Controlling Pathogens in Tomales Bay, California

Total Maximum Daily Load:
Background, Problem Statement and Numeric Targets

Progress Report

June 30, 2000

California Regional Water Quality Control Board
San Francisco Bay Region

INTRODUCTION

This document is a progress report from the California Regional Water Quality Control Board, San Francisco Bay Region (RWQCB), to U.S. EPA on a Total Maximum Daily Load (TMDL) for pathogens in Tomales Bay, California. This report includes the background, problem statement and numeric targets for the TMDL, describes the progress that has been made with a stakeholder group concerning pathogens in Tomales Bay and, in general, develops a framework for the TMDL and Implementation Plan. Although we don't expect the background, problem statement or numeric targets contained in this report to change substantially, additional information will probably be added to these sections as the project progresses. The next steps will be to define sources, evaluate linkages between loadings and in-stream response and to calculate waste allocations. On a parallel track we will focus on implementation actions and linking those actions to the proposed targets.

BACKGROUND

Description of Water Body

Tomales Bay is an estuary located in western Marin County, California, approximately 50 km (40 miles) northwest of San Francisco (Figures 1&2). The Bay has an area of approximately 28 square kilometers (11 square miles). The mouth of Tomales Bay is at the southern end of Bodega Bay, and extends in a southeasterly direction along the line of the San Andreas Fault. The Bay is about 12 miles in length with an average width of less than 1 mile. Tomales Bay is characterized by relatively shallow water, with the average depth being less than 20 feet. Hydrographic studies conducted from 1966-70 (Smith, et al., 1971) indicated that the currents in the Bay are predominantly influenced by tidal cycles rather than wind-driven. They suggested that the Bay consists of three regimes, with significant flushing taking place in the lower-bay from the mouth to approximately Hog Island near the Walker Creek Delta, sluggish mixing in the mid-bay (Pelican Point to Double Point) and even less water exchange in the portion of the upper-bay (south of Double Point). These studies were done in the summer and fall periods so they do not reflect the influence of increased inflow from runoff.

The Tomales Bay watershed, consistent with the "Mediterranean" climate of the central coast of California, receives intense rain during the winter months (November through March), with 85% of the annual rain usually falling during this period. Another 10% of the annual precipitation falls during October and April, with the remaining 5% during the other five months of the dry season. Average annual rainfall ranges from 26 inches per year in the north and east part of the watershed to 39 inches per year in the south (Fischer et al., 1996).

The watershed drainage area for Tomales Bay is approximately 561 km^2 (216 square miles) with four major sources of input: (1) the immediate drainage from small tributaries along the west and east shores (73 km^2; 28 mi^2); (2) Lagunitas Creek (241 km^2; 93 mi^2) to the southeast; (3) Olema Creek (50 km^2; 19 mi^2), which flows into Lagunitas Creek close to the

head of the Bay; and (4) Walker Creek (196 km^2; 76 mi^2) to the northeast (Table 1; Figure 2) (Fischer et al. 1996).

The U.S. Geological Survey maintains stream gauges on both Walker and Lagunitas creeks. These gauges measure only a portion of the runoff from their respective watersheds, as well as any water released from catchment reservoirs (Table 2). Fischer, et al. (1996) estimated that about two-thirds of the runoff into Tomales Bay comes through the Lagunitas-Olema Creek drainage even though this area only makes up about half of the watershed (Table 1 &3). The Walker Creek drainage, which includes Chileno, Arroyo Sausal, Salmon, and Keyes Creeks, makes up about 35% of the Tomales Bay watershed area, but produces about 25% of the annual runoff into the Bay (Fischer, et al. 1996). The remainder of the runoff into the Bay (approximately 10%) comes from the local bay shore drainages, which make up 13% of the total watershed area. It is estimated that sediment runoff from the major creeks and tributaries into Tomales Bay may be as high as 48,600 tons/year. Approximately one third of the sediment is carried into the Bay from the Walker/Keyes Creek drainage.

Marin Municipal Water District (MMWD) maintains five water catchment reservoirs in the Lagunitas watershed (four on Lagunitas Creek and one on Nicasio Creek) with a total capacity of approximately 69,000 acre feet. MMWD also has a reservoir on a tributary to Walker Creek, with a capacity of 10,572 acre-feet.

Land Use

The Tomales Bay watershed is a major recreational area and is used for hiking, boating, camping, picnicking, clamming, fishing, and birding. The Bay also supports the commercial cultivation and harvesting of shellfish, including oysters, mussels, and clams. Herring and halibut are also harvested commercially from wild populations, and there is a sport fishery for halibut in the Bay.

The major land uses in the watershed are livestock grazing, dairy farming, low-density residential, and parklands. Beef, sheep, and dairy farms have been an important part of the local economy since the mid-1800s, although the number of dairies has been declining since there has been an increase in competition from large Central Valley dairies. The number of livestock and associated manure production in the watershed was estimated in 1990 (Table 4). However, since some dairies have switched to raising beef cattle and others have increased the size of their dairy herds, it is unclear, at this time, how the number of animals in the watershed has changed.

There are nine small towns within the watershed, with limited commercial development and no industry. According to the 1990 census, the west side of Tomales Bay has a population of 1392, with a total of 650 households. The east side of the Bay, from Dillon Beach to Point Reyes Station, has a population of 3217, with 1246 households. The population has probably increased since the last census due to some new residential development. All of the towns are served by onsite sewage disposal systems except the town of Tomales, which is served by a centralized wastewater treatment plant. There are seven small sewage treatment systems within the watershed, and one facility that accepts septage waste (Table 5). The Regional Water Quality Control Board (RWQCB) prohibits direct discharge from treatment systems into Tomales Bay or the creeks within the watershed. A number of the sewage treatment systems have holding ponds and are permitted to discharge to irrigation fields during the dry season.

Regulatory Responsibilities/Beneficial Uses/Shellfish Harvesting

The RWQCB has been designated authority by U.S. EPA to administer the Clean Water Act (CWA) in Tomales Bay. Under this authority, the RWQCB designates beneficial uses for Tomales Bay and adopts standards to protect those beneficial uses. The RWQCB has adopted a Water Quality Control Plan (Basin Plan) that contains a list of beneficial uses for each water body in the Region and the standards and implementation measures necessary to protect those beneficial uses. The beneficial uses of Tomales Bay listed in the Basin Plan related to pathogens are shellfish harvesting, water contact recreation and non-contact water recreation. Numerical water quality objectives for fecal and total coliforms have been developed for each of these beneficial uses and are listed in the Basin Plan (Table 7). In accordance with section 303(d) of the CWA the RWQCBs are required to develop lists of impaired waterbodies in their region, along with the causes of impairment. The RWQCB has listed Tomales Bay as an impaired water body for pathogens, sediments, and nutrients. The listing of Tomales Bay as impaired due to pathogens is based on the exceedence of water quality standards for shellfish harvesting, the listing of Tomales Bay as "threatened" under the state's Shellfish Protection Act, the prohibition on commercial harvesting during rainfall periods, regulated by the California Department of Health Services, and an illness outbreak from the consumption of shellfish that illustrated the inability to protect human health, under current conditions, even when coliform objectives are being met.

The California Department of Health Services (DHS) has separate authority and standards to regulate commercial shellfish growing areas. These standards supersede those contained in Regional Basin Plans. In the San Francisco Bay Region, Basin Plan standards for fecal coliforms in shellfish growing waters are that water cannot exceed a median of 14 MPN/100mL or the 90th percentile cannot exceed 43 MPN/100mL. Although DHS used a median value in the past, they now use a geometric mean of 14 MPN/100mL. DHS standards follow criteria developed by the National Shellfish Sanitation Program (NSSP), which is administered by the U.S. Food and Drug Administration (FDA) (U.S.FDA, 1997). These standards allow for a median or a geometric mean to be used. The NSSP standards are based on acceptable levels of fecal coliform in shellfish and shellfish growing waters. The NSSP fecal coliform standard for shellfish is a market standard of 230 MPN/100 grams (U.S.FDA, 1995). DHS has developed rainfall closure rules, when shellfish cannot be harvested, for different areas of Tomales Bay based on the analysis of water column and shellfish data. These closure rules have become very site specific as the amount of data has increased and the data analysis has become more refined. Rainfall closure rules have also become more stringent. The latest and most stringent rules were issued in 1997.

