Big Creek and Sunset Bay Bacteria Investigation

Gregory Silver, Thomas Lossen, Shane Bennett, and Michael Mulvey

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State of Oregon
Department of
Environmental
Quality

Laboratory and Environmental Assessment Division
7202 NE Evergreen Parkway, Suite 150
Hillsboro, OR 97124
Phone: 503-693-5700
800-452-4011
Fax: 503-229-6762
Contact: Thomas Lossen
www.oregon.gov/DEQ

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This report prepared by:

Oregon Department of Environmental Quality
Laboratory and Environmental Assessment Division
7202 NE Evergreen Parkway, Suite 150
Hillsboro, OR 97124
1-800-452-4011
www.oregon.gov/deq

Contact:
Thomas Lossen
503-693-5729

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1. Executive Summary

Since 2002, the Oregon Department of Environmental Quality has monitored the fecal bacteria during summer months of Sunset Bay in Oregon's Coos County. Over the nearly two decades of data collection, the fecal bacteria in Sunset Bay frequently exceeded levels safe for contact recreation. Our monitoring during the fall of 2018 indicates that the bacteria come from fresh water streams entering Sunset Bay. Sunset Bay and some tributary streams are now listed as not meeting water quality standards in DEQ's Integrated Report as required by Section 303d of the Clean Water Act. The results of this investigation will guide future efforts to decrease fecal bacteria contamination in Sunset Bay and improve swimmer safety.

2. Introduction

2.1. Background

The Oregon Beach Monitoring Program (OBMP), a partnership between the Oregon Department of Environmental Quality (DEQ) and the Oregon Health Authority (OHA), has monitored recreational water quality at Oregon's coastal beaches since 2002. Annual grants from the U.S. Environmental Protection Agency funds the OBMP (USEPA, 2000). The primary goal of the program is to protect public health by monitoring fecal bacteria contamination in marine and freshwater at Oregon's coastal beaches.

The OBMP routinely monitors coastal beaches for the fecal indicator bacteria (FIB) *Enterococcus sp.* between Memorial Day and Labor Day each year. Concentrations of FIB provide an estimate of possible contamination from disease-causing bacteria, viruses, and protozoans in sampled water bodies (NRC 2004), and are useful predictors of the potential for human illness to result from exposure to contaminated waters. *Enterococcus sp.* have been shown to be good predictors of gastrointestinal illness (GI) in both fresh and marine waters, while *E. coli* is a good predictor of GI in freshwater, according to epidemiological studies conducted by the EPA (USEPA 2012).

In addition to annual routine monitoring of beaches, the OBMP may also conduct focused investigations as needs arise and resources allow in order to better understand the sources of FIB contamination at beaches. Investigative sampling is generally conducted in autumn after the routine sampling season has concluded. Over the course of Oregon's dry summers, bacteria can accumulate in areas such as tributary watersheds and city drainage systems (DEQ 2012; DEQ12-LAB-0036-SAP). The onset of autumn precipitation washes these contaminated waters downstream, providing potential clues as to the source, type, and location of FIB. Thus, synchronizing investigative sampling with first flush autumn precipitation may aid in identifying potential sources of FIB contamination.

In the fall of 2018, DEQ conducted additional sampling to better understand the sources of bacterial contamination in and around Sunset Bay State Park in Coos County. The beach at Sunset Bay State Park is both a popular recreation site and an area where high FIB counts (and water contact advisories) have repeatedly occurred since routine monitoring began in 2002. Exceedances of *Enterococcus sp.* in marine waters of Sunset Bay have typically corresponded to high *Enterococcus sp.* counts in Big Creek, the main tributary input to Sunset Bay. These results indicate that Big Creek is the likely source of marine water contamination

in Sunset Bay. DEQ conducted investigative sampling of both Sunset Bay marine waters, and Big Creek and its tributaries during October and November 2018, after the routine summer monitoring season.

Because of the high *Enterococcus sp*. levels, DEQ listed the marine water of Sunset Bay as a water quality limited waterbody for fecal bacteria in the 2012 Water Quality Assessment (DEQ 2012).

In 2007, scientists from the South Slough National Estuarine Research Reserve in Charleston, Oregon conducted a similar investigative study of fecal bacteria contamination at Sunset Bay and Big Creek (Rumrill and Grupe. 2008). They performed a detailed assessment of *Enterococcus sp.* FIB found elevated levels of *Enterococcus sp.* at numerous locations in marine waters of Sunset Bay and freshwater in Big Creek. The authors of the report concluded that elevated FIB counts in Sunset Bay marine waters were terrestrial in origin and delivered to Sunset Bay by Big Creek (Rumrill and Grupe. 2008). The 2007 investigation found the highest *Enterococcus sp.* concentrations during early rainfall events. No regulatory action of bacterial loading in Big Creek by DEQ or other agencies occurred following publication of the 2007 study because *Enterococcus sp.* was not the appropriate FIB for freshwater streams in Oregon.

The current sampling investigation described in this report is a follow-up to the 2007 assessment. The purposes of this investigation are to better understand FIB source location(s) contributing to impaired water quality in Big Creek and Sunset Bay and to provide data needed for determining whether Big Creek watershed warrants listing on the Oregon Integrated Report of impaired waterways as required by Section 303d of the Clean Water Act. Oregon's water quality standards for bacteria uses *Enterococcus sp.* in coastal (marine) water and *Escherichia coli* (*E. coli*) in freshwater as fecal bacteria indicators (OAR 340-041-0009). We assessed both bacteria indicators at four marine locations in Sunset Bay, six freshwater sites in the Big Creek watershed, and two intermittent fresh water drainage ditches flowing directly into Sunset Bay in five monitoring events in October and November of 2018. This sampling period coincided with the seasonal change in coastal Oregon weather from dry to rainy weather and thus captured the autumn first flush rain events.

Sunset Bay has ranked as a high priority beach for monitoring by the OBMP because of both its popularity for contact recreation and persistently high fecal bacteria contamination.

2.2. Study Area

Sunset Bay is a semi-enclosed bay southwest of Coos Bay/North Bend in Coos County, Oregon (Figure 1). The Coos Bay/North Bend metropolitan area is the most populated area on the Oregon Coast. The bay has a narrow outlet to the Pacific Ocean through rocky headlands, making it both scenic and popular for swimming, kayaking, stand-up paddling, as well as beachcombing and other sightseeing activities. The bay is located within Sunset Bay State Park, which includes popular day use sandy beach, and hiking trails along rocky cliffs and headlands. A large, year-round campground, located across Cape Arago Highway from the beach/day use area, is also part of the Sunset Bay State Park complex. Annual day use of the state park is nearly 1.4 million people, with annual overnight camper use at nearly 76,000 people (Oregon State Parks. 2019). Many visitors to the area pass through Sunset Bay State Park on the way to visit the adjacent Shoreline and Cape Arago State Parks.

Sunset Bay has one perennial and two intermittent freshwater tributaries. Big Creek is a perennial stream that originates in forested coastal mountains and is the primary freshwater input to Sunset Bay. The creek drains a watershed area of approximately 3600 acres. Big Creek flows through mixed land use that includes forest in the upper portion of the drainage, low-gradient fallow pasture and wetlands in middle portion of the drainage, and a public golf course and state park in the lower portion of the drainage. In 2018, DEQ staff observed one horse as the single domesticated livestock grazing in the fallow pasture between the golf course and the forest, although elk heavily used this area. The state park has campground has 65 recreational vehicle sites, 67 tent sites, and 8 yurts. The state park has four restroom facilities, and a day use area around Sunset Bay beach with three parking areas and two additional restroom facilities. Freshwater also enters Sunset Bay from two small drainage ditches that run through the parking lots of the day use area. The ditches are ephemeral and generally contain flowing water only after heavy rainfall.

Roads in the watershed are few and unimproved along Big Creek upstream of the golf course. Except for a single home at the golf course, residential land use in the basin is mostly along Seven Devils Road near the watershed divide. These homes likely use an on-site septic system, as they are not located within the local Charleston Sanitation District service area (Scott Perkins, personal communication, February 6, 2020).

3. Methods

3.1. Sites Selection

We chose sampling locations to better understand potential sources of bacteria to Big Creek and Sunset Bay. Table 1 has site descriptions and Figures 1 and 2 are maps of the sampling sites. Most of the site locations were the same as those sampled by Rumrill and Grupe in 2007 (Rumrill and Grupe. 2008). Two of the sites in the 2007 study, were located on private land that we could not obtain permission to access (the red sites in Figure 1). Sites within the Big Creek drainage were located upstream and downstream of possible sources of fecal bacteria including a meadow heavily used by elk, the Sunset Bay Golf Course, campground, and park day use area.

Four sites were located in forested land and fallow pasture above Sunset Bay Golf Course. A new site, 40608, was located on a small unnamed tributary to Big Creek that is downstream of a residence on Seven Devils Road and site 40563 was located below the confluence of this tributary and about 700 m upstream of the golf course in an area heavily used by elk. Site 40566 was within Sunset Bay Golf Course. Two sites, 30921 and 30447, were within Sunset Bay State Park campground (Figure 2). The lower most site in Big Creek (Site 31450) was located near the confluence of the creek and the ocean, in a day use area downstream of the campground. Two sample sites were located in small ephemeral drainage ditches (one site each in ‘Seep Creek’ Site 30933 and ‘North Parking Lot Creek’ Site 30934) that intermittently flow through the day use area parking areas into Sunset Bay. Four sample sites

were delineated in marine waters of Sunset Bay, starting at the confluence of Big Creek, and moving northward around the shore of Sunset Bay.

See Table 1 for a brief description of the sampling sites and Appendix A for detailed site descriptions, photographs, and geographic coordinates of the sample locations.

3.2. Field Methods

3.2.1. Bacteria Sample Collection and Quantification

Five weekly sampling events were conducted during October and November 2018 with two consecutive sample days were per week, resulting in a minimum of 10 sample visits at each site. Water samples were collected from marine and freshwater sites in Whirl-paks® (Nasco Sampling/Whirl-Pak, Madison, Wisconsin). Samples were stored on wet ice and analyzed in DEQ's mobile bacteria laboratory within 8 hours of collection following the DEQ Water Quality Monitoring Mode of Operations Manual Vol. 4 Field Analytical Methods (DEQ 2016) using Enterolert ® and Colilert ® methods (IDEXX Laboratories, Inc., Westbrook, ME) for *Enterococcus sp.* and *E. coli*, respectively. Results from these methods are quantified using a probability table and are reported as a most probable number (MPN) of bacteria per 100 milliliters of sample water.

Total coliforms are a group of bacteria that include bacteria of both fecal and non-fecal origin. If total coliform bacteria are detected, but no *E. coli* or *Enterococcus sp.*, it is likely that sources from soil or vegetation are present, or it may provide a warning that more serious contamination could follow, especially after heavy rain.

3.2.2. Water Quality Measurements

At freshwater sample sites, water temperature, specific conductivity, and salinity were measured, while at marine sample sites, water temperature and salinity were measured. All parameters were quantified using an YSI EcoSense EC300A® conductivity meter (YSI, Yellow Springs, OH). Meter calibration verification was conducted twice daily (at the lab or in the field) with high and low salinity standards. Stream flow in Big Creek was measured once per day using a Marsh-McBirney Flo-Mate Model 2000 flow meter and top-setting rod at a transect located approximately 100 m upstream of the creek mouth. All field analysis followed the DEQ Water Quality Monitoring Mode of Operations Manual Vol. 4, Field Analytical Methods (DEQ 2016).

Table 1. Summary of monitoring sites with descriptions and land use, from upstream to downstream. The two most upstream sites, East and West Fork Big Creek, could not be sampled because of lack of access. Figure 1 is a map of the sites.

Station ID	Site Name	Ownership/ Land Use	Media	Site Description
40564	West Fork Big Creek 4350 m upstream, forest	Private Forest/timber	Fresh	Upstream tributary to Big Creek. Unable to sample in 2018 because of no landowner access permission.
40565	East Fork Big Creek 4070 m upstream, forest	Private Forest/timber	Fresh	Upstream tributary to Big Creek. Unable to sample in 2018 because of no landowner access permission.
40608	Unnamed Tributary to Big Creek	Private Forest/timber	Fresh	Small tributary impounded by beaver dam below the sample site. Flow diverts around dam during rain events. Residential land use at the higher part of the tributary basin.
40563	Big Creek 3000 m Upstream Between Golf Course and Forest	Private Forest/Pasture	Fresh	Incised, low gradient reach in broad valley wetland and fallow pasture. This area is heavily used by elk. Below unnamed tributary confluence and above golf course.
40566	Big Creek in Sunset Bay Golf Course, 1480 m Upstream	Private Golf Course	Fresh	Incised, low-gradient reach between two fairways within Sunset Bay Golf Course.
31447	Big Creek at site D21 in Campground	Public Campground	Fresh	Rocky, riffle with measurable stream flow at upstream end of Sunset Bay Campground (Figure 2)
30921	Big Creek at Sunset Bay SP, Site B9 in Campground	Public Campground	Fresh	Low velocity, low gradient reach in middle of Sunset Bay Campground (Figure 2)
31450	Big Creek at Sunset Bay SP Footbridge	Public Day Use Park	Fresh	Low velocity, low gradient reach downstream of campground and approximately 150 m above the confluence of the creek and ocean.
29315	Sunset Bay SP Beach at the Mouth of Big Creek	Public Day Use Park	Marine	Confluence of Big Creek and Pacific Ocean, exact location can vary by 50-100 m depending on tidal stage.
40562	Sunset Bay SP Beach at South End Near Mouth of Big Creek	Public Day Use Park	Marine	Surf zone at south end of Sunset Bay about 75 m NE of Big Creek mouth.
29316	Sunset Bay SP Beach at restroom	Public Day Use Park	Marine	Surf zone in middle of Sunset Bay about 200 m North of Big Creek mouth.
29317	Sunset Bay SP Beach at North Beach Access	Public Day Use Park	Marine	Surf zone at north end of bay about 350 m North of from Big Creek mouth.
30933	Sunset Bay SP, Seep Creek	Public Day Use Park	Fresh	Ephemeral ditch that drains day use parking lot and flows through dune via excavated channel. Non-flowing water except during heavy rain.
30934	Sunset Bay SP, North Parking Lot Creek	Public Day Use Park	Fresh	Ephemeral creek that drains northern day use parking lot. Non-flowing except during heavy rain.

