2010-2011 Annual Water Quality Report
and Program Summary for the Tomales Bay Wetlands
Restoration and Monitoring Program

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Cover Photo: WQ Program Manager, Rob Carson, sampling on Lagunitas Creek. Photo by Neysa King
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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**
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

![Nutrient Results Diagrams]

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 sponsored 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.
Introduction

Watershed Description
Located in western Marin County, California, approximately 40 miles northwest of San Francisco, the Tomales Bay Watershed encompasses almost 220-square miles bounded by the slopes of Mt. Tamalpais to the south, the Inverness Ridge to the west and the agricultural lands to the east. Tomales Bay itself is an approximately 12 miles long flooded valley, covering 10.8 square-miles, straddling the San Andreas Fault. The Bay is less than a mile wide, and has an average depth of less than 20 feet (RWQCB 2007).

Figure 1 – Major Watersheds of Tomales Bay

Most of the freshwater delivered to the Bay originates in two major sub watersheds, Lagunitas Creek and Walker Creek. The Lagunitas Creek watershed, which includes San Geronimo Creek, is the largest sub-watershed to Tomales Bay and, together with the Olema Creek watershed, delivers nearly two-thirds of the freshwater input to the Bay, despite representing only 52% of the watershed area (Fischer, et al 1996). The second-largest drainage is the Walker Creek watershed to the northeast of the Bay. The Walker Creek watershed, which includes the Keys, Chileno, Sausal, Salmon and Arroyo Creek drainages, makes up about 35% of the Tomales Bay watershed area, but produces only about 25% of the freshwater delivery to the Bay (Fischer, et al. 1996). The approximately 10% of remaining freshwater input is delivered by the small drainages that line the east and west shores of the Bay and represent about 13% of the watershed area.

The following section offers a description of the major sub-watersheds of the Tomales Bay watershed, as well as locations of Trends Program sampling sites.
The Lagunitas Creek watershed covers an area of 83.1 square miles and includes the monitored subwatershed of San Geronimo Creek watershed that covers an area of approximately 9.37 square miles. Another significant tributary of Lagunitas Creek is the Olema Creek watershed which covers an area of 14.7 square miles. The Trends program has established four fixed-site monitoring stations at the following locations: the most upstream site is on San Geronimo Creek (SG1) at the MMWD stream gauge on Lagunitas Rd.; the next downstream site is on Lagunitas Creek at Samuel P. Taylor State Park (LAGSPT) at the USGS stream gauge (USGS 11460400); one site on Olema Creek below the Bear Valley Road bridge at the NPS stream gauge; and the most downstream site, Lagunitas Creek at green bridge just south of Point Reyes Station (LAG1). There is an additional site further downstream (LAG6) at the Lagunitas/Tomales Bay interface in the Giacomini wetlands. The LAG6 site is included below in the Tomales Bay site grouping, and includes the input from Olema Creek, the storm water system of Point Reyes Station, and small coastal drainages. Land-use in this watershed is a mix of agriculture, livestock grazing, dairy farming, low-density residential and park lands. Most residents in the watershed are served by onsite sewage disposal systems, with the exception of four small sewage treatment systems (RWQCB 2001). The Lagunitas Creek watershed provides 75% of the drinking water for residents in eastern Marin County by way of five water catchment reservoirs operated by Marin Municipal Water
District (MMWD). Four are in the upper Lagunitas watershed (Lake Lagunitas, Bon Tempe Lake, Alpine Lake and Kent Lake), and the fifth is the Nicasio Reservoir which spills to Lagunitas Creek about 2 miles south of Point Reyes Station.

**East and West-Shore Coastal Tributaries**

Coastal tributaries (those emptying directly into Tomales Bay) are numerous, though they contribute only about 10% of the freshwater input to the Bay (Fischer et al 1996). The Trends program has established four fixed-site monitoring stations in coastal drainages, two on the west shore, and two on the east. First Valley Creek (FV1) which drains an area of 0.80 square miles and is representative of the small coastal drainages along the west shore of the Bay with perennial flow originating from springs and fog-drip from the Inverness Ridge. The land-use in the drainage includes mostly residential (a significant number of which are only seasonally-used), and state and federal lands. White Gulch (WG1) which flows from the west, through the Tomales Point Tule elk reserve, encompasses an area of 0.34 square miles on the east side of Tomales Point and drains to the cove near Hog Island. Millerton Gulch (MC1) which drains an area of 3.7 square miles on the east just south of Millerton Point. The land-use in the Millerton Gulch drainage includes livestock grazing, a septic waste pond, and California State Park lands. During WY08, samples from Millerton Gulch were collected at the highway 1 bridge (MC1a), which is under significant tidal influence. The sampling site was moved upstream to the current sampling location at the southeastern end of state park lands to minimize these effects. Because of significant differences in field parameter values between the sites, the results are not combined in the analysis for WY08. The fourth coastal drainage is a small east shore tributary just south of the Marconi Conference Center (MP36.17) which drains an area of 0.4 square miles with minimal current human activity. The WG1 and MP36.17 sites are included as reference tributaries due to their relatively minimal development and impact from current human activities.

**Walker Creek Watershed**

The Walker Creek watershed covers an area of 75.5 square miles, which includes the monitored sub watershed of Keys Creek with an area of 9.37 square miles. The Trends program has established three fixed-site monitoring stations at the following locations: Walker Creek upstream site at Walker Creek Ranch (WKR2), approximately 1/4-mile upstream of the USGS streamgauge (USGS 11460750); Keys Creek at shoreline highway (KYS1); and Walker Creek downstream site at shoreline highway, just upstream of the Keys Creek confluence (WKR1). Land-use in this watershed is dominated by agriculture, livestock grazing and dairy farming, with some low-density residential. All households are served by onsite sewage disposal systems except the town of Tomales, which is served by a centralized wastewater treatment plant. There is one drinking water reservoir (Soulajule) in the Walker Creek watershed operated by MMWD.

**Tomales Bay**

The Trends program also monitors Bay water at four fixed-site stations along the length of Tomales Bay. The three northern sites were selected because they are located on shellfish leases and have been monitored for bacteria by the California Department of Public Health (CDPH). The outermost site (TB2) is located just outside the mouth of Walker Creek. The mid-Bay site (TB4) is in the Bay about a mile north of the Marshall-
The Tomales Bay Watershed Council (TBWC) Watershed Stewardship Plan (TBWC 2003) adopted in 2004 was to "Ensure water quality in Tomales Bay and tributary streams is sufficient to support natural resources and sustain beneficial uses.” This goal is central to the past and current activities and interests of the TBWC and its members.

In order to best identify future restoration needs, trends in water quality, and sources of nonpoint water pollution, TBWC is currently assessing surface water quality throughout the watershed through this program. TBWC also provides a clearinghouse for regional water quality data, collected by member and outside agencies and groups leading to compilation and analysis of all available data to provide the "big picture” that is necessary to inform our resource management decisions and priorities (TBWC 2007).

A number of federally and state endangered [FE] [SE] and threatened [FT] [ST] species have historically or recently been documented in the watershed. Freshwater systems within the watershed support a variety of protected species including the California freshwater shrimp (Syncharis pacifica) [FE], coho salmon (Oncorhynchus kisutch) [FE/SE], steelhead trout (Oncorhynchus mykiss) [FT], and the California red-legged frog (Rana aurora draytonii) [FT]. Saltwater, or brackish systems in the watershed support the tidewater goby (Eucyclogobius newberryi) [FE]. Avian species occurring in the watershed that are listed as threatened or endangered include the California clapper rail (Rallus longirostris obsoletus) [FE; SE], Least Bell’s vireo (Vireo bellii pusillus) [FE, SE], American peregrine falcon (Falco peregrinus anatum) [SE], California black rail (Laterallus jamaicensis coturniculus) [ST], bank swallow (Riparia riparia) [ST], and sandhill crane (Grus Canadensis tabida) [ST]. (NPS 2007)

In addition to the occurrence of threatened or endangered species in the watershed, several water resources are listed by the Regional Water Quality Control Board (RWQCB) as impaired under Section 303(d) of the Clean Water Act. These listings imply that the listed water resources consistently fail to meet water quality standards set to ensure continuation of beneficial uses in these waters.

Beneficial uses of water bodies in the Tomales Bay watershed include contact and non-contact recreation, fish spawning and migration, cold freshwater habitat, and wildlife habitat. Water quality also has a direct impact on several other resources including water quality, mariculture, federal and state protected stream species and fish assemblages, amphibians and reptiles, riparian habitat, wetlands and aquatic macroinvertebrates.
The impairment listings under Section 303(d) in the watershed include: Tomales Bay, listed as impaired by pathogens, nutrients, sediment and mercury; Lagunitas Creek (including the Olema Creek watershed), listed as impaired by pathogens, nutrients and sediment; and Walker Creek, listed as impaired by pathogens, nutrients, sediment and mercury. There is currently a Total Maximum Daily Load (TMDL) in place for the watershed for pathogen contamination.

The occurrence of special status species, the listing of encompassed watersheds as impaired in Section 303(d) of the Clean Water Act, and the numerous projects to improve management practices on ranches and public lands underlines the importance of collecting and analyzing water quality data from the watershed as a whole to allow the evaluation of long-term water quality trends, and the positive or negative impacts of our activities in the watershed.

Program Overview

Funding Program: Initial funding for this project was provided through the SWRCB Prop. 50 Coastal Nonpoint Source Pollution Control Program (Grant Agreement number 06-344-552-0) through December 17, 2008. Funding for the project was restored through the SWRCB State Revolving Fund (SRF) Project No. C-06-6926-110, Agreement No. 08-304-550-0 starting on December 18, 2008.

