Kitsap County Health District Water Quality Program

BOAT WASTE WATER QUALITY STUDY REPORT

October 25, 2006

1. Introduction

Water quality standard violations in many Kitsap County embayments are generally the result of cumulative contaminant loading from a variety of nonpoint sources. A suspected source of water quality contamination in marine waters is untreated sewage discharges from transient and liveaboard vessels. Although the volume of the sewage potentially discharged by boats is relatively small, the concentrated sewage combined with the poor flushing and dilution characteristics of many marinas may have a significant water quality impact.

In 1991, the Health District completed a water quality study of four (4) Kitsap County marinas to test the hypothesis that a significant difference in water quality existed inside a marina as opposed to outside a marina. This study documented that fecal coliform (FC) bacteria levels were significantly higher within marinas. This finding, along with the findings of other marina water quality studies, led to the development of the Health District's Boat Waste Control Program and the Bremerton-Kitsap County Board of Health Ordinance 1999-13 "Marina Sewage Regulations" which were intended to govern the collection and disposal of sewage generated by vessels in Kitsap County.

Since its inception, all of the Kitsap County marinas have come into compliance with the Marina Sewage Regulations. As facilities change in size and/or operations, re-inspections are necessary to ensure that the requirements of the regulations are met. Currently, there are no permits and no fees associated with the operation of this program. To evaluate the effectiveness of the current Marina Sewage Regulations, and assess the need for revisions of the ordinance, the Health District conducted a new water quality study to assess current water quality conditions in marinas. The Health District analyzed FC bacteria in marine waters within and near selected Kitsap County marinas.

2. Monitoring Goals and Objectives

The primary objective of the study was to quantitatively and qualitatively characterize the current water quality conditions in and near selected Kitsap County marinas. The primary quantitative objective of this study is to test the null hypothesis that there is no difference in concentrations of fecal coliform bacteria inside as opposed to outside a marina. The alternative hypothesis is that the water quality inside the marina has higher concentrations of bacteria as a result of boat sewage discharges inside the marina. To test the null hypothesis, a sampling study has been designed to factor out other sources of contamination to the maximum extent possible. Sampling occurred only during defined tide, weather, and boater use periods.

The hypotheses to be tested are:

H_0: μmarina = μexternal
H_1: μmarina > μexternal

In addition to the primary objective, data from the study was used to address a secondary null hypothesis that FC bacteria levels are equal on heavy boat use days (weekends) compared to lower boat use days (weekday, non-holidays). This question is answered separately for the marina areas and the external areas. The secondary hypotheses to be tested were:

H_0: μweekend = μweekday
H_1: μweekend > μweekday

The study was not designed to determine the relative impact of boat wastes as compared to the impact from other contaminant sources. Additionally, the study was not intended to rank the water quality conditions at Kitsap County's marinas. Rather, it was designed in general to evaluate the likelihood of water quality impacts from boats in Kitsap County.

3. Water Quality Standards and Criteria

The Washington State Department of Ecology (Ecology) establishes surface water quality standards in Chapter 173-201A Washington Administrative Code (WAC). The Health District continues to compare against the current Washington State water quality standards, as amended. Surface waters in Kitsap County are designated in the WAC as either Primary Contact or Extraordinary Primary Contact waters. Both earn this designation by markedly and uniformly exceeding established criteria related to watershed use and water quality. Applicable marine water quality standards are summarized in **Table 1**.

TABLE 1
Marine Water Quality Standards and Related Criteria

Parameter	Marine Water Standard	
	Extraordinary Primary Contact	**Primary Contact**
Fecal Coliform Bacteria	Part 1: ≤14 FC/100 mL (geomean). Part 2: Not more than 10% of all samples obtained for calculating a geomean >43 FC/100 mL.	same as EP

3. Monitoring Parameters

Fecal coliform bacteria data will be compared to the Washington State Water Quality Standards. The samples were collected in separate 100 mL sterile water bottles, stored at 4^0C, and transported to the Health District contract laboratory for analysis. Fecal Coliform Procedure 9221-E, "Fecal Coliform Direct Test (A-1 Medium)", described in Standard Methods for the Examination of Water and Wastewater (APHA, 1998) was used to analyze the samples. See

Table 2 for more information about analytical procedures, method detection limits, and method accuracies.

