Total Maximum Daily Loads for the Hanalei Bay Watershed

PHASE 1 – Streams and Estuaries

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Contents

ACKNOWLEDGEMENTS ..... **VI**

EXECUTIVE SUMMARY ..... **VII**

1. INTRODUCTION **1**

2. PROBLEM STATEMENT **3**

2.1. PROJECT AREA DESCRIPTION 4
2.2. IMPAIRMENT OVERVIEW 7

3. NUMERIC TARGET SELECTION **10**

4. DATA INVENTORY AND ANALYSIS **17**

4.1. DATA INVENTORY 17
4.1.1. Water Quality Data *17*
4.1.2. Hydrologic Data *18*
4.1.3. Meteorological Data *20*
4.1.4. Watershed Characteristic Data *20*
4.2. LONG-TERM HYDROLOGIC ANALYSIS 21
4.3. WATER QUALITY DATA ANALYSES 22
4.3.1. Review of Impaired Segments *22*
4.3.2. Trends and Relationships *27*
4.3.2.1. Spatial Trends 27
4.3.2.2. Streamflow Correlations 32
4.3.2.3. Correlative Analyses 33

5. SOURCE ANALYSIS **36**

5.1. POINT SOURCES 37
5.2. NONPOINT SOURCES 37

6. LINKAGE ANALYSIS **42**

6.1. MODEL SELECTION CRITERIA 42
6.1.1. Technical Criteria *43*
6.1.1.1. Physical Domain 43
6.1.1.2. Source Contributions 43
6.1.1.3. Constituents 44
6.1.2. Regulatory Criteria *44*
6.1.3. User Criteria *45*
6.2. MODEL SELECTION AND OVERVIEW 45
6.2.1. Watershed Model: Loading Simulation Program in C++ *46*
6.2.2. Receiving Water Model: Environmental Fluid Dynamics Code *46*
6.3. MODEL APPLICATION 47

7. TMDL CALCULATIONS AND ALLOCATIONS **48**

7.1. METHODOLOGY 48
7.2. TMDL CALCULATION 49
7.2.1. Waste Load Allocations *50*

7.2.2. Load Allocations *50*
7.2.3. Margin of Safety *50*
7.3. TMDL RESULTS AND ALLOCATIONS 51
7.4. CRITICAL CONDITIONS AND SEASONAL VARIATION 52

8. IMPLEMENTATION FRAMEWORK FOR PHASED TMDL APPROACH 65

8.1. WATERBODY CLASSES AND USES 67
8.2. LAND OWNERSHIP 68
8.3. REGULATORY AND MANAGEMENT AUTHORITY 69
8.4. LAND COVER AND DEGRADING ACTIVITIES (PROBLEM AREAS) 71
8.5. IMPLEMENTATION TOOLS/TECHNICAL ASSISTANCE 72
8.6. FINANCIAL ASSISTANCE 73
8.7. PREVIOUS/ONGOING EFFORTS 73
8.8. PHASED TMDL DEVELOPMENT AND IMPLEMENTATION SCHEDULE 75
8.9. IMPLEMENTATION ASSURANCE 77

9. PUBLIC PARTICIPATION 78

10. REFERENCES 81

APPENDICES

Appendix A: Data Analyses
Appendix B: Hanalei Bay Watershed Bacteria, Nutrients, and Sediment Model Development and Application
Appendix C: Relative Land Cover Loadings
Appendix D: Additional LSPC Hydrology Validation Results
Appendix E: LSPC Water Quality Calibration and Validation Results
Appendix F: EFDC Water Quality Calibration and Validation Results
Appendix G: Waterbody Information Sheets, 2006 §303(d) List, and EPA Checklist
Appendix H: Documentation of Public Participation Process, with Public Comments and DOH Response

List of Figures

Figure 1. Hanalei Bay watershed 5
Figure 2. Kaua'i rainfall distribution 6
Figure 3. Hanalei Bay watershed land cover distribution (NOAA, 2000)..... 7
Figure 4. Factors affecting waterbody Class within the Hanalei Bay watershed 11
Figure 5. Stream Bioassessment Results, Hanalei Stream..... 16
Figure 6. Water quality monitoring stations by location type 19
Figure 7. Monthly Flow Values – June 1987 through May 2006..... 21
Figure 8. Upstream to downstream *enterococcus* concentrations on the Hanalei River . 28
Figure 9. Upstream to downstream total suspended solids concentrations on the Hanalei River..... 29
Figure 10. Upstream to downstream turbidity on the Hanalei River..... 29
Figure 11. Upstream to downstream ammonia concentrations on the Hanalei River 30
Figure 12. Upstream to downstream nitrite plus nitrate concentrations on the Hanalei River..... 30
Figure 13. Upstream to downstream total nitrogen concentrations on the Hanalei River31
Figure 14. Upstream to downstream total phosphorous concentrations on the Hanalei River..... 31
Figure 15. Turbidity and TSS relationship in the Hanalei Bay watershed 34
Figure 16. Relationships between sediment and nutrients..... 35
Figure 17. Land cover 38
Figure 18. Difference between stormflow enterococcus values at Weke Road and USGS Gage 41
Figure 19. Difference between baseflow enterococcus values at Weke Road and USGS Gage 41
Figure 20. Overlapping Regulatory and Management Frameworks in the Hanalei Bay Watershed 70

List of Tables

Table ES-1. Summary of Listings, Exceedances, and Current Application (Table 10)…….viii
Table ES-2 Wet and Dry Season TMDL Allocations to Existing Sources and Load Reductions Required to Achieve Hanalei Stream and Estuary Turbidity Standards (Table 14)……..xii
Table ES-3. Wet and Dry Season TMDL Allocations to Existing Sources and Load Reductions Required to Achieve Hanalei Stream and Estuary Bacterial Standards (Table 15)……..xiii

Table 1. Watershed Area (State of Hawai'i, 2006)..... 6
Table 2. Water Quality Limited Segments Addressed in This Analysis (HIDOH, 2008). 8
Table 3. Waterbody-Pollutant Combinations Addressed by the Hanalei Bay Watershed TMDLs..... 8
Table 4. Waterbody-Pollutant Combinations Addressed with Informative TMDLs and Load Targets 9
Table 5. Estuary Numeric Targets 13
Table 6. Stream Numeric Targets 14
Table 7. Inventory of Data and Information 17
Table 8. Seasonal and Flow Regime Distribution of Water Quality Data..... 19
Table 9. Monthly Flow Statistics – June 1987 through May 2006..... 21
Table 10. Summary of Listings, Exceedances, and Current Application 23
Table 11. Percent Exceedances Associated with Comparing Observed Data to WQC... 26
Table 12. Summary Statistics for Drainage Culvert Monitoring Stations 32
Table 13. Relative Loadings by Land Cover for the Hanalei Bay Watershed..... 39
Table 14. Total Suspended Solids TMDL Load Allocations and Load Reductions Required to Achieve TMDLs (Note: key to table continues on following page)..... 53
Table 15. *Enterococcus* TMDL Load Allocations and Load Reductions Required to Achieve TMDLs 54
Table 16. Total Suspended Solids Informative TMDLs and Suggested Reductions..... 55
Table 17. *Enterococcus* Informative TMDLs and Suggested Reductions..... 56
Table 18. Wet Season Ammonia Informative TMDLs and Load Targets and Suggested Reductions..... 57
Table 19. Dry Season Ammonia Informative TMDLs and Load Targets and Suggested Reductions..... 58
Table 20. Wet Season Nitrite Plus Nitrate Informative TMDLs and Suggested Reductions..... 59
Table 21. Dry Season Nitrite Plus Nitrate Informative TMDLs and Suggested Reductions..... 60
Table 22. Wet Season Total Nitrogen Informative TMDLs and Suggested Reductions. 61
Table 23. Dry Season Total Nitrogen Informative TMDLs and Suggested Reductions . 62
Table 24. Wet Season Total Phosphorous Informative TMDLs and Suggested Reductions..... 63
Table 25. Dry Season Total Phosphorous Informative TMDLs and Suggested Reductions 64
Table 26. Example – TMDL Implementation Matrix..... 74

List of Abbreviations

BASINS	Better Assessment Science Integrating Point and Nonpoint Sources
BMP	Best Management Practice
C-CAP	Coastal Change Analysis Program
CFR	Code of Federal Regulations
CWA	Clean Water Act
DEM	Digital Elevation Model
EFDC	Environmental Fluids Dynamic Code
Entero	Enterococcus
EPO	(Hawai'i State Department of Health) Environmental Planning Office
GIS	Geographic Information System
HAR	Hawai'i Administrative Rules
HIDOH	Hawai'i State 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
MS4	Municipal Separate Storm Sewer System
NCDC	National Climatic Data Center
NH_4	Ammonia
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrite Plus Nitrate
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NTE	Not to Exceed
NTU	Nephelometric Turbidity Units
#/day	Number Per Day
NWR	National Wildlife Refuge
SSC	Suspended Sediment Concentration
SSM	Single Sample Maximum
STATSGO	State Soil Geographic Database
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
Toolbox	TMDL Modeling Toolbox
TP	Total Phosphorous
TSS	Total Suspended Solids
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WLA	Waste Load Allocation
WQC	Water Quality Criteria
WQLS	Water Quality Limited Segment

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Executive Summary

The State of Hawaii Department of Health (DOH) proposes establishing a total of eight (8) Total Maximum Daily Loads (TMDLs) for streams and estuaries in 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 (CWA) Section 303(d) list. 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 inland waters (streams and estuaries) so that the designated and existing uses of waterbodies throughout the Hanalei Bay watershed 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. In response to the 2006 List of Impaired Waters in Hawai'i Prepared under Clean Water Act (CWA) §303(d), DOH proposes Total Maximum Daily Loads (TMDLs) for total suspended solids (TSS; TSS is included as a surrogate for turbidity TMDLs) 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 (Table ES-2); and for and *enterococci* in the Hanalei Stream System (table ES-3). Implementing these sediment and bacteria TMDLs will result in the attainment of water quality criteria for turbidity and *enterococcus* in the Hanalei Stream System and for turbidity in the other nearby streams and estuaries in the Hanalei Bay watershed.

DOH also calculated Informative TMDLs and Load Targets (both not for EPA approval) to help guide nonpoint source pollution management efforts (Tables 16 through 26). Table ES-1 identifies the §303(d) listings, exceedances based on data analyses, and how the waterbody-pollutant combination was addressed in this current study (TMDL, informative TMDL, or Load Target). DOH proposes 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.

Federal regulations and guidance require that the State of Hawai'i Department of Health (HIDOH) allocate the approved TMDLs between point source discharges regulated under discharge permit (Waste Load Allocations) and nonpoint source runoff that is not regulated by discharge permit (Load Allocations). However, since no MS4 (Municipal Separate Storm Sewer System) or other individual National Pollutant Discharge Elimination System (NPDES) permits for point sources have been issued covering Hanalei receiving waters, this report only provides Load Allocations (LAs) for nonpoint source runoff in the Hanalei watershed. 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).

Table ES-1. Summary of Listings, Exceedances, and Current Application (Table 10)

Waterbody	Description	Entero	Turbidity	NH4	NOx	TN	TP	TSS
Estuary								
Hanalei River Estuary	Included on 2006 303(d) list[a]	**Y**	**Y**	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	**TMDL**	**Verification**	IT	IT	IT	IT	**TMDL**
Waioli Stream Estuary	Included on 2006 303(d) list[a]	N	**Y**	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Waipa Stream Estuary	Included on 2006 303(d) list[a]	N	**Y**	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	—	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Waikoko Stream Estuary	Included on 2006 303(d) list[a]	N	**Y**	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Stream								
Hanalei Stream	Included on 2006 303(d) list[a]	**Y**	**D**	N	N	N	N	N
	Criteria exceeded[b]	√	W/D		—	W	W	W
	Current application[c]	**TMDL**	**Verification**	LT	IT	IT	IT	**TMDL**
Waioli Stream	Included on 2006 303(d) list[a]	N	N	N	N	N	N	N
	Criteria exceeded[b]	no data	D		—	—	—	—
	Current application[c]	IT	—	LT	IT	IT	IT	IT
Waipa Stream	Included on 2006 303(d) list[a]	N	**D**	N	N	N	N	N
	Criteria exceeded[b]	no data	D		—	—	—	—
	Current application[c]	IT	**Verification**	LT	IT	IT	IT	**TMDL**
Waikoko Stream	Included on 2006 303(d) list[a]	N	N	N	N	N	N	N
	Criteria exceeded[b]	no data	no data		no data	no data	no data	no data
	Current application[c]	IT	—	LT	IT	IT	IT	IT

[a]**Y** = year-round impairment; **D** = dry season impairment; **W** = wet season impairment; N = not listed

[b]For estuaries, exceedances are associated with year-round criteria (√). For streams, *enterococcus* is associated with year-round criteria (√), but all other parameters have separate wet (W) and dry (D) season standards that can be exceeded. These letters indicate that one or more of the applicable WQC were exceeded (additional details regarding these exceedances are presented in Table 11. Shading indicates no applicable standard. Waterbody-pollutant combinations not exhibiting any exceedances in the available data are represented by "–."

[c]**TMDL** = TMDLs were calculated as part of the current application; **Verification** = data and model output were used to confirm impairments and/or verify attainment of WQC through TSS TMDL implementation; IT = Informative TMDLs were calculated as part of the current application. LT = Load Targets were calculated as part of the current application; Waterbody-pollutant combinations not specifically addressed by any loading calculations are represented by "–."

The Hanalei Bay watershed is a 32.3 square-mile area draining to Hanalei Bay along the north shore of Kaua'i, including the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream watersheds (Figure 1). The Hanalei River watershed is the largest of these watersheds, making up 73.2% of the Hanalei Bay drainage area (23.6 square-miles). The Waioli Stream watershed is the second largest drainage area with nearly 5.5 square-miles, followed by the 2.5 square-mile Waipa Stream watershed and the 0.7 square-mile Waikoko Stream watershed.

The watershed originates at the summit of 5,240 foot Mount Wai'ale'ale, which receives an average of 450 inches of rainfall per year, while the coastal areas receive less than 100 inches of rainfall annually (University of Hawai'i, 2002, and see Figure 2). Much of the rainfall occurs during the wet season from November through April. Hanalei has a tropical climate with an average annual temperature in the mid-seventies and an average humidity in the low eighties (Weather Underground, 2006). The rainfall patterns tend to follow the elevation contours in the region, with higher rainfall occurring in the higher elevations. Many of the higher elevation areas also have very steep slopes.

The Halelea Forest Reserve makes up a majority of the headwaters area (see Figure 4). Agriculture, grassland, and urban areas also drain into the Hanalei River and other tributaries that eventually discharge to the Hanalei Bay (Figure 3). In addition, the 16 mile Hanalei River, which was designated an American Heritage River in 1998, passes through the Hanalei National Wildlife Refuge (NWR), which includes taro pondfields and several bird impoundments. The urban areas, which make up less than 1% of the land area, are primarily located in Hanalei town center along the Kuhio Highway (University of Hawai'i, 2002).

Water quality monitoring data for streams, estuaries, and drainage culverts (see Figure 5) were compared to the water quality criteria (WQC), evaluated spatially, analyzed for correlations, and compared with stream flow measurements at the United States Geological Survey (USGS) stream flow gage (station 1610300). These analyses support the sediment and bacteria impairments as well as other sediment, bacteria, and nutrient concerns in the watershed. Available data were also used to configure, calibrate, and validate a customized modeling framework developed to support *enterococcus* and turbidity TMDLs as well as the Informative TMDLs and Load Targets. This framework consists of a series of watershed models (based on the Loading Simulation Program in C++ [LSPC]) and a receiving water model (based on the Environmental Fluids Dynamic Code [EFDC]). The watershed models predicted pollutant loadings for each of the four primary watersheds draining to Hanalei Bay, while the receiving water model of the estuaries and Hanalei Bay simulated water circulation and pollutant transport in the tidally-influenced waterbodies.

The models were configured using key datasets to represent hydrology, hydrodynamics, and land practices in the Hanalei Bay watershed. These datasets, which include watershed boundaries, meteorological data, land cover, soils, reach characteristics, water quality data, bathymetry, and circulation and tidal data, were incorporated into the LSPC or EFDC models during model setup. The LSPC model was then calibrated and validated for both hydrology and water quality for May 2001 – May 2006. Model results were compared to flow and water quality data during this process. The loads from the LSPC model were then incorporated into the EFDC model of the Hanalei River Estuary, Waioli Stream Estuary, Waipa Stream Estuary, Waikoko Stream Estuary, and the Hanalei Bay. The EFDC model was then calibrated and validated for hydrodynamics and water quality for 2004-2005 by comparing the model results to observed data. Both the LSPC and EFDC models achieved good fit between modeled and observed results.

Output from the LSPC and EFDC models were used to determine existing loads based on current conditions as well as TMDLs for the *enterococcus* and turbidity impaired waterbodies and Informative TMDLS and Load Targets for other waterbody-pollutant combinations in the Hanalei Bay watershed. The TMDL values were compared against existing loads to determine the load reductions necessary to meet the water quality criteria. LSPC model output was also used to assess land cover-specific contributions to the total existing watershed load for each pollutant.

Specific measures for reducing pollutant loads, improving water quality, and repairing and protecting aquatic ecosystems in the Hanalei watershed may be found in the Hanalei Watershed Action Plan and other Hanalei Watershed Hui planning documents; U.S. Fish and Wildlife Service Refuge Management Plan; State of Hawai'i forest management plans; soil and water conservation plans for agricultural lands; watershed-based plans and TMDL implementation plans prepared or accepted by the HIDOH; and other government and private planning initiatives. By incorporating the LA objectives presented below, activities that take action to reduce pollutant loading may unlock the door to additional Clean Water Act §319(h) incremental funds (administered by HIDOH) for water quality improvement projects.

Contributing sources and load allocations of the Hanalei Stream System TMDLs for TSS and *enterococcus* are summarized in the tables presented below, along with the load reductions required to achieve these allocations. These tables present the TMDLs associated with all applicable WQC (geometric mean, 10% not-to-exceed, and 2% not-to-exceed WQC for TSS and 30-day geometric mean and single sample maximum WQC for *enterococcus*) and are also presented by wet and dry (calendrical) seasons, although only the stream standards vary by season. Estuary TMDL results are based on achieving the year-round estuary standards. The annual load results are presented seasonally to maintain consistency with the stream TMDLs and for implementation purposes.

With regard to implementing the bacterial TMDLs, in general DOH 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 DOH on-site disposal system strategy and water quality monitoring strategies, any implementation activities conducted should first focus on inventory and inspection of sanitary sewer collection systems and individual wastewater systems; repairing and upgrading failing and sub-standard systems (as indicated by inspection results); and completing watershed sanitary surveys and wastewater source tracking to complement information obtained from system inventory/inspection and ambient receiving water monitoring.

This TMDL decision rationale reviews historical and existing conditions in the Hanalei Bay watershed and presents an analysis of pollutant load distributions and resulting water quality in streams and estuaries (inland waters) of the Hanalei, Waioli, Waipa, and Waikoko stream systems. We provide calculations of waterbody pollutant loading capacities, and of their allocations to identified pollutant sources such that water

quality standards for turbidity and enterococcus would be achieved. Thus implementing these pollutant load allocations is expected to contribute to the achievement of State water quality goals throughout the watershed.

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 Hawai'i's Implementation Plan for Polluted Runoff Control (HIDOH, 2001), Hawaii's Coastal Nonpoint Pollution Control Program Management Plan (State of Hawai'i, 1996), and Watershed-based Plans and TMDL Implementation Plans that address the nine elements required by USEPA guidance for awarding additional Clean Water Act §319(h) incremental funds (USEPA, 2003a). Watershed Based Plans and TMDL Implementation Plans are expected to incorporate the LA objectives from the tables below and Table 14 and Table 15 in Section 7.3 of this report.

In the following tables summarizing the proposed TMDL decision (ES-2 and ES-3):

- TMDL allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

- Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

*Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows).

Acronyms: LA = Load Allocation

MOS = Margin of Safety

TMDL = Total Maximum Daily Load

kgd = kilograms per day

Table ES-2 Wet and Dry Season TMDL Allocations to Existing Sources and Load Reductions Required to Achieve Hanalei Stream and Estuary Turbidity Standards (Table 14)

Total Suspended Solids						
Wet Season Baseflow*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	1431.3	75.3	1506.6	6550.7	5044.0	77.0%
Hanalei River Estuary	1520.6	80.0	1600.6	6959.2	5358.6	77.0%
Waioli Stream Estuary	117.5	6.2	123.7	1124.9	1001.1	89.0%
Waipa Stream	49.5	2.6	52.1	452.8	400.7	88.5%
Waipa Stream Estuary	53.7	2.8	56.5	491.6	435.1	88.5%
Waikoko Stream Estuary	2.3	0.1	2.4	110.8	108.4	97.8%
Wet Season 10% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2220.0	116.8	2336.8	6550.7	4213.9	64.3%
Hanalei River Estuary	2358.4	124.1	2482.5	6959.2	4476.7	64.3%
Waioli Stream Estuary	187.5	9.9	197.4	1124.9	927.4	82.5%
Waipa Stream	63.3	3.330	66.6	452.8	386.2	85.3%
Waipa Stream Estuary	68.7	3.6	72.3	491.6	419.3	85.3%
Waikoko Stream Estuary	3.9	0.2	4.1	110.8	106.7	96.3%
Wet Season 2% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2894.1	152.3	3046.4	6550.7	3504.3	53.5%
Hanalei River Estuary	3074.5	161.8	3236.4	6959.2	3722.9	53.5%
Waioli Stream Estuary	318.2	16.8	334.9	1124.9	789.9	70.2%
Waipa Stream	59.8	3.147	62.9	452.8	389.8	86.1%
Waipa Stream Estuary	64.9	3.4	68.3	491.6	423.3	86.1%
Waikoko Stream Estuary	6.3	0.3	6.7	110.8	104.1	94.0%
Dry Season Baseflow*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	1415.8	74.5	1490.3	6479.5	4989.2	77.0%
Hanalei River Estuary	1504.1	79.2	1583.2	6883.6	5300.4	77.0%
Waioli Stream Estuary	116.3	6.1	122.4	1112.6	990.2	89.0%
Waipa Stream	48.9	2.6	51.5	447.9	396.4	88.5%
Waipa Stream Estuary	53.1	2.8	55.9	486.3	430.4	88.5%
Waikoko Stream Estuary	2.3	0.1	2.4	109.6	107.2	97.8%
Dry Season 10% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2195.8	115.6	2311.4	6479.5	4168.1	64.3%
Hanalei River Estuary	2332.8	122.8	2455.6	6883.6	4428.0	64.3%
Waioli Stream Estuary	185.5	9.8	195.3	1112.6	917.4	82.5%
Waipa Stream	62.6	3.294	65.9	447.9	382.0	85.3%
Waipa Stream Estuary	67.9	3.6	71.5	486.3	414.7	85.3%
Waikoko Stream Estuary	3.8	0.2	4.0	109.6	105.6	96.3%
Dry Season 2% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2862.6	150.7	3013.3	6479.5	3466.2	53.5%
Hanalei River Estuary	3041.1	160.1	3201.2	6883.6	3682.4	53.5%
Waioli Stream Estuary	314.7	16.6	331.3	1112.6	781.3	70.2%
Waipa Stream	59.2	3.113	62.3	447.9	385.6	86.1%
Waipa Stream Estuary	64.2	3.4	67.6	486.3	418.7	86.1%
Waikoko Stream Estuary	6.3	0.3	6.6	109.6	103.0	94.0%

Table ES-3. Wet and Dry Season TMDL Allocations to Existing Sources and Load Reductions Required to Achieve Hanalei Stream and Estuary Bacterial Standards (Table 15)

Enterococcus						
Wet Season Baseflow* (Geometric Mean)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+12	2.3E+11	4.6E+12	7.0E+12	2.5E+12	35.0%
Hanalei River Estuary	4.9E+12	2.6E+11	5.1E+12	7.9E+12	2.8E+12	35.0%
Wet Season Runoff* (Single Sample Maximum)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+10	2.3E+09	4.6E+10	7.0E+12	7.0E+12	99.4%
Hanalei River Estuary	4.9E+10	2.6E+09	5.1E+10	7.9E+12	7.8E+12	99.4%
Dry Season Baseflow* (Geometric Mean)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+12	2.3E+11	4.5E+12	7.0E+12	2.4E+12	35.0%
Hanalei River Estuary	4.8E+12	2.5E+11	5.1E+12	7.8E+12	2.7E+12	35.0%
Dry Season Runoff* (Single Sample Maximum)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+10	2.3E+09	4.5E+10	7.0E+12	6.9E+12	99.4%
Hanalei River Estuary	4.8E+10	2.5E+09	5.1E+10	7.8E+12	7.8E+12	99.4%

1. Introduction

Section 303(d) of the Clean Water Act (CWA) requires states to identify waterbodies (also referred to as receiving waters) that are not meeting their designated uses even though pollutant sources have implemented technology-based controls. In general, these waterbodies (i.e. receiving waters) are identified by comparing observed monitoring data to applicable water quality criteria (WQC) and waterbodies exceeding their WQC at a pre-defined frequency are considered impaired. These impaired waterbodies can be referred to as water quality limited segments (WQLSs) and are placed on the State's CWA §303(d) list. The CWA also requires states to establish a priority ranking of these WQLSs and to establish Total Maximum Daily Loads (TMDLs) for such waters. A TMDL establishes the allowable load of a pollutant or other quantifiable parameter based on the relationship between pollutant sources and in-stream water quality. It provides the scientific basis for a state to establish water quality-based controls to reduce pollution from both point and nonpoint sources and restore and protect the beneficial uses of the state's water resources (USEPA, 1991).

TMDLs represent a strategy for meeting WQC by allocating quantitative limits for 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 [40 CFR 130.2] such that the capacity of the waterbody to assimilate pollutant loading (i.e., the loading capacity) is not exceeded.

The TMDL process begins with the development of a technical analysis which includes the following components: (1) a **Problem Statement** describing which WQC are not being attained and which beneficial uses are impaired; (2) identification of **Numeric Targets** which will result in attainment of the WQC and protection of beneficial uses; (3) a **Source Analysis** to identify all of the point and nonpoint sources of the impairing pollutant in the watersheds and to estimate the current pollutant loading for each source; (4) a **Linkage Analysis** to calculate the Loading Capacity of the waterbodies for the pollutant; i.e., the maximum amount of the pollutant that may be discharged to the waterbodies without causing exceedances of WQC and impairment of 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 in the watersheds, wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint and background sources; (7) a description of how **Seasonal Variation and Critical Conditions** are accounted for in the TMDL determination; and (8) a discussion of the **Public Participation** process.

The State of Hawai'i Department of Health (HIDOH) and the United States Environmental Protection Agency (USEPA) have coordinated a watershed assessment and modeling study to support the calculation of *enterococcus* and turbidity TMDLs for several waterbodies (or receiving waters) in the Hanalei Bay watershed, which are listed as impaired on the 2006 §303(d) list. These TMDLs are presented as load allocations for the nonpoint sources as well as the load reductions required (from existing loading levels) to achieve the TMDLs. Since turbidity is not a mass-based constituent and loads cannot be calculated, TSS TMDLs were used as a surrogate for turbidity

TMDLs (HIDOH, 2005; Oceanit Laboratories, Inc., et al., 2002), but turbidity WQC were incorporated into the TMDL calculation process for estuaries to ensure attainment of WQC.

Additional analyses were also performed to address waterbody-pollutant combinations that are not currently on the §303(d) list. Specifically, Informative TMDLs and Load Targets, and suggested load reductions, have been calculated in the Hanalei Bay watershed for nutrients and other pollutants where these targets may be helpful to achieve the TMDLs in the impaired waterbodies by addressing upstream segments or they may improve water quality in waterbodies showing exceedances, but not enough data are currently available to warrant placement on the §303(d) list, as described in Section 2. This document presents the results of the study and describes each TMDL component listed above, as it pertains to Hanalei Bay watershed receiving waters. Specifically, Section 3 describes the numeric WQC used for TMDL analyses, Section 4 compares the observed monitoring data to these WQC and analyzes water quality and hydrology monitoring data over the wet and dry seasons, Section 5 presents a source analysis, Section 6 describes the linkage analysis, Section 7 addresses the TMDL calculation methodology and results, and Section 9 discusses the public participation process. Section 8 fulfills EPA requirements for the phased TMDL approach and discusses an implementation framework that can be used to inform and support additional planning, monitoring, assessment, and polluted runoff control measures over time.

2. Problem Statement

The Hanalei River is one of Hawai'i'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 from its discharge to Hanalei Bay, which is also fed by the Waioli, Waipa, and Waikoko Stream estuaries. These watersheds (Hanalei, Waioli, Waipa, and Waikoko) are collectively referred to as the Hanalei Bay watershed. They support a variety of natural and anthropogenic activities, which are associated with different pollutants, including bacteria, sediment, and nutrients.

Enterococcus densities in the Hanalei River Estuary have exceeded the numeric WQC during at a sufficient frequency to place the waterbody on the §303(d) list (HIDOH, 2008). Although the *enterococcus* water quality standards are written in terms of density of indicator bacteria colonies, the actual risk to human health is caused by the potential presence of disease-causing pathogens, which can cause illness in recreational water users. When the risk to human health from pathogens in the water is so great that waterbodies or downstream beaches are posted with warnings, or closed, the quality and beneficial use of the water are impaired. At present, measuring pathogens directly is difficult and expensive, and for this reason, high concentrations of bacteria, which originate from the intestinal flora of warm-blooded animals, are used to indicate the presence of pathogens.

Sources of bacteria under all conditions vary widely and include natural sources such as feces from aquatic and terrestrial wildlife, and anthropogenic sources such as cesspools, septic tanks, illegal sewage disposal from boats along the coastline, trash, and pet waste. Once in the environment, bacteria can also regrow and multiply (Byappanahalli and Fujioka, 1998). Bacteria sources and their transport mechanisms to receiving waters are discussed in greater detail in Section 5.

The Hanalei River Estuary is also on the 2006 §303(d) list for turbidity, along with the Hanalei River, Waioli Stream Estuary, Waipa Stream Estuary, and Waikoko Stream Estuary, due to turbidity measurements in these waterbodies exceeding their associated wet and/or dry season numeric WQC (HIDOH, 2008). Turbidity measures the degree to which light is scattered and absorbed rather than transmitted in straight lines in a sample. It is caused by suspended matter (such as sediment, algae, bacteria, etc.) and provides an estimate of the opacity of the water. In addition to turbidity, total suspended solids (TSS) are often evaluated to characterize potential sources and quantify loadings of sediment. Sediment concentrations are associated with anthropogenic activities, including the introduction of 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.

In addition to these listed impairments, several waterbodies also appear to be threatened by excessive nutrients; however, the monitoring datasets are not yet large enough to warrant placement on the §303(d) list. Nutrient loadings are generally lower in the freshwater segments than the estuarine areas and are associated with several watershed sources, which are discussed in Section 5. These sources include sediment, wildlife,

fertilizers, and sewage. Nutrient TMDLs are not required by law because they are not currently on the §303(d) list; however, to inhibit further water quality degradation and to understand the reductions necessary to achieve applicable WQC, Informative TMDLs and Load Targets for nutrients have been calculated for the Hanalei Stream and Estuary, Waioli Stream and Estuary, Waipa Stream and Estuary, and Waikoko Stream and Estuary.

Various locations in Hanalei Bay are listed on the 2006 §303(d) list for exceeding the enterococcus and/or turbidity WQC (HIDOH, 2008). It is assumed that most of the pollutants in the Bay are transported via the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream; therefore, reducing the pollutant loads from these tributaries should improve the water quality in Hanalei Bay. Water quality within the Bay will become more thoroughly monitored and assessed in subsequent phases of TMDL development, when separate TMDLs will established for the Bay. Therefore, the TMDLs, Informative TMDLs, and Load Targets for streams and estuaries in the Hanalei Bay watershed are subject to refinement as the TMDL process continues.

2.1. Project Area Description

The Hanalei Bay watershed covers a 32.3 square-mile area draining to Hanalei Bay along the north shore of the Hawaiian island of Kaua'i. This drainage area includes the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream watersheds. Figure 1 illustrates the geographic location of each watershed and Table 1 identifies the area associated with each watershed. The Hanalei River watershed is the largest watershed in the Hanalei Bay system, making up 73.2% of the drainage area (23.6 square-miles). The Waioli Stream watershed is the second largest drainage area with nearly 5.5 square-miles, followed by the 2.5 square-mile Waipa Stream watershed and the 0.7 square-mile Waikoko Stream watershed.

The watershed originates atop the 5,240 foot Mount Wai'ale'ale, which receives an average of 450 inches of rainfall per year, while the coastal areas receive less than 100 inches of rainfall annually (University of Hawai'i, 2002). Figure 2 illustrates the incredibly wide rainfall distributions in the region. Much of the rainfall occurs during the wet season from November through April. Hanalei has a tropical climate with an average annual temperature in the mid-seventies and an average humidity in the low eighties (Weather Underground, 2006).

The rainfall patterns tend to follow the elevation contours in the region, with higher rainfall occurring in the higher elevations. Many of the higher elevation areas also have very steep slopes. This combination of steep slopes and high precipitation has a significant potential for erosion; thus contributing to the high turbidity values observed further downstream (see Section 5).

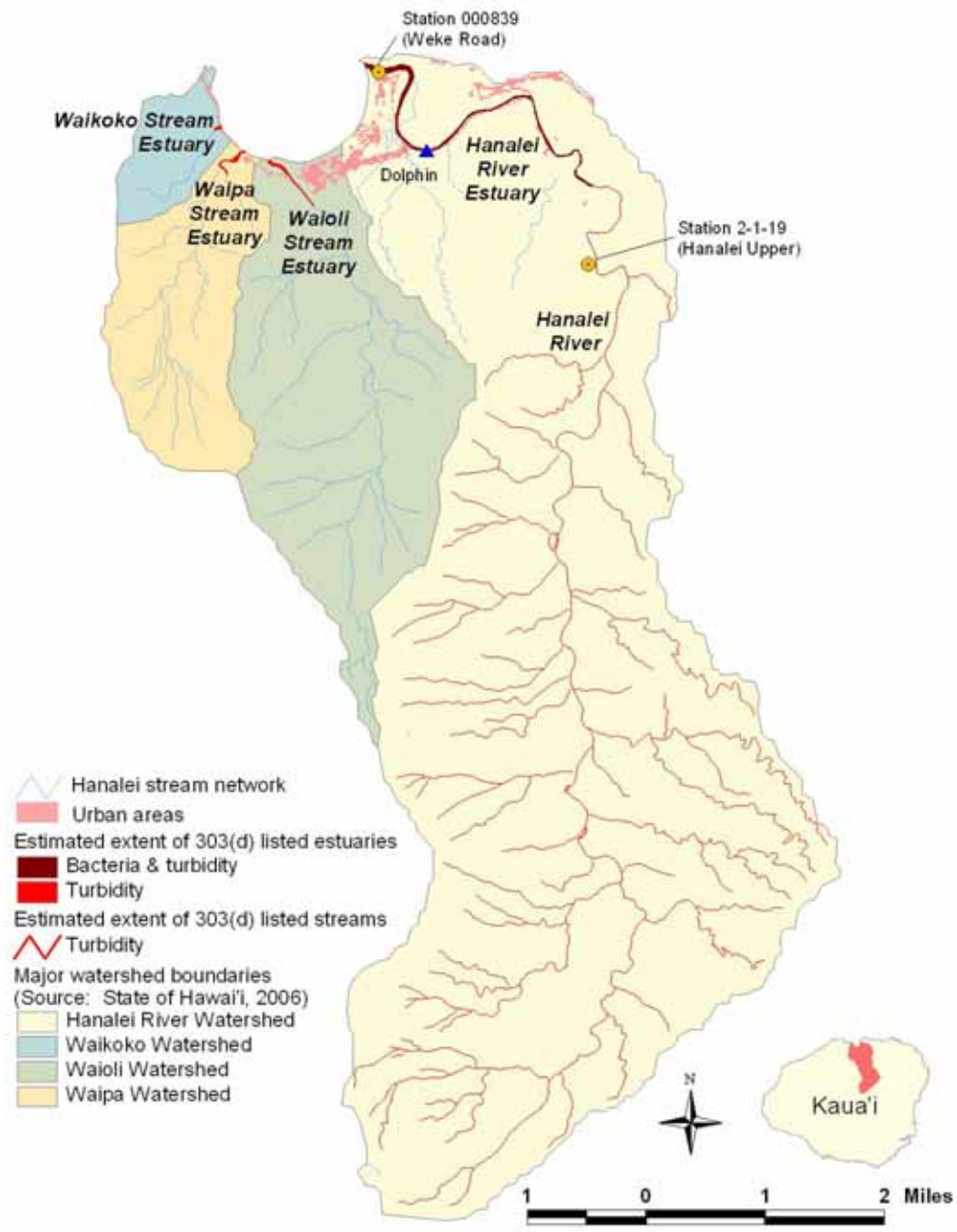


Figure 1. Hanalei Bay watershed

The Halelea Forest Reserve makes up a majority of the headwaters area. Agriculture, grassland, and urban areas are also drained before the Hanalei River and other tributaries discharge to the Hanalei Bay. In addition, the 16 mile Hanalei River passes through the Hanalei National Wildlife Refuge (NWR), which includes taro pondfields and several bird impoundments. The urban areas, which make up less than 1% of the land area, are primarily located in Hanalei town center along the Kuhio Highway (University of

Hawai'i, 2002). Figure 3 illustrates the percentage of total land area for each land cover category in the Hanalei Bay watershed (NOAA, 2000).

Table 1. Watershed Area (State of Hawai'i, 2006)

Watershed Name	Area (acres)	Area (square miles)	Percent of Total Area
Hanalei River	15,125.5	23.63	73.2%
Waioli Stream	3,482.7	5.44	16.9%
Waipa Stream	1,591.8	2.49	7.7%
Waikoko Stream	458.0	0.72	2.2%
Grand Total	*20,658.0*	*32.28*	*100%*

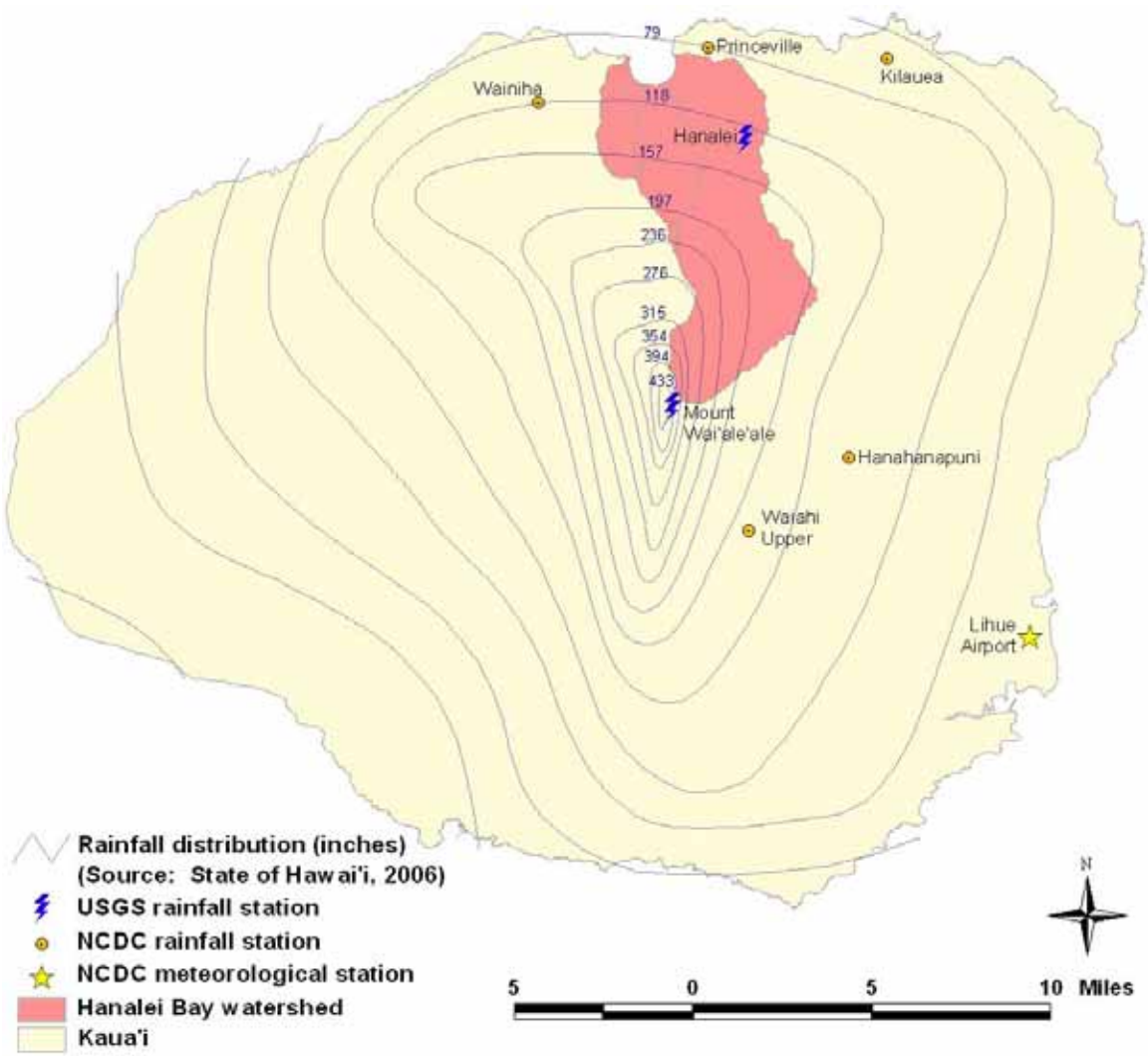


Figure 2. Kaua'i rainfall distribution

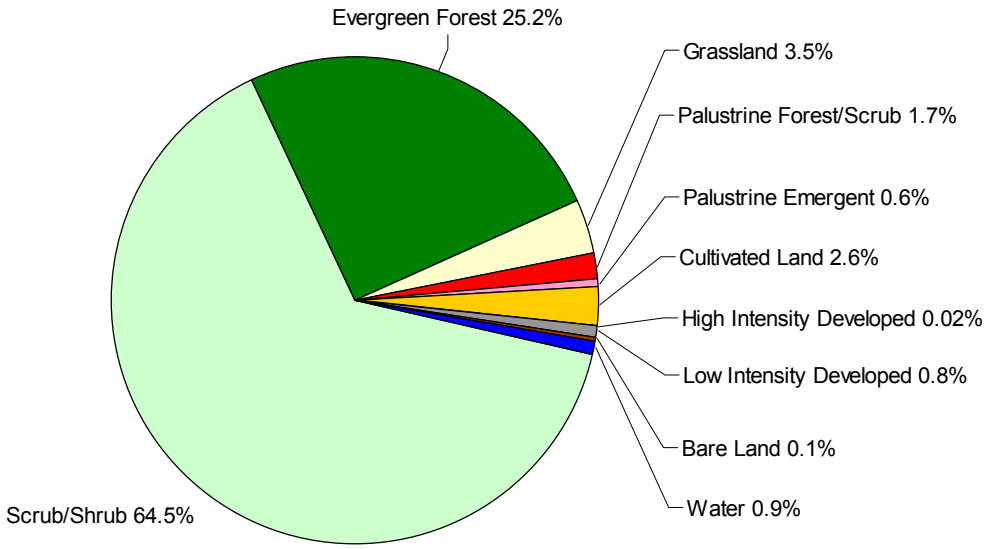


Figure 3. Hanalei Bay watershed land cover distribution (NOAA, 2000)

2.2. Impairment Overview

The waterbodies included in this project were listed as impaired due to non-attainment of the indicator bacteria and/or turbidity WQC. For streams, separate wet and dry season (defined as November to April and May to October, respectively) WQC are applicable, while seasonal variation is not considered in the estuary and the WQC are applicable throughout the year. The §303(d) listings, which were determined from comparing monitoring data with the appropriate WQC, are identified in Figure 1 and Table 2. This table also identifies the watershed that drains or contributes to the impaired waterbody, the basis for listing, and geographic scope of the listing, while Figure 1 illustrates the locations of the water quality monitoring stations represented in the station number column and the extent of the waterbodies (including the location of the Dolphin Restaurant [represented by a blue triangle] along the Hanalei River Estuary, which is referenced in the turbidity listing). For the Hanalei Stream and Waipa Stream turbidity listings, only the dry season (May to October) stream WQC was exceeded, while all of the estuary listings are applicable year-round (Table 2).

The current TMDL process reflects a consolidation of listings for inland waterbodies rather than individual stations within a waterbody (i.e. TMDLs address entire streams and/or entire estuaries). Specifically, three listings in the Hanalei River Estuary were consolidated into two waterbody-pollutant combinations. The Hanalei River Estuary turbidity impairments associated with two geographic areas [upstream of Dolphin and Weke Road station (Figure 1)] were grouped to address the entire estuary. The Hanalei River Estuary is also listed for *enterococcus* impairments. This consolidation process ultimately resulted in TMDL development for eight (8) waterbody-pollutant combinations in the Hanalei Bay watershed. These waterbody-pollutant combinations are identified below in
Table 3.

Table 2. Water Quality Limited Segments Addressed in This Analysis (HIDOH, 2008)

Watershed	Scope of Assessment	Pollutant	Basis for Listing	Geocode ID	Standard*
Waipa	Waipa Stream – Entire Network	turbidity	numeric assessment	2-1-17	dry season
Hanalei River	Hanalei Stream – Entire Network	turbidity *enterococcus*	numeric assessment	2-1-19	dry season
Hanalei River	Hanalei Bay upstream of Dolphin (Estuary)	turbidity	numeric assessment	HIW00160	year round
Hanalei River	Hanalei River (Estuary)	turbidity *enterococcus*	numeric assessment	HI385259	year round
Waikoko	Waikoko Estuary	turbidity	numeric assessment	HIW00162	year round
Waioli	Waioli Stream Estuary	turbidity	numeric assessment	HIW00163	year round
Waipa	Waipa Stream Estuary	turbidity	numeric assessment	HIW00164	year round

Table 3. Waterbody-Pollutant Combinations Addressed by the Hanalei Bay Watershed TMDLs

Listed Waterbody	Pollutant	Standard*	Watershed
Hanalei Stream	turbidity	dry season	Hanalei River
Hanalei Stream	*enterococcus*	year round	Hanalei River
Hanalei River Estuary	turbidity	year round	Hanalei River
Hanalei River Estuary	*enterococcus*	year round	Hanalei River
Waioli Stream Estuary	turbidity	year round	Waioli
Waipa Stream	turbidity	dry season	Waipa
Waipa Stream Estuary	turbidity	year round	Waipa
Waikoko Stream Estuary	turbidity	year round	Waikoko

*Streams have wet and dry season turbidity standards (November to April and May to October, respectively; however, estuary standards are applied throughout the year (see Table 5 and Table 6 below). *Enterococcus* standards for estuary and stream are applied throughout the year.

As described previously, various locations in Hanalei Bay are listed on the 2006 §303(d) list for exceeding the enterococcus and/or turbidity WQC (HIDOH, 2008). Separate TMDLs for Hanalei Bay have not been developed at this time, but will be considered in the next phase of TMDL development.

In addition to the waterbody-pollutant combinations identified in Table 3, Informative TMDLs and Load Targets were also calculated for several other combinations (Table 4). These calculations serve several purposes. In some instances achieving them will contribute to meeting WQC in the §303(d) listed waterbodies and can be used as an implementation tool (for example, Informative TMDLs for nutrients contribute to the achievement of the turbidity WQC). They are also helpful to reduce pollutant loads in other receiving waters where water quality monitoring and assessment data suggest that reductions may be required, although current datasets are not yet robust enough to warrant placement on the §303(d) list (for example, several waterbodies in the Hanalei Bay watershed appear to be threatened by nutrients, as described in Section 4), and to

provide a quantitative measure against which the success of the State antidegradation policy can be evaluated. “Load Targets” are calculated only for ammonia concentrations in streams, based on the assumption that achieving the estuary ammonia criteria in streams (where it is not an explicit part of the standards, otherwise these would be Informative TMDLs) would be protective of stream nitrogen and turbidity standards.

Table 4. Waterbody-Pollutant Combinations Addressed with Informative TMDLs and Load Targets

Waterbody	Pollutant	Watershed
INFORMATIVE TMDLs		
Hanalei Stream	nitrite plus nitrate total nitrogen total phosphorous	Hanalei River
Hanalei River Estuary	ammonia nitrite plus nitrate total nitrogen total phosphorous	Hanalei River
Waioli Stream	*enterococcus* nitrite plus nitrate total nitrogen total phosphorous total suspended solids turbidity	Waioli
Waioli Stream Estuary	*enterococcus* ammonia nitrite plus nitrate total nitrogen total phosphorous	Waioli
Waipa Stream	*enterococcus* nitrite plus nitrate total nitrogen total phosphorous total suspended solids	Waipa
Waipa Stream Estuary	*enterococcus* ammonia nitrite plus nitrate total nitrogen total phosphorous	Waipa
Waikoko Stream	*enterococcus* nitrite plus nitrate total nitrogen total phosphorous total suspended solids turbidity	Waikoko
Waikoko Stream Estuary	*enterococcus* ammonia nitrite plus nitrate total nitrogen total phosphorous	Waikoko
LOAD TARGETS		
Hanalei Stream	ammonia	Hanalei River
Waioli Stream	ammonia	Waioli
Waipa Stream	ammonia	Waipa
Waikoko Stream	ammonia	Waikoko

3. Numeric Target Selection

When calculating TMDLs, numeric targets are established to meet WQC and subsequently ensure the protection of beneficial uses. Beneficial uses in Hanalei inland receiving waters are Class 1 or Class 2, depending upon underlying land use designations and regulations, as described below and shown in Figure 4:

Class 1 It is the objective of Class 1 waters that these waters remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source. To the extent possible, the wilderness character of these areas shall be protected. Waste discharge into these waters is prohibited. Any conduct which results in a demonstrable increase in levels of point or nonpoint source contamination in Class 1 waters is prohibited (HIDOH, 2004).

Class 1.a. The uses to be protected in Class 1.a waters are scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other nondegrading uses which are compatible with the protection of the ecosystems associated with waters of this class (HIDOH, 2004).

Class 1.b. The uses to be protected in Class 1.b waters are domestic water supplies, food processing, protection of native breeding stock, the support and propagation of aquatic life, baseline references from which human-caused changes can be measured, scientific and educational purposes, compatible recreation, and aesthetic enjoyment. Public access to these waters may be restricted to protect drinking water supplies (HIDOH, 2004). These restricted areas are protective subzones within the conservation district. The objective of a protective subzone is to protect valuable resources in designated areas such as restricted watersheds, marine, plant, and wildlife sanctuaries, and sites, and other designated unique areas, as described in Chapter 13-5 of the Hawai'i Administrative Rules (DLNR, 1994).

Class 2 The objective of Class 2 waters is to protect their use for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation. The uses to be protected in this class of waters are all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class. No new treated sewage discharges shall be permitted within estuaries (HIDOH, 2004).

Portions of Hanalei Stream System that run through the National Wildlife Refuge (lower stream reach and upper estuary shown in yellow on Figure 4 below) and through recently-designated critical habitat areas (shown in white with magenta borders on Figure 4 below) for the federally-endangered Newcomb's snail (*Erinna newcombi*) are Class 1.a. Hanalei Stream headwaters, and a portion of upper reach tributaries, are Class 1.b., as are

the upper reaches of Waioli Stream and Waipa Stream (areas shown with red hatching on Figure 4 below). All remaining waters, including a large portion of Hanalei Stream upper reaches; the lower reach of Hanalei Estuary; the lower reaches of Waioli Stream and Waipa Stream and their estuaries; and the entire Waikoko Stream System (stream and estuary) are Class 2 (other areas in Figure 4 below).

Existing uses of these waterbodies have not been fully confirmed, however the only designated uses that may not be presently occurring in the respective segments are Class 1.b. domestic water supplies and food processing and Class 2 shipping and industrial water supplies. Many Class 1 uses currently exist in Class 2 waters, and perhaps vice-versa, such as scientific, educational, biological (natives), and aesthetic use of Class 2 waters and agricultural and commercial (navigation) use of Class 1 waters. Support of traditional and customary native Hawaiian beliefs, values, and practices is an ongoing use of all waters, along with many of the other "reasonable and beneficial uses" and instream uses protected under the State Water Code (Hawaii Revised Statutes Chapter 174C).