The vast majority of shellfish harvesting in Tomales Bay is from commercial shellfish growing areas. There are currently eight certified commercial shellfish harvesters in Tomales Bay, with a combined aquaculture lease area of 483 acres (Table 6; Figure 4). With one exception, all commercial growers in Tomales Bay operate on eastern shoreline leases granted by the California Department of Fish and Game (DFG). The exception is the Frank Spenger Company, which operates on a Point Reyes National Seashore lease on the western shore. Shellfish cultivation in Tomales Bay is primarily devoted to Pacific oysters (*Crassostrea gigas*) and bay mussels (*Mytilus edulis* and *M. galloprovincialis*). In addition, there is a small amount of commercial production of Eastern oysters (*Crassostrea*

virginica), European oysters (*Ostrea edulis*), Kumomoto oysters (*Crassostrea gigas kumomoto*), and Manila clams (*Tapes semidecussata*). There is a fairly large amount of recreational harvesting for horseneck clams north of the Walker Creek Delta during the spring and fall. There is also a small bed of cockles and clams used for recreational harvesting near Hamlet, just south of the Walker Creek Delta.

The RWQCB has authority under the Clean Water Act to issue NPDES permits for point source discharges in to state waters. The state's Porter Cologne Water Quality Control Act also gives the RWQCB authority to issue Waste Discharge Requirements (WDRs) for nonpoint sources of contamination. The RWQCB has delegated authority for the regulation of individual on-site sewage disposal systems in Marin County to the County Health Officer, through Resolution 84-12, which waives Waste Discharge Requirements for individual systems. Under a county ordinance approved by the Board of Supervisors in August 1984, the Marin County Environmental Health Department has responsibility for overseeing individual on-site sewage disposal systems. This includes the responsibility for siting and design, installation and repair standards, and monitoring and inspection programs.

Tomales Bay is part of the Point Reyes-Farallon Islands National Marine Sanctuary which is regulated by the National Oceanic and Atmospheric Administration. Rules and regulations governing the Sanctuary are contained in 15 CFR Part 936. Regulations for the Sanctuary prohibit the discharge of any materials or substances in to the Sanctuary except: 1) fish or parts and chumming material, 2) water (including cooling water) and other biodegradable effluents incidental to vessel use of the sanctuary generated by marine sanitation devices, routine vessel maintenance (e.g., deck wash down), engine exhaust or meals on board vessels, 3) dredge material disposed of at a designated dumpsite outside of Tomales Bay and 4) municipal sewage provided such discharges are permitted by the appropriate authorities.

On October 10, 1993, legislation was passed by the California legislature that enacted the Shellfish Protection Act of 1993. This legislation is incorporated in the Porter Cologne Water Quality Control Act (California Water Code, Division 7, Chapter 24, Section 14950-14958). Under this law the RWQCB is required to form a technical advisory committee for any commercial shellfish growing area that is determined to be threatened. One of the criteria for a "threatened" area is the number of days the area is closed to shellfish harvesting due to pollution threats. The Shellfish Protection Act states that a shellfish area shall be designated as threatened if it is closed to harvesting for more than thirty days in each of three consecutive calendar years. Based on the California Department of Health Services' (DHS) letter of January 5, 1994, notifying the RWQCB that Tomales Bay met the threatened designation, the RWQCB passed a resolution on January 19, 1994, authorizing formation of the Tomales Bay Shellfish Technical Advisory Committee (TBSTAC). The RWQCB staff organized the TBSTAC and held its first meeting on February 15, 1994. According to the Shellfish Act, the purpose of the TBSTAC is to advise and assist the RWQCB in developing an investigation and remediation strategy to reduce pollution affecting the shellfish growing areas.

At the first TBSTAC meeting, the committee members determined that a study was necessary to investigate the sources of water quality degradation in Tomales Bay, and they appointed a study design subcommittee to develop a study plan. The study design subcommittee presented a plan to the TBSTAC in the summer of 1994. Originally scheduled for the winter of 1994-95, the study was postponed until the following winter

(1995-96). During the winter of 1994-95, staff from the DHS's Environmental Management Branch conducted a preliminary survey of the watershed sampling sites identified in the study plan, with the RWQCB providing financial support to the DHS's Environmental Microbial Diseases Laboratory for all sample analyses. The results of this preliminary survey, together with recommended changes to the study design, were presented to the TBSTAC on July 26, 1995. The study design subcommittee distributed a final version of the study plan on September 5, 1995, and the study was carried out in the winter of 1995-96.

The study was designed to address potential sources of fecal contamination from rainfall runoff to Tomales Bay from: 1) nonpoint sources along the west and east shore of the Bay, and 2) nonpoint sources originating from the predominantly agriculture-influenced watershed. In addition, the study investigated several potential indicator organisms in addition to the standard fecal coliform indicator group.

PROBLEM STATEMENT

The basis for listing Tomales Bay as impaired due to pathogens under Clean Water Act section 303(d) is:

1. Tomales Bay exceeds water quality objectives contained in the California Regional Water Quality Control Board, San Francisco Bay Region's Water Quality Control Plan (Basin Plan) and Ca. Dept. of Health Services and FDA standards from the National Shellfish Sanitation Program. Since DHS rainfall closure rules are based on fecal coliform concentrations in water and shellfish, we can use the number of days Tomales Bay is closed for harvesting as a surrogate for the number of days fecal coliform concentrations exceed standards. We have estimated that Tomales Bay is closed to harvesting approximately 90 days per year, therefore, we assume that standards are exceeded for a approximately 90 days per year;
2. Under the state's Porter Cologne Water Quality Control Act (California Water Code, Division 7, Chapter 24, Section 14950-14958), the Shellfish Protection Act, Tomales Bay is considered "threatened" due to the conditions listed under #1;
3. DHS prohibits shellfish harvesting during periods of rainfall based on the results of bacteriological studies. As stated in #1 the Bay is closed to harvesting approximately 90 days per year. In 1997, closure rules for shellfish harvesting were made more stringent. Therefore, the beneficial use of shellfish harvesting is not protected during this season; and
4. During a period without rainfall and when bacteriological objectives were met there was a major human illness outbreak of a virus of human origin from consumption of oysters; therefore, beneficial uses were not protected even when water quality objectives were met.

Monthly water quality monitoring for fecal coliforms in Tomales Bay is conducted by shellfish growers under the authority of DHS. In addition, several intensive studies have been conducted on bacteriological water quality in relation to shellfish harvesting over the past 26 years**.** These studies were: 1) a shellfish and water quality study was conducted in

1974 by the DHS (Sharpe, 1974), 2) a shoreline and watershed water quality survey was carried out in 1976-77 and 1977-78 by the RWQCB (Jarvis et al., 1978), 3) a sanitary survey was conducted by the Department of Health and Human Services of FDA (Musselman, 1980), 4) DHS conducted a pilot study in the winter of 1994-95 to test sampling methods and locations for the 1995-96 study and 5) in 1995-96 a State Water Resources Control Board (SWRCB) funded study was conducted by DHS and the RWQCB, under the auspices of the TBSTAC. The results of these studies are discussed briefly below.

1974 Study – California Department of Health Services

The 1974 study by the DHS (Sharpe, 1974) was designed to determine the water quality of Tomales Bay and tributary streams during wet weather conditions and relate the results to the bacteriological quality of the shellfish grown in the Bay. The study also included a sanitary survey for potential pollutant sources, with a detailed description of the potential of contamination from land uses and recreational uses in and along Tomales Bay. Water samples were collected at 17 Bay sampling stations, 19 shoreline stations and 49 tributary stream stations for 12 days in December, following a three-day rain event totaling 1.98 inches. Samples were analyzed for total and fecal coliforms. Shellfish from six locations were also sampled for coliforms and heavy metals.

