Analytical Framework and Technical Analysis for the Upper Willapa River Fecal Coliform Bacteria TMDL

Prepared by:
Tetra Tech, Inc.
10306 Eaton Place
Suite 340
Fairfax, Virgina 22030

Prepared for:
U.S. Environmental Protection Agency, Region 10
1200 Sixth Avenue
Seattle, Washington 98101

June 24, 2004

Contents

Tables

Figures

Introduction

The Upper Willapa River constitutes the fresh water, non-tidal portion of the Willapa River, which ultimately flows into the Willapa Bay, Washington. The river flows in a northeasterly direction through a predominantly Agricultural – Farming area. Washington State Department of Ecology has listed the Willapa River in the 2004 303(d) list for not meeting water quality standards for Fecal Coliform (FC) bacteria because of point and nonpoint sources.

Data Source/Analysis

Data for the Willapa River basin were collected at several locations along the Upper Willapa and have been reported in the *Willapa River Dissolved Oxygen and Fecal Coliform Bacteria Total Daily Load* study (Pickett, 2000). Figure 1 shows the study area and the sampling locations. Sampling was conducted for one year (1998) at seven locations along the main stem from near the headwaters below Patton Creek to the Camp One Rd site near Bullard Road and at six tributaries stations (Table 1).

Table 1. Fecal Coliform Sampling along the Upper Willapa River (1998)

Mainstem RM	Tributary RM	Sampling Station	Site Code	Count
41.2		Willapa R below Patton Creek	WRPA-1	16
37.5	0.3	Falls Ck above Retreat Center	FALLS	8
37.1		Willapa R at Swiss Picknik Rd	WRSW-1	15
36.2	0.4	Fern Creek at Elk Prairie Rd	FERN-1	15
33.2		Willapa R at Lebam	WRLE	16
30.5	0.25	Fork Creek at State Hatchery	FORK-1	16
30		Willapa R above Trap Creek	WRTR-1	16
29.9	0.15	Trap Creek above Hwy 6	TRAP-1	14
25.2		Willapa R at Oxbow Road	WROX-1	14
24.2	0.5	Stringer Ck at Highland-Stringer Rd	STRINGER	16
21.4		Willapa R at SR 6 near Menlo	WRMN-1	15
17.9	0.3	Mill Creek at 1st Mill Ck Rd Br	MILLCK	15
17.5		Willapa R at Camp One Rd	WRC1-1	35

The data have been analyzed in the *Willapa River Dissolved Oxygen and Fecal Coliform Bacteria Total Daily Load* study (Pickett, 2000) to determine compliance with water quality standards. The analysis showed that exceedances occurred at different times during the year (anytime from May through December) at different locations and that there was no seasonal trend in the exceedances that could define a critical period. Since the sampling at these sites is monthly and random without bias to climatological or hydrological events, it is assumed that this data covers the range of critical conditions. However, it should be noted that additional monitoring would increase the statistical power of the long-term random sampling, as it would include several other high bacteria loading events (e.g., intense storms).

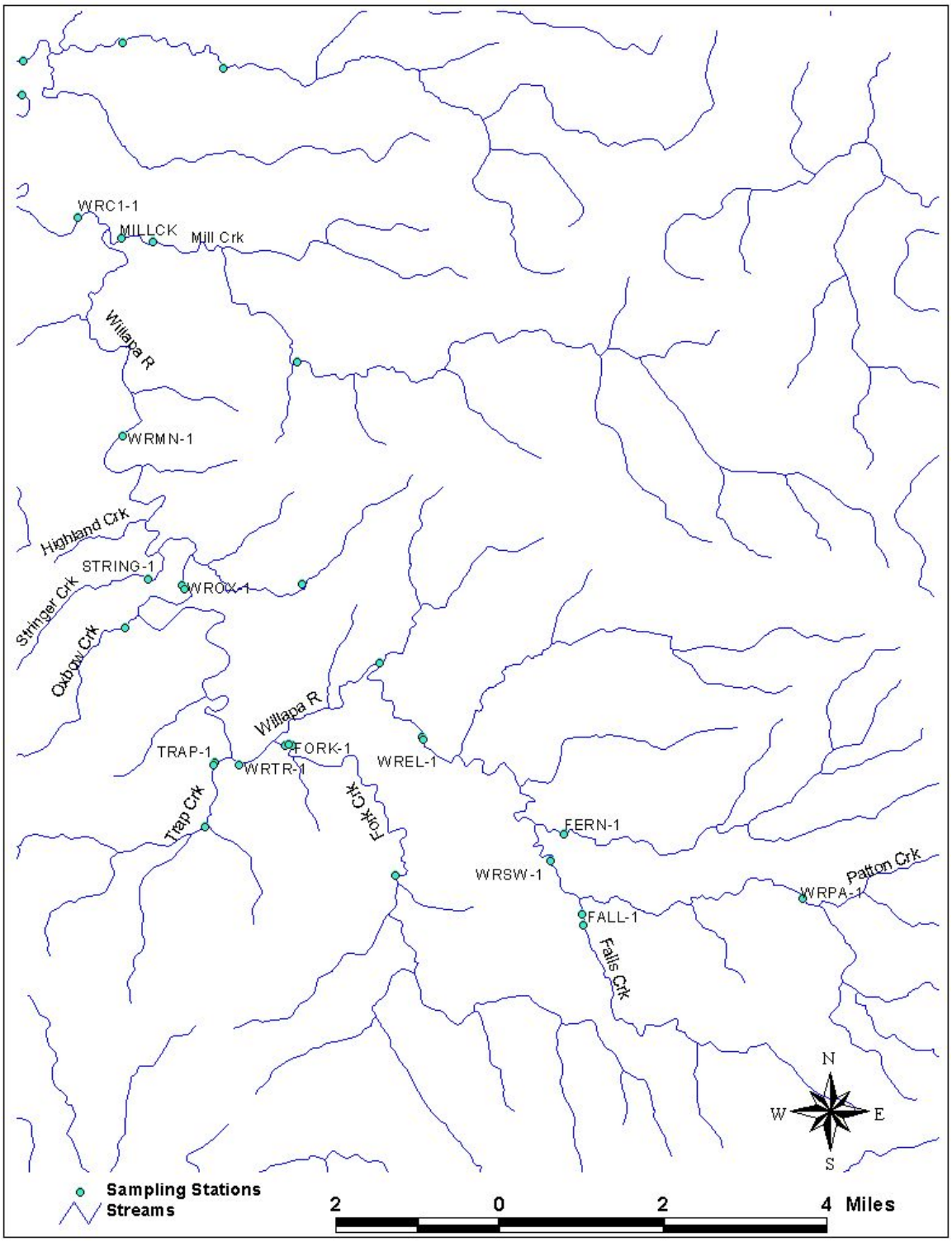


Figure 1. Fecal Coliform Sampling Locations along the Upper Willapa River

Methodology

The Statistical Roll Back Method (Ott, 1995) was used to analyze the distribution of FC counts and derive the corresponding reductions for the TMDL. This method has been successfully applied by the Washington State Department of Ecology in other FC bacteria TMDL evaluations (Cusimano and Giglio, 1995; Pelletier and Seidders, 2000; Ecology, 2000; Coots, 2002).

The following is a brief summary of the Statistical Theory of Rollback (STR) from *Environmental Statistics and Data Analysis* by Ott (1995) (Ecology, 2000). The major theorems and corollaries associated with the method are given below:

1. If Q = the concentration of a contaminant at a source, and D = the dilution-diffusion factor and X = the concentration of the contaminant at the monitoring site, then $X = Q * D$
2. Successive random dilution and diffusion of a contaminant Q in the environment often result in a lognormal distribution of the contaminant X at a distant monitoring site.
3. The coefficient of variation (CV) of Q is the same before and after applying a "rollback", i.e., the CV in the post-control state will be the same as the CV in the pre-control state. If the rollback factor =r, a reduction factor expressed as a decimal (a 70% reduction would be a rollback factor of 0.3). The random variable Q represents a pre-control source output state and rQ represents the post-control state.
4. If D remains consistent in the pre-control and post-control state (long-term hydrological and climatic conditions remain unchanged), then CV(Q)*CV(D)=CV(X), and CV(X) will be the same before and after the rollback is applied.
5. If X is multiplied by the rollback factor r, then the variance in the post-control state will be multiplied by r^2, and the post-control standard deviation will be multiplied by r.
6. If X is multiplied by the rollback factor r, the quantiles of the concentration distribution will be scaled geometrically.
7. If any random variable is multiplied by a factor r, then its expected value and standard deviation also will be multiplied by r, and its CV will be unchanged. (Ott uses "expected value" for the mean).

Class A freshwater quality standards apply to the Upper Willapa River. The Class A fecal coliform standard requires that the fecal coliform criteria be met on two levels: the geometric mean must not exceed 100 cfu/100 mL, and not more than 10% of the samples can exceed 200 cfu/100 mL. The statistical roll back method (Ott, 1995) affords a way to determine if the FC distribution statistics for individual sites meet the water quality criteria in the Willapa River basin. The statistical roll back method describes a way to use the statistical characteristics of a set of water quality parameter results to estimate the distribution of future results after abatement processes are applied to sources. The method relies on basic dispersion and dilution assumptions and their effect on the mean and standard deviation of chemical or bacteria sample results at a monitoring site downstream from a source. The rollback method then provides a statistical estimate of the new population after a chosen reduction factor is applied to the existing pollutant source (Ecology, 2000). The amount of reduction required for the fecal coliform bacteria TMDL was based upon meeting the most restrictive of the two fecal coliform bacteria criteria.

As with many water quality parameters, fecal coliform counts collected over time at individual sites from the Upper Willapa River follow a lognormal distribution. The probability density functions (PDF) were plotted to check if they followed a lognormal distribution. In general, at all the stations the data tended towards having the characteristic lognormal distribution curve (skewed and having a long tail). It should be noted that more samples would be required to fully verify lognormality of the data (i.e., at least 30 or greater) at the individual sites. However, a further check was done by lumping all the data along the main stem (to get more data points) and then plotting the PDF, which confirms the lognormality of the data. An example plot showing the PDF using the monitored fecal coliform data for all the stations is shown below in Figure 2.

