Fecal Bacteria in King County Waters: Current Conditions, Long-term Trends, and Landscape Factors

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King County

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EXECUTIVE SUMMARY

This report analyzed fecal indicator bacteria monitoring data in King County to evaluate current conditions, long-term trends, and what land use factors influence surface water contamination levels. The findings of this report can be used to inform Seattle-King County Public Health Environmental Health water pollution control planning and prioritization.

Bacterial contamination of Puget Sound, lakes, rivers, and streams is a widespread problem throughout King County.

- There are 172 waterbodies in King County listed as impaired for bacteria in the Washington State Department of Ecology's Water Quality Assessment – about a third (59) of these have a pollution control plan in place.
- Bacterial contamination has led to the closure of many commercial and recreational shellfish harvest areas in King County.
    - There are 9,612 acres of commercial shellfish growing areas in King County. About half are open for year-round harvest. The remainder are closed or have not been classified. Additionally, a 124-acre area in Poverty Bay is closed from June 1 to November 30 due to season contamination concerns.
    - There are 37 public shellfish beaches in King County, and over half (21) are closed for the harvest of all shellfish due to fecal contamination concerns.

Monitoring data revealed that onsite sewage systems (also referred to as septic systems), runoff from developed areas, and areas with small farms and livestock, are important factors affecting bacterial levels in surface waters.

Multivariate regression analysis was completed to examine how land use and environmental factors are linked to surface water bacterial concentrations. The analysis indicated that monitoring sites in a watershed with higher concentrations of on-site sewage systems (OSS), population and/or agricultural land uses, tended to have higher levels of fecal indicator bacteria.

The good news is that bacteria levels in surface waters have decreased at many long-term monitoring sites since the 1970s.

Bacteria levels were found to be significantly decreasing at the majority of long-term freshwater monitoring sites. Significant decreasing trends were also found for several marine sites. Few of the Department of Health shellfish sites had decreasing trends and no increasing trends were found. This study did not attempt to statistically assess the factors contributing to those decreased bacterial levels in surface waters. Several factors are hypothesized to be driving the decreasing trends in fecal indicator bacteria in the region:

- Stormwater management by public agencies and the private sector per and beyond state regulations
- Conversion of aging OSS to sewered or updated OSS
- Decreasing agricultural land cover and improved manure management

- Increased resident awareness and stewardship

For the future, to ensure that shellfish harvested from King County beaches are safe to eat and that swimmers are protected from harmful pathogens, further comprehensive fecal contamination controls are likely to be needed.

Bacteria levels in the King County region have largely improved over the past 40 years, but the amount of fecal material in our waters remains a threat to public and environmental health. To successfully mitigate fecal contamination, implementing or expanding existing programs may be considered that address: (1) on-site sewage systems (e.g., proper operation and maintenance, and repairing failures), (2) problems in built environments (e.g., stormwater treatment, pet waste management, wildlife control, sanitary facilities for homeless people), and (3) agriculture (e.g., livestock/manure management plans) may be considered.

1.0 INTRODUCTION

Fecal contamination of surface waters threatens public health through direct and indirect exposure to pathogens. Swimming, wading, and other contact with water can lead to incidental swallowing or exposure of skin cuts. Shellfish are also impacted by fecal contamination. Molluscan shellfish such as clams, oysters, and mussels feed by filtering large volumes of seawater. Along with food particles they can also absorb bacteria, viruses, and other contaminants that are present. If contaminant levels are high enough, shellfish harvested from these areas can make people sick.

This report summarizes the fecal indicator bacteria data for the various surface water monitoring programs operating in King County and watersheds draining to King County. This report also includes an analysis of the influence of watershed agriculture, population density, and density of on-site sewage systems (OSS) on bacteria levels within surface waters.

1.1 Fecal Indicator Bacteria

A primary concern related to bacterial contamination in bodies of water is the potential human health risk. Human health risks may be assessed by directly measuring pathogens in surface water, including viruses, protozoa, and bacteria). Directly measuring pathogens, however, is very challenging and expensive. Instead, agencies typically use fecal indicator bacteria that are symptomatic with fecal pollution. Fecal indicator bacteria include specific bacteria genera and species (i.e., *Enterococcus* spp. or *E. coli*) or certain bacteria groups (i.e., fecal coliform and streptococci bacteria). Fecal coliform bacteria have been the primary indictor until relatively recently when the U.S. Environmental Protection Agency (EPA) began recommending *Enterococcus* or *E. coli* as indicators of health risk. Washington State water quality criteria and U.S. Food and Drug Administration shellfish bed criteria use fecal coliform bacteria as the indicator bacteria.

1.1.1 Washington State Water Quality Criteria

Washington State Water Quality Standards include criteria for fecal coliform bacteria. The State water quality criteria for fecal coliform are presented in Table 1. The criteria are based on a geometric mean (GM) and a statistical threshold value (STV) of routine bacteria monitoring samples for single site. The GM should be calculated as a rolling annual average with samples collected with no more than 30 days between the previous and following sampling dates. The STV should not be exceeded in more than 10 percent of the samples.

Table 1. Washington State water quality criteria for fecal coliform bacteria (WAC 173-201A). CFU: colony forming unit(s).

Category	Criteria (CFU/100 mL)	
	GM	STV
Freshwater: Extraordinary Primary Contact Recreation	50	100
Freshwater: Primary Contact Recreation	100	200
Freshwater: Secondary Contact Recreation	200	400
Marine: Primary Contact Recreation	14	43

Definitions of contact
"Extraordinary primary contact" means waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.
"Primary contact recreation" means activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.
"Secondary contact recreation" means activities where a person's water contact would be limited (e.g., wading or fishing) to the extent that bacterial infections of eyes, ears, respiratory or digestive systems, or urogenital areas would normally be avoided.

As of the writing of this report, the Washington State Department of Ecology is proposing to amend Chapter 173-201A WAC, Water Quality Standards for Surface Waters of the State of Washington to adopt new bacterial indicator and numeric criteria.[1] The proposed rule change would remove fecal coliform as the indicator bacteria, replacing it with *E. coli* in freshwater and *Enterococcus* in saltwater. Use of fecal coliform bacteria as indicator is proposed to expire at end of the year 2020. The proposed rule change would also remove the extraordinary and secondary contact criteria and set a single primary contact criterion. The rulemaking is being done in consideration of the EPA Recommended Recreation Water Quality Criteria (see Section 1.1.3).

1.1.2 Washington State Department of Health Shellfish Bed Standards

The Washington State Department of Health (DOH) uses fecal coliform bacteria in its determination of the closure of shellfish beds based on guidance from the National Shellfish Sanitation Program (FDA, 2015). Sanitary surveys are conducted in commercial and recreational growing areas to determine their suitability for shellfish harvest. The surveys include water quality monitoring and pollution source evaluations of the surrounding area. The standard for approved shellfish growing waters is fecal coliform geometric mean not greater than 14 CFU/100 mL with an estimated 90th percentile not greater than 43 CFU/100 mL. At least 30 samples are to be used in generating the aforementioned statistics.

[1] https://ecology.wa.gov/Regulations-Permits/Laws-rules-rulemaking/Rulemaking/WAC-173-201A-Aug17

1.1.3 EPA Recreational Water Quality Criteria

The EPA, in its release of the 2012 Recreational Water Quality Criteria (EPA, 2012), recommended criteria for marine and freshwaters. The recommend criteria are based on concentrations of the enteric bacteria, *Enterococcus* spp. (marine and freshwater) and *E. coli* (for freshwater only). These recommendations are a non-regulatory, scientific assessment of effects on human health. The purpose of these recommendations are to inform Federal and State agencies pursuant to section 304(a) of the Clean Water Act. EPA provides two sets of recommended criteria based on estimated illness rate of either 36 or 32 per 1,000 primary contact recreators. [2] The magnitude of the bacterial indicators are described by both a geometric mean (GM) and a statistical threshold value (STV) for the bacteria samples for a single monitoring site. Table 2 summarizes the magnitude components of the recommendations.

Table 2. EPA Recommended 2012 RWQC. CFU: colony forming unit(s).

Criteria Elements	Estimated Illness Rate: 36 per 1,000 primary contact recreators		Estimated Illness Rate: 32 per 1,000 primary contact recreators	
	Magnitude		Magnitude	
Indicator	GM (CFU/100 mL)	STV (CFU/100 mL)	GM (CFU/100 mL)	STV (CFU/100 mL)
Enterococci – marine and freshwater	35	130	30	110
E. coli – freshwater only	126	410	100	320

Duration and Frequency: The water body GM should not be greater than the selected GM magnitude in any 30-day interval. There should be no greater than a ten percent excursion frequency of the selected STV magnitude in the same 30-day interval.

1.2 Existing Bacteria Impairments in King County

There are 172 listings for bacteria impairments in King County under Category 5, 4A, or 4B in the 2014 EPA-approved Water Quality Assessment (Figure 1). Table 4 summarizes the listings for bacteria by Watershed Resource Inventory Area (WRIA) that have been assessed by the Washington State Department of Ecology. See Appendix B for a list of the impaired waterbodies.

[2] The EPA believes both criteria sets are protective of the designated use of primary contact recreation. The 36 per 1,000 rate corresponds to the 1986 EPA water quality criteria. The 32 per 1,000 rate is meant to encourage incremental improvement in water quality (EPA, 2012).

Table 3. Water quality assessment categories.

Listing Category	Description
Category 1	Meets tested standards for clean waters
Category 2	Waters of concern - some evidence of a water quality problem, but not enough to show persistent impairment.
Category 3	Insufficient data
Category 4	Impaired waters that do not require a TMDL
Category 4A	Impaired water already has an EPA-approved TMDL plan in place and implemented.
Category 4B	Impaired water has a pollution control program, similar to a TMDL plan that is expected to solve the pollution problems.
Category 4C	Water impaired by causes that cannot be addressed through a TMDL plan.
Category 5	Polluted waters that require a water improvement project

Table 4. Department of Ecology 2014 Water Quality Assessment categories for bacteria in King County waters.

Type	Category						
WRIA	1	2	3	4A	4B	4C	5
WRIA 7	**13**	**2**		**19**			
Rivers/Streams	13	2		19			
WRIA 8	**41**	**6**		**31**	**1**		**66**
Lakes	22	4					7
Marine	9	1					7
Rivers/Streams	10	1		31	1		52
WRIA 9	**27**	**9**		**1**			**46**
Lakes	4	6					2
Marine	13	2					13
Rivers/Streams	10	1		1			31
WRIA 10	**8**	**3**		**7**			**1**
Lakes		1					
Marine	4	1					
Rivers/Streams	4	1		7			1
WRIA 15 (Vashon)	**13**	**11**					
Marine	13	11					
TOTAL	**102**	**31**		**58**	**1**		**113**

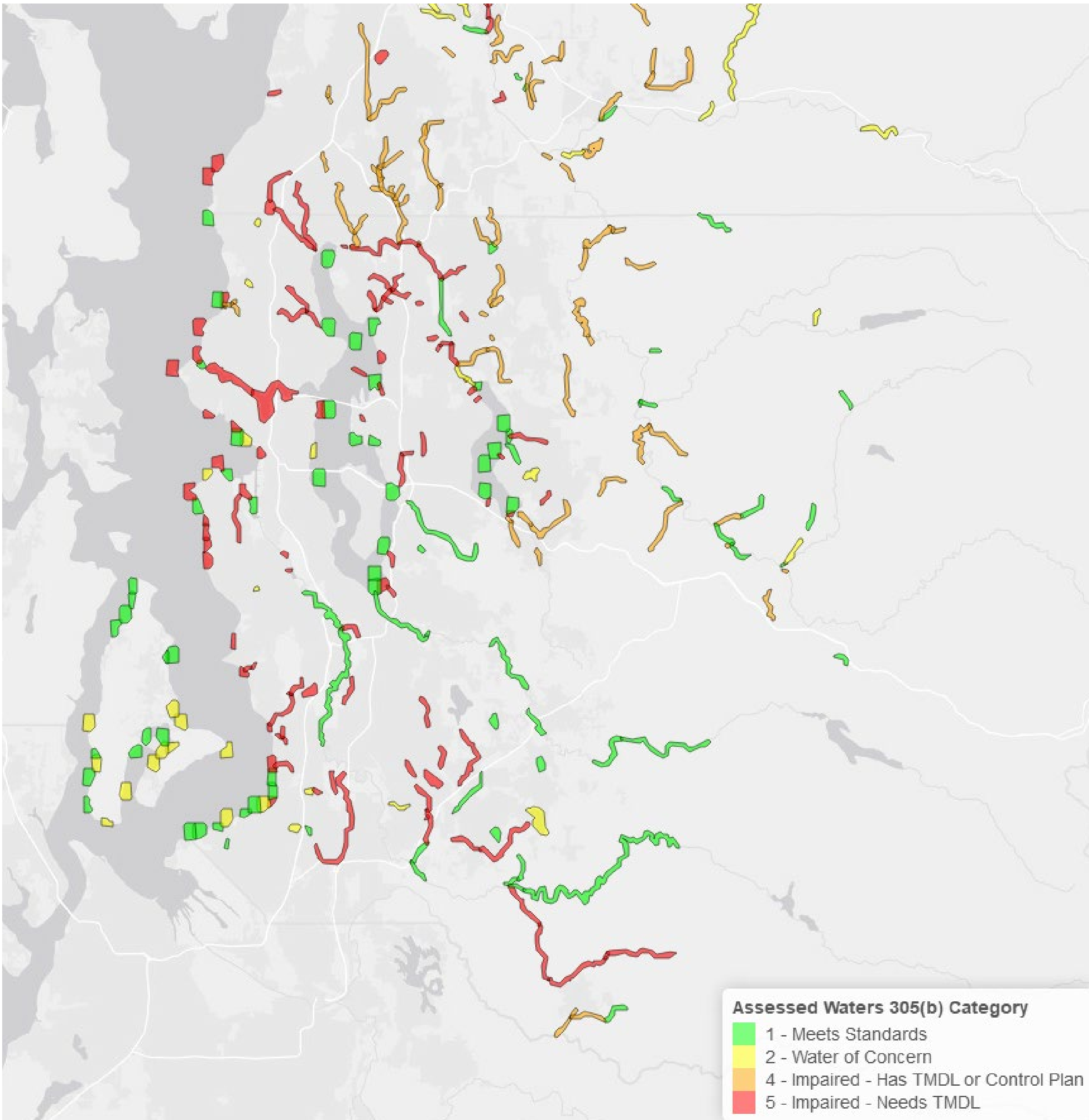

Figure 1. Department of Ecology 2014 Water Quality Assessment for bacteria in in King County waters and waters draining to King County.

1.3 Shellfish Recreational and Commercial Harvesting Status

The DOH Commercial Shellfish Program licenses and regulates the commercial harvest of shellfish in Washington waters. The regulation includes approving commercial harvest areas where water quality does not pose a threat to public health and closing harvest areas if there is a threat. The DOH Recreational Shellfish Program provides information to the public about where and how to harvest molluscan shellfish that are safe to eat.

Commercial and recreational shellfish beaches may be closed due to bacterial contamination and/or marine biotoxins. Marine biotoxins are produced by certain type of algae and are not linked to bacterial water quality contamination. Closures are not permanent and reflect recent beach conditions. This report present shellfish status as of October 25, 2018.

1.3.1 Commercial Shellfish Growing Areas

There are about 9,594 acres of commercial shellfish beds in King County. About half (4,830 acres) of the commercial shellfish beds in King County are approved for harvest (Table 5; Figure 2). Sixteen percent (1,509 acres) of beds are prohibited from harvest. One percent (152 acres) of beds are conditionally open to harvest – these are located in Poverty Bay and are closed from June 1 to November 30. Thirty-three percent (3103 acres) are not classified and harvest is not recommended. As of October 25, 2018, no growing area in King County is closed due to marine biotoxin concern. See Appendix C for the status and size of each of subareas within the Commercial Shellfish Growing Areas

Table 5. Summary of commercial shellfish growing areas classifications in King County growing areas as of October 25, 2018.

Growing Area	Approved	Conditional	Prohibited	Unclassified	Total
Colvos Passage	1728		201	282	2211
East Passage	1657		81	136	1874
Poverty Bay	387	152	517	295	1351
Quartermaster Harbor	774		453	2000	3227
Three Tree Point	284		257	390	931
Total	**4830**	**152**	**1509**	**3103**	**9594**

Table 6. Definition of commercial shellfish growing areas classifications.

Classification	Definition
Approved	Sanitary survey shows that the area is not subject to contamination that presents an actual or potential public health hazard. An Approved classification authorizes commercial shellfish harvest for direct marketing.
Conditionally Approved	The areas meets Approved criteria some of the time, but does not during predictable periods. During these periods the area is closed. The length of closure is predetermined for each Conditionally Approved area, and is based on water sample data that show the amount of time it takes for water quality to recover and again meet Approved criteria. Once that time period has elapsed, the area is reopened.
Prohibited	When the sanitary survey indicates that fecal material, pathogenic microorganisms, or poisonous or harmful substances may be present in concentrations that pose a health risk to shellfish consumers. Growing areas adjacent to sewage treatment plant outfalls, marinas, and other persistent or unpredictable pollution sources are classified as Prohibited. Commercial shellfish harvests are not allowed from Prohibited areas.
Restricted	Water quality does not meet standards for an Approved classification, but the sanitary survey indicates a limited degree of pollution from non-human sources. Shellfish harvested from Restricted growing areas cannot be marketed directly. They must be relayed (transplanted) to Approved growing areas for a specified amount of time, allowing shellfish to naturally cleanse themselves of contaminants before they are harvested for market.
Unclassified	Health standards have not been evaluated for this growing area.

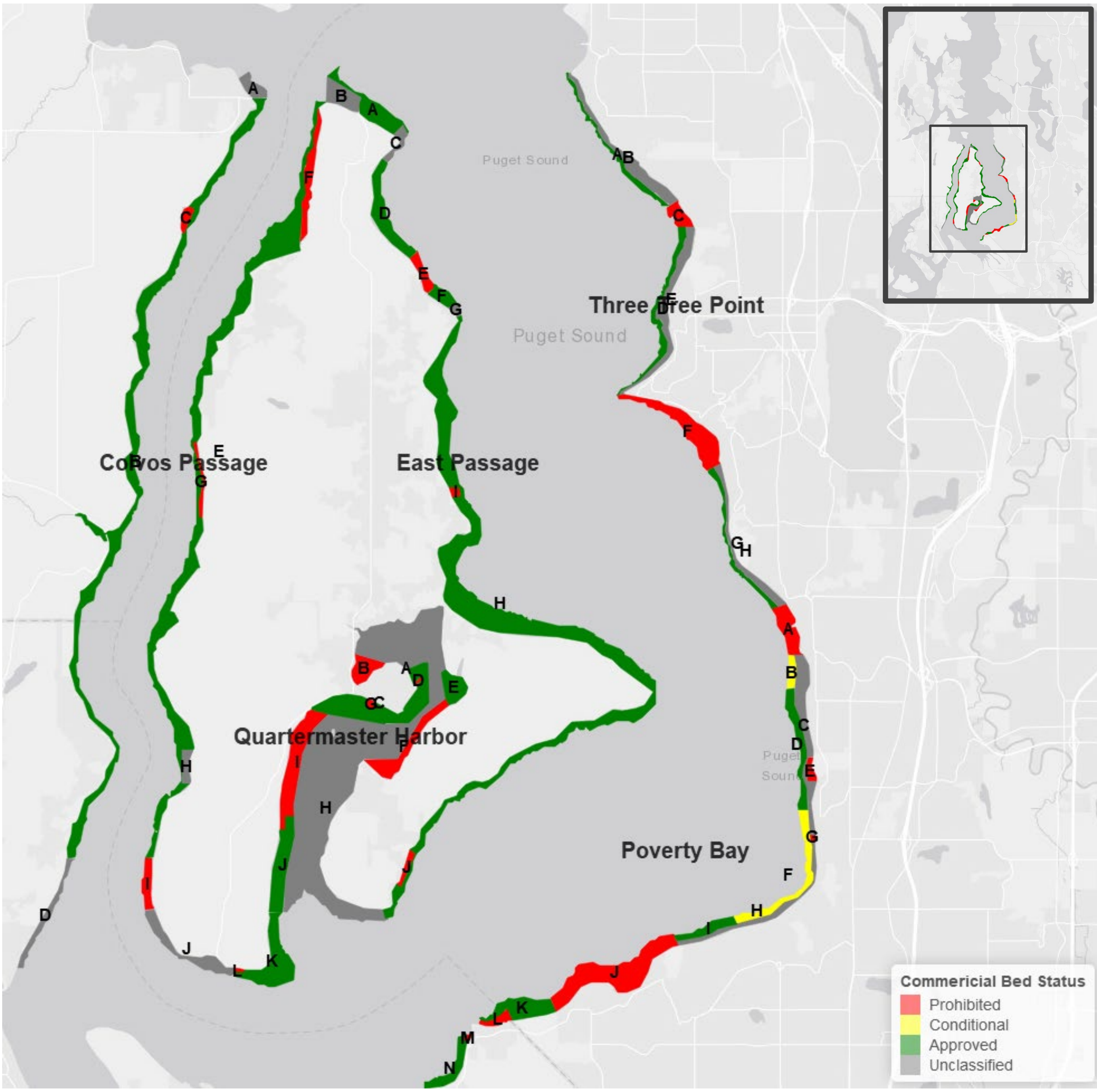

Figure 2. Status of commercial shellfish growing areas in Colvos Passage, East Passage, Quartermaster Harbor, Poverty Bay, and Three Tree Point as of October 25, 2018.

1.3.2 Public Recreational Shellfish Beaches

Table 7 summarize the classifications for public recreation shellfish beaches. As of October 25, 2018, all 37 recreational beaches in King County are closed for harvest due to biotoxin. Some beaches, in addition to the potential for marine biotoxins, are also closed due to fecal contamination concerns.

As of October 25, 2018, 18 recreational beaches in King County are closed for the harvest of all species of shellfish due to fecal contamination concerns. The beaches are closed for several reasons:

- The beach is near densely populated urban areas where contamination from sewage treatment outfalls and stormwater runoff are a concern.
- The beach is within an area of known contamination based on monitoring data.
- A shoreline survey indicated that conditions do not meet bacteria standards.