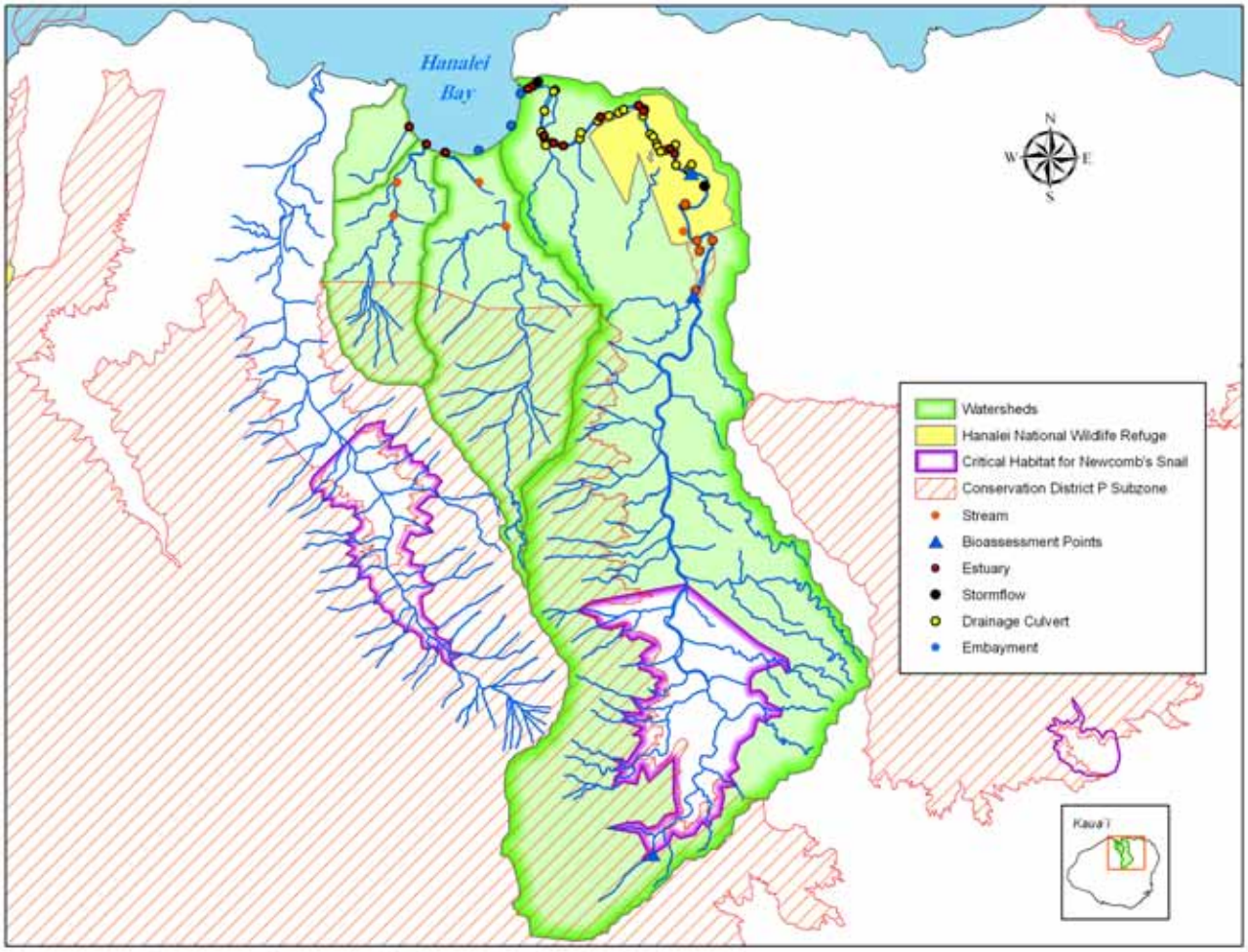


Figure 4. Factors affecting waterbody Class within the Hanalei Bay watershed

TMDLs were calculated for each impaired waterbody and for each pollutant listed in Table 3 using the WQC identified in the Hawai'i Administrative Rules (HAR) Title 11, Department of Health Chapter 54, Water Quality Standards, which were approved on August 31, 2004 (HIDOH, 2004). Load targets for the waterbody-pollutant combinations listed in Table 4 were developed using criteria identified in the same source. The numeric targets selected in the TMDL and load reduction analyses depended on whether the impaired waterbody was a stream or estuary. In addition, different dry and wet season numeric targets were used for the streams, consistent with the HAR (HIDOH, 2004). The HAR presents four different types of "not to exceed" (NTE) numeric criteria, which are described below:

Geometric mean	For the nutrient and sediment parameters, the geometric mean of all samples should not exceed this value. For *enterococcus*, the geometric mean is calculated on not less than five samples spaced to cover a period between 25 and 30 days. However, if five *enterococcus* samples are not collected within a 30 day period, the geometric mean is calculated on the samples taken within the 30-day period.
Not to exceed more than 10% of the time	For the nutrient and sediment parameters, no more than 10% of all time-averaged samples should exceed this value (does not apply to *enterococcus*).
Not to exceed more than 2% of the time	For the nutrient and sediment parameters, no more than 2% of all time-averaged samples should exceed this value (does not apply to *enterococcus*).
Single sample maximum	For *enterococcus* only, no single sample shall exceed this value (does not apply to the nutrient and sediment parameters).

The numeric targets for the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream Estuaries are presented in Table 5, while the targets for the Hanalei River, which are separated by season, are presented in Table 6. These tables include the numeric targets for parameters associated with the TMDL calculations (for waterbody-pollutant combinations identified in
Table 3 and 4) as well as load targets (for waterbody-pollutant combinations identified in 5). As indicated previously, TSS was used as a surrogate for turbidity during TMDL and load target analyses because turbidity is not mass-based and therefore cannot be used to calculate loads (HIDOH, 2005; Oceanit Laboratories, Inc., et al., 2002). However, stream and estuary turbidity WQC were incorporated into the TMDL analyses to ensure attainment of WQC in the estuaries (where no TSS WQC exists). Correlative analyses confirm the relationship between TSS and turbidity (R^2 value of 0.7175, as described below in Section 4.3.2.3 and illustrated in Figure 15), further justifying this approach.

The numeric targets used for TMDL and load target development are based on the WQC presented in the HAR (HIDOH, 2004). These WQC are limits or levels that were

established for the protection of designated uses of the waters of the state. Therefore, attainment of these WQC will result in restoration and protection of the designated uses described above. Bacteria WQC provide an example of a fairly direct relationship between WQC attainment and use attainment. Specifically, achieving the *enterococcus* WQC results in the attainment of the recreational beneficial use, based on assumption that that the WQC represents an acceptable threshold of public health risk for full-body contact. For other designated uses, the relationship between use attainment and the attainment of one or more WQC is generally less well-defined.

Table 5. Estuary Numeric Targets

Parameter (units)	Application in Hanalei Bay watershed	NTE geometric mean	NTE more than 10% of the time	NTE more than 2% of the time
Total Nitrogen (milligrams per liter [mg/L])	Informative TMDL calculation [a]	0.200	0.350	0.500
Ammonia Nitrogen (mg/L)	Informative TMDL[b] and Load Target[c] calculation	0.006	0.010	0.020
Nitrite + Nitrate Nitrogen (mg/L)	Informative TMDL calculation[d]	0.008	0.025	0.035
Total Phosphorous (mg/L)	Informative TMDL calculation [a]	0.025	0.050	0.075
Turbidity (Nephelometric Turbidity Units [NTU])	TMDL calculation[e]	1.5	3	5

Parameter	Application in Hanalei Bay watershed	NTE geometric mean[c]	Single sample maximum
Enterococcus (cfu/100mL)	TMDL and Informative TMDL calculation	33	89

[a] Also protective of turbidity standards
[b] Also protective of Total Nitrogen, Nitrate+Nitrogen, and turbidity standards
[c] Also protective of Total Nitrogen, Nitrate+Nitrogen, and turbidity standards in streams when applied to stream concentrations and loadings
[d] Also protective of Total Nitrogen and turbidity standards
[c] Numeric target for TSS loading based on statistical relationship with TSS concentrations
[e] Geometric mean based on a minimum of five samples spaced between 25 and 30 days

Table 6. Stream Numeric Targets

Parameter	Season[a]	Application in Hanalei Bay watershed	NTE geometric mean	NTE more than 10% of the time	NTE more than 2% of the time
Total Nitrogen (mg/L)	Wet	Informative TMDL calculation[b]	0.250	0.520	0.800
	Dry		0.180	0.380	0.600
Nitrite + Nitrate Nitrogen (mg/L)	Wet	Informative TMDL calculation[c]	0.070	0.180	0.300
	Dry		0.030	0.090	0.170
Total Phosphorous (mg/L)	Wet	Informative TMDL calculation[b]	0.050	0.100	0.150
	Dry		0.030	0.060	0.080
Total Suspended Solids (mg/L)	Wet	TMDL and Informative TMDL calculation[d]	20	50	80
	Dry		10	30	55
Turbidity (NTU)	Wet	TMDL and Informative TMDL calculation	5	15	25
	Dry		2	5.5	10

Parameter	Application in Hanalei Bay watershed	NTE geometric mean[e]	Single sample maximum
Enterococcus (cfu/100mL)	TMDL and Informative TMDL calculation	33	89

[a] Wet season = November 1 through April 30; Dry season = May 1 through October 31
[b] Also protective of turbidity standards
[c] Also protective of Total Nitrogen and turbidity standards
[d] Used as numeric target for turbidity endpoint in estuaries based on statistical relationship with turbidity values. Also protective of Total Nitrogen, Total Phosphorous, and enterococcus standards in streams and estuaries when applied to stream and estuary concentrations and loadings.
[e] Geometric mean based on a minimum of five samples spaced between 25 and 30 days

Stream biological assessment scores provide an evaluative measure of ecosystem health that can be used to develop numeric targets for stream environmental improvements. DOH's assessment methodology employs a holistic approach that evaluates the entire watershed as an extended ecological unit. Instead of simply evaluating specific points along the stream to determine species composition and abundance, we consider multiple lines of evidence to diagnose the overall health of the entire system. These lines of evidence include the habitat available for various species, both native and introduced; riparian zone integrity and composition; evidence of erosion, scour, and deposition; bottom types and substrate composition; and water chemistry, as well as information obtained from previous studies, water and land use records, and land cover classifications.

The Hawaii Stream Bioassessment Protocol (HSBP), version 3.01 (Kido, 2002), and the Hawaii Stream Visual Assessment Protocol (HSVAP) (NRCS, 2001) were conducted between August 29, 2006 and September 1, 2006 at 4 sites in the Hanalei Stream watershed. The assessments were conducted on relatively sunny days with a few light rain showers. Figure 5 shows the Hanalei HSBP results in relation to HSBP scores for three high-quality reference streams (including nearby Hanakapiai, Kauai).

Both upper sites are located in relatively intact native forest with a small percentage of invasive plant species cover. The upper Mai'a site contains invasive Australian Fern and Clidemia as the dominant invasive, while the upper LZ-15 site contains Yellow Guava as the dominant invasive species. No stream channel alterations were present, and no fine

sediment was observed, or indicated by turbidity, bottom type and bank stability scores. The investigation was conducted along a 100 meter length of stream channel in each location.

The Mai'a site is high gradient >10% slope, 2 to 5 meters wide, and located above a significant waterfall. The water temperature was 17.6° Centigrade. The only aquatic species noted at this site was 'Opae Kala'ole (Atyoida bisulcata). Additional species noted included a significant number of aquatic flies, and adult native dragonfly and damselflies were seen throughout the sampling site.

The LZ-15 site is medium gradient, >5% slope, 4 to 10 meters wide, with no significant migration barriers noted downstream. The water temperature was 20.7° Centigrade. This site contained native fish of species 'O'opu Nakea (Awaous guamensis) and 'O'opu Alamo'o (Lentipes concolor), but in very small numbers with a total of only 5 fish found in 100 meters of reach. 'Opae Kala'ole were also found in low numbers within this reach. Bullfrog juveniles (Rata catesbeiana) were the only invasive aquatic species identified. Again, native dragonfly and damselfly adults were seen along the stream corridor.

Overall, the upper sites are in good condition. The HSBP scores for the Mai'a site were Habitat - 95%, Biotic Integrity – 69%. The HSVAP score was 1.8 of 2.0. The HSBP scores for the LZ-15 site were Habitat – 96%, Biotic Integrity – 71%. The HSVAP score was 1.75 of 2.0. These scores reflect excellent supporting habitat with a borderline, moderately impaired biotic component, apparently due to limited recruitment, biomass, and diversity of native species.

The two lower elevation sites are significantly different from the upper sites. Invasive forest of Hau (Hibiscus tiliaceus), Rose apple (Syzygium jambos), Bamboo, Banyan (Ficus microcarpa), ginger and Albizia (Albizia lebbeck) dominates the riparian zone. The great width of the stream required that the reaches assessed be 400 and 600 meters long.

The Middle site, located at the USGS stream gauge, is low gradient, < 4% slope, and very wide. The width ranged from 25 to 37 meters and the temperature was 23.6° Centigrade. The bottom substrate was dominated by cobble and rock, with silt and clay deposits in the pools. Banks were severely eroded with undercuts evident. This degraded habitat offered refuge for several species of invasive aquatic species including Tahitian prawns (Macrobrachium lar), Smallmouth bass (Micropterus dolomieu) and swordtails (Xiphophorus helleri). The native species observed within this reach included 'O'opu nakea (Awaous guamensis), 'O'opu nopili (Sicyopterus stimpsoni), 'O'opu 'akupa (Eleotris sandwicensis), 'Aholehole (Kuhlia sandwicensis) and 'O'opu naniha (Stenogobius hawaiiensis). No native crustaceans or snails were observed.

The Lower site located near the Ducks Unlimited property (but above the estuary) was very murky and had significant erosion problems along the banks. However, the reach also had several riffle habitat areas that provided good habitat for native species. Severe undercutting was observed on the right bank within an overhanging Hau grove. This degraded habitat offered refuge for several species of invasive aquatic species including

Tahitian prawns (Macrobrachium lar), Smallmouth bass (Micropterus dolomieu) and swordtails (Xiphophorus helleri). The native species observed within this reach included ‘O’opu nakea (Awaous guamensis), ‘O’opu ‘akupa (Eleotris sandwicensis), ‘Aholehole (Kuhlia sandwicensis) and ‘O’opu naniha (Stenogobius hawaiiensis). No native crustaceans or snails were observed.

The HSBP scores for the Middle site were Habitat - 81%, Biotic Integrity – 53 %. The HSVAP score was 1.3 of 2.0. The HSBP scores for the Lower site were Habitat – 56%, Biotic Integrity – 53%. The HSVAP score was 1.2 of 2.0.

Previous investigations by various researchers indicate that a significant population of introduced species, including several predacious species, has been established in Hanalei. Results from our assessments indicate that a relatively healthy aquatic community was present in the watershed. Overall species composition was favorable, but habitat was degraded in the lower sites by bank erosion and riparian degradation.

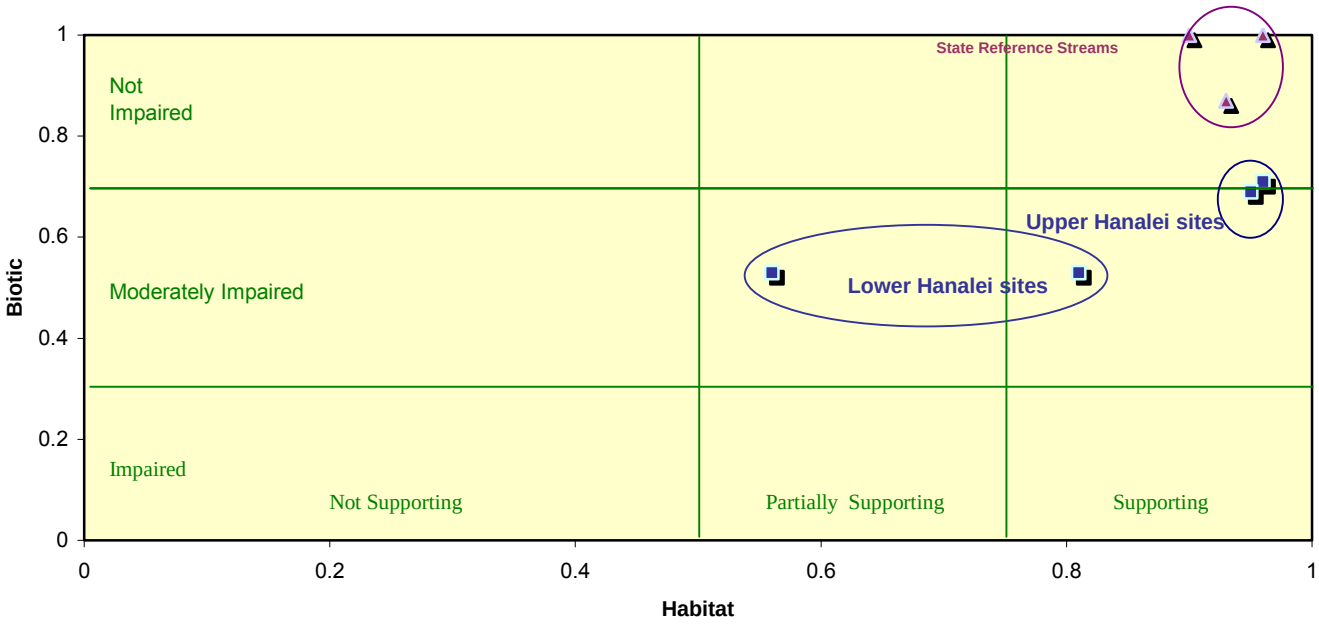


Figure 5. Stream Bioassessment Results, Hanalei Stream

4. Data Inventory and Analysis

Data from numerous sources were used to represent the watersheds and estuaries, characterize their water quality conditions, identify potential sources associated with *enterococcus*, sediment, and nutrients, and support the calculation of TMDLs and load targets. Some of these data were used to configure watershed and receiving water models, while other data and information were used in data analyses to provide an understanding of the conditions that result in water quality impairments. The remainder of this section provides an inventory of data, a summary of hydrologic conditions in the watershed, and analyses to review the impairments and threatened segments.

4.1. Data Inventory

The categories of data used in developing these TMDLs include physiographic data that describe the physical conditions of the watershed and environmental monitoring data that identify past and current conditions and support the identification of potential pollutant sources. Table 7 presents the various data types and data sources used in the development of these TMDLs. The following sections describe the key data sets used for TMDL development and analyses: water quality, hydrologic, meteorological, and watershed characteristic data.

Table 7. Inventory of Data and Information

Data Type	Data Source(s)
Environmental Monitoring Data	
Water quality monitoring data	HIDOH (HIDOH, 2006); Hanalei Watershed Hui (Berg, 2006); United States Geological Survey (USGS; USGS, 2006)
Streamflow data	USGS (USGS, 2006); HIDOH (HIDOH, 2006); Hanalei Watershed Hui (Berg, 2006)
Meteorological data	USGS (USGS, 2006); National Oceanic and Atmospheric Administration - National Climatic Data Center (NOAA-NCDC, 2006)
Physiographic Data	
Stream network	Hawai'i Statewide GIS Program (State of Hawai'i, 2006)
Land cover	NOAA Coastal Change Analysis Program (C-CAP) (NOAA, 2000)
Soils	USDA State Soil Geographic Data Base (STATSGO) (USDA, 2006)
Watershed boundaries	Hawai'i Statewide GIS Program (State of Hawai'i, 2006)
Topographic and digital elevation models (DEMs)	United States Geological Survey (USGS, 2005); Hawai'i Statewide GIS Program (State of Hawai'i, 2006)

4.1.1. Water Quality Data

Water quality monitoring data for bacteria, sediment, and nutrients in the Hanalei Bay watershed were obtained from the HIDOH Clean Water Branch (HIDOH, 2006), the Hanalei Watershed Hui (Hui) (Berg, 2006), and the United States Geological Survey

(USGS, 2006). These data were collected at 62 stations located within or tributary to impaired or threatened waterbodies. Figure 6. illustrates the spatial distribution of water quality monitoring stations by location type. These data, which were collected between January 1995 and May 2006, were well distributed among the wet and dry seasons, as indicated in Table 8; however, the number of samples collected at each station varied significantly. The number of samples collected under baseflow and stormflow conditions is also presented in Table 8. Days were classified as baseflow or stormflow by obtaining average daily flow values at the USGS gage for January 1995 through May 2006 (which overlaps with the water quality data record). The days corresponding to the highest ten percent of flows were assigned to the stormflow category and then the number of samples falling under the stormflow and baseflow categories was tabulated. With the exception of the suspended sediment concentration (SSC) data collected by USGS, a vast majority of the records summarized in Table 8 were grab samples. The SSC data and a few samples collected in March 2006 were collected using automatic samplers. Water quality data were analyzed to evaluate seasonal distribution, waterbody type (i.e. stream, estuary, etc.), and relationships between parameters. The results of these analyses are presented in Section 4.3. Some of these data were also used for watershed and receiving water calibration and validation, which are described in the Modeling Report, Appendix B.

4.1.2. Hydrologic Data

Several sources of flow data were available for the Hanalei Bay watershed, including both continuous and discrete measurements. The continuous flow measurements include data collected at the USGS gage on the Hanalei River (station 16103000). Continuous flow data have been obtained for this station from May 1, 2001 – May 31, 2006 (USGS, 2006). Discrete flow measurements were collected between November 2001 and September 2005 as part of the water quality sampling protocol during several events (Berg, 2006; HIDOH, 2006).

While there are no National Pollutant Discharge Elimination System (NPDES) dischargers that are major point sources of flow or pollutants in the Hanalei Bay watershed, there are flow diversions to wetland impoundments and taro pondfields at the Hanalei National Wildlife Refuge (NWR). These diversions are estimated to have an average constant withdrawal from the irrigation ditch system of 34 cubic feet per second (cfs) (USFWS, 2005). It was estimated that an average 65 percent (22.1 cfs) of the inflows return to the Hanalei River because consumptive use is lower than the inflow requirements (USFWS, 2005).

These flow measurements were incorporated into the watershed and receiving water models and were utilized for model calibration and validation, as described in the Modeling Report, Appendix B. The continuous flow measurements were also analyzed to summarize the Hanalei River flow ranges observed during wet and dry seasons, as described in Section 4.2.

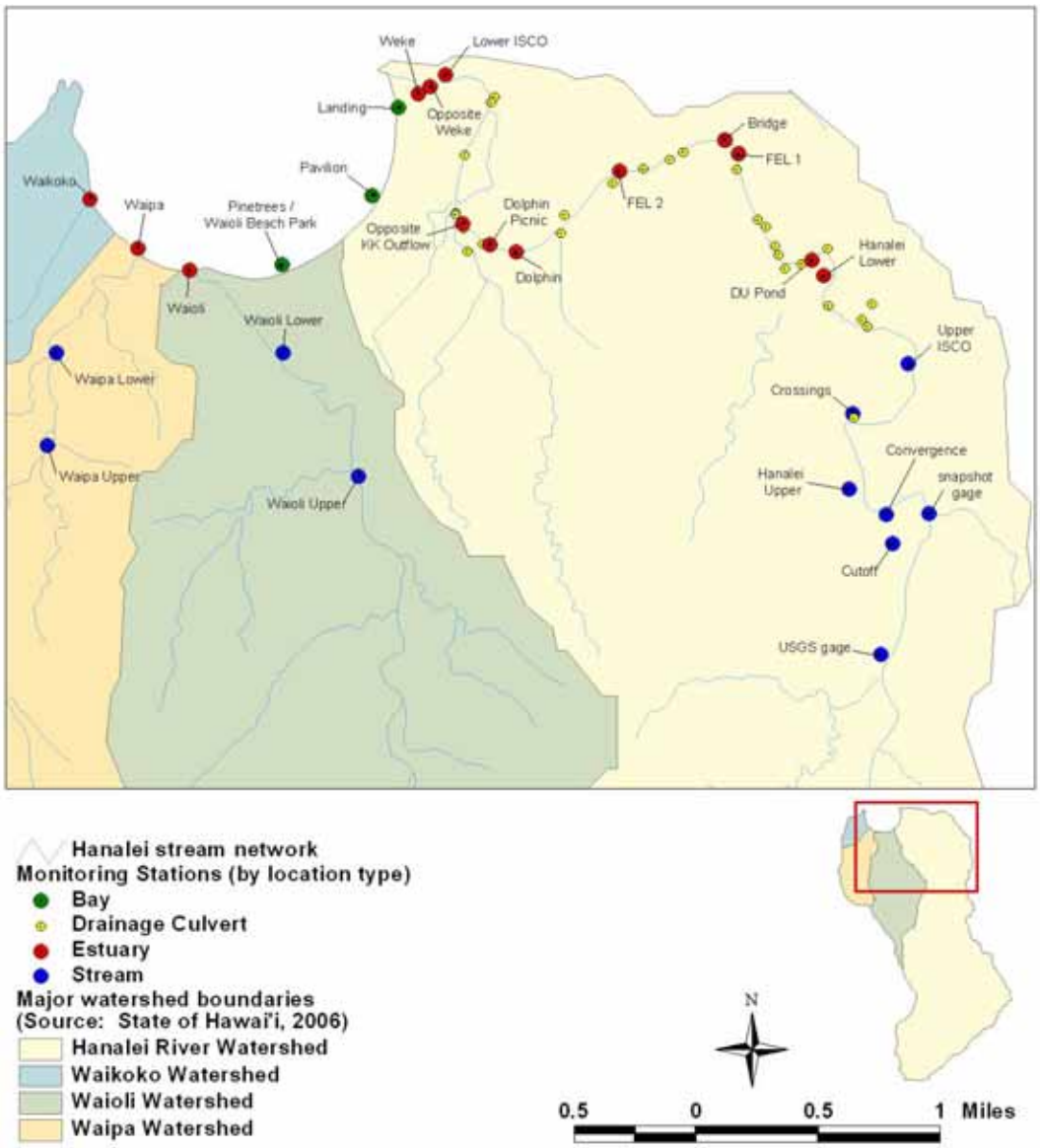


Figure 6. Water quality monitoring stations by location type

Table 8. Seasonal and Flow Regime Distribution of Water Quality Data

Parameter (units)	Number of Samples			
	Dry Season	Wet Season	Baseflow	Stormflow
Bacteria				
Enterococci (#/100mL)	2351	2062	3914	499
Sediment				
Turbidity (NTU)	1303	1519	2460	362
TSS (mg/L)	88	104	148	44
Suspended sediment (mg/L)	375	439	690	124
Nutrients				
Ammonia (mg/L)	88	99	145	42
Nitrite plus Nitrate (mg/L)	90	99	147	42
Total Nitrogen (mg/L)	89	98	146	41
Total Phosphorous (mg/L)	89	98	146	41

4.1.3. Meteorological Data

The Hanalei Bay watershed has an incredibly wide distribution of rainfall, as depicted in Figure 2. The headwaters are near Mount Wai'ale'ale, which receives over 450 inches of rainfall annually and is one of the rainiest places on earth, and the coastal areas near the mouth of the watersheds (less than 10 miles from Mount Wai'ale'ale) receive less than 100 inches of rain per year. Because of this extreme variability and its impact on stream flows, it was important to represent the rainfall distribution in the watershed using appropriate rainfall gages.

United States Geological Survey (USGS) and National Oceanic and Atmospheric Administration-National Climatic Data Center (NOAA-NCDC) precipitation data were reviewed based on geographic location, rainfall distribution, period of record, and missing data to determine the most appropriate meteorological stations (USGS, 2006; NOAA-NCDC, 2006). Hourly rainfall data were obtained from two USGS rainfall stations located near the Hanalei Bay watershed (Figure 2): Mount Wai'ale'ale and Hanalei. Data for these stations were obtained from USGS for May 1, 2001 through May 31, 2006.

In addition, hourly potential evapotranspiration values were calculated using data from the Lihue Airport NCDC station. Solar radiation, wind speed, cloud cover, air temperature, and dew point data were also obtained for the watershed modeling, which were supplemented by relative humidity, wind direction, and sea level pressure from Lihue Airport for the receiving water model.

4.1.4. Watershed Characteristic Data

Various types of watershed characteristic data were incorporated into the modeling study of the Hanalei Bay watershed. These data include, but are not limited to, land cover, soils, and elevation. The National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover image from a remote sensing study in 2000 (NOAA, 2000) was used to represent land cover in the watershed. There were originally thirteen C-CAP land cover categories present in the Hanalei Bay watershed. To simplify model parameterization, land categories that share hydrologic or pollutant loading characteristics were grouped, resulting in ten land cover categories for modeling, which are described and illustrated in the Modeling Report, Appendix B.

Soils data were obtained from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) database (USDA, 2006), digital elevation model (DEM) data were obtained from the USGS (USGS, 2005), and elevation contours were obtained from the Hawai'i Statewide GIS Program (State of Hawai'i, 2006). Because steep slopes have the potential to contribute larger amounts of sediment than gentler slopes, areas with steep slopes were identified using the DEM. The soils in these areas were identified as having high erosive potential in the modeling study.

4.2. Long-Term Hydrologic Analysis

Twenty years of average daily flows at the USGS gage Hanalei River station (station 16103000) were evaluated to characterize temporal patterns over a range of hydrologic conditions. Specifically, monthly minimum, maximum, mean, and median flows were calculated based on daily measurements for June 1987 through May 2006. These summary statistics are presented in Table 9 and illustrated in Figure 7.7.

Table 9. Monthly Flow Statistics – June 1987 through May 2006

Month	Flow for June 1987 – May 2006 (cfs)				
	Number of Daily Measurements	Minimum	Maximum	Mean	Median
January	589	66	4,770	257	121
February	537	66	4,380	243	125
March	589	58	4,880	272	133
April	570	56	2,660	246	180
May	589	60	1,750	186	129
June	570	57	901	165	121
July	589	54	3,040	192	138
August	589	70	1,800	169	130
September	570	60	3,210	206	131
October	589	71	2,040	206	136
November	570	70	7,100	299	167
December	589	72	4,550	263	158

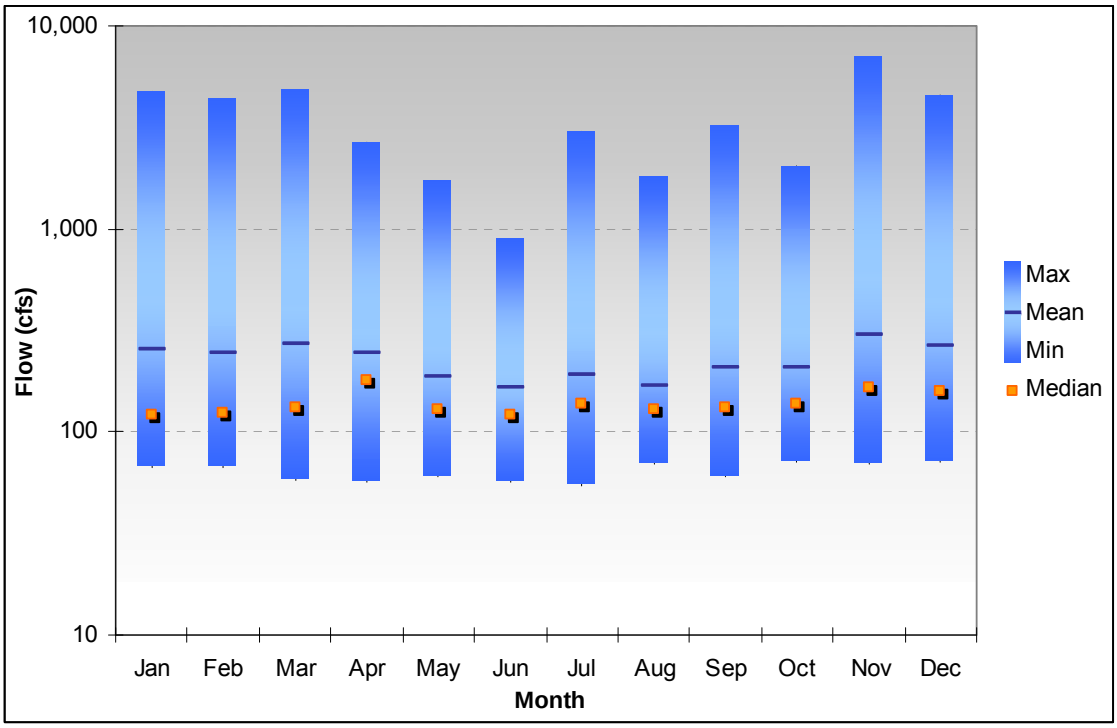


Figure 7. Monthly Flow Values – June 1987 through May 2006

The HAR defines the wet season in Hawai'i as November 1 through April 30 and the dry season as May 1 through October 31 (HIDOH, 2004). The above table and figure show that November through April have higher mean flows than May through October, which is consistent with the HAR definitions of wet and dry seasons. The minimum flow for each month is similar (range of 54 to 72 cfs) and, as expected, the maximum flows exhibit much wider variability over the 20 year period. In general, November through April have higher maximum flows than the other months, except for July and September, which show higher maximum values than in April. These data indicate that although November through April are the wettest months of the year, large storms also occur during the dry season, which may result in significant loads to the watershed.

4.3. Water Quality Data Analyses

Bacteria, sediment, and nutrients data collected from stream, estuary, and bay segments were analyzed to provide guidance for the source assessment. These data include wet and dry season sampling conducted by the Hui (Berg, 2006) and HIDOH (HIDOH, 2006) as well as stormwater monitoring. The primary stormwater monitoring was conducted as a collaborative effort between HIDOH, the Hui, and Tetra Tech. This monitoring resulted in bacteria, sediment, and/or nutrients data collected with automatic samplers (ISCOs), grab samples, and field measurements during or immediately after two storm events in March 2006. These data generally indicate higher pollutant concentrations during or after storms, as described below. USGS has been collecting additional suspended sediment concentration data at the USGS gage, including storm samples. These samples also indicate higher concentrations during storm events.

Analyses of the stormwater and non-stormwater data included a comparison of water quality monitoring results to applicable WQC including summary statistics, spatial patterns, relationships between pollutants, and correlation to streamflow analyses. Results of these analyses are reported in the following sections.

4.3.1. Review of Impaired Segments

Several waterbody-pollutant combinations are included on the 2006 §303(d) list of impaired waterbodies (Table 2 and Appendix G). To further evaluate these waterbodies, all available water quality data were compared against the applicable water quality criteria. TMDLs, Informative TMDLs, or Load Targets were developed for each pollutant-waterbody combination, depending on the waterbody, pollutant, and listing status [i.e. TMDLs were developed for all combinations on the 2006 §303(d) list, while Informative TMDLs were calculated for most other combinations]. Table 10 summarizes the listing status, whether one of the criterion (single sample maximum and 30-day geometric mean for *enterococcus* and geometric mean, 10% NTE, and 2% NTE WQC for all other parameters) was exceeded based on data analyses, and how each waterbody-pollutant combination is being addressed as part of this current effort. The remainder of this section provides additional details regarding the data analyses performed to evaluate the exceedance of applicable WQC.

Table 10. Summary of Listings, Exceedances, and Current Application

Waterbody	Description	Entero	Turbidity	NH4	NOx	TN	TP	TSS
Estuary								
Hanalei River Estuary	Included on 2006 303(d) list[a]	**Y**	**Y**	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	**TMDL**	**Verification**	IT	IT	IT	IT	**TMDL**
Waioli Stream Estuary	Included on 2006 303(d) list[a]	N	**Y**	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Waipa Stream Estuary	Included on 2006 303(d) list[a]	N	**Y**	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	—	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Waikoko Stream Estuary	Included on 2006 303(d) list[a]	N	**Y**	N	N	N	N	N
	Criteria exceeded[b]	√	√	√	√	√	√	
	Current application[c]	IT	**Verification**	IT	IT	IT	IT	**TMDL**
Stream								
Hanalei River	Included on 2006 303(d) list[a]	**Y**	**D**	N	N	N	N	N
	Criteria exceeded[b]	√	W/D		—	W	W	W
	Current application[c]	**TMDL**	**Verification**	LT	IT	IT	IT	**TMDL**
Waioli Stream	Included on 2006 303(d) list[a]	N	N	N	N	N	N	N
	Criteria exceeded[b]	no data	D		—	—	—	—
	Current application[c]	IT	—	LT	IT	IT	IT	IT
Waipa Stream	Included on 2006 303(d) list[a]	N	**D**	N	N	N	N	N
	Criteria exceeded[b]	no data	D		—	—	—	—
	Current application[c]	IT	**Verification**	LT	IT	IT	IT	**TMDL**
Waikoko Stream	Included on 2006 303(d) list[a]	N	N	N	N	N	N	N
	Criteria exceeded[b]	no data	no data		no data	no data	no data	no data
	Current application[c]	IT	—	LT	IT	IT	IT	IT

[a]Y = year-round impairment; D = dry season impairment; W = wet season impairment; N = not listed

[b]For estuaries, exceedances are associated with year-round criteria (√). For streams, *enterococcus* is associated with year-round criteria (√), but all other parameters have separate wet (W) and dry (D) season standards that can be exceeded. These letters indicate that one or more of the applicable WQC were exceeded (additional details regarding these exceedances are presented in Table 11. Shading indicates no applicable standard. Waterbody-pollutant combinations not exhibiting any exceedances in the available data are represented by "–."

[c]TMDL = TMDLs were calculated as part of the current application; Verification = data and model output were used to confirm impairments and/or verify attainment of WQC through TSS TMDL implementation; IT = Informative TMDLs were calculated as part of the current application. LT = Load Targets were calculated as part of the current application; Waterbody-pollutant combinations not specifically addressed by any loading calculations are represented by "–."

To expand on the previous summary, observed bacteria, sediment, and nutrients data in the estuaries and streams were compared to their applicable WQC to determine exceedances of the standards. Data for individual stations were combined by waterbody. Figure 6.6 illustrates the stations used; however, all parameters were not sampled at all stations. The point symbols indicate how the stations were grouped (i.e. stream, estuary, etc.), while the color coding for the watershed boundaries indicates the waterbody with which they are associated. Water quality data were provided from HIDOH (HIDOH, 2006) and the Hanalei Watershed Hui (Berg, 2006). These analyses characterize the

water quality data and quantify exceedances of the water quality criteria. The estuary and stream analyses are presented below.

Estuary data were compared against their applicable estuary WQC to evaluate the magnitude of *enterococcus* (30-day geometric mean and single sample maximum WQC), turbidity (geometric mean, 10% NTE, and 2% NTE WQC), and nutrients (geometric mean, 10% NTE, and 2% NTE WQC) exceedances. These analyses are presented in Figures A-1 through A-28 of Appendix A. For comparative purposes, estuary TSS data were compared against the stream WQC because no WQC exists for TSS in estuaries. A summary of the percent exceedances for each WQC calculated from these analyses is presented in Table 11 with the number of measurements included in parentheses (for the geometric mean WQC, the number of measurements is equal to the number of geometric means calculated, but for the single sample maximum and not-to-exceed WQC, these values are equal to the sample sizes). Essentially, the data confirm all current estuary impairments (*enterococcus* in the Hanalei River Estuary and turbidity in all four estuaries). In addition, several other pollutant-waterbody combinations consistently exceeded one or more of the WQC.

For all four estuaries, *enterococcus* concentrations exceeded both the geometric mean (based on a running 30-day geometric mean) and single sample maximum WQC regularly; however, only the Hanalei River Estuary is on the 303(d) list for *enterococcus* [(as discussed previously (Table 4), Informative TMDLs for *enterococcus* were developed for the other estuaries that are not currently listed). This trend also persists for the geometric mean and both not-to-exceed standards for turbidity. While nutrients are not currently on the §303(d) list for any of the waterbodies studied, the data indicate that the ammonia, nitrite plus nitrate, and total phosphorous WQC are consistently exceeded in all five estuaries. Exceedances of the total nitrogen WQC are less consistent. For example, data associated with the Hanalei River, Waioli Stream, and Waipa Stream Estuaries do not exceed the total nitrogen geometric mean, while data indicate that the Waikoko Stream Estuary exceeds it. The two not-to-exceed criteria are exceeded for total nitrogen in all estuaries (percent exceedances range from 4 to 27%) except for the 2% not-to-exceed criteria in the Waipa Stream Estuary. There is currently no TSS standard for estuaries; however, estuary TSS data were compared to the stream standards for comparative purposes. These estuary data routinely exceed the stream not-to-exceed TSS criteria (but at varying frequencies), but only the Waikoko Stream Estuary exceeds the TSS geometric mean stream criteria. As stated previously, these analyses confirm the existing impairments in the estuaries and also identify several other pollutant-waterbody combinations that are exceeding the WQC, although sample sizes for some parameters are small (less than 25 samples) and, therefore, more data are needed to draw more definitive conclusions (Table 11).

Stream data were also compared against their applicable freshwater WQC to evaluate the magnitude of *enterococcus* (30-day geometric mean and single sample maximum WQC), turbidity (wet and dry season WQC for geometric mean, 10% NTE, and 2% NTE), and nutrient (wet and dry season WQC for geometric mean, 10% NTE, and 2% NTE WQC) exceedances. These analyses are presented in Figures A-29 through A-62 of Appendix A. For comparative purposes, stream ammonia data were compared against the estuary WQC because no WQC exists for ammonia in streams. Similar to the estuary analyses, a

summary of the percent exceedances for each WQC calculated from these analyses is presented in Table 11. The separate wet and dry season WQC were compared against data collected during their associated months. Essentially, the data confirm the current stream impairment for turbidity in Hanalei Stream and Waipa Stream and, similar to the estuary analyses, additional pollutant-waterbody combinations exceeding one or more of the WQC.

The stream analyses showed similar results for *enterococcus* and turbidity when comparing observed data to the various WQC; however, the percent exceedances were generally lower than those in the estuary (Figures A-29 through A-62 of Appendix A and Table 11). Data for Hanalei Stream indicate that the turbidity geometric mean criteria were exceeded during both wet and dry seasons [although the 2006 §303(d) listing is only for dry season exceedance], while data for Waipa Stream wholly confirm the dry season-only listing. In Hanalei Stream the 10% not-to-exceed criteria were exceeded 43% and 35%, respectively, for the wet and dry season and the 2% not-to-exceed criteria were exceeded 7% of the time during the wet season and 24% of the time during the dry season. In Waipa Stream the 10% not-to-exceed criteria were exceeded 0% and 13%, respectively, for the wet and dry season and the 2% not-to-exceed criteria were not exceeded at all. No *enterococcus* data were available for the freshwater portions of Waioli, Waipa, and Waikoko Streams; therefore, the only exceedances presented are those for Hanalei Stream (82% exceedance of the geometric mean WQC and 41% exceedance of the single sample maximum criteria). Nutrient and TSS data were less consistent; however, they do show exceedances of some WQC. Specifically, total nitrogen, total phosphorous, and TSS show exceedances of the not-to-exceed criteria in Hanalei Stream.

Table 11. Percent Exceedances Associated with Comparing Observed Data to WQC

Water-body	Water Quality Criteria[a]	Percent Exceedance of Numeric WQC by Parameter (number of measurements)[b,c]												
		Entero	Turbidity		NH_4	NO_x		TN		TP		TSS		
Estuary Comparisons														
Hanalei River Estuary	Geometric mean	**99 (804)**	**100 (1)**		**100 (1)**	**100 (1)**		0 (1)		**100 (1)**		0 (1)[d]		
	SSM	**75 (867)**	N/A		N/A	N/A		N/A		N/A		N/A		
	10% NTE	N/A	**78 (702)**		**56 (59)**	**32 (59)**		**12 (59)**		**15 (59)**		**21 (66)[d]**		
	2% NTE	N/A	**51 (702)**		**37 (59)**	**20 (59)**		**12 (59)**		**12 (59)**		**11 (66)[d]**		
Waioli Stream Estuary	Geometric mean	**100 (262)**	**100 (1)**		**100 (1)**	**100 (1)**		0 (1)		**100 (1)**		0 (1)[d]		
	SSM	**91 (286)**	N/A		N/A	N/A		N/A		N/A		N/A		
	10% NTE	N/A	**54 (169)**		**83 (23)**	**74 (23)**		4 (23)		**13 (23)**		9 (22)[d]		
	2% NTE	N/A	**38 (169)**		**65 (23)**	**52 (23)**		**4 (23)**		**4 (23)**		**5 (22)[d]**		
Waipa Stream Estuary	Geometric mean	**100 (261)**	**100 (1)**		**100 (1)**	**100 (1)**		0 (1)		100 (1)		0 (1)[d]		
	SSM	**86 (285)**	N/A		N/A	N/A		N/A		N/A		N/A		
	10% NTE	N/A	**77 (167)**		**74 (23)**	**39 (23)**		9 (22)		9 (22)		9 (22)[d]		
	2% NTE	N/A	**41 (167)**		**43 (23)**	**17 (23)**		0 (22)		**5 (22)**		0 (22)[d]		
Waikoko Stream Estuary	Geometric mean	**100 (215)**	**100 (1)**		**100 (1)**	**100 (1)**		**100 (1)**		**100 (1)**		**100 (1)[d]**		
	SSM	**96 (236)**	N/A		N/A	N/A		N/A		N/A		N/A		
	10% NTE	N/A	**99 (167)**		**100 (23)**	**70 (23)**		**27 (22)**		**41 (22)**		9 (22)[d]		
	2% NTE	N/A	**96 (167)**		**91 (23)**	**52 (23)**		**9 (22)**		**14 (22)**		**5 (22)[d]**		
Water-body	**Water Quality Criteria[a]**	**Percent Exceedance of Numeric WQC by Parameter (number of measurements)[b,c]**												
		Entero	**Turbidity**		**NH_4**	**NO_x**		**TN**		**TP**		**TSS**		
			Wet	**Dry**		**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	
Stream Comparisons														
Hanalei River	Geometric mean	**82 (115)**	**100 (1)**	**100 (1)**	**100 (1)[e]**	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	
	SSM	**41 (155)**	N/A		N/A	N/A		N/A		N/A		N/A		
	10% NTE	N/A	**43 (145)**	**35 (143)**	6 (31)[e]	0 (19)	0 (11)	**16 (19)**	0 (11)	**16 (19)**	0 (11)	**16 (19)**	0 (10)	
	2% NTE	N/A	**7 (145)**	**24 (143)**	0 (31)[e]	0 (19)	0 (11)	**5 (19)**	0 (11)	**16 (19)**	0 (11)	**16 (19)**	0 (10)	
Waioli Stream	Geometric mean	no data	0 (1)	**100(1)**	**100 (1)[e]**	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	
	SSM		N/A		N/A	N/A		N/A		N/A		N/A		
	10% NTE	N/A	0 (5)	0 (9)	0 (7)[e]	0 (1)	0 (7)	0 (1)	0 (7)	0 (1)	0 (7)	0 (1)	0 (7)	
	2% NTE	N/A	0 (5)	0 (9)	0 (7)[e]	0 (1)	0 (7)	0 (1)	0 (7)	0 (1)	0 (7)	0 (1)	0 (7)	
Waipa Stream	Geometric mean	no data	0 (1)	**100 (1)**	**100 (1)[e]**	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	0 (1)	
	SSM		N/A		N/A	N/A		N/A		N/A		N/A		
	10% NTE	N/A	0 (6)	**13 (8)**	0 (14)[e]	0 (4)	0 (9)	0 (4)	0 (9)	0 (4)	0 (9)	0 (4)	0 (9)	
	2% NTE	N/A	0 (6)	0 (8)	0 (14)[e]	0 (4)	0 (9)	0 (4)	0 (9)	0 (4)	0 (9)	0 (4)	0 (9)	
Waikoko Stream	Geometric mean	no data	no data		no data	no data		no data		no data		no data		
	SSM		N/A		N/A	N/A		N/A		N/A		N/A		
	10% NTE	N/A	no data		no data	no data		no data		no data		no data		
	2% NTE	N/A	no data		no data	no data		no data		no data		no data		

[a]The *enterococcus* geometric mean is based on a 30-day running average, while the geometric mean for the other parameters is based on the entire dataset (i.e. a single geometric mean was calculated). The number of measurements is equal to the number of geometric means calculated.

[b]Abbreviations: Entero = *enterococcus*; NH_4 = Ammonia; NO_x = nitrite plus nitrate; TN = total nitrogen; TP = total phosphorous; TSS = total suspended solids; N/A = not applicable

[c]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.

[d]There is no estuary WQC for TSS. For comparative purposes, the estuary TSS analyses are based on the dry stream.

[e]There is no stream WQC for ammonia. For comparative purposes, the stream ammonia analyses are based on the estuary WQC.

4.3.2. Trends and Relationships

Several different analyses were conducted to obtain a better understanding of the conditions contributing to water quality problems. These include spatial analyses, stream flow and water quality comparisons, and correlative analyses between parameters.

4.3.2.1. Spatial Trends

To evaluate spatial trends on the Hanalei River, data for each pollutant were graphed at all in-stream monitoring stations (see Figure 6.6) from upstream to downstream. These graphs are presented in Figure 88 through Figure 14. Freshwater stations are shown in blue and the estuary stations are shown in yellow. Essentially, just downstream of the Upper ISCO station, the system changes from non-tidal (freshwater) to tidal (estuary). The bars in these figures illustrate the geometric mean values, while the error bars represent the minimum and maximum observed values.

These graphs presented in Figure 88 through Figure 14only suggest a general trend in the data collected through the Hanalei River and its estuary and this trend is less pronounced in the *enterococcus* and sediment measurements. In general, the estuary stations have higher geometric mean values than the freshwater stations; however, the ranges illustrate that high (or low) observations can occur throughout the system. In most cases, only a few samples were available for each station; therefore, the results at these stations carry much less weight than the stations with larger sample sizes. When only evaluating the stations with more than 20 samples, the upstream to downstream increase in geometric mean concentrations is gradual for all pollutants other than ammonia, which has a much larger increase upstream to downstream. In addition, it is difficult to directly compare these results without having a better understanding of the temporal distribution of data with respect to storm events. Despite these limitations, it is useful to have a general understanding of the spatial distribution of water quality results in the Hanalei River watershed and because the pollution sources are similar in the Waioli, Waipa, and Waikoko Stream watersheds, similar patterns can be expected in those watersheds. Spatial trends for each pollutant are described below.

For *enterococcus*, the results are presented on a logarithmic scale (Figure 8). Overall, the freshwater geometric mean observations are slightly lower than the estuarine values; however, the geometric mean concentrations at all stations were generally within an order of magnitude. The geometric mean at the Upper ISCO freshwater station is about an order of magnitude higher than the other freshwater stations. Data for the Upper ISCO station were generally high across all parameters. This may be due to the sample timing (these samples were collected immediately after a storm; therefore, it is expected that the results would have higher concentrations) or it may be caused by specific conditions in the watershed on those sample dates or sampling error. Closer evaluation of the data at the USGS station indicates that the high maximum value is associated with a sample event in December 2003 with an extremely high *enterococcus* reading (24,196 cfu/100 milliliters [mL]). Even with this high value, the geometric mean is similar to the geometric means at the other freshwater stations. The Lower ISCO estuary station was

sampled during the same events and follow similar pattern as the Upper ISCO station. While many of the samples at the other stations were collected during the wet season, they were not necessary corresponding to a storm event (depending on parameter, between 10 and 30 percent of samples were collected on high-flow days; Table 8).

The TSS results (Figure 99) follow a similar pattern to the *enterococcus* results. Specifically, the geometric mean freshwater values are lower than those collected in the estuarine portion of the Hanalei River, with the obvious exception of the Upper ISCO station, which, as described above, was sampled during or immediately after a storm event. The turbidity results (Figure 10) are also impacted by the high value at the Upper ISCO station. Except for the Upper ISCO station, the geometric mean values are below 20 NTU for turbidity; however, the maximum values are generally high among all stations. If this station, which only has two samples associated with it, is removed from the analyses, the geometric means at the other stations clearly show that the estuary has higher values than the freshwater segment.

