TO: File: Russian River; TMDL Development and Planning

FROM: Steve Butkus

DATE: September 20, 2013

SUBJECT: SEASONALITY OF FECAL INDICATOR BACTERIA LOADS

Background

Potential pathogen contamination has been identified in the lower and middle Russian River watershed leading to the placement of waters within these areas on the federal Clean Water Act Section 303(d) list of impaired waters. The contamination identified has been linked to impairment of the water contact recreation (REC-1) and non-contact water recreation (REC-2) designated beneficial uses. Health advisories for these waters have been published and posted by Sonoma County and the City of Santa Rosa authorities.

The North Coast Regional Water Quality Control Board (Regional Water Board) staff are developing Russian River Total Maximum Daily Loads (TMDLs) for pathogen indicators to identify and control contamination impairing recreational water uses. TMDLs require the identification of critical conditions and seasonal variation of the beneficial use impairment (CSWRCB 2005). This memorandum serves to assess the seasonality of fecal indicator bacteria loads using an analysis approach recommended by the U.S. Environmental Protection Agency (USEPA 2007)

Data Sources

The Regional Water Board and the Sonoma County Water Agency have been collecting water samples for analysis of fecal indicator bacteria (FIB) concentrations from various locations in the Russian River watershed. Recreational criteria have been used with FIB concentrations to indicate a potential health risk from exposure to pathogens in numerous surface waters of the Russian River watershed. Most strains of FIB do not directly pose a health risk to primary contact recreation, but FIB often co-occur with human pathogens and FIB concentrations are easier to measure that the actual pathogens that may pose a risk of illness. Since 2002, numerous measurements of *E. coli* and *Enterococcus* spp. bacteria concentrations have been made watershed-wide to assess potential health risk to primary contact recreation. Table 1 shows the Russian River watershed locations and dates where data on FIB concentrations have been collected since 2002.

FIB concentration data and stream flow data were used to assess bacterial loads in the watershed. The full historical records of daily mean stream flows were obtained from each of the nearby U.S. Geological Survey stream gages identified in Table 1. Stream flow data are not available downstream of Hacienda Bridge so load duration curves could not be calculated. Instead, the historical record of mean daily river stage (i.e., river surface elevation) measured at Johnson's Beach was used to develop a percent cumulative frequency distribution for lower river monitoring locations lacking stream flow measurements. The data sets were ranked low to high and the percent cumulative frequency calculated for each stream flow or stage value.

In samples where the measured FIB concentrations were outside the minimum or maximum analytical detection limits, the minimum or maximum detection limit values were used to represent FIB concentrations in the sample. The median FIB concentration values were used for concurrently collected replicate samples.

Load Duration Curves

The load duration curve approach describes water quality concentrations at different flow regimes. The approach provides a visual display of the relationship between stream flow and loading capacity (USEPA 2007). A load duration curve evaluates the frequency and magnitude of the exceedance of a water quality criterion, the allowable loads, and the size of load reductions needed to support beneficial uses. The load duration curve approach addresses the seasonality component of a TMDL by investigating loads over different stream flows.

Load duration curves are derived using flow duration curves. A flow duration curve describes the cumulative frequency of historic flows by presenting the percent of time a particular stream flow value is met or below. The flow duration curve provides a scale between 0% and 100%, based on the ranked historical data. The USEPA (2007) load duration curve examples present high flow loads to low flow loads along the x-axis. The load duration curve figures in this memorandum show low flows near 0% and high flows near 100% flow percent rank.

The red lined curve on Figures 1 through 30 is the load duration curve for the U.S. Environmental Protection Agency Beach Action Value (BAV) for an estimated illness rate of 36 per 1,000 primary contact recreators (USEPA 2012). The BAV is applied to single sample measurements and are recommended for decisions on posting beach swimming advisories. The BAV for *E. coli* bacteria concentrations is 235 colony-forming units (cfu)/100 mL. The BAV for *Enterococcus* bacteria concentrations is 70 cfu/100 mL.

The U.S. Environmental Protection Agency Beach Action Value (BAV) are presented in concentration units of colony-forming units (cfu)/100 mL derived from the membrane filter analytical technique (USEPA (2002a) Method 1600 for *Enterococcus* bacteria and USEPA (2002b) Method 1603 for *E. coli* bacteria). The FIB measurements collected in the Russian River are based on the IDEXX (2001; Colilert® and Enterolert® Quanti-Tray/2000) analytical methods that are also approved by the U.S. Environmental Protection Agency in the Code of Federal Regulations (40 CFR 136.3). The results from the IDEXX (2001) analytical methods are presented as the "Most Probable Number" per 100 mL (MPN/100mL). This assessment assumed that the FIB concentrations presented as MPN/100mL were equivalent to the concentrations presented as cfu/100mL based on the membrane filter analytical methods. These IDEXX (2001) analytical methods have been shown to produce equivalent results as the membrane filtration methods (Budnick et al. 1996; Yakub et al. 2002)

Figures 1 through 30 present the FIB loads over a range of flows compared to the BAV load duration curves for all locations listed in Table 1. Instantaneous loads are calculated from the FIB measurement and the daily average flow on the date of the sample. Loads that plot above the curve indicate an exceedance of the BAV, while those below the load duration curve show attainment. Figures 31 and 42 present the stage duration curve for the lower Russian River locations without available stream flow measurements.

The figures show that in most of the locations, FIB measurements meet the BAV. In general, *Enterococcus* bacteria appear to exceed the BAV load more often than *E. coli* bacteria. Also, FIB concentrations measured in watershed tributary locations exceed the BAV more often than samples collected from mainstem Russian River locations. The figures also show that the BAV is exceeded at several of the locations in the lower Russian River, mostly at Monte Rio Beach.

Stream Flow Hydrologic Zones

Load duration curves present loading as an indicator of hydrologic conditions. Load duration curves can be grouped into categories that describe general stream flow zones. Grouping information into these zones can help identify patterns that inform TMDL implementation. The zonal information can be used to help focus efforts on stream flow conditions that contribute FIB loads beyond a target condition. USEPA (2007) recommends dividing the load duration curve in to the five zones shown in Table 2. This approach to dividing the curve places the midpoints of the dry conditions, mid-range flows, and wet condition zones at the 40th, 50th, and 60th percentiles respectively (i.e., the quartiles). The low flow zone is centered at the 5th percentile, while the high flow zone is centered at the 95th percentile. Measured FIB loads were grouped into the stream flow zones for each location.

FIB Load Reductions

The amount of load reduction needed to meet the BAV was determined for each sampling location (Table 1) and stream flow hydrologic zone (Table 2). Target loads for each stream flow hydrologic zone were established as the minimum load for that zone. Use of the minimum assures that loads are met across the full range of the hydrologic zone. Figure 43 presents the example of *E. coli* bacteria load target selection for each hydrologic zone from the Laguna de Santa Rosa. Note that no measurements are available for the Low Flow hydrologic zone.

FIB concentration measurements are highly variable resulting in a large range of FIB loads at any particular site. If an median value of a FIB load is used to assess the needed reduction, one would expect to exceed that value about half of the time. Therefore, the 90th percentile of the distribution of the measured FIB loads is used to calculate the current FIB load for each hydrologic zone category. Basing the current condition on the 90th percentile of measured data is consistent with USEPA protocol (USEPA 2007) and the 90th percentile FIB load is equivalent to the 10% allowable rate for exceeding criteria used in California to assess beneficial use impairment for the Clean Water Act section 303(d) list of impaired waters (Table 4.2 in CSWRCB 2004). As an example, Table 3 shows the difference in reductions needed to meet the Beach Action Value load targets for *E. coli* bacteria in the Laguna de Santa Rosa. Much higher reductions are required to provide a 90% assurance that the Beach Action Value target load will be achieved.

Figure 44 visually presents the change as boxplots showing the load distribution for different *E. coli* bacteria load reductions. For each hydrologic zone, the first boxplot shows the current distribution. The second and third boxplots show the distribution with reduction needed to meet the median target loads and the 90th percentile target loads respectively. Selection of the 90th percentile for the reduction target assures that the variability of FIB measurements are addressed.

Table 4 presents the percent of the *E. coli* bacteria load that needs to be reduced in order to meet the BAV in each stream flow hydrologic zone category. For all the mainstem Russian River locations with available data, the results show that no reduction in *E. coli* bacteria load is needed. However, two tributaries (Laguna de Santa Rosa and Santa Rosa Creek) show an increasing need for *E. coli* load reductions with higher flows. The higher *E. coli* bacteria loads associated with higher flows likely come from nonpoint sources that mobilize and are transported during storm events.

Table 5 presents the percent of the *Enterococcus* bacteria load that needs to be reduced in order to meet the BAV in each stream flow hydrologic category. For those locations with available data, the results show that reductions in *Enterococcus* bacteria loads are most needed in the middle reach of the mainstem Russian River (i.e. Alexander Valley) during lower stream flows. The higher loads during low flows likely come from unknown continuous point sources that concentrate during low flows. Reductions in *Enterococcus* bacteria loads are not needed in the lower mainstem Russian River. The *Enterococcus* bacteria results also show the tributaries (Laguna de Santa Rosa, Santa Rosa Creek, and Mark West Creek) show an increasing need for load reduction with higher flows. The higher *Enterococcus* bacteria loads associated with higher flows likely come from nonpoint sources that mobilize and are transported during storm events.

Finally, it must be emphasized that the percent load reductions that were derived from the load duration curves are based on the single-sample BAV, which is a tool for states to use for beach notification purposes, such as swimming advisories. USEPA (2012) *E. coli* and *Enterococcus* bacteria criteria for recreation are expressed as a geometric mean and statistical threshold value (STV). The geometric mean and STV should be evaluated to assess FIB impairment, although beach swimming advisories can also be considered. Since load duration curves require a single-sample value, the BAV was used instead of the geometric mean or STV.

Findings

- Load duration curves were developed for each of the Russian River watershed locations with historical measurements of *E. coli* and *Enterococcus* bacteria concentrations compared to the USEPA Beach Action Values (BAV) and USGS stream flow measurements.

- *Enterococcus* bacteria appear to exceed the BAV load more often than *E. coli* bacteria.

- FIB concentrations measured in watershed tributary locations exceed the BAV load more often than samples collected from mainstem Russian River locations.

- The BAV load is exceeded at several locations in the lower Russian River, mostly at Monte Rio Beach.

- No reduction in *E. coli* bacteria load is needed at any location in the mainstem Russian River. However, the tributaries (Laguna de Santa Rosa and Santa Rosa Creek) show an increasing need for *E. coli* load reductions with higher flows. The higher *E. coli* bacteria loads associated with higher flows likely come from nonpoint sources that mobilize and are transported during storm events.

- Reductions in *Enterococcus* bacteria loads are most needed in the middle reach of the mainstem Russian River (i.e. Alexander Valley) during lower stream flows. The higher loads during low flows likely represent unknown continuous point sources loads that concentrate during low flows. Reductions in *Enterococcus* bacteria loads are not needed in the lower mainstem Russian River.

- The *Enterococcus* bacteria results show the tributaries (Laguna de Santa Rosa, Santa Rosa Creek, and Mark West Creek) show increasing need for load reduction with higher flows. The higher *Enterococcus* bacteria loads with higher flows likely from nonpoint sources that stream flows mobilize and transport the bacteria during storm events.

CITATIONS

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USEPA 2007. An Approach for Using Load Duration Curves in the Development of TMDLs. Publication No. EPA 841-B-07-006. U.S. Environmental Protection Agency, Washington, DC.

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Yakub,G.P., Castric, D.A., Stadterman-Knauer, K.L., , Tobin, M.J., Blazina, M., Heineman, T.N., Yee, G.Y. and L. Frazier. 2002. Evaluation of Colilert and Enterolert Defined Substrate Methodology for Wastewater Applications. Water Environment Research Vol. 74, No. 2 (Mar. - Apr., 2002), pp. 131-135.

TABLES

Table 1. Fecal Indicator Bacteria Measurements Dates and Locations in the Russian River Watershed

Stream	Location	Dates with Measurement Data	Number of Measurements	Nearest USGS Streamgage ID
Russian River	Hopland	2012	17	11462080
Russian River	Commisky Station Road	2009 - 2012	61	11463000
Russian River	Cloverdale River Park	2009 - 2012	50	11463000
Russian River	Crocker Road	2012	24	11463000
Russian River	Jimtown Bridge	2009 - 2012	87	11463682
Russian River	Digger's Bend	2012	20	11463980
Russian River	Camp Rose Beach	2002 - 2012	197	11464000
Russian River	Healdsburg Memorial Beach	2002 - 2012	199	11464000
Russian River	Riverfront Park	2012	21	11465390
Russian River	Steelhead Beach	2002 - 2012	189	11467000
Russian River	Forestville Access Beach	2007 - 2012	126	11467000
Russian River	Hacienda Bridge	2012	21	11467000
Russian River	Johnsons Beach	2002 - 2012	133	11467002*
Russian River	Monte Rio Beach	2002 - 2012	148	11467002*
Russian River	Casini Ranch	2012	13	11467002*
Russian River	Duncans Mills	2012	13	11467002*
Russian River	Bridgehaven	2012	13	11467002*
Russian River	Jenner Boat Ramp	2009 - 2012	28	11467002*
Laguna de Santa Rosa	Sebastopol Community Center	2009 - 2012	28	11465750
Mark West Creek	Trenton-Healdsburg Road	2012	9	11466800
Santa Rosa Creek	Railroad Street	2001 - 2011	14	11466200

* Only stage measurements were available

Table 2. Stream Flow Hydrologic Zones Recommended by USEPA (2007)

Hydrologic Zone	Rank Percentile
Low Flows	<= 10%
Dry Conditions	>10% to <40%
Mid-Range Flows	40% to 60%
Wet Conditions	>60% to <90%
High Flows	>= 90%

Table 3. Comparison of Recommended *E. coli* Bacteria Load Reduction Targets in the Laguna de Santa Rosa by Flow Regime

Hydrologic Zone	Reduction needed to meet Median load (%)	Reduction needed to meet 90 Percentile load
Low Flows	No data to assess	No data to assess
Dry Conditions	65%	94%
Mid-Range Flows	59%	98%
Wet Conditions	97%	99%
High Flows	90%	99.5%

Table 4. Load Reductions Needed to Meet the *E. coli* Bacteria Beach Action Values.