Results from the Bay samples generally showed that the Bay waters did not exceed the median standard of 14 MPN/100 mL for shellfish waters but some stations did exceed the requirement that the 90th percentile of samples may not exceed 43 MPN/100mL. Shoreline samples showed elevated total and fecal coliform levels at numerous stations, which were attributed to the possibility of shoreline drainage, tributary streams entering the Bay, and possible failing septic systems. Shellfish samples were also elevated in most instances. In spite of fairly low runoff because of dry conditions in the watershed, results from tributary samples showed high total and fecal coliform counts. The streams were considered the major source of pollutants to the Bay. The study concluded that the high coliform counts were due to contribution of wastes by upstream dairies and, in lower Keyes Creek from raw sewage discharges from the town of Tomales. This study predates the adoption of RWQCB requirements to improve handling of animal wastes on dairy farms and the construction of the Tomales sewage treatment plant.

1976-78 Study – Regional Water Quality Control Board

The San Francisco Bay RWQCB conducted a shoreline and tributary sampling survey during the winters of 1976-77 and 1977-78 (Jarvis et al., 1978), with the purpose of evaluating the effectiveness of the RWQCB's recent requirements for dairy waste practices. The RWQCB adopted "Minimum Guidelines for Protection of Water Quality from Animal Wastes" in 1973 and required dairies to be in compliance with manure handling practices by September 1, 1976. Samples were taken from 20 stream stations and six shoreline stations (not every station was sampled during each survey nor during both years). Samples were analyzed for total and fecal coliforms, total organic carbon, and ammonia. Samples were only taken during the rainy season (from November through March in 1976-77 and November through January in 1977-78).

Results indicated improvement in stream conditions in areas where dairies had come into compliance with the minimum guidelines, although none of the shoreline or stream stations sampled met coliform objectives for water contact and non-contact recreation following periods of rainfall. The 1976-77 season had very light rainfall and the January 3, 1977, sampling event was the first major rain (approx. 2 inches in three days). The January 14, 1978 sampling event followed a 2.5 inch rain event in three days; however, there was significant rainfall in November and December, so that the runoff from the watershed was greater than the previous year's. There were much higher coliform levels along the shoreline in the 1977-78 season as compared with the previous year; this was attributed to greater freshwater inflows into the Bay during 1977-78. Stream stations showed decreases in coliform between 1976-77 and 1977-78 following implementation of the Minimum Guidelines. The report also concluded that sewering of the town of Tomales in June 1977 resulted in decreased levels of coliform in Keyes Creek below the town.

1980 Study – U.S. Food and Drug Administration

The 1980 sanitary survey was conducted from February 24 through March 12 by the FDA to determine the degree of pollution and recovery rate of the Bay during periods of rainfall. Samples were taken from 45 stations in the Bay and on tributary stations close to the Bay. A total of 393 samples were collected and analyzed for total and fecal coliform and fecal streptococci. Shellfish samples were taken from two sites in the Bay and analyzed for total and fecal coliforms.

Results showed that the shellfish market standard for fecal coliforms was exceeded in all Bay water quality stations during wet periods. The dry period samples met the standard, with the exception of stations at the head of the Bay and near the mouth of Walker Creek. Seven out of eight shellfish samples exceeded the market standard. Tributary samples ranged from low fecal coliform densities during the dry periods to high densities during rainfall events. In order to quantify the numbers of bacteria entering the Bay, daily estimates of stream flow were made on major streams (Walker, Keyes, Lagunitas, Olema, and Bear Valley Creeks) and several eastshore tributaries to the Bay (Millerton Gulch, Tomasini Creek, Grand Canyon Creek, and Cypress Grove). It was determined that the fecal coliform densities in the streams during dry weather were equal to sewage from about 150 to 200 people. During wet weather, fecal coliform densities increased to the equivalent of sewage from 1500 to 2000 people or 500 to 700 cows. The highest loadings following rains revealed a bacterial equivalent of 40,000 to 50,000 people or 15,000 to 20,000 cows.

The 1980 study concluded that the portions of the Bay most seriously affected by pollution from rainfall and runoff were the head of the Bay (Millerton Point south) and the Walker Creek delta. Rural and livestock sources of nonpoint pollution were considered to be the most likely cause of high fecal coliform densities in the Bay.

1994-95 Pilot Study – Department of Health Services

The pilot study conducted by the DHS in the winter of 1994-95 was a prelude to the study during 1995-96 (DHS, 1996). Both of these studies were a result of Tomales Bay being considered "threatened" under the Shellfish Protection Act and the formation of the

TBSTAC. This study was designed to evaluate indicator species, test sampling methods and laboratory analyses, and finalize site selection of watershed sampling stations for the 1995-96 study. A total of 352 samples were collected from 12 stations in the Bay and from 35 watershed stations on nine different sampling dates during both closed and open harvesting periods. Samples were analyzed for total and fecal coliform, *Enterococci*, anaerobic bacterial indicators, and Methylene Blue-Active Substances (MBAS), which are common surfactants in detergent. A total of 26 shellfish samples were collected for total and fecal coliform analysis.

Results showed the impact of rainfall on the water quality of the tributaries entering Tomales Bay and on the water quality of the Bay itself following runoff events. The data supported the study's theory that the major source of fecal contamination to the Bay is rainfall-related runoff from the tributaries. Two seasonal patterns of fecal coliform concentrations were observed: 1) sites that showed declining fecal coliform densities throughout the winter, suggesting a nonrenewable source and, 2) sites that exhibited high fecal coliform densities throughout the season, suggesting a renewable source. The results of this pilot study were used to determine what types of analyses would be used for the full-scale study during the 1995-96 winter season and which stations should be added or deleted from the sampling design.

1995-96 Study – TBSTAC, SWRCB, DHS, RWQCB

In the winter of 1995-96 the RWQCB and DHS, under the auspices of the TBSTAC and funded by the SWRCB, conducted an intensive study of bacteriological and pathogen levels in the water of Tomales Bay and its watershed. Concentrations of fecal coliforms in oyster tissue were also measured. Samples were collected before and after the rainfall season and throughout rainfall events, including the day the Bay would normally be opened for shellfish harvesting (day X). The study was conducted during the winter of 1995-1996, and consisted of 40 sampling stations throughout the Bay and watersheds (Figure 4). Samples were collected during two dry season periods and during four rainfall events. All samples were analyzed for four standard indicators of microbiological water quality: total coliform, fecal coliform, enterococcus, and *Escherichia coli* (*E. coli*). In addition, several sites were analyzed for coliphage and the anaerobic bacterium *Bacteriodes vulgatus*, indicators that are thought to be more specific for human fecal sources than the standard indicator organisms. A limited number of analyses were performed to detect the presence of pathogenic bacteria. *Salmonella typhirium* and *E. coli*:0157 were identified in separate watershed samples.

Watershed Water Quality

Bacterial densities usually exceeded the standards within the first one or two days of each rainfall event, then typically decreased to acceptable levels by the last day of sampling. Consistently high bacterial levels were detected during most of the study at sites within the Walker/Keyes/Chileno watershed and along the eastern shoreline watershed. Slightly lower concentrations of fecal coliform were detected throughout the Lagunitas/Olema subwatershed. In contrast, bacterial levels at the western shoreline watershed stations were generally 10 to 100 times lower than those from all other subwatersheds.

Fecal coliform loadings were calculated to estimate the amount of fecal coliform contributed by each subwatershed on a daily basis. The highest loadings occurred within the Walker/Keyes/Chileno Creek and the Lagunitas/Olema subwatersheds. The former region

is primarily dairy and livestock grazing with some residential dwellings, while the latter contains a mix of agriculture, commercial, and residential uses. Within the Walker/Keyes/Chileno Creek watershed, the highest fecal coliform loadings occurred in the Chileno Creek subwatershed. Within the eastern shoreline watershed, the highest fecal coliform loadings generally occurred in the subwatersheds represented by stations Milepost 40.35, Milepost 34.95, Millerton Creek, Milepost 32.12, Grand Canyon Creek, and Tomasini Creek. Within the Lagunitas/Olema watershed, Lagunitas Creek contributed the largest share of the fecal load, followed by Olema Creek. The Bear Valley drainage contributed the lowest loadings for this subwatershed. Fecal coliform loadings from the western subwatershed were less than that contributed by the other subwatersheds.