TABLE 2
Analysis Methods, Detection Limits, and Accuracy

Parameter	Method of Analysis	Method Detection Limits	Accuracy
Fecal Coliform Bacteria	APHA Procedure 9221-E, MPN Fecal Coliform Direct Test (A-1 Medium)	2 to 1,600 col/100 mL (without dilution)	1 col/100 mL

4. Marina Selection

Based on Health District surveys of Kitsap County marinas, three (3) marinas were selected as being representative study areas. The marina selection process was based primarily on the geographical location of the marinas and the size of the marinas and usage type, including liveaboard tenants. Marinas that would be impacted by nearby known pollution sources were not selected for the study. The three marinas selected for the study were:

- Port of Poulsbo (Site 1)
- Bremerton Yacht Club (Site 2)
- Port Orchard Yacht Club (Site 3)

Information about each of these marinas is located in Appendix A. A map showing the location of the three study marinas is provided in Figure 1.

5. Monitoring Station Locations

In order to collect representative water quality samples from each sampling area, five (5) samples were collected from within the marina area and five (5) samples from a nearby area away from the marina's influence. A sampling grid was used to randomly select the sampling locations within the defined areas. For each location, a grid with five (5) columns and ten (10) rows was applied to the area. The grid was pre-set in size to have columns that are one hundred (100) feet wide and rows that are fifty (50) feet tall. A sample was collected from each column, and the row within that column was randomly selecting using a spreadsheet formula. During the random selection process, if any grid cell selection fell outside the marina area based on the grid application and selected marina shape, a different cell was reselected. To the maximum extent possible, the sample was collected from the center of the grid cell. For each sample event, the random process was repeated, and the sampling locations were generated prior to the site visit. To the maximum extent possible, the outside marina locations were located in an area of similar depth and distance to shore as compared to the inside marina locations. Health District staff used GIS mapping to determine the latitude and longitude coordinates of the center of each grid cell.

6. Monitoring Schedule

To decrease the influence of outside pollutant sources and test only the water quality differences between internal and external marina waters, as well as collect samples during representative use conditions, sampling events were planned to meet the following conditions:

1. Dry weather (no more than 0.3 inches of rain in the last 48 hours).
2. High or low slack tides (slack tides are one hour on either side of a low or high tide peak).
3. Two events during a high boater use period (dry weather weekend).
4. Two events during a low boater use period (Monday through Thursday, non-holiday).

Four sampling events were conducted between July 31, 2006 and October 1, 2006. The sampling events occurred on the following dates:

Event 1. Monday, July 31
Event 2. Sunday, August 27
Event 3. Sunday, September 10
Event 4. Wednesday, September 27

7. Monitoring Procedures

Samples were collected in accordance with Health District monitoring procedures as described in the *Water Quality Trend Monitoring Plan, Streams and Marine Waters,* November 2005. Internal samples were collected from the marina floats and external samples from the Health District boat. During sample collection, Health District staff noted any other bacteria pollution sources that may have been present in the area (birds, sea mammals, pumpout spillage, etc.). The Sample IDs were based on the following:

- Site number (1, 2, or 3)
- Internal or External to the marina
- Column ID (A, B, C, D, or E)
- Row ID (1 - 10)
- Example ID: 1EA3

8. Data Review and Assessment

Because samples collected within the same area and within the same timeframe can demonstrate correlation or dependence, sample data was analyzed to assess the amount of spatial and temporal dependence that may exist. Using the latitude and longitude coordinates of the sampling grid cells, no spatial dependence was found and because the samples were collected over 14 days apart, the samples are considered temporally independent.