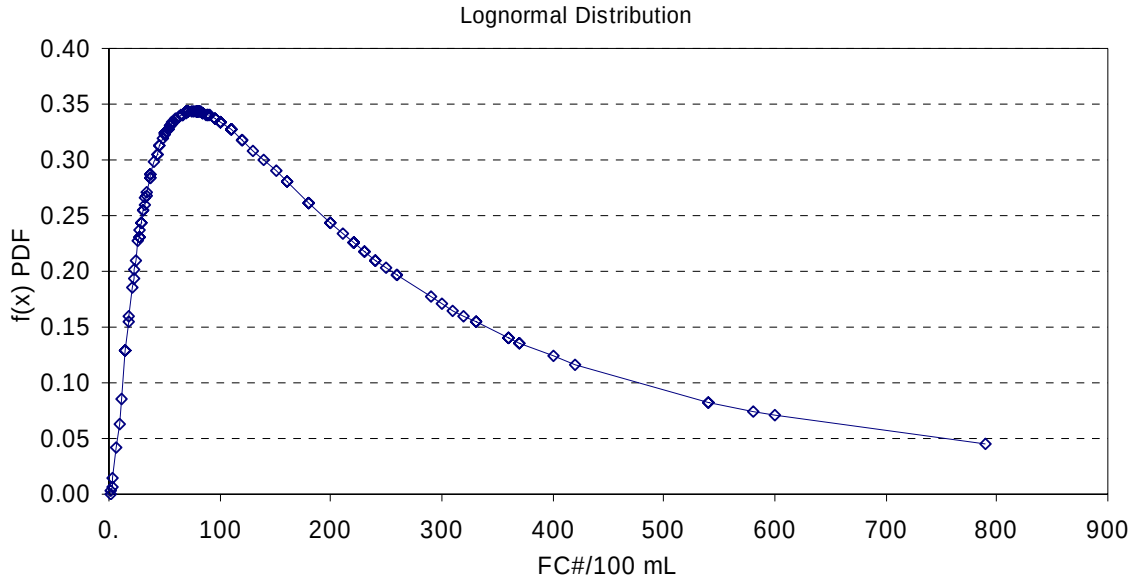


Figure 2. Lognormal distribution of FC data in the Upper Willapa River (128 observations, mean 131, standard deviation = 140).

The lognormal probability was then calculated for the monthly fecal coliform data. The fecal coliform data were then plotted on a logarithmic-probability graph. When plotted the data appear to form nearly a straight line (Figure 3). This essentially shows the cumulative lognormal distribution. The 50^{th} percentile which is an estimate of the geometric mean, and the 90^{th} percentile, a representation of the level over which 10% of the samples lie, can be located along a line plotted from an equation estimating the original monthly fecal coliform equation. An example plot showing the cumulative lognormal distribution (using the monitored fecal coliform data for all the stations) to which the statistical rollback method is applied is shown below in Figure 3.

In the graphical example given in Figure 3 the 50^{th} and 90^{th} percentile on the line estimating the existing condition monthly fecal coliform correspond to 72.37 cfu/100 mL and 362.74 cfu/100 mL. For this case the geometric mean criteria of 100 cfu/100 mL is met but the 90 percentile (not more than 10% of the samples) of 200 cfu/100 mL is exceeded. Using the statistical rollback method, the regression line for the data is shifted or "rolled back" so that the 90^{th} percentile value is equal to 200 cfu/100 mL (even though the geometric mean criteria is met). The new distribution is plotted parallel to the original and is used to identify the TMDL targets to

meet water quality standards. The estimate of the geometric mean for this new distribution, located at the 50th percentile, is 39.90 cfu/100 mL. The result is a geometric mean target of a sample distribution that would likely have less than 10% of its over 200 cfu/100 mL (Ecology, 2000). A 44.86% fecal coliform reduction is required (i.e., roll back factor of ~ 0.55) from the combined sources to meet this target distribution [(362.74 - 200)/ 362.74 = 0.4486 *100 = 44.86%].

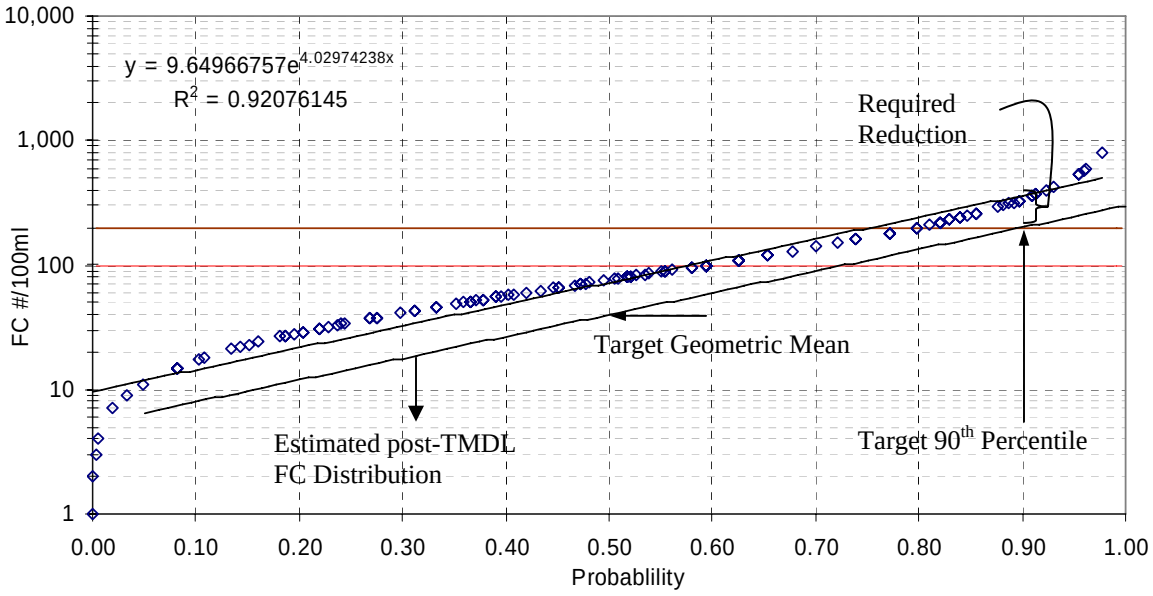


Figure 3. Figure 3. Example graphical demonstration of the statistical rollback method (Ott, 1995) used to calculate the fecal coliform TMDL target for the Upper Willapa River.

The statistical rollback method described above was applied to each of the main-stem and tributary fecal coliform sampling locations to identify necessary reductions. Graphical analysis of the rollback method applied to each sampling location is provided in the Appendix.

TMDL Allocation and Results

The TMDL fecal coliform targets for this fecal coliform TMDL were calculated based on a concentration rather than fecal coliform count loads. To meet the TMDL, concentration-based load allocations were established for all monitoring stations in the Upper Willapa River. An allocation of fecal coliform loads does not address the criteria compliance requirements under various hydrologic conditions at the site. For example, a high fecal coliform count out of compliance under low-low conditions may have a lower load than a lower count within compliance under higher flow conditions (Ecology 2004). The calculated fecal coliforms targets along with the required reductions using the statistical rollback method along the main-stem (upstream to downstream) and tributaries are shown below in Tables 2 and 3 respectively. The reductions along the mainstem varied from zero to 67 percent along the mainstem and zero to 70 percent along the tributaries.

Table 2. Recommended Fecal Coliform TMDL targets and reductions along the mainstem of the Upper Willapa River

Waterbody Listing ID	Location	Count	Existing		Limiting Criteria	Required Reduction
			Geometric Mean	90th Percentile		
YN05JR67.467	Willapa R below Patton Creek	16	15.90	87.28	-	0.00%
YN05JR59.129	Willapa R at Swiss Picknik Rd	15	174.69	613.23	200	67.39%
YN05JR56.690	Willapa R at Lebam	16	144.77	375.45	200	46.73%
YN05JR49.716	Willapa R above Trap Creek	16	57.38	123.42	-	0.00%
YN05JR41.711	Willapa R at Oxbow Road	14	74.12	445.48	200	55.11%
YN05JR34.991	Willapa R at SR 6 near Menlo	15	97.54	460.28	200	56.55%
YN05JR28.147	Willapa R at Camp One Rd	35	74.96	257.34	200	22.28%

Table 3. Recommended Fecal Coliform TMDL targets and reductions for the Upper Willapa River tributaries

Location	Count	Existing		Limiting Criteria	Required Reduction
		Geometric Mean	90th Percentile		
Falls Ck above Retreat Center	8	51.37	259.85	200	23.03%
Fern Creek at Elk Prairie Rd	15	193.31	669.37	200	70.12%
Fork Ck at A-400 Bridge	16	29.49	240.00	200	0.00%[a]
Trap Creek at B-Line Bridge	14	19.86	107.86	-	0.00%
Stringer Creek at Highland-Stringer Rd	16	17.50	62.78	-	0.00%
Mill Ck at 3rd Mill Ck Rd Br	15	50.50	162.26	-	0.00%

a: No reduction was applied since only one sample exceeds the 90th percentile (<10% of all samples) criteria which is the controlling criteria

Figure 4 presents the locations of the listed segments and the corresponding stations where reductions were calculated. The 303(d) listed segments for fecal coliform along the Upper Willapa River were based on the Proposed 2002 Water Quality Assessment GIS shapefiles (proposed listing as of January 15, 2004). A separate GIS shapefile was created for the 303(d) listed segments based on the fecal coliform listed segments shown in the map in the Water Quality Assessment website for Category 5 listed segments (Figure 4) <http://apps.ecy.wa.gov/wqawa/viewer.htm>