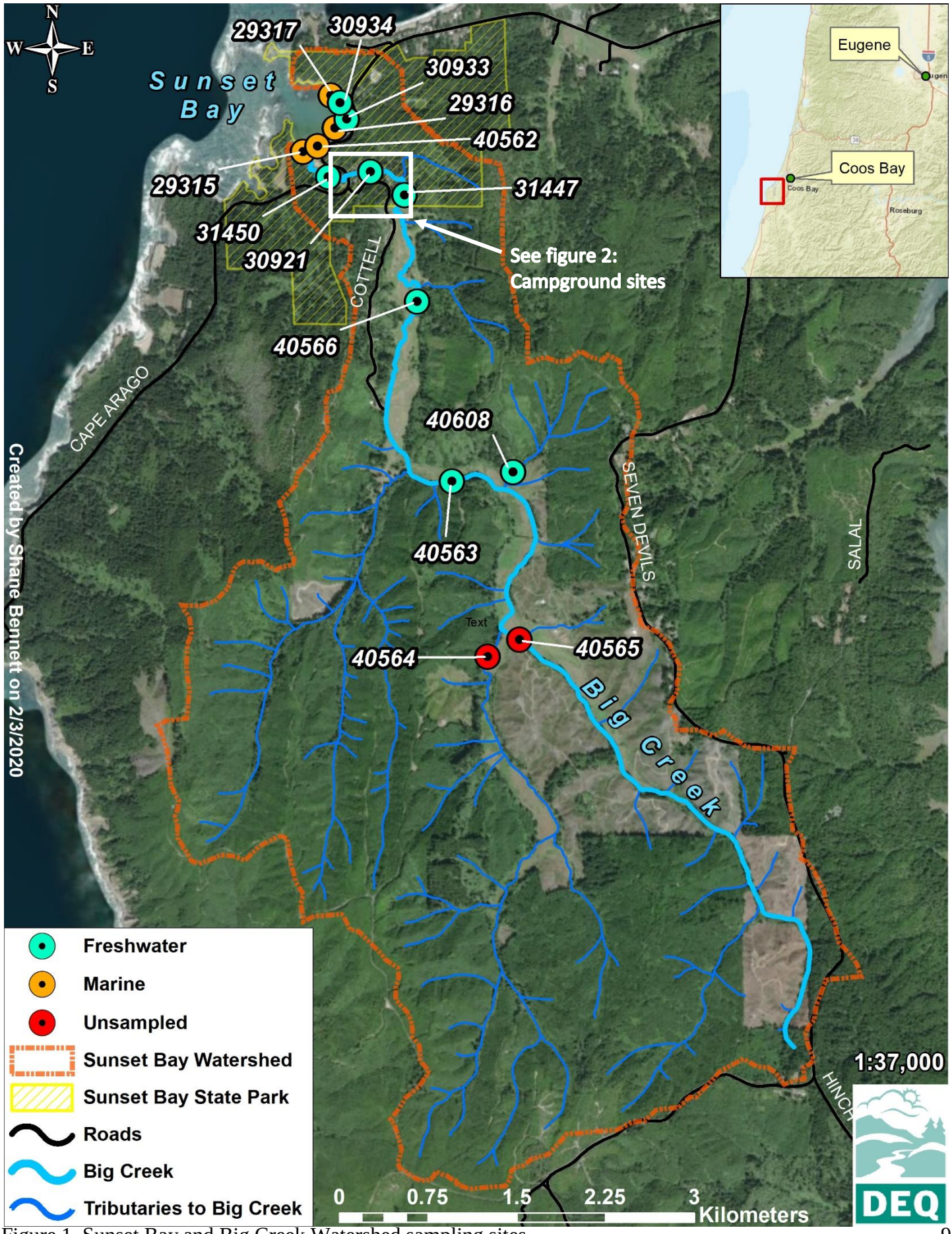


Figure 1. Sunset Bay and Big Creek Watershed sampling sites.

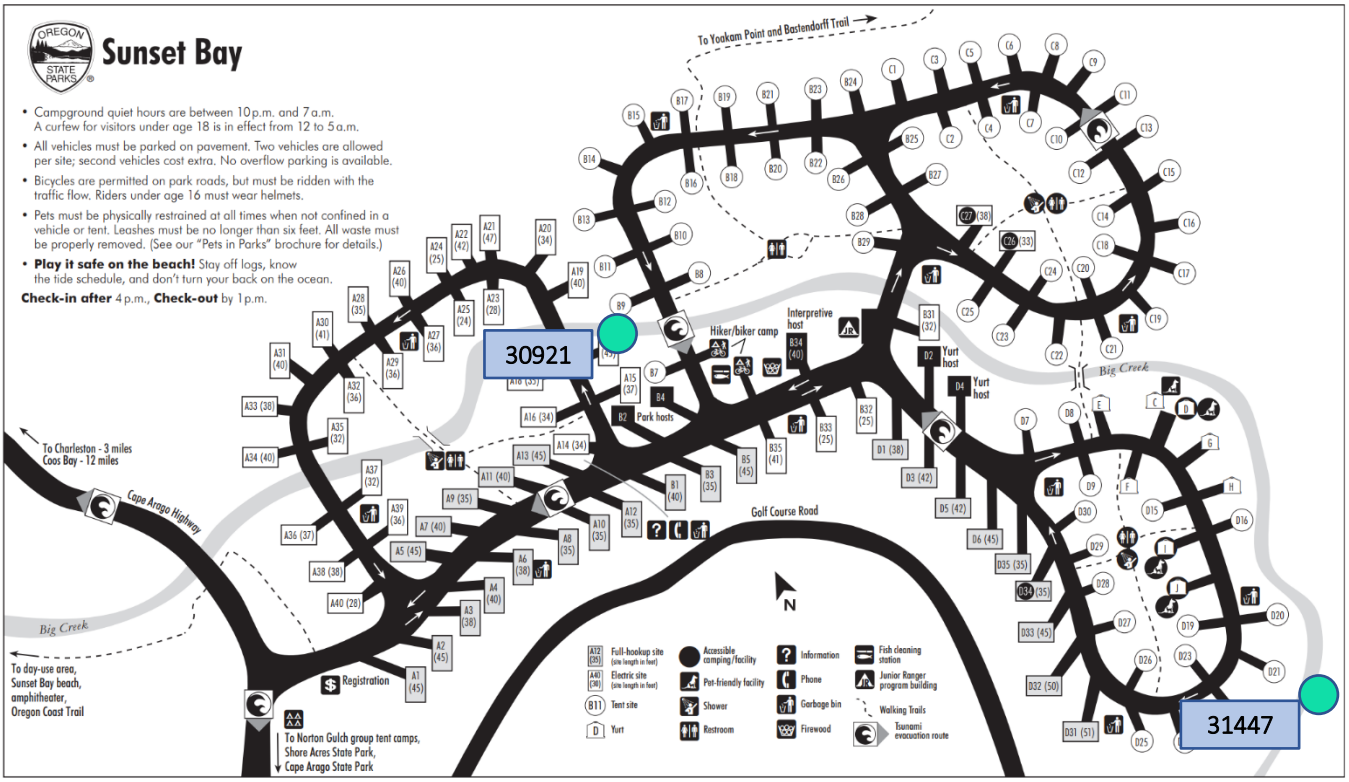


Figure 2. Sunset Bay State Park Campground and sampling sites 30921 and 31447 (Oregon State parks).

Table 2. Summary of water sample collection and handling field methods.

Media	Analytical Parameters	Sample Type	Container	Preservation	Holding Time	Method Reporting Limit	Reference Method
Marine Water	Total coliforms	Grab	Whirl-Pak ®	Wet ice	8 h	10 MPN/100 ml	1
Marine Water	*E. coli*	Grab	Whirl-Pak ®	Wet ice	8 h	10 MPN/100 ml	1
Marine Water	*Enterococcus sp.*	Grab	Whirl-Pak ®	Wet Ice	8 h	10 MPN/100 ml	1
Marine Water	Salinity, Temperature	Grab	Whirl-Pak ®	None	None	0.1 parts per thousand,	1
Fresh Water (creek)	*Enterococcus sp.*	Grab	Whirl-Pak ®	Wet ice	8 h	10 MPN/100 ml	1
Fresh Water (creek)	*E. coli*	Grab	Whirl-Pak ®	Wet ice	8 h	10 MPN/100 ml	1
Fresh Water (creek)	Total coliforms	Grab	Whirl-Pak ®	Wet ice	8 h	10 MPN/100 ml	1
Fresh Water (creek)	Specific Conductivity, Temperature	Grab	Whirl-Pak ®	None	None	1 µS/cm	1
Fresh water (creek)	Stream flow	Grab	None	None	None	0.01 cfs	1

1. *DEQ. 2016. Water Quality Monitoring Mode of Operations Manual, Volume 4: Field Analysis Methods.* DEQ03-LAB-0036-SOP. Oregon Department of Environmental Quality, Laboratory and Environmental Assessment Division.

3.3. Quantitative Methods

Ninety-day geometric mean for bacteria results were calculated following guidance by the EPA's Recreational Water Quality Criteria document (USEPA 2012). Results were evaluated using Oregon's water quality for water contact recreational in Table 3 (OAR 340-041-0009). One half the method reporting limit, or 5 MPN /100 mL, was used in calculations and graphs for non-detect results less than the method reporting limit of 10 MPN/100 mL. This analysis followed the approach ODEQ uses in Clean Water Act Integrated Report for analysis using non-detect data (Anthony 2019).

In addition to the geometric mean, a second metric used by ODEQ to evaluate water quality is the Statistical Threshold Value (STV) for *Enterococcus*. In this case, no more than 10% of samples may be above the STV value. This metric is in addition to the geometric mean criteria and either can be used to list a water body as impaired (OAR 340-041-0009).

3.3.1. Bacteria Loading

Load is the total amount of something (i.e.: bacteria, nutrients, pollutants) passing a particular point in a stream or river in a specified amount of time. Loading is the product of concentration and stream flow. Stream flow was measured near the mouth of Big Creek at most sampling events. Loading rates are provided in Appendix B. Determining the load of bacteria to Sunset Bay during rainy weather may be more useful for future water quality improvement plans than just the concentration of bacteria alone (USEPA 2019).

Table 3. Oregon recreational water quality criteria (Oregon Administrative Rules 340-041-0009).

Water Quality Criteria for Bacteria in Marine Recreational Water		
	90-Day Geometric Mean	Statistical Threshold Value (10% or less of samples)
Enterococcus sp. Criteria	**35 *Enterococcus* per 100 ml**	**130 *Enterococcus* per 100 ml**
Water Quality Criteria for Bacteria in Fresh Recreational Waters		
	90-Day Geometric Mean	Single Sample Maximum
E. coli Criteria	**126 *E. coli* per 100 ml**	**406 *E. coli* per 100 ml**

4. Results

4.1. Bacteria Results

Eleven sets of samples at all sites and two partial sets of samples were collected between October 2, 2018 and December 4, 2018. Bacteria results are summarized in Table 4. Figures 3, 4, 5, and 6 are maps displaying the location and bacteria results for each site. All sample results are plotted in Figures 7 and 8 and are available in Appendix B. Field duplicate quality assurance samples were collected at sites 29315 and 31450 during each visit, resulting in higher sample numbers for these sites. Site 30934, contained flowing water during only four of eleven visits. The highest bacteria result reportable with this method is 24,196 MPN/100 ml, and the lowest reportable value is 10 MPN/100 ml. For results greater than the method can report, 24,196 MPN/100 ml was used in calculations and graphing. For results less than 10 MPN/100 ml, half the reporting limit or 5 MPN/100 ml was used.

4.1.1. Big Creek

Of the six Big Creek watershed sites, the most upstream site, 40608 unnamed tributary, had the highest *E. coli* single sample, highest geometric mean, and the highest percent of samples exceeding the single sample criterion. The second highest single sample site was the most downstream site, 31450 Big Creek at the footbridge, also violated the geometric mean *E. coli* criterion. 40565 Big Creek upstream of the golf course, the second most upstream site in the basin, also exceeded both the single sample and geometric mean criteria. The *Enterococcus* sp. results for the six Big Creek sites follows a pattern similar to *E. coli* with the footbridge sites being the highest in bacteria.

4.1.2. Sunset Bay

Both *Enterococcus* sp. and *E. coli* results in four Sunset Bay sites followed the same pattern with the highest marine bacteria values at the mouth of Big Creek with decreasing bacteria values from south to north. Both the single sample and percent exceedance *Enterococcus* sp. criteria were exceeded at the 29315, Sunset Bay at the mouth of Big Creek, and 40562, Sunset Bay north of the mouth of Big Creek, while 29316, Sunset Bay near the restrooms, violated only the percent over 130 MPN/100 ml.

4.1.3. Sunset Bay Small Freshwater Tributary Sites

Two small, intermittent streams flow directly into Sunset Bay north of Big Creek. The northernmost Sunset Bay tributary site, 30934 Sunset Bay North Parking Lot Tributary, had the highest *Enterococcus* sp. and *E. coli* results of this study. This site was sampled only four times because did not contain water during all sampling evens.

4.1.4. Temporal and Spatial Trends in Bacteria

Figure 7 plots all bacteria results and geometric mean per site. The number of non-detect (<10 MPN/100ml) are shown as bars and are plotted as half the detection concentration of 5 MPN/100 ml. Site 30934, Sunset Bay at north parking lot, had the largest number of non-detects with 7 out of 11 samples with less than 10 MPN/100 ml.

Table 4. Summary of bacteria results. Sites are listed from upstream to downstream order and grouped by freshwater or marine water. Sites exceeding applicable water quality criteria are shown in **bold** font. *E.coli* criteria apply only in freshwater and *Enterococcus sp.* criteria apply only in marine water.

