Total Maximum Daily Loads for the Hanalei Bay Watershed

PHASE 2 – Embayment

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List of Abbreviations

BMP	Best Management Practice
CFR	Code of Federal Regulations
CFU	Colony Forming Units
CWA	Clean Water Act
CWB	Clean Water Branch (HIDOH)
EFDC	Environmental Fluids Dynamic Code
Entero	Enterococcus
EPO	Environmental Planning Office (HIDOH)
GIS	Geographic Information System
HAR	Hawaii Administrative Rules
HIDOH	State of Hawaii Department of Health
HSPF	Hydrologic Simulation Program – Fortran
KGD	Kilograms Per Day
LA	Load Allocation
LSPC	Loading Simulation Program in C++
MOS	Margin of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NH4	Ammonia
NOAA	National Oceanic and Atmospheric Administration
NOx	Nitrite Plus Nitrate
NPDES	National Pollutant Discharge Elimination System
NTE	Not to Exceed
NTU	Nephelometric Turbidity Units
#/day	Number Per Day
NWR	National Wildlife Refuge
SSM	Single Sample Maximum
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
Toolbox	TMDL Modeling Toolbox
TP	Total Phosphorous
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQC	Water Quality Criteria
WQLS	Water Quality Limited Segment

Acknowledgements

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Executive Summary

The State of Hawaii Department of Health (HIDOH) proposes establishing a total of two (2) Total Maximum Daily Loads (TMDLs) for the marine water embayment of the Hanalei Bay Watershed on the island of Kauai, Hawaii. TMDLs are required for pollutant-impaired water bodies on the State's Clean Water Act Section 303(d) list [CWA §303(d)]. The primary objectives of the proposed TMDLs are to stimulate and guide action that will control sources of excessive nutrients, sediment, and pathogens, and to improve the water quality of the embayment waters so that their designated and existing uses will be protected and sustained. These uses include protection of native breeding stock; the support and propagation of aquatic life, shellfish, and other marine life; conservation of coral reefs and marine wilderness areas; recreation; aesthetic enjoyment; and support for traditional and customary native Hawaiian beliefs, values, and practices.

Ongoing water quality monitoring and assessment efforts point to sediments, nutrients, and microbial pathogens as the pollutants of concern in this watershed. HIDOH employs a phased approach to the ongoing development and implementation of TMDLs throughout the Hanalei Bay watershed, so that new information obtained in the next phases of the TMDL process can be used to revisit impairment decisions, load allocations, and implementation strategies and tactics. In Phase 1 (2008), HIDOH established Total Maximum Daily Loads (TMDLs) for total suspended solids in Hanalei Stream and Hanalei Estuary (together defined as the Hanalei Stream System), Waipa Stream and Estuary (Waipa Stream System), and in the Waioli, Waipa, and Waikoko Estuaries; and for *enterococcus* in the Hanalei Stream System. The Phase 2 analysis of marine embayment waters confirms that implementing the Phase 1 and Phase 2 sediment and bacteria TMDLs will result in the attainment of water quality criteria for turbidity and *enterococcus* in Hanalei Bay.

Federal regulations and guidance require that HIDOH allocate the approved TMDLs between point source discharges regulated under NPDES discharge permits (Waste Load Allocations) and nonpoint source runoff that is not regulated by discharge permit (Load Allocations). However, because no NPDES permits that require Waste Load Allocations have been issued in the Hanalei Bay Watershed, this TMDL decision document only provides Load Allocations (LAs) for nonpoint source runoff. If Waste Load Allocations (WLAs) are required to accommodate future point source discharges, then the LAs would have to be revised and the overall changes in the TMDL allocations would have to be approved by the U.S. Environmental Protection Agency (USEPA).

The *enterococcus* TMDL is based on the geometric mean criterion only. For implementation purposes, in general, HIDOH does not consider chronic exceedances of *enterococcus* criteria to unequivocally represent threats to human health or impairments of recreational use. Before taking action to implement bacterial indicator TMDLs, it is important to acquire more conclusive evidence that human sewage or human-pathogenic organisms are present at levels that indicate an unacceptable public health risk. According to the HIDOH on-site disposal system strategy and water quality monitoring strategy, any implementation activities

conducted should first focus on inventory and inspection of sanitary sewer collection systems and individual wastewater systems; repair and upgrade of failing and sub-standard systems (as indicated by inspection results); and completion of watershed sanitary surveys and wastewater source tracking to complement information obtained from system inventory/inspection and ambient receiving water monitoring.

If WLAs are required to accommodate future point source dischargers, the State will assure implementation of approved TMDL WLAs through the enforcement of NPDES permit conditions (HAR §11-55). The State will pursue implementation of LAs through Hawaii's Implementation Plan for Polluted Runoff Control (HIDOH, 2001), Hawaii's Coastal Nonpoint Pollution Control Program Management Plan (Hawaii Coastal Zone Management Program, 1996), the Clean Water State Revolving Fund Intended Use Plan (annual), and Watershed Based Plans and TMDL Implementation Plans that address the nine elements required by USEPA guidance for awarding Clean Water Act §319(h) funds (USEPA, 2003a). HIDOH Watershed Based Plans and TMDL Implementation Plans are expected to incorporate the LA objectives from Table 10 and Table 11 in Section 7.4 of this decision document, reproduced here as Table ES-1 and Table ES-2. The plans may also be guided by the estimated distribution of existing loads by land cover shown in Table 9) and by the distribution of TMDL allocations by estuary/sub-watershed shown in Figures 21 and 22.

Table ES-1. Total Suspended Solids TMDL Load Allocations and Load Reductions Required to Achieve TMDLs for Hanalei Bay

TMDL Allocations		**Total Suspended Solids TMDLs***		
		Geometric Mean	**10% Not-to-Exceed**	**2% Not-to-Exceed**
LA	**(kgd)**	842.4	1,302.1	1,722.5
MOS	**(kgd)**	44.3	68.5	90.7
TMDL	**(kgd)**	886.8	1,370.6	1,813.2
Existing Load	**(kgd)**	4,319.5	4,319.5	4,319.5
Reduction Required	**(kgd)**	3,432.7	2,948.9	2,506.3
	(%)	79.5%	68.3%	58.0%

Note: TMDL allocations in kilograms per day are obtained by dividing annual values by 366 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram; thus,

(a) **Totals** may be different than the sum of their parts, and
(b) **TMDLs**, **Existing Loads** and **Reductions Required** may actually be greater than 0.

Embayment loads are inclusive of Phase 1estuary and stream loads.

*Based on attainment of wet condition criteria, which apply to an embayment when the average daily fresh water inflow to the embayment equals or exceeds one percent of the embayment volume. For 2004, fresh water inflow exceeded one percent of the embayment volume each day (Data Inventory and Analysis).

Acronyms: LA = Load Allocation; MOS = Margin of Safety; TMDL = Total Maximum Daily Load; kgd = kilograms per day

Table ES-2. *Enterococcus* TMDL Load Allocations and Load Reductions Required to Achieve TMDLs for Hanalei Bay

TMDL Allocations		***Enterococcus* TMDL***	
		Geometric Mean	Single Sample Maximum
LA – Surface Water	**(CFU/day)**	3.1E+12	3.1E+10
LA – Groundwater	**(CFU/day)**	1.4E+11	1.5E+09
MOS	**(CFU/day)**	1.7E+11	1.7E+09
TMDL	**(CFU/day)**	3.4E+12	3.4E+10
Existing Load	**(CFU/day)**	5.3E+12	5.3E+12
Reduction Required	**(CFU/day)**	2.0E+12	5.3E+12
	(%)	36.9%	99.4%

Note: TMDL allocations in colony forming units (CFU) per day are obtained by dividing annual values by 366 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 CFU; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs**, **Existing Loads** and **Reductions Required** may actually be greater than 0.

Embayment loads are inclusive Phase 1 estuary and stream loads.

*The TMDL decision is based on the attainment of the revised geometric mean marine recreational criterion adopted in 2009 (35 cfu/100 ml). The single sample maximum analysis is presented for informational and diagnostic purposes only. The 303(d) listings are based on geomean analysis, therefore they are addressed by the geomean TMDL.

Acronyms: LA = Load Allocation; MOS = Margin of Safety; TMDL = Total Maximum Daily Load; #/day = number per day

1. Introduction

Section 303(d) of the Clean Water Act (CWA) requires that a state identify waterbodies that do not attain their designated uses, even after technology-based controls are applied to pollutant sources. In general, we identify a non-attaining waterbody by applying an assessment methodology that focuses on comparing measured water quality to applicable water quality criteria (WQC) and other evaluative measures; a waterbody that exceeds WQC and other measures at a pre-defined threshold is "impaired," and is placed on the state's 303(d) list. The CWA also requires a state to prioritize the development of Total Maximum Daily Loads (TMDLs) for its impaired waters. A TMDL establishes the allowable load of a pollutant—or other quantifiable parameter—that will achieve WQC, based on the relationship between pollutant sources and receiving water quality. The TMDL process provides a scientific basis for a state to establish water quality-based controls that reduce pollution from both point and nonpoint sources, and restore and protect the beneficial uses of the state's water resources (USEPA, 1991).

TMDLs provide a strategy for achieving WQC by allocating quantitative limits for pollutant loads from point and nonpoint pollution sources. A TMDL is defined as the sum of the individual waste load allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background, such that the capacity of the waterbody to assimilate pollutant loading (i.e., the loading capacity) is not exceeded. 40 CFR §130.2. The TMDL process includes a technical analysis with the following components:

(1) a **Problem Statement** describing the waterbody impairment, including uses and WQC;

(2) identification of **Numeric Targets** for attaining the WQC and protecting beneficial uses;

(3) a **Source Analysis** to identify all of the point and nonpoint sources of the impairing pollutant and to estimate the current pollutant loading for each source;

(4) a **Linkage Analysis** to calculate the Loading Capacity of the waterbody for the pollutant; i.e., the maximum amount of the pollutant that may be present in the waterbodies without exceeding WQC thresholds and impairing beneficial uses;

(5) a **Margin of Safety** (MOS) to account for uncertainties in the analyses;

(6) the division and **Allocation of the TMDL** among each of the contributing sources - wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint and background sources;

(7) a description of how the TMDL decision accounts for **Seasonal Variation and Critical Conditions**; and

(8) a description of the **Public Participation** process that explains how it influenced the TMDL decision.

The State of Hawaii Department of Health (HIDOH) and the United States Environmental Protection Agency (USEPA) coordinated a watershed assessment and modeling project to support the calculation of *enterococcus* and total suspended solids (TSS) TMDLs for Hanalei Bay, based on the water quality impairments identified on the 2006 section 303(d) list. Figure 1 presents the general location of Hanalei Bay and its contributing watersheds.

This effort builds upon a previous TMDL decision and is therefore called "Phase 2 – Embayment." In Phase 1, TMDLs, Informative TMDLs, and load targets for bacteria, sediment, and nutrients were developed for the impaired streams and estuaries of the Hanalei Bay Watershed (Tetra Tech and HIDOH, 2008).

Figure 2 illustrates the waterbody impairments associated with Phase 1 (streams and estuaries) and Phase 2 (embayment).

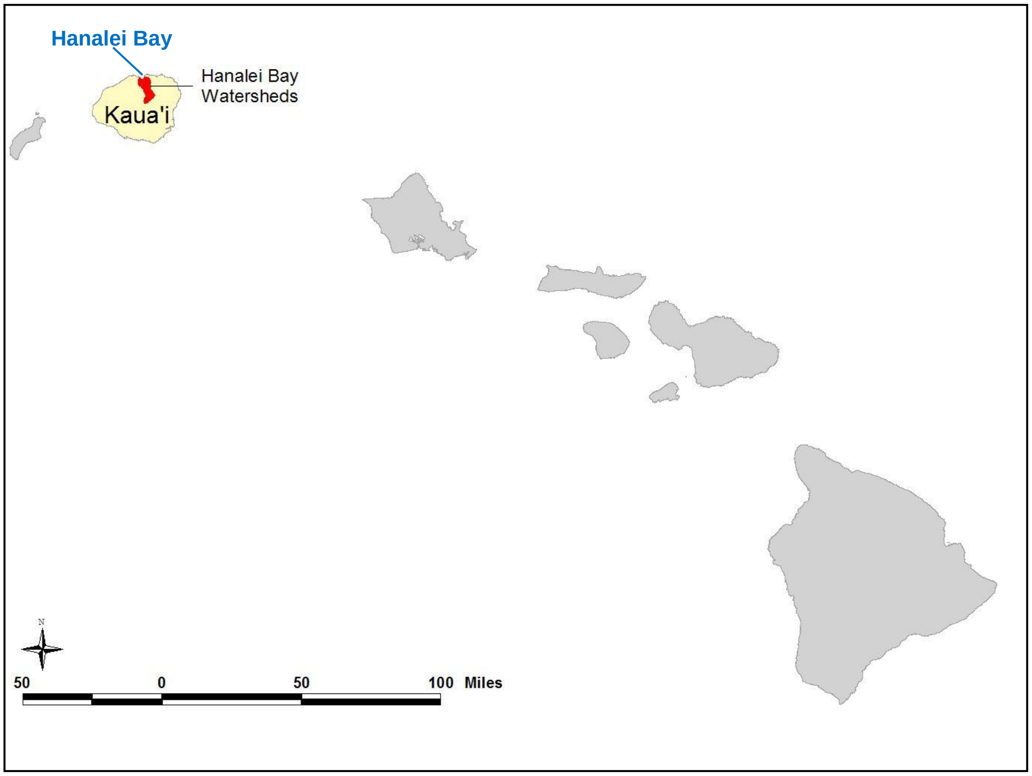


Figure 1. Location of the Hanalei Bay and watershed

This Phase 2 rationale develops TMDLs for *enterococcus* and sediment in Hanalei Bay itself. These TMDLs are expressed as load allocations for the nonpoint sources and as the load reductions required (from existing loading levels) to achieve the TMDLs. Because turbidity is not usually treated as a mass-based constituent, calculating turbidity loads is problematic. Therefore, we used TSS targets as a surrogate for turbidity (see HIDOH, 2005; Oceanit Laboratories, Inc., et al., 2002). However, we incorporated the turbidity WQC into the TMDL calculation for the embayment to ensure the attainment of the turbidity criteria.

The results of the Phase 2 embayment analysis address the eight TMDL components listed above. Section 2 provides an overview of the watershed and its water quality impairments.

Section 3 describes the numeric WQC used for TMDL analyses, and Section 4 compares measured water quality to these WQC. Section 5 presents the source analysis, while Section 6 presents the linkage analysis. Section 7 explains how we calculated the TMDLs and shows the results of the calculations. Section 8 discusses alternatives for implementing the TMDLs and achieving water quality improvements, and Section 9 describes and explains the public participation process.

2. Problem Statement

The Hanalei River is one of Hawaii's largest rivers, and was designated as an American Heritage River in 1998. It drains into the Hanalei River Estuary approximately 3.5 river miles upstream from Hanalei Bay, which is also fed by the Puupoa (Waileia subwatershed), Waioli, Waipa, and Waikoko stream systems. These five subwatersheds are collectively referred to as the Hanalei Bay Watershed. They support a variety of natural processes and anthropogenic activities, which are associated with different pollutants including bacteria, sediment, and nutrients.

TMDLs, Informative TMDLs, and load targets for the streams and estuaries of the Hanalei Bay Watershed were completed for bacteria, sediment, and nutrients in Phase 1 of the Hanalei TMDL (Tetra Tech and HIDOH, 2008). Phase 2 of the Hanalei TMDL develops TMDLs for *enterococcus* and sediment in Hanalei Bay itself. We assume that most of the bacteria and sediment entering the Bay is transported via the inland surface waters; therefore, reducing the pollutant loads from the stream systems should significantly improve embayment water quality. Other sources of Hanalei Bay pollutant loading include submarine groundwater discharge (SGD), as described in Section 5.2; stormwater runoff along the shoreline; and oceanic fluxes. The waterbody impairments associated with Phase 1 (streams and estuaries) and Phase 2 (embayment) are illustrated in Figure 2.

Enterococcus densities at various locations in the Hanalei Bay, when assessed in combination with levels of *Clostridium perfringens*, a secondary indicator, exceeded the numeric WQC at a sufficient frequency to place the waterbody on the 303(d) list (HIDOH, 2008a). Although the *enterococcus* WQC are written in terms of the density of indicator bacteria colonies, risks to human health stem from the presence of other, pathogenic microorganisms that can cause illness and disease when recreational water users ingest or absorb them. Direct measurement of pathogens is difficult and expensive. Therefore, high counts of other bacteria (those that originate from the intestinal flora of warm-blooded animals) are used to indicate the presence of pathogens.

Sources of bacteria vary widely. They include natural sources, such as feces from aquatic and terrestrial wildlife, and anthropogenic sources, such as cesspools, septic tanks, livestock, trash, pet waste, and illegal sewage disposal from boats. Bacteria can also regrow and multiply in the environment (Byappanahalli and Fujioka, 1998). Sources of bacteria, and mechanisms that transport bacteria to receiving waters, are discussed in greater detail in Section 5.2.

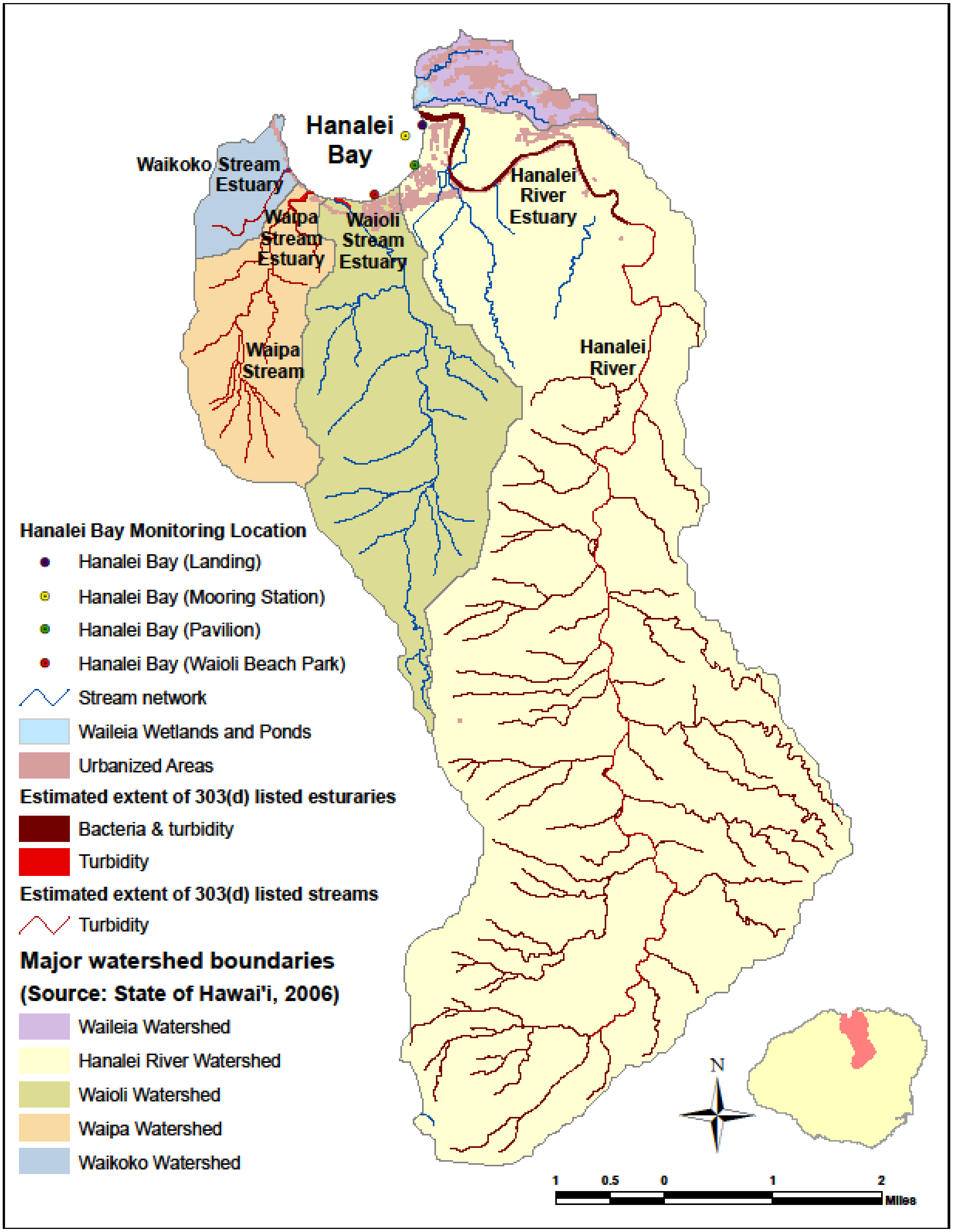


Figure 2. Water quality impairments in the Hanalei Bay Watershed

Turbidity levels at various locations in the Hanalei Bay also exceeded the numeric WQC at a sufficient frequency to place the waterbody on the 303(d) list (HIDOH, 2008a), as described in Section 4.2.1. Turbidity measurements express the opacity of the water by estimating the degree to which light is scattered and absorbed in the water column. This scattering and absorption is caused by suspended matter (such as sediment, algae, bacteria, etc.). Therefore, in addition to turbidity, total suspended solids (TSS) is often measured to evaluate sediment source areas and quantify sediment loadings. TSS concentrations may be elevated due to anthropogenic activities—including disturbance by feral livestock and agricultural and construction activities—as well as natural conditions, such as high precipitation and steep slopes. Sediment and turbidity sources in the Hanalei Bay Watershed are further described in Section 5.2.

2.1. Project Area Description

Hanalei Bay is a marine embayment covering approximately 1.2 square miles of ocean water along the north shore of Kauai (Figure 3). The crescent shaped bay is approximately 1¼ miles wide between the two headlands, and has two fringing reefs and six distinct reef habitats that support a high diversity of fish species (Friedlander and Parish, 1998). The Bay is a federally protected marine sanctuary for the humpback whale (Figure 4), and is heavily used for ocean recreation and subsistence fishing. The town of Hanalei (population 478), fronts the central portion of the bay, west of the Hanalei River mouth, and the resort community at Princeville (population 1,698) is located toward the eastern end of the bay (US Census, 2000).

Figure 3. Aerial image and recreational use of Hanalei Bay

The Hanalei Bay Watershed covers a 33.1 square-mile area draining to Hanalei Bay. This drainage area includes the Waileia (Puupoa streams), Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream subwatersheds (see Table 1). Figure 2 illustrates the geographic location of each subwatershed as well as the bay, and Figure 5 shows the distribution of land cover across the Phase 1 subwatersheds (Hanalei, Waioli, Waipa, and Waikoko) and within the Waileia subwatershed (Princeville), which has greater percentages of grassland and developed land than the Phase 1 areas. The watershed setting is described in greater detail, including topography and weather patterns, in the Phase 1 TMDL (Tetra Tech & HIDOH, 2008).