Program Description: 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. Tomales Bay and its watershed is a precious Pacific coast ecosystem at risk from existing and emerging threats. 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.

Program goal: This integrated restoration and monitoring program seeks to determine long-term trends and to characterize and reduce threats to water quality and critical habitats in the Tomales Bay Watershed, as well as to assess the impacts of the Giacomini Wetlands Restoration Project (GWRP) on water quality. Based on the information gathered through this monitoring program, the Council will work to identify water quality problems, to develop solutions to these problems, and to provide support to realize these solutions by working with partners and landowners in the watershed to improve and protect water quality.

It is the desire of the Council to provide needed water quality information that will assist individuals, organizations and agencies that are responsible for and/or advocating for water quality protection and improvement within the Tomales Bay watershed. The information collected through this program will ultimately be used to increase our collective understanding about the benefits of specific efforts to improve water quality, and our ability to effectively and adaptively manage human impacts on water quality. All water quality data funded by this grant is public and will be disseminated through reports to the funders and to the public, and by request. Private property rights will be recognized, statutory responsibilities will be
maintained, and voluntary cooperation will be encouraged and protected with data sensitivity considerations.

A complete program description, and more detailed information about methods can be found in the project Monitoring Plan and Quality-Assurance Project Plan (Carson, 2007). These documents and other program reports are available on our website at: http://www.tomalesbaywatershed.org/waterquality.html.

Program Objectives
The Monitoring Plan provides direction for a water quality monitoring program with an initial 3-year timeframe. Restoration of funding and changes to funding contracts will allow the continuation of this program, in some form, through September 2012. It is envisioned, however, that monitoring of long-term water quality trends in the watershed will continue indefinitely, if funding allows.

Water Quality Monitoring Project (WQMP) Objectives:
- Provide the watershed community with the required data and analysis to determine improving, constant, or declining trends in Bay and tributary water quality;
- Form and maintain a clearinghouse of water quality data and monitoring activities that facilitates effective and efficient use of limited resources;
- Serve as source of information that will inform and promote actions to improve water quality; and
- Provide an understanding of source areas and categories for constituents of concern both in the Bay and on a sub-watershed and/or tributary scale.

Giacomini Wetland Restoration Project (GWRP) Water Quality Monitoring Objectives:
These objectives address the water quality monitoring of the GWRP. For a complete assessment of all long-term monitoring objectives of the GWRP, see complete project literature, including Parsons (2005).

- Provide strategic water quality monitoring before, during, and after a phased restoration effort to determine the short- and long-term effects of restoration on water quality within the Project Area and on the amount of contaminants delivered to Tomales Bay.
- Compare water quality conditions in the Project Area before, during, and after restoration to those of natural undiked tidal marshes in the Tomales Bay and adjacent watersheds to determine the degree of divergence prior to restoration and how well over time conditions in the restored Project Area move toward those of natural marshes after restoration.
Questions to be addressed by this monitoring program:

A. Questions to be addressed by the TBWC monitoring program:

- What are the natural ranges and the storm, seasonal and annual variability in water quality parameters in the Bay and its tributaries?
- At what locations do parameters fall outside the natural range and to what duration and extent?
- What are the pollutant loadings from controllable and uncontrollable sources and in the watershed, and how do the Bay and tributaries relate in this regard?
- What are the trends in the levels, fate and transport of pollutants in the watershed and the Bay, and how do the Bay and tributaries relate in these regards?
- How effective are actions to reduce pollutant loads?

B. Questions to be addressed by GWRP water quality monitoring:

- What is the response to restoration activities with respect to nutrients, pathogen indicators and carbon/productivity indicators?
- Over time, do conditions within the restored Project Area improve relative to pre-restoration conditions, and do they begin to move closer toward those in natural undiked tidal marshes in the Tomales Bay and adjacent watersheds?
- Does restoration of the Giacomini wetlands appear to have an effect on the quality of water delivered downstream to undiked natural marshes and Tomales Bay?

Program Summary

Project Milestones

Important milestones for this project:
May 2007 – Prop. 50 Grant Contract finalized with the TBWCF
September, 2007 – Contractor was hired by TBWC to prepare program documentation, and implement monitoring.
October 2007 – Completed and received approval from SWRB for project documentation, including project Monitoring Plan (Carson, 2007), and project Quality Assurance Project Plan (Carson, 2007)
November, 2007 – Received approval to begin sampling
December, 2007 – Began monitoring for long-term Trends Program, and two source-area sub-watersheds.
December 2008 – Project funding was suspended during the state fiscal crisis. Sampling at long-term Trends sites continued during the funding suspension.
June 2009 – Project funding was restored through the SWRCB State Revolving Fund (SRF). Funding restoration was retroactive to December 18, 2008.
Long-Term Trend Monitoring

Trend monitoring will generate water quality data of sufficient duration and representation to assess long-term shifts in water quality within Tomales Bay and its tributaries. There are numerous stakeholder efforts to manage sources of pollution for which feedback is needed to assess impacts and the effectiveness of restoration efforts. There are also regulatory and statutory needs for long-term trend water quality monitoring. This component of the monitoring program will give the watershed community the needed benchmarks to determine the success of management efforts and efficacy of regulatory policies.

Parameters

The water quality parameters collected as part of the long-term Trends monitoring include core field parameters: temperature, conductivity/salinity, dissolved oxygen (DO) and pH; and lab parameters related to the 303d-list Clean Water Act impairments in the watershed: fecal indicator bacteria (total coliforms (TC), fecal coliforms (FC)); nutrient parameters: nitrate (NO₃), ammonia (NH₃), organic nitrogen, total phosphorus; and one sediment parameter: turbidity. Water quality parameters collected for the Source Area program include the core field parameters listed above in addition to parameters of interest for target sub-watersheds. These additional parameters may include metals, oil and grease, and/or (Volatile Organic Compounds (VOC’s). Fecal indicator bacteria for the Source Area program will be measured through total coliform and E.coli MPN/100mL using defined substrate methods. Nutrient and sediment parameters will be the same as the Trends program.

In addition to these water quality parameters or “response variables”, descriptive or “explanatory variables” were collected. These include tidal stage, discharge, cumulative precipitation, and others. Because discharge measurements are often time consuming, and are problematic during both high- and low-flow conditions, use of existing stream-gauging stations, rating curves, installation of staff plates and estimates of flow are used where appropriate. Analytical methods will follow accepted procedures such as those outlined in the Standard Methods for the Examination of Water and Wastewater (Eaton et al., 2005) as outlined in the program QAPP.

A description of target parameters, and their significance for water quality and ecosystem health is offered with the results from Trends monitoring.

Sampling Frequency and Duration

Trend sampling is conducted on a weekly basis during the rainy season (late Fall, Winter and early Spring), and twice monthly during summer base flow conditions. During the first year (2007-08) of monitoring, weekly monitoring began on December 17, 2007 and continued through April 8, 2008. Twice monthly monitoring was conducted from April 22, 2008 through the end of the water year (Sept. 30, 2008). For the second water year (2008-09), twice-monthly sampling continued from October 1, 2008 through October 28, 2008. Wet-season, weekly sampling began on November 4, 2008 and continued through March 31, 2009. Twice-monthly, dry season sampling resumed on April 7, 2009 and continued through the end of the water year (September 30, 2009). During WY10, twice-monthly dry season sampling continued through October 6, 2009. Weekly sampling began on October 13th, 2009 and continued through May 18th, 2010. Twice-monthly sampling resumed on June 1, 2010 and continued through the end of the water year (September 30, 2010). For the current reporting year (WY11), weekly sampling began on October 19th, 2010 and continued through April 19th, 2011.
Weekly sampling more accurately captures changing conditions during the storm season and allows for a moving 5-week geometric mean for bacteria to be maintained. Dry season conditions have much less variation, and sampling every two weeks provides adequate data for analysis.

**Sampling Locations**
Trend sampling was conducted at 11 tributary sites in the watershed, and 4 Bay sites along the longitudinal transect of Tomales Bay. A list of Trends program sampling locations, along with location information (description, latitude/longitude, etc) is available in appendix B. Tributary sites are located at the lower end of tributary watersheds, often just upstream of their discharge to Tomales Bay, or to dependent streams.

Due to logistical limitations of partners sampling in the Bay, data collection for inner-, mid- and outer-Bay sites was limited to once-per-month sampling on the first Tuesday of each month (this sampling is concurrent with California DPH Shellfish Program sampling), typically only when the Bay is open to shellfish harvesting. Many sites were selected due to their inclusion in previous monitoring efforts through the RWQCB pathogen TMDL, and NPS water quality program.

The existence of this legacy data, and its incorporation into our water quality database, will enable longer-term inference of water quality trends than could be accomplished by the data generated by this program alone.

