APPENDIX C
EFFECT OF RUSSIAN RIVER DRY SEASON STREAM FLOW MANAGEMENT ON E.COLI BACTERIA CONCENTRATIONS

The Sonoma County Water Agency (Water Agency) is the primary supplier of wholesale drinking water to municipalities and water districts in Sonoma and Marin Counties. The Water Agency controls and coordinates water supply releases from the Coyote Valley Dam and Warm Springs Dam projects in accordance with minimum instream flow requirements specified by the State Water Resources Control Board (State Water Board). These minimum instream flow requirements vary based on water supply conditions. This memorandum evaluates the relationship between measured *E. coli* bacteria concentrations and the management of dry season instream flows in the Russian River.

The State Water Board adopted Decision 1610 on April 17, 1986 that specifies minimum instream flow requirements for the Russian River and Dry Creek. Decision 1610 requires a minimum flow of 25 cubic feet per second (cfs) in the East Fork of the Russian River from Coyote Valley Dam to the confluence with the West Fork of the Russian River under all water supply conditions. From this location to Dry Creek, the Decision 1610 requires minimum Russian River instream flows of 185 cfs from April through August and 150 cfs from September through March during *Normal* water supply condition. Several different minimum instream flow requirements are specified during different water years depending on the combined water storage in Lake Pillsbury and Lake Mendocino.

In addition to being the primary source of drinking water for Sonoma County, the Russian River provides habitat for three salmonid species that are listed as threatened or endangered species under the Federal Endangered Species Act: coho salmon (*Oncorhynchus kisutch*), steelhead (*Oncorhynchus mykiss*), and Chinook salmon (*Oncorhynchus tshawytscha*). Coho salmon is also listed as endangered under the California Endangered Species Act. In September 2008, the National Marine Fisheries Service (NMFS) issued the Russian River Biological Opinion (Biological Opinion) regarding the impacts of the water Agency and U.S. Army Corps of Engineer's water supply and flood control operations in the Russian River Watershed on the survival of these listed fish species (NMFS 2005).

NMFS (2005) concluded that the minimum instream flows required by Decision 1610 are too high for optimal juvenile salmonid habitat in the Upper Russian River and Dry Creek. In addition, NMFS (2005) concluded that the historical practice of breaching the sandbar that builds up and frequently closes the mouth of the Russian River during the summer and fall may adversely affect the listed species. To address these issues, NMFS's Biological Opinion requires the Water Agency and Corps to implement a series of actions to modify existing water supply and flood control activities that are intended to minimize impacts to listed salmon species.

The Biological Opinion requires the Water Agency to request that the minimum flow requirements be changed to the following during *Dry* water supply conditions:

- 70 cfs between May 1 and October 15 at the U.S. Geological Survey (USGS) Gage No. 11467000 (near Guerneville)
- 125 cfs between May 1 and October 15 at the USGS Gage No. 11464000 (near Healdsburg)

Since 2002, the Water Agency has requested several temporary changes to the Decision 1610 minimum instream flow requirements from the State Water Board. The Water Agency filed Temporary Urgency Change Petitions (TUCP) in 2002, 2004, 2007 and 2009 to request reductions in Russian River instream flows to address low storage levels in Lake Mendocino. TUCPs filed from 2010 through 2014 were required by the Biological Opinion to reduce instream flow conditions to improve habitat for the threatened and endangered fish species.

Since 2001, the Regional Water Quality Control Board (Regional Water Board) and the Water Agency have collected water samples to measure *E. coli* bacteria concentrations at several locations in the Russian River to assess impairment to recreational uses. These measured bacteria concentrations were compared to instream flow measurements from the Russian River on the same day. *E. coli* bacteria concentration measurements from Camp Rose Beach and Veteran's Memorial Beach were compared to daily mean stream flows measured near Healdsburg (USGS Gage No 11464000). *E. coli* bacteria concentration measurements from Steelhead Beach, Johnson's Beach and Monte Rio Beach were compared to daily mean stream flows measured near Guerneville (USGS Gage No 11467000).

Correlation between Bacteria Concentration and Stream Flow

E. coli bacteria concentrations in the Russian River were compared to stream flow measurements using Pearson's correlation coefficient. The correlation coefficient is derived by dividing the covariance of two variables by the product of their standard deviations. The correlation coefficient is +1 for a perfect increasing linear relationship and −1 for a perfect decreasing linear relationship. Correlation coefficients between −1 and 1 indicate the degree of linear dependence between the variables. Correlation coefficients closer to zero indicate there is less of a relationship between the variables.

A valid Pearson's correlation coefficient requires that the population distribution follow a linear normal data distribution. Data were log-transformed prior to deriving the coefficient since both stream flow and *E. coli* bacteria concentration data distributions followed a log-normal distribution. A correlation coefficient was considered statistically significant when the resulting probability of rejecting the null hypothesis was equal or lower than 0.05.