Bay Water Quality

Outer-bay sampling stations were adversely affected within the first two days following significant rainfall. Fecal coliform concentrations often remained elevated three days after the rainfall event and did not always return to acceptable levels by the day shellfish growing waters were reopened for harvest (day X). This indicated either a long residence time in the outer-bay or a prolonged source of contamination. The highest fecal coliform concentrations were observed at station 34, which is in the direct influence of the branch of Walker/Keyes Creek that flows around Preston Point. Mid-bay stations had fecal coliform levels that were generally lower than either the outer or inner-bay regions, although all Bay stations experienced elevated concentrations of fecal coliform immediately following rainfall. The inner-bay monitoring stations had levels of fecal contamination slightly greater than those of the mid-bay, and did not always return to acceptable levels by the day shellfish growing waters were reopened for harvest (day X). During rainfall event 3, both inner-bay monitoring stations showed an obvious spike of fecal coliform on day X that greatly exceeded the concentrations detected within the first three days of rainfall. A possible explanation for this sharp increase would be a pulse of contamination from the watershed or nearshore area.

Shellfish Quality

The fecal coliform concentrations in oysters in the outer-bay reached extremely high levels following significant rainfall. In addition, these data suggest a pattern of increasing concentration throughout the winter, perhaps as a result of the continuous high fecal concentrations contributed by the watershed. In addition, lower water temperatures in winter may result in a reduced metabolic rate in the oysters, which in turn would lengthen the time necessary for satisfactory cleansing of contaminated shellfish. Consequently, oysters in the outer-bay do not always return to the National Shellfish Sanitation Program (NSSP) market standard by the time the outer-bay is reopened for harvesting.

Within the outer-bay stations, samples were collected from sites representing two different culture techniques: top-culture (i.e., floating bags) and bottom-culture (i.e., rack and bag). The top-culture station was significantly higher than the NSSP market standard during the first dry season sampling. It is likely that these elevated levels of fecal coliform are the result of localized contamination, possibly from birds roosting and defecating on the floating bags.

Oysters from the mid-bay were found to exceed the NSSP standard following significant rainfall but generally returned to acceptable levels for fecal coliform by day X. Oysters

from the inner-bay typically exceed the NSSP market standard after significant rainfall, and the magnitude of contamination was generally equivalent to the observed levels in the outer-bay oysters.

Conclusions

The results of this study support the conclusions of earlier surveys, that the lands along the eastern watershed and the southern watershed drainages contribute significant fecal pollution during and immediately following significant rainfall. The primary land use in these eastern subwatersheds consists of dairies and cattle grazing land. Primary land uses in the southern subwatersheds include dairying, cattle grazing, public open space and watershed land, and residential. This study evaluated general trends in water quality and contaminant sources on a watershed and subwatershed scale. As such, individual or localized sources of fecal coliform such as domestic sewage disposal systems or individual incidents of direct disposal of sewage (i.e., illegal dumping) into the Bay were not specifically evaluated. Degradation of Bay water quality coincided with the pulses of fecal contamination from the watershed after rainfall. As a result of this study and previous supporting data the rainfall closure requirements that DHS applies to harvesting shellfish in Tomales Bay were made more stringent. More detailed conclusions are included in the final draft report (TBSTAC et al., 2000).

Comparisons of Fecal Coliform Results Among Studies

In order to try to assess trends in fecal coliform numbers over time, data from all studies were compared for selected Bay and watershed stations as part of the report on the 1995-96 study (TBSTAC et al., 2000). Sampling locations were chosen that were common to all or the majority of the studies. Since there were few overlaps in sampling stations on the south and west sides of the Bay, stations were chosen along the east shore where the sampling record was more consistent. The rainy seasons were variable from study to study and not all studies included the complete rainy season. None of the earlier studies sampled during the dry season. The 1974 study sampled the first significant rainfall of the season (December) and therefore the results reflect a low runoff from tributary streams. The 1976-77 and 1977-78 studies reflect a lower than average and moderately heavy rainfall year, respectively. The 1980 samples were taken beginning in late February following several months of moderate to heavy rainfall. Sampling dates of February 29th and March 3rd were included in the comparison since both followed periods of moderate rainfall (1.37 inches on February 28th and 0.78 inch cumulative rainfall on the 3rd). Both the 1994-95 and 1995-96 samples were taken over a complete rainy season, with overall moderate rainfall, including several major rain events.

Since the data sampling schedules were so variable, the studies were compared using the highest, lowest, and median fecal coliform values over the course of each study. Pre- and post-wet season samples from the 1995-96 study were not included. Data were compared for four watershed stations (Walker Creek, Millerton Creek, Grand Canyon Creek, and Olema Creek at Bear Valley Road) and four Bay stations (Walker Creek delta, Marconi Cove, Blake's Landing, and Tomales Bay Oyster Company).

Lack of data on other environmental variables related to sampling (e.g., streamflow and precipitation) and variability in rainfall, streamflow, and soil saturation make it difficult to

come to any clear conclusion about fecal coliform trends over the years from 1974 to 1996. In general, results for Bay stations showed that the coliform levels were lowest during the low rainfall years (1974 and 1976-77). The lowest levels have remained essentially the same over the years, with some increases in 1977-78 (as noted, this was a higher rainfall year than either of the previous years). Median values also increased in 1977-78 and 1980 and returned to earlier levels in 1995. In general, levels of fecal coliform have stayed high during moderate to high rainfall periods over the past twenty years, particularly at the Walker Creek and TBOC stations.

Results for the watershed stations showed a somewhat different pattern, with highest fecal coliform levels remaining elevated in all studies. Low and median values consistently remained higher than in Bay stations, with watershed stations in many cases an order of magnitude higher than Bay stations. Although initially there seemed to be an improvement in water quality between the 1974 and 1976-78 study, long-term there were no clear overall trends of increasing or decreasing fecal coliform levels in the watershed stations except for Millerton Creek, which showed an increase in high coliform levels over the course of the studies. Highest numbers overall were at Olema Creek in the 1974 study and Grand Canyon Creek in the 1995-96 study.

Illness Outbreak

On May 13, 1998 DHS was notified of a food borne illness outbreak associated with the consumption of oysters from Tomales Bay. DHS closed the Bay to shellfish harvesting and launched an investigation, which included several divisions at DHS, the U.S. Food and Drug Administration, the Center for Disease Control and Prevention and several local county health departments. This illness effected 171 people and was determined to be caused by a virus of human fecal origin. An investigation determined that the oysters causing the illness were harvested from the mid and outer-bay. DHS had been in the Bay collecting water and shellfish samples on the earliest dates that the contaminated shellfish could have been harvested. This was after a rainfall closure and there was no additional rainfall after this time. Data showed that both water and shellfish met fecal coliform standards. After subsequent studies, DHS opened the mid and outer-bay leases to shellfish harvesting on August 4th.

Based on existing knowledge of the Bay and additional shoreline survey work, DHS determined that the two most likely causes for the outbreak were the substandard and potentially failing septic systems along the shoreline or overboard discharge(s) of toilet wastes from a recreational or commercial boater. This outbreak reinforces the need to evaluate those sources of fecal contamination that were not adequately addressed in previous studies, including onsite sewage disposal systems and recreational and commercial boating and camping activities. It also reinforces the need to manage those sources and not to rely solely on the attainment of fecal coliform standards to protect human health and shellfish harvesting.

NUMERIC TARGETS

We propose using three different numeric targets for this TMDL: 1) the fecal coliform objective for water found in the RWQCB Basin Plan to protect shellfish harvesting, 2)

the fecal coliform shellfish tissue standard used by DHS to determine if shellfish have been contaminated by fecal waste and used by FDA as a market standard and 3) a zero discharge of human waste in order to protect the public from human viruses.

The first target is the fecal coliform objective for water that is contained in the RWQCB Basin Plan and in the NSSP to protect shellfish harvesting (Table 7). That objective is that fecal coliform concentrations cannot exceed a median of 14 MPN/100mL and that the 90th percentile cannot exceed 43 MPN/100mL. The RWQCB also lists a total coliform objective in the Basin Plan to protect the beneficial use of shellfish harvesting. Fecal coliforms will be used as targets and not total coliforms because they are a better indicator of fecal contamination.