Table 1. Watershed Area (Office of Planning, 2006)

Watershed Name	Area (acres)	Area (square miles)	Percent of Total Area
Waileia (Puupoa streams)	509.1	0.82	2.4%
Hanalei River	15,125.5	23.63	71.5%
Waioli Stream	3,482.7	5.44	16.4%
Waipa Stream	1,591.8	2.49	7.5%
Waikoko Stream	458.0	0.72	2.2%
Grand Total	*21,167.1*	*33.1*	*100%*

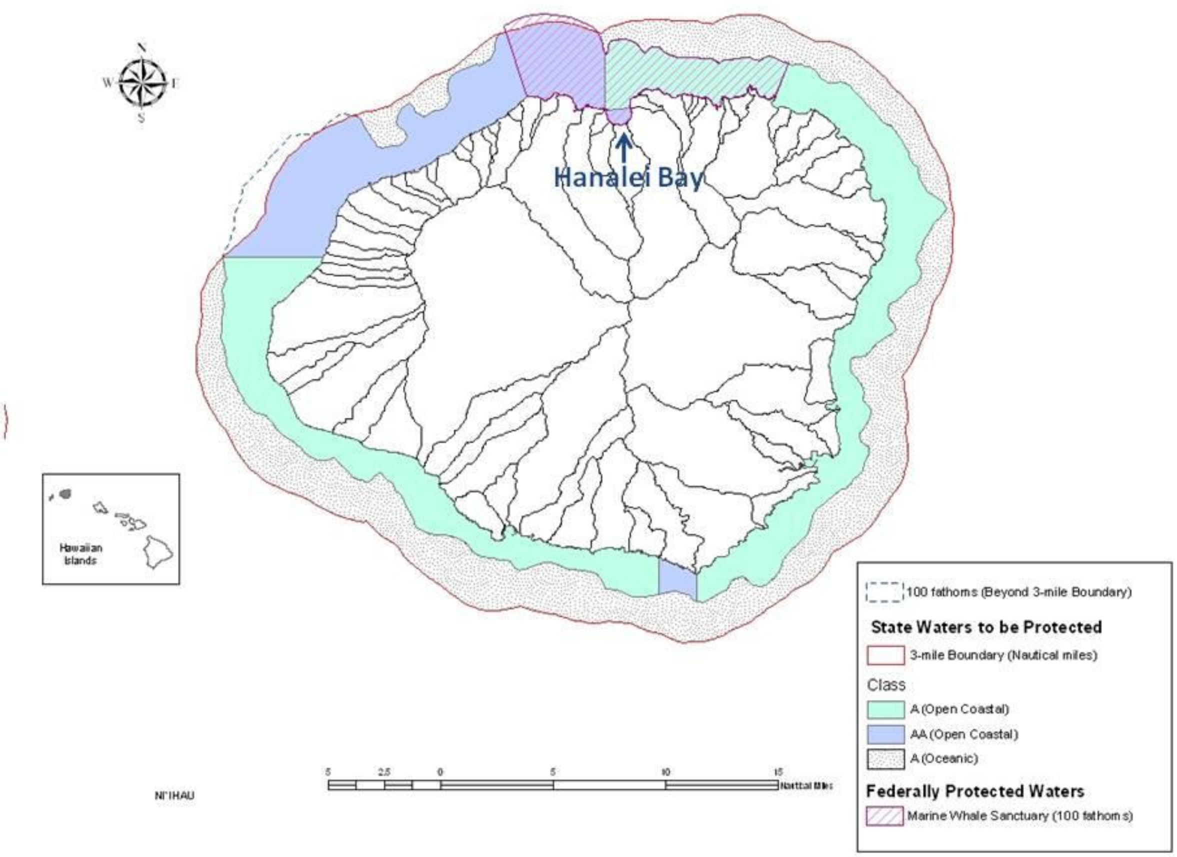
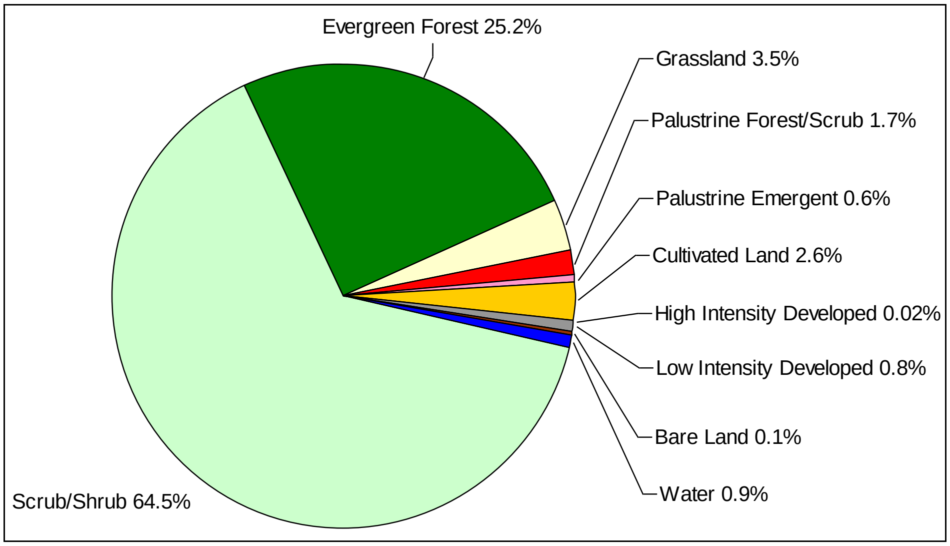


Figure 4. Kauai marine waterbody designations
(after HIDOH 2008a)

The Halelea Forest Reserve makes up a majority of the headwaters area. The Hanalei River passes through the Hanalei National Wildlife Refuge (NWR), which includes taro pond fields and other impoundments harboring endangered native waterbirds. The urbanized areas, which make up less than 1% of the total land area of the five subwatersheds, are primarily located near the ocean in Hanalei town center along the Kuhio Highway, and in Princeville (Department of Urban & Regional Planning, 2002).

Phase 1 land cover, combined (Hanalei, Waioli, Waipa, Waikoko), 20,658 acres



Additional Phase 2 land cover, Waileia, 509.1 acres

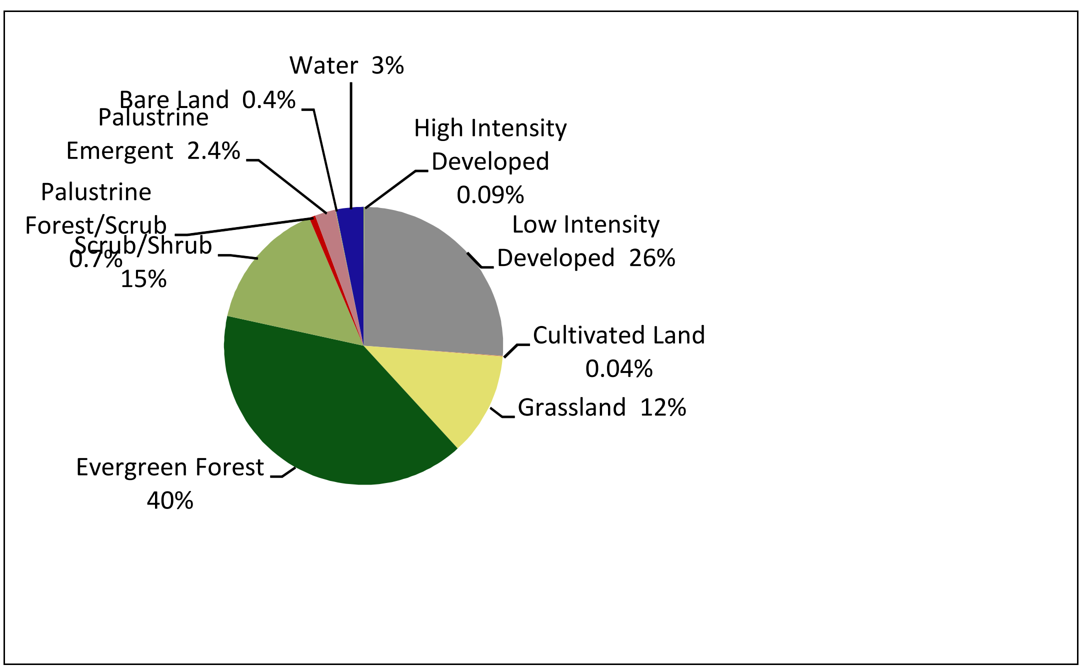


Figure 5. Hanalei Bay Watershed land cover distribution, Phase 1 and Additional Phase 2 (NOAA, 2000)

2.2. Impairment Overview

The embayment locations included in the Phase 2 TMDL analysis were listed as impaired due to non-attainment of the water quality criteria (WQC) thresholds for indicator bacteria or turbidity (HIDOH, 2008a). Numeric WQC for indicator bacteria are fixed to a single value, regardless of climatic conditions. However, WQC for turbidity are determined by climate-driven hydrologic conditions. The criteria for wet conditions apply where the average fresh water inflow to the embayment equals or exceeds one percent of the total embayment volume per day; alternatively, the criteria for dry conditions apply where fresh water inflow is less than one percent of the total volume of the embayment per day. Due to extreme precipitation in the headwaters, fresh water inflow consistently accounts for greater than one percent of the total volume of Hanalei Bay (Figure 6). Therefore, the impairment analysis and the TMDL are based on wet condition criteria for embayment turbidity (Table 2).

The results of the impairment analysis [the 2006 303(d) listings] are shown in Figure 2, Table 2, and Appendix II. Figure 2 illustrates the locations of the monitoring stations used to evaluate water quality in the bay, while Table 2 presents their corresponding *enterococcus* and turbidity impairments. The Phase 2 TMDLs (see Section 7) apply to the entire embayment, and address all of the embayment waterbody-pollutant combinations listed in Table 2.

Table 2. Water Quality Limited Segments Addressed by the Phase 2 Embayment TMDLs

Waterbody (Monitoring Station)	**Geocode ID**	**Condition**	***Enterococcus*** (geomean)	**Turbidity** (geomean)
Hanalei Bay (Landing)	HIW00093	Wet	Not attained	Not attained
Hanalei Bay (Pavilion)	HIW00092	Wet	Not attained	Not attained
Hanalei Bay (Mooring station)	HIW00157	Wet	Not attained	Unknown
Hanalei Bay (Waioli Beach)	HIW00091	Wet	Attained	Not attained

3. Numeric Target Selection

To calculate TMDLs, numeric targets are established for meeting WQC and thus ensuring the protection of beneficial uses. Hanalei Bay is used and protected as a Class AA receiving water, as described below, and as a federally protected marine sanctuary for the humpback whale (HAR §11-54-6; HIDOH, 2009):

Class AA It is the objective of Class AA waters that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. To the extent practicable, the wilderness character of these areas shall be protected.

No zones of mixing shall be permitted in this class:
(A) Within a defined reef area, in waters of a depth less than 18 meters (ten fathoms); or
(B) In waters up to a distance of 300 meters (one thousand feet) off shore if there is no defined reef area and if the depth is greater than 18 meters (ten fathoms). The uses to be protected in this class of waters are oceanographic research, the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, compatible recreation, and aesthetic enjoyment. The classification of any water area as Class AA shall not preclude other uses of the waters compatible with these objectives and in conformance with the criteria applicable to them (HAR §11-54-3(c)(1)).

The numeric targets for ensuring the protection of these uses are based on existing water quality standards (HIDOH, 2009). These standards include newly revised WQC for *enterococcus*, and the Phase 2 TMDL analysis is based on these new criteria. The standards present four different types of numeric criteria:

Geometric mean	For turbidity and TSS, the geometric mean of all time-averaged samples should not exceed the criterion value. For *enterococcus*, the geometric mean is calculated on not less than five samples collected during a 25 to 30 day period. However, if less than five samples were collected, the geometric mean is calculated on the samples that were collected within the 30-day period (essentially a 30 day running geometric mean).
Not to exceed more than 10% of the time	For turbidity, no more than 10% of all time-averaged samples should exceed this criterion value (does not apply to *enterococcus*).
Not to exceed more than 2% of the time	For turbidity, no more than 2% of all time-averaged samples should exceed this criterion value (does not apply to *enterococcus*).
Single sample maximum	For *enterococcus* only, a single sample should not exceed this criterion value (does not apply to turbidity). The single sample maximum criterion is primarily used as an indicator of acute water quality conditions that may pose immediate, short-term threats to human health. A preponderance of public health warnings, based on frequent exceedances of the single sample maximum, may be indicative of more chronic, long-term water quality impairments.

The numeric targets for the Phase 2 TMDL Hanalei Bay are presented in Table 3. TSS was used as a surrogate for turbidity during TMDL and load target analyses because turbidity is not expressed as a mass-based pollutant, and is therefore difficult to use as an endpoint for load calculations (HIDOH, 2005; Oceanit Laboratories, Inc., et al., 2002). However, turbidity WQC were incorporated into the TMDL analyses to ensure attainment of WQC in the bay, because the water quality standards do not include TSS criteria for embayments. Correlative analyses confirmed the relationship between TSS and turbidity (R^2 value of 0.7175, as described below in Section 4.2.2 and illustrated in Figure 17), further justifying this approach (Tetra Tech and HIDOH, 2008).

Table 3. Embayment Numeric Targets

Parameter (units)	**Application in Hanalei Bay**	**Condition**	**geometric mean**	**NTE more than 10% of the time**	**NTE more than 2% of the time**
Turbidity (Nephelometric Turbidity Units [NTU])	TMDL calculation and confirmation of impairments	**Wet**[a]	**1.5**	**3**	**5**
		~~Dry~~[b]	~~0.4~~	~~1.0~~	~~1.5~~
Parameter	**Application in Hanalei Bay**	**geometric mean**		single sample maximum	
Enterococcus (Colony Forming Units [CFU]/100mL)	TMDL calculation and confirmation of impairments	**35**		104[c]	

[a] Wet criteria apply when the average fresh water inflow from the land equals or exceeds one per cent of the embayment volume per day.
[b] Dry criteria apply when the average fresh water inflow from the land is less than one per cent of the embayment volume per day. Not applicable in Hanalei (see Figure 6).
[c] Single sample maximum criterion is primarily used as an indicator of acute water quality conditions that may pose immediate, short-term threats to human health. For TMDL implementation purposes—intended to address chronic, long-term water quality impairments—it is more appropriate to focus on the geometric mean criterion.

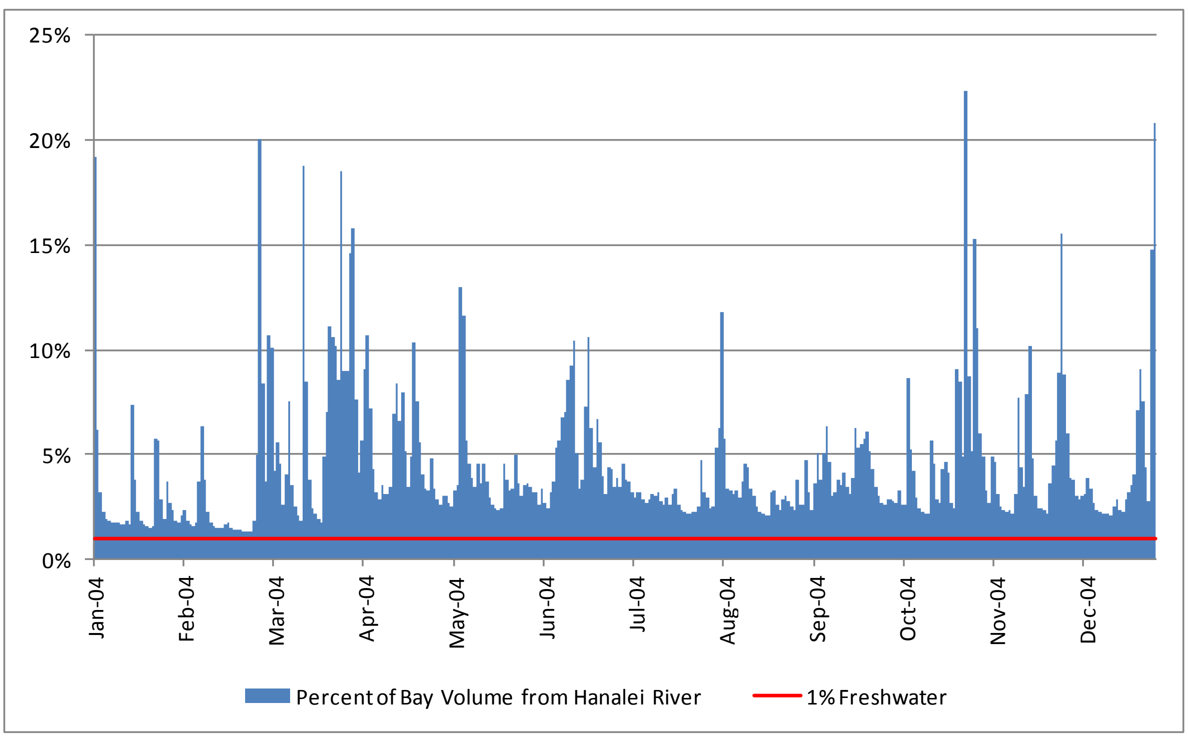


Figure 6. Freshwater inflows to Hanalei Bay water (as % of embayment volume)

4. Data Inventory and Analysis

In the Phase 1 TMDL, we used information from numerous sources to represent sub-watershed and estuary hydrology; characterize their water quality conditions; identify potential pollutant sources associated with *enterococcus*, sediment, and nutrients; and support the calculation of TMDLs, Informative TMDLs, and load targets (Tetra Tech and HIDOH, 2008). Some of these data were used to configure models of watershed and receiving water behavior, while other information was used during watershed analysis to provide an understanding of the conditions that result in water quality impairments.

The Phase 2 TMDL analysis develops TMDLs for *enterococcus* and sediment in Hanalei Bay, based on an assumption that most of the pollutant loads entering the Bay are transported via the inland surface waters. Therefore, the pollutant loadings computed for the Phase 1 TMDL, along with monitoring data from the embayment, form the basis for the Phase 2 analysis. The remainder of this section provides an inventory of the data used in the Phase 2 analysis, and summarizes the data analyses for reviewing the embayment water quality impairments and for developing embayment TMDLs for *enterococcus* and sediment.

4.1. Data Inventory

The Phase 1 TMDL document presents the data used to develop TMDLs for inland waters (Tetra Tech and HIDOH, 2008). Table 4 summarizes the additional datasets used to assess the marine water impairments associated with the Phase 2 TMDLs for Hanalei Bay. The results of these analyses are presented in Section 4.2.1. In addition to CWB data (HIDOH, 2006; HIDOH, 2008b), we used embayment data for bacteria and turbidity obtained from the Hanalei Watershed Hui (Hui) (Berg, 2006; Rosener, 2008) that were collected between 1995 and 2008 at the four monitoring stations located along Hanalei Bay.

Figure 2 illustrates the spatial distribution of these stations, as well as the delineation of the four sub-watersheds draining to Hanalei Bay. Some of these data were also used for receiving water calibration and validation, which are described in Appendix F of the Phase 1 TMDL (Tetra Tech and HIDOH, 2008).

Table 4. Monitoring Periods for Hanalei Phase 2 TMDL Analysis

Monitoring Station	Monitoring Period	
	Enterococcus	**Turbidity**
Hanalei Bay (Pavilion)	1/9/1995-9/15/2008	10/20/2003-9/15/2008
Hanalei Bay (Landing)	1/9/1995-9/15/2008	4/12/2003-9/15/2008
Hanalei Bay (Mooring Station)	6/5/2000-9/9/2003	No data
Hanalei Bay (Waioli Beach)	1/9/1995-9/15/2008	10/20/2003-9/15/2008

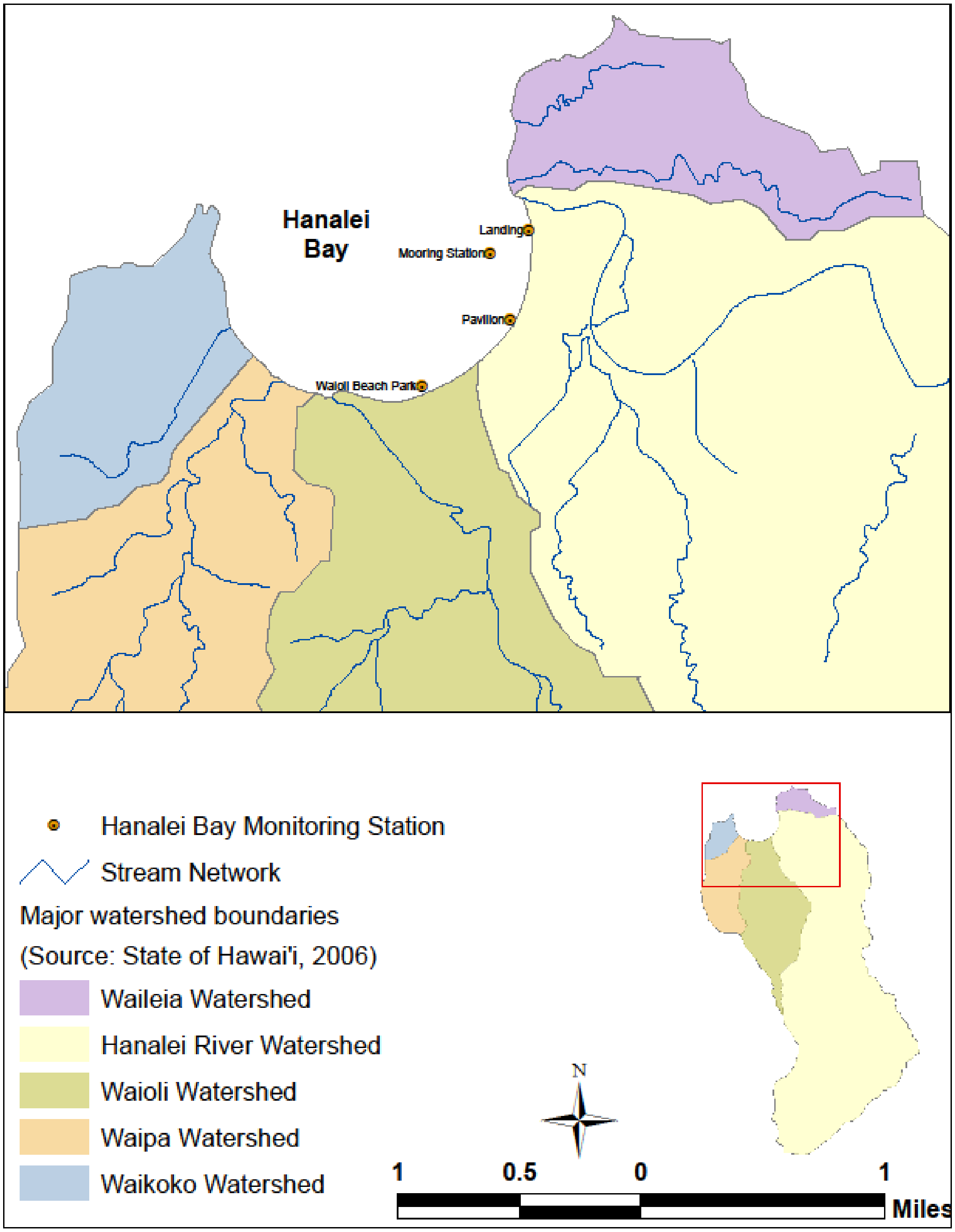


Figure 7. Hanalei Bay monitoring locations

4.2. Water Quality Data Analyses

Bacteria and sediment data collected in Hanalei Bay were analyzed to verify embayment impairments, establish TMDLs, and provide guidance for the source assessment. Data analysis focused on comparing water quality monitoring results to applicable WQC, and describing summary statistics, monthly patterns, temporal trend analyses, and relationships between pollutants. Results of these analyses are reported in the following sections.