A statistical t-test for independent samples was used for the first hypotheses. This is a one-tailed test with a level of significance of $\alpha=0.05$. Figure 1 shows a box plot comparison between

all marina and external data. The box plots appear to be very similar except for 2 extreme values that came from marina samples.

Figure 1. Comparison between FC Concentration in Marinas and in External Areas

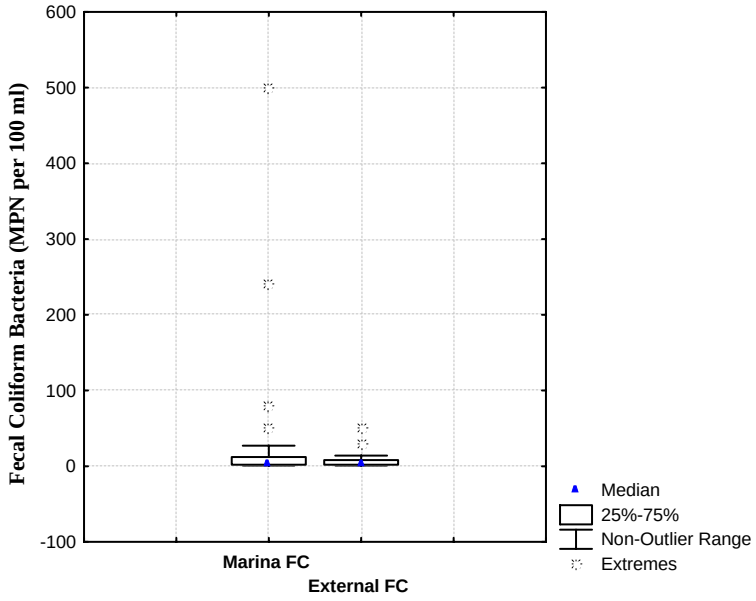
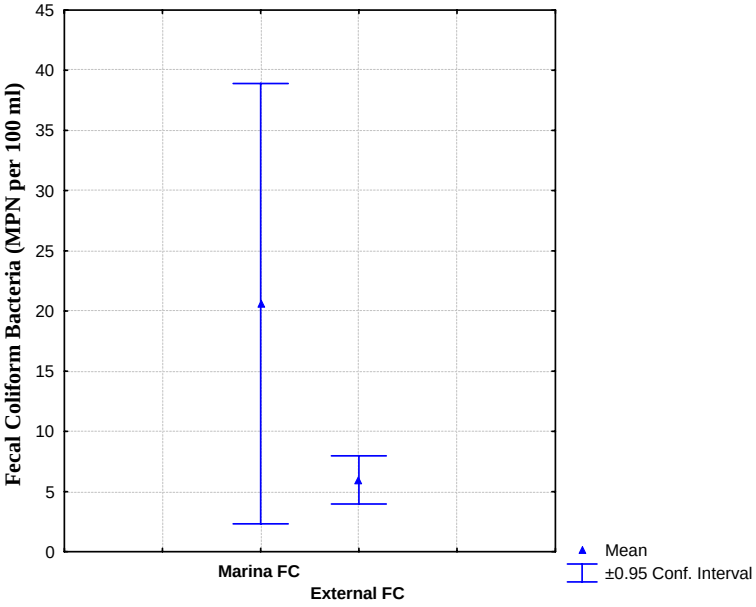


Figure 2 shows a mean with 95% confidence interval comparison of the same data as was used for figure 1. The mean and 95% confidence interval for the marina data is substantially greater than for the external data because of the extreme values that contribute to a higher standard deviation.

Figure 2: Comparison between FC Concentration in Marinas and in External Areas



Statistics for marina and external water samples are shown in Table 1.

Table 1. Marina and External FC Statistics				
	Sample Size	Mean	Median	Standard Deviation
Marina	60	20.6	4.0	70.8
External	60	6.0	2.0	7.7

The hypothesis test shows that the difference in Fecal Coliform concentration between marina and external waters is not significant (p=0.057)

A statistical t-test for independent samples was used for the second hypotheses as well. This is a one-tailed test with a level of significance of α=0.05. Figure 3 shows a box-plot comparison between all marina and external data, subdivided into weekend and weekday categories.