**Figure 3 – TBWC Trends Program Water Quality Monitoring Sites**
Project Data Summary

The following sections offer detailed summary of watershed data from this program for the 2008-2011 water years. Sections includes rainfall and discharge (stream-flow) record and Trends Project results (site visits, summary statistics for field, nutrient, sediment and bacteria measurements)

Available Sources of Rainfall and Discharge Monitoring in the Watershed

There are numerous rain gauges in the watershed, including a network maintained by MMWD, several gauges maintained by Marin County, and several by the National Park Service. There is a general orthographic trend of decreasing rainfall totals from South to North, and from West to East. For the sake of consistency, the rain gauge maintained by the NPS in the Olema Valley at the Point Reyes National Seashore headquarters is used in this report. Data from this station is available online at:

http://raws.wrh.noaa.gov/cgi-bin/roman/meso_base.cgi?stn=OVYC1&time=GMT

Discharge is monitored in the watershed by the US Geological Survey (USGS) at two sites on Lagunitas Creek (11460400 at Samuel P. Taylor State Park and 11460600 near Point Reyes Station), and one site on Walker Creek (11460750 at Walker Creek Ranch near Marshall). Data from these gauges are available in real-time at:

http://waterdata.usgs.gov/ca/nwis/rt. In addition, MMWD maintains a streamgauge on San Geronimo Creek (http://www.balancehydrologics.com/geronimo/creek/index.php), and the National Park Service maintains a streamgauge on Olema Creek (data not available online). Approximately 25% of the Lagunitas Creek watershed area, 60% of the Walker Creek watershed area, and all of the coastal drainages on the east and west shores of Tomales Bay are ungauged (Fischer et al. 1996)

Rainfall and Discharge Record

The rainfall during water-years 2008, 2009, 2010 and 2011 (measured at the NPS weather station at the Olema Valley headquarters) was 31.55 inches, 31.74 inches, 47.52 inches and 53.75 inches respectively. The cumulative rainfall for the first two reporting years were both lower than the 30-year average of 37.5 inches (NPS, unpublished data), although this 30-year average conceals the significant variance in average annual rainfall which ranges from about 17 inches in 1976-77 to about 82 inches in 1982-83. The cumulative rainfall for WY10 exceeded the 30-year average by almost 27-percent and rainfall for WY11 exceeded the average by 43%.
Stream-flow from the first four years of the program is summarized in the following figures. The mean daily discharge record from the USGS stream gauge station (11460600 - Lagunitas Creek near Point Reyes Station) is used to represent the hydrograph for each water year. Two other USGS stream gauge stations are maintained in the watershed (station 114060400 on Lagunitas Creek at Samuel P. Taylor State Park and station 11460750 on Walker Creek), and data from these stations is used to report instantaneous discharge at Trends stations LAGSPT and WKR2 respectively. In addition, the Marin Municipal Water District (MMWD) operates a stream gauge on San Geronimo Creek that is located at a TBWC Trend station (Data from this gauge is used to report instantaneous discharge at our station SG1).

As can be seen by the magnitude of the discharge from water-year 2009, dry conditions prevailed and likely influenced the results of water quality monitoring. The rainfall from water-years 2010 and 2011 illustrates significantly more rainfall than the first two years of monitoring. These conditions resulted in an increased number of storm-related samples for these two water years, and the consequences are reflected in the frequency and magnitude of elevated levels of sediment and bacteria in particular. These results are detailed in the following section.
Sampling at Trends Program sites began in December 2007 and continues through the reporting period. As described in the previous section, each site is visited weekly during the wet season, and twice monthly during base-flow conditions (sampling frequency is reduced when regular, significant rains are over for the year). Frequency is increased again with the arrival of a significant rain event in October or November which causes a significant response in streamflow or runoff conditions. The following section describes the results of Trends Program sampling during the 2011 water year (October 1, 2010-September 30, 2011). There is a short description of each sampled sub-watershed then results of field, nutrient, sediment and bacteria analysis. The results include descriptive statistics for each site and parameter for the WY11 season, as well as sampling results with box-plots by water year (WY08-WY11), and time-series graphs for most parameters.

A summary of sites, the period of record for the current water year, and the number of samples per site are shown in Table 1 below. Tables for the site visits during the 2008-2010 water years are available in the appendix C.
### Table 1 – Site Visits for 2011 Water Year

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Site Type</th>
<th>Description</th>
<th>Period of Record</th>
<th>Number of Sampling Visits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagunitas Creek</td>
<td>Tributary Site</td>
<td>San Geronimo Creek at Lagunitas Rd</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>LAGSPT</td>
<td>Mainstem Stream Site</td>
<td>Lagunitas Creek in SPT State Park (at USGS streamgage)</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>OLMI1</td>
<td>Tributary Site</td>
<td>Olema Creek at NPS streamgage</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>LAG1</td>
<td>Mainstem Stream Site</td>
<td>Lagunitas Creek at Hwy. 1 (Green Bridge)</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>West Shore</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FV1</td>
<td>Mainstem Stream Site</td>
<td>First Valley Creek at 500 Blvd.</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>WG1</td>
<td>Mainstem Stream Site</td>
<td>White Gulch upstream of Bay Inflow</td>
<td>10/5-10/9/20/11</td>
<td>34</td>
</tr>
<tr>
<td>East Shore</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC1</td>
<td>Mainstem Stream Site</td>
<td>Millerton Gulch at upstream CA State Park boundary</td>
<td>11/9-10/8/15/11</td>
<td>32</td>
</tr>
<tr>
<td>MP36.17</td>
<td>Mainstem Stream Site</td>
<td>Reference stream at Hwy. 1</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>Walker Creek</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WKR2</td>
<td>Mainstem Stream Site</td>
<td>Walker Creek at Walker Creek Ranch</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>WKR1</td>
<td>Mainstem Stream Site</td>
<td>Walker Creek at Hwy. 1</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>KYS1</td>
<td>Tributary Site</td>
<td>Keys Creek at Hwy. 1</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
<tr>
<td>Tomales Bay Sites</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TB2</td>
<td>Outer Bay Site</td>
<td>Bay Site near Walker Crk Input</td>
<td>10/5-10/9/6/11</td>
<td>10</td>
</tr>
<tr>
<td>TB4</td>
<td>Mid-Bay Site</td>
<td>Bay Site North of Marshall</td>
<td>10/5-10/9/6/11</td>
<td>10</td>
</tr>
<tr>
<td>TB11</td>
<td>Inner Bay Site</td>
<td>Bay Site near Millerton Point</td>
<td>10/5-10/9/6/11</td>
<td>6</td>
</tr>
<tr>
<td>LAG6</td>
<td>Wetlands/Bay Interface</td>
<td>Lagunitas Creek downstream of levees</td>
<td>10/5-10/9/20/11</td>
<td>38</td>
</tr>
</tbody>
</table>

### Detailed trends results by sub-watershed

A basic statistical analysis of Trends Program data through WY11 was undertaken and the following section shows results from the year-to-year comparison by site. The analysis is presented for each type of measurement (i.e. field measurements, nutrient, bacteria and sediment) for each major sub-watershed to Tomales Bay. In the Watershed Description (above), Figure 1 shows the delineation of monitored subwatersheds for this program.

### Field Parameters Results for Trends Program WY08-WY11

Field measurements made by this program are standard water quality parameters recommended for monitoring by both the US Environmental Protection Agency (EPA) and the US Geological Survey (USGS). These parameters are crucial not only to describe in-situ environmental conditions, but also to determine chemical characteristics of laboratory-analyzed parameters. Measurements were made using calibrated single-, or multi-parameter meters. This program uses a YSI85 to measure temperature, conductivity, and dissolved oxygen; and an Oakton or YSI meter for pH measurements. All equipment calibrations are conducted and logged according to the protocol established by our monitoring plan and QAPP (Carson 2007).

**Temperature** – specifically water temperature- is critical for the reproduction and survival of cold-water fish, amphibian and benthic invertebrate species that are present in the watershed. The thermal tolerance ranges for coho salmon are 12-19 degrees centigrade, while steelhead trout can tolerate warmer temperatures ranging from 13-21 degrees centigrade. Ideal temperatures for rearing juvenile coho salmon range from 10-15.6-degrees C (Armour, 1991). Temperature also has important implications for dissolved oxygen levels in the water, with lower temperatures able to store more oxygen for use by aquatic organisms. Temperature also plays a
role in both pH and the level of toxic un-ionized ammonia. Higher temperatures and higher pH values result in higher amounts of the toxic ammonia.

**Conductivity** – is the measurement of the ability of ions in an aqueous solution to carry electrical current due to the levels of dissolved salts. It is essentially an estimate of dissolved ionic “pollution” in a sample. Results are reported in microSiemens per centimeter (uS/cm). Specific Conductance is defined as the conductivity normalized to 25-degrees centigrade. This value is the standard reporting value because it can be compared across samples without knowing the water temperature. This value is also used to calculate and report a value for salinity. Elevated conductivity is indicative of a significant salt source and, because of osmotic processes, has implications for aquatic organisms’ ability to regulate water concentrations in their bodies. Conductivity in our watershed streams is affected primarily by the geology of the area through which the water flows, depending on whether the substrate does or does not ionize (dissolve into ionic components) when washed into the water.

**Dissolved Oxygen** – is a measure of the oxygen available in the water for aquatic organisms, and is reported as a concentration (mg/L) or as a percent saturation (%). The oxygen levels are highly dependent on water temperature with warmer water able to hold less oxygen than colder water. Another factor that affects the level of oxygen in water is the turbulence of flow, with riffles and falls increasing the atmospheric oxygen introduced into the water column. The RWQCB’s Basin Plan (RWQCB 2007) established water quality objectives for warm and cold water habitat at 5.0mg/L and 7.0 mg/L, respectively.

**pH** – is a measure of the acidity or basicity of a solution. It is a proxy measure for the activity of hydrogen (H\(^+\)) ions in the solution, and is measured relative to standard solutions of known pH. The pH of water bodies has significant implications for natural chemical processes. For example, under low pH conditions, toxic elements such as aluminum are more easily leached into the water from surrounding soils. pH also plays an important role in ammonia chemistry, with higher pH values leading to the conversion of ammonium (NH\(_4^+\)) to more toxic un-ionized ammonia (NH\(_3\)). The RWQCB’s Basin Plan (RWQCB 2007) established water quality objectives for pH as less than 8.5 and greater than 6.5.