Two beaches have not been evaluated by DOH for fecal contamination.

Table 7. Definition of recreational shellfish bed classifications.

Classification	Definition
Open	The beach meets health standards and the area is safe to harvest.
Conditionally Open	The beach meets health standards and the area is safe to harvest; however, certain conditions can cause an unsafe harvest and the beach will be closed. The beach may also contain multiple classifications. Excessive rainfall, boating, and certain seasons may result in permanent or temporary beach closures.
Emergency Closure	Occasionally an event occurs that degrades water quality. Floods, sewage spills, and other pollution events can create conditions that make shellfish unsafe for human consumption. When this happens we impose an emergency (temporary) closure on the affected area. The emergency closure remains in effect until water quality returns to previous levels and shellfish have had time to naturally cleanse themselves of contaminants.
Closed	The beach does not meet health standards and is closed. Shellfish are not safe to eat.
Unclassified	Health standards have not been evaluated for this beach. Shellfish harvesting is not recommended.

Figure 3 displays the location of the beaches and their status as of October 25, 2018. See Appendix C for the status and DOH comment for each public shellfish beach in King County.

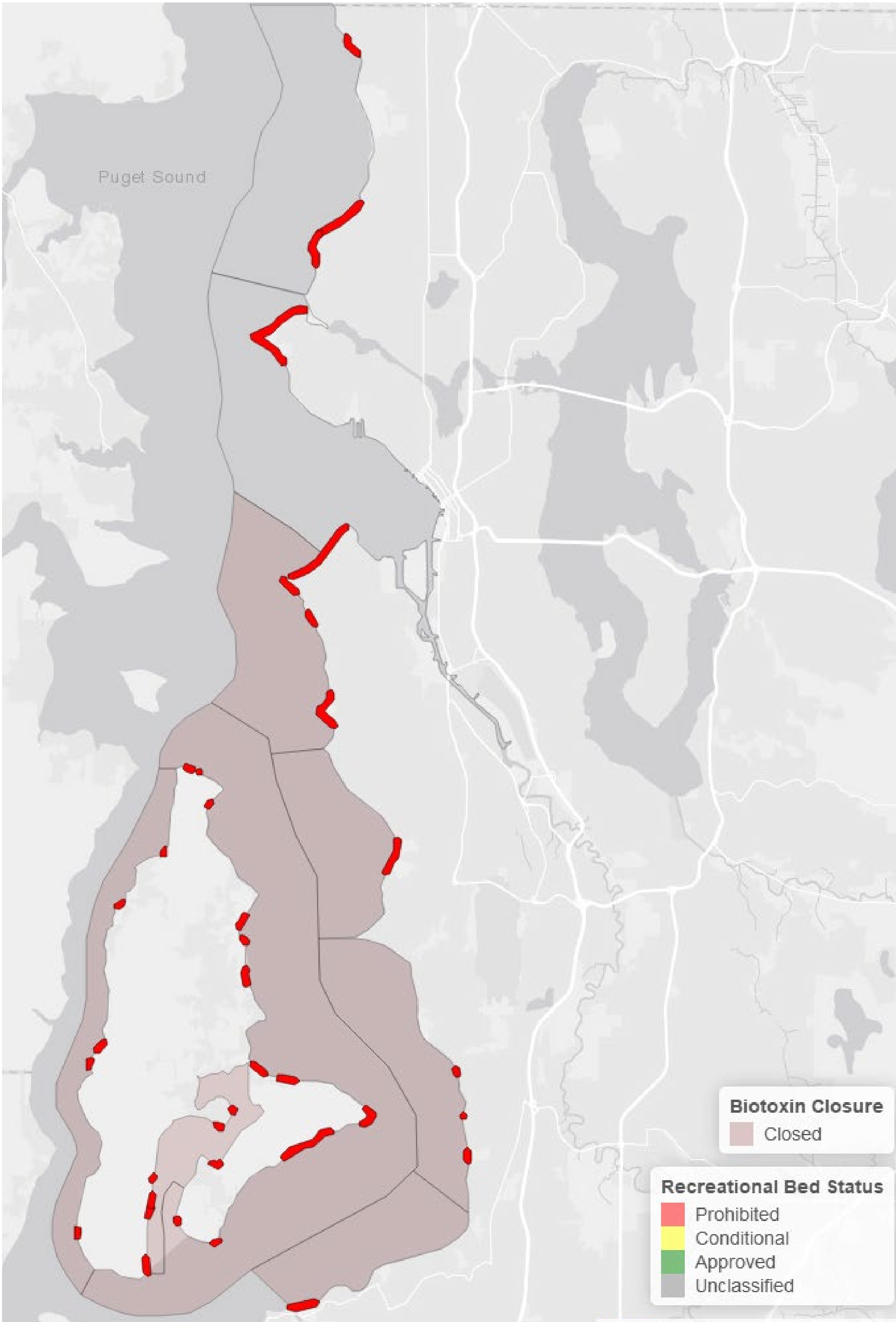

Figure 3. Status of public recreational shellfish beaches and biotoxin closure areas (October 25, 2018).

1.4 Factors Influencing Fecal Contamination of Surface Waters

Surface water contamination occurs when untreated fecal material from humans, pets, livestock, and wildlife directly or indirectly enters waters through a variety of pathways. Table 8 describes the pathways and sources of fecal contamination.

Table 8. Factors influencing fecal contamination of surface waters.

Pathway	Fecal Source(s)	Description
Stormwater Runoff	Human Pet Wildlife	Stormwater runoff is rain that falls on streets, parking areas, sports fields, gravel lots, rooftops or other developed land and flows directly into nearby lakes, rivers and Puget Sound. The drizzling or pounding rain picks up and mixes with what is on the ground, including feces.
Combined Sewer Overflow (CSO)	Human Pet Wildlife	Older parts of Seattle are served by a combined sewer system. This system was designed in the early 20th Century to carry sewage from buildings as well as stormwater runoff in a single pipe to a wastewater treatment plant. During dry weather, wastewater flows to a wastewater treatment plant. When it rains, the pipes can become overloaded. A mixture of stormwater (about 90 percent) and raw sewage may overflow into surface waters. CSOs discharge into Lake Washington, Lake Union/Ship Canal, Longfellow Creek, Elliott Bay, and Puget Sound.
Sanitary Sewer Overflow (SSO)	Human	Sanitary sewer overflows may be caused by: • Build-up of fats, oils, and grease or debris • Root intrusion • Pump station failure • Down-pipe capacity constraint • Line breaks • Sewer defects or improper design SSOs may enter surface waters by overland flow or through stormwater conveyance.
Agricultural Runoff	Livestock Wildlife	Rainfall on forage pasture and animal containment areas may be contaminated by manure and wildlife feces. Sufficient rainfall events may result in overflows from manure lagoons.
Failing Side Sewers and Leaky Sewer Pipes	Human	Failing side sewers may leak wastewater into the surrounding soils, contaminating groundwater. Via groundwater, pathogens may be transported to surface waters. Failing systems may also cause septage to surface, which may be transported by rainfall runoff.
Failing OSS	Human	Failing OSS may leak wastewater into the surrounding soils, contaminating groundwater. Via groundwater, pathogens may be transported to surface waters. Failing systems may also cause septage to surface, which may be transported by rainfall runoff.
Vessel Discharges	Human	Vessels may illegally discharge blackwater. Greywater may legally be discharged but may also contain fecal material.

Pathway	Fecal Source(s)	Description
Direct Deposition	Human Livestock Pet Wildlife	Animals may directly defecate into streams, lakes, and marine waters. Waterfowl and gulls are common contaminations sources along the shoreline. Humans without access to sanitary facilities may directly defecate in surface waters. Livestock may directly defecate in waters without exclusion fencing.

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2.0 DATA SOURCES AND METHODS

2.1 Surface Water Bacteria Monitoring Data Sources

Existing fecal indicator bacteria data were collated from monitoring programs operated by King County, Snohomish County, Washington State Department of Ecology, and Washington State Department of Health. Each program is operated individually and independently, and as such, both field and laboratory methods and protocols differ. Table 9 describes each of the monitoring programs, and Figure 4 displays the monitoring stations.

Table 9. Fecal indicator bacteria monitoring programs.

Program	Sampling Period	Sampling Frequency	Bacteria Monitored in 2013-2017	Laboratory Method	SAP or QAPP
King County Routine Streams	Full-year	Monthly	Fecal coliform	SM 9222D[a]	King County, 2002
Snohomish County Streams	Full-year	Monthly	Fecal coliform	SM 9222D[a]	Snohomish County, 2015
Ecology Streams	Full-year	Monthly	Fecal coliform	SM 9222D[a]	Ecology, 2003; Ecology, 2012
King County Routine Lakes	Full-year	Monthly (Oct. to Feb.) Bimonthly (Mar. to Sep.)	Fecal coliform	SM 9222D[a]	King County, 2017
King County Freshwater Swimming Beaches	Mid-May to Labor Day	Weekly	Fecal coliform	SM 9222D[a]	King County, 2005
King County Marine Beaches	Full-year	Monthly	Fecal coliform *Enterococcus*	SM 9222D[a] SM 9230C[b]	King County, 2003
Ecology Marine BEACH	Mid-May to Labor Day	Weekly	*Enterococcus*	ASTM D6503[c]	Ecology, 2014
DOH Shellfish Monitoring	Full-year	Randomized (between 6 and 12 times per year)	Fecal coliform	SM 9221E2[d]	FDA, 2015

a. Fecal Coliform by Membrane Filtration using mFC Medium
b. *Enterococcus* by Membrane Filtration using m*Enterococcus* Medium
c. Standard Test Method for Enterococci in Water Using Enterolert (TM)
d. Multiple-tube fermentation technique in A-1 medium.

Data collected between 2013 and 2017 were summarized to characterize current conditions in this report. Historic data were used to evaluate long-term trends. Within each monitoring program, the number and location of sites often changes from year to year. For this report, only sites with at least two full sampling periods are included. For the purposes of long-term trend analysis, historic *E. coli* and *Enterococcus* data for King County streams, lakes, and swimming beaches were also included.

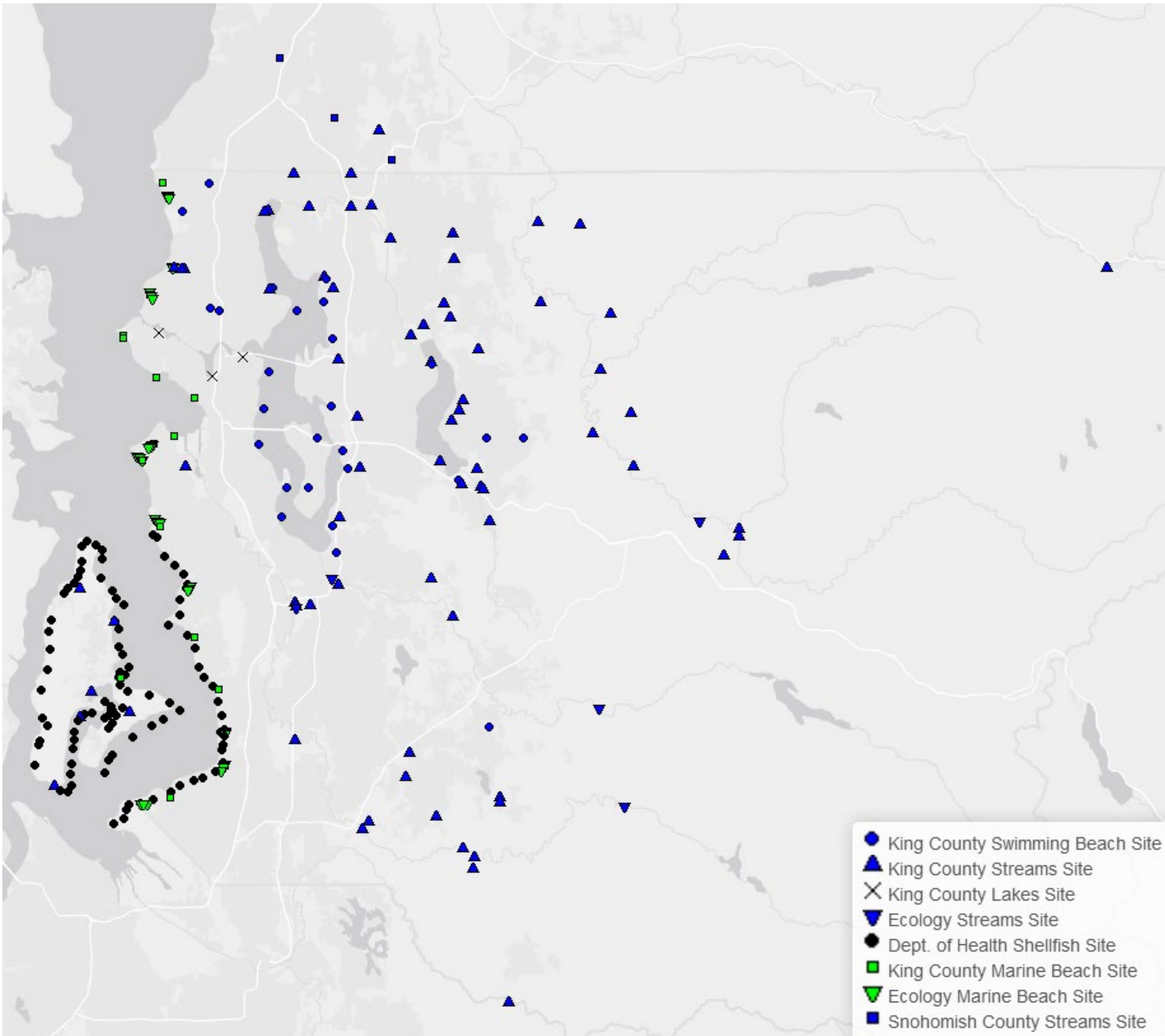

Figure 4. Bacteria monitoring stations sampled between 2013 and 2017 as part of long-term routine monitoring programs.

2.2 Watershed Delineation and Land Use Classification

Watershed land cover characteristics for areas draining to the monitoring stations was determined using the spatial data detailed in Table 10. The watershed characteristics were used in the development of a multivariate linear regression to assess how landscape factors influence bacteria levels in surface waters (see section 2.5 and Chapter 5).

Table 10. Spatial data sources and metadata.

Layer	Description	Year of Data	Resolution	Notes
Digital Ground Model (DGM)	Bare earth elevation	2016	3 ft	Used to delineate watersheds. DGM is an interpretation of the earth's surface where 90-95% of vegetation and man-made elevated features have been removed.
Stream Watershed	Stream watershed delineated by topography	2016	3 ft	Watersheds delineated using the ArcGIS Spatial Analyst tools (i.e., Flow Direction, Flow Accumulation, Watershed) and corrected as needed.
Lake and marine beach drainage areas	Lake and marine beach sampling site drainage areas delineated by topography	2016	3 ft	Beach drainage areas were defined as the upland area draining within a half-mile of the sampling site. Drainage areas were delineated using the ArcGIS Spatial Analyst tools (i.e., Flow Direction, Flow Accumulation, Watershed) and corrected as needed.
National Land Cover Database (NLCD) 2011 Land Cover	NLCD with 16 land cover classifications	2011	98 ft (30 m)	Homer et al., 2015
King County Agricultural Land Use 2013	Agricultural Land Uses identified through aerial photography and confirmed in some areas with field verification.	2013	Parcel	Complete coverage within the Agricultural Production Districts and on Vashon-Maury Island; partial coverage in rural areas.
King County OSS Parcels	Parcels identified by Seattle-King County Public Health as a high likelihood for using on-site sewage systems.	2015	Parcel	See section 2.3
Snohomish County OSS Parcels	Parcels identified as OSS in Snohomish Land Characteristics table	2017	Parcel	
Snohomish County Agricultural Use Parcels	Parcels identified as agricultural land use	2017	Parcel	Agricultural land use in Snohomish County was determined by parcels classified by a use code of: • 816 – Farms & Ranches – Livestock (Not Dairy) • 817 – Farms – Poultry • 818 – Farms – General • 819/829 – Other Agriculture & Related Activities • 822 – Animal Husbandry & Veterinary Services

Layer	Description	Year of Data	Resolution	Notes
				• 830 – Open Space Agriculture
2010 Census Block Population	Total population from 2010 Decennial Census	2010	Census Block	

The NCLD 2011 land cover dataset contains two agricultural classifications: Pasture/Hay and Cultivated Crops. In 2013, King County released a partial coverage of agricultural land use by individual parcel. Visual comparison of the two spatial datasets show apparent discrepancies (Figure A-1 in Appendix A). The NLCD 2011 dataset generally underestimated the amount of agricultural land in King County, specifically horse ranches, which are instead classified as Developed, Open Space or Developed, Low Intensity. Appendix A further details the comparison between the two datasets.

For the purpose of this analysis, it was important to capture livestock and equestrian land cover. Unmanaged or poorly managed manure may be a source of fecal bacteria to surface waters through runoff or direct defecation in flow paths. The 2013 King County land use dataset was selected for estimating the agricultural land cover in the watershed.

2.3 On-site Sewage Systems Inventory

A comprehensive database identifying OSS in King County was developed between late 2015 and early 2018. The database was developed by examining all 2015 parcels and the sewer pipelines/connections mapped by sewer companies/ districts, cities and other entities. Seattle-King County Public Health program staff looked at each parcel individually and determined whether a sewage system would most likely be needed and if the parcel was currently connected to the sewer according to existing records. The parcels identified in the database are not confirmed to have OSS. Seattle-King County Public Health does not necessarily have a specific record of an OSS on the parcel. The OSS inventory provides a reasonable estimate for the number OSS systems in King County watersheds.

2.4 Long-term Trend Analyses

Long-term trends in bacteria levels were evaluated for monitoring sites with ten or more years of monitoring data. This dataset includes many sites that are no longer monitored, especially within lakes Washington and Sammamish. Fecal coliform bacteria were monitored in these lakes since the 1970s and 1980s thorough 2008.

The seasonal Mann-Kendall test was employed. The seasonal Mann-Kendall test is a non-parametric test that evaluates monotonic trends in a seasonally-impacted dataset. A monotonic trend is a consistent upward and downward trend. For this analysis, months were used as the block group, i.e., trends were evaluated separately for January observations, for February observations, etc., and an overall test statistic is determined based on the results from each month. The "rkt" package was used to evaluate trends in R v3.5.0 (Marchetto, 2017).

2.5 Robust Multivariate Linear Regression

Multiple regression analyses were completed to estimate the contribution of the land cover and OSS density on surface water bacteria levels at routinely monitored sites. Multivariate linear regression models were constructed for King County stream, freshwater swim beach, and marine beach data, for Ecology marine BEACH data, and for DOH data. Snohomish County and Ecology stream sites were not used because they were upstream of nearby King County stream sites. In cases where several monitoring sites existed on one stream, only the furthest downstream site was used in the regression analysis. Sites in Lake Union/Ship Canal were not used because they are not located near the shoreline.

The geometric mean and 90th percentile of the fecal coliform concentration for data collected between 2013 and 2017 were regressed on landscape metrics and, where applicable, average salinity. For King County streams and marine beach programs, the geometric mean and 90th percentile statistics were log-transformed to normalize the residuals and linearize the relationship with the landscape factors. This was done based on diagnostic plots of the residuals. Table 11 details the landscape metrics and their caveats.

$$FIB_{GM} = a + B_1 * OSS + B_2 * AGRI + \ B_3 * Pop.Dens + B_4 * Salinity$$
$$FIB_{90TH} = a + B_1 * OSS + B_2 * AGRI + \ B_3 * Pop.Dens + B_4 * Salinity$$

Or for log-transformed statistics (King County streams and marine beaches):

$$FIB_{GM} = \exp(a + B_1 * OSS + B_2 * AGRI + \ B_3 * Pop.Dens + B_4 * Salinity)$$
$$FIB_{90TH} = \exp(a + B_1 * OSS + B_2 * AGRI + \ B_3 * Pop.Dens + B_4 * Salinity)$$

where:

FIB_{GM} = Fecal coliform or *enterococcus* bacteria geometric mean for years 2013 to 2017
FIB_{90TH} = Fecal coliform or *enterococcus* bacteria 90th percentile for years 2013 to 2017
a = intercept
B_x = Slope factor (coefficient)
OSS = Number of OSS users per acres in the watershed
AGRI = Fraction of watershed that is an agricultural land use
Pop.Dens = Population density in watershed (based on 2010 Census block data)
Salinity = Average salinity (2013 – 2017; ppt) – only used for marine programs

Variance inflation factors were used to detect multi-collinearity in the regression models. Inclusion of a strongly correlated model variable can interfere with regression results. When two variables were strongly correlated (i.e., a variance inflation factor value greater than 10), the variable with weaker correlation with the dependent variable was excluded. For example, the population density and the percent forested area were strongly negatively correlated, and because population density had a stronger correlation with the dependent variable, percent forested was excluded from the regression model.

Robust linear regression was used instead of ordinary least squares regression. While being the most common regression technique, ordinary least squares regressions are highly sensitive to outliers. Robust linear regression, an alternative to least squares regression, was used because of its ability to handle outliers, such as non-normally distributed measurement errors (Maronna and Yohaj 2000; Todorov and Filzmoser 2009). The 'lmrob' script in the "robustbase" R package was used for applying robust linear regressions (Maechler et al. 2017; Todorov and Filzmoser, 2009). This function computes an MM-type regression estimator as described in Yohai (1987) and Koller and Stahel (2011). See Maronna et al. (2006) and Anderson (2008) for more discussion of robust statistical analysis.

The regression models only look at upstream, upland land use and do not consider transport caused by tides and currents at the marine sites and freshwater swimming beaches. Unlike streams where water movement is typically unidirectional, lakes and marine waters may be influenced from many directions. Since marine water is saline, it is not expected bacteria will survive for an extended period and be transported to distant areas along the shoreline. Bacteria survives longer in freshwaters and water movement within lakes caused by wind and currents may influence a greater area. To better consider the influence of water movement, marine and lake watersheds were delineated based on the land area that drains 1000 feet up-shore and 1000 feet down-shore of the sampling site. This attempts to capture all upland land use that may influence bacteria levels.