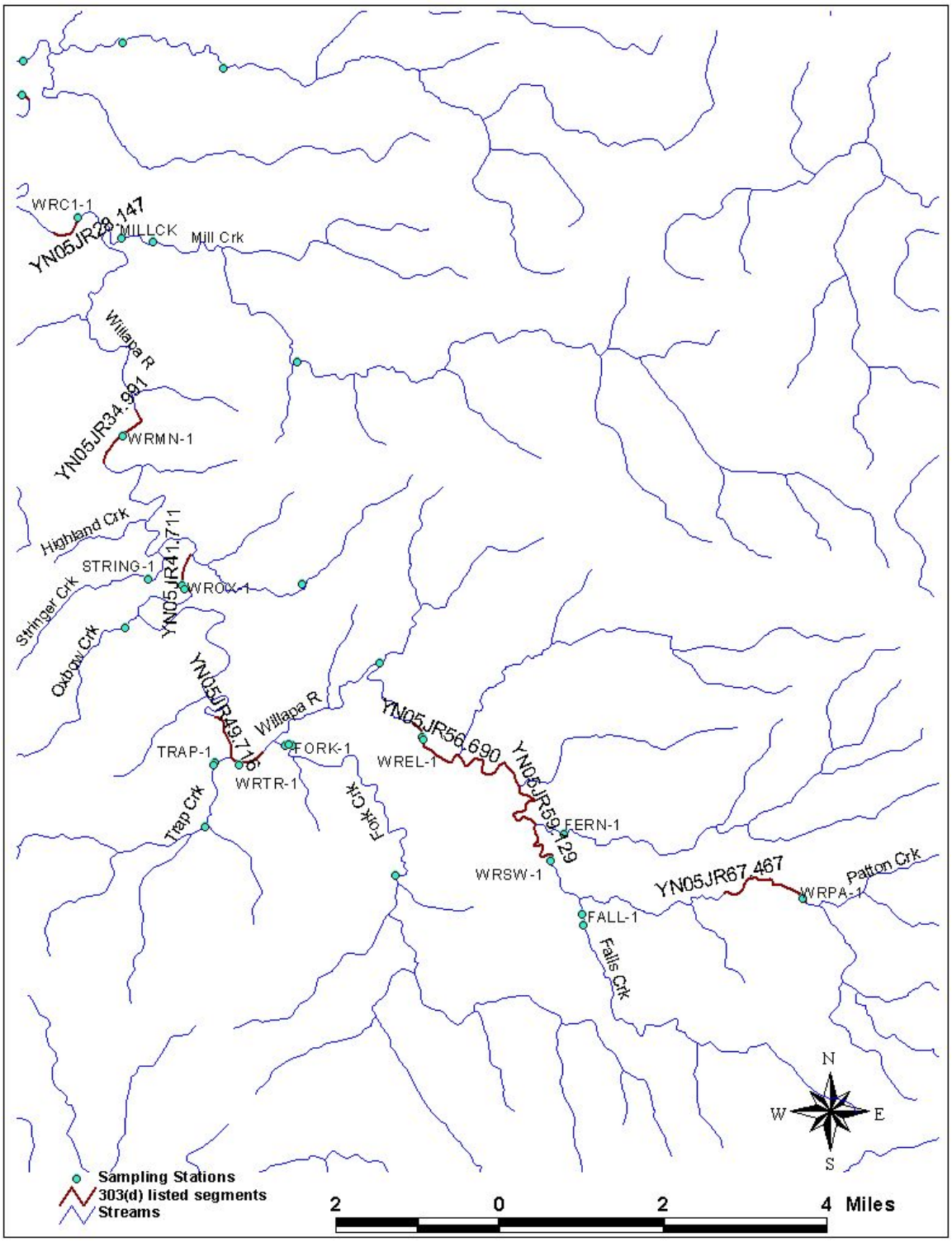


Figure 4 . 303(d) listed segments

References

Coots, R. 2002. *Colville River Fecal Coliform Total Maximum Daily Load Study*. Washington State Department of Ecology, Olympia, WA. Pub. No. 02-03-036.

Cusimano, R, and Giglio, D. 1995. *Salmon Creek Nonpoint Source Pollution TMDL*. Washington State Department of Ecology, Olympia, WA. Pub. No. 95-355.

Ecology, 2000. Nooksack River Watershed Bacteria Total Maximum Daily Load. Pub No. 00-10-036.

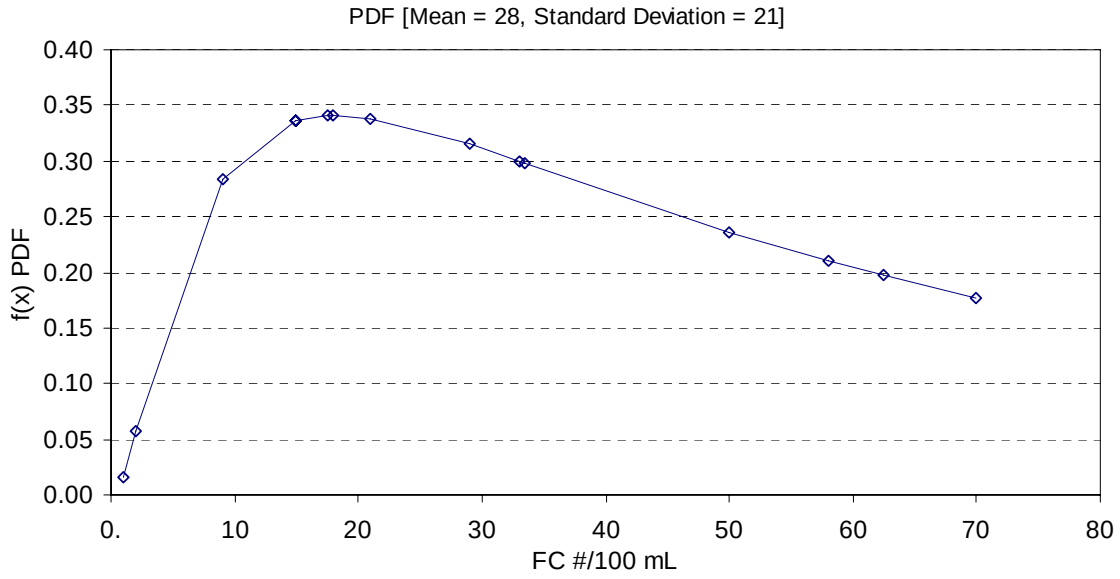
Ecology, 2004. Stillaguamish River Watershed Fecal Coliform, Dissolved Oxygen, pH, Mercury, and Arsenic Total Maximum Daily Load Study. Pub. No. 03-03-042

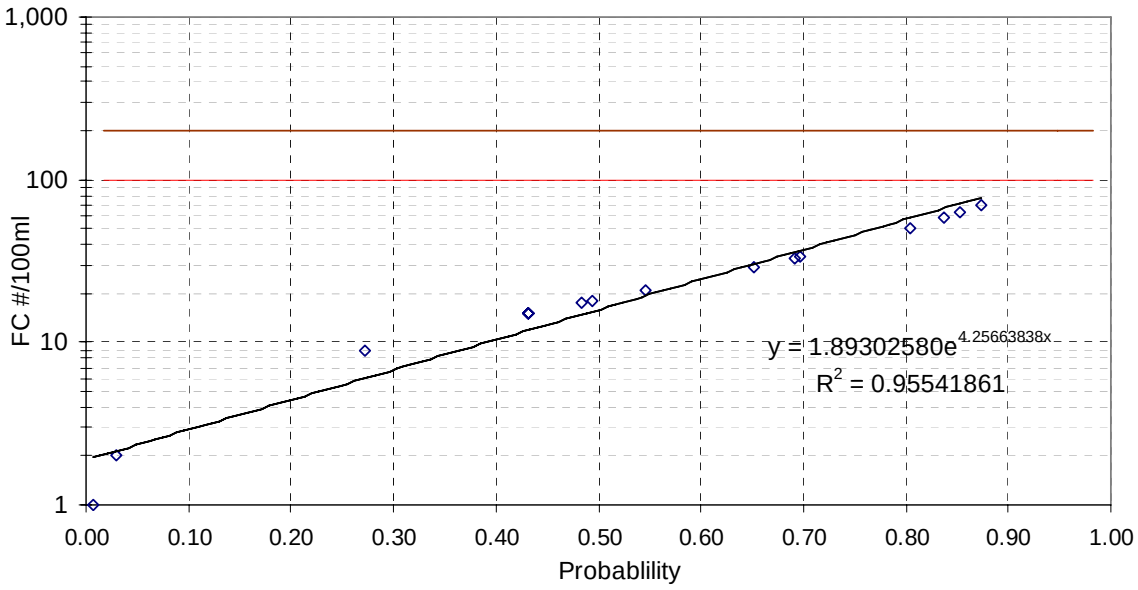
Ott, W., 1995. Environmental Statistics and Data Analysis. Lewis Publishers, New York, NY.

Pelletier, G, and Seiders, K, 2000. *Grays Harbor Fecal Coliform Total Maximum Daily Load Study*. Washington State Department of Ecology, Olympia, WA. Pub. No. 00-03-020.

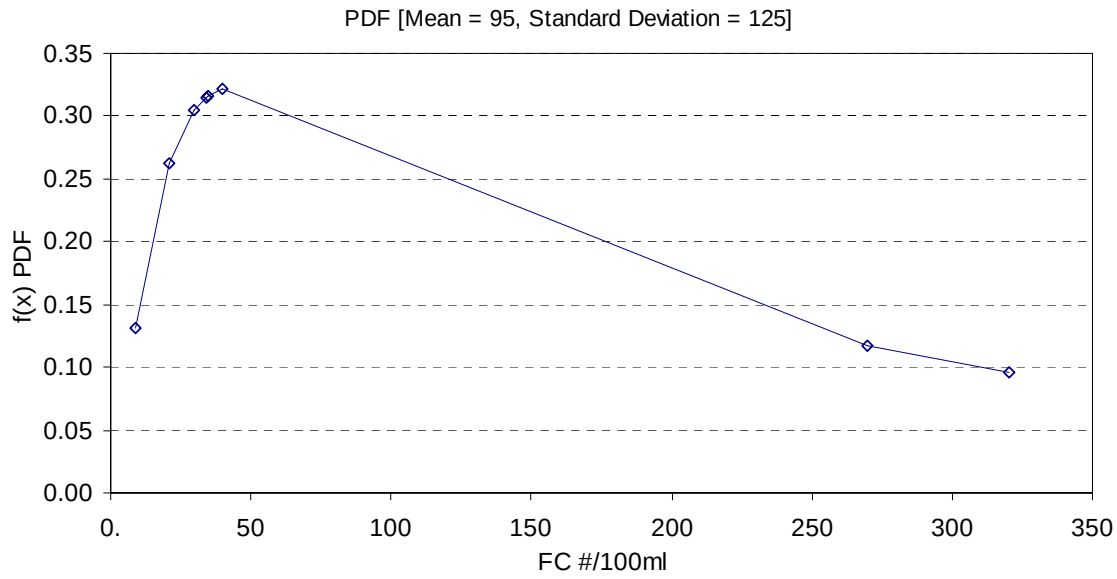
Pickett, P.J., 2000. Willapa River Total Maximum Daily Load Study Data Summary Report. Pub. No. 00-03-005.

