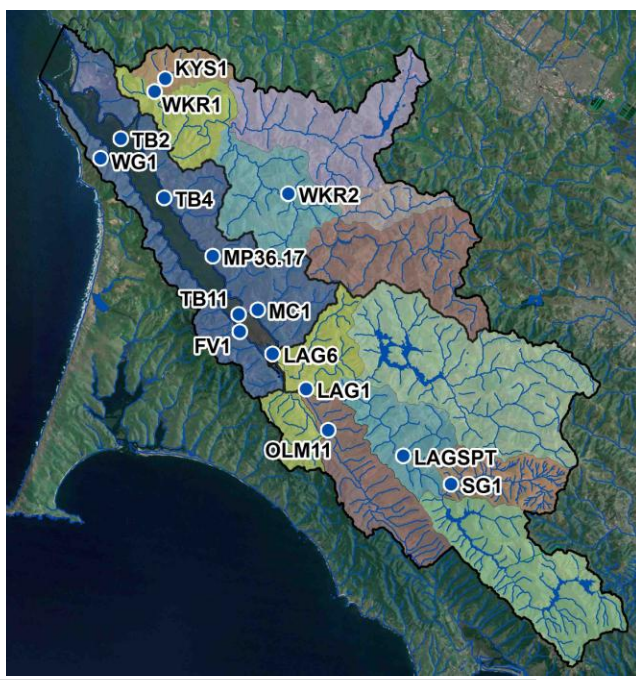
Executive Summary

The Tomales Bay Watershed Council Foundation (TBWCF) and Point Reyes National Seashore Association (PRNSA) are collaborating on this project to integrate the restoration of the Giacomini Wetland and water quality monitoring to reduce and eliminate existing threats, and to identify emerging threats that face this critically important watershed. By nesting a major restoration effort within a comprehensive monitoring program, this project employs an integrated strategy to both improve water quality and to assess the effectiveness of restoration efforts in improving water quality at the watershed scale. The information collected during this program will inform future restoration activities and priorities.

The project has three main water quality components: 1) The Trends Program which focuses on long-term monitoring at fixed sites throughout the watershed to monitor water quality trends; 2) the Source Area Program which focuses on identifying and characterizing existing water quality threats in target sub-watersheds selected annually; and 3) the Giacomini Wetlands Restoration Project which monitors the restoration project area and local reference areas before, during and after restoration to evaluate changes in water quality conditions. This report presents Trends Program and Source Area Program activities, particularly summary and analysis of water quality data collected from December 2007 through September 30, 2011. Data in this report is summarized by water year (i.e. October 1, 2010-September 30, 2011 is WY11). The summary and analysis of the Giacomini Wetland Restoration Project water quality data is provided in Appendix A of this document.

Monitoring Overview

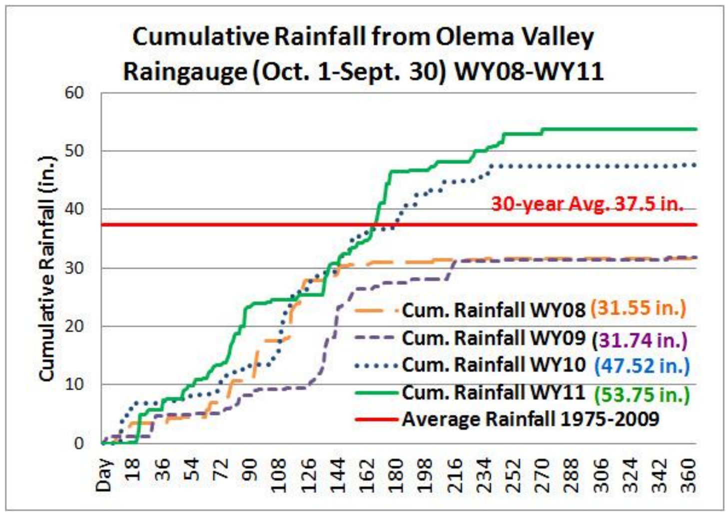
Monitoring methods followed the approved protocol contained in the project Monitoring Plan (MP) and Quality Assurance Project Plan (QAPP) (Carson, 2007). Sampling includes collection of both field and lab measured water quality parameters. Core parameters measured in the field include temperature (air and water), dissolved oxygen, pH, specific conductance, salinity and discharge where available. Laboratory analyzed parameters include indicator bacteria (total and fecal coliform bacteria), nutrients (ammonia, nitrate, total Kjeldahl nitrogen (TKN), total phosphorus (TP)), and sediment (turbidity).