Table 1 presents the Pearson's correlation coefficients and associated probabilities of *E. coli* bacteria concentrations compared to daily mean stream flows in the Russian River. None of the Russian River locations evaluated showed any statistically significant correlation between *E. coli* bacteria concentrations and daily mean stream flows. The lack of a correlation can be observed in Figures 1-5 that show a visual comparison between the variables. No relationship between *E. coli* bacteria concentrations and daily mean stream flows is apparent at any of the Russian River locations.

Table 1. Pearson's correlation coefficients of *E. coli* bacteria concentrations and daily mean stream flows

Variables		Pearson's correlation coefficient	Probability
E. coli Bacteria Concentration at Camp Rose Beach	Daily Mean Stream Flow near Healdsburg	-0.009	0.904
E. coli Bacteria Concentration at Veteran's Memorial Beach	Daily Mean Stream Flow near Healdsburg	0.079	0.268
E. coli Bacteria Concentration at Steelhead Beach	Daily Mean Stream Flow near Guerneville	0.173	0.017
E. coli Bacteria Concentration at Johnson's Beach	Daily Mean Stream Flow near Guerneville	0.037	0.604
E. coli Bacteria Concentration at Monte Rio Beach	Daily Mean Stream Flow near Guerneville	0.065	0.335

Evaluation of Reduced Stream Flows on Bacteria Concentrations

Statistical hypothesis tests were made between the measured E. coli bacteria concentrations and different management scenarios of Russian River stream flows. E. coli bacteria concentrations collected during years of reduced stream flow (i.e., years with a TUCP) were compared to E. coli bacteria concentrations collected during years without reduced stream flow (i.e., years without a TUCP).

The Mann-Whitney U statistical hypothesis test was applied to assess the difference between the distributions of E. coli bacteria concentrations and daily mean Russian River stream flows during years with and without a TUCP. The Mann-Whitney U Test is a non-parametric test for assessing whether two samples of observations come from the same distribution (Helsel and Hirsch 2002). The test is similar to performing an ordinary parametric two-sample t test, but is based on ranking the data set. This statistical test is a nonparametric (i.e., distribution-free) inferential statistical method. The test makes no assumption of the frequency distributions. Nonparametric methods are the most appropriate approach for assessing water quality data which can have widely varying frequency distributions. Hypothesis tests were considered statistically significantly different if the resulting probability of rejecting the null hypothesis was equal or lower than 0.05.

Table 2 presents the associated probabilities of the Mann-Whitney U statistical hypothesis tests evaluating *E. coli* bacteria concentrations and daily mean stream flows in the Russian River. Stream flows showed a statistically significant difference between years with a TUCP and years without a TUCP. Most of the Russian River locations evaluated showed no statistically significant difference in *E. coli* bacteria concentrations from reduced stream flows due to the TUCPs. However, *E. coli* bacteria concentrations at Monte Rio Beach did show a difference. The distribution of *E. coli* bacteria concentrations during reduced stream flows were significantly lower that during stream flow years with no TUCP.

Table 2. Associated Probabilities of the Mann-Whitney U Statistical Hypothesis Tests

Variable	Russian River Location	Mann-Whitney U Probability	Statistical Difference
Daily Mean Stream Flow	USGS Gage No. 11464000 near Healdsburg	**<0.001**	**Yes**
	USGS Gage No. 11467000 near Guerneville	**<0.001**	**Yes**
E. coli Bacteria Concentration	Camp Rose Beach	0.730	No
	Veteran's Memorial Beach	0.243	No
	Steelhead Beach	0.228	No
	Johnson's Beach	0.825	No
	Monte Rio Beach	**0.047**	**Yes**

Bold Blue font indicates a statistically significant difference due to reduced stream flow management.

Distributions of the measured E. coli bacteria concentrations between reduced and normal stream flow management were compared visually using box and whisker plots (Figures 6 – 10). The boxes represent the interquartile range of the distribution around the median and the whiskers represent the 10th and 90th percentiles. The figures visually verify the results of the statistical hypothesis tests.

Figures 6 & 7 show statistically significant difference in stream flows between years with a TUCP and years without a TUCP. Figures 8 – 11 show essentially no difference in E. coli bacteria concentrations at most Russian River locations. However, Figure 12 shows significantly lower E. coli bacteria concentrations at Monte Rio Beach during reduced stream flows (with TUCP) as compared to normal stream flow years with no TUCP.

Findings

Based on the evaluation of *E. coli* bacteria concentrations and stream flows in the Russian River presented in this memorandum, Regional Water Board staff can make the following findings:

- None of the Russian River locations evaluated showed any statistically significant correlation between *E. coli* bacteria concentrations and daily mean stream flows.