Figure 3: Comparison between FC Concentration in Marinas and in External Areas

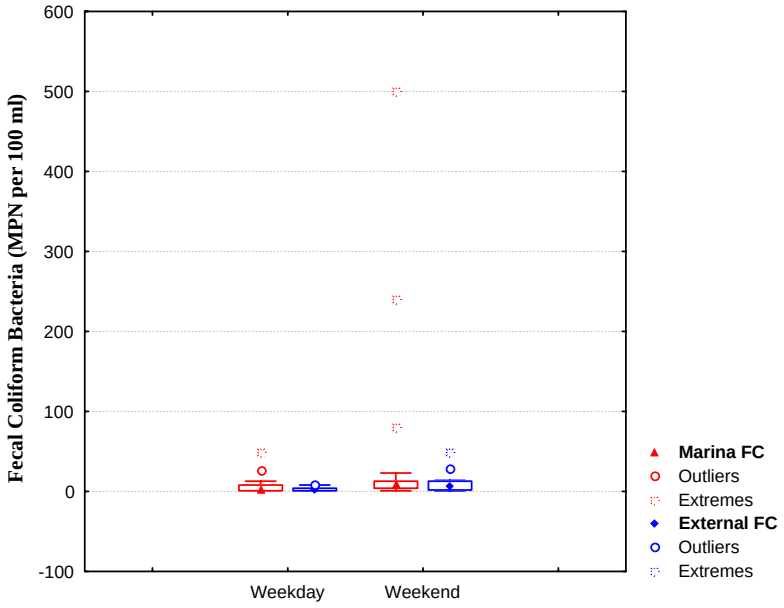
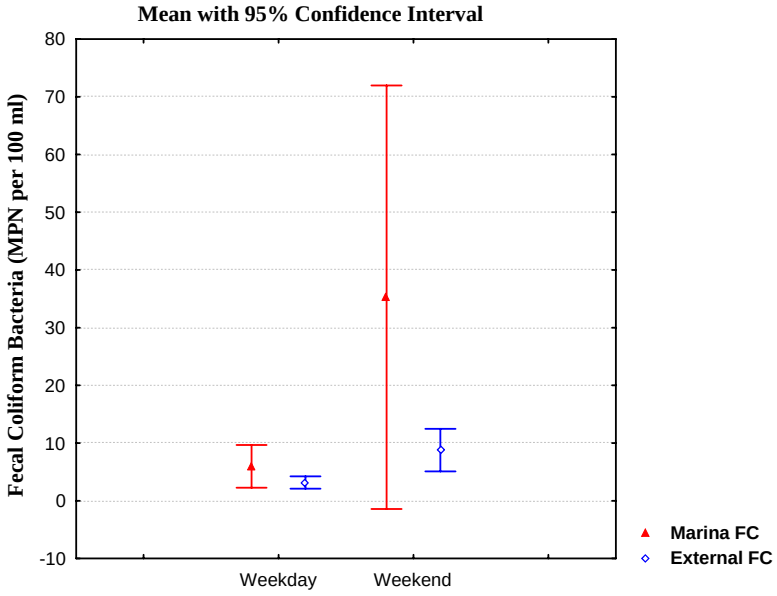


Figure 4 shows a mean-with-95%-confidence-interval comparison between all marina and external data, subdivided into weekend and weekday categories.

Figure 4: Comparison between FC Concentration in Marinas and in External Areas



Statistics for marina water samples are shown in Table 2. Statistics for external water samples are shown in Table 3.