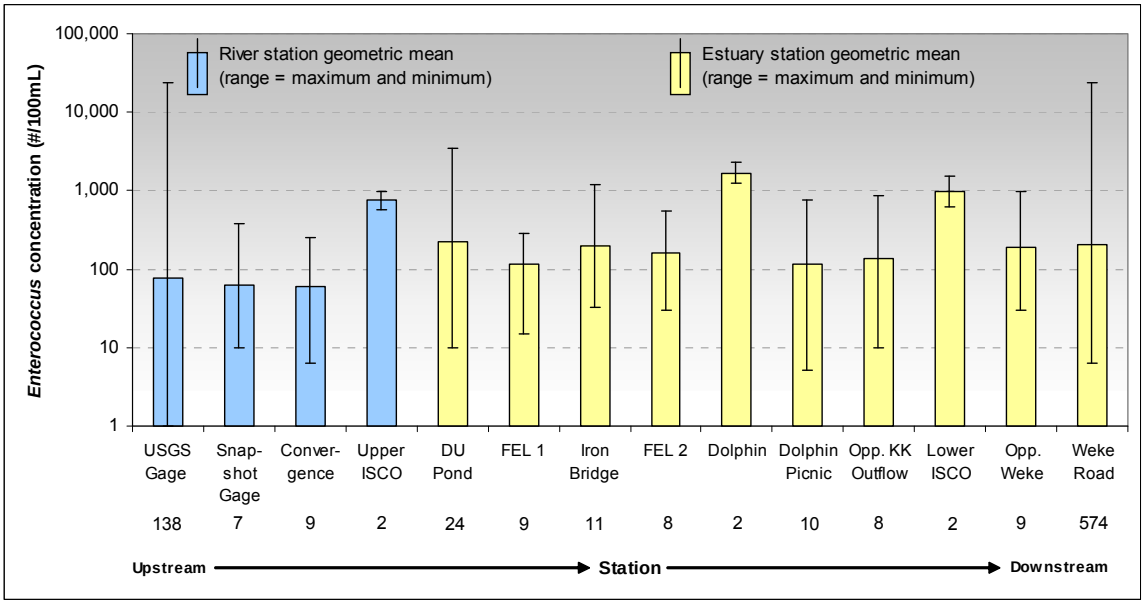


Figure 8. Upstream to downstream *enterococcus* concentrations on the Hanalei River

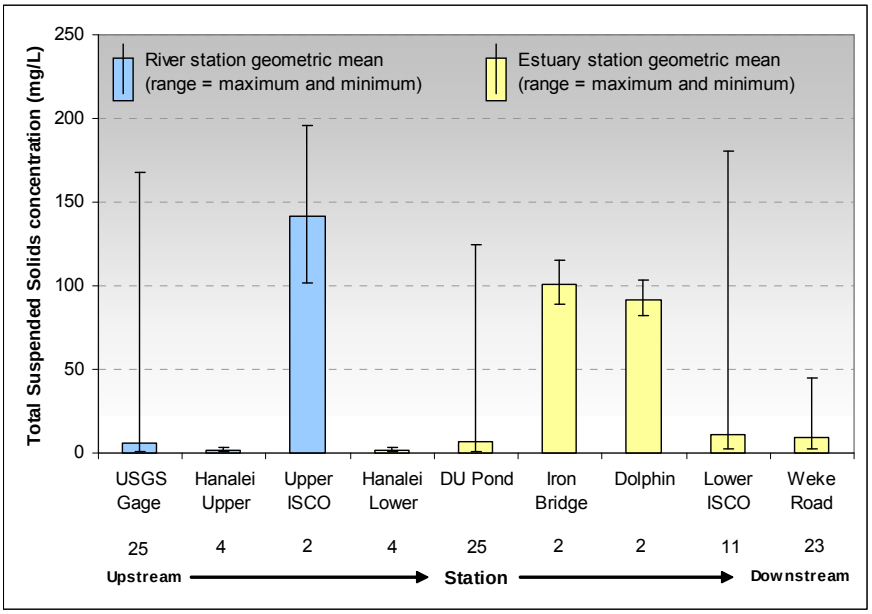


Figure 9. Upstream to downstream total suspended solids concentrations on the Hanalei River

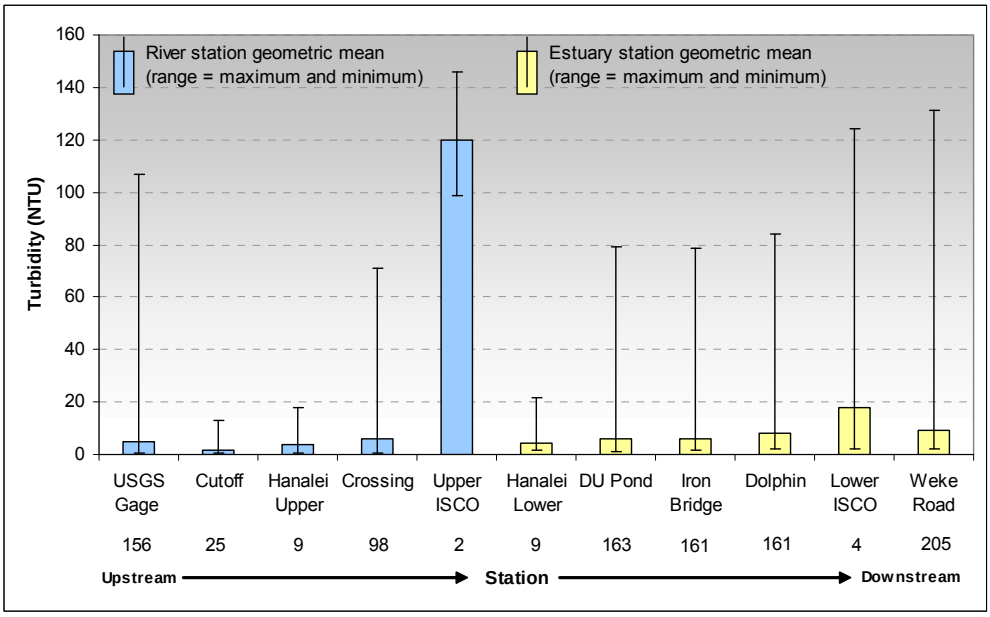


Figure 10. Upstream to downstream turbidity on the Hanalei River

The nutrient results follow the same general relationship described above; however, the upstream to downstream patterns are more pronounced. Figure 11 through Figure 14 illustrate the number, geometric mean, minimum, and maximum values for ammonia, nitrite plus nitrate, total nitrogen, and total phosphorous, respectively. Elevated concentrations at the Upper ISCO station are more prominent in the total nitrogen and total phosphorous graphs, when compared to ammonia and nitrite plus nitrate.

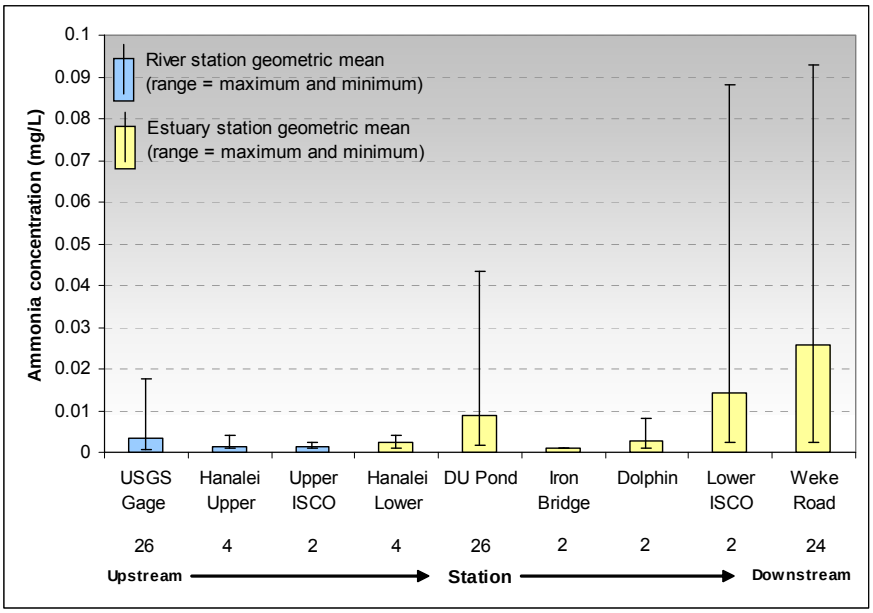


Figure 11. Upstream to downstream ammonia concentrations on the Hanalei River

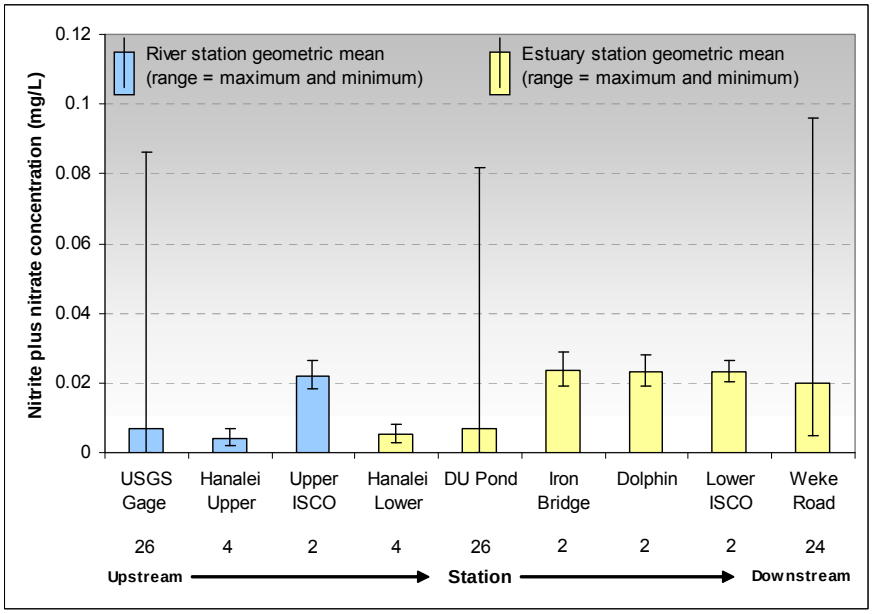


Figure 12. Upstream to downstream nitrite plus nitrate concentrations on the Hanalei River

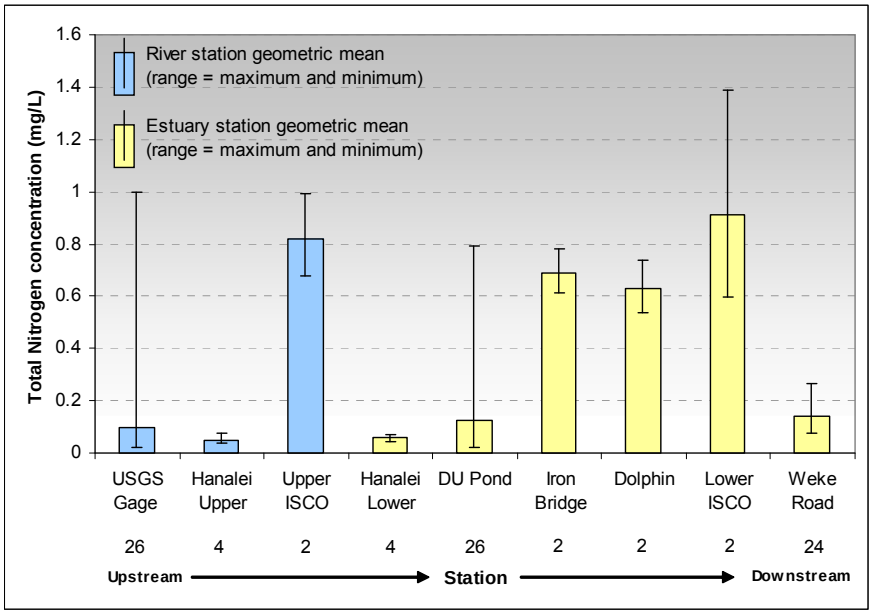


Figure 13. Upstream to downstream total nitrogen concentrations on the Hanalei River

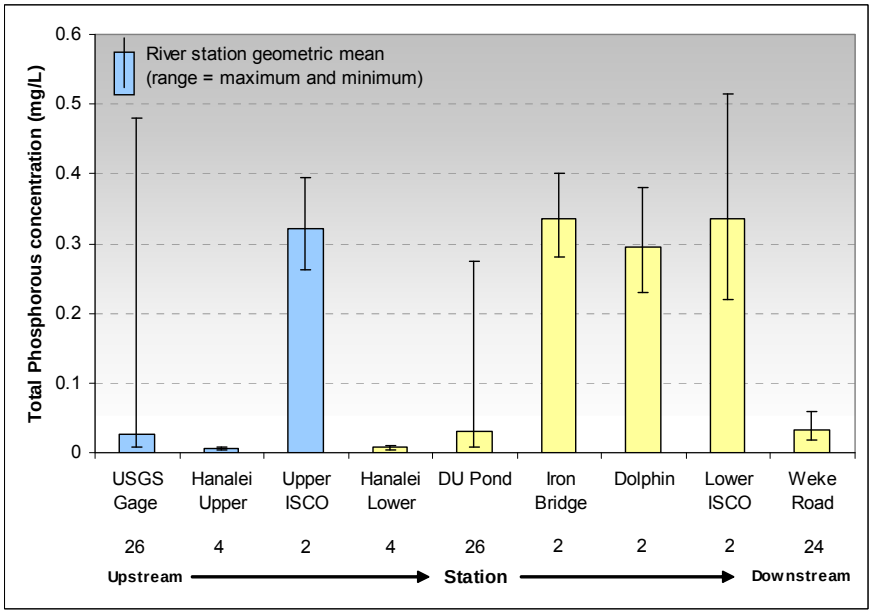


Figure 14. Upstream to downstream total phosphorous concentrations on the Hanalei River

Available *enterococcus* and turbidity data collected in the ditches and drainage culverts, which collect runoff throughout the agricultural areas and act as tributary inflows, were also evaluated. For these analyses, data for all stations in the Hanalei River Estuary were combined and summary statistics were calculated and are presented in Table 12. When the drainage culvert data are considered collectively, the geometric mean *enterococcus* value of 192 cfu/100 mL is higher than the geometric mean of eight of the 14 stations illustrated in Figure 88 (geometric means for the 14 stations range from 60.3 to 965.9

cfu/100 mL). However, the drainage culvert and in-stream geometric mean values are all within the same order of magnitude. The maximum *enterococcus* value in the drainage culverts was higher than 12 of the 14 stations shown in Figure 88. For turbidity, the geometric mean value in the drainage culverts is greater than six of the 11 stations identified in Figure 10 and its maximum is greater than seven out of the 11 stations. These data suggest that the drainage culverts are likely contributing to the high *enterococcus* and turbidity levels in the Hanalei River Estuary, especially under specific conditions that may be causing higher values; however, when combined into a single dataset the drainage culvert values are not significantly higher than those observed in-stream (i.e. the *enterococcus* concentrations are within the same order of magnitude). Unfortunately, nutrients data in the drainage culverts were not available to assess ammonia, nitrite plus nitrate, total nitrogen, and total phosphorous concentrations.

Table 12. Summary Statistics for Drainage Culvert Monitoring Stations

Parameter	Sampling Period	Number of Samples	Summary Statistics			
			Minimum	Maximum	Geometric Mean	Median
Enterococcus (cfu/100mL)	11/14/00-5/18/06	211	7	11,199	192	161
Turbidity (NTU)	4/12/03-5/18/06	840	0.48	90.60	6.15	6.29

4.3.2.2. Streamflow Correlations

To further understand the impact of stream flow on water quality in the Hanalei River, a statistical comparison of flow versus each pollutant was performed. Specifically, flow data for the USGS Hanalei River gage (station 1610300) were compared with water quality data at the same location. Because this is the only station with flow measurements that overlap with the water quality data, these flow results were also compared with water quality data at the Weke Road station near the mouth of the estuary. Although these flow measurements are not directly comparable, they provide a reasonable relative comparison, especially during storm events.

Figures A-63 through A-70 of Appendix A show the flow and water quality comparisons at the USGS gage, while Figures A-71 through A-77 of Appendix A illustrate the results using the Weke Road water quality data. Each figure presents the results of two analyses: flow-associated trend assessment and seasonal trend assessment. The flow-associated analyses illustrate the flow-weighted concentrations for all samples within a flow percentile and can be used to identify trends in pollutant levels associated with different flow regimes. The seasonal analyses show flow-weighted concentrations for all samples collected in the same month of the year, which helps to identify monthly or seasonal differences that may be caused by seasonal land management activities or environmental conditions.

In general, high *enterococcus* levels were observed at the highest flows, but there was no clear seasonal pattern as high concentrations can occur in any month. The sediment-related data (turbidity, TSS, and suspended sediment concentration [SSC]), followed

similar patterns. Specifically, there were higher values observed during high flow conditions and no seasonal pattern, except that the values during the wet season were generally slightly higher than the other months for TSS (this seasonal pattern only persists for January through March for SSC; however, it should be noted that the SSC data collected after September 2005 was considered provisional at the time of analysis). Ammonia and nitrite plus nitrate did not follow any obvious flow-associated or seasonal patterns, with the exception of consistently high nitrite plus nitrate values in December. The total nitrogen and total phosphorous analyses at the USGS station indicated that higher concentrations were observed under higher flow conditions and there was no clear seasonal pattern except for elevated concentrations in March.

Data for the same parameters at Weke Road showed much wider variability. In general, the total nitrogen results increased along with flow and concentrations were generally higher during the wet season when compared to the dry months. Total phosphorous at Weke Road followed the same seasonal pattern; however, there was no discernable flow-associated trend. These analyses indicate that high concentrations are observed year round, suggesting that critical conditions can occur during any month. Therefore, it is important to consider each WQC throughout the course of the year. It should be noted that there were high water quality concentrations during December 2003 for several pollutants collected at both stations that are weighting the analyses towards the high flow-high concentration pattern. It is assumed that these samples were collected during or after a storm event, thereby resulting in high concentrations (and loads), because they are similar in magnitude to the post-storm samples collected at the ISCO stations (described in Section 4.3.2.1).

4.3.2.3. Correlative Analyses

To evaluate the relationships between water quality parameters, correlative analyses were performed. These analyses indicate that TSS and turbidity are strongly correlated in the Hanalei Bay watershed, with an R^2 value of 0.7175 (Figure 15) based on 183 samples (collected by HIDOH and the Hui); thus justifying the use of TSS as a surrogate for turbidity in the calculation of TMDLs and load targets. This strong relationship is particularly evident at lower observed values (which are generally associated with lower flows) and become less predictable at higher values (which are generally associated with higher flows [see Figure A-49 and A-50 of Appendix A for turbidity and TSS flow comparisons, respectively, at the USGS gage]). An independent analysis performed by the Hui on their TSS and turbidity data collected from November 2003 through April 2004 verifies this correlation (Berg et al., 2004).

The TSS and turbidity data used for this correlation, which came from all four watersheds, two waterbody types (stream and estuary), and two seasons (wet and dry), were evaluated several different ways according to these characteristics. Although the 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. However, careful reevaluation of the numeric targets for turbidity endpoints, including more robust multivariate analysis of turbidity and TSS correlations, will be

conducted during the next phase of TMDL development, with subsequent changes to the loading analysis as necessary in future revisions of the TMDL decision.

Upon evaluation of the available data collected on concurrent days, it was determined that *enterococcus* was not linearly related to TSS (R^2 = 0.039). However, observed data indicate that total phosphorous and total nitrogen concentrations have a strong relationship with sediment concentrations (R^2 = 0.8345 and 0.7293, respectively); however, ammonia and nitrite plus nitrate did not have a strong correlation (R^2 = 0.0001 and 0.0033, respectively; Figure 16). Because ammonia and nitrite plus nitrate did not exhibit a relationship to sediment, it was assumed that organic nitrogen was causing the strong correlation.

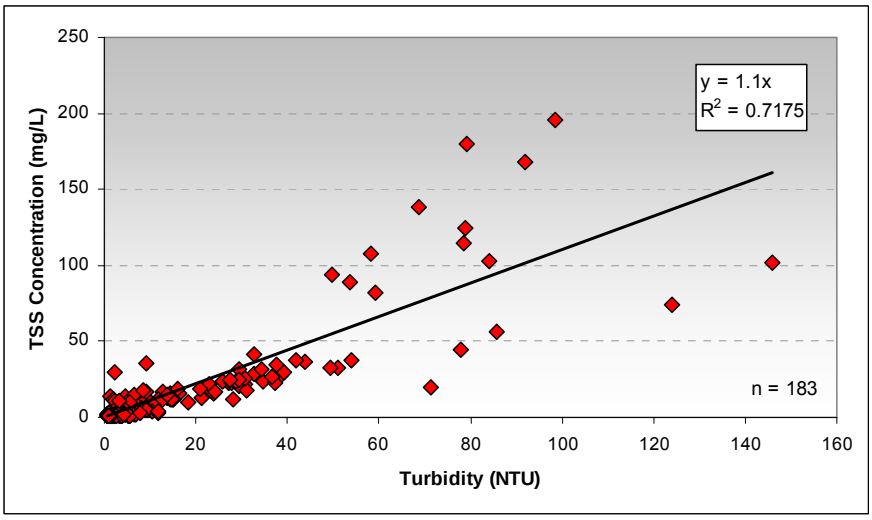


Figure 15. Turbidity and TSS relationship in the Hanalei Bay watershed

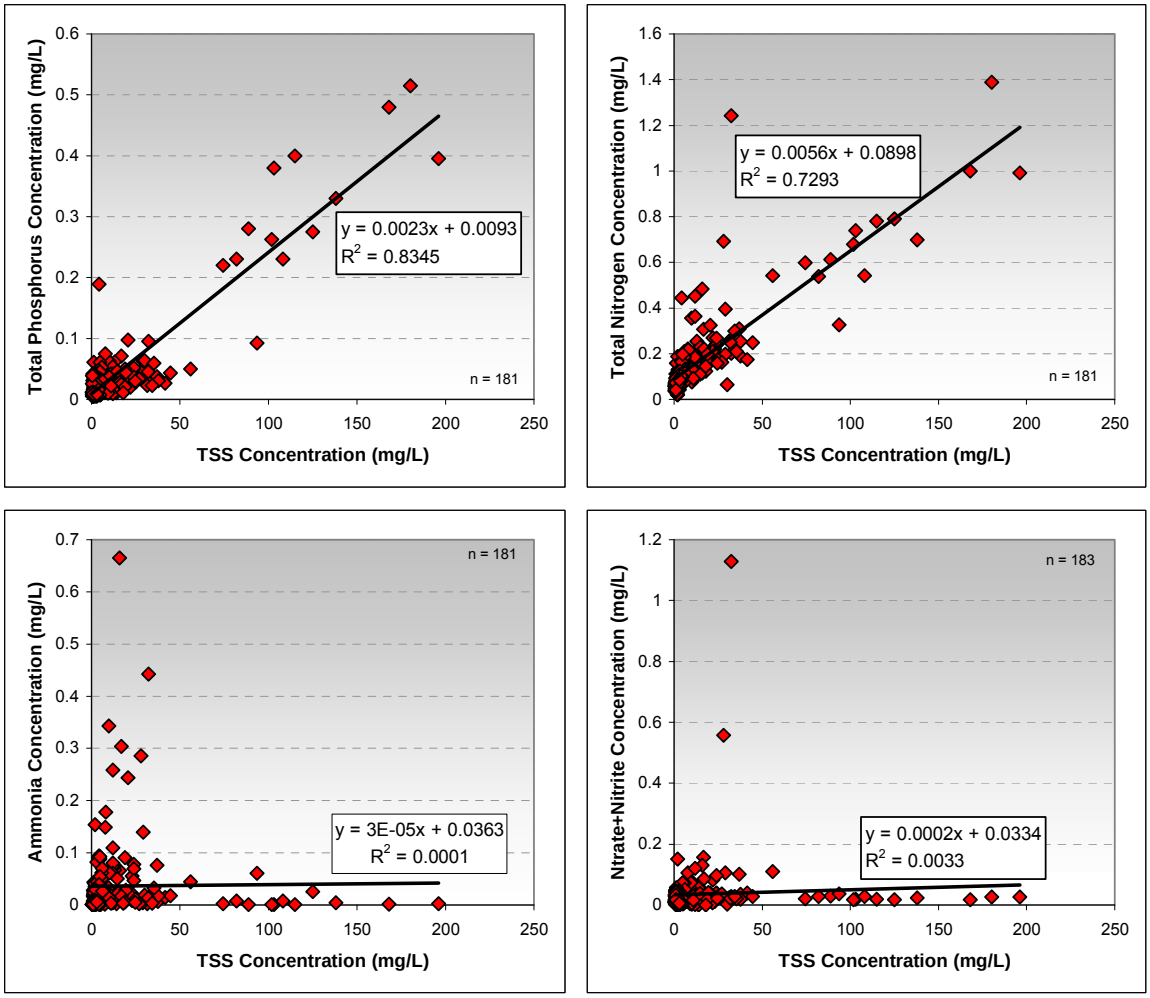


Figure 16. Relationships between sediment and nutrients

5. Source Analysis

The purpose of the source analysis is to identify and quantify the sources of pollutants to the impaired waterbodies. In-stream and watershed data were used to identify potential sources and characterize the relationship between point and nonpoint source loadings and in-stream response, under both wet and dry seasons. Point sources typically discharge at a specific location from pipes, outfalls, and conveyance channels from, for example, municipal 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 Hawai'i, groundwater occurs as either basal or high-level groundwater. Basal groundwater is groundwater floating on and displacing seawater, while high-level groundwater is impounded within compartments formed by impermeable dikes or on low-permeable layers. The basal groundwater in Hanalei likely discharges to marshy areas and in-stream channels along the inland edge of the coastal plain without causing large visible springs (MacDonald et al., 1960). Much of the high-level groundwater in the Hanalei region is diffused in small springs and seeps in valley walls or stream channels with some sources (MacDonald et al., 1960). However, a recent study suggests that under certain conditions, groundwater may contribute up to 20 percent of the flow to Hanalei Bay (Knee et al., 2005, 2006).

During both wet weather and dry weather periods, multiple sources of bacteria, sediment, and nutrients associated with both natural and anthropogenic activities contribute to overall loads to the impaired waterbodies. Bacteria are deposited directly to the waterways and also onto land surfaces. 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 NWR have increased over the past thirty years (Asquith and Melgar, 1999) and introduced mammals such as feral cats, dogs, and rats on the Hanalei NWR are considered problem species (Berg et al., 1997). These wildlife populations are also potential sources contributing to elevated bacteria concentrations in the watershed. Further downstream from the Hanalei NWR, there are pastures with bison ranching (Berg et al., 1997) along with the town of Hanalei, which has no centralized waste treatment. Waste disposal is through onsite septic & cesspool systems except for small treatment plants that serve the commercial centers (Fujimoto, 1977; Griffin, 2000). All of these sources have the potential to contribute to the elevated *enterococcus* concentrations measured throughout the watershed. In addition, a groundwater study conducted in 2005 found that bacteria concentrations were lower in groundwater than in the Hanalei River, Hanalei Bay, and other streams; however, relatively high levels of *Escherichia coli* was 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).

Sediment concentrations are also associated with both natural and anthropogenic activities. Although there are occasionally high erosion rates due to high precipitation and steep slopes in the headwaters, sediment loads from the headwaters are also associated with alteration of the forest landscape due to human inhabitants, introduction of feral livestock (pigs and goats), and alien tree and plant species (Griffin, 2000). Based on the evaluation of turbidity and suspended sediment data, sediment yields increase in

the more downstream portions of the watershed (Berg et al., 1997). Specifically, sediment yields double through the Hanalei NWR and turbidity values increase as well (Berg et al., 1997). While sediment plumes have been observed in return flows to the Hanalei River, the total sediment load may be minor compared to the sediment generated during natural flood events (the Hanalei River load was estimated at 30-80 times the load from ditches and impoundments) (Berg et al., 1997).

Nutrients are also associated with a variety of land-based activities. The presence of wildlife in wetlands, grasslands, and forested areas, fertilization of agricultural areas, and various activities in urban areas are all potential sources of nutrients (Berg, 1995; Berg et al., 1997; USEPA, 2005; Schueler and Holland, 2000). Nutrients in the agricultural areas of the Hanalei River watershed have been previously studied by Berg (Berg et al., 1997; Berg, 1995). These studies concluded that due to fertilization of taro ponds, or lo'i, nitrogen loads in return waters were 4-40 times higher when compared to inflow waters on the Hanalei NWR (Berg et al., 1997). Other potential sources of nutrients, such as wildlife and urban activities (poor sewage treatment, residential fertilization, pet waste, etc.), are not quantified in the Hanalei Bay watershed; however, they are well documented sources of nutrients (USEPA, 2005; Schueler and Holland, 2000). Groundwater, which is influenced by several sources such as cesspools, agricultural areas, soil, and urban runoff, is also a potential source of nutrients to the Hanalei Bay watershed. Specifically, nutrient concentrations were found to be higher in groundwater than in the Hanalei River or other streams (Knee et al., 2005, 2006). Increased nutrients concentrations from upstream to downstream (i.e. freshwater to saltwater) are also confirmed by the data collected in the Hanalei River watershed, as presented in Section 4.3.2.1.

5.1. Point Sources

There are no NPDES dischargers that are major point sources of pollutants in the Hanalei Bay watershed. Therefore, no point sources are discussed in this Source Analyses and there no waste load allocations (WLA) are included in the TMDL.

5.2. Nonpoint Sources

In this analysis, pollutant sources were quantified by land cover type since loadings can be highly correlated with land-based activities (Figure 1717). For *enterococcus*, ammonia, and nitrite plus nitrate, wash-off of these pollutants from various land covers during wet weather events is considered the primary mechanism for transport. After they build up on the land surface as the result of various land sources and associated management practices, many of the pollutants are washed off the surface during rainfall events. The amount of runoff and associated pollutant concentrations are therefore highly dependent on land-based activities. This methodology of correlating land cover to *enterococcus*, ammonia, and nitrite plus nitrate sources produced successful modeling results. The methodology used for quantification of pollutant concentrations from various land cover types is discussed in the Modeling Report, Appendix B.

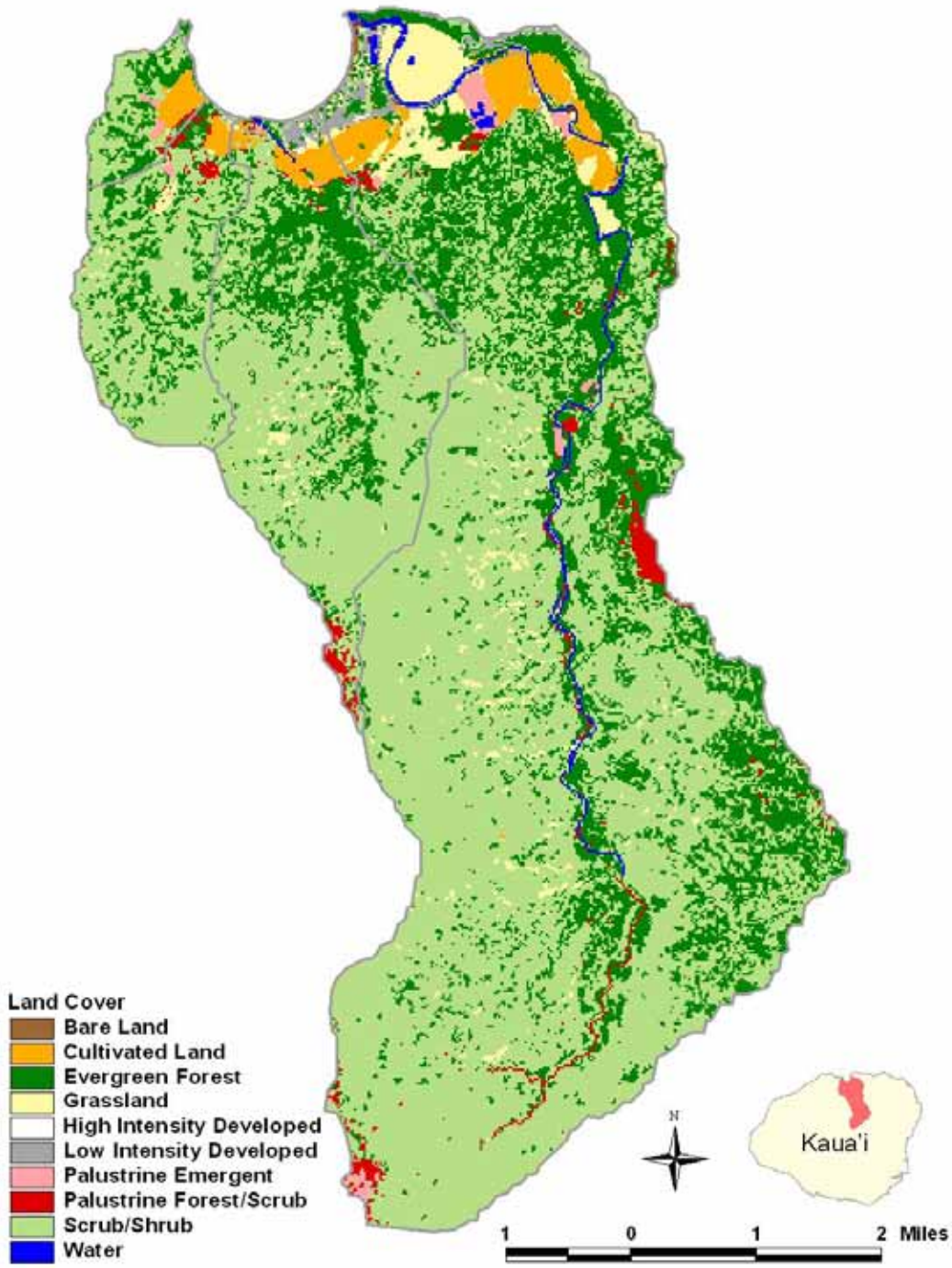


Figure 17. Land cover

Because the observed data indicated that total phosphorous and total nitrogen concentrations were strongly correlated to sediment concentrations (Figure 1616), these nutrients were represented through their association with sediment. Sediment production is highly dependent on land-based activities, while its wash-off depends on rainfall

intensity and the amount of sediment available for removal. The ratio between total nitrogen and total phosphorous concentrations and total suspended sediment varies by land cover. This methodology is further described in Appendix B.

A series of charts were developed that show relative pollutant loads by land cover type for the Hanalei River, Waioli, Waipa, and Waikoko watersheds based on model results of existing conditions, which were calibrated to observed data (Appendix C). These results are summarized for the entire Hanalei Bay watershed in Table 13. In general, the scrub/shrub and evergreen forest land covers contribute 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 (Figure 3). Existing bird impoundments overlapped with the palustrine emergent land cover and taro pondfields are generally located in the cultivated lands. While some land covers may contribute relatively high concentrations of certain pollutants, their impact on the overall loading (which is represented for the entire Hanalei Bay watershed in Table 13 and individually for the Hanalei River, Waioli, Waipa, and Waikoko watersheds in Appendix C) may be fairly minor due to their small land area and resulting runoff volume.

Table 13. Relative Loadings by Land Cover for the Hanalei Bay Watershed

Land cover category	Percent of total land area	Percent of total load					
		Enterococcus	TSS	Ammonia	Nitrite plus nitrate	Total nitrogen	Total phosphorous
Bare Land	0.1%	0.01%	0.1%	0.02%	0.04%	0.04%	0.05%
Cultivated Land	2.6%	2%	2%	64%	20%	6%	8%
Evergreen Forest	25.2%	27%	16%	6%	14%	17%	17%
Grassland	3.5%	0.4%	2%	1%	2%	1%	2%
High Intensity Developed	0.02%	0.1%	0.1%	0.01%	0.1%	0.003%	0.003%
Low Intensity Developed	0.8%	0.4%	1%	0.2%	1%	0.2%	0.2%
Palustrine Emergent	0.6%	7%	2%	4%	7%	3%	2%
Palustrine Forest/Scrub	1.7%	0.3%	2%	1%	1%	2%	2%
Scrub/Shrub	64.5%	63%	75%	24%	55%	70%	69%
Water	0.9%	0%	0.2%	0.1%	0.3%	0.3%	0.4%

The relative loadings presented in Table 13 are based on an accounting of overall gross loads from the calibrated model. As indicated by the second column in the above table, the land covers with the greatest relative land area generally contribute the highest relative loading. While many of the land covers with the highest area are often considered “background,” anthropogenic sources also impact water quality in the system, as described below.

To further characterize pollutant sources in the watershed, *enterococcus* data collected on the same date at the USGS gage and Weke Road monitoring stations were reviewed. These stations were selected because they had a significant number of samples collected on the same date and their locations represent different sources in the watershed. The USGS gage is located upstream of nearly all anthropogenic activities, while the Weke

Road station is downstream of these activities and, therefore, represents the contributions of both the anthropogenic and natural sources in the Hanalei River watershed. To evaluate the upstream and downstream sources, the difference between the log of the *enterococcus* concentrations at Weke Road and the USGS gage were calculated (samples were collected on the same date). These results are presented for stormflow samples in Figure 18 and baseflow samples in Figure 19. Days were classified as baseflow or stormflow by obtaining average daily flow values at the USGS gage for January 1995 through May 2006. The days corresponding to the highest ten percent of flows were assigned to the stormflow category and all other days were assigned to the baseflow category.

The blue bars in both graphs represent dates on which the Weke Road *enterococcus* concentration was higher than the concentration at the USGS gage, while the orange bars represent higher concentrations at the USGS gage. These data indicate that there is clearly a difference between the concentrations at these two locations. Approximately 75 percent of all samples were higher at Weke Road than the USGS gage (represented by the blue bars in both graphs). Specifically, on storm days 15 of the 20 storm samples (75.0 percent) and during baseflow 78 of the 103 samples (75.7 percent) were higher at Weke Road. Similar analyses were performed by separating the data into wet (November through April) and dry (May through October) seasons. These results were consistent with the stormflow and baseflow analyses. Specifically, during the wet season, 53 of the 63 samples (84 percent) were higher at Weke Road than the USGS gage and during the dry season 40 of the 60 samples (67 percent) were higher at Weke Road. The anthropogenic sources draining to the Weke Road station are likely causing the higher concentrations observed at this station and these contributions are particularly influential during the wet season.

Figure 18. Difference between stormflow enterococcus values at Weke Road and USGS Gage

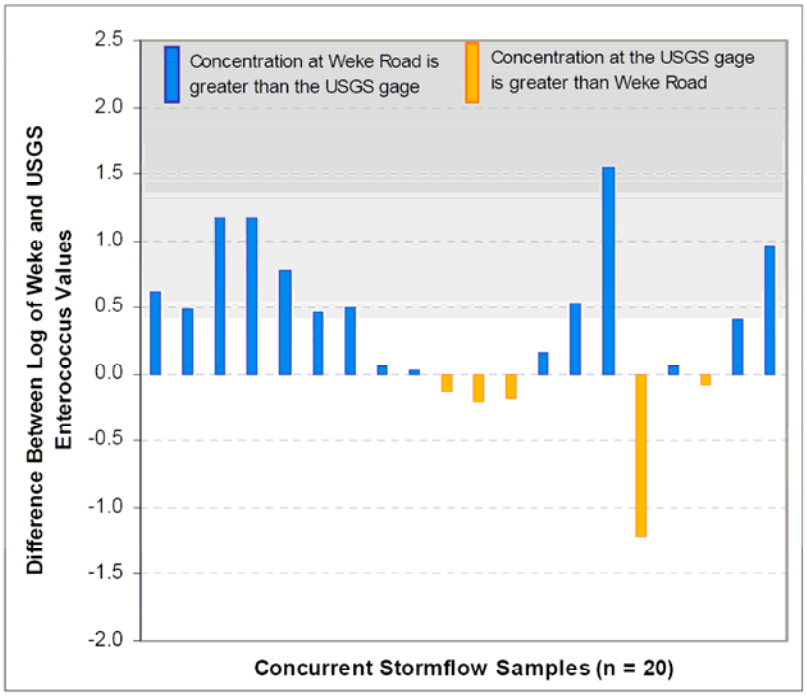
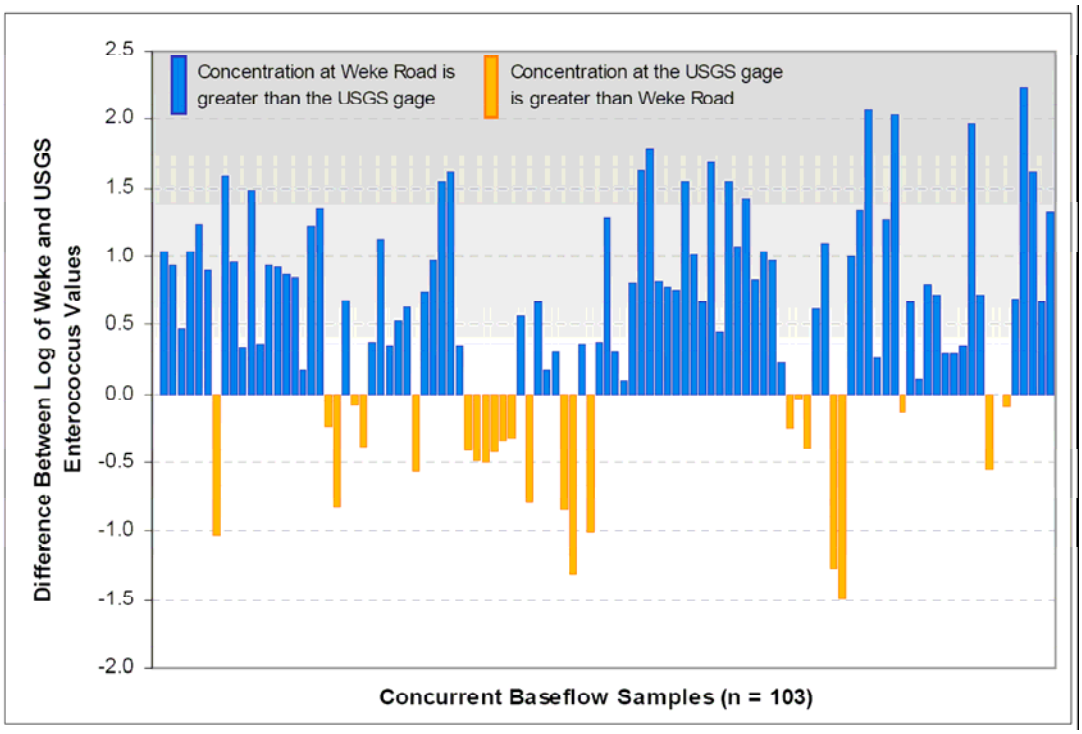


Figure 19. Difference between baseflow enterococcus values at Weke Road and USGS Gage



6. Linkage Analysis

The technical analysis of pollutant loading from watersheds and the receiving waterbody response to this loading is referred to as the linkage analysis. The purpose of the analysis is to quantify the maximum allowable loading for each pollutant to the impaired waterbody resulting in attainment of WQC. This value is in fact, the TMDL. TMDLs (or similarly calculated load targets) were calculated for each waterbody-pollutant combination described in Section 2 using model output. Because the numeric targets are set equal to the numeric WQC for *enterococcus*, turbidity, and nutrients, attainment of these numeric targets will result in attainment of WQC. The percent reduction from the total existing load needed in order to attain WQC was also calculated for each waterbody.

To support the TMDL objectives outlined by HIDOH and USEPA and using available data, the development of a comprehensive linked watershed/receiving water modeling system was necessary to represent the Hanalei Bay watershed system. A watershed model is essentially a series of algorithms applied to watershed characteristics and meteorological data to simulate 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 are composed of a series of algorithms applied to characteristics data to simulate flow and water quality of the waterbody. The characteristics data represent physical and chemical aspects of a lake, river, or estuary. 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 occurring in the water column.

The remainder of this section describes the model selection criteria, the selected models, and general model application. The models were used to calculate both existing conditions and the TMDLs (or Informative TMDLs or Load Targets).

6.1. Model Selection Criteria

In selecting an appropriate modeling approach for TMDL calculation, technical, regulatory, and user criteria were considered. Technical criteria include the physical system in question, including watershed or receiving water characteristics and processes and the constituent(s) of interest. Regulatory criteria include WQC or procedural protocol. User criteria comprise the operational or economical constraints imposed by the end-user and include factors such as hardware/software compatibility and financial resources. The following discussion details the considerations in each of these categories. Based on these considerations, appropriate models were chosen to simulate watershed and receiving water conditions.

6.1.1. Technical Criteria

The watershed and surface waters of the Hanalei Bay watershed system present a challenging system for modeling hydrology and water quality. This section outlines key functions and processes that are necessary for consideration in the selection of an appropriate modeling strategy. These technical criteria are divided into three main topics: physical domain, source contributions, and constituents. Consideration of each topic was critical in selecting the most appropriate modeling system to address the types of sources and the numeric targets associated with the impaired waters.

6.1.1.1. Physical Domain

Representation of the physical domain is perhaps the most important consideration in model selection. The physical domain is the focus of the modeling effort – typically described by either the receiving water itself or a combination of the contributing watershed and the receiving water. Selection of the appropriate modeling domain depends on the constituents of interest and the conditions under which the receiving water exhibits impairment. For a receiving water dominated by point source inputs that exhibits impairments under only low-flow conditions, a steady-state approach is typically used. This type of modeling approach focuses on only in-stream (receiving water) processes during a user-specified condition. For receiving waters affected additionally or solely by rainfall-driven flow and pollutant contributions, a dynamic approach is recommended.

Dynamic models consider time-variable nonpoint source contributions from a watershed surface or subsurface, or throughout the water column of a receiving water body. Some models consider monthly or seasonal variability, while others enable assessment of conditions immediately before, during, and after individual rainfall events. Dynamic models require a substantial amount of information regarding input parameters and data for calibration purposes. The Hanalei River watershed is dominated by rainfall-driven flow and pollutant contributions that deposit directly to tributaries and their receiving waters.

6.1.1.2. Source Contributions

Primary sources of pollution to a waterbody must be considered in the model selection process. Accurately representing contributions from permitted point sources and nonpoint source contributions from urban, agricultural, and natural areas is critical in properly representing the system and ultimately evaluating potential load reduction scenarios.

Water quality monitoring data were not sufficient to fully characterize all sources of bacteria, sediment, and nutrients in the watersheds draining to impaired waterbodies. However, analyses of the available data indicate that the main sources are open areas, runoff from agriculture, and bird impoundments. Watershed sources can be addressed

through the model calibration and validation process and major source categories considered controllable for TMDL implementation purposes can be simulated based on varying assumptions for management scenarios.

6.1.1.3. Constituents

Another important consideration in model selection and application is the constituent(s) to be assessed. Choice of state variables is a critical part of model application. The more state variables included, the more difficult the model is to apply and calibrate. However, if key state variables are omitted from the simulation, the model might not simulate all necessary aspects of the system and might produce unrealistic results. A delicate balance must be met between minimal constituent simulation and maximum applicability.

The focus of development of this study is on *enterococcus*, turbidity, and nutrients (specifically, total nitrogen, total phosphorous, ammonia, and nitrite plus nitrate). Factors affecting the survival of *enterococcus* bacteria include soil moisture content, pH, solar radiation, and available nutrients. In-stream bacteria dynamics can be extremely complex, and accurate estimation of bacteria concentrations relies on a host of interrelated environmental factors. Bacteria concentrations in the water column are influenced by die-off, regrowth, partitioning of bacteria between water and sediment during transport, settling, and resuspension of bottom materials. First-order die-off is likely the most important dynamic process to simulate as it represents all unknown bacteria losses, despite observations that bacteria regrow in certain conditions (Byappanahalli and Fujioka, 1998).

Turbidity cannot be directly simulated using most watershed and receiving water models. A turbidity load cannot be calculated because its measurements are not mass-based. To overcome this limitation, a mass-based surrogate must be used during model development. Because turbidity and TSS had a strong relationship, as described in Section 4.3.2.3, TSS was considered a suitable surrogate for model application.

Nutrient cycling is extremely complex and accurate estimation of nutrient loading relies on a host of interrelated factors. The transport of nutrients from point of origin into stream channels, from streams into their estuaries, and ultimately within the estuaries, is also influenced by multiple factors. The relative impact of external nutrient loading to the estuaries and internal loading must be represented by the modeling system.

6.1.2. Regulatory Criteria

A properly designed and applied model provides the source-response linkage component of the TMDL and enables accurate assessment of assimilative capacities and allocation distribution. A waterbody's assimilative capacity is determined by assuming adherence to WQC. The HAR establishes, for all waters in the State, the beneficial uses for each waterbody to be protected, the WQC that protect those uses, and the water quality certification process in place to ensure standards are met. The modeling platform must enable direct comparison of model results to in-stream concentrations and allow for the

analysis of the duration of those concentrations. For the watershed and receiving water loading analyses and for future implementation activities, it is also important that the modeling platform enables examination of gross land cover loading as well as in-stream concentration.

6.1.3. User Criteria

User criteria are determined by the needs, expectations, and resources of HIDOH and USEPA. Modeling software must be compatible with existing personal-computer-based hardware platforms, and due to future use for planning and permitting decisions, should be well-documented, tested, and accepted. From a resource perspective, the level of effort required to develop, calibrate, and apply the model must be commensurate with available funding, without compromising the ability to meet technical criteria. In addition to these primary criteria, the required time-frame for model development, application, and completion is important.

6.2. Model Selection and Overview

Establishing the relationship between the in-stream 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 in-stream responses for TMDL development in the Hanalei Bay watershed.

Modeling the Hanalei Bay watershed presents a challenge using currently available modeling tools. The system involves various unique hydraulic features including: steep upland watersheds with adjacent lowland floodplains, sediment and nutrient settling in the estuaries, internal and external loading of nutrients and *enterococcus*, and agricultural diversions and return flows in the Hanalei River Estuary. In addition, to assist in TMDL and load target development and to provide decision support for watershed management, the model will 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 processes essential 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 (which was used as a boundary condition).

The models selected for the Hanalei Bay watershed TMDLs are components of USEPA's TMDL Modeling Toolbox (Toolbox), which has been developed through a joint effort between USEPA and Tetra Tech, Inc. (USEPA, 2003b). The Toolbox is a collection of models, modeling tools, and databases that have been utilized over the past decade in the determination of TMDLs for impaired waters. Loading Simulation Program in C++ (LSPC) is the primary watershed hydrology and pollutant loading model and the Environmental Fluids Dynamic Code (EFDC) is the receiving water hydrodynamic and water quality model in the Toolbox modeling package. A detailed description of each component of the proposed modeling system follows.

6.2.1. 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 to the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream Estuaries (Shen et al., 2004; USEPA, 2003c). 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 observation data are sparse. The model can simulate *enterococcus*, sediment, and nutrient contributions from specific source areas (e.g., subwatershed or land cover areas). This is important in terms of 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).

6.2.2. Receiving Water Model: Environmental Fluid Dynamics Code

The Environmental Fluids Dynamic Code (EFDC) was used for the hydrodynamic and water quality modeling of the Hanalei River Estuary, Waioli Stream Estuary, Waipa Stream Estuary, and Waikoko Stream Estuary. The LSPC watershed model was linked to EFDC and provided all freshwater 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 watershed TMDL project. In this study, only the hydrodynamic and water quality sub-models were applied to simulate the water circulation and water quality interaction in Hanalei Bay and its estuaries.

6.3. Model Application

A complete discussion of the LSPC and EFDC models is provided in the Modeling Report, Appendix B. This document 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. The models were initially calibrated to observed hydrologic and water quality data to characterize existing conditions in the watersheds and estuaries. 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 loads associated with the numeric target attainment simulations were the TMDLs or load targets. 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 TMDL results in terms of loading capacities and required load reductions for the stream and estuary segments listed on Hawai'i's 2006 §303(d) list due to *enterococcus* and turbidity impairments (Figure 1 and
Table 3) (HIDOH, 2008). It also provides Informative TMDLs and Load Targets for the Hanalei River and Estuary, Waioli Stream and Estuary, Waipa Stream and Estuary, and Waikoko Stream and Estuary for the waterbody-pollutant combinations presented in Table 4.

7.1. Methodology

To determine load targets as well as existing loads and TMDLs for the e*nterococcus* and turbidity impaired waterbodies, two models were used: the LSPC watershed loading model and the EFDC receiving water model. The LSPC model was calibrated and validated for a five year period (May 2001 to May 2006) and the EFDC model was calibrated and validated for two overlapping years (2004 and 2005). 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 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*, TSS, and nutrients existing nonpoint source loads were estimated in the 41 modeled subbasins 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 as lateral boundary conditions for more detailed analysis of in-stream water quality associated with the estuary fate and transport during baseline (existing) conditions. Subsequently, water quality parameters were reduced in the LSPC model and a series of simulations were performed. These results were incorporated into the EFDC model until the various water quality criteria were achieved in the estuaries (Table 5; i.e. geometric mean, 10% NTE, and 2% NTE WQC for nutrient and sediment constituents and 30-day geometric mean and single sample maximum WQC for *enterococcus*). Once these water quality criteria were reached in the estuaries, the associated loadings from the watershed were output from the model and summarized. These values are the TMDLs, Informative TMDLs, and Load Targets. The percent reductions for *enterococcus* and turbidity and the other parameters were then calculated by comparing the difference between the model results of the existing loads and the TMDLs (or Informative TMDLs or Load Targets). Load allocations were then determined by subtracting the margin of safety from the TMDL (or Informative TMDL or Load Target).

Similar analyses were performed to address the stream TMDLs, Informative TMDLs, and Load Targets. Specifically, the water quality parameters associated with existing conditions were reduced in the LSPC model until the water quality criteria were met during their associated season (Table 6; i.e. wet and dry season geometric mean, 10%

NTE, and 2% NTE WQC for nutrient and sediment constituents and 30-day geometric mean and single sample maximum WQC for *enterococcus*). The loadings associated with these model runs were output from the model and summarized to calculate the TMDLs (or load targets). The existing loads from the LSPC model were compared with these values to calculate percent reductions for the TMDLs and load targets in the freshwater segments. Load allocations were then determined by subtracting the margin of safety from the TMDL (or Informative TMDL or Load Target).

Because most of the water quality criteria in the estuary are more stringent than the stream criteria, meeting the estuary criteria will generally ensure that the stream criteria are achieved (the total nitrogen geometric mean standard is the one exception; the dry season freshwater standard is 0.180 mg/L, while the estuary standard if 0.200 mg/L). If a pollutant was listed in the estuary and the stream, the lower water quality criterion was used to ensure that the waterbody meets the most stringent criteria at all times. In addition, during the TMDL simulations, compliance with the WQC was checked at several locations in the watersheds and estuaries. For the final TMDL simulations, WQC were achieved in both the estuaries and the freshwater segments draining to those estuaries, even if the freshwater segments were not listed as impaired to ensure watershed-wide compliance; therefore, the TMDLs and load targets are conservative because they attain the most stringent WQC.

