

Newaukum River Effectiveness Monitoring: First Year (2018 Water Year) Water Quality Summary



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Abstract

This report presents a data summary of water quality parameters measured in the Newaukum River watershed by the Washington State Department of Ecology (Ecology) during the 2018 Water Year (Oct 1, 2017 – Sept 30, 2018).

During this time period, Ecology conducted water quality sampling monthly at five ambient sites. Also, in situ water quality was measured and biological samples were collected at these five sites as well as other sites during Ecology's Watershed Health Monitoring (WHM) assessments.

Water conditions at ambient monitoring stations failed to meet criteria for five parameters:

- **Temperature**- The seven-day average of the daily maximum water temperature (7-DADMax) failed to meet both basic and supplemental criteria at all locations.
- **Dissolved oxygen**- Failed to meet minimum criteria at all locations.
- **pH**- Two sites had excursions above (not meeting) pH criteria: South Fork Newaukum at river mile (RM) 11.2 and Newaukum at RM 4.1.
- **Fecal coliform**- Three sites failed to meet fecal coliform criteria: Middle Fork at RM 0.1, Newaukum at RM 4.1, and North Fork at RM 0.3. Two sites had one exceedance of the secondary criterion: South Fork at RM 11.2 and South Fork at RM 23.1.
- **E. coli**- One site failed to meet the geometric mean criterion and had one exceedance of the secondary criterion: Middle Fork at RM 0.1. All other sites were in compliance.

Benthic macroinvertebrate data were also collected at several sites throughout the watershed, and their scores were compared to reference scores for the Puget Sound Lowland Ecoregion. Three sites scored below (did not meet) the criteria threshold of 65: Middle Fork at RM 0.2, Newaukum at RM 4.6, and North Fork at RM 1.9. All other sites scored above (met) the criteria threshold.

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Background

Located near the town of Chehalis, the Newaukum River and several of its tributaries are on the 2012 303(d) list of impaired waterbodies. These locations are currently not meeting one or more Washington State water quality standards. This study focuses on the mainstem Newaukum River and its three main tributaries: North Fork, Middle Fork, and South Fork.

Currently the Newaukum River watershed is part of a long-term effectiveness monitoring study. The intention of this study is to collect data to help assess the effectiveness of multiple best management practices (BMPs) on improving water quality and habitat conditions in the watershed. Results can be measured at site-specific and basin wide scales to track change over time (Collyard, 2018).

This report summarizes water quality data collected from 10/1/2017 through 9/30/2018. During that time, data were collected on a monthly basis at five ambient sites (Figure 1). Two Washington State Department of Ecology (Ecology) units contributed to this work: the Effectiveness Monitoring (EM) Unit and the Freshwater Monitoring (FM) Unit. Limited water quality and benthic macroinvertebrate data from Ecology's Watershed Health Monitoring (WHM) surveys during September 2017 are also included in this report.

Results from WHM surveys can be found at

<https://apps.ecology.wa.gov/eim/search/WHM/WHMSearch.aspx?State=newsearch&Section=all>.
Search Study ID WHM_EFF3.

Category Listings

Ecology has established designated uses for the mainstem Newaukum River and all three of its forks: North, Middle, and South. These designated uses are established to protect aquatic life, recreation, water supply, and other miscellaneous uses. The Newaukum River and all three forks are designated for primary contact recreation. In addition, the mainstem Newaukum is designated for core summer habitat, and its three forks are designated for char spawning and rearing (WAC 173- 201A-600).

In January 2019, Ecology's Water Quality Program revised [Chapter 173-201A WAC](#)¹ to include *Escherichia coli* (*E. coli*) as the chosen indicator for bacteria in freshwater samples (Ecology, 2019). In anticipation of this change and in an effort to provide data that align with future bacteria standards, both fecal coliform and *E. coli* were collected at all ambient sampling locations. During the transition period, fecal coliform was allowed as an alternate indicator through 12/31/2020.

¹ <https://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-200>

Table 1. Applicable water quality criteria for the Newaukum River watershed

Parameter	Criteria
Bacteria	Fecal coliform ¹ organism levels must not exceed a geometric mean value of 100 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 200 colonies /100 mL.
	E. coli organism levels within an averaging period must not exceed a geometric mean value of 100 CFU or MPN per 100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained within the averaging period exceeding 320 CFU or MPN per 100 mL.
Dissolved Oxygen	Dissolved oxygen concentration will not fall below 9.5 mg/L more than once every ten years on average. When a water body's DO is lower than 9.5 mg/L (or within 0.2 mg/L) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the DO of that water body to decrease more than 0.2 mg/L
Temperature	7-day average of the daily maximum temperature (7-DADMax) will not exceed 12°C for char spawning and rearing and 16°C for core summer salmonid habitat more than once every ten years on average. When a water body's temperature is warmer than the criteria (or within 0.3°C) and that condition is due to natural conditions, then human actions considered cumulatively may not cause the 7-DADMax temperature of that water body to increase more than 0.3°C.
Turbidity	Turbidity shall not exceed: 5 nephelometric turbidity units (NTU) over background when the background is 50 NTU or less or a 10 percent increase in turbidity when the background is more than 50 NTU.
pH	pH shall be within the range of 6.5 to 8.5 with a human-caused variation within above range of less than 0.5 units.

¹ The use of fecal coliform organism levels to determine compliance expired December 31, 2020.

Table 2. Water quality impairments for the Newaukum River watershed.

Waterbody Name	Parameter	Impairment Category
Mainstem Newaukum	Temperature	4a
	Dissolved Oxygen	4a
	Bacteria	4a
South Fork Newaukum	Temperature	4a
	Dissolved Oxygen	4a
	Bacteria	2
	Temperature	2
Middle Fork Newaukum	Dissolved Oxygen	4a
	Bacteria	2
	pH	2
	Temperature	2
North Fork Newaukum	Temperature	4a
	Dissolved Oxygen	4a

Category 2 – water of concern

Category 4a – impaired with a water quality improvement project in place

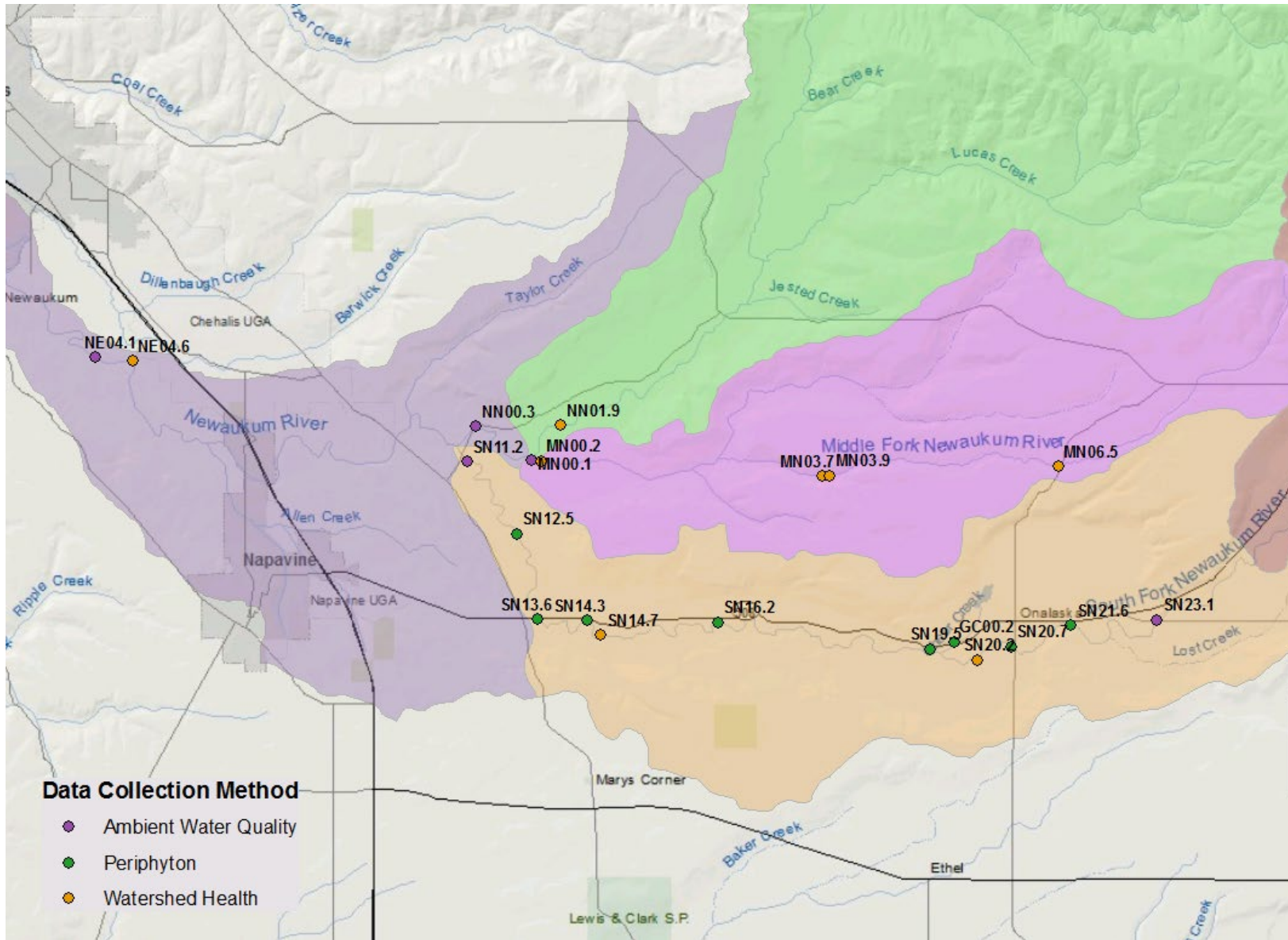


Figure 1. Newaukum site locations by sampling protocol.

