL
BCP02	Cold Creek	Storm 1 – Round 1	8/29/2015 8:48	L62729-10	2,200	0.01	<MDL
BCP03	Cottage Lake Outlet	Base 3	6/25/2015 10:13	L63051-9	63	0.01	<MDL
		Storm 1 – Round 1	8/29/2015 8:19	L62729-9	150	0.01	<MDL
		Storm 1 – Round 2	8/29/2015 18:18	L62730-9	51	0.01	<MDL
BCP04	Struve Creek – North Fork	Base 3	6/25/2015 11:22	L63051-12	250	1	JU
		Storm 1 – Round 1	8/29/2015 10:21	L62729-12	4,800	2.3	JU
		Storm 1 – Round 2	8/29/2015 19:10	L62730-12	690	0.01	<MDL
BCP06	Seidel Creek	Base 3	6/25/2015 9:34	L63051-7	190	0.95	JU
		Storm 1 – Round 1	8/29/2015 10:00	L62729-7	3,600	0.76	JU
		Storm 1 – Round 2	8/29/2015 20:00	L62730-7	760	0.85	JU
BCP08	Monticello Creek	Base 3	6/25/2015 9:08	L63051-5	600	0.19	JU
		Storm 1 – Round 1	8/29/2015 9:30	L62729-5	5,300	9.1	JU
		Storm 1 – Round 2	8/29/2015 19:25	L62730-5	880	0.28	JU
		Base 5	10/15/2015 11:25	L63888-5	75	0.01	<MDL
		Storm 3 – Round 1	10/30/2015 9:35	L63950-5	500	1.2	JU
		Storm 3 – Round 2	10/30/2015 18:30	L63951-5	130	6.5	JU
		Storm 3 – Round 3	10/31/2015 9:45	L63952-5	690	0.85	JU
BCP09	Stensland Creek	Base 3	6/25/2015 7:56	L63051-2	27	0.01	<MDL
		Storm 1 – Round 1	8/29/2015 8:00	L62729-2	40	0.01	<MDL
		Storm 1 – Round 2	8/29/2015 18:10	L62730-2	26	0.01	<MDL

Locator	Site Name	Flow	Sample Date and Time	Sample Number	Fecal Coliform (CFU/100 mL)	Hu-2-Bacteroidales (copies/mL)	Hu-2 Flag
BCP10	Upper Bear Trib	Base 3	6/25/2015 11:46	L63051-13	58	0.01	<MDL
		Storm 1 – Round 1	8/29/2015 9:55	L62729-13	9,000	0.95	JU
		Storm 1 – Round 2	8/29/2015 19:32	L62730-13	510	1	JU
C484	Bear Creek - Lower	Base 3	6/25/2015 7:45	L63051-1	230	0.47	JU
		Storm 1 – Round 1	8/29/2015 7:45	L62729-1	1,400	840	JU
		Storm 1 – Round 2	8/29/2015 18:00	L62730-1	1,300	3.7	JU
		Base 5	10/15/2015 9:32	L63888-1	67	2.3	JU
		Storm 3 – Round 1	10/30/2015 8:00	L63950-1	350	170	JU
		Storm 3 – Round 2	10/30/2015 19:05	L63951-1	680	84	JU
		Storm 3 – Round 3	10/31/2015 8:35	L63952-1	3,100	1	JU
ET484	Mackey Creek	Base 3	6/25/2015 8:11	L63051-3	70	0.66	JU
		Storm 1 – Round 1	8/29/2015 8:20	L62729-3	46,000	0.66	JU
		Storm 1 – Round 2	8/29/2015 18:30	L62730-3	820	1.2	JU
		Base 5	10/15/2015 10:04	L63888-3	510	2.2	JU
		Storm 3 – Round 1	10/30/2015 8:40	L63950-3	530	28	JU
		Storm 3 – Round 2	10/30/2015 19:30	L63951-3	3,700	15	JU
		Storm 3 – Round 3	10/31/2015 9:00	L63952-3	1,400	5.4	JU
J484	Bear Creek - Middle	Base 3	6/25/2015 9:23	L63051-6	130	0.01	<MDL
		Storm 1 – Round 1	8/29/2015 9:50	L62729-6	1,500	1.6	JU
		Storm 1 – Round 2	8/29/2015 19:40	L62730-6	350	0.66	JU
		Base 5	10/15/2015 11:40	L63888-6	35	0.01	<MDL
		Storm 3 – Round 1	10/30/2015 9:45	L63950-6	120	2.3	JU
		Storm 3 – Round 2	10/30/2015 18:40	L63951-6	470	1.3	JU
		Storm 3 – Round 3	10/31/2015 10:00	L63952-6	720	0.01	<MDL

Locator	Site Name	Flow	Sample Date and Time	Sample Number	Fecal Coliform (CFU/100 mL)	Hu-2-Bacteroidales (copies/mL)	Hu-2 Flag
N484	Cottage Lake Creek	Base 3	6/25/2015 9:58	L63051-8	50	0.66	JU
		Storm 1 – Round 1	8/29/2015 7:35	L62729-8	7,300	0.47	JU
		Storm 1 – Round 2	8/29/2015 18:00	L62730-8	460	0.01	<MDL
		Base 5	10/15/2015 11:17	L63888-8	20	0.01	<MDL
		Storm 3 – Round 1	10/30/2015 8:01	L63950-8	72	3.1	JU
		Storm 3 – Round 2	10/30/2015 17:47	L63951-8	180	0.66	JU
		Storm 3 – Round 3	10/31/2015 8:31	L63952-8	310	0.01	<MDL
SOUTH SEIDEL_YSI	Seidel Creek - South	Base 3	6/25/2015 8:40	L63051-4	28	0.01	<MDL
		Storm 1 – Round 1	8/29/2015 9:00	L62729-4	14,000	16	JU
		Storm 1 – Round 2	8/29/2015 19:00	L62730-4	390	0.19	JU

Appendix D: Instantaneous Loadings Summary

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Table D-1. Instantaneous loadings at Lower Bear Creek (C484).