Some of the watersheds for DOH monitoring sites were small (10 to 200 acres). At this scale, upland conditions may not strongly influence water quality. Tidal and current movement of surrounding waters may drive the water quality at these small watershed sites. Furthermore, in smaller watersheds, the assumptions associated with OSS, population density, and agricultural land use shown in Table 11 are more unlikely to hold due to uncertainty at such a fine scale. For example, OSS failures are expected to occur at a consistent rate across large landscapes, but in a small watershed with a small number of OSS, the actual rate may be very different than that seen on average. Therefore, the analysis was only completed for DOH watersheds greater than 200 acres in area.

Table 11. Explanation of independent variables used in multivariate regression analysis.

Variable	Explanation	Caveats and Assumptions
OSS Users Per Acre	Proxy for failing or improperly sited OSS that discharge bacteria to waterbodies.[a]	Assumes consistent rate of failure across region. Does not consider likelihood of effluent to reach waterbody (i.e., soil type, distance to water, OSS treatment technology)
Population Density	Population density is a proxy for many types of bacteria pollution present in the urban environment, including: • Failing side sewers and leaking public sewer lines (including mis-connected) • Urban runoff of pet and wildlife (e.g., rodent, bird) fecal waste • Combined and sanitary sewer overflows • Encampments without sanitary facilities	Pollutant generation is variable across the urban environment based on age of side sewers, presence of urban forest areas, nearshore landscaping, and presence of sewer and stormwater outfalls. Based on 2010 Census data

Variable	Explanation	Caveats and Assumptions
Agricultural Land Use	Represents potential for fecal contamination due to poorly and improperly managed manure, application of manure as fertilizer to fields, and unrestricted access to streams.	Does not consider installed agricultural best management practices and manure management plans.
Average Salinity	Bacteria survivorship has been shown to be greatly impacted by water salinity. Only used for marine program regression.	Temperature and sunlight are additional environmental factors that significantly impact bacteria survivorship. These variables were not measured consistently across programs.

a. Studies reviewed by USEPA cite failure rates ranging from 10 to 20 percent (EPA, 2003). System failure surveys typically do not include systems that might be contaminating surface or ground water, a situation that often is detectable only through site-level monitoring.

The OSS users per acre independent variable assumes the influence of OSS on the bacteria levels in surface waters is consistent in each watershed. This does not consider the geographic distribution of different OSS technology, OSS age, soil drainage type, and OSS distance to water body. Calculating an OSS Risk of Contamination variable based on the identified factors was considered. Unfortunately, no such method for weighting OSS exists in the literature and it was determined that the weights would be arbitrary. While exploring the creation of this variable for this analysis, it was consistently found that the overall density of OSS in a watershed drove the estimated OSS risk statistic. Therefore, it was determined that OSS density was a suitable proxy for failing or improperly sited OSS that discharge bacteria to waterbodies. During source investigation and control efforts in individual watersheds, it is recommended that the identified risk factors be evaluated in targeting initial efforts.

Table 12 provides the summary statistics for the variables assessed in the regression analysis.

Table 12. Summary statistics for factors assessed for regression analysis.

Monitoring Program	Statistic	OSS Users Per Acre	Population Density	Agricultural Area	Average Salinity
King County Streams	**Average**	0.39	2.87	3.53	*Not Assessed*
	Standard Deviation	0.40	3.31	6.97	
	25th Percentile	0.09	0.43	0.03	
	75th Percentile	0.62	4.27	4.10	
King County Marine Beaches	**Average**	0.47	6.93	*Not Assessed (few watershed with agricultural land cover)*	27.1
	Standard Deviation	0.78	5.67		1.5
	25th Percentile	0.00	1.53		26.0
	75th Percentile	0.75	10.8		28.1

Monitoring Program	Statistic	OSS Users Per Acre	Population Density	Agricultural Area	Average Salinity
King County Freshwater Swimming Beaches	**Average**	0.10	7.71	*Not Assessed (no watershed with agricultural land cover)*	*Not Assessed*
	Standard Deviation	0.22	5.28		
	25th Percentile	0.00	4.52		
	75th Percentile	0.07	9.34		
Ecology Marine Beaches	**Average**	0.24	7.04	*Not Assessed (few watershed with agricultural land cover)*	28.1
	Standard Deviation	0.42	3.89		1.5
	25th Percentile	0.00	5.31		27.3
	75th Percentile	0.21	10.60		29.1
DOH Shellfish Sites	**Average**	1.00	1.92	2.90	27.5
	Standard Deviation	1.04	2.45	5.73	1.1
	25th Percentile	0.29	0.36	0.00	26.6
	75th Percentile	1.25	2.39	2.48	28.4

3.0 FECAL INDICATOR BACTERIA CURRENT CONDITIONS

This chapter summarizes the fecal indicator bacteria levels measured by King County, Snohomish County, Department of Ecology, and Department of Health at routine monitoring locations on streams, rivers, freshwater beaches, large lakes, and Puget Sound beaches. The summary statistics for monitoring data from 2013 to 2017 for each site is presented in Appendix D.

Each site was compared to the relevant water quality criteria or guidelines for each year sampled. If any year failed to meet the criteria or guidelines, the site was designated as not meeting standards. The exception was DOH shellfish sites where all samples collected between 2013 and 2017 at a site were used to calculate the geometric mean and estimated 90th percentile.

Of the 237 sites monitored for fecal indicator bacteria in King County from 2013 to 2017, 83 sites exceeded water quality criteria or guidelines for either fecal coliform or *Enterococcus* (Table 13; Figure 5). Seven stream sites in the Lake Washington watershed monitored in Snohomish County by Snohomish County or King County also exceeded criteria for fecal coliform bacteria.

Table 13. Water quality stations exceeding water quality criteria or guidelines in King County waters from 2013 to 2017.

Program	Fecal Indicator Bacteria	Number of Sites	Number of Sites Above Geometric Mean Criterion or Guideline	Number of Sites Above STV Criterion or Guideline	Number Above Either GM or STV	Criteria or Guideline Used
King County Routine Streams	Fecal Coliform	74	27	50	50	WA Freshwater Primary Contact
Snohomish County Streams	Fecal Coliform	3	2	3	3	WA Freshwater Primary Contact
Ecology Streams	Fecal Coliform	5	0	1	1	WA Freshwater Primary Contact
King County Routine Lakes	Fecal Coliform	3	0	0	0	WA Freshwater Primary Contact
King County Swimming Beaches	Fecal Coliform	26	5	18	18	WA Freshwater Primary Contact

Program	Fecal Indicator Bacteria	Number of Sites	Number of Sites Above Geometric Mean Criterion or Guideline	Number of Sites Above STV Criterion or Guideline	Number Above Either GM or STV	Criteria or Guideline Used
King County Marine Beaches	Fecal Coliform	20	8	16	16	WA Marine Primary Contact
	Enterococcus	20	0	8	8	EPA
Ecology BEACH	*Enterococcus*	10	0	0	0	EPA
DOH Shellfish Monitoring	Fecal Coliform	102	0	1	1	DOH
All Sites	Fecal Coliform, or *Enterococcus*	**243**	**42**	**90**	**90**	**WA, EPA, or DOH**

STV: statistical threshold value. EPA and DOH guidelines compare to 90th percentile and WA State Water Quality Standards use "no more than 10 percent of samples exceed"

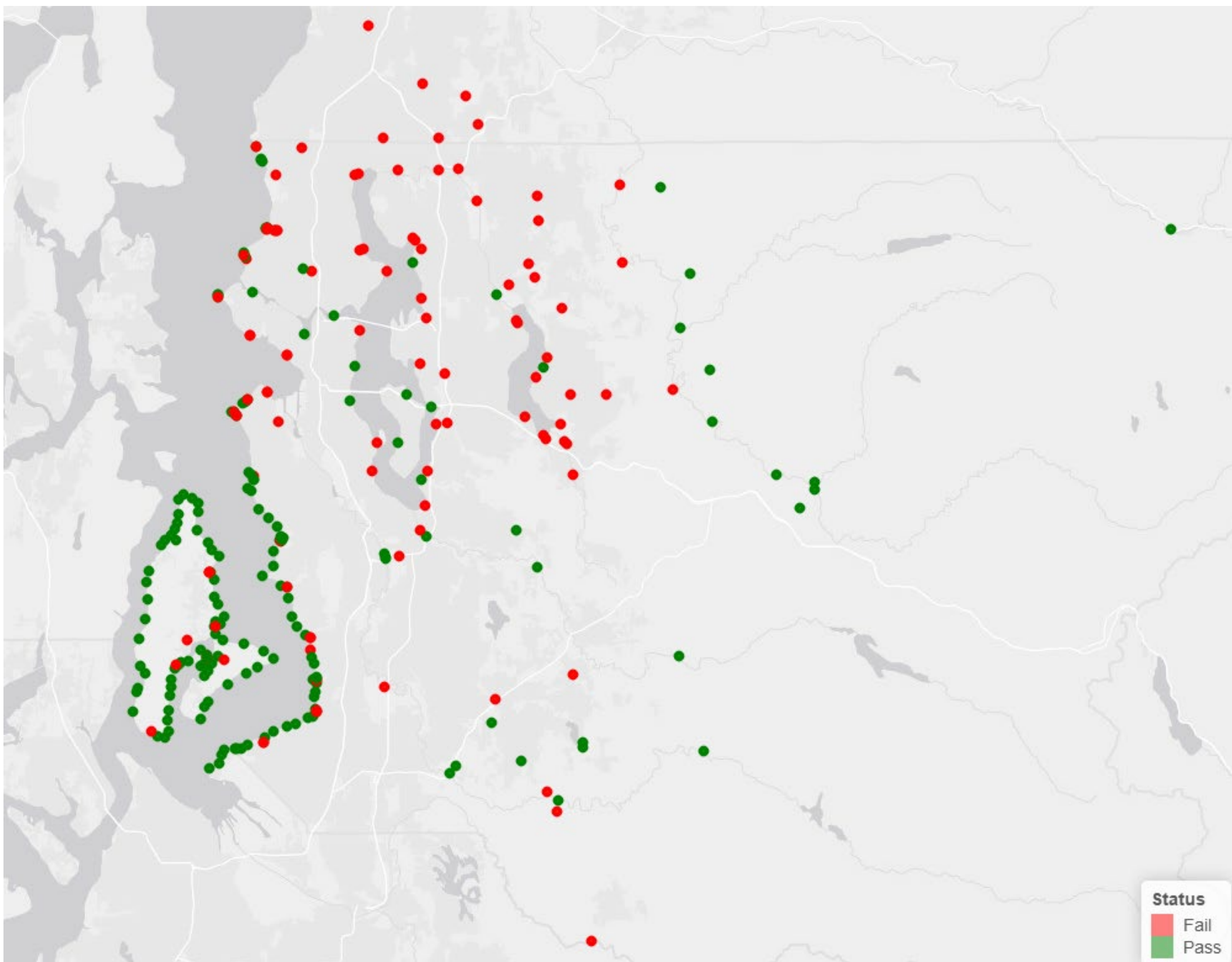

Figure 5. Surface water monitoring sites compared to WA state water quality criteria and EPA or DOH guidelines (data from 2013 to 2017).

4.0 RELATIONSHIP BETWEEN BACTERIA, LAND USE, AND ON-SITE SEWAGE SYSTEMS

The influence of OSS and other land use factors on regional water quality was assessed. Multivariate linear regression models were constructed for King County stream, freshwater swim beach, and marine beach data, for Ecology marine BEACH data, and for DOH data. The statistically significant regression coefficients are displayed in Table 14.

Figure 6 summarizes the regression results using standardized coefficients for each variable and monitoring program. Standardized coefficients show the relative influence of each variable. See Appendix F for details on each regression. Appendix G presents the data employed in the regression.

The density of OSS in a watershed was found to positively influence bacteria for all programs for the geometric mean, the 90th percentile, or both. In most cases, with increasing OSS density, there was a strong association with increased bacteria levels, while taking into account the effects of population density and, if applicable, agricultural land use and salinity. King County's swimming beaches were the most sensitive to increases in OSS users, with the statistics greatly increasing for each addition user per acre (51.8 and 818 CFU/100 mL per user/acre for the GM and 90th percentile respectively).

Population density most commonly had a strong, positive influence on bacteria levels (i.e., greater population density was associated with greater bacteria levels). Exceptions included King County freshwater swimming beaches and Ecology BEACH sites. Swimming beach sites had no specific directional relationship with population density. The marine BEACH sites showed a tendency toward a positive influence of population density, but there was insufficient evidence. Public beaches often have landscaping that is conducive to waterfowl. At these beaches, population density may not capture the pollution generation associated with the park, e.g., resident waterfowl, dog waste. The model could be better refined with data on dog use and waterfowl density.

The influence of agriculture could be assessed for only King County stream sites and DOH sites. All other programs lacked a sufficient number of watersheds with agricultural land use to adequately assess its influence. Agricultural land use was found to significantly influence bacteria levels in streams, but no such relationship was seen for the DOH sites.

Salinity was a significant negative factor for bacteria levels at all marine sites. The influence of salinity was not assessed in freshwaters. Numerous studies have shown decreasing survivorship of fecal coliform, *E. coli*, and *enterococcus* with increasing salinity.

Model R^2 may be used to assess how effective the model is in predicting the bacteria levels, i.e., the model explains what percent of the variability. The King County swimming beaches models performed the most poorly, accounting for less than 10 percent of the variability in bacteria levels. For the other programs, the models explained between 34 and 76 percent of the variability. This suggests that additional factors not included in the model are influencing bacteria levels, in addition to the natural variability seen in bacteria data. These factors likely include, but are not limited to, frequency and type of recreational use, adjacency to stormwater or CSO outfalls, presence of homeless encampments, pet and wildlife usage, and vessel discharge. These factors are likely to vary between sites, season, and year. In urban areas, wooded stream ravines are among the few undeveloped regions and may serve as an important refuge for wildlife.

Table 14. Significant (p<0.10) factor coefficients for annualized fecal indicator bacteria statistics. Due to log-transformation, the coefficients for King County streams and marine beaches are relative percent increases.

Monitoring Program	Statistic	OSS Users Per Acre	Population Density	Agricultural Area	Average Salinity
	Unit	Change in CFU/100 mL per 1 OSS user increase per acre	Change in CFU/100 mL per 1 person increase per acre	Change in CFU/100 mL per 1% increase in agriculture	Change in CFU/100 mL per 1 ppt increase in salinity
King County Streams	Geometric Mean	No significant relationship	23.6%	5.7%	*Not Assessed*
	90th Percentile	51.7%	24.1%	7.0%	
King County Marine Beaches	Geometric Mean	No significant relationship	2.9%	*Not Assessed (few watershed with agricultural land cover)*	-22.6%
	90th Percentile	24.4%	5.8%		--37.3%
King County Freshwater Swimming Beaches	Geometric Mean	51.8	No significant relationship	*Not Assessed (no watershed with agricultural land cover)*	*Not Assessed*
	90th Percentile	819	No significant relationship		
Ecology Marine Beaches	Geometric Mean	No significant relationship	No significant relationship	*Not Assessed (few watershed with agricultural land cover)*	-2.1
	90th Percentile	25.6	No significant relationship		-12.1
DOH Shellfish Sites	Geometric Mean	0.4	0.2	No significant relationship	-0.2
	90th Percentile	6.4	1.9	No significant relationship	No significant relationship

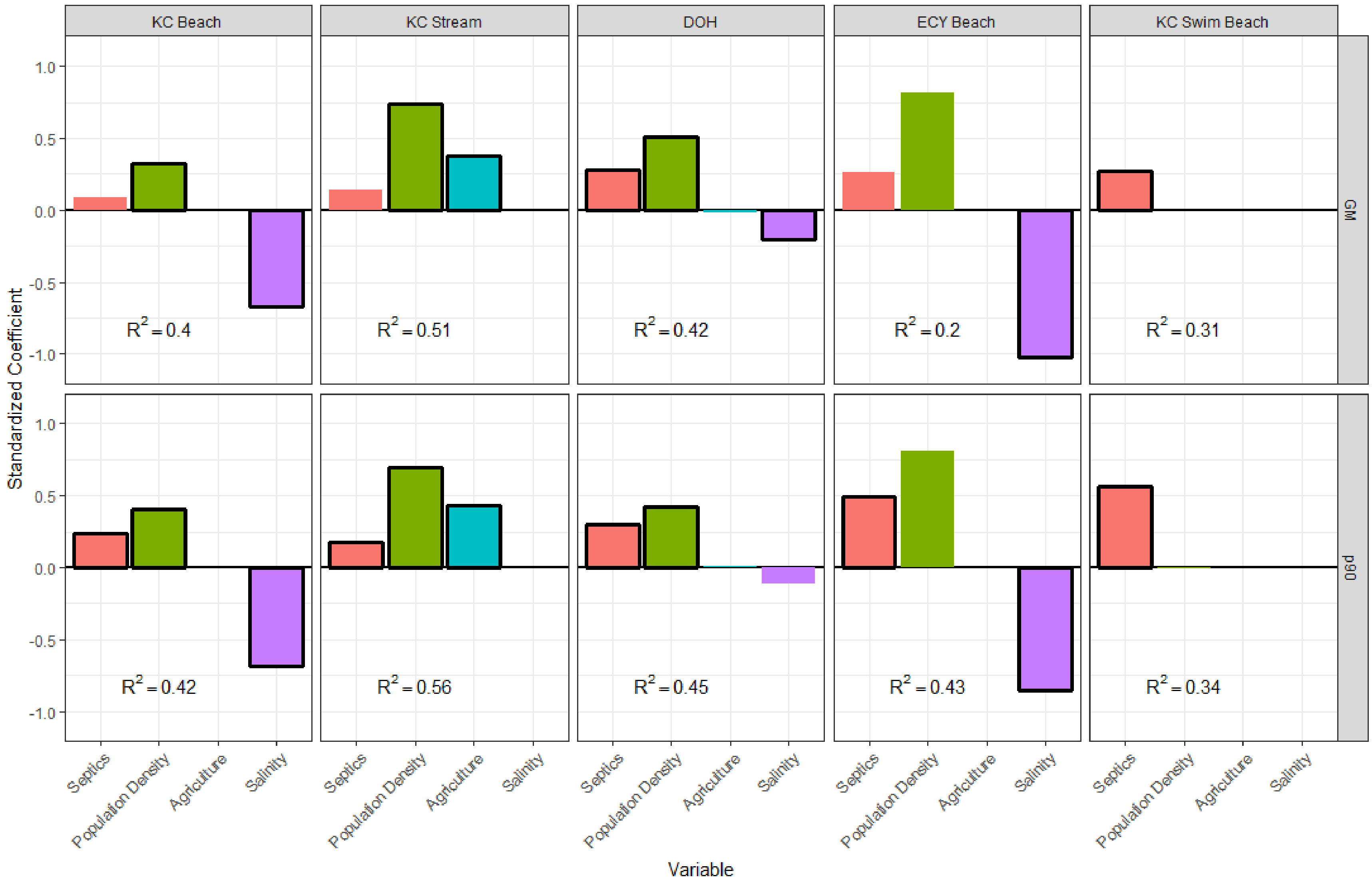

Figure 6. Standardized coefficients for the robust multivariate regression for the geometric mean (top row) and 90th percentile (bottom row) indicator bacteria levels for all seasons. Significant coefficients at the α=0.10 level of significance outlined in bold. Note that the Ecology Beach and King County swim beach program sampling in the spring and summer.

5.0 TRENDS IN BACTERIA LEVELS

Long-term trends in bacteria levels were evaluated for surface water monitoring sites with ten or more years of monitoring data. The seasonal Mann-Kendall test was used. Results for the trend test for each site are presented in Appendix E. Table 15 summarizes the direction of the statistically significant trends for each monitoring program.

The majority of long-term freshwater monitoring sites had decreasing levels of bacteria. One of the greatest decreases was Bear Creek, which decreased from a geometric average of 640 CFU/100 mL in the 1970s to 59 CFU/100 mL in 2013-2017. A summary of freshwater trends is provided below:

- The majority of streams sites monitored by King County since the 1970s showed significant decrease in fecal coliform (47 of 63 sites). May and Covington creeks had increasing trends for *enterococcus* from 1989 to 2002, but May Creek had a decreasing trend for fecal coliform from 1977 to 2017. No long-term trend for fecal coliform in Covington Creek from 1977 to 2017 was found.
- One of Snohomish County's three long-term streams sites (Swamp Creek) showed significant decrease in fecal coliform since the mid-2000s.
- Three of Ecology's five long-term sites showed significant decrease in fecal coliform since the 1970s. One site increased significantly from an average of 8 to 11 CFU/100 mL (07D130 – Snoqualmie River at Snoqualmie, WA).
- Twenty-one of King County's 25 lakes sites showed significant decrease in fecal coliform.
- Six of King County's 20 swimming beach sites showed significant decrease in fecal coliform. (Juanita Beach, Matthews Beach, Mount Baker Beach, Meydenbauer Bay Beach, Madison Park Beach, Madrona Beach).

The King County marine beach data indicates four of six sites with significantly decreasing bacteria levels, including Richmond Beach where levels decreased from a geometric average of 26 CFU/100 mL in the 1970s to 7 CFU/100 mL in 2013-2017. A summary of marine trends is provided below:

- Three of King County five marine beaches showed significant decrease in fecal coliform and *enterococcus* since the 1970s and 1980s. (Richmond Beach, two West Point beaches). One site (Gorsuch Road Beach [Vashon Island]) showed significant decrease from 2002 to 2017 for *enterococcus* but no trend was found for fecal coliform.
- No Ecology BEACH site showed significant decrease in *enterococcus* since 2004. One site (Alki Beach) increased significantly from an average of 11 to 14 CFU/100 mL.
- Three of DOH's 80 sites showed significant decrease since the 1980s. In many cases, fecal coliform bacteria were not detected in DOH samples

Table 15. Seasonal Mann-Kendall trend results for monitoring location with 10 or more years of data.