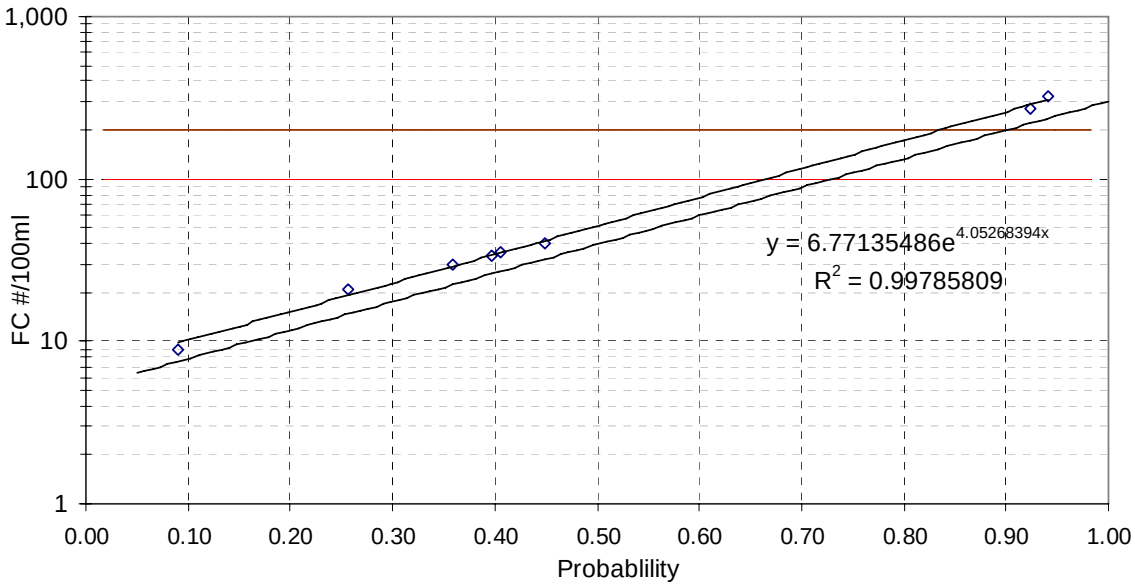
Appendix



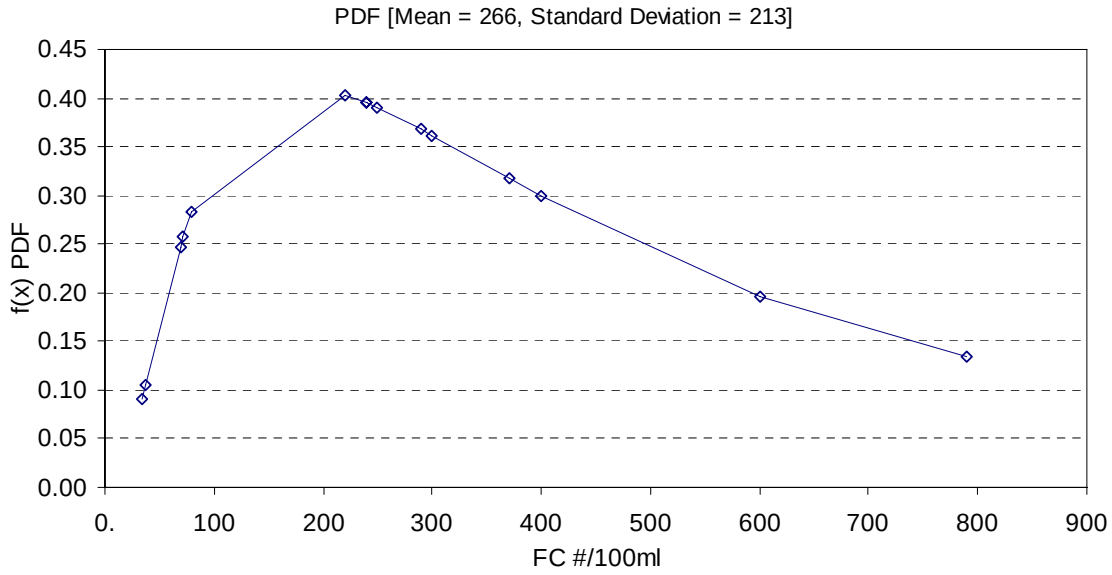


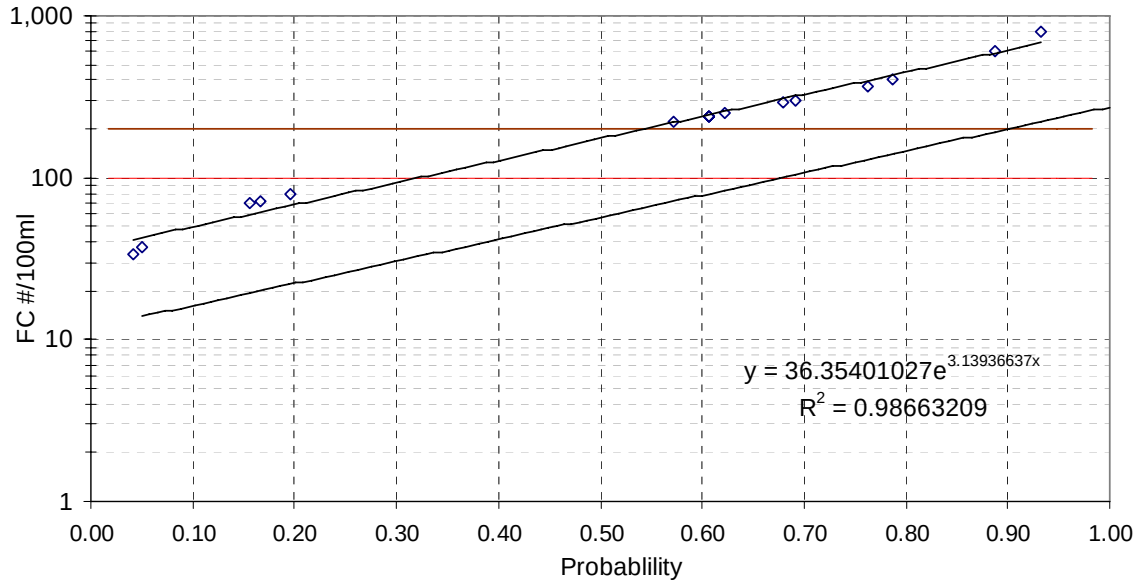
Willapa River below Patton Creek



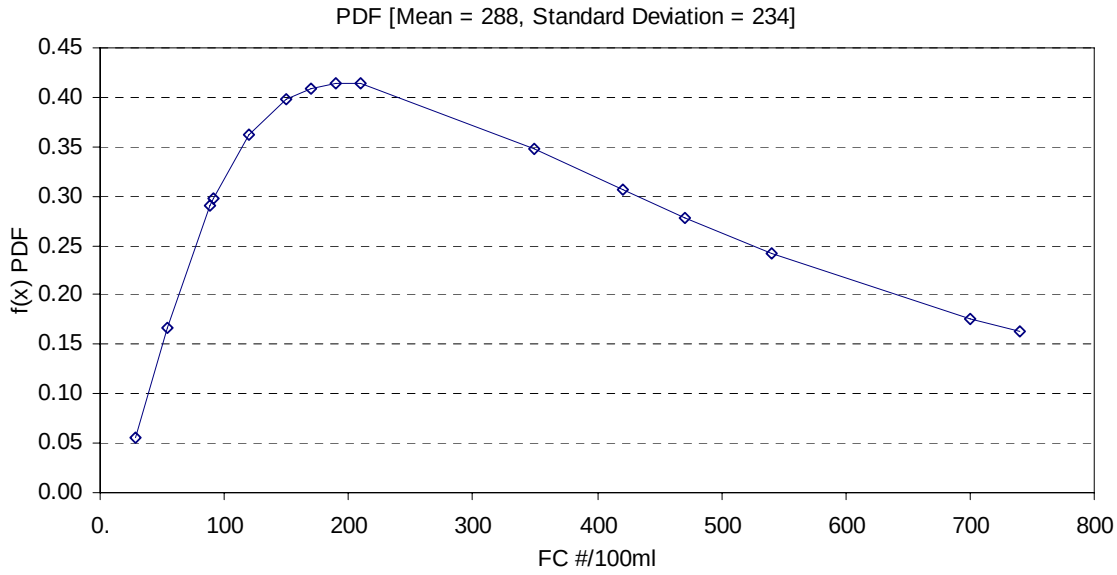


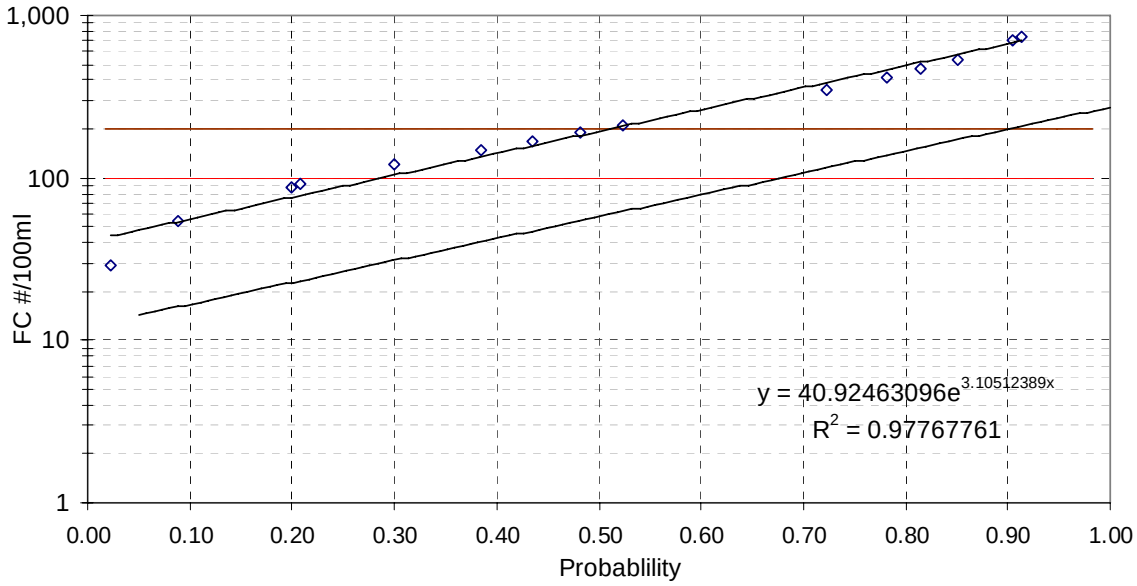
Falls Ck above Retreat Center