Sample Number	L61008-1	L61009-1	L62555-1	L62556-1	L62729-1	L62730-1	L62731-1	L63051-1	L63448-1	L63674-1	L63676-1	L63677-1	L63888-1
Flow Type	**Base**	**Base**	**Base**	**Base**	**Storm**	**Storm**	**Storm**	**Base**	**Base**	**Storm**	**Storm**	**Storm**	**Base**
Date	**3/4/2015**	**3/4/2015**	**4/28/2015**	**4/28/2015**	**8/29/2015**	**8/30/2015**	**8/30/2015**	**6/25/2015**	**8/27/2015**	**10/10/2015**	**10/10/2015**	**10/11/2015**	**10/15/2015**
Time	**7:06**	**15:00**	**7:20**	**15:01**	**7:45**	**18:00**	**7:35**	**7:45**	**15:20**	**8:00**	**16:30**	**7:40**	**9:32**
Discharge (cfs)	43.39	43.62	30.38	31	18.6	20.56	50.44	12.49	11.67	21.6	55.1	46.82	18.73
Ammonia Nitrogen (mg/s)	0.51	0.57	0.3	0.24	1.5	0.17	0.52	0.19	0.13	2.3	0.83	0.88	0.32
Copper, Dissolved (µg/s)	22	25	22	22	38	25	96	5.2	4.1	26	94	46	8.4
Copper, Total (µg/s)	37	31	30	20	60	27	190	7.4	5.5	37	230	70	11
Fecal Coliform (CFU/s)	6500	6500	1.20E+05	1.60E+04	2.60E+05	2.70E+05	2.20E+06	2.90E+04	1.10E+04	5.60E+05	2.10E+06	2.40E+05	1.30E+04
Nitrite + Nitrate Nitrogen (mg/s)	40	39	18	18	7.4	7.6	22	5.4	3.1	12	30	19	7.3
Total Nitrogen (mg/s)	50	55	27	28	14	14	78	8.4	5.1	17	67	44	12
Total Suspended Solids (mg/s)	400	250	210	71	200	72	2300	57	23	200	4200	840	58
Zinc, Dissolved (µg/s)	38	37	25	24	66	21	120	8.4	6.8	76	240	94	21
Zinc, Total (µg/s)	110	65	46	31	170	39	440	16	12	150	1200	180	34
Sample Number	**L63950-1**	**L63951-1**	**L63952-1**	**L64170-1**	**L64171-1**	**L64172-1**	**L64252-1**	**L64432-1**	**L64433-1**	**L64434-1**	**L64489-1**	**L64490-1**	**L64491-1**
Flow Type	**Storm**	**Storm**	**Storm**	**Storm**	**Storm**	**Storm**	**Base**	**Storm**	**Storm**	**Storm**	**Storm**	**Storm**	**Storm**
Date	**10/30/2015**	**10/31/2015**	**10/31/2015**	**12/3/2015**	**12/4/2015**	**12/4/2015**	**12/28/2015**	**12/17/2015**	**12/18/2015**	**12/18/2015**	**1/13/2016**	**1/14/2016**	**1/14/2016**
Time	**8:00**	**19:05**	**8:35**	**6:55**	**16:30**	**7:50**	**8:06**	**7:30**	**16:40**	**8:30**	**7:15**	**16:01**	**8:02**
Discharge (cfs)	22.54	36.58	93.42	58.5	66.77	70.01	103.4	71.29	100.3	248.2	80.84	136.1	104.3
Ammonia Nitrogen (mg/s)	0.37	0.3	1.3	1.4	0.92	1.3	1.6	1.2	1.8	3.8	2.4	3.3	1.7
Copper, Dissolved (µg/s)	17	40	150	54	55	66	110	61	97	320	78	160	100
Copper, Total (µg/s)	29	76	400	99	87	98	140	110	160	570	150	330	140
Fecal Coliform (CFU/s)	7.90E+04	2.50E+05	2.90E+06	9.90E+04	6.60E+04	2.00E+05	4.40E+04	4.50E+04	9.80E+04	3.50E+05	6.50E+05	1.10E+06	1.90E+05
Nitrite + Nitrate Nitrogen (mg/s)	11	14	58	50	59	63	120	80	110	270	73	120	98
Total Nitrogen (mg/s)	17	26	130	71	83	90	150	100	150	360	100	180	140
Total Suspended Solids (mg/s)	120	610	8600	1300	760	900	1100	890	1600	8600	1500	4500	1600
Zinc, Dissolved (µg/s)	52	110	210	94	80	110	180	93	140	450	170	260	180
Zinc, Total (µg/s)	92	300	1100	270	190	160	300	200	360	1200	450	820	320

Table D-2. Instantaneous loadings at Stensland Creek (BCP09).

Sample Number	L61008-14	L61009-14	L62555-2	L62556-2	L62729-2	L62730-2	L62731-2	L63051-2	L63448-2	L63674-2	L63676-2	L63677-2	L63888-2
Flow Type	Base	Base	Base	Base	Storm	Storm	Storm	Base	Base	Storm	Storm	Storm	Base
Date	3/4/2015	3/4/2015	4/28/2015	4/28/2015	8/29/2015	8/30/2015	8/30/2015	6/25/2015	8/27/2015	10/10/2015	10/10/2015	10/11/2015	10/15/2015
Time	7:19	15:15	7:29	15:15	8:00	18:10	7:45	7:56	15:40	8:30	16:45	7:50	9:49
Discharge (cfs)	1.18	1.02	0.58	0.75	0.36	0.44	1.56	0.19	0.33	0.44	1.9	1.18	1.36
Ammonia Nitrogen (mg/s)	<0.0024	0.0028	0.0037	0.0054	0.012	0.011	0.055	0.0054	0.0065	0.013	0.042	0.038	0.045
Copper, Dissolved (µg/s)	0.77	0.65	0.57	0.7	0.18	0.25	1.1	0.12	0.16	0.44	2.1	1.8	1.9
Copper, Total (µg/s)	0.85	0.78	0.58	0.67	0.3	0.24	1.4	0.12	0.2	0.48	2.3	1.9	2
Fecal Coliform (CFU/s)	12	<10	230	190	140	110	8400	51	69	92	7400	1.00E+04	1800
Nitrite + Nitrate Nitrogen (mg/s)	1.3	1.1	0.37	0.4	0.038	0.054	0.54	0.0093	0.018	0.21	1.2	0.86	0.89
Total Nitrogen (mg/s)	1.6	1.5	0.58	0.66	0.14	0.18	0.99	0.09	0.1	0.35	1.6	1.2	1.2
Total Suspended Solids (mg/s)	3.8	1.6	1.6	2.5	1.5	0.62	3.9	0.65	0.4	0.33	2.7	3.1	1.4
Zinc, Dissolved (µg/s)	0.79	0.64	0.38	0.4	0.19	0.22	1.2	<0.095	<0.16	0.66	3	2.1	1.9
Zinc, Total (µg/s)	1.3	0.62	0.48	0.68	0.43	0.41	1.4	0.18	<0.16	1.1	3.8	2.8	2

Sample Number	L63950-2	L63951-2	L63952-2	L64170-2	L64171-2	L64172-2	L64252-2	L64432-2	L64433-2	L64434-2	L64489-2	L64490-2	L64491-2
Flow Type	Storm	Storm	Storm	Storm	Storm	Storm	Base	Storm	Storm	Storm	Storm	Storm	Storm
Date	10/30/2015	10/31/2015	10/31/2015	12/3/2015	12/4/2015	12/4/2015	12/28/2015	12/17/2015	12/18/2015	12/18/2015	1/13/2016	1/14/2016	1/14/2016
Time	8:25	19:15	8:45	7:10	16:40	8:00	8:19	7:45	16:50	8:50	7:35	16:10	8:14
Discharge (cfs)	1.36	2.42	3.77	3.42	3.24	3.8	2.74	1.11	1.91	3.42	2.58	4.31	3.42
Ammonia Nitrogen (mg/s)	0.051	0.087	0.13	0.046	0.036	0.065	0.045	0.02	0.03	0.11	0.044	0.099	0.093
Copper, Dissolved (µg/s)	1.1	2.3	5.3	3.1	2.9	3.7	4.7	1.3	2.1	4.8	1.7	4.7	4.1
Copper, Total (µg/s)	1.5	2.4	5.7	3.4	3.2	4.2	3.8	1.3	2.3	6.8	2.3	5.6	4.1
Fecal Coliform (CFU/s)	350	1700	2.50E+04	2700	3900	8400	1600	67	95	4100	1500	3700	2400
Nitrite + Nitrate Nitrogen (mg/s)	1.1	1.8	3.1	5.9	5.5	6.5	4.9	2	3.6	5.6	4.1	6.3	4.8
Total Nitrogen (mg/s)	1.4	2.4	4	6.8	6.5	7.6	5.5	2.3	4.1	6.9	4.7	7.8	6.2
Total Suspended Solids (mg/s)	1.6	2.4	10	3.1	4.2	4.9	3.8	0.67	2.2	15	3.4	20	8.9
Zinc, Dissolved (µg/s)	2.3	4.4	6.8	2.4	2.1	3.8	3.3	1.6	2.5	4.4	2.8	6	5.8
Zinc, Total (µg/s)	2.9	6	7.9	4.8	5.8	3.2	9.3	2.2	3.4	11	4.1	13	7.5