Table 2: Marina Water Sample Statistics				
	Sample Size	Mean	Median	Standard Deviation
Weekday	30	6.0	2.00	10.0
Weekend	30	35.3	8.00	98.3

Table 3: External Water Sample Statistics				
	Sample Size	Mean	Median	Standard Deviation
Weekday	30	3.2	2.00	2.8
Weekend	30	8.8	7.00	9.9

The results of the t-test show that there is not a significant difference between weekday and weekend samples for the marina waters ($p = 0.055$). There was, however, a significant difference between weekday and weekend samples for external waters ($p = 0.002$).

9. Conclusions

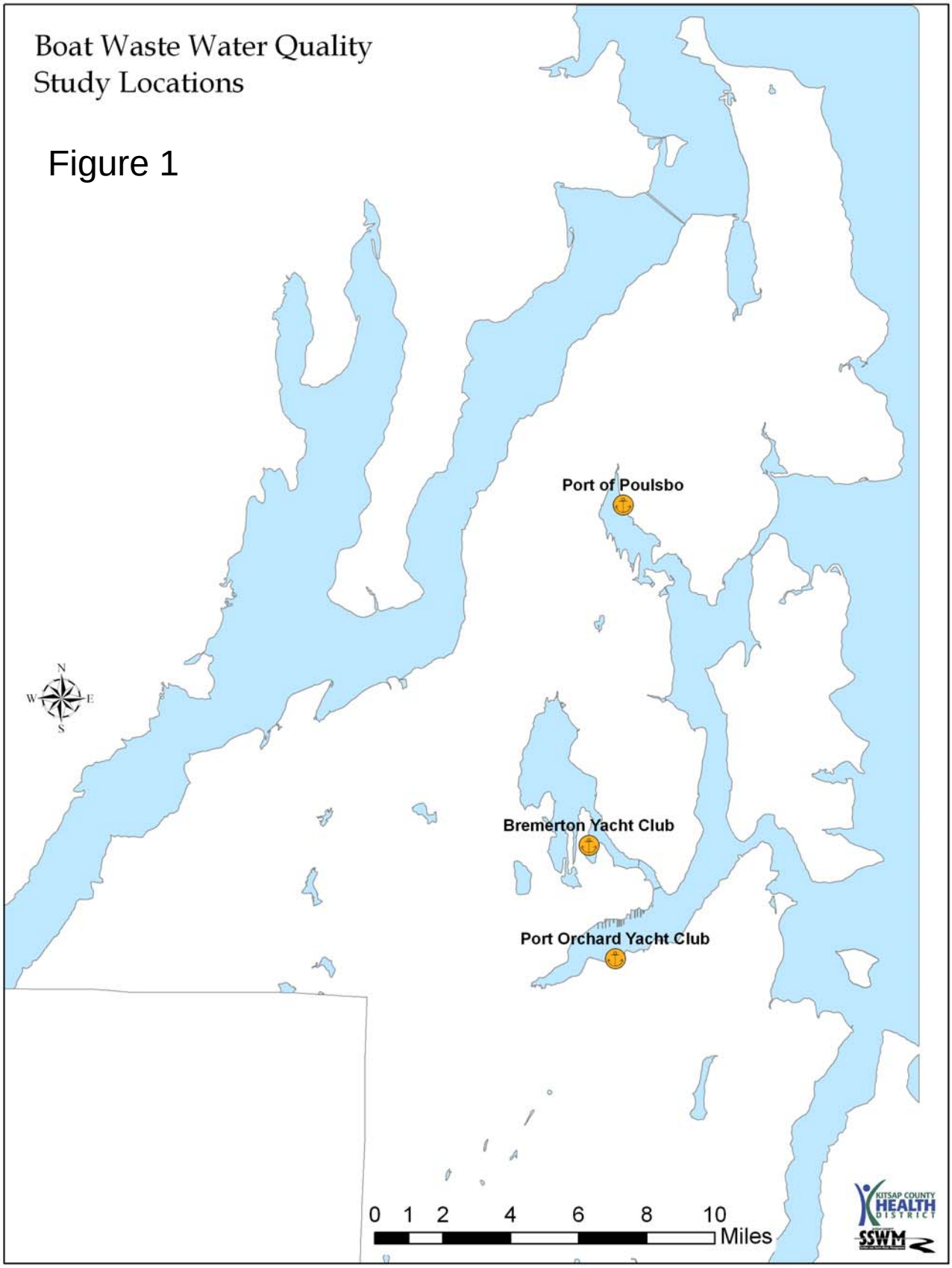
The only significant finding from the study data is that a difference exists between weekday and weekend FC concentrations for marina external waters. For all other tested hypotheses, the