Methods

Details on site locations, sample frequency, methods, etc. are described in the Quality Assurance Project Plan (Collyard, 2018).

Water quality sampling procedures followed those outlined in Standard Operating Procedures (SOPs) for the Collection, Processing, and Analysis of Stream Samples (Ward, 2016).

Sample containers and hold times followed those outlined in the Manchester Environmental Laboratory User's Manual (MEL, 2016).

For WHM surveys, all sampling was conducted in accordance with associated [Standard Operating Procedures](#).²

Results

Continuous Monitoring

Temperature

Continuous water temperature was measured with a combination of Onset® U20L pressure transducers and FTS® DTS-12 turbidity probes for the duration of Water Year 2018 (October 1, 2017-September 30, 2018) at five sites (Figure 1). The seven-day average of the daily maximum water temperature (7-DADMax) failed to meet both basic and supplemental criteria at all stations (Table 3 and Figure 2).

Table 3. Continuous water temperature summary for Water Year 2018 (°C)

Station	Criterion	Supplemental Criterion	1-DMax		7-DADMax ^a		Days in Exceedance	Days of Record ^c	Percentage Exceeding Criteria
			Max	Date	Max	Date ^b			
MN00.1	16.0	13.0	21.0	6/20/18	19.96	7/14/18	86	330	26.0
NE04.1	16.0	13.0	27.8	7/26/18	27.37	7/27/18	160	365	43.8
NN00.3	16.0	13.0	26.8	7/29/18	26.46	7/28/18	143	353	40.5
SN11.2	16.0	13.0	25.1	7/29/18	24.53	7/28/18	157	365	43.0
SN23.1	16.0	13.0	23.8	7/29/18	22.99	7/28/18	150	365	41.1

^a 7-DADMax: 7-day average of the daily maximum temperature.

^b Date is the middle of the averaged 7-day period.

^c MN00.1 and NN00.3 missing measurements due to equipment failure.

²[https://apps.ecology.wa.gov/publications/UIPages/PublicationList.aspx?IndexTypeName=Topic&NameValue=Standard+Operating+Procedure+\(SOP\)+%e2%80%94+Watershed+Health+Monitoring&DocumentTypeName=Publication](https://apps.ecology.wa.gov/publications/UIPages/PublicationList.aspx?IndexTypeName=Topic&NameValue=Standard+Operating+Procedure+(SOP)+%e2%80%94+Watershed+Health+Monitoring&DocumentTypeName=Publication)

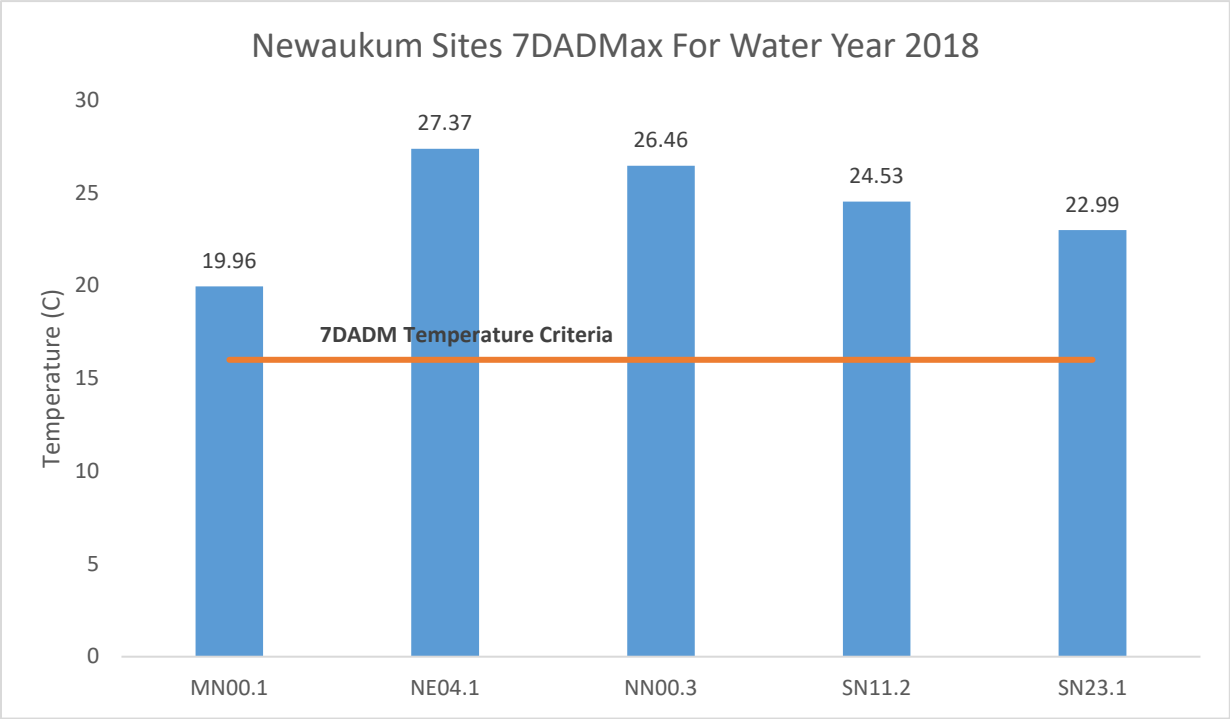


Figure 2. 7-DADMax temperature results for Water Year 2018.

Short-term Multi-Parameter Sonde Deployments

YSI® EXO multi-parameter sondes were installed at five ambient site locations during the period from 8/2/2018-8/14/2018 in an effort to capture conditions during the summer critical period. Sondes were set to collect measurements every 15 minutes.

pH

Two sites, NE04.1 and SN11.2, had excursions above the upper limit criterion of 8.5 standard units (Figure 3). Data are not available for NN00.3 due to a faulty pH probe.

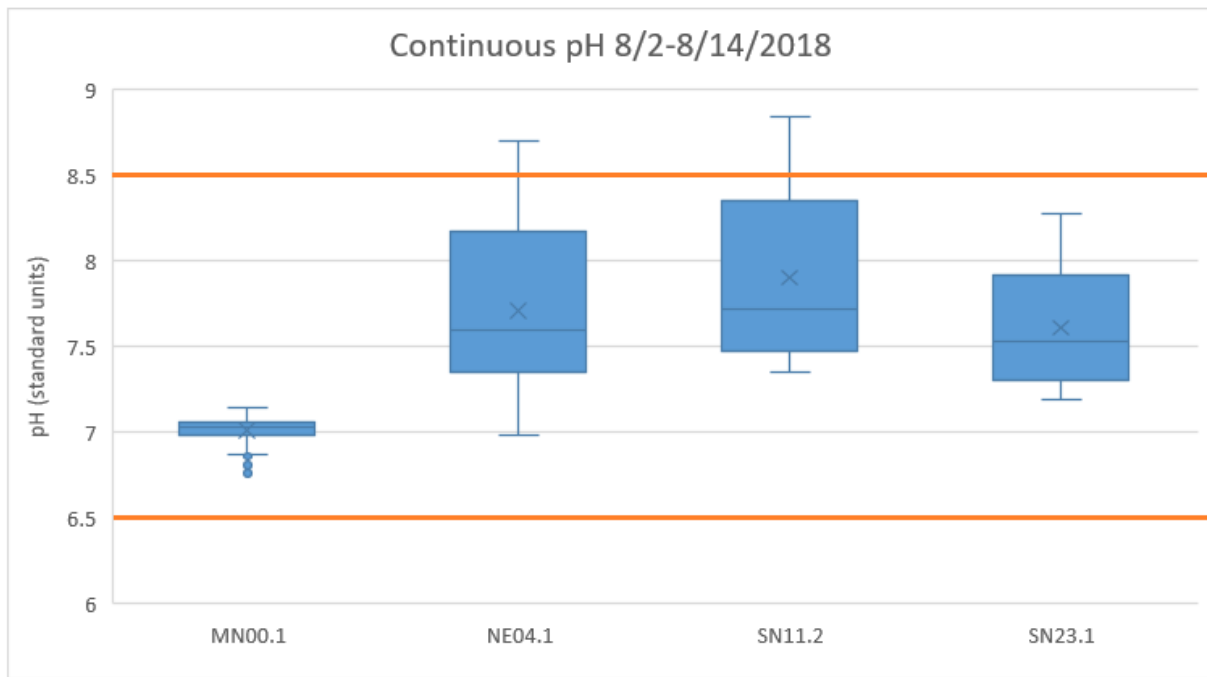


Figure 3. pH during short-term deployment.³

Boxplot showing solid black bars as the median, 'x' as the mean, the boxes representing the 25th and 75th percentiles, and the whiskers being the maximum and minimum values. Outliers are 1.5 times the interquartile range.