Program	Parameter	Monitoring Program Period	Sites with 10+ Years of Data	Sites with Significant Positive Slope	Sites with Significant Negative Slope
King County Routine Streams	Fecal Coliform	Mid-1970s to Present	63	**0**	**47**
	E. coli	1998-2008	13	**1**	**5**
	Enterococcus	Late-1980s to 2002	42	**3**	**2**
Snohomish County Streams	Fecal Coliform	Mid-2000s to Present	3	**0**	**1**
Ecology Streams	Fecal Coliform	Early-1970s to present	5	**1**	**3**
King County Routine Lakes	Fecal Coliform	Mid-1970s to Present	25	**0**	**21**
	E. coli	1999-2014	3	**0**	**1**
	Enterococcus	1989-2002	15	**0**	**10**
King County Swimming Beaches	Fecal Coliform	Mid-1990s to Present	20	**0**	**6**
	E. coli	1999-2008	12	**0**	**3**
King County Marine Beaches	Fecal Coliform	Early-1970s to Present	6	**0**	**3**
	Enterococcus	Early-1980s to Present	6	**0**	**4**
Ecology BEACH	*Enterococcus*	2004 to Present	21	**1**	**0**
DOH Shellfish Monitoring	Fecal Coliform	Late-1980s to Present	80	**0**	**3**

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6.0 SUMMARY

Bacteria contamination of Puget Sound, lakes, rivers, and streams is a widespread problem throughout King County.

- There are 172 waterbody areas listed as impaired for bacteria in King County according to the Washington State Department of Ecology's Water Quality Assessment – 59 of these have a pollution control plan in place.
- Bacteria contamination has led to the closure of many commercial and recreational shellfish harvest areas in King County.
- There are 9,612 acres of commercial shellfish growing areas in King County. About half are open for year-round harvest. Additionally, a 163-acre area in Poverty Bay is closed from June 1 to November 30.
- There are 37 public shellfish beaches in King County. As of October 25, 2018, all are closed due to biotoxin concerns and sixteen are closed due to fecal contamination concerns.

Bacteria monitoring data from King County, Snohomish County, Ecology, and DOH support that bacteria is a regional water quality issue.

OSS, urban pollution and development, and agricultural activity are important factors driving bacteria levels in surface waters.

Multivariate regression analysis was completed to examine how land use and environmental factors are linked to surface bacteria concentrations. The density of OSS, population, and agricultural land use were included in the analysis. Salinity was also considered for marine programs. Table 16 summarizes the findings of the regression analysis.

The OSS density was linked to increased bacteria levels in surface waters for all assessed monitoring programs. Failing or improperly sited OSS may leach insufficiently treated effluent into groundwater or allow septage to surface. Through groundwater transport or runoff of septage, surface waters may be contaminated.

Population density showed strong association with bacteria levels for all programs except King County's freshwater swimming beach and Ecology's BEACH programs. These beaches are each associated with public parks. Public beaches often have landscaping that is conducive to waterfowl. Beach users may also contaminate surface waters, such as children with soiled diapers. At these beaches, population density may not capture the pollution generation associated with the park (e.g., resident waterfowl, dog waste).

Agricultural land use was found have a significant positive relationship with bacteria levels for King County's stream program and no other program. This is due, in part, to the low number of watersheds in the other programs with substantial levels of agriculture. The stream program regression results indicate that agricultural land use may be associated with greater bacteria levels. In King County, agricultural is generally concentrated in the

Snoqualmie Valley, Vashon Island, the Enumclaw Plateau, and the Sammamish Valley, with some small-scale hobby and equestrian farms throughout rural King County. No relationship was found for agricultural area for the DOH shellfish program. Watersheds with agriculture contributing to DOH sites were found on Vashon Island only.

Salinity was an important factor for marine monitoring sites. Increased salinity is expected to result in decreased bacteria survivorship.

Table 16. Summary of relationship between fecal indicator bacteria from 2013 to 2017, landscape attributes, and average salinity (marine sites only) based on multivariate regression results. Significance evaluated at α=0.10.

Monitoring Program	OSS Users Per Acre	Population Density	Agricultural Area	Average Salinity
King County Streams	**Significant Positive Relationship**	**Significant Positive Relationship**	**Significant Positive Relationship**	*Not Assessed*
King County Marine Beaches	**Significant Positive Relationship**	**Significant Positive Relationship**	*Not Assessed (few watershed with agricultural land cover)*	**Significant Negative Relationship**
King County Freshwater Swimming Beaches	**Significant Positive Relationship**	No significant relationship	*Not Assessed (no watershed with agricultural land cover)*	*Not Assessed*
Ecology Marine Beaches	**Significant Positive Relationship**	No significant relationship	*Not Assessed (few watershed with agricultural land cover)*	**Significant Negative Relationship**
DOH Shellfish Sites	**Significant Positive Relationship**	**Significant Positive Relationship**	No significant relationship	**Significant Negative Relationship**

Bacteria levels in surface waters have decreased across the region since the 1970s. Several long-term monitoring programs have measured fecal indicator bacteria levels in the region since the 1970s. Bacteria levels were found to be significantly decreasing at the majority of long-term freshwater monitoring sites. Significant decreasing trends were also found for several marine sites. Three of the DOH sites had decreasing trends. Increasing trends were found at few sites.

The regression analysis concluded that population density was a significant positive factor for differences in bacteria levels between watersheds. Yet, despite increasing population density throughout the region, bacteria levels have decreased.
Several factors are hypothesized to be driving the decreasing trends in fecal indicator bacteria in the region:

- Stormwater management by public agencies and the private sector per and beyond state regulations
- Conversion of aging OSS to sewered or updated OSS
- Decreasing agricultural land cover and improved manure management

- Increased resident awareness and stewardship

Population density is a proxy for several factors: density and age of sewer systems (the densest urban areas often have the oldest infrastructure in place), homeless encampments, rodent and pet waste generation, impervious surfaces and stormwater infrastructure that convey contaminated runoff to surface waters, and point sources such as combined sewer overflows. Breaking out these components in future analyses could further reveal what factors are driving surface water contamination and how cities can approach improve bacteria issues in dense urban areas.

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Appendix A: Comparison between NLCD 2011 Agricultural Land Use and King County 2013 Agricultural Land Use

The National Land Cover Database (NLCD) 2011 land cover dataset contains two agricultural classifications: Pasture/Hay and Cultivated Crops. In 2013, King County released a partial coverage of agricultural land use by individual parcel. Visual comparison of the two spatial datasets show apparent discrepancies (Figure A-1). The NLCD 2011 dataset generally underestimated the amount of agricultural land in King County, specifically horse ranches, which are instead classified as Developed, Open Space or Developed, Low Intensity. Figure A-2 provides an example of the disagreement between the two data sources.

For the purpose of this analysis, it was important to capture livestock and equestrian land cover. Unmanaged or poorly managed manure may be a major source of fecal bacteria to surface waters through runoff or direct defecation in flow paths.

The King County 2013 Current Use dataset likely overestimates the total amount of area dedicated to agricultural activities. Portions of an identified parcel may not be used for agricultural purposes, such as homesteads or lawn/landscape. On average, the NLCD dataset resulted in 68 percent of the agricultural land estimated using the parcel dataset.

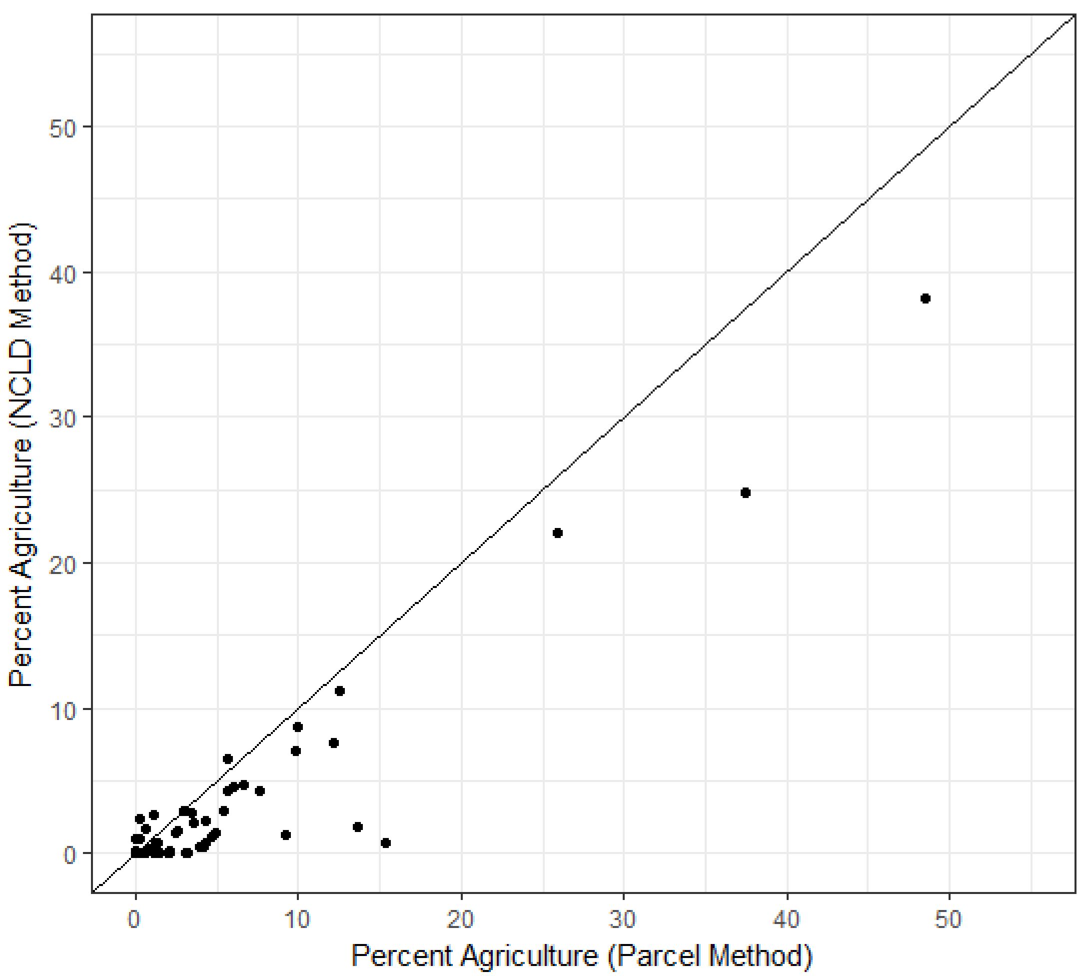

Figure A-1. Watershed comparison of the NLCD 2011 agricultural land cover classification and parcel identified as agricultural use by King County. One-to-one ratio line shown.

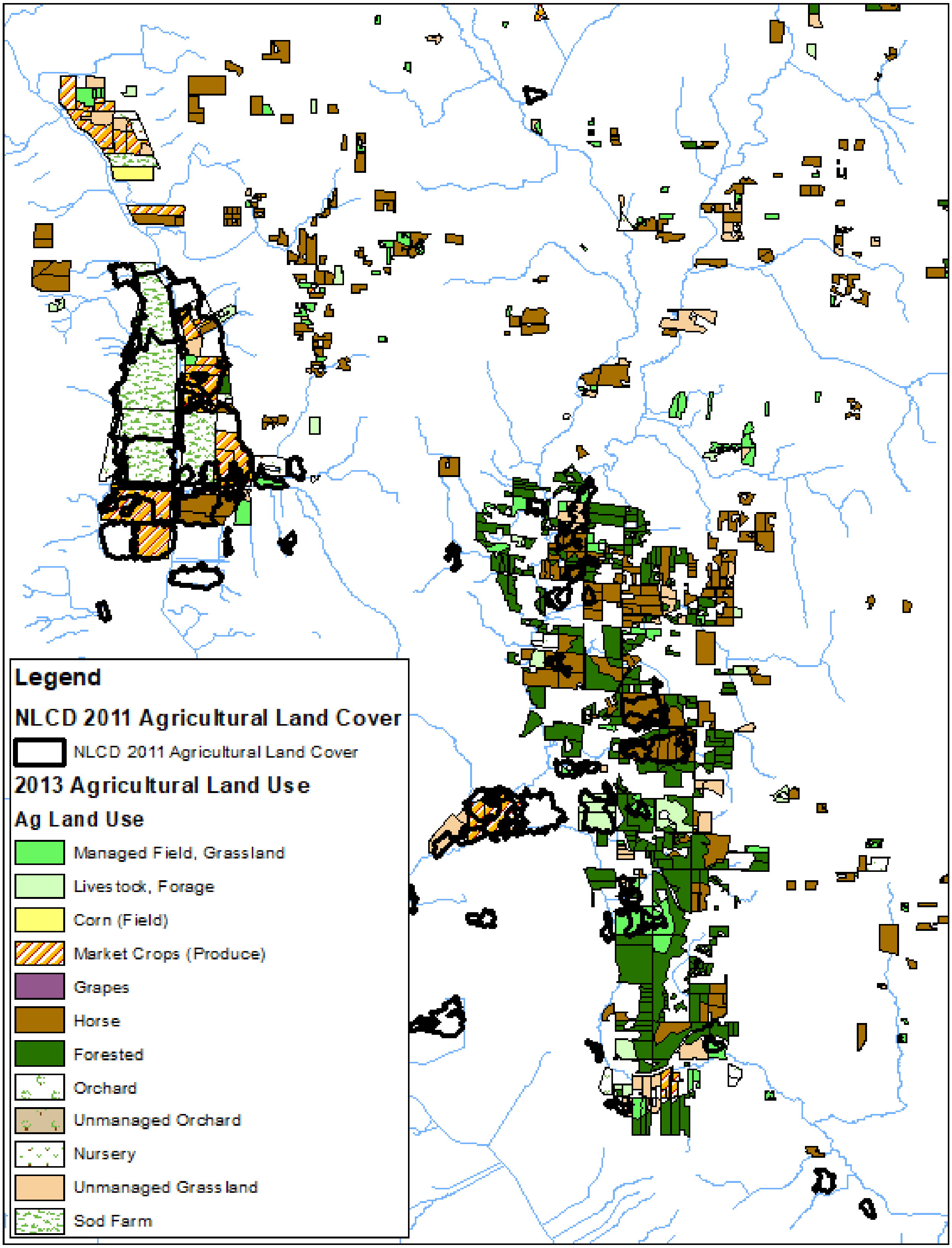

Figure A-2. Example comparison of the NLCD 2011 agricultural land cover classification and parcel identified as agricultural use by King County.

Table A-1. Watershed comparison of the NLCD 2011 agricultural land cover classification and parcel identified as agricultural use by King County.

Locator	Percent Agriculture (Parcel Method)	Percent Agriculture (NLCD Method)
0309	5.7	4.4
0311	6.0	4.5
0317	0.3	1.1
0321	2.9	2.9
0322	48.5	38.2
0430	0.0	0.0
0434	0.0	0.0
0438	1.3	0.8
0440	4.2	0.4
0442	0.0	0.1
0444	0.6	0.0
0446	0.0	0.0
0450	2.5	1.4
0450CC	3.5	2.1
0456A	0.0	0.0
0470	0.5	0.0
0474	0.0	0.1
0478	0.0	0.0
0484	4.7	1.1
0486	2.6	1.5
0631	4.3	2.3
0632	0.9	0.3
3106	6.0	4.5
A315	5.7	6.5
A319	6.6	4.7
A320	3.4	2.8
A432	0.0	0.0
A438	1.2	0.7
A499	0.0	0.0
A617	0.0	0.0
A620	0.0	0.0
A631	5.3	2.9
A670	1.4	0.0
A680	3.1	0.0
A685	0.0	0.0
A690	1.1	0.0

Locator	Percent Agriculture (Parcel Method)	Percent Agriculture (NLCD Method)
AMES_1	25.9	22.1
B319	1.1	0.5
B484	4.3	0.7
B499	0.0	0.0
BB470	0.0	0.0
BSE_ 1MUDMTNRD	12.6	11.2
C320	1.2	2.6
C370	0.0	0.0
C484	4.0	0.5
CHERRY_1	1.9	0.0
D320	4.9	1.4
D474	0.0	0.1
FF321	0.6	1.7
G320	7.6	4.3
GRIFFIN	0.1	0.0
HARRIS_1	3.2	0.0
KSHZ06	0.0	0.0
KTHA02	0.0	0.0
KTHA03	0.0	0.0
LSIN1	0.2	2.4
LSIN9	0.0	0.9
MFK_SNQ	0.1	0.0
N484	1.3	0.1
NFK_SNQ	0.2	0.1
PATTER_3	9.9	8.8
RAGING_MTH	0.6	0.0
S478	0.0	0.1
S484	2.1	0.2
SFK_SNQ	0.2	0.0
SKYKOMISH	0.0	0.0
SNQDUVALL	9.8	7.0
TOLT_MTH	0.0	0.0
VA12A	13.6	1.8
VA37A	2.1	0.0
VA41A	37.5	24.8
VA42A	12.1	7.7
VA45A	9.2	1.3

Locator	Percent Agriculture (Parcel Method)	Percent Agriculture (NLCD Method)
VA65A	15.4	0.8
X630	0.0	0.1

Appendix B: 303(d) Listed Waterbodies in King County for Bacteria Impairment

Table B-1. Impaired waterbodies of King County

Waterbody Name	Listing ID(s)	Category	Water Quality Improvement Project (if any)	Watershed
Bear Creek	13133 13144 13146	4A	Bear Evans Watershed Bacteria TMDL	Cedar-Sammamish
Cottage Lake Creek	13147	4A	Bear Evans Watershed Bacteria TMDL	Cedar-Sammamish
Daniels Creek	72239	4A	Bear Evans Watershed Bacteria TMDL	Cedar-Sammamish
Evans Creek	13142	4A	Bear Evans Watershed Bacteria TMDL	Cedar-Sammamish
Issaquah Creek	9842 12560 46447 46448	4A	Issaquah Creek Basin Bacteria TMDL	Cedar-Sammamish
Issaquah Creek, north fork	15769	4A	Issaquah Creek Basin Bacteria TMDL	Cedar-Sammamish
Lewis Lane (Hope) Creek	46449	4A	Issaquah Creek Basin Bacteria TMDL	Cedar-Sammamish
Little Bear Creek	13132	4A	Little Bear Creek Bacteria TMDL	Cedar-Sammamish
Mohlendorph Creek	74670 74671	4A	Bear Evans Watershed Bacteria TMDL	Cedar-Sammamish
Pipers Creek	15798	4A	Pipers Creek Bacteria TMDL	Cedar-Sammamish
Swamp Creek	13130	4A	Swamp Creek Bacteria TMDL	Cedar-Sammamish
Tibbetts Creek	13138 15779	4A	Issaquah Creek Basin Bacteria TMDL	Cedar-Sammamish
Unnamed creek (trib to Bear Creek)	42154	4A	Bear Evans Watershed Bacteria TMDL	Cedar-Sammamish
Unnamed creek (trib to Cottage Lake)	72240	4A	Bear Evans Watershed Bacteria TMDL	Cedar-Sammamish
Unnamed creek (trib to Daniels Creek)	74781	4A	Bear Evans Watershed Bacteria TMDL	Cedar-Sammamish
Unnamed creek (trib to Pipers Creek)	74669 74673 74674 74675 74676 74677	4A	Pipers Creek Bacteria TMDL	Cedar-Sammamish
Unnamed creek (trib to Swamp Creek)	72254	4A	Swamp Creek Bacteria TMDL	Cedar-Sammamish

Waterbody Name	Listing ID(s)	Category	Water Quality Improvement Project (if any)	Watershed
Venema Creek	15776 74672	4A	Pipers Creek Bacteria TMDL	Cedar-Sammamish
Unnamed creek (5050 at w lake sammamish pkwy)	42139	4B	Tosh Creek Watershed Restoration Project 4B	Cedar-Sammamish
Bridlecrest Creek	42142	5		Cedar-Sammamish
Derby Creek	36163	5		Cedar-Sammamish
Eden Creek	13141	5		Cedar-Sammamish
Elliott Bay	15802 15803 45577	5		Cedar-Sammamish
Fairweather Bay Creek	15773	5		Cedar-Sammamish
Forbes Creek	13129	5		Cedar-Sammamish
Idylwood Creek	42130	5		Cedar-Sammamish
Johns Creek	74338	5		Cedar-Sammamish
Juanita Creek	13127 13143 74352	5		Cedar-Sammamish
Kelsey Creek (Mercer Slough)	13126 46931 13145	5		Cedar-Sammamish
Lake Sammamish	12163	5		Cedar-Sammamish
Lake Union / Lake Washington Ship Canal	74449	5		Cedar-Sammamish
Lake Washington	12193 12206 74775	5		Cedar-Sammamish
Laughing Jacobs Creek	15755	5		Cedar-Sammamish
Lewis Creek	13137	5		Cedar-Sammamish
Lyon Creek	13122	5		Cedar-Sammamish
Marymoor Creek	42145	5		Cedar-Sammamish
May Creek	13124	5		Cedar-Sammamish
Peters Creek	42082 42093	5		Cedar-Sammamish
Pine Lake Creek	13139	5		Cedar-Sammamish
Puget Sound (Central)	42490 42491	5		Cedar-Sammamish

Waterbody Name	Listing ID(s)	Category	Water Quality Improvement Project (if any)	Watershed
	42492 45040 45090			
Salmon Bay	12172	5		Cedar-Sammamish
Sammamish River	12561 12562 13128 46974 74448	5		Cedar-Sammamish
Thornton Creek	13123 74431	5		Cedar-Sammamish
Thornton creek, south fork	6402	5		Cedar-Sammamish
Unnamed creek (116th ditch)	42157	5		Cedar-Sammamish
Unnamed creek (46th st at w lake sammamish pkwy)	42136	5		Cedar-Sammamish
Unnamed creek (birdcage)	42116	5		Cedar-Sammamish
Unnamed creek (overlake sears trunkline)	42133	5		Cedar-Sammamish
Unnamed creek (Redmond HS creek)	42148 42151	5		Cedar-Sammamish
Unnamed creek (trib to Juanita Creek)	74346	5		Cedar-Sammamish
Unnamed creek (trib to Juanita Creek)	74349	5		Cedar-Sammamish
Unnamed creek (trib to Juanita Creek)	74351	5		Cedar-Sammamish
Unnamed creek (trib to Juanita Creek)	74354	5		Cedar-Sammamish
Unnamed creek (trib to Juanita Creek)	74356	5		Cedar-Sammamish
Unnamed creek (trib to Juanita Creek)	74357	5		Cedar-Sammamish
Unnamed creek (trib to Juanita Creek)	74362	5		Cedar-Sammamish
Unnamed creek (trib to Juanita Creek)	74789	5		Cedar-Sammamish
Unnamed creek (trib to Lake Washington)	74447	5		Cedar-Sammamish
Unnamed creek (trib to Sammamish River)	72243 74358	5		Cedar-Sammamish
Unnamed creek (trib to Thornton Creek)	45854	5		Cedar-Sammamish
Unnamed creek (trib to Thornton Creek)	74445	5		Cedar-Sammamish
Unnamed pond	74350	5		Cedar-Sammamish
Villa marina creek	42127	5		Cedar-Sammamish