Table D-3. Instantaneous loadings at Mackey Creek (ET484).

Sample Number	L61008-2	L61009-2	L62555-3	L62556-3	L62729-3	L62730-3	L62731-3	L63051-3	L63448-3	L63674-3	L63676-3	L63677-3	L63888-3
Flow Type	Base	Base	Base	Base	Storm	Storm	Storm	Base	Base	Storm	Storm	Storm	Base
Date	3/4/2015	3/4/2015	4/28/2015	4/28/2015	8/29/2015	8/30/2015	8/30/2015	6/25/2015	8/27/2015	10/10/2015	10/11/2015	10/11/2015	10/15/2015
Time	7:35	15:35	7:43	15:30	8:20	18:30	8:10	8:11	15:00	8:50	17:00	8:05	10:04
Discharge (cfs)	2.06	1.69	0.66	0.87	NA	NA	NA	0.47	NA	NA	NA	NA	NA
Ammonia Nitrogen (mg/s)	0.023	0.019	0.0069	0.0076	NA	NA	NA	0.0053	NA	NA	NA	NA	NA
Copper, Dissolved (µg/s)	1.1	0.96	0.46	0.74	NA	NA	NA	0.16	NA	NA	NA	NA	NA
Copper, Total (µg/s)	1.6	1	0.55	0.57	NA	NA	NA	0.18	NA	NA	NA	NA	NA
Fecal Coliform (CFU/s)	370	68	330	87	NA	NA	NA	330	NA	NA	NA	NA	NA
Nitrite + Nitrate Nitrogen (mg/s)	1.9	1.9	0.39	0.91	NA	NA	NA	0.21	NA	NA	NA	NA	NA
Total Nitrogen (mg/s)	2.3	2.5	0.56	1.1	NA	NA	NA	0.32	NA	NA	NA	NA	NA
Total Suspended Solids (mg/s)	26	4	3.2	1.3	NA	NA	NA	1.2	NA	NA	NA	NA	NA
Zinc, Dissolved (µg/s)	1.7	3.9	0.66	1.7	NA	NA	NA	<0.24	NA	NA	NA	NA	NA
Zinc, Total (µg/s)	3.3	5.2	0.86	1.9	NA	NA	NA	0.56	NA	NA	NA	NA	NA

Sample Number	L63950-3	L63951-3	L63952-3	L64170-3	L64171-3	L64172-3	L64252-3	L64432-3	L64433-3	L64434-3	L64489-3	L64490-3	L64491-3
Flow Type	Storm	Storm	Storm	Storm	Storm	Storm	Base	Storm	Storm	Storm	Storm	Storm	Storm
Date	10/30/2015	10/31/2015	10/31/2015	12/3/2015	12/4/2015	12/4/2015	12/28/2015	12/17/2015	12/18/2015	12/18/2015	1/13/2016	1/14/2016	1/14/2016
Time	8:40	19:30	9:00	7:20	16:55	8:10	8:35	7:55	17:00	9:00	7:49	16:20	8:25
Discharge (cfs)	NA	NA	NA	3	2.27	2.39	3.79	2.63	4.21	7.28	NA	NA	NA
Ammonia Nitrogen (mg/s)	NA	NA	NA	0.021	0.013	0.022	0.052	0.028	0.043	0.067	NA	NA	NA
Copper, Dissolved (µg/s)	NA	NA	NA	5.4	3.9	3.3	3.3	3.4	5.1	12	NA	NA	NA
Copper, Total (µg/s)	NA	NA	NA	5.7	3.2	2.9	4.9	3.2	7.2	15	NA	NA	NA
Fecal Coliform (CFU/s)	NA	NA	NA	1.50E+04	2700	3100	2000	600	2.10E+04	1.40E+04	NA	NA	NA
Nitrite + Nitrate Nitrogen (mg/s)	NA	NA	NA	2.4	1.8	1.9	4.5	2.8	4.1	6.9	NA	NA	NA
Total Nitrogen (mg/s)	NA	NA	NA	3.4	2.5	2.6	5.5	3.5	5.4	9.6	NA	NA	NA
Total Suspended Solids (mg/s)	NA	NA	NA	34	5.4	6.2	31	7.1	30	81	NA	NA	NA
Zinc, Dissolved (µg/s)	NA	NA	NA	7.9	5.4	5.7	5.3	6.3	11	21	NA	NA	NA
Zinc, Total (µg/s)	NA	NA	NA	19	7.9	5.5	9.5	9.5	20	35	NA	NA	NA

Table D-4. Instantaneous loadings at Monticello Creek (BCP08).

Sample Number	L61008-13	L61009-13	L62555-5	L62556-5	L62729-5	L62730-5	L62731-5	L63051-5	L63448-5	L63674-5	L63676-5	L63677-5	L63888-5
Flow Type	Base	Base	Base	Base	Storm	Storm	Storm	Base	Base	Storm	Storm	Storm	Base
Date	3/4/2015	3/5/2015	4/28/2015	4/28/2015	8/29/2015	8/30/2015	8/30/2015	6/25/2015	8/27/2015	10/10/2015	10/11/2015	10/11/2015	10/15/2015
Time	8:32	16:42	8:41	16:38	9:30	19:25	9:00	9:08	14:35	9:30	17:45	8:50	11:25
Discharge (cfs)	0.77	0.51	0.41	0.36	1.39	0.46	2.55	0.15	0.15	1.85	3.4	1.39	0.41
Ammonia Nitrogen (mg/s)	0.011	0.0068	0.0041	0.0037	0.055	0.0025	0.032	0.0012	0.0036	0.019	0.02	0.0099	0.0045
Copper, Dissolved (µg/s)	0.51	0.38	0.39	0.3	1.9	0.44	3.8	0.082	0.066	2.2	6.1	1.7	0.27
Copper, Total (µg/s)	0.55	0.41	0.36	0.31	4.4	0.51	5.4	0.092	0.081	15	16	5.1	0.29
Fecal Coliform (CFU/s)	130	56	140	100	7.40E+04	4000	4.60E+04	900	1500	7.80E+04	3.10E+04	6700	310
Nitrite + Nitrate Nitrogen (mg/s)	0.34	0.21	0.098	0.09	0.43	0.058	0.56	0.045	0.029	0.39	1.4	0.33	0.074
Total Nitrogen (mg/s)	0.46	0.34	0.19	0.18	1.5	0.21	1.9	0.089	0.052	2.4	4.6	1.3	0.15
Total Suspended Solids (mg/s)	1.9	0.8	0.67	0.79	49	1.2	25	0.88	<0.075	200	500	85	0.49
Zinc, Dissolved (µg/s)	4	2.6	1.8	1.4	5.3	1.4	23	0.52	0.52	10	29	11	2.1
Zinc, Total (µg/s)	4.7	3.2	2	1.7	29	2.4	36	1	0.67	150	150	50	2.5