³ Data for NE04.1 are provisional

Dissolved Oxygen

All sites had excursions below the minimum criterion of 9.5 mg/L (Figure 4). In addition, all measurements at MN00.1 were below the criterion; this site has very low flow during the summer months and may be influenced by groundwater upwelling.

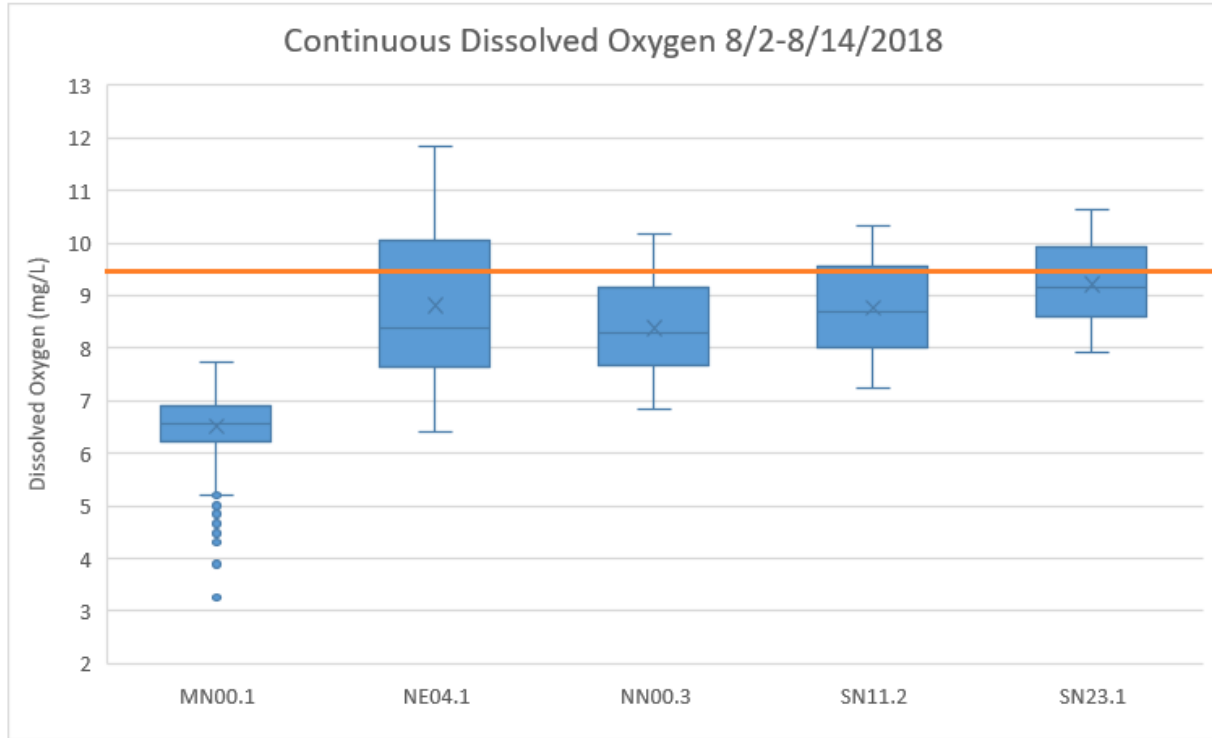


Figure 4. Dissolved oxygen during short-term deployment.^{4, 5}

⁴ Data for NE04.1 are provisional

⁵ Data for MN00.1 are flagged estimate due to sensor drift

Monthly Ambient Monitoring

pH

For pH, site NE04.1 had one excursion above the upper limit criterion of 8.5 standard units (Figure 5). All other sites were within criteria.

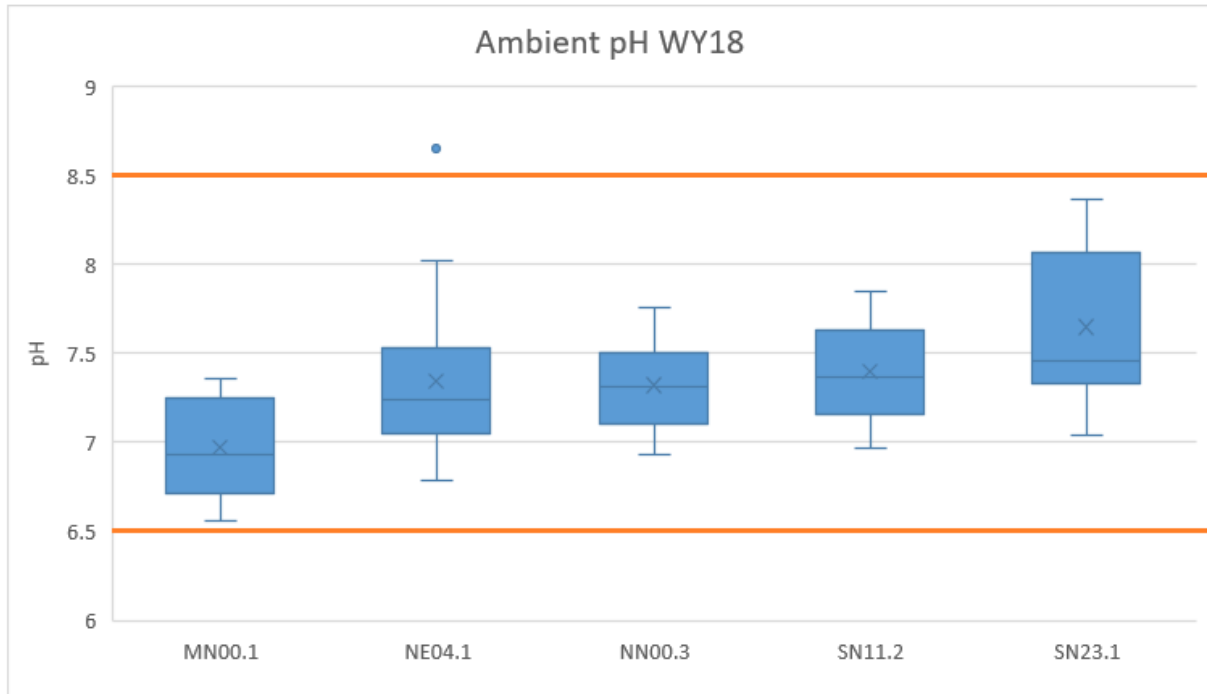


Figure 5. Monthly monitoring results for pH.

Dissolved Oxygen

For dissolved oxygen, all sites had excursions below the minimum criterion of 9.5 mg/L (Figure 6).

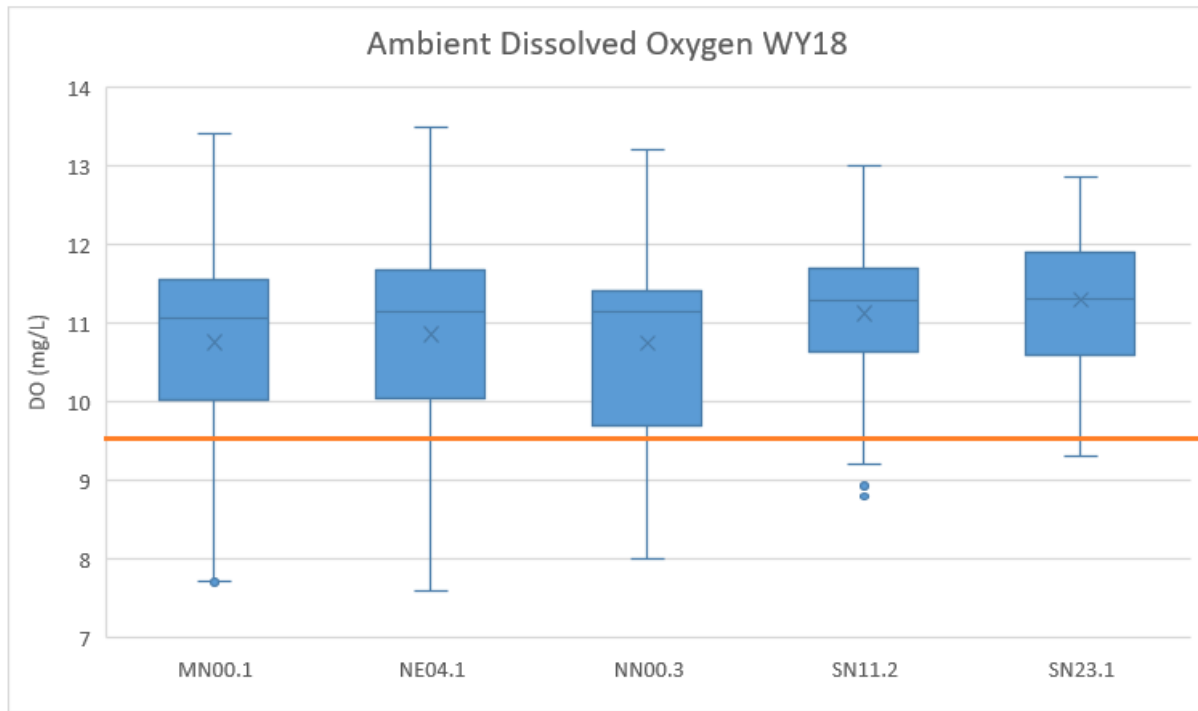


Figure 6. Monthly monitoring results for dissolved oxygen.