Location	Percent Reduction Needed to Meet *E. coli* Bacteria Beach Action Values				
	Low Flows	**Dry Conditions**	**Mid-Range Flows**	**Wet Conditions**	**High Flows**
Hacienda Bridge	91%	0%	0%	-	-
Forestville Access Beach	93%	0%	0%	0%	-
Steelhead Beach	95%	0%	0%	0%	-
Riverfront Park	-	0%	0%	0%	-
Healdsburg Memorial Beach	52%	0%	0%	0%	-
Camp Rose Beach	31%	0%	0%	0%	-
Digger's Bend	-	0%	0%	0%	-
Jimtown Bridge	0%	0%	0%	0%	0%
Crocker Road	54%	0%	-	-	-
Cloverdale River Park	30%	0%	0%	-	-
Commisky Station Road	67%	0%	0%	-	-
Hopland	-	0%	0%	-	-
Laguna de Santa Rosa	0%	94%	98%	99%	99.5%
Mark West Creek	98%	69%	-	-	-
Santa Rosa Creek at Railroad Street	-	94%	97%	99%	95%

- No measurements available

Table 5. Load Reductions Needed to Meet the *Enterococcus* Bacteria Beach Action Values

Location	Percent Reduction Needed to Meet *Enterococcus* Bacteria Beach Action Values				
	Low Flows	**Dry Conditions**	**Mid-Range Flows**	**Wet Conditions**	**High Flows**
Hacienda Bridge	97%	0%	0%	-	-
Forestville Access Beach	98%	0%	0%	0%	-
Steelhead Beach	99%	0%	0%	0%	-
Riverfront Park	-	0%	0%	0%	-
Healdsburg Memorial Beach	85%	0%	0%	91%	-
Camp Rose Beach	91%	0%	0%	0%	-
Digger's Bend	-	0%	0%	0%	-
Jimtown Bridge	57%	64%	0%	0%	0%
Crocker Road	93%	44%	-	-	-
Cloverdale River Park	91%	0%	0%	-	-
Commisky Station Road	88%	22%	55%	-	-
Hopland	-	0%	0%	-	-
Laguna de Santa Rosa	-	98%	99%	99.8%	91%
Mark West Creek	99%	98%	-	-	-
Santa Rosa Creek at Railroad Street	-	93%	95%	99%	99%

\- No measurements available

FIGURES

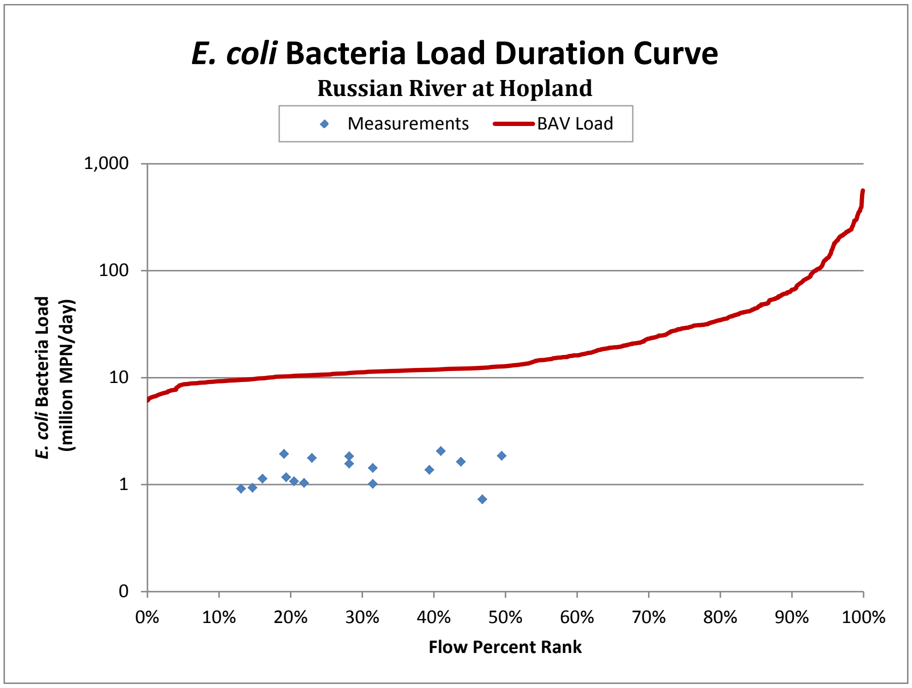

Figure 1. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Hopland

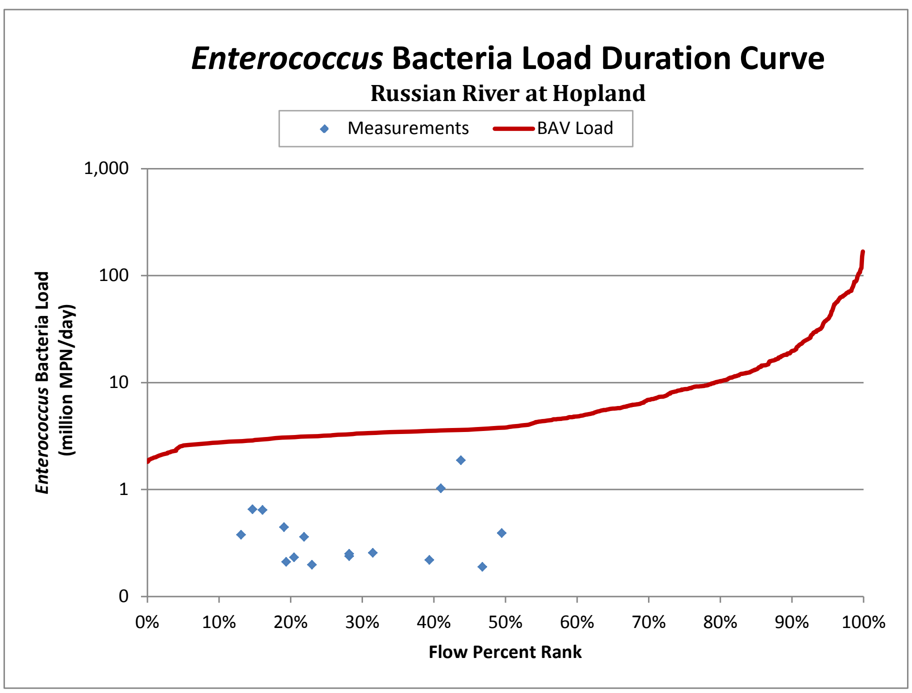

Figure 2. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Hopland

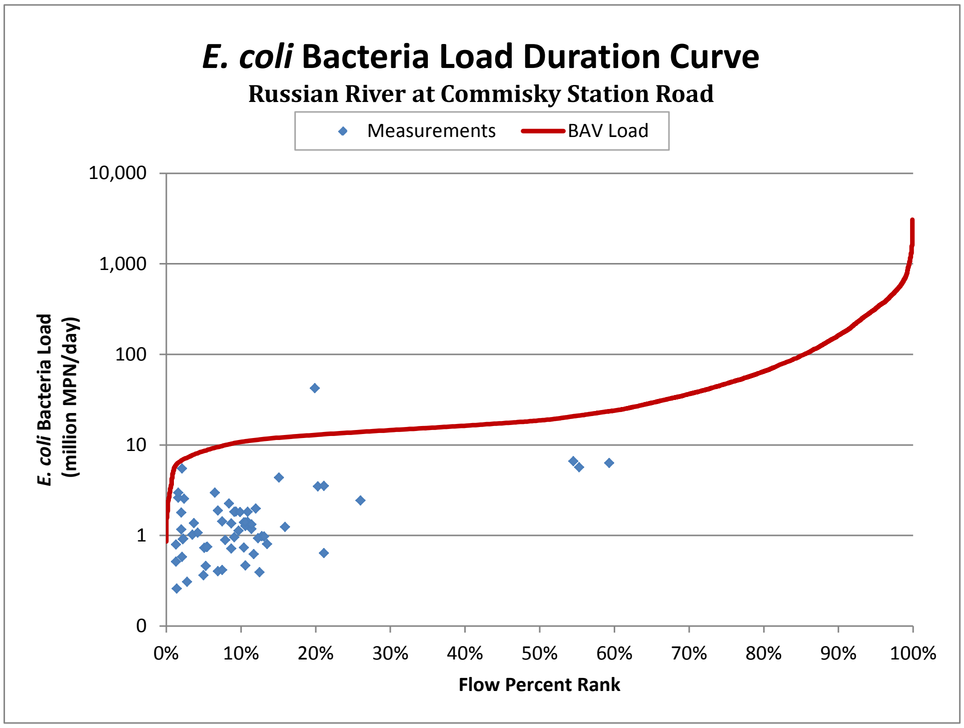

Figure 3. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Commisky Station Road

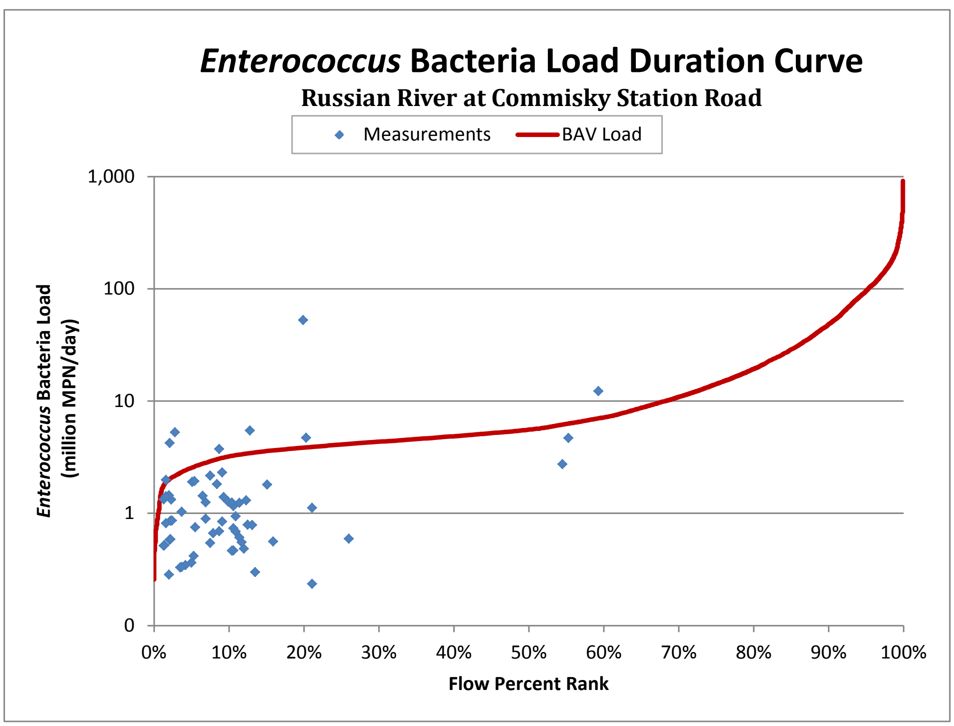

Figure 4. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Commisky Station Road

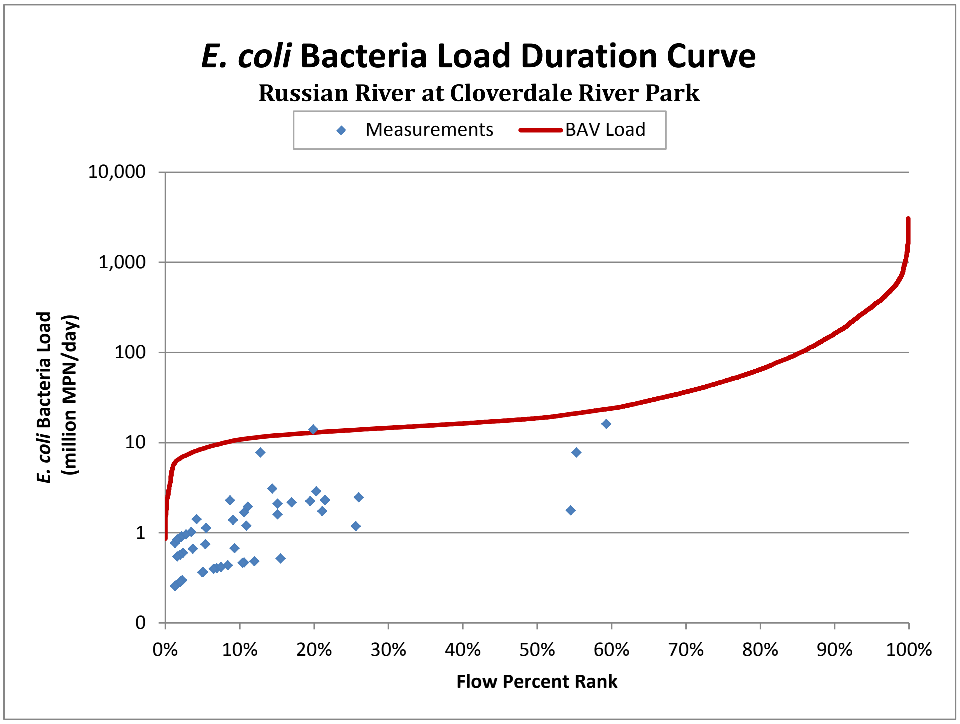

Figure 5. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Cloverdale River Park

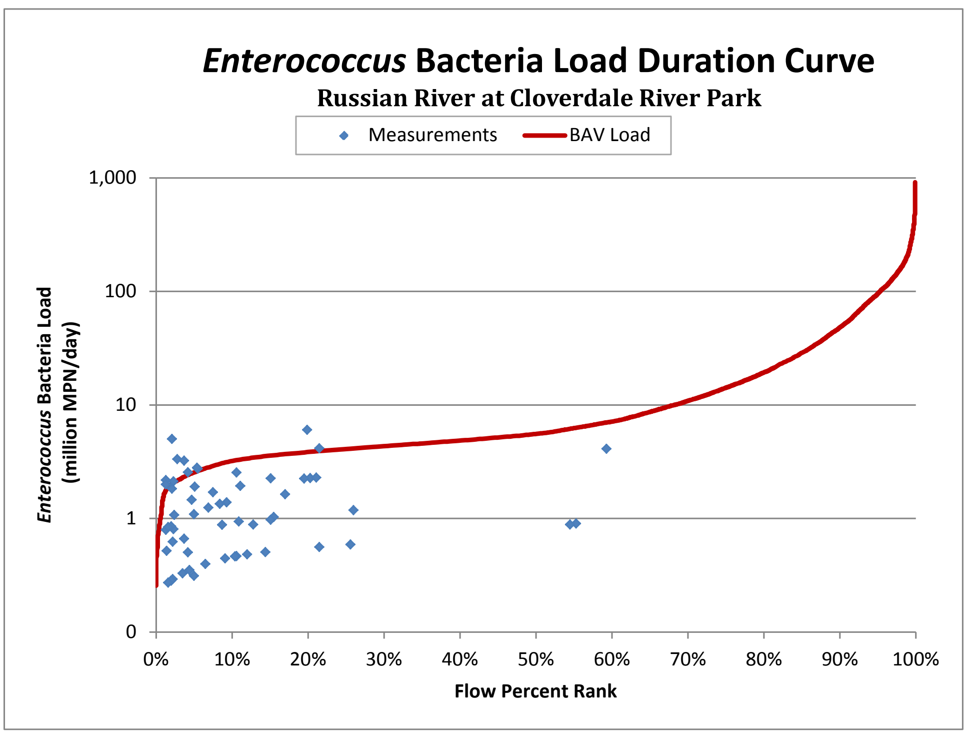

Figure 6. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Cloverdale River Park