Sample Number	L63950-5	L63951-5	L63952-5	L64170-5	L64171-5	L64172-5	L64252-5	L64432-5	L64433-5	L64434-5	L64489-5	L64490-5	L64491-5
Flow Type	Storm	Storm	Storm	Storm	Storm	Storm	Base	Storm	Storm	Storm	Storm	Storm	Storm
Date	10/30/2015	10/31/2015	10/31/2015	12/3/2015	12/4/2015	12/4/2015	12/28/2015	12/17/2015	12/18/2015	12/18/2015	1/13/2016	1/14/2016	1/14/2016
Time	9:35	18:30	9:45	7:30	17:00	8:25	9:47	8:05	18:00	9:10	8:01	17:00	8:34
Discharge (cfs)	1.39	2.71	3.59	2.4	1.73	1.85	2.4	1.28	2.55	4.19	3.59	2.87	1.73
Ammonia Nitrogen (mg/s)	0.01	0.015	0.027	0.023	0.012	0.018	0.026	0.021	0.039	0.052	0.098	0.046	0.023
Copper, Dissolved (µg/s)	1.4	4.1	6.8	3.6	3.1	2.4	2.9	1.3	3.3	7.1	6.5	3.7	2.9
Copper, Total (µg/s)	3.8	11	12	6.2	3.9	6	4.8	1.9	4.6	18	19	8	4.6
Fecal Coliform (CFU/s)	7000	3500	2.50E+04	2900	550	2200	3800	4100	4100	3400	7200	950	420
Nitrite + Nitrate Nitrogen (mg/s)	0.16	0.51	1.8	0.62	0.54	0.69	1.6	0.9	1.6	2.8	1.4	1.3	0.81
Total Nitrogen (mg/s)	1.2	2	3.8	1.5	1	1.9	2.3	1.2	2.2	5.5	5.9	2.7	1.6
Total Suspended Solids (mg/s)	56	440	190	160	110	290	25	35	28	340	520	320	150
Zinc, Dissolved (µg/s)	5.9	15	31	32	25	25	20	8.9	21	35	25	21	13
Zinc, Total (µg/s)	33	89	81	58	41	62	37	17	33	150	160	61	38

Table D-5. Instantaneous loadings at Cottage Lake Creek (N484).

Sample Number	L61008-4	L61009-4	L62555-8	L62556-8	L62729-8	L62730-8	L62731-8	L63051-8	L63448-8	L63674-8	L63676-8	L63677-8	L63888-8
Flow Type	Base	Base	Base	Base	Storm	Storm	Storm	Base	Base	Storm	Storm	Storm	Base
Date	3/4/2015	3/4/2015	4/28/2015	4/28/2015	8/29/2015	8/30/2015	8/30/2015	6/25/2015	8/27/2015	10/10/2015	10/10/2015	10/11/2015	10/15/2015
Time	7:10	15:00	7:13	15:00	7:35	18:00	7:27	9:58	13:03	8:04	16:38	7:40	11:17
Discharge (cfs)	17.41	15.77	10.31	11.09	9.23	9.8	16.74	6.42	7.1	9.61	19.49	18.09	9.42
Ammonia Nitrogen (mg/s)	0.23	0.046	0.12	0.14	0.37	0.086	0.27	0.048	0.075	0.19	0.2	0.45	0.12
Copper, Dissolved (µg/s)	7.7	7.4	6.6	5.9	19	2.9	11	1.7	1.4	6.1	13	18	2.7
Copper, Total (µg/s)	9.2	8.2	5.7	5.2	28	2.8	17	1.5	1.8	9.4	25	18	3
Fecal Coliform (CFU/s)	4700	3900	5300	1900	6.70E+05	4.50E+04	1.70E+05	3200	1.10E+04	1.10E+05	2.90E+05	8.50E+04	1900
Nitrite + Nitrate Nitrogen (mg/s)	16	14	5.4	5.9	4.4	3.3	5.5	2	1.9	4.5	10	6.4	4.7
Total Nitrogen (mg/s)	21	21	8.8	9.5	8.8	6	13	3.9	3.4	8.4	24	19	7.2
Total Suspended Solids (mg/s)	55	60	15	14	110	48	120	16	13	62	680	160	17
Zinc, Dissolved (µg/s)	19	21	9.2	7.9	21	5.2	27	3.9	<3.6	14	39	25	18
Zinc, Total (µg/s)	21	33	9.7	11	50	14	40	12	5	30	110	40	19
Sample Number	L63950-8	L63951-8	L63952-8	L64170-8	L64171-8	L64172-8	L64252-8	L64432-8	L64433-8	L64434-8	L64489-8	L64490-8	L64491-8
Flow Type	Storm	Storm	Storm	Storm	Storm	Storm	Base	Storm	Storm	Storm	Storm	Storm	Storm
Date	10/30/2015	10/31/2015	10/31/2015	12/3/2015	12/4/2015	12/4/2015	12/28/2015	12/17/2015	12/18/2015	12/18/2015	1/13/2016	1/14/2016	1/14/2016
Time	8:01	17:47	8:31	6:48	16:23	7:45	10:37	7:22	16:48	8:32	7:15	16:00	7:57
Discharge (cfs)	10.56	14.83	23.23	20.21	20.21	20.94	35.04	27.73	32.19	54.69	24.82	31.73	27.73
Ammonia Nitrogen (mg/s)	0.16	0.17	0.52	0.65	0.59	0.67	0.77	0.78	0.86	1.1	0.83	0.98	0.79
Copper, Dissolved (µg/s)	7.1	13	16	12	12	13	27	24	25	51	20	26	23
Copper, Total (µg/s)	9.2	18	26	16	13	15	31	26	30	54	37	31	22
Fecal Coliform (CFU/s)	7600	2.70E+04	7.20E+04	7500	1.10E+04	7300	1.60E+04	2200	4500	3.90E+04	2.20E+04	2.60E+04	2.10E+04
Nitrite + Nitrate Nitrogen (mg/s)	5.7	7.6	11	17	16	16	34	25	33	53	20	27	24
Total Nitrogen (mg/s)	9.6	13	25	24	24	24	47	35	43	69	33	42	37
Total Suspended Solids (mg/s)	42	140	360	77	46	50	59	69	93	180	260	190	100
Zinc, Dissolved (µg/s)	16	25	46	24	22	23	70	39	52	110	45	63	44
Zinc, Total (µg/s)	23	50	83	42	26	50	100	58	83	190	110	100	55

Table D-6. Instantaneous loadings at Middle Bear Creek (J484).