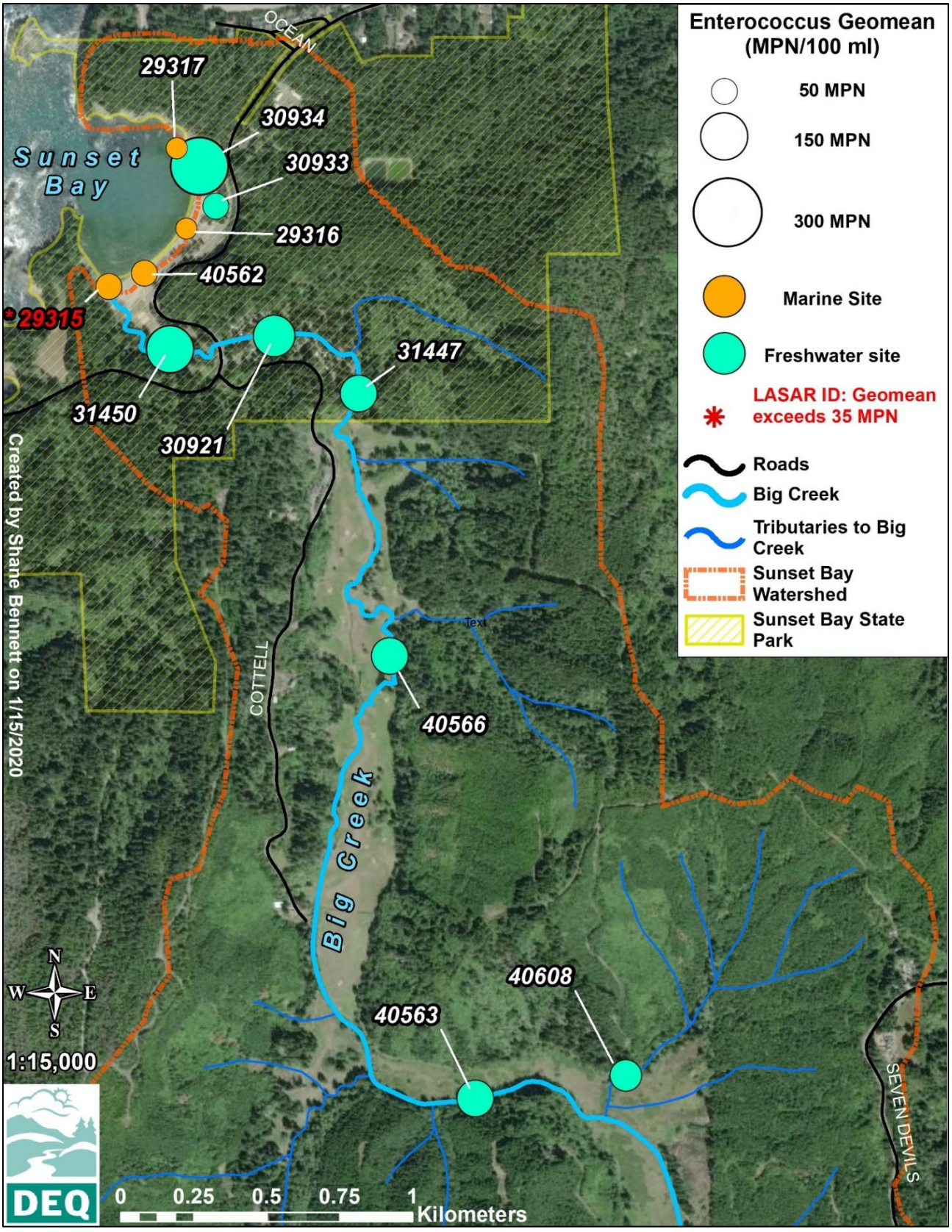
	Station ID	*Site Name*	*Enterococcus sp.*				*E. coli*			
			Total Samples	Single Sample Max (MPN/100 ml)	90-day Geomean (MPN/100 ml)	Percent Exceedance >130 MPN/100 ml	Total Samples	Single Sample Max (MPN/100 ml)	90-day Geomean (MPN/100 ml)	Percent Exceedance > 406 MPN/100 ml
		OAR Criteria:	N/A	N/A	35 MPN/100 ml	10% over 130 MPN/100 ml	N/A	406 MPN/100 ml	126 MPN/100 ml	N/A
UPSTREAM ↓ DOWNSTREAM	**Freshwater**	**Big Creek Sites**								
	40608	Unnamed tributary to Big Creek	11	933	78	27%	11	**2495**	**297**	27%
	40563	Big Creek 3000 m Upstream Between Golf Course and Forest	10	420	82	30%	10	**521**	**143**	20%
	40566	Big Creek in Sunset Bay Golf Course, 1480 m Upstream	11	315	95	45%	11	**441**	103	9%
	31447	Big Creek at site D21 in Campground	11	359	83	36%	11	**749**	64	9%
	30921	Big Creek at Sunset Bay State Park, Site B9 in Campground	11	315	104	45%	11	**504**	88	9%
	31450	Big Creek at Sunset Bay State Park footbridge	26	1374	125	46%	24	**1374**	**126**	17%
	Marine Water	**Sunset Bay Sites**								
	29315	Sunset Bay State Park Beach at the mouth of Big Creek	25	959	**39**	**24%**	22	384	71	0%
	40562	Sunset Bay State Park Beach at South End Near Mouth of Big Creek	11	399	**35**	**18%**	11	364	47	0%
	29316	Sunset Bay State Park Beach at restroom	12	134	15	**17%**	11	253	36	0%
	29317	Sunset Bay State Park Beach at North Beach Access	12	109	12	0%	11	158	34	0%
	Freshwater	**Sunset Bay Small Freshwater Tributary Sites**								
	30933	Sunset Bay State Park, Seep Creek	11	311	42	18%	11	228	34	0%
	30934	Sunset Bay State Park, North Parking Lot Creek	4	5172	187	50%	4	**8664**	**281**	50%

Increased concentrations of *Enterococcus sp.* and *E. coli* FIB in Big Creek appear to correlate with high rainfall events, although the bacteria data are sparse during the two dry periods of this investigation (Figure 8). Peaks in FIB counts in Big Creek typically followed periods of precipitation measured during the calendar day preceding sample collection. Rainfall data was retrieved from PRISM Climate Group and is binned to 24-hour days ending at 12pm on the date shown (PRISM 2019). Figure 8 depicts the geometric mean of all data collected on each sampling day over time in order to show the average response of FIB to rainfall on a watershed scale.

Figure 9 is a plot of the geometric mean of the Big Creek sites from most upstream on the left to the most downstream site on the right. The graph shows that fecal bacteria are highest at the most upstream site, decrease as Big Creek flows through the area upstream of the golf course and through the golf course, and then increases as it flows through the state park.

4.2. Water Quality Results

Table 5 summarizes the field water quality parameters collected at the same time as the bacteria samples. All results are presented in Appendix B. Over all, these water quality results are not particularly remarkable, although conductivity does appear to track with *E. coli*. Compare Figure 9 *E. coli* geometric means with average conductivities in Table 5. The highest conductivity fresh water site is also the site with the highest bacteria: 30934 Sunset Bay north parking lot creek. Conductivity in Big Creek basin sites is higher at 40608, the unnamed tributary, compared to the next downstream site (40563), as is *E. coli*. Both E. coli and conductivity increase as Big Creek flows through golf course and campground towards the footbridge site and the ocean.



.Figure 3. *Enterococcus sp*. geometric mean values (MPN/100 ml) with OAR's *Enterococcus sp.* exceedances in red.

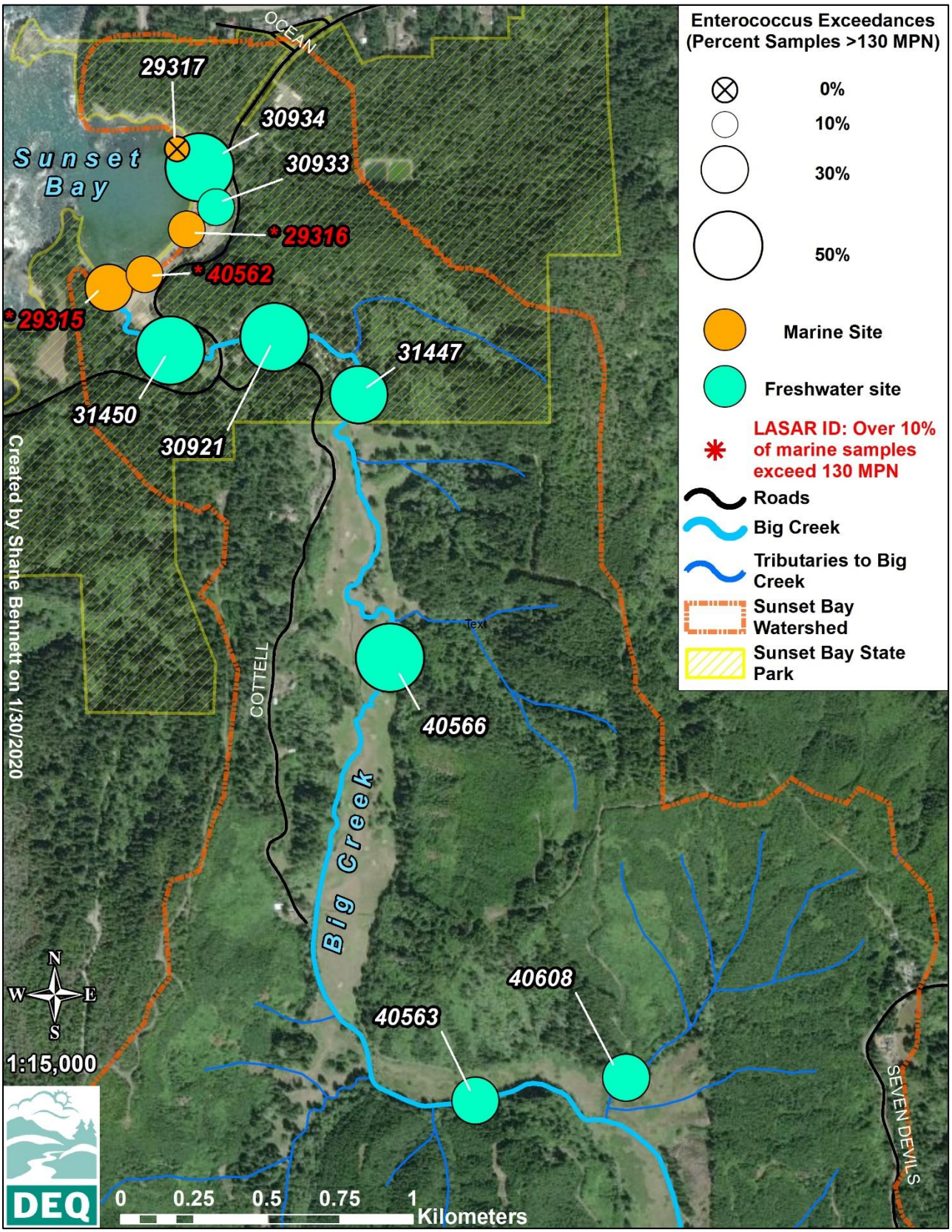
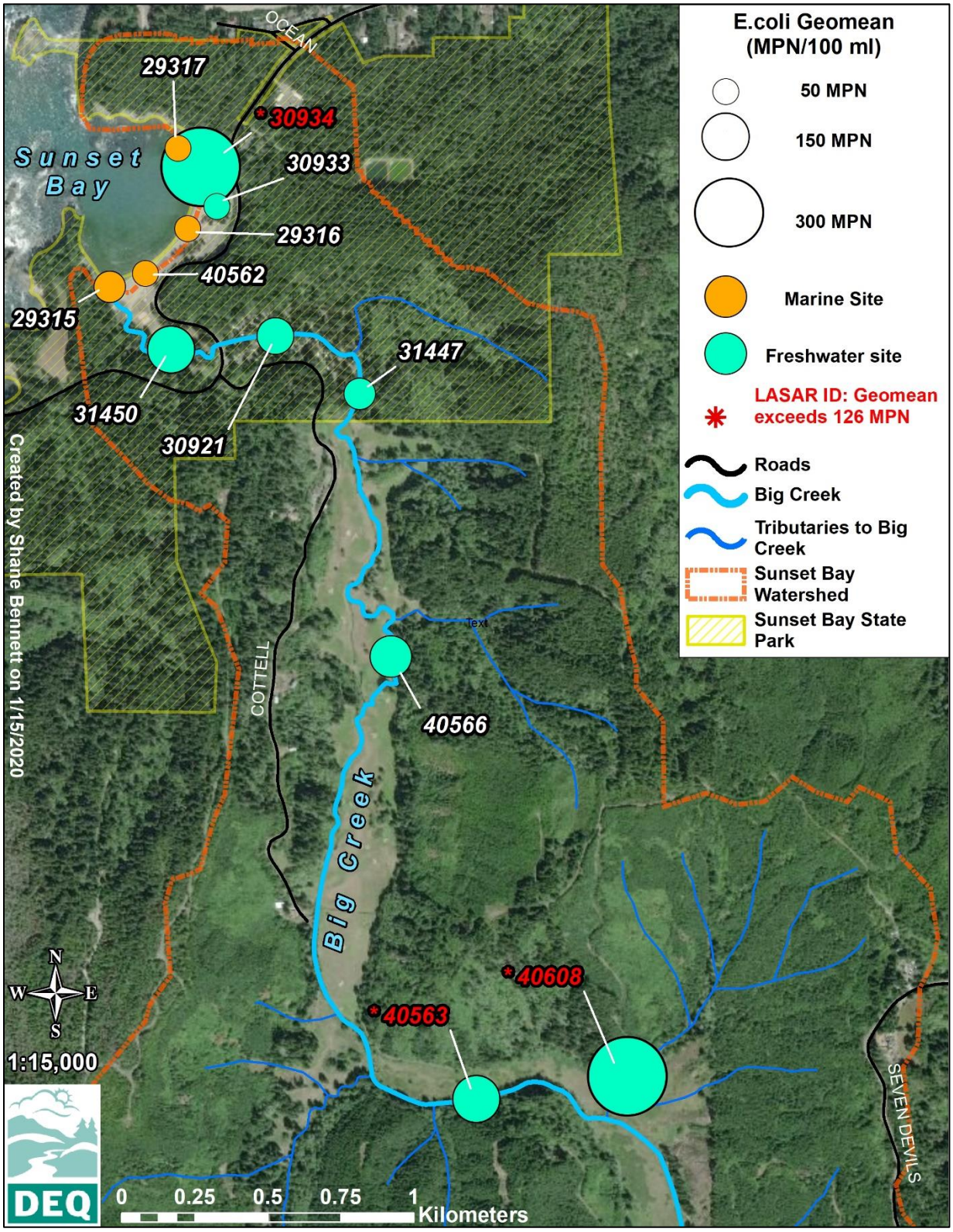


Figure 4. *Enterococcus sp.* exceedances of 130 MPN/100 ml, with exceedances of OAR's STV criteria in red.



.Figure 5. *E. coli.* geometric mean values (MPN/100 ml) with OAR's *E. coli.* exceedances in red

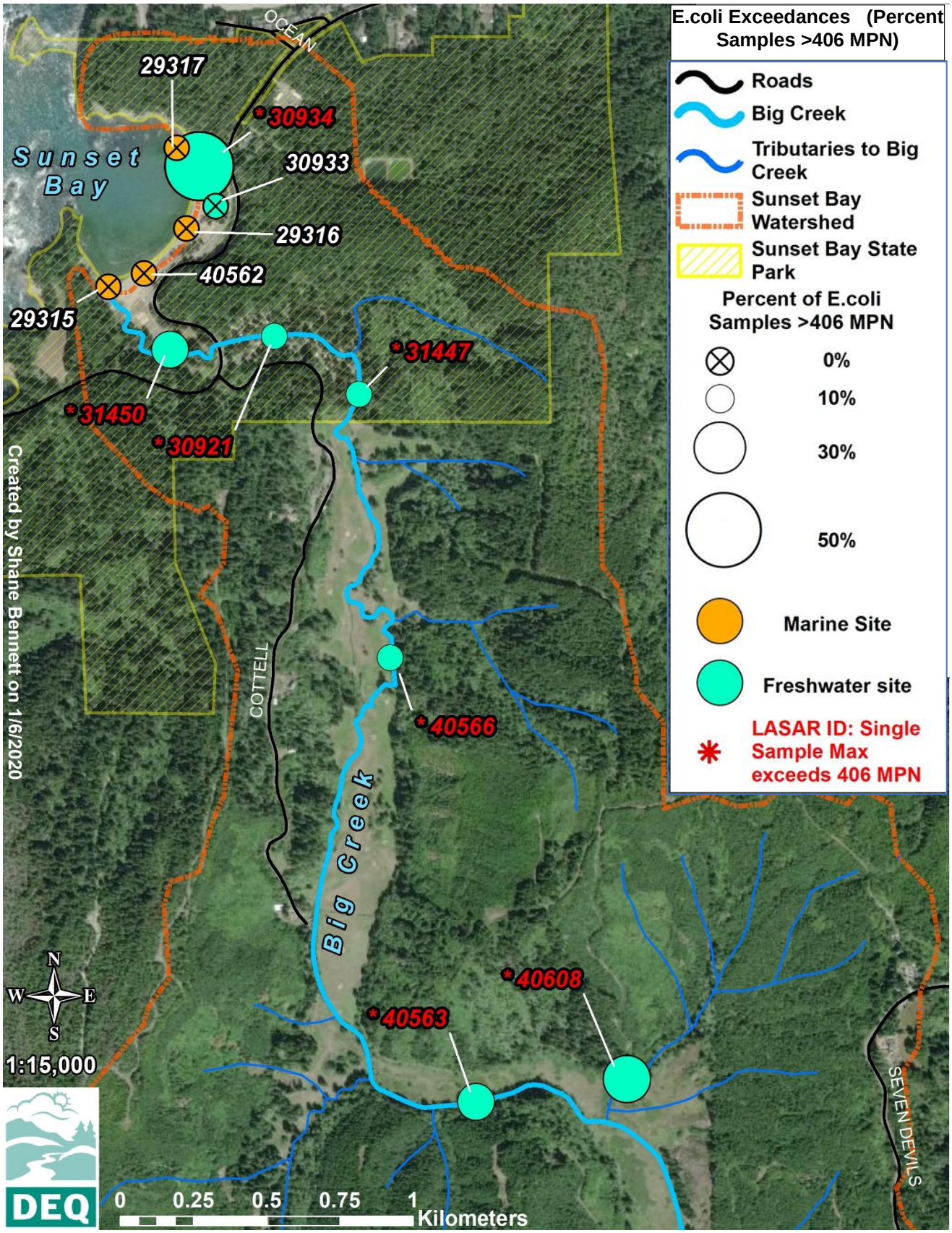


Figure 6 *E.coli* percent exceedances of 406 MPN/100 ml, with exceedances of OAR's freshwater single sample max criteria in red.