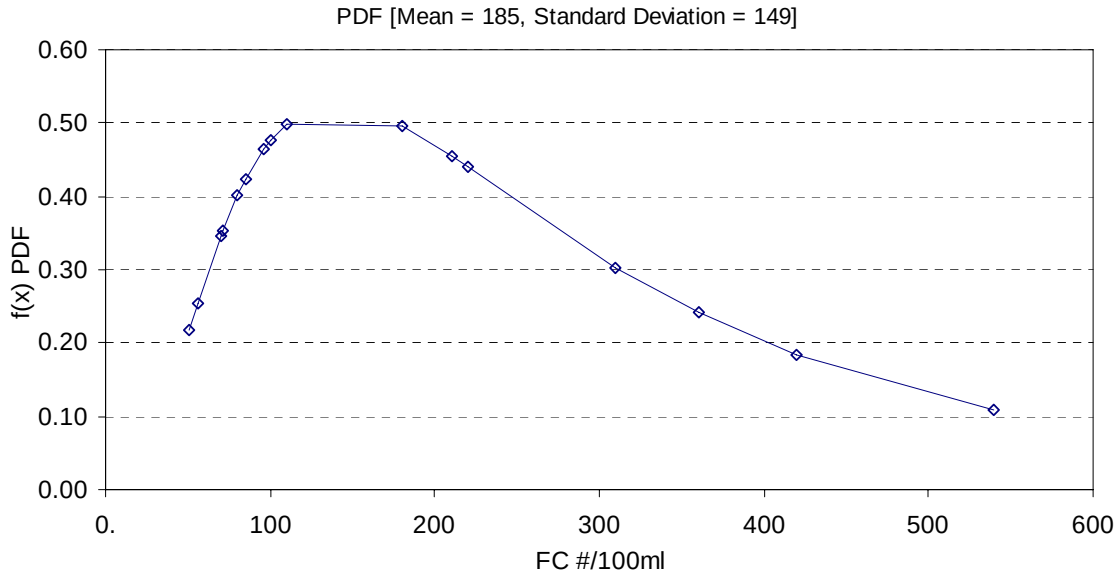


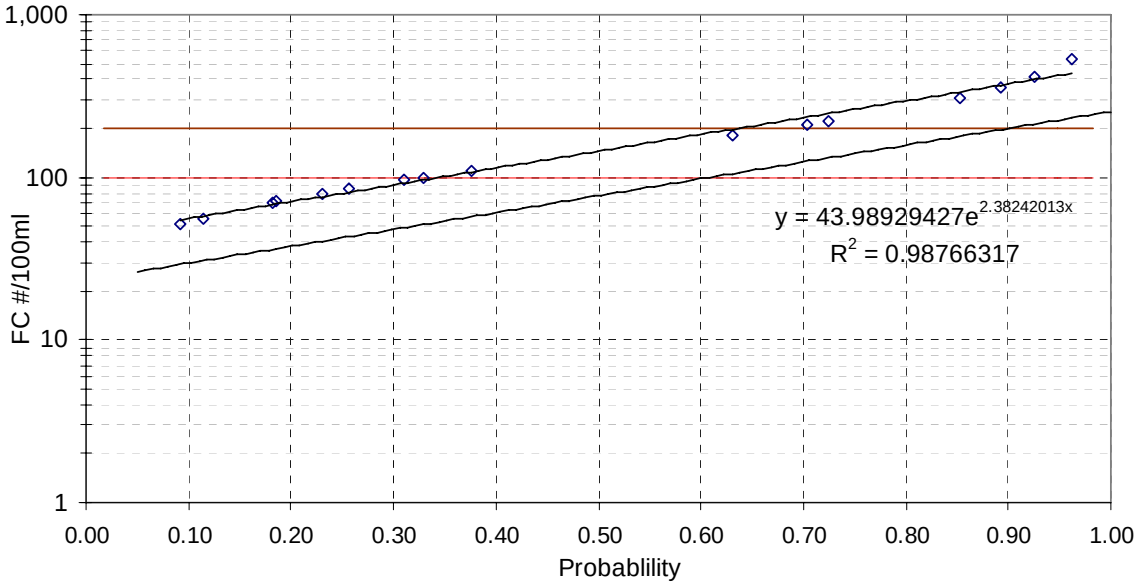
Willapa R at Swiss Picknik Rd



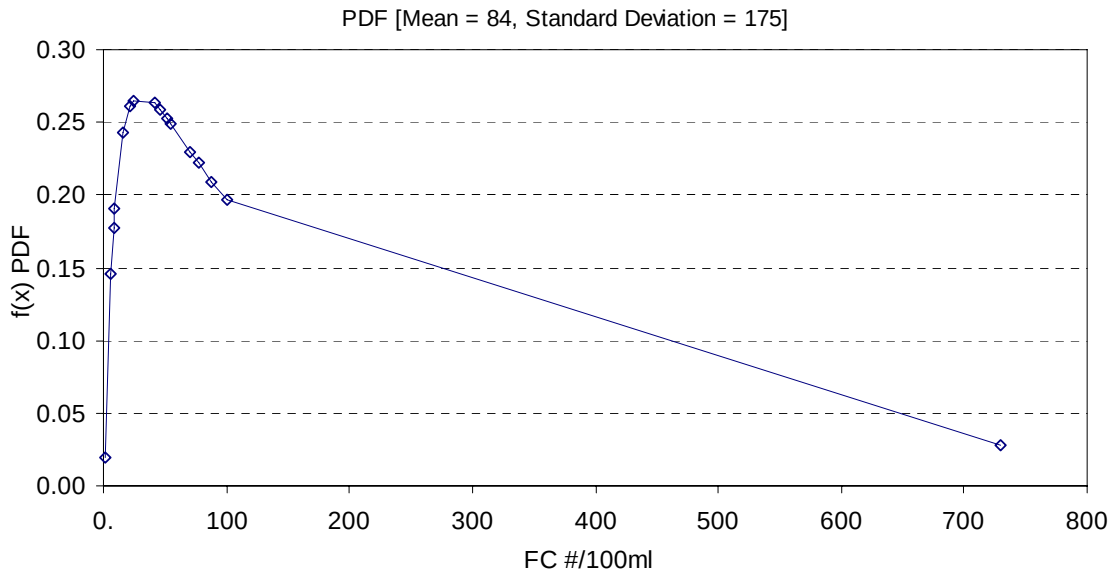


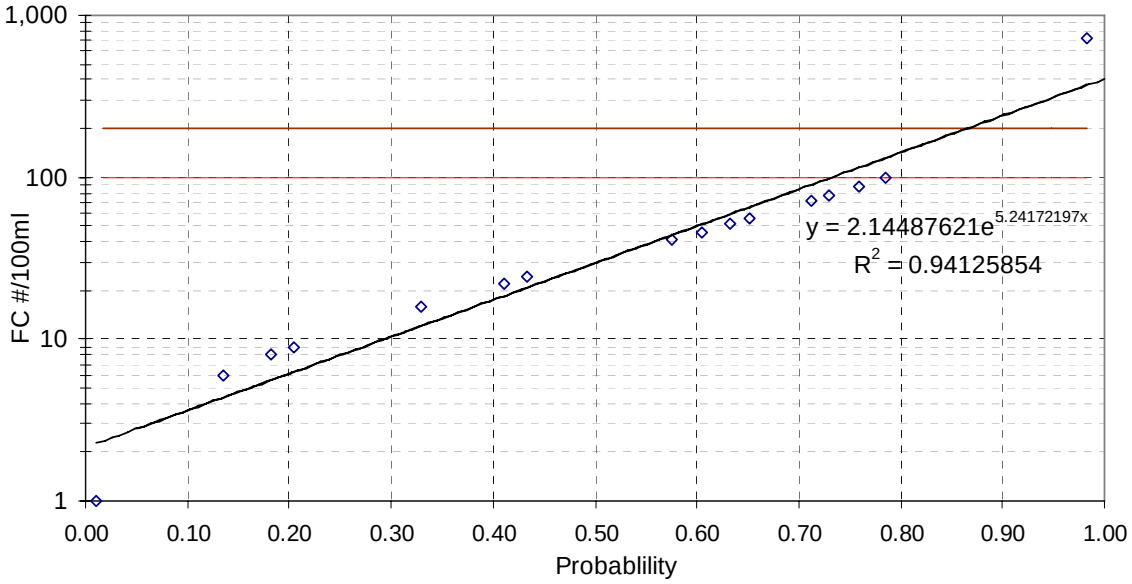
Fern Creek at Elk Prairie Rd



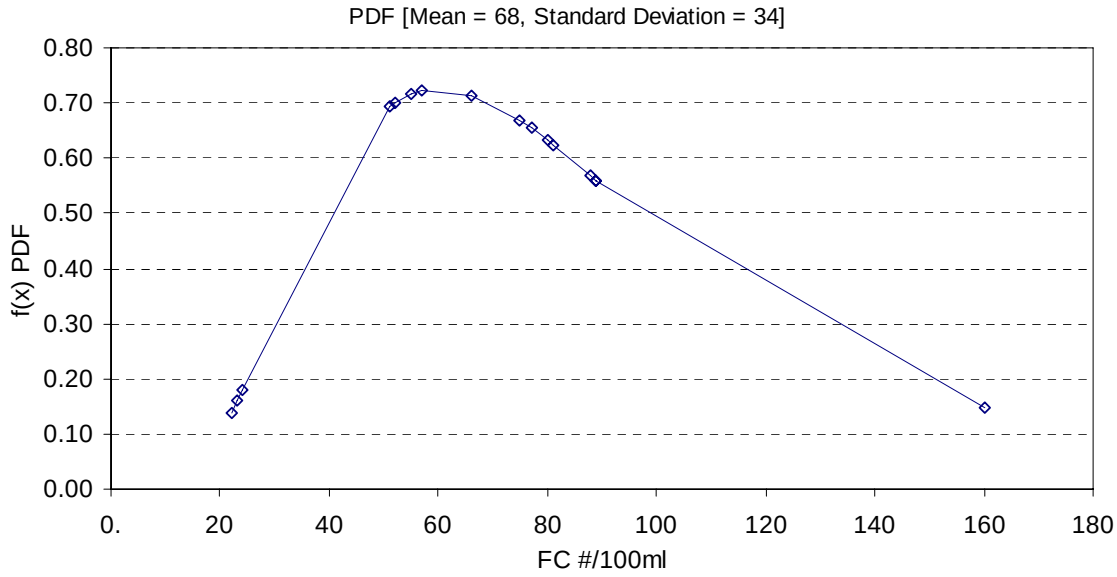