Because turbidity cannot be directly simulated using the watershed and receiving water models (Section 6.1.1.3), TSS was simulated as a surrogate. Achieving TSS TMDLs and nutrient load targets will contribute to meeting the turbidity criteria. Turbidity and TSS had a strong relationship (R^2 value of 0.7175), as described in Section 4.3.2.3, particularly at lower values; therefore, this relationship was used to convert the TSS concentrations to turbidity values for comparison with the appropriate WQC. Specifically, after model simulations were performed for TSS, these results were divided by 1.1 (using the equation presented in Figure 15) to determine the associated turbidity value. These turbidity values were then compared with the WQC to determine compliance with estuary and stream standards. It was important to evaluate both standards because there is no TSS WQC for estuaries and compliance with the streams turbidity standards was necessary to ensure attainment of the downstream estuary TMDLs. The TSS concentrations associated with the model simulation that resulted in compliance of the estuary and stream 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 of pollutant that can be assimilated by the receiving waterbody while still achieving the numeric targets. 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. TMDLs can be expressed on a mass loading basis (e.g., number of bacteria per year) or as a concentration in accordance with 40 CFR 130.2(l).

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:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

TMDLs were established for each segment identified in Table 2 using the methodology described above, while similarly calculated Informative TMDLs and Load Targets were determined for each waterbody-pollutant combinations in Table 4. These calculations identify and allocate appropriate loadings to the subwatersheds that cause or contribute to the impairment. The WLA portion of this equation is the total loading assigned to point sources. 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. An implicit MOS was used for this TMDL.

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 MS4 or other individual NPDES permits for point sources have been issued 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 or background loading. This nonpoint source runoff 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 report only provides LAs associated with the *enterococcus* and turbidity TMDLs.

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 the Hanalei Bay watershed included both an explicit and implicit MOS. The explicit MOS was computed as 5 percent of the calculated TMDL value. The implicit MOS was incorporated through the use of

conservative assumptions during the TMDL development process. Specifically, the benthic nutrient fluxes for nitrogen and phosphorus were kept constant for both the existing and TMDL conditions. It is likely, however, that these fluxes will be reduced under TMDL conditions due to the reduction in source nutrient contributions.

7.3. TMDL Results and Allocations

The LSPC and EFDC models for were run for 2004 for the baseline (existing) conditions. The TMDL allocations and other allocation applications were then determined by performing a series of simulations that involved reducing the watershed loads of bacteria, sediment, and nutrients until each of the numeric targets described in Section 3 were achieved (i.e. geometric mean, 10% NTE, and 2% NTE WQC for nutrient and sediment constituents [while considering different wet and dry season WQC in streams] and 30-day geometric mean and single sample maximum WQC for *enterococcus*). Associated loads were then determined for each of these targets. While only the stream standards vary by storm season, estuary TMDL results are based on achieving the year-round estuary standards. The annual load results are presented seasonally to maintain consistency with the stream TMDLs and for implementation purposes. In the 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). Additional scenarios can also be performed that can vary the relative land cover contributions for each parameter and would be further enhanced with additional modeling that better identified and quantified sources.

The baseline and allocation TSS and *enterococcus* loads associated with each WQC for the §303(d) listed impaired waterbodies (
Table 3 and Figure 1) during the wet season and dry season are presented in Table 14 and Table 15, 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 and percent). Model results indicate that for TSS the load reductions from baseline range from 77.0 to 97.8 percent to achieve the geometric mean WQC, 64.3 to 96.3 percent to achieve the 10% NTE WQC, and 53.5 to 94.0 percent to achieve the 2% NTE WQC , depending on the waterbody. In the Hanalei River Estuary, a 35 percent reduction from baseline load is necessary to achieve the 30-day running geometric mean WQC for *enterococcus*, while a 99.4 percent reduction is necessary to meet the single sample maximum WQC.

Informative TMDLs, Load Targets, and suggested reductions (in mass and percent) for the waterbody-pollutant combinations listed in Table 4 are presented in Table 16 through Table 25. Specifically, Table 16 presents the wet and dry season values for TSS and Table 17 presents the same information for *enterococcus*. Wet and dry season allocations and suggested reductions for nutrients are presented in Table 18 through Table 25. The suggested percent reductions for nutrients are identical to the TSS values in the same watershed because implementation strategies expected to reduce sediment and nutrients are assumed to be the similar, especially since sediment was found to be correlated to total nitrogen and total phosphorous. Ammonia and nitrite plus nitrate were not correlated with TSS; however, management strategies that address total nitrogen and total phosphorous are

likely to also reduce other nutrients, thus these parameters were reduced similarly in the model runs used to determine the Informative TMDLs and Load Targets.

7.4. Critical Conditions and Seasonal Variation

TMDLs are required to consider critical conditions and seasonal variation for 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 the Hanalei Bay watershed, the critical conditions for *enterococcus* and turbidity impairments coincide with storm events. The Data Analysis section (Section 4) 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. Although large storms in the wet season (November to April) of the critical year were associated with large volumes of runoff that transported large loads, storms during the dry season (May to October) also provided large loads. To consider the variability among seasons and ensure the greatest protection of the receiving waters, the TMDLs were calculated so wet and dry WQC, where applicable, were attained during the appropriate season and the additional year-round WQC were attained throughout the year.

Table 14. Total Suspended Solids TMDL Load Allocations and Load Reductions Required to Achieve TMDLs (Note: key to table continues on following page)

Total Suspended Solids						
Wet Season Baseflow*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	1431.3	75.3	1506.6	6550.7	5044.0	77.0%
Hanalei River Estuary	1520.6	80.0	1600.6	6959.2	5358.6	77.0%
Waioli Stream Estuary	117.5	6.2	123.7	1124.9	1001.1	89.0%
Waipa Stream	49.5	2.6	52.1	452.8	400.7	88.5%
Waipa Stream Estuary	53.7	2.8	56.5	491.6	435.1	88.5%
Waikoko Stream Estuary	2.3	0.1	2.4	110.8	108.4	97.8%
Wet Season 10% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2220.0	116.8	2336.8	6550.7	4213.9	64.3%
Hanalei River Estuary	2358.4	124.1	2482.5	6959.2	4476.7	64.3%
Waioli Stream Estuary	187.5	9.9	197.4	1124.9	927.4	82.5%
Waipa Stream	63.3	3.330	66.6	452.8	386.2	85.3%
Waipa Stream Estuary	68.7	3.6	72.3	491.6	419.3	85.3%
Waikoko Stream Estuary	3.9	0.2	4.1	110.8	106.7	96.3%
Wet Season 2% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2894.1	152.3	3046.4	6550.7	3504.3	53.5%
Hanalei River Estuary	3074.5	161.8	3236.4	6959.2	3722.9	53.5%
Waioli Stream Estuary	318.2	16.8	334.9	1124.9	789.9	70.2%
Waipa Stream	59.8	3.147	62.9	452.8	389.8	86.1%
Waipa Stream Estuary	64.9	3.4	68.3	491.6	423.3	86.1%
Waikoko Stream Estuary	6.3	0.3	6.7	110.8	104.1	94.0%
Dry Season Baseflow*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	1415.8	74.5	1490.3	6479.5	4989.2	77.0%
Hanalei River Estuary	1504.1	79.2	1583.2	6883.6	5300.4	77.0%
Waioli Stream Estuary	116.3	6.1	122.4	1112.6	990.2	89.0%
Waipa Stream	48.9	2.6	51.5	447.9	396.4	88.5%
Waipa Stream Estuary	53.1	2.8	55.9	486.3	430.4	88.5%
Waikoko Stream Estuary	2.3	0.1	2.4	109.6	107.2	97.8%
Dry Season 10% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2195.8	115.6	2311.4	6479.5	4168.1	64.3%
Hanalei River Estuary	2332.8	122.8	2455.6	6883.6	4428.0	64.3%
Waioli Stream Estuary	185.5	9.8	195.3	1112.6	917.4	82.5%
Waipa Stream	62.6	3.294	65.9	447.9	382.0	85.3%
Waipa Stream Estuary	67.9	3.6	71.5	486.3	414.7	85.3%
Waikoko Stream Estuary	3.8	0.2	4.0	109.6	105.6	96.3%
Dry Season 2% Runoff*	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei Stream	2862.6	150.7	3013.3	6479.5	3466.2	53.5%
Hanalei River Estuary	3041.1	160.1	3201.2	6883.6	3682.4	53.5%
Waioli Stream Estuary	314.7	16.6	331.3	1112.6	781.3	70.2%
Waipa Stream	59.2	3.113	62.3	447.9	385.6	86.1%
Waipa Stream Estuary	64.2	3.4	67.6	486.3	418.7	86.1%
Waikoko Stream Estuary	6.3	0.3	6.6	109.6	103.0	94.0%

Note: TMDL allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)
Acronyms: LA = Load Allocation; MOS = Margin of Safety; TMDL = Total Maximum Daily Load; kgd = kilograms per day

Table 15. *Enterococcus* TMDL Load Allocations and Load Reductions Required to Achieve TMDLs

Enterococcus						
Wet Season Baseflow* (Geometric Mean)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+12	2.3E+11	4.6E+12	7.0E+12	2.5E+12	35.0%
Hanalei River Estuary	4.9E+12	2.6E+11	5.1E+12	7.9E+12	2.8E+12	35.0%
Wet Season Runoff* (Single Sample Maximum)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+10	2.3E+09	4.6E+10	7.0E+12	7.0E+12	99.4%
Hanalei River Estuary	4.9E+10	2.6E+09	5.1E+10	7.9E+12	7.8E+12	99.4%
Dry Season Baseflow* (Geometric Mean)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+12	2.3E+11	4.5E+12	7.0E+12	2.4E+12	35.0%
Hanalei River Estuary	4.8E+12	2.5E+11	5.1E+12	7.8E+12	2.7E+12	35.0%
Dry Season Runoff* (Single Sample Maximum)	**LA**	**MOS**	**TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Hanalei River	4.3E+10	2.3E+09	4.5E+10	7.0E+12	6.9E+12	99.4%
Hanalei River Estuary	4.8E+10	2.5E+09	5.1E+10	7.8E+12	7.8E+12	99.4%

Note: TMDL allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.
* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (generally, the highest 10% of flows)
Acronyms: LA = Load Allocation; MOS = Margin of Safety; TMDL = Total Maximum Daily Load; #/day = number per day

Table 16. Total Suspended Solids Informative TMDLs and Suggested Reductions

Total Suspended Solids						
Wet Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	112.2	5.9	118.1	1073.9	955.8	89.0%
Waikoko Stream	2.2	0.1	2.3	106.4	104.1	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	179.0	9.423	188.5	1073.9	885.4	82.5%
Waikoko Stream	3.7	0.196	3.9	106.4	102.5	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	303.8	15.988	319.8	1073.9	754.2	70.2%
Waikoko Stream	6.1	0.320	6.4	106.4	100.0	94.0%
Dry Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	111.0	5.8	116.8	1062.2	945.4	89.0%
Waikoko Stream	2.2	0.1	2.3	105.2	102.9	97.8%
Dry Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	177.1	9.321	186.4	1062.2	875.8	82.5%
Waikoko Stream	3.7	0.194	3.9	105.2	101.4	96.3%
Dry Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Waioli Stream	300.5	15.814	316.3	1062.2	746.0	70.2%
Waikoko Stream	6.0	0.317	6.3	105.2	98.9	94.0%

Note: Informative TMDLS and load allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 17. *Enterococcus* Informative TMDLs and Suggested Reductions

Enterococcus						
Wet Season Baseflow* (Geometric Mean)	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	8.5E+11	4.5E+10	9.0E+11	1.8E+12	8.6E+11	49.0%
Waioli Stream	8.1E+11	4.3E+10	8.5E+11	1.7E+12	8.2E+11	49.0%
Waipa Stream Estuary	6.2E+11	3.3E+10	6.5E+11	8.3E+11	1.7E+11	21.0%
Waipa Stream	5.7E+11	3.0E+10	6.0E+11	7.6E+11	1.6E+11	21.0%
Waikoko Stream Estuary	8.9E+10	4.7E+09	9.4E+10	2.6E+11	1.7E+11	64.0%
Waikoko Stream	8.7E+10	4.6E+09	9.1E+10	2.5E+11	1.6E+11	64.0%
Wet Season Runoff* (Single Sample Maximum)	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	1.0E+10	5.5E+08	1.1E+10	1.8E+12	1.7E+12	99.4%
Waioli Stream	9.9E+09	5.2E+08	1.0E+10	1.7E+12	1.7E+12	99.4%
Waipa Stream Estuary	4.6E+09	2.4E+08	4.9E+09	8.3E+11	8.2E+11	99.4%
Waipa Stream	4.3E+09	2.2E+08	4.5E+09	7.6E+11	7.6E+11	99.4%
Waikoko Stream Estuary	8.7E+08	4.6E+07	9.1E+08	2.6E+11	2.6E+11	99.7%
Waikoko Stream	8.4E+08	4.4E+07	8.9E+08	2.5E+11	2.5E+11	99.7%
Dry Season Baseflow* (Geometric Mean)	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	8.4E+11	4.4E+10	8.9E+11	1.7E+12	8.5E+11	49.0%
Waioli Stream	8.0E+11	4.2E+10	8.5E+11	1.7E+12	8.1E+11	49.0%
Waipa Stream Estuary	6.1E+11	3.2E+10	6.5E+11	8.2E+11	1.7E+11	21.0%
Waipa Stream	5.7E+11	3.0E+10	6.0E+11	7.5E+11	1.6E+11	21.0%
Waikoko Stream Estuary	8.8E+10	4.6E+09	9.3E+10	2.6E+11	1.6E+11	64.0%
Waikoko Stream	8.6E+10	4.5E+09	9.0E+10	2.5E+11	1.6E+11	64.0%
Dry Season Runoff* (Single Sample Maximum)	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Reduction Required**	
Waterbody	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(#/day)**	**(%)**
Waioli Stream Estuary	1.0E+10	5.4E+08	1.1E+10	1.7E+12	1.7E+12	99.4%
Waioli Stream	9.8E+09	5.1E+08	1.0E+10	1.7E+12	1.6E+12	99.4%
Waipa Stream Estuary	4.6E+09	2.4E+08	4.8E+09	8.2E+11	8.1E+11	99.4%
Waipa Stream	4.2E+09	2.2E+08	4.4E+09	7.5E+11	7.5E+11	99.4%
Waikoko Stream Estuary	8.6E+08	4.5E+07	9.0E+08	2.6E+11	2.6E+11	99.7%
Waikoko Stream	8.3E+08	4.4E+07	8.8E+08	2.5E+11	2.5E+11	99.7%

Note: Load Targets and allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (generally, the highest 10% of flows)

Acronyms: MOS = Margin of Safety; #/day = number per day

Table 18. Wet Season Ammonia Informative TMDLs and Load Targets and Suggested Reductions

Ammonia						
Wet Season Baseflow*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	9.1	0.481	9.6	41.8	32.2	77.0%
Hanalei River	*4.4*	*0.233*	*4.7*	*20.2*	*15.6*	*77.0%*
Waioli Stream Estuary	1.5	0.077	1.5	14.1	12.5	89.0%
Waioli Stream	*1.0*	*0.052*	*1.0*	*9.4*	*8.4*	*89.0%*
Waipa Stream Estuary	0.5	0.025	0.5	4.4	3.9	88.5%
Waipa Stream	*0.1*	*0.007*	*0.1*	*1.3*	*1.1*	*88.5%*
Waikoko Stream Estuary	0.1	0.008	0.2	7.1	6.9	97.8%
Waikoko Stream	0.1	0.007	0.1	6.5	6.4	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	14.2	0.745	14.9	41.8	26.9	64.3%
Hanalei River	*6.9*	*0.361*	*7.2*	*20.2*	*13.0*	*64.3%*
Waioli Stream Estuary	2.3	0.123	2.5	14.1	11.6	82.4%
Waioli Stream	*1.6*	*0.083*	*1.7*	*9.4*	*7.8*	*82.4%*
Waipa Stream Estuary	0.6	0.032	0.6	4.4	3.7	85.3%
Waipa Stream	*0.2*	*0.009*	*0.2*	*1.3*	*1.1*	*85.3%*
Waikoko Stream Estuary	0.2	0.013	0.3	7.1	6.8	96.3%
Waikoko Stream	0.2	0.012	0.2	6.5	6.3	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	18.5	0.972	19.4	41.8	22.4	53.5%
Hanalei River	*8.9*	*0.471*	*9.4*	*20.2*	*10.8*	*53.5%*
Waioli Stream Estuary	4.0	0.209	4.2	14.1	9.9	70.2%
Waioli Stream	*2.7*	*0.140*	*2.8*	*9.4*	*6.6*	*70.2%*
Waipa Stream Estuary	0.6	0.030	0.6	4.4	3.8	86.1%
Waipa Stream	*0.2*	*0.009*	*0.2*	*1.3*	*1.1*	*86.1%*
Waikoko Stream Estuary	0.4	0.021	0.4	7.1	6.7	94.0%
Waikoko Stream	*0.4*	*0.020*	*0.4*	*6.5*	*6.1*	*94.0%*

Note: Informative TMDLs, Load Allocations, and Load Targets in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 19. Dry Season Ammonia Informative TMDLs and Load Targets and Suggested Reductions

Ammonia						
Dry Season Baseflow*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	9.0	0.475	9.5	41.3	31.8	77.0%
Hanalei River	*4.4*	*0.230*	*4.6*	*20.0*	*15.4*	*77.0%*
Waioli Stream Estuary	1.5	0.077	1.5	13.9	12.4	89.0%
Waioli Stream	*1.0*	*0.051*	*1.0*	*9.3*	*8.3*	*89.0%*
Waipa Stream Estuary	0.5	0.025	0.5	4.3	3.8	88.5%
Waipa Stream	*0.1*	*0.007*	*0.1*	*1.3*	*1.1*	*88.5%*
Waikoko Stream Estuary	0.1	0.008	0.2	7.0	6.9	97.8%
Waikoko Stream	*0.1*	*0.007*	*0.1*	*6.5*	*6.3*	*97.8%*
Dry Season 10% Runoff*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	14.0	0.737	14.7	41.3	26.6	64.3%
Hanalei River	*6.8*	*0.357*	*7.1*	*20.0*	*12.9*	*64.3%*
Waioli Stream Estuary	2.3	0.122	2.4	13.9	11.5	2.3
Waioli Stream	*1.6*	*0.082*	*1.6*	*9.3*	*7.7*	*1.6*
Waipa Stream Estuary	0.6	0.032	0.6	4.3	3.7	0.6
Waipa Stream	*0.2*	*0.009*	*0.2*	*1.3*	*1.1*	*0.2*
Waikoko Stream Estuary	0.2	0.013	0.3	7.0	6.8	0.2
Waikoko Stream	*0.2*	*0.012*	*0.2*	*6.5*	*6.2*	*0.2*
Dry Season 2% Runoff*	**Informative Load Allocation or *Load Target Allocation***	**MOS**	**Informative TMDL or *Load Target***	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	18.3	0.961	19.2	41.3	22.1	53.5%
Hanalei River	*8.8*	*0.466*	*9.3*	*20.0*	*10.7*	*53.5%*
Waioli Stream Estuary	3.9	0.207	4.1	13.9	9.8	70.2%
Waioli Stream	*2.6*	*0.139*	*2.8*	*9.3*	*6.5*	*70.2%*
Waipa Stream Estuary	0.6	0.030	0.6	4.3	3.7	86.1%
Waipa Stream	*0.2*	*0.009*	*0.2*	*1.3*	*1.1*	*86.1%*
Waikoko Stream Estuary	0.4	0.021	0.4	7.0	6.6	94.0%
Waikoko Stream	*0.4*	*0.019*	*0.4*	*6.5*	*6.1*	*94.0%*

Note: : Informative TMDLs, Load Allocations, and Load Targets in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 20. Wet Season Nitrite Plus Nitrate Informative TMDLs and Suggested Reductions

Nitrite plus Nitrate						
Wet Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	10.3	0.541	10.8	47.0	36.2	77.0%
Hanalei River	8.2	0.432	8.6	37.6	28.9	77.0%
Waioli Stream Estuary	1.1	0.059	1.2	10.8	9.6	89.0%
Waioli Stream	0.9	0.050	1.0	9.0	8.0	89.0%
Waipa Stream Estuary	0.4	0.024	0.5	4.1	3.6	88.5%
Waipa Stream	0.3	0.017	0.3	3.0	2.6	88.5%
Waikoko Stream Estuary	0.1	0.003	0.1	3.0	2.9	97.8%
Waikoko Stream	0.1	0.003	0.1	2.8	2.7	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	15.9	0.839	16.8	47.0	30.3	64.3%
Hanalei River	12.7	0.670	13.4	37.6	24.2	64.3%
Waioli Stream Estuary	1.8	0.094	1.9	10.8	8.9	82.4%
Waioli Stream	1.5	0.079	1.6	9.0	7.5	82.4%
Waipa Stream Estuary	0.6	0.030	0.6	4.1	3.5	85.3%
Waipa Stream	0.4	0.022	0.4	3.0	2.5	85.3%
Waikoko Stream Estuary	0.1	0.005	0.1	3.0	2.9	96.3%
Waikoko Stream	0.1	0.005	0.1	2.8	2.7	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	20.8	1.093	21.9	47.0	25.2	53.5%
Hanalei River	16.6	0.874	17.5	37.6	20.1	53.5%
Waioli Stream Estuary	3.0	0.160	3.2	10.8	7.6	70.2%
Waioli Stream	2.6	0.135	2.7	9.0	6.3	70.2%
Waipa Stream Estuary	0.5	0.028	0.6	4.1	3.5	86.1%
Waipa Stream	0.4	0.021	0.4	3.0	2.5	86.1%
Waikoko Stream Estuary	0.2	0.009	0.2	3.0	2.8	94.0%
Waikoko Stream	0.2	0.008	0.2	2.8	2.6	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 21. Dry Season Nitrite Plus Nitrate Informative TMDLs and Suggested Reductions

Nitrite plus Nitrate						
Dry Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	10.2	0.535	10.7	46.5	35.8	77.0%
Hanalei River	8.1	0.428	8.6	37.2	28.6	77.0%
Waioli Stream Estuary	1.1	0.059	1.2	10.6	9.5	89.0%
Waioli Stream	0.9	0.049	1.0	8.9	8.0	89.0%
Waipa Stream Estuary	0.4	0.023	0.5	4.0	3.6	88.5%
Waipa Stream	0.3	0.017	0.3	2.9	2.6	88.5%
Waikoko Stream Estuary	0.1	0.003	0.1	3.0	2.9	97.8%
Waikoko Stream	0.1	0.003	0.1	2.8	2.7	97.8%
Dry Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	15.8	0.829	16.6	46.5	29.9	64.3%
Hanalei River	12.6	0.663	13.3	37.2	23.9	64.3%
Waioli Stream Estuary	1.8	0.093	1.9	10.6	8.8	82.4%
Waioli Stream	1.5	0.078	1.6	8.9	7.4	82.4%
Waipa Stream Estuary	0.6	0.030	0.6	4.0	3.4	85.3%
Waipa Stream	0.4	0.021	0.4	2.9	2.5	85.3%
Waikoko Stream Estuary	0.1	0.005	0.1	3.0	2.9	96.3%
Waikoko Stream	0.1	0.005	0.1	2.8	2.7	96.3%
Dry Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	20.5	1.082	21.6	46.5	24.9	53.5%
Hanalei River	16.4	0.864	17.3	37.2	19.9	53.5%
Waioli Stream Estuary	3.0	0.158	3.2	10.6	7.5	70.2%
Waioli Stream	2.5	0.133	2.7	8.9	6.3	70.2%
Waipa Stream Estuary	0.5	0.028	0.6	4.0	3.5	86.1%
Waipa Stream	0.4	0.020	0.4	2.9	2.5	86.1%
Waikoko Stream Estuary	0.2	0.009	0.2	3.0	2.8	94.0%
Waikoko Stream	0.2	0.008	0.2	2.8	2.6	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 22. Wet Season Total Nitrogen Informative TMDLs and Suggested Reductions

Total Nitrogen						
Wet Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	80.3	4.225	84.5	367.4	282.9	77.0%
Hanalei River	69.0	3.630	72.6	315.7	243.1	77.0%
Waioli Stream Estuary	8.0	0.423	8.5	77.0	68.5	89.0%
Waioli Stream	7.1	0.373	7.5	67.8	60.3	89.0%
Waipa Stream Estuary	3.3	0.173	3.5	30.0	26.6	88.5%
Waipa Stream	2.6	0.135	2.7	23.4	20.7	88.5%
Waikoko Stream Estuary	0.3	0.018	0.4	16.7	16.3	97.8%
Waikoko Stream	0.3	0.017	0.3	15.6	15.3	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	124.5	6.552	131.0	367.4	236.4	64.3%
Hanalei River	107.0	5.629	112.6	315.7	203.1	64.3%
Waioli Stream Estuary	12.8	0.676	13.5	77.0	63.5	82.4%
Waioli Stream	11.3	0.595	11.9	67.8	55.9	82.4%
Waipa Stream Estuary	4.2	0.221	4.4	30.0	25.6	85.3%
Waipa Stream	3.3	0.172	3.4	23.4	20.0	85.3%
Waikoko Stream Estuary	0.6	0.031	0.6	16.7	16.0	96.3%
Waikoko Stream	0.5	0.029	0.6	15.6	15.0	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	162.3	8.543	170.9	367.4	196.6	53.5%
Hanalei River	139.5	7.340	146.8	315.7	168.9	53.5%
Waioli Stream Estuary	21.8	1.147	22.9	77.0	54.1	70.2%
Waioli Stream	19.2	1.009	20.2	67.8	47.6	70.2%
Waipa Stream Estuary	4.0	0.209	4.2	30.0	25.9	86.1%
Waipa Stream	3.1	0.163	3.3	23.4	20.2	86.1%
Waikoko Stream Estuary	1.0	0.050	1.0	16.7	15.7	94.0%
Waikoko Stream	0.9	0.047	0.9	15.6	14.7	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 23. Dry Season Total Nitrogen Informative TMDLs and Suggested Reductions

Total Nitrogen						
Dry Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	79.4	4.179	83.6	363.4	279.8	77.0%
Hanalei River	68.2	3.591	71.8	312.2	240.4	77.0%
Waioli Stream Estuary	8.0	0.419	8.4	76.2	67.8	89.0%
Waioli Stream	7.0	0.369	7.4	67.0	59.7	89.0%
Waipa Stream Estuary	3.2	0.171	3.4	29.7	26.3	88.5%
Waipa Stream	2.5	0.133	2.7	23.2	20.5	88.5%
Waikoko Stream Estuary	0.3	0.018	0.4	16.5	16.1	97.8%
Waikoko Stream	0.3	0.017	0.3	15.4	15.1	97.8%
Dry Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	123.1	6.481	129.6	363.4	233.8	64.3%
Hanalei River	105.8	5.568	111.4	312.2	200.9	64.3%
Waioli Stream Estuary	12.7	0.669	13.4	76.2	62.8	82.4%
Waioli Stream	11.2	0.588	11.8	67.0	55.3	82.4%
Waipa Stream Estuary	4.2	0.218	4.4	29.7	25.3	85.3%
Waipa Stream	3.2	0.170	3.4	23.2	19.8	85.3%
Waikoko Stream Estuary	0.6	0.030	0.6	16.5	15.9	96.3%
Waikoko Stream	0.5	0.028	0.6	15.4	14.9	96.3%
Dry Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	160.5	8.450	169.0	363.4	194.4	53.5%
Hanalei River	137.9	7.260	145.2	312.2	167.0	53.5%
Waioli Stream Estuary	21.5	1.134	22.7	76.2	53.5	70.2%
Waioli Stream	19.0	0.998	20.0	67.0	47.1	70.2%
Waipa Stream Estuary	3.9	0.206	4.1	29.7	25.6	86.1%
Waipa Stream	3.1	0.161	3.2	23.2	19.9	86.1%
Waikoko Stream Estuary	0.9	0.050	1.0	16.5	15.5	94.0%
Waikoko Stream	0.9	0.047	0.9	15.4	14.5	94.0%

Note: informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 24. Wet Season Total Phosphorous Informative TMDLs and Suggested Reductions

Total Phosphorous						
Wet Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	19.2	1.012	20.2	88.0	67.7	77.0%
Hanalei River	17.4	0.915	18.3	79.5	61.3	77.0%
Waioli Stream Estuary	1.9	0.098	2.0	17.8	15.8	89.0%
Waioli Stream	1.7	0.090	1.8	16.4	14.6	89.0%
Waipa Stream Estuary	0.8	0.041	0.8	7.1	6.3	88.5%
Waipa Stream	0.7	0.035	0.7	6.1	5.4	88.5%
Waikoko Stream Estuary	0.1	0.003	0.1	2.8	2.7	97.8%
Waikoko Stream	0.1	0.003	0.1	2.6	2.6	97.8%
Wet Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	29.8	1.569	31.4	88.0	56.6	64.3%
Hanalei River	27.0	1.419	28.4	79.5	51.2	64.3%
Waioli Stream Estuary	3.0	0.156	3.1	17.8	14.6	82.4%
Waioli Stream	2.7	0.144	2.9	16.4	13.5	82.4%
Waipa Stream Estuary	1.0	0.052	1.0	7.1	6.1	85.3%
Waipa Stream	0.8	0.045	0.9	6.1	5.2	85.3%
Waikoko Stream Estuary	0.1	0.005	0.1	2.8	2.7	96.3%
Waikoko Stream	0.1	0.005	0.1	2.6	2.5	96.3%
Wet Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	38.9	2.045	40.9	88.0	47.1	53.5%
Hanalei River	35.1	1.850	37.0	79.5	42.6	53.5%
Waioli Stream Estuary	5.0	0.264	5.3	17.8	12.5	70.2%
Waioli Stream	4.6	0.244	4.9	16.4	11.5	70.2%
Waipa Stream Estuary	0.9	0.049	1.0	7.1	6.1	86.1%
Waipa Stream	0.8	0.042	0.8	6.1	5.2	86.1%
Waikoko Stream Estuary	0.2	0.008	0.2	2.8	2.6	94.0%
Waikoko Stream	0.2	0.008	0.2	2.6	2.5	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

Table 25. Dry Season Total Phosphorous Informative TMDLs and Suggested Reductions

Total Phosphorous						
Dry Season Baseflow*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	19.0	1.001	20.0	87.0	67.0	77.0%
Hanalei River	19.0	1.001	20.0	87.0	67.0	77.0%
Waioli Stream Estuary	1.8	0.097	1.9	17.6	15.6	89.0%
Waioli Stream	1.7	0.089	1.8	16.2	14.4	89.0%
Waipa Stream Estuary	0.8	0.040	0.8	7.0	6.2	88.5%
Waipa Stream	0.7	0.034	0.7	6.0	5.3	88.5%
Waikoko Stream Estuary	0.1	0.003	0.1	2.7	2.7	97.8%
Waikoko Stream	0.1	0.003	0.1	2.6	2.5	97.8%
Dry Season 10% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	29.5	1.552	31.0	87.0	56.0	64.3%
Hanalei River	26.7	1.403	28.1	78.7	50.6	64.3%
Waioli Stream Estuary	2.9	0.154	3.1	17.6	14.5	82.4%
Waioli Stream	2.7	0.142	2.8	16.2	13.3	82.4%
Waipa Stream Estuary	1.0	0.052	1.0	7.0	6.0	85.3%
Waipa Stream	0.8	0.044	0.9	6.0	5.1	85.3%
Waikoko Stream Estuary	0.1	0.005	0.1	2.7	2.6	96.3%
Waikoko Stream	0.1	0.005	0.1	2.6	2.5	96.3%
Dry Season 2% Runoff*	**Informative Load Allocation**	**MOS**	**Informative TMDL**	**Existing Load**	**Suggested Reduction**	
Waterbody	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(kgd)**	**(%)**
Hanalei River Estuary	38.4	2.023	40.5	87.0	46.5	53.5%
Hanalei River	34.8	1.829	36.6	78.7	42.1	53.5%
Waioli Stream Estuary	5.0	0.261	5.2	17.6	12.3	70.2%
Waioli Stream	4.6	0.241	4.8	16.2	11.4	70.2%
Waipa Stream Estuary	0.9	0.049	1.0	7.0	6.1	86.1%
Waipa Stream	0.8	0.042	0.8	6.0	5.2	86.1%
Waikoko Stream Estuary	0.2	0.008	0.2	2.7	2.6	94.0%
Waikoko Stream	0.1	0.008	0.2	2.6	2.4	94.0%

Note: Informative TMDLs and Load Allocations in kilograms or number per day are obtained by dividing wet season values by 182 days and dry season values by 184 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 or number; 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.

Estuary loads are inclusive of the stream loads since they represent the entire upstream loadings.

* Wet season is defined at November 1 through April 30 and dry season is May 1 through October 31. Baseflow is associated with the 90% lowest flows and runoff is associated with storm flows (the highest 10% and 2% of flows)

Acronyms: MOS = Margin of Safety; kgd = kilograms per day

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 integrity of aquatic ecosystems. These 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 presented here 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.

Due to the difficulty of drawing precise links between nonpoint sources (including natural background, endangered waterbirds, wildlife, livestock, and wetland farming) and waterbody impairment in the Hanalei Bay Watershed, we propose employing a phased approach to the development and implementation of these TMDL load allocations. 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, this TMDL decision is a starting point for nonpoint source implementation activities that can be adapted as new information becomes available, and that are intended to include ongoing review and future revision of the TMDL decision.

Numerous public comments received about the draft TMDL expressed concerns about the feasibility of TMDL implementation given the seemingly extreme load reductions required and the accompanying threat of potentially damaging implementation mandates, costs, and societal impacts. These concerns seem to be best addressed on the context of ongoing phased TMDL development, watershed based planning, and other DOH water pollution control and water quality management program activities in Hanalei. Therefore, this TMDL implementation framework and the upcoming Watershed Based Plan are intended 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. While highlighting some of the more important, potentially fruitful, or oppressive choices for this effort, DOH 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.

Providing more information and explanation concerning the scientific basis of the load reductions, and other aspects of the TMDL process, is an important objective of the upcoming TMDL development phases. In accordance with the selection of Hanalei by DOH and EPA as one of three areas in the state where water quality improvements may be possible and multiple clean water program tools may be applied to help make these improvements, DOH will have to spend more time and effort reaching out to the Hanalei community,

Hawaii's Implementation Plan for Polluted Runoff Control (Coastal Zone Management Program and Polluted Runoff Control Program, 2000) and Hawaii's Coastal Nonpoint Pollution Control Program (Hawaii Coastal Zone Management Program, 1996) establish a foundation for voluntary and regulatory approaches to improving and maintaining watershed health. Both these plans are being updated and revised to better address, among other objectives, implementation of TMDL allocations. Specific implementation measures for the Hanalei watershed may be imported or adapted from a number of existing and pending planning documents, including:

Dong, Dacheng et al. 2002. Building Collaboration: Toward Co-management for the Hanalei Ahupua'a, Kaua'i, Hawai'i – Planning Practicum Fall 2002. University of Hawaii at Manoa, Department of Urban and Regional Planning.

Hanalei Watershed Hui. 2006. Final Report to U.S. Environmental Protection Agency – Hanalei Targeted Watershed Initiative Grant.

Hanalei Watershed Hui. nd. Hanalei Watershed Hui Watershed Action Plan.
www.hanaleiwatershedhui.org/wap.htm

Hanalei Watershed Hui Program. 2005. Environmental Protection Agency's Watershed Initiative Grant – Project Update.
www.hanaleiwatershedhui.org/science/research/WIG.pdf.pdf

Kauai Watershed Alliance. 2005. Management Plan.

State of Hawaii Department of Education. Site-specific Storm Water Management Program Plans for NPDES Phase 2 MS4 facilities.

State of Hawaii Department of Land and Natural Resources. Halelea Forest Reserve forest resource management plans and conservation district use permits/plans.

State of Hawaii Department of Transportation, Highways Division. Storm Water Management Plans for NPDES Phase 1 MS4 permit (Oahu).

U.S. Environmental Protection Agency et al. 2004. Hawaii's Local Action Strategy to Address Land-Based Pollution Threats to Coral Reefs.
www.hawaii.gov/health/environmental/water/cleanwater/prc/pdf/LAS.CR-LBP_fnl_3-22-04.pdf

U.S. Fish and Wildlife Service. Hanalei Refuge Management Plan.

Various. Site-specific Storm Water Management Program Plans for NPDES Phase 2 MS4 facilities (Oahu).

Various. Soil and Water Conservation Plans, Comprehensive Nutrient Management Plans, and other Farm Bill Program plans for agricultural lands, and other public and private planning initiatives (see ***Land ownership*** and ***Regulatory and management authority*** below).

By using these general approaches and specific measures, incorporating the LAs and implementation framework from the TMDLs, and/or conducting the actions prescribed by a Watershed Based Plan, an implementation project can potentially access additional Clean Water Act §319(h) incremental funds for water quality improvement projects. Such projects may also qualify for construction funding from the DOH Clean Water State Revolving Fund Program. Questions of where to focus project activities and how to complete them can be addressed 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) – each of which is discussed below. Other resources for these efforts include:

> Nonpoint Source Control Branch. 2005. EPA Handbook for developing watershed plans to restore and protect our waters (Draft). U.S. Environmental Protection Agency Office of Water. www.epa.gov/nps/watershed_handbook, and other EPA publications at www.epa.gov/owow/nps/pubs.html
>
> Center for Watershed Protection. Various resources at www.cwp.org.

8.1. Waterbody classes and uses

The TMDL process provides strategies for achieving and maintaining water quality standards. A water quality standard consists of the designated use(s) for the water, water quality criteria designed to protect the use(s), and an antidegradation policy. The Clean Water Act also demands that existing uses (as of November 28, 1975) be protected. Thus the TMDL Implementation Framework incorporates these uses, criteria, and policy as organizing concepts for identifying specific implementation activities and approaches.

For example, Hanalei Bay is a Class AA marine waterbody (embayment) that is to receive "an absolute minimum of pollution or alteration of water quality from any human-caused source or actions," and its designated uses include "conservation of coral reefs and wilderness areas ... and aesthetic enjoyment." Thus the relative importance of an inland waterbody segment's impact upon embayment pollution minimization, water quality alteration, coral reefs, and aesthetic enjoyment could be factors for prioritizing implementation activities that affect inland waters (streams and estuaries). Similarly, a combination of Class 1 and Class 2 inland waterbody segments are pollutant sources for the Bay (see Figure 4). Assuming equal importance of embayment impact among these inland segments, implementation activities affecting Class 1 inland segments may be a higher priority than those affecting Class 2 inland segments, since Class 1 inland waters are to "remain in their natural state as nearly as possible with an absolute minimum of pollution from any human caused source."

Designated uses of Class 1 inland waters such as "protection of native breeding stock" and "aesthetic enjoyment" don't extend to Class 2 inland waters. Thus, as with the embayment example above, the relative importance of

upstream/downstream segment interaction upon Class 1 natural state maintenance, pollution minimization, native breeding stock, and aesthetic enjoyment could be factors for prioritizing implementation activities that affect inland waters. However, when assuming equal importance of Class 1 impact among these upstream/downstream segments, implementation activities affecting Class 1 inland segments may not necessarily be a higher priority than those affecting Class 2 inland segments. This is based on the fact that Hawaii stream ecosystems and the amphidromous organisms that travel through them don't recognize human divisions between Class 1 and Class 2 waters. Thus factors for prioritizing implementation activities throughout the watershed should also emphasize habitat quality, biotic integrity, and related existing uses (such as support for traditional and customary native Hawaiian beliefs, values, and practices and for other "reasonable and beneficial uses" and instream uses protected under the State Water Code (Hawai'i Revised Statutes Chapter 174C; State of Hawai'i, 2004).

8.2. Land ownership

Less than 15 landowners control a large majority of the Hanalei watershed area and riparian property. Detailed planning efforts can use the relative magnitude and importance of each landowner's water quality impacts as factors for prioritizing implementation activities. This can be further refined according to each landowner's interest and capability (resources). Initial analysis from this perspective suggests that the State of Hawaii Department of Land and Natural Resources (DLNR), Princeville corporations, U.S. Fish and Wildlife Service (USFWS), Kamehameha Schools, and Waikoko Land Corp. are the most critical landowners for supporting implementation activities, due to the large areas they control and their potentially greater ability to access private and public funding and technical resources.

At this stage in the TMDL implementation process, DOH's role is mainly to identify a wide range of implementation alternatives, not necessarily to select them. As explained on our response to public comments on the draft TMDL, DOH is neither encouraging nor discouraging landowners from imposing restrictions on farmers in their agricultural leases. A multitude of public and private landowners and their tenants; other public and private watershed users; and various local, state, and federal regulatory authorities are all responsible for achieving the State's water quality goals. The purpose of our Implementation Framework is to identify all the responsible parties, their relationships with each other, and the possible ways they could affect and effect TMDL implementation. It is not to pass judgment on how they should or should not conduct these relationships, which is more appropriately the role and responsibility of community-driven TMDL implementation planning.

8.3. Regulatory and management authority

The scope of regulatory and management authority available to support implementation activities varies across land use designations and agency responsibilities. Although we believe it is our duty to fully identify potential implementation mandates (including those largely beyond DOH control, such as legislation, approval and permitting conditions by other agencies, lease conditions, and third-party lawsuits), DOH is not recommending any particular mandates in Hanalei at this time. Instead, we advocate a community-driven adaptive approach to implementing nonpoint source load allocations based on TMDL decisions, other watershed planning results, and local knowledge and experience. Detailed planning efforts, such as the upcoming Watershed Based Plan for Hanalei, can identify how particular authorities can be used to achieve specific results. Public landowners, when regulating and managing their own lands (in this case, primarily DLNR, USFWS, State of Hawaii Department of Transportation, and County of Kauai), may be the most viable group for supporting implementation activities from this perspective. For example, how can the U.S. Fish and Wildlife Service coordinate implementation activities with its regulation of agricultural leases, management of critical and refugial habitats, and planning of species conservation and recovery? How can DLNR coordinate implementation activities with its management of the State Forest Reserve? Initial analysis of this last question might, for example, compare the high vegetation resource value of native forest areas with the draft management guidelines (e.g., "resource management is not a principle objective of game animal management") for some of these same areas, as illustrated below in Figure 20 and further documented at DLNR's website (www.state.hi.us/dlnr/dofaw/guidelines/mg_jw03/index.html).

As co-trustees of publicly-owned water resources, DLNR, DOH, County of Kauai, and other government regulators and managers can also exert their influence across land ownership boundaries to enable and promote implementation activities. The State Water Code (HRS 174C-3) provides a mandate for DLNR's Commission on Water Resource Management to achieve water quality objectives through various regulatory actions (e.g. water reservations, instream flow standards, water management areas, water use permits, and stream channel alteration permits) and complaint/dispute resolution and planning processes. In particular, the Hawaii Water Plan can link these state objectives with county objectives via the Kauai County Water Use and Development Plan Ordinance (www.hawaii.gov/dlnr/cwrm/planning/index.htm).

How can DLNR's regulation and management of lands in the Conservation District be linked with DOH water quality objectives? In one example, the present sandwiching of a Class 2 segment of Hanalei Stream between two Class 1 segments (the lower in the Hanalei National Wildlife Refuge, the upper in the Newcomb's snail critical habitat) could be eliminated by extending the Preservation Subzone of the Conservation District to cover the existing Class 2 segment (see Figure 4) . A similar linkage could be achieved by extending the Preservation Subzone to cover all critical habitat areas. In a third scenario where the Preservation Subzone isn't extended, DOH could perhaps achieve class 1-level protection for the class 2 segment by designating it as an Outstanding National Resource Water.

DOH water quality management and water pollution control efforts overlap and interface with several County of Kauai implementation mechanisms. The Kauai General Plan (e.g. Chapter 3, Caring for Land, Water and Culture) can be used to link broad planning objectives across jurisdictions (www.kauai.gov/Default.aspx?tabid=130). The Department of Budget and Finance (www.kauai.gov/default.aspx?tabid=162) finds and administers the funding to achieve these objectives, and the Department of Public Works Engineering Division (www.kauai.gov/default.aspx?tabid=65) is where detailed water quality strategies and tactics are developed and used for enforcement (Grubbing, Grading and Stockpiling Ordinance; Flood Ordinance), operations (Storm Water Management Program), and planning and development purposes (Roads and Drainage Facilities Design and Construction Program; Subdivisions/Consolidations, Zoning, and Use Permit Review Program).

As implementation proceeds, we recognize that county governments have a special role in setting public policy for land uses. We note that water quality standards also embody an important public policy, to protect the designated uses of state waters, and standards-based TMDLs are a required vehicle for implementing this statewide policy. Given that both state and county governments have public trust duties to protect state waters, TMDLs should be an important tool and consideration in water quality project assessment and land use decisionmaking.

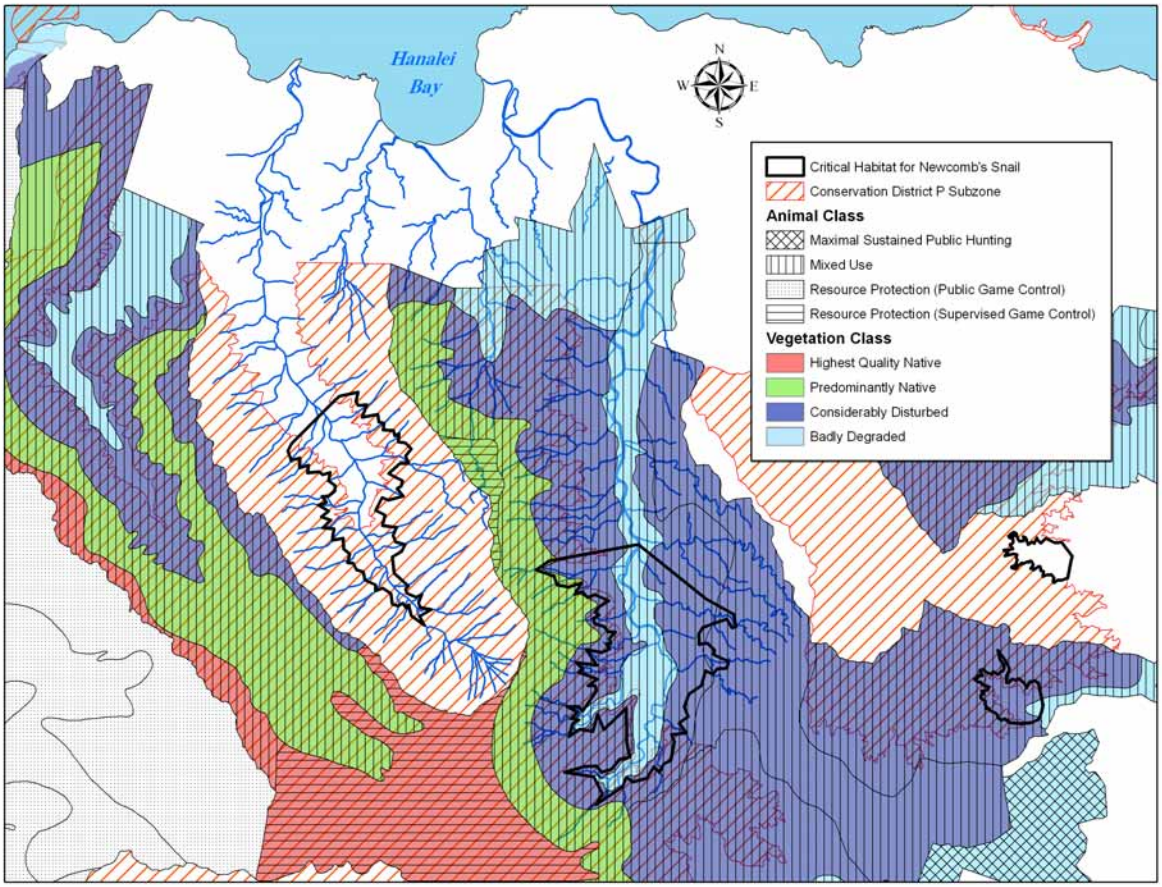


Figure 20. Overlapping Regulatory and Management Frameworks in the Hanalei Bay Watershed

8.4. Land cover and degrading activities (problem areas)

Water quality monitoring data are generally not sufficient to fully characterize all sources of bacteria, sediment, and nutrients in the watersheds draining to impaired waterbodies Analyses of the available data, for example as presented in Appendix C (Relative Land Cover Loadings), provides a starting point for identifying source areas that can be prioritized for further examination. These major source categories are considered controllable for TMDL implementation purposes, and the potential effectiveness of implementation activities can be simulated for an array of management scenarios. Generally, the higher the percentage of a particular land cover class the higher the pollutant load contribution. Additional information to consider in identifying the type and location of specific implementation activities includes the relationship between site characteristics (such as slope, soil type, vegetation type, and disturbance type and intensity) and the loading characteristics of various pollutants.

Initial results suggest that the main pollutant sources are open areas (scrub/shrub and evergreen forest land cover types), runoff from agriculture, and waterbird impoundments. Among these, the bulk of the bacterial source areas appear to include wildlands and wetlands in the larger watersheds (Hanalei, Waioli, Waipa) and cultivated lands in Waikoko. Management strategies that address TSS are likely to also reduce total N and total P, and the main source areas for sediment appear to be unmanaged lands in the larger watersheds. Cultivated lands in Waikoko are suggested as a major contributor of total N and total P, and cultivated lands throughout the watershed seem to represent the main source of ammonia and nitrate nitrogen.

Three potential causes of water quality degradation are prominent in various parts of the watershed and deserve additional attention in the detailed planning process. Most of the Hanalei watershed is serviced by cesspools or septic systems, and the Hanalei Watershed Hui, EPA, and DOH placed an early emphasis on onsite wastewater disposal systems. the Hui has formed a Wastewater Working Group to working with Kauai County to solve these problems with the County. Existing County of Kauai plans call for improved wastewater treatment, and government agencies can acquire low interest loans from DOH's State Revolving Fund (SRF) to assist with upgrading cesspools to septic system.

Invasive species are an ongoing threat to the biological integrity of the waterbodies, and DLNR strategies for their control (State of Hawaii Aquatic Invasive Species Management Plan, www.hawaii.gov/dlnr/dar/pubs/ais_mgmt_plan_final.pdf) could perhaps be integrated with the DOH mission to protect and restore the biological, chemical, and physical integrity of state waters. Feral pigs are widely believed to accelerate erosional processes and act as sources of nutrient and bacterial input. DLNR’s recent Plan to Reduce the Statewide Feral Pig Population (www.hawaii.gov/dlnr/reports/FW07-Feral_Pig_Report%20_HCR_98_SD1-06_.pdf) is one reference for planning specific pig control activities.

Much of the information above is based upon Section 5 (Source Analysis) and provides a relative breakdown of pollutant contribution by landcover class. Generally, the higher the percentage of a particular land cover class the higher the overall pollutant load contribution. Further, in the TMDL allocation scenarios each land cover class was given

a uniform reduction. This raises a few questions to be addressed in subsequent TMDL phases:

1) Does the relative pollutant loading by land cover class provide enough information to potential implementers to make informed decisions about specific implementation activities (both locations and type of practice)?
2) Are there additional allocation scenarios (more/less reduction from particular land cover class) that may be more appropriate and increase the likelihood of water quality improvements?
3) Relative to the land cover classes, will additional information need to be considered to identify the type and location of specific implementation activities (e.g., do certain areas within the scrub/shrub land cover class with a particular slope, soil type or specific vegetation cover type have more importance relative to TSS, Enterococcus or nutrients?

The high percentage reductions proposed in the TMDL have alarmed readers, particularly taro farmers, who recognize the current uncertainty about the extent of their individual and collective responsibility for pollutant loading. Clarification of which farming locations and practices may be more or less responsible for increasing the conveyance of high TSS discharge to the stream and estuaries, and how, is a potential activity for phased development and adaptive implementation of the TMDLs. We hope that addressing these kinds of concerns in cooperation with farming organizations and agency resources will teach us all how to use the TMDL process to achieve environmental results in a reasonable manner.

The definition of and approach to “natural sources” can also be addressed in future phases of TMDL development. However, depending upon this definition and approach, loading from “natural sources” is not necessarily irreducible, and is still required to result in full achievement of the water quality standards. Factors affecting this source identification and analysis include the impacts of native and naturalized wildlife, invasive plants and animals, watershed-scale erosional processes and mass wasting, climate variability and change, and social capacity for meaningful large-scale intervention and repair. Examples of these factors identified during TMDL development include egrets nesting in large groups in hau bush overhanging the stream; albizzia trees that colonize landslide scars; the interplay between rainfall, streamflow, ocean circulation, and sea-level; and the role of fencing in controlling feral pigs for both water quality and game management purposes.