Bacteria

Bacteria results include a combination of FM Unit and EM Unit data. Data are presented for Water Year 2018, as well as broken into three-month periods. Appendix A contains bacteria summary tables for each site.

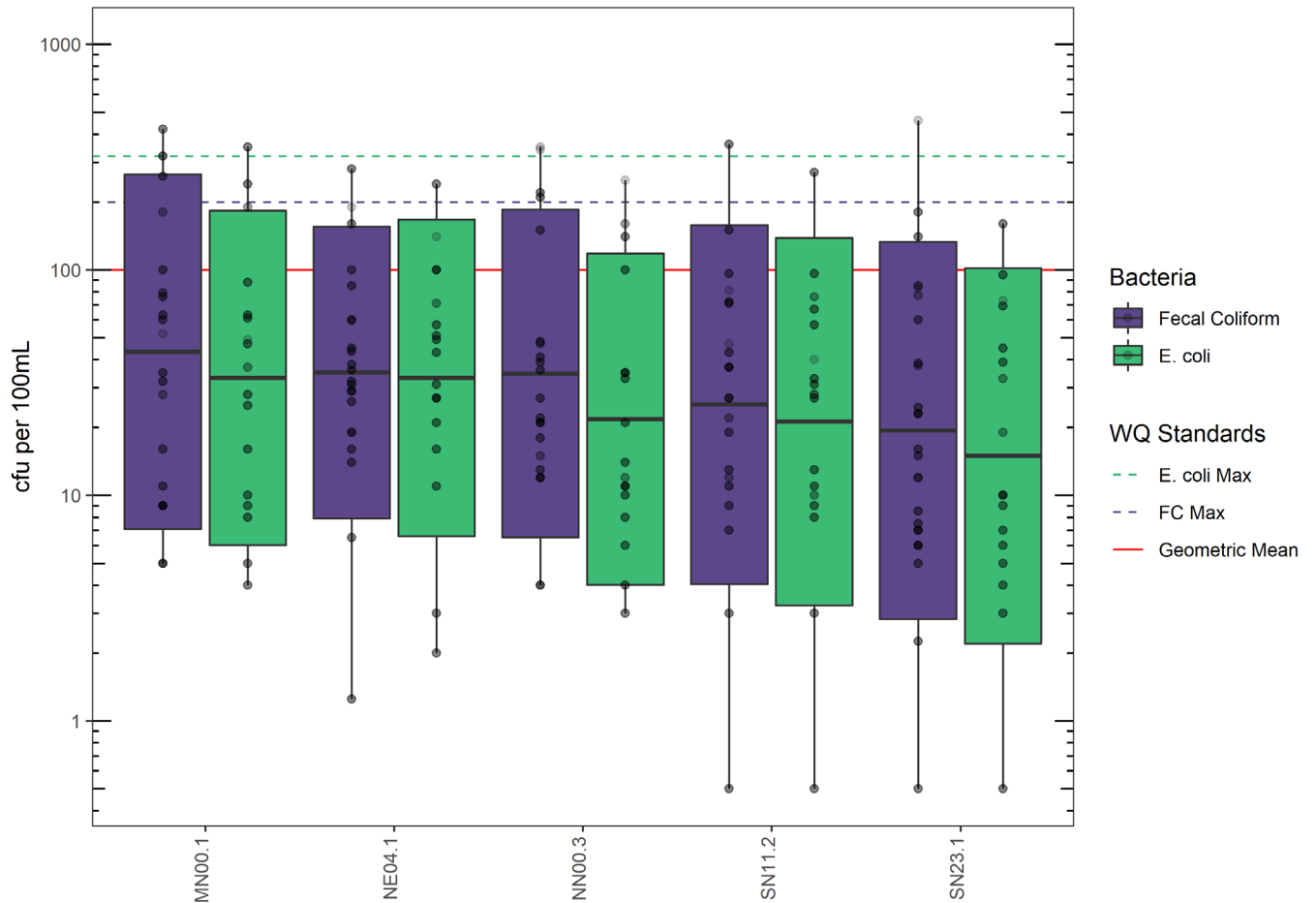


Figure 7. Bacteria boxplot for WY18.

With the solid black bars as the geometric mean, the boxes representing the 10th and 90th percentiles, and the whiskers being the maximum and minimum values. All individual data points are grey points in the background.

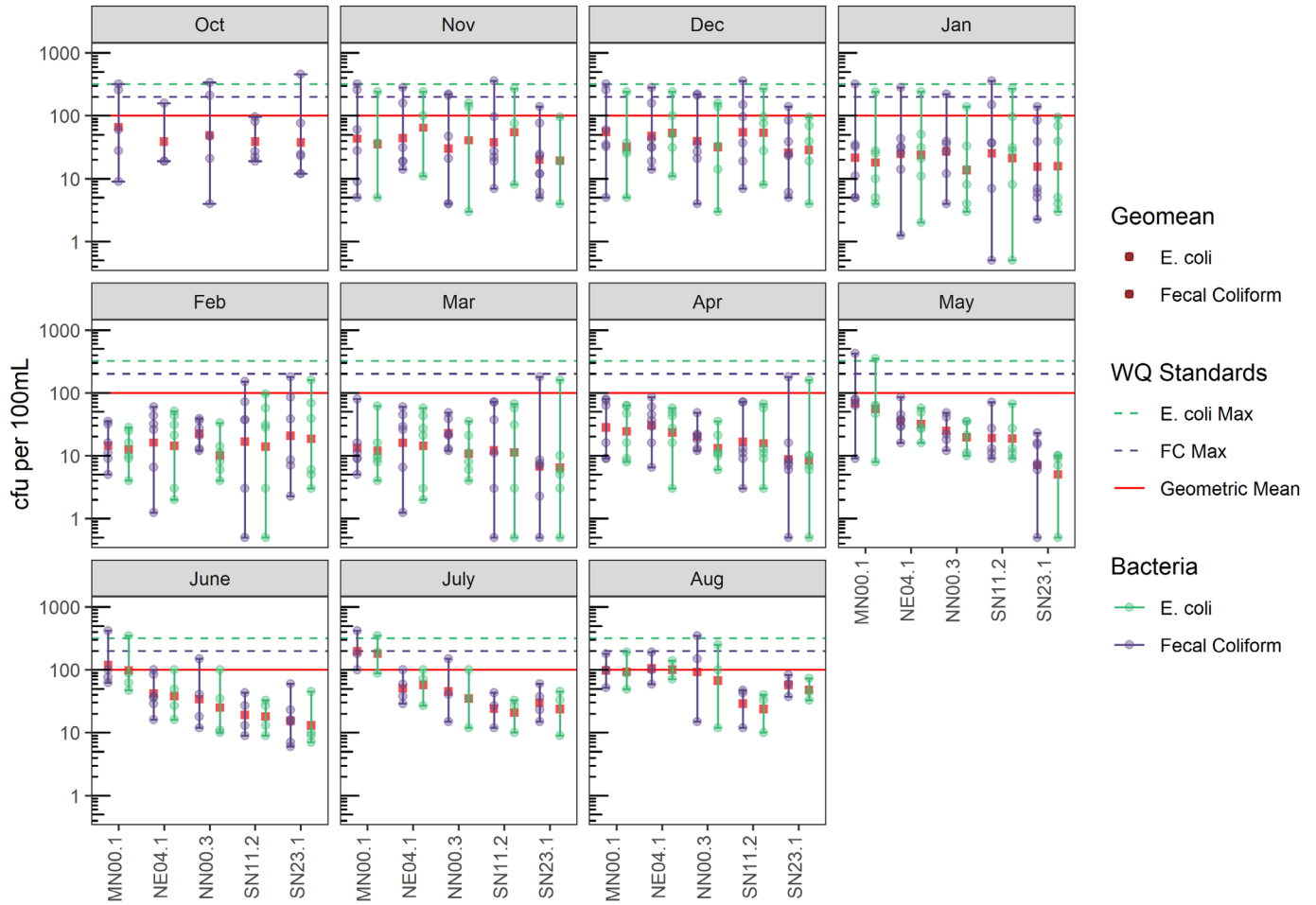


Figure 8. Bacteria data divided into three-month periods.