4.2.1. Review of Impaired Segments

Several waterbody-pollutant combinations in Hanalei Bay are included on the 2006 303(d) list of impaired waterbodies (Table 2). The 303(d) list identifies impairments at four water quality monitoring stations in the bay. To further evaluate monitoring data in the bay and confirm impairments for the entire embayment, all available *enterococcus* and turbidity water quality data were compared against the applicable water quality criteria for Hanalei Bay. TMDLs were developed for the entire Bay, thus addressing all the waterbody-pollutant combinations shown in Table 2. Table 5 summarizes the status of each station for (1) 303(d) listing; (2) WQC exceedance; and (3) how each waterbody-pollutant impairment is being addressed in the Phase 2 TMDL. The remainder of this section provides additional details regarding the data analyses performed to evaluate the exceedance of applicable WQC.

Table 5. Summary of Listings, Exceedances, and Current Application

Decision Unit	Description	***Enterococcus*** (geomean)	**Turbidity** (Wet geomean)
Hanalei Bay Pavilion	Included on 2006 303(d) list	Yes	Yes
	Criteria exceeded	Yes	Yes
	Current application	TMDL	TSS TMDL
Hanalei Bay Landing	Included on 2006 303(d) list	Yes	Yes
	Criteria exceeded	Yes	Yes
	Current application	TMDL	TSS TMDL
Hanalei Bay Mooring Station	Included on 2006 303(d) list	Yes	Yes
	Criteria exceeded	Yes	No
	Current application	TMDL	TMDL*
Hanalei Bay Waioli Beach	Included on 2006 303(d) list	No	Yes
	Criteria exceeded	Yes	Yes
	Current application	TMDL*	TSS TMDL

Additional details regarding these exceedances, including the WQC exceeded, are presented in Table 6.
TMDL = TMDLs were calculated as part of the current application
TSS TMDL = turbidity data were used to confirm impairments and/or verify attainment of WQC; however, TMDLs were developed for TSS as a surrogate for turbidity
TMDL* = not currently listed; however, waterbody-pollutant combination is included as part of the TMDL for the entire Bay.

Data from four monitoring stations along the Hanalei Bay shoreline were compared with the applicable embayment WQC to evaluate the magnitude of *enterococcus* and turbidity exceedances. Figure 8 through Figure 11 show the results of the *enterococcus* analysis, and

Figure 13 through Figure 15 show the results of the turbidity analysis. The analysis used to construct these figures is described in Appendix A of the Phase 1 TMDL (Tetra Tech and HIDOH, 2008). These results are also presented in Table 6, along with time series graphs of *enterococcus* and turbidity levels (Figure 12 and Figure 16, respectively). The data confirm all existing embayment impairments; however, *enterococcus* at the Mooring Station only exceeded the single sample maximum WQC, which is not necessarily indicative of chronic impairment. In addition, *enterococcus* exceedances were identified for the Waioli Beach Station (geometric mean and single sample maximum WQC).

Table 6. Percent Exceedances Associated with Comparing Observed Data to WQC

Monitoring Station	Water Quality Criteria[a]	Percent Exceedance of Numeric WQC by Parameter (number of measurements)[b]	
		Enterococcus	**Turbidity**
Hanalei Bay Pavilion	Geometric mean	**8%** (1808)	**93%** (179)
	SSM	**12%** (1904)	N/A
	10% NTE	N/A	**63%** (178)
	2% NTE		**44%** (178)
Hanalei Bay Landing	Geometric mean	**46%** (803)	**100%** (206)
	SSM	**23%** (904)	N/A
	10% NTE	N/A	**83%** (205)
	2% NTE		**56%** (205)
Hanalei Bay Mooring Station	Geometric mean	0% (26)	No data
	SSM	**9%** (57)	
	10% NTE	N/A	
	2% NTE		
Hanalei Bay Waioli Beach	Geometric mean	**5%** (693)	**95%** (178)
	SSM	**7%** (783)	N/A
	10% NTE	N/A	**57%** (177)
	2% NTE		**40%** (177)

[a] For purposes of this table, the % exceedance of turbidity and *enterococcus* geometric means was based on a running 30-day geometric mean. In this case, the number of measurements (in parentheses) is equal to the number of geometric means calculated.

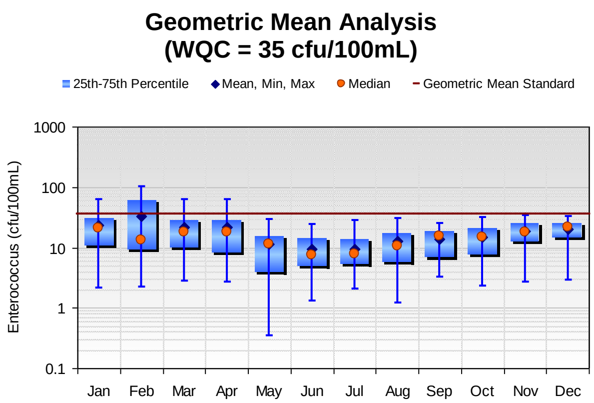
[b] Red bold font indicates an exceedance of the water quality criteria. For the 10% and 2% not-to-exceed criteria, fonts were changed if the percent exceedance of the numeric standard is greater than 10% or 2%, respectively.

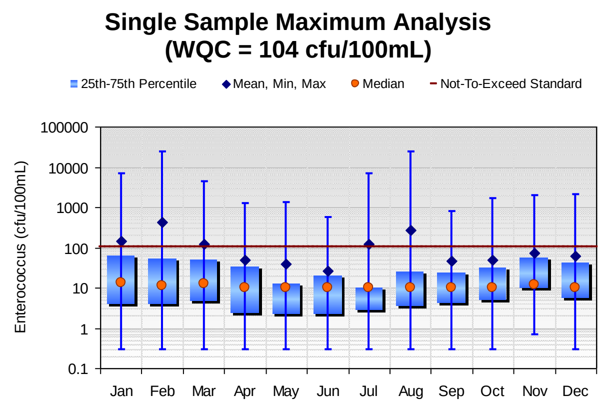
As shown in Table 6, *enterococcus* counts exceeded the geometric mean WQC at three of four monitoring locations. As might be expected, there were no exceedances at the location that is farthest from shore (Mooring Station), and the greatest frequency of exceedances occurred at the location that is closest to the Hanalei river mouth (Hanalei Bay Landing). Exceedances of the single sample maximum WQC exhibit a similar pattern, with the addition of exceedances at the Mooring Station. Although the Waioli Beach Station is not currently on the 303(d) list for *enterococcus* (see Section 2.2; Table 2), this waterbody-pollutant combination is included in the TMDL for the entire bay.

The *enterococcus* time series graphs present the observed counts at each station through the entire data period (Figure 12). These graphs show that the Landing and Pavilion monitoring stations have the highest counts. In addition, beginning in 2001 there is a general trend of increased counts at all stations, except for the Mooring Station (note: fewer samples were collected at this station and for a shorter time period, so comparison is difficult). This trend plateaus until 2007, when counts began to decrease slightly. The red line in each of these graphs is the moving average, which illustrates these temporal trends. These graphs also illustrate monthly counts and exceedances. In general, exceedances of the *enterococcus* geometric mean and single sample maximum WQC are highest in the winter months; however, the highest single counts tend to occur in the summer, when embayment mixing and dispersion may be lower during storm events than in winter (Figure 8 through Figure 11).

Turbidity data were available for three of the four monitoring stations (Pavilion, Landing, and Waioli Beach). All three of the turbidity WQC were exceeded at each of these locations (Figure 12 through Figure 15; Table 6), verifying the turbidity impairments on the 2006 303(d) list (Table 2). Geometric mean exceedances ranged from 93 to 100%; while the 10% not-to-exceed standard was exceeded 57 to 83% of the time and the 2% not-to-exceed standard was exceeded 40 to 56% of the time (Table 6). In addition to overall summary statistics, these graphs also illustrate monthly measurements and exceedances. In general, exceedances of the turbidity WQC are lower in the summer months for the Pavilion, Landing, and Waioli Beach monitoring stations.

The turbidity time series graphs present the observed measurements at each station through the entire data period (Figure 16). Logarithmic scales were used for these graphs so that results between 1 and 100 NTU are easier to distinguish. These graphs show that the location closest to the Hanalei river mouth (Hanalei Bay Landing) has the highest turbidity measurements. There was a break in data collection efforts during part of 2006 and most of 2007; therefore, temporal trends are difficult to determine. However, there does appear to be a slight decrease in measured values over time, as indicated by the red line in each of these graphs, which represents the moving average.





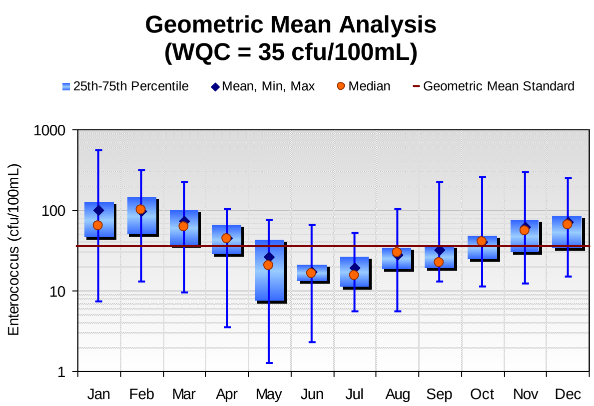
Summary Statistics (Data: 1/9/1995 to 9/15/2008)

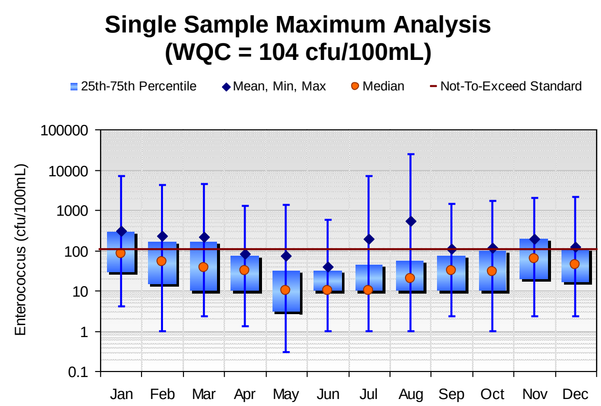
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	23	21	2	63	11	30	25:132	19%
Feb	33	13	2	104	9	60	53:138	38%
Mar	22	18	3	64	10	28	26:157	17%
Apr	22	18	3	63	8	29	35:159	22%
May	11	12	0	30	4	15	0:149	0%
Jun	10	8	1	25	5	14	0:146	0%
Jul	10	8	2	28	5	14	0:166	0%
Aug	13	11	1	30	6	17	0:152	0%
Sep	14	15	3	25	7	19	0:162	0%
Oct	15	15	2	32	8	21	0:141	0%
Nov	19	18	3	35	13	25	0:162	0%
Dec	20	21	3	33	15	26	0:144	0%
All Data	17	14	0	104	7	22	139:1808	8%

Summary Statistics (Data: 1/9/1995 to 9/15/2008)

Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	143	13	0	6867	4	63	32:149	21%
Feb	416	11	0	24192	4	52	29:154	19%
Mar	124	12	0	4352	5	48	30:173	17%
Apr	50	10	0	1259	2	34	14:160	9%
May	39	10	0	1354	2	13	11:156	7%
Jun	27	10	0	561	2	20	10:165	6%
Jul	120	10	0	6867	3	10	11:162	7%
Aug	272	10	0	24192	4	26	10:172	6%
Sep	46	10	0	810	4	24	16:151	11%
Oct	49	10	0	1669	5	31	16:159	10%
Nov	74	12	1	1993	10	55	29:159	18%
Dec	62	10	0	2105	6	41	20:144	14%
All Data	119	10	0	24192	4	31	228:1904	12%

Figure 8. Enterococcus analyses for Hanalei Bay (Pavilion)





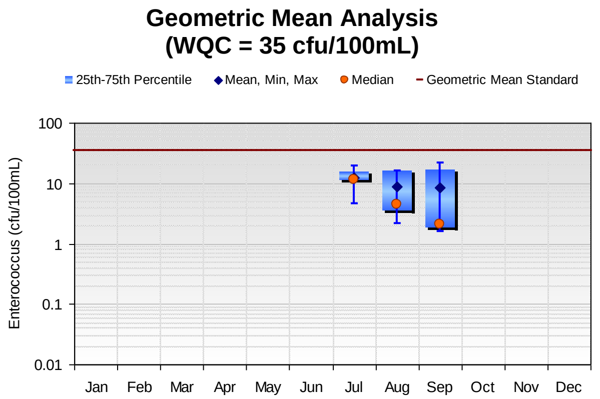
Summary Statistics (Data: 1/9/1995 to 9/15/2008)

Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	100	64	7	543	47	126	48:56	86%
Feb	98	100	13	310	50	145	46:60	77%
Mar	74	62	9	223	37	101	44:57	77%
Apr	45	43	4	103	28	65	44:66	67%
May	26	20	1	76	8	42	21:69	30%
Jun	17	16	2	65	13	21	2:65	3%
Jul	19	15	6	52	11	26	3:83	4%
Aug	28	29	6	104	19	34	19:78	24%
Sep	32	22	13	219	19	36	20:79	25%
Oct	41	40	11	253	25	48	31:59	53%
Nov	61	55	12	295	30	75	45:66	68%
Dec	71	65	15	251	34	84	46:65	71%
All Data	48	33	1	543	18	62	369:803	46%

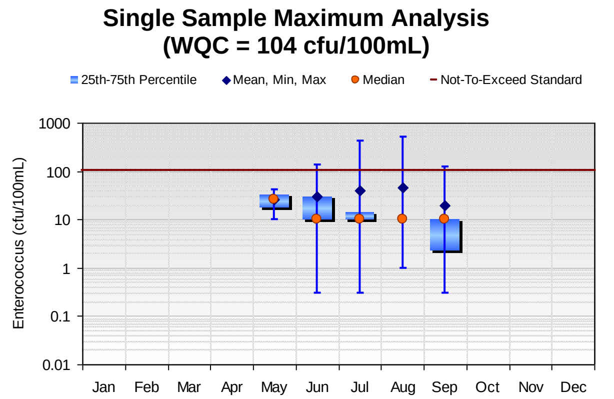
Summary Statistics (Data: 1/9/1995 to 9/15/2008)

Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	297	80	4	6867	30	281	31:68	46%
Feb	223	52	1	4106	15	158	24:69	35%
Mar	222	36	2	4352	10	160	24:76	32%
Apr	84	31	1	1259	10	74	15:74	20%
May	72	10	0	1354	3	31	10:79	13%
Jun	40	10	1	561	10	32	8:83	10%
Jul	192	10	1	6867	10	43	8:87	9%
Aug	531	20	1	24192	10	54	8:88	9%
Sep	109	31	2	1400	10	75	14:69	20%
Oct	114	29	1	1669	10	100	17:74	23%
Nov	192	63	2	2000	20	196	27:71	38%
Dec	121	43	2	2105	16	108	18:66	27%
All Data	187	31	0	24192	10	93	204:904	23%

Figure 9. Enterococcus analyses for Hanalei Bay (Landing)

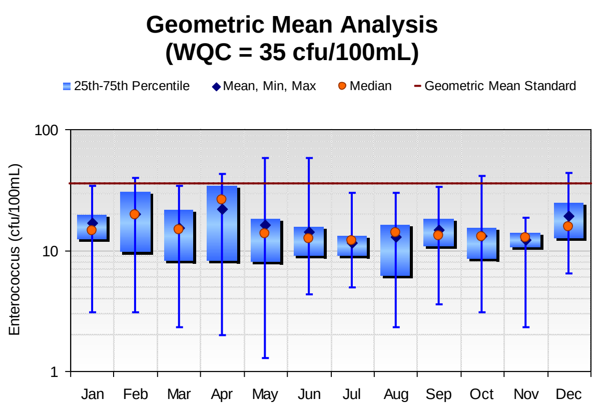


Summary Statistics (Data: 6/5/2000 to 9/9/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0	0	0	0	0	0	0:0	n/a
Feb	0	0	0	0	0	0	0:0	n/a
Mar	0	0	0	0	0	0	0:0	n/a
Apr	0	0	0	0	0	0	0:0	n/a
May	0	0	0	0	0	0	0:0	n/a
Jun	0	0	0	0	0	0	0:0	n/a
Jul	12	11	5	19	11	15	0:13	0%
Aug	9	4	2	16	4	16	0:7	0%
Sep	9	2	2	22	2	17	0:6	0%
Oct	0	0	0	0	0	0	0:0	n/a
Nov	0	0	0	0	0	0	0:0	n/a
Dec	0	0	0	0	0	0	0:0	n/a
All Data	11	11	2	22	4	16	0:26	0%

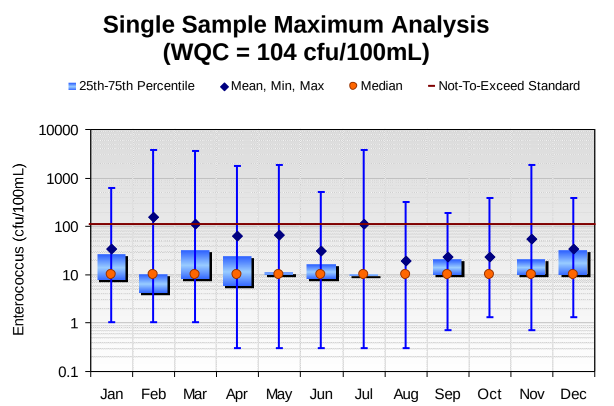


Summary Statistics (Data: 6/5/2000 to 9/9/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0	0	0	0	0	0	0:0	n/a
Feb	0	0	0	0	0	0	0:0	n/a
Mar	0	0	0	0	0	0	0:0	n/a
Apr	0	0	0	0	0	0	0:0	n/a
May	26	26	10	41	18	33	0:2	0%
Jun	30	10	0	135	10	31	1:15	7%
Jul	40	10	0	430	10	14	2:18	11%
Aug	46	10	1	504	10	10	1:13	8%
Sep	19	10	0	122	2	10	1:9	11%
Oct	0	0	0	0	0	0	0:0	n/a
Nov	0	0	0	0	0	0	0:0	n/a
Dec	0	0	0	0	0	0	0:0	n/a
All Data	35	10	0	504	10	11	5:57	9%

Figure 10. Enterococcus analyses for Hanalei Bay (Mooring Station)



Summary Statistics (Data: 1/9/1995 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	17	14	3	34	12	19	0:46	0%
Feb	20	20	3	40	10	30	5:51	10%
Mar	15	15	2	34	8	21	0:56	0%
Apr	22	26	2	43	8	34	13:60	22%
May	16	14	1	58	8	18	6:51	12%
Jun	14	12	4	58	9	16	3:57	5%
Jul	12	12	5	30	9	13	0:66	0%
Aug	13	14	2	30	6	16	0:63	0%
Sep	15	13	4	33	11	18	0:67	0%
Oct	13	13	3	41	9	15	2:58	3%
Nov	12	13	2	19	11	14	0:65	0%
Dec	19	16	6	43	13	25	4:53	8%
All Data	16	13	1	58	10	19	33:693	5%



Summary Statistics (Data: 1/9/1995 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	35	10	1	605	8	25	3:59	5%
Feb	151	10	1	3654	4	10	6:55	11%
Mar	111	10	1	3609	8	30	8:70	11%
Apr	62	10	0	1723	6	23	5:60	8%
May	66	10	0	1842	10	11	4:58	7%
Jun	31	10	0	510	8	16	6:73	8%
Jul	111	10	0	3784	9	10	4:68	6%
Aug	19	10	0	316	10	10	1:79	1%
Sep	24	10	1	185	10	20	3:67	4%
Oct	24	10	1	373	10	10	2:68	3%
Nov	55	10	1	1785	10	20	5:67	7%
Dec	33	10	1	380	10	31	5:59	8%
All Data	59	10	0	3784	10	20	52:783	7%

Figure 11. Enterococcus analyses for Hanalei Bay (Waioli Beach)

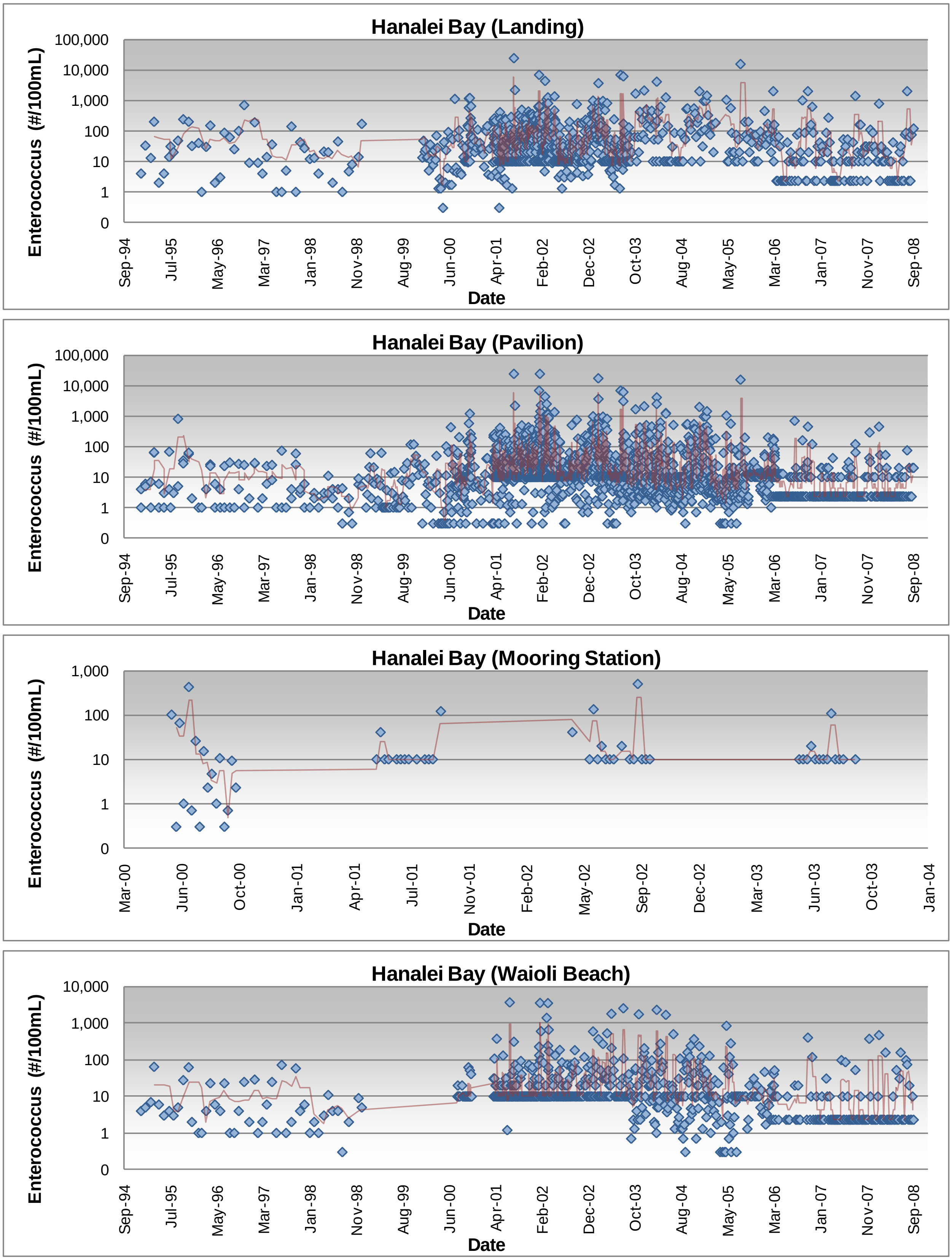
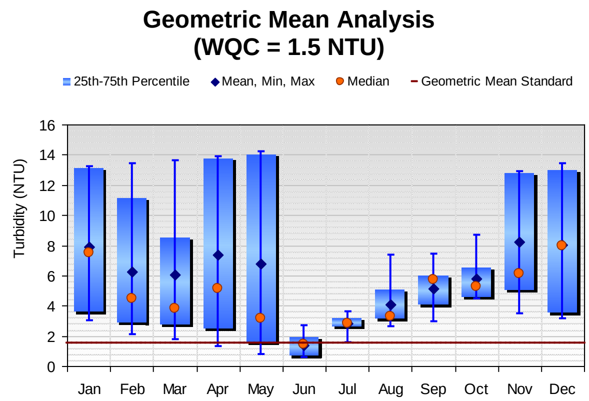
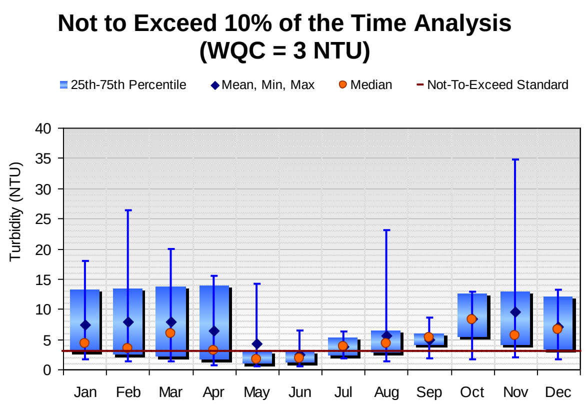