The data is presented by major sub-watershed (Lagunitas and Walker Creeks), or by groups of sites in the case of the Bay sites and the east- and west-shore coastal drainages.

The long-term Trends Program monitored 11 tributary sites, and four Bay sites (see map at right) during weekly wet-season site visits (approximately October or November through April or May), and twice-monthly site visits during the dry season (April or May through October or November). Tributary stations were visited between 28 and 41 times each year (fewer in the case of intermittent streams). Bay sites were sampled at least 24 times in WY08 covering both the wet and dry season. Starting during the WY09 season, Bay sites were not regularly sampled during the wet season due to logistical constraints of sampling partners. As a result, we cannot assess year-round water quality conditions in Bay waters using our program data.

The parameters of greatest concern for the Trends Program monitoring are those for which there are either Regional Water Quality Control Board (RWQCB) water quality objectives or Environmental Protection Agency (EPA) Clean Water Act impairment listings (303d list). The former include pH and dissolved oxygen (DO). The latter includes pathogens, nutrients and sediment for Lagunitas Creek, Walker Creek and Tomales Bay itself. Walker Creek and Tomales Bay are also both listed as impaired by mercury due to legacy cinnabar (mercury ore) mining in the Walker Creek watershed.



Results and Analysis

The first four years of monitoring encompassed very different hydrologic conditions, with a recorded range of cumulative precipitation from 31.55-inches to 53.75-inches. The 30-year average for this gauge is 37.5-inches (with a range of about 17-inches in 1977 to 82-inches in 1983).

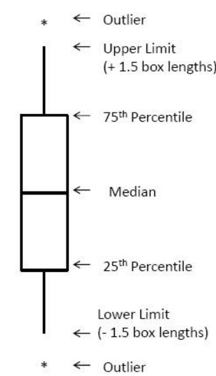
Field Measurements

At tributary sites, samples met the RWQCB water quality objectives to support beneficial uses during most sampling visits. An analysis of the entire Trends Program dataset shows that measured dissolved oxygen (DO) met the RWQCB DO objective of 7.0 mg/L in 91.5% of all samples (WY08-WY11), and met the RWQCB pH objective (>6.5 and <8.5) in 96% of all samples (WY08-WY11).

Bacteria

The TBWC's water quality monitoring results suggest that the monitored tributaries are not complying with bacteria objectives proposed in the pathogen TMDL for Tomales Bay. For pathogens, the RWQCB set a contact recreation fecal coliform objective that no more than 10% of samples exceed 400 MPN/100mL, and a shellfish harvesting objective that no more than 10% of samples exceed 43 MPN/100mL (RWQCB 2001). Combined fecal coliform results from all tributary sites and all water years shows that more than 30% of samples exceeded 400 MPN/100mL. When considering combined WY08-WY11 data by each tributary site, no site had fewer than 10% of samples exceeding 400 MPN/100mL. We are currently conducting an analysis of RWQCB monitoring results collected for their Tomales Bay pathogen TMDL program for the duration of monitoring (2004-2012) to assess compliance using their own monitoring data. This analysis will be included in the final technical report for this program in 2012.

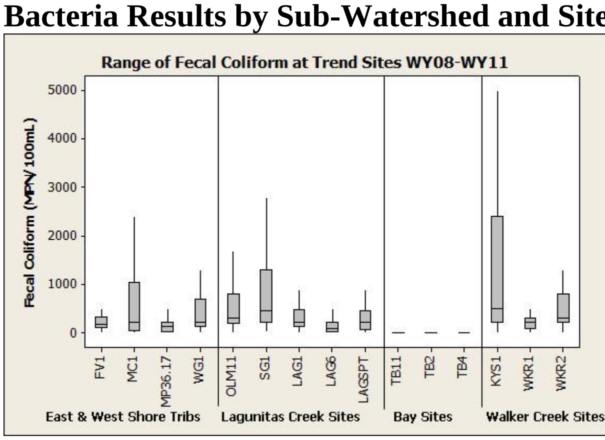
At outer-, mid-, and inner-Tomales Bay sites, where the shellfish harvesting objective is more appropriate, 10% of samples exceeded the single-sample objective for shellfish harvesting over WY08-WY11, although sampling did not occur at Bay sites during wet-season, adverse weather events, or during Bay closure due to recent cumulative precipitation, when bacteria levels are most likely to be elevated. The consequence is that program data for the Bay sites is insufficient to capture the true range of annual water quality conditions, because it does not include what we suspect would be results at the upper end of the annual range.