Sample Number	L61008-3	L61009-3	L62555-6	L62556-6	L62729-6	L62730-6	L62731-6	L63051-6	L63448-6	L63674-6	L63676-6	L63677-6	L63888-6
Flow Type	Base	Base	Base	Base	Storm	Storm	Storm	Base	Base	Storm	Storm	Storm	Base
Date	3/4/2015	3/5/2015	4/28/2015	4/28/2015	8/29/2015	8/30/2015	8/30/2015	6/25/2015	8/27/2015	10/10/2015	10/11/2015	10/11/2015	10/15/2015
Time	8:47	16:57	8:56	16:58	9:50	19:40	9:15	9:23	13:22	9:50	18:00	9:10	11:40
Discharge (cfs)	27.18	20.67	13.85	14.69	9.32	9.89	31.63	6.24	6.5	13.44	36.31	25.95	10.72
Ammonia Nitrogen (mg/s)	0.31	0.25	0.13	0.13	0.17	0.1	0.54	0.092	0.088	0.22	0.34	0.39	0.14
Copper, Dissolved (µg/s)	<11	10	7.8	8.1	17	4.7	32	1.7	1.7	10	34	17	4
Copper, Total (µg/s)	16	10	7.8	7.2	22	4.4	47	1.6	1.6	13	54	19	4.3
Fecal Coliform (CFU/s)	2400	2700	2600	1300	1.40E+05	3.50E+04	5.10E+05	8100	3300	4.30E+04	5.10E+05	7.80E+04	3800
Nitrite + Nitrate Nitrogen (mg/s)	21	15	5	5.3	0.94	0.94	8.5	0.92	0.2	2.5	13	9	2.5
Total Nitrogen (mg/s)	27	21	8.7	9.1	3.6	3.3	25	2.6	1.3	6.6	33	16	4.8
Total Suspended Solids (mg/s)	230	54	35	38	83	30	380	16	9.1	94	1300	130	53
Zinc, Dissolved (µg/s)	23	25	14	8.8	<4.7	<4.9	23	<3.1	<3.2	15	65	26	12
Zinc, Total (µg/s)	52	39	14	11	11	8.7	63	4.8	<3.2	73	160	44	5.7

Sample Number	L63950-6	L63951-6	L63952-6	L64170-6	L64171-6	L64172-6	L64252-6	L64432-6	L64433-6	L64434-6	L64489-6	L64490-6	L64491-6
Flow Type	Storm	Storm	Storm	Storm	Storm	Storm	Base	Storm	Storm	Storm	Storm	Storm	Storm
Date	10/30/2015	10/31/2015	10/31/2015	12/3/2015	12/4/2015	12/4/2015	12/28/2015	12/17/2015	12/18/2015	12/18/2015	1/13/2016	1/14/2016	1/14/2016
Time	9:45	18:40	10:00	8:20	17:55	9:10	10:03	8:55	18:10	10:00	8:50	17:14	9:15
Discharge (cfs)	15.14	24.53	55.43	33.57	38.17	42.27	63.25	41.58	64.06	130.3	52.4	69.77	65.67
Ammonia Nitrogen (mg/s)	0.18	0.23	0.69	0.7	0.79	0.82	0.74	0.55	1	1.3	1.1	1.4	0.89
Copper, Dissolved (µg/s)	11	23	72	25	29	31	50	33	54	120	49	59	79
Copper, Total (µg/s)	12	37	100	33	35	34	52	36	64	140	73	77	51
Fecal Coliform (CFU/s)	1.80E+04	1.20E+05	4.00E+05	1.70E+04	4.20E+04	1.80E+04	1.80E+04	3.30E+04	5.80E+04	1.40E+05	7.30E+05	3.60E+05	1.50E+05
Nitrite + Nitrate Nitrogen (mg/s)	4.8	7.2	29	30	35	37	78	49	74	160	42	61	58
Total Nitrogen (mg/s)	9	33	61	41	47	52	91	62	93	200	63	87	81
Total Suspended Solids (mg/s)	67	430	1300	180	170	120	120	120	300	600	980	490	240
Zinc, Dissolved (µg/s)	13	29	83	26	38	38	76	36	70	170	63	98	110
Zinc, Total (µg/s)	21	65	170	57	61	37	150	58	120	250	160	190	110

Table D-7. Instantaneous loadings at South Seidel Creek (SOUTH_SEIDEL_YSI).

Sample Number	L61008-5	L61009-5	L62555-4	L62556-4	L62729-4	L62730-4	L62731-4	L63051-4	L63448-4	L63674-4	L63676-4	L63677-4	L63888-4
Flow Type	Base	Base	Base	Base	Storm	Storm	Storm	Base	Base	Storm	Storm	Storm	Base
Date	3/4/2015	3/5/2015	4/28/2015	4/28/2015	8/29/2015	8/30/2015	8/30/2015	6/25/2015	8/27/2015	10/10/2015	10/11/2015	10/11/2015	10/15/2015
Time	8:03	16:05	8:09	16:08	9:00	19:00	8:35	8:40	14:05	9:15	17:20	8:30	10:38
Discharge (cfs)	0.76	0.54	NA	NA	0.96	0.28	0.96	0.24	0.2	0.66	0.8	0.24	0.2
Ammonia Nitrogen (mg/s)	0.0097	0.0073	NA	NA	0.015	0.0033	0.016	0.0027	0.0045	0.0082	0.0082	0.0031	0.002
Copper, Dissolved (µg/s)	<0.3	0.28	NA	NA	0.66	0.095	0.76	0.055	0.052	0.45	0.79	0.1	0.046
Copper, Total (µg/s)	<0.3	<0.22	NA	NA	3.3	0.12	1.2	0.072	0.074	1.3	0.88	0.1	0.054
Fecal Coliform (CFU/s)	15	11	NA	NA	1.30E+05	1100	2.60E+04	67	64	9200	2800	55	18
Nitrite + Nitrate Nitrogen (mg/s)	0.24	0.16	NA	NA	0.48	0.057	0.43	0.065	0.047	0.16	0.38	0.054	0.045
Total Nitrogen (mg/s)	0.36	0.28	NA	NA	1.5	0.13	1.1	0.12	0.093	0.79	0.86	0.11	0.073
Total Suspended Solids (mg/s)	3.8	1.7	NA	NA	82	1.9	18	2	1.6	40	9.3	0.94	0.32
Zinc, Dissolved (µg/s)	0.62	0.45	NA	NA	1.2	0.2	1.5	<0.12	0.14	1.8	1.7	0.31	0.15
Zinc, Total (µg/s)	1.1	0.7	NA	NA	9.4	0.42	2.7	0.26	0.32	4.4	5.6	0.43	0.11
Sample Number	L63950-4	L63951-4	L63952-4	L64170-4	L64171-4	L64172-4	L64252-4	L64432-4	L64433-4	L64434-4	L64489-4	L64490-4	L64491-4
Flow Type	Storm	Storm	Storm	Storm	Storm	Storm	Base	Storm	Storm	Storm	Storm	Storm	Storm
Date	10/30/2015	10/31/2015	10/31/2015	12/3/2015	12/4/2015	12/4/2015	12/28/2015	12/17/2015	12/18/2015	12/18/2015	1/13/2016	1/14/2016	1/14/2016
Time	9:05	18:00	9:20	7:55	17:20	8:50	9:08	8:30	17:25	9:35	8:28	16:39	8:50
Discharge (cfs)	0.66	1.6	1.12	0.48	0.48	0.6	1.04	0.6	0.88	1.49	1.49	1.12	0.8
Ammonia Nitrogen (mg/s)	0.0073	0.017	0.014	0.006	0.0069	0.0098	0.012	0.0093	0.013	0.016	0.022	0.015	0.01
Copper, Dissolved (µg/s)	0.3	1.6	1.1	0.22	0.19	0.27	0.52	0.56	0.48	1.2	0.74	0.75	0.54
Copper, Total (µg/s)	0.73	5.3	1.3	0.28	0.26	0.25	0.71	0.28	0.67	1.3	3.8	1.1	0.5
Fecal Coliform (CFU/s)	920	5.80E+04	3200	150	24	30	31	18	88	610	1800	170	8
Nitrite + Nitrate Nitrogen (mg/s)	0.12	0.57	0.64	0.11	0.12	0.15	0.35	0.19	0.26	0.57	0.38	0.35	0.22
Total Nitrogen (mg/s)	0.49	2.7	1.2	0.25	0.26	0.29	0.59	0.32	0.54	1.1	1.9	0.77	0.42
Total Suspended Solids (mg/s)	13	130	11	2	2.7	0.96	2.7	2.5	6.3	6.1	120	9.1	2.9
Zinc, Dissolved (µg/s)	0.59	2.4	1.7	<0.24	<0.24	0.32	0.54	0.6	<0.44	1.1	0.91	0.95	0.8
Zinc, Total (µg/s)	1.8	14	2.1	0.77	0.53	<0.3	1.6	0.78	1.3	2.4	9.9	2.9	1