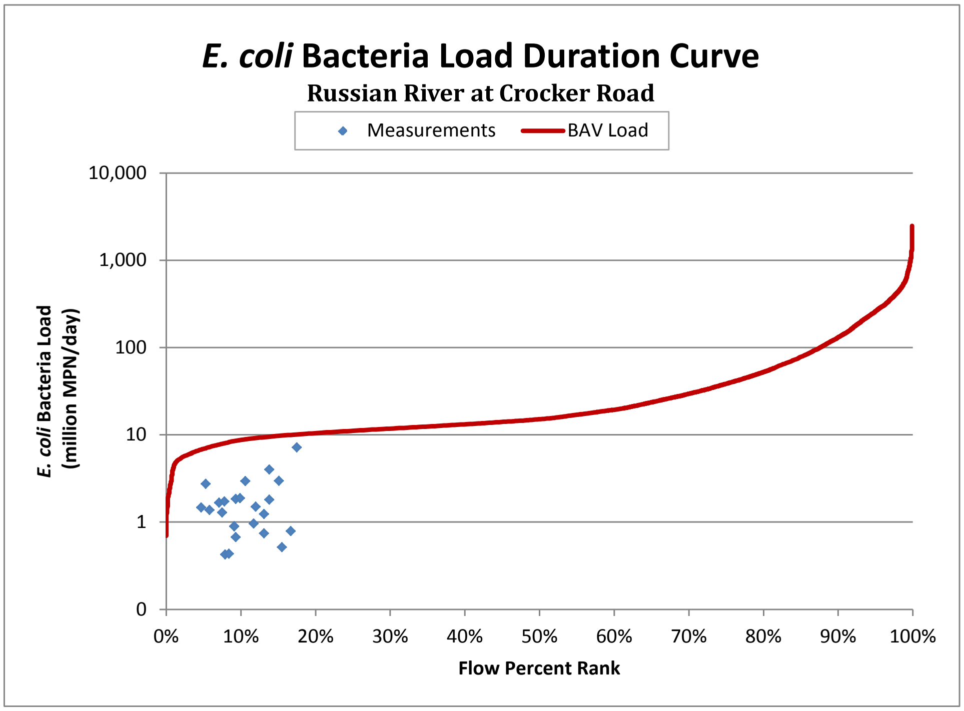

Figure 7. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Crocker Road

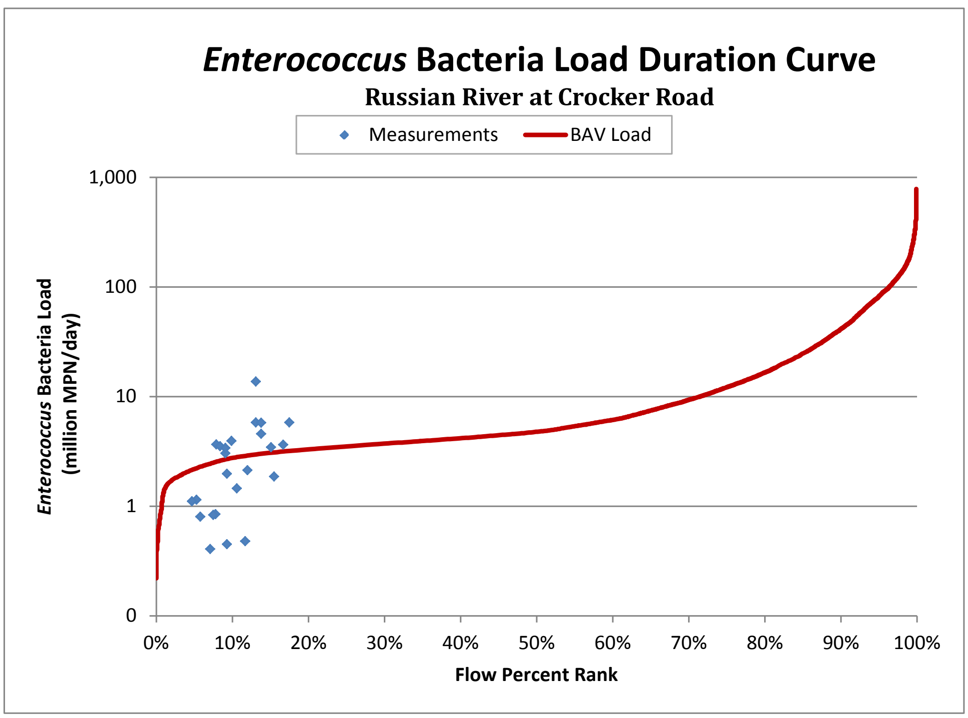

Figure 8. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Crocker Road

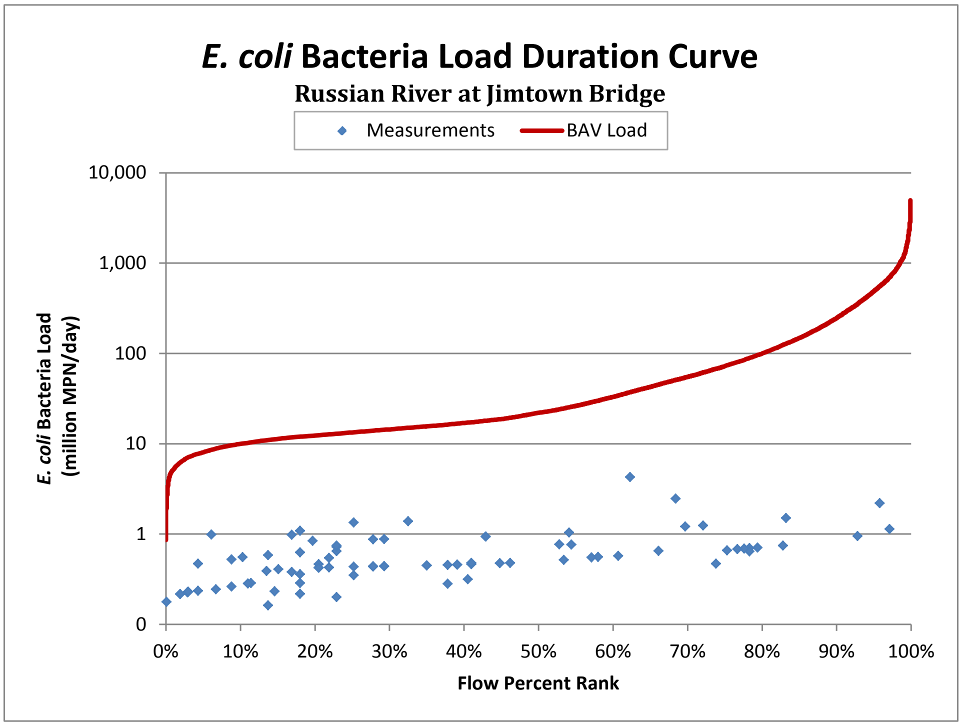

Figure 9. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Jimtown Bridge

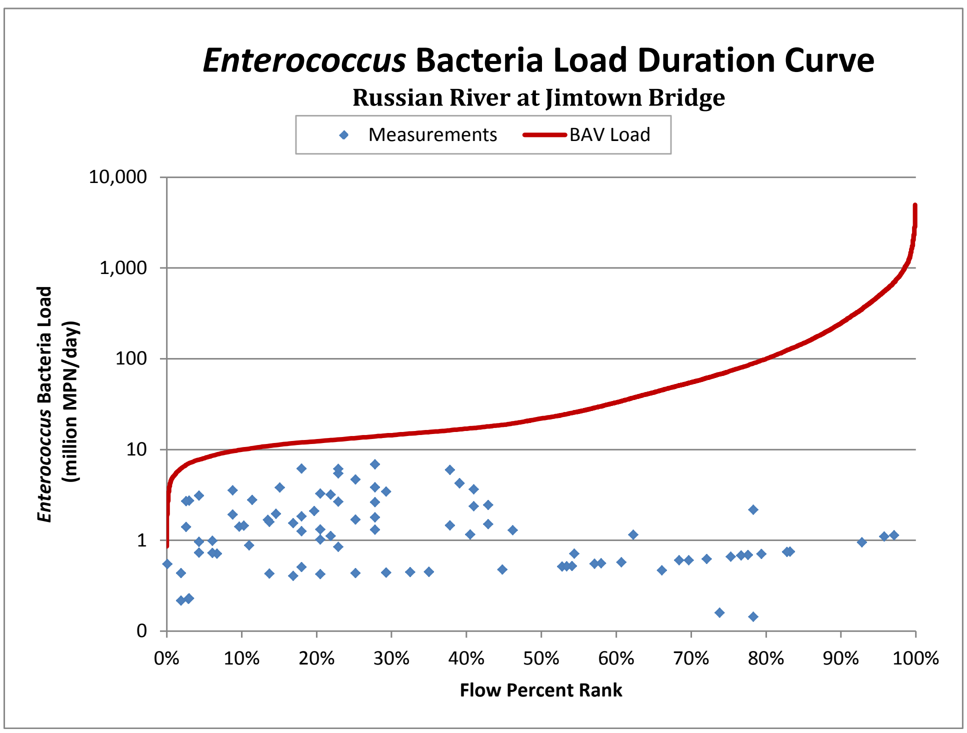

Figure 10. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Jimtown Bridge

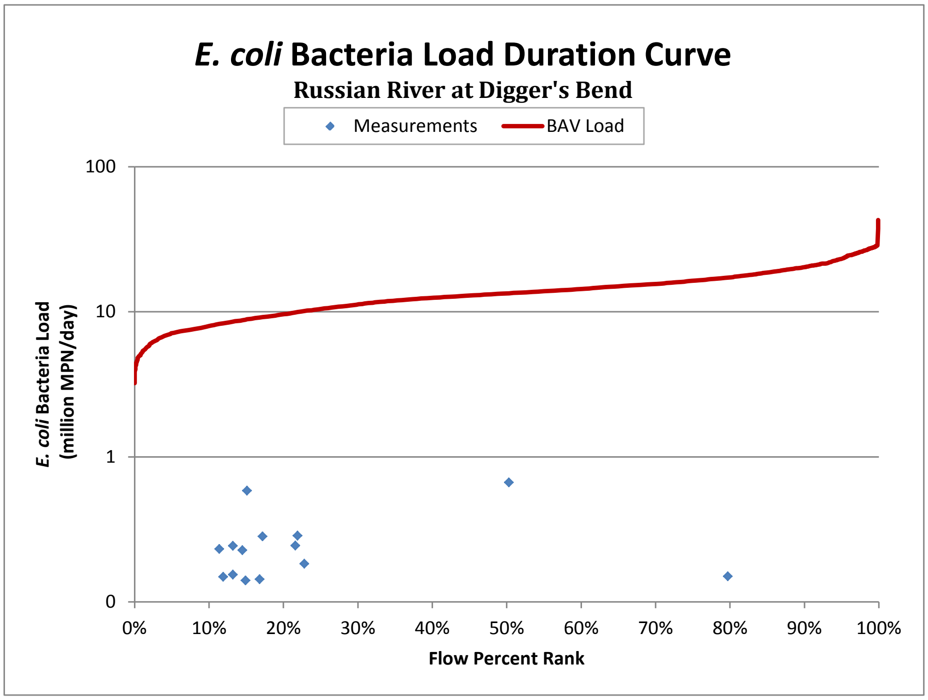

Figure 11. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Digger's Bend