Waterbody Name	Listing ID(s)	Category	Water Quality Improvement Project (if any)	Watershed
Willows Creek	42124	5		Cedar-Sammamish
Woodin Creek	36162	5		Cedar-Sammamish
Yarrow Bay Creek	15796	5		Cedar-Sammamish
Fauntleroy Creek	6656	4A	Fauntleroy Creek Bacteria TMDL	Duwamish-Green
Angle Lake	12613	5		Duwamish-Green
Barnes Creek	42304	5		Duwamish-Green
Big Soos Creek	15870 15871	5		Duwamish-Green
Black River	12567	5		Duwamish-Green
Covington Creek	13162 74201	5		Duwamish-Green
Dalco Passage and East Passage	15395 45329	5		Duwamish-Green
Des Moines Creek	12568 42314	5		Duwamish-Green
Des Moines Creek, east tributary	42351	5		Duwamish-Green
Duwamish Waterway	13150 13151	5		Duwamish-Green
Hamm Creek	74203	5		Duwamish-Green
Lake Meridian	6316	5		Duwamish-Green
Little Soos Creek	13167	5		Duwamish-Green
Little Soosette Creek	15832 15837 15849	5		Duwamish-Green
Longfellow Creek	7490	5		Duwamish-Green
Massey Creek	42340 42347	5		Duwamish-Green
McSorley Creek	42316	5		Duwamish-Green
Mill Creek	7485	5		Duwamish-Green
Miller Creek	42542	5		Duwamish-Green
Mullen Slough	15767	5		Duwamish-Green
Newaukum Creek	13157 13166 13168 13971	5		Duwamish-Green

Waterbody Name	Listing ID(s)	Category	Water Quality Improvement Project (if any)	Watershed
Puget sound (South Central)	15804 60140	5		Duwamish-Green
Puget sound (South Central) and East Passage	6654 15805 15807 15808 15809 45435	5		Duwamish-Green
Redondo Creek	13965	5		Duwamish-Green
Soosette Creek	15840	5		Duwamish-Green
Springbrook (Mill) Creek	16704	5		Duwamish-Green
Unnamed creek (trib to Newaukum Creek)	15846	5		Duwamish-Green
Unnamed creek (wdf# 09.0046)	15885	5		Duwamish-Green
Walker Creek	74701	5		Duwamish-Green
Boise Creek	16706 74205	4A	Puyallup River Bacteria TMDL	Puyallup-White
Bowman Creek	9844	4A	Puyallup River Bacteria TMDL	Puyallup-White
Unnamed creek (trib to Boise Creek)	74206	4A	Puyallup River Bacteria TMDL	Puyallup-White
Unnamed creek (trib to White River)	45691	4A	Puyallup River Bacteria TMDL	Puyallup-White
Unnamed creek (trib to White River)	45737	4A	Puyallup River Bacteria TMDL	Puyallup-White
White River	16708	4A	Puyallup River Bacteria TMDL	Puyallup-White
Hylebos Creek	15887	5		Puyallup-White
Ames Creek	6652	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Cherry Creek	7266 7267 46129	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Griffin Creek	6649	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Kimball Creek	6650	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish

Waterbody Name	Listing ID(s)	Category	Water Quality Improvement Project (if any)	Watershed
Lynch Creek	46901	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Patterson creek	6648 7287 7289	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Raging River	16693	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Snoqualmie River	6645 6647 6651 7147	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Snoqualmie river, Middle Fork	16701	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Snoqualmie river, South Fork	46114	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Tokul Creek	46118	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish
Tuck Creek	45529	4A	Snoqualmie River Watershed Multiparameter TMDL	Snohomish

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Appendix C: Shellfish Commercial Growing Areas and Recreational Beach Status in King County

Table C-1. Commercial shellfish bed classifications as of October 25, 2018.

Name	Sub Area	Acres	Classification	Reason
Colvos Passage	A	50	Unclassified	None
	B	808	Approved	None
	C	24	Prohibited	Nonpoint Pollution
	D	75	Unclassified	None
	E	940	Approved	None
	F	94	Prohibited	Nonpoint Pollution
	G	25	Prohibited	Nonpoint Pollution
	H	35	Unclassified	None
	I	57	Prohibited	None
	J	122	Unclassified	None
East Passage	A	128	Approved	None
	B	90	Unclassified	None
	C	35	Unclassified	None
	D	148	Approved	None
	E	44	Prohibited	Nonpoint Pollution
	F	42	Approved	None
	G	11	Unclassified	None
	H	1339	Approved	None
	I	13	Prohibited	Nonpoint Pollution
	J	24	Prohibited	Nonpoint Pollution
Poverty Bay	A	96	Prohibited	Wastewater Treatment Plant Outfall, Marina / Boating
	B	29	Conditional	Nonpoint Pollution
	C	183	Approved	None
	D	125	Unclassified	None
	E	22	Prohibited	Nonpoint Pollution
	F	124	Conditional	The Conditionally Approved portion of Poverty Bay will be closed from June 1st through November 30th, based on seasonal water quality conditions.
	G	5	Prohibited	Nonpoint Pollution
	H	110	Unclassified	None
	I	62	Approved	None
	J	357	Prohibited	Wastewater Treatment Plant Outfall
	K	135	Approved	None
	L	33	Prohibited	Nonpoint Pollution
	M	5	Prohibited	Nonpoint Pollution
	N	79	Unclassified	None

Name	Sub Area	Acres	Classification	Reason
Quartermaster Harbor	A	736	Unclassified	None
	B	73	Prohibited	Marina / Boating
	C	317	Approved	None
	D	4	Prohibited	Nonpoint Pollution
	E	75	Approved	None
	F	135	Prohibited	Marina / Boating, Nonpoint Pollution
	G	9	Prohibited	None
	H	1264	Unclassified	None
	I	227	Prohibited	Nonpoint Pollution
	J	176	Approved	None
	K	206	Approved	None
	L	5	Prohibited	Nonpoint Pollution
Three Tree Point	A	82	Approved	None
	B	153	Unclassified	None
	C	48	Prohibited	Wastewater Treatment Plant Outfall
	D	122	Approved	None
	E	145	Unclassified	None
	F	209	Prohibited	Wastewater Treatment Plant Outfall
	G	79	Approved	None
	H	93	Unclassified	None

Table C-2. Beach status for recreational shellfish harvest as of October 25, 2018. Note all beaches are closed for butter and varnish clam harvest due to biotoxin concerns except where noted otherwise.

Beach Name	Beach Status	DOH Comment	Closed Species	WDFW Harvest Seasons
ALKI BEACH PARK	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
ALKI POINT	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
BURTON ACRES	Closed		All Species	**Clams and Oysters:** Open year-round.
CAMP BURTON	Closed		All Species	**Clams and Oysters:** Open year-round.
DASH POINT STATE PARK	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
DES MOINES CITY PK	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
DISCOVERY PARK	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
DNR 77	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
DNR-78	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
DNR-79	Closed		All Species	**Clams and Oysters:** Open year-round.

Beach Name	Beach Status	DOH Comment	Closed Species	WDFW Harvest Seasons
DNR-83	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
DNR-85	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
DOCKTON CP	Closed	This beach resides within an area of known contamination. Commercial harvest is PROHIBITED. Recreational harvest is CLOSED. Shellfish are unsafe for human consumption.	All Species	**Clams and Oysters:** Closed year-round.
FERN COVE	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
GOLDEN GARDENS	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
HITCHINGS PROPERTY	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
INSPIRATION POINT NATURAL AREA	Closed	Shoreline survey information does not meet Washington State standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
LINCOLN PARK	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
LISABEULA PARK	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
LOST LAKE	Closed		All Species	**Clams and Oysters:** Open year-round.

Beach Name	Beach Status	DOH Comment	Closed Species	WDFW Harvest Seasons
MANZANITA NATURAL AREA	Closed	This beach has not been evaluated by the Department of Health for pollution problems. Contact your local health department for local information about pollution problems in this area.	All Species	**Clams and Oysters:** Open year-round.
MAURY ISLAND MARINE PARK	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
MEE-KWA-MOOKS PARK	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
N PT HEYER	Closed	This beach has not been evaluated by the Department of Health for pollution problems. Contact your local health department for local information about pollution problems in this area.	All Species	**Clams and Oysters:** Open year-round.
N. END BOAT RAMP	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
NEILL POINT NATURAL AREA	Closed		All Species	**Clams and Oysters:** Open year-round.
PINER PT	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
POINT ROBINSON PARK	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
RICHMOND BEACH	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.

Beach Name	Beach Status	DOH Comment	Closed Species	WDFW Harvest Seasons
S CARKEEK PK	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
SALTWATER SP	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
SEAHURST CP	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
SOUTH 239TH ST PK CONSERVATION AREA	Closed	This beach is located in a densely populated urban area. Large sewage treatment outfalls and urban stormwater runoff are sources of contamination concern.	All Species	**Clams and Oysters:** Closed year-round.
SOUTHWORTH FERRY DOCK	Closed	Shoreline survey information does not meet Washington State standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Closed year-round.
SPRING BEACH	Closed	Shoreline survey information does not meet Washington State standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
TRAMP HARBOR	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.
WINGEHAVEN PARK	Closed	Water quality and shoreline conditions meet public health standards for recreational shellfish harvesting.	All Species	**Clams and Oysters:** Open year-round.

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Appendix D: Summary of Fecal Indicator Bacteria Data

Table D-1. Summary of fecal coliform levels in streams monitored by King County for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
0311	Green	40/40	31.7	85
0317	**Springbrook**	**61/61**	**193.9**	**1500**
0321	Crisp	59/60	39.2	160
0322	**Newaukum**	**61/61**	**100.1**	**1100**
0430	**Lyon**	**62/62**	**164.2**	**689**
0434	**Thornton**	**62/62**	**210.0**	**754**
0438	Cedar	60/61	26.4	68
0440	May	61/61	41.4	160
0442	**Coal**	**60/60**	**41.6**	**202**
0444	**Kelsey**	**60/60**	**45.1**	**287**
0446	**Juanita**	**161/161**	**243.7**	**560**
0450CC	Sammamish	61/61	32.7	170
0456A	Forbes	60/60	52.3	194
0470	**Swamp**	**61/61**	**108.9**	**310**
0474	**North**	**61/61**	**441.1**	**2300**
0478	**Little Bear**	**61/61**	**97.1**	**530**
0484	**Bear**	**60/60**	**62.0**	**266**
0486	Sammamish	61/61	12.3	44
0631	**Issaquah**	**64/64**	**46.3**	**257**
0632	**Issaquah-North Fork**	**43/43**	**44.5**	**352**
3106	Green	61/61	29.8	99
A315	**Mill**	**60/60**	**77.0**	**324**
A319	Green	40/40	19.1	65.3
A320	Soos	60/60	39.0	111
A432	**McAleer**	**61/61**	**78.1**	**340**
A438	Cedar	36/39	6.9	32.2
A499	Cochran Springs	39/39	22.7	126
A617	**Lewis**	**60/60**	**53.7**	**314**
A620	**Idylwood**	**158/158**	**162.2**	**844**
A631	Issaquah	59/60	33.6	163
A670	**Laughing Jacob**	**40/40**	**38.5**	**210**
A680	**Pine Lake**	**61/61**	**33.0**	**200**
A685	Ebright	59/60	17.1	131
A690	**Eden**	**38/40**	**24.6**	**272**
AMES_1	**Ames**	**62/62**	**113.0**	**644**
B319	Green	57/61	5.9	22
B484	Evans	59/59	33.2	140
BB470	**Swamp**	**40/40**	**79.4**	**260**

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
BSE_ 1MUDMTNRD	**Boise**	**44/44**	**100.8**	**416**
C320	Covington	60/60	20.8	133
C370	**Longfellow**	**59/59**	**170.6**	**718**
C484	**Bear**	**86/86**	**110.8**	**800**
CHERRY_1	Cherry	62/62	14.8	59
D320	Jenkins	61/61	18.3	50
D474	**North**	**40/40**	**106.0**	**395**
FF321	Crisp	65/69	9.2	47.2
G320	**Little Soos**	**60/60**	**51.6**	**270**
GRIFFIN	Griffin	58/61	12.7	79
HARRIS_1	Harris	62/62	18.7	57.4
J484	**Bear**	**26/26**	**133.6**	**1400**
KSHZ06	**Pipers (Mouth)**	**62/62**	**124.5**	**1200**
KTHA01	**Pipers (Upper)**	**71/71**	**78.6**	**320**
KTHA02	**Pipers (Lower)**	**40/40**	**142.8**	**780**
KTHA03	**Venema**	**61/61**	**28.4**	**380**
LSIN1	Rock	38/38	22.5	62
LSIN9	Ravensdale	36/41	4.7	22
MFK_SNQ	Middle Fork Snoqualmie	47/61	6.0	31
N484	**Cottage**	**87/87**	**61.7**	**304**
NFK_SNQ	North Fork Snoqualmie	57/61	8.7	36
PATTER_3	**Patterson**	**61/61**	**56.7**	**350**
RAGING_MTH	Raging	59/61	18.8	130
S478	**Little Bear**	**40/40**	**34.3**	**260**
S484	Evans	39/39	9.7	52.8
SFK_SNQ	South Fork Snoqualmie	60/61	13.7	60
SKYKOMISH	Skykomish	41/62	2.0	5
SNQDUVALL	**Snoqualmie**	**61/62**	**13.8**	**179.4**
TOLT_MTH	Tolt	59/62	6.3	32.7
VA12A	Shinglemill	45/45	29.4	160
VA37A	**Tahlequah**	**45/45**	**54.9**	**266**
VA41A	**Fisher**	**45/45**	**81.2**	**426**
VA42A	**Judd**	**61/61**	**111.3**	**800**
VA45A	**Mileta**	**45/45**	**27.9**	**202**
VA65A	**Gorsuch**	**59/60**	**34.3**	**260**
X630	**Tibbetts**	**60/60**	**77.8**	**291**

Table D-2. Summary of fecal coliform levels in streams monitored by Ecology for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
07A090	Lower Snohomish River	55/56	15.3	46.0
07C070	Skykomish River above Snohomish	46/56	5.5	28.5
07D050	Snoqualmie River above Snohomish	57/57	19.1	65.0
07D130	Snoqualmie River below fork confluence	53/56	13.0	50.0
08C070	Lower Cedar River at Renton	54/57	19.3	76.2
08C110	Upper Cedar River	43/55	4.5	23.0
09A080	Lower Green River near I-405	57/57	28.2	76.8
09A190	Upper Green River	48/54	6.9	25.4

Table D-3. Summary of fecal coliform levels in streams monitored by Snohomish County for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
ACLU	**Allen Creek**	**22/22**	**109.5**	**445**
LBLD	**Little Bear Creek**	**22/22**	**97.2**	**239**
NCMU	**North Creek**	**22/22**	**166.8**	**788**
SCLU	Swamp Creek	22/22	42.7	179

Table D-4. Summary of fecal coliform levels in Lake Union/Ship Canal for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
0512	Salmon Bay	107/107	19.2	52.0
A522	SW Lake Union	102/2017	5.8	18.4
0540	Montlake Cut	90/108	2.6	8.0

Table D-5. Summary of fecal coliform levels at freshwater swimming beaches monitored by King County for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
0207SB	**Hidden Lake Beach**	**116/116**	**140.4**	**1100**
0602SB	**Idylwood Park Beach (Lake Samm.)**	**108/110**	**37.7**	**260**
0615SB	**Lake Sammamish State Park Beach (Lake Samm.)**	**101/106**	**19.5**	**280**

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
0806SB	**Juanita Beach (Lake WA)**	**156/156**	**172.6**	**745**
0813SB	**Andrews Bay Beach (Lake WA)**	**96/98**	**21.5**	**220**
0818SB	**Matthews Beach (Lake WA)**	**117/117**	**40.8**	**250**
0820SB	Mount Baker Park Beach (Lake WA)	83/95	5.1	46
0826SB	Magnuson Park Beach (Lake WA)	96/101	17.3	160
0828SB	**Gene Coulon Park Beach (Lake WA)**	**139/139**	**97.3**	**544**
0834SB	**Meydenbauer Bay Beach (Lake WA)**	**85/85**	**27.2**	**340**
083930SB	**Newcastle Beach (Lake WA)**	**124/124**	**48.9**	**541**
0852SB	Madison Park Beach (Lake WA)	101/104	13.3	134
4903SB	Pritchard Island Beach (Lake WA)	91/98	12.1	133
A422SB	**Houghton Beach (Lake WA)**	**108/109**	**43.1**	**520**
A709SB	**Beaver Lake Beach**	**55/55**	**37.5**	**268**
A734SB	East Green Lake Beach	76/77	18.2	110
A734WSB	West Green Lake Beach	94/95	12.6	59
A764SB	**Echo Lake Park Beach**	**98/98**	**43.0**	**486**
E708SB	**Pine Lake Beach**	**96/96**	**76.9**	**1200**
ENATAISB	Entai Park Beach (Lake WA)	86/98	6.4	72
GROVELDSB	Groveland Park Beach (Lake WA)	37/53	1.7	8
KNYDALESB	Kennydale Park Beach (Lake WA)	82/93	3.7	22
O717SB	**Lake Wilderness Park Beach**	**108/109**	**31.7**	**330**
SD007SB	Madrona Park Beach (Lake WA)	83/95	4.8	24
SD017SB	Luther Burbank Park Beach (Lake WA)	86/98	5.0	43
WAVRLYPSB	Waverly Park Beach (Lake WA)	82/89	6.5	34

Table D-6. Summary of fecal coliform levels at marine nearshore sites monitored by King County for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
ITCARKEEKP	Carkeek Park	32/39	3.9	15.2
JSVW04	**Richmond Beach**	**57/60**	**8.5**	**54.4**
KSHZ03	**Carkeek Park – Piper's Creek outflow**	**29/31**	**14.5**	**150**
KSLU03	Golden Gardens Park	36/39	10.0	46
KSSN04	West Point North Beach	56/67	2.8	13.4
KSSN05	West Point South Beach	62/67	5.7	36.4
KSYV02	**Magnolia CSO**	**31/32**	**11.1**	**47.8**
LSGY01	Seacrest Park	30/32	3.9	25.5
LSHV01	Alki Beach	28/39	2.6	20.4
LSKR01	Alki Outfall	31/32	5.7	33
LSKS01	Constellation Park	33/39	6.7	38.8
LSVW01	Fauntleroy Cove Beach	26/32	2.6	11.9
LTBD27	**SAM Sculpture Park**	**28/32**	**11.9**	**113**
MSJL01	**Vashon Outfall Beach**	**53/60**	**6.3**	**59.3**
MSSM05	Tramp Harbor	56/60	4.1	26.3
MSXK01	Burton Acres Park	44/60	2.8	21.1
MTLD03	Normandy Park	28/32	2.6	15.8
MTUJ01	**Des Moines Creek Park**	**32/32**	**15.6**	**96.8**
NSJY01	**Dumas Bay**	**51/59**	**7.7**	**120**
NTFK01	**Redondo Beach**	**56/58**	**13.3**	**170**

Table D-7. Summary of *enterococcus* levels at marine nearshore sites monitored by King County for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
ITCARKEEKP	Carkeek Park	28/39	2.3	12
JSVW04	Richmond Beach	58/60	5.1	34
KSHZ03	Carkeek Park – Piper's Creek outflow	28/31	6.2	48
KSLU03	Golden Gardens Park	34/39	5.6	26
KSSN04	West Point North Beach	45/67	2.5	14
KSSN05	West Point South Beach	52/67	3.8	29.4
KSYV02	**Magnolia CSO**	**30/32**	**10.7**	**96.6**
LSGY01	Seacrest Park	23/32	3.4	37.5

LSHV01	Alki Beach	31/39	4.1	24.4
LSKR01	Alki Outfall	25/32	5.3	27
LSKS01	**Constellation Park**	**31/39**	**6.0**	**50.6**
LSVW01	Fauntleroy Cove Beach	26/32	3.6	21.2
LTBD27	**SAM Sculpture Park**	**28/32**	**11.1**	**168**
MSJL01	Vashon Outfall Beach	46/59	4.2	38.4
MSSM05	Tramp Harbor	48/59	3.1	26
MSXK01	Burton Acres Park	49/59	3.6	23.4
MTLD03	Normandy Park	23/32	2.6	16.7
MTUJ01	Des Moines Creek Park	**26/32**	**7.7**	**109**
NSJY01	Dumas Bay	**50/60**	**8.9**	**162**
NTFK01	Redondo Beach	**56/58**	**8.1**	**59**

Table D-8. Summary of *enterococcus* levels at marine nearshore sites monitored by Ecology for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90^{th} Percentile
KIN001A	Richmond Beach	9/45	6.7	16
KIN001B		6/45	5.6	10
KIN001C		19/47	8.1	20
KIN003A	Carkeek Park	32/67	10.2	35
KIN003B		28/68	8.2	30.3
KIN003C		18/67	6.8	20
KIN004A	Golden Gardens	50/70	19.3	85
KIN004B		36/71	11.4	52
KIN004C		32/70	8.7	21.18
KIN023A	Alki Beach	28/65	9.6	30.6
KIN023B		32/65	9.9	41
KIN023C		27/65	8.4	30
KIN025A	**Richey Viewpoint**	**23/40**	**15.7**	**111**
KIN025B		19/40	12.0	76
KIN025C		14/39	9.4	33
KIN032A	Lincoln Park	35/68	12.4	74.3
KIN032B		21/67	7.1	20
KIN032C		20/66	7.0	15
KIN035A	Seahurst Park	21/58	8.3	30.3
KIN035B		32/59	11.2	41
KIN035C		35/58	11.9	62.3
KIN050A	Saltwater State Park	34/78	9.6	34
KIN050B		**46/79**	**16.3**	**119.4**
KIN050C		33/78	9.6	44

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
KIN055A	Redondo County Park	29/69	8.9	24.2
KIN055B		41/76	12.6	63
KIN055C		36/76	10.9	57.5
KIN060A	Dash Point State Park	16/60	7.1	20
KIN060B		27/60	8.9	30.1
KIN060C		14/60	7.4	11

Table D-9. Summary of fecal coliform levels at marine nearshore sites monitored by DOH for samples collected from 2013 to 2017. All values in CFU/100 mL.