Table D-8. Instantaneous loadings at Struve Creek (BCP04).

Sample Number	L61008-9	L61009-9	L62555-12	L62556-12	L62729-12	L62730-12	L62731-12	L63051-12	L63448-12	L63674-12	L63676-12	L63677-12	L63888-12
Flow Type	Base	Base	Base	Base	Storm	Storm	Storm	Base	Base	Storm	Storm	Storm	Base
Date	3/4/2015	3/5/2015	4/28/2015	4/29/2015	8/29/2015	8/30/2015	8/30/2015	6/25/2015	8/27/2015	10/10/2015	10/11/2015	10/11/2015	10/15/2015
Time	9:33	16:15	8:37	19:15	10:21	19:10	8:49	11:22	12:00	9:53	17:58	8:52	10:00
Discharge (cfs)	1.4	0.88	0.38	0.51	0.19	0.08	1.57	0.03	0.04	0.44	1.57	0.68	0.27
Ammonia Nitrogen (mg/s)	0.0049	0.0042	0.0022	0.0029	0.0022	0.00063	0.019	0.00031	0.00036	0.0034	0.0057	0.0048	0.0015
Copper, Dissolved (µg/s)	0.6	0.38	0.24	0.29	0.21	0.067	1.2	0.017	0.021	0.26	1.7	0.32	0.11
Copper, Total (µg/s)	<0.56	0.4	0.22	0.31	0.25	0.075	2	0.013	0.022	0.44	2.4	0.37	0.11
Fecal Coliform (CFU/s)	210	44	220	100	9100	550	1.40E+04	75	24	2000	9400	350	24
Nitrite + Nitrate Nitrogen (mg/s)	1.7	1.1	0.25	0.3	0.12	0.055	0.53	0.023	0.0067	0.13	0.8	0.21	0.045
Total Nitrogen (mg/s)	1.9	1.3	0.35	0.45	0.21	0.079	1.3	0.032	0.014	0.25	1.7	0.34	0.096
Total Suspended Solids (mg/s)	1.5	2.2	0.53	0.61	0.8	0.17	14	0.042	0.12	4.2	28	1.6	0.19
Zinc, Dissolved (µg/s)	2.4	0.88	0.61	0.51	0.27	0.075	1.4	0.1	0.15	0.66	2.2	0.63	0.49
Zinc, Total (µg/s)	2	0.97	0.49	0.56	0.56	0.11	3.3	0.11	0.11	1.9	6.7	0.95	0.8
Sample Number	L63950-12	L63951-12	L63952-12	L64170-12	L64171-12	L64172-12	L64252-12	L64432-12	L64433-12	L64434-12	L64489-12	L64490-12	L64491-12
Flow Type	Storm	Storm	Storm	Storm	Storm	Storm	Base	Storm	Storm	Storm	Storm	Storm	Storm
Date	10/30/2015	10/31/2015	10/31/2015	12/3/2015	12/4/2015	12/4/2015	12/28/2015	12/17/2015	12/18/2015	12/18/2015	1/13/2016	1/14/2016	1/14/2016
Time	9:24	18:51	9:33	8:04	17:28	8:48	12:26	8:18	17:58	9:37	8:30	17:08	9:16
Discharge (cfs)	0.32	1.57	2.84	1.93	1.74	1.93	4.04	2.36	5.15	8.03	4.76	4.76	4.39
Ammonia Nitrogen (mg/s)	0.0012	0.012	0.015	0.012	0.011	0.012	0.016	0.012	0.037	0.069	0.056	0.044	0.019
Copper, Dissolved (µg/s)	0.22	2.2	2.1	1.3	1	1.2	3	1.9	4.4	7.5	4.2	3.9	7.5
Copper, Total (µg/s)	0.28	4.6	3.1	1.9	1.4	1.4	3.3	1.7	5.7	8	8.6	4	2.9
Fecal Coliform (CFU/s)	190	2.80E+04	6500	890	230	480	81	71	2100	1600	4300	2000	400
Nitrite + Nitrate Nitrogen (mg/s)	0.048	0.66	2.1	2.4	2.3	2.8	8.5	5.2	10	17	5.8	7.1	6.9
Total Nitrogen (mg/s)	0.15	2.1	3.2	3.1	2.8	3.4	9.3	5.9	12	19	8	8.5	8.5
Total Suspended Solids (mg/s)	1.5	76	34	19	9	6.9	2	8.7	45	39	92	16	5.3
Zinc, Dissolved (µg/s)	0.48	2.2	2.8	0.96	1.2	1.2	4.8	2.4	7.7	12	7.6	7.1	8.3
Zinc, Total (µg/s)	1	14	7.8	4.2	1.7	4.2	8.5	4	17	20	28	9	6.1

Table D-9. Instantaneous loadings at Upper Bear Creek (BCP01).