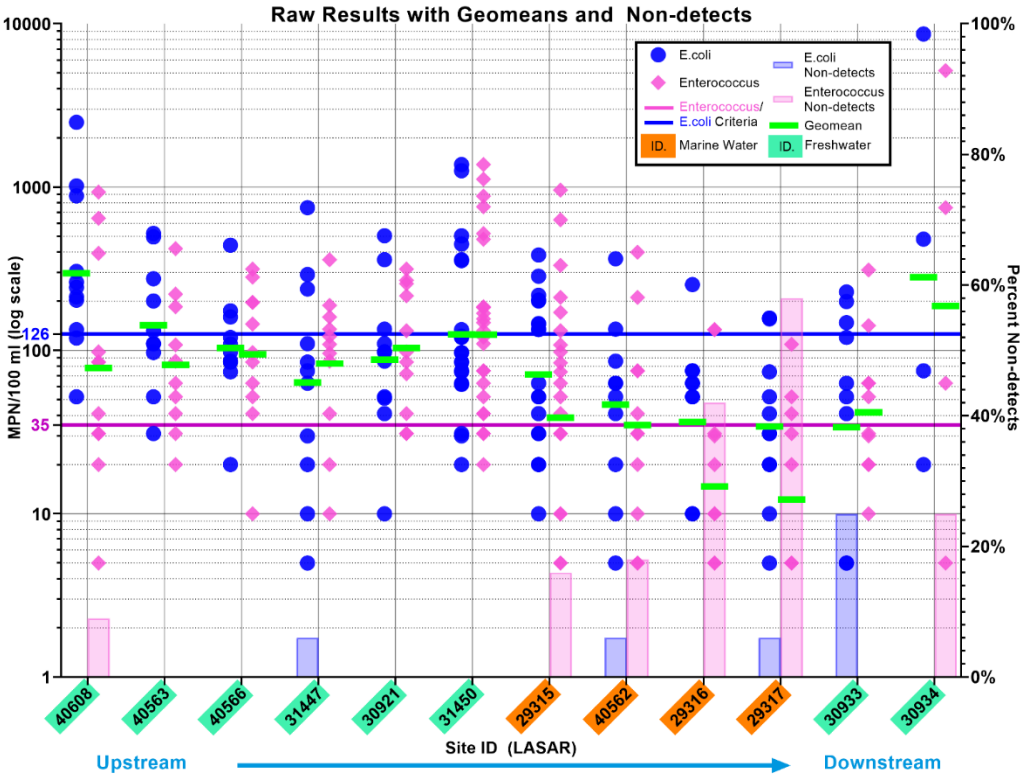


Figure 7. Results by Site ID with geometric mean values (green lines), OAR geometric mean criteria for *E.coli* and EPA/OAR geometric mean criteria for *Enterococcus sp.* shown as horizontal blue/pink lines, and percentage of nondetects as columns on right y-axis.

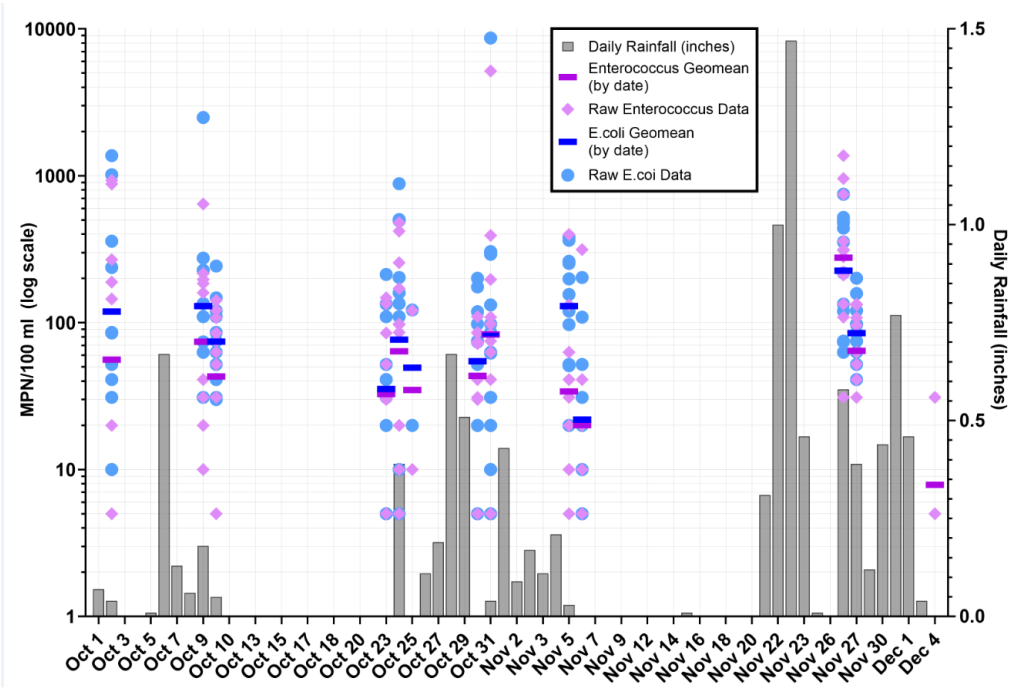


Figure 8. *E.coli* and *Enterococcus sp.* raw data grouped with the daily geometric means of all data per sampling day, and daily 24 hour rainfall (in inches) on right y-axis.

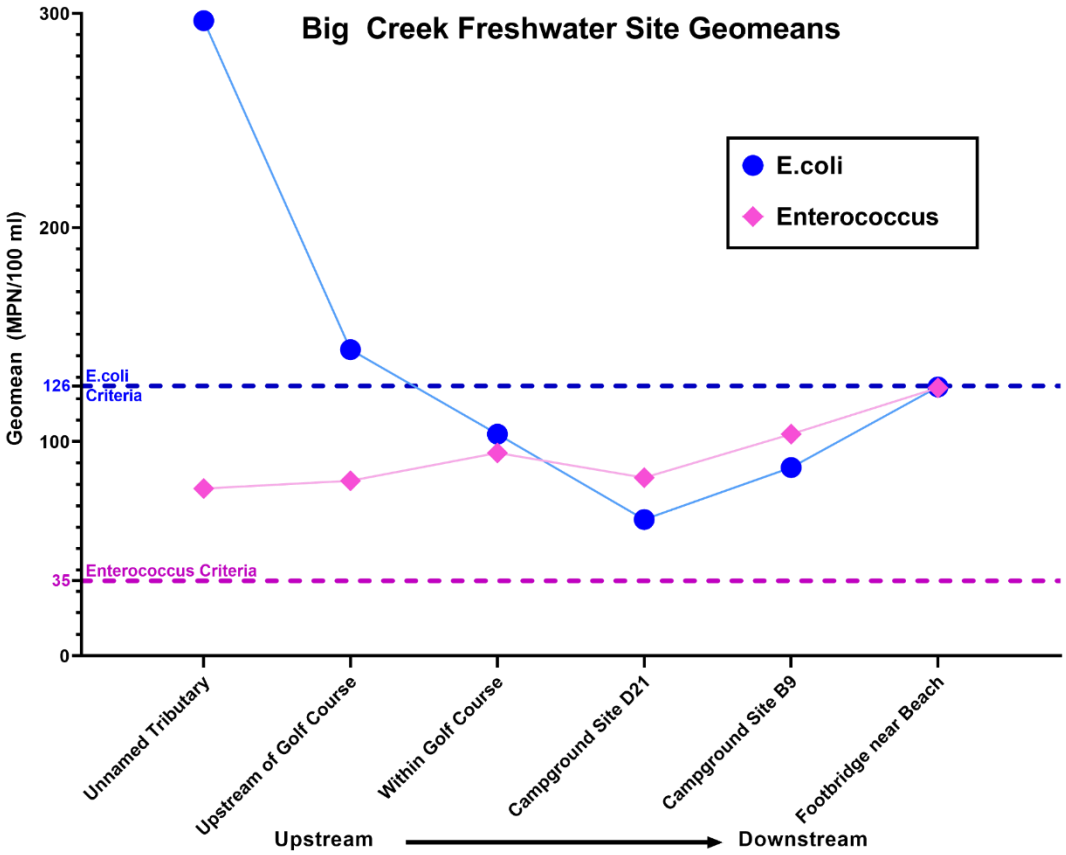


Figure 9. Upstream-to-downstream representation of Big Creek freshwater site geomeans with OAR's *E.coli* and EPA's *Enterococcus sp.* criteria for freshwaters.

4.1. Stream Flow Measurements and Bacteria Loading

Stream flow measurements were collected on eight occasions at Big Creek between mouth and the footbridge site. Discharge and bacteria concentration were used to calculate bacterial loading from big Creek to Sunset Bay (Table 8). These differences in stream flow track with rainfall events (Figure 8). The highest loading of total coliforms, *Enterococcus sp.* and *E. coli* from Big Creek to Sunset Bay occurred on November 27, the day with the highest measured stream flow following rainy weather.

Table 5. Temperature, specific conductivity, and salinity from freshwater and marine sample sites in Big Creek, Sunset Bay, and two small tributary streams. All data shown are arithmetic mean ± standard deviation.

Station ID	Site	Media	Temperature °C	Specific Conductivity (µS/cm)	Salinity (parts per thousand)
40608	Unnamed Tributary to Big Creek	Fresh	11.4 ± 1.2	175 ± 15	N/A
40563	Big Creek 3000 m Upstream Between Golf Course and Forest	Fresh	10.8 ± 1.2	163 ± 14	N/A
40566	Big Creek in Sunset Bay Golf Course, 1480 m Upstream	Fresh	11.7 ± 1.5	180 ± 12	N/A
31447	Big Creek at site D21 in Campground	Fresh	11.3 ± 1.4	183 ± 11	N/A
30921	Big Creek at Sunset Bay SP, Site B9 in Campground	Fresh	11.2 ± 1.4	186 ± 11	N/A
31450	Big Creek at Sunset Bay SP Footbridge	Fresh	11.3 ± 1.7	198 ± 16	N/A
29315	Sunset Bay SP Beach at the Mouth of Big Creek	Marine	12.5 ± 0.7	N/A	26.8 ± 7.8
40562	Sunset Bay SP Beach at South End Near Mouth of Big Creek	Marine	12.4 ± 1.1	N/A	30.5 ± 2.3
29316	Sunset Bay SP Beach at Restroom	Marine	12.2 ± 1.2	N/A	30.8 ± 1.9
29317	Sunset Bay SP Beach at North Beach Access	Marine	12.3 ± 1.3	N/A	31.3 ± 1.7
30933	Sunset Bay SP, Seep Creek	Fresh	12.1 ± 1.6	183 ± 23	N/A
30934	Sunset Bay SP, North Parking Lot Creek	Fresh	12.3 ± 1.9	227 ± 89	N/A

Table 6. Daily stream discharge in cubic feet per second and bacterial loading in MPN per hour calculated from flow measurements made in lower Big Creek.

Date	Discharge, River/Stream, cfs	Total Coliform Loading, MPN/hour	Enterococcus Loading, MPN/hour	E. coli Loading, MPN/hour
9-Oct	1.3	1.8E+09	2.4E+08	8.3E+07
10-Oct	0.8	1.0E+09	5.8E+07	9.3E+07
24-Oct	0.9	2.2E+10	4.4E+08	4.7E+08
30-Oct	1.3	5.5E+09	1.5E+08	9.9E+07
31-Oct	1.4	3.4E+09	5.8E+07	8.8E+07
7-Nov	1.9	2.9E+09	7.9E+07	6.0E+07
27-Nov	26.1	6.4E+11	3.7E+10	9.5E+09
28-Nov	16.5	6.1E+10	2.2E+09	2.0E+09

5. Conclusions

The purpose of this investigation was to locate sources of fecal bacteria in Sunset Bay that impair water quality for contact recreation, as well as determine if the fresh water tributaries to Sunset Bay should be listed as water quality limited in DEQ's Integrated Report under section 303d in the federal Clean Water Act. There are several possible sources including failed septic systems, leaky sewage pipes, poorly managed recreational vehicle waste water, livestock, dogs on the beach, and wildlife such as elk, deer, beavers, seagulls, and seals.

While we cannot definitively identify specific sources, this investigation suggests that the bacteria sources in Sunset Bay are likely terrestrial rather than marine, and that bacteria enter the bay primarily from Big Creek. Of the three marine sites, the site closest to the mouth of Big Creek had the highest fecal bacteria, with bacteria decreasing with increased distance from Big Creek. Although site 30934, the small tributary at the north end of Sunset Bay, had more 8,664 MPN E. coli per 100 ml on Oct. 31, 2018 the highest measured fecal bacteria of this investigation, this stream does not appear to be a significant source of bacteria to the bay because of its small size and intermittent flow. This small stream contained water during only four of the eleven sampling events in this investigation. The marine site closest to this tributary, 29317, had the overall lowest fecal indicator bacterial measured in this investigation. However, the public still could be at risk from directly contacting the freshwater stream on the beach when it is flowing since it did exceed the *E. coli* safe contact recreation standard of 406 MPN.

The highest bacteria measured in the Big Creek basin was at the most upstream site (40608). The drainage basin of this unnamed tributary contains residences on Seven Devils Road. We recommend that the function of the septic systems of these residences be investigated.

The streamside meadow area in the Big Creek basin upstream of the golf course is heavily used by elk. DEQ field crews observed abundant fresh elk droppings in this area. It also contains one horse, the only domestic livestock observed by the DEQ field crews. The geometric mean *E. coli* decline as Big Creek flows through the elk meadow, horse pasture, and golf course (Figure 9), indicating that these land uses are not likely significant sources of fecal bacteria in Big Creek.

However, this declining trend in *E. coli* reverses as Big Creek flows through the state park to Sunset Bay (Figure 9). This indicates possible bacteria sources within the state park campground and day use area. We recommend that factors within the campground that could contribute to fecal contamination of Big Creek also be investigated.

The source of the very high levels of fecal indicator bacteria in the small, intermittent stream at the north end of Sunset Bay (39034) should also be investigated.

Fecal indicator bacteria are present in the gut of warm blooded animals such as birds and mammals, including humans. Unfortunately, we were not able to use microbial source tracking methods which would have identified more specifically where the bacteria originated. We recommend a future follow up study to provide a more refined assessment of bacterial sources in Sunset Bay.