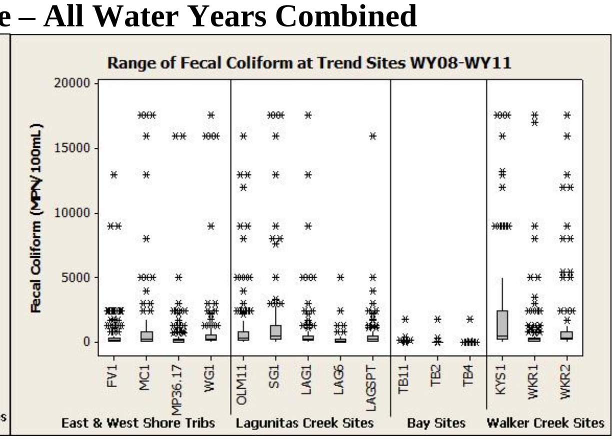


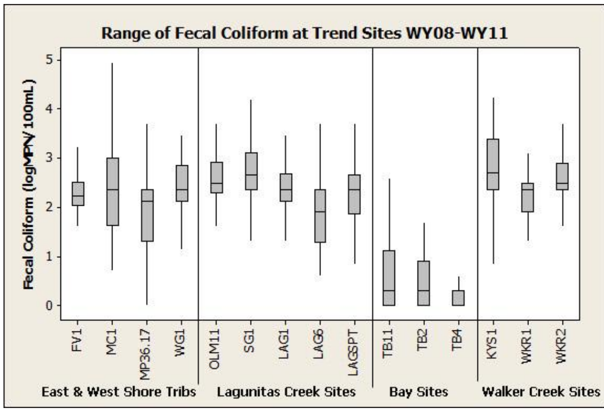
Below are graphs (boxplots) of lab sample results by station through WY11. A boxplot displays information about the range and distribution of data within the range (see figure at right). For the graphs below, those on the left side do not include outlier results (those above or below the limits defined by the whisker length of 1.5-times the middle 50% range box). The graphs on the right include outlier results, shown by the asterisks (*) and so, these graphs show the true range of results (with exceptions noted below graphs).

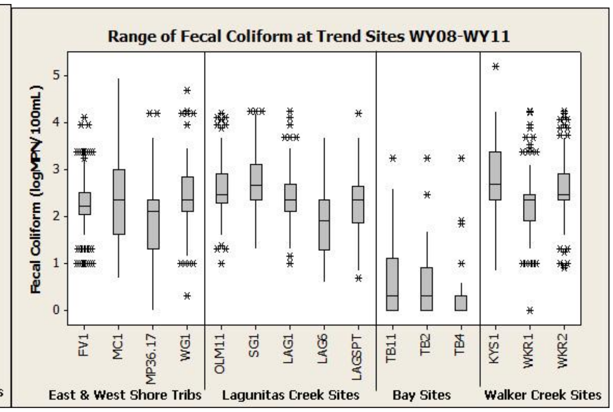
The first set of graphs shows the range of fecal coliform bacteria results. The first side-by-side set of graphs below is the actual fecal coliform 'most probable number' or MPN per 100mL of sample water. The second side-by-side set shows the range of log values of the fecal coliform results which enables comparison of the wide-ranging values like bacteria results on a smaller scale with more resolution. For example, the relative difference among Bay sites, with the inner-Bay site (TB11) elevated compared to the outer- and mid-Bay sites, is only apparent on the graphs of the log values of the fecal coliform results. The results also show that elevated levels of bacteria are chronic for some tributaries, including Keys Creek (KYS1), San Geronimo Creek (SG1) and Millerton Gulch (MC1). Also evident, however, is that periodically most monitored tributaries had elevated, or extremely elevated bacteria results shown in the scatter of extreme outliers on the graphs at right.