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
587	Colvos Passage	8/30	2.1	4.1
588	Colvos Passage	10/30	2.0	2.0
589	Colvos Passage	12/30	2.3	4.5
590	Colvos Passage	13/29	2.7	7.8
592	Colvos Passage	7/30	1.8	2.0
732	Colvos Passage	12/30	2.2	2.3
733	Colvos Passage	11/30	2.3	4.8
734	Colvos Passage	13/30	3.1	15.9
736	Colvos Passage	14/30	2.2	2.3
737	Colvos Passage	6/30	2.0	2.0
738	Colvos Passage	9/30	2.3	4.7
739	Colvos Passage	8/30	2.0	2.0
740	Colvos Passage	15/30	2.3	4.5
741	Colvos Passage	7/30	2.0	2.0
742	Colvos Passage	6/1	2.0	2.0
743	Colvos Passage	6/30	1.9	2.0
840	Colvos Passage	4/23	2.0	2.0
375	East Passage	15/30	2.5	4.7
376	East Passage	13/30	2.9	13.0
377	East Passage	10/30	2.9	11.2
378	East Passage	9/30	2.1	4.5
379	East Passage	11/30	2.6	4.7
380	East Passage	10/29	2.2	4.1
381	East Passage	16/32	3.1	12.2
382	East Passage	11/30	2.2	2.0
383	East Passage	9/29	2.7	7.1
384	East Passage	13/30	2.8	14.9
385	East Passage	8/30	1.9	2.0

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
386	East Passage	15/30	2.5	4.5
387	East Passage	7/30	2.1	2.0
388	East Passage	11/30	2.8	7.4
389	East Passage	11/30	2.9	7.4
390	East Passage	5/30	1.9	2.0
391	East Passage	10/30	2.4	7.8
392	East Passage	16/30	2.5	4.5
393	East Passage	15/30	2.8	8.3
394	East Passage	19/30	2.8	8.1
395	East Passage	23/30	2.7	4.7
600	East Passage	8/30	2.1	2.3
647	East Passage	13/30	3.5	25.6
675	East Passage	11/30	2.9	11.2
676	East Passage	11/30	2.3	4.5
696	East Passage	14/30	3.7	25.3
697	East Passage	10/30	2.6	8.7
567	Poverty Bay	16/44	2.7	9.1
568	Poverty Bay	24/44	3.8	19.3
570	Poverty Bay	26/44	3.6	13.0
571	Poverty Bay	18/44	2.5	4.5
572	Poverty Bay	22/44	3.3	12.4
617	Poverty Bay	27/47	3.7	11.8
701	Poverty Bay	19/31	4.5	11.0
702	Poverty Bay	13/30	2.6	7.8
703	Poverty Bay	15/30	2.4	4.5
704	Poverty Bay	14/30	3.5	14.0
705	Poverty Bay	15/30	3.0	7.8
706	Poverty Bay	13/33	3.2	21.8
707	Poverty Bay	20/37	3.5	27.0
720	Poverty Bay	20/37	5.0	49.0
721	Poverty Bay	25/37	4.8	33.4
722	Poverty Bay	19/38	4.1	26.0
756	Poverty Bay	29/48	6.7	73.3
835	Poverty Bay	23/33	5.0	17.0
836	Poverty Bay	21/33	4.4	17.0
837	Poverty Bay	22/33	3.8	13.4
857	Poverty Bay	3/19	1.8	1.9
630	Quartermaster Harbor	11/30	2.6	4.5
631	Quartermaster Harbor	9/30	2.9	12.2

Locator	Description	Frequency of Detection	Geometric Mean	90th Percentile
632	Quartermaster Harbor	13/29	2.9	11.5
688	Quartermaster Harbor	11/30	2.9	11.0
689	Quartermaster Harbor	10/30	2.3	4.1
690	Quartermaster Harbor	14/30	2.4	4.5
691	Quartermaster Harbor	15/30	2.5	4.5
692	Quartermaster Harbor	15/31	3.6	14.0
693	Quartermaster Harbor	15/30	3.1	15.0
361	Quartermaster Harbor	12/30	3.0	14.0
362	Quartermaster Harbor	12/30	2.7	14.0
363	Quartermaster Harbor	14/30	3.0	8.3
364	Quartermaster Harbor	12/30	3.1	13.0
365	Quartermaster Harbor	12/30	2.6	4.7
366	Quartermaster Harbor	17/30	3.3	7.8
367	Quartermaster Harbor	18/30	3.6	13.4
368	Quartermaster Harbor	16/30	3.4	13.1
369	Quartermaster Harbor	13/30	3.6	17.6
371	Quartermaster Harbor	12/30	3.3	33.0
372	Quartermaster Harbor	13/30	3.2	20.2
373	Quartermaster Harbor	13/30	3.5	17.6
771	Quartermaster Harbor	10/30	2.4	4.5
783	Three Tree Point	24/47	3.3	11.0
784	Three Tree Point	22/46	2.6	6.2
785	Three Tree Point	30/46	4.4	26.5
786	Three Tree Point	26/46	3.7	30.0
787	Three Tree Point	14/46	2.4	4.5
788	Three Tree Point	21/46	2.7	9.4
789	Three Tree Point	24/46	3.6	22.5
790	Three Tree Point	28/46	5.6	28.0
791	Three Tree Point	23/46	3.4	20.0
792	Three Tree Point	18/46	2.7	6.2
793	Three Tree Point	20/45	3.3	13.0
794	Three Tree Point	24/46	3.3	17.0
795	Three Tree Point	23/46	2.8	7.8
796	Three Tree Point	14/46	2.5	6.2
797	Three Tree Point	24/46	3.0	9.4

Appendix E: Long-term Bacteria Trends

Table E-1. Seasonal Mann-Kendall trend results for bacteria for DOH monitoring data.

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
361	Fecal Coliform	1988	2017	27	3	3	0.311	0.00
362	Fecal Coliform	1988	2017	27	3	3	0.077	0.00
363	Fecal Coliform	1988	2017	27	4	3	0.100	0.00
364	Fecal Coliform	1990	2017	26	3	3	0.775	0.00
365	Fecal Coliform	1995	2017	23	3	3	0.227	0.00
366	Fecal Coliform	1995	2017	23	3	3	0.387	0.00
367	Fecal Coliform	1995	2017	23	4	4	0.601	0.00
368	Fecal Coliform	1995	2017	23	4	3	0.178	0.00
369	Fecal Coliform	1997	2017	21	3	3	0.477	0.00
371	Fecal Coliform	1999	2017	19	3	3	0.101	0.00
372	Fecal Coliform	1999	2017	19	3	3	0.302	0.00
373	Fecal Coliform	1999	2017	19	3	4	0.190	0.00
375	Fecal Coliform	1995	2017	23	3	3	0.903	0.00
376	Fecal Coliform	1995	2017	23	3	3	0.697	0.00
377	Fecal Coliform	1995	2017	23	2	3	0.734	0.00
378	Fecal Coliform	1995	2017	23	2	2	0.212	0.00
379	Fecal Coliform	1995	2017	23	2	2	0.133	0.00
380	Fecal Coliform	1995	2017	23	2	2	0.835	0.00
381	Fecal Coliform	1995	2017	23	3	3	0.371	0.00
382	Fecal Coliform	1995	2017	23	2	2	0.121	0.00
383	Fecal Coliform	1996	2017	22	3	3	0.087	0.00
384	Fecal Coliform	1996	2017	22	2	3	0.747	0.00
385	Fecal Coliform	1996	2017	22	2	2	0.488	0.00
386	Fecal Coliform	1996	2017	22	2	3	0.501	0.00
387	Fecal Coliform	1996	2017	22	2	2	0.009	0.00
388	Fecal Coliform	1996	2017	22	2	3	0.842	0.00
389	Fecal Coliform	1996	2017	22	2	3	0.382	0.00
390	Fecal Coliform	1997	2017	21	2	2	0.128	0.00
391	Fecal Coliform	1997	2017	21	2	2	0.170	0.00
392	Fecal Coliform	1997	2017	21	3	2	0.123	0.00
393	Fecal Coliform	1997	2017	21	3	3	0.086	0.00
394	Fecal Coliform	1997	2017	21	3	3	0.295	0.00
395	Fecal Coliform	1997	2017	21	4	3	0.206	0.00
567	Fecal Coliform	2000	2017	18	3	3	0.626	0.00
568	Fecal Coliform	2000	2017	18	2	4	0.450	0.00
570	Fecal Coliform	2000	2017	18	9	3	0.066	0.00
571	Fecal Coliform	2000	2017	18	3	3	0.575	0.00

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
572	Fecal Coliform	2000	2017	18	3	3	0.704	0.00
587	Fecal Coliform	2002	2017	16	2	2	0.646	0.00
588	Fecal Coliform	2002	2017	16	2	2	0.418	0.00
589	Fecal Coliform	2002	2017	16	4	2	0.058	0.00
590	Fecal Coliform	2002	2017	16	2	3	0.622	0.00
592	Fecal Coliform	2002	2017	16	2	2	0.635	0.00
600	Fecal Coliform	2003	2017	15	3	2	0.372	0.00
617	Fecal Coliform	2002	2017	16	4	3	0.481	0.00
630	Fecal Coliform	2002	2017	16	2	3	0.387	0.00
631	Fecal Coliform	2002	2017	16	2	3	0.914	0.00
632	Fecal Coliform	2002	2017	16	3	3	0.971	0.00
647	Fecal Coliform	2003	2017	15	3	4	0.260	0.00
675	Fecal Coliform	2004	2017	14	3	3	0.524	0.00
676	Fecal Coliform	2004	2017	14	2	2	NA	0.00
688	Fecal Coliform	2005	2017	13	4	4	0.851	0.00
689	Fecal Coliform	2005	2017	13	2	2	0.771	0.00
690	Fecal Coliform	2005	2017	13	3	3	0.474	0.00
691	Fecal Coliform	2005	2017	13	4	3	0.280	0.00
692	Fecal Coliform	2005	2017	13	3	5	0.618	0.00
693	Fecal Coliform	2005	2017	13	3	3	0.743	0.00
696	Fecal Coliform	2006	2017	12	2	3	0.320	0.00
697	Fecal Coliform	2006	2017	12	2	2	0.155	0.00
701	Fecal Coliform	2006	2017	12	3	4	0.208	0.00
702	Fecal Coliform	2006	2017	12	3	3	0.596	0.00
703	Fecal Coliform	2006	2017	12	4	2	0.354	0.00
704	Fecal Coliform	2006	2017	12	3	3	0.541	0.00
705	Fecal Coliform	2006	2017	12	3	3	0.668	0.00
706	Fecal Coliform	2006	2017	12	3	3	0.970	0.00
707	Fecal Coliform	2006	2017	12	3	3	0.467	0.00

Table E-2. Seasonal Mann-Kendall trend results for bacteria for Ecology marine beach monitoring data.

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
KIN001A	*Enterococcus*	2004	2017	10	10	12	0.279	0.00
KIN001B	*Enterococcus*	2004	2017	10	11	10	0.220	0.00
KIN001C	*Enterococcus*	2004	2017	10	13	12	0.128	0.00
KIN003A	*Enterococcus*	2004	2017	14	18	13	0.061	-0.30
KIN003B	*Enterococcus*	2004	2017	14	12	12	0.710	0.00
KIN003C	*Enterococcus*	2004	2017	14	14	11	0.282	0.00
KIN004A	*Enterococcus*	2004	2017	14	18	21	0.490	0.06
KIN004B	*Enterococcus*	2004	2017	14	11	16	0.072	0.41
KIN004C	*Enterococcus*	2004	2017	14	14	13	0.603	0.00
KIN023A	*Enterococcus*	2004	2017	14	11	15	0.076	0.00
KIN023B	*Enterococcus*	2004	2017	14	11	14	0.037	0.24
KIN023C	*Enterococcus*	2004	2017	14	13	12	0.406	0.00
KIN025A	*Enterococcus*	2004	2017	10	27	22	0.635	0.01
KIN025B	*Enterococcus*	2004	2017	10	18	18	0.892	0.00
KIN025C	*Enterococcus*	2004	2017	10	17	15	0.861	0.00
KIN032A	*Enterococcus*	2004	2017	14	13	16	0.150	0.00
KIN032B	*Enterococcus*	2004	2017	14	11	12	0.494	0.00
KIN032C	*Enterococcus*	2004	2017	14	11	11	0.922	0.00
KIN035A	*Enterococcus*	2004	2017	13	12	13	0.301	0.00
KIN035B	*Enterococcus*	2004	2017	13	12	16	0.738	0.00
KIN035C	*Enterococcus*	2004	2017	13	12	16	0.057	0.00
KIN050A	*Enterococcus*	2004	2017	14	12	14	0.512	0.00
KIN050B	*Enterococcus*	2004	2017	14	14	21	0.052	0.71
KIN050C	*Enterococcus*	2004	2017	14	13	14	0.346	0.00
KIN055A	*Enterococcus*	2004	2017	14	19	13	0.212	-0.01
KIN055B	*Enterococcus*	2004	2017	14	21	16	0.439	-0.07
KIN055C	*Enterococcus*	2004	2017	14	28	15	0.075	-0.60
KIN060A	*Enterococcus*	2004	2017	9	4	11	0.094	0.21
KIN060B	*Enterococcus*	2004	2017	9	8	13	0.713	0.00
KIN060C	*Enterococcus*	2004	2017	9	6	13	0.359	0.00

Table E-3. Seasonal Mann-Kendall trend results for bacteria for Ecology stream monitoring data.

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean	Ending Geometric Mean	p-value	Sen Slope
07D130	Fecal Coliform	1976	2017	41	8	11	0.009	0.08
08C070	Fecal Coliform	1970	2017	45	33	21	0.001	-0.43
08C110	Fecal Coliform	1977	2017	40	3	4	0.066	0.00
09A080	Fecal Coliform	1990	2017	28	97	29	0.000	-1.45
09A190	Fecal Coliform	1975	2017	43	4	6	0.018	0.00

Table E-4. Seasonal Mann-Kendall trend results for bacteria for King County lake monitoring data.

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
0512	*E. coli*	1999	2014	11	42	33	0.179	-1.57
0512	*Enterococcus*	1989	2002	14	19	9	0.027	-0.82
0512	Fecal Coliform	1976	2017	42	74	19	0.000	-1.64
0518	Fecal Coliform	1974	2009	20	37	19	0.005	-0.99
0536	Fecal Coliform	1986	2008	18	30	13	0.001	-1.39
0540	*E. coli*	1999	2014	11	7	5	0.035	-0.29
0540	*Enterococcus*	1989	2002	14	6	2	0.004	-0.33
0540	Fecal Coliform	1976	2017	42	24	2	0.000	-0.57
0611	Fecal Coliform	1994	2008	15	2	2	0.303	0.00
0612	*Enterococcus*	1983	2002	18	4	1	0.003	0.00
0612	Fecal Coliform	1979	2008	28	2	2	0.000	0.00
0614	*Enterococcus*	1987	2002	16	3	3	0.624	0.00
0614	Fecal Coliform	1983	2008	26	3	3	0.031	-0.03
0617	Fecal Coliform	1983	2008	19	3	2	0.001	-0.03
0622	Fecal Coliform	1984	2008	20	2	3	0.713	0.00
0625	Fecal Coliform	1995	2008	14	4	3	0.098	0.00
0804	*Enterococcus*	1987	2002	16	5	2	0.001	-0.06
0804	Fecal Coliform	1981	2008	27	15	3	0.000	-0.50
0807	*Enterococcus*	1987	2002	16	4	2	0.010	0.00
0807	Fecal Coliform	1981	2008	28	7	3	0.000	-0.20
0814	*Enterococcus*	1987	2002	16	2	1	0.009	0.00
0814	Fecal Coliform	1982	2008	27	7	3	0.000	-0.17
0817	Fecal Coliform	1982	2008	17	8	2	0.000	-0.25
0826	Fecal Coliform	1982	2008	18	3	2	0.001	0.00
0829	Fecal Coliform	1983	2008	19	23	9	0.003	-0.52
0831	Fecal Coliform	1983	2008	19	7	6	0.003	-0.21

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
0832	*Enterococcus*	1987	2002	16	4	2	0.010	0.00
0832	Fecal Coliform	1983	2008	26	9	3	0.000	-0.36
0834	*Enterococcus*	1983	2002	18	7	3	0.001	-0.23
0834	Fecal Coliform	1983	2008	26	10	5	0.000	-0.36
0840	Fecal Coliform	1995	2008	14	7	3	0.003	-0.24
0852	Fecal Coliform	1994	2008	15	3	2	0.004	0.00
0890	Fecal Coliform	1995	2008	14	4	2	0.034	0.00
4903	Fecal Coliform	1995	2008	14	72	16	0.001	-3.00
A522	*E. coli*	1999	2014	11	18	13	0.425	-0.50
A522	*Enterococcus*	1987	2002	16	6	5	0.356	0.00
A522	Fecal Coliform	1979	2017	36	33	7	0.000	-0.92
M621	Fecal Coliform	1993	2008	16	2	2	0.055	0.00

Table E-5. Seasonal Mann-Kendall trend results for bacteria for King County marine beach monitoring data.

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean	Ending Geometric Mean	p-value	Sen Slope
JSVW04	*Enterococcus*	1981	2017	34	15	5	0.001	-0.14
JSVW04	Fecal Coliform	1972	2017	46	26	7	0.000	-0.33
KSSN04	*Enterococcus*	1981	2017	34	7	2	0.001	0.00
KSSN04	Fecal Coliform	1970	2017	48	21	4	0.000	-0.39
KSSN05	*Enterococcus*	1981	2017	34	8	4	0.055	0.00
KSSN05	Fecal Coliform	1970	2017	48	22	6	0.000	-0.38
MSJL01	*Enterococcus*	2002	2017	16	18	5	0.026	-0.50
MSJL01	Fecal Coliform	2002	2017	16	12	5	0.165	-0.17
MSSM05	*Enterococcus*	1990	2017	20	6	3	0.149	0.00
MSSM05	Fecal Coliform	1990	2017	20	10	4	0.217	0.00
MTEC01	*Enterococcus*	1989	2010	12	2	6	0.106	0.21
MTEC01	Fecal Coliform	1989	2010	12	9	4	0.369	-0.08

Table E-6. Seasonal Mann-Kendall trend results for bacteria for King County stream monitoring data.