Our findings corroborate those of Rumrill and Grupe (2008) and are likewise supported by many years of OBMP data collected during the routine monitoring season.

This 2018 investigation of the bacteria of Sunset Bay and freshwater tributaries included both the freshwater and marine fecal indicator bacteria used in DEQ recreational water criteria. As a result, Big Creek as well as Sunset Bay are now listed as impaired waters in the DEQ Integrated Report under Section 303(d) of the Clean Water Act. This listing is the first step in addressing water quality issues in Big Creek and Sunset Bay and improving public safety.

6. References

Anthony, Becky. 2019. *Methodology for Oregon's 2018 Water Quality Report and List of Water Quality Limited Waters*. Oregon Department of Environmental Quality. September 2019.

Borok, Aron. 2016. *Issue Paper: Revisions to the Water Quality Standard for Bacteria.* Oregon Department of Environmental Quality. August 2016.

DEQ. 1995. *Final Issue Paper – Bacteria 1992-1994 Water Quality Standards Review.* Oregon Department of Environmental Quality. June 1995.

DEQ. 2006. *Oregon Coastal Beach Monitoring Quality Assurance Project Plan.* Hillsboro, OR: ODEQ, DEQ03-LAB-0042-QAPP.

DEQ. 2012. Water Quality Assessment – Oregon's 2012 Integrated Report Assessment Database and 303(d) List. https://www.deq.state.or.us/wq/assessment/rpt2012/search.asp. Web page accessed April 10, 202.

DEQ. 2012, October 11. *Beach Monitoring Investigative Sampling at Cannon and Tolovana Beaches.* Hillsboro, OR: ODEQ, DEQ12-LAB-0036-SAP.

DEQ. 2013. *Beach Monitoring Investigative Sampling at Cannon and Tolovana Beaches.* Hillsboro, OR.

DEQ. 2014. *Water Quality Monitoring Mode of Operations Manual Volume 3: Field Collection Methods.* Hillsboro, OR: DEQ03-LAB-0036-SOP_V3

DEQ. 2016. *Beach Monitoring Investigative Sampling at Rockaway and Twin Rocks Beaches*. Hillsboro, OR: ODEQ, DEQ16-LAB-0040-SAP

DEQ. 2016a. *Water Quality Monitoring Mode of Operations Manual Volume 4: Field Analysis Methods.* Hillsboro, OR: DEQ03-LAB-0036-SOP_V4.

Helsel, Dennis R. 2012. *Statistics for Censored Environmental Data Using Minitab® and R. Second Edition.* John Wiley & Sons, Inc., Hoboken, New Jersey, 2012. ISBN 978-0-470-47988-9.

IDEXX. 2013. *Enterolert*. Retrieved from IDEXX: http://www.idexx.com/view/xhtml/en_us/water/products/enterolert.jsf?conversationId=185704

NOAA, N. C. 2016. *Astoria, Oregon*. Retrieved from National Climate Data Center: http://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00094224/detail

NRC. 2004. *Indicators for Waterborne Pathogens*. National Research Council. The National Academies Press, Washington, DC.

OAR. 2016. *Water Quality Standards: Beneficial Uses, Policies, and Criteria for Oregon*. Division 41. 340-041-0009. https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=68695

ODHS. (2010). *Oregon Department of Human Services.* Retrieved from Oregon State Library: http://library.state.or.us/repository/2009/200909221537032/DHS_ph_beaches_docs_summer2010_beachevaluation_finaldraft.pdf

Oregon State Parks, 2020. *Sunset Bay State Park Campground Brochure*. Accessed 2020-01-22. https://oregonstateparks.org/index.cfm?do=main.loadFile&load=_siteFiles%2Fpublications%2Fsunset_bay_LOW_RES044722.pdf

PRISM. 2019. *PRISM Time Series Data – Daily Precipitation.* PRISM Climate Group, Oregon State University. Accessed 12/28/2019. http://prism.oregonstate.edu/

Rumrill, S. and B. Grupe. 2008. *Partnership for Monitoring and Assessment of NPS Bacterial Contamination of South Coast Beaches. Part B. Temporal and Spatial Patterns in the Delivery and Distribution of Fecal Indicator Bacteria Within Sunset Bay.* Final Report.

USEPA. 1986. *Ambient Water Quality Criteria for Bacteria - 1986.* Office of Water EPA440/5-84-002, Washington. Retrieved from United States Environmental Protection Agency: http://water.epa.gov/action/advisories/drinking/upload/2009_04_13_beaches_1986crit.pdf

USEPA. 2000, October 10. *Beaches Environmental Assessment and Coastal Health Act of 2000, H. R. 999, 106th Cong., 2nd Sess. (2000).* Retrieved from US Environmental Protection Ageny: http://water.epa.gov/lawsregs/lawsguidance/beachrules/act.cfm

USEPA. 2012. *Recreational Water Quality Criteria*. EPA 820-F-12-058. Office of Water, Washington, DC. https://www.epa.gov/sites/production/files/2015-10/documents/rwqc2012.pdf

USEPA. 2019. *Beacon 2.0 – Beach Advisory and Closing On-line Notification Reports.* United States Environmental Protection Agency. https://watersgeo.epa.gov/beacon2/reports.html

USEPA. n.d. *Questions and Answers*. Retrieved from United States Environmental Protection Agency: http://www.epa.gov/region1/eco/beaches/qa.html

USEPA. n.d. *Water: Monitoring & Assessment* . Retrieved from United States Environmental Protection Agency: http://water.epa.gov/type/rsl/monitoring/vms511.cfm

Oregon State Parks. 2019. Web site accessed May 15, 2019. Sunset Bay State Park annual use dat. https://oregonstateparks.org/index.cfm?do=parkPage.dsp_parkHistory&parkId=70.

Oregon State Parks. 2020. Sunset Bay State Park. Web page accessed April 6, 2020. https://oregonstateparks.org/index.cfm?do=parkPage.dsp_parkHistory&parkId=70

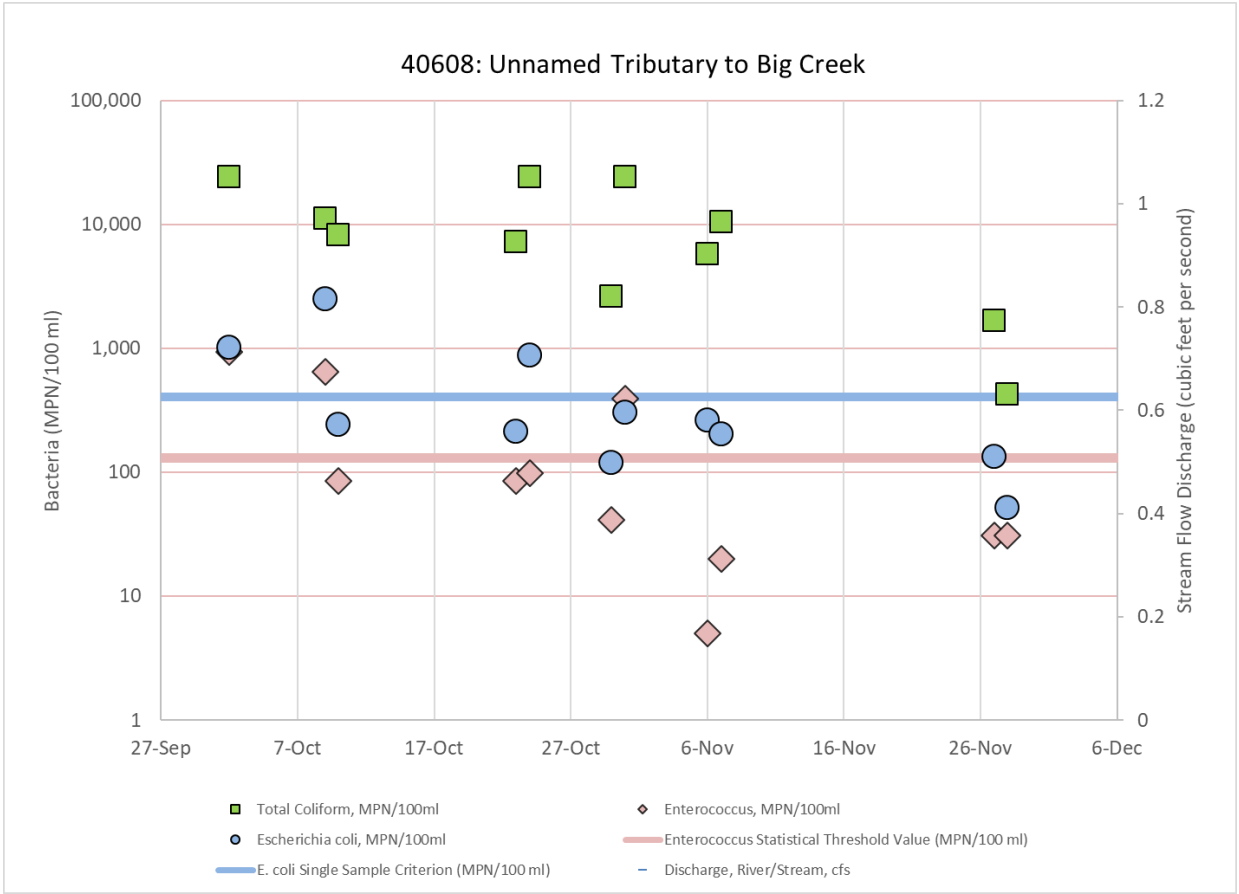
7. Appendix A

The following table lists the coordinates of the Sunset Bay Investigation sampling locations. Additionally, photos and site descriptions are included in the following pages.

Station ID	Site Name	Latitude	Longitude
40608	Unnamed Tributary to Big Creek	43.3146	-124.3591
40563	Big Creek 3000 m Upstream Between Golf Course and Forest	43.3141	-124.3638
40566	Big Creek in Sunset Bay Golf Course, 1480 m Upstream	43.3240	-124.3670
31447	Big Creek at Site D21 in Campground	43.3299	-124.3674
30921	Big Creek at Sunset Bay SP Site B9 in Campground	43.3312	-124.3701
31450	Big Creek at Sunset Bay SP Footbridge	43.3309	-124.3732
29315	Sunset Bay SP Beach at the Mouth of Big Creek	43.3323	-124.3751
40562	Sunset Bay SP Beach at South End Near Mouth of Big Creek	43.3326	-124.3751
29316	Sunset Bay SP Beach at Restroom	43.3336	-124.3727
29317	Sunset Bay SP Beach at North Beach Access	43.3354	-124.3726
30933	Sunset Bay SP, Seep Creek	43.3341	-124.3718
30934	Sunset Bay SP, North Parking Lot Creek	43.3350	-124.3723

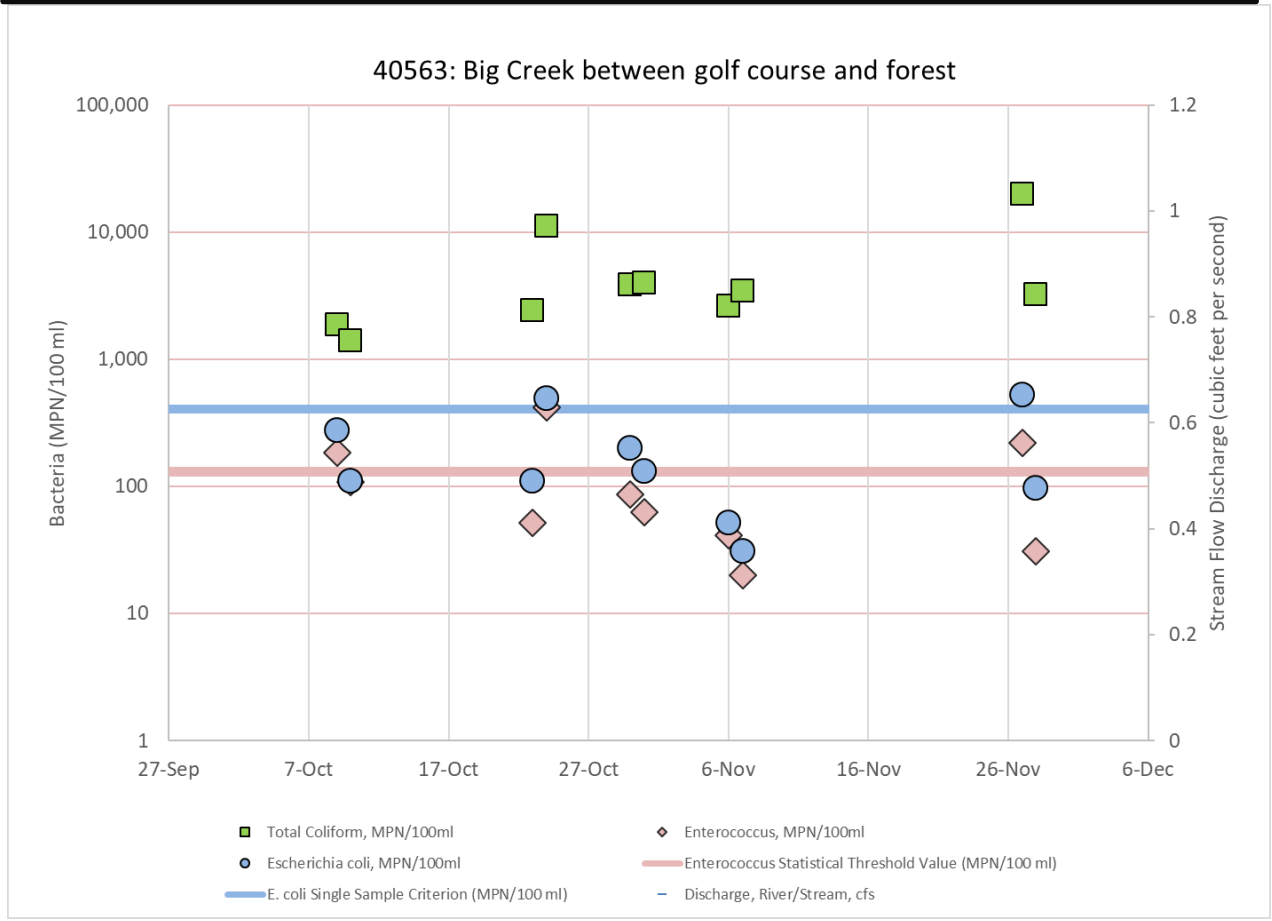
40608. Unnamed Tributary to Big Creek

This is a small tributary to Big Creek . The site is approximately 100 meters upstream of the tributary's confluence with Big Creek and is the most upstream site sampled. The basin upstream of this site is forested with residences at the headwaters along Seven Devils Road. It had the highest bacteria values of the Big Creek basin sites.



40563. Big Creek 3000 m Upstream Between Golf Course and Forest

This site is located about 500 meters downstream of the tributary containing Site 40608, and about 700 meters upstream of the golf course. Here Big Creek flows through a wide, low-gradient valley that is primarily wetland and fallow pasture, with wooded relatively steep slopes. The stream channel is incised into the valley floor several feet. No agricultural or grazing land use are known to occur in the area. Elk usage is common with many elk droppings in the fallow pasture.