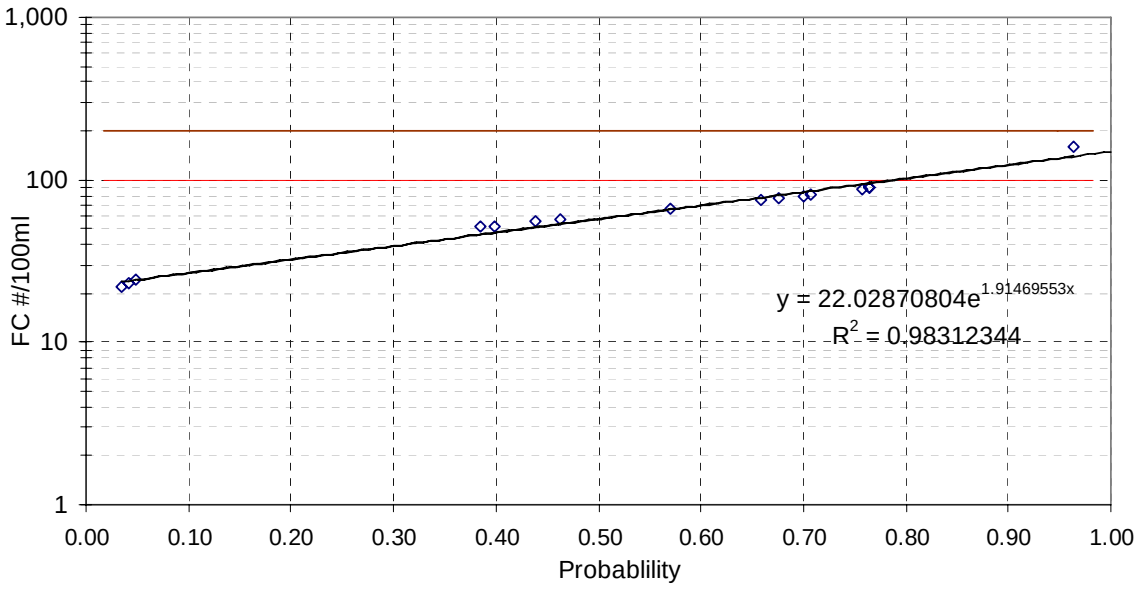
Willapa River at Lebam



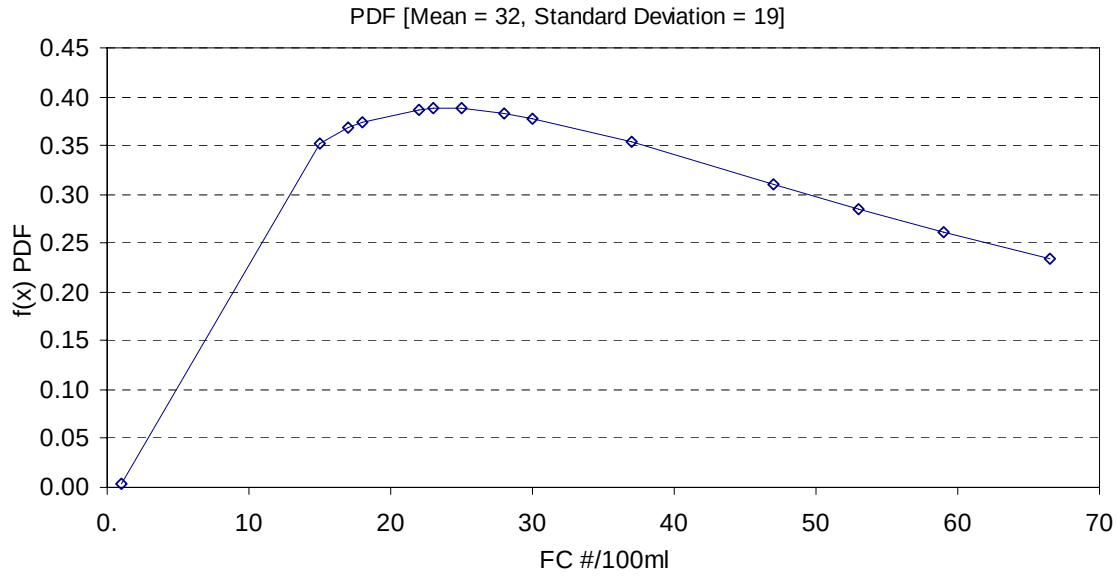


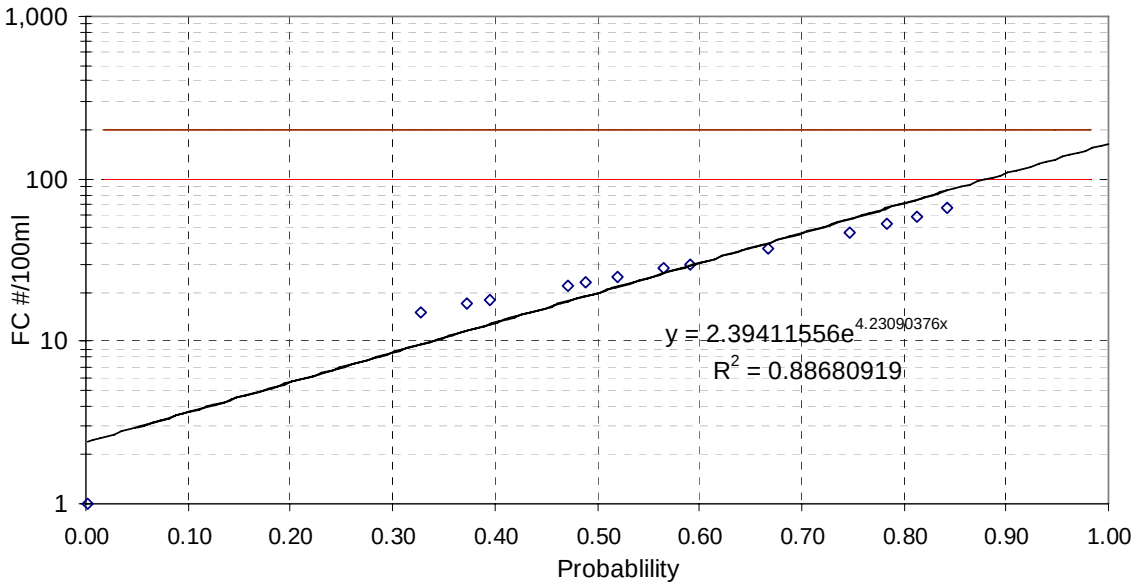
Fork Ck at A-400 Bridge



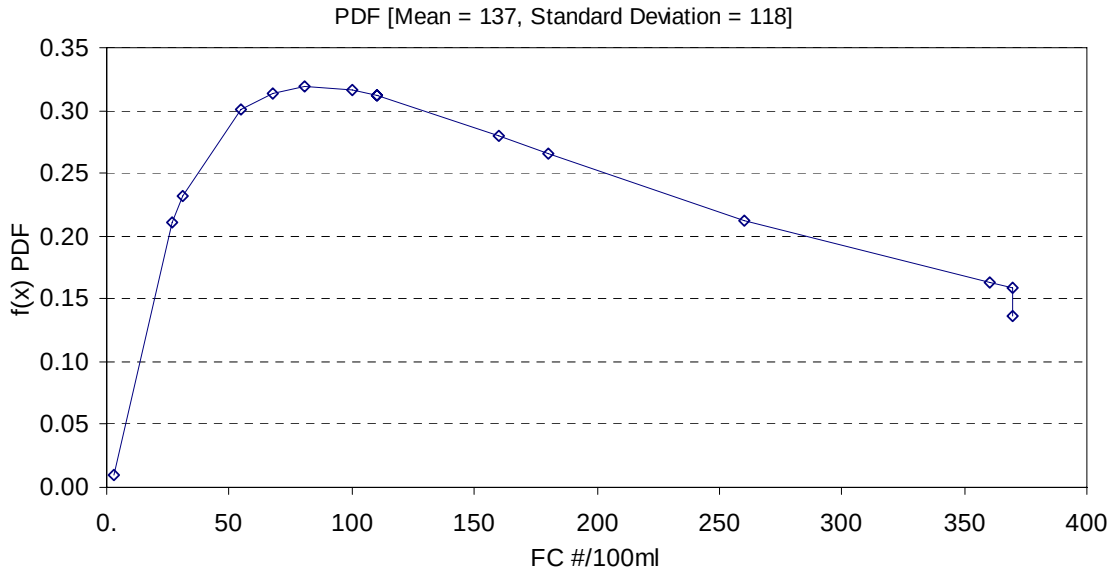


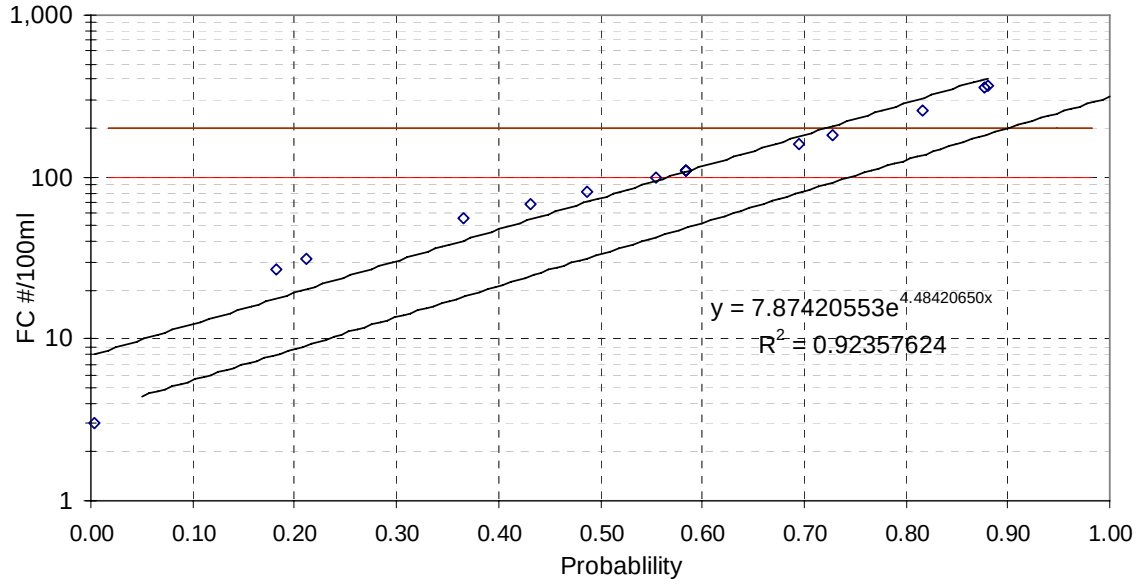
Willapa River above Trap Creek