Water contact recreation (REC1) and non-contact recreation (REC2) are two other beneficial uses listed for Tomales Bay that have fecal and total coliform objectives which are designed to protect against the transmission of pathogens. The fecal coliform objectives to protect these uses (REC-1 log mean <200MPN/100mL and 90%<400 MPN/100mL, REC-2 mean<2000 MPN/100mL and 90%<4000 MPN/100mL) are much higher than the objectives used to protect shellfish harvesting (Table 7). By requiring water quality to meet the fecal coliform objective to protect shellfish harvesting, the objectives to protect the other beneficial uses will be met in areas where shellfish are harvested. In general, shellfish are harvested on the east side of the Bay, although one lease is on the west side. On the west side of the Bay, where most bathing beaches are located, levels of fecal coliforms are lower. One station sampled in the 1995-96 study, Teachers Beach Creek, is a creek that discharges at a bathing beach. This station met fecal coliform objectives to protect water contact recreation throughout the study and no sample exceeded the maximum total coliform objective, although the median total coliform objective was exceeded. These samples were collected in the creek during worst-case conditions and not where people actually bathe, therefore, coliform levels at the beach where people bathe were probably much lower. Other bathing beaches north of Teachers Beach are in more remote areas or in Tomales Bay State Park and less influenced by runoff that may be contaminated. Therefore, although additional studies may be warranted, we currently believe that the targets designed to decrease pathogens and fecal coliforms in the Bay to protect shellfish harvesting will also be sufficient to protect other beneficial uses.

We propose a fecal coliform tissue target of a median of 230 MPN/100 grams and the 95^{th} percentile not to exceed 700 MPN/100 grams. The 230 MPN is the standard used by DHS to help identify shellfish that have been contaminated by fecal waste and that is used by FDA as a market standard. DHS has calculated the 95^{th} percentile based on the 95% confidence limits for the method. Using a tissue standard has proven to be very valuable because it integrates water quality over time. A water quality sample is an instantaneous sample. There is no way of knowing what the shellfish were exposed to 24 or 48 hours before sampling. Concentrations of fecal coliforms in shellfish are accumulated over several days and, therefore, are a better indicator of exposure than water alone. In addition, shellfish are what people are actually going to consume, therefore, they are a more direct measure of risk. There have been several instances

where the DHS shellfish program identified contamination problems by analyzing shellfish that were not apparent from water samples. Therefore, we feel that this tissue target is essential in determining if beneficial uses are protected and is a refinement of the water quality objective.

The third target is zero discharge of human waste to the waters of Tomales Bay and its tributaries. This target is based on the knowledge that human waste is a source of pathogenic organisms, including viruses, and attainment of fecal coliform objectives by themselves does not necessarily protect human health. Fecal coliforms are bacterial indicators that have different characteristics than other pathogens, particularly viruses, that cause disease in humans. Both animal and human waste contain microorganisms that can cause disease in humans. Although animal waste is associated with a variety of bacterial pathogens, human waste can contain both bacterial and viral pathogens and is the greatest concern relative to human health impacts from contaminated water. Because it would be impossible to routinely monitor for all pathogenic organisms, and because viruses are particularly difficult to measure, indicator organisms are used to assess microbiological water quality. Indicator organisms, such as fecal coliforms, are not necessarily pathogenic, but are easily detected and are abundant in wastes from warm-blooded animals. However, we know, based on the human disease outbreak in Tomales Bay in 1998, as well as other evidence, that meeting fecal coliform objectives does not necessarily protect human health.

We believe that an essential component of measures to protect human health from the transmission of viruses is to have a target of zero discharge of human waste in to Tomales Bay or its tributaries. The RWQCB already prohibits discharge from sewage treatment systems into Tomales Bay or the creeks within the watershed based on a prohibition in the Basin Plan in Table 4 -1 which states: " It shall be prohibited to discharge: #5. Any wastewater which has particular characteristics of concern to beneficial uses to Tomales Bay, Drakes Estero, Limantour Estero, Bolinas Lagoon, or Richardson Bay (between Sausalito Point and Peninsula Point)". This prohibition is applicable to discharge of human waste from recreational activities (boating, camping etc.) as well as septic systems. Septic systems that discharge to land and that are in accordance with accepted design standards (new systems) or performance standards (existing systems) and are properly operated and maintained are acceptable. There is currently legislation being considered (AB 885) that would require DHS to develop performance standards for septic systems in the coastal zone. In addition, Marin County is revising its regulations in regard to septic systems. The County is forming a technical advisory committee, that includes members of the public, that will advise them on the revision of these regulations. We believe these efforts will result in design and performance standards that can be implemented by the County.

We consider all three targets water quality objectives or specific refinements of water quality objectives or prohibitions included in the RWQCBs Basin Plan. The first target is a water quality objective included in the RWQCBs Basin Plan to protect the beneficial use of shellfish harvesting. The second tissue target is a DHS and FDA standard from the NSSP (U.S.FDA, 1995). We consider the tissue target a refinement of the water quality objective. The third target, the prohibition on the discharge of human waste, we consider under the discharge prohibitions in the RWQCB Basin Plan.

Progress Report

There are many efforts currently taking place that are directed at remediating Tomales Bay by reducing pathogens. The TBSTAC has developed recommendations and is currently considering how to implement those recommendations. Their recommendations are:

TBSTAC Recommendations

The RWQCB will continue to work with the TBSTAC in developing a remediation strategy to reduce pollution affecting the commercial shellfish growing areas, as directed by the Shellfish Protection Act of 1993. As noted in the Act, the RWQCB will work with other agencies, the shellfish growers, and the agricultural community representatives to "develop and implement specific remediation strategies". The shellfish study pointed out the impacts to the Bay from the eastern watershed streams that primarily flow through dairy and grazing lands. In addition to these sources of contamination, the RWQCB and the DHS are working with the National Park Service, California State Parks, and the County of Marin to address the pollutant impacts from on-site domestic and commercial sewage systems and from recreational activities such as boating and camping.

Remediation strategies in response to the findings of the 1995-96 study and other information was developed by the TBSTAC, whose membership includes the responsible regulatory agencies, park service staff, agricultural representatives, shellfish growers, local environmental groups, and community members. Although many recommendations identify the TBSTAC as the lead, the responsibility for follow-up will likely be delegated to the responsible agency or agencies, a subcommittee of the TBSTAC, or by other represented groups participating in this effort.

Pathogen Source Control Measures

Agriculture

1. The Tomales Bay Agricultural Group (TBAG) should develop a performance-based program for each dairy in the watershed, which will include custom-based farm plans that will be designed to prevent water quality violations. These plans will include nutrient budgets; pond capacity; stream protection; and manure management, including spreading and irrigation, erosion control, animal housing, and record keeping of application of animal wastes. It will also include a self-monitoring third-party testing program to reduce fecal coliform. The entire program will be developed with the help of the U.C. Cooperative Extension and other experts. Progress reports and results of pilot projects should be included as part of the program, along with details on the strategy and approach. Inclusion of other agricultural producers should be included as the situation warrants.

2. The TBSAC should develop a priority list of pilot watershed projects to address impacts of animal waste facilities on water quality. For example, projects designed to

make improvements in animal confinement areas, use of innovative animal waste treatment technologies, improvements in manure disposal strategies, and riparian corridor protection projects could have a major beneficial impact to water quality in Tomales Bay and its watershed. If deemed a priority, livestock numbers in the watershed, both existing and historical, should be quantified.

Domestic and Municipal Wastewater/Sewage Systems

1. The TAC should encourage and support efforts to develop community consensus on proposed East Shore Planning Group (ESPG) proposals as follows: As a residential non-profit with a varied membership, the ESPG will need time to develop and establish a consensus of the community on a course of action. Their annual meeting was held on September 26th, 1999. Proposals to the community were presented at that time.

   The East Shore Planning Group has adopted the following programs:
   Formation of a subcommittee to explore the viability of establishing a separate local non-profit entity comprised of property owners on the east shore of Tomales Bay. This proposed organization could tentatively be called the Marshall Water Quality Association (MWQA). This ESPG subcommittee will seek property owners' consensus to identify the most appropriate measures that would continue to maintain Tomales Bay water quality.