Bacteria Results by Sub-Watershed and Site – All Water Years Combined









Note: Two extreme outlier results of 50,000 (WG1) and 90,000 (MC1) were omitted from bacteria graphs on right.

Nutrients

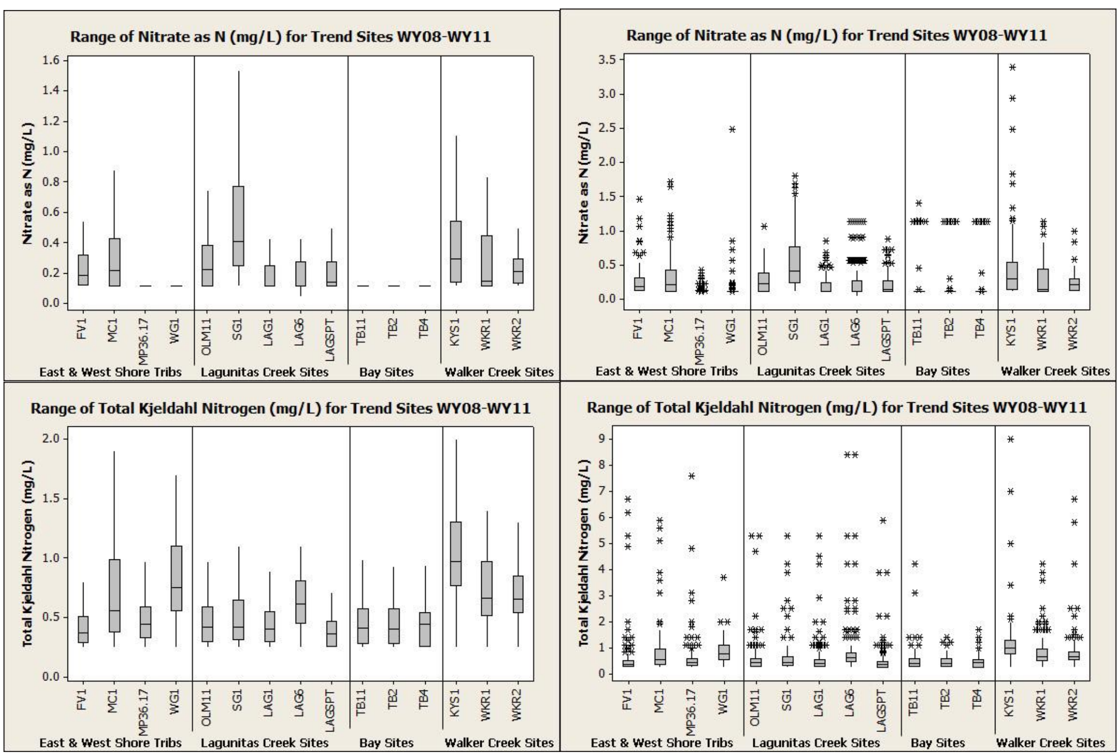
While there are no nutrient water quality objectives established by the RWQCB for surface waters, observed nutrient levels in the watershed were relatively low. We detected forms of nitrogen in most samples from both tributary and Bay sites during WY11 (nitrate (NO_3) detections over 58% of samples; TKN detections over 98% of samples). Ammonia (NH_3) and total phosphorus (TP) detections were very low (ammonia about 3% of samples from WY08-WY10; and TP about 14% of samples from WY08-WY10). The very low levels of phosphorus detected in samples, and the ample available nitrogen suggests that phosphorus is the limiting nutrient in the watershed. Despite the importance of monitoring the limiting nutrient, we discontinued the analysis of samples for TP during WY10 and ammonia in WY11 because the number of detections for total phosphorus (TP) and ammonia at monitored locations was very low and our contract laboratory was unable to provide more sensitive analysis.