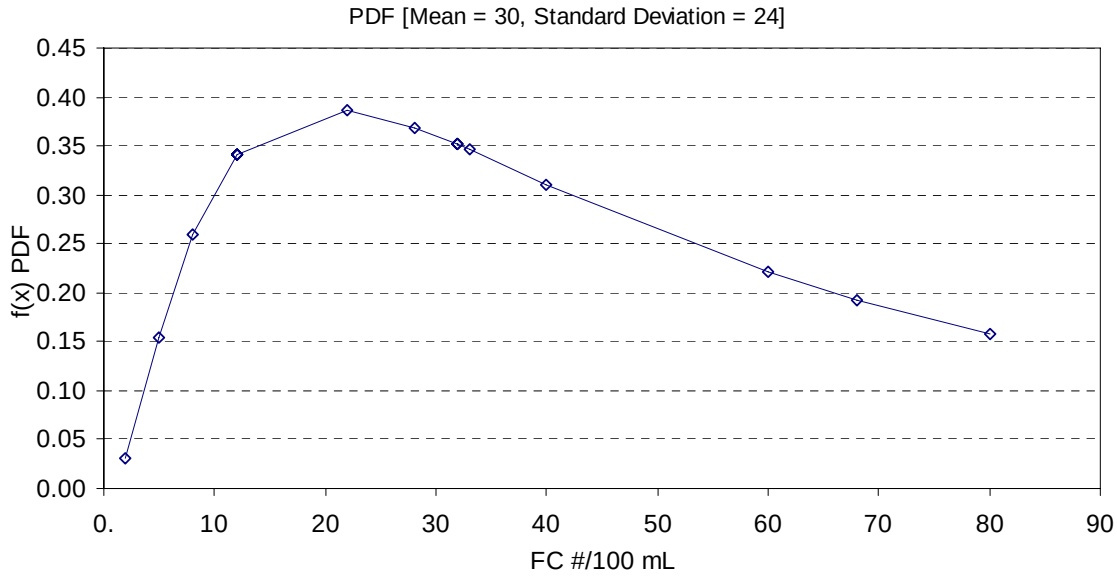


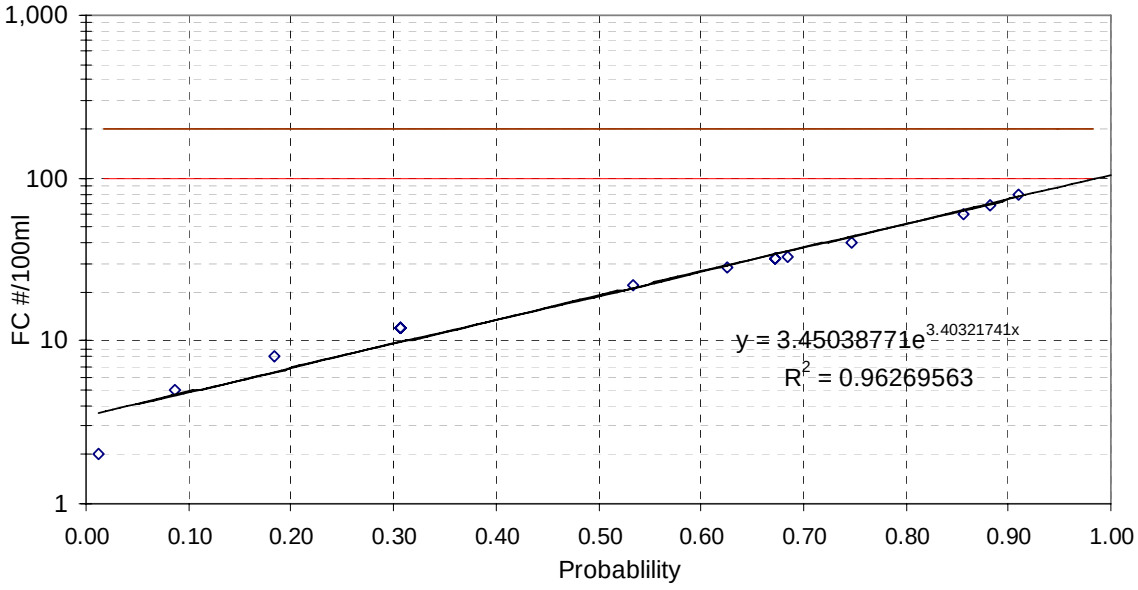
Trap Creek at B-Line Bridge



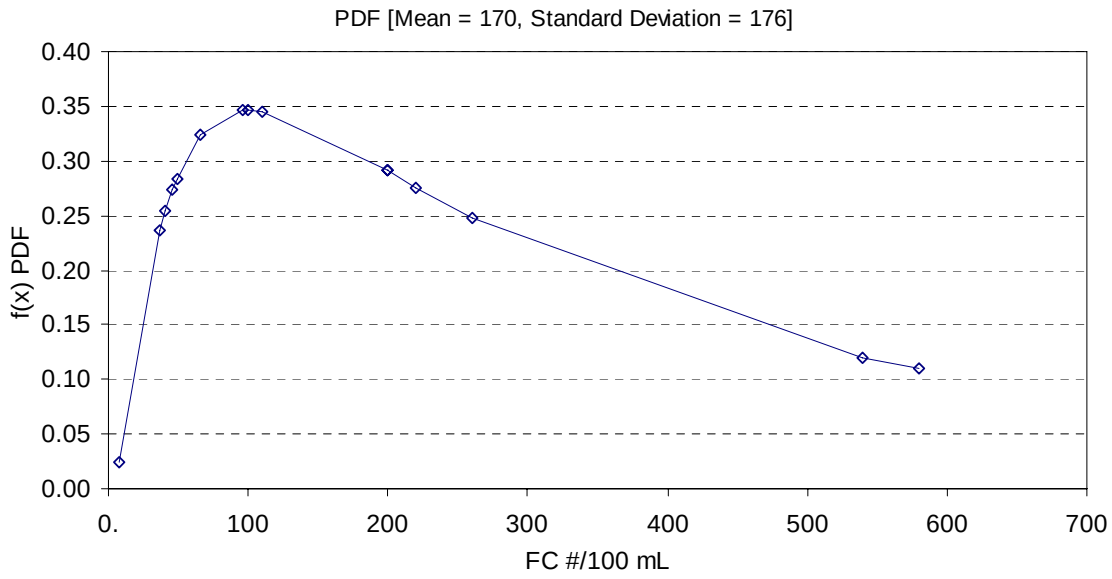


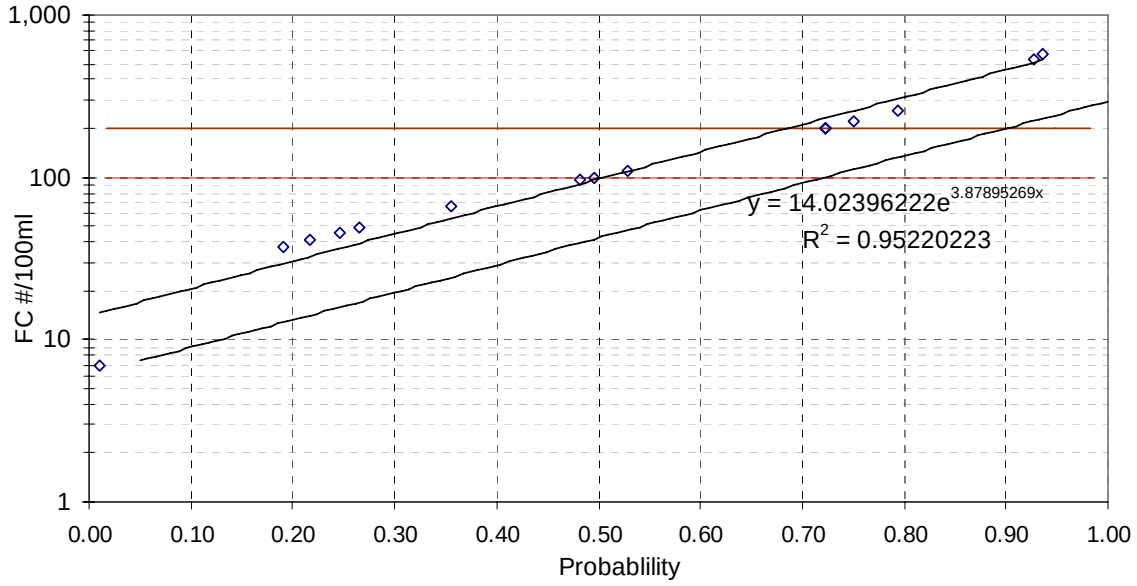
Willapa River at Oxbow Road



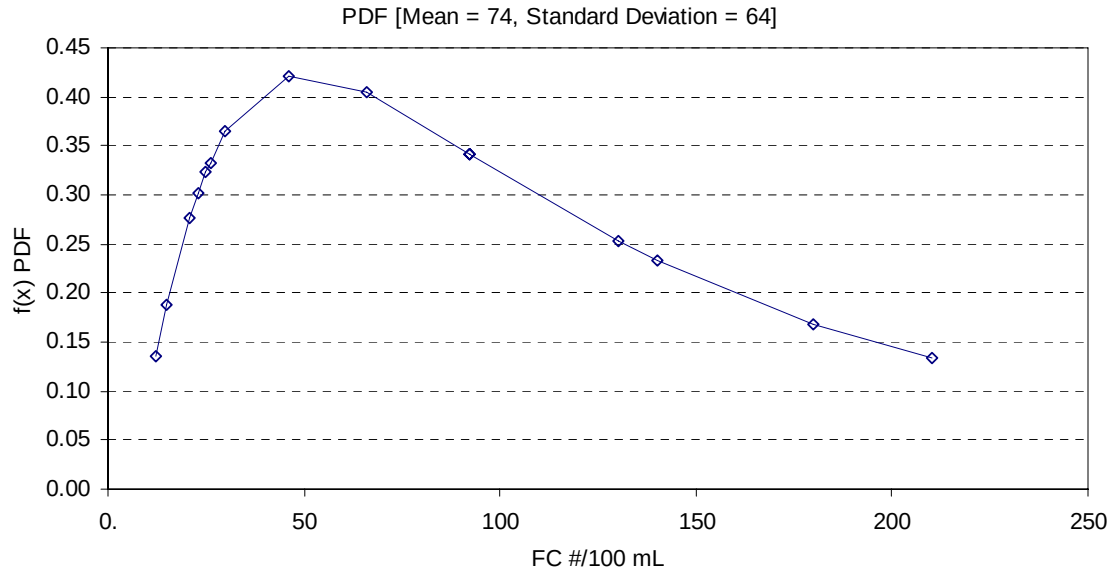