Period includes month listed, month preceding, and month following. Line spans minimum and maximum values. Red square indicates geomean. September 2018 did not have the minimum number of samples to calculate geomean.

Fecal coliform

Three sites, MN00.1, NE04.1 and NN00.3, failed to meet fecal coliform criteria as outlined in WAC 173-201A. Two sites, SN11.2 and SN23.1, each had one exceedance of the secondary criterion (Table 4, Figures 8 and 9, Appendix A2 and A3).

Table 4. Fecal coliform three-month summary

Location	Site ID	Status	Details
Middle Fork Newaukum River RM 0.1	MN00.1	Failing	Exceeds geomean in June and July. Exceeds max in Sept ('17), Nov, Dec, June
Newaukum River RM 4.1	NE04.1	Failing	Exceeds geomean Aug. Exceeds max in Dec
North Fork Newaukum River RM 0.3	NN00.3	Failing	Exceeds max in Sept ('17), Nov, Dec, Sept ('18)
South Fork Newaukum River RM 11.2	SN11.2	Meeting*	Exceeds max in Dec
South Fork Newaukum River RM 23.1	SN23.1	Meeting*	Exceeds max in Sept ('17)

*At least two samples must exceed the associated criterion magnitude during the water year to be considered for listing

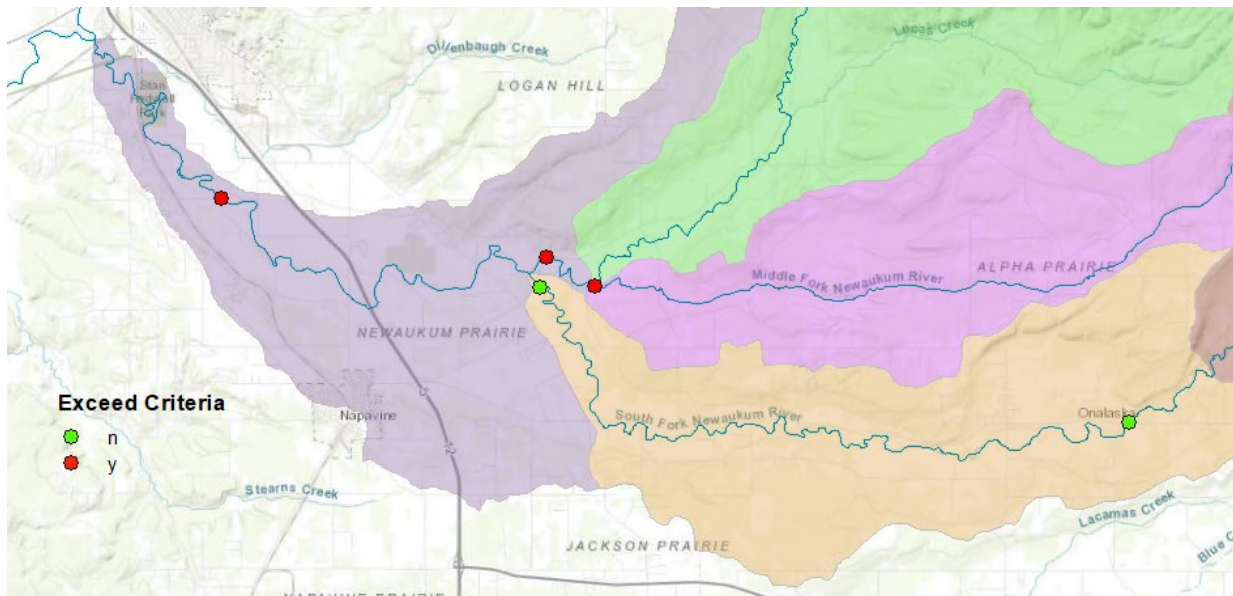


Figure 9. Map of sites exceeding fecal coliform criteria.

E. coli

One site, MN00.1, exceeded (failed to meet) the geomean criterion for *E. coli* and had one exceedance of the secondary criterion. All other sites were in compliance (Table 5, Figures 8 and 10, Appendix A4 and A5).

Table 5. *E. coli* three-month summary

Location	Site ID	Status	Details
Middle Fork Newaukum River RM 0.1	MN00.1	Failing	Exceeds geomean in July Exceeds max in June
Newaukum River RM 4.1	NE04.1	Meeting	No exceedances
North Fork Newaukum River RM 0.3	NN00.3	Meeting	No exceedances
South Fork Newaukum River RM 11.2	SN11.2	Meeting	No exceedances
South Fork Newaukum River RM 23.1	SN23.1	Meeting	No exceedances

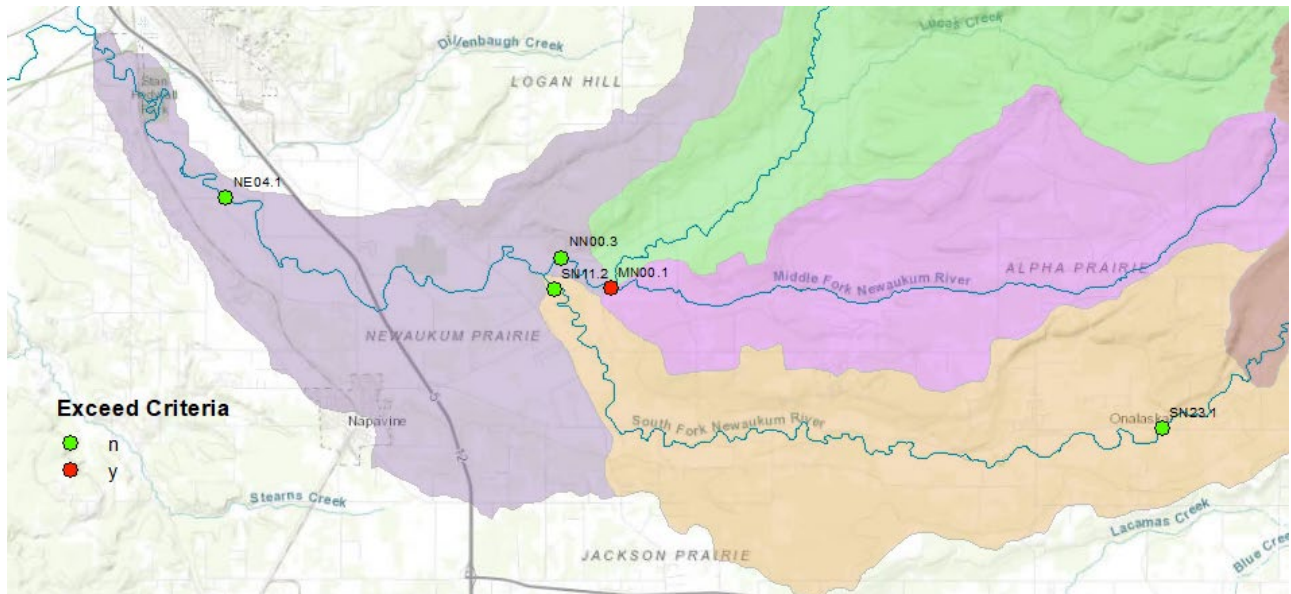


Figure 10. Map of sites that exceeded *E. coli* criteria.

Discrete Measurements

In addition to Ambient and Continuous measurements, in situ water quality was measured at select locations during WHM assessments and periphyton sampling (Figure 1). Table 6 summarizes those results.

Table 6. Discrete water quality measurements in Newaukum watershed.

Site ID	Date	Dissolved Oxygen (mg/L)	pH (s.u.)	Temperature (°C)
GC00.2	9/11/2017	8.54	7.31	17.4
MN00.2	9/18/2017	7.75	7.05	13.2
MN03.7	10/4/2017	10.05	7.35	12.8
MN03.9	10/3/2017	10.05	7.35	12.8
MN06.5	10/4/2017	10.34	7.18	10.5
NE04.6	9/27/2017	9.39	7.41	18.1
NN01.9	10/10/2017	10.72	7.55	10.8
SN12.5	9/12/2017	9.7	7.66	17.8
SN13.6	9/12/2017	9.9	7.62	18
SN14.3	9/12/2017	9.77	7.52	17.8
SN14.7	9/26/2017	10.05	7.37	16.5
SN16.2	9/11/2017	9.84	7.65	17.7
SN19.5	9/11/2017	10.23	7.99	17.8
SN20.2	9/21/2017	10.43	7.51	13.2
SN20.7	9/11/2017	10.42	7.64	16.3
SN21.6	9/11/2017	10.43	7.76	15.4

*Values in bold exceed criteria for parameter

Benthic Macroinvertebrates

Benthic macroinvertebrates were collected during WHM surveys in the summer of 2017. Macroinvertebrate data are used to calculate a benthic index of biotic integrity (BIBI) score on a scale from 0-100 for each sampling site. Sites located in the Puget Sound Lowland with scores less than 65 are considered impaired (Water Quality Program, 2018 and WAC 173-201A-260 & -300). For any site to be assessed for listing on the 303(d) list, there must be at least two years of data (Table 7). Results in this report are from locations that have been sampled only once; therefore, these scores serve as a snap shot of the current status of sites and are not sufficient for listing purposes.