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
0309	*Enterococcus*	1989	2002	14	32	33	0.750	-0.14
0309	Fecal Coliform	1970	2008	39	146	52	0.000	-4.00
0311	*Enterococcus*	1987	2002	16	33	25	0.024	-0.94
0311	Fecal Coliform	1970	2017	43	85	46	0.000	-1.97
0317	*Enterococcus*	1987	2002	16	187	168	0.296	-2.55
0317	Fecal Coliform	1972	2017	42	457	142	0.000	-5.29
0321	Fecal Coliform	1972	2017	29	38	40	0.742	-0.05
0322	*Enterococcus*	1989	2002	14	63	103	0.742	0.25
0322	Fecal Coliform	1972	2017	43	324	79	0.000	-5.69
0430	*Enterococcus*	1987	2002	16	265	393	0.562	2.04
0430	Fecal Coliform	1972	2017	44	352	156	0.000	-5.68
0434	*Enterococcus*	1989	2002	14	350	541	0.365	5.11
0434	Fecal Coliform	1974	2017	42	477	257	0.001	-8.33
0438	Fecal Coliform	1976	2017	16	39	29	0.127	-0.20
0440	*Enterococcus*	1989	2002	14	41	175	0.037	2.83
0440	Fecal Coliform	1977	2017	41	105	46	0.003	-1.32
0442	*Enterococcus*	1988	2002	15	73	113	0.583	0.33
0442	Fecal Coliform	1977	2017	37	61	40	0.090	-0.57
0444	*Enterococcus*	1988	2002	15	128	225	0.202	2.18
0444	Fecal Coliform	1977	2017	37	227	68	0.000	-4.21
0446	*Enterococcus*	1987	2002	16	222	353	0.656	1.67
0446	Fecal Coliform	1975	2017	42	331	229	0.014	-2.37
0450	*Enterococcus*	1989	2003	8	44	45	0.792	-0.17
0450	Fecal Coliform	1976	2008	26	280	91	0.000	-6.00
0456A	*Enterococcus*	1987	2002	16	77	124	0.785	0.60
0456A	Fecal Coliform	1979	2017	35	344	66	0.000	-6.36
0470	*Enterococcus*	1989	2002	14	68	138	0.406	1.49
0470	Fecal Coliform	1972	2017	44	242	175	0.009	-1.70
0474	*Enterococcus*	1989	2002	14	70	103	0.981	0.00
0474	Fecal Coliform	1972	2017	44	434	246	0.025	-3.31
0478	*Enterococcus*	1989	2002	14	151	190	0.778	0.79
0478	Fecal Coliform	1972	2017	44	224	94	0.000	-3.39
0484	*Enterococcus*	1987	2002	16	93	103	0.950	-0.12
0484	Fecal Coliform	1974	2017	42	637	59	0.000	-13.33
0486	*Enterococcus*	1989	2004	16	13	12	0.534	-0.14
0486	Fecal Coliform	1976	2017	42	26	12	0.000	-0.33
0498	*Enterococcus*	1989	2002	14	240	233	0.570	-2.44
0498	Fecal Coliform	1975	2008	32	707	153	0.001	-11.50

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
0631	*Enterococcus*	1988	2002	15	60	95	0.828	0.09
0631	Fecal Coliform	1975	2017	41	125	41	0.000	-1.67
0632	*E. coli*	1999	2011	12	71	46	0.019	-3.67
0632	*Enterococcus*	1989	2002	14	57	77	0.256	0.53
0632	Fecal Coliform	1975	2017	39	114	46	0.000	-1.45
3106	*Enterococcus*	1987	2002	16	28	35	0.552	-0.24
3106	Fecal Coliform	1970	2017	48	77	47	0.000	-2.06
A315	*Enterococcus*	1987	2003	17	137	208	0.069	4.29
A315	Fecal Coliform	1977	2017	37	812	88	0.000	-17.02
A319	*Enterococcus*	1988	2002	15	13	10	0.197	-0.20
A319	Fecal Coliform	1976	2017	37	38	18	0.001	-0.39
A320	*Enterococcus*	1988	2003	16	43	100	0.311	0.93
A320	Fecal Coliform	1979	2017	39	56	38	0.011	-0.47
A432	*E. coli*	1999	2014	11	170	173	0.012	-13.33
A432	*Enterococcus*	1988	2002	15	213	218	0.938	0.00
A432	Fecal Coliform	1976	2017	37	229	108	0.000	-3.33
A438	*Enterococcus*	1988	2002	15	13	29	0.055	0.50
A438	Fecal Coliform	1976	2017	37	28	13	0.000	-0.38
A499	*Enterococcus*	1989	2002	14	26	58	0.192	0.84
A499	Fecal Coliform	1975	2017	36	35	26	0.102	-0.20
A617	Fecal Coliform	1995	2017	19	67	55	0.128	-0.84
A620	*E. coli*	1999	2014	13	403	230	0.087	-10.00
A620	Fecal Coliform	1995	2017	23	448	170	0.002	-7.79
A630	Fecal Coliform	1975	1997	21	276	183	0.044	-3.13
A631	*Enterococcus*	1989	2002	14	40	44	0.557	0.40
A631	Fecal Coliform	1975	2017	37	73	46	0.000	-0.71
A670	Fecal Coliform	1987	2017	6	36	29	0.665	-0.39
A680	*Enterococcus*	1987	2002	10	38	145	0.168	3.29
A680	Fecal Coliform	1987	2017	25	59	39	0.002	-1.18
A685	Fecal Coliform	1996	2017	18	47	18	0.002	-1.00
A690	*Enterococcus*	1987	2002	10	42	59	0.727	0.14
A690	Fecal Coliform	1987	2017	20	18	25	0.112	0.21
AMES_1	Fecal Coliform	2005	2017	9	171	107	0.152	-5.93
B319	*Enterococcus*	1987	2002	16	4	4	0.206	0.00
B319	Fecal Coliform	1972	2017	44	12	5	0.000	-0.13
B484	*Enterococcus*	1989	2002	14	47	39	0.117	-1.31
B484	Fecal Coliform	1972	2017	39	183	40	0.000	-2.60
BB470	Fecal Coliform	1999	2017	14	107	83	0.493	-1.00

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
C320	*Enterococcus*	1989	2002	14	16	36	0.007	1.29
C320	Fecal Coliform	1977	2017	37	28	27	0.821	0.00
C370	*Enterococcus*	1992	2003	12	239	605	0.725	5.12
C370	Fecal Coliform	1979	2017	26	379	153	0.006	-7.00
C446	Fecal Coliform	1976	2008	32	264	272	0.173	1.60
C484	*E. coli*	1999	2014	11	84	93	0.751	-0.83
C484	*Enterococcus*	1989	2002	14	105	85	0.421	-1.50
C484	Fecal Coliform	1974	2017	38	278	104	0.000	-5.00
CHERRY_1	Fecal Coliform	2004	2017	10	27	16	0.433	-0.18
D320	*Enterococcus*	1989	2002	14	37	38	0.888	-0.09
D320	Fecal Coliform	1977	2017	41	56	22	0.000	-0.97
D444	*Enterococcus*	1989	2002	14	103	167	0.201	3.86
D444	Fecal Coliform	1977	2008	32	216	149	0.285	-1.19
D474	Fecal Coliform	1973	2017	18	325	99	0.002	-3.60
FF321	*E. coli*	1999	2017	11	7	5	0.567	0.00
FF321	Fecal Coliform	1993	2017	21	7	8	0.532	0.00
G320	*Enterococcus*	1987	2002	16	152	94	0.008	-3.35
G320	Fecal Coliform	1972	2017	39	339	59	0.000	-7.08
HARRIS_1	Fecal Coliform	2005	2017	9	17	19	NA	0.00
J370	Fecal Coliform	1992	2008	17	550	251	0.016	-20.00
J484	Fecal Coliform	1974	2016	35	91	71	0.002	-0.90
KSHZ06	*E. coli*	1999	2016	11	287	110	0.014	-7.50
KSHZ06	*Enterococcus*	1987	2002	16	114	311	0.012	5.23
KSHZ06	Fecal Coliform	1987	2017	31	159	108	0.002	-2.67
KTHA01	*E. coli*	2000	2016	4	235	103	NA	NA
KTHA01	*Enterococcus*	1981	2017	32	129	94	0.054	-1.09
KTHA01	Fecal Coliform	1970	2017	48	276	89	0.000	-2.00
KTHA02	*E. coli*	1999	2016	11	342	98	0.020	-10.00
KTHA02	*Enterococcus*	1987	2002	16	116	239	0.327	3.62
KTHA02	Fecal Coliform	1987	2017	26	170	135	0.020	-3.24
KTHA03	*E. coli*	1999	2016	11	112	41	0.064	-2.84
KTHA03	*Enterococcus*	1987	2002	16	53	101	0.192	1.11
KTHA03	Fecal Coliform	1987	2017	27	75	30	0.030	-1.11
LSIN1	Fecal Coliform	1994	2017	6	60	27	0.131	-1.71
LSIN9	Fecal Coliform	1994	2017	6	7	7	0.731	-0.19
N484	*E. coli*	1999	2014	11	93	89	0.202	-2.00
N484	*Enterococcus*	1989	2002	14	65	70	0.935	-0.10
N484	Fecal Coliform	1974	2017	38	157	67	0.000	-2.60

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
PATTER_3	Fecal Coliform	2005	2017	9	53	62	0.778	0.34
S478	Fecal Coliform	1974	2017	12	79	34	0.028	-1.80
S484	*Enterococcus*	1989	2002	14	26	21	0.210	-0.67
S484	Fecal Coliform	1981	2017	32	127	14	0.000	-2.77
VA12A	Fecal Coliform	2006	2017	11	26	34	0.713	-0.20
VA37A	Fecal Coliform	2006	2017	6	29	36	1.000	0.00
VA41A	Fecal Coliform	2006	2017	11	84	92	0.094	-1.50
VA42A	*E. coli*	2006	2017	8	121	69	0.352	-5.50
VA42A	Fecal Coliform	2006	2017	12	139	138	0.608	-1.00
VA45A	Fecal Coliform	2006	2017	11	26	22	0.498	-0.54
VA65A	Fecal Coliform	2006	2017	10	22	68	0.065	1.50
X438	Fecal Coliform	1996	2009	14	82	46	0.140	-3.33
X630	Fecal Coliform	1997	2017	17	169	79	0.005	-2.56

Table E-7. Seasonal Mann-Kendall trend results for bacteria for King County swimming beach monitoring data.

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
0207SB	Fecal Coliform	2004	2017	14	60	182	0.718	1.93
0602SB	Fecal Coliform	1996	2017	22	63	37	0.056	-2.00
0615SB	*E. coli*	2001	2016	9	12	7	0.022	-1.69
0615SB	Fecal Coliform	2001	2017	17	15	20	0.786	0.19
0806SB	Fecal Coliform	1996	2017	21	318	149	0.027	-10.87
0813SB	Fecal Coliform	1996	2017	21	12	20	0.547	0.28
0818SB	Fecal Coliform	1996	2017	21	94	39	0.011	-4.00
0820SB	Fecal Coliform	1996	2017	22	23	5	0.000	-1.38
0826SB	Fecal Coliform	1996	2017	21	28	18	0.358	-0.81
0828SB	Fecal Coliform	1996	2017	22	80	96	0.288	-2.74
0834SB	Fecal Coliform	1996	2016	19	146	25	0.010	-7.59
083930SB	Fecal Coliform	1996	2017	21	35	52	0.746	-0.36
0852SB	Fecal Coliform	1996	2017	22	42	13	0.001	-2.57
4903SB	Fecal Coliform	1996	2017	19	36	11	0.088	-1.66
A422SB	*E. coli*	1998	2012	3	56	41	NA	NA
A422SB	Fecal Coliform	1996	2017	12	72	33	0.763	-1.08
A734SB	Fecal Coliform	1996	2017	10	38	20	0.063	-0.88
A734WSB	Fecal Coliform	2003	2017	15	11	11	0.278	0.33

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean (CFU/100 mL)	Ending Geometric Mean (CFU/100 mL)	p-value	Sen Slope (CFU/100 mL per year)
A764SB	Fecal Coliform	2004	2017	14	30	58	0.852	0.28
E708SB	*E. coli*	2001	2017	13	33	150	0.297	15.38
E708SB	Fecal Coliform	2001	2017	13	34	88	0.526	3.96
O717SB	Fecal Coliform	2001	2017	14	10	30	0.200	1.26
SD007SB	Fecal Coliform	1996	2017	22	30	5	0.000	-2.50
SD017SB	Fecal Coliform	1996	2017	21	13	5	0.160	-0.36

Table E-8. Seasonal Mann-Kendall trend results for bacteria for Snohomish County stream monitoring data.

Locator	Parameter	Start Year	End Year	No. Years	Start Geometric Mean	Ending Geometric Mean	p-value	Sen Slope
LBLD	Fecal Coliform	2004	2017	11	387	67	0.107	-8.62
NCMU	Fecal Coliform	2006	2017	7	58	198	0.623	4.40
SCLU	Fecal Coliform	2004	2017	11	110	31	0.012	-4.90

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Appendix F: Regression Results

Table F-1. Results of regression for King County marine beaches.

Parameter	Season	Dependent Statistic	Variable	Estimate	Standard Error	t-value	p-value	VIF	Model Adjusted R^2
Fecal Coliform	Fall	log(GM)	*(Intercept)*	11.4887	1.1977	9.5927	0.0000	NA	***0.70***
			OSS	0.1049	0.1030	1.0188	0.3269	3.8479	
			Pop.Dens	0.0489	0.0124	3.9343	0.0017	1.0293	
			AveSal	-0.3595	0.0488	-7.3728	0.0000	3.9000	
		log(p90)	*(Intercept)*	12.4541	4.8232	2.5821	0.0228	NA	***0.34***
			OSS	0.1336	0.2629	0.5083	0.6198	2.2453	
			Pop.Dens	0.0469	0.0251	1.8700	0.0842	1.3205	
			AveSal	-0.3274	0.1779	-1.8407	0.0886	2.5965	
	Winter	log(GM)	*(Intercept)*	10.1545	1.6708	6.0776	0.0000	NA	***0.38***
			OSS	0.1333	0.0863	1.5444	0.1465	1.9664	
			Pop.Dens	0.0169	0.0137	1.2378	0.2377	1.0285	
			AveSal	-0.3181	0.0642	-4.9555	0.0003	1.9556	
		log(p90)	*(Intercept)*	14.3279	2.4942	5.7445	0.0001	NA	***0.37***
			OSS	0.2710	0.1248	2.1721	0.0489	1.5435	
			Pop.Dens	0.0283	0.0222	1.2752	0.2246	1.4548	
			AveSal	-0.4079	0.0923	-4.4170	0.0007	1.2535	
	Spring	log(GM)	*(Intercept)*	10.4404	2.1241	4.9152	0.0003	NA	***0.28***
			OSS	0.2307	0.1162	1.9847	0.0687	2.5389	
			Pop.Dens	0.0146	0.0152	0.9635	0.3529	1.1438	
			AveSal	-0.3221	0.0805	-3.9986	0.0015	2.3471	
		log(p90)	*(Intercept)*	14.4658	3.6793	3.9317	0.0017	NA	***0.29***
			OSS	0.3507	0.1722	2.0372	0.0625	1.9385	
			Pop.Dens	0.0300	0.0259	1.1582	0.2676	1.4510	
			AveSal	-0.4025	0.1339	-3.0047	0.0101	1.8129	
	Summer	log(GM)	*(Intercept)*	12.5129	2.5388	4.9287	0.0003	NA	***0.39***
			OSS	0.1921	0.1375	1.3974	0.1857	5.5997	
			Pop.Dens	0.0186	0.0147	1.2630	0.2288	1.0229	
			AveSal	-0.3842	0.0971	-3.9584	0.0016	5.6052	
		log(p90)	*(Intercept)*	15.7160	3.2423	4.8471	0.0003	NA	***0.31***
			OSS	0.3522	0.1742	2.0223	0.0642	2.4851	
			Pop.Dens	0.0156	0.0238	0.6544	0.5242	1.2629	
			AveSal	-0.4321	0.1213	-3.5615	0.0035	2.1160	
	All Year	log(GM)	*(Intercept)*	10.1545	1.6708	6.0776	0.0000	NA	***0.38***
			OSS	0.1333	0.0863	1.5444	0.1465	1.9664	
			Pop.Dens	0.0169	0.0137	1.2378	0.2377	1.0285	
			AveSal	-0.3181	0.0642	-4.9555	0.0003	1.9556	

Parameter	Season	Dependent Statistic	Variable	Estimate	Standard Error	t-value	p-value	VIF	Model Adjusted R^2
		log(p90)	*(Intercept)*	14.3279	2.4942	5.7445	0.0001	NA	***0.37***
			OSS	0.2710	0.1248	2.1721	0.0489	1.5435	
			Pop.Dens	0.0283	0.0222	1.2752	0.2246	1.4548	
			AveSal	-0.4079	0.0923	-4.4170	0.0007	1.2535	
Enterococcus	Fall	log(GM)	*(Intercept)*	9.3747	1.0276	9.1231	0.0000	NA	***0.72***
			OSS	0.0816	0.0843	0.9682	0.3506	1.4339	
			Pop.Dens	0.0577	0.0077	7.4524	0.0000	1.6936	
			AveSal	-0.2730	0.0383	-7.1351	0.0000	2.1596	
		log(p90)	(Intercept)	11.7049	7.2116	1.6231	0.1286	NA	0.23
			OSS	0.1437	0.1882	0.7640	0.4585	1.2506	
			Pop.Dens	0.0635	0.0527	1.2051	0.2497	4.7187	
			AveSal	-0.2891	0.2480	-1.1657	0.2647	4.5505	
	Winter	log(GM)	*(Intercept)*	7.4544	1.1946	6.2400	0.0000	NA	***0.40***
			OSS	0.0534	0.0643	0.8297	0.4217	1.1797	
			Pop.Dens	0.0293	0.0105	2.7938	0.0152	1.3755	
			AveSal	-0.2257	0.0440	-5.1262	0.0002	1.4680	
		log(p90)	*(Intercept)*	13.2480	3.4080	3.8873	0.0019	NA	***0.42***
			OSS	0.2435	0.1125	2.1637	0.0497	1.5408	
			Pop.Dens	0.0579	0.0251	2.3012	0.0386	3.1522	
			AveSal	-0.3732	0.1182	-3.1569	0.0076	2.4545	
	Spring	log(GM)	*(Intercept)*	7.3646	1.6513	4.4598	0.0006	NA	***0.26***
			OSS	0.1241	0.0864	1.4358	0.1747	1.5994	
			Pop.Dens	0.0294	0.0120	2.4520	0.0291	1.3838	
			AveSal	-0.2193	0.0601	-3.6480	0.0029	1.5303	
		log(p90)	*(Intercept)*	15.0043	4.6302	3.2405	0.0064	NA	***0.37***
			OSS	0.2786	0.1504	1.8517	0.0869	1.3875	
			Pop.Dens	0.0489	0.0305	1.6030	0.1329	2.9336	
			AveSal	-0.4256	0.1600	-2.6597	0.0196	2.3557	
	Summer	log(GM)	*(Intercept)*	9.0871	2.1390	4.2482	0.0010	NA	***0.37***
			OSS	0.2034	0.0785	2.5908	0.0224	1.2571	
			Pop.Dens	0.0412	0.0102	4.0535	0.0014	1.5044	
			AveSal	-0.2677	0.0763	-3.5077	0.0039	1.8108	
		log(p90)	(Intercept)	18.1832	13.0305	1.3954	0.1863	NA	0.33
			OSS	0.3254	0.3821	0.8514	0.4099	4.3007	
			Pop.Dens	0.0535	0.0870	0.6150	0.5492	11.0526	
			AveSal	-0.5130	0.4288	-1.1965	0.2529	6.7250	

Parameter	Season	Dependent Statistic	Variable	Estimate	Standard Error	t-value	p-value	VIF	Model Adjusted R^2
	All Year	log(GM)	*(Intercept)*	7.4544	1.1946	6.2400	0.0000	NA	***0.40***
			OSS	0.0534	0.0643	0.8297	0.4217	1.1797	
			Pop.Dens	0.0293	0.0105	2.7938	0.0152	1.3755	
			AveSal	-0.2257	0.0440	-5.1262	0.0002	1.4680	
		log(p90)	*(Intercept)*	13.2480	3.4080	3.8873	0.0019	NA	***0.42***
			OSS	0.2435	0.1125	2.1637	0.0497	1.5408	
			Pop.Dens	3.9593	2.1333	1.8559	0.0863	7.8337	
			AveSal	-23.3196	10.8453	-2.1502	0.0509	4.3116	

Table F-2. Regression results for King County streams. All regressions based on fecal coliform.

Season	Dependent Statistic	Variable	Estimate	Standard Error	t-value	p-value	VIF	Model Adjusted R^2
Fall	log(GM)	*(Intercept)*	2.8778	0.1879	15.3122	0.0000	NA	***0.40***
		OSS	0.2398	0.2834	0.8461	0.4005	1.0875	
		Pop.Dens	0.1911	0.0255	7.4983	0.0000	1.3053	
		Pct.Ag	0.0479	0.0120	3.9798	0.0002	1.2110	
	log(p90)	*(Intercept)*	4.0121	0.2057	19.5001	0.0000	NA	***0.47***
		OSS	0.6536	0.3099	2.1093	0.0386	1.0391	
		Pop.Dens	0.2693	0.0321	8.3853	0.0000	1.1066	
		Pct.Ag	0.0855	0.0157	5.4351	0.0000	1.0870	
Winter	log(GM)	*(Intercept)*	2.6226	0.1880	13.9507	0.0000	NA	***0.51***
		OSS	0.3646	0.2220	1.6423	0.1051	1.0487	
		Pop.Dens	0.2359	0.0309	7.6452	0.0000	1.1943	
		Pct.Ag	0.0572	0.0140	4.0830	0.0001	1.1491	
	log(p90)	*(Intercept)*	4.0854	0.1794	22.7737	0.0000	NA	***0.56***
		OSS	0.5168	0.1923	2.6876	0.0090	1.1586	
		Pop.Dens	0.2406	0.0232	10.3670	0.0000	1.4025	
		Pct.Ag	0.0704	0.0101	6.9481	0.0000	1.2283	
Spring	log(GM)	*(Intercept)*	2.8951	0.1860	15.5668	0.0000	NA	***0.47***
		OSS	0.3959	0.2097	1.8873	0.0634	1.0340	
		Pop.Dens	0.2218	0.0311	7.1385	0.0000	1.1835	
		Pct.Ag	0.0511	0.0153	3.3376	0.0014	1.1574	
	log(p90)	*(Intercept)*	4.1742	0.1677	24.8837	0.0000	NA	***0.54***
		OSS	0.6090	0.2146	2.8383	0.0060	1.0608	
		Pop.Dens	0.2442	0.0239	10.2264	0.0000	1.2131	
		Pct.Ag	0.0657	0.0083	7.9098	0.0000	1.1494	

Season	Dependent Statistic	Variable	Estimate	Standard Error	t-value	p-value	VIF	Model Adjusted R^2
Summer	log(GM)	*(Intercept)*	3.1318	0.1819	17.2158	0.0000	NA	***0.42***
		OSS	0.4026	0.2124	1.8958	0.0622	1.0169	
		Pop.Dens	0.2083	0.0308	6.7532	0.0000	1.1631	
		Pct.Ag	0.0421	0.0150	2.8039	0.0066	1.1477	
	log(p90)	*(Intercept)*	4.3161	0.1867	23.1171	0.0000	NA	***0.50***
		OSS	0.6348	0.3057	2.0763	0.0416	1.0669	
		Pop.Dens	0.2575	0.0273	9.4286	0.0000	1.1491	
		Pct.Ag	0.0529	0.0215	2.4570	0.0166	1.1674	
All Year	log(GM)	*(Intercept)*	2.6226	0.1880	13.9507	0.0000	NA	***0.51***
		OSS	0.3646	0.2220	1.6423	0.1051	1.0487	
		Pop.Dens	0.2359	0.0309	7.6452	0.0000	1.1943	
		Pct.Ag	0.0572	0.0140	4.0830	0.0001	1.1491	
	log(p90)	*(Intercept)*	4.0854	0.1794	22.7737	0.0000	NA	***0.56***
		OSS	0.5168	0.1923	2.6876	0.0090	1.1586	
		Pop.Dens	0.2406	0.0232	10.3670	0.0000	1.4025	
		Pct.Ag	0.0704	0.0101	6.9481	0.0000	1.2283	

Table F-3. Regression Results for DOH sites. All regressions based on fecal coliform.