**Trend Program Field Parameter Results WY08-WY11**

The following table shows results for field parameter measurements taken during the 2011 water year. The minimum, maximum and mean values for each field measurement (water temperature, specific conductance, salinity, dissolved oxygen and pH) are shown for each station. Summary tables for WY08, WY09 and WY10 are available in Appendix C.
Results show that water temperature exceeded ideal conditions for coho and steelhead during the year at several stations, including several sites in the Lagunitas watershed, and one in the Walker Creek watershed. But, because field measurements of temperature do not represent the diurnal or seasonal range of conditions at the sites, these measurements are inadequate to evaluate the environmental conditions for salmonids. We have placed temperature loggers (Onset – HOBO® Water Temp Pro v2) at seven of the Trend Program sites (SG1, LAGSPT, OLM11, LAG1, FV1 and WKR2) to evaluate the long-term temperature cycles at sampling locations. Data from these temperature loggers will be included in the final technical report for this project.

Salinity results show the annual range of salinities at each site. Some sites (WG1, MC1, KYS1) are on intermittent streams whose salinity increases as the freshwater inflow slows or stops. Other sites (WKR1, LAG1, LAG6, and WG1) are under some degree of tidal influence, reflected in the wider range of measured values.

Mean measurements of dissolved oxygen for all sites do not fall below the objective of 7 mg/L. However, minimum measurements at WG1, MC1, KYS1 are reflective of low oxygen conditions in low-, to no-flow conditions in summer. Of note, were low dissolved oxygen measurements in San Geronimo, Lagunitas and Walker Creeks that fell below the objective of 7 mg/L. All were taken during summer low-flow conditions, and represent conditions at the sampling point, not necessarily in refuge habitat such as shaded pools or undercut banks that may be utilized by salmonids during periods of stress.

Measurements of pH show that all measurements were below the upper limit of 8.5 established by the RWQCB in the Basin Plan (2007). However, some measurements fell below the lower limit of 6.5 at times during the year. The mean pH values for all sites
were well within the objective range throughout this water year. The graphs below show (boxplots) of field parameters for each site, each water year, by subwatershed grouping (Walker, Lagunitas, Coastal tributaries and Bay sites). A boxplot displays information about the range and distribution of data within the range (see figure at right). For the graphs in this report, the whiskers extending above and below the box are 1.5-times the middle 50% range box, with outliers shown by the asterisks (*). This treatment, which is a common variation on traditional boxplots whose whiskers extend to the minimum and maximum values, allows for the identification of outliers and extreme outliers that demonstrate the distribution and frequency of such results. To present the data in the most useful form, outliers are omitted from the box-plot graphs below, but are included in graphs in Appendix D of this document.

Figure 9 – Lagunitas Creek Watershed Field Parameters by Water Year
Figure 10 – East & West Shore Tributaries Field Parameters by Water Year

Figure 11 – Walker Creek Watershed Field Parameters by Water Year
The field parameters other than water temperature and salinity are not measured regularly in the outer, middle and inner Bay sites, so these sites cannot be evaluated for their achievement of pH or dissolved oxygen water quality objectives.

**Nutrient Parameters Results for Trends Program WY08-WY11**

Nutrient parameters measured by this program focus on nitrogen and phosphorus as one of these two is usually the limiting factor for primary production in aquatic systems. With the exception of ammonia, there are no criteria established by State regulators for nutrient levels in streams, but the EPA has recommended criteria for nutrient levels in regional rivers and streams that is included with the appropriate parameters below.

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. Natural 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 chemical fertilizers, 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. Nitrate is very soluble and is flushed out of soils relatively easily. 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 (NO$_3$)** – is the most common form of nitrogen found in surface waters. It is essential to biotic production. Depending on the system, either nitrogen or phosphorus is the nutrient limiting primary productivity. When there is an excess of nitrogen is present, increased production of algae or other aquatic plants may result. Where algal blooms occur, the productivity leads to super-saturated levels of dissolved oxygen, as the algae die, their decomposition consumes most of the oxygen in the system, leading to fish kills. Nitrate is very responsive to storm events, being mobilized by runoff from sinks such as fertilized areas, ponds or lagoons and being delivered to surface waters by overland or shallow sub-surface flow. The State of California has no established numeric water quality criteria for nitrate in surface waters, but the US EPA has established a numeric criterion only for human consumption of nitrate at 10mg/L, and a recommended total nitrogen criteria for aggregate ecoregion III of 0.38 mg/L (EPA 2000). Because nitrogen pollution is a problem of accumulation in the ecosystem rather than direct toxicity to particular organisms, there has been little guidance developed for acceptable levels in local streams. Results from nitrate analysis are reported as mg/L of Nitrogen, enabling the comparison of nitrogen levels across chemical forms of nitrate, nitrite, TKN and ammonia.

**Ammonia (NH$_3$)** – is another important natural form of nitrogen. 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$_3$) in well-oxygenated waters with neutral pH. The consequence of this is that its detection usually suggests a proximate source such as livestock and wildlife. Most ammonia in aquatic systems occurs in its’ ionized (or charged) form of NH$_4^+$, but temperature and pH conditions control the conversion to the more toxic un-ionized form of NH$_3$. For example, at 15°C and pH 7.0 only 0.3% of total ammonia is un-ionized, while at pH 9.0, the un-ionized ammonia is 21% of the total. High levels of un-ionized ammonia is directly toxic to aquatic organisms, and, as it is converted to nitrate, it consumes dissolved oxygen in the water, adversely affecting aquatic life. The RWQCB’s Basin Plan (RWQCB 2007) sets a criteria for un-ionized ammonia in surface waters as an annual median <0.025 mg/L as N, and <0.16 mg/L as N in estuarine waters. Results from ammonia analysis are reported as mg/L of nitrogen, enabling the comparison of nitrogen levels across chemical forms of nitrate, nitrite, TKN and ammonia. Because had a very low number of detections of ammonia, and our contract laboratory was unable to provide more sensitive analysis, the program dropped analysis of ammonia during WY11.

**Total Kjeldahl Nitrogen (TKN)** – is the sum of organic nitrogen and ammonia in the sample. By adding TKN and nitrate/nitrite results, the total nitrogen can be calculated. This program does not measure nitrite levels, but because nitrite is quickly oxidized to nitrate in the environment, total nitrogen calculation can be estimated using program data. 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. There are no numeric water quality criteria established for TKN in surface waters, though the EPA recommended criteria for total nitrogen in rivers and streams of aggregate ecoregion III is 0.38 mg/L. Results from TKN analysis are reported as mg/L of N, enabling the comparison of nitrogen levels across chemical forms of nitrate, nitrite, TKN and ammonia.

**Total Phosphorus (TP)** – is a measure of the total phosphorus (P). Phosphorus is an essential element for primary productivity, and, like nitrogen, can be the limiting element in the environment (i.e. the availability of phosphorus governs the rate of growth of many organisms). Because there is no gaseous form of phosphorus, once it is in an aquatic system without a large outflow, it tends to cycle back and forth between the water column and the sediments without leaving the system (Horne and Goldman, 1994). The EPA recommends a total P criteria for Aggregate Ecoregion III streams and rivers of 0.02 mg-P/L (EPA 2000), with a range of reference conditions from 0.01-0.05 mg-P/L (EPA, 2000). Our monitoring of phosphorus in the watershed shows that levels are very low in watershed streams (most below our laboratories detection limit), suggesting that phosphorus is the limiting nutrient in this system. Because we were unable to get a lower detection limit for total phosphorus from our contract laboratory, the analysis was dropped during WY10.

**Table 3 – WY11 Nutrient Parameter Results for Trends Monitoring by Station**

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Nitrates as N (mg/L)</th>
<th>Total Kjeldahl Nitrogen (mg/L)</th>
<th>Ammonia as N (mg/L)**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># of detections</td>
<td># of non-detects</td>
<td>Min.</td>
</tr>
<tr>
<td>Lagunitas Creek</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG1</td>
<td>38</td>
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<tr>
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<td>23</td>
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</tr>
<tr>
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<td>5</td>
<td>&lt;0.11</td>
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<tr>
<td>LAG1</td>
<td>23</td>
<td>15</td>
<td>&lt;0.11</td>
</tr>
<tr>
<td>West Shore</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV1</td>
<td>23</td>
<td>10</td>
<td>&lt;0.11</td>
</tr>
<tr>
<td>WG1</td>
<td>3</td>
<td>31</td>
<td>&lt;0.11</td>
</tr>
<tr>
<td>East Shore</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC1</td>
<td>18</td>
<td>14</td>
<td>&lt;0.11</td>
</tr>
<tr>
<td>MP36.17</td>
<td>6</td>
<td>32</td>
<td>&lt;0.11</td>
</tr>
<tr>
<td>Walker Creek</td>
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<td></td>
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<td>&lt;0.11</td>
</tr>
<tr>
<td>WKR1</td>
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</tr>
<tr>
<td>KYS1</td>
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<td>&lt;0.11</td>
</tr>
<tr>
<td>Tomales Bay Sites</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TB2</td>
<td>2</td>
<td>8</td>
<td>&lt;0.11</td>
</tr>
<tr>
<td>TB4</td>
<td>1</td>
<td>8</td>
<td>&lt;0.11</td>
</tr>
<tr>
<td>TB11</td>
<td>0</td>
<td>6</td>
<td>&lt;0.11</td>
</tr>
<tr>
<td>LAG5</td>
<td>15</td>
<td>20</td>
<td>&lt;0.11</td>
</tr>
</tbody>
</table>

† Censored data (<QL: *non-detects) handled by Kaplan Meier Method which cannot estimate a mean if more than 50% of data is censored.