   The ESPG subcommittee will explore and evaluate through MWQA the coordination and possible cost sharing of the following septic management properties:

   a. Evaluation
   b. Water quality monitoring
   c. Pumping
   d. Maintenance
   e. Repairs
   f. Education
   g. Water conservation

   MWQA would explore options for specific individual or neighbourhood septic management programs, which fit each of the area's geographic conditions and respective complex site conditions. MWQA will enlist expertise and material support from the County, State and federal agencies, which have the responsibility for Tomales Bay water quality.

2. All on-site systems need to be addressed by regular evaluation. Communities should be encouraged to develop their own plans for on-site system evaluation and monitoring. The County and Regional Board should provide support for these community efforts.

Recreational Activities

1. The National Park Service, as lead agency, working with state and county parks departments, should develop a needs assessment and management plan, with a timeline for implementation, to improve boater facilities and procedures for day use and overnight camping waste collection, including: a) pollution controls (including pack out provisions) on unimproved beaches, b) increased public education and signs at points of entry, and c) enhanced and coordinated enforcement.

Education and Outreach Activities

1. The TBSTAC should identify educational and outreach needs to reach ranchers, media, local communities and visitors, to educate them about the resource values of Tomales Bay, the impacts to the Bay from different pollutant sources, and the remediation efforts that are currently underway or that need to be addressed.

2. The TBSTAC should develop local library repositories of information on Tomales Bay, with links to similar efforts in other areas.

3. The TBSTAC should evaluate existing data and the need to identify ways to publicise advisories to users that water quality may not meet the standards for water contact and recreational shellfish harvesting following significant rainfall events.

Policy Development

1. Designate the shoreline region of Tomales Bay as a sensitive zone relative to potential impacts to beneficial uses. Activities within this designated area would require greater oversight by all users and the responsible agencies to ensure protection of all beneficial uses and public health. As part of this effort, the RWQCB should investigate the requirements and desirability of having the Environmental Protection Agency designate Tomales Bay as a no-discharge area for vessel sewage wastes. This would include an investigation of the existing regulations in the National Marine Sanctuary regarding vessel wastes and mooring regulations.

2. Obtain support from the Marin County Board of Supervisors and the Marin County Environmental Health Department to assign a high priority to the protection of the beneficial uses of Tomales Bay.

Monitoring and Assessment

1. Compare land use practices and water sources in the subwatersheds represented by the sampling stations at Mileposts 36.17 and 38.54, which had low coliform counts, with the remaining eastern shoreline subwatersheds that exhibited high fecal coliform loadings.

2. In those areas that experience high levels of fecal contamination but where obvious sources of fecal contamination cannot be identified, a monitoring strategy should be

developed for impacted waterbodies and pollutant sources, based on the results of the current shellfish study. The purpose of the monitoring would be to identify specific point sources of fecal coliform in order to be able to develop specific remediation activities. This effort should be coordinated with the Tomales Bay Agricultural Group actions where appropriate.

3. Pursue the identification of sources of fecal contamination in the watershed, with a priority on the watersheds for Chileno and Lagunitas creeks. This may involve the development of a priority list and plan of action for surveying the areas of concern. This effort should be coordinated with the Tomales Bay Agricultural Group actions where appropriate.

4. Investigate the use of DNA fingerprinting techniques and other indicator studies as to usefulness of determining specific sources of coliforms.

5. Promote studies aimed at improving our understanding of pathogen transport processes.

6. Develop a monitoring program to track the environmental fate of pathogens, aimed at evaluating spatial and temporal pathogen concentration trends and loadings, and the effectiveness of source control efforts.

7. Develop a study to clarify the concentrations, movement and longevity of human pathogens in Tomales Bay.

Implementation of Recommendations

Agriculture

In order to implement measures that would reduce the input of fecal coliforms from animal facilities the TBAG is collaborating with the University of California, Cooperative Extension Program to assist the community to better understand the relationship between coliform levels in Tomales Bay and land use practices. This project will include implementing best management practices at these facilities. and monitoring their effectiveness. The objectives of this project are to: 1) provide a science-based link between coliform inputs to the Bay and agricultural practices within the watershed, 2) evaluate animal waste management practices to reduce pollution and 3) develop resources management policies and a Hazard Analysis and Critical Control Points (HACCP) plan for waste management that would reduce coliform contamination of shellfish growing waters by tracking potential pathogens in the environment and identifying critical points where they can be eliminated or where management practices can be implemented to reduce exposure. This project is currently underway.

Septic Systems

The Environmental Action Committee and other community groups sponsored a "Septic Social" that was attended by approximately 70 residents. This social was a positive and

successful event designed to provide information to homeowners and to encourage improvements and maintenance of septic systems.

The Marin County Board of Supervisors is currently appointing members to a newly established Septic system Technical Advisory Committee (SepTAC). The new committee will review all aspects of current County ordinances, regulations, policies and procedures concerning septic systems in Marin County. The committee will be appointed for a one-year term and will make recommendations to the Marin County Board of Supervisors at the six-month and one-year points.

Recreation

Marin County and the National Park Service have increased the number of portable toilets at recreational sites. The County is planning to put a pump-out facility and improved restrooms at Miller Park.

Education and Outreach

The National Park Service and commercial recreation companies have increased efforts to educate the public not to deposit any human waste in or near Tomales Bay. In addition, a Tomales Bay Watershed Council has been established. One of the main activities of the council will be public education and outreach on environmental issues concerning Tomales Bay.

Monitoring and Assessment

The monitoring and assessment of water quality in Tomales Bay and its tributaries is continuing. During the winter of 1999-2000 water samples were collected and analysed for fecal coliforms by several groups and agencies that include the RWQCB, Ca. Dept of Fish and Game, DHS, shellfish growers, National Park Service, UC Cooperative Extension and the Inverness Public Utility District. The DHS is currently conducting a sanitary survey of Tomales Bay. A report is expected in approximately September 2000.

For the winter of 2000-2001 the TBSTAC monitoring subcommittee will help coordinate the efforts of the various agencies and organizations conducting monitoring so that monitoring can be more efficient and useful in identifying sources, verifying loads, determining what types of land use practices contribute to high fecal coliform concentrations and developing information for the TMDL.