8.5. Implementation tools/technical assistance

Implementation tools and technical assistance are widely available. DOH and EPA recently designated Hanalei as one of three priority areas for achieving water quality improvements, and detailed planning efforts can strive to link with ongoing scientific research and DOH programs (e.g. additional TMDL development and other monitoring and assessment activities). Some readily available sources of tools and technical assistance for planning specific implementation activities include:

- U.S. Department of Agriculture Natural Resource Conservation Service (USDA-NRCS) Hawaii Field Office Technical Guide and other materials (www.hi.nrcs.usda.gov/technical)
- DLNR Best Management Practices for Maintaining Water Quality in Hawaii (www.state.hi.us/dlnr/dofaw/pubs/BMPs_bestmanagement.pdf)
- EPA National Management Measures to Control Nonpoint Source Pollution; Stream Corridor Restoration Handbook; other materials (www.epa.gov/owow/nps/pubs.html)
- Center for Watershed Protection (www.cwp.org)

8.6. Financial assistance

Information about several government and non-government funding sources, including many of those listed below, is compiled in *Funding Sources for Communities – A Watershed Focus* (Environmental Planning Office 2001). This DOH information packet is available from the Environmental Planning Office. Contact Barbara Matsunaga at 586-4337 (barbara.matsunaga@doh.hawaii.gov). Principal sources of financial assistance include:

- DOH Polluted Runoff Control Program grants under Section 319(h) of the Clean Water Act
- DOH State Water Pollution Control Revolving Fund programs
- DLNR Watershed Partnerships
- U.S./Hawaii Coral Reef Initiative, including Local Action Strategy
- State of Hawaii Department of Business, Economic Development, and Tourism Coastal Non-Point Implementation Program grants
- USDA-NRCS farm bill programs
- U.S. Environmental Protection Agency (www.epa.gov/owow/nps/funding.html)
- The National Fish and Wildlife Federation coral reef conservation projects

8.7. Previous/ongoing efforts

Detailed planning efforts can use the results and momentum of previous and ongoing implementation efforts for prioritizing and mobilizing implementation activities. Recent efforts by the Waipa Foundation, Hanalei Watershed Hui, and others have provided valuable experience in a number of different structural and non-structural best management practices. Given the prevalence of wetland farming in Hanalei, and the ability of wetlands to enhance water quality, projects like lo'i restoration (see Dye, T.S. 2004. Description and mapping of a lo`i system in Waipa, Kauai. T.S. Dye & Colleagues, Archaeologists, Inc. Honolulu) and adjustment of contemporary farming practices (e.g. fertilization, irrigation, and drainage) deserve serious consideration.

The table below suggests how the TMDL implementation framework could be constructed as a matrix of pollutants, source types and locations (see Section 5, Source Analysis), and potential implementation tools/resources to address source control and pollutant load reduction. Hanalei residents are the ultimate force for reducing pollutant loads and improving water quality, and will hopefully take the lead in filling out this matrix with specific implementation strategies and tasks. While the TMDL report did 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.

Solutions that are developed from a watershed perspective for integrating water quality management throughout Hanalei and adjacent drainage basins will have the greatest impact. This is always challenging given the many residences, businesses, and public facilities that produce polluted groundwater and polluted runoff and the multiple agencies that have management duties, regulatory authority, and planning responsibility for water quality. In such an environment, it may be useful to carefully strategize ways to best represent community water quality concerns, mobilize community water quality improvement efforts, and to track and participate in related agency activities.

Table 26. Example – TMDL Implementation Matrix

POLLUTANT and Waterbody	POTENTIAL SOURCE	LOCATION	RECOMMENDATIONS	IMPLEMENTERS
TURBIDITY (SEDIMENT) Hanalei Stream/Estuary Waipa Stream/Estuary Waioli, Waikoko Estuaries	Alteration of forested landscape by feral livestock, alien tree and plant species Streambank erosion Landslides Cultivated land/taro lo'i	Forested portions of watershed	Fishpond/stream restoration Trail restoration/road management Sedimentation basins Determine natural vs. anthropogenic sediment contributions	Kauai County, Hanalei Watershed Hui, DLNR (DOFAW), USFWS, Watershed Partnership, DOH, taro farmers, Waipa Foundation, Kamehameha Schools
ENTEROCOCCUS Hanalei Stream/Estuary	Individual wastewater systems Feral and domestic animals Soil background	wildlands and wetlands in the larger watersheds (Hanalei, Waioli, Waipa) and cultivated lands in Waikoko	Cesspool closure/upgrade Septic system installation/upgrade Centralized wastewater treatment system Ungulate fencing/management	Kauai County, Hanalei Watershed Hui, DLNR (DOFAW), USFWS, Watershed Partnership, DOH, , taro farmers, Waipa Foundation, Kamehameha Schools
NUTRIENTS Hanalei Stream/Estuary; Waioli Stream/Estuary; Waipa Stream/Estuary; Waikoko Stream/Estuary	Individual wastewater systems Agriculture (fertilizers) Residential use of fertilizer? Pet waste? Watershed background	Cultivated lands	Cesspool closure/upgrade Septic system installation/upgrade Centralized wastewater treatment system Education (pet waste, residential fertilizer, etc) Sediment management	Kauai County, Hanalei Watershed Hui, DLNR (DOFAW), USFWS, Watershed Partnership, DOH, taro farmers, Waipa Foundation, Kamehameha Schools

8.8. Phased TMDL Development and Implementation Schedule

A phased TMDL process is an approach for developing TMDLs that require long-term loading reductions from difficult-to-solve problem, while pursuing near-term allocations for more readily addressed sources. Phased TMDLs are useful in situations (as in Hanalei) where lack of available information makes it uncertain that the control strategies will work to achieve water quality standards, and nonpoint source reductions are difficult to predict, so that load allocations should be iterative. Also, since the TMDL process for Hanalei was initiated to complement the multi-year, EPA-funded Targeted Watershed Initiative Grant (to the Hanalei Watershed Hui), which implemented several control measures on readily-addressable sources, a phased TMDL approach is appropriate. Finally, the extent of ongoing interest, commitment, and resources for further monitoring, analysis, and management actions in the watershed assures that phased TMDL development and implementation is a sound water quality improvement strategy.

Therefore, the implementation timeline presented in the Draft TMDL has been modified based on DOH adoption of this phased approached and related program actions occurring in 2007 and 2008. Completed activities are indicated by italic type, those in progress by bold type, and those not yet mandated or initiated by regular type.

2007

- *Nonpoint source management measures for many readily addressed sources installed over the last several years as a result of ongoing community efforts.*
- **DOH begins using the TMDLs to guide water quality management and water pollution control decisions.**
- **Partners and sponsors establish TMDL implementation priorities and fund/support related activities.**

2008

- *EPA approves DOH 2006 Water Quality Monitoring and Assessment Report.*
- **DOH clarifies remaining TMDL requirements.**
- **EPA and DOH begin Phase 2 TMDL development for Hanalei embayment (marine waters), with associated review of stream and estuary data and allocations.**
- **Scientific research, water pollution control (permitting and enforcement), water quality monitoring and assessment, and polluted runoff control efforts continue to become better coordinated and integrated through collaborative efforts.**
- **Initial TMDL implementation projects, funded by 319(h) and other sources, are completed.**
- *DOH requests proposals for further implementation of a Watershed Based Plan and/or TMDL Implementation Plan priorities.*
- **EPA approves Phase 1 TMDL for Hanalei streams and estuaries.**

2009

- EPA approves Phase 2 TMDLs (marine waters), DOH and/or others revise implementation plans accordingly.

2009 (Continued)

- Development of a Watershed Based Plan is the focus of Phase 3, including BMP assessment and selection and development of an associated watershed monitoring strategy.
- DOH and/or others complete stream biological assessments for Waioli, Waipa, and Waikoko.

2010

- Watershed Based Plan (with TMDL Implementation Plan?) completed.
- TMDL implementation actions continue, now tied specifically to Watershed Based Plan and effectiveness monitoring.
- Collaborators develop a watershed–wide monitoring and assessment strategy for documenting water quality problems and trends, environmental results, and management measure efficiency.

2011

- Phase 3 TMDL development and approval incorporates information gained from the previous three years of scientific and management efforts to improve identification of pollutant sources and their linkages with stream and estuary impairments.
- Identify and initiate monitoring activities to fill Phase 4 (whole watershed) information gaps.

2012

- Phase 4 TMDL development, based on comprehensive review and synthesis of all activities with focus on marine waters and coral reef conservation

The current focus of Phase 2 TMDL development for Hanalei marine waters is obtaining new scientific information about ocean circulation dynamics, embayment water quality status, and groundwater sources of pathogens and nutrients. Data from ongoing USGS hydrologic measurements and sediment monitoring, BMP monitoring by taro farmers and the U.S. Fish and Wildlife Service, and ambient monitoring by DOH, Hanalei Watershed Hui, and Surfrider Foundation may also be used in the analysis. The Hanalei Watershed Hui proposal to develop a watershed plan, which was submitted in response to the Department of Health (DOH)-Polluted Runoff Control Program (PRCP) Request for Proposals Number 08-01, was selected for funding on July 18, 2008. Development of the watershed plan is anticipated to be completed within 13 months from the receipt of the notice to proceed from DOH (early 2010) and will address the Environmental Protection Agency's nine elements for watershed-based plans. Specific components that will aid with the phased TMDL include the collection of additional data/information in order to gain a better understanding of pollutant sources and their relative contributions to total pollutant loads; watershed characterization to include a synthesis of existing information and Identify important gaps in data and knowledge bases and suggestions for additional information needs and priorities for the future. The approach to developing this plan will include the synthesis of all previous water quality-related work in the Hanalei watersheds, further assessment of water quality conditions through focused assessment/data collection activities to identify specific pollutant sources in the

watersheds, identification of appropriate best management practices or pollution control measures, and community involvement through public meetings and an education and outreach campaign.

We expect that future phases of TMDL development and implementation in this EPA and DOH priority watershed will continue to be supported by DOH 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 establish measurable milestones, determine if the pollution control measures being implemented are resulting in actual load reductions with watershed-scale effects, and deciding how to change course if they are not.

8.9. Implementation Assurance

Implementation of the load allocations and required load reductions will result in attainment of the water quality standards for turbidity in six waterbodies (Hanalei Stream, Hanalei estuary, Waioli estuary, Waipa Stream, Waipa estuary, and Waikoko estuary) and for *enterococcus* in two waterbodies (Hanalei Stream and estuary). The State will pursue implementation of the approved load allocations through Hawai'i's Implementation Plan for Polluted Runoff Control (HIDOH, 2001), Hawaii's Coastal Nonpoint Pollution Control Program Management Plan (State of Hawaii Department of Business, Economic Development, and Tourism) (State of Hawai'i, 1996), and the Clean Water State Revolving Fund Intended Use Plan (DOH), all of which serve the State Water Quality Standards (HAR §11-54) (HIDOH, 2004).

Hawaii's Implementation Plan for Polluted Runoff Control and Management Plan for Coastal Nonpoint Pollution Control are both being updated and revised to better address, among other objectives, implementation of TMDL allocations. In addition, the development of watershed-based plans and TMDL Implementation Plans would provide specific measures for reducing loads in the Hanalei Bay watershed. If such plans address the nine elements required by USEPA guidance (USEPA, 2003) and incorporate the LA objectives identified in Table 14 and Table 15, they will assist in the application for additional Clean Water Act §319(h) incremental funds for water quality improvement projects.

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.

9. Public Participation

TMDL development in the Hanalei watershed is an outcome of over ten years of public participation in initiating and sustaining environmental protection programs. Public nomination of the Hanalei River led to a 1996 waterbody assessment by DOH and a 1998 designation by President Clinton as an American Heritage River. The community-based Limits of Acceptable Change planning process identified in the Heritage River nomination established an interest in monitoring and environmental standards, and DOH partnership in the Heritage River program began with collaborative assessment of the water quality impact of summer boating and other water quality sampling activities.

Based on the results of the 1996 waterbody assessment, Hanalei River was added to the State's §303(d) list in 2001. The 2000 Hanalei Watershed Hui (HWH) Action Plan ranked TMDL development 14th out of its 46 priority actions. The DOH TMDL program began working with HWH in 2002, assisting with the completion of the University of Hawaii Department of Urban & Regional Planning student practicum (Building Collaboration: Toward Co-management for the Hanalei Ahupua'a, Kauai, Hawaii) and supporting the submittal of the HWH Targeted Watershed Initiative Grant (TWIG) proposal to EPA. The TWIG was awarded to HWH in 2003 and completed in 2006.

In support of the TWIG and associated TMDL development, HWH invited the Hanalei community to participate in six community meetings and various volunteer activities, and the Waipa Foundation played a major role in community outreach and school education through their existing programs. HWH newsletters were produced irregularly for distribution throughout the community, providing project updates and opportunities for involvement. A community bulletin board in the local shopping mall provided information about HWH and latest beach bacterial counts/warnings. Community forums on specific projects were convened, video recorded and broadcast on local public access television, with tapes available for borrowing at the Kaua‘i public libraries and the HWH office. HWH also participated with booths in numerous community events (Ocean Festival, Earth Day, Taro Festival). The HWH "Water Sciences in the Ahupua'a" education program provides classroom and/or field learning experiences for hundreds of students each year. HWH maintains a website (www.hanaleiwatershedhui.org) where general information updates and water quality data are posted monthly (Hanalei Watershed Hui, 2006).

Various aspects of TMDL development and other Hanalei watershed management concerns have been the subject of numerous articles and presentations by HWH, agencies, and scholars for a diverse range of audiences on Kauai, statewide, and nationally, and globally. The HWH applied a broad-based approach to community outreach in its attempts to reach as much of the diverse North Shore community as possible, and built a firm foundation, with good name recognition, for cleaning up the water and protecting our natural resources. However, maintaining direct community involvement in and community financial support for HWH programs is an ongoing challenge. One of the lessons learned from the Heritage River, TWIG, and TMDL processes to date (see public comments in Appendix H) is that subsequent phases of the

TMDL process and ongoing HWH efforts must reach out more directly for greater community involvement and support (Hanalei Watershed Hui, 2006).

During TMDL scoping, data collection, loading analysis, and draft report writing, Tetra Tech, HWH, and DOH-EPO staff consulted with various interested parties and sources of information, including but not limited to:

State of Hawaii Department of Health (Clean Water Branch, Safe Drinking Water Branch, and Wastewater Branch)
U.S. Environmental Protection Agency
University of Hawaii (Department of Urban and Regional Planning, Sea Grant Extension Program, Center for Conservation Research and Training, and College of Tropical Agriculture and Human Resources)
Waipa Foundation
U.S. Department of Agriculture Natural Resources Conservation Service
U.S. Department of Agriculture Forest Service (Pacific Southwest Research Station, Institute of Pacific Islands Forestry)
U.S. Fish and Wildlife Service (Hanalei National Wildlife Refuge)
U.S. Geological Survey (Pacific Water Science Center, Pacific Islands Ecosystem Research Center, Pacific Island Ecological Services Office, and Western Coastal and Marine Geology Group)
Stanford University (various investigators)

These discussions included a field orientation in February 2004, which led to the finalization of the project data collection plan. On July 08, 2004, the DOH TMDL Coordinator presented the project data collection plan to a HWH community forum and discussed TMDL development and other Kauai water quality improvement projects with the group attending.

After internal DOH review and preliminary DOH approval, a draft TMDL report was published for public review and a public information meeting was scheduled for February 20, 2007 to present and discuss the results. Public notices announcing the availability of the draft report and inviting participation in the public review process were published in local newspapers on February 04, 2007 (see Affidavits of Publication in Appendix H) and on the DOH-EPO website. Letters announcing the availability of the draft report and inviting participation in the public review process were mailed circa February 01, 2007 to a total of 23 landowners of record or other individuals and organizations with known connections to water quality management and watershed health within the planning area (see distribution list in Appendix H). These notices and letters, along with informal communication among the project network (telephone, email, and word of mouth), generated attendance by approximately 40 people at the public information meeting (see sign-in sheet listing 33 people in Appendix H) and a great deal of follow-up discussion. During the same week, a number of Hanalei citizens also attended a Hanalei Watershed Science Workshop hosted by HWH and USGS (pubs.usgs.gov/of/2007/1219).

After the public information meeting, additional meetings were held with the Kauai Taro Growers Association and the Princeville Corporation at their request, and additional discussions were held with various organizations and individuals. DOH received 13 written comments on the draft report, and a consolidated response was mailed to each commenter on September 29, 2008 (see Appendix H). Ongoing communication between

HWH, DOH water programs, Tetra Tech, and other participants in the TMDL process currently focuses on:

- water quality monitoring (sediment sampling at USGS station and monitoring of coastal recreational waters by HWH) and related public health decisions (beach postings);

- completing a watershed based plan that addresses community concerns, initiates TMDL implementation, and refines pollutant source identification; and

- scoping the next phase of TMDL development (embayment waters) and integrating it with the watershed based plan efforts and the review and potential revision of stream and estuary load allocations.

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Appendix A:
Data Analyses

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Introduction and Methodology

The following analyses characterize and quantify in-stream exceedances of the various Hawai'i water quality criteria (HIDOH, 2004b) in estuaries and streams (see Sections A.1 and A.2, respectively). In addition, Section A.3 provides analyses of water quality data at the USGS gage and Weke Road stations while considering the various flow conditions at the USGS gage. The remainder of this section provides further detail on the methodologies used to conduct these analyses.

Sections A.1 and A.2: Review of Impaired Segments

To perform these analyses, in-stream data for estuaries and streams were compared against the applicable WQC (Table 5 and Table 6, respectively). Data for individual stations were grouped by waterbody to facilitate analyses and increase samples sizes.

For the *enterococcus* analyses in both the estuaries and streams, the 30-day geometric mean (based on 5 or more samples) and the single sample maximum criteria were evaluated. Similarly, for the nutrients and sediment parameters, the geometric mean (based on the entire dataset), not-to-exceed 10 percent of the time, and not-to-exceed 2 percent of the time WQC were also evaluated. During the stream analyses, wet and dry WQC were considered separately and compared to data collected in the same season.

For the *enterococcus* analyses, the number of geometric means is less than the number of samples because the geometric means calculated are based on 5 or more samples collected in a 30-day period. Some data records did not meet this criterion and were excluded from the geometric mean analyses. For all other parameters, the geometric mean was based on the entire dataset (i.e. no specified number of samples or number of days); therefore, only a single geometric mean value was calculated. During the geometric mean analyses, the calculated geometric mean(s) for each waterbody was compared to the applicable WQC. Values above the WQC were considered exceedances (identified by "XS" in the analysis tables) and the total number of geometric means calculated was summed (identified by "Count" in the analysis tables). Percent exceedances ("XS%" in the analysis tables) were calculated by dividing the number of exceedances by the number of measurements.

For the single sample maximum (*enterococcus*) and not-to-exceed analyses, each individual sample was compared against the associated WQC. For the *enterococcus* evaluations, any value greater than the WQC was considered an exceedance (identified by "XS" in the analysis tables) and the total number of samples was summed (identified by "Count" in the analysis tables). For the not-to-exceed analyses, exceedances of the standard are permitted in 10% and 2% of the samples, depending on the WQC considered. Once this threshold is reached, any value greater than the WQC was considered an exceedance (identified by "XS" in the analysis tables) and the total number of samples was summed (identified by "Count" in the analysis tables). For both types of analysis, percent exceedances ("XS%" in the analysis tables) were calculated by dividing the number of exceedances by the number of measurements.

Summary graphs and a table of summary statistics were also included for each analysis. An example of the summary table is presented below with descriptions in red.

Month
Summary statistics are separated by month to characterize exceedances

XS:Count
The ratio of the number of exceedances of the numeric standard (XS) and the number of measurements (Count).

Summary Statistics (Data: 10/31/2003 to 9/22/2005)

Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.717	0.717	0.191	1.243	0.454	0.980	1:2	50%
Feb	0.339	0.339	0.195	0.484	0.267	0.411	0:2	0%
Mar	0.199	0.199	0.157	0.242	0.178	0.221	0:2	0%
Apr	0.216	0.216	0.212	0.221	0.214	0.219	0:2	0%
May	0.19	0.1	0.19	0.19	0.19	0.19	0:1	0%
Jun	0.1	0.1	0.1	0.155	0.156	0.2	0:2	0%
Jul	0.3	0.342	0.32	0.36	0.334	0.3	0:2	0%
Aug	0.146	0.146	0.121	0.172	0.134	0.159	0:2	0%
Sep	0.336	0.336	0.221	0.451	0.279	0.394	0:2	0%
Oct	0.183	0.183	0.010	0.357	0.097	0.270	0:2	0%
Nov	0.351	0.351	0.307	0.396	0.329	0.374	0:2	0%
Dec	0.465	0.465	0.238	0.692	0.351	0.578	1:2	50%
All Data	**0.312**	**0.238**	**0.010**	**1.243**	**0.193**	**0.358**	**2:23**	**9%**

EXAMPLE

Summary statistics
Presented: (1) by month and (2) based on all measurements. These calculations include the mean, median, minimum, maximum, and the 25th and 75th percentiles of the observed or calculated measurements.

XS%
The percent of measurements that exceed the numeric WQC (by month and overall)

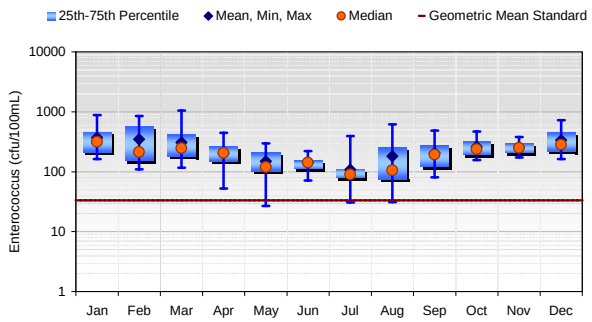
Section A.3: Streamflow Comparisons

Critical and seasonal conditions impacting water quality at the USGS gage and Weke Road stations were assessed using the daily average flow values from the USGS gage on the same date as the water quality samples. Flow-associated trends are shown on the left side of each figure. These trends, which are presented in a graph and table, were evaluated by determining flow-weighted concentrations for all samples and presenting them by percentile range of flow. The graphs can help identify trends in pollutant levels caused by different flow conditions (high flows, low flows, etc.).

Seasonal trends are illustrated on the right side of each figure in Section A.3. These graphs show the monthly flow-weighted concentrations for all samples and all years. Viewing the data as an annualized monthly profile may identify trends in pollutant levels attributable to upstream land management. To further characterize the data, monthly flow percentile analyses were performed and presented in tabular format. The flow percentiles were based on the entire dataset and percentiles were not calculated individually for each month due to small sample sizes. These monthly flow percentile tables present the average monthly pollutant concentration and number of samples.

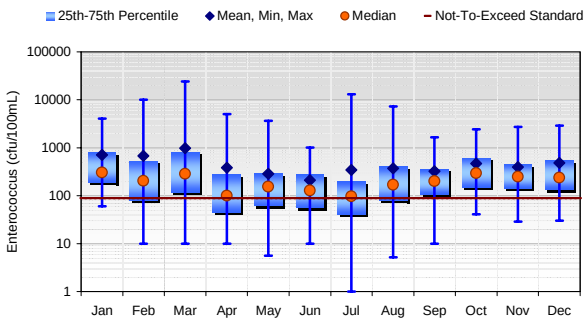
A-1. Review of Impaired Segments – Estuaries

Geometric Mean Analysis
(WQC = 33 cfu/100mL)



Summary Statistics (Data: 1/9/1995 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	374	315	163	884	212	463	45:45	100%
Feb	349	214	109	850	153	572	48:48	100%
Mar	308	249	116	1042	179	420	78:78	100%
Apr	204	205	52	445	151	265	69:69	100%
May	149	120	27	296	103	210	50:52	96%
Jun	140	141	71	222	113	154	74:74	100%
Jul	108	90	31	395	79	111	65:67	97%
Aug	183	106	31	615	76	255	69:70	99%
Sep	206	192	81	485	121	273	90:90	100%
Oct	263	240	157	472	194	316	74:74	100%
Nov	257	250	172	381	208	298	71:71	100%
Dec	338	283	163	725	219	451	66:66	100%
All Data	234	207	27	1042	131	289	799:804	99%

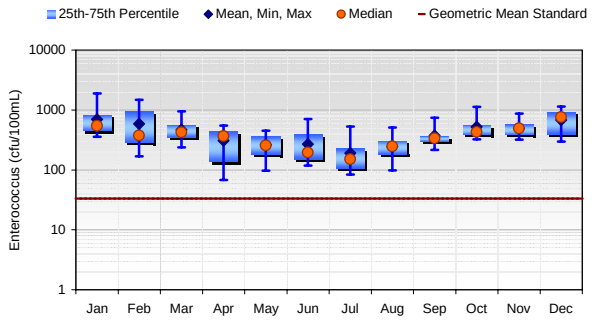
Single Sample Maximum Analysis
(WQC = 89 cfu/100mL)



Summary Statistics (Data: 1/9/1995 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	712	305	60	4039	190	801	48:53	91%
Feb	680	205	10	10112	82	527	54:76	71%
Mar	975	288	10	24196	120	802	65:75	87%
Apr	386	101	10	5012	46	272	36:61	59%
May	288	155	6	3654	62	292	49:77	64%
Jun	210	129	10	1011	57	273	44:71	62%
Jul	344	97	1	12997	41	195	37:73	51%
Aug	374	170	5	7270	80	399	71:97	73%
Sep	322	201	10	1664	109	353	64:79	81%
Oct	471	294	41	2419	153	612	65:72	90%
Nov	396	249	29	2723	145	451	73:79	92%
Dec	484	237	30	2900	135	546	47:54	87%
All Data	463	195	1	24196	92	450	653:867	75%

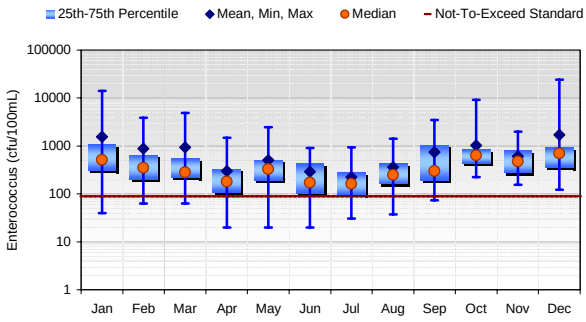
Figure A-1. Enterococcus analyses for the Hanalei River Estuary

Geometric Mean Analysis
(WQC = 33 cfu/100mL)



Summary Statistics (Data: 8/5/2001 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	698	548	357	1896	455	826	22:22	100%
Feb	590	378	170	1487	287	942	22:22	100%
Mar	467	424	238	949	355	555	20:20	100%
Apr	309	367	68	549	137	440	13:13	100%
May	264	256	97	452	181	365	22:22	100%
Jun	268	195	118	706	152	393	25:25	100%
Jul	191	152	84	532	107	228	24:24	100%
Aug	245	249	98	511	181	307	29:29	100%
Sep	374	339	215	744	307	363	24:24	100%
Oct	526	433	326	1130	393	561	18:18	100%
Nov	492	492	322	871	390	573	18:18	100%
Dec	680	761	297	1145	396	913	25:25	100%
All Data	421	361	68	1896	239	501	262:262	100%

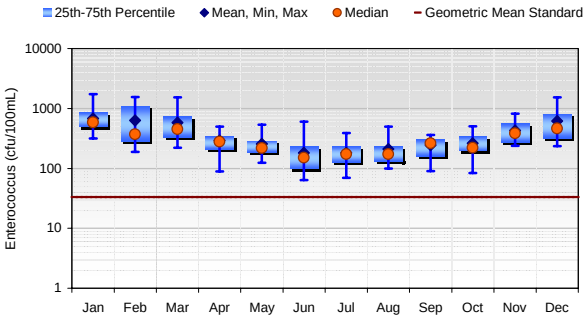
Single Sample Maximum Analysis
(WQC = 89 cfu/100mL)



Summary Statistics (Data: 8/5/2001 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	1551	516	40	14136	311	1080	21:22	95%
Feb	879	350	63	3873	203	644	19:21	90%
Mar	938	282	63	4884	221	559	17:20	85%
Apr	298	179	20	1483	109	331	18:22	82%
May	504	329	20	2489	192	504	24:26	92%
Jun	289	171	20	908	103	437	21:27	78%
Jul	225	161	31	933	97	282	20:25	80%
Aug	360	249	37	1421	161	434	30:32	94%
Sep	742	298	74	3448	191	1043	21:23	91%
Oct	1036	633	223	9208	443	842	21:21	100%
Nov	612	477	155	1989	277	817	24:24	100%
Dec	1716	697	122	24196	353	920	23:23	100%
All Data	731	341	20	24196	171	641	259:286	91%

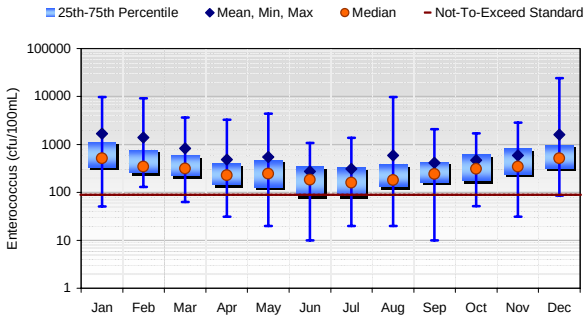
Figure A-2. Enterococcus analyses for the Waioli Stream Estuary

Geometric Mean Analysis
(WQC = 33 cfu/100mL)



Summary Statistics (Data: 11/24/2001 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	679	587	319	1740	498	862	22:22	100%
Feb	633	374	189	1547	282	1099	22:22	100%
Mar	578	454	221	1530	337	738	20:20	100%
Apr	294	281	88	498	211	345	13:13	100%
May	258	219	124	539	188	287	21:21	100%
Jun	183	152	64	605	99	230	25:25	100%
Jul	182	173	69	391	125	231	24:24	100%
Aug	210	173	99	501	131	230	29:29	100%
Sep	243	264	90	363	159	300	25:25	100%
Oct	264	222	84	507	198	345	18:18	100%
Nov	433	387	238	820	277	563	18:18	100%
Dec	614	465	235	1535	321	807	24:24	100%
All Data	**375**	**280**	**64**	**1740**	**188**	**449**	**261:261**	**100%**

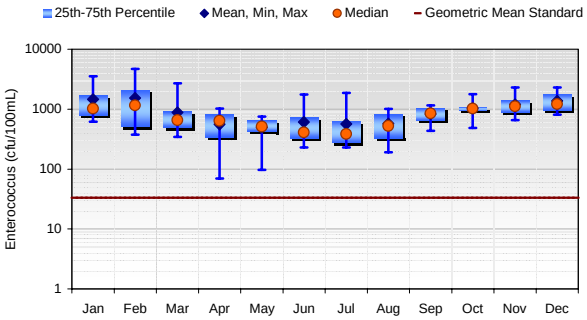
Single Sample Maximum Analysis
(WQC = 89 cfu/100mL)



Summary Statistics (Data: 11/24/2001 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	1677	517	51	9804	338	1120	20:22	91%
Feb	1391	345	131	9139	256	771	21:21	100%
Mar	825	314	63	3654	223	600	19:20	95%
Apr	483	226	31	3255	146	402	18:21	86%
May	545	244	20	4360	128	468	21:26	81%
Jun	273	183	10	1081	86	352	20:27	74%
Jul	308	160	20	1376	86	331	17:25	68%
Aug	595	179	20	9804	133	375	23:30	77%
Sep	412	241	10	2105	164	431	20:23	87%
Oct	471	309	52	1722	175	605	19:21	90%
Nov	587	345	31	2851	238	815	24:25	96%
Dec	1596	513	86	24196	326	966	23:24	96%
All Data	**744**	**298**	**10**	**24196**	**146**	**591**	**245:285**	**86%**

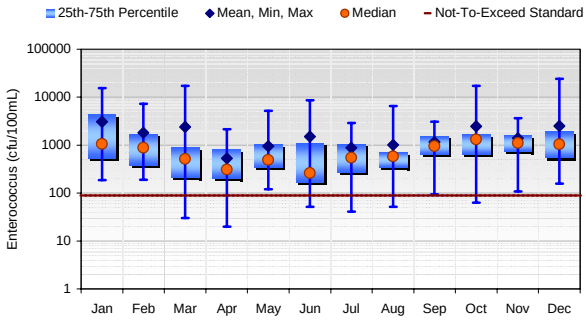
Figure A-3. Enterococcus analyses for the Waipa Stream Estuary

Geometric Mean Analysis
(WQC = 33 cfu/100mL)



Summary Statistics (Data: 9/21/2002 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	1454	1024	619	3568	796	1671	23:23	100%
Feb	1537	1158	374	4739	509	2084	20:20	100%
Mar	882	655	343	2705	496	902	19:19	100%
Apr	562	638	70	1026	342	805	13:13	100%
May	497	510	97	752	426	648	17:17	100%
Jun	612	413	230	1765	335	726	15:15	100%
Jul	563	387	231	1876	278	632	17:17	100%
Aug	570	526	192	1012	329	814	21:21	100%
Sep	829	853	436	1158	656	1032	15:15	100%
Oct	1040	1028	488	1778	965	1063	13:13	100%
Nov	1193	1117	657	2314	892	1398	18:18	100%
Dec	1369	1208	812	2302	973	1764	24:24	100%
All Data	**966**	**812**	**70**	**4739**	**503**	**1103**	**215:215**	**100%**

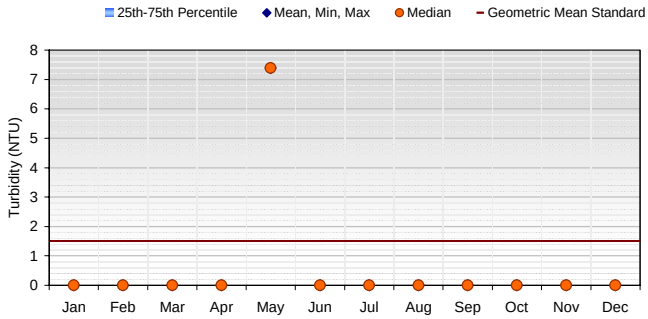
Single Sample Maximum Analysis
(WQC = 89 cfu/100mL)



Summary Statistics (Data: 9/21/2002 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	3070	1056	185	15531	536	4352	21:21	100%
Feb	1815	886	189	7270	383	1693	20:20	100%
Mar	2406	511	30	17329	212	915	19:20	95%
Apr	533	311	20	2140	201	833	14:17	82%
May	955	492	120	5172	349	1032	18:18	100%
Jun	1512	259	52	8664	170	1097	16:18	89%
Jul	885	547	41	2909	275	1043	16:17	94%
Aug	1006	583	52	6488	345	703	20:21	95%
Sep	1158	959	94	3076	645	1529	17:17	100%
Oct	2471	1314	63	17329	657	1669	20:21	95%
Nov	1410	1110	109	3654	741	1609	23:23	100%
Dec	2520	1043	156	24196	547	1965	23:23	100%
All Data	**1697**	**763**	**20**	**24196**	**345**	**1490**	**227:236**	**96%**

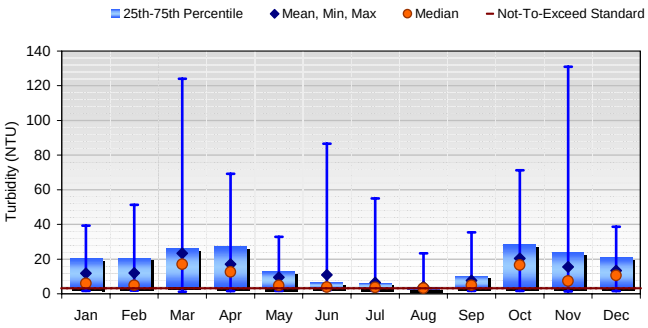
Figure A-4. Enterococcus analyses for the Waikoko Stream Estuary

Geometric Mean Analysis
(WQC = 1.5 NTU)



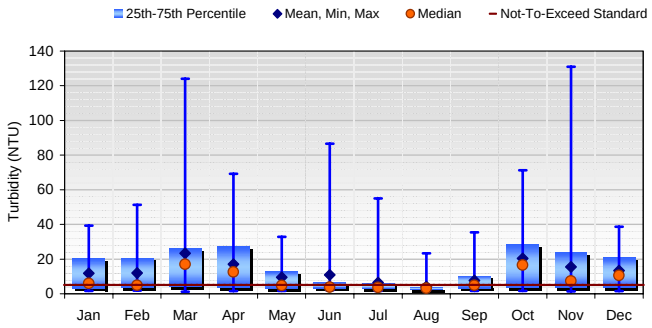
Summary Statistics (Data: 11/5/2001 to 5/24/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0	0	0	0	0	0	0:0	n/a
Feb	0	0	0	0	0	0	0:0	n/a
Mar	0	0	0	0	0	0	0:0	n/a
Apr	0	0	0	0	0	0	0:0	n/a
May	7.39	7.39	7.39	7.39	7.39	7.39	1:1	100%
Jun	0	0	0	0	0	0	0:0	n/a
Jul	0	0	0	0	0	0	0:0	n/a
Aug	0	0	0	0	0	0	0:0	n/a
Sep	0	0	0	0	0	0	0:0	n/a
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	**7.39**	**7.39**	**7.39**	**7.39**	**7.39**	**7.39**	**1:1**	**100%**

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



Summary Statistics (Data: 11/5/2001 to 5/24/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	11.80	5.96	1.65	39.30	3.10	20.35	42:55	76%
Feb	11.97	4.89	1.91	51.20	3.42	20.78	50:58	86%
Mar	23.40	17.00	1.19	124.00	4.12	26.20	55:65	85%
Apr	17.02	12.60	1.55	69.20	3.55	27.20	59:69	86%
May	9.51	4.72	1.65	32.80	2.91	12.98	54:74	73%
Jun	10.83	3.89	2.04	86.60	3.21	6.47	43:51	84%
Jul	6.38	3.73	1.76	54.90	2.78	6.07	31:48	65%
Aug	4.13	3.19	1.83	23.30	2.46	3.88	31:56	55%
Sep	7.63	4.92	1.67	35.50	3.25	10.48	45:56	80%
Oct	20.44	16.60	1.63	71.30	3.43	28.63	45:56	80%
Nov	15.46	7.38	1.38	131.00	3.90	23.90	49:59	83%
Dec	13.36	10.60	1.50	38.70	3.54	20.95	44:55	80%
All Data	**12.89**	**5.34**	**1.19**	**131.00**	**3.18**	**19.70**	**548:702**	**78%**

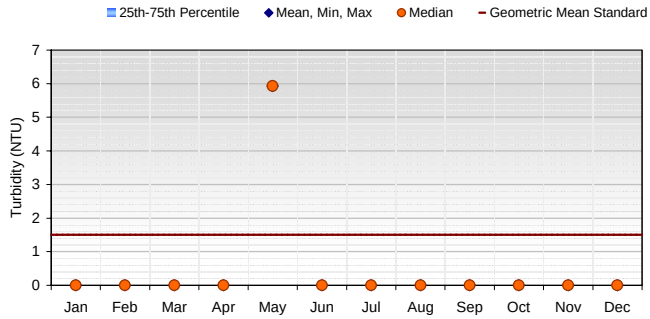
Not to Exceed 2% of the Time Analysis
(WQC = 5 NTU)



Summary Statistics (Data: 11/5/2001 to 5/24/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	11.80	5.96	1.65	39.30	3.10	20.35	31:55	56%
Feb	11.97	4.89	1.91	51.20	3.42	20.78	29:58	50%
Mar	23.40	17.00	1.19	124.00	4.12	26.20	44:65	68%
Apr	17.02	12.60	1.55	69.20	3.55	27.20	45:69	65%
May	9.51	4.72	1.65	32.80	2.91	12.98	35:74	47%
Jun	10.83	3.89	2.04	86.60	3.21	6.47	15:51	29%
Jul	6.38	3.73	1.76	54.90	2.78	6.07	17:48	35%
Aug	4.13	3.19	1.83	23.30	2.46	3.88	7:56	13%
Sep	7.63	4.92	1.67	35.50	3.25	10.48	28:56	50%
Oct	20.44	16.60	1.63	71.30	3.43	28.63	38:56	68%
Nov	15.46	7.38	1.38	131.00	3.90	23.90	37:59	63%
Dec	13.36	10.60	1.50	38.70	3.54	20.95	34:55	62%
All Data	**12.89**	**5.34**	**1.19**	**131.00**	**3.18**	**19.70**	**360:702**	**51%**

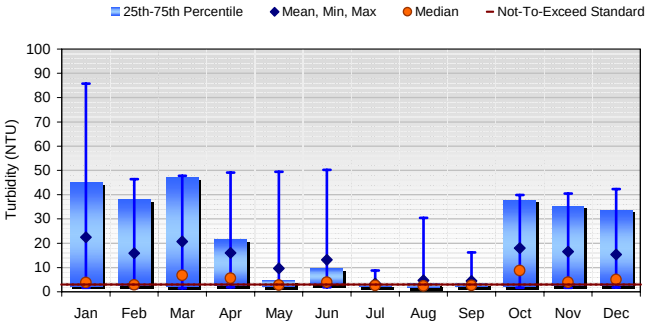
Figure A-5. Turbidity analyses for the Hanalei River Estuary

Geometric Mean Analysis
(WQC = 1.5 NTU)



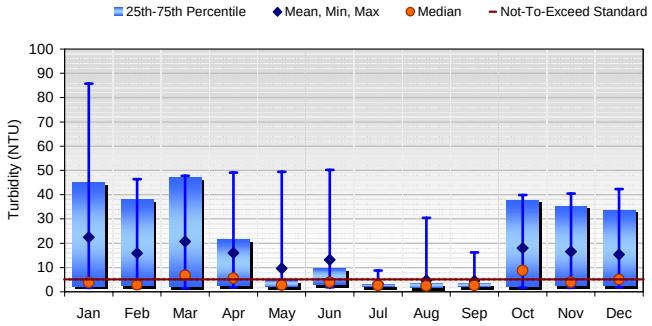
Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0	0	0	0	0	0	0:0	n/a
Feb	0	0	0	0	0	0	0:0	n/a
Mar	0	0	0	0	0	0	0:0	n/a
Apr	0	0	0	0	0	0	0:0	n/a
May	5.93	5.93	5.93	5.93	5.93	5.93	1:1	100%
Jun	0	0	0	0	0	0	0:0	n/a
Jul	0	0	0	0	0	0	0:0	n/a
Aug	0	0	0	0	0	0	0:0	n/a
Sep	0	0	0	0	0	0	0:0	n/a
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	**5.93**	**5.93**	**5.93**	**5.93**	**5.93**	**5.93**	**1:1**	**100%**

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



Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	22.47	3.83	1.68	85.80	2.27	44.95	9:15	60%
Feb	15.89	2.87	1.57	46.40	2.51	38.13	7:14	50%
Mar	20.69	6.76	1.48	47.80	2.03	47.00	9:15	60%
Apr	16.01	5.62	1.87	49.10	2.46	21.60	8:13	62%
May	9.61	2.76	1.73	49.50	2.02	4.76	7:14	50%
Jun	13.17	3.92	1.83	50.20	3.11	9.65	7:10	70%
Jul	3.36	2.64	1.70	8.78	2.11	3.07	4:13	31%
Aug	4.74	2.37	1.51	30.50	1.80	3.62	4:15	27%
Sep	4.50	2.64	1.75	16.20	2.07	3.66	6:15	40%
Oct	18.04	8.76	1.62	39.90	2.06	37.83	12:16	75%
Nov	16.60	3.99	1.66	40.50	2.33	35.50	9:15	60%
Dec	15.35	5.02	1.80	42.30	2.36	33.65	9:14	64%
All Data	**13.48**	**3.14**	**1.48**	**85.80**	**2.12**	**19.30**	**91:169**	**54%**

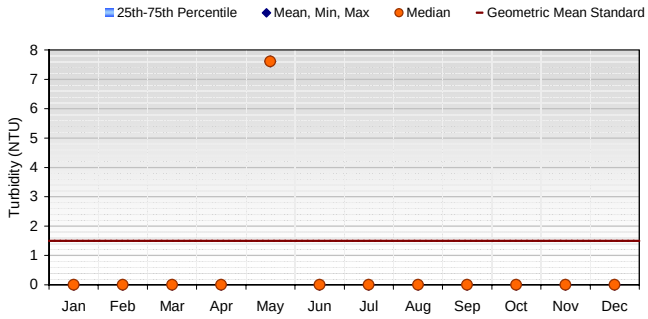
Not to Exceed 2% of the Time Analysis
(WQC = 5 NTU)



Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	22.47	3.83	1.68	85.80	2.27	44.95	7:15	47%
Feb	15.89	2.87	1.57	46.40	2.51	38.13	5:14	36%
Mar	20.69	6.76	1.48	47.80	2.03	47.00	8:15	53%
Apr	16.01	5.62	1.87	49.10	2.46	21.60	7:13	54%
May	9.61	2.76	1.73	49.50	2.02	4.76	3:14	21%
Jun	13.17	3.92	1.83	50.20	3.11	9.65	3:10	30%
Jul	3.36	2.64	1.70	8.78	2.11	3.07	2:13	15%
Aug	4.74	2.37	1.51	30.50	1.80	3.62	2:15	13%
Sep	4.50	2.64	1.75	16.20	2.07	3.66	3:15	20%
Oct	18.04	8.76	1.62	39.90	2.06	37.83	11:16	69%
Nov	16.60	3.99	1.66	40.50	2.33	35.50	7:15	47%
Dec	15.35	5.02	1.80	42.30	2.36	33.65	7:14	50%
All Data	**13.48**	**3.14**	**1.48**	**85.80**	**2.12**	**19.30**	**65:169**	**38%**

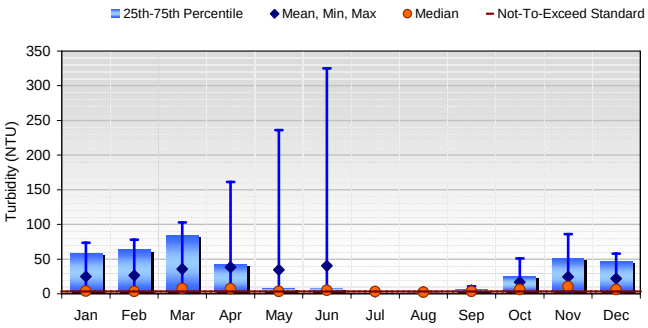
Figure A-6. Turbidity analyses for the Waioli Stream Estuary

Geometric Mean Analysis
(WQC = 1.5 NTU)



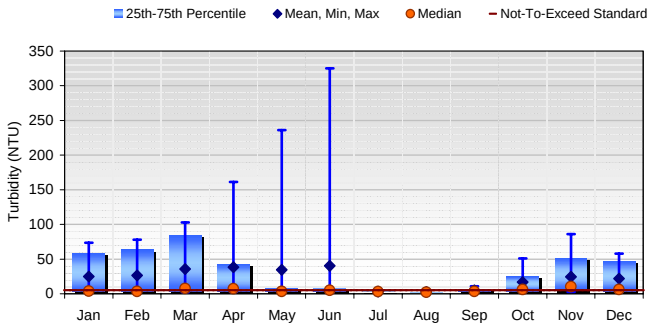
Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	**Mean**	**Median**	**Min**	**Max**	**25th**	**75th**	**XS:Count**	**XS%**
Jan	0	0	0	0	0	0	0:0	n/a
Feb	0	0	0	0	0	0	0:0	n/a
Mar	0	0	0	0	0	0	0:0	n/a
Apr	0	0	0	0	0	0	0:0	n/a
May	7.60	7.60	7.60	7.60	7.60	7.60	1:1	100%
Jun	0	0	0	0	0	0	0:0	n/a
Jul	0	0	0	0	0	0	0:0	n/a
Aug	0	0	0	0	0	0	0:0	n/a
Sep	0	0	0	0	0	0	0:0	n/a
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	**7.60**	**7.60**	**7.60**	**7.60**	**7.60**	**7.60**	**1:1**	**100%**

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



Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	**Mean**	**Median**	**Min**	**Max**	**25th**	**75th**	**XS:Count**	**XS%**
Jan	25.05	3.81	2.31	73.70	2.85	59.15	10:14	71%
Feb	26.65	3.59	2.67	77.90	3.20	64.13	12:14	86%
Mar	35.58	7.62	2.20	103.00	3.39	84.70	13:15	87%
Apr	38.27	7.21	2.55	161.00	3.07	43.00	11:13	85%
May	34.66	3.59	2.02	236.00	2.69	8.10	10:14	71%
Jun	40.41	4.91	1.97	325.00	3.49	8.61	7:10	70%
Jul	3.23	3.12	1.81	4.98	2.84	3.86	8:13	62%
Aug	2.68	2.39	1.47	4.77	2.03	3.05	5:15	33%
Sep	4.87	3.49	1.90	10.80	2.76	6.56	9:15	60%
Oct	17.04	6.23	2.53	51.20	3.45	25.15	15:15	100%
Nov	24.66	10.40	2.83	85.80	4.26	51.75	14:15	93%
Dec	21.92	6.28	3.19	57.80	3.42	47.65	14:14	100%
All Data	**22.35**	**3.94**	**1.47**	**325.00**	**3.05**	**12.20**	**128:167**	**77%**

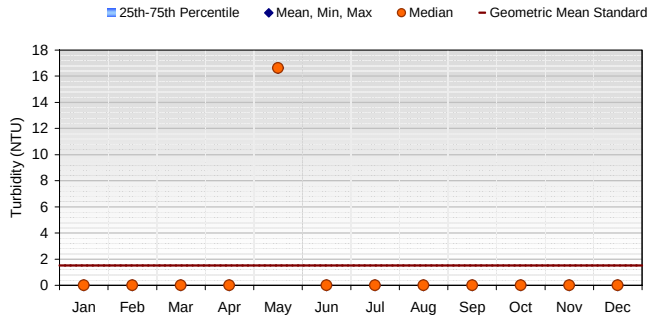
Not to Exceed 2% of the Time Analysis
(WQC = 5 NTU)



Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	**Mean**	**Median**	**Min**	**Max**	**25th**	**75th**	**XS:Count**	**XS%**
Jan	25.05	3.81	2.31	73.70	2.85	59.15	6:14	43%
Feb	26.65	3.59	2.67	77.90	3.20	64.13	6:14	43%
Mar	35.58	7.62	2.20	103.00	3.39	84.70	8:15	53%
Apr	38.27	7.21	2.55	161.00	3.07	43.00	7:13	54%
May	34.66	3.59	2.02	236.00	2.69	8.10	5:14	36%
Jun	40.41	4.91	1.97	325.00	3.49	8.61	4:10	40%
Jul	3.23	3.12	1.81	4.98	2.84	3.86	0:13	0%
Aug	2.68	2.39	1.47	4.77	2.03	3.05	0:15	0%
Sep	4.87	3.49	1.90	10.80	2.76	6.56	7:15	47%
Oct	17.04	6.23	2.53	51.20	3.45	25.15	9:15	60%
Nov	24.66	10.40	2.83	85.80	4.26	51.75	9:15	60%
Dec	21.92	6.28	3.19	57.80	3.42	47.65	8:14	57%
All Data	**22.35**	**3.94**	**1.47**	**325.00**	**3.05**	**12.20**	**69:167**	**41%**

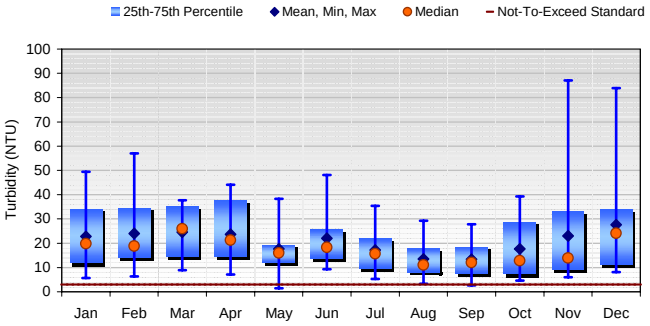
Figure A-7. Turbidity analyses for the Waipa Stream Estuary

Geometric Mean Analysis
(WQC = 1.5 NTU)



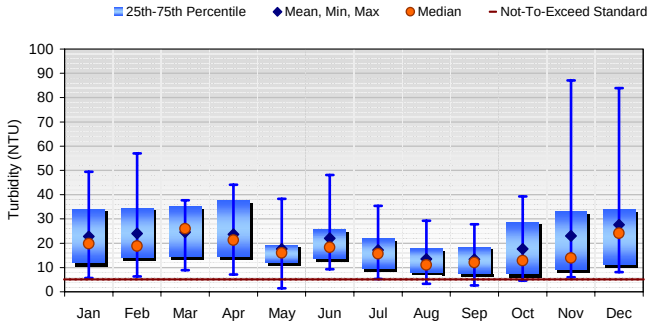
Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	**Mean**	**Median**	**Min**	**Max**	**25th**	**75th**	**XS:Count**	**XS%**
Jan	0	0	0	0	0	0	0:0	n/a
Feb	0	0	0	0	0	0	0:0	n/a
Mar	0	0	0	0	0	0	0:0	n/a
Apr	0	0	0	0	0	0	0:0	n/a
May	16.62	16.62	16.62	16.62	16.62	16.62	1:1	100%
Jun	0	0	0	0	0	0	0:0	n/a
Jul	0	0	0	0	0	0	0:0	n/a
Aug	0	0	0	0	0	0	0:0	n/a
Sep	0	0	0	0	0	0	0:0	n/a
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	**16.62**	**16.62**	**16.62**	**16.62**	**16.62**	**16.62**	**1:1**	**100%**