**Ammonia levels were analyzed during one event in WY11 before the program dropped the analysis due to >90% non-detects (WY08-WY10).**

The following graphs (boxplots) show the results of nutrient monitoring (nitrate, total Kjeldahl nitrogen) at Trends Program sites by site for each subwatershed grouping. A boxplot displays information about the range and distribution of data within the range.
(see figure at right). For the graphs in this report, the whiskers extending above and below the box are 1.5-times the middle 50% range box, with outliers shown by the asterisks (*). This treatment, which is a common variation on traditional boxplots whose whiskers extend to the minimum and maximum values, allows for the identification of outliers and extreme outliers that demonstrate the distribution and frequency of such results. To present the data in the most useful form, outliers are omitted from the box-plot graphs below, but are included in graphs in Appendix D of this document.

**Figure 13 – Lagunitas Creek Watershed Nutrient Parameters by Water Year**

![Lagunitas Creek Watershed Nutrient Results WY08-WY11](image)
Figure 14 – Lagunitas Creek Watershed Nitrate (NO₃) Time Series WY08-WY11

Figure 15 – Lagunitas Creek Watershed TKN Time Series WY08-WY11
Nutrient results from sites in the Lagunitas Creek watershed demonstrate that the watershed as a whole, and one site in particular, shows elevated nutrient levels, mainly nitrogen, especially during storm events. The box-plots and time-series graphs of nitrate (NO₃ as N) shows that the site in San Geronimo Creek (SG1) has the highest mean, widest range, and highest frequency of elevated values for nitrate in the Lagunitas Creek watershed. This suggests a persistent loading source of nitrate in the San Geronimo Creek watershed. Potential sources include the well-documented presence of compromised septic systems (TBWC 2007, Fall Creek Engineering 2007) and chemical fertilizer runoff from home gardens or the golf course. The results total Kjeldahl nitrogen (TKN) analysis shows relatively low levels, with significant elevation of concentration during storm events. Peak loading events from all sites in the watershed are of similar magnitude, with little signal of dilution occurring from upstream to downstream. These results suggest that there is loading of organic nitrogen (the main component of TKN) throughout the watershed, mainly during major storm events. Organic nitrogen is frequently associated with sediment particles in the water column. This suggests that the hydrologic response of our watershed tributaries and associated runoff mobilizes sediment and nutrients during winter storm events, and that this response can be seen in nitrogen loading throughout the Lagunitas Creek watershed.

Figure 16 – East & West Shore Tributaries Nutrient Parameters by Water Year

![East & West Shore Tributaries Nutrient Results WY08-WY11](image)

**Figure 16 notes:** These graphs do not include outlier results at the upper extreme. See Appendix D for matching graphs that do include outlier results.
Figure 17 – East & West Shore Tributary Nitrate (NO₃) Time Series WY08-WY11

Figure 18 – East & West Shore Tributaries TKN Time Series WY08-WY11

Figure 18 Note: Omitted values from: MC1 10/20/09 39.0 mg/L & WG1 3/24/09 of 15.0 mg/L; See Appendix D for timeseries plot of TKN including omitted extreme values.
Nutrient results from east and west-shore tributaries suggest persistent loading sources in several coastal creeks, with occasional, but severe, spikes during storm events. The magnitude of occasional spikes of nutrient parameters, particularly those from Millerton Gulch (MC1), suggests serious nutrient sources are connected to the larger watershed during periodic events, and that the local water quality conditions in some coastal streams has a direct negative impact on aquatic life in these areas (Peak result from MC1 in WY09 of more than 10 mg/L ammonia (NH₃ as N) represents toxic conditions for local aquatic species). It should be noted that discharge, or flow rates, are much lower in the east and west-shore coastal tributaries than those of most sites in the larger Lagunitas and Walker Creek watersheds, resulting in lower loading rates to Tomales Bay even during severe runoff events. Like most streams in the watershed, elevated levels of both nitrate and TKN are associated with storm-related runoff events. Results of TKN analysis show that some sites have severe spikes (MC1 = 39 mg/L and WG1 = 15.0 mg/L) which demonstrate significant episodic loading of organic nitrogen and/or ammonia.

**Figure 19 – Walker Creek Watershed Nutrient Parameters by Water Year**
Figure 20 – Walker Creek Watershed Nitrate (NO₃) Time Series WY08-WY11

Figure 21 – Walker Creek Watershed TKN Time Series WY08-WY11
Results of nutrient analysis of sites in the Walker Creek watershed suggest that the watershed is a source of significant nutrient input, particularly during storm events. Peak input levels for nitrate and TKN are similar to sites in other sub-watersheds in the area, although concentrations during peak events tended to be higher at the Keys Creek (KYS1) and upper Walker Creek site (WKR2), with lower levels at the lower Walker Creek site, indicating some dilution from the lower watershed, or from tidal influx. Again, as noted for other sub-watersheds, the peak nutrient concentrations were associated with storm events. The highest levels of both nitrate (NO₃ as N) and TKN were observed at the site near the bottom of the Keys Creek watershed. It should be noted that discharge, or flow rates, from Keys Creek are much lower than those of most sites in the larger Lagunitas and mainstem Walker Creek watersheds, resulting in lower loading rates to Tomales Bay even during severe runoff events.

**Figure 22 – Tomales Bay Sites Nutrient Parameters by Water Year**
Figure 23 – Tomales Bay Sites Nitrate (NO₃) Time Series WY08-WY11

Figure 24 – Tomales Bay Sites TKN Time Series WY08-WY11
Analysis of nutrient results from sites along the length of Tomales Bay suggests that inner-Bay sites (LAG6 and TB11) are more strongly affected by nutrient inputs from tributary sites in the area. Results from the mid- and outer-Bay sites (TB4 and TB2 respectively) show very low levels of both nitrate and TKN during the sampling period. It should be noted again that samples from Bay sites were not taken during storm events in WY09, WY10 or WY11, making a true assessment of storm-related conditions at Bay sites impossible. The elevated levels seen in the time-series graphs of nitrate during late 2008-May 2009 is an artifact of a higher reporting limit due to site salinity from a different contract lab during this period, it does not necessarily reflect actual nutrient levels. It should be noted that LAG6 site is in Lagunitas Creek, upstream of Tomales Bay itself, and it thus more directly influenced by conditions in the Lagunitas Creek watershed than those in the Bay. The inner-Bay site (TB11) is near Millerton Point, and is heavily influenced by input from Millerton Gulch, which has demonstrated episodically high levels of nutrient input during storm events.

**Results of Sediment Trends Monitoring for WY08-WY11**

Elevated levels of sediment, measured through turbidity or total suspended solids can have detrimental effects on aquatic organisms indirectly through increased difficulty locating food, and directly by clogging organisms’ gills, or by smothering developing eggs in the stream substrate. In coastal streams, high levels of sediment are common in winter during high water flow. This is a natural result of the dry climate and low-frequency, high intensity storms. The dry climate leaves large areas of the watershed covered only by dry grass that provides little protection from erosion. The interpretation of high sediment levels as pollution, or as a natural event depends largely on the circumstances. Conventional pollution, such as some nutrients and metals are often attached to sediment particles that are mobilized during runoff. So, high sediment levels often mean increased levels of these other conventional pollutants.

Lagunitas and Walker Creeks, as well as Tomales Bay are listed as impaired by sediment. The Trends program monitored levels of turbidity as well as total suspended solids (TSS) during the first year of monitoring. Total suspended solids is a time-consuming and expensive test, and it was determined that the more general measurement of turbidity was sufficient to document the relative level of sediment pollution in this watershed, with occasional TSS samples collected during storm events to build on correlations with existing data.

The RWQCB has begun the process of planning for the sediment TMDL for impairments in this watershed, and data generated by this program as well as results we have compiled from other studies should help inform the TMDL development process.

**Turbidity** – is a measure of the clarity of a water sample. It is a proxy for the amount of suspended solids in a water sample and is determined by measuring the light transmission or visibility through a disturbed sample. Turbidity is reported in nephelometric turbidity units (NTU). A correlation between turbidity and total suspended solids (TSS) can be developed for a stream, making quantification of
sediment pollution easier. RWQCB’s Basin Plan (RWQCB 2007) does not establish numeric criteria for turbidity, but states the following: “Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses”. The EPA guidance to states on numeric water quality objectives provides recommended turbidity criteria for aggregate ecoregion III rivers and streams of 2.34 NTU.

**Total Suspended Solids (TSS)** – is a measure of the total weight of solids suspended in a water sample. A water sample is filtered, and the dry weight of the filtrand (or residue on the filter) is totaled to determine TSS in mg/L. Both turbidity and TSS are measures of the sediment or other suspended materials in surface water. Elevated sediment levels can impact aquatic life in two ways: Extremely high levels can clog fish gills, or cover gravel spawning beds, suffocating both fish and eggs; Long-lasting turbidity can affect the ability of aquatic organisms to feed. The RWQCB’s Basin Plan (RWQCB 2007) does not establish numeric criteria for TSS, but states the following: “The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.”