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FIGURES

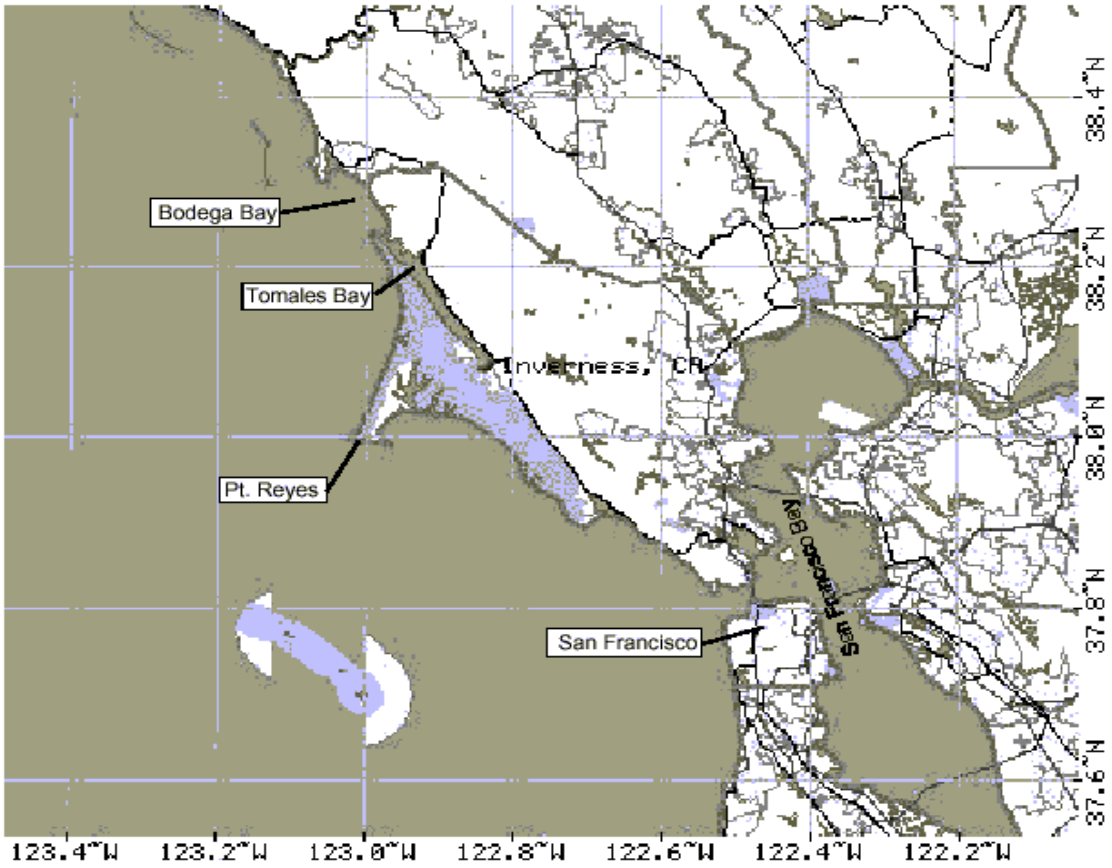

Figure 1. Location of Tomales Bay, Marin County, California (U.S. Census Tiger Map).

Figure 2. Tomales Bay

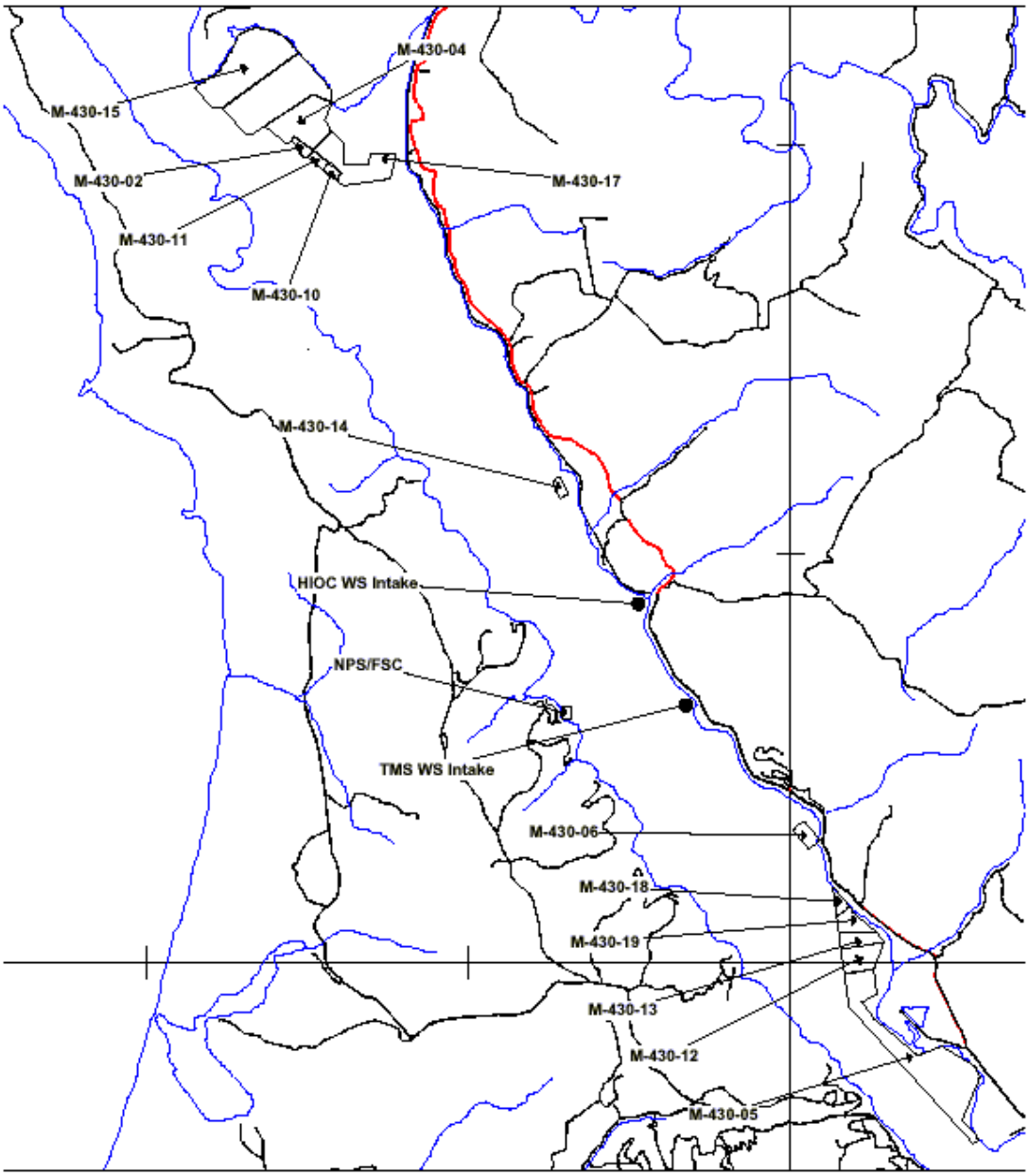

Figure 3. General location of commercial shellfish growing area leases in Tomales Bay, California.