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



Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	**Mean**	**Median**	**Min**	**Max**	**25th**	**75th**	**XS:Count**	**XS%**
Jan	22.80	19.90	5.66	49.50	11.80	34.18	14:14	100%
Feb	24.04	18.85	6.33	57.00	13.93	34.62	14:14	100%
Mar	24.59	26.00	8.90	37.70	14.35	35.20	15:15	100%
Apr	23.66	21.30	7.12	44.10	14.50	37.80	13:13	100%
May	17.65	16.05	1.40	38.30	11.95	19.30	13:14	93%
Jun	22.02	18.35	9.29	48.10	13.83	25.78	10:10	100%
Jul	17.24	15.70	5.29	35.40	9.39	22.00	13:13	100%
Aug	13.51	11.10	3.30	29.30	8.02	18.00	15:15	100%
Sep	13.36	12.10	2.60	27.90	7.47	18.50	14:15	93%
Oct	17.66	12.80	4.65	39.20	7.20	28.80	15:15	100%
Nov	22.99	13.90	6.03	87.10	9.10	33.25	15:15	100%
Dec	27.68	24.15	8.15	83.90	11.23	33.98	14:14	100%
All Data	**20.50**	**16.50**	**1.40**	**87.10**	**10.35**	**32.50**	**165:167**	**99%**

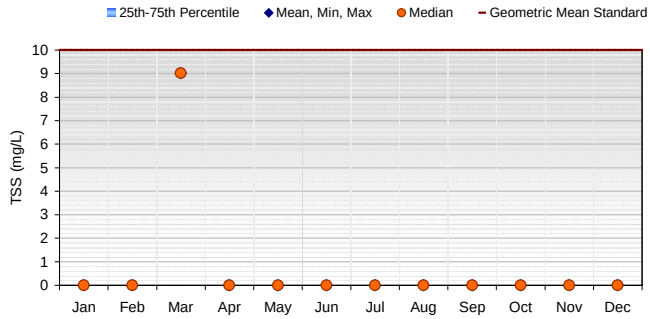
Not to Exceed 2% of the Time Analysis
(WQC = 5 NTU)



Summary Statistics (Data: 7/14/2003 to 5/18/2006)								
Month	**Mean**	**Median**	**Min**	**Max**	**25th**	**75th**	**XS:Count**	**XS%**
Jan	22.80	19.90	5.66	49.50	11.80	34.18	14:14	100%
Feb	24.04	18.85	6.33	57.00	13.93	34.62	14:14	100%
Mar	24.59	26.00	8.90	37.70	14.35	35.20	15:15	100%
Apr	23.66	21.30	7.12	44.10	14.50	37.80	13:13	100%
May	17.65	16.05	1.40	38.30	11.95	19.30	13:14	93%
Jun	22.02	18.35	9.29	48.10	13.83	25.78	10:10	100%
Jul	17.24	15.70	5.29	35.40	9.39	22.00	13:13	100%
Aug	13.51	11.10	3.30	29.30	8.02	18.00	13:15	87%
Sep	13.36	12.10	2.60	27.90	7.47	18.50	14:15	93%
Oct	17.66	12.80	4.65	39.20	7.20	28.80	13:15	87%
Nov	22.99	13.90	6.03	87.10	9.10	33.25	15:15	100%
Dec	27.68	24.15	8.15	83.90	11.23	33.98	14:14	100%
All Data	**20.50**	**16.50**	**1.40**	**87.10**	**10.35**	**32.50**	**161:167**	**96%**

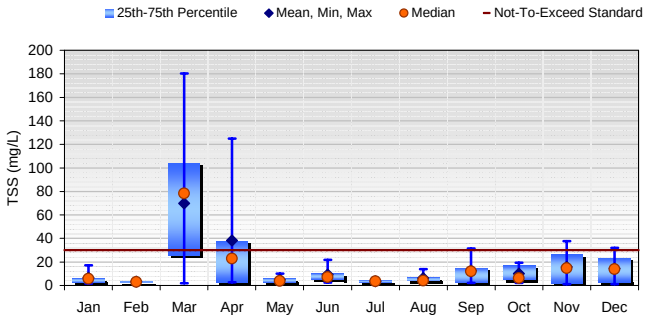
Figure A-8. Turbidity analyses for the Waikoko Stream Estuary

Geometric Mean Analysis*+
(stream dry WQC = 10 mg/L)



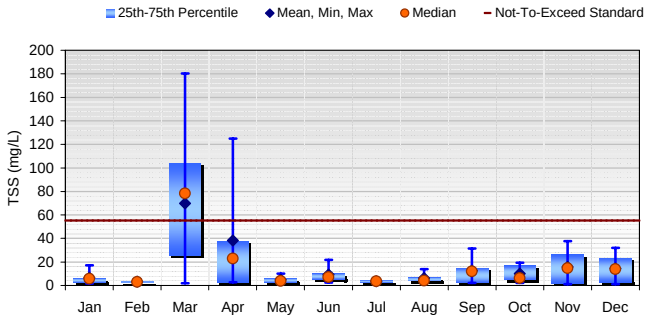
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0	0	0	0	0	0	0:0	n/a
Feb	0	0	0	0	0	0	0:0	n/a
Mar	9.02	9.02	9.02	9.02	9.02	9.02	0:1	0%
Apr	0	0	0	0	0	0	0:0	n/a
May	0	0	0	0	0	0	0:0	n/a
Jun	0	0	0	0	0	0	0:0	n/a
Jul	0	0	0	0	0	0	0:0	n/a
Aug	0	0	0	0	0	0	0:0	n/a
Sep	0	0	0	0	0	0	0:0	n/a
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	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**	**9.02**	**0:1**	**0%**

Not to Exceed 10% of the Time Analysis*
(stream dry WQC = 30 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	7	6	2	17	3	6	0:5	0%
Feb	3	3	2	5	3	3	0:5	0%
Mar	70	78	2	180	26	104	9:12	75%
Apr	38	23	3	125	3	38	1:5	20%
May	5	4	2	10	3	6	0:4	0%
Jun	9	7	2	22	5	10	0:5	0%
Jul	3	3	2	5	3	4	0:2	0%
Aug	6	4	2	14	4	7	0:5	0%
Sep	13	12	2	32	2	15	1:5	20%
Oct	10	6	2	20	5	17	1:5	20%
Nov	16	15	1	38	2	27	1:7	14%
Dec	14	14	1	32	3	24	1:6	17%
All Data	**23**	**6**	**1**	**180**	**3**	**24**	**14:66**	**21%**

Not to Exceed 2% of the Time Analysis*
(stream dry WQC = 55 mg/L)

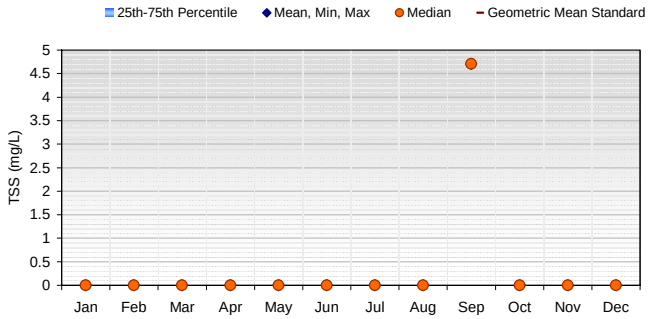


Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	7	6	2	17	3	6	0:5	0%
Feb	3	3	2	5	3	3	0:5	0%
Mar	70	78	2	180	26	104	7:12	58%
Apr	38	23	3	125	3	38	0:5	0%
May	5	4	2	10	3	6	0:4	0%
Jun	9	7	2	22	5	10	0:5	0%
Jul	3	3	2	5	3	4	0:2	0%
Aug	6	4	2	14	4	7	0:5	0%
Sep	13	12	2	32	2	15	0:5	0%
Oct	10	6	2	20	5	17	0:5	0%
Nov	16	15	1	38	2	27	0:7	0%
Dec	14	14	1	32	3	24	0:6	0%
All Data	**23**	**6**	**1**	**180**	**3**	**24**	**7:66**	**11%**

*Standard is based on the dry season stream TSS water quality criteria because there is no estuary TSS standard.
+Where the standard is missing from the graph, observed data are well below the water quality criteria.

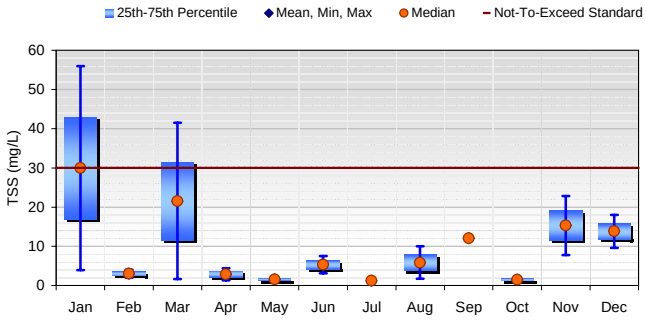
Figure A-9. TSS analyses for the Hanalei River Estuary

Geometric Mean Analysis*+
(stream dry WQC = 10 mg/L)



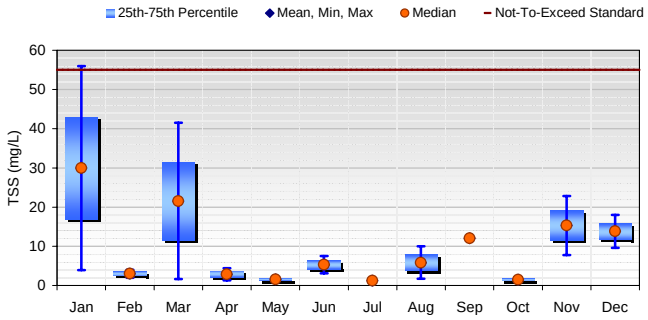
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	4.71	4.71	4.71	4.71	4.71	4.71	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**4.71**	**4.71**	**4.71**	**4.71**	**4.71**	**4.71**	**0:1**	**0%**

Not to Exceed 10% of the Time Analysis*
(stream dry WQC = 30 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	30	30	4	56	17	43	1:2	50%
Feb	3	3	2	4	3	4	0:2	0%
Mar	22	22	2	42	12	32	1:2	50%
Apr	3	3	1	4	2	4	0:2	0%
May	2	2	1	2	1	2	0:2	0%
Jun	5	5	3	8	4	6	0:2	0%
Jul	1	1	1	1	1	1	0:1	0%
Aug	6	6	2	10	4	8	0:2	0%
Sep	12	12	12	12	12	12	0:1	0%
Oct	2	2	1	2	1	2	0:2	0%
Nov	15	15	8	23	12	19	0:2	0%
Dec	14	14	10	18	12	16	0:2	0%
All Data	**10**	**4**	**1**	**56**	**2**	**10**	**2:22**	**9%**

Not to Exceed 2% of the Time Analysis*
(stream dry WQC = 55 mg/L)

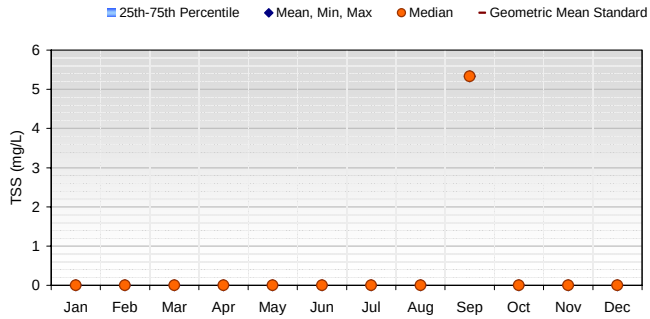


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	30	30	4	56	17	43	1:2	50%
Feb	3	3	2	4	3	4	0:2	0%
Mar	22	22	2	42	12	32	0:2	0%
Apr	3	3	1	4	2	4	0:2	0%
May	2	2	1	2	1	2	0:2	0%
Jun	5	5	3	8	4	6	0:2	0%
Jul	1	1	1	1	1	1	0:1	0%
Aug	6	6	2	10	4	8	0:2	0%
Sep	12	12	12	12	12	12	0:1	0%
Oct	2	2	1	2	1	2	0:2	0%
Nov	15	15	8	23	12	19	0:2	0%
Dec	14	14	10	18	12	16	0:2	0%
All Data	**10**	**4**	**1**	**56**	**2**	**10**	**1:22**	**5%**

*Standard is based on the dry season stream TSS water quality criteria because there is no estuary TSS standard.
+Where the standard is missing from the graph, observed data are well below the water quality criteria.

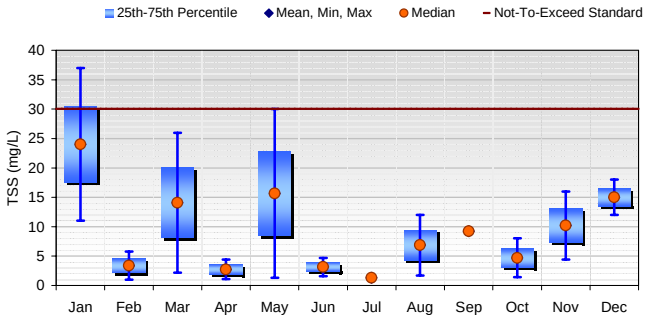
Figure A-10. TSS analyses for the Waioli Stream Estuary

Geometric Mean Analysis*+
(stream dry WQC = 10 mg/L)



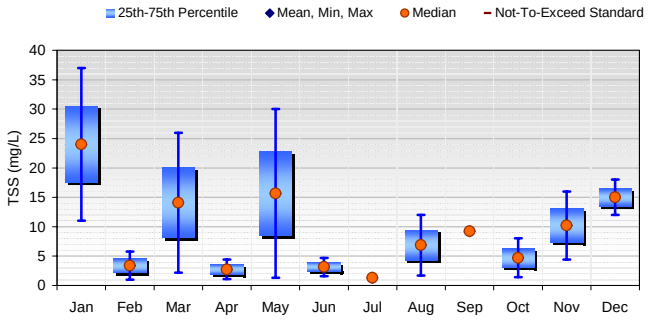
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	5.33	5.33	5.33	5.33	5.33	5.33	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**5.33**	**5.33**	**5.33**	**5.33**	**5.33**	**5.33**	**0:1**	**0%**

Not to Exceed 10% of the Time Analysis*
(stream dry WQC = 30 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	24	24	11	37	18	31	1:2	50%
Feb	3	3	1	6	2	5	0:2	0%
Mar	14	14	2	26	8	20	0:2	0%
Apr	3	3	1	4	2	4	0:2	0%
May	16	16	1	30	8	23	1:2	50%
Jun	3	3	2	5	2	4	0:2	0%
Jul	1	1	1	1	1	1	0:1	0%
Aug	7	7	2	12	4	9	0:2	0%
Sep	9	9	9	9	9	9	0:1	0%
Oct	5	5	1	8	3	6	0:2	0%
Nov	10	10	4	16	7	13	0:2	0%
Dec	15	15	12	18	14	17	0:2	0%
All Data	**10**	**5**	**1**	**37**	**2**	**12**	**2:22**	**9%**

Not to Exceed 2% of the Time Analysis*+
(stream dry WQC = 55 mg/L)

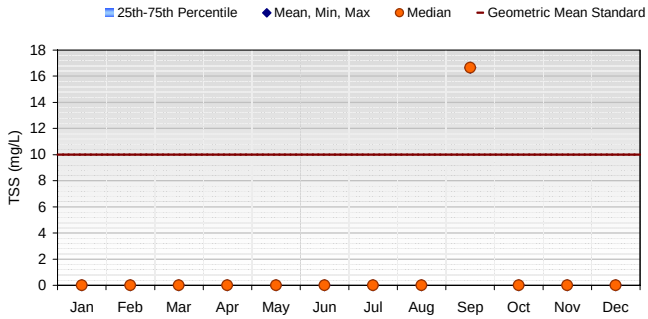


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	24	24	11	37	18	31	0:2	0%
Feb	3	3	1	6	2	5	0:2	0%
Mar	14	14	2	26	8	20	0:2	0%
Apr	3	3	1	4	2	4	0:2	0%
May	16	16	1	30	8	23	0:2	0%
Jun	3	3	2	5	2	4	0:2	0%
Jul	1	1	1	1	1	1	0:1	0%
Aug	7	7	2	12	4	9	0:2	0%
Sep	9	9	9	9	9	9	0:1	0%
Oct	5	5	1	8	3	6	0:2	0%
Nov	10	10	4	16	7	13	0:2	0%
Dec	15	15	12	18	14	17	0:2	0%
All Data	**10**	**5**	**1**	**37**	**2**	**12**	**0:22**	**0%**

*Standard is based on the dry season stream TSS water quality criteria because there is no estuary TSS standard.
+Where the standard is missing from the graph, observed data are well below the water quality criteria.

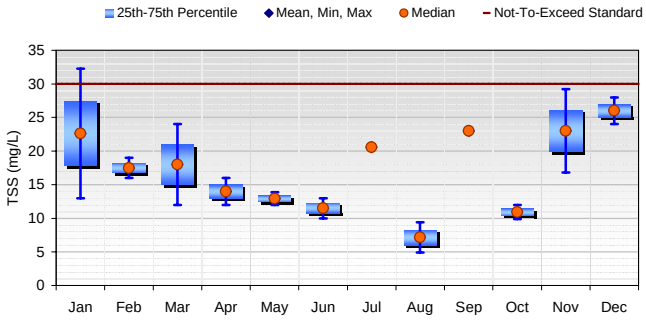
Figure A-11. TSS analyses for the Waipa Stream Estuary

Geometric Mean Analysis*
(stream dry WQC = 10 mg/L)



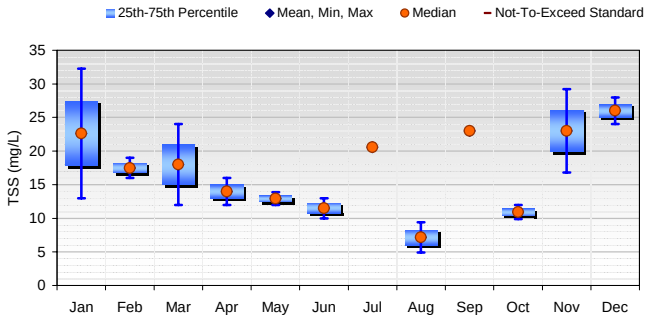
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	16.64	16.64	16.64	16.64	16.64	16.64	1:1	100%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**16.64**	**16.64**	**16.64**	**16.64**	**16.64**	**16.64**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis*
(stream dry WQC = 30 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	23	23	13	32	18	27	1:2	50%
Feb	18	18	16	19	17	18	0:2	0%
Mar	18	18	12	24	15	21	0:2	0%
Apr	14	14	12	16	13	15	0:2	0%
May	13	13	12	14	12	13	0:2	0%
Jun	12	12	10	13	11	12	0:2	0%
Jul	21	21	21	21	21	21	0:1	0%
Aug	7	7	5	9	6	8	0:2	0%
Sep	23	23	23	23	23	23	0:1	0%
Oct	11	11	10	12	10	11	0:2	0%
Nov	23	23	17	29	20	26	0:2	0%
Dec	26	26	24	28	25	27	1:2	50%
All Data	**17**	**15**	**5**	**32**	**12**	**22**	**2:22**	**9%**

Not to Exceed 2% of the Time Analysis*+
(stream dry WQC = 55 mg/L)

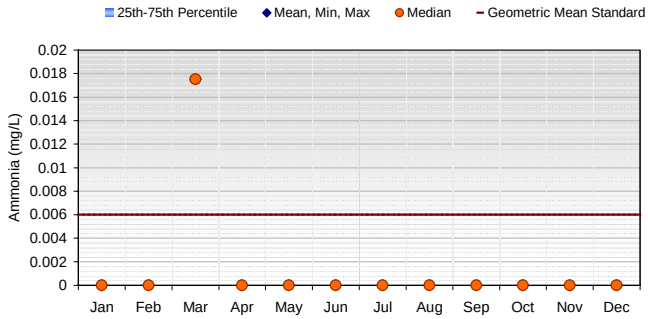


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	23	23	13	32	18	27	0:2	0%
Feb	18	18	16	19	17	18	0:2	0%
Mar	18	18	12	24	15	21	0:2	0%
Apr	14	14	12	16	13	15	0:2	0%
May	13	13	12	14	12	13	0:2	0%
Jun	12	12	10	13	11	12	0:2	0%
Jul	21	21	21	21	21	21	0:1	0%
Aug	7	7	5	9	6	8	0:2	0%
Sep	23	23	23	23	23	23	0:1	0%
Oct	11	11	10	12	10	11	0:2	0%
Nov	23	23	17	29	20	26	0:2	0%
Dec	26	26	24	28	25	27	1:2	50%
All Data	**17**	**15**	**5**	**32**	**12**	**22**	**1:22**	**5%**

*Standard is based on the dry season stream TSS water quality criteria because there is no estuary TSS standard.
+Where the standard is missing from the graph, observed data are well below the water quality criteria.

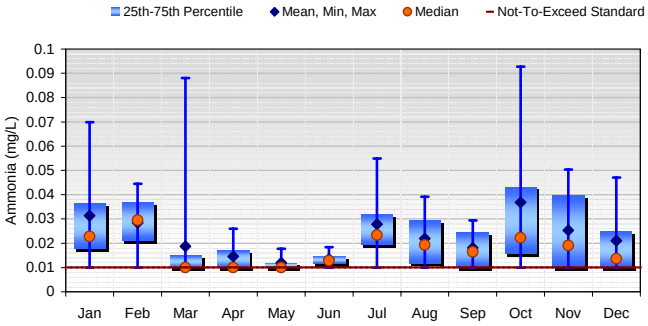
Figure A-12. TSS analyses for the Waikoko Stream Estuary

Geometric Mean Analysis
(WQC = 0.006 mg/L)



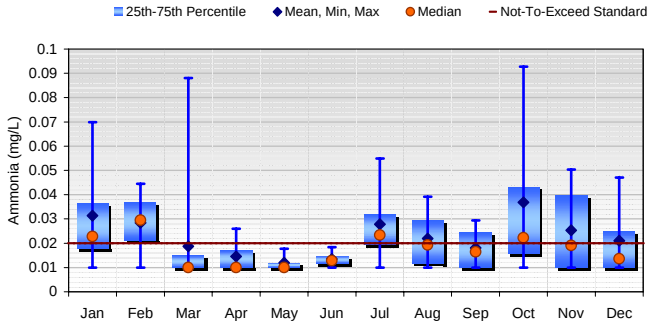
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.018	0.018	0.018	0.018	0.018	0.018	1:1	100%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.018**	**0.018**	**0.018**	**0.018**	**0.018**	**0.018**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.010 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.03	0.02	0.01	0.07	0.02	0.04	3:4	75%
Feb	0.03	0.03	0.01	0.04	0.02	0.04	3:4	75%
Mar	0.02	0.01	0.01	0.09	0.01	0.01	4:11	36%
Apr	0.01	0.01	0.01	0.03	0.01	0.02	2:5	40%
May	0.01	0.01	0.01	0.02	0.01	0.01	1:4	25%
Jun	0.01	0.01	0.01	0.02	0.01	0.01	3:4	75%
Jul	0.03	0.02	0.01	0.05	0.02	0.03	3:4	75%
Aug	0.02	0.02	0.01	0.04	0.01	0.03	3:4	75%
Sep	0.02	0.02	0.01	0.03	0.01	0.02	2:4	50%
Oct	0.04	0.02	0.01	0.09	0.02	0.04	3:4	75%
Nov	0.03	0.02	0.01	0.05	0.01	0.04	3:6	50%
Dec	0.02	0.01	0.01	0.05	0.01	0.02	3:5	60%
All Data	**0.02**	**0.01**	**0.01**	**0.09**	**0.01**	**0.03**	**33:59**	**56%**

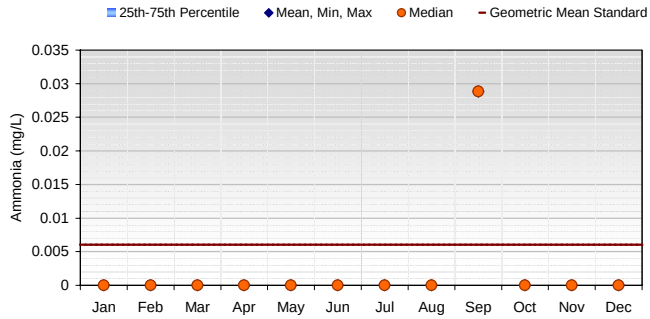
Not to Exceed 2% of the Time Analysis
(WQC = 0.020 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.03	0.02	0.01	0.07	0.02	0.04	3:4	75%
Feb	0.03	0.03	0.01	0.04	0.02	0.04	3:4	75%
Mar	0.02	0.01	0.01	0.09	0.01	0.01	1:11	9%
Apr	0.01	0.01	0.01	0.03	0.01	0.02	0:5	0%
May	0.01	0.01	0.01	0.02	0.01	0.01	0:4	0%
Jun	0.01	0.01	0.01	0.02	0.01	0.01	1:4	25%
Jul	0.03	0.02	0.01	0.05	0.02	0.03	3:4	75%
Aug	0.02	0.02	0.01	0.04	0.01	0.03	2:4	50%
Sep	0.02	0.02	0.01	0.03	0.01	0.02	2:4	50%
Oct	0.04	0.02	0.01	0.09	0.02	0.04	2:4	50%
Nov	0.03	0.02	0.01	0.05	0.01	0.04	2:6	33%
Dec	0.02	0.01	0.01	0.05	0.01	0.02	3:5	60%
All Data	**0.02**	**0.01**	**0.01**	**0.09**	**0.01**	**0.03**	**22:59**	**37%**

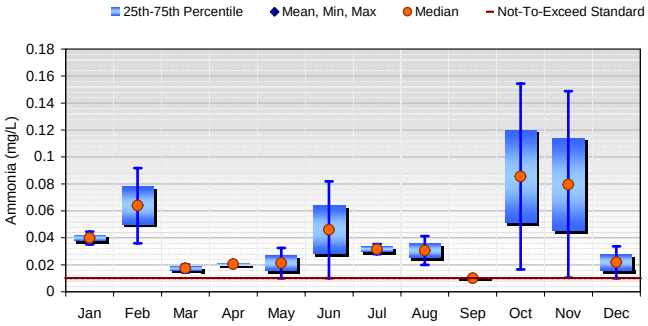
Figure A-13. Ammonia analyses for the Hanalei River Estuary

Geometric Mean Analysis
(WQC = 0.006 mg/L)



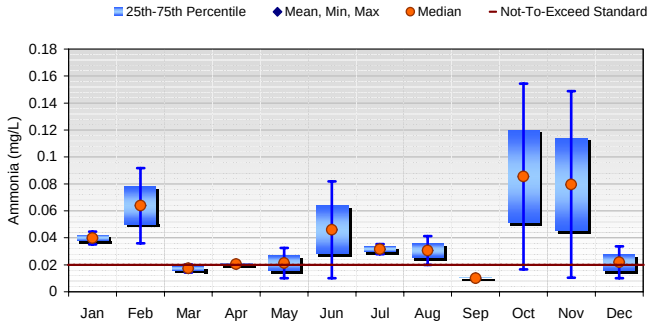
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.029	0.029	0.029	0.029	0.029	0.029	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.029**	**0.029**	**0.029**	**0.029**	**0.029**	**0.029**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.010 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.04	0.04	0.04	0.04	0.04	0.04	2:2	100%
Feb	0.06	0.06	0.04	0.09	0.05	0.08	2:2	100%
Mar	0.02	0.02	0.01	0.02	0.02	0.02	2:2	100%
Apr	0.02	0.02	0.02	0.02	0.02	0.02	2:2	100%
May	0.02	0.02	0.01	0.03	0.02	0.03	1:2	50%
Jun	0.05	0.05	0.01	0.08	0.03	0.06	1:2	50%
Jul	0.03	0.03	0.03	0.04	0.03	0.03	2:2	100%
Aug	0.03	0.03	0.02	0.04	0.03	0.04	2:2	100%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.09	0.09	0.02	0.15	0.05	0.12	2:2	100%
Nov	0.08	0.08	0.01	0.15	0.04	0.11	1:2	50%
Dec	0.02	0.02	0.01	0.03	0.02	0.03	2:2	100%
All Data	**0.04**	**0.03**	**0.01**	**0.15**	**0.02**	**0.04**	**19:23**	**83%**

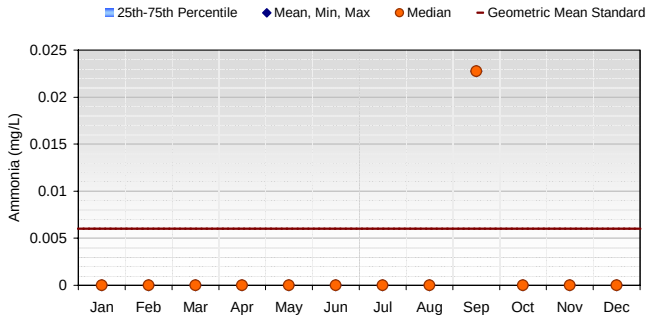
Not to Exceed 2% of the Time Analysis
(WQC = 0.020 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.04	0.04	0.04	0.04	0.04	0.04	2:2	100%
Feb	0.06	0.06	0.04	0.09	0.05	0.08	2:2	100%
Mar	0.02	0.02	0.01	0.02	0.02	0.02	1:2	50%
Apr	0.02	0.02	0.02	0.02	0.02	0.02	1:2	50%
May	0.02	0.02	0.01	0.03	0.02	0.03	1:2	50%
Jun	0.05	0.05	0.01	0.08	0.03	0.06	1:2	50%
Jul	0.03	0.03	0.03	0.04	0.03	0.03	2:2	100%
Aug	0.03	0.03	0.02	0.04	0.03	0.04	1:2	50%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.09	0.09	0.02	0.15	0.05	0.12	1:2	50%
Nov	0.08	0.08	0.01	0.15	0.04	0.11	1:2	50%
Dec	0.02	0.02	0.01	0.03	0.02	0.03	2:2	100%
All Data	**0.04**	**0.03**	**0.01**	**0.15**	**0.02**	**0.04**	**15:23**	**65%**

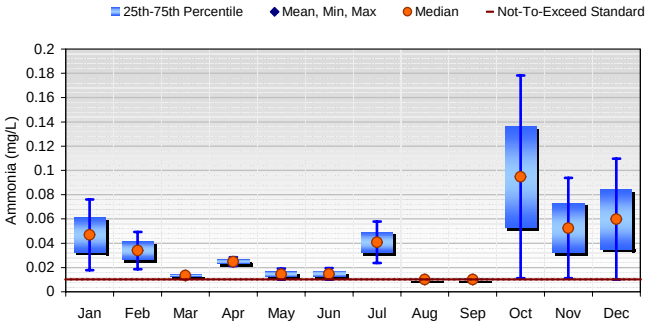
Figure A-14. Ammonia analyses for the Waioli Stream Estuary

Geometric Mean Analysis
(WQC = 0.006 mg/L)



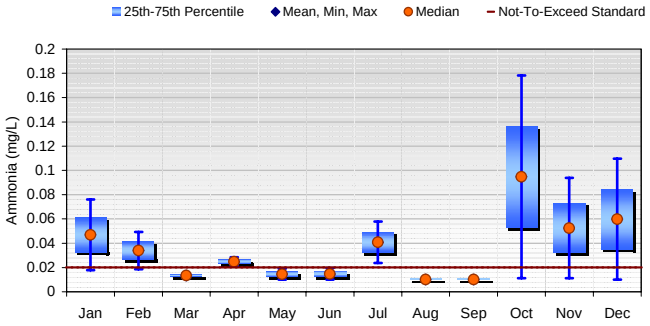
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.023	0.023	0.023	0.023	0.023	0.023	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.023**	**0.023**	**0.023**	**0.023**	**0.023**	**0.023**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.010 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.05	0.05	0.02	0.08	0.03	0.06	2:2	100%
Feb	0.03	0.03	0.02	0.05	0.03	0.04	2:2	100%
Mar	0.01	0.01	0.01	0.02	0.01	0.01	2:2	100%
Apr	0.02	0.02	0.02	0.03	0.02	0.03	2:2	100%
May	0.01	0.01	0.01	0.02	0.01	0.02	1:2	50%
Jun	0.01	0.01	0.01	0.02	0.01	0.02	1:2	50%
Jul	0.04	0.04	0.02	0.06	0.03	0.05	2:2	100%
Aug	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.09	0.09	0.01	0.18	0.05	0.14	2:2	100%
Nov	0.05	0.05	0.01	0.09	0.03	0.07	1:2	50%
Dec	0.06	0.06	0.01	0.11	0.03	0.08	2:2	100%
All Data	**0.04**	**0.02**	**0.01**	**0.18**	**0.01**	**0.04**	**17:23**	**74%**

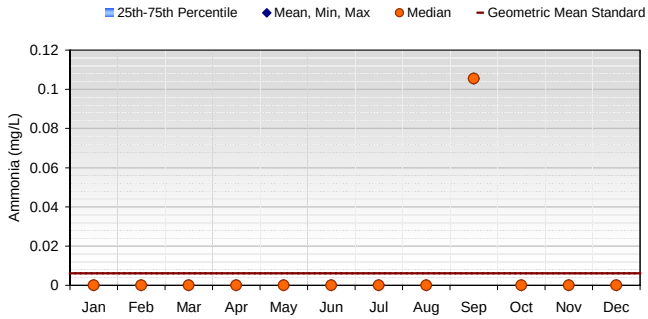
Not to Exceed 2% of the Time Analysis
(WQC = 0.020 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.05	0.05	0.02	0.08	0.03	0.06	1:2	50%
Feb	0.03	0.03	0.02	0.05	0.03	0.04	1:2	50%
Mar	0.01	0.01	0.01	0.02	0.01	0.01	0:2	0%
Apr	0.02	0.02	0.02	0.03	0.02	0.03	2:2	100%
May	0.01	0.01	0.01	0.02	0.01	0.02	0:2	0%
Jun	0.01	0.01	0.01	0.02	0.01	0.02	0:2	0%
Jul	0.04	0.04	0.02	0.06	0.03	0.05	2:2	100%
Aug	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.09	0.09	0.01	0.18	0.05	0.14	1:2	50%
Nov	0.05	0.05	0.01	0.09	0.03	0.07	1:2	50%
Dec	0.06	0.06	0.01	0.11	0.03	0.08	2:2	100%
All Data	**0.04**	**0.02**	**0.01**	**0.18**	**0.01**	**0.04**	**10:23**	**43%**

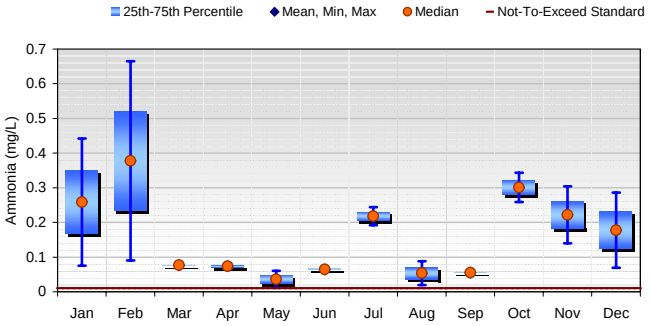
Figure A-15. Ammonia analyses for the Waipa Stream Estuary

Geometric Mean Analysis
(WQC = 0.006 mg/L)



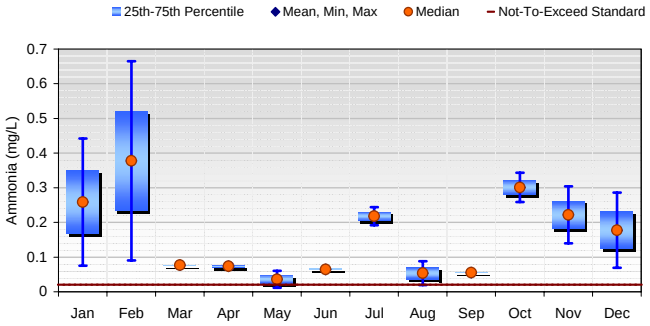
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.105	0.105	0.105	0.105	0.105	0.105	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.105**	**0.105**	**0.105**	**0.105**	**0.105**	**0.105**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.010 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.26	0.26	0.08	0.44	0.17	0.35	2:2	100%
Feb	0.38	0.38	0.09	0.66	0.23	0.52	2:2	100%
Mar	0.08	0.08	0.07	0.08	0.08	0.08	2:2	100%
Apr	0.07	0.07	0.07	0.08	0.07	0.08	2:2	100%
May	0.04	0.04	0.01	0.06	0.02	0.05	2:2	100%
Jun	0.06	0.06	0.06	0.07	0.06	0.07	2:2	100%
Jul	0.22	0.22	0.19	0.24	0.20	0.23	2:2	100%
Aug	0.05	0.05	0.02	0.09	0.04	0.07	2:2	100%
Sep	0.06	0.06	0.06	0.06	0.06	0.06	1:1	100%
Oct	0.30	0.30	0.26	0.34	0.28	0.32	2:2	100%
Nov	0.22	0.22	0.14	0.30	0.18	0.26	2:2	100%
Dec	0.18	0.18	0.07	0.29	0.12	0.23	2:2	100%
All Data	**0.16**	**0.08**	**0.01**	**0.66**	**0.07**	**0.25**	**23:23**	**100%**

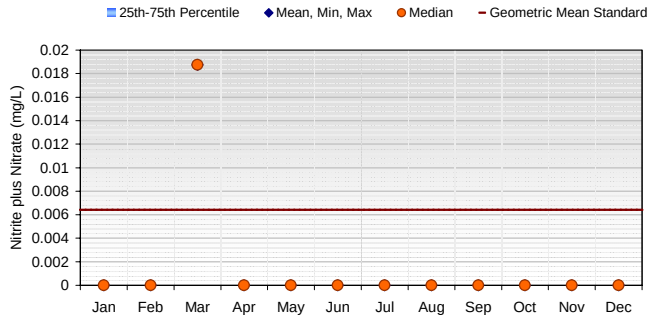
Not to Exceed 2% of the Time Analysis
(WQC = 0.020 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.26	0.26	0.08	0.44	0.17	0.35	2:2	100%
Feb	0.38	0.38	0.09	0.66	0.23	0.52	2:2	100%
Mar	0.08	0.08	0.07	0.08	0.08	0.08	2:2	100%
Apr	0.07	0.07	0.07	0.08	0.07	0.08	2:2	100%
May	0.04	0.04	0.01	0.06	0.02	0.05	1:2	50%
Jun	0.06	0.06	0.06	0.07	0.06	0.07	2:2	100%
Jul	0.22	0.22	0.19	0.24	0.20	0.23	2:2	100%
Aug	0.05	0.05	0.02	0.09	0.04	0.07	1:2	50%
Sep	0.06	0.06	0.06	0.06	0.06	0.06	1:1	100%
Oct	0.30	0.30	0.26	0.34	0.28	0.32	2:2	100%
Nov	0.22	0.22	0.14	0.30	0.18	0.26	2:2	100%
Dec	0.18	0.18	0.07	0.29	0.12	0.23	2:2	100%
All Data	**0.16**	**0.08**	**0.01**	**0.66**	**0.07**	**0.25**	**21:23**	**91%**

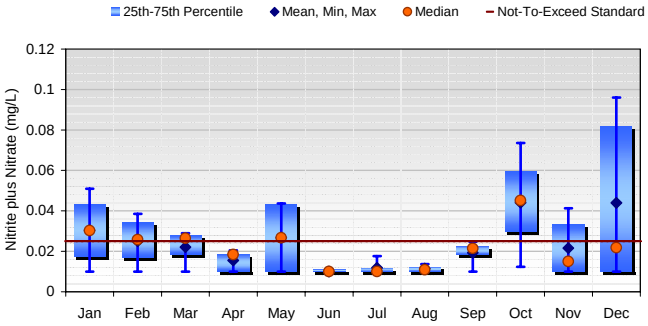
Figure A-16. Ammonia analyses for the Waikoko Stream Estuary

Geometric Mean Analysis
(WQC = 0.008 mg/L)



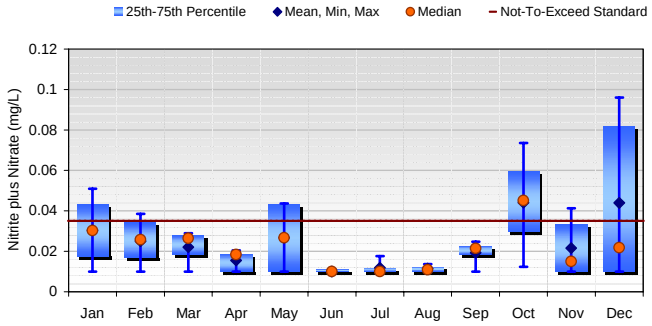
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.019	0.019	0.019	0.019	0.019	0.019	1:1	100%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	0.019	0.019	0.019	0.019	0.019	0.019	1:1	100%

Not to Exceed 10% of the Time Analysis
(WQC = 0.025 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.03	0.03	0.01	0.05	0.02	0.04	2:4	50%
Feb	0.03	0.03	0.01	0.04	0.02	0.03	2:4	50%
Mar	0.02	0.03	0.01	0.03	0.02	0.03	6:11	55%
Apr	0.02	0.02	0.01	0.02	0.01	0.02	0:5	0%
May	0.03	0.03	0.01	0.04	0.01	0.04	2:4	50%
Jun	0.01	0.01	0.01	0.01	0.01	0.01	0:4	0%
Jul	0.01	0.01	0.01	0.02	0.01	0.01	0:4	0%
Aug	0.01	0.01	0.01	0.01	0.01	0.01	0:4	0%
Sep	0.02	0.02	0.01	0.02	0.02	0.02	0:4	0%
Oct	0.04	0.05	0.01	0.07	0.03	0.06	4:4	100%
Nov	0.02	0.02	0.01	0.04	0.01	0.03	1:6	17%
Dec	0.04	0.02	0.01	0.10	0.01	0.08	2:5	40%
All Data	0.02	0.02	0.01	0.10	0.01	0.03	19:59	32%

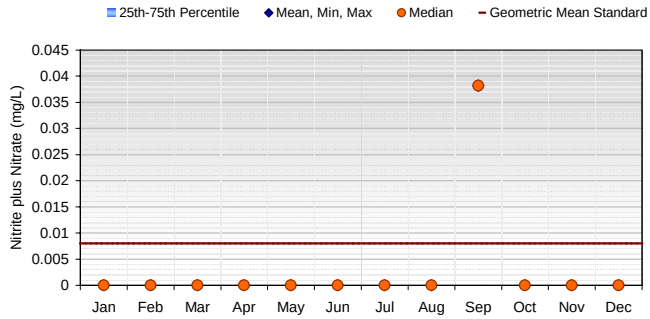
Not to Exceed 2% of the Time Analysis
(WQC = 0.035 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.03	0.03	0.01	0.05	0.02	0.04	2:4	50%
Feb	0.03	0.03	0.01	0.04	0.02	0.03	1:4	25%
Mar	0.02	0.03	0.01	0.03	0.02	0.03	0:11	0%
Apr	0.02	0.02	0.01	0.02	0.01	0.02	0:5	0%
May	0.03	0.03	0.01	0.04	0.01	0.04	2:4	50%
Jun	0.01	0.01	0.01	0.01	0.01	0.01	0:4	0%
Jul	0.01	0.01	0.01	0.02	0.01	0.01	0:4	0%
Aug	0.01	0.01	0.01	0.01	0.01	0.01	0:4	0%
Sep	0.02	0.02	0.01	0.02	0.02	0.02	0:4	0%
Oct	0.04	0.05	0.01	0.07	0.03	0.06	4:4	100%
Nov	0.02	0.02	0.01	0.04	0.01	0.03	1:6	17%
Dec	0.04	0.02	0.01	0.10	0.01	0.08	2:5	40%
All Data	0.02	0.02	0.01	0.10	0.01	0.03	12:59	20%

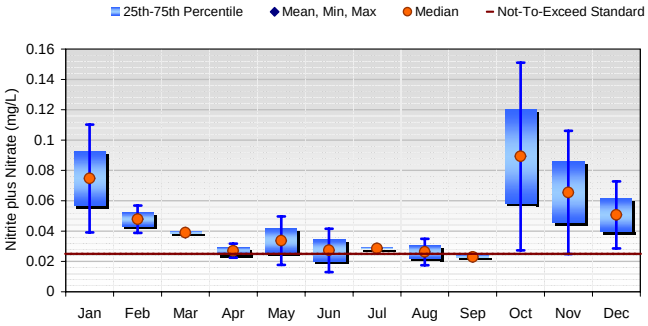
Figure A-17. Nitrate plus nitrite analyses for the Hanalei River Estuary

Geometric Mean Analysis
(WQC = 0.008 mg/L)



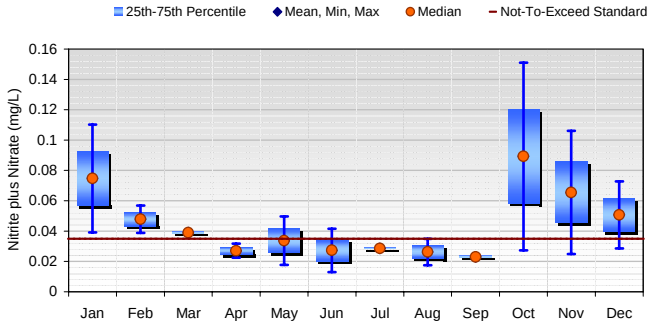
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.038	0.038	0.038	0.038	0.038	0.038	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.038**	**0.038**	**0.038**	**0.038**	**0.038**	**0.038**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.025 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.07	0.07	0.04	0.11	0.06	0.09	2:2	100%
Feb	0.05	0.05	0.04	0.06	0.04	0.05	2:2	100%
Mar	0.04	0.04	0.04	0.04	0.04	0.04	2:2	100%
Apr	0.03	0.03	0.02	0.03	0.02	0.03	1:2	50%
May	0.03	0.03	0.02	0.05	0.03	0.04	1:2	50%
Jun	0.03	0.03	0.01	0.04	0.02	0.03	1:2	50%
Jul	0.03	0.03	0.03	0.03	0.03	0.03	2:2	100%
Aug	0.03	0.03	0.02	0.04	0.02	0.03	1:2	50%
Sep	0.02	0.02	0.02	0.02	0.02	0.02	0:1	0%
Oct	0.09	0.09	0.03	0.15	0.06	0.12	1:2	50%
Nov	0.07	0.07	0.02	0.11	0.05	0.09	2:2	100%
Dec	0.05	0.05	0.03	0.07	0.04	0.06	2:2	100%
All Data	**0.05**	**0.04**	**0.01**	**0.15**	**0.03**	**0.05**	**17:23**	**74%**

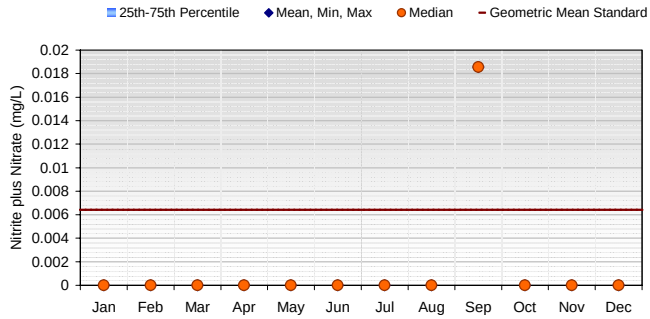
Not to Exceed 2% of the Time Analysis
(WQC = 0.035 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.07	0.07	0.04	0.11	0.06	0.09	2:2	100%
Feb	0.05	0.05	0.04	0.06	0.04	0.05	2:2	100%
Mar	0.04	0.04	0.04	0.04	0.04	0.04	2:2	100%
Apr	0.03	0.03	0.02	0.03	0.02	0.03	0:2	0%
May	0.03	0.03	0.02	0.05	0.03	0.04	1:2	50%
Jun	0.03	0.03	0.01	0.04	0.02	0.03	1:2	50%
Jul	0.03	0.03	0.03	0.03	0.03	0.03	0:2	0%
Aug	0.03	0.03	0.02	0.04	0.02	0.03	0:2	0%
Sep	0.02	0.02	0.02	0.02	0.02	0.02	0:1	0%
Oct	0.09	0.09	0.03	0.15	0.06	0.12	1:2	50%
Nov	0.07	0.07	0.02	0.11	0.05	0.09	1:2	50%
Dec	0.05	0.05	0.03	0.07	0.04	0.06	2:2	100%
All Data	**0.05**	**0.04**	**0.01**	**0.15**	**0.03**	**0.05**	**12:23**	**52%**

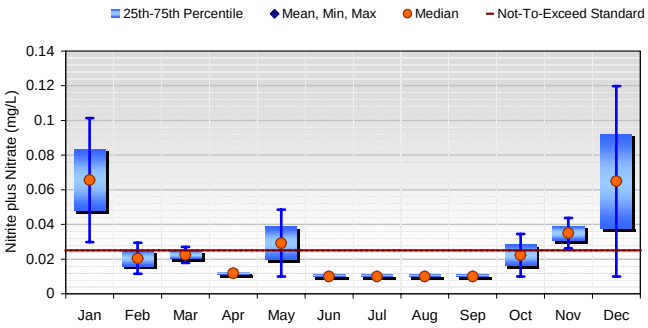
Figure A-18. Nitrate plus nitrite analyses for the Waioli Stream Estuary

Geometric Mean Analysis
(WQC = 0.008 mg/L)



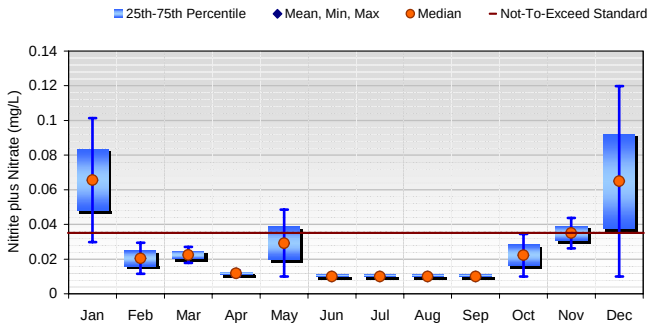
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.019	0.019	0.019	0.019	0.019	0.019	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.025 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.07	0.07	0.03	0.10	0.05	0.08	2:2	100%
Feb	0.02	0.02	0.01	0.03	0.02	0.02	1:2	50%
Mar	0.02	0.02	0.02	0.03	0.02	0.02	1:2	50%
Apr	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
May	0.03	0.03	0.01	0.05	0.02	0.04	1:2	50%
Jun	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
Jul	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
Aug	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.02	0.02	0.01	0.03	0.02	0.03	2:2	100%
Nov	0.03	0.03	0.03	0.04	0.03	0.04	1:2	50%
Dec	0.06	0.06	0.01	0.12	0.04	0.09	1:2	50%
All Data	**0.03**	**0.01**	**0.01**	**0.12**	**0.01**	**0.03**	**9:23**	**39%**

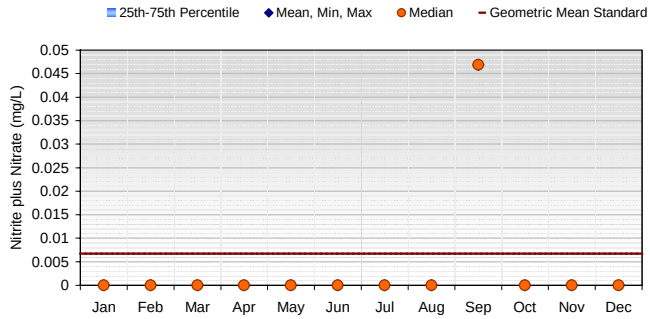
Not to Exceed 2% of the Time Analysis
(WQC = 0.035 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.07	0.07	0.03	0.10	0.05	0.08	1:2	50%
Feb	0.02	0.02	0.01	0.03	0.02	0.02	0:2	0%
Mar	0.02	0.02	0.02	0.03	0.02	0.02	0:2	0%
Apr	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
May	0.03	0.03	0.01	0.05	0.02	0.04	1:2	50%
Jun	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
Jul	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
Aug	0.01	0.01	0.01	0.01	0.01	0.01	0:2	0%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.02	0.02	0.01	0.03	0.02	0.03	0:2	0%
Nov	0.03	0.03	0.03	0.04	0.03	0.04	1:2	50%
Dec	0.06	0.06	0.01	0.12	0.04	0.09	1:2	50%
All Data	**0.03**	**0.01**	**0.01**	**0.12**	**0.01**	**0.03**	**4:23**	**17%**