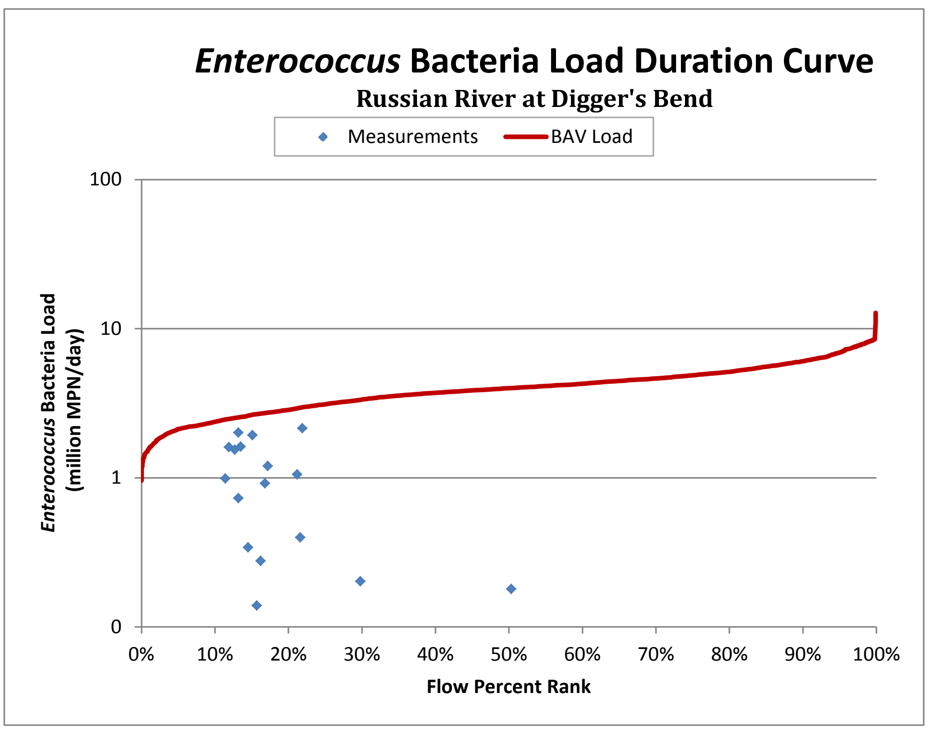

Figure 12. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Digger's Bend

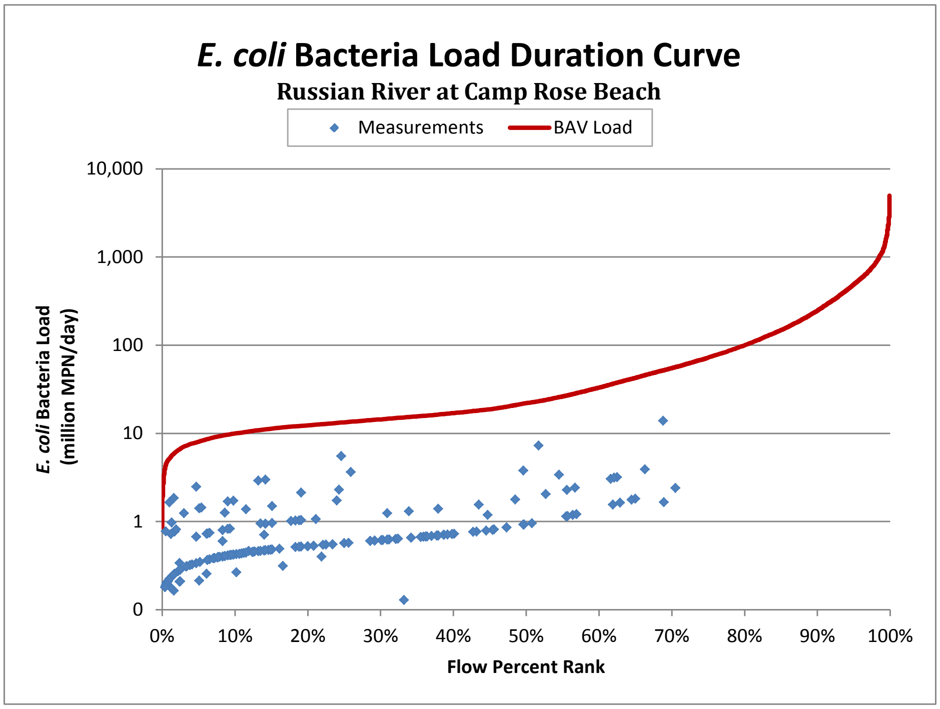

Figure 13. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Camp Rose Beach

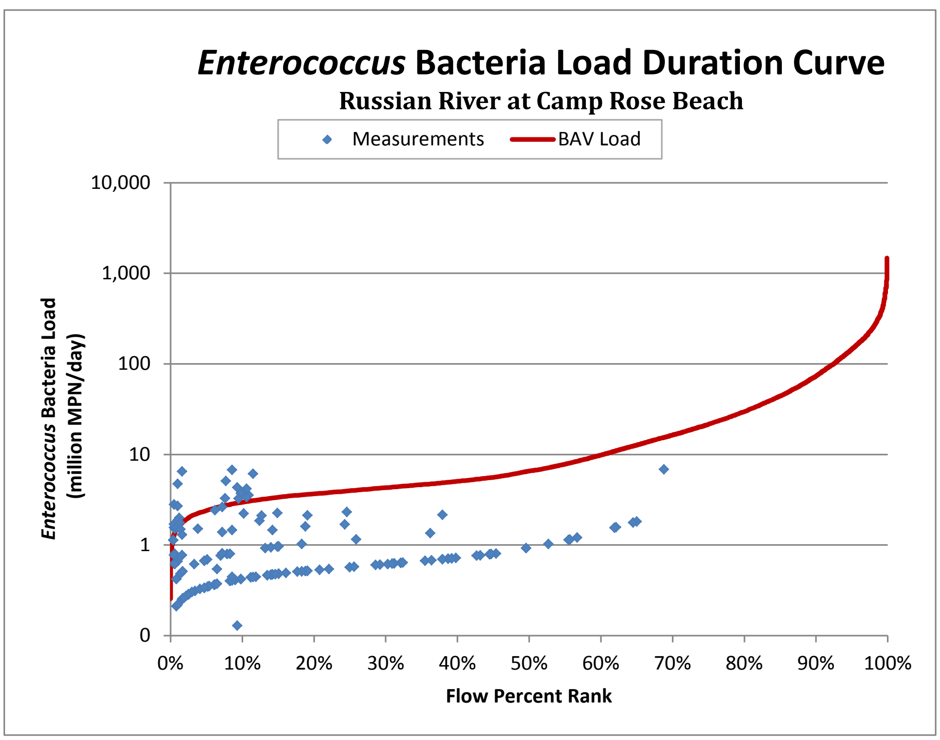

Figure 14. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Camp Rose Beach

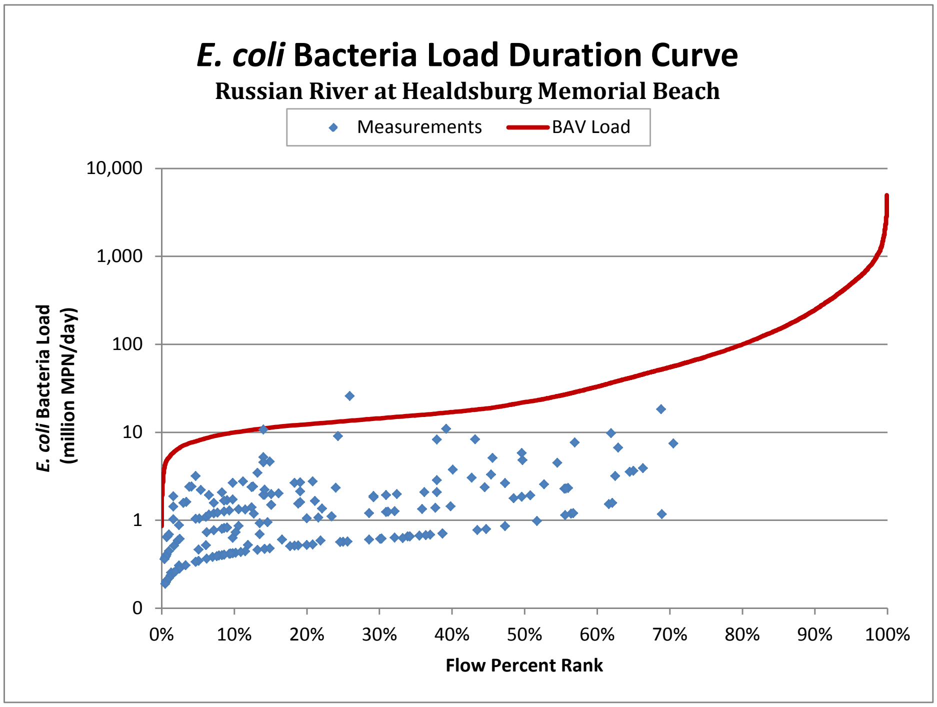

Figure 15. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Healdsburg Memorial Beach

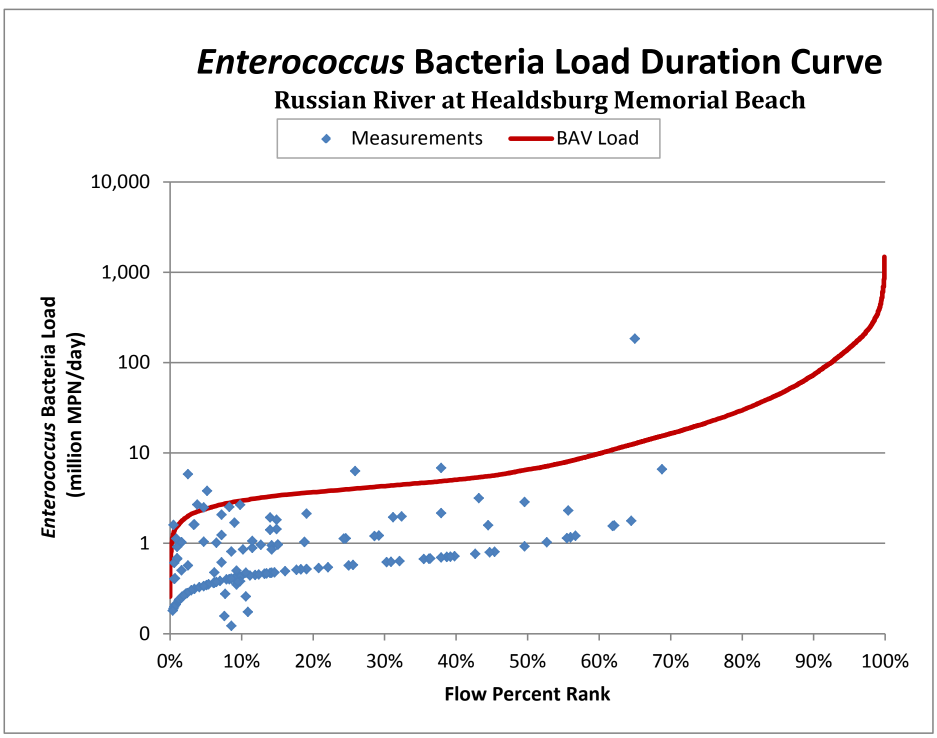

Figure 16. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Healdsburg Memorial Beach