**Table 4 – WY11 Sediment Parameter Results for Trends Monitoring by Station**

<table>
<thead>
<tr>
<th>Site Name</th>
<th>WY11 Sediment Lab Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># of detections</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Lagunitas Creek</td>
<td></td>
</tr>
<tr>
<td>SG1</td>
<td>38</td>
</tr>
<tr>
<td>LAGSPT</td>
<td>37</td>
</tr>
<tr>
<td>OLM11</td>
<td>38</td>
</tr>
<tr>
<td>LAG1</td>
<td>38</td>
</tr>
<tr>
<td>West Shore</td>
<td></td>
</tr>
<tr>
<td>FV1</td>
<td>38</td>
</tr>
<tr>
<td>WG1</td>
<td>34</td>
</tr>
<tr>
<td>East Shore</td>
<td></td>
</tr>
<tr>
<td>MC1</td>
<td>32</td>
</tr>
<tr>
<td>MP36.17</td>
<td>38</td>
</tr>
<tr>
<td>Walker Creek</td>
<td></td>
</tr>
<tr>
<td>WKR2</td>
<td>38</td>
</tr>
<tr>
<td>WKR1</td>
<td>38</td>
</tr>
<tr>
<td>KYS1</td>
<td>35</td>
</tr>
<tr>
<td>Tomales Bay Sites</td>
<td></td>
</tr>
<tr>
<td>TB2</td>
<td>10</td>
</tr>
<tr>
<td>TB4</td>
<td>9</td>
</tr>
<tr>
<td>TB11</td>
<td>6</td>
</tr>
<tr>
<td>LAG5</td>
<td>36</td>
</tr>
</tbody>
</table>
The following graphs show (boxplots) of the results of sediment monitoring (Turbidity) at Trends Program sites by site for each subwatershed grouping. A boxplot displays information about the range and distribution of data within the range (see figure at right). For the graphs in this report, the whiskers extending above and below the box are 1.5-times the middle 50% range box, with outliers shown by the asterisks (*). This treatment, which is a common variation on traditional boxplots whose whiskers extend to the minimum and maximum values, allows for the identification of outliers and extreme outliers that demonstrate the distribution and frequency of such results. To present the data in the most useful form, outliers are omitted from the box-plot graphs below, but are included in graphs in Appendix D of this document.

Figure 25– Lagunitas Creek Watershed Turbidity by Water Year
Analysis of turbidity results from the Lagunitas Creek watershed shows that most sites in the watershed show very high levels of sediment during storm events. Turbidity levels do appear to decline between the upper Lagunitas sites (SG1 and LAGSPT) and the lower Lagunitas Creek sites (LAG1 and LAG6) suggesting that some dilution or settling does occur in the lower watershed. Levels of sediment loading are heavily influenced by storm events, as can be seen by the increased frequency of elevated results during the 2010 and 2011 water years which had much more frequent storm events, and so, more storm samples represented in the dataset.
Figure 27 – East & West Shore Tributaries Turbidity by Water Year

Figure 28 – East & West Shore Tributaries Turbidity Time Series by Water Year
Analysis of turbidity results from the east- and west-shore watershed sites shows that levels are relatively low at all sites during most of the year, with occasional spikes during significant storm events. The MP36.17 site and Millerton Gulch shows more frequent spikes than do other sites in the coastal watersheds, perhaps because it is the largest of the coastal watersheds, perhaps because of land-use and soils in the watershed. Again, discharge rates from coastal tributaries are a fraction of that from most other sites in the watershed, and so, loading rates of sediment at a given concentration from these tributaries are lower than those from most other sites in the Tomales Bay watershed.

**Figure 29– Walker Creek Watershed Turbidity by Water Year**

**Figure 30 – Walker Creek Turbidity Time Series WY08-WY11**

**Figure 30 Note:** One outlier result from WKR2 of 1000.0 NTU from WY10 omitted from graph.
Analysis of turbidity results from the Walker Creek watershed shows that some sites in the watershed show very high levels of sediment during storm events. Turbidity levels do not appear to decline between the upper Walker Creek site (WKR2) and the lower Walker Creek site (WKR1) suggesting that loading is occurring throughout the watershed. Levels of sediment loading are heavily influenced by storm events, as can be seen by the increased frequency of extreme results during the 2010 water year which had much more frequent storm events, and so, more storm samples represented in the dataset.

**Figure 31 – Tomales Bay Sites Turbidity by Water Year**

![Figure 31](image)

**Figure 32 – Tomales Bay Sites Turbidity Time Series WY08-WY1**

![Figure 32](image)
Analysis of turbidity results from sites along the length of Tomales Bay shows that most sites in the watershed show relatively low levels of sediment, although it should be noted again that samples from Bay sites were not taken during storm events in WY09, WY10 and WY11 making a true assessment of storm-related conditions at Bay sites impossible. Turbidity levels do appear to decline between the upper Lagunitas sites (SG1, LAGSPT and LAG1) and the lowest Lagunitas Creek site (LAG6) suggesting that some dilution, settling or filtration does occur in the wetland and lower watershed.

**Bacteria Monitoring Results for Trends Program WY08-WY11**

Bacteria monitoring is an essential element of the Trends program. Because Lagunitas and Walker Creeks as well as Tomales Bay are listed as impaired for pathogens, significant efforts by regulatory authorities, land-owners and citizen groups have been made to understand the nature of the problem. The RWQCB has a pathogen TMDL implementation plan for the watershed, and various state and federal agencies have been conducting studies of bacteria in the watershed including the U.S. EPA (Smith, et al., 1971) and the California Dept. of Health Services (Sharpe, 1974). For more information on past studies, see the Data Management and Legacy Datasets section of this report.

The levels of certain bacteria groups are used as a proxy for the likelihood of the presence of disease-causing bacteria (pathogens) for which there are no reliable direct tests. This watershed is characterized by large winter rain events which trigger significant surface runoff, and saturate soils connecting sub-surface sources with the streams. This results in relatively low levels of detected bacteria during the dry season, with exponentially-higher levels resulting from rain events during the winter. The pattern in this system makes it difficult, or maybe impossible to meet year-round compliance with strict numeric targets for bacteria. This program seeks to document long-term trends, including the location, timing, magnitude and duration of bacteria loading throughout the watershed.

**Bacteria** – Certain types of bacteria (like coliform bacteria) are used as indicators of pathogen contamination in water samples. The coliform bacteria are ubiquitous in the environment, even growing in soils. Fecal coliform bacteria grow only in the intestinal tracts of warm-blooded animals. While most coliform are harmless, the levels of Total Coliform (TC) and Fecal Coliform (FC) (a subset of TC) are used as an indicator for the potential presence of other pathogenic, disease-causing bacteria and viruses. Samples are analyzed by culturing any TC/FC bacteria present, counting the number of colonies, and using statistical models to generate a Most Probable Number (MPN) of bacteria present in 100mL of sample water. Because it is an indirect measure of potential threat to human health, fecal coliform bacteria is widely-acknowledged to be an inadequate method for identifying levels of pathogens in water. While new methods of determining source organisms and direct pathogen detection are emerging, they remain inconsistent and prohibitively expensive at present.

The RWQCB’s Basin Plan (RWQCB 2007) established numeric objectives for total and fecal coliform bacteria in surface waters based on three beneficial uses: Contact Recreation, Non-Contact Recreation and Shellfish Harvesting. (see table 1 for numeric targets below).
### Table 5 – Beneficial Uses Coliform Bacteria Criteria (RWQCB, 2007)

<table>
<thead>
<tr>
<th>Beneficial Use</th>
<th>Total Coliform (TC)</th>
<th>Fecal Coliform (FC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact Recreation</td>
<td>Median: &lt; 240 MPN/100mL</td>
<td>Log mean &lt; 200 MPN/100mL*</td>
</tr>
<tr>
<td></td>
<td>No sample &gt; 10,000 MPN/100mL</td>
<td>90th Percentile &lt; 400 MPN/100mL</td>
</tr>
<tr>
<td>Non-Contact Recreation</td>
<td></td>
<td>Log mean &lt; 2,000 MPN/100mL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90th percentile &lt; 4,000 MPN/100mL</td>
</tr>
<tr>
<td>Shellfish Harvesting</td>
<td>Median &lt; 70MPN/100mL</td>
<td>Median &lt; 14 MPN/100mL</td>
</tr>
<tr>
<td></td>
<td>90th percentile &lt; 230 MPN/100mL</td>
<td>90th percentile &lt; 43 MPN/100mL</td>
</tr>
</tbody>
</table>

*Based on five consecutive samples equally-spaced in time.

Table 6 below shows summary statistics by site for bacteria data (Total Coliform and Fecal Coliform) collected by the Trends Program during WY11. Following this are summaries by major sub-watershed for the same data. For the purposes of comparison, only the fecal coliform data is included in the sub-watershed analysis. During the state funding freeze in 2008-2009, no samples were analyzed for total coliform bacteria.