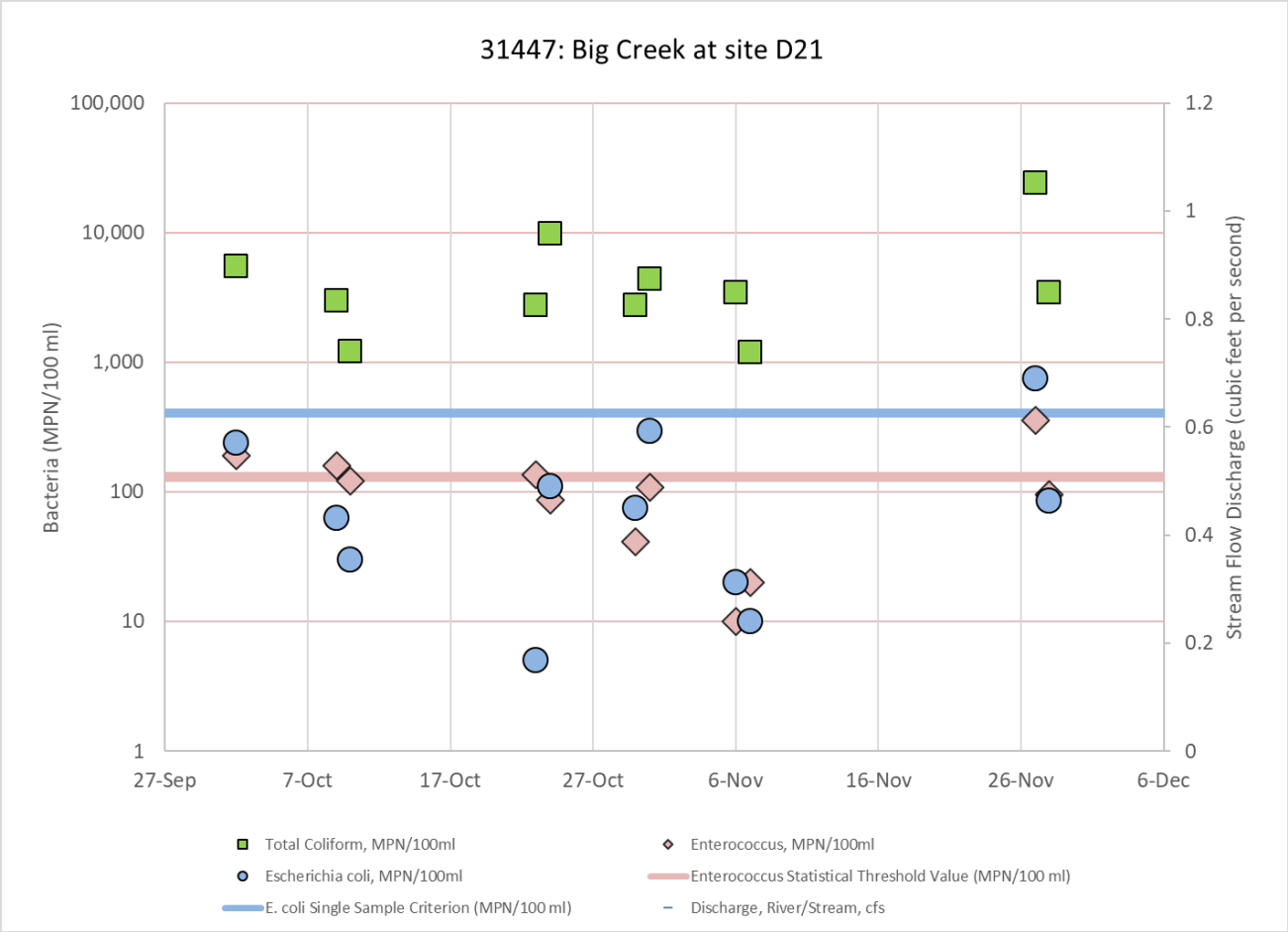


40566. Big Creek in Sunset Bay Golf Course, 1480 m Upstream

This site is between two fairways within the Sunset Bay Golf Course. The reach is low gradient and flows through a culvert under the cart path just upstream of the sample site. There is one residence at the upstream end of the golf course near this site.

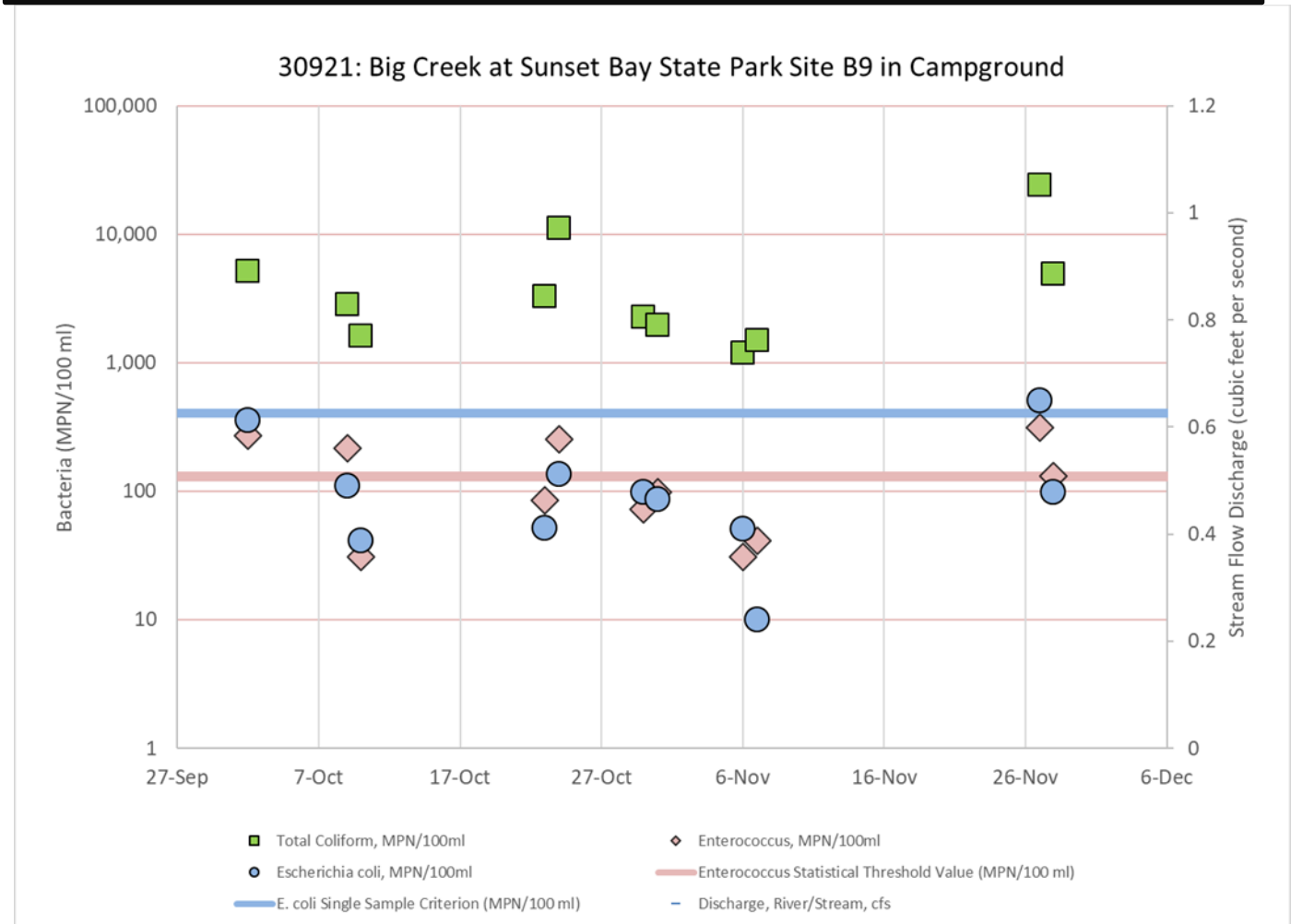
31447. Big Creek in Sunset Bay S.P. Campground near Site D21

This site is located at the upstream end of Sunset Bay State Park Campground, about 100 meters downstream of property boundary with Sunset Bay Golf Course. This site had the lowest *E. coli* geometric mean of the Big Creek basin sites.



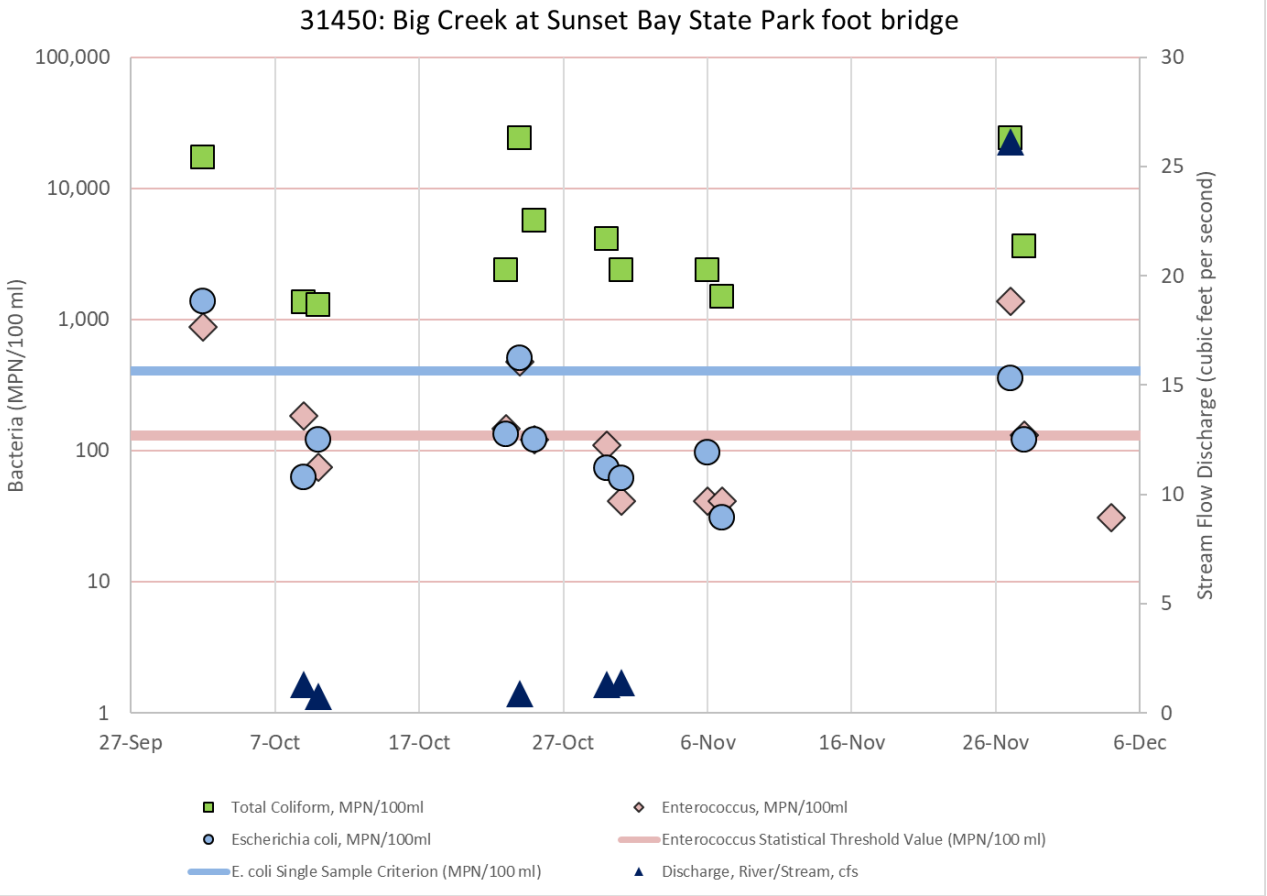
30921. Big Creek in Sunset Bay S.P. Campground near Site B9

This reach is characterized by low gradient and low velocity habitats. The site is located at about the midpoint of the reach of Big Creek that passes through Sunset Bay SP Campground. This site is located downstream from two campground loops that contain several yurts, numerous tent and RV sites, and two restroom facilities.



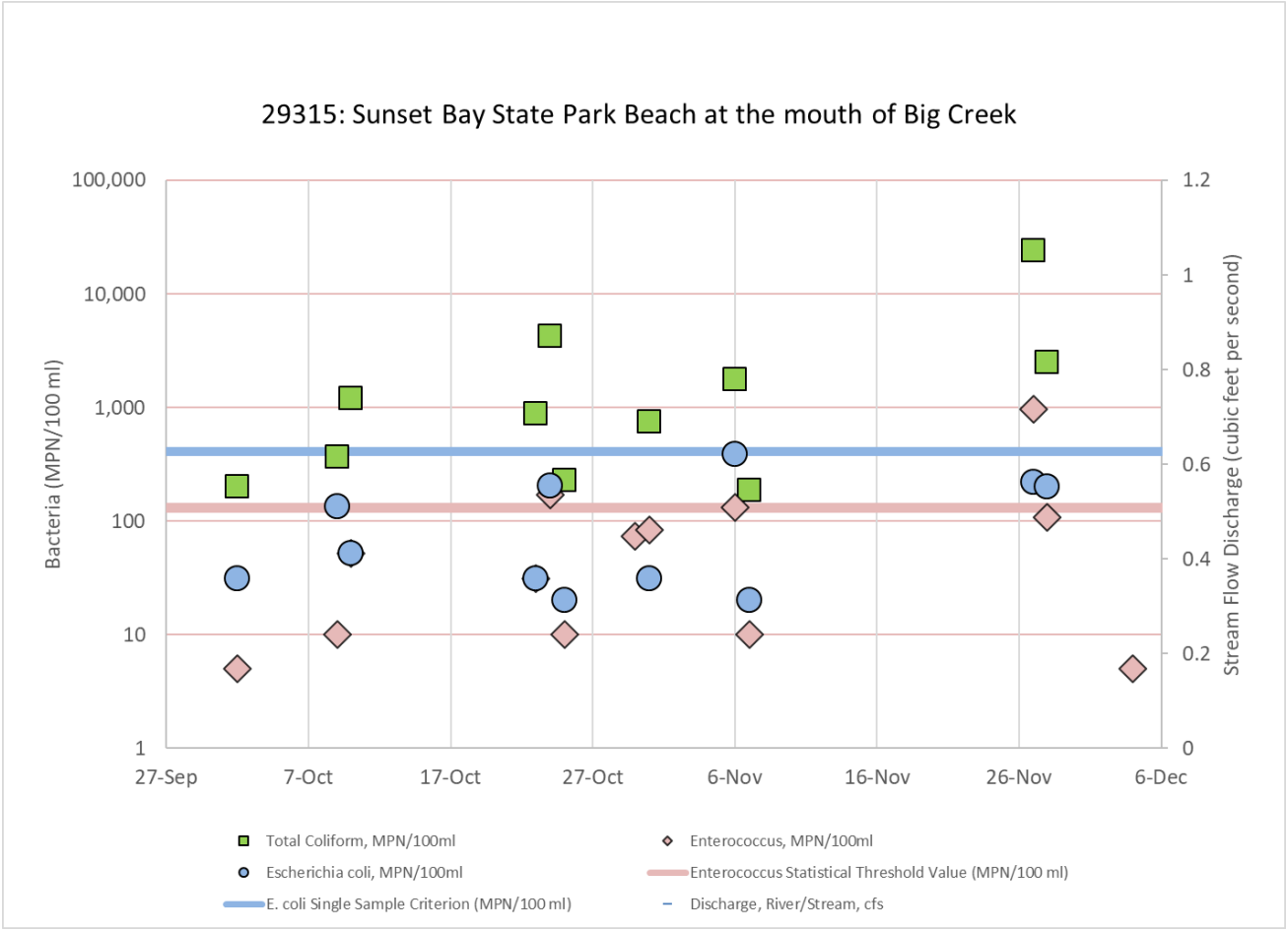
31450. Big Creek at Sunset Bay S.P.