Nitrogen is an abundant nutrient in our watershed tributaries and in the Bay. The dynamics of the nitrogen cycle, and the relative abundance of each form, can provide additional information about the types of sources and impacts on the aquatic system. Major potential sources of nitrogen in the watershed include decomposing organic material, human and animal waste, and fertilizers. The Trends Program primarily monitors concentrations of nitrate (NO_3) and total Kjeldahl nitrogen (TKN). The former is the most stable, and most abundant, form of dissolved nitrogen, and the latter is the sum of organic nitrogen and ammonia. Sources of nitrates include animal (domestic, livestock and wildlife) waste, human waste from compromised septic systems or treatment system spills, as well as decomposed ammonia, nitrite and organic nitrogen. The main sources of organic nitrogen are decomposing organic material like vegetation (leaf litter, plants, roots, etc.), animals, etc. Organic nitrogen is often associated with soil particles, increasing with erosion and sediment-laden runoff. . In general, ammonia is very short-lived (though potentially lethal) in aquatic systems, quickly undergoing chemical transformation to nitrite (NO_2), then to nitrate (NO_3). The consequence of this is that its detection usually suggests a proximate source such as livestock and wildlife.

Nitrate as nitrogen and TKN levels were elevated relative to the recommended EPA criteria for Total Nitrogen of 0.38 mg/L for ecoregion III rivers and streams (EPA 2000), but never exceeded the EPA drinking water standard of 10 mg/L nitrate-N (44 mg/L nitrate NO_3). Comparison of total Kjeldahl nitrogen (TKN), ammonia and nitrate results suggests that organic nitrogen is the largest available nutrient constituent in the watershed, and that spikes in most nutrient concentrations appear to be driven by storm-related runoff and hydrologic connection to upstream sources.

Again, the nutrient results show that elevated levels of nitrate are chronic in some tributaries, including Keys Creek (KYS1), San Geronimo Creek (SG1), Olema Creek (OLM11) and Millerton Gulch (MC1). The results of TKN analysis (the second side-by-side set of graphs) demonstrate that organic nitrogen is a major nutrient source in the tributaries, with the most elevated results occurring during storm runoff events. This is particularly evident from the sites in the Walker Creek watershed, and consistent with the association between organic nitrogen and sediment particles in the water column. Also of note is that San Geronimo Creek site does not demonstrate strongly elevated TKN relative to other Lagunitas Creek watershed sites, contrary to a comparison nitrate results in Lagunitas Creek sites. This suggests that while the nitrogen input in the San Geronimo Creek watershed includes organic nitrogen, it is at levels consistent with other Lagunitas watershed sites. It also suggests that there is a significant source of dissolved nitrate in the San Geronimo Creek watershed itself. Potential sources include the well-documented presence of compromised septic systems (TBWC 2007) and chemical fertilizer runoff from home gardens or the golf course.

Nutrient Results by Sub-Watershed and Site – All Water Years Combined



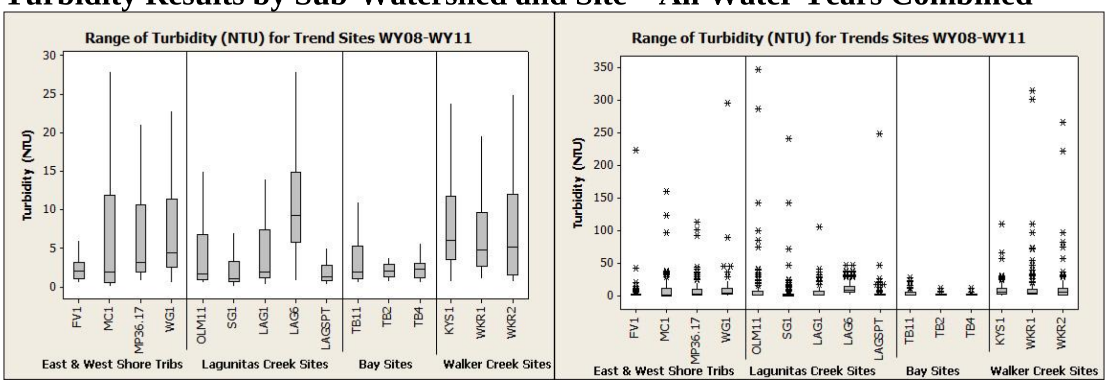
Note: Two extreme outlier results of 15 mg/L (WG1) and 39 mg/L (MC1) were omitted from TKN graphs.