- Stream flows showed a statistically significant difference between years with a TUCP and years without a TUCP.

- The Russian River at Camp Rose Beach, Veteran's Memorial Beach, Steelhead Beach, and Johnson's Beach showed no statistically significant difference in *E. coli* bacteria concentrations from reduced stream flows due to the TUCPs.

- *E. coli* bacteria concentrations at Monte Rio Beach did show a difference. The distribution of *E. coli* bacteria concentrations during reduced stream flows were significantly lower that during normal stream flow years with no TUCP.

Citations

Butkus, S. 2013. Evaluation of Fecal Indicator Bacteria Types. Memorandum dated October 9, 2013 to the File: Russian River Pathogen TMDL Development and Planning, North Coast Water Quality Control Board. Santa Rosa, CA.

Helsel, D.R. and R. M. Hirsch, 2002. Statistical Methods in Water Resources Techniques of Water Resources Investigations, Book 4, Chapter A3. U.S. Geological Survey, Reston, VA.

National Marine Fisheries Service (NMFS) 2005. Biological opinion for the U.S. Army Corps of Engineers proposed issuance of a section 404 permit to the Sonoma County Water Agency for breaching the Russian River estuary, May 20, 2005.

North Coast Regional Water Quality Control Board (NCRWQCB) 2011. Water Quality Control Plan for the North Coast Region, Santa Rosa, CA.

Figures

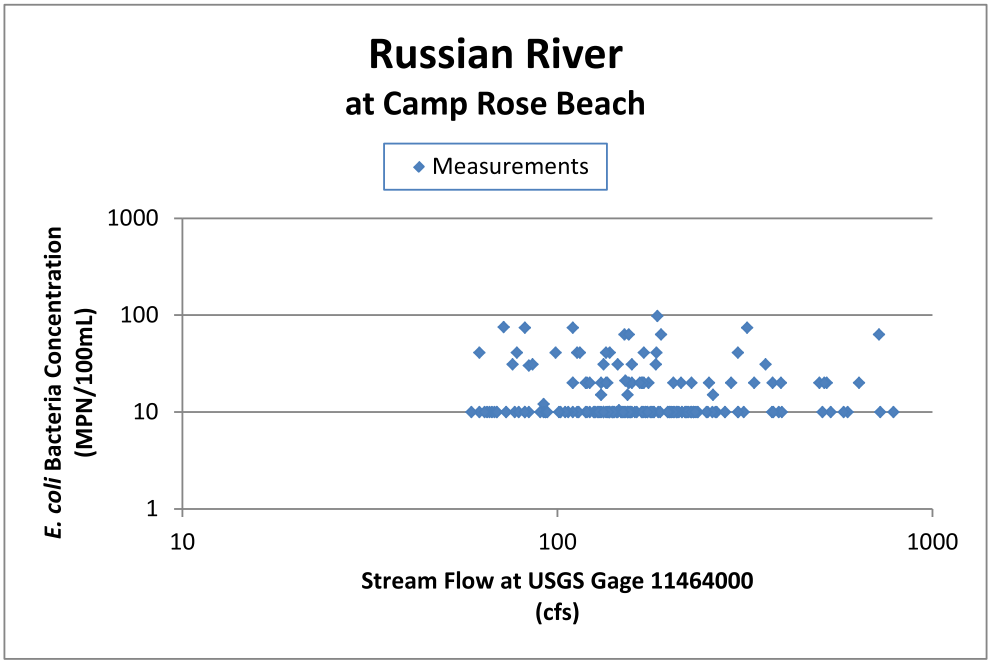

Figure 1. Correlation between E coli Bacteria Concentration and Stream Flow Measurements at Camp Rose Beach