BIBI scores were downloaded from [Puget Sound Stream Benthos](https://pugetsoundstreambenthos.org).⁶

Table 7. Listing criteria for benthic macroinvertebrates

Bioassessment	The average BIBI score from the most recent two years with data is less than the 10 th percentile of reference site scores for the Puget Sound Lowland Level III Ecoregion (2018 BIBI 10 th Percentile = 65)
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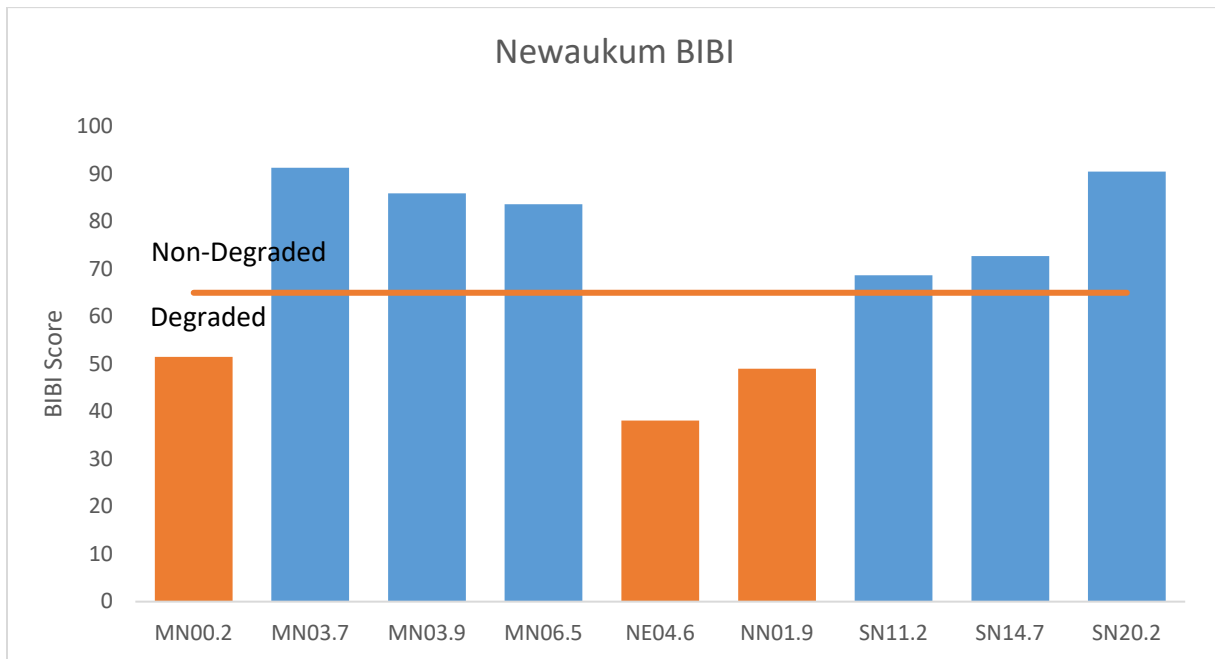


Figure 11. BIBI scores for Newaukum sites.

⁶ <https://pugetsoundstreambenthos.org/Biotic-Integrity-Map.aspx>

Table 8. BIBI scores for Newaukum sites.

Location	Site ID	Collection Date	BIBI Score	Impaired
Middle Fork Newaukum RM 0.2	MN00.2	9/18/2017	51.5	Yes
Middle Fork Newaukum RM 3.7	MN03.7	10/4/2017	91.3	No
Middle Fork Newaukum RM 3.9	MN03.9	10/3/2017	85.9	No
Middle Fork Newaukum RM 6.5	MN06.5	10/4/2017	83.6	No
Newaukum River RM 4.6	NE04.6	9/27/2017	38.1	Yes
North Fork Newaukum RM 1.9	NN01.9	10/10/2017	49	Yes
South Fork Newaukum RM 11.2	SN11.2	9/25/2017	68.7	No
South Fork Newaukum RM 14.7	SN14.7	9/26/2017	72.7	No
South Fork Newaukum RM 20.2	SN20.2	9/21/2017	90.5	No

Table 9. Summary of water quality criteria exceedances at ambient sites.

Location	Exceeds Criteria					
	Site ID	Dissolved Oxygen	pH	Temperature	Fecal Coliform	E. coli
Middle Fork Newaukum RM 0.1	MN00.1	Yes	No	Yes	Yes	Yes
Newaukum River RM 4.1	NE04.1	Yes	Yes	Yes	Yes	No
North Fork Newaukum RM 0.3	NN00.3	Yes	No	Yes	Yes	No
South Fork Newaukum RM 11.2	SN11.2	Yes	Yes	Yes	No	No
South Fork Newaukum RM 23.1	SN23.1	Yes	No	Yes	No	No

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<https://apps.ecology.wa.gov/publications/SummaryPages/1810035.html>
- Water Quality Standards for Surface Waters of the State of Washington Section 173-201A.
<https://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A>

Appendices

Appendix A. Water Quality Data

Table A1. Raw data for EM Unit and FM Unit sampling events

Site	Date	Conductivity, Specific (at 25 deg C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	E. coli (cfu/100mL)	Fecal Coliform (cfu/100mL)	pH	Temperature (°C)
SN23.1	9/11/2017	85.5	10.83	106.1	-	-	7.77	14
SN11.2	9/12/2017	88.5	10.13	108.9	-	-	7.93	18.6
NN00.3	9/19/2017	102.7	9.64	93.8	-	340	7.53	13.6
SN11.2	9/19/2017	86.6	10.46	102.8	-	81	7.83	14
MN00.1	9/19/2017	69	8.8	84.5	-	320	7.22	12.9
SN23.1	9/19/2017	81	10.46	101.3	-	460	7.84	12.9
SN11.2	9/25/2017	-	10.11	98.9	-	-	7.57	-
SN11.2	9/25/2017	-	11.34	113.3	-	-	8.48	-
NN00.3	10/2/2017	105.7	9.72	92.7	-	47	7.44	13.1
SN11.2	10/2/2017	90.5	10.84	103.5	-	27	7.82	13.3
MN00.1	10/2/2017	72.1	9.67	90	-	28	7.36	12.1
SN23.1	10/2/2017	89.1	11.04	104.3	-	77	7.87	12.3
SN23.1	10/10/2017	89	-	-	-	12	7.8	8.8
NE04.1	10/10/2017	101	-	-	-	19	7.87	11.9
SN11.2	10/17/2017	-	11.31	98.1	-	22	7.55	9
NN00.3	10/17/2017	-	11.25	96	-	4	7.49	8.4
MN00.1	10/17/2017	-	11.11	92.2	-	9	7.25	7.3
SN23.1	10/17/2017	-	12.03	104.6	-	12	7.87	8.8
NE04.1	10/19/2017	96.2	10.39	94.9	-	-	7.29	10.6
SN23.1	10/19/2017	70.2	10.82	98.1	-	-	7.04	9.7
NN00.3	10/19/2017	88	10.37	94.3	-	-	7.33	10.3
SN11.2	10/19/2017	86.9	10.53	96.8	-	-	7.43	10.7
MN00.1	10/19/2017	64	10.34	93.1	-	-	7.22	9.8
NE04.1	10/23/2017	51.9	10.75	93.4	-	-	6.79	9.9
SN23.1	10/23/2017	47.4	11.34	97.9	-	-	7.14	9.1
NN00.3	10/23/2017	53.1	10.73	93.3	-	-	6.93	9.8
SN11.2	10/23/2017	41.5	10.96	95.5	-	-	6.97	9.9
MN00.1	10/23/2017	36	10.75	93.7	-	-	6.56	9.9
MN00.1	11/1/2017	37.4	11.26	95.3	-	60	7.09	7.7
NN00.3	11/1/2017	76.4	11.24	96.4	-	21	7.29	8.3
SN11.2	11/1/2017	69.9	11.44	99.6	-	19	7.39	8.9