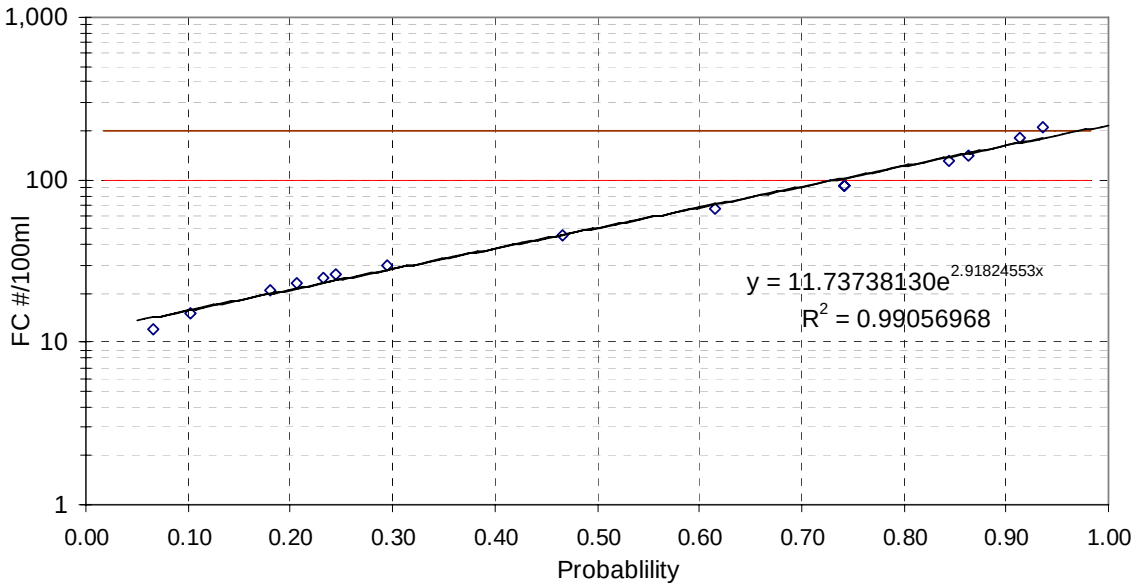
Stringer Ck at Highland-Stringer Rd



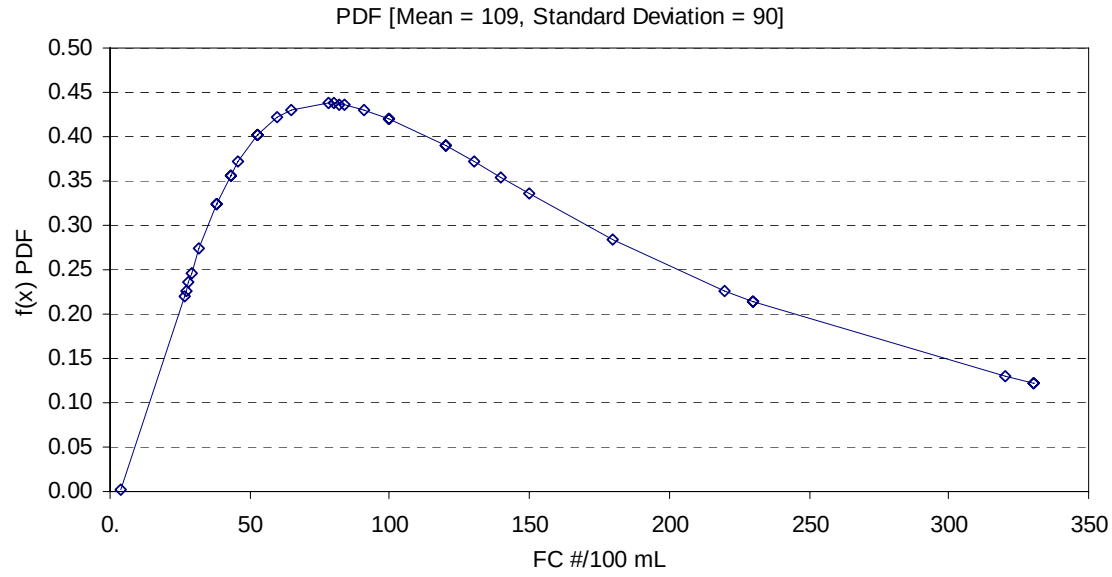


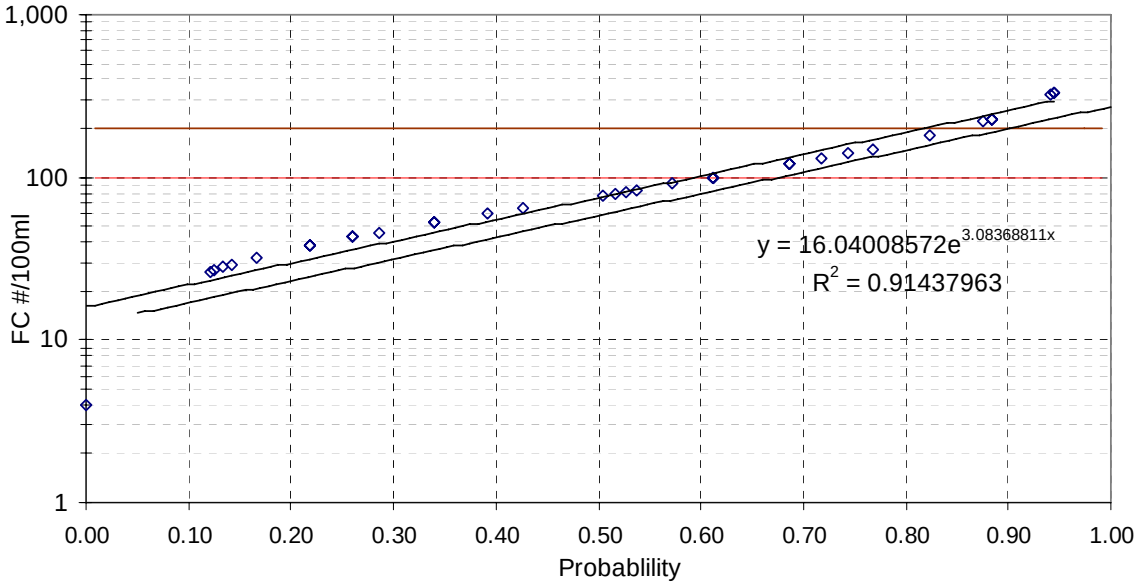
Willapa River at SR 6 nr Menlo





Mill Ck at 3rd Mill Ck Rd Br





Willapa River at Camp One Rd (Bullard Rd)