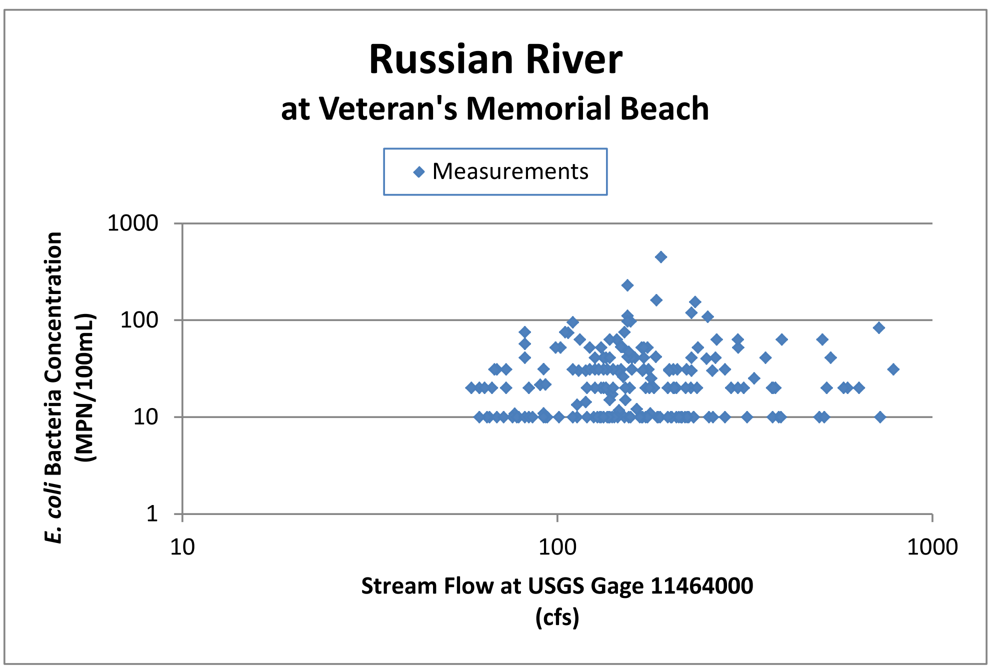

Figure 2. Correlation between E coli Bacteria Concentration and Stream Flow Measurements at Veteran's Memorial Beach

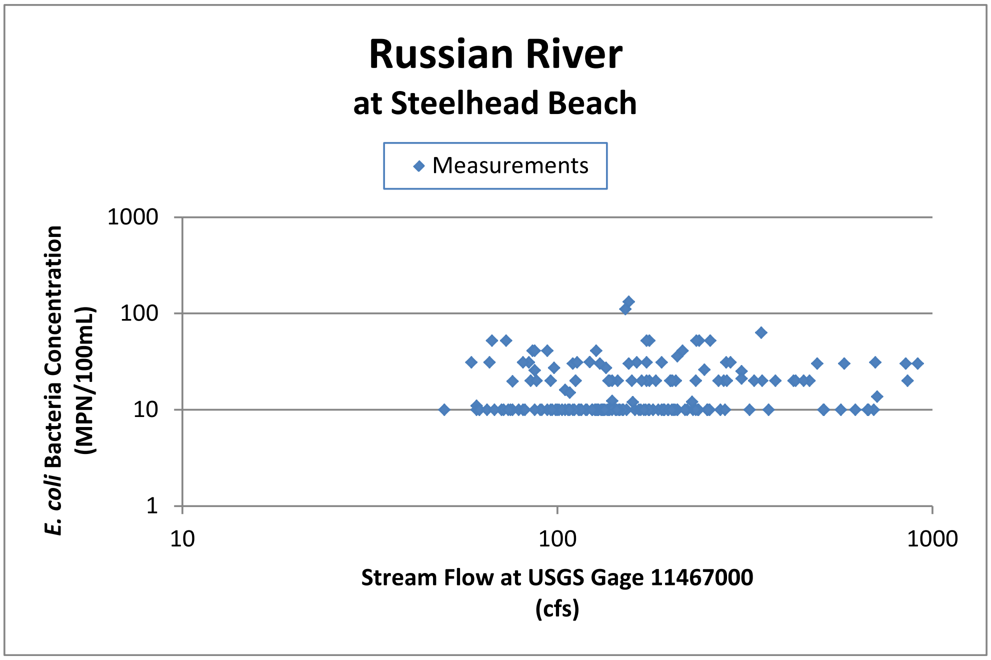

Figure 3. Correlation between E coli Bacteria Concentration and Stream Flow Measurements at Steelhead Beach