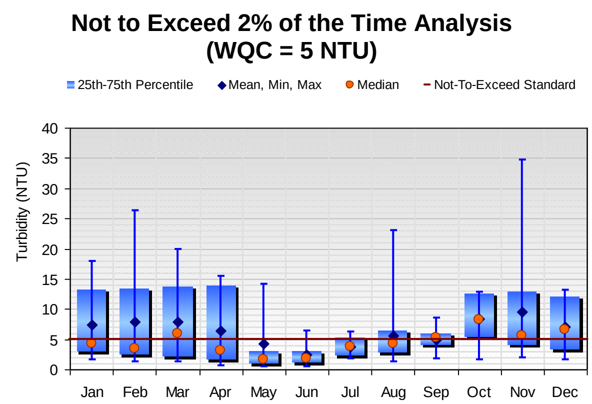
Figure 12. Time series enterococcus graphs for each embayment station



Summary Statistics (Data: 10/20/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	8	7	3	13	4	13	13:13	100%
Feb	6	4	2	13	3	11	14:14	100%
Mar	6	4	2	14	3	8	20:20	100%
Apr	7	5	1	14	3	14	19:20	95%
May	7	3	1	14	2	14	19:23	83%
Jun	1	1	1	3	1	2	6:13	46%
Jul	3	3	2	4	3	3	12:12	100%
Aug	4	3	3	7	3	5	14:14	100%
Sep	5	6	3	7	4	6	15:15	100%
Oct	6	5	4	9	5	7	8:8	100%
Nov	8	6	3	13	5	13	12:12	100%
Dec	8	8	3	13	4	13	15:15	100%
All Data	6	4	1	14	3	8	167:179	93%

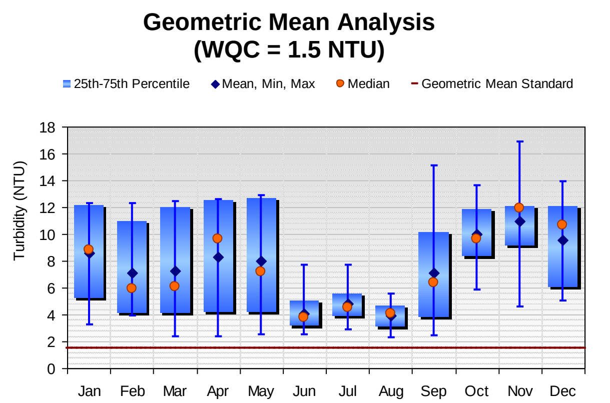


Summary Statistics (Data: 10/20/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	7	4	2	18	3	13	11:15	73%
Feb	8	3	1	26	2	13	10:17	59%
Mar	8	6	1	20	2	14	14:23	61%
Apr	6	3	1	15	2	14	9:17	53%
May	4	2	1	14	1	3	5:18	28%
Jun	2	2	0	6	1	3	3:13	23%
Jul	4	4	2	6	2	5	7:12	58%
Aug	6	4	1	23	3	6	10:14	71%
Sep	5	5	2	9	4	6	8:10	80%
Oct	8	8	2	13	5	13	9:10	90%
Nov	10	6	2	35	4	13	13:15	87%
Dec	7	7	2	13	3	12	13:14	93%
All Data	6	4	0	35	2	13	112:178	63%

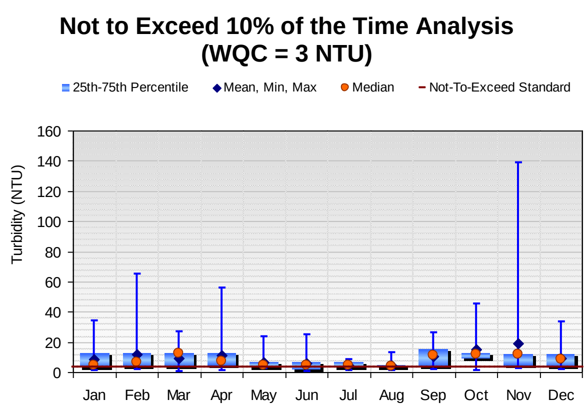


Summary Statistics (Data: 10/20/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	7	4	2	18	3	13	7:15	47%
Feb	8	3	1	26	2	13	6:17	35%
Mar	8	6	1	20	2	14	12:23	52%
Apr	6	3	1	15	2	14	6:17	35%
May	4	2	1	14	1	3	4:18	22%
Jun	2	2	0	6	1	3	2:13	15%
Jul	4	4	2	6	2	5	5:12	42%
Aug	6	4	1	23	3	6	6:14	43%
Sep	5	5	2	9	4	6	6:10	60%
Oct	8	8	2	13	5	13	8:10	80%
Nov	10	6	2	35	4	13	8:15	53%
Dec	7	7	2	13	3	12	9:14	64%
All Data	6	4	0	35	2	13	79:178	44%

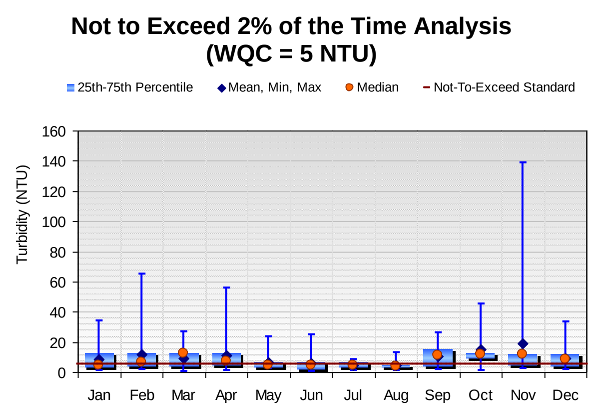
Figure 13. Turbidity analyses for Hanalei Bay (Pavilion)



Summary Statistics (Data: 4/12/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	9	9	3	12	5	12	13:13	100%
Feb	7	6	4	12	4	11	14:14	100%
Mar	7	6	2	12	4	12	20:20	100%
Apr	8	10	2	13	4	13	20:20	100%
May	8	7	3	13	4	13	27:27	100%
Jun	4	4	3	8	3	5	18:18	100%
Jul	5	5	3	8	4	6	16:16	100%
Aug	4	4	2	6	3	5	18:18	100%
Sep	7	6	2	15	4	10	19:19	100%
Oct	10	10	6	14	8	12	12:12	100%
Nov	11	12	5	17	9	12	14:14	100%
Dec	10	11	5	14	6	12	15:15	100%
All Data	7	6	2	17	4	12	206:206	100%



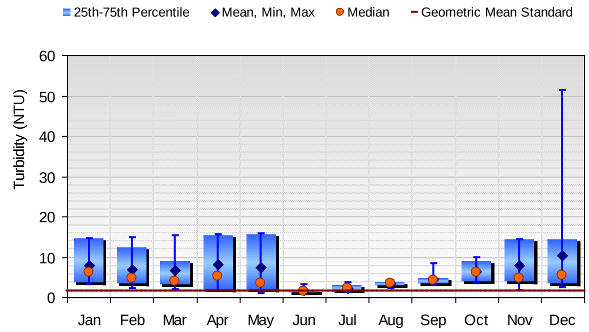
Summary Statistics (Data: 4/12/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	9	5	1	34	3	12	11:15	73%
Feb	12	7	2	65	4	12	15:17	88%
Mar	9	12	1	27	4	13	18:23	78%
Apr	11	7	1	56	4	13	18:21	86%
May	7	5	2	24	4	7	20:22	91%
Jun	6	4	1	25	2	6	12:18	67%
Jul	5	5	1	9	3	7	13:16	81%
Aug	4	4	1	13	3	5	13:17	76%
Sep	10	11	2	27	4	15	12:15	80%
Oct	15	12	2	46	9	13	11:12	92%
Nov	19	12	2	139	5	12	14:15	93%
Dec	9	8	2	33	4	12	13:14	93%
All Data	9	6	1	139	4	12	170:205	83%



Summary Statistics (Data: 4/12/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	9	5	1	34	3	12	7:15	47%
Feb	12	7	2	65	4	12	10:17	59%
Mar	9	12	1	27	4	13	14:23	61%
Apr	11	7	1	56	4	13	14:21	67%
May	7	5	2	24	4	7	11:22	50%
Jun	6	4	1	25	2	6	8:18	44%
Jul	5	5	1	9	3	7	7:16	44%
Aug	4	4	1	13	3	5	3:17	18%
Sep	10	11	2	27	4	15	10:15	67%
Oct	15	12	2	46	9	13	10:12	83%
Nov	19	12	2	139	5	12	10:15	67%
Dec	9	8	2	33	4	12	10:14	71%
All Data	9	6	1	139	4	12	114:205	56%

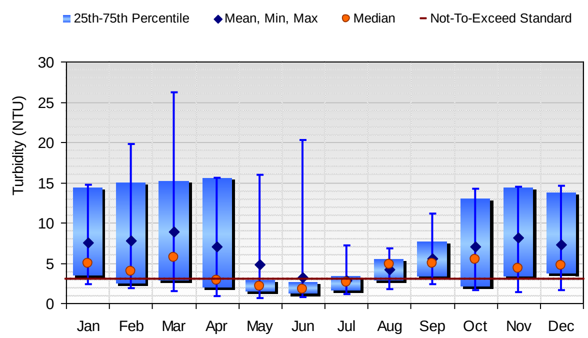
Figure 14. Turbidity analyses for Hanalei Bay (Landing)

Geometric Mean Analysis (WQC = 1.5 NTU)



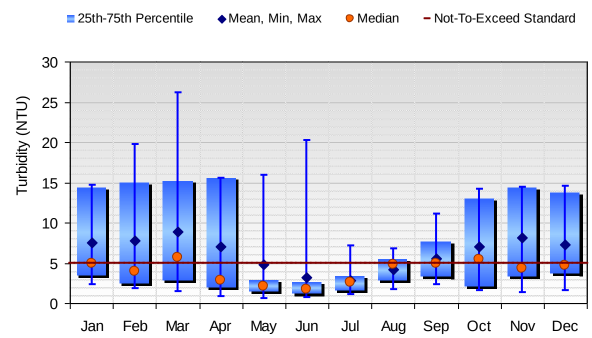
Summary Statistics (Data: 10/20/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	8	6	3	15	4	15	13:13	100%
Feb	7	5	2	15	3	12	14:14	100%
Mar	7	4	2	15	3	9	20:20	100%
Apr	8	5	2	16	2	15	20:20	100%
May	8	3	1	16	2	16	20:23	87%
Jun	2	2	1	3	1	2	8:13	62%
Jul	2	2	1	4	2	3	11:12	92%
Aug	3	3	2	4	3	4	14:14	100%
Sep	4	4	3	8	3	5	14:14	100%
Oct	6	6	3	10	4	9	8:8	100%
Nov	8	5	2	14	4	14	12:12	100%
Dec	10	5	2	51	3	14	15:15	100%
All Data	6	4	1	51	3	8	169:178	95%

Not to Exceed 10% of the Time Analysis (WQC = 3 NTU)



Summary Statistics (Data: 10/20/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	8	5	2	15	3	14	12:15	80%
Feb	8	4	2	20	2	15	11:17	65%
Mar	9	6	1	26	3	15	16:23	70%
Apr	7	3	1	16	2	16	7:17	41%
May	5	2	1	16	2	3	4:18	22%
Jun	3	2	1	20	1	3	2:13	15%
Jul	3	3	1	7	2	3	4:12	33%
Aug	4	5	2	7	3	5	8:13	62%
Sep	6	5	2	11	3	8	8:10	80%
Oct	7	5	2	14	2	13	6:10	60%
Nov	8	4	1	14	3	14	11:15	73%
Dec	7	5	2	15	4	14	12:14	86%
All Data	6	4	1	26	2	14	101:177	57%

Not to Exceed 2% of the Time Analysis (WQC = 5 NTU)



Summary Statistics (Data: 10/20/2003 to 9/15/2008)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	8	5	2	15	3	14	7:15	47%
Feb	8	4	2	20	2	15	6:17	35%
Mar	9	6	1	26	3	15	12:23	52%
Apr	7	3	1	16	2	16	7:17	41%
May	5	2	1	16	2	3	4:18	22%
Jun	3	2	1	20	1	3	1:13	8%
Jul	3	3	1	7	2	3	2:12	17%
Aug	4	5	2	7	3	5	6:13	46%
Sep	6	5	2	11	3	8	5:10	50%
Oct	7	5	2	14	2	13	6:10	60%
Nov	8	4	1	14	3	14	6:15	40%
Dec	7	5	2	15	4	14	8:14	57%
All Data	6	4	1	26	2	14	70:177	40%

Figure 15. Turbidity analyses for Hanalei Bay (Waioli Beach)

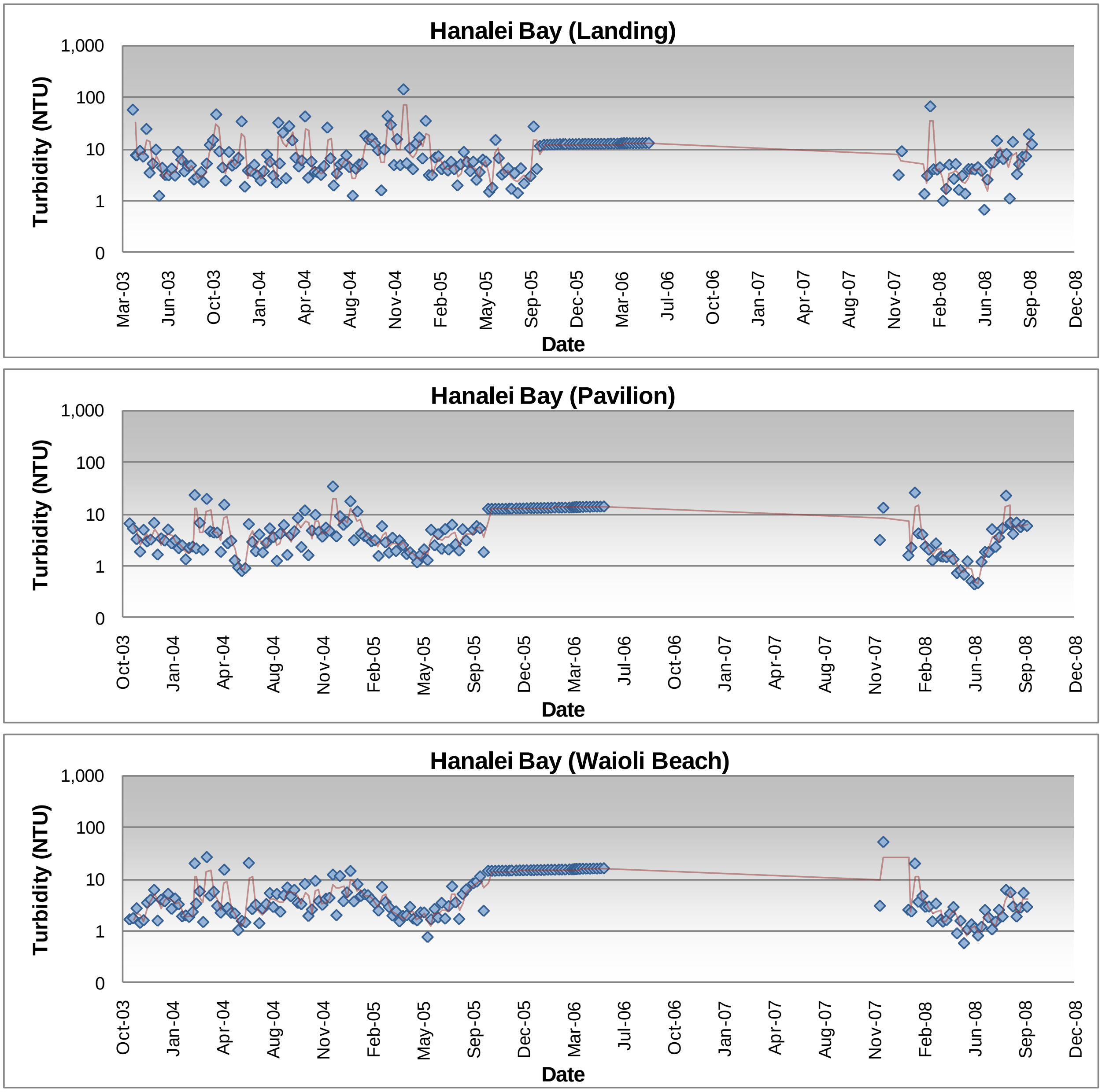


Figure 16. Time series turbidity graphs for Hanalei Bay

4.2.2. Correlative Analyses

Correlative analyses were performed to evaluate the relationships between water quality parameters. These analyses indicate that TSS and turbidity are strongly correlated in the Hanalei Bay Watershed, with an R^2 value of 0.7175 (Figure 17) based on 183 samples (collected by HIDOH and the Hui). This supports our use of TSS as a surrogate for turbidity in the TMDL calculations. An independent analysis performed by the Hui on its TSS and turbidity data collected from November 2003 through April 2004 verifies this correlation (Berg et al., 2004).

Correlations between TSS and turbidity data from all four subwatersheds, two waterbody types (stream and estuary), and two regulatory seasons (wet and dry) were evaluated in several different ways. Although these results showed some variability in the resulting TSS values, we judged the use of a larger, combined dataset to establish a single regression—that reflects the mid-range of all the correlations and corresponding TSS values—as the most reasonable choice for the current analysis. This regression was also used for the Phase 1 TMDL [Tetra Tech and HIDOH, 2008]).

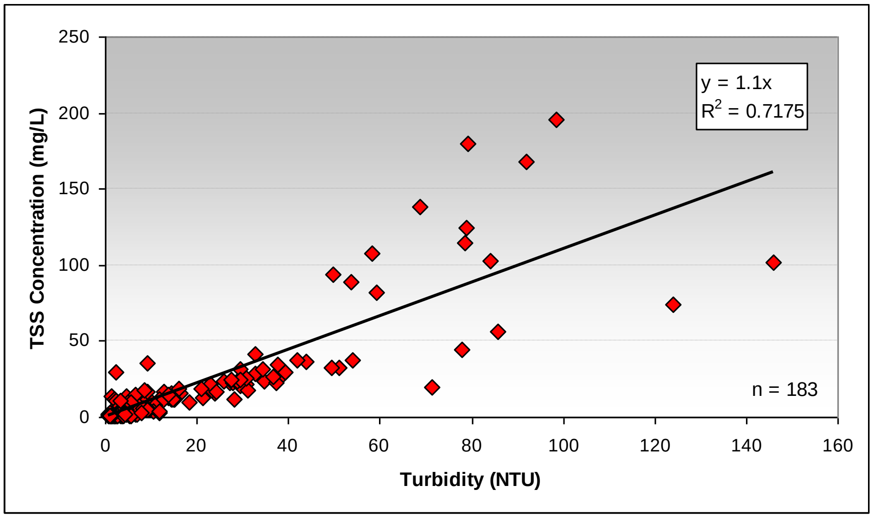


Figure 17. Turbidity and TSS relationship in the Hanalei Bay Watershed

To further examine use of this correlation for embayment TMDLs, fresh water inflow data from the Hanalei River were analyzed with embayment turbidity data for the Landing, Pavilion, and Waioli Beach monitoring stations. We used the Kendall Tau rank correlation coefficient, which is a non-parametric test to estimate the degree of correspondence and assess the significance of correspondence, to evaluate the relationship between embayment turbidity and fresh water flow.

The Kendall Tau test determines the correlation between two sets of data without considering their magnitudes. For all arrangements of data (i.e., all rankings), Tau lies between 0 and 1; an increasing value implies increasing agreement between rankings (average values or independent datasets have a Tau value of 0). For the three monitoring stations analyzed (Landing, Pavilion, and Waioli Beach), Tau values ranged from 0.235 to 0.450 (Table 7), suggesting increasing agreement. In addition, Kendall Tau analyses resulted in p-values of <0.01 or <0.05 for all combinations of observations (Table 7). This indicates that there is a statistically significant trend (at a level of confidence of 99% or 95%) between flow and turbidity at each of the three monitoring stations. Regressions were also performed to further evaluate the relationship between fresh water flow and embayment turbidity. As shown in Figure 18; the R^2 values ranged from 0.220 to 0.366. While some data points are not explained by these equations (especially some of the higher turbidity values, which may be caused by embayment processes such as wave movement), most of the turbidity measurements are related to the freshwater inflow.

This relationship between the in-stream flow and embayment turbidity establishes the linkage between inland water conditions and Hanalei Bay conditions. Specifically, the statistical significance of the Kendall Tau analyses supports the assumption that turbidity values in the Bay are largely associated with watershed inflows. This further justifies use of the turbidity-TSS correlation calculated from the inland waters (Figure 17) for use in the Phase 2 embayment sediment TMDLs.