Site	Date	Conductivity, Specific (at 25 deg C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	E. coli (cfu/100mL)	Fecal Coliform (cfu/100mL)	pH	Temperature (°C)
SN23.1	11/1/2017	67.5	11.29	98.8	-	23	7.42	8.7
NE04.1	11/1/2017	75.8	11.5	100.4	-	19	7.4	9.1
NN00.3	11/14/2017	54.8	11.14	94.7	160	210	6.98	8.1
SN11.2	11/14/2017	54.2	11.47	97.3	76	96	7.16	8
MN00.1	11/14/2017	33.6	11.1	95.2	37	260	6.62	8.4
SN23.1	11/14/2017	51.4	11.61	99.4	19	19	7.28	7.9
SN23.1	11/14/2017	50	-	-	-	30	7.37	8
NE04.1	11/14/2017	55.7	11.32	97.2	100	190	7.1	8.4
NE04.1	11/14/2017	55	-	-	-	130	7.18	8.5
NE04.1	12/5/2017	53.6	12.31	96.7	11	14	6.92	5.8
SN23.1	12/5/2017	50.8	12.66	99	4	5	7.15	5.1
MN00.1	12/5/2017	29	12.48	97.4	5	5	6.67	5.4
NN00.3	12/5/2017	53.6	12.47	97.5	3	4	7.03	5.5
SN11.2	12/5/2017	51.8	12.51	98.6	8	7	7.13	5.8
SN23.1	12/12/2017	57	-	-	-	6	7.45	4.7
NE04.1	12/12/2017	62	-	-	-	31	7.28	3.6
NE04.1	12/19/2017	56.6	11.64	97.4	240	280	7.17	6.9
SN23.1	12/19/2017	48.6	11.59	98.5	95	140	7.29	7.1
NN00.3	12/19/2017	51.3	11.46	95.9	140	220	7.11	6.9
MN00.1	12/19/2017	30.2	11.45	94.3	240	320	6.61	6.3
SN11.2	12/19/2017	48.9	11.6	97	270	360	7.09	6.9
SN11.2	1/9/2018	46.7	11.58	96.7	96	150	6.99	6.9
NN00.3	1/9/2018	46.9	11.44	95.9	33	36	6.94	7.1
MN00.1	1/9/2018	28.2	11.62	96.6	28	32	6.59	6.7
SN23.1	1/9/2018	48	-	-	-	36	7.35	7.3
SN23.1	1/9/2018	48.2	11.62	98.8	39	41	7.2	7.3
NE04.1	1/9/2018	47	-	-	-	36	7.21	7.4
NE04.1	1/9/2018	47.7	11.55	97	51	51	7.01	7.3
NE04.1	1/23/2018	51	11.9	96.6	31	32	7	6.2
SN11.2	1/23/2018	49.9	11.98	97.3	28	37	7.16	6.2
NN00.3	1/23/2018	50.4	11.85	96.7	14	27	7.1	6.3
MN00.1	1/23/2018	29.4	11.87	96.4	25	35	6.71	6.1
SN23.1	1/23/2018	48.5	11.99	99	69	85	7.3	6.3
NE04.1	2/13/2018	60.2	12.98	97.2	2	2	7.16	3.6
MN00.1	2/13/2018	31.6	13.42	98	10	11	6.86	2.5
NN00.3	2/13/2018	62.2	13.22	99.3	4	12	7.24	3.5
SN11.2	2/13/2018	56.1	13	100.9	0.5	0.5	7.36	4.7

Site	Date	Conductivity, Specific (at 25 deg C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	E. coli (cfu/100mL)	Fecal Coliform (cfu/100mL)	pH	Temperature (°C)
SN23.1	2/13/2018	55	-	-	-	0.5	7.34	5.32
SN23.1	2/13/2018	54.3	12.66	100.8	3	4	7.53	5.3
NE04.1	2/13/2018	60	-	-	-	0.5	7.21	4.6
NE04.1	2/27/2018	54.2	12.72	97.3	21	26	6.91	4.2
SN11.2	2/27/2018	52.5	12.92	98.9	31	37	7.19	4.1
NN00.3	2/27/2018	53.1	12.83	98.7	8	39	7.12	4.3
MN00.1	2/27/2018	30	12.98	99.4	4	5	6.83	4.1
SN23.1	2/27/2018	53.6	12.87	101.4	5	7	7.4	4.8
NE04.1	3/13/2018	57.9	11.21	96.3	3	6	7.12	8.2
NN00.3	3/13/2018	59.5	11.41	96.8	11	13	7.46	7.7
SN11.2	3/13/2018	53.7	11.64	98.8	3	3	7.37	7.8
SN23.1	3/13/2018	50.8	11.81	100.3	6	6	7.42	7.4
SN23.1	3/13/2018	50	-	-	-	11	7.45	7.9
MN00.1	3/13/2018	31.7	11.54	98	9	9	6.93	7.8
NE04.1	3/13/2018	58	-	-	-	7	7.3	8.2
NE04.1	3/27/2018	55.5	12.01	96.6	43	60	7.05	6.9
NN00.3	3/27/2018	56.4	12.07	97.2	6	21	7.21	6.4
SN11.2	3/27/2018	52.4	12.31	99.2	57	72	7.28	6.9
MN00.1	3/27/2018	30.2	12.23	99.1	16	16	6.88	6.6
SN23.1	3/27/2018	48.8	12.34	100.8	160	180	7.37	6.6
NE04.1	4/10/2018	47.2	11.07	95.4	57	63	6.9	8.5
SN11.2	4/10/2018	45.2	11.27	96.6	67	71	7.06	8.2
NN00.3	4/10/2018	48.3	11.21	96.4	35	48	7.03	8.5
MN00.1	4/10/2018	28.5	11.18	97.8	61	79	6.83	9.2
SN23.1	4/10/2018	44.5	11.46	100.7	10	10	7.28	8.9
SN23.1	4/10/2018	45	-	-	-	5	7.15	9.9
NE04.1	4/10/2018	48	-	-	-	27	6.91	10.9
NE04.1	4/24/2018	57.7	10.92	96.1	27	29	7.03	9.8
NN00.3	4/24/2018	59.6	11.35	97.4	21	22	7.19	8.7
SN11.2	4/24/2018	53.9	11.45	101.4	11	11	7.36	9.9
SN23.1	4/24/2018	52.4	11.12	102.5	0.5	0.5	7.47	11.2
MN00.1	4/24/2018	29.8	11.04	101.5	8	9	7.06	11.4
NE04.1	5/8/2018	69.3	10.05	97.5	49	85	7.27	13.9
NN00.3	5/8/2018	72.5	10.65	101.5	11	12	7.43	13
SN11.2	5/8/2018	63.3	11	107.9	13	13	7.7	14.2
MN00.1	5/8/2018	37.6	10.37	103.1	47	63	7.26	14.7
SN23.1	5/8/2018	60.2	10.76	108.5	10	16	7.97	15

Site	Date	Conductivity, Specific (at 25 deg C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	E. coli (cfu/100mL)	Fecal Coliform (cfu/100mL)	pH	Temperature (°C)
SN23.1	5/15/2018	64	-	-	-	6	8.06	13.5
NE04.1	5/15/2018	74	-	-	-	36	7.88	18.2
NE04.1	5/22/2018	77.6	10.09	98.7	16	16	7.45	14.1
SN11.2	5/22/2018	71.3	10.65	104.4	9	9	7.63	14.1
NN00.3	5/22/2018	80.2	11.08	109.2	10	18	7.76	14.3
MN00.1	5/22/2018	45.5	10.03	99.8	63	76	7.32	14.7
SN23.1	5/22/2018	67.6	10.62	109.8	7	7	8.07	16
SN23.1	6/12/2018	72	-	-	-	23	8.11	14.1
NE04.1	6/12/2018	79	-	-	-	38	8.02	16.9
NE04.1	6/19/2018	88	8.94	98.2	27	29	7.55	19.9
SN11.2	6/19/2018	81.9	9.39	100.7	27	27	7.63	18.6
NN00.3	6/19/2018	90.6	9.29	101.2	35	41	7.63	19.4
MN00.1	6/19/2018	54	8.83	92.5	350	420	7.34	17.4
SN23.1	6/19/2018	77.3	10.64	109.9	9	15	8.07	16.3
SN23.1	7/10/2018	81	-	-	-	-	8.05	17.2
NE04.1	7/10/2018	93	-	-	-	-	7.87	21
NE04.1	7/17/2018	97.9	7.72	88.2	100	100	7.48	21.9
NN00.3	7/17/2018	102.8	8.04	91.1	100	150	7.42	21.3
SN11.2	7/17/2018	90.5	8.94	102.2	33	43	7.63	21.8
MN00.1	7/17/2018	66.4	7.82	85.7	88	100	7.23	19.6
SN23.1	7/17/2018	84.5	9.42	108.1	45	60	7.96	21.5
SN23.1	8/2/2018	86.7	9.84	-	-	-	7.68	16.3
SN11.2	8/2/2018	92.3	8.95	-	-	-	7.79	19.9
NN00.3	8/2/2018	105.8	8.62	-	-	-	7.63	20.4
NE04.1	8/14/2018	100.4	8.78	97.2	71	76	7.52	20
NN00.3	8/14/2018	106	8.79	98.2	12	15	7.55	20.4
SN11.2	8/14/2018	93.7	9.43	106.2	10	12	7.85	20.7
MN00.1	8/14/2018	70.5	7.98	87.7	190	180	7.27	19.4
SN23.1	8/14/2018	87	-	-	-	39	8.3	20
SN23.1	8/14/2018	86.8	10.07	113.7	33	36	8.37	20.3
NE04.1	8/14/2018	101	-	-	-	43	8.65	25.2
NE04.1	9/11/2018	107	8.71	91.4	140	200	7.43	17.5
SN11.2	9/11/2018	92.9	9.34	96.2	40	47	7.51	16.5
NN00.3	9/11/2018	113.3	9.23	96.1	250	350	7.61	17
MN00.1	9/11/2018	71.4	7.72	77.7	49	52	7.16	15.4
SN23.1	9/11/2018	89	-	-	-	77	8.16	15.8
SN23.1	9/11/2018	89.7	10.75	109.6	73	89	8.2	15.5

Site	Date	Conductivity, Specific (at 25 deg C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation)	E. coli (cfu/100mL)	Fecal Coliform (cfu/100mL)	pH	Temperature (°C)
NE04.1	9/11/2018	99	-	-	-	180	7.92	19.07
NN00.3	10/30/2018	-	-	-	-	-	-	9.1
MN00.1	10/30/2018	-	-	-	-	-	-	9.1
SN11.2	10/30/2018	-	-	-	-	-	-	10.2

*FM Unit study did not collect E. coli or in situ dissolved oxygen samples.