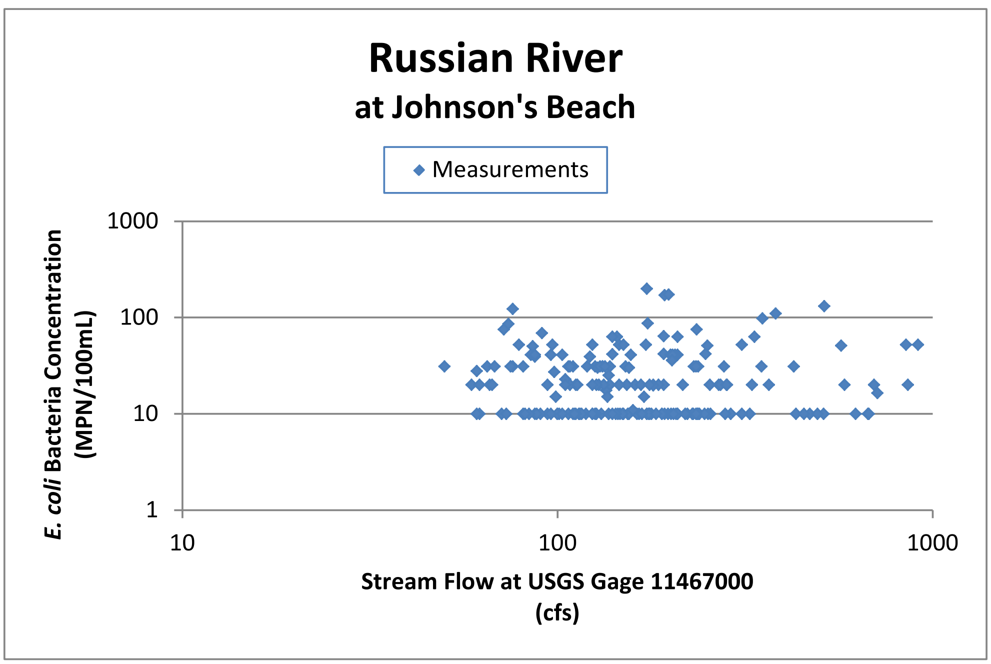

Figure 4. Correlation between E coli Bacteria Concentration and Stream Flow Measurements at Johnson's Beach

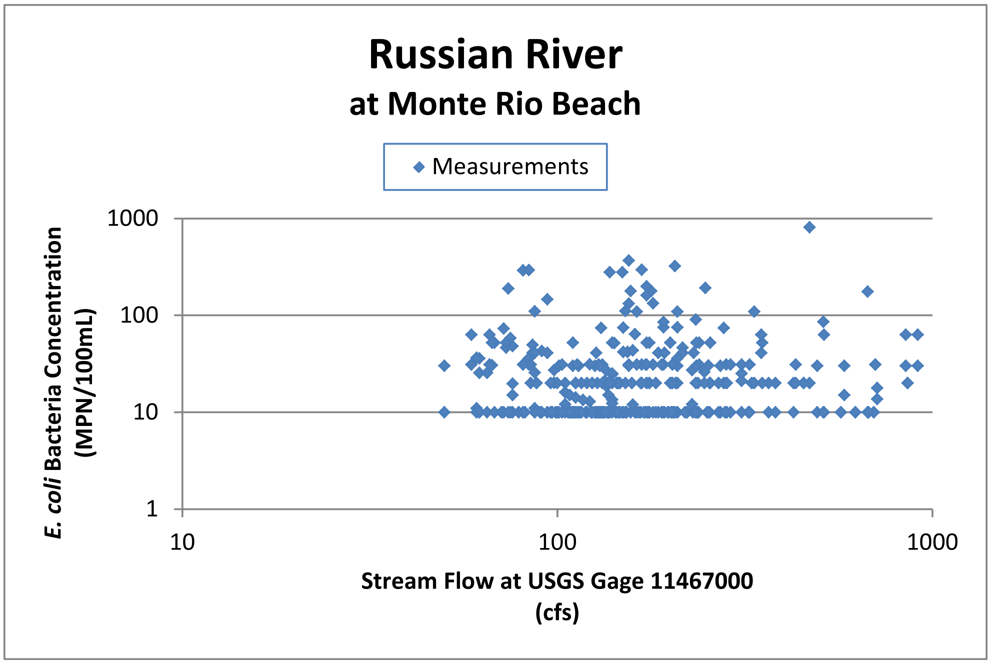

Figure 5. Correlation between E coli Bacteria Concentration and Stream Flow Measurements at Monte Rio Beach