Table 7. Kendall Tau Analysis of Fresh Water Flow and Embayment Turbidity

Monitoring Station	p-value	Kendall Tau	Level of Significance	R^2
Landing	4.21E-06	0.450	<0.01	0.366
Pavilion	0.013226	0.235	<0.05	0.247
Waioli Beach	0.001176	0.308	<0.01	0.220

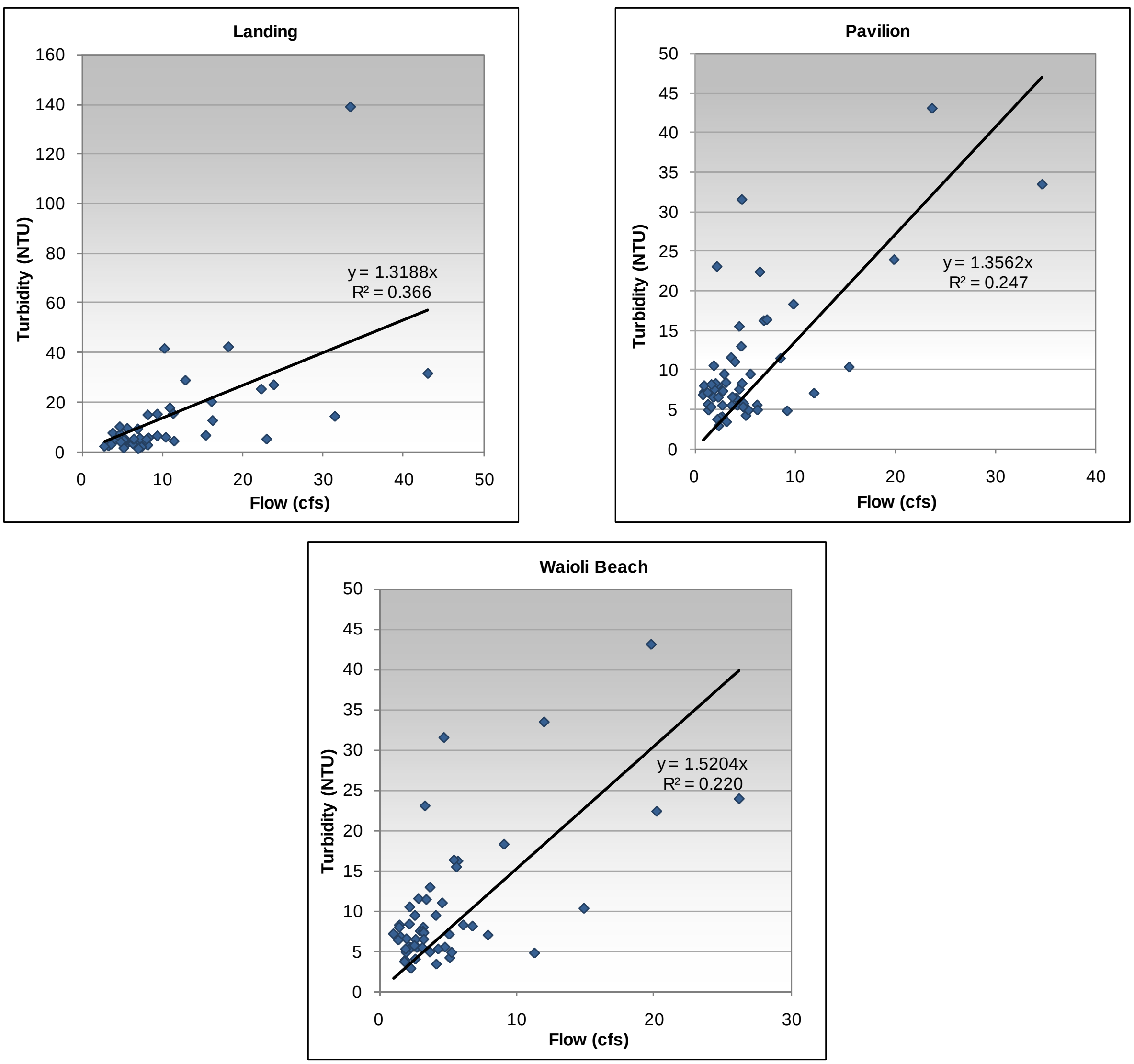


Figure 18. Regression analysis between fresh water flow and embayment turbidity

5. Source Analysis

The purpose of the source analysis is to identify and quantify the sources of pollutants that are transported to the impaired waterbodies. For the Hanalei Bay impairments, it is important to examine the upstream watersheds and tributaries (Waileia, Hanalei River, Waioli Stream, Waipa Stream, and the Waikoko Stream) as significant sources of *enterococcus* and turbidity/sediment; it is assumed that the predominate source of bacterial and sediment loading to the Bay originates in the Hanalei Bay Watershed. The Phase 1 TMDL evaluated in-stream and watershed data to (1) identify potential sources and (2) characterize the relationship between nonpoint source loadings and the in-stream response (Tetra Tech and HIDOH, 2008).

Point sources typically discharge at a specific location from pipes, outfalls, and conveyance channels from facilities such as wastewater treatment plants or municipal separate storm sewer systems (MS4s). Nonpoint sources, including groundwater, are diffuse sources that have multiple routes of entry into surface waters. In Hawaii, groundwater occurs as either basal or high-level groundwater. Basal groundwater floats on and displaces seawater, while high-level groundwater is impounded within compartments formed by impermeable dikes, often resting on and traveling along low-permeability soils. The basal groundwater in Hanalei likely discharges to marshy areas and stream channels along the inland edge of the coastal plain without causing large visible springs, and much of the high-level groundwater is diffused in small springs and seeps in valley walls or stream channels (MacDonald et al., 1960). However, recent studies suggest that under certain conditions, groundwater may contribute up to 20 percent of the flow to Hanalei Bay, and a significant portion of embayment nutrient loading (Knee et al., 2005, 2006). Groundwater may enter the bay via direct submarine discharges, or indirectly via discharges to inland waters that then drain to the Bay.

The Phase 1 TMDL identified numerous pathways of bacterial loading to the impaired inland waters that ultimately drain to Hanalei Bay. For example, the forested portion of the watershed includes unknown populations of feral pigs and goats, as well as several species of birds (Griffin, 2000), which are potential sources of bacteria. In addition, bird populations in the Hanalei National Wildlife Refuge (NWR) have increased over the past thirty years (Asquith & Melgar, 1999), and introduced mammals such as feral cats, dogs, and rats are considered problem species (Berg et al., 1997). These wildlife populations are also potential sources of elevated bacteria counts in the areas draining to Hanalei Bay. Additionally, there are many wetland and dryland pastures adjacent to the Hanalei NWR (Berg et al., 1997) and in the Waileia subwatershed, and the town of Hanalei does not have centralized wastewater treatment. Wastewater disposal is through onsite septic and cesspool systems, except for small package treatment plants that serve the commercial centers (Fujimoto, 1977; Griffin, 2000). East of Hanalei, the resort community of Princeville contains dense residential development, including resort lodging and a golf course. Wastewater generated by Princeville is treated at the community's wastewater treatment and reused for golf course irrigation. All of these sources have the potential to contribute to the elevated *enterococcus* counts measured throughout the Hanalei Bay Watershed. Sludge from the treatment process is applied to ranchland in the adjacent Anini Watershed, however this practice is scheduled to end as soon as Princeville begins trucking the sludge to a regional disposal facility in the Poipu area.

A groundwater study conducted in 2005 found that bacteria counts were lower in groundwater than in the Hanalei River, Hanalei Bay, and other streams; however, relatively high levels of *Escherichia coli* were detected in groundwater seaward of a cesspool. These findings suggest that groundwater is a potential a source of bacteria during periods of high discharge (Knee et al., 2005). To further supplement these results, a limited number of shallow groundwater samples were collected near Hanalei Bay in March 2005, August 2006, and February 2007 (Knee et. al., 2008). Objectives of this study included estimation and characterization of the groundwater influx to Hanalei Bay and River as well as identification of potential sources of nutrients and bacteria. However, the objectives did not include evaluation of data against applicable WQC.

We obtained these data from the study authors (Knee et. al., 2008) for comparison with embayment WQC Geometric means were calculated for each site and each sampling event. Data that were non-detects were originally reported as <10 MPN/100mL; to ensure conservative estimates of the geometric mean values, non-detects were represented as 10 MPN/100mL in the calculations. As indicated in Table 8, none of the groundwater geometric means exceeded the 35 cfu/100mL WQC. Furthermore, the counts collected at Pavilion, Pier/Landing, and Waioli were all below the single-sample maximum WQC of 104 cfu/100mL (maximum counts were 35, 85 and 25 MPN/100mL, respectively).

Further analysis of the Knee et al. 2008 data suggest that groundwater is not a significant source of bacteria loading to Hanalei Bay. However, the study also identified a single positive groundwater sample (out of four samples; Table 8) for the enterococcal surface protein (*esp*) gene that can be used to identify whether some *enterococci* were of human fecal origin, warranting suspicion of localized human fecal contamination in groundwater (Knee et. al., 2008). Given that the data did not exceed either the geometric mean or the single-sample maximum WQC and only a single sample tested positive for the *esp* gene, it is important to recognize that there is certainly the potential of human contamination in groundwater near the bay, yet this is not a significant contributor of bacteria loading when compared with other sources.

Table 8. Groundwater Data Collected near Hanalei Bay (Knee et al., 2008)

Monitoring Station (Number of Samples)	*Enterococci* Geometric Mean (MPN/100 mL) (Number of Samples)			Number of Positive *esp* Samples /Total Samples
	March 2006	August 2006	February 2007	
Pavilion (22)	*10 (2)**	10 (7)	11.4 (13)	1 / 1
Pier/Landing (28)	*10 (2)**	12.4 (9)	10.9 (17)	0 / 2
Waioli (12)	*10 (1)**	10 (7)	*12.6 (4)**	0 / 1

Sediment concentrations are also associated with both natural and anthropogenic activities throughout the watershed; therefore, the hydrological connections between the upstream tributaries and Hanalei Bay are important to consider when evaluating sediment sources, transport, and associated turbidity impairments. For example, the Hanalei Bay Watershed headwaters region occasionally experiences high erosion rates due to high precipitation and steep slopes, as well as sediment loads associated with the alteration of the forest landscape due to human activity, feral ungulates (pigs and goats), and invasive plant species (Griffin, 2000). While sediment plumes have been observed in irrigation return flows to the Hanalei River, the total sediment load from agricultural drainage may be minor compared to the sediment generated during natural flood events. For example, evaluations of turbidity and suspended sediment data suggest that the total Hanalei River load is 30-80 times the load from ditches and impoundments (Berg et al., 1997).

5.1. Point Sources

There are no NPDES permits that allow discharges to embayment waters. Therefore, point sources are not included in the loading analysis, and the TMDL waste load allocations (WLA) are zero (0).

5.2. Nonpoint Sources

In this analysis, source quantification was divided between both groundwater and other nonpoint sources (based on land cover type, see Figure 19). Groundwater loading was quantified from the calibrated watershed model output, which included *enterococcus* counts similar to the geometric means presented in Table 8. The calibrated watershed model was also used to quantify other nonpoint sources in the Hanalei Bay Watershed by land cover type, because these loadings can be highly correlated with land-based activities. Wash-off of pollutants such as *enterococcus* and sediment from various land covers during wet weather events is considered the primary mechanism for transport.

Due to various natural processes, land-based activities, and associated management practices, pollutants build up on the land surface. Then during rainfall events, many of the pollutants are washed from the surface (depending on the rainfall intensity and amount of pollutants available for removal) and into the receiving waterbody (which, in this case, ultimately discharges to Hanalei Bay). The amount of runoff and associated pollutant concentrations are therefore, highly dependent on land-based activities. For Hanalei Bay, it is important to consider land-based activities throughout the entire drainage area (Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream). The methodology used for quantification of pollutant concentrations from various land cover types is discussed in the Phase 1 TMDL (Tetra Tech and HIDOH, 2008).

A series of charts were developed that show relative pollutant loading by land cover category for the Phase 1 subwatersheds (Hanalei, Waioli, Waipa, and Waikoko), based on model results of existing conditions, which were calibrated to observed data (Phase 1 TMDL, Appendix C). Table 9 summarizes these results for the combined subwatershed areas. Waileia subwatershed (Princeville) is not included in this analysis because it was not included in the Phase 1 modeling and there was no water quality data available from its inland waters to characterize existing conditions.

In general, scrub/shrub and evergreen forest land cover contributes a vast majority of the loads. This is not surprising given that they make up nearly 90% of the land cover area for the watershed. Existing waterbird impoundments overlap with the palustrine emergent land cover, and taro pondfields are generally located within the cultivated land cover category. While other land covers may contribute relatively high concentrations of certain pollutants, their impact on the overall loading (which is represented for the entire Phase 1 Watershed in Table 9 and individually for the subwatersheds in Figure 21 and Figure 22, and in Appendix C of the Phase 1 TMDL) may be fairly minor due to their small land area and resulting runoff volume.

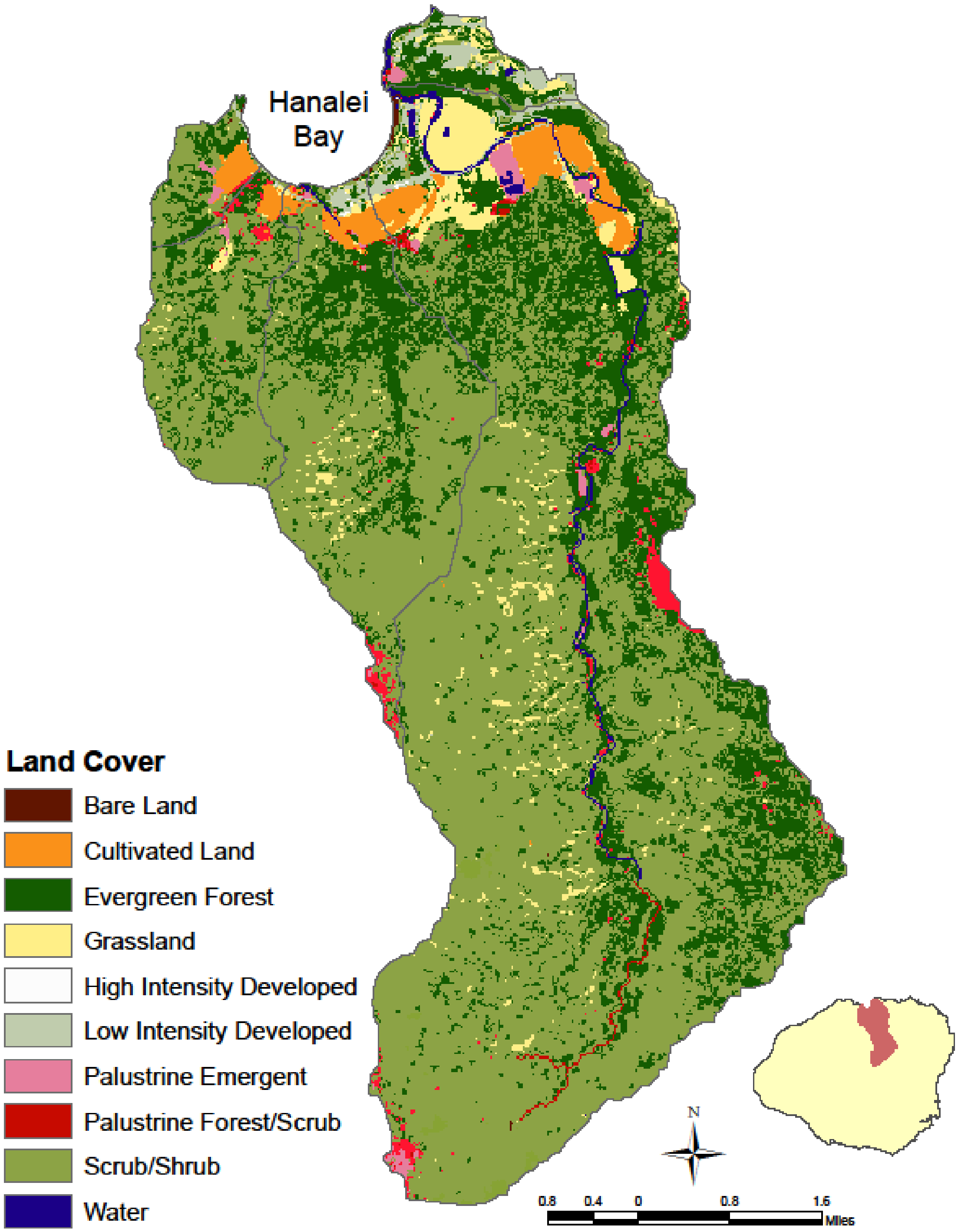


Figure 19. Land cover in the Hanalei Bay Watershed (NOAA, 2000)

The relative loadings presented in Table 9 are based on an accounting of overall loads from the calibrated model. As indicated by the second column in the table, the model suggests that land cover categories with the greatest relative land area generally contribute the highest relative loading. The application of these relative loadings within each sub-watershed produced the spatially-distributed pattern of load allocations shown in Figure 21 and Figure 22.

Table 9. Relative Loadings by Land Cover for the Hanalei Bay Watershed

Land cover category	Percent of total land area	Percent of total load	
		Enterococcus	TSS
Bare Land	0.1%	0.01%	0.1%
Cultivated Land	2.6%	2%	2%
Evergreen Forest	25.2%	27%	16%
Grassland	3.5%	0.4%	2%
High Intensity Developed	0.02%	0.1%	0.1%
Low Intensity Developed	0.8%	0.4%	1%
Palustrine Emergent	0.6%	7%	2%
Palustrine Forest/Scrub	1.7%	0.3%	2%
Scrub/Shrub	64.5%	63%	75%
Water	0.9%	0%	0.2%

6. Linkage Analysis

Linkage analysis is the technical evaluation of waterbody response to pollutant loading. The purpose of the analysis is to quantify the maximum allowable loading for each pollutant that will result in attainment of WQC in the receiving water, which is the TMDL. TMDLs were calculated for each waterbody-pollutant combination described in Section 2. Because the numeric targets are set equal to the numeric WQC for *enterococcus* and turbidity, attainment of these numeric targets will result in attainment of WQC. The mass reduction, and the percent reduction from the existing load, needed to attain WQC were also calculated for each waterbody.

To support the TMDL objectives outlined by HIDOH and USEPA for the Phase 1 TMDLs, we developed a comprehensive linked watershed/receiving water modeling to represent the Hanalei Bay Watershed system (Tetra Tech and HIDOH, 2008). A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data that simulates naturally occurring land-based processes over an extended period, including hydrology and pollutant transport. Many watershed models are also capable of simulating in-stream processes, using land-based calculations as input.

Receiving water models apply a series of algorithms to characteristics data to simulate flow and water quality of the waterbody. The characteristics data represent physical and chemical aspects of a waterbody. These models vary from simple 1-dimensional box models to complex 3-dimensional models capable of simulating water movement, salinity, temperature, sediment transport, pollutant transport, and bio-chemical interactions in the water column.

The Phase 1 TMDL explains why the selected models were chosen. The model selection criteria address technical, regulatory, and user-associated issues. Technical criteria describe the physical system in question, including watershed and receiving water characteristics, and processes and the constituent(s) of interest. Regulatory criteria include WQC and related interpretive policies. User criteria comprise the operational or economical constraints imposed by the end-user, and include factors such as hardware/software compatibility and financial resources. Based on these considerations, appropriate models were chosen to simulate watershed and receiving water conditions (Tetra Tech and HIDOH, 2008).

The remainder of this section describes the selected models and general model application, as they relate to the Phase 2 embayment TMDLs. Details associated with the Phase 1 TMDLs for streams and estuaries are described by Tetra Tech and HIDOH [2008]). The models were used to calculate existing conditions and the TMDLs.

6.1. Model Selection and Overview

Establishing the relationship between the receiving water quality targets and source loading is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired source load reductions. The link can be established through a number of techniques, ranging from qualitative assumptions based on sound scientific principles to sophisticated modeling techniques. Ideally, the linkage will be supported by monitoring data that allow the TMDL developer to associate certain waterbody responses to flow and loading conditions. The objective of this section is to present the approach taken to develop the linkage between sources and receiving water responses for TMDL development in Hanalei Bay.

Modeling the Hanalei Bay and its watershed presents a challenge using currently available modeling tools. The system involves various unique hydrologic features including: steep upland watersheds with adjacent lowland floodplains, sediment settling in the estuaries, internal and external loading of *enterococcus* and sediment, and agricultural diversions and return flows in the Hanalei River Estuary. In addition, to assist in TMDL development and to provide decision support for watershed management, the models can be used to simulate various scenarios and may require future modifications to address specific management and environmental factors. Such scenarios may result from the augmentation of input data to be collected in ensuing monitoring efforts, future implementation of various management strategies or best management practices (BMPs), or adaptation and linkage to additional models developed in subsequent projects. Therefore, model flexibility is a key attribute for model selection.

The proposed modeling system was divided into two components representative of the essential processes for accurately modeling hydrology, hydrodynamics, and water quality. The first component of the modeling system was a watershed model that predicted runoff and external pollutant loading as a result of rainfall events. The second component was a hydrodynamic and water quality model that simulated the complex water circulation and pollutant transport patterns in the estuaries and Hanalei Bay. For the Phase 2 Embayment TMDLs, the watershed model developed during Phase 1 was used as an input to the Hanalei Bay receiving water model; this is described below and in Appendices B [Phase 1] and I [Phase 2]).

The models selected for the Hanalei Bay TMDLs are components of USEPA's TMDL Modeling Toolbox (Toolbox), developed through the joint efforts of USEPA and Tetra Tech, Inc. (USEPA, 2003a). The Toolbox is a collection of models, modeling tools, and databases that have been utilized over the past decade to calculate TMDLs for impaired waters. Loading Simulation Program in C++ (LSPC) is the primary watershed hydrology and pollutant loading model in the Toolbox, and the Environmental Fluids Dynamic Code (EFDC) is the receiving water hydrodynamic and water quality model.

6.1.1. Watershed Model: Loading Simulation Program in C++

LSPC was selected for simulation of watershed processes, including hydrology and pollutant accumulation and wash-off, and to represent flow and water quality in the streams that drain the subwatersheds (Shen et al., 2004; USEPA, 2003b). LSPC integrates a geographical information system (GIS), comprehensive data storage and management capabilities, a dynamic watershed model (a recoded version of USEPA's Hydrological Simulation Program – FORTRAN [HSPF]), and a data analysis/post-processing system into a convenient PC-based windows interface that dictates no software requirements.

The LSPC model is capable of predicting water quantity and quality from complex watersheds with variable land covers, elevations, and soils. Because it is largely physically based, the model requires specific input data, such as weather, soils, land cover, and topography. This offers the ability to apply the model in areas where water quality data are sparse. The model can simulate *enterococcus* and sediment contributions from specific source areas (e.g., sub-basin areas or land cover categories), which is useful for TMDL development and allocation analysis. Details regarding the theoretical structure of the LSPC model and its modules can be found in the HSPF User's Manual (Bicknell, et al., 2001).

LSPC was used to simulate loadings from the watershed areas as part of the Phase 1 TMDL. These results were used to calculate TMDLs for stream impairments, as well as associated Informative TMDLs and load targets for unassessed segments. In addition, the watershed model was used as an input to the EFDC receiving water model of the estuaries (Tetra Tech and HIDOH, 2008). For Phase 2 TMDL development in Hanalei Bay, the LSPC model was again used as an input the EFDC receiving water model, this time to simulate loadings and attainment of WQC in Hanalei Bay, as described below.