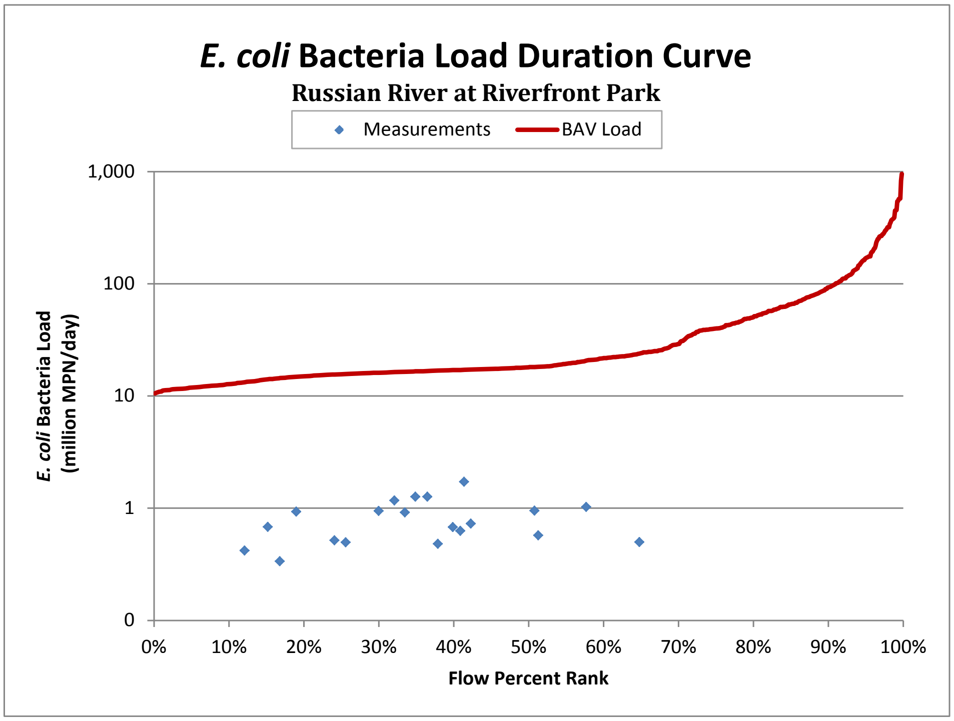

Figure 17. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Riverfront Park

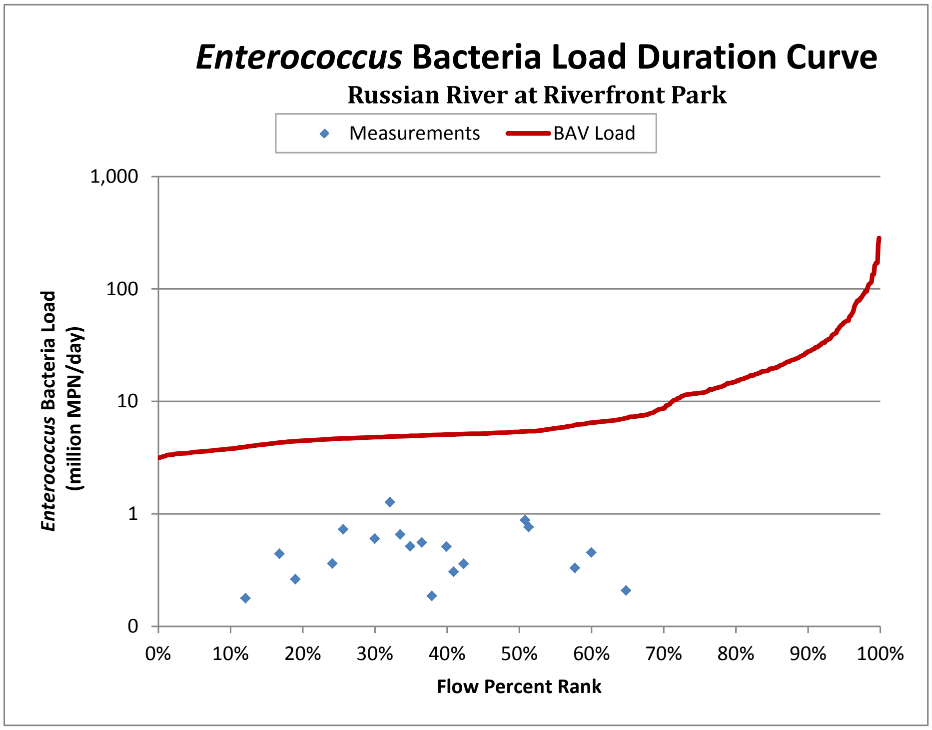

Figure 18. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Riverfront Park

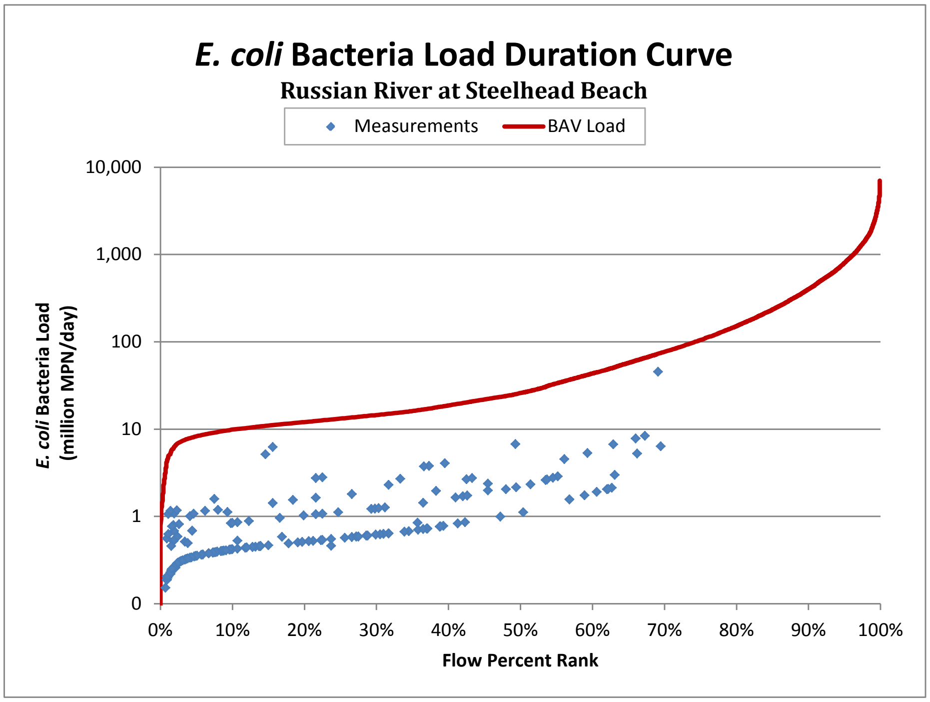

Figure 19. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Steelhead Beach

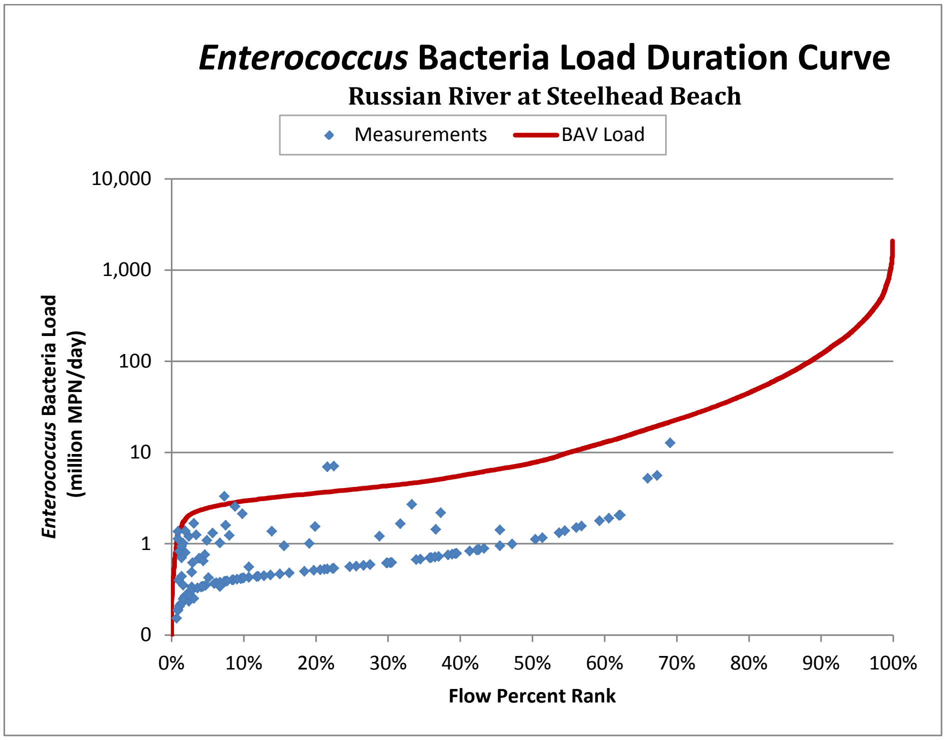

Figure 20. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Steelhead Beach

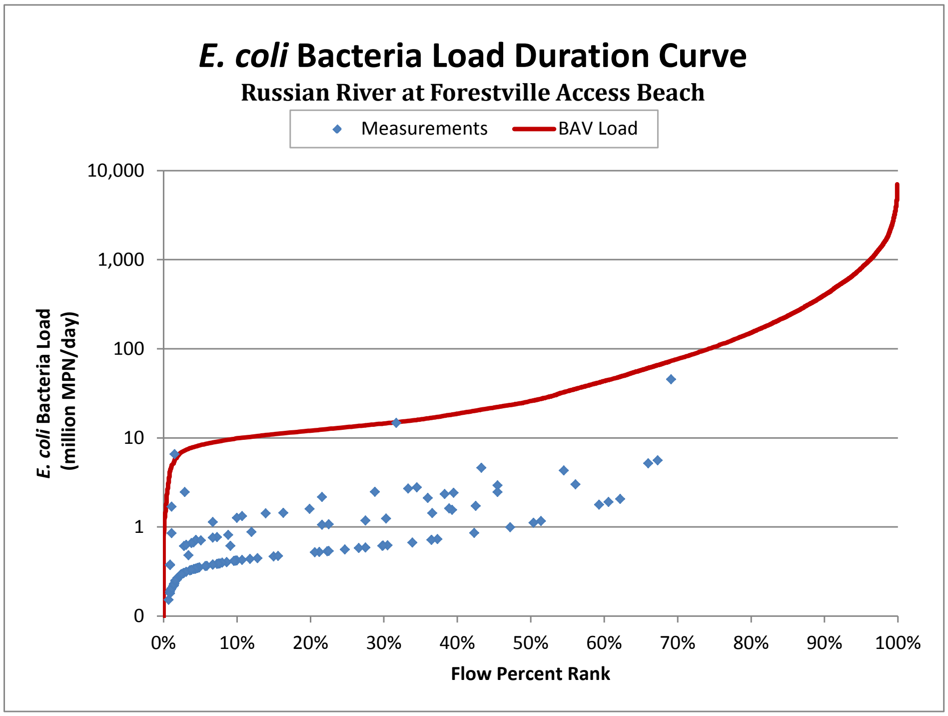

Figure 21. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Forestville Access Beach

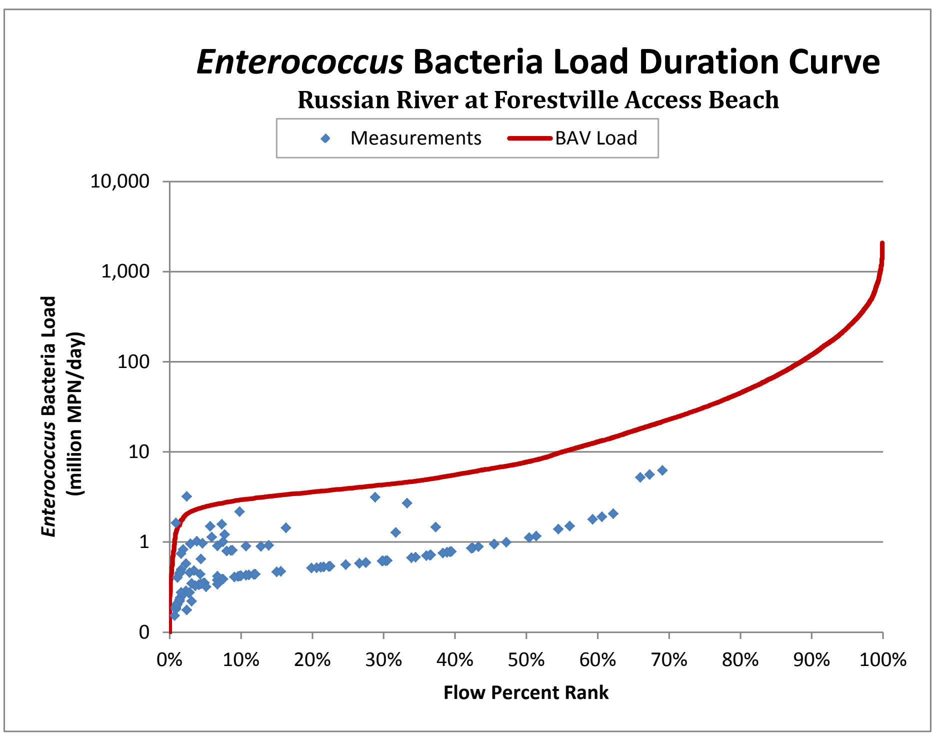

Figure 22. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Forestville Access Beach

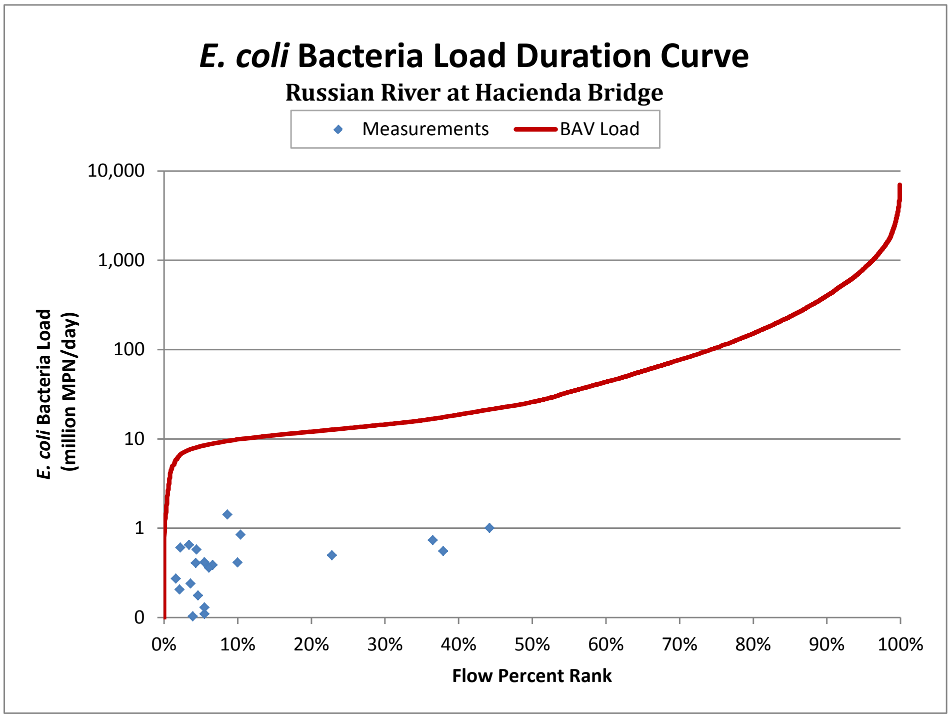

Figure 23. *E. coli* Bacteria Load Duration Curve for measurement made in the Russian River at Hacienda Bridge

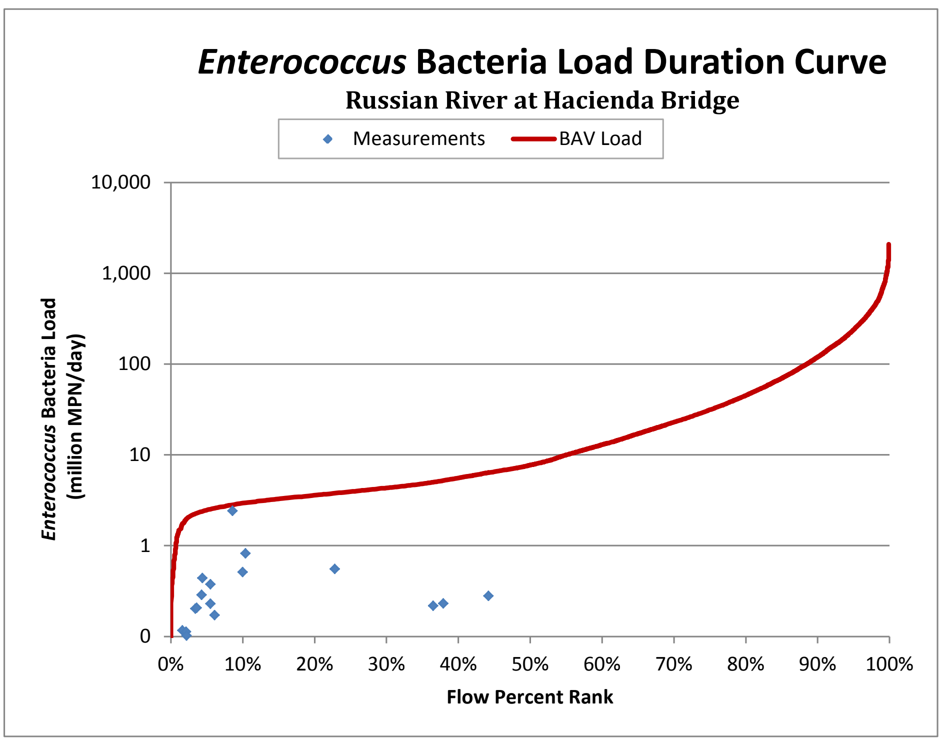

Figure 24. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Russian River at Hacienda Bridge

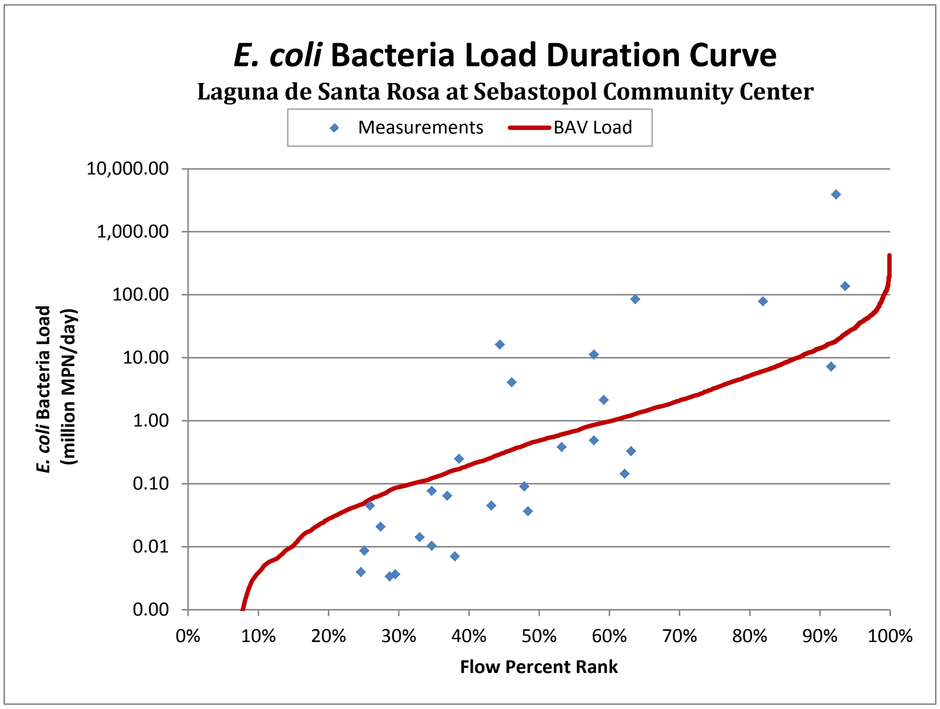

Figure 25. *E. coli* Bacteria Load Duration Curve for measurement made in the Laguna de Santa Rosa at the Sebastopol Community Center