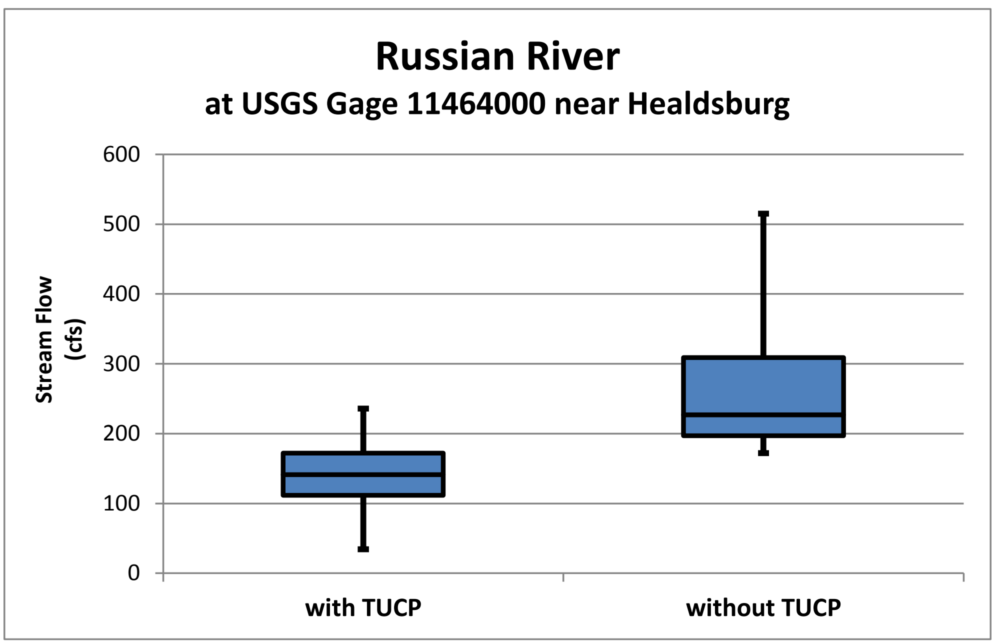

Figure 6. Comparison of Distribution of Stream Flows near Healdsburg during Years With and Without TUCP Reduced Flows

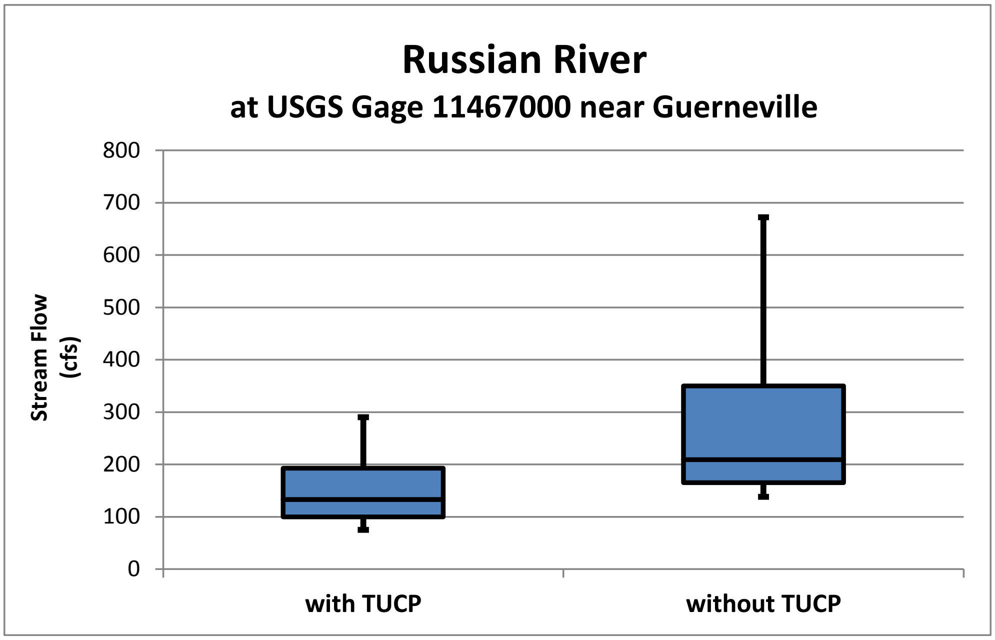

Figure 7. Comparison of Distribution of Stream Flows near Guerneville during Years With and Without TUCP Reduced Flows

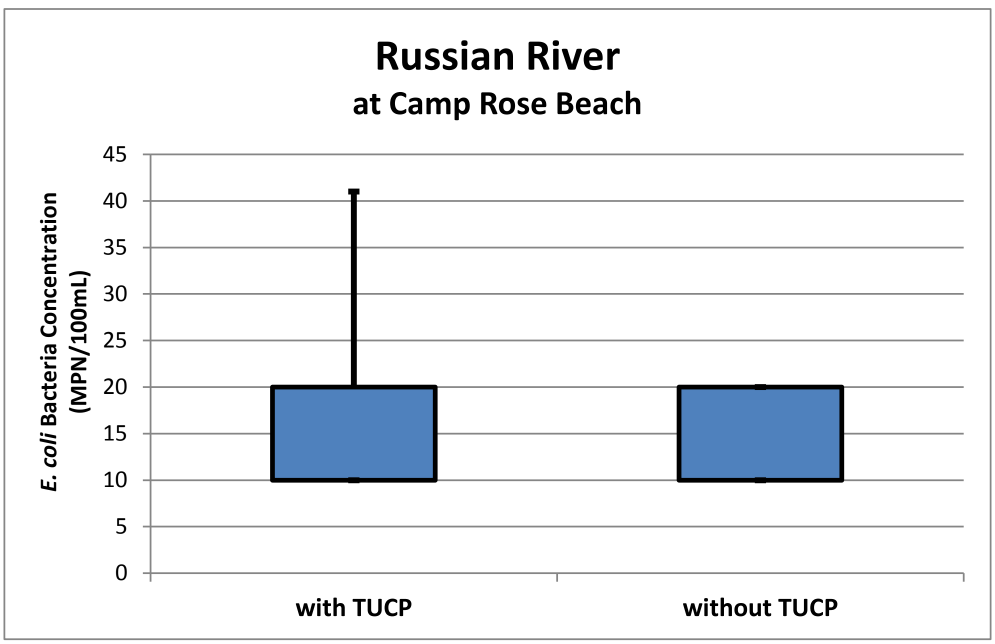

Figure 8. Comparison of Distribution of *E. coli* Bacteria Concentrations at Camp Rose Beach during Years With and Without TUCP Reduced Flows