6.1.2. Receiving Water Model: Environmental Fluid Dynamics Code

The Environmental Fluids Dynamic Code (EFDC) was used for hydrodynamic and water quality modeling of Hanalei Bay. The Phase 1 effort used this model to simulate the Hanalei River Estuary, Waioli Stream Estuary, Waipa Stream Estuary, and Waikoko Stream Estuary (Tetra Tech and HIDOH, 2008), and the Phase 2 embayment model built upon this previous model. The LSPC watershed model was linked to EFDC and provided all fresh water flows and concentrations as model input. EFDC is a general purpose modeling package for simulating one- or multi-dimensional flow, transport, and bio-geochemical processes in surface water systems including rivers, lakes, estuaries, reservoirs, wetlands, and coastal regions. The EFDC model was originally developed by Hamrick (1992) at the Virginia Institute of Marine Science for estuarine and coastal applications, and is considered public domain software. This model is now USEPA-supported as a component of the Toolbox, and has been used extensively to support TMDL development throughout the country. In addition to hydrodynamic, salinity, and temperature transport simulation capabilities, EFDC is capable of simulating cohesive and non-cohesive sediment transport, near field and far field discharge dilution from multiple sources, eutrophication processes, the transport and fate of toxic contaminants in the water and sediment phases, and the transport and fate of various life stages of finfish and shellfish. The EFDC model has been extensively tested, documented, and applied to environmental studies world-wide by universities, governmental agencies, and environmental consulting firms.

The structure of the EFDC model includes four major modules: (1) a hydrodynamic model, (2) a water quality model, (3) a sediment transport model, and (4) a toxics model. The EFDC hydrodynamic model is composed of six transport modules including dynamics, dye, temperature, salinity, near field plume, and a tracer module which simulates the movement of neutrally buoyant drifters released in each model cell at specified time sequences. The water quality portion of the model simulates the spatial and temporal distributions of 22 water quality parameters including dissolved oxygen, suspended algae (3 groups), attached algae, various components of carbon, nitrogen, phosphorus and silica cycles, and bacteria. These capabilities encompass the requirements of the Hanalei Bay TMDL project. In this study, the hydrodynamic, water quality, and sediment transport sub-models were applied to simulate the water circulation and water quality interaction (*enterococcus* and sediment) in Hanalei Bay and its estuaries.

6.2. *Model Application*

A complete discussion of the LSPC and EFDC models is provided in Appendix B of the Phase 1 TMDL, which describes model configuration, hydrologic and hydrodynamic calibration and validation, and water quality calibration and validation. It also provides a list of assumptions specific to each modeling system and a discussion of model application (Tetra Tech and HIDOH, 2008). Appendix I of the Phase 2 TMDL (this document) discusses modifications made to the EFDC model for the Phase 2 embayment model. The models were initially calibrated to observed hydrologic and water quality data to characterize existing conditions. After the models were calibrated, iterative simulations were performed by reducing the pollutant loading factors until numeric targets were achieved in the receiving waters. The estuary WQC for *enterococcus* and turbidity are either identical to or more stringent than the embayment WQC; therefore, the load reductions required for the estuaries were applied to Hanalei Bay and the model was used to verify that the Bay WQC were attained under these conditions. The loads associated with the numeric target attainment simulations were the TMDLs. Percent reductions were calculated based on the difference between the TMDLs and the loads associated with the existing conditions (calibrated model results).

7. TMDL Calculations and Allocations

This section discusses the methodology used for TMDL development, and presents TMDL results in terms of loading capacities, load allocations, and required load reductions for the *enterococcus* and turbidity impairments included on Hawaii's 303(d) list for Hanalei Bay (Figure 2, Table 2, and Table 5) (HIDOH, 2008a).
Figure 2

7.1. Methodology

Two models were used to estimate existing loads and TMDLs for the *enterococcus* and turbidity impairments: the LSPC watershed loading model and the EFDC receiving water model. The LSPC model was calibrated and validated as part of Phase 1 TMDL development for streams and estuaries (Tetra Tech and HIDOH, 2008). Five sub-basins immediately adjacent to the bay (sub-basins 100, 101, 200, 300, and 400 in the Phase 1 TMDL, see Figure 20) were delineated to drain to the estuary because fine-scale localized data were not available to delineate direct drainage areas along the shoreline. Flow and loading from these sub-basins were routed through the estuaries to ensure pollutant loading associated with the land cover and groundwater were accounted for in the model results; however, these results were divided during assignment of *enterococcus* load allocations into groundwater and surface water-related loading. Groundwater loading included *enterococcus* counts similar to the geometric means presented in Table 8.

Results from the LSPC model were then used as input to the EFDC model of Hanalei Bay and its estuaries. The EFDC model was originally developed to calculate the Phase 1 TMDLs for the estuaries, for which Hanalei Bay was included as a boundary condition. This Phase 2 effort focuses on TMDL development for Hanalei Bay; therefore, the EFDC model was updated for the bay (see Appendix I).

The EFDC receiving water model was calibrated and validated for two overlapping years (2004 and 2005; see Appendices B and F of the Phase 1 TMDL [Tetra Tech and HIDOH, 2008] and Appendix I). 2005 was a high flow year (annual flow was 28 percent above the 35-year average flow) and 2004 was a fairly average flow year (annual flow was 5 percent above the 35-year average flow). Both the LSPC and EFDC models were run using the two year EFDC simulation period to calculate the existing and allocation loads. The year 2004 required greater load reductions than 2005; therefore, 2004 was selected as the TMDL critical year.

The *enterococcus* and TSS existing nonpoint source loads, including groundwater and surface water loading, were estimated in 41 modeled sub-basins in the Hanalei Bay Watershed using LSPC for the critical TMDL time period of 2004. The nonpoint source loads were then input to the EFDC receiving water model of the bay as lateral boundary conditions to the estuaries for more detailed analysis of receiving water quality associated with the embayment fate and transport during baseline (existing) conditions.

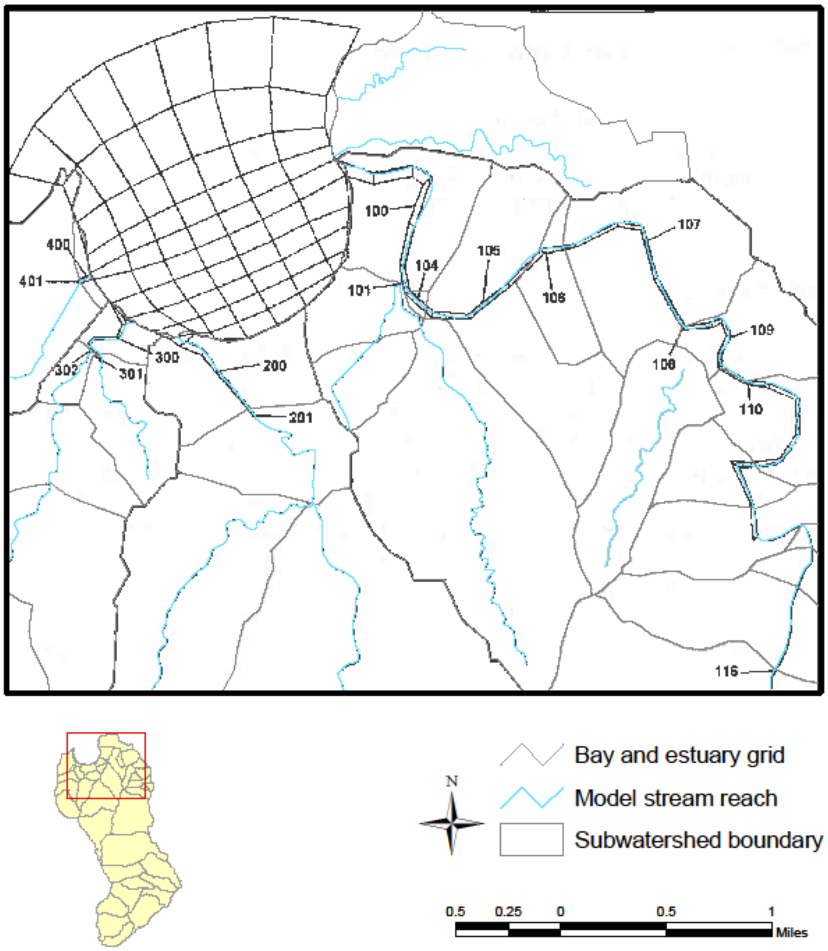


Figure 20. Inflows to the EFDC model grid

(The model does not include inflows from the Waileia subwatershed, which is shown for reference only in the northeast corner of this figure)

During TMDL development for the streams and estuaries, load reduction simulations were performed using the models to determine watershed loadings (from the LSPC model) that resulted in attainment of WQC in the impaired streams and estuaries (Tetra Tech & HIDOH, 2008). It is assumed that most of the pollutants entering the bay are transported via the inland stream systems. The loadings from these terrestrial inputs are diluted in the larger volume of embayment water (Data Inventory and Analysis). Because the estuary WQC for *enterococcus* and turbidity are either identical to or more stringent than the embayment WQC, meeting the estuary criteria will generally ensure that the embayment criteria are achieved. Therefore, the load reductions determined for the Phase 1 TMDLs for the estuaries (Tetra Tech and HIDOH, 2008) were applied to Hanalei Bay, and the EFDC model was used to verify that the Bay WQC were attained under these conditions. In addition, during the TMDL simulations, compliance with the WQC was checked at several locations in the Bay.

Once these water quality criteria were reached in the embayment, the associated loadings from the watershed model were summarized. These values are the TMDLs. The percent reductions for *enterococcus* and turbidity were then calculated by comparing the difference between the results of the existing loads and the Hanalei Bay TMDLs. Load allocations were determined by subtracting the margin of safety from the TMDL and assigning the loads to the appropriate sources, including separate groundwater and surface water loads. For the final TMDL simulations, to ensure system-wide compliance, WQC were achieved in the embayment and the Phase 1 estuaries and freshwater segments, even if those segments were not listed as impaired. Therefore, the TMDLs are conservative because they attain the most stringent WQC.

Some of this conservatism is offset by the fact that the Waileia subwatershed—which only represents about 2.4% of the total embayment contributing area—was not included in the Phase 1 LSPC model (because its inland waters are not listed as impaired), and the Phase 2 loading calculations did not include loading from its two streams. However, because these two streams are predominantly ephemeral and have the smallest contributing areas of any stream systems in the greater Hanalei Bay Watershed, we believe that their potential impact on the TMDL equation is well within the TMDL margin of safety. Nonetheless, reducing pollutant loads from Waileia would help to implement the embayment TMDLs.

Because turbidity cannot be directly simulated using the watershed and receiving water models (Section 3), TSS was simulated as a surrogate. Achieving TSS TMDLs and managing nutrient loads will contribute to meeting the turbidity criteria. Turbidity and TSS had a strong relationship (R^2 value of 0.7175), as described in Section 4.2.2, particularly at lower values. Therefore, this relationship was used to convert the TSS concentrations to turbidity values for comparison with the appropriate WQC. After model simulations were performed for TSS, these results were divided by 1.1 (using the equation presented in Figure 17) to determine the associated turbidity value. These turbidity values were then compared with the WQC to determine compliance with embayment standards. The TSS concentrations associated with the model simulation that resulted in compliance of the embayment WQC for turbidity were used to calculate a TSS loading for TMDL development (i.e. TSS TMDLs were used as a surrogate for turbidity, although compliance was determined by comparing to the applicable turbidity WQC).

7.2. TMDL Calculation

The TMDL is the total amount (mass) of a pollutant that can be assimilated by the receiving waterbody while still achieving the numeric targets (based on WQC). In TMDL development, allowable loadings from pollutant sources that cumulatively amount to no more than the TMDL must be established; this provides the basis to establish water quality-based controls.

A TMDL for a given pollutant and waterbody is comprised of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, to account for the uncertainty in the relationship between pollutant loads and the quality in the receiving waterbody. Conceptually, this definition is represented by the equation:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

TMDLs were established for Hanalei Bay using the methodology described above. The impairments addressed by these TMDLs are identified in Table 2, and the unlisted waterbody-pollutant combinations were also addressed using this method to ensure comprehensive future compliance. These TMDLs identify and allocate appropriate loadings to the subwatersheds, separated by surface water and groundwater loads, that cause or contribute to the impairment. The WLA portion of this equation is the total loading assigned to point sources, which in this case is zero. The LA portion is the loading assigned to nonpoint sources. The MOS is the portion of loading reserved to account for any uncertainty in the data and computational methodology, as described in Section 7.2.3. The MOS used for this TMDL included both implicit and explicit components.

7.2.1. Waste Load Allocations

Federal regulations (40 CFR 130.7) require TMDLs to include individual WLAs for each point source discharge regulated under a discharge permit. However, no individual permits, municipal separate storm sewer systems (MS4), or discharges of stormwater associated with industrial activities are currently operating under NPDES regulations in the Hanalei Bay Watershed. If WLAs are required to accommodate future point source discharges, then the LAs will be revised and the overall changes in TMDL allocations will be submitted to USEPA for approval.

7.2.2. Load Allocations

According to federal regulations (40 CFR 130.2(g)), load allocations are best estimates of the nonpoint source and background loading. This addresses all loadings that are not regulated by a discharge permit (which are allocated as WLAs). Because there are no WLAs in the Hanalei Bay Watershed, this decision only provides LAs associated with the *enterococcus* and turbidity TMDLs. LAs are provided for the land use-based nonpoint sources as well as for groundwater loading to Hanalei Bay. The division of these loads between surface water and groundwater sources was based on the watershed model output, which specifies the amount of loading from different sources or types of water.

7.2.3. Margin of Safety

The statute and regulations require that a TMDL include a margin of safety (MOS) to account for any uncertainty in the data and the computational methodology used for TMDL analysis. There are two ways to incorporate the MOS (USEPA, 1991): (1) implicitly incorporate the MOS using conservative model assumptions to develop allocations and (2) explicitly specify a portion of the total TMDL as the MOS and use the remainder for allocations. The TMDLs for Hanalei Bay included both an explicit and implicit MOS. The explicit MOS was computed as five percent of the calculated TMDL value. An implicit MOS was also incorporated through the use of conservative assumptions during the TMDL development process, such as application of the estuary load reductions to achieve embayment WQC.

7.3. TMDL Results and Allocations

The LSPC and EFDC models for were run for 2004 for the baseline (existing) conditions. The TMDL allocation conditions for Hanalei Bay were then determined by applying the load reduction simulations determined for the Phase 1 estuary TMDLs (Tetra Tech and HIDOH, 2008) and then confirming that the Bay WQC were attained under these same conditions. Associated loads were determined for each of these targets. The embayment TMDL results are based on achieving the year-round embayment standards for *enterococcus* and the wet condition WQC for turbidity (as previously noted, the wet condition turbidity WQC were applied year-round since the fresh water inflow to the Bay is greater than one percent of the total embayment volume; see Data Inventory and Analysis section).

In the LSPC allocation scenarios, contributions from all land covers were reduced uniformly to obtain general watershed-wide reductions (i.e., all land covers had the same percent reduction). Scenarios that vary the relative land cover contributions for each parameter would be particularly useful with additional information that better identifies and quantifies sources. Loads from the watershed are the only controllable source of sediment. While additional processes (especially wave impacts) likely impact turbidity in Hanalei Bay, reducing the watershed loads of sediment will ultimately decrease the amount of material available for resuspension by these other processes, thereby reducing turbidity.

The maximum TSS and *enterococcus* loads that will attain the WQC for Hanalei Bay are presented in Table 10 and

Table 11, respectively. As noted previously, the TSS TMDLs are a surrogate for turbidity. These tables also present the reductions necessary to meet the TMDLs (presented as both mass reductions and percent reductions), as well as the load allocations to nonpoint sources associated with groundwater and surface water inputs. Model results suggest that for TSS, the load reductions required are 79.5 percent to achieve the geometric mean WQC, 68.3 percent to achieve the 10% NTE WQC, and 58.0 percent to achieve the 2% NTE WQC. For *enterococcus*, a 36.9 percent reduction is necessary to achieve the 30-day running geometric mean WQC.

Charts were also developed to describe a distribution of this TMDL allocation scenario among the sub-watersheds/estuaries. In this scenario, TSS WQC were attained with approximately 90 percent of the TSS loading from the Hanalei River Estuary, and 7 percent, 2 to 3 percent, and less than 1 percent from the Waioli, Waipa, and Waikoko Estuaries, respectively (Figure 21). Similarly, the *enterococcus* geomean criterion was attained with approximately 75 percent of bacterial loading is from the Hanalei River Estuary, followed by Waioli (about 1/5 of the Hanalei estuary load), Waipa, and Waikoko (Figure 22).

Table 10. Total Suspended Solids TMDL Load Allocations and Load Reductions Required to Achieve TMDLs for Hanalei Bay

TMDL Allocations		Total Suspended Solids TMDLs*		
		Geometric Mean	**10% Not-to-Exceed**	**2% Not-to-Exceed**
LA	**(kgd)**	842.4	1,302.1	1,722.5
MOS	**(kgd)**	44.3	68.5	90.7
TMDL	**(kgd)**	886.8	1,370.6	1,813.2
Existing Load	**(kgd)**	4,319.5	4,319.5	4,319.5
Reduction Required	**(kgd)**	3,432.7	2,948.9	2,506.3
	(%)	79.5%	68.3%	58.0%

Note: TMDL allocations in kilograms per day are obtained by dividing annual values by 366 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 kilogram; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs**, **Existing Loads** and **Reductions Required** may actually be greater than 0.

Embayment loads are inclusive of the Phase estuary and stream loads.
*Based on attainment of wet condition criteria, which apply to an embayment when the average daily fresh water inflow to the embayment equals or exceeds one percent of the embayment volume. For 2004, fresh water inflow exceeded one percent of the embayment volume each day (Data Inventory and Analysis).
Acronyms: LA = Load Allocation; MOS = Margin of Safety; TMDL = Total Maximum Daily Load; kgd = kilograms per day

Table 11. *Enterococcus* TMDL Load Allocations and Load Reductions Required to Achieve TMDLs for Hanalei Bay

TMDL Allocations		***Enterococcus*** **TMDL***	
		Geometric Mean	Single Sample Maximum
LA – Surface Water	**(CFU/day)**	3.1E+12	3.1E+10
LA – Groundwater	**(CFU/day)**	1.4E+11	1.5E+09
MOS	**(CFU/day)**	1.7E+11	1.7E+09
TMDL	**(CFU/day)**	3.4E+12	3.4E+10
Existing Load	**(CFU/day)**	5.3E+12	5.3E+12
Reduction Required	**(CFU/day)**	2.0E+12	5.3E+12
	(%)	36.9%	99.4%

Note: TMDL allocations in colony forming units (CFU) per day are obtained by dividing annual values by 366 days (the critical year for TMDL development was a leap year; therefore, the total number of days is equal to 366). Loads and Load Reductions rounded to the nearest 0.1 CFU; thus,

(a) **Totals** may be different than the sum of their parts and
(b) **TMDLs**, **Existing Loads** and **Reductions Required** may actually be greater than 0.

Embayment loads are inclusive of the estuary and stream loads since they represent the entire upstream loadings.
* The TMDL decision is based on the attainment of the revised geometric mean marine recreational criterion adopted in 2009 (35 cfu/100 ml). The single sample maximum analysis is presented for informational and diagnostic purposes only. The 303(d) listings are based on geomean analysis, therefore they are addressed by the geomean TMDL.

Acronyms: LA = Load Allocation; MOS = Margin of Safety; TMDL = Total Maximum Daily Load; #/day = number per day

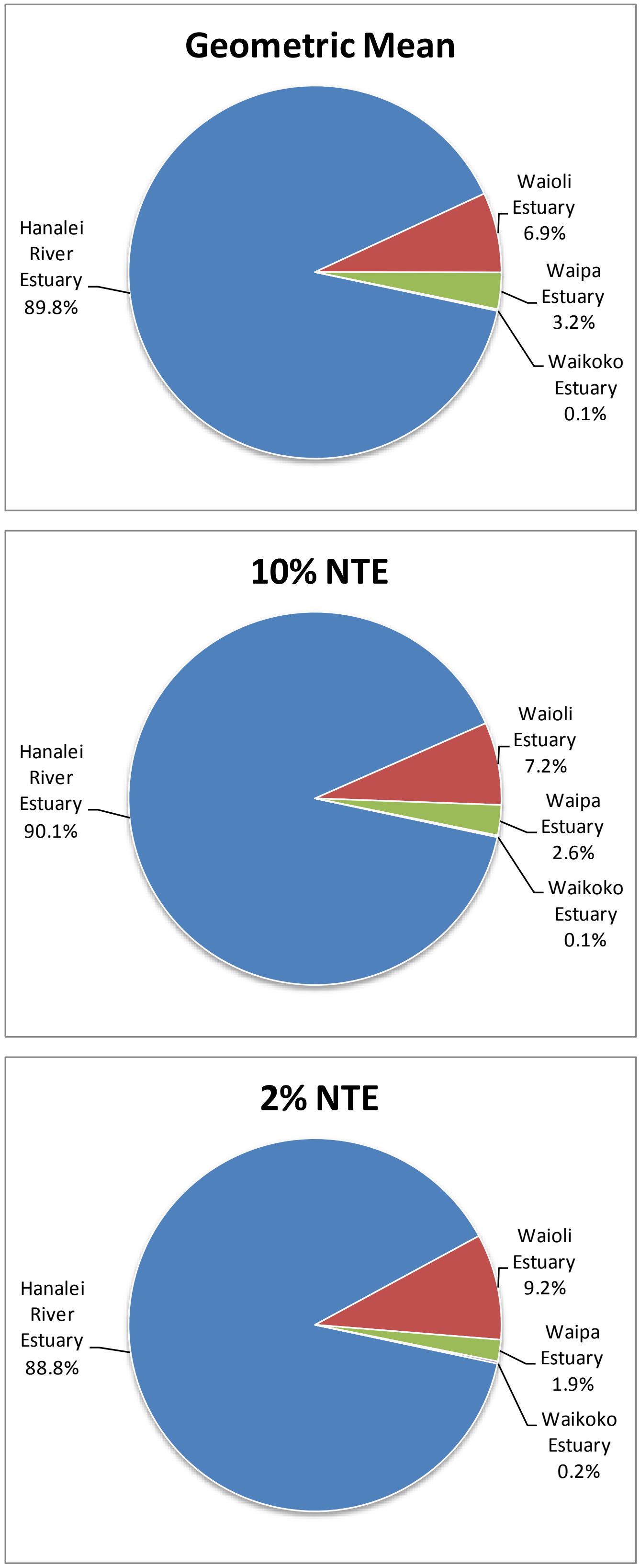


Figure 21. Distribution of TSS Loadings by Estuary

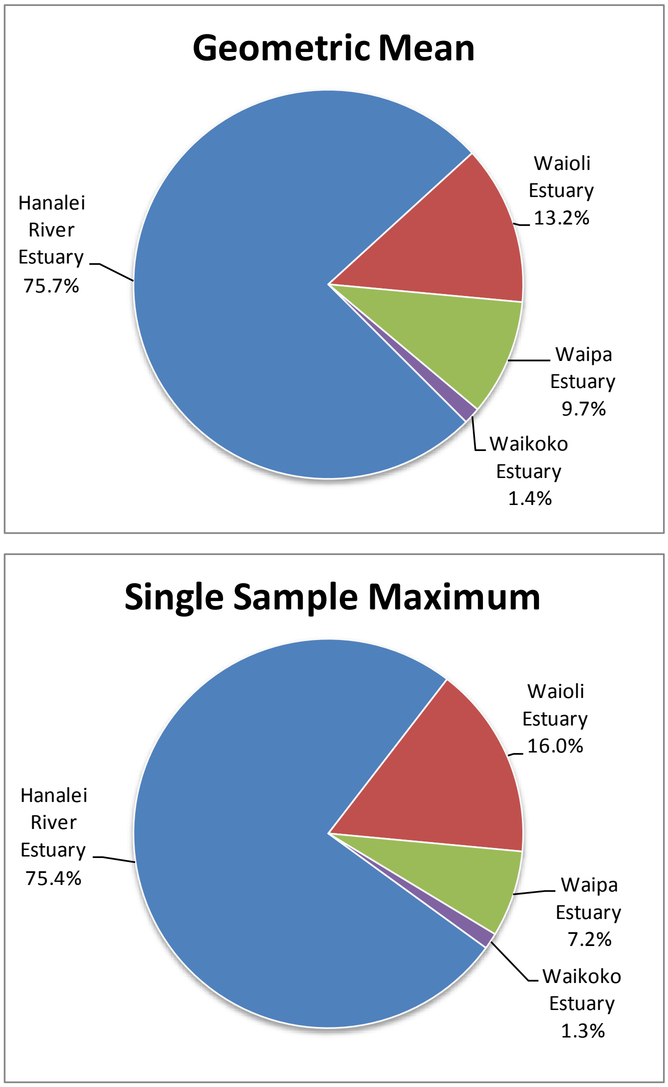


Figure 22. Distribution of Enterococcus Loadings by Estuary

7.4. Critical Conditions and Seasonal Variation

A TMDL must consider critical conditions and seasonal variation of streamflow, loading, and water quality parameters. The critical condition is the set of environmental conditions for which controls designed to protect water quality will ensure attainment of WQC for all other conditions. The intent of this requirement is to ensure protection of water quality in waterbodies during periods when they are most vulnerable. In Hanalei Bay, the critical conditions for *enterococcus* and turbidity impairments coincide with storm events. The Data Analysis section (Section 4.2) illustrates that such events can occur throughout the year.