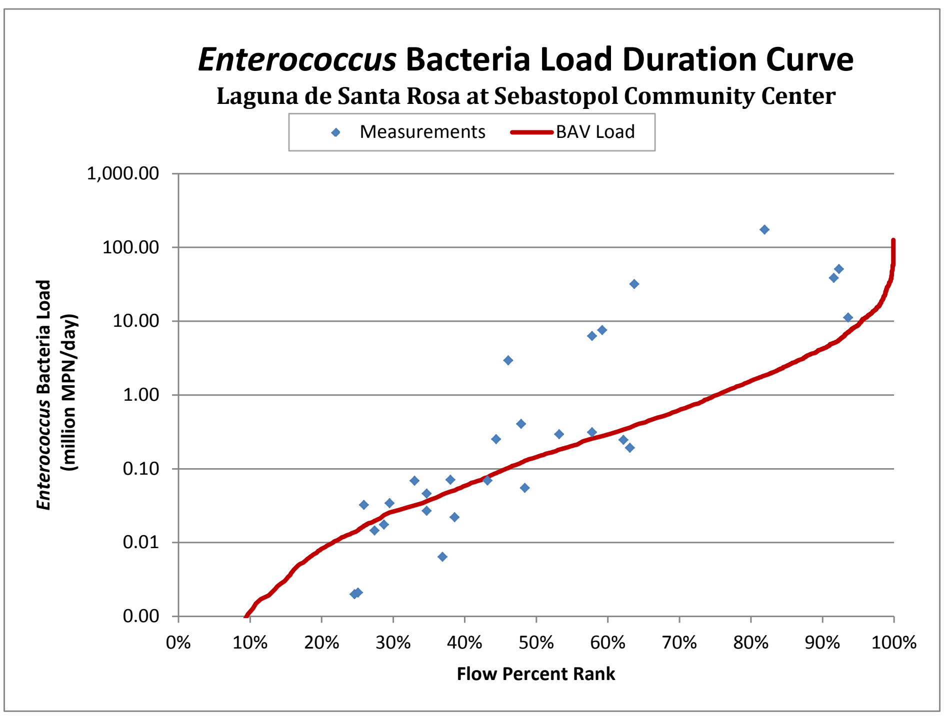

Figure 26. *Enterococcus* Bacteria Load Duration Curve for measurement made in the Laguna de Santa Rosa at the Sebastopol Community Center

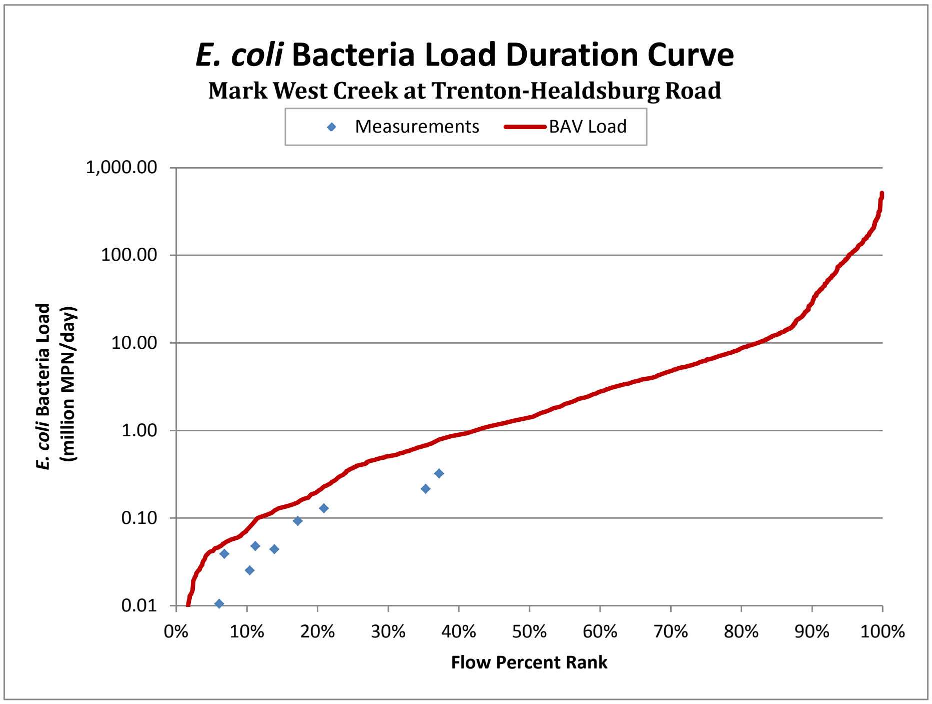

Figure 27. *E. coli* Bacteria Load Duration Curve for measurement made in Mark West Creek at Trenton-Healdsburg Road

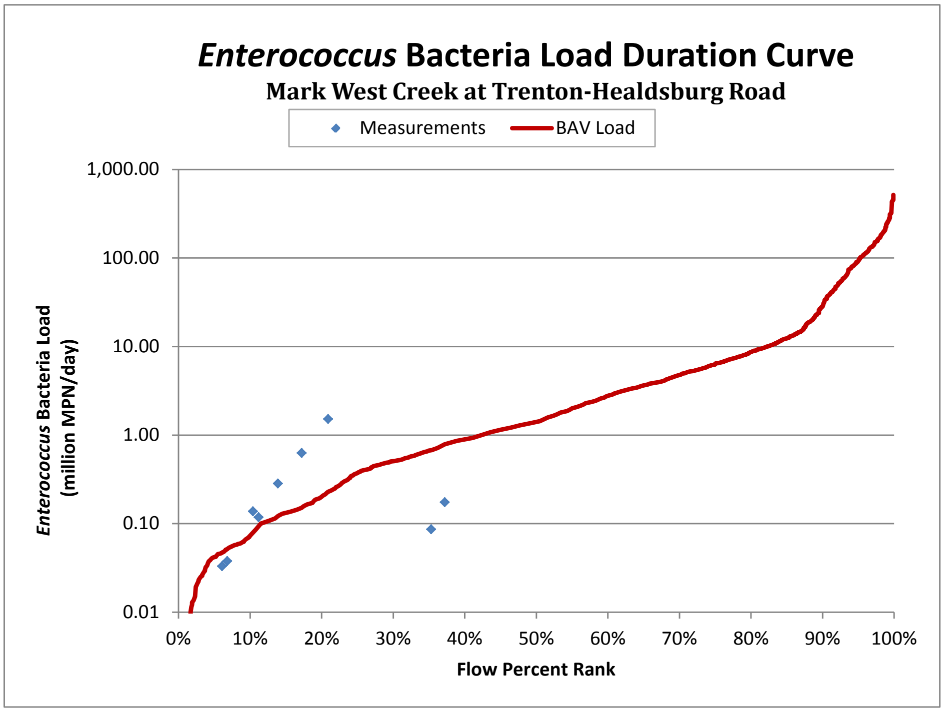

Figure 28. *Enterococcus* Bacteria Load Duration Curve for measurement made in Mark West Creek at Trenton-Healdsburg Road

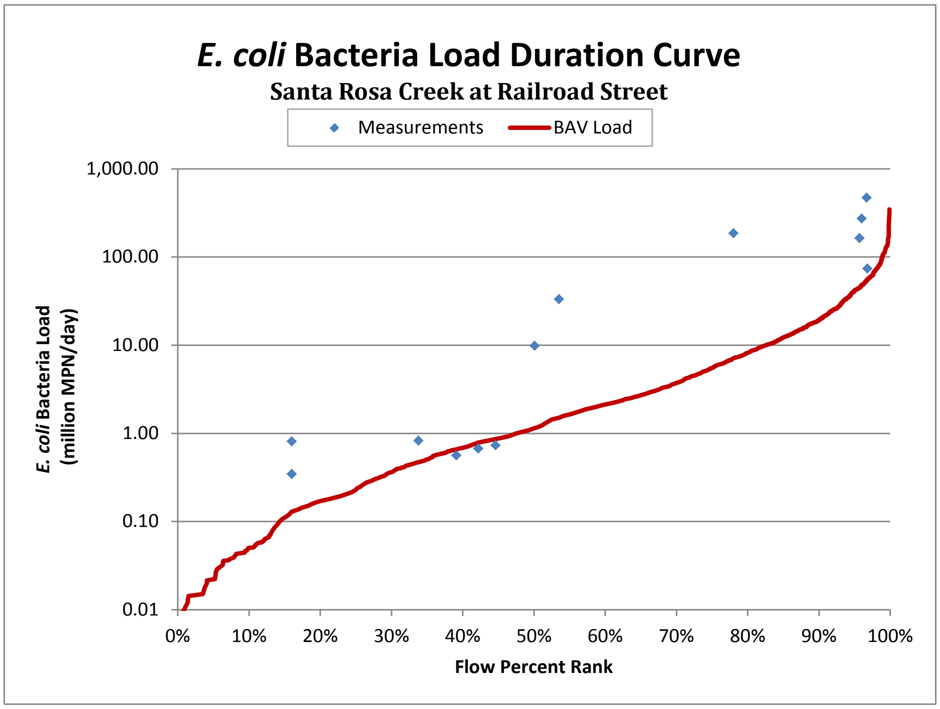

Figure 29. *E. coli* Bacteria Load Duration Curve for measurement made in Santa Rosa Creek at Railroad Street

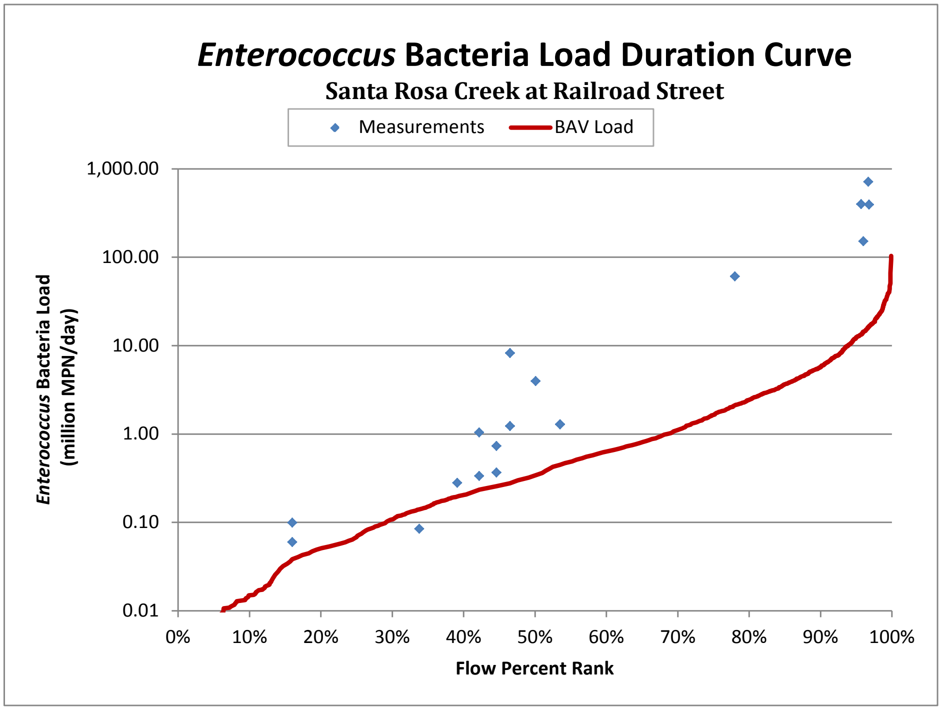

Figure 30. *Enterococcus* Bacteria Load Duration Curve for measurements made in Santa Rosa Creek at Railroad Street

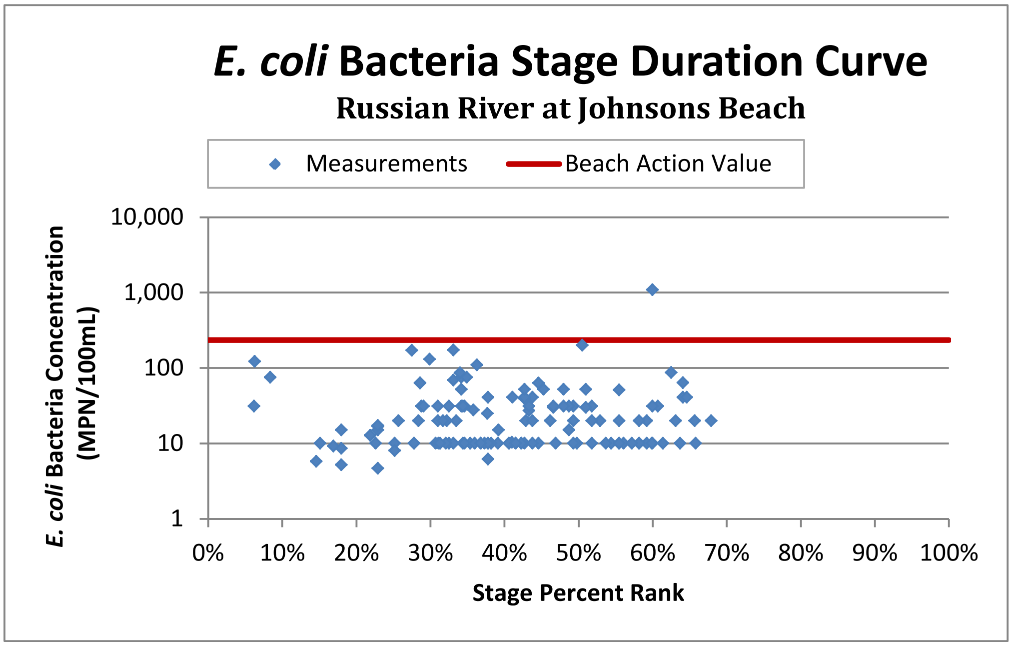

Figure 31. *E. coli* Bacteria Stage Duration Curve for measurements made in the Russian River at Johnsons Beach