Sediment

There is no turbidity or other sediment water quality objectives set by the RWQCB, but the Basin Plan states that “waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses.” The EPA guidance provides recommended turbidity criteria for ecoregion III rivers and streams of 2.34 NTU. The mean turbidity for most monitored tributaries exceeded this recommended level in all water years.

The turbidity levels observed in the watershed are heavily driven by storms and runoff events at both tributary and Bay sites. Almost all elevated turbidity levels occurred during or after runoff events. Only at intermittent tributaries did we observe elevated turbidity during summer months as freshwater input slowed, and algal growth flourished. Bay sites (not including LAG6) had a mean turbidity of 3.06 NTU (n=71) in WY08 and 2.15 NTU (n=41) in WY09; 4.13 NTU (n=27) in WY10; and 4.05 NTU (n=25) in WY11. Tributary sites (including LAG6) had a mean turbidity of 5.77 NTU (n=283) in WY08; 7.83 NTU (n=302) in WY09; 19.27 (n=466) in WY10 and 8.02 (n=440) in WY11. The observed increase in mean turbidity in WY10 may likely be due to higher stream-flows observed during the 2009-10 water year. Sites with elevated turbidity were present in each major watershed grouping, and almost all sites had periodic extreme values noted on the graph below at right. Of note are the consistently lower levels at First Valley Creek (FV1) on the west shore, and at upper Lagunitas Creek (LAGSPT). At the Bay sites, the inner-Bay site (TB11) demonstrates a higher range of values reflecting the strong influence of Lagunitas Creek on water clarity in the inner Bay.

Turbidity Results by Sub-Watershed and Site – All Water Years Combined



Note: Two extreme outlier results of 899 NTU (LAG1) & 1,000 NTU (WKR2) were omitted from Turbidity graph.

Source Area Program

Source Area Program sampling resumed during the 2010-2011 wet season with efforts focused on capturing storm profiles of pollutant concentrations in the San Geronimo Creek, Olema Creek, First Valley Creek and Millerton Gulch watersheds. The goal of this effort was to measure the severity and duration of elevated pollutant loads resulting from different storm events. To accomplish this, staff sampled on day 1 (rising limb), day 2 (peak or falling limb), day 3 (falling limb) and/or days 4 or 5 (return to static flow) of targeted storms. The close spacing of storms during WY11 frustrated attempts to gather the latter (day 3-5) samples, however differences between monitored watersheds were observed. This data will be compiled with regular Trend Program monitoring from the same sites, and compared to cumulative and recent rainfall amounts to determine patterns. Analysis of all Source Area Program data will be provided in the final project technical report, late in 2012.

Outreach and Education

Program outreach and education activities during 2010 and 2011 included sposored a State of the Bay conference, participation in teacher training and maintenance of our on-line water quality data resource. The Tomales Bay Watershed Council planned and sponsored the 5th State of the Bay Conference on October 22-23, 2010 which brought together scientists, policy makers and concerned citizens to learn about current scientific information, what is being done, and what is needed for the future of the Bay and its watershed. Complete proceedings from the conference, including agenda, abstracts, speaker biographies, presentations and video of nearly all presentations is available on our website at:
http://www.tomalesbaywatershed.org/stateofthebay2010.html

Program staff also led a day of watershed and water quality educational training for teachers through an ongoing seminar program through the Salmon Protection and Watershed Network (SPAWN).

Conclusions and Next Steps

A more complete analysis of program data is underway and will be compiled in the final technical report for the program. Initial analysis of gathered data compared with rainfall data suggests that there are not discernible downward trends in pollutant concentrations across the watershed. Storm-related runoff appears to be the primary driver of adverse water quality conditions including bacteria, nutrients and sediment levels. The program has maintained consistent monitoring during five wet-seasons, capturing significant climatic variability which should allow for a more robust analysis of both legacy data and future TBWC program data. The Tomales Bay Watershed Council water quality monitoring program will continue through the 2012 water year. The Trends Program will continue at the same sampling intensity, for the same parameters through September 2012. The Source Area Program will focus on monitoring profiles of pollutant concentrations in the Walker Creek watershed, and on shellfish leases in the mouth of Walker Creek. The Giacomini Wetland Restoration Project water quality monitoring will continue quarterly monitoring of project and reference areas through September 2012. Funding for each program element after September 2012 will depend on the available resources of the organizations involved in monitoring.