A long-term continuous simulation is the one way to determine when the pollutants are above the target endpoints; therefore, models were run for a two year period (2004 and 2005). The more critical of the two years simulated (i.e., the year that required the greatest percent reductions) was 2004, which is characterized by both low flows during the dry season and high-flow events during storms (wet and dry seasons). This year was used for TMDL analyses to ensure that the WQC are attained during the most critical conditions.

Through simulation of an entire critical year, daily concentrations were estimated for all seasons of that year and compared to the numeric targets to determine necessary reductions. Model simulation of a full year accounted for seasonal variations in rainfall, evaporation, and associated impacts on runoff and transport of bacteria and sediment loads to receiving waters. To consider the variability among seasons and ensure the greatest protection of the receiving waters, the TMDLs were calculated so WQC were attained throughout the year (note: turbidity impairments in the Bay were associated with wet conditions when the fresh water inflow was at least one percent of the total embayment volume; this wet condition occurred each day of the 2004 critical period [see Data Inventory and Analysis section]).

8. Implementation Framework for Phased TMDL Approach

The TMDL process provides a technical basis for activities that reduce pollutant loads, improve water quality, and repair the health and integrity of aquatic ecosystems. Because the TMDL analysis suggests that implementing the Phase 1 TMDLs for inland waters will result in the attainment of the embayment water quality criteria (Phase 2 TMDL targets), the implementation framework is the same for both phases, with the addition of the Waileia subwatershed to the implementation area.

A phased TMDL process is an approach for developing TMDLs that require long-term loading reductions from difficult-to-solve problems, while pursuing near-term allocations for more readily addressed sources. Phased TMDLs are useful in situations where iterative load allocations are justified because (1) a lack of available information makes it uncertain that the control strategies will work to achieve water quality standards, and (2) nonpoint source reductions are difficult to predict, as in Hanalei.

The Phase 1 TMDL included an implementation framework that addressed questions of where to focus project activities, and how to complete them, by viewing the watershed from various perspectives - such as regulatory-based (waterbody classes and uses), property-based (land ownership), management-based (regulatory and management authority), problem-based (land cover and degrading activities), and solution-based (implementation tools, technical/financial assistance, and previous/ongoing efforts). This framework, which remains valid, also included a table that suggested how the TMDL implementation framework could be constructed as a matrix of pollutants, source types and locations, and potential implementation tools/resources to address source control and pollutant load reduction.

Water quality improvement activities are more likely to be funded by certain federal programs when they are supported by a detailed planning document such as a TMDL Implementation Plan or a Watershed Based Plan. The TMDL implementation framework is a starting point for this type of detailed planning effort. It provides general prescriptions for watershed health and explains how key results from TMDL development suggest where to focus implementation activities and how to complete them.

Additional suggestions about specific activities (what, where, why, how, when, by whom, at what cost, and with what funding sources?) and their relative feasibility, benefits, and priorities will hopefully be generated during the upcoming development of a Watershed Based Plan for Hanalei. By using these general approaches and specific measures—incorporating the load allocations and implementation framework from the TMDLs, or conducting the actions prescribed by a Watershed Based Plan—an implementation project can potentially access additional Clean Water Act §319(h) funds for water quality improvement projects. A project may also qualify for construction funding from the HIDOH Clean Water State Revolving Fund Program to support efforts that address polluted runoff control.

8.1. Adaptive Implementation - Community and Government Roles

Due to the difficulty of drawing precise links between nonpoint sources and waterbody impairment in the Hanalei Bay Watershed, we continue to employ a phased approach to TMDL development and implementation. This phased approach allows us to use available information to establish interim targets, begin to implement needed controls and restoration activities, monitor waterbody response to these actions, and plan for TMDL review and revision in the future, including further assessment of how realistic or unrealistic the load reductions required may be. Thus, the Phase 2 TMDL decision is the next point along a continuum of nonpoint source implementation activities that can be adapted as new information becomes available, and that will include ongoing review and future revision of the TMDL decisions, as necessary.

We intend for the TMDL implementation framework and future Watershed Based Plans to inform and guide, not mandate, the manner in which the watershed community chooses to achieve load reductions, meet water quality standards, manage costs, minimize negative societal impacts, and maximize environmental effectiveness. HIDOH advocates a community-based adaptive approach to implementing nonpoint source load allocations —based on TMDL decisions, other watershed planning results, and local knowledge and experience—that prevents and reduces nonpoint source pollution while balancing health, environmental, economic and social concerns. While the implementation of TMDLs and the attainment of water quality standards is our legal mandate, we also value the protection of native wildlife and preservation of taro growing—even though each contributes to pollutant loading—and we do not want to threaten their survival with overburdensome water quality regulation.

As implementation proceeds, HIDOH recognizes that county governments have a special role in setting public land use policy, and in basing that policy, in part, on environmental goals. Water quality standards establish important environmental goals and public policy for protecting the designated uses of state waters and preventing water quality degradation. TMDLs based on water quality standards are a required vehicle for implementing this statewide policy. Therefore, given that both state and county governments have public trust duties to protect state waters, TMDLs are an important tool and consideration in assessing water quality impacts and making well-informed land use decisions.

Hanalei residents are the ultimate force for reducing pollutant loads and improving water quality, and will hopefully take the lead in defining specific implementation strategies and tasks. While the TMDL decisions do not pinpoint sources of the pollutants that are overloading the streams and estuaries, it is clear that our everyday behavior creates many water quality problems. We encourage each resident and user of the watershed to accept responsibility for its health and future by refining this everyday behavior, and to work with neighbors to develop community-based solutions to the larger problems in the watershed.

8.2. Previous and Ongoing Water Quality Improvement Activities

In December 2006, HIDOH and EPA identified the Hanalei Watershed as a priority area for working with local watershed representatives to achieve water quality improvements by 2012, including improvements in coral reef ecosystem function and health. Hanalei is also one of three priority watersheds in the state that was selected for the development of local action strategies to address land-based pollution impacts on coral reefs (UESPA et al., 2004). Since the Phase 1 TMDLs were approved in 2008, local watershed representatives upgraded wastewater disposal systems; restored fishponds; removed invasive forest weeds; constructed fences to exclude feral ungulates from agricultural lands, and livestock from stream corridors and wetlands; repaired mountain trails to reduce erosion from trail sources; installed treatments and adopted practices to reduce nutrient and sediment loading from taro pondfields; and conducted water quality monitoring to document ambient, pre-treatment, and post-treatment conditions in various waterbodies (see Table 13 at the end of this section, "Hanalei Watershed Management Documents, 2000-2010"). Although recently completed ungulate exclusion fencing on the East Alaka'i plateau may protect a very small area of Hanalei headwaters, it is unlikely to assist with the management of Hanalei pig populations, which are probably separate from Alaka'i populations, with minimal interbasin population transfer. (The Nature Conservancy, 2009; Menard, 2011).

In December 2009, HIDOH and EPA discussed nine potential actions that would support further implementation of Hanalei TMDLs and achieve water quality improvements. These nine actions, and their current status, are listed in Table 12. In addition, HIDOH routinely monitors water quality at Hanalei beaches; tracks the EPA inventory of large capacity cesspools (LCCs)[1] and manages underground injection control permit issuance and compliance in the watershed (see discussion below); and is developing its Groundwater Monitoring and Assessment Strategy to guide future groundwater monitoring in the area. Kauai County and other system operators of public water supply systems are now responsible for routine monitoring of area drinking water sources area to determine their compliance with drinking water regulations under the Safe Drinking Water Act.

Individual Wastewater Systems

As of December 2010, ten LCCs have been closed in Hanalei. Six known LCCs have not been closed yet, and EPA is working with the individual property owners to close them. EPA suspects that approximately fifty additional parcels may have an LCC on the property, and EPA has requested that each property owner submit a schedule to close the LCC, or if there is no LCC on the property, to provide the appropriate documentation to demonstrate that the current wastewater system that is in use is not an LCC.

[1] Under federal regulations, a large capacity cesspool (LCC) is a cesspool which serves multiple dwellings, or for non-residential facilities has the capacity to serve 20 or more persons per day. A dwelling consists of a room or group of rooms with facilities for living, sleeping, food preparation and eating, and a food preparation area contains a sink, stove (or equivalent heating appliance) and refrigerator.
In 1999, EPA promulgated regulations under the Safe Drinking Water Act's Underground Injection Control (UIC) Program which prohibited the construction of new large capacity cesspools as of April 2000 and required the closure of all existing large capacity cesspools by April 5, 2005 (see 40 C.F.R. § 144.88). **Operation of a large capacity cesspool after April 5, 2005 is a federal violation that may subject the owner/operator to enforcement and penalties.**

In conjunction with its Targeted Watershed Initiative Grant from EPA, the Hanalei Watershed Hui identified fifteen priority homes for cesspool replacement with new septic tank/leach field systems, and fourteen of the fifteen households were interested in a replacement project. However, the exact number of LCCs involved in this project, and the number of priority replacements completed, is not reported (*see* Hanalei Watershed Hui, 2005 & 2006). Regardless, the dozens of cesspool replacements that may be required and desired potentially represent both positive and negative economic impacts for the community. Therefore, the faster EPA can complete its LCC inventory task, the sooner the community will know how much cesspool closure is legally required, and the more accurately these closures and other individual wastewater system upgrades can be addressed in the Watershed Based Plan.

Table 12. Actions to support the implementation of Hanalei TMDLs and achieve water quality improvements

Action	Status
Work with local stakeholders to determine if an updated watershed plan to identify priority implementation activities is viable, and by whom.	Contracting in progress (HIDOH Polluted Runoff Control Program and Hanalei Watershed Hui).
Use the Hawaii Association of Conservation Districts (HACD) contract that supports the Kauai conservation specialist to target efforts to develop and implement conservation plans associated with taro pondfield agriculture in the Hanalei Bay watersheds.	HACD contract in place (HIDOH Polluted Runoff Control Program).
Initiate water quality monitoring and complete stream bioassessment for Hanalei watershed streams adequate to make an assessment decision for inclusion in the 2012 Water Quality Monitoring & Assessment Report.	No action.
Monitor initial USDA Conservation Effects Assessment Program (CEAP) effort to determine if it will provide incentives and promote the use of appropriate agricultural BMPs in the Hanalei watersheds.	CEAP effort underway on Oahu, in collaboration with DLNR, University of Hawaii, and NGOs.
EPA will work with U.S. Fish and Wildlife Service, NRCS, and HIDOH to determine if Hanalei NWR comprehensive conservation planning process offers opportunities to promote on-the-ground implementation activities and potential water quality restoration in the Hanalei watersheds. *See* http://www.fws.gov/hanalei/planning.html.	Draft plan and environmental assessment targeted for release in Fall/Winter 2010. The seven preliminary goals developed by the planning team do not explicitly include water quality improvement. However, discussions with refuge managers indicate that water quality will be a significant planning concern.
HIDOH will determine number of NPDES permits in the Hanalei Bay watersheds and share with EPA for inspection/compliance prioritization.	No active permits.
HIDOH will determine if Individual Wastewater System (IWS) inspections in these watersheds are warranted based upon system type, etc., and will prioritize areas for inspections. The closure of large capacity cesspools LCCs), and improvements to legacy IWS and IWS approved under emergency procedures, are likely to result in pollutant load reductions.	Inventory completed. Inspection of records for the first priority (Hanalei Dolphin) indicated that there are no LCCs on the property, the septic system has been fitted with an aerobic unit, and the individual cesspools are properly documented. However, as with other facilities constructed in the wake of Hurricane Iniki (1992), emergency procedures allowed builders to bypass normal HIDOH IWS design requirements and approvals. Also, the design of older "legacy" cesspools statewide may have been approved by HIDOH or county government under historic practices for which records may not be available.
HIDOH will target distribution of Individual Wastewater System operation and maintenance educational materials in these watersheds.	Initiated.
EPA and HIDOH will place a priority on the use of Section 404/401 authorities in these watersheds to insure projects requiring permits from the US Army Corps of Engineers will have minimal impacts on aquatic resources.	Initiated.

8.3. Phased TMDL Development and Implementation Schedule

Due to changes in local conditions, the implementation timeline presented in the Phase 1 TMDL is no longer valid. HIDOH will reevaluate future phasing of implementation activities and Hanalei TMDL development after (1) completing the 2008/2010 Water Quality Monitoring and Assessment Report, and (2) initiating contract work on a Watershed Based Plan. We expect that future TMDL development and implementation in Hanalei may continue to be supported by HIDOH water pollution control and water quality management grant funds and other EPA regional and national programs. Considerable and sustained long-term effort will be needed to (1) establish measurable milestones, (2) determine if the pollution control measures being implemented are resulting in actual load reductions with watershed-scale effects, (3) and decide how to change course if load reductions are not achieved and milestones are not reached.

However, several basic, short-term tasks that would inform these long-term efforts remain to be completed. A separate assessment of the Waileia sub-watershed would help determine if its inland waters achieve water quality standards. A more detailed analysis of Waileia hydrology, land cover, land use, and human activity would help estimate the extent of sub-watershed contributions to water quality impairments in Hanalei Bay, and identify opportunities for pollutant load reduction. Further assessment of inland waters in the Waioli. Waipa, and Waikoko sub-watersheds could establish benchmarks for time-series surveys of biological indicators and promote the reevaluation of bacterial, nutrient, and sediment impairment status for the 2012 EPA reporting cycle. Repeat monitoring of four biological survey sites on the Hanalei River, using the Hawaii Stream Bioassessment Protocol, would establish a new data points for a time-series intended to evaluate changes in the biological community that was benchmarked in 2006.

8.4. Implementation Assurance

Implementation of the load allocations and required load reductions will result in attainment of the water quality standards for *enterococcus* and turbidity in Hanalei Bay. The State will pursue implementation of the approved load allocations through Hawaii’s Implementation Plan for Polluted Runoff Control (HIDOH, 2001), Hawaii’s Coastal Nonpoint Pollution Control Program Management Plan (Hawaii Coastal Zone Management Program, 1996), and the Clean Water State Revolving Fund Intended Use Plan (HIDOH, 2010), all of which serve the State Water Quality Standards (HAR §11-54) (HIDOH, 2009). Planning and regulatory decisions of the County of Kauai also serve these standards, particularly under county ordinances governing planning, zoning and subdivision; building design and construction (including wastewater disposal systems); drainage and flood management; and sediment and erosion control.

The Kauai sediment and erosion control ordinance (Council of the County of Kauai, 2003) requires that all grading, grubbing, and stockpiling activities "incorporate BMPs to the maximum extent practicable to prevent damage by sedimentation to streams, watercourses, natural areas, and the property of others," and identifies minimum BMPs that the County Engineer may require, as determined by specific site requirements, *see* Id., §22-7.5. These BMP requirements apply regardless of whether a permit is required or an exemption is applicable, thus providing the county with an enforceable mechanism that is independent of the shield from permitting requirements that is provided by the exemptions in §22-7.6. Id.

An agricultural operation may obtain an exemption from the county requirement to obtain a grading, grubbing, or stockpiling permit if the operation is managed in accordance with (1) soil conservation practices acceptable to the appropriate soil & water conservation district directors (SWCD), and (2) an actively pursued comprehensive conservation plan that:

- was approved by the appropriate SWCD Board,
- does not alter the drainage pattern, and
- includes best agricultural management practices. Id., §§22-7.6.(e) and (e)(1)(A), (B), and (D).

However, the exemption can only be secured by submitting the approved Conservation Plan, along with additional information and permissions, to the County Engineer (Engineering Division, 2004). An exemption from permit requirements is terminated if:

- the SWCD cancels the Conservation Plan,
- the County Engineer cancels the exemption, or
- a Conservation Plan that was approved more than ten years ago is not appropriately modified, and reviewed and re-approved by the SWCD. Id., §§22-7.6.(e)(5) and (7).

An SWCD approves or cancels a Conservation Plan under the SWCD power to "enter into agreements with . . . any occupier of lands . . . for carrying on soil and water control conservation and operations . . . ." HRS §180-13(3). SWCD approval indicates the Plan's acceptability for meeting county erosion and sediment control standards that are required by state law, *see* HRS §180C-2. However, (1) DLNR has not adopted administrative rules governing the implementation of SWCD statutes, (2) many SWCDs, including East Kauai, apparently do not have bylaws governing the exercise of SWCD powers granted by HRS §180-13, and (3) existing SWCD Bylaws that we reviewed do not establish criteria for determining if soil conservation practices are acceptable or if a Conservation Plan should be cancelled.

An SWCD also has the power to develop plans for conservation of soil and water resources and control and prevention of erosion within the district. HRS §180-13(6). Some SWCDs develop annual work plans and five-year plans (see Kona SWCD bylaws, available at http://kswcd.org/PDF/By-Laws.pdf). Although the East Kauai SWCD publishes an annual report (see ftp://ftpfc.sc.egov.usda.gov/HI/pub/partnerships/2010/WEB_Annual_Report_for_NRCS_Site.pdf), we have not yet obtained any of its current work plans. The annual report notes that eighteen East Kauai SWCD cooperators entered new contracts with the U.S. Department of Agriculture in 2010, under the Natural Resources Conservation Service Environmental Quality Incentives Program (EQIP). However it is unknown whether or not any of these contracts apply to lands within the Hanalei Bay watershed, and what practices the cooperators are bound to implement.

The U.S. Fish & Wildlife Service is preparing a Comprehensive Conservation Plan (CCP) for the Hanalei National Wildlife Refuge and an environmental assessment to evaluate the potential effects of various CCP alternatives, including cooperative farming and wetland management activities. During the CCP planning process, the USFWS will analyze methods for protecting refuge resources while providing quality opportunities for wildlife-dependent recreation (U.S. Fish & Wildlife Service, 2009).

Watershed Based Plans and TMDL Implementation Plans may provide detailed information about specific measures for reducing pollutant loads in the Hanalei Bay watershed. If a plan addresses the nine elements required by USEPA Section 319 Program guidance (USEPA, 2003), and incorporates the load allocation objectives identified in a TMDL decision, then the water quality improvement projects in the plan should have a positive effect on water quality, and are more likely to and be selected for funding with Clean Water Act §319(h) funds. Other prominent sources of funding include Garden Island Resource Conservation & Development, Inc. (GIRCD), whose objectives include support of erosion and sedimentation controls and other water quality protection and improvement practices (GIRCD, 2009), and U.S. Department of Agriculture Farm Bill programs such as EQIP, *see* http://www.pia.nrcs.usda.gov/.

Additional information and resources for establishing the Watershed Based Plans, targeting implementation, implementing best management practices, and assessing and evaluating implementation progress is available from a wide range of sources, as previously identified in section 8 of the Phase 1 TMDL. Since the completion of the Phase 1 TMDL in 2008, the State of Hawaii updated its management measures for the coastal nonpoint pollution control program (Stewart, 2009a & 2009b) and published the "Hawaii Watershed Guidance" for developing and implementing "watershed plans that have the greatest potential for achieving water quality goals" (Tetra Tech, Inc., 2010) and as a means to reintroduce the Coastal Zone Management 6217(g) measures (Coastal Nonpoint Pollution Program, 2010).

Table 13. Hanalei Watershed Management Documents, 2000-2010

Year	**Lead Author**	**Waterbodies/Sampling Targets**	**Measurements/Analysis**	**Dates**	**Conclusions about Hanalei Watershed**
2010	Boehm	4 stream mouths (Hanalei, Waioli, Waipa, Waikoko); urban drainage (discharge to Waioli); cesspool; animal feces	*Enterococcus*, fecal coliform, dissolved inorganic nitrogen, soluble reactive phosphorus, molecular DNA/RNA, flow rate	3/2008, 3/2009	"[C]ultivated and urban land cover may be sources of nutrients to coastal waters." "Bacterial and nutrient areal loading rates were highest for watersheds with the largest urban and cultivated fractions . . ." Feral and domesticated animals and humans are implicated as sources of microbial pollutants.
2010	Knee	surface water and groundwater at 5 shoreline locations (4 at Hanalei Bay); Princeville WWTP effluent	carbaryl, metalaxyl, metribuzin, caffeine	8/2006, 2/2007	Metribuzin was detected in 5 of 61 samples (locations not identified). Caffeine was detected in 35 of 61 samples at concentrations "consistent with a terrestrial caffeine source located close to the shoreline and suggestive of a sewage source." Caffeine was not detected in Hanalei River (upstream) or offshore (open coastal). *See also* Knee et al., 2008.
		Hanalei River (upstream)		3/2008	
		offshore (open coastal)		3/2008	
2010	Rodgers	Waipa Stream (diverted flow); Waipa and Waikoko irrigation systems (various inflow/outflow); Waikoko estuary	turbidity, ammonium, and *Enterococcus* on a weekly to monthly basis	9/2007 to 9/2009	78m^2 of floating racks harvested at 6-month intervals produced maximum yields of 10.84 lbs of Nitrogen that was removed and sequestered in the plant material, and approximately 998 lbs of wet mud that was attached to the roots on the plants.
		Waikoko reef	coral larval recruitment	2003-2008	declined at 3 of 4 embayment sites
			live coral cover	2007-2009	increased
			coral infection	2007-2008 2008-2009	decreased increased
			reef sediment	2007-2009	% terrigenous sediment increased; % fines/silt/clay particles decreased; higher levels of nutrients, mud, and terrigenous sediment at deeper sites

Hanalei Watershed Management Documents, 2000-2010 (continued)

Year	Lead Author	Waterbodies/Sampling Targets	Measurements/Analysis	Dates	Conclusions about Hanalei Watershed
2010	Rodgers (cont.)	Waikoko *lo'i* and floodplain soil	pH; nutrient content (P, K, Ca, Mg, NH_4); % total carbon; % total nitrogen; soil particle size	9/2007 to 9/2009	When regular fertilizer was tilled in, "ammonium [was] available in the surface water for at least four weeks after initial flooding of fields." When fertilizer was tilled in or applied on the water, slow-release fertilizer produced less ammonium in the water than did regular fertilizer. "[T]the cost of using slow-release fertilizer is approximately equal to that of regular fertilizer."
2010	Ragosta	Waipa Stream (24 riparian plots and 7 stream sites)	riparian canopy over; *Enterococcus* in soil. manure, and stream water; salinity, dissolved oxygen, turbidity	7/2004 to 6/2005	"*Enterococcus* concentrations (MPN/g) are much higher in cattle manure than in surface soil, and . . . by decreasing riparian canopy cover %, *Enterococcus* geometric mean concentrations in stream water could increase, perhaps due to overgrazing near streams, removal of riparian zone canopy, and increased fecal surface runoff due to soil compaction. It is possible that previous contamination, followed by degradation and disappearance of the fecal matrix, may leave *Enterococci* in tropical island soils even though feces do not appear to be present."
2010	Stock	Hanalei River	suspended sediment loads	10/2004 to 09/2008	"50% of the load was transported on 0.5% of the days, and 90% of the load was transported on 5.1% of the days . . . average annual load was 1,361 tons/mi^2." "[T]he primary source of fines . . . is from erosion of banks or other channel-proximal deposits, rather than large unvegetated areas."