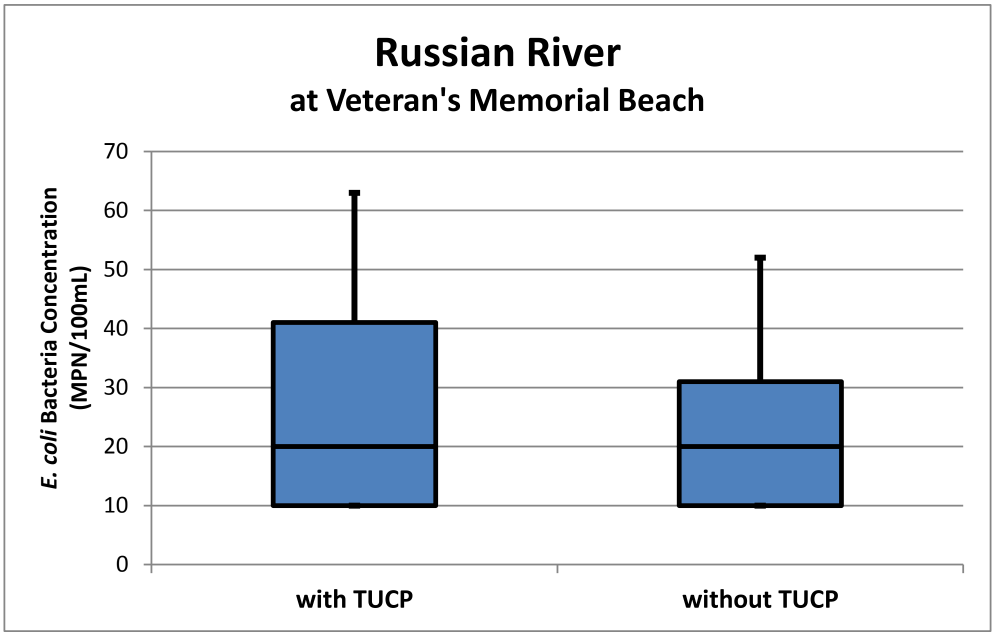

Figure 9. Comparison of Distribution of *E. coli* Bacteria Concentrations at Veteran's Memorial Beach during Years With and Without TUCP Reduced Flows

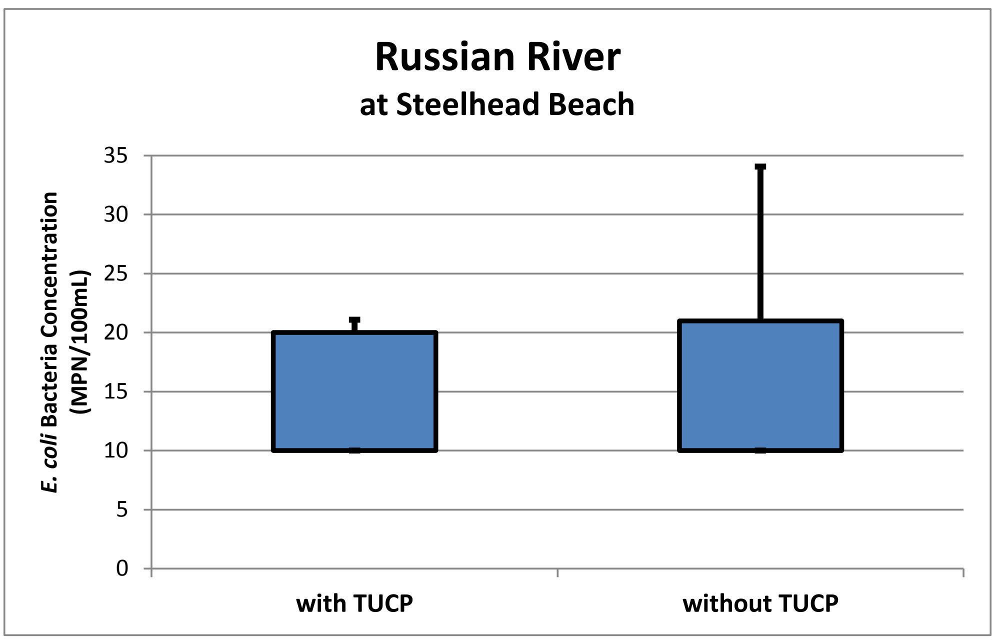

Figure 10. Comparison of Distribution of *E. coli* Bacteria Concentrations at Steelhead Beach during Years With and Without TUCP Reduced Flows