This site is located in a day use area of Sunset Bay State Park. It is located approximately 50 meters below a restroom facility and about 150 of the Pacific Ocean. The reach is generally low gradient and low flow. The sample is collected from a large pool just below the footbridge. The transect for stream flow measurement was just downstream from this site.



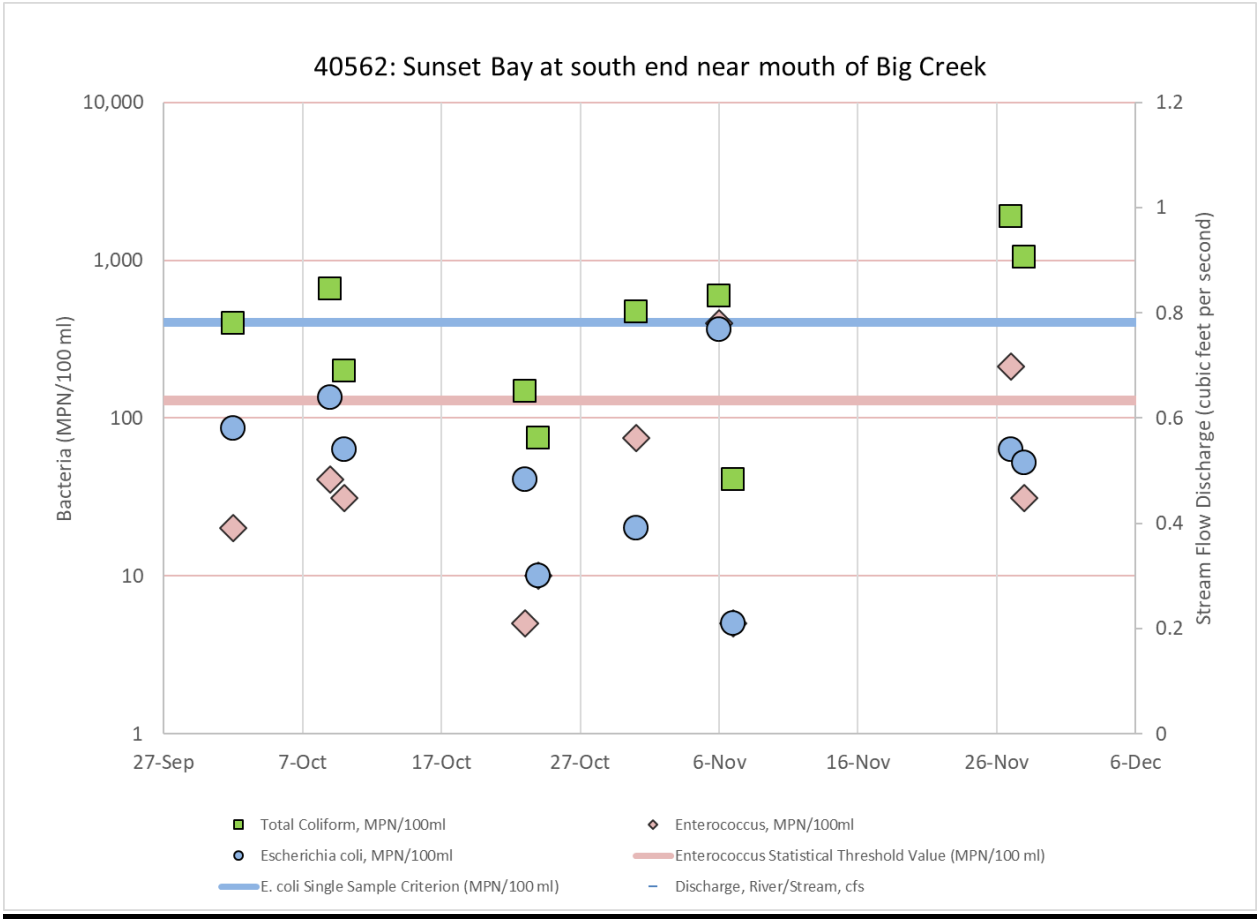
29315. Sunset Bay S.P. Beach at the Mouth of Big

This marine site is located at confluence of Big Creek and Sunset Bay, along the south bank/headland of the bay. The exact location may vary approximately 50 to 100 meters depending on tidal stage and height at the time of sampling. Samples were collected from the mixing zone/interface of freshwater from Big Creek and marine water of the Pacific Ocean.



40562. Sunset Bay S.P. Beach at South End, Near the Mouth of Big Creek

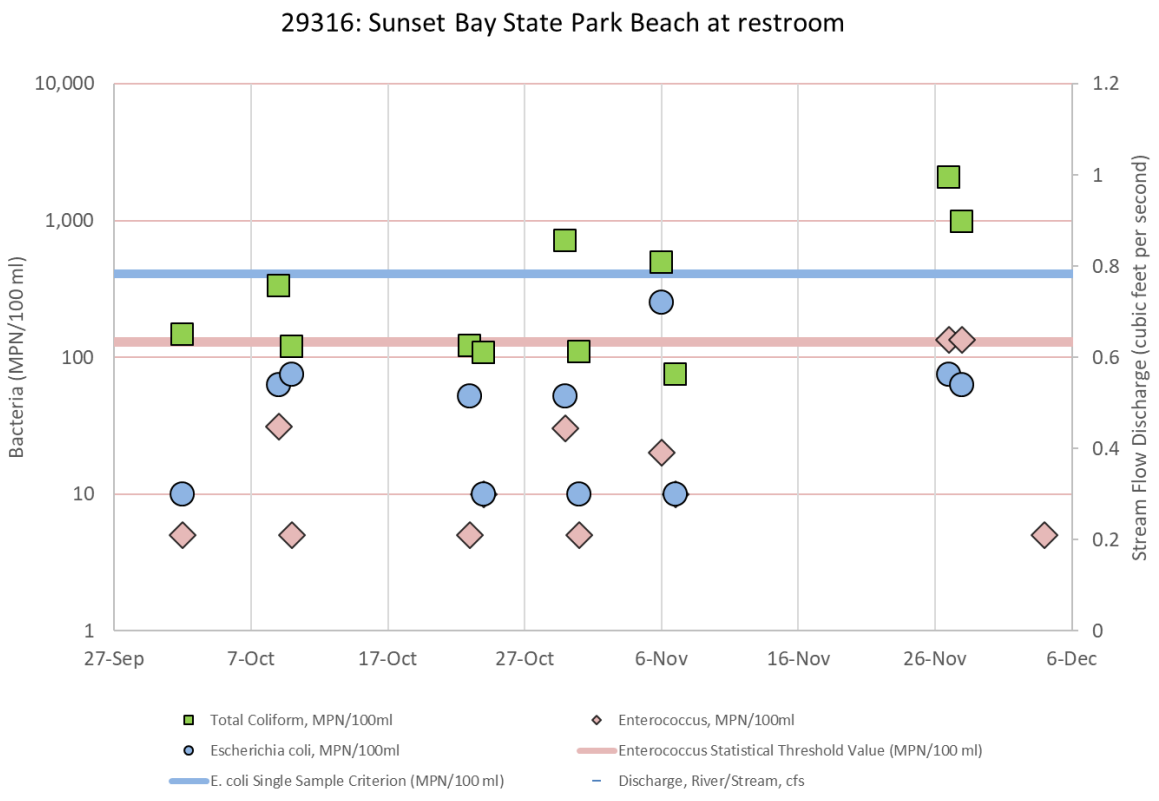
This marine site is located about 150 meters north of Site 29315 (confluence of Big Creek and the ocean). It is the closest marine site to Big Creek.



29316. Sunset Bay S.P. Beach at the Restrooms

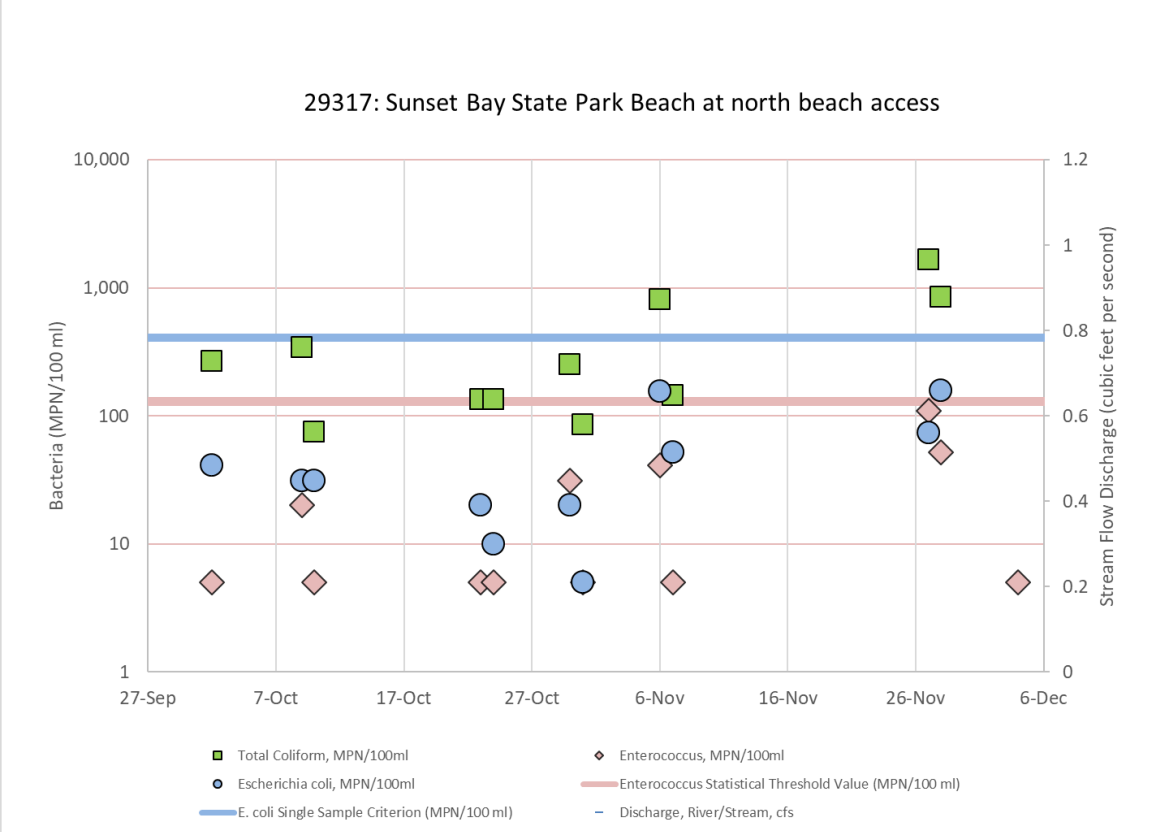
This marine site is located at about the mid-point around the semi-enclosed bay between the north and south headlands. The narrow entrance to the bay (pictured below) and the headlands shelter the bay from heavy surf and reduce water exchange in the bay.

Photo 1 Sample collection at the restroom site.



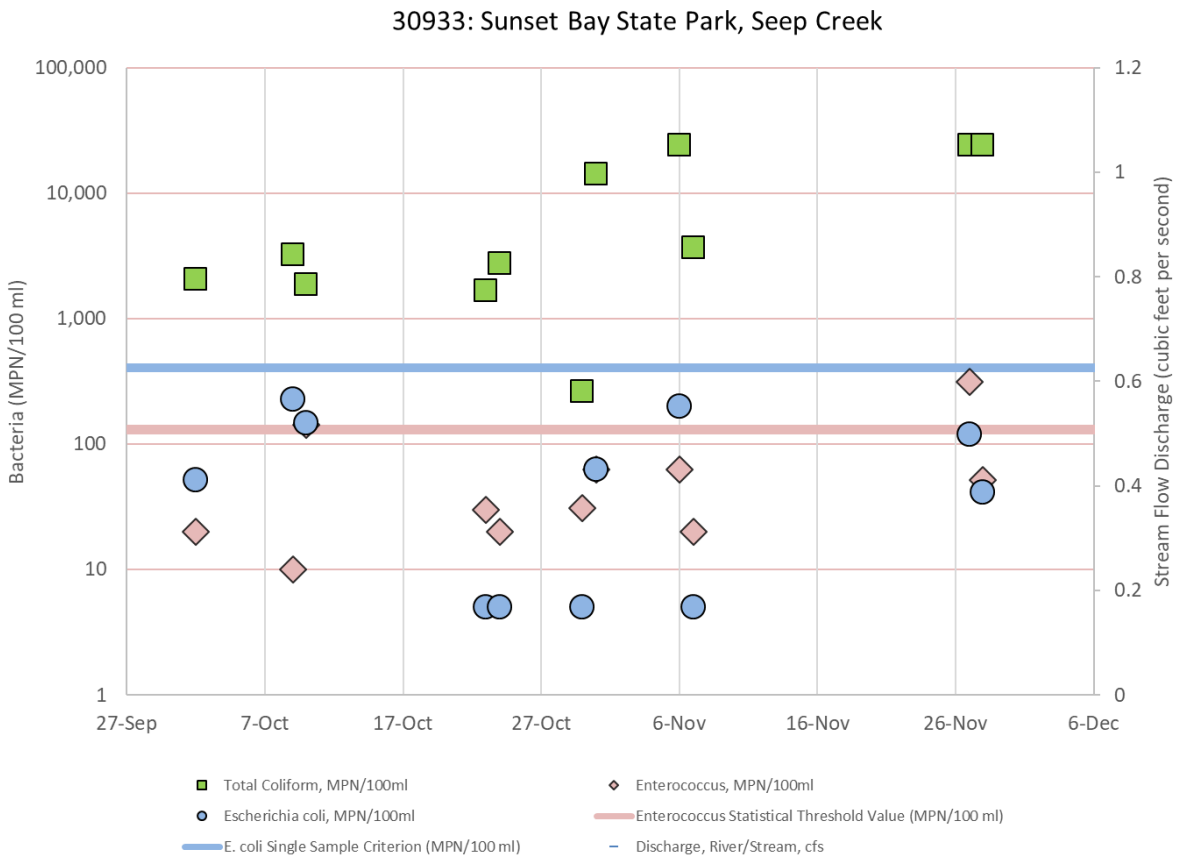
29317. Sunset Bay S.P. Beach at the North Access

This marine site is located on the north shore of Sunset Bay, near the occasional confluence of North Parking Lot Creek. It is across the bay from the mouth of Big Creek and the furthest marine site from the mouth.