Hanalei Watershed Management Documents, 2000-2010 (continued)

Year	Lead Author	Waterbodies/Sampling Targets	Measurements/Analysis	Dates	Conclusions about Hanalei Watershed
2009	Draut	Sediment in Hanalei Bay/River	Sedimentary facies and isotopic properties	c. 2006	"In Hanalei Bay, the youngest and thickest terrigenous sediment was consistently present near the river mouth and in a bathymetric depression that acted as at least a temporary sediment sink." "In most years, flood sediment accumulating in the bay and on its fringing reefs would be remobilized and advected out of the bay during winter, when the wave climate is energetic. Turbidity and sedimentation on corals resulting from late spring and summer floods during low wave energy could have a greater impact on coral-reef ecosystems than floods in other seasons, an effect that could be exacerbated if the incidence and sediment load of tropical summer floods increase due to urbanization and climate change." *See also* Draut 2006, 2007.
2009	Hagedorn	Hanalei River	estimated runoff and suspended sediment fluxes	2005-2008	"Overall, FLO-2D performs well in small tropical river systems where climate and soil properties are well constrained. The model allows identification of areas prone to sediment loading and is proposed as a valuable tool in long-term catchment management."
2009	Takesue	Sediment (suspended and deposited) in Hanalei Bay, Hanalei River, lower Hanalei watershed	nearshore and terrestrial sediment characteristics "^{7}Be activities increase with annual rainfall and elevation."	6/2006 to 9/2006	"[A]t least some terrestrial runoff during a moderate flood . . . came from farmland used for taro cultivation . . ." "Non-point source stormwater runoff from roads probably contributed to elevated Ni, Cu, Zn, and Pb in flood sediment." "[L]ow Co values and ^{7}Be and ^{137}Cs activities suggest that terrestrial runoff was mobilized by river undercutting on the west side of Hanalei valley . . ." "[E]levated ^{7}Be in river suspended sediment indicated that rainfall mobilized surficial soil in the upper watershed . . ."

Hanalei Watershed Management Documents, 2000-2010 (continued)

Year	Lead Author	Waterbodies/Sampling Targets	Measurements/Analysis	Dates	Conclusions about Hanalei Watershed
2009	Storlazzi	Hanalei Bay (4 locations)	waves, winds, currents, and sediment dynamics using bottom-mounted instrument packages; sediment physical and chemical properties	6/2006 to 9/2006	"[W]hile elevated near-bed suspended sediment concentrations . . . occurred due to both wave resuspension and floods, post-depositional reworking of flood deposit material can potentially cause the most harm to corals due to its proximity to the corals themselves and the longer duration of impact." Summertime flood deposits can persist for up to a month during the dominant period of coral spawning.
2008	Knee	surface water (2-D transects) and groundwater at 5 shoreline locations (4 at Hanalei Bay); 9 streams (5 in Hanalei Bay watershed - Pu'u Poa, Hanalei, Waioli, Waipa, Waikoko); Princeville WWTP; cesspools and septic systems; beach sand at 5 beaches	salinity; nutrients; fecal indicator bacteria (FIB); enterococcal surface protein (*esp*); submarine groundwater discharge (SGD) flux estimates using ^{224}Ra as a groundwater tracer	3/2005, 8/2006, 2/2007	SGD is "an important source of nitrate+nitrite and perhaps also of phosphate and ammonium, while the Hanalei River and smaller local streams appear to be an important sources of all nutrients and the dominant sources of silica and FIB." "Groundwater samples were enriched in nutrients relative to the nearshore ocean, and nutrient concentrations showed site-dependent, generally inverse correlations to salinity in the coastal aquifer." "[A]griculture may be an important nitrogen source to groundwater." "Although SGD does not appear to be an important contributor to FIB in the nearshore zone, the very presence of FIB in groundwater, even at a low level, as well as the presence of the *esp* gene on some ENT, indicates contamination by human sewage and warrants further investigation." FIB were detected in sand at four of five beaches sampled. *See also* Knee et al., 2010.

Hanalei Watershed Management Documents, 2000-2010 (continued)

Year	Lead Author	Waterbodies/Sampling Targets	Measurements/Analysis	Dates	Conclusions about Hanalei Watershed
2008	Storlazzi	Hanalei Bay	waves, currents, temperature, salinity, turbidity, and PAR using vertical profile casts at 14 locations and bottom-mounted instrument packages at 5 of the profiling locations	6/2006 to 9/2006	"The water in Hanalei Bay is generally more saline and cooler farther offshore and with increasing depth. This general trends is . . . many times masked by an opposite trend brought about by greatly influenced by the presence of freshwater either discharged from the river and streams that drain into the bay or submarine groundwater discharge." "Circulation was sluggish during the study period . . ." "[T]idal currents were primarily oriented parallel to shore and showed no net mean flow. The subtidal wind- and wave-driven currents showed anti-cyclonic net near-surface flow and net onshore flow near the seabed." "Waves were generally small during the deployments and primarily driven by northeast trade winds. "Both waves and currents were more energetic in the western part of the bay that was more directly exposed to the trade winds." "Lower salinities and higher turbidities were observed closer to shore, especially near the mouths of the Hanalei River and smaller streams discharging into the south and eastern parts of the bay." "The highest turbidity levels were measured close to the bed at the Inner and Outer Wall Sites during the Hanalei River flood on August 6-7 . . turbidity was also high in the southern part of the bay . . . likely due to resuspension of sediment from wave stresses during times of high waves."
2007	Cheng	Hanalei Watershed	AnnAGNPS model	Underpredicted annual sediment loads and runoff & sediment for larger storms, and overpredicted for smaller storms. Monthly & daily load predictions correlated with observed data at $R^2 < 0.40$.	

Hanalei Watershed Management Documents, 2000-2010 (continued)

Year	Lead Author	Waterbodies/Sampling Targets	Measurements/Analysis	Dates	Conclusions about Hanalei Watershed
2007	CSV Consultants	Hanalei Bay Focus Group participants	Identify strategies and develop tools for resolving ocean recreation user conflicts	5/2006 to 3/2007	(1) "would like to see regulation of commercial fishing activities in Hanalei Bay regardless of boat length" and "regulations controlling the number of unguided kayaks allowed" on the Hanalei River. (2) "are concerned that there are no regulations in place mandating responsible safety, cultural, and environmental etiquette for commercial operators pt mandating hours and locations of operations." (3) "interest[d] in tapping into tourism dollars to help support local resource conservation efforts."
2007	Derse	Hanalei Bay shoreline (5 sites and 4 offshore locations)	nitrogen isotopic signature of nitrate sources and macroalgae; N:P ratios of macroalgae	6/2005, 8/2006, 2/2007	Low nitrogen isotope ratios in macroalgae implicated fertilizer, rather than sewage, as an important external source of nitrogen.
2007	Draut	Hanalei Bay sediment cores (9 locations) and sediment traps (5 sites); grab samples from seabed (27 sites), riverbed (4 sites), and uplands (16 sites)	isotope activity, grain size, percent carbonate, magnetic properties	6/2006, 9/2006	"The youngest and thickest terrigenous sediment was present on the eastern side of the bay, near the Hanalei river mouth and in the black hole bathymetric depression, which acts as at least a temporary sediment sink." Variations in magnetic properties indicate many sources of upland terrigenous sediment. "[T]he timing (seasonality) and magnitude of sediment input to the coastal ocean, relative to seasonal variations in wave and current energy, could have significant ecological consequences for coral reefs . . ." *See also* Draut 2006, 2009
2007	Field	Hanalei Watershed Workshop	30 contributions on various aspects of watershed science and policy.		
2007	Gee	Hanalei National Wildlife Refuge, endangered waterbirds (EWBs)	habitat characterization and utilization; population, behavior, and nesting	not given	effective wetlands management was not possible because the water control infrastructure did not allow for the effective transfer/discharge of water to promote optimal habitat conditions for EWBs.

Hanalei Watershed Management Documents, 2000-2010 (continued)

2007	Gee (cont.)	Hanalei National Wildlife Refuge	responses to rototilling, wetland management, and seasonal vegetation changes	not given	"[R]efuge wetlands must be reconfigured into larger units based on soil texture and a water distribution system developed to allow management activities that will result in habitat conditions for all EWB life-history stages."
2007	Polyakov	Hanalei Bay Watershed	simulate runoff and soil erosion	2003-2004	"Among the input parameters the model [sediment yield] was most sensitive to the values of ground residue cover and canopy cover." "RUSLE erosion factor K, which is directly related to soil properties, was the single most important parameter, which influenced spatial variability of sediment losses." "Overall, the model performed reasonably well, and can be used as a management tool on tropical watersheds to estimate and compare sediment loads, and to identify 'hot spots' on the landscape." "Daily performance for both water and sediment yields was poor."
2006	Carr	Sediment porewater from 11 sites in Hanalei Bay and a reference site at Ke'e Beach.	salinity, dissolved oxygen, pH, temperature, ammonia; fertilization and embryological development toxicity tests	8/2005	"Three porewater samples in the fertilization test were found to be toxic when compared to the reference station . . . [n]o porewater samples were found to be toxic in the embryological development test" using purple-spined sea urchin (*Arbuncia punculata*).
2006	Draut	Hanalei Bay sediment cores (7 locations), Hanalei River bed grab samples (4 locations)	measure radioisotopes to trace the thickness and distribution of terrestrial sediment in order to assess spatial and temporal patterns of sediment deposition and remobilization	6/2005, 8/2005	"The youngest and thickest terrigenous sediment is located on the east side of the bay near the Hanalei river mouth and in the black hole bathymetric depression, which apparently acts as a sediment trap." "Deposition on and burial of corals by sediment during summer floods, when wave and current energy are low and sediment would not be readily remobilized, could have significant effects on the reef ecosystem." *See also* Draut 2007, 2009.

Hanalei Watershed Management Documents, 2000-2010 (continued)

2006	Friedlander	Hanalei Bay	coral cover, settlement, and community patterns; fish assemblage patterns	1993-2004	"Between 1993 and 1999 there was an increase of 5% absolute (34% relative) in live coral cover from 14% to 19%. Form 1999 to 2004 coral cover remained relatively stable." "Coral settlement in 2003 and 2004 was higher in the outer bay compared to locations in the inner bay." "Coral larval settlement was observed to he higher in Hanalei bay compared to other regions around the world and may help explain the increase in coral cover observed over the past decade." "Fish assemblage characteristics did not vary significantly between 1993 and 2004 although trends in biomass are suggestive of an increase over time. Three introduced fish species (bluestripe snapper, blacktail snapper, and peacock grouper) have become well established . . . and their contribution to total fish biomass has increased from 15% in 1993 to as high as 39% in 1999." "[I]t appears that natural factors such as large wave events are likely more important in structuring the coral community . . . than anthropogenic factors."
2006 2005	Hanalei Watershed Hui	Hanalei Bay Watershed Targeted Watershed Initiative Grant activities and outreach	Included wastewater treatment demonstration project; strategic wastewater planning; taro lo'i demonstration project/study; ungulate fencing demonstration project; biological resources survey, mapping, and assessment; water quality monitoring	10/2003 to 10/2006	Cesspools were assessed and a prioritized replacement program was established (including 15 priority homes and 4 public facilities). In addition, portable toilets are brought to the County parks on holiday weekends and during sporting events . . . to accommodate the anticipated over-capacity use of existing facilities. Recommendations include: - a centralized wastewater collection and treatment system in Hanalei town.

Hanalei Watershed Management Documents, 2000-2010 (continued)

2006	Hanalei Watershed Hui (cont.)			10/2003 to 10/2006	-design and build checkgates, dams with removal boards, to turn taro drainage ditches into retention basins. U.S. Fish & Wildlife did finally install 6 - checkgates on the refuge. -hog-fence the perimeter of the agricultural area to exclude feral pigs, and to place the free-ranging cattle in barbed-wire paddocks.
2006 2005	Knee Knee	local beaches; 3 streams; Hanalei River; several groundwater pits; Hanalei Bay	fecal indicator bacteria (FIB); submarine 3groundwater discharge (SGD); nutrients	3/2005, 6/2005	"Groundwater had lower concentrations of all FIB than the Hanalei River, the streams, or the bay, indicating that SGD was not contributing bacteria directly to the coastal zone over the course of this study. However, E. coli was detected at relative high levels in groundwater seaward of a cesspool, suggesting that during periods of high discharge, SGD could transport fecal bacteria to the bay." Groundwater had lower concentrations of all FIB Concentrations of all nutrients were higher in groundwater than in Hanalei Bay, and nitrate concentrations were higher in groundwater than in the Hanalei River or the streams. Additionally, nitrate concentrations in groundwater and in Hanalei Bay were coupled with radium activities, suggesting a common source, most likely SGD. Mass balance calculations, based on residence times of 2 and 6 hours for the surf zone, indicate that the SGD flux into Hanalei Bay may be as high as 1200 L/s, or 20 percent of the Hanalei River's average March flow rate, and that SGD may contribute more nitrate to Hanalei Bay than does the Hanalei River. These nutrient subsidies could impact nearshore ecosystems by promoting the growth of bacteria and/or algae."

Hanalei Watershed Management Documents, 2000-2010 (continued)

2006	Storlazzi	Hanalei Bay	waves, currents, temperature, salinity, and turbidity using vertical profile casts at 14 locations and bottom-mounted instrument packages at 5 of the profiling locations	6/2005 to 8/2005	"The water in Hanalei Bay is generally more saline and cooler farther offshore and with increasing depth. Theses general trends, however, are greatly influenced by the presence of freshwater either from river/stream discharge or groundwater effluence." "Flow was relatively weak and circulation was sluggish during the study period." Net near-surface flow was generally oriented parallel to shore, into the eastern portion of the bay and out of the western portion. Net near-bed flows had an opposite pattern. Waves were relatively small and primarily driven by Northeast Trade Winds. "Both waves and currents were more energetic in the western portion of the bay that was more directly exposed to the Trade Winds." "Lower salinities and higher turbidities were observed closer to shore, especially near the mouths of the Hanalei River and the Waipa and Waioli Streams." "In general the waters were more turbid inside the bay, especially close to the shore and close to the seafloor. The highest turbidity levels were . . . closest to the Hanalei River mouth. The turbidity was slightly higher in the western part of the bay . . . than in the middle of the bay, likely due to discharge from the Waipa and Waioli Streams."
2005	Kauai Watershed Alliance	eastern Alaka'i	establish a line of defense against invasive forest weeds, which will create a buffer zone between the more heavily infested area and the East Alaka‘i.	ongoing	"Kahili ginger, Australian tree fern, and Strawberry guava to be the most urgent weed threats to the eastern Alaka‘i." http://www.kauaiwatershed.org/managementprograms_weeds.html

Hanalei Watershed Management Documents, 2000-2010 (continued)

2005	Kubo	Hanalei Bay Watershed	estimate sediment discharge; develop management measures	7/2003 to 6/2005	"[T]he areal divergence in rainfall . . . requires development of numerous climate datasets to account for its variability." "[N]o adequate, systematic study of the erosion or runoff characteristics of the many types of forested areas found in the islands is available to estimate erosion and runoff coefficients." "[S]heet and rill erosion accounts for a significant portion of the sediment discharged from the valley." "Thin-bedded landslides that extend longitudinally from valley crease to ridgetop are a prevalent feature in the watershed . . ." "[T]he elimination and exclusion of feral pigs will reduce erosion on the stream benches, but may or may not stimulate recovery of native plant species."
2005	Wurster	Wildlife Refuge irrigation system (8 stations)	surface water flow/discharge	12/2003 to 11/2004	"If more refuge land is converted to taro production or wetland impoundments the ditch system or water use practices will have to be modified to improve water availability."
2005	Vithanage	cesspools (Pavilion)	FRNA coliphages	not given	80/81 male-specific coliphage isolates were associated with human feces.
2004	Hanalei Watershed Hui	Hanalei Bay Watershed		1998-2005	The Action Plan describes 46 priority actions for protecting and restoring watershed health.
2004	USEPA	coral reefs	address land-based pollution threats	2003-2004	"Long-term monitoring is needed . . . using indicators sensitive to land-based pollution impacts on coral reefs and consistent protocols." Proposed actions also include construction of wastewater treatment system for Hanalei town, implementation of native forest protection for Hanalei watershed, and sedimentation and sediment transport modelling in Hanalei Bay.

Hanalei Watershed Management Documents, 2000-2010 (continued)

2004	Uyehara	taro farms statewide	develop conservation practices for native wildlife habitat on wetland taro farms	10/2003 to 5/2004	Modified standards and specifications for Practice 646 Shallow Water Development and Management for Wildlife, with supporting Biology Technical Notes.
2003	Dollar	open coastal (Princeville), 6 transects	coral cover/species	1980, 2002	At T-6 (just outside Hanalei Bay), significant increase in coral cover, no change in species number, slight decrease in species diversity
2003	Everson	Hanalei Bay fishery	commercial fish landings (self-reported); creel surveys; remote visual surveillance of fishing vessels and individual fishers	12/1990 to 12/1993	Total annual harvest was 15,801 kg, including 85 taxa from 43 families. "The most common complaint from fishers are that large jacks and moi (*Polydactylus sexfilis*) are no longer commonly caught . . ." "The small sizes at which some fishes are being caught and retained is a matter of concern for management of the stocks." "Total annual yield . . . was 2.7 t km^{-2} yr^{-1} for the entire catch and 0.8 t km^{-2} yr^{-1} excluding small coastal pelagics." "[S]urround netting for akule was the dominant fishery by weight . . ." (69.1%), with a mean catch of 213 kg/effort-day, followed by line fishing (13.2%) and gill netting (5.3%). "High rainfall events increase the discharge of nutrient-rich material into the bay that in turn results in high concentrations of the kuhonu or white crab (*Portunus sanguinolentus*) that feed on this material." "[D]ata derived from the Hanalei bay creel survey was substantially greater than the state's commercial catch data for the entire north shore of kauai'i for the same time period." "[C]ommercial fishers report the catches aggregated into standardized geographical areas, which . . . may not be commensurate with the spatial patterns of the species being harvested."

Hanalei Watershed Management Documents, 2000-2010 (continued)

2002	Calhoun	Hanalei Bay sediment budget	sedimentological and geophysical methods	not shown	"[S]iliciclastic grains . . . from the Hanalei River watershed draining shield volcanic highlands are the most common individual grain type ($\sim$27%) and form a zone of high concentration from the mouth of the Hanalei River into the center of the bay. "Net carbonate sediment deposition in Hanalei Bay peaked at a rate of 15,500 m^3 $year^{-1}$ between 5000 and 3000 years ago (when sea level may have been 2 m above present) diminishing to 3890 m^3 $year^{-1}$ from 1000 years ago to the present."
2002	Department of Urban & Regional Planning	Hanalei community	Analyze issues in order to assist the community with identifying and selecting alternatives for wastewater disposal, taro farming, and tourism.	2002	"Of the four [wastewater] treatment systems reviewed (standard centralized, wetland, living machine, and septic), several wetland cluster systems should serve problem areas, with the option of centralized wetlands . . . system reserved for consideration only after potential unwanted growtjh effects have been weighed." "The use permit should be imposed in order to control the amount of vacation rentals in the town." "[A]n environmental, economic, social, and cultural impact assessment on Hanalei should be carried out before proposing further tourism development."
2002	Lyons	Hanalei National Wildlife Refuge	nene distribution and habitat preferences	not reviewed	
2002 2001	Orazio Orazio	surface water, bed sediment, and aquatic biota in the Hanalei two reaches of the Hanalei River (brackish and fresh water)	organochlorine (OC) pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), EPA priority pollutant elements	12/2001	Very low or non-detectable concentrations found, "below probable adverse effects screening levels set by USEPA for aquatic organisms." "Inclusion of additional chemicals such as those associated with wastewater treatment effluents, right-of-way and golf course maintenance, and chemicals of emerging concern would provide a more complete description of the occurrence of pollutant[s] . . ."

9. Public Participation

TMDL development in the Hanalei watershed is an outcome of years of public participation in initiating and sustaining environmental protection programs. Since the completion of Phase 1 TMDLs in 2008, ongoing communication between HIDOH water programs, Tetra Tech, the Hanalei Watershed Hui (HWH), Surfrider Foundation Kauai Chapter (SFKC), and other participants in the TMDL process has focused on:

- monitoring of coastal recreational waters by HWH and SFKC, and related public health decisions (beach notification) by HIDOH;
- initiating a Clean Water Act Section 319 grant for developing a Watershed Based Plan that addresses community concerns, initiates TMDL implementation, and refines pollutant source identification; and
- completing the second phase of TMDL development (embayment waters).

During the development of the Phase 2 TMDL, Tetra Tech and HIDOH staff consulted with various interested parties and sources of information, including but not limited to:

East Kauai Soil & Water Conservation District
Kauai Taro Growers Association
Stanford University (various investigators)
State of Hawaii Department of Health (Environmental Health Administration, Environmental Planning Office, Environmental Management Division, Clean Water Branch, Safe Drinking Water Branch, and Wastewater Branch)
Kauai Watershed Alliance/The Nature Conservancy Kauai Program
Princeville Resort
University of Hawaii (College of Tropical Agriculture and Human Resources)
U.S. Department of Agriculture, Natural Resources Conservation Service
U.S. Department of Commerce, National Oceanic & Atmospheric Administration
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service (Hanalei National Wildlife Refuge)
U.S. Geological Survey (Pacific Water Science Center, and Western Coastal & Marine Geology Group)
Waipa Foundation

After internal HIDOH review and administrative approval, HIDOH published a draft TMDL decision document, and scheduled a public information meeting for November 16, 2010 to present and discuss the results. Public notices announcing the availability of the draft TMDL decision and inviting participation in the public review process were published in local newspapers on October 31, 2010 and on the HIDOH-CWB website, and distributed via email bulletins. DOH mailed letters announcing the availability of the draft TMDL decision, and inviting participation in the public review process, to numerous landowners of record and other individuals and organizations with known connections to water quality management and watershed health within the planning area. Appendix III documents various aspects of public participation, including all comments received during the public comment period that ended November 30, 2010, and the DOH responses to those comments.

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