Sample Number	L61008-6	L61009-6	L62555-11	L62556-11	L62729-11	L62730-11	L62731-11	L63051-11	L63448-11	L63674-11	L63676-11	L63677-11	L63888-11
Flow Type	Base	Base	Base	Base	Storm	Storm	Storm	Base	Base	Storm	Storm	Storm	Base
Date	3/4/2015	3/4/2015	4/28/2015	4/29/2015	8/29/2015	8/30/2015	8/30/2015	6/25/2015	8/27/2015	10/10/2015	10/11/2015	10/11/2015	10/15/2015
Time	8:45	15:49	8:12	17:43	9:33	18:51	8:15	10:47	12:42	9:18	17:28	8:20	10:33
Discharge (cfs)	15.82	14.79	9.16	9.53	6.51	6.51	12.42	4.41	5.13	7.76	16.89	14.79	8.09
Ammonia Nitrogen (mg/s)	0.26	0.28	0.22	0.28	0.12	0.1	0.24	0.062	0.068	0.23	0.24	0.36	0.23
Copper, Dissolved (µg/s)	<6.3	<5.9	3.5	3.2	1.5	<1.3	<2.5	<0.88	<1	<1.6	12	3.8	1.6
Copper, Total (µg/s)	<6.3	<5.9	2.7	2.9	<1.3	<1.3	4.1	<0.88	<1	1.6	11	3.8	<1.6
Fecal Coliform (CFU/s)	320	590	270	380	6400	5300	3.90E+04	7500	560	8.50E+04	8.40E+04	4.70E+04	1900
Nitrite + Nitrate Nitrogen (mg/s)	11	10	3.4	3.5	0.57	0.53	1.7	0.26	0.43	1.4	3	4.1	2
Total Nitrogen (mg/s)	15	15	5.9	7.6	2.1	2.1	5.5	2.2	1.4	3.9	8.7	7.2	3.8
Total Suspended Solids (mg/s)	31	25	16	66	4.6	6.5	12	22	<2.6	11	27	19	<4
Zinc, Dissolved (µg/s)	13	16	5.8	4.8	<3.3	<3.3	9.2	<2.2	<2.6	12	37	22	13
Zinc, Total (µg/s)	16	<7.4	<4.6	6.2	4.1	8.5	7.2	2.4	<2.6	20	61	16	<4

Sample Number	L63950-11	L63951-11	L63952-11	L64170-11	L64171-11	L64172-11	L64252-11	L64432-11	L64433-11	L64434-11	L64489-11	L64490-11	L64491-11
Flow Type	Storm	Storm	Storm	Storm	Storm	Storm	Base	Storm	Storm	Storm	Storm	Storm	Storm
Date	10/30/2015	10/31/2015	10/31/2015	12/3/2015	12/4/2015	12/4/2015	12/28/2015	12/17/2015	12/18/2015	12/18/2015	1/13/2016	1/14/2016	1/14/2016
Time	8:59	18:31	9:13	7:43	17:05	8:25	11:55	8:42	17:38	9:15	8:00	16:40	8:50
Discharge (cfs)	9.16	15.82	25.63	17.44	19.17	21.64	33.24	26.28	33.99	62.5	26.28	31.77	31.04
Ammonia Nitrogen (mg/s)	0.44	0.56	1.2	1.2	1.3	1.6	0.79	0.59	0.72	1.5	1	1.3	1.1
Copper, Dissolved (µg/s)	2.1	3.2	7.7	6.3	7.7	8.4	14	17	22	46	24	14	16
Copper, Total (µg/s)	1.9	4.6	9	8.5	8.4	8.7	23	16	19	40	11	14	15
Fecal Coliform (CFU/s)	4700	3.80E+05	3.80E+04	2400	2700	6900	1700	1.50E+04	3400	2.80E+04	5800	1600	2200
Nitrite + Nitrate Nitrogen (mg/s)	3.6	5.6	11	14	16	18	37	28	39	68	21	26	24
Total Nitrogen (mg/s)	5.4	9.3	17	20	22	26	44	36	48	84	29	35	34
Total Suspended Solids (mg/s)	4.6	36	21	17	17	15	30	42	24	38	29	<16	28
Zinc, Dissolved (µg/s)	8.3	15	46	9.6	17	30	40	23	32	75	34	29	27
Zinc, Total (µg/s)	8.2	14	25	30	15	15	93	37	44	94	34	35	26

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Appendix E: Suspended Particle Size Distribution

Table E-1. Particle size distribution by sampling event and round. All values in percent of suspended solids by mass.

Site	Locator	Event/Round	Clay	Sand<500	Silt	Total
Bear Creek - Lower	C484	Base 1 Round 1	4.57	29.27	65.88	99.72
		Base 1 Round 2	*3.83*	*18.37*	*53.71*	*75.91*
		Base 2 Round 1	9.18	0.01	90.82	100.01
		Base 2 Round 2	5.17	0.01	94.83	100.01
		Storm 1 Round 1	5.88	15.05	79.08	100.01
		Storm 1 Round 2	*2.96*	*11.95*	*14.06*	*28.97*
		Storm 1 Round 3	3.02	26.87	65.88	95.77
		Storm 2 Round 1	4.92	18.56	76.52	100
		Storm 2 Round 2	3.49	25.56	70.88	99.93
		Storm 2 Round 3	2.95	19.48	58.15	80.58
Stensland Creek	BCP09	Base 1 Round 1	12.05	0.01	87.95	100.01
		Base 1 Round 2	14.18	0.01	85.82	100.01
		Base 2 Round 1	*5.01*	*0.01*	*35.35*	*40.37*
		Base 2 Round 2	15.43	0.01	84.57	100.01
		Storm 1 Round 1	*15.18*	*0.01*	*60.54*	*75.73*
		Storm 1 Round 2	6.23	21.2	72.57	100
		Storm 1 Round 3	13.12	0.01	86.88	100.01
		Storm 2 Round 1	*1.85*	*0.01*	*12.97*	*14.83*
		Storm 2 Round 2	17.13	0.01	82.87	100.01
		Storm 2 Round 3	20.37	0.01	79.63	100.01
Mackey Creek	ET484	Base 1 Round 1	3.31	31.07	57.65	92.03
		Base 1 Round 2	5.69	20.22	74.09	100
		Base 2 Round 1	10.21	0.01	79.58	89.8
		Base 2 Round 2	6.87	0.01	93.13	100.01
		Storm 1 Round 1	4.48	25.82	69.7	100
		Storm 1 Round 2	*11.45*	*0.01*	*65.16*	*76.62*
		Storm 1 Round 3	*1.44*	*14.53*	*29.95*	*45.92*
		Storm 2 Round 1	7.77	18.68	73.54	99.99
		Storm 2 Round 2	3.31	32.89	63.8	100
		Storm 2 Round 3	*2.66*	*12.39*	*39.24*	*54.29*
Monticello Creek	BCP08	Base 1 Round 1	2.81	25.63	58.81	87.25
		Base 1 Round 2	5.15	0.01	94.85	100.01
		Base 2 Round 1	*1.72*	*0.01*	*75.54*	*77.27*
		Base 2 Round 2	*0.07*	*0.01*	*75.37*	*75.45*
		Storm 1 Round 1	2.56	33.44	61.55	97.55
		Storm 1 Round 2	*6.21*	*0.01*	*52.6*	*58.82*
		Storm 1 Round 3	4.48	31.64	63.87	99.99
		Storm 2 Round 1	2	43.77	51.21	96.98
		Storm 2 Round 2	2.49	38.73	55.93	97.15