Trends Program data are compared to the single-sample contact recreation standard (90th percentile <400 MPN/10mL) for tributary sites (including LAG6), and to the shellfish harvesting standard (90th percentile <43 MPN/100mL) for Bay sites (TB2, TB4, TB11). This standard means that no more than 10% of samples from a site for a given time period may exceed the appropriate standard. No tributary sites met this standard for the period of record. A detailed summary of each watershed and site is provided in the following section. The secondary standards for contact recreation and shellfish harvesting uses the geometric or log mean of a minimum of five consecutive samples equally spaced over a 30-day period. Fecal coliform results from each site are presented, along with the calculated geometric mean compared to the appropriate standard. Graphs of geometric means for each site are calculated using the previous five samples, which are weekly during the wet season, and twice monthly during the dry season. Normally, geometric means are calculated from 5 samples in a 30-day period. While the dry-season data treatment is a slightly unconventional in using 5 samples spanning more than 2 months, it does provide a useful visual depiction of data distribution and relation to the appropriate water quality criteria.
Table 6 – WY11 Bacteria Parameter Results for Trends Monitoring by Station

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Total Coliform Bacteria (MPN/100mL)</th>
<th>Fecal Coliform Bacteria (MPN/100mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># of samples</td>
<td>Detect</td>
</tr>
<tr>
<td>Lagunitas Creek</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG1</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>LAG5PT</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>OLM11</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>LAG1</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>West Shore</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FV1</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>WG1</td>
<td>31</td>
<td>0</td>
</tr>
<tr>
<td>East Shore</td>
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<td></td>
</tr>
<tr>
<td>MC1</td>
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<td>MP36.17</td>
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<td>Walker Creek</td>
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<td>KVS1</td>
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<td>0</td>
</tr>
<tr>
<td>Tomales Bay Sites</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TB2</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>TB4</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>TB11</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>LAG6</td>
<td>35</td>
<td>1</td>
</tr>
</tbody>
</table>

* Censored Data handled by substitution:
(Present=QL=1.1*Upper Quantification Limit; *Non-Detect=0.5*Lower Quantification Limit)

The following graphs show (boxplots) of the results of fecal coliform bacteria monitoring at Trends Program sites by site for each sub-watershed grouping (Lagunitas, Walker, Coastal and Bay sites). A boxplot displays information about the range and distribution of data within the range (see figure at right). For the graphs in this report, the whiskers extending above and below the box are 1.5-times the middle 50% range box, with outliers shown by the asterisks (*). This treatment, which is a common variation on traditional boxplots whose whiskers extend to the minimum and maximum values, allows for the identification of outliers and extreme outliers that demonstrate the distribution and frequency of such results. To present the data in the most useful form, outliers are omitted from the box-plot graphs below, but are included in graphs in Appendix D of this document.
Figure 33 – Lagunitas Creek Watershed Fecal Coliform by Water Year

![Boxplot of Fecal Coliform Results WY08-WY11 for Lagunitas Creek Watershed](image)

Figure 34 – Fecal Coliform Trends from sites in the Lagunitas Creek Watershed

![Graphs showing fecal coliform trends for San Geronimo Creek and Ojai Creek](image)
The coliform bacteria results from the Lagunitas Creek watershed demonstrate elevated bacterial pollution in the watershed. The RWQCB set a contact recreation standard for fecal coliform bacteria that the 90th percentile of all samples should not exceed 400 MPN/100mL and that the geometric mean of five consecutive samples should not exceed 200 MPN/100mL.

An analysis of Trends program results show that over the program to date (Dec. 2007-Sept. 2011) over 32% of all samples from the Lagunitas Creek watershed (including LAG6) exceeded the contact recreation single sample objective for fecal coliform bacteria, and the 90th percentile value for all sites in the watershed was 2400 MPN/100mL.

Considered by water year, sites in the Lagunitas Creek watershed exceeded the single-sample objective in 43% of samples from WY08, 27% of samples from WY09, 34% of samples from WY10 and 27% of samples from WY11. The 90th percentile fecal coliform values for sites in the watershed each water year were: 2,400 MPN/100mL in WY08, 1,300 MPN/100mL in WY09, 5,000 MPN/100mL in WY10 and 1,300 MPN/100mL in WY11.

Of the five sites in the watershed, two showed a high percentage of exceedences over the period of record: San Geronimo Creek (SG1) with over 52% of site samples, and Olema Creek (OLM11) with nearly 38% of site samples exceeding the contact recreation, single-sample fecal coliform objective. The 90th percentile fecal coliform value for WY08-WY10 samples at SG1 and OLM11 was 3,000 MPN/100mL and 2400 MPN/100mL respectively.

**Figure 35 – East & West Shore Tributaries Fecal Coliform by Water Year**
Figure 3-Fecal Coliform Trends from Sites on East and West Shore Tributaries

The coliform bacteria results from the four sites in small coastal watersheds draining directly to Tomales Bay demonstrate a contribution of bacterial pollution in the watershed even from these small drainages, although loading rates are a small fraction of those from the two large drainages in the watershed. Overall, results from the four sites on coastal drainages show over 28% of samples from Dec. 2007-Sept. 2011 exceeded the contact recreation single-sample fecal coliform objective, and the 90th percentile value over the period of record for all sites in coastal watersheds was 2,400 MPN/100mL. Considered by water year, sites in the coastal watersheds exceeded the single-sample objective in over 35% of samples from WY08, over 18% of samples from WY09, over 36% of samples from WY10, and over 22% of samples from WY11. The 90th percentile fecal coliform values for sites in the watershed each water year were: 2,400 MPN/100mL in WY08, 1,300 MPN/100mL in WY09, 3,000 MPN/100mL in WY10 and 1,300 MPN/100mL in WY11.

The coastal watershed with the highest percentage of single-sample exceedences during the period of record was Millerton Gulch (MC1) with nearly 35% of site samples exceeding the single-sample contact recreation standard for fecal coliform. The 90th percentile fecal coliform value for WY08-WY11 samples at MC1 was 5,000 MPN/100mL.
Figure 37 – Walker Creek Watershed Fecal Coliform by Water Year

Figure 38 - Fecal Coliform Trends from Sites in the Walker Creek Watershed
The coliform bacteria results from the three sites in the Walker Creek watershed also demonstrates elevated bacterial pollution in the watershed. An analysis of Trends program results show that over the program duration (Dec. 2007-Sept. 2011) over 38% of all samples from the Walker Creek watershed exceeded the contact recreation single sample objective for fecal coliform bacteria and the 90th percentile value for all Walker watershed samples WY08-WY11 was 3,500 MPN/100mL.

Considered by water year, sites in the Walker Creek watershed exceeded the single-sample objective in nearly 43% of samples from WY08, over 23% of samples from WY09, 49% of samples from WY10 and over 27% of samples from WY11. The 90th percentile fecal coliform values for sites in the watershed each water year were: 2,400 MPN/100mL in WY08, 2,400 MPN/100mL in WY09, 5,000 MPN/100mL in WY10 and 2,400 MPN/100mL in WY11.

Of the three sites in the watershed, two showed a high percentage of exceedences over the period of record: Upper Walker Creek (WKR2) with over 41% of site samples, and Keys Creek (KYS1) with over 52% of site samples exceeding the contact recreation, single-sample fecal coliform objective. The 90th percentile fecal coliform value for WY08-WY11 samples at WKR2 and KYS1 was 2,400 MPN/100mL and 9,000 MPN/100mL respectively.

**Tomales Bay Fecal Coliform Results.**

*Figure 39 – Tomales Bay Sites Fecal Coliform by Water Year*
An analysis of Trends program results show that over the program duration (Dec. 2007-Sept. 2011) 10% of all samples from Tomales Bay sites (Outer-, mid-, and inner-Bay sites only) exceeded the contact recreation single sample objective for fecal coliform bacteria, and the 90th percentile fecal coliform value for all sites was 34 MPN/100mL. This value is well within the contact recreation standard of 400 MPN/100mL, and under the more appropriate shellfish harvesting objective of 43 MPN/100mL. It should be noted the Bay sites were not sampled during rainfall closures during the winter, so the assessment of true water quality conditions year-round cannot be assessed through this program data. The 90th percentile values for each water year from Bay sites were 130, 2013 and 14 MPN/100mL respectively for WY08, WY09, WY10 and WY11 respectively. This breakdown demonstrates that the three last water years represented by samples taken during open harvesting periods, meet the appropriate objective. Considered by water year, Tomales Bay sites exceeded the single-sample objective in about 19% of samples from WY08 (which included some winter samples), over 4% of samples from WY09 and 0% of samples from WY10 and WY11.

Our data from sites in Tomales Bay suggest acceptable conditions that meet state and federal water quality objectives for bacteria. It should be understood, however, that data from Bay sites during storm events, or Bay closure were not collected beginning in WY09, making a true assessment of Bay water quality under year-round conditions not possible.
Conclusions

The results presented in this report demonstrate that the Tomales Bay watershed faces significant water quality issues related to bacteria, nutrients and sediment. In general, fecal coliform (FC) results show that all tributaries fail to meet RWQCB objectives for contact recreation during some of the year, with the highest percentage of exceedences occurring in the San Geronimo Creek, Olema Creek, and Walker Creek watersheds. Usually, sites in Tomales Bay met RWQCB shellfish harvesting objectives for most samples, with exceedences occurring during storm events. Most tributary sites met RWQCB objectives for dissolved oxygen and pH. Those tributaries that failed to meet these objectives were intermittent streams that do not support salmonid species. Analysis of sediment parameters suggests that there are significant sources of sediment affecting most tributary sites during the wet season. Nutrient analysis shows relatively high levels of nitrogen in the tributary systems, with many sites having mean nitrate plus TKN values that exceed the EPA recommended criteria of 0.38 mg/L Total Nitrogen for our region’s rivers and streams. The ample available nitrogen, and the low levels of phosphorus suggest that phosphorus is the limiting nutrient in the watershed. The results from nitrate and total Kjeldahl nitrogen analyses show periodic spikes (usually related to storm events), and suggest that organic nitrogen is the largest source of nitrogen in watershed surface waters.