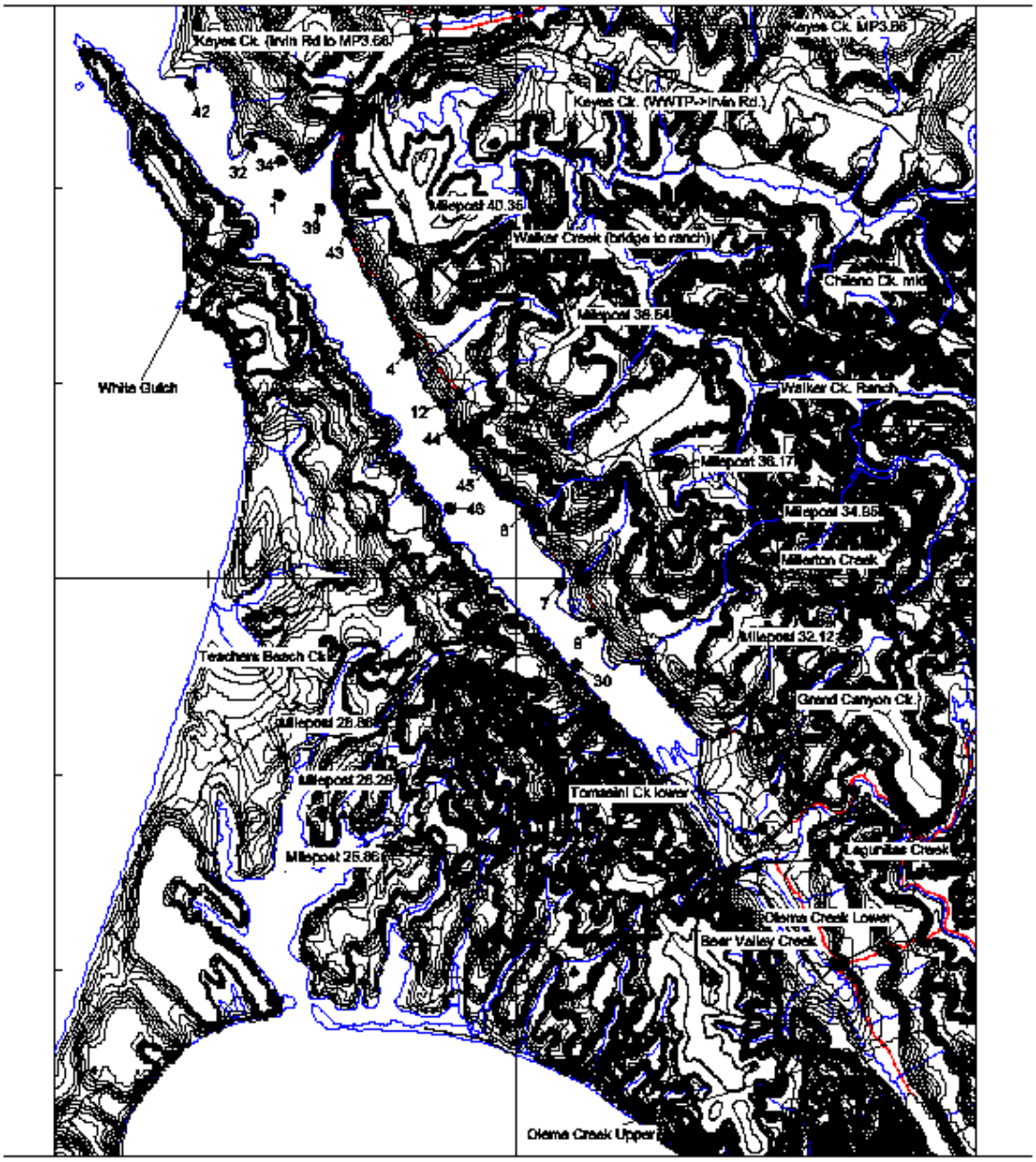

Figure 4. Location of Tomales Bay sampling stations, and tributary stations with their respective subwatersheds. (Scale: 1 inch = 1.9 miles)

TABLES

Table 1. Tomales Bay watershed area estimates, including reservoirs (adapted from Fischer, 1996).

WATERSHED	AREA (km^2)	AREA (%)
Walker	196.35	35
Lagunitas	241.72	43
Olema	50.0	9
Remainder	72.93	13
TOTALS	**561**	**100%**

Table 2. Area estimates for the gauged portions of the Tomales watershed, including release and spill from catchment reservoirs and unimpaired flow from the watershed below the reservoirs (Fischer, 1996).

WATERSHED	AREA (km^2)	AREA (%)
Walker	78.54	14
Lagunitas	213.18	38
Remainder	269.28	48
TOTALS	**561**	**100%**

Table 3. Estimates of watershed contributions to runoff into Tomales Bay (Fischer, 1996).

WATERSHED	% of TOTAL
Walker	25
Lagunitas	66
Remainder	9
TOTALS	**100%**

Table 4. Estimated numbers of livestock[1] and manure production in Tomales Bay watershed (totals/watershed/day)[2].

DRAINAGE	DAIRY (Cows and Heifers)	MANURE Lbs/Day	BEEF	MANURE Lbs/Day	SHEEP	MANURE Lbs/Day	TOTAL HEAD	TOTAL MANURE
Chileno Creek	2592	231,693	230	12,834	---	---	2563	244,527
Keyes Creek	786	70,151	---	---	---	---	786	70,151
Walker Creek	1182	105,553	540	30,132	1000	7200	2722	142,885
Marshall to Pt. Reyes Station	3847	343,553	550	30,690	---	---	4397	374,243
Lagunitas/Nicasio Reservoir	2563	229,135	230	12,834	---	---	2563	241,969
Totals	10,970	980,084	1320	86,490	1000	7200	11,254	1,448,018

[1] Approximate numbers based on rough estimates by the University of California Cooperative Extension

[2] Table adapted from R. Bennett and S. Larson, *Preventing Animal Wastes from Degrading Water Quality: The Case for Tomales Bay, California, 1990.*

Table 5. Permitted sewage treatment systems in the Tomales Bay watershed, which are regulated under Waste Discharge Requirements from the San Francisco Bay Regional Water Quality Control Board.

NAME	LOCATION	WASTE (GPD[3])	WASTE SOURCE	TREATMENT TYPE	DISPOSAL	OPERATOR
Tomales Wastewater Treatment Plant	3 miles from Bay along Keyes Creek	38,000 (design) 11,000 (average)	Tomales (89 homes & school dist.)	Aerated storage ponds	Spray Irrigation April to November	North Marin Water District
Marconi Conference Center	Highway 1 at Marconi Cove	25,000 (design) 13,500 (actual)	Conference facilities	Package plant secondary treatment	Leaching trench w/backup irrigation	California State Parks
Borello Sewage Ponds	NE of Millerton Point above Millerton Creek	3400 (average)	Domestic and commercial septage	Holding ponds	Spray irrigation April-October	Owner operated
Skywalker Ranch	Lucas Valley Road, upper Nicasio Creek	8975 (maximum)	250 daytime users	Three septic tanks	Dual leachfields	Skywalker Ranch
Olema Campground	3.5 miles SW of Tomales Bay along Olema Creek	18,000 daily maximum	238 unit Campground	Septic tanks, holding tank, storage ponds	Spray irrigation, April – October	Campground owner
Samuel P. Taylor Park	10 miles SE of Bay along Lagunitas Creek	80,000 (design) 45,000 (actual)	Campground, park	Digestor, primary clarifier, trickling filter	Leachfields, spray disposal if necessary	California State Parks
Blue Mountain	2 miles E of Tomales on Keyes Creek	4000 (actual)	50 residents, day use	Septic tanks, holding tank, 2 evaporation ponds	Discharge to leachfields	Blue Mountain Center
Spirit Rock	Sir Francis Drake Blvd. in Woodacre	9000 (design) 4875 (actual)	Residents, classes	2 Septic, one conventional, one sand filter	Leach fields	Insight Meditation Center
Walker Creek Ranch	11 miles from Bay, on Petaluma-Pt. Reyes Road	20,000 (design) 14,000 (actual)	100-220 overnighters, 230 day use	Package plant, activated sludge	Holding pond, pasture irrigation May – Sept.	Marin County Office of Education

[3] GPD = Gallons per Day

Table 6. Commercial shellfish growers and wet storage operators in Tomales Bay.

COMPANY	REG. NO.	DFG LEASE	NO. ACRES	PRODUCTS
Marin Oyster Company	00256	M-430-02	5	Pacific Oysters
Charles Todd Friend	00256	M-430-04	62	Pacific Oysters
Bay Bottom Beds, Inc.	00256	M-430-04	25	Pacific Oysters
Cove Mussel Co.	00311	M-430-06	10	Bay Mussels, Pacific Oysters
Hog Island Oyster Co. Inc.	00265 00364	M-430-10 M-430-11 M-430-15 M-430-12	5 5 98 25	Pacific Oysters, Eastern Oysters, European Oysters, Manila Clams, Bay Mussels
Point Reyes Oyster Co.	00416	M-430-13 M-430-14 M-430-17	25 5 62	Pacific Oysters, European Oysters, Kumamoto Oysters, Bay Mussels
Frank Spenger Co.	00280	None: PRNS Parcel	1	Pacific Oysters
Tomales Bay Shellfish Farms, Inc.	00330	M-430-05 Intake	156	Pacific Oysters, Bay Mussels, Manila Clams, European Flat Oysters

Table 7. Water quality objectives for coliform bacteria[4]. (From Regional Water Quality Control Plan [Basin Plan], 1995).

Beneficial Use	Fecal Coliform	Total Coliform
Water Contact Recreation[5]	log mean < 200	median < 240
	90th percentile < 400	no sample > 10,000
Shellfish Harvesting[6]	Median < 14	Geometric Mean < 70
	90th Percentile < 43	90th Percentile < 230[7]
Non-Contact Water[8,9]	Mean < 2000	
	90th Percentile < 4000	
Municipal Supply:		
surface water[10]	Log Mean < 20	Log Mean < 100
ground water		< 1.1[11]

[4] Based on a minimum of five consecutive samples equally spaced over a 30-day period.
[5] Freshwater and ocean water. Freshwater values are based on DHS recommended values.
[6] Source: National Shellfish Sanitation Program.
[7] Based on a five-tube decimal dilution test. Use 300 MPN/100 mL when a three-tube decimal dilution test is used.
[8] Source: Report of the Committee on Water Quality Criteria, National Technical Advisory Committee, 1968.
[9] Freshwater
[10] Source: DHS recommendation.
[11] Based on multiple tube fermentation technique; equivalent test results based on other analytical techniques, as specified in the National Primary Drinking Water Regulation, 40 CFR, Part 141.21(f), revised June 10, 1992, are acceptable.