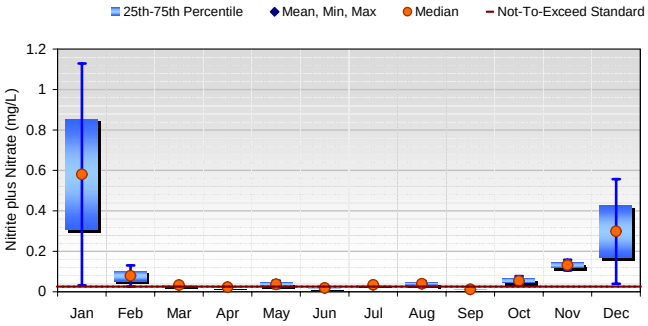
Figure A-19. Nitrate plus nitrite analyses for the Waipa Stream Estuary

Geometric Mean Analysis
(WQC = 0.008 mg/L)



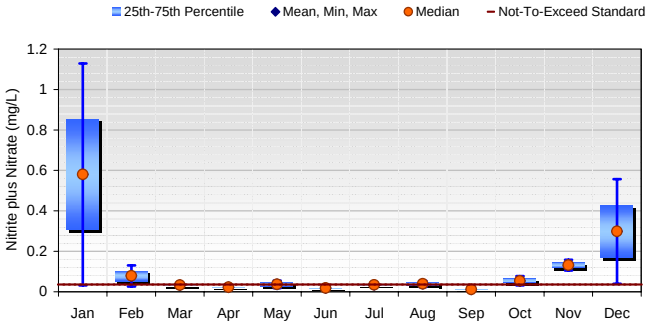
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.047	0.047	0.047	0.047	0.047	0.047	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.047**	**0.047**	**0.047**	**0.047**	**0.047**	**0.047**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.025 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.58	0.58	0.03	1.13	0.31	0.85	2:2	100%
Feb	0.08	0.08	0.03	0.13	0.05	0.10	2:2	100%
Mar	0.03	0.03	0.03	0.04	0.03	0.04	2:2	100%
Apr	0.02	0.02	0.02	0.02	0.02	0.02	0:2	0%
May	0.04	0.04	0.02	0.06	0.03	0.05	1:2	50%
Jun	0.02	0.02	0.02	0.02	0.02	0.02	0:2	0%
Jul	0.03	0.03	0.03	0.04	0.03	0.04	2:2	100%
Aug	0.04	0.04	0.02	0.05	0.03	0.05	1:2	50%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.05	0.05	0.03	0.08	0.04	0.07	2:2	100%
Nov	0.13	0.13	0.11	0.16	0.12	0.14	2:2	100%
Dec	0.30	0.30	0.04	0.56	0.17	0.43	2:2	100%
All Data	**0.12**	**0.03**	**0.01**	**1.13**	**0.02**	**0.07**	**16:23**	**70%**

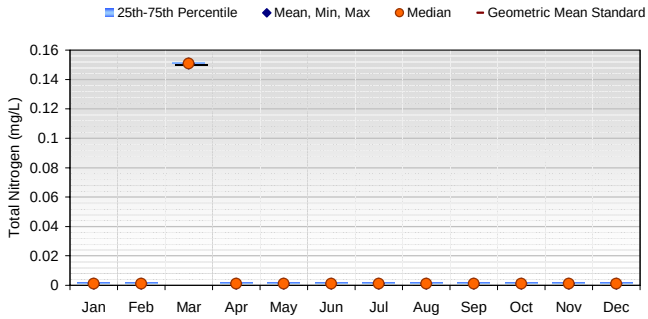
Not to Exceed 2% of the Time Analysis
(WQC = 0.035 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.58	0.58	0.03	1.13	0.31	0.85	1:2	50%
Feb	0.08	0.08	0.03	0.13	0.05	0.10	1:2	50%
Mar	0.03	0.03	0.03	0.04	0.03	0.04	1:2	50%
Apr	0.02	0.02	0.02	0.02	0.02	0.02	0:2	0%
May	0.04	0.04	0.02	0.06	0.03	0.05	1:2	50%
Jun	0.02	0.02	0.02	0.02	0.02	0.02	0:2	0%
Jul	0.03	0.03	0.03	0.04	0.03	0.04	1:2	50%
Aug	0.04	0.04	0.02	0.05	0.03	0.05	1:2	50%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.05	0.05	0.03	0.08	0.04	0.07	2:2	100%
Nov	0.13	0.13	0.11	0.16	0.12	0.14	2:2	100%
Dec	0.30	0.30	0.04	0.56	0.17	0.43	2:2	100%
All Data	**0.12**	**0.03**	**0.01**	**1.13**	**0.02**	**0.07**	**12:23**	**52%**

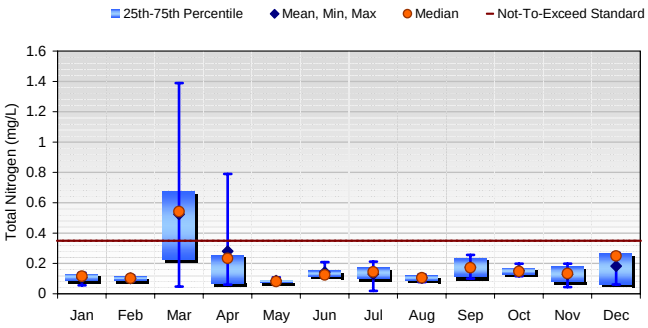
Figure A-20. Nitrate plus nitrite analyses for the Waikoko Stream Estuary

Geometric Mean Analysis*
(WQC = 0.200 mg/L)



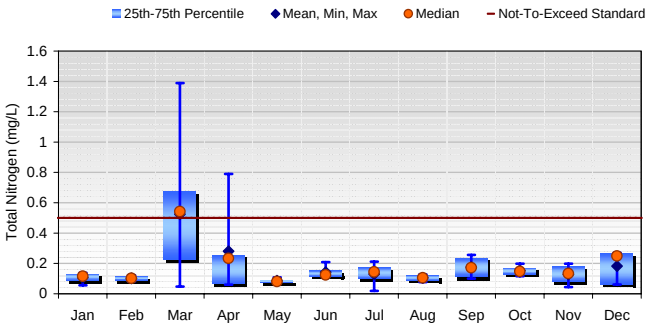
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.151	0.151	0.151	0.151	0.151	0.151	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.151**	**0.151**	**0.151**	**0.151**	**0.151**	**0.151**	**0:1**	**0%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.350 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.11	0.12	0.06	0.14	0.09	0.13	0:4	0%
Feb	0.10	0.10	0.08	0.12	0.09	0.12	0:4	0%
Mar	0.52	0.54	0.05	1.39	0.23	0.68	7:11	64%
Apr	0.28	0.23	0.06	0.79	0.06	0.25	0:5	0%
May	0.09	0.08	0.07	0.11	0.08	0.09	0:4	0%
Jun	0.14	0.12	0.11	0.21	0.11	0.15	0:4	0%
Jul	0.13	0.14	0.02	0.21	0.10	0.18	0:4	0%
Aug	0.10	0.11	0.08	0.13	0.09	0.12	0:4	0%
Sep	0.17	0.17	0.10	0.26	0.11	0.24	0:4	0%
Oct	0.15	0.15	0.12	0.20	0.13	0.17	0:4	0%
Nov	0.13	0.13	0.04	0.20	0.08	0.18	0:6	0%
Dec	0.18	0.25	0.06	0.27	0.06	0.27	0:5	0%
All Data	**0.22**	**0.13**	**0.02**	**1.39**	**0.09**	**0.23**	**7:59**	**12%**

Not to Exceed 2% of the Time Analysis
(WQC = 0.500 mg/L)

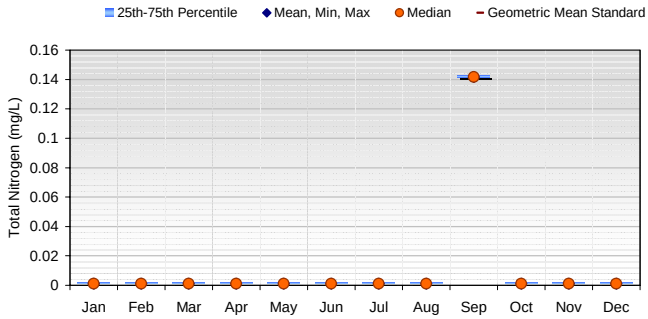


Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.11	0.12	0.06	0.14	0.09	0.13	0:4	0%
Feb	0.10	0.10	0.08	0.12	0.09	0.12	0:4	0%
Mar	0.52	0.54	0.05	1.39	0.23	0.68	7:11	64%
Apr	0.28	0.23	0.06	0.79	0.06	0.25	0:5	0%
May	0.09	0.08	0.07	0.11	0.08	0.09	0:4	0%
Jun	0.14	0.12	0.11	0.21	0.11	0.15	0:4	0%
Jul	0.13	0.14	0.02	0.21	0.10	0.18	0:4	0%
Aug	0.10	0.11	0.08	0.13	0.09	0.12	0:4	0%
Sep	0.17	0.17	0.10	0.26	0.11	0.24	0:4	0%
Oct	0.15	0.15	0.12	0.20	0.13	0.17	0:4	0%
Nov	0.13	0.13	0.04	0.20	0.08	0.18	0:6	0%
Dec	0.18	0.25	0.06	0.27	0.06	0.27	0:5	0%
All Data	**0.22**	**0.13**	**0.02**	**1.39**	**0.09**	**0.23**	**7:59**	**12%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

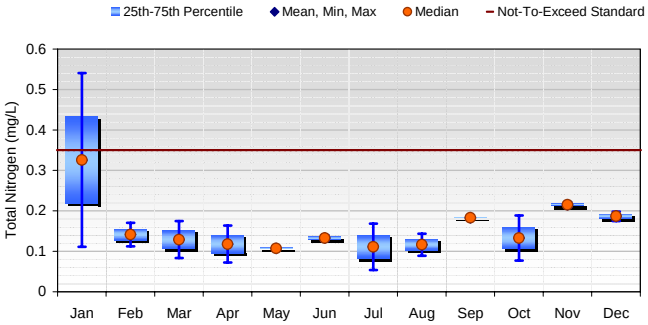
Figure A-21. Total nitrogen analyses for the Hanalei River Estuary

Geometric Mean Analysis*
(WQC = 0.200 mg/L)



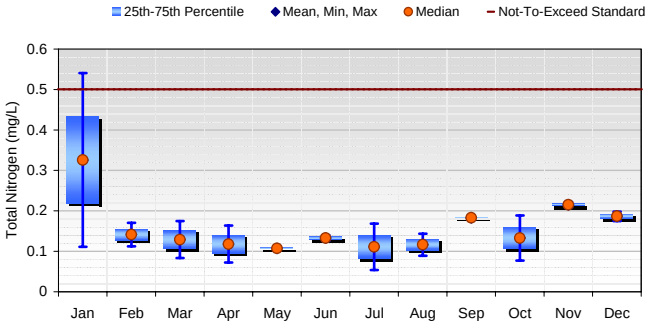
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.142	0.142	0.142	0.142	0.142	0.142	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.142**	**0.142**	**0.142**	**0.142**	**0.142**	**0.142**	**0:1**	**0%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.350 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.33	0.33	0.11	0.54	0.22	0.43	1:2	50%
Feb	0.14	0.14	0.11	0.17	0.13	0.16	0:2	0%
Mar	0.13	0.13	0.08	0.17	0.11	0.15	0:2	0%
Apr	0.12	0.12	0.07	0.16	0.10	0.14	0:2	0%
May	0.11	0.11	0.10	0.11	0.11	0.11	0:2	0%
Jun	0.13	0.13	0.13	0.14	0.13	0.14	0:2	0%
Jul	0.11	0.11	0.05	0.17	0.08	0.14	0:2	0%
Aug	0.12	0.12	0.09	0.14	0.10	0.13	0:2	0%
Sep	0.18	0.18	0.18	0.18	0.18	0.18	0:1	0%
Oct	0.13	0.13	0.08	0.19	0.11	0.16	0:2	0%
Nov	0.22	0.22	0.21	0.22	0.21	0.22	0:2	0%
Dec	0.19	0.19	0.18	0.20	0.18	0.19	0:2	0%
All Data	**0.16**	**0.14**	**0.05**	**0.54**	**0.11**	**0.18**	**1:23**	**4%**

Not to Exceed 2% of the Time Analysis
(WQC = 0.500 mg/L)

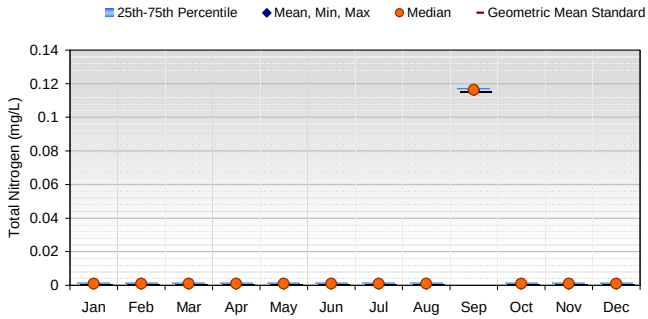


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.33	0.33	0.11	0.54	0.22	0.43	1:2	50%
Feb	0.14	0.14	0.11	0.17	0.13	0.16	0:2	0%
Mar	0.13	0.13	0.08	0.17	0.11	0.15	0:2	0%
Apr	0.12	0.12	0.07	0.16	0.10	0.14	0:2	0%
May	0.11	0.11	0.10	0.11	0.11	0.11	0:2	0%
Jun	0.13	0.13	0.13	0.14	0.13	0.14	0:2	0%
Jul	0.11	0.11	0.05	0.17	0.08	0.14	0:2	0%
Aug	0.12	0.12	0.09	0.14	0.10	0.13	0:2	0%
Sep	0.18	0.18	0.18	0.18	0.18	0.18	0:1	0%
Oct	0.13	0.13	0.08	0.19	0.11	0.16	0:2	0%
Nov	0.22	0.22	0.21	0.22	0.21	0.22	0:2	0%
Dec	0.19	0.19	0.18	0.20	0.18	0.19	0:2	0%
All Data	**0.16**	**0.14**	**0.05**	**0.54**	**0.11**	**0.18**	**1:23**	**4%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

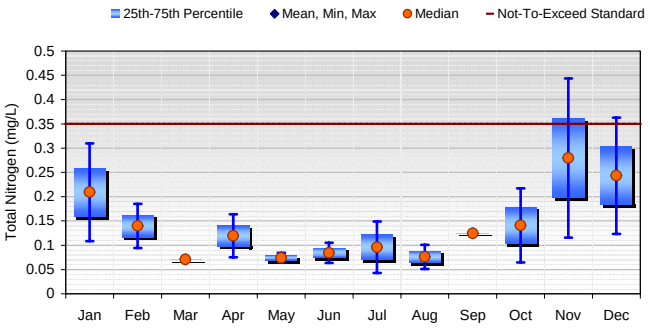
Figure A-22. Total nitrogen analyses for the Waioli Stream Estuary

Geometric Mean Analysis*
(WQC = 0.200 mg/L)



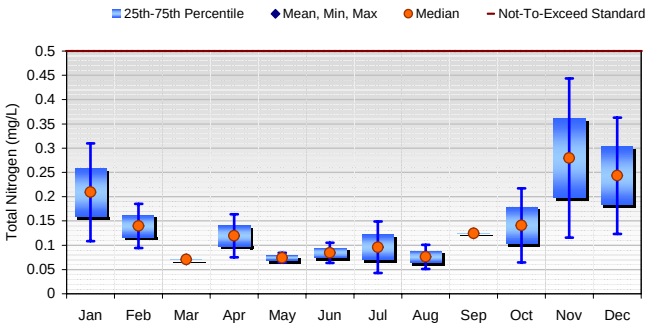
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.116	0.116	0.116	0.116	0.116	0.116	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.116**	**0.116**	**0.116**	**0.116**	**0.116**	**0.116**	**0:1**	**0%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.350 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.21	0.21	0.11	0.31	0.16	0.26	0:2	0%
Feb	0.14	0.14	0.09	0.19	0.12	0.16	0:2	0%
Mar	0.07	0.07	0.07	0.07	0.07	0.07	0:1	0%
Apr	0.12	0.12	0.08	0.16	0.10	0.14	0:2	0%
May	0.07	0.07	0.06	0.08	0.07	0.08	0:2	0%
Jun	0.08	0.08	0.06	0.11	0.07	0.09	0:2	0%
Jul	0.10	0.10	0.04	0.15	0.07	0.12	0:2	0%
Aug	0.08	0.08	0.05	0.10	0.06	0.09	0:2	0%
Sep	0.12	0.12	0.12	0.12	0.12	0.12	0:1	0%
Oct	0.14	0.14	0.06	0.22	0.10	0.18	0:2	0%
Nov	0.28	0.28	0.12	0.44	0.20	0.36	1:2	50%
Dec	0.24	0.24	0.12	0.36	0.18	0.30	1:2	50%
All Data	**0.14**	**0.11**	**0.04**	**0.44**	**0.07**	**0.16**	**2:22**	**9%**

Not to Exceed 2% of the Time Analysis*
(WQC = 0.500 mg/L)

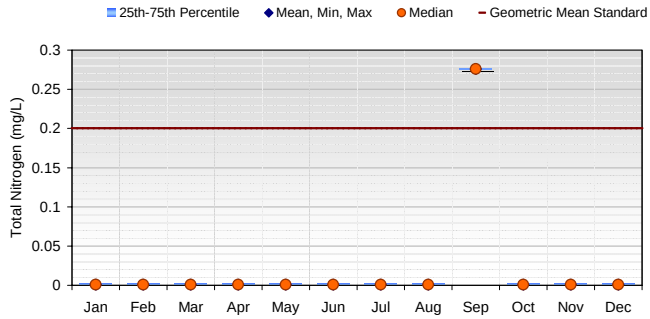


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.21	0.21	0.11	0.31	0.16	0.26	0:2	0%
Feb	0.14	0.14	0.09	0.19	0.12	0.16	0:2	0%
Mar	0.07	0.07	0.07	0.07	0.07	0.07	0:1	0%
Apr	0.12	0.12	0.08	0.16	0.10	0.14	0:2	0%
May	0.07	0.07	0.06	0.08	0.07	0.08	0:2	0%
Jun	0.08	0.08	0.06	0.11	0.07	0.09	0:2	0%
Jul	0.10	0.10	0.04	0.15	0.07	0.12	0:2	0%
Aug	0.08	0.08	0.05	0.10	0.06	0.09	0:2	0%
Sep	0.12	0.12	0.12	0.12	0.12	0.12	0:1	0%
Oct	0.14	0.14	0.06	0.22	0.10	0.18	0:2	0%
Nov	0.28	0.28	0.12	0.44	0.20	0.36	0:2	0%
Dec	0.24	0.24	0.12	0.36	0.18	0.30	0:2	0%
All Data	**0.14**	**0.11**	**0.04**	**0.44**	**0.07**	**0.16**	**0:22**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

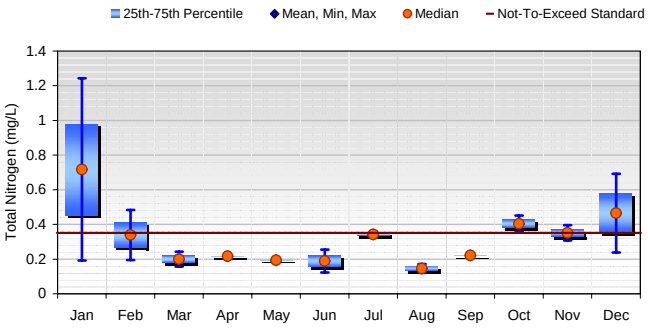
Figure A-23. Total nitrogen analyses for the Waipa Stream Estuary

Geometric Mean Analysis
(WQC = 0.200 mg/L)



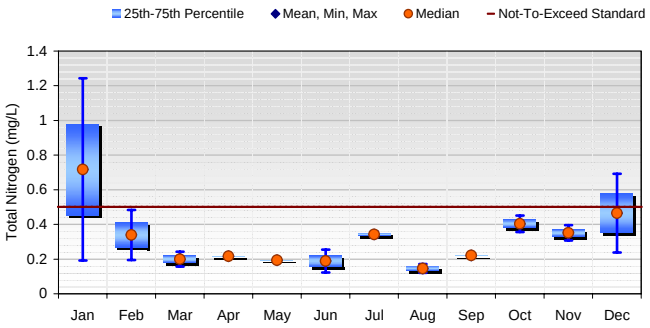
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.276	0.276	0.276	0.276	0.276	0.276	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.276**	**0.276**	**0.276**	**0.276**	**0.276**	**0.276**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.350 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.72	0.72	0.19	1.24	0.45	0.98	1:2	50%
Feb	0.34	0.34	0.20	0.48	0.27	0.41	1:2	50%
Mar	0.20	0.20	0.16	0.24	0.18	0.22	0:2	0%
Apr	0.22	0.22	0.21	0.22	0.21	0.22	0:2	0%
May	0.19	0.19	0.19	0.19	0.19	0.19	0:1	0%
Jun	0.19	0.19	0.12	0.26	0.16	0.22	0:2	0%
Jul	0.34	0.34	0.33	0.36	0.33	0.35	1:2	50%
Aug	0.15	0.15	0.12	0.17	0.13	0.16	0:2	0%
Sep	0.22	0.22	0.22	0.22	0.22	0.22	0:1	0%
Oct	0.40	0.40	0.36	0.45	0.38	0.43	2:2	100%
Nov	0.35	0.35	0.31	0.40	0.33	0.37	0:2	0%
Dec	0.46	0.46	0.24	0.69	0.35	0.58	1:2	50%
All Data	**0.33**	**0.24**	**0.12**	**1.24**	**0.19**	**0.36**	**6:22**	**27%**

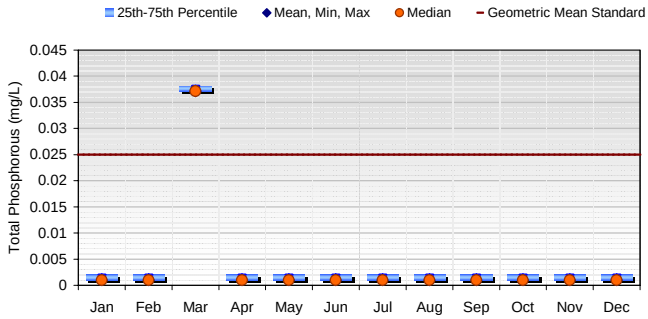
Not to Exceed 2% of the Time Analysis
(WQC = 0.500 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.72	0.72	0.19	1.24	0.45	0.98	1:2	50%
Feb	0.34	0.34	0.20	0.48	0.27	0.41	0:2	0%
Mar	0.20	0.20	0.16	0.24	0.18	0.22	0:2	0%
Apr	0.22	0.22	0.21	0.22	0.21	0.22	0:2	0%
May	0.19	0.19	0.19	0.19	0.19	0.19	0:1	0%
Jun	0.19	0.19	0.12	0.26	0.16	0.22	0:2	0%
Jul	0.34	0.34	0.33	0.36	0.33	0.35	0:2	0%
Aug	0.15	0.15	0.12	0.17	0.13	0.16	0:2	0%
Sep	0.22	0.22	0.22	0.22	0.22	0.22	0:1	0%
Oct	0.40	0.40	0.36	0.45	0.38	0.43	0:2	0%
Nov	0.35	0.35	0.31	0.40	0.33	0.37	0:2	0%
Dec	0.46	0.46	0.24	0.69	0.35	0.58	1:2	50%
All Data	**0.33**	**0.24**	**0.12**	**1.24**	**0.19**	**0.36**	**2:22**	**9%**

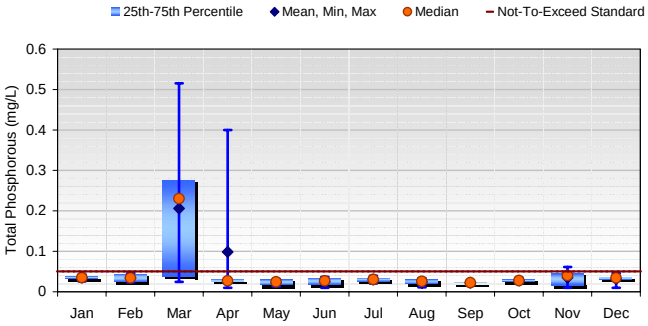
Figure A-24. Total nitrogen analyses for the Waikoko Stream Estuary

Geometric Mean Analysis
(WQC = 0.025 mg/L)



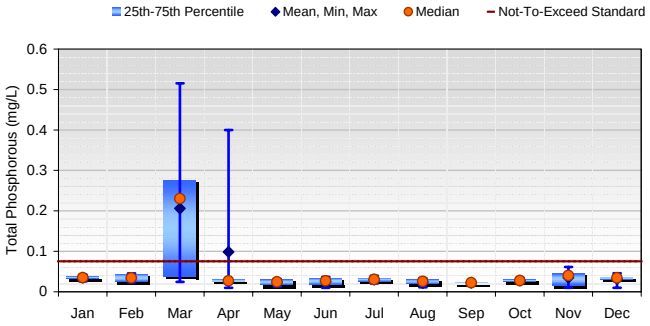
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.037	0.037	0.037	0.037	0.037	0.037	1:1	100%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.037**	**0.037**	**0.037**	**0.037**	**0.037**	**0.037**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.050 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.03	0.04	0.03	0.04	0.03	0.04	0:4	0%
Feb	0.03	0.03	0.02	0.05	0.02	0.04	0:4	0%
Mar	0.21	0.23	0.02	0.52	0.04	0.28	7:11	64%
Apr	0.10	0.03	0.01	0.40	0.03	0.03	0:5	0%
May	0.02	0.02	0.01	0.03	0.02	0.03	0:4	0%
Jun	0.03	0.03	0.01	0.04	0.02	0.03	0:4	0%
Jul	0.03	0.03	0.02	0.04	0.03	0.03	0:4	0%
Aug	0.02	0.03	0.01	0.03	0.02	0.03	0:4	0%
Sep	0.02	0.02	0.02	0.02	0.02	0.02	0:4	0%
Oct	0.03	0.03	0.02	0.03	0.02	0.03	0:4	0%
Nov	0.03	0.04	0.01	0.06	0.02	0.05	1:6	17%
Dec	0.03	0.03	0.01	0.05	0.03	0.04	1:5	20%
All Data	**0.07**	**0.03**	**0.01**	**0.52**	**0.02**	**0.04**	**9:59**	**15%**

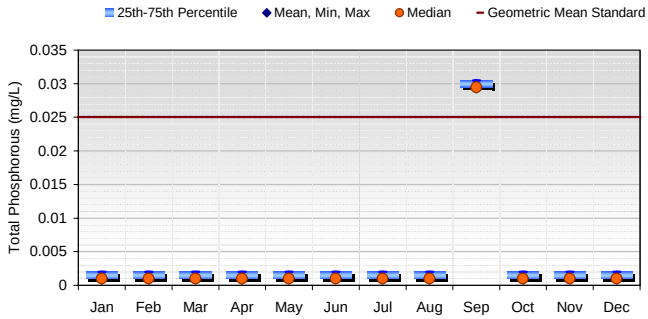
Not to Exceed 2% of the Time Analysis
(WQC = 0.075 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.03	0.04	0.03	0.04	0.03	0.04	0:4	0%
Feb	0.03	0.03	0.02	0.05	0.02	0.04	0:4	0%
Mar	0.21	0.23	0.02	0.52	0.04	0.28	7:11	64%
Apr	0.10	0.03	0.01	0.40	0.03	0.03	0:5	0%
May	0.02	0.02	0.01	0.03	0.02	0.03	0:4	0%
Jun	0.03	0.03	0.01	0.04	0.02	0.03	0:4	0%
Jul	0.03	0.03	0.02	0.04	0.03	0.03	0:4	0%
Aug	0.02	0.03	0.01	0.03	0.02	0.03	0:4	0%
Sep	0.02	0.02	0.02	0.02	0.02	0.02	0:4	0%
Oct	0.03	0.03	0.02	0.03	0.02	0.03	0:4	0%
Nov	0.03	0.04	0.01	0.06	0.02	0.05	0:6	0%
Dec	0.03	0.03	0.01	0.05	0.03	0.04	0:5	0%
All Data	**0.07**	**0.03**	**0.01**	**0.52**	**0.02**	**0.04**	**7:59**	**12%**

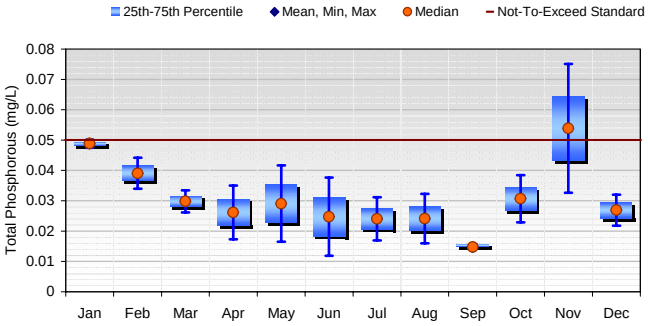
Figure A-25. Total phosphorus analyses for the Hanalei River Estuary

Geometric Mean Analysis
(WQC = 0.025 mg/L)



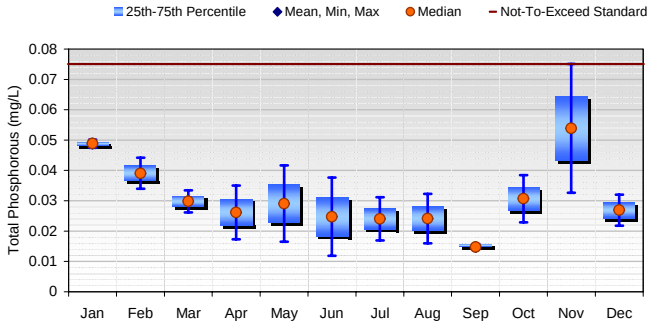
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.029	0.029	0.029	0.029	0.029	0.029	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.029**	**0.029**	**0.029**	**0.029**	**0.029**	**0.029**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.050 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.05	0.05	0.05	0.05	0.05	0.05	1:2	50%
Feb	0.04	0.04	0.03	0.04	0.04	0.04	0:2	0%
Mar	0.03	0.03	0.03	0.03	0.03	0.03	0:2	0%
Apr	0.03	0.03	0.02	0.04	0.02	0.03	0:2	0%
May	0.03	0.03	0.02	0.04	0.02	0.04	0:2	0%
Jun	0.02	0.02	0.01	0.04	0.02	0.03	0:2	0%
Jul	0.02	0.02	0.02	0.03	0.02	0.03	0:2	0%
Aug	0.02	0.02	0.02	0.03	0.02	0.03	0:2	0%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.03	0.03	0.02	0.04	0.03	0.03	0:2	0%
Nov	0.05	0.05	0.03	0.08	0.04	0.06	1:2	50%
Dec	0.03	0.03	0.02	0.03	0.02	0.03	1:2	50%
All Data	**0.03**	**0.03**	**0.01**	**0.08**	**0.02**	**0.04**	**3:23**	**13%**

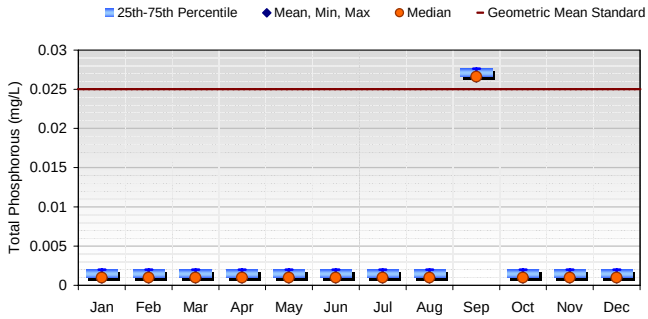
Not to Exceed 2% of the Time Analysis
(WQC = 0.075 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.05	0.05	0.05	0.05	0.05	0.05	0:2	0%
Feb	0.04	0.04	0.03	0.04	0.04	0.04	0:2	0%
Mar	0.03	0.03	0.03	0.03	0.03	0.03	0:2	0%
Apr	0.03	0.03	0.02	0.04	0.02	0.03	0:2	0%
May	0.03	0.03	0.02	0.04	0.02	0.04	0:2	0%
Jun	0.02	0.02	0.01	0.04	0.02	0.03	0:2	0%
Jul	0.02	0.02	0.02	0.03	0.02	0.03	0:2	0%
Aug	0.02	0.02	0.02	0.03	0.02	0.03	0:2	0%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.03	0.03	0.02	0.04	0.03	0.03	0:2	0%
Nov	0.05	0.05	0.03	0.08	0.04	0.06	1:2	50%
Dec	0.03	0.03	0.02	0.03	0.02	0.03	0:2	0%
All Data	**0.03**	**0.03**	**0.01**	**0.08**	**0.02**	**0.04**	**1:23**	**4%**

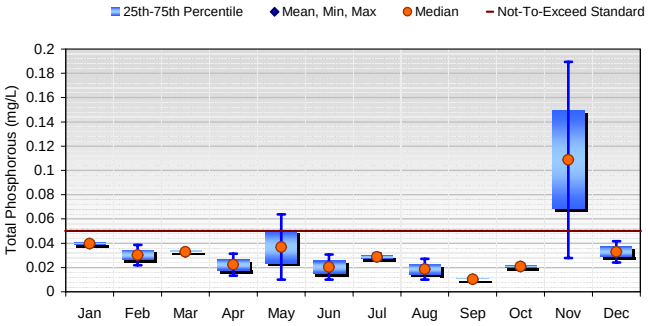
Figure A-26. Total phosphorus analyses for the Waioli Stream Estuary

Geometric Mean Analysis
(WQC = 0.025 mg/L)



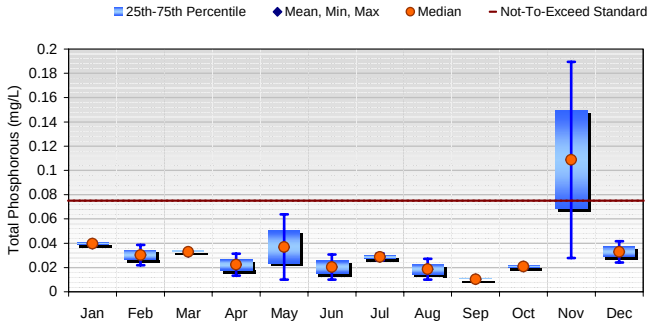
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.027	0.027	0.027	0.027	0.027	0.027	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.027**	**0.027**	**0.027**	**0.027**	**0.027**	**0.027**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.050 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.04	0.04	0.04	0.04	0.04	0.04	0:2	0%
Feb	0.03	0.03	0.02	0.04	0.03	0.03	0:2	0%
Mar	0.03	0.03	0.03	0.03	0.03	0.03	0:1	0%
Apr	0.02	0.02	0.01	0.03	0.02	0.03	0:2	0%
May	0.04	0.04	0.01	0.06	0.02	0.05	1:2	50%
Jun	0.02	0.02	0.01	0.03	0.02	0.03	0:2	0%
Jul	0.03	0.03	0.03	0.03	0.03	0.03	0:2	0%
Aug	0.02	0.02	0.01	0.03	0.01	0.02	0:2	0%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.02	0.02	0.02	0.02	0.02	0.02	0:2	0%
Nov	0.11	0.11	0.03	0.19	0.07	0.15	1:2	50%
Dec	0.03	0.03	0.02	0.04	0.03	0.04	0:2	0%
All Data	**0.03**	**0.03**	**0.01**	**0.19**	**0.02**	**0.04**	**2:22**	**9%**

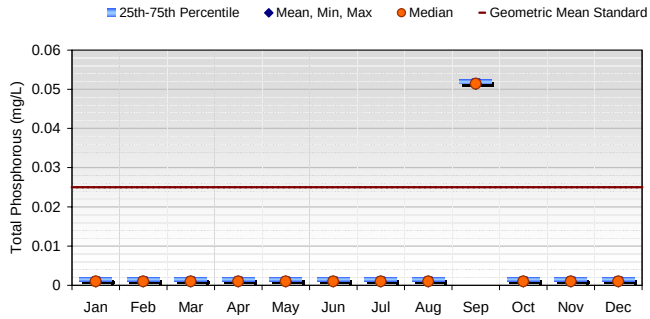
Not to Exceed 2% of the Time Analysis
(WQC = 0.075 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.04	0.04	0.04	0.04	0.04	0.04	0:2	0%
Feb	0.03	0.03	0.02	0.04	0.03	0.03	0:2	0%
Mar	0.03	0.03	0.03	0.03	0.03	0.03	0:1	0%
Apr	0.02	0.02	0.01	0.03	0.02	0.03	0:2	0%
May	0.04	0.04	0.01	0.06	0.02	0.05	0:2	0%
Jun	0.02	0.02	0.01	0.03	0.02	0.03	0:2	0%
Jul	0.03	0.03	0.03	0.03	0.03	0.03	0:2	0%
Aug	0.02	0.02	0.01	0.03	0.01	0.02	0:2	0%
Sep	0.01	0.01	0.01	0.01	0.01	0.01	0:1	0%
Oct	0.02	0.02	0.02	0.02	0.02	0.02	0:2	0%
Nov	0.11	0.11	0.03	0.19	0.07	0.15	1:2	50%
Dec	0.03	0.03	0.02	0.04	0.03	0.04	0:2	0%
All Data	**0.03**	**0.03**	**0.01**	**0.19**	**0.02**	**0.04**	**1:22**	**5%**

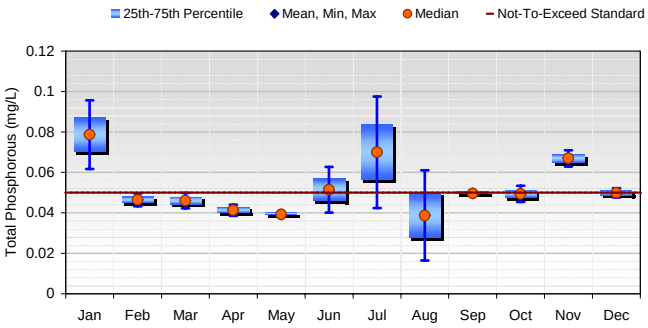
Figure A-27. Total phosphorus analyses for the Waipa Stream Estuary

Geometric Mean Analysis
(WQC = 0.025 mg/L)



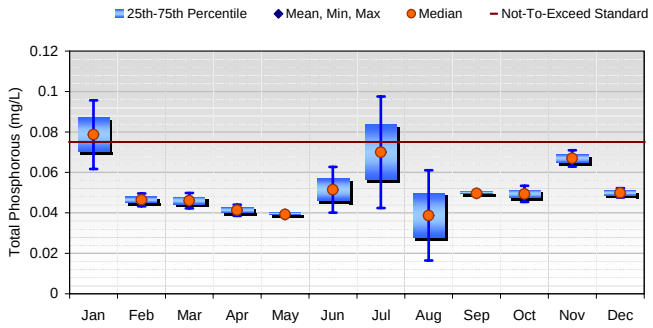
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.051	0.051	0.051	0.051	0.051	0.051	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.051**	**0.051**	**0.051**	**0.051**	**0.051**	**0.051**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis
(WQC = 0.050 mg/L)



Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.08	0.08	0.06	0.10	0.07	0.09	2:2	100%
Feb	0.05	0.05	0.04	0.05	0.04	0.05	0:2	0%
Mar	0.05	0.05	0.04	0.05	0.04	0.05	0:2	0%
Apr	0.04	0.04	0.04	0.04	0.04	0.04	0:2	0%
May	0.04	0.04	0.04	0.04	0.04	0.04	0:1	0%
Jun	0.05	0.05	0.04	0.06	0.05	0.06	1:2	50%
Jul	0.07	0.07	0.04	0.10	0.06	0.08	1:2	50%
Aug	0.04	0.04	0.02	0.06	0.03	0.05	1:2	50%
Sep	0.05	0.05	0.05	0.05	0.05	0.05	0:1	0%
Oct	0.05	0.05	0.05	0.05	0.05	0.05	1:2	50%
Nov	0.07	0.07	0.06	0.07	0.06	0.07	2:2	100%
Dec	0.05	0.05	0.05	0.05	0.05	0.05	1:2	50%
All Data	**0.05**	**0.05**	**0.02**	**0.10**	**0.04**	**0.06**	**9:22**	**41%**

Not to Exceed 2% of the Time Analysis
(WQC = 0.075 mg/L)

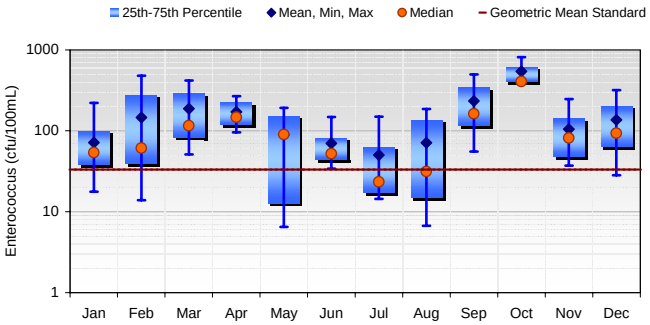


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.08	0.08	0.06	0.10	0.07	0.09	1:2	50%
Feb	0.05	0.05	0.04	0.05	0.04	0.05	0:2	0%
Mar	0.05	0.05	0.04	0.05	0.04	0.05	0:2	0%
Apr	0.04	0.04	0.04	0.04	0.04	0.04	0:2	0%
May	0.04	0.04	0.04	0.04	0.04	0.04	0:1	0%
Jun	0.05	0.05	0.04	0.06	0.05	0.06	0:2	0%
Jul	0.07	0.07	0.04	0.10	0.06	0.08	1:2	50%
Aug	0.04	0.04	0.02	0.06	0.03	0.05	0:2	0%
Sep	0.05	0.05	0.05	0.05	0.05	0.05	0:1	0%
Oct	0.05	0.05	0.05	0.05	0.05	0.05	0:2	0%
Nov	0.07	0.07	0.06	0.07	0.06	0.07	0:2	0%
Dec	0.05	0.05	0.05	0.05	0.05	0.05	1:2	50%
All Data	**0.05**	**0.05**	**0.02**	**0.10**	**0.04**	**0.06**	**3:22**	**14%**

Figure A-28. Total phosphorus analyses for the Waikoko Stream Estuary

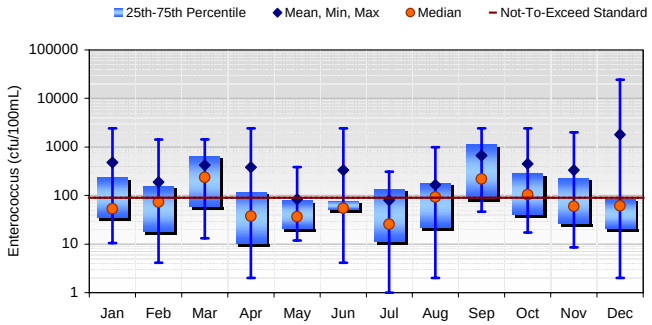
A-2. Review of Impaired Segments – Streams

Geometric Mean Analysis
(WQC = 33 cfu/100mL)



Summary Statistics (Data: 5/5/2001 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	72	54	18	222	38	99	12:14	86%
Feb	146	61	14	481	39	281	11:14	79%
Mar	188	115	51	418	83	294	11:11	100%
Apr	171	148	96	267	118	225	5:5	100%
May	89	90	7	192	13	152	6:9	67%
Jun	70	52	34	148	44	82	6:6	100%
Jul	50	23	14	150	17	63	4:9	44%
Aug	71	31	7	186	15	136	6:12	50%
Sep	234	163	55	500	115	345	7:7	100%
Oct	540	407	397	816	402	612	3:3	100%
Nov	105	81	37	247	48	142	10:10	100%
Dec	137	93	28	320	63	202	13:15	87%
All Data	**129**	**88**	**7**	**816**	**41**	**163**	**94:115**	**82%**

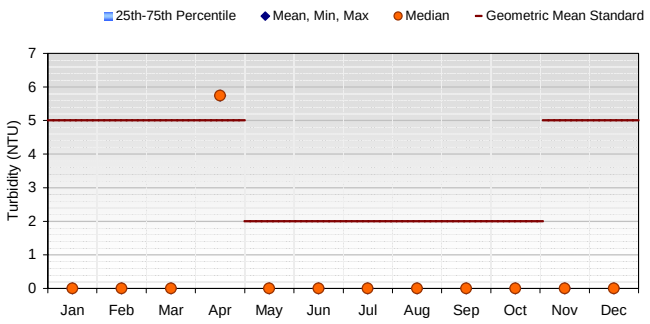
Single Sample Maximum Analysis
(WQC = 89 cfu/100mL)



Summary Statistics (Data: 5/5/2001 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	482	53	10	2420	35	236	6:14	43%
Feb	187	73	4	1414	18	155	8:17	47%
Mar	424	237	13	1447	58	659	8:12	67%
Apr	381	37	2	2420	10	120	3:9	33%
May	84	37	12	388	21	79	4:16	25%
Jun	332	55	4	2420	50	77	2:9	22%
Jul	80	26	1	308	11	138	3:10	30%
Aug	166	93	2	980	21	182	8:15	53%
Sep	662	219	47	2420	84	1120	6:9	67%
Oct	452	104	17	2420	40	291	6:12	50%
Nov	332	60	9	1986	26	230	7:18	39%
Dec	1802	61	2	24196	20	84	3:14	21%
All Data	**443**	**57**	**1**	**24196**	**24**	**225**	**64:155**	**41%**

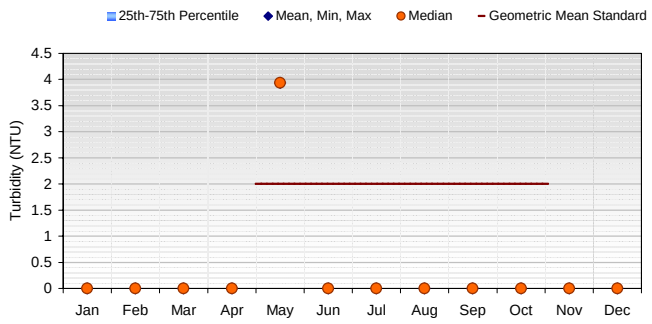
Figure A-29. Enterococcus analysis for Hanalei River

***Wet Season* Geometric Mean Analysis**
(WQC = 5 NTU)



Summary Statistics (Data: 11/5/2001 to 4/27/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	5.74	5.74	5.74	5.74	5.74	5.74	1:1	100%
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**5.74**	**5.74**	**5.74**	**5.74**	**5.74**	**5.74**	**1:1**	**100%**

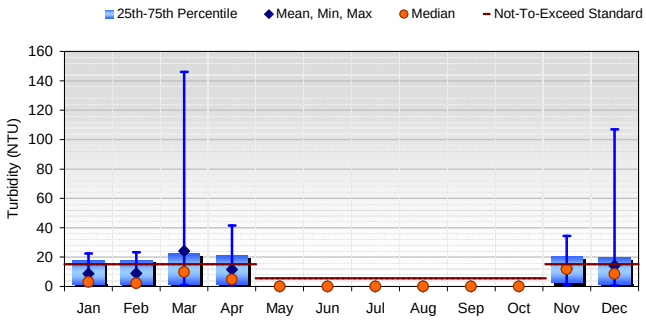
***Dry Season* Geometric Mean Analysis**
(WQC = 2 NTU)



Summary Statistics (Data: 5/1/2002 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	3.94	3.94	3.94	3.94	3.94	3.94	1:1	100%
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**3.94**	**3.94**	**3.94**	**3.94**	**3.94**	**3.94**	**1:1**	**100%**

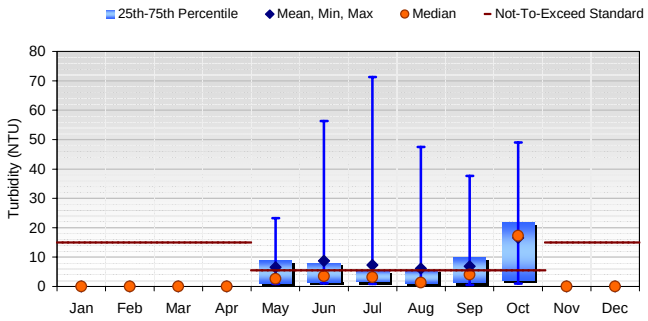
Figure A-30. Geometric mean turbidity analyses for Hanalei River

Wet Season Not to Exceed 10% of the Time Analysis (WQC = 15 NTU)



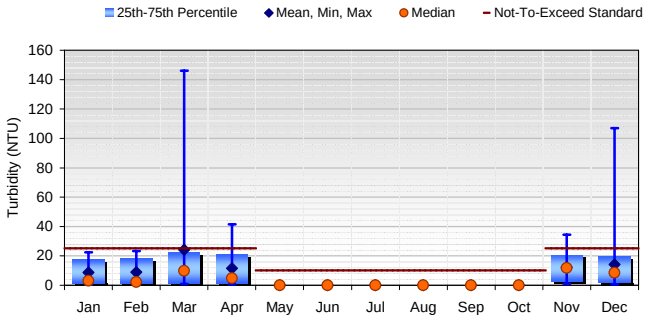
Summary Statistics (Data: 11/5/2001 to 4/27/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	8.76	2.95	0.53	22.40	1.36	17.70	8:23	35%
Feb	9.05	2.18	0.77	23.30	1.37	18.10	9:23	39%
Mar	24.32	9.89	0.77	146.00	1.33	22.50	12:25	48%
Apr	11.56	4.80	0.71	41.50	1.62	21.00	11:25	44%
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	12.14	11.80	0.77	34.40	2.55	20.70	12:26	46%
Dec	14.18	8.59	0.68	107.00	1.74	19.80	10:23	43%
All Data	**13.44**	**4.80**	**0.53**	**146.00**	**1.59**	**19.80**	**62:145**	**43%**

Dry Season Not to Exceed 10% of the Time Analysis (WQC = 5.5 NTU)



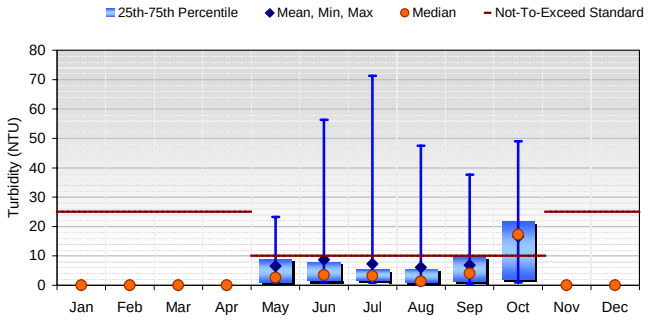
Summary Statistics (Data: 5/1/2002 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	6.54	2.65	0.83	23.20	1.12	8.83	10:29	34%
Jun	8.75	3.53	1.13	56.30	1.56	8.01	5:22	23%
Jul	7.28	3.15	0.82	71.30	1.68	5.46	6:22	27%
Aug	6.14	1.26	0.51	47.50	1.06	5.54	6:24	25%
Sep	6.85	4.05	0.59	37.70	1.31	9.78	8:23	35%
Oct	16.63	17.20	0.99	49.00	2.15	21.75	15:23	65%
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**8.60**	**3.28**	**0.51**	**71.30**	**1.29**	**9.22**	**50:143**	**35%**

Wet Season Not to Exceed 2% of the Time Analysis (WQC = 25 NTU)



Summary Statistics (Data: 11/5/2001 to 4/27/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	8.76	2.95	0.53	22.40	1.36	17.70	0:23	0%
Feb	9.05	2.18	0.77	23.30	1.37	18.10	0:23	0%
Mar	24.32	9.89	0.77	146.00	1.33	22.50	5:25	20%
Apr	11.56	4.80	0.71	41.50	1.62	21.00	1:25	4%
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	12.14	11.80	0.77	34.40	2.55	20.70	3:26	12%
Dec	14.18	8.59	0.68	107.00	1.74	19.80	1:23	4%
All Data	**13.44**	**4.80**	**0.53**	**146.00**	**1.59**	**19.80**	**10:145**	**7%**

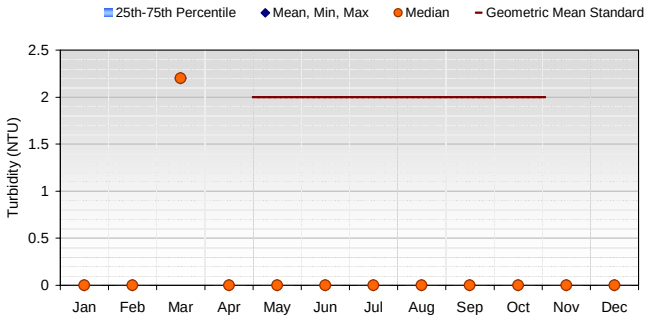
Dry Season Not to Exceed 2% of the Time Analysis (WQC = 10 NTU)



Summary Statistics (Data: 5/1/2002 to 5/18/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	6.54	2.65	0.83	23.20	1.12	8.83	6:29	21%
Jun	8.75	3.53	1.13	56.30	1.56	8.01	3:22	14%
Jul	7.28	3.15	0.82	71.30	1.68	5.46	3:22	14%
Aug	6.14	1.26	0.51	47.50	1.06	5.54	3:24	13%
Sep	6.85	4.05	0.59	37.70	1.31	9.78	6:23	26%
Oct	16.63	17.20	0.99	49.00	2.15	21.75	14:23	61%
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**8.60**	**3.28**	**0.51**	**71.30**	**1.29**	**9.22**	**35:143**	**24%**