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, and that subwatershed-level results reflect land-use patterns across the watershed. The program has maintained consistent water quality 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 for detectable long-term trends.

Data Limitations

It is significant and necessary to note that the results shown for the WY08 ranges reflect less than a full water-year of sampling data because sampling was not initiated until December 17th, 2007. The WY09, WY10 and WY11 results that are reported cover the full water-year (October 1-September 30 of the corresponding year).

All ranges listed reflect certain treatment of censored data. For the purposes of field parameters, all measurements that failed quality controls were excluded, all censored bacteria data was handled by substitution using the following rules: 1) If the result was less than the reporting limit, one-half of the lower reporting limit was substituted; 2) If the result was greater than the reporting limit, 1.1 x the upper reporting limit was substituted. For nutrient parameters, because of the significant number of non-detect results, the following data handling rules were followed: if non-detects represented less than 50% of results, descriptive statistics were generated using Kaplan-Meier which
assumes no distribution; if non-detects exceeded 50% of the sample results, descriptive statistics were generating using MLE (Maximum-Likelihood Estimation). This treatment of non-detect water quality data is recommended by Helsel (2005).

During the period from the end of December 2008 through May 2009, nutrient analyses were conducted by a different commercial lab than was used for the rest of the program data. This lab had a reporting limit for Ammonia results at (0.5 mg/L) which is in contrast to the lower reporting limit for the remainder of the ammonia data (0.1 mg/L). The difference in reporting limits is responsible for the seemingly elevated levels shown in the WY09 ammonia graphs. Without omitting non-detect ammonia results from this period, there is no way to remove this artifact.

During WY09, logistical constraints of sampling partners forced a reduction in sampling frequency for sites in Tomales Bay (TB2, TB4 and TB11). From that point forward samples were collected only once per month when compliance samples for CA DPH were being collected. Consequently, Tomales Bay sites were not regularly sampled during the wet season due to logistical constraints of sampling partners; this means that we cannot assess year-round water quality conditions in Bay waters using our program data.

It is one of the goals of the project to leverage existing data from outside agencies and groups to extend the range of inference for water quality trends. In future reports the program will include this data, where available, in the appropriate analyses. For a discussion of this data compilation, see the Data Management and Legacy Datasets section of this report.

**Source Area Monitoring**

Source area monitoring efforts are focused on identifying sources and quantities of water pollutants to Tomales Bay and its freshwater tributaries. While Trend monitoring is dependent on long-term sampling at a suite of permanent sampling sites, source area monitoring is both flexible and responsive based on the data collected. The intent of source area monitoring is to support and prioritize future watershed or sub-watershed water quality improvement efforts, and to document conditions in order to evaluate the effectiveness of past efforts to improve water quality on private and public lands. This program builds on stormwater monitoring conducted in 2006 in the stormwater systems in the towns of Woodacre, Tomales and Point Reyes Station. More details on this project are detailed in a TBWC report (TBWC 2006).

Sampling sub-watersheds and sites are determined based upon the results of previous sampling and through prioritization of known source areas by the Water Quality Technical Advisory Committee (WQ TAC). Priority sub-watersheds for the 2008 water year were selected and finalized at a meeting of the WQ TAC in October, 2007. During the first year, monitoring of the rural stormwater sub-sheds continued, along with Heart’s Desire State Park. The WQ TAC met again in June 2008 to begin to reprioritize potential source areas for sampling during the 2009 water year. Results of source area sampling
are presented to WQ TAC members at regular meetings, and with involved groups in the prioritized areas where appropriate.

Data from source area sampling in the 2008 water year was detailed in the 2007-08 Annual Water Quality Report (Carson, 2008). Because the program funding was suspended due to the state financial crisis during the 2008-09 wet season, the source area element of the program was suspended before significant rainfall occurred. At a meeting in September 2009, the WQTAC decided that two of the sub-watersheds (Tomasini Creek and Keyes Creek) that had been selected for 2009 should be sampled during the 2009-10 wet season. In addition, we would continue sampling on Third Valley Creek during storm events, and coordinate with the Salmon Protection And Watershed Network (SPAWN) to analyze data from samples on San Geronimo Creek. Results of this sampling were presented to the WQ TAC in April 2010. The difficulty of accessing some sites in these sub-watersheds has hampered our ability to collect sufficient data to define source areas in many of these small watersheds. Other issues are the timing of storms, and the varying response of different watersheds to rain events.

In order to improve the useful data coming out of the Source Area Program, the WQ TAC determined that remaining Source Area Program funding would be used to target selected Trends sites in major watersheds with intensive sampling (i.e. rising, falling limb, 1, 2 and/or 3, 4, or 5, days after a significant rain event) around 3-5 storm events each winter. The goal would be to gain an understanding not only of the magnitude and duration of pollutant loading in major contributing sub-watersheds, but also whether there are thresholds of precipitation that correspond to loading events. This methodology was implemented during the 2011 water-year, and will take place at our Trends Program sites in the Millerton Gulch and San Geronimo, Olema and First Valley Creeks. The close spacing of storms during WY11 frustrated attempts to gather the latter (day3-5) 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, in 2012.

**Giacomini Wetland Restoration Water Quality Monitoring**
This project funded portions of the Giacomini wetland restoration, and continues to fund the long-term monitoring of the project area and in nearby reference marshes. The results and analysis of the monitoring conducted by the National Park Service, Point Reyes National Seashore is detailed in the report: Year Three of the Giacomini Wetland Restoration Project: Analysis of Changes in Water Quality Conditions in the Project Area and Downstream which is appended to this report as appendix A.

**Data Management and Legacy Datasets**
Program data has all been verified through the project’s QA/QC measures and is integrated into the TBWC water quality database. We have been working with staff at the San Francisco Estuary Project to facilitate the migration of our direct project data into the CEDEN data system, enabling access by a wide audience, including regulators. In
addition, we continue to pursue outside datasets focused on water quality in the Tomales Bay watershed.

One of the goals of this project is to research, collect and compile reliable baseline data describing the concentrations of contaminants in the waters of Tomales Bay and tributary streams. This is being accomplished through the population of a water quality database with legacy data sets provided by outside agencies and groups who have collected water quality data in the watershed. The establishment and population of a water quality monitoring database for the entire watershed and the capacity to analyze data and to develop trends, will benefit the agencies and organizations that are currently collecting data, and those responsible for tracking and protecting water quality.

Progress on this objective was significant during the first four years of this program. An EPA-STORET-compatible Access-based database developed by the NPS (accessible online at: http://www.nature.nps.gov/water/infoanddata/index.cfm) is being used to collect, compile and analyze data for this program. All relevant metadata regarding the project, stations, and sampling events was created. Results from this program have been entered into this database through the current sampling events, and the reports and descriptive statistics included in the appendices of this report were produced using imbedded reporting functions.

In addition to data from this program and the related sub-projects, datasets from outside groups and agencies have also been obtained, and are currently in the process of documentation and entry into the system. See Appendix D for a table summarizing water quality datasets that have been documented and imported into the TBWC water quality database thus far. Additional datasets remain to be imported, including several from several decades ago (Smith et. al. 1971 and Sharpe 1974) which should provide a means to compare long-term pollutant concentrations from watershed sources. The largest challenge associated with these data sets is the documentation of metadata including precise sampling location, analytical methods and detection limits, and the nature of quality control measures to evaluate the quality of the data. A SWAMP-compatibility checklist was developed and distributed to members of the WQ TAC and to outside agencies and groups in order to expedite the metadata documentation and data entry processes.

Ultimately, this compilation of watershed water quality data is of central importance to extend the period of inference in the determination of long-term trends. Because some of the sampling locations of these outside programs are the same as those in the current effort, this should be directly relevant to such a comparison.

Appendix E provides a summary table of water quality datasets that have been identified and documented for import into the TBWC water quality database. The summary provided the source group, the project, the time period covered by data, outline of sites and sampling watershed, parameters and status of the dataset’s of inclusion in the TBWC Water Quality database. Datasets that are imported will be provided to inform future analysis of water quality conditions in the watershed.

A web-based data communication effort to allow for direct dissemination of some Trends project results to the public through the TBWC website is ongoing. This effort provides
members of the public to view recent water quality conditions at Trend sites and mean conditions for past years, as well as a comparison to the appropriate use standard for each site.

**Outreach and Education**

Program outreach and education activities during 2010 and 2011 included hosting a State of the Bay conference, participation in teacher training and maintenance of our on-line water quality data resource.

On October 22nd and 23rd, 2010, the Tomales Bay Watershed Council presented the *State of the Bay 2010 - A Conference about Tomales Bay and its' Watershed*, gathering leading scientists, agency representatives and policy-makers with an interest in Tomales Bay and its watershed. It was the fifth State of the Bay Conference, but the first in ten years. It was a successful event, gathering nearly 100 people each day to learn about the current state of scientific knowledge, resource management and the state of important resources in the watershed from twenty-seven scientists, policy makers, non-profit organization leaders and stakeholders.

Complete digital proceedings are available on the conference webpage of our site: [www.tomalesbaywatershed.org/StateoftheBay2010.html](http://www.tomalesbaywatershed.org/StateoftheBay2010.html)

Conference agenda, short biographies, presentation abstracts, and presentations are available for download as pdf’s, and the conference was video-taped and individual presentations can be viewed through links at our site.

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

Outreach and education are an on-going and important element of both this program and the Council’s mission to foster understanding of watershed issues.

**Next Steps for the Program**

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 Wetlands 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.
Literature Cited:


Station, CA, Golden Gate National Recreation Area/Point Reyes National Seashore.