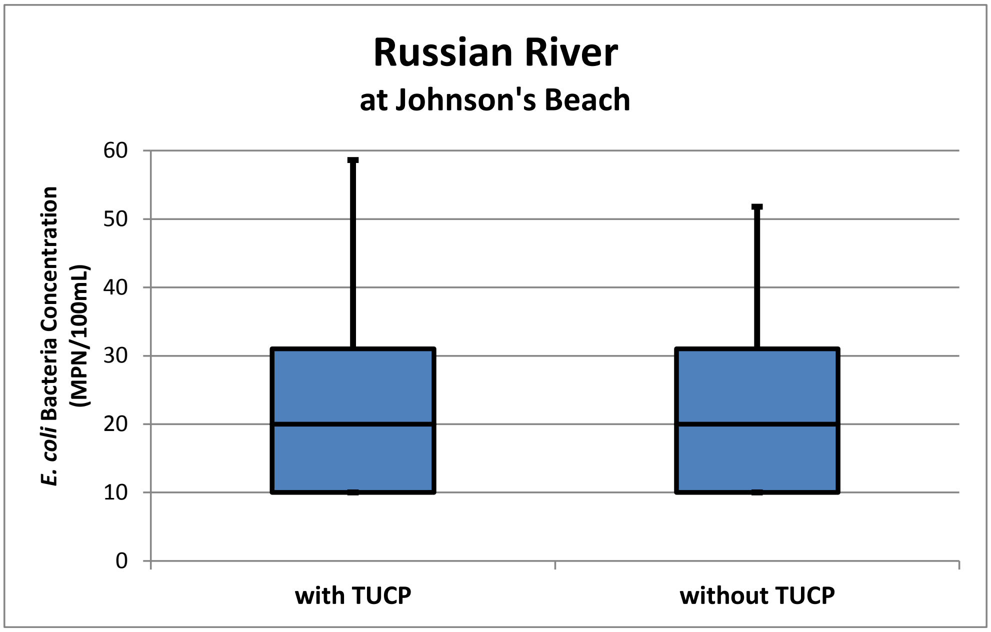

Figure 11. Comparison of Distribution of *E. coli* Bacteria Concentrations at Johnson's Beach during Years With and Without TUCP Reduced Flows

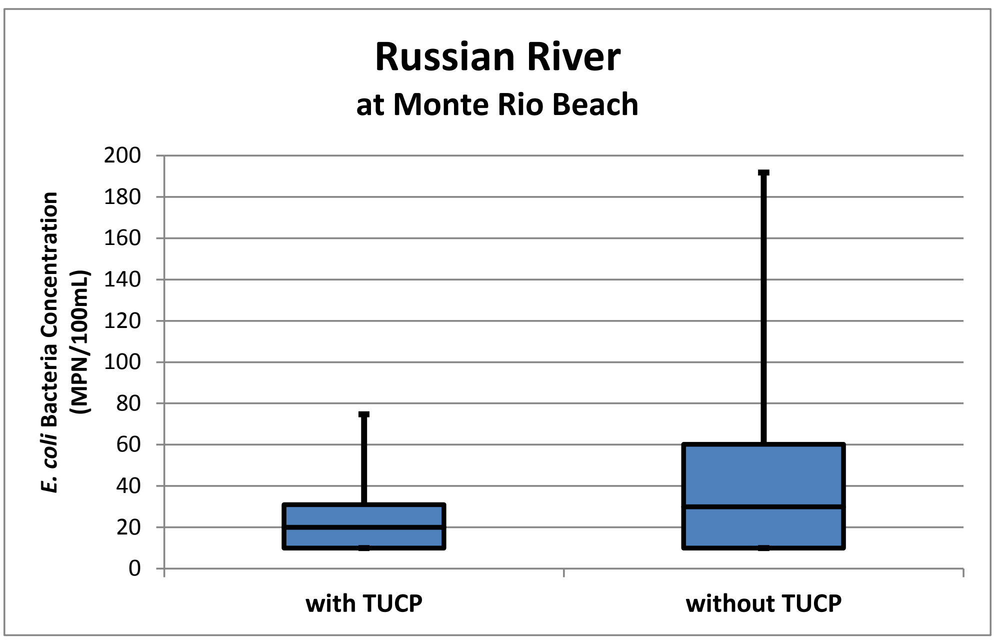

Figure 12. Comparison of Distribution of *E. coli* Bacteria Concentrations at Monte Rio Beach during Years With and Without TUCP Reduced Flows