*EM Unit study started E. coli sample collection in November 2017.

Table A2. Fecal coliform geomean values for three-month periods

Three-month period	Site				
	MN00.1	NE04.1	NN00.3	SN11.2	SN23.1
Sept-Oct-Nov	66	39	49	39	38
Oct-Nov-Dec	43	44	30	37	20
Nov-Dec-Jan	55	47	39	54	26
Dec-Jan-Feb	21	25	27	25	16
Jan-Feb-March	14	16	22	17	21
Feb-March-April	13	16	23	12	7
March-April-May	28	31	20	16	9
April-May-June	68	35	25	19	7
May-June-July	119	42	34	19	16
June-July-Aug	196	51	45	24	30
July-Aug-Sept ¹	98	104	92	29	57

¹ Insufficient data to calculate geomean for September 2018

* Values in bold exceed criterion

Table A3. Fecal coliform max values for three-month periods

Month	MN00.1		NE04.1		NN00.3		SN11.2		SN23.1	
	Month Max	Period Max ^a	Month Max	Period Max	Month Max	Period Max	Month Max	Period Max	Month Max	Period Max
September	320	320	NA	19	340	340	81	81	460	460
October	28	320	19	160	47	340	27	96	77	460
November	260	320	160	280	210	220	96	360	25	140
December	320	320	280	280	220	220	360	360	140	140
January	35	320	44	280	36	220	150	360	85	140
February	11	35	26	60	39	39	37	150	7	180
March	16	79	60	60	21	48	72	72	180	180
April	79	79	45	85	48	48	71	72	8	180
May	76	420	85	85	18	48	13	71	16	23
June	420	420	38	100	41	150	27	43	23	60
July	100	420	100	100	150	150	43	43	60	60
August	180	180	60	190	15	350	12	47	38	83
September	52	180	190	190	350	350	47	47	83	83

^a Period Max values are based on a 90-day time frame including month listed, month preceding and month following
 Values in **bold** exceed criterion

Shading shows monthly max value that determines period max

NA- no sample collected

Table A4. E. coli geomean values for three-month periods

Three-month period	Site				
	MN00.1	NE04.1	NN00.3	SN11.2	SN23.1
Nov-Dec ¹	35	64	41	55	19
Nov-Dec-Jan	32	53	32	54	29
Dec-Jan-Feb	18	24	14	21	16
Jan-Feb-March	13	14	10	14	18
Feb-March-April	12	14	11	11	6
March-April-May	24	23	13	16	8
April-May-June	55	32	20	19	5
May-June-July	98	38	25	18	13
June-July-Aug	180	58	35	21	24
July-Aug-Sept ²	94	100	67	24	48

¹ No E. coli samples collected in October 2017

² Insufficient data to calculate geomean for September

* Values in bold exceed criterion

Table A5. E. coli max values for three-month periods

Month	MN00.1		NE04.1		NN00.3		SN11.2		SN23.1	
	Month Max	Period Max ^a	Month Max	Period Max	Month Max	Period Max	Month Max	Period Max	Month Max	Period Max
October	NA	37	NA	100	NA	160	NA	76	NA	19
November	37	240	100	240	160	160	76	270	19	95
December	240	240	240	240	140	160	270	270	95	95
January	28	240	51	240	33	140	96	270	69	95
February	10	28	21	51	8	33	31	96	5	160
March	16	61	43	57	11	35	57	67	160	160
April	61	63	57	57	35	35	67	67	10	160
May	63	350	49	57	11	35	13	67	10	10
June	350	350	27	100	35	100	27	33	9	45
July	88	350	100	100	100	100	33	33	45	45
August	190	190	71	140	12	250	10	40	33	73
September	49	190	140	140	250	250	40	40	73	73

^a Period Max values are based on a 90-day time frame including month listed, month preceding and month following

Values in **bold** exceed criterion

Shading shows monthly max value that determines period max

NA- no sample collected

Appendix B. Quality Assurance

Both continuous (DTS-12 and U20L) and discrete (ProDSS) probe calibration values were compared to the measurement quality objectives (MQOs) outlined in Table B1 (McCarthy and Mathieu, 2017).

Table B1. Multi-parameter sonde MQOs

Parameter	Unit	Accept	Qualify	Reject
Dissolved Oxygen	% Saturation	$\leq \pm 5\%$	$> \pm 5\%$ and $\leq \pm 15\%$	$> \pm 15\%$
	mg/L	$\leq \pm 0.5$	$> \pm 0.5$ and $\leq \pm 1.0$	$> \pm 1.0$
pH	Standard unit	$\leq \pm 0.5$	$> \pm 0.2$ and $\leq \pm 0.8$	$> \pm 0.8$
Specific Conductance	uS/cm	$\leq \pm 10\%$	$> \pm 10\%$ and $\leq \pm 20\%$	$> \pm 20\%$
Water Temperature	°C	$\leq \pm 0.2$	$> \pm 0.2$ and $\leq \pm 0.8$	$> \pm 0.8$

Criteria expressed as a percentage of readings; for example, buffer = 100.2 uS/cm and Hydrolab = 98.7 uS/cm; $(100.2-98.7)/100.2 = 1.49\%$ variation, which would fall into the acceptable data criteria of less than 5%.

Discrete field meter measurements

Discrete field meter measurements met post-check MQOs throughout the study with the following exception: temperature on December 12, 2017 did not pass the post-check MQO, but was within qualifying criteria. Data collected that day from five ambient sites were flagged as 'J' for estimate before being entered into EIM.

Continuous multi-parameter sondes

All sondes were calibrated before deployment and calibrations were post-checked upon retrieval. In situ measurements were taken with a field check sonde for temperature, pH and dissolved oxygen at time of deployment and retrieval. Of the five sondes deployed, all passed MQOs with the exception of pH at NN00.3. These data were rejected and not loaded into EIM. Dissolved oxygen data from a second site, MN00.1, was qualified as estimate due to sensor drift during deployment.

Continuous Temperature

In situ temperature measurements were collected monthly at ambient sites during sampling events using a sonde checked against a NIST-certified thermometer. Over the period of the water year, 148 measurements were recorded. These values were then compared against continuous temperature records at five sites. All sites passed MQOs.

Field Duplicates

Over the course of the project, eleven field duplicate measurements were collected in situ with the same field check sonde. These measurements were collected at the same time as our replicate laboratory samples. All sonde measurements met MQOs listed in Table B2.

Table B2. Field duplicate MQOs

Parameter	Precision-Field Duplicates (median)	Actual Field Duplicates (median)	Meets MQO Criteria
Water Temperature	±0.2 °C	0.2 °C	Yes
Conductivity/ Specific Conductance	5% RSD	0 % RSD	Yes
Dissolved Oxygen	5 % RSD	0.64 % RSD	Yes
pH	± 0.2 s.u.	0.03 s.u.	Yes
Turbidity	15% RSD	5.66% RSD	Yes

* QA analysis completed by Niamh O'Rourke

Table B3. General chemistry MQOs

Analysis	Precision-Field Duplicates (median)	Actual Field Duplicates (median) ^a	Meets MQO Criteria
Dissolved Oxygen - Winkler	± 0.2 mg/L	± 0.2 mg/L	Yes
Fecal coliform - MF	50% of replicate pairs < 20% RSD	45% of replicate pairs <20% RSD	No
	90% of replicate pairs <50% RSD ^b	91% of replicate pairs <50% RSD	Yes
E. coli - MPN or MF	50% of replicate pairs < 20% RSD	27% of replicate pairs <20% RSD	No
	90% of replicate pairs <50% RSD ^b	91% of replicate pairs <50% RSD	Yes

^a Field duplicate results with a mean of less than or equal to 5x the reporting limit are included

* QA analysis completed by Niamh O'Rourke