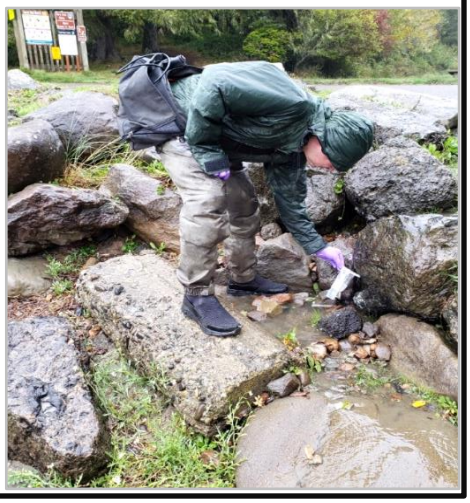
30933. Sunset Bay S.P., Seep Creek

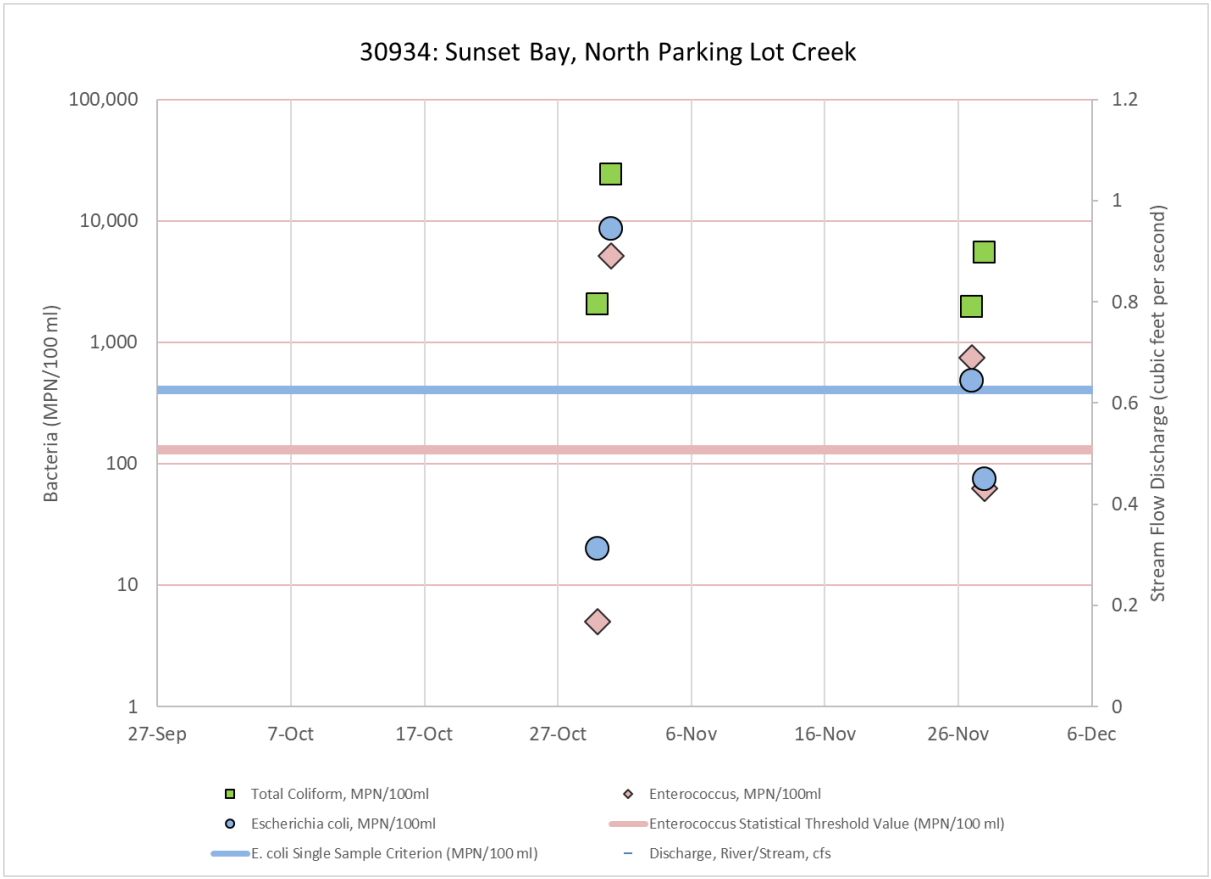
This site is a small, intermittently flowing drainage ditch creek located near the north end of the parking area of Sunset Bay SP day use area. It collects and drains water from the slopes above the park and drains under the parking lot and exits to the beach through a small channel excavated through sandy dune habitat. The creek contained standing water on all visits. It was not observed flowing above the land surface into the ocean at any visit during the study.



30934. Sunset Bay S.P., North Parking Lot Creek

This small, ephemeral creek was dry seven of eleven visits. At only four out of eleven visits did it contained sufficient water for sampling during or just after heavy rainfall. This creek drains the hillside above the parking lot and through the north portion of the parking lot to the beach. This site had the highest *E. coli* measured in this investigation.





8. Appendix B

2-Oct	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	148	0.1	13.9	933	1017	>24196
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	190	0.1	13.8	145	85	2489
31447: Big Creek @ site D21	196	0.1	13.9	189	238	5475
30921: Big Creek at Sunset Bay State Park	200	0.1	13.9	269	359	5172
31450: Big Creek at Sunset Bay SP footbridge	205	0.1	14.2	880	1374	17330
29315: Sunset Bay State Park Beach at the mouth of Big Creek		33	12.9	<10	31	199
40562: Sunset Bay surf zone south end near mouth of Big Creek		32	13.6	20	86	399
29316: Sunset Bay State Park Beach at restroom		33	13.7	<10	10	146
29317: Sunset Bay State Park Beach at north beach access		33	13.5	<10	41	265
30933: Sunset Bay, seep creek	158	0.1	15.7	20	52	2046
9-Oct	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	188	0.1	13.2	644	2495	11200
40563: Big Creek 3000 m upstream between golf course and privately owned forest	173	0.1	13.2	185	275	1872
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	184	0.1	14.4	197	74	1664
31447: Big Creek @ site D21	188	0.1	13.2	160	63	2987
30921: Big Creek at Sunset Bay State Park	192	0.1	12.9	216	110	2851
31450: Big Creek at Sunset Bay SP footbridge	230	0.1	13	185	63	1354
29315: Sunset Bay State Park Beach at the mouth of Big Creek		32	13.7	10	135	364
40562: Sunset Bay surf zone south end near mouth of Big Creek		31	13.9	41	135	657
29316: Sunset Bay State Park Beach at restroom		31	13.9	31	63	331
29317: Sunset Bay State Park Beach at north beach access		31	14.7	20	31	341
30933: Sunset Bay, seep creek	175	0.1	13.2	10	228	3255

10-Oct	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	170	0.1	11.3	85	243	8164
40563: Big Creek 3000 m upstream between golf course and privately owned forest	162	0.1	11.5	108	110	1396
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	171	0.1	12.8	63	86	1723
31447: Big Creek @ site D21	176	0.1	11.5	122	30	1201
30921: Big Creek at Sunset Bay State Park	181	0.1	11.1	31	41	1607
31450: Big Creek at Sunset Bay SP footbridge	201	0.1	12	75	121	1296
29315: Sunset Bay State Park Beach at the mouth of Big Creek		31	12.6	52	52	1211
40562: Sunset Bay surf zone south end near mouth of Big Creek		32	12.1	31	63	199
29316: Sunset Bay State Park Beach at restroom		32	12.3	<10	75	120
29317: Sunset Bay State Park Beach at north beach access		32	12.1	<10	31	75
30933: Sunset Bay, seep creek	167	0.1	11.2	142	148	1860
23-Oct	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	155		10.4	85	213	7270
40563: Big Creek 3000 m upstream between golf course and privately owned forest	155		10.6	52	110	2415
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	166		10.7	52	20	8164
31447: Big Creek @ site D21	170		10.7	135	<10	2755
30921: Big Creek at Sunset Bay State Park	172		11.6	85	52	3282
31450: Big Creek at Sunset Bay SP footbridge	190	0.1	11.7	148	134	2382
29315: Sunset Bay State Park Beach at the mouth of Big Creek		30	11.6	31	31	882
40562: Sunset Bay surf zone south end near mouth of Big Creek		32	12.2	<10	41	148
29316: Sunset Bay State Park Beach at restroom		32	11.5	<10	52	122
29317: Sunset Bay State Park Beach at north beach access		33	10.5	<10	20	135
30933: Sunset Bay, seep creek	161		11.5	30	<10	1664

24-Oct	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	170		10.8	98	884	>24196
40563: Big Creek 3000 m upstream between golf course and privately owned forest	160		10.9	420	495	11200
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	166		11.3	97	160	8664
31447: Big Creek @ site D21	170		11	86	110	9804
30921: Big Creek at Sunset Bay State Park	173		10.9	256	135	11200
31450: Big Creek at Sunset Bay SP footbridge	202	0.1	11.5	479	504	>24196
29315: Sunset Bay State Park Beach at the mouth of Big Creek		14	12.4	171	203	4225
40562: Sunset Bay surf zone south end near mouth of Big Creek		32	10.9	10	10	75
29316: Sunset Bay State Park Beach at restroom		32	11.3	10	10	108
29317: Sunset Bay State Park Beach at north beach access		32	11.5	<10	10	135
30933: Sunset Bay, seep creek	168	0.1	11.7	20	<10	2755
25-Oct	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
31450: Big Creek at Sunset Bay SP footbridge	184	0.1	11	121	122	5717
29315: Sunset Bay State Park Beach at the mouth of Big Creek		32	12.1	10	20	228

30-Oct	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	162	0.1	10	41	119	2613
40563: Big Creek 3000 m upstream between golf course and privately owned forest	194	0.1	9.5	86	201	3873
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	186	0.1	10.8	85	175	2481
31447: Big Creek @ site D21	189	0.1	10.4	41	75	2755
30921: Big Creek at Sunset Bay State Park	190	0.1	10.2	72	98	2282
31450: Big Creek at Sunset Bay SP footbridge	206	0.1	10.6	110	74	4106
29315: Sunset Bay State Park Beach at the mouth of Big Creek		22	12.5	74		
29316: Sunset Bay State Park Beach at restroom		28	12	30	52	712
29317: Sunset Bay State Park Beach at north beach access		31	12.9	31	20	253
30933: Sunset Bay, seep creek		31	12.7	31	<10	262
30934: Sunset Bay, North Parking Lot Creek	197	0.1	10.3	<10	20	2064
31-Oct	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	178	0.1	11.3	393	305	24200
40563: Big Creek 3000 m upstream between golf course and privately owned forest	162	0.1	11.1	63	132	3968
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	182	0.1	11.5	197	98	3654
31447: Big Creek @ site D21	187	0.1	11.3	109	292	4352
30921: Big Creek at Sunset Bay State Park	190	0.1	11.1	98	86	1968
31450: Big Creek at Sunset Bay SP footbridge	205	0.1	11.4	41	62	2382
29315: Sunset Bay State Park Beach at the mouth of Big Creek		29	13.4	84	31	743
40562: Sunset Bay surf zone south end near mouth of Big Creek		29	13.5	75	20	471
29316: Sunset Bay State Park Beach at restroom		32	13.5	<10	10	110
29317: Sunset Bay State Park Beach at north beach access		32	13.5	<10	<10	85
30933: Sunset Bay, seep creek	178	0.1	12.8	63	63	14140
30934: Sunset Bay, North Parking Lot Creek	116	0.1	14.9	5172	8664	>24196

6-Nov	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	187	0.1	11.8	<10	262	5794
40563: Big Creek 3000 m upstream between golf course and privately owned forest	165	0.1	10	41	52	2603
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	196	0.1	11	10	120	2142
31447: Big Creek @ site D21	198	0.1	10.5	10	20	3448
30921: Big Creek at Sunset Bay State Park	198	0.1	10.3	31	51	1198
31450: Big Creek at Sunset Bay SP footbridge	207	0.1	10.2	41	97	2382
29315: Sunset Bay State Park Beach at the mouth of Big Creek		28	12.4	132	384	1780
40562: Sunset Bay surf zone south end near mouth of Big Creek		32	12.9	399	364	594
29316: Sunset Bay State Park Beach at restroom		32	13	20	253	496
29317: Sunset Bay State Park Beach at north beach access		32	13.2	41	156	805
30933: Sunset Bay, seep creek	212	0.1	11	63	199	>24196
7-Nov	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	183		10	20	203	10460
40563: Big Creek 3000 m upstream between golf course and privately owned forest	165		8.7	20	31	3448
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	196		9.2	315	109	4352
31447: Big Creek @ site D21	197		8.6	20	10	1187
30921: Big Creek at Sunset Bay State Park	198		8.4	41	10	1497
31450: Big Creek at Sunset Bay SP footbridge				41	31	1497
29315: Sunset Bay State Park Beach at the mouth of Big Creek		32	12.2	10	20	185
40562: Sunset Bay surf zone south end near mouth of Big Creek		32	11.5	<10	<10	41
29316: Sunset Bay State Park Beach at restroom		32	11.6	10	10	75
29317: Sunset Bay State Park Beach at north beach access		32	11.5	<10	52	145
30933: Sunset Bay, seep creek	195		9.5	20	<10	3654

27-Nov	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	190	0.1	11.7	31	134	1664
40563: Big Creek 3000 m upstream between golf course and privately owned forest	141	0.1	11.3	221	521	19860
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	163	0.1	11.6	281	441	13000
31447: Big Creek @ site D21	169	0.1	11.5	359	749	24200
30921: Big Creek at Sunset Bay State Park	172	0.1	11.6	315	504	>24196
31450: Big Creek at Sunset Bay SP footbridge	176	0.1	11.6	1374	355	24200
29315: Sunset Bay State Park Beach at the mouth of Big Creek		9	11.6	959	218	>24196
40562: Sunset Bay surf zone south end near mouth of Big Creek		26	11.4	211	63	1892
29316: Sunset Bay State Park Beach at restroom		28	11.4	134	75	2064
29317: Sunset Bay State Park Beach at north beach access		28	11.3	109	74	1670
30933: Sunset Bay, seep creek	187	0.1	12.4	311	120	>24196
30934: Sunset Bay, North Parking Lot Creek	283	0.1	12.1	748	480	1956
28-Nov	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
40608: Big Creek unnamed tributary at south end of golf course	190	0.1	11.3	31	52	426
40563: Big Creek 3000 m upstream between golf course and privately owned forest	149	0.1	11.2	31	97	3255
40566: Big Creek in Sunset Bay Golf Course, 1480 m upstream	177	0.1	11.3	41	85	2755
31447: Big Creek @ site D21	177	0.1	11.3	96	85	3448
30921: Big Creek at Sunset Bay State Park	177	0.1	11.3	132	98	4884
31450: Big Creek at Sunset Bay SP footbridge				132	121	3609
29315: Sunset Bay State Park Beach at the mouth of Big Creek				108	201	2489
40562: Sunset Bay surf zone south end near mouth of Big Creek		27	11.5	31	52	1050
29316: Sunset Bay State Park Beach at restroom		28	11.6	134	63	987
29317: Sunset Bay State Park Beach at north beach access		28	11.6	52	158	842
30933: Sunset Bay, seep creek	227	0.1	11.6	52	41	>24196
30934: Sunset Bay, North Parking Lot Creek	312	0.2	11.9	63	75	5475

4-Dec	Conductivity, umho/cm	Salinity, ppth	Temperature, water, deg C	Enterococcus, MPN/100ml	Escherichia coli, MPN/100ml	Total Coliform, MPN/100ml
31450: Big Creek at Sunset Bay SP footbridge	175	0.1	7.4	31		
29315: Sunset Bay State Park Beach at the mouth of Big Creek		29	10.2	<10		
29316: Sunset Bay State Park Beach at restroom		30	10.1	<10		
29317: Sunset Bay State Park Beach at north beach access		32	10.8	<10		