comparison between marina and external waters, and the weekday / weekend difference in marina waters were not significant *based on the level of significance chosen*.

Because the non-significant results are very close to being statistically significant, a review of the meaning of p-value and level of significance is provided. The t-test statistic is determined by taking the difference between mean values (and normalizing it using the standard deviations). For two populations with identical means and standard deviations, one would expect that the difference between the mean of samples taken from these populations would be approximately 0. It is possible, however, that the difference is much greater than (or less than) 0. The probability of two equal populations producing sample means that are far apart is very small. Consequently, if that happens, the conclusion is to reject the null hypothesis and accept the alternate hypothesis. The p-value is a probability given to the t-test statistic. If the p-value is small, it indicates that the sample was unlikely to have come from the population as described by the null hypothesis. Thus, a small p-value leads to a significant result.

Since small is a relative term, researchers have two choices. One choice is to simply publish the p-value and allow the reader to decide if it is significant. The second choice, which is what has been done with all the analyses for the Health District, is to predetermine the level of significance. That is the number that serves as the borderline between significant and non-significant p-values. This level is traditionally 0.05. Thus p-values less than 0.05 are significant and the alternate hypothesis is considered correct. P-values greater than 0.05 are not significant and the null hypothesis is considered correct. A P-value of 0.05 means that 95% of the time we can be confident that accepting or rejecting the hypothesis is correct. In this study, marina waters statistics, and consequently the two tests involving the marina, are influenced by two extreme values. Those values affect both the mean and standard deviation and consequently the t-test statistic and the p-value.

In regard to evaluating the effectiveness of the current Marina Sewage Regulations, the Health District concludes that the presence of appropriate marina sewage infrastructure has prevented the pollution of internal marina waters as compared to nearby external waters. In regard to the need for revisions of the ordinance, the Health District concludes that based on the difference between water quality on heavy boat use days as opposed to light boat use days, an ordinance that more adequately addresses individual boat sewage discharges both inside and outside marina areas, may more adequately protect marine water quality.


Boat Waste Water Quality
Study Locations
Figure 1
Port of Poulsbo
Bremerton Yacht Club
Port Orchard Yacht Club
N
W
E
S
0 1 2 4 6 8 10
Miles
KITSAP COUNTY HEALTH DISTRICT
SSWM

BIBLIOGRAPHY

American Public Health Association, American Water Works Association, and Water Environment Federation, Standard Methods for the Examination of Water and Wastewater, 20th Edition, Washington DC, 1998.

United States Environmental Protection Agency, Ambient Water Quality Criteria for Bacteria - 1986, EPA-440/5-84-002, 1986.

United States Environmental Protection Agency, Puget Sound Estuary Program, Recommended Protocols for Microbiological Studies in Puget Sound, 1986.

Washington State, Chapter 173-201A of the Washington Administration Code, 2003.

Appendix A – Marina Details

Marina	Marina Address	Total Slips	Liveaboards	Stationary Pumpouts	Portable Pumpouts	Pumpout Holding Tanks	Dump Stations	Indoor Public Restrooms
Bremerton Yacht Club	2700 Yacht Haven Way, Bremerton, WA 98312	198	11	1		2 x 500 gal tanks		yes
Port of Poulsbo	18809 Front Street, Poulsbo, WA 98370	399	9	1	1	direct to sewer	1	yes
Port Orchard Yacht Club	201 Bay Street, Port Orchard, WA 98366	220	17	1	1	direct to sewer		yes