Site	Locator	Event/Round	Clay	Sand<500	Silt	Total
		Storm 2 Round 3	1.95	45.15	50.5	97.6
Bear Creek - Middle	J484	Base 1 Round 1	2	34.15	56.94	93.09
		Base 1 Round 2	3.52	25.1	71.38	100
		Base 2 Round 1	*2.77*	*0.01*	*53.32*	*56.1*
		Base 2 Round 2	7.65	0.01	92.35	100.01
		Storm 1 Round 1	3.58	20.22	75.87	99.67
		Storm 1 Round 2	*6.03*	*0.01*	*50.27*	*56.31*
		Storm 1 Round 3	3.29	29.28	67.43	100
		Storm 2 Round 1	3.37	22.97	73.66	100
		Storm 2 Round 2	*0.6*	*8.37*	*15.93*	*24.9*
		Storm 2 Round 3	3.94	27.17	68.89	100
Seidel Creek	BCP06	Base 1 Round 1	7.96	0.01	92.04	100.01
		Base 1 Round 2	10.98	0.01	89.02	100.01
		Base 2 Round 1	*11.02*	*0.01*	*10.35*	*21.38*
		Base 2 Round 2	*3.1*	*0.01*	*67.87*	*70.98*
		Storm 1 Round 1	3.2	20.85	75.73	99.78
		Storm 1 Round 2	58.1	0.01	41.9	100.01
		Storm 1 Round 3	*2.03*	*23.43*	*48.48*	*73.94*
		Storm 2 Round 1	3.12	25.56	71.31	99.99
		Storm 2 Round 2	2.44	26.37	68.17	96.98
		Storm 2 Round 3	40.74	0.01	59.26	100.01
Seidel Creek - South	SOUTH SEIDEL_YSI	*Base 1 Round 1*	*2.7*	*19.76*	*63.72*	*86.18*
		Base 1 Round 2	3.11	17.62	79.27	100
		Base 2 Round 1	5.3	0.06	94.64	100
		Base 2 Round 2	*2.03*	*18.34*	*56.82*	*77.19*
		Storm 1 Round 1	1.95	38.18	50.46	90.59
		Storm 1 Round 2	*0.94*	*14.73*	*24.31*	*39.98*
		Storm 1 Round 3	2.31	35.05	57.56	94.92
		Storm 2 Round 1	2.16	39.72	55.85	97.73
		Storm 2 Round 2	2.42	38.95	58.63	100
		Storm 2 Round 3	2.52	33.2	64.28	100
Struve Creek - North Fork	BCP04	Base 1 Round 1	3.39	26.92	69.69	100
		Base 1 Round 2	3.58	27	69.41	99.99
		Base 2 Round 1	51.81	0.01	48.19	100.01
		Base 2 Round 2	*0.77*	*25.1*	*27.4*	*53.27*
		Storm 1 Round 1	7.79	0.01	80.69	88.49
		Storm 1 Round 2	*16.81*	*0.01*	*13.39*	*30.21*
		Storm 1 Round 3	2.48	36.92	60.6	100
		Storm 2 Round 1	2.09	40.71	57.2	100
		Storm 2 Round 2	*1.22*	*19.82*	*38.92*	*59.96*

Site	Locator	Event/Round	Clay	Sand<500	Silt	Total
		Storm 2 Round 3	*1.83*	*19.92*	*43.21*	*64.96*
Upper Bear Trib	BCP10	*Base 1 Round 1*	*3.59*	*10.24*	*58.75*	*72.58*
		Base 1 Round 2	10.74	0.01	89.26	100.01
		Base 2 Round 1	10.42	0.01	89.58	100.01
		Base 2 Round 2	6.23	0.01	93.77	100.01
		Storm 1 Round 1	2.82	37.57	59.61	100
		Storm 1 Round 2	*28.17*	*0.01*	*0.01*	*28.19*
		Storm 1 Round 3	3.59	36.14	60.27	100
		Storm 2 Round 1	2.1	39.41	56.7	98.21
		Storm 2 Round 2	2.51	31.66	55.02	89.19
		Storm 2 Round 3	3.31	32.89	63.8	100
Bear Creek - Upper	BCP01	Base 1 Round 1	3.71	23.94	72.35	100
		Base 1 Round 2	10.77	0.01	89.23	100.01
		Base 2 Round 1	7.97	0.01	92.03	100.01
		Base 2 Round 2	4.35	0.01	89.62	93.98
		Storm 1 Round 1	59.29	0.01	40.71	100.01
		Storm 1 Round 2	*23.78*	*0.01*	*19.08*	*42.87*
		Storm 1 Round 3	57.15	0.01	42.85	100.01
		Storm 2 Round 1	11.6	0.01	88.4	100.01
		Storm 2 Round 2	*6.64*	*0.01*	*65.49*	*72.14*
		Storm 2 Round 3	*0.83*	*0.01*	*7.05*	*7.89*
Cottage Lake Creek	N484	*Base 1 Round 1*	*2.3*	*26.2*	*51.18*	*79.68*
		Base 1 Round 2	4.21	14.3	81.48	99.99
		Base 2 Round 1	4.03	0.01	95.97	100.01
		Base 2 Round 2	*1.82*	*0.01*	*45.76*	*47.59*
		Storm 1 Round 1	1.63	50.68	47.69	100
		Storm 1 Round 2	1.68	51.58	46.74	100
		Storm 1 Round 3	*0.89*	*27.88*	*27.04*	*55.81*
		Storm 2 Round 1	2.29	41.92	55.79	100
		Storm 2 Round 2	1.29	39.9	49.53	90.72
		Storm 2 Round 3	1.68	44.69	53.62	99.99
Cottage Lake Outlet	BCP03	Base 1 Round 1	2.57	4.67	92.75	99.99
		Base 1 Round 2	2.03	0.01	97.97	100.01
		Base 2 Round 1	6.5	0.01	93.5	100.01
		Base 2 Round 2	*3.36*	*0.01*	*55.18*	*58.55*
		Storm 1 Round 1	46.11	0.01	53.89	100.01
		Storm 1 Round 2	43.89	0.01	56.11	100.01
		Storm 1 Round 3	*17.42*	*0.01*	*32.03*	*49.46*
		Storm 2 Round 1	8.4	0.01	91.6	100.01
		Storm 2 Round 2	*2.17*	*21.79*	*38.28*	*62.24*

Site	Locator	Event/Round	Clay	Sand<500	Silt	Total
		Storm 2 Round 3	5.2	0.01	94.8	100.01
Cold Creek	BCP02	*Base 1 Round 1*	*22.35*	*1.64*	*29.01*	*53*
		Base 1 Round 2	8.81	0.01	91.19	100.01
		Base 2 Round 1	55.97	0.01	44.03	100.01
		Base 2 Round 2	3.45	21.1	72.38	96.93
		Storm 1 Round 1	No sample - no flow			--
		Storm 1 Round 2	6.29	14.38	59.64	80.31
		Storm 1 Round 3	22.44	0.01	77.56	100.01
		Storm 2 Round 1	16.11	5.39	72.54	94.04
		Storm 2 Round 2	10.66	12.91	68.05	91.62
		Storm 2 Round 3	No sample - no flow			--

Italic represents results with total volume less than 80%