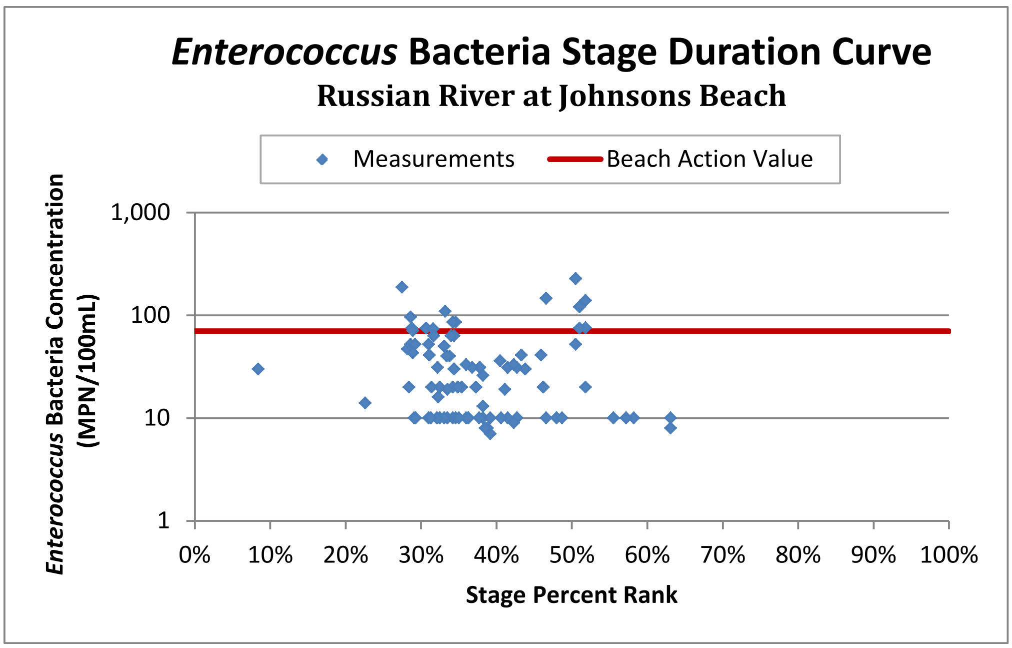

Figure 32. *Enterococcus* Bacteria Stage Duration Curve for measurements made in the Russian River at Johnsons Beach

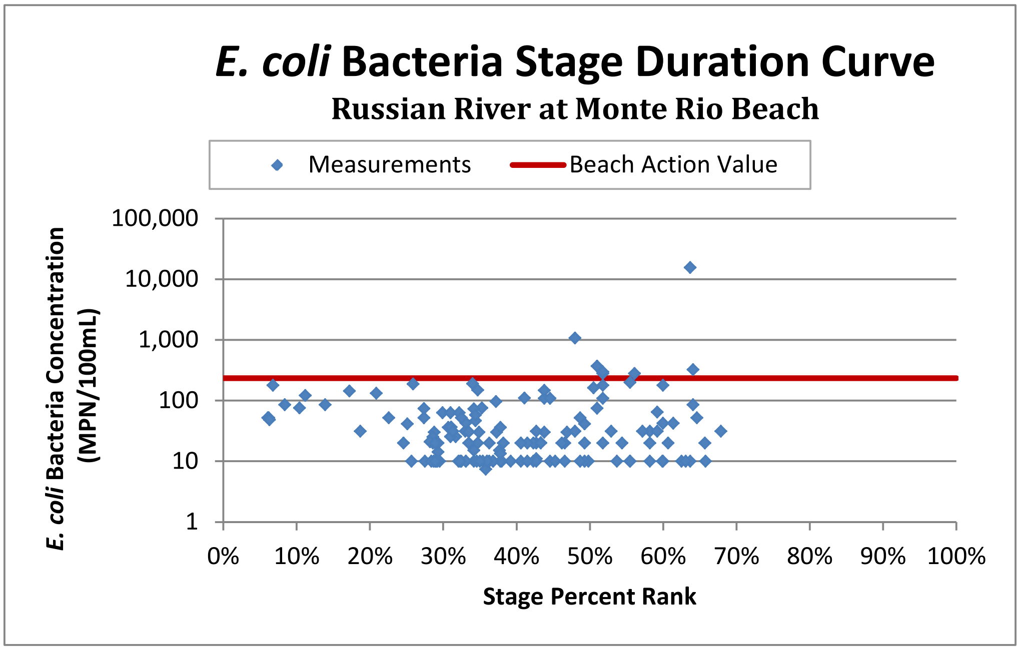

Figure 33. *E. coli* Bacteria Stage Duration Curve for measurements made in the Russian River at Monte Rio Beach

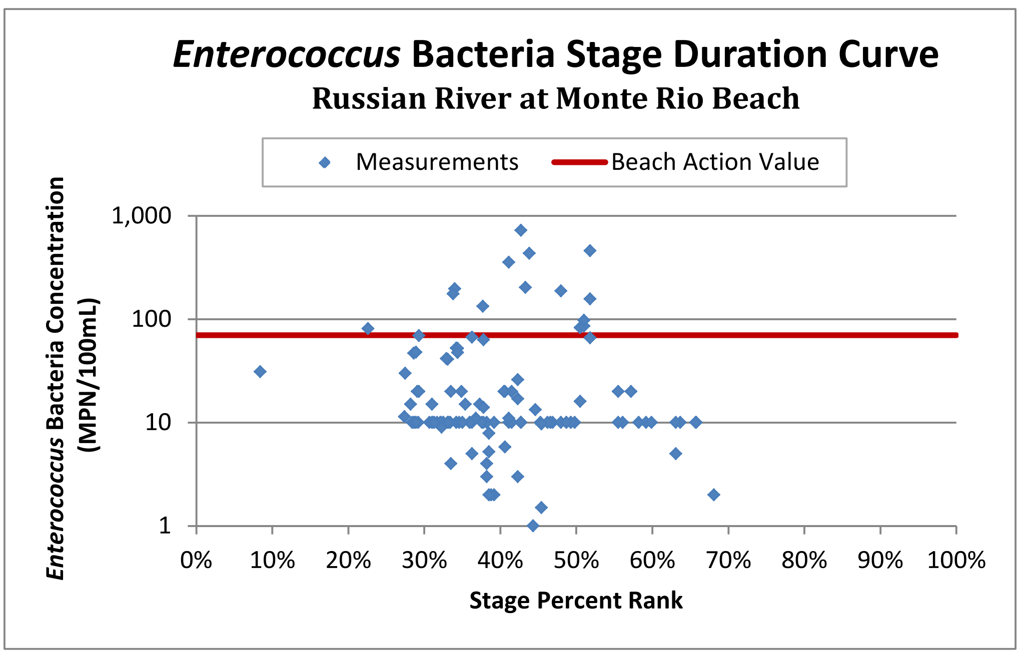

Figure 34. *Enterococcus* Bacteria Stage Duration Curve for measurements made in the Russian River at Monte Rio Beach

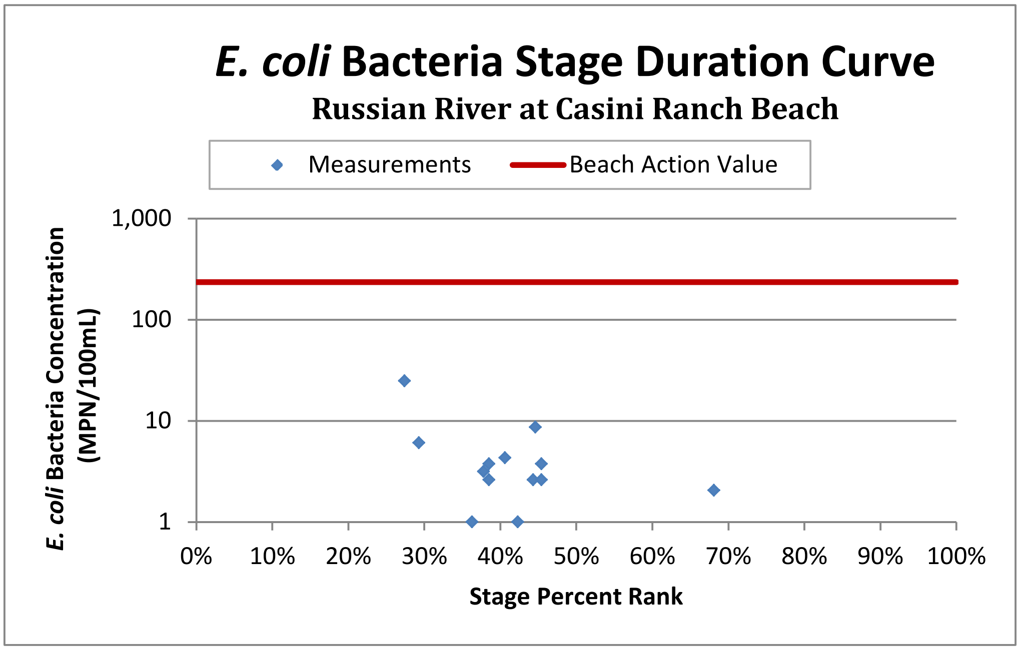

Figure 35. *E. coli* Bacteria Stage Duration Curve for measurements made in the Russian River at Casini Ranch Beach

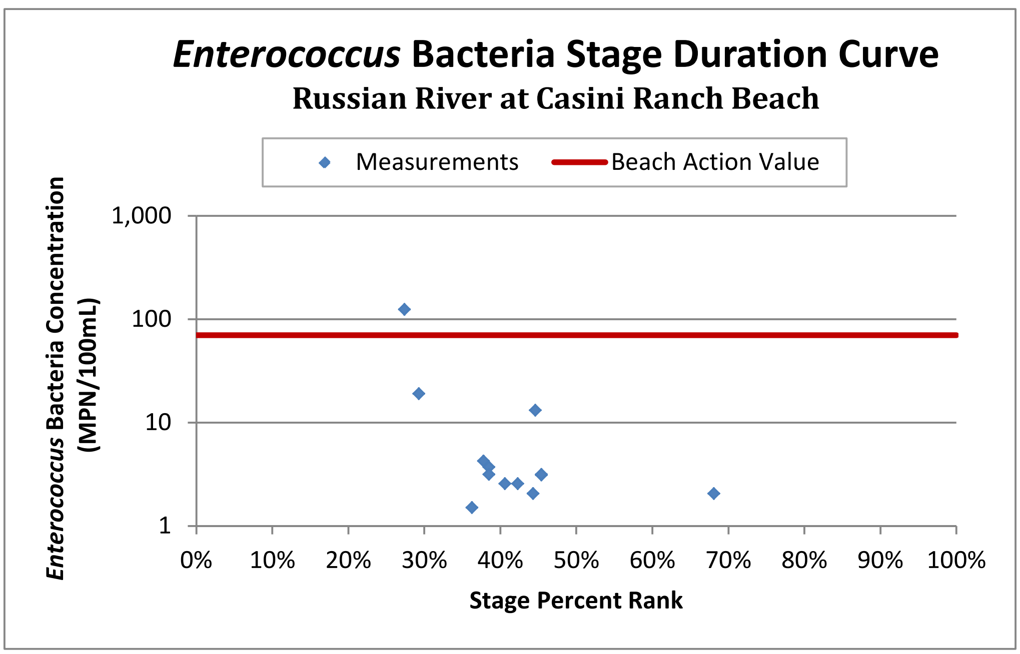

Figure 36. *Enterococcus* Bacteria Stage Duration Curve for measurements made in the Russian River at Casini Ranch Beach

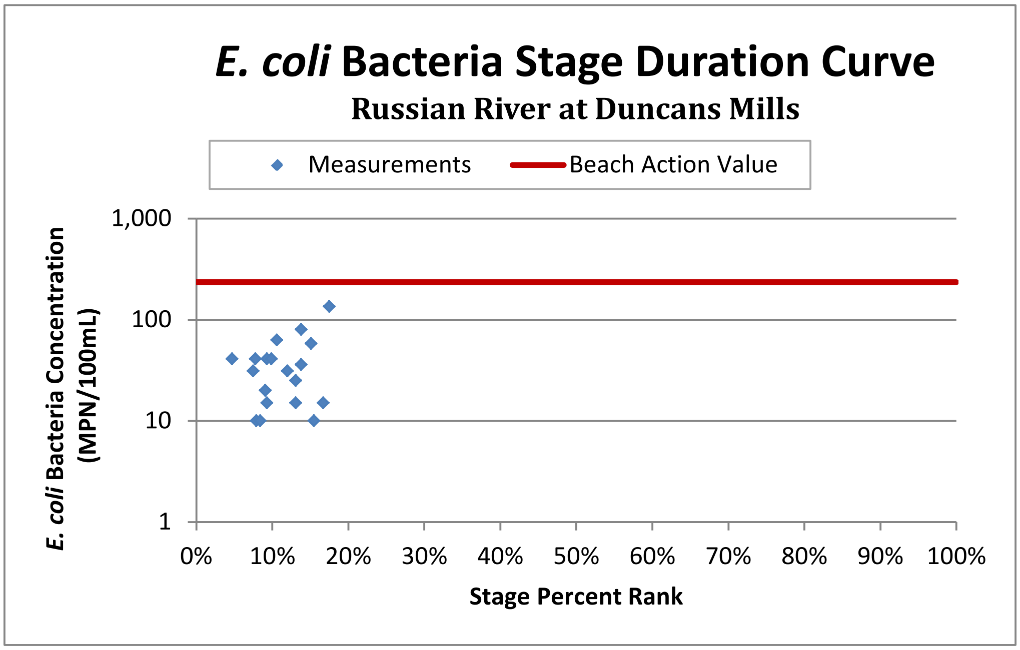

Figure 37. *E. coli* Bacteria Stage Duration Curve for measurements made in the Russian River at Duncans Mills

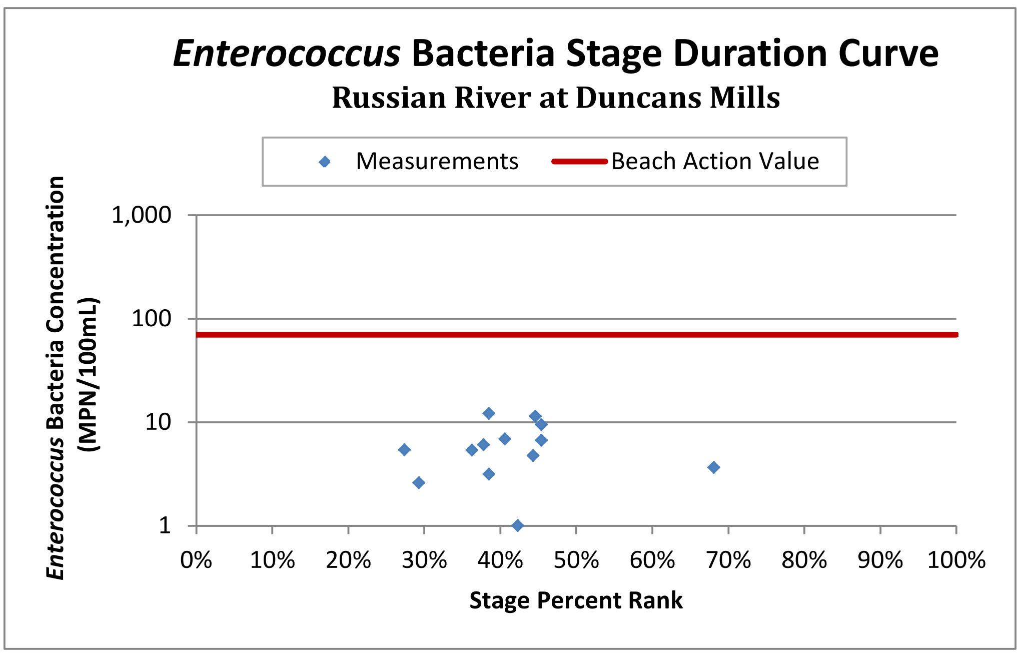

Figure 38. *Enterococcus* Bacteria Stage Duration Curve for measurements made in the Russian River at Duncans Mills