Season	Dependent Statistic	*Variable*	*Estimate*	*Standard Error*	*t-value*	*p-value*	*VIF*	*Model Adjusted R^2*
Fall	GM	***(Intercept)***	29.9083	7.3719	4.0571	0.0005	NA	***0.44***
		OSS	0.5063	0.2425	2.0877	0.0486	1.2698	
		Pop.Dens	0.1920	0.1350	1.4223	0.1690	1.9918	
		Pct.Ag	-0.0324	0.0449	-0.7225	0.4776	1.9973	
		AveSal	-0.9401	0.2566	-3.6642	0.0014	1.2731	
	p90	***(Intercept)***	254.2145	146.9465	1.7300	0.0976	NA	***0.36***
		OSS	6.1197	4.3595	1.4038	0.1744	3.8501	
		Pop.Dens	-0.0001	0.6991	-0.0002	0.9999	2.6023	
		Pct.Ag	-0.6136	0.3205	-1.9141	0.0687	2.8223	
		AveSal	-8.3358	5.1184	-1.6286	0.1176	4.3975	
Winter	GM	***(Intercept)***	8.1611	3.2374	2.5209	0.0195	NA	***0.42***
		OSS	0.4317	0.1274	3.3887	0.0026	1.4591	
		Pop.Dens	0.1698	0.0807	2.1039	0.0470	2.0575	
		Pct.Ag	-0.0026	0.0140	-0.1856	0.8544	1.4368	
		AveSal	-0.2091	0.1199	-1.7447	0.0950	1.8287	
	p90	***(Intercept)***	48.3484	31.9086	1.5152	0.1440	NA	***0.45***
		OSS	6.3693	2.2711	2.8045	0.0103	1.7021	

Season	Depen-dent Statistic	*Variable*	*Estimate*	*Standard Error*	*t-value*	*p-value*	*VIF*	*Model Adjusted R^2*
		Pop.Dens	1.9443	0.8441	2.3033	0.0311	1.8164	
		Pct.Ag	0.0229	0.1583	0.1444	0.8865	1.7486	
		AveSal	-1.5872	1.2346	-1.2856	0.2120	1.8440	
Spring	GM	***(Intercept)***	11.7922	3.7641	3.1328	0.0048	NA	***0.47***
		OSS	0.5958	0.1787	3.3341	0.0030	1.4632	
		Pop.Dens	0.2405	0.0856	2.8084	0.0102	1.5105	
		Pct.Ag	-0.0059	0.0170	-0.3477	0.7314	1.4063	
		AveSal	-0.3352	0.1388	-2.4150	0.0245	1.3353	
	p90	***(Intercept)***	151.5011	62.0901	2.4400	0.0232	NA	***0.54***
		OSS	13.3310	3.3186	4.0171	0.0006	2.7315	
		Pop.Dens	2.5806	1.1870	2.1741	0.0407	3.1984	
		Pct.Ag	-0.2479	0.2834	-0.8749	0.3911	2.3107	
		AveSal	-5.2207	2.2539	-2.3163	0.0302	1.8573	
Summer	GM	***(Intercept)***	19.8922	6.7343	2.9539	0.0073	NA	***0.67***
		OSS	1.1205	0.2612	4.2894	0.0003	1.4566	
		Pop.Dens	0.3545	0.0976	3.6316	0.0015	1.5954	
		Pct.Ag	0.0047	0.0156	0.3010	0.7662	1.3264	
		AveSal	-0.6275	0.2393	-2.6220	0.0156	1.2592	
	p90	***(Intercept)***	194.1343	112.4555	1.7263	0.0983	NA	***0.38***
		OSS	24.3806	13.3758	1.8227	0.0820	1.1548	
		Pop.Dens	2.4951	1.5842	1.5750	0.1295	1.3123	
		Pct.Ag	-0.1910	0.3847	-0.4966	0.6244	1.2971	
		AveSal	-6.6679	4.0489	-1.6468	0.1138	1.0790	
All Year	GM	***(Intercept)***	8.1611	3.2374	2.5209	0.0195	NA	***0.42***
		OSS	0.4317	0.1274	3.3887	0.0026	1.4591	
		Pop.Dens	0.1698	0.0807	2.1039	0.0470	2.0575	
		Pct.Ag	-0.0026	0.0140	-0.1856	0.8544	1.4368	
		AveSal	-0.2091	0.1199	-1.7447	0.0950	1.8287	
	p90	***(Intercept)***	48.3484	31.9086	1.5152	0.1440	NA	***0.45***
		OSS	6.3693	2.2711	2.8045	0.0103	1.7021	
		Pop.Dens	1.9443	0.8441	2.3033	0.0311	1.8164	
		Pct.Ag	0.0229	0.1583	0.1444	0.8865	1.7486	
		AveSal	-1.5872	1.2346	-1.2856	0.2120	1.8440	

Table F-3. Regression results for Ecology BEACH sites. All regressions based on *enterococcus*.

Season	Depen-dent Statistic	*Variable*	*Estimate*	*Standard Error*	*t-value*	*p-value*	*VIF*	*Model adjusted R^2*
Spring	GM	*(Intercept)*	70.1551	17.6271	3.9800	0.0073	NA	***0.20***
		OSS	1.9844	1.0678	1.8583	0.1125	2.1354	
		Pop.Dens	0.6516	0.3754	1.7357	0.1333	5.4543	
		AveSal	-2.1004	0.6983	-3.0079	0.0238	3.7759	
	p90	*(Intercept)*	348.9833	133.2005	2.6200	0.0396	NA	***0.43***
		OSS	25.6360	8.9158	2.8753	0.0282	4.7579	
		Pop.Dens	4.4904	3.0554	1.4697	0.1920	11.7860	
		AveSal	-12.1173	5.2823	-2.2939	0.0616	7.5786	
Summer	GM	(Intercept)	85.9099	17.3623	4.9481	0.0026	NA	0.23
		OSS	0.4546	1.2052	0.3772	0.7190	2.9748	
		Pop.Dens	0.5419	0.4276	1.2674	0.2520	9.4981	
		AveSal	-2.5946	0.7029	-3.6913	0.0102	5.5746	
	p90	*(Intercept)*	44.8952	22.2958	2.0136	0.0839	NA	***0.10***
		OSS	35.1942	9.5170	3.6980	0.0077	1.0433	
		Pop.Dens	0.0836	2.5711	0.0325	0.0750	1.0433	
		AveSal	Dropped due to high correlation with OSS and PopDens					
All Year	GM	*(Intercept)*	70.1551	18.0199	3.8932	0.0080	NA	***0.20***
		OSS	1.9844	1.0462	1.8969	0.1066	2.0598	
		Pop.Dens	0.6516	0.3719	1.7520	0.1303	5.6671	
		AveSal	-2.1004	0.7132	-2.9450	0.0258	4.1679	
	p90	*(Intercept)*	348.9833	133.2004	2.6200	0.0396	NA	***0.43***
		OSS	25.6360	8.9158	2.8753	0.0282	4.7579	
		Pop.Dens	4.4904	3.0554	1.4697	0.1920	11.7860	
		AveSal	-12.1173	5.2823	-2.2939	0.0616	7.5786	

Table F-4. Regression results for King County Swimming Beach sites. All regressions based on fecal coliform.

Season	Depen-dent Statistic	*Variable*	*Estimate*	*Standard Error*	*t-value*	*p-value*	*VIF*	*Model adjusted R^2*
Spring	GM	*(Intercept)*	17.3151	7.7816	2.2251	0.0362	NA	***0.31***
		OSS	51.8153	14.8630	3.4862	0.0020	1.5224	
		Pop.Dens	0.0131	0.4291	0.0305	0.9759	1.5224	
	p90	*(Intercept)*	186.4169	78.8853	2.3631	0.0270	NA	***0.34***
		OSS	818.8617	458.8348	1.7847	0.0875	1.0433	
		Pop.Dens	-0.7604	4.8231	-0.1577	0.8761	1.0433	

Season	Dependent Statistic	*Variable*	*Estimate*	*Standard Error*	*t-value*	*p-value*	*VIF*	*Model adjusted* R^2
Summer	GM	*(Intercept)*	14.4443	9.8741	1.4628	0.1570	NA	***0.39***
		OSS	58.8233	14.0889	4.1752	0.0004	2.1526	
		Pop.Dens	0.1272	0.4343	0.2930	0.7722	2.1526	
	p90	*(Intercept)*	198.0777	107.2744	1.8465	0.0777	NA	***0.26***
		OSS	502.3261	194.3554	2.5846	0.0166	1.4129	
		Pop.Dens	-4.8630	5.6063	-0.8674	0.3947	1.4129	
All Year	GM	*(Intercept)*	17.3151	7.7816	2.2251	0.0362	NA	***0.31***
		OSS	51.8153	14.8630	3.4862	0.0020	1.5224	
		Pop.Dens	0.0131	0.4291	0.0305	0.9759	1.5224	
	p90	*(Intercept)*	186.4169	78.8853	2.3631	0.0270	NA	***0.34***
		OSS	818.8617	458.8347	1.7847	0.0875	1.0433	
		Pop.Dens	-0.7604	4.8231	-0.1577	0.8761	1.0433	

Appendix G: Landscape and Enivironmental Variable Data

Table G-1. Landscape and environmental variable data used in stream regressions.

Locator	Geometric Mean (CFU/100 mL)	90th Percentile (CFU/100 mL)	Septic Users Per Acre	Percent Agriculture	Population Density (persons per acre)
0311	32	85	0.23	5.2	0.89
0317	194	1,500	0.22	0.2	5.09
0321	39	160	0.43	1.3	0.46
0322	100	1,100	0.32	43.8	0.59
0430	164	689	0.09	0.0	7.20
0434	210	754	0.00	0.0	10.09
0438	26	68	0.18	1.2	0.45
0440	41	160	0.90	4.0	2.78
0442	42	202	0.07	0.0	3.22
0444	45	287	0.30	0.6	5.88
0446	244	560	0.19	0.0	8.58
0450CC	33	170	0.67	3.2	1.93
0456A	52	194	0.61	0.0	6.14
0470	109	310	0.09	0.5	6.74
0474	441	2,300	0.17	0.0	6.52
0478	97	530	0.69	0.4	1.90
0484	62	266	1.18	4.2	1.91
0486	12	44	0.42	2.4	1.63
0631	46	257	0.40	4.0	0.56
0632	44	352	0.33	0.7	5.00
3106	30	99	0.23	5.2	0.89
A315	77	324	0.77	4.9	4.04
A319	19	65	0.07	5.8	0.10
A320	39	111	0.75	3.1	2.75
A432	78	340	0.10	0.0	7.33
A438	7	32	0.11	1.2	0.13
A499	23	126	0.60	0.0	2.33
A617	54	314	0.13	0.0	4.40
A620	162	844	0.00	0.0	8.64
A631	34	163	0.43	4.9	0.39
A670	38	210	0.67	1.4	3.67
A680	33	200	1.23	3.1	2.19
A685	17	131	1.03	0.0	2.18
A690	25	272	1.18	1.1	4.23
AMES_1	113	644	0.44	23.1	0.39
B319	6	22	0.02	0.9	0.02
B484	33	140	0.90	4.1	2.44
BB470	79	260	0.03	0.0	6.96

Locator	Geometric Mean (CFU/100 mL)	90th Percentile (CFU/100 mL)	Septic Users Per Acre	Percent Agriculture	Population Density (persons per acre)
BSE_1MUDMTNRD	101	416	0.10	12.4	0.49
C320	21	133	0.47	1.1	1.18
C370	171	718	0.00	0.0	11.33
C484	111	800	1.34	3.7	1.59
CHERRY_1	15	59	0.09	1.5	0.09
D320	18	50	0.81	4.5	2.71
D474	106	395	0.17	0.0	6.59
FF321	9	47	0.62	0.1	0.66
G320	52	270	1.25	6.7	2.53
GRIFFIN	13	79	0.00	0.0	0.01
HARRIS_1	19	57	0.26	3.0	0.23
KSHZ06	125	1,200	0.01	0.0	11.67
KTHA02	143	780	0.00	0.0	12.91
KTHA03	28	380	0.01	0.0	10.75
LSIN1	23	62	0.09	0.2	0.55
LSIN9	5	22	0.07	0.0	0.75
MFK_SNQ	6	31	0.02	0.1	0.02
N484	62	304	1.76	1.0	1.54
NFK_SNQ	9	36	0.01	0.2	0.01
PATTER_3	57	350	0.45	8.6	0.80
RAGING_MTH	19	130	0.10	0.6	0.13
S478	34	260	0.63	0.8	2.15
S484	10	53	0.93	1.8	2.48
SFK_SNQ	14	60	0.15	0.2	0.16
SKYKOMISH	2	5	0.00	0.0	0.00
SNQDUVALL	14	179	0.17	8.4	0.47
TOLT_MTH	6	33	0.00	0.0	0.01
VA12A	29	160	0.40	12.0	0.46
VA37A	55	266	0.27	1.8	0.26
VA41A	81	426	0.30	29.7	0.22
VA42A	111	800	0.30	11.1	0.31
VA45A	28	202	0.28	6.9	0.16
VA65A	34	260	0.78	7.0	1.31
X630	78	291	0.12	0.0	1.52

Table G-2. Landscape and environmental variable data used in freshwater swimming beach regressions.

Locator	Geometric Mean (CFU/100 mL)	90th Percentile (CFU/100 mL)	Septic Users Per Acre	Percent Agriculture	Population Density (persons per acre)
0207SB	139	1,140	0.00	0.0	7.71
0602SB	38	260	0.00	0.0	8.46
0615SB	19	280	0.12	0.0	2.08
0806SB	173	755	0.21	0.0	8.75
0813SB	22	220	0.00	0.0	6.31
0818SB	40	250	0.00	0.0	9.99
0820SB	5	46	0.00	0.0	7.95
0826SB	17	160	0.00	0.0	0.00
0828SB	97	544	0.00	0.0	5.03
0834SB	27	340	0.00	0.0	11.39
083930SB	49	541	0.00	0.0	2.03
0852SB	13	134	0.00	0.0	27.48
4903SB	12	133	0.00	0.0	8.14
A422SB	43	520	0.09	0.0	7.55
A709SB	37	268	0.55	0.0	2.14
A734SB	18	110	0.00	0.0	11.22
A734WSB	13	59	0.00	0.0	14.54
A764SB	43	488	0.00	0.0	10.35
E708SB	77	1,200	0.91	0.0	3.60
ENATAISB	6	72	0.00	0.0	6.32
GROVELDSB	2	8	0.00	0.0	4.34
KNYDALESB	4	22	0.02	0.0	8.63
O717SB	32	330	0.51	0.0	3.19
SD007SB	5	24	0.00	0.0	9.54
SD017SB	5	43	0.00	0.0	6.26
WAVRLYPSB	7	34	0.09	0.0	7.58

Table G-3. Landscape and environmental variable data used in King County marine beach regressions.

Locator	Geometric Mean (CFU/100 mL)	90th Percentile (CFU/100 mL)	Septic Users Per Acre	Percent Agriculture	Population Density (persons per acre)	Average Salinity (ppt)
ITCARKEEKP	2	12	0.01	0.0	11.53	27.8
JSVW04	5	34	0.22	0.0	7.57	27.9
KSLU03	6	26	0.00	0.0	0.80	24.3
KSSN04	3	14	0.00	0.0	0.11	27.9
KSYV02	11	97	0.00	0.0	9.35	26.6

Locator	Geometric Mean (CFU/100 mL)	90th Percentile (CFU/100 mL)	Septic Users Per Acre	Percent Agriculture	Population Density (persons per acre)	Average Salinity (ppt)
LSGY01	3	38	0.00	0.0	10.83	27.0
LSHV01	4	24	0.00	0.0	12.47	28.7
LSKS01	6	51	0.08	0.0	10.98	28.6
LSVW01	4	21	0.00	0.0	9.11	28.3
LTBD27	11	168	0.00	0.0	21.58	24.9
MSJL01	4	38	0.73	10.3	0.94	28.1
MSSM05	3	26	3.10	0.0	1.53	28.8
MSXK01	4	23	1.05	0.0	0.53	27.2
MTLD03	3	17	0.97	0.0	6.30	28.0
MTUJ01	8	109	0.85	0.0	4.06	24.9
NSJY01	9	162	0.25	0.0	4.77	25.0
NTFK01	8	59	0.75	0.0	5.31	26.0

Table G-4. Landscape and environmental variable data used in Ecology BEACH regressions.

Locator	Geometric Mean (CFU/100 mL)	90th Percentile (CFU/100 mL)	Septic Users Per Acre	Percent Agriculture	Population Density (persons per acre)	Average Salinity (ppt)
KIN001	12	19	0.06	0.0	6.31	28.9
KIN003	14	27	0.01	0.0	11.48	28.9
KIN004	20	63	0.00	0.0	1.13	24.6
KIN023	15	41	0.00	0.0	11.38	29.1
KIN025	20	71	0.07	0.0	11.25	29.4
KIN032	15	42	0.00	0.0	8.31	29.4
KIN035	16	36	0.07	0.0	5.36	28.5
KIN050	20	82	1.26	0.0	8.67	28
KIN055	18	64	0.72	0.0	5.29	27
KIN060	13	24	0.26	0.0	1.18	26.9

Table G-5. Landscape and environmental variable data used in DOH site regressions.

Locator	Geometric Mean	90th Percentile	OSS Users Per Acre	Percent Agriculture	Population Density	Average Salinity
361	3	14	0.79	0.0	0.52	26.60
362	3	14	0.27	0.0	0.55	26.70
363	3	8	2.41	0.0	0.79	26.50
364	3	13	0.08	0.0	0.53	26.43
365	3	5	0.43	0.1	0.21	25.57
366	3	8	0.00	0.0	0.65	25.30
367	4	13	0.61	0.0	0.64	25.13
368	3	13	1.65	2.0	0.63	25.70

Locator	Geometric Mean	90th Percentile	OSS Users Per Acre	Percent Agriculture	Population Density	Average Salinity
369	4	18	0.37	0.0	0.51	26.80
371	3	33	0.55	0.0	0.45	26.17
372	3	20	0.96	1.8	0.72	25.97
373	4	18	0.48	17.2	0.40	26.50
375	3	5	0.16	0.0	0.21	27.87
376	3	13	1.09	0.8	0.24	28.80
377	3	11	0.39	18.6	0.33	28.23
378	2	5	1.37	8.4	0.59	28.27
379	3	5	1.81	0.0	0.78	28.37
381	3	12	0.71	10.7	0.72	28.84
382	2	2	2.03	0.0	1.29	28.40
383	3	7	1.26	0.0	0.78	28.03
384	3	15	0.78	10.2	0.63	28.43
385	2	2	3.14	1.1	0.62	28.67
386	3	5	0.75	1.3	0.47	28.97
387	2	2	0.35	1.8	0.31	28.23
388	3	7	1.93	0.2	0.84	29.03
389	3	7	1.21	6.5	1.42	28.87
390	2	2	1.42	2.1	0.80	27.87
391	2	8	0.06	0.0	0.24	28.23
392	3	5	4.31	0.0	1.43	28.30
393	3	8	2.21	0.0	0.31	27.87
394	3	8	1.20	4.6	0.32	27.87
395	3	5	0.66	0.8	0.31	27.57
567	3	9	1.12	0.0	6.48	27.43
568	4	19	0.27	0.0	1.02	27.11
570	4	13	1.14	0.0	8.70	26.59
572	3	12	0.07	0.0	8.68	27.09
587	2	4	0.39	19.2	0.27	28.27
588	2	2	0.50	0.0	0.21	28.53
589	2	5	0.53	0.8	0.23	28.00
590	3	8	0.63	7.9	0.61	28.07
592	2	2	0.78	12.7	0.49	28.73
600	2	2	0.53	18.5	0.38	28.23
617	4	12	0.09	0.0	4.51	27.40
630	3	5	2.72	5.5	0.72	25.57
631	3	12	0.07	0.0	0.22	25.97
632	3	11	0.17	3.7	0.42	25.72
647	4	26	1.81	0.0	1.52	28.60

Locator	Geometric Mean	90th Percentile	OSS Users Per Acre	Percent Agriculture	Population Density	Average Salinity
675	3	11	0.58	4.4	0.47	28.10
676	2	5	0.61	10.3	0.94	28.50
688	3	11	0.23	28.4	0.23	25.90
689	2	4	0.15	24.0	0.26	25.97
690	2	5	0.70	0.0	0.38	26.23
691	3	5	0.82	0.0	0.24	25.73
692	4	14	0.23	2.1	0.31	25.13
693	3	15	0.16	2.6	0.23	25.33
696	4	25	2.81	6.4	2.04	28.70
697	3	9	2.82	0.4	1.81	28.90
702	3	8	0.25	0.0	1.27	25.30
703	2	5	4.41	0.0	2.06	25.13
705	3	8	2.19	0.0	2.44	26.47
706	3	22	3.35	0.0	2.83	27.48
707	4	27	0.62	0.0	3.63	27.32
720	5	49	1.97	0.0	7.18	27.41
721	5	33	0.72	0.0	5.19	27.76
722	4	26	2.64	0.0	5.25	27.84
732	2	2	0.43	0.0	0.20	28.80
733	2	5	0.00	0.0	0.07	28.47
734	3	16	0.00	0.0	0.06	28.47
736	2	2	0.36	5.5	0.29	28.20
737	2	2	0.41	5.5	0.25	28.37
738	2	5	0.48	8.8	0.50	28.07
739	2	2	0.40	11.6	0.46	27.60
740	2	5	0.89	0.1	0.39	28.47
741	2	2	0.35	0.0	0.35	28.33
742	2	2	1.24	2.0	0.46	28.42
743	2	2	3.62	0.5	1.66	28.30
756	7	73	0.50	0.0	8.57	26.60
771	2	5	1.13	0.0	0.49	25.63
783	3	11	0.00	0.0	5.20	28.04
784	3	6	0.00	0.0	4.73	28.83
785	4	27	0.03	0.0	7.66	28.22
786	4	30	0.03	0.0	9.56	27.50
787	2	5	0.00	0.0	4.07	27.91
788	3	9	0.93	0.0	5.22	28.15
789	4	23	0.72	0.0	2.71	28.02
790	6	28	0.96	0.0	6.28	26.91

Locator	Geometric Mean	90th Percentile	OSS Users Per Acre	Percent Agriculture	Population Density	Average Salinity
791	3	20	1.59	0.0	5.91	27.65
792	3	6	0.68	0.0	1.60	27.93
793	3	13	2.87	0.0	2.24	27.78
794	3	17	0.85	0.0	4.03	27.43
795	3	8	0.00	0.0	7.08	28.74
796	3	6	3.80	0.0	3.95	28.07
797	3	9	0.11	0.0	5.74	28.28
840	2	2	0.57	3.7	0.41	28.39