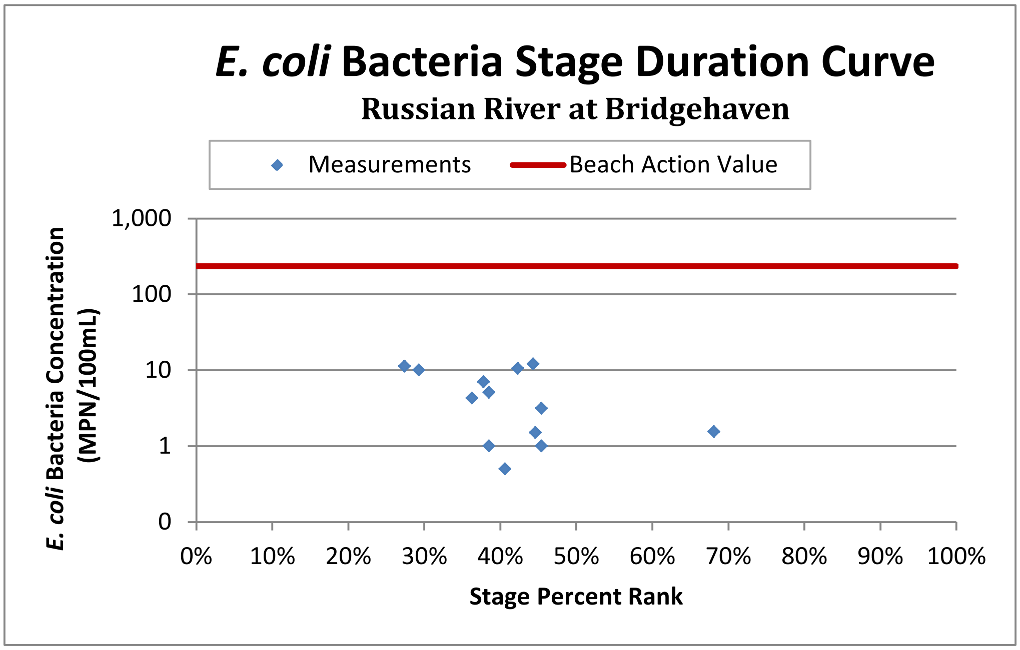

Figure 39. *E. coli* Bacteria Stage Duration Curve for measurements made in the Russian River at Bridgehaven

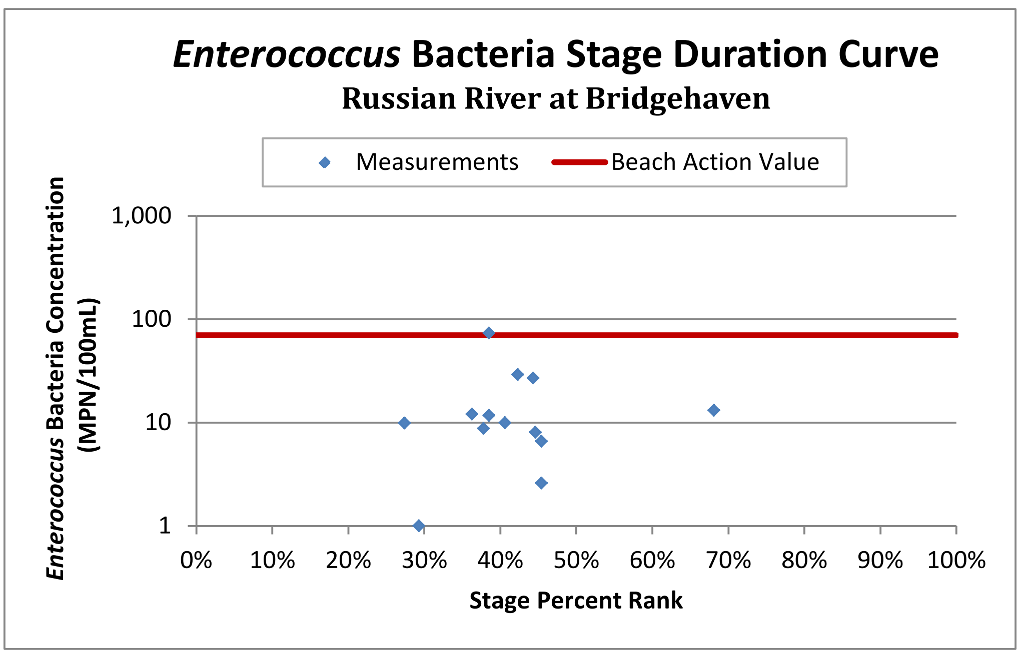

Figure 40. *Enterococcus* Bacteria Stage Duration Curve for measurements made in the Russian River at Bridgehaven

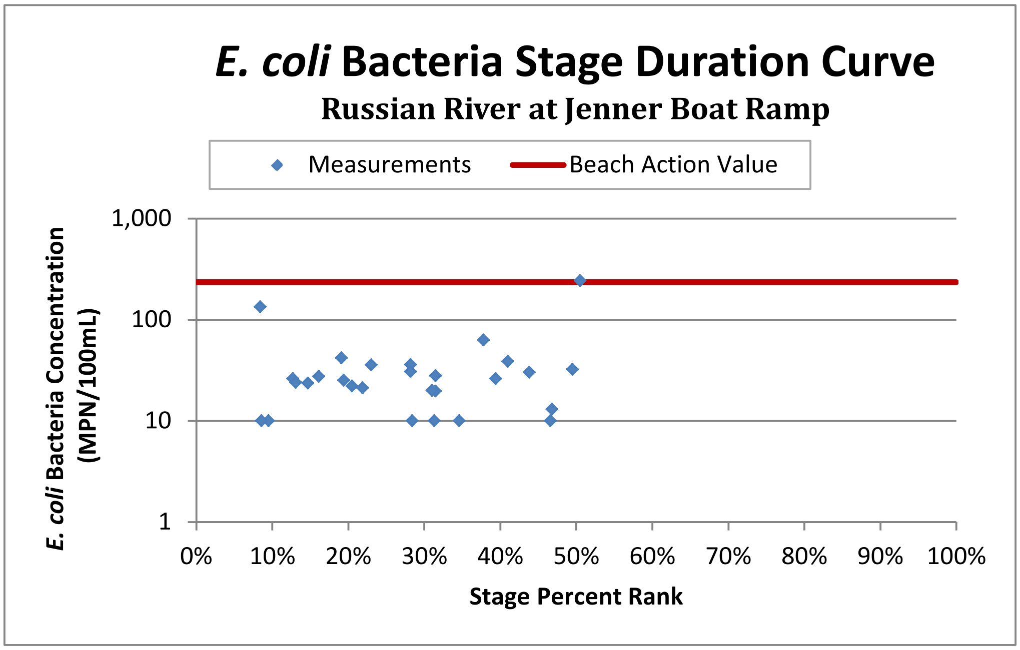

Figure 41. *E. coli* Bacteria Stage Duration Curve for measurements made in the Russian River at Jenner Boat Ramp

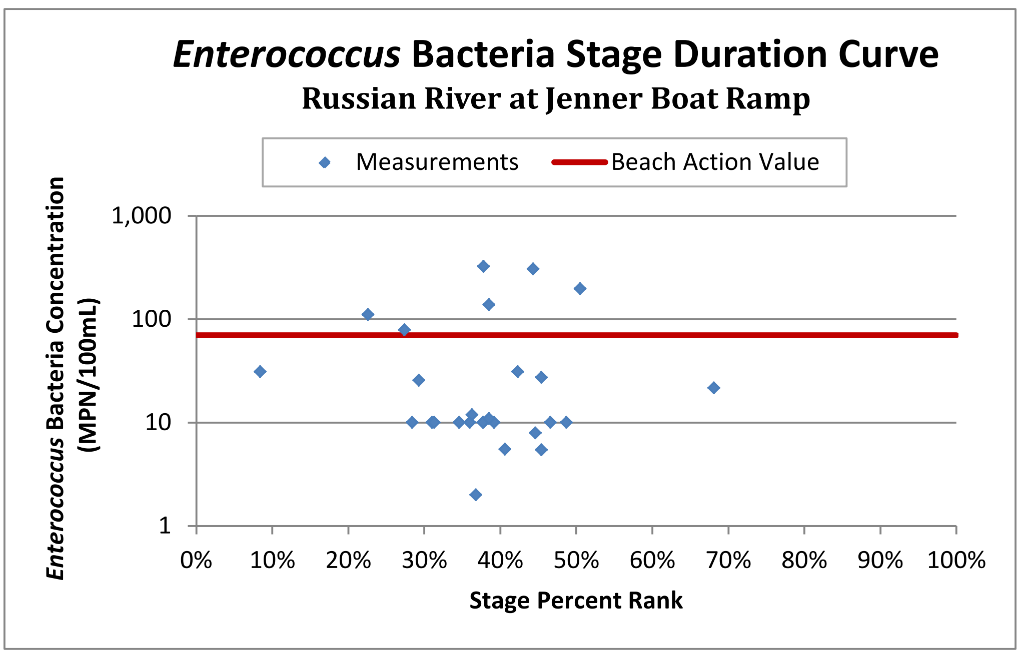

Figure 42. *Enterococcus* Bacteria Stage Duration Curve for measurements made in the Russian River at Jenner Boat Ramp

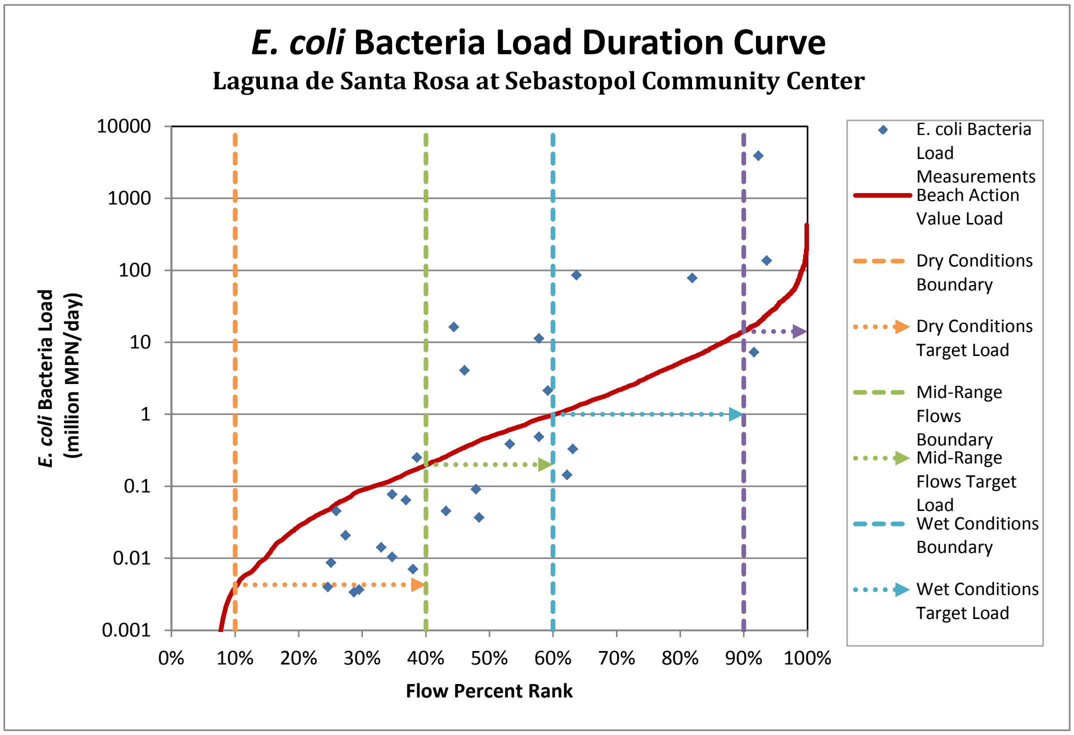

Figure 43. *E. coli* Bacteria Flow Regime Target Loads

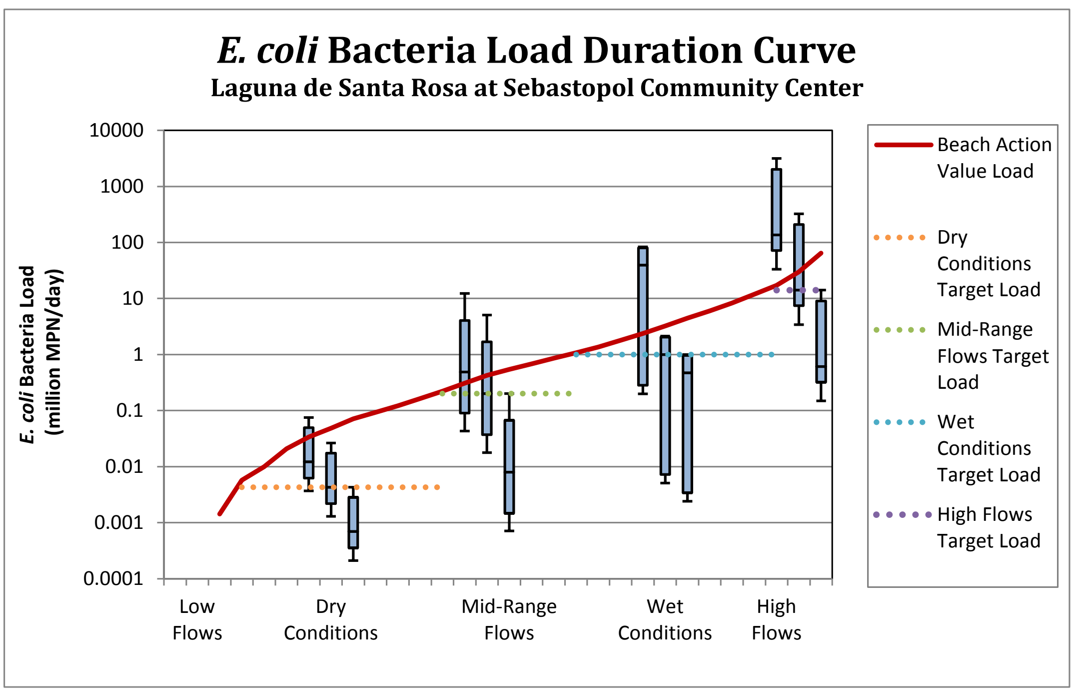

Figure 44. Comparison of *E. coli* Bacteria Load Distribution Reductions