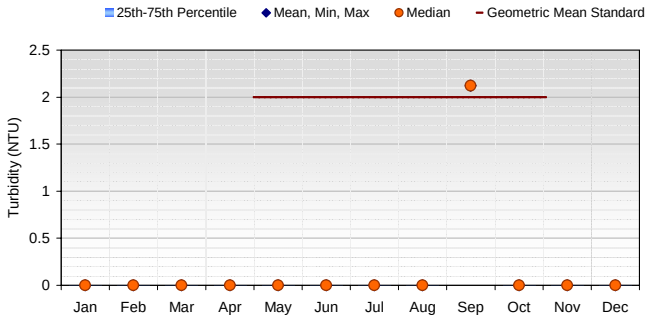
Figure A-31. Not-to-exceed turbidity analyses for Hanalei River

Wet Season Geometric Mean Analysis* (WQC = 5 NTU)



Summary Statistics (Data: 11/5/2001 to 3/6/2002)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	2.20	2.20	2.20	2.20	2.20	2.20	0:1	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.20**	**2.20**	**2.20**	**2.20**	**2.20**	**2.20**	**0:1**	**0%**

Dry Season Geometric Mean Analysis (WQC = 2 NTU)

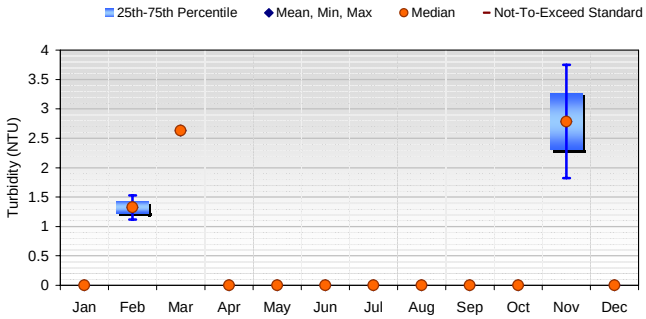


Summary Statistics (Data: 5/1/2002 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	2.12	2.12	2.12	2.12	2.12	2.12	1:1	100%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.12**	**2.12**	**2.12**	**2.12**	**2.12**	**2.12**	**1:1**	**100%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

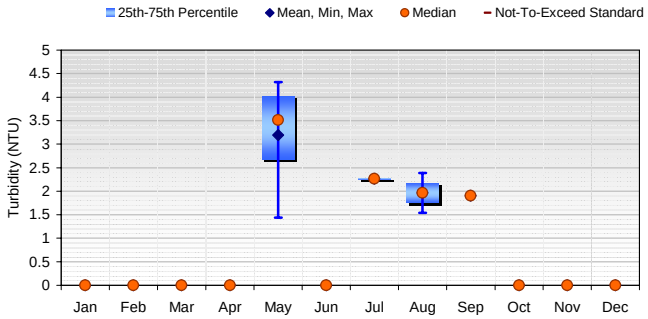
Figure A-32. Geometric mean turbidity analyses for Waioli Stream

Wet Season Not to Exceed 10% of the Time Analysis* (WQC = 15 NTU)



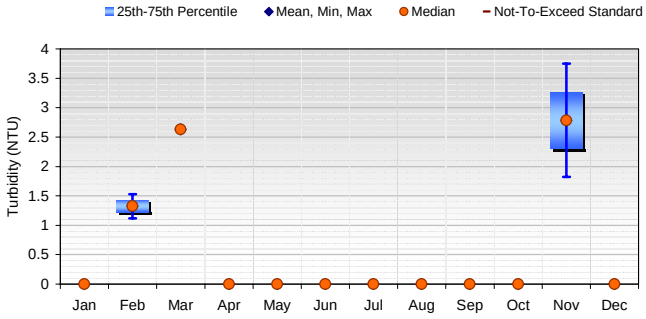
Summary Statistics (Data: 11/5/2001 to 3/6/2002)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	1.33	1.33	1.12	1.53	1.22	1.43	0:2	0%
Mar	2.63	2.63	2.63	2.63	2.63	2.63	0:1	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	2.79	2.79	1.82	3.75	2.30	3.27	0:2	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.17**	**1.82**	**1.12**	**3.75**	**1.53**	**2.63**	**0:5**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 5.5 NTU)



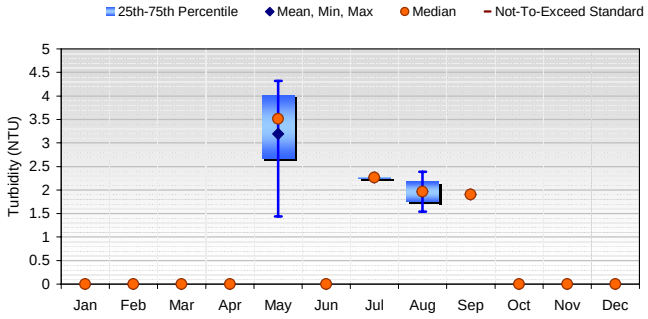
Summary Statistics (Data: 5/1/2002 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	3.20	3.51	1.44	4.32	2.68	4.03	0:4	0%
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	2.27	2.27	2.24	2.29	2.25	2.28	0:2	0%
Aug	1.97	1.97	1.54	2.39	1.75	2.18	0:2	0%
Sep	1.90	1.90	1.90	1.90	1.90	1.90	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.57**	**2.29**	**1.44**	**4.32**	**1.90**	**3.09**	**0:9**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 25 NTU)



Summary Statistics (Data: 11/5/2001 to 3/6/2002)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	1.33	1.33	1.12	1.53	1.22	1.43	0:2	0%
Mar	2.63	2.63	2.63	2.63	2.63	2.63	0:1	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	2.79	2.79	1.82	3.75	2.30	3.27	0:2	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.17**	**1.82**	**1.12**	**3.75**	**1.53**	**2.63**	**0:5**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 10 NTU)

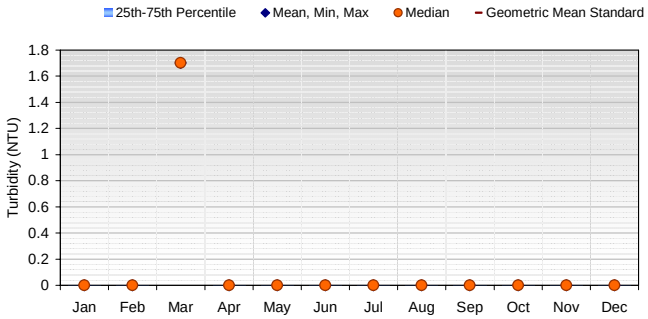


Summary Statistics (Data: 5/1/2002 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	3.20	3.51	1.44	4.32	2.68	4.03	0:4	0%
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	2.27	2.27	2.24	2.29	2.25	2.28	0:2	0%
Aug	1.97	1.97	1.54	2.39	1.75	2.18	0:2	0%
Sep	1.90	1.90	1.90	1.90	1.90	1.90	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.57**	**2.29**	**1.44**	**4.32**	**1.90**	**3.09**	**0:9**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

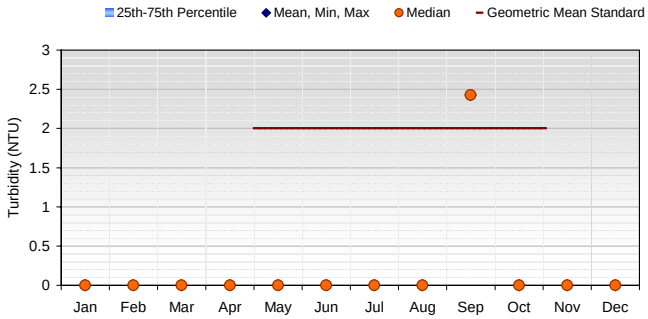
Figure A-33. Not-to-exceed turbidity analyses for Waioli Stream

Wet Season Geometric Mean Analysis* (WQC = 5 NTU)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	1.70	1.70	1.70	1.70	1.70	1.70	0:1	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**0:1**	**0%**

Dry Season Geometric Mean Analysis (WQC = 2 NTU)

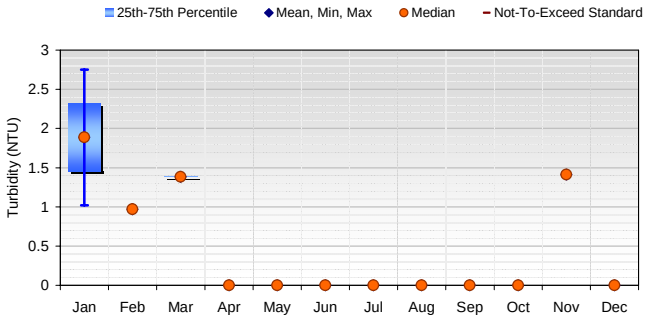


Summary Statistics (Data: 5/2/2002 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	2.43	2.43	2.43	2.43	2.43	2.43	1:1	100%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.43**	**2.43**	**2.43**	**2.43**	**2.43**	**2.43**	**1:1**	**100%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

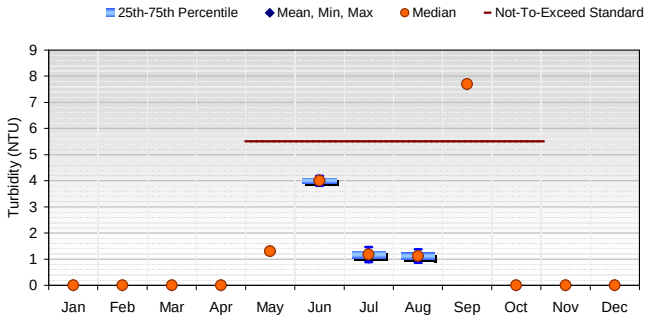
Figure A-34. Geometric mean turbidity analyses for Waipa Stream

Wet Season Not to Exceed 10% of the Time Analysis (WQC = 15 NTU)



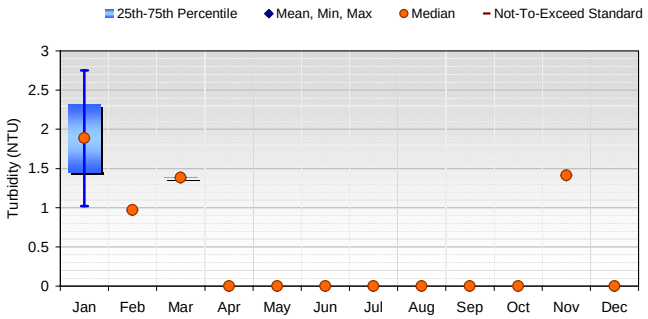
Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	1.89	1.89	1.02	2.75	1.45	2.32	0:2	0%
Feb	0.97	0.97	0.97	0.97	0.97	0.97	0:1	0%
Mar	1.39	1.39	1.38	1.39	1.38	1.39	0:2	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	1.41	1.41	1.41	1.41	1.41	1.41	0:1	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.49**	**1.39**	**0.97**	**2.75**	**1.11**	**1.41**	**0:6**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis (WQC = 5.5 NTU)



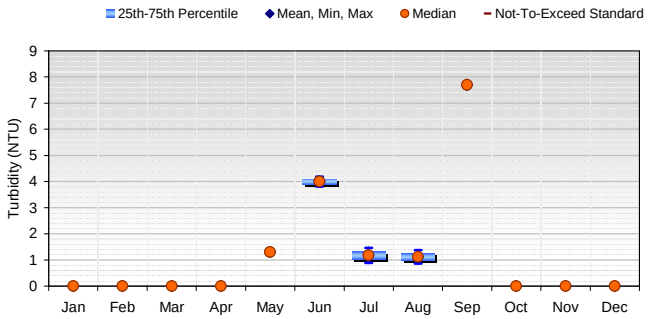
Summary Statistics (Data: 5/2/2002 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	1.30	1.30	1.30	1.30	1.30	1.30	0:1	0%
Jun	4.00	4.00	3.81	4.19	3.91	4.10	0:2	0%
Jul	1.18	1.18	0.89	1.46	1.03	1.32	0:2	0%
Aug	1.12	1.12	0.86	1.38	0.99	1.25	0:2	0%
Sep	7.70	7.70	7.70	7.70	7.70	7.70	1:1	100%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.70**	**1.42**	**0.86**	**7.70**	**1.20**	**3.91**	**1:8**	**13%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 25 NTU)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	1.89	1.89	1.02	2.75	1.45	2.32	0:2	0%
Feb	0.97	0.97	0.97	0.97	0.97	0.97	0:1	0%
Mar	1.39	1.39	1.38	1.39	1.38	1.39	0:2	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	1.41	1.41	1.41	1.41	1.41	1.41	0:1	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.49**	**1.39**	**0.97**	**2.75**	**1.11**	**1.41**	**0:6**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 10 NTU)

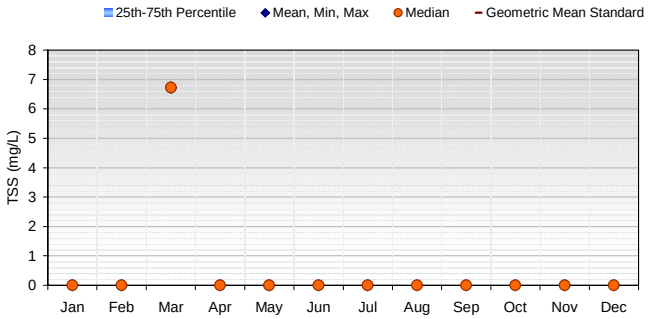


Summary Statistics (Data: 5/2/2002 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	1.30	1.30	1.30	1.30	1.30	1.30	0:1	0%
Jun	4.00	4.00	3.81	4.19	3.91	4.10	0:2	0%
Jul	1.18	1.18	0.89	1.46	1.03	1.32	0:2	0%
Aug	1.12	1.12	0.86	1.38	0.99	1.25	0:2	0%
Sep	7.70	7.70	7.70	7.70	7.70	7.70	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**2.70**	**1.42**	**0.86**	**7.70**	**1.20**	**3.91**	**0:8**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

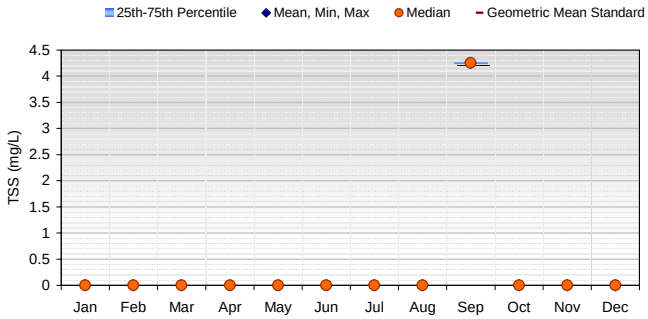
Figure A-35. Not-to-exceed turbidity analyses for Waipa Stream

Wet Season* Geometric Mean Analysis
(WQC = 20 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	6.73	6.73	6.73	6.73	6.73	6.73	0:1	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**6.73**	**6.73**	**6.73**	**6.73**	**6.73**	**6.73**	**0:1**	**0%**

Dry Season* Geometric Mean Analysis
(WQC = 10 mg/L)

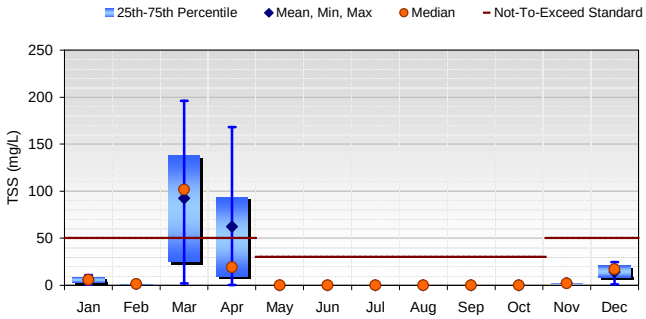


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	4.26	4.26	4.26	4.26	4.26	4.26	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**4.26**	**4.26**	**4.26**	**4.26**	**4.26**	**4.26**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

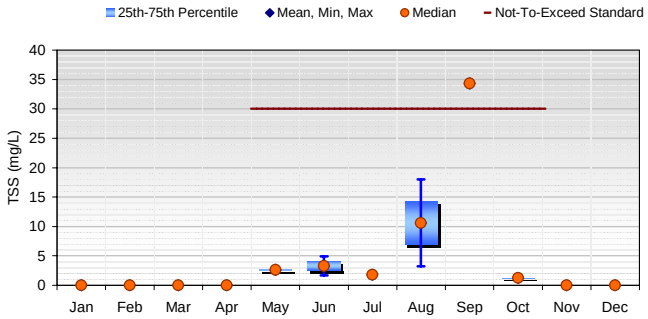
Figure A-36. Geometric mean TSS analyses for Hanalei River

Wet Season Not to Exceed 10% of the Time Analysis (WQC = 50 mg/L)



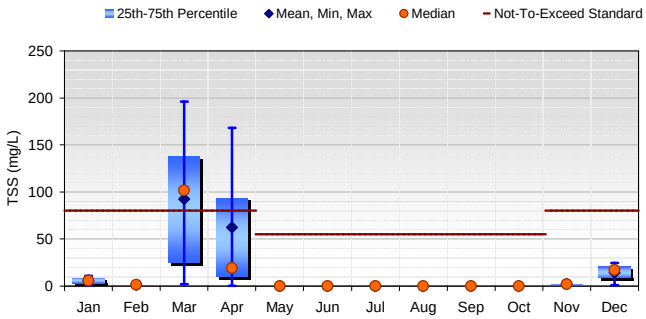
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	5.90	5.90	0.80	11.00	3.35	8.45	0:2	0%
Feb	1.20	1.20	0.80	1.60	1.00	1.40	0:2	0%
Mar	92.53	101.75	1.90	196.00	25.00	138.00	3:5	60%
Apr	62.50	19.00	0.50	168.00	9.75	93.50	0:3	0%
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	2.23	2.00	1.90	3.00	1.98	2.25	0:4	0%
Dec	14.20	17.00	1.00	24.60	9.00	20.80	0:3	0%
All Data	**37.68**	**3.00**	**0.50**	**196.00**	**1.75**	**24.80**	**3:19**	**16%**

Dry Season Not to Exceed 10% of the Time Analysis (WQC = 30 mg/L)



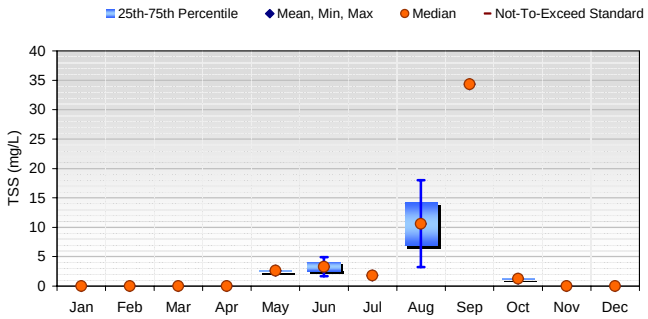
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	2.60	2.60	2.30	2.90	2.45	2.75	0:2	0%
Jun	3.30	3.30	1.70	4.90	2.50	4.10	0:2	0%
Jul	1.80	1.80	1.80	1.80	1.80	1.80	0:1	0%
Aug	10.60	10.60	3.20	18.00	6.90	14.30	0:2	0%
Sep	34.30	34.30	34.30	34.30	34.30	34.30	1:1	100%
Oct	1.25	1.25	1.20	1.30	1.23	1.28	0:2	0%
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**7.16**	**2.60**	**1.20**	**34.30**	**1.73**	**4.48**	**1:10**	**10%**

Wet Season Not to Exceed 2% of the Time Analysis (WQC = 80 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	5.90	5.90	0.80	11.00	3.35	8.45	0:2	0%
Feb	1.20	1.20	0.80	1.60	1.00	1.40	0:2	0%
Mar	92.53	101.75	1.90	196.00	25.00	138.00	3:5	60%
Apr	62.50	19.00	0.50	168.00	9.75	93.50	0:3	0%
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	2.23	2.00	1.90	3.00	1.98	2.25	0:4	0%
Dec	14.20	17.00	1.00	24.60	9.00	20.80	0:3	0%
All Data	**37.68**	**3.00**	**0.50**	**196.00**	**1.75**	**24.80**	**3:19**	**16%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 55 mg/L)

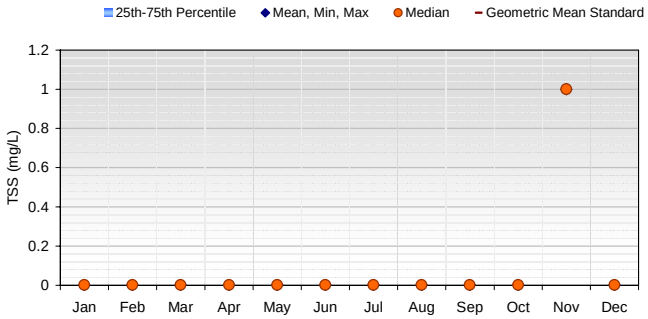


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	2.60	2.60	2.30	2.90	2.45	2.75	0:2	0%
Jun	3.30	3.30	1.70	4.90	2.50	4.10	0:2	0%
Jul	1.80	1.80	1.80	1.80	1.80	1.80	0:1	0%
Aug	10.60	10.60	3.20	18.00	6.90	14.30	0:2	0%
Sep	34.30	34.30	34.30	34.30	34.30	34.30	0:1	0%
Oct	1.25	1.25	1.20	1.30	1.23	1.28	0:2	0%
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**7.16**	**2.60**	**1.20**	**34.30**	**1.73**	**4.48**	**0:10**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

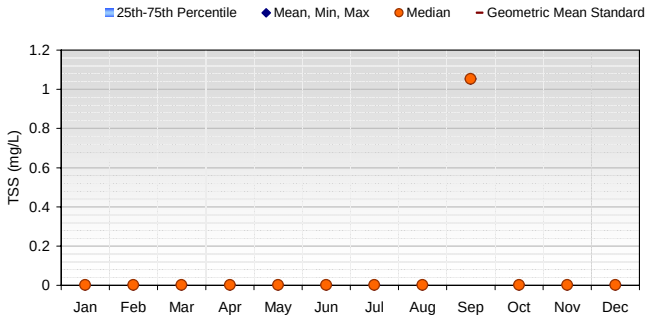
Figure A-37. Not-to-exceed TSS analyses for Hanalei River

Wet Season Geometric Mean Analysis*
(WQC = 20 mg/L)



Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	1.00	1.00	1.00	1.00	1.00	1.00	0:1	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0:1**	**0%**

Dry Season Geometric Mean Analysis*
(WQC = 10 mg/L)

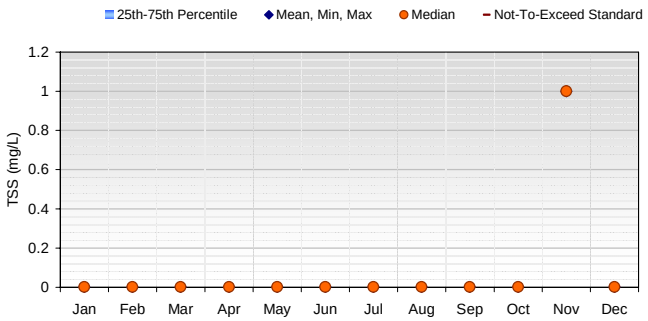


Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	1.05	1.05	1.05	1.05	1.05	1.05	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.05**	**1.05**	**1.05**	**1.05**	**1.05**	**1.05**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

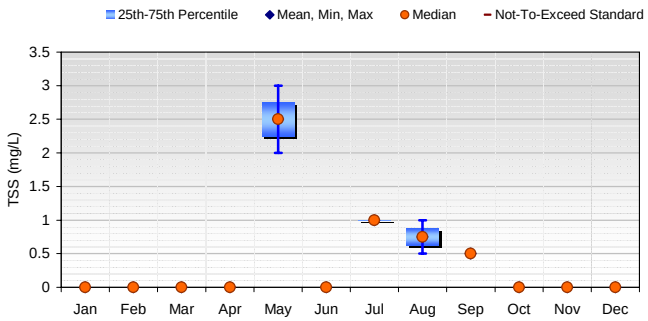
Figure A-38. Geometric mean TSS analyses for Waioli Stream

Wet Season Not to Exceed 10% of the Time Analysis* (WQC = 50 mg/L)



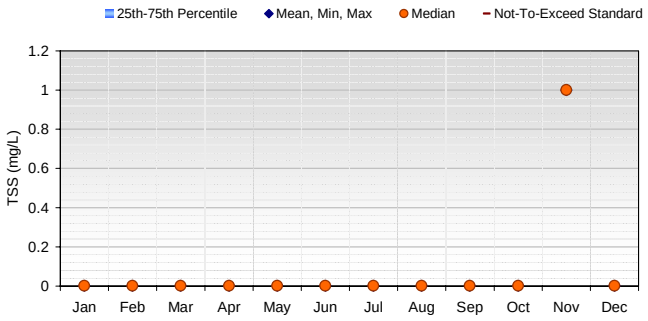
Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	1.00	1.00	1.00	1.00	1.00	1.00	0:1	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0:1**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 30 mg/L)



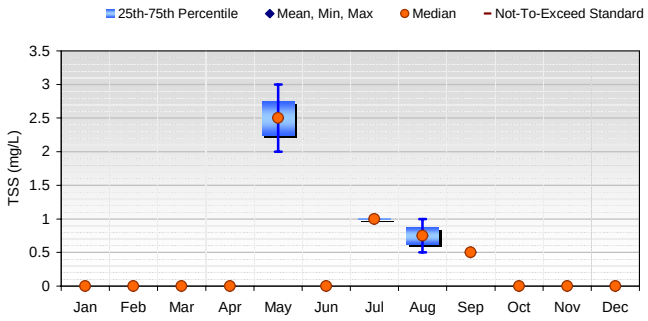
Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	2.50	2.50	2.00	3.00	2.25	2.75	0:2	0%
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	1.00	1.00	1.00	1.00	1.00	1.00	0:2	0%
Aug	0.75	0.75	0.50	1.00	0.63	0.88	0:2	0%
Sep	0.50	0.50	0.50	0.50	0.50	0.50	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.29**	**1.00**	**0.50**	**3.00**	**0.75**	**1.50**	**0:7**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 80 mg/L)



Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	1.00	1.00	1.00	1.00	1.00	1.00	0:1	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**0:1**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 55 mg/L)

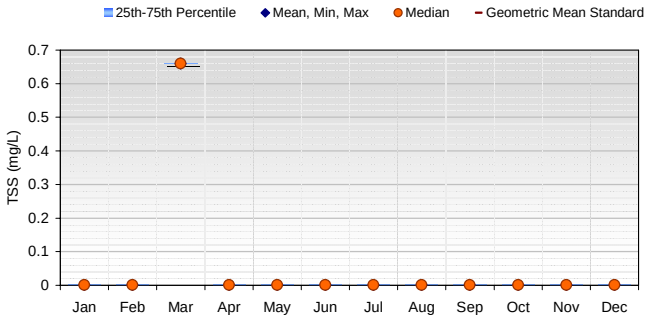


Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	2.50	2.50	2.00	3.00	2.25	2.75	0:2	0%
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	1.00	1.00	1.00	1.00	1.00	1.00	0:2	0%
Aug	0.75	0.75	0.50	1.00	0.63	0.88	0:2	0%
Sep	0.50	0.50	0.50	0.50	0.50	0.50	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.29**	**1.00**	**0.50**	**3.00**	**0.75**	**1.50**	**0:7**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

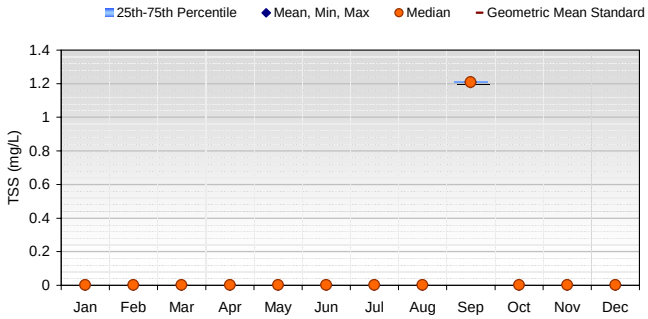
Figure A-39. Not-to-exceed TSS analyses for Waioli Stream

Wet Season Geometric Mean Analysis* (WQC = 20 mg/L)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.66	0.66	0.66	0.66	0.66	0.66	0:1	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**0.66**	**0.66**	**0.66**	**0.66**	**0.66**	**0.66**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 10 mg/L)

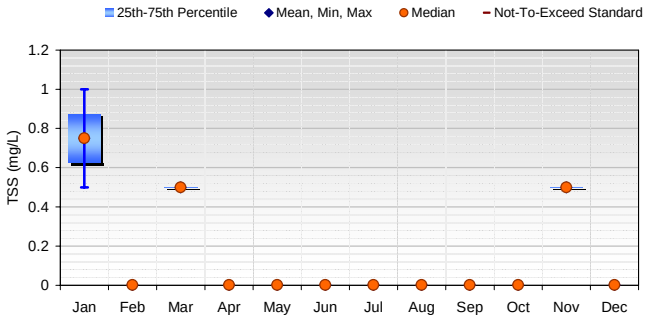


Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	1.21	1.21	1.21	1.21	1.21	1.21	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.21**	**1.21**	**1.21**	**1.21**	**1.21**	**1.21**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

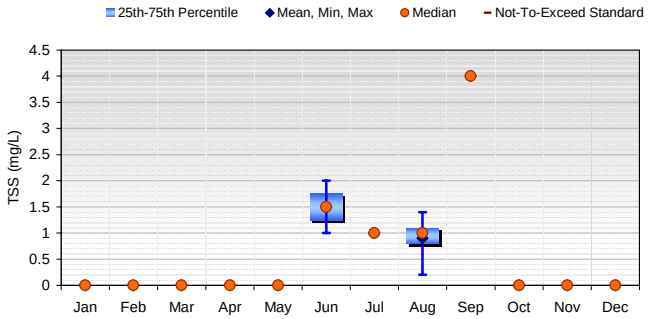
Figure A-40. Geometric mean TSS analyses for Waipa Stream

Wet Season Not to Exceed 10% of the Time Analysis* (WQC = 50 mg/L)



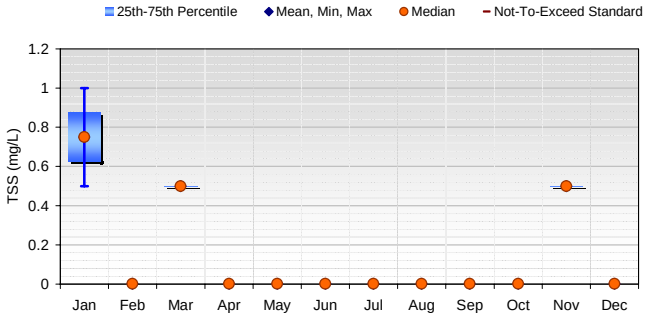
Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.75	0.75	0.50	1.00	0.63	0.88	0:2	0%
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.50	0.50	0.50	0.50	0.50	0.50	0:1	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.50	0.50	0.50	0.50	0.50	0.50	0:1	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**0.63**	**0.50**	**0.50**	**1.00**	**0.50**	**0.63**	**0:4**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 30 mg/L)



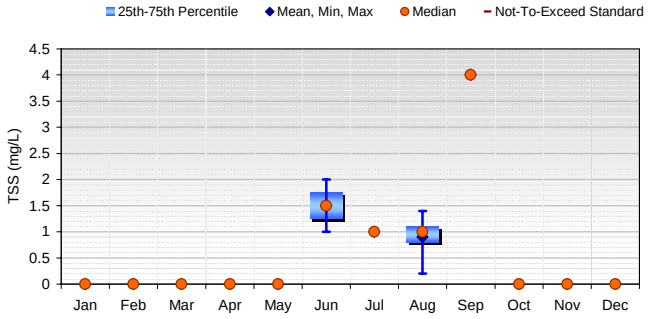
Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	1.50	1.50	1.00	2.00	1.25	1.75	0:2	0%
Jul	1.00	1.00	1.00	1.00	1.00	1.00	0:2	0%
Aug	0.90	1.00	0.20	1.40	0.80	1.10	0:4	0%
Sep	4.00	4.00	4.00	4.00	4.00	4.00	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.40**	**1.00**	**0.20**	**4.00**	**1.00**	**1.40**	**0:9**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 80 mg/L)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.75	0.75	0.50	1.00	0.63	0.88	0:2	0%
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.50	0.50	0.50	0.50	0.50	0.50	0:1	0%
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.50	0.50	0.50	0.50	0.50	0.50	0:1	0%
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**0.63**	**0.50**	**0.50**	**1.00**	**0.50**	**0.63**	**0:4**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 55 mg/L)

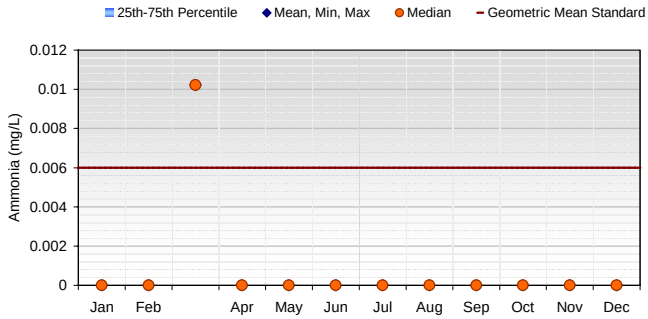


Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
May	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Jun	1.50	1.50	1.00	2.00	1.25	1.75	0:2	0%
Jul	1.00	1.00	1.00	1.00	1.00	1.00	0:2	0%
Aug	0.90	1.00	0.20	1.40	0.80	1.10	0:4	0%
Sep	4.00	4.00	4.00	4.00	4.00	4.00	0:1	0%
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0:0	n/a
All Data	**1.40**	**1.00**	**0.20**	**4.00**	**1.00**	**1.40**	**0:9**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

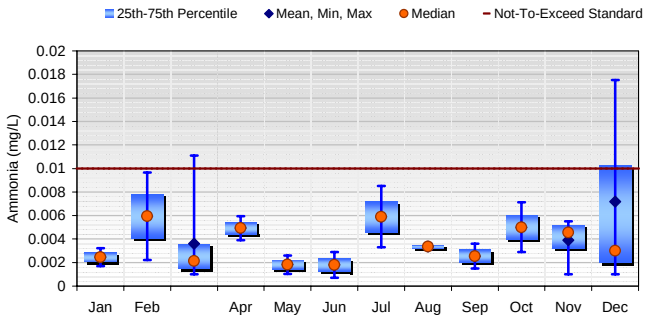
Figure A-41. Not-to-exceed TSS analyses for Waipa Stream

Geometric Mean Analysis*
(estuary WQC = 0.006 mg/L)



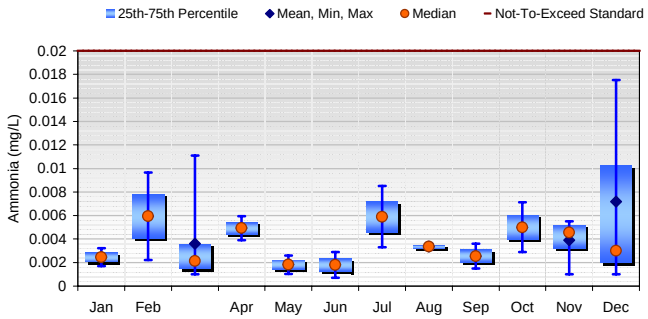
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.010	0.010	0.010	0.010	0.010	0.010	1:1	100%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	0.010	0.010	0.010	0.010	0.010	0.010	1:1	100%

Not to Exceed 10% of the Time Analysis*
(estuary WQC = 0.010 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.002	0.002	0.002	0.003	0.002	0.003	0:2	0%
Feb	0.006	0.006	0.002	0.010	0.004	0.008	0:2	0%
Mar	0.004	0.002	0.001	0.011	0.001	0.004	1:5	20%
Apr	0.005	0.005	0.004	0.006	0.004	0.005	0:3	0%
May	0.002	0.002	0.001	0.003	0.001	0.002	0:2	0%
Jun	0.002	0.002	0.001	0.003	0.001	0.002	0:2	0%
Jul	0.006	0.006	0.003	0.009	0.005	0.007	0:2	0%
Aug	0.003	0.003	0.003	0.004	0.003	0.003	0:2	0%
Sep	0.003	0.003	0.002	0.004	0.002	0.003	0:2	0%
Oct	0.005	0.005	0.003	0.007	0.004	0.006	0:2	0%
Nov	0.004	0.005	0.001	0.006	0.003	0.005	0:4	0%
Dec	0.007	0.003	0.001	0.018	0.002	0.010	1:3	33%
All Data	0.004	0.003	0.001	0.018	0.002	0.004	2:31	6%

Not to Exceed 2% of the Time Analysis*+
(estuary WQC = 0.020 mg/L)



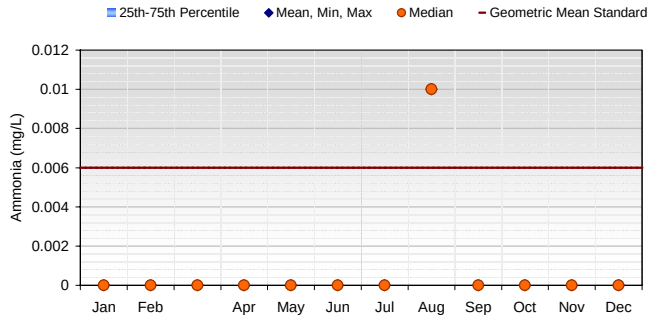
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.002	0.002	0.002	0.003	0.002	0.003	0:2	0%
Feb	0.006	0.006	0.002	0.010	0.004	0.008	0:2	0%
Mar	0.004	0.002	0.001	0.011	0.001	0.004	0:5	0%
Apr	0.005	0.005	0.004	0.006	0.004	0.005	0:3	0%
May	0.002	0.002	0.001	0.003	0.001	0.002	0:2	0%
Jun	0.002	0.002	0.001	0.003	0.001	0.002	0:2	0%
Jul	0.006	0.006	0.003	0.009	0.005	0.007	0:2	0%
Aug	0.003	0.003	0.003	0.004	0.003	0.003	0:2	0%
Sep	0.003	0.003	0.002	0.004	0.002	0.003	0:2	0%
Oct	0.005	0.005	0.003	0.007	0.004	0.006	0:2	0%
Nov	0.004	0.005	0.001	0.006	0.003	0.005	0:4	0%
Dec	0.007	0.003	0.001	0.018	0.002	0.010	0:3	0%
All Data	0.004	0.003	0.001	0.018	0.002	0.004	0:31	0%

*Standard is based on the estuary water quality criteria because there is no stream ammonia standard.

+Where the standard is missing from the graph, observed data are well below the water quality criteria.

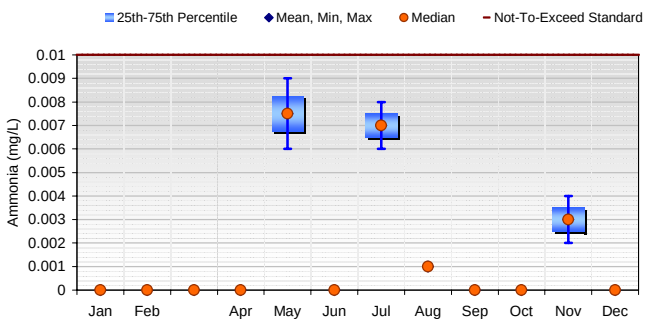
Figure A-42. Ammonia analyses for the Hanalei River

Geometric Mean Analysis*
(estuary WQC = 0.006 mg/L)



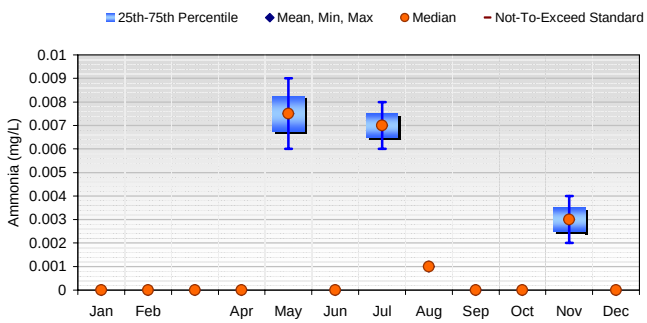
Summary Statistics (Data: 11/5/2001 to 8/4/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.010	0.010	0.010	0.010	0.010	0.010	1:1	100%
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis*+
(estuary WQC = 0.010 mg/L)



Summary Statistics (Data: 11/5/2001 to 8/4/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.008	0.008	0.006	0.009	0.007	0.008	0:2	0%
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.007	0.007	0.006	0.008	0.007	0.008	0:2	0%
Aug	0.001	0.001	0.001	0.001	0.001	0.001	0:1	0%
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.003	0.003	0.002	0.004	0.003	0.004	0:2	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.005**	**0.005**	**0.001**	**0.009**	**0.002**	**0.007**	**0:7**	**0%**

Not to Exceed 2% of the Time Analysis*+
(estuary WQC = 0.020 mg/L)



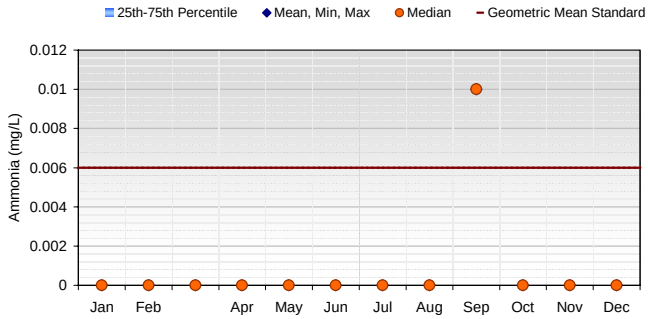
Summary Statistics (Data: 11/5/2001 to 8/4/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.008	0.008	0.006	0.009	0.007	0.008	0:2	0%
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.007	0.007	0.006	0.008	0.007	0.008	0:2	0%
Aug	0.001	0.001	0.001	0.001	0.001	0.001	0:1	0%
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.003	0.003	0.002	0.004	0.003	0.004	0:2	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.005**	**0.005**	**0.001**	**0.009**	**0.002**	**0.007**	**0:7**	**0%**

* Standard is based on the estuary water quality criteria because there is no stream ammonia standard.

+Where the standard is missing from the graph, observed data are well below the water quality criteria.

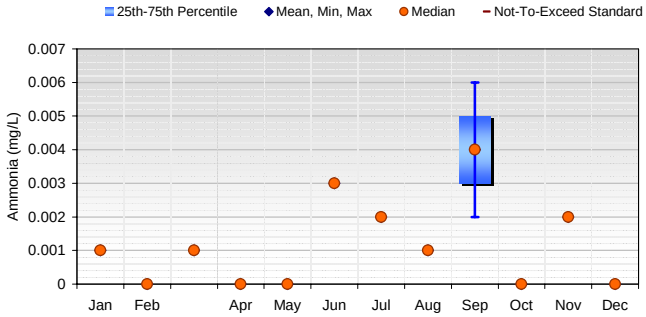
Figure A-43. Ammonia analyses for the Waioli Stream

Geometric Mean Analysis*
(estuary WQC = 0.006 mg/L)



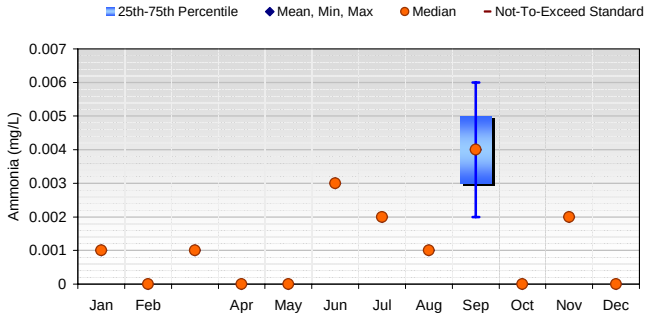
Summary Statistics (Data: 11/6/2001 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.010	0.010	0.010	0.010	0.010	0.010	1:1	100%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**1:1**	**100%**

Not to Exceed 10% of the Time Analysis*
(estuary WQC = 0.010 mg/L)



Summary Statistics (Data: 11/6/2001 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.001	0.001	0.001	0.001	0.001	0.001	0:2	0%
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.001	0.001	0.001	0.001	0.001	0.001	0:2	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.003	0.003	0.003	0.003	0.003	0.003	0:2	0%
Jul	0.002	0.002	0.002	0.002	0.002	0.002	0:2	0%
Aug	0.001	0.001	0.001	0.001	0.001	0.001	0:4	0%
Sep	0.004	0.004	0.002	0.006	0.003	0.005	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.002	0.002	0.002	0.002	0.002	0.002	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.002**	**0.001**	**0.001**	**0.006**	**0.001**	**0.002**	**0:14**	**0%**

Not to Exceed 2% of the Time Analysis*+
(estuary WQC = 0.020 mg/L)



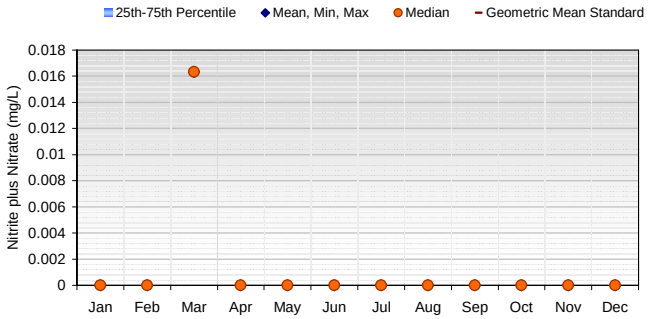
Summary Statistics (Data: 11/6/2001 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.001	0.001	0.001	0.001	0.001	0.001	0:2	0%
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.001	0.001	0.001	0.001	0.001	0.001	0:2	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.003	0.003	0.003	0.003	0.003	0.003	0:2	0%
Jul	0.002	0.002	0.002	0.002	0.002	0.002	0:2	0%
Aug	0.001	0.001	0.001	0.001	0.001	0.001	0:4	0%
Sep	0.004	0.004	0.002	0.006	0.003	0.005	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.002	0.002	0.002	0.002	0.002	0.002	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.002**	**0.001**	**0.001**	**0.006**	**0.001**	**0.002**	**0:14**	**0%**

* Standard is based on the estuary water quality criteria because there is no stream ammonia standard.

+Where the standard is missing from the graph, observed data are well below the water quality criteria.

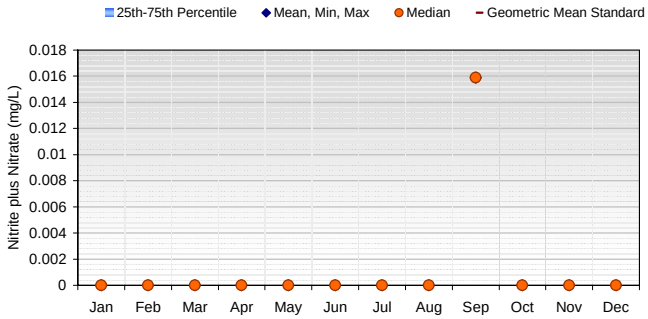
Figure A-44. Ammonia analyses for the Waipa Stream

Wet Season Geometric Mean Analysis* (WQC = 0.070 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.016	0.016	0.016	0.016	0.016	0.016	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.030 mg/L)

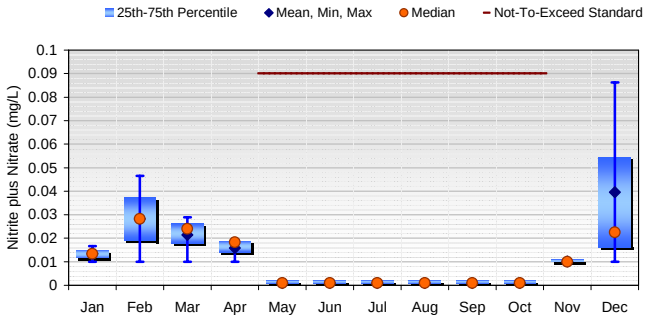


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.016	0.016	0.016	0.016	0.016	0.016	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

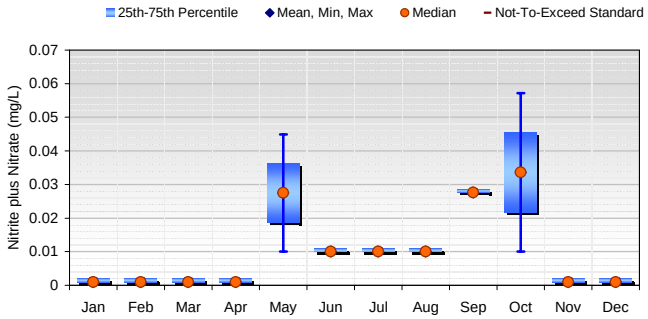
Figure A-45. Geometric mean nitrite plus nitrate analyses for Hanalei River

Wet Season Not to Exceed 10% of the Time Analysis* (WQC = 0.180 mg/L)



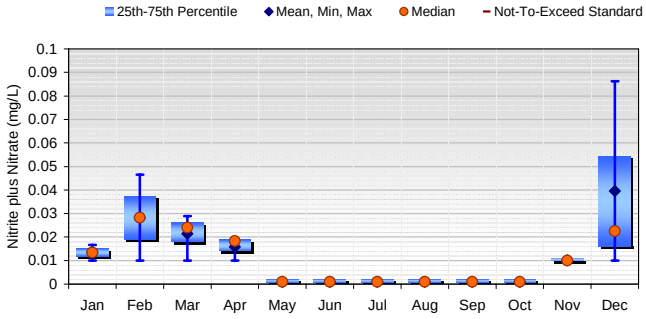
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.013	0.013	0.010	0.017	0.012	0.015	0:2	0%
Feb	0.028	0.028	0.010	0.047	0.019	0.037	0:2	0%
Mar	0.021	0.024	0.010	0.029	0.018	0.026	0:5	0%
Apr	0.016	0.018	0.010	0.019	0.014	0.019	0:3	0%
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.010	0.010	0.010	0.010	0.010	0.010	0:4	0%
Dec	0.040	0.023	0.010	0.086	0.016	0.054	0:3	0%
All Data	**0.021**	**0.017**	**0.010**	**0.086**	**0.010**	**0.023**	**0:19**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 0.090 mg/L)



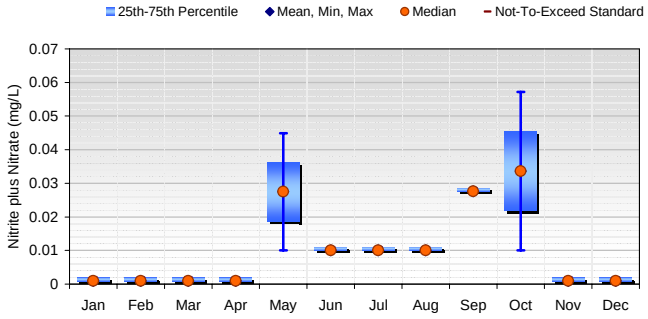
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.027	0.027	0.010	0.045	0.019	0.036	0:2	0%
Jun	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Jul	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Aug	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Sep	0.028	0.028	0.028	0.028	0.028	0.028	0:1	0%
Oct	0.034	0.034	0.010	0.057	0.022	0.045	0:2	0%
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.019**	**0.010**	**0.010**	**0.057**	**0.010**	**0.019**	**0:11**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 0.300 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.013	0.013	0.010	0.017	0.012	0.015	0:2	0%
Feb	0.028	0.028	0.010	0.047	0.019	0.037	0:2	0%
Mar	0.021	0.024	0.010	0.029	0.018	0.026	0:5	0%
Apr	0.016	0.018	0.010	0.019	0.014	0.019	0:3	0%
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.010	0.010	0.010	0.010	0.010	0.010	0:4	0%
Dec	0.040	0.023	0.010	0.086	0.016	0.054	0:3	0%
All Data	**0.021**	**0.017**	**0.010**	**0.086**	**0.010**	**0.023**	**0:19**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.170 mg/L)

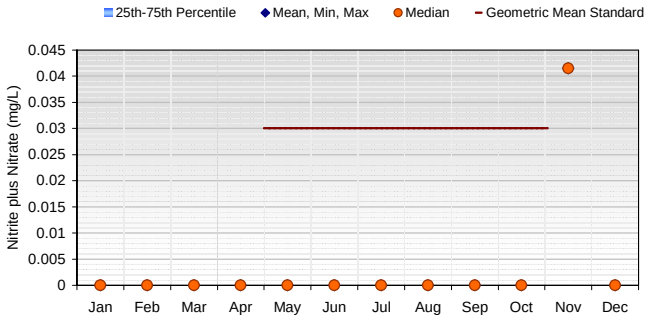


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.027	0.027	0.010	0.045	0.019	0.036	0:2	0%
Jun	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Jul	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Aug	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Sep	0.028	0.028	0.028	0.028	0.028	0.028	0:1	0%
Oct	0.034	0.034	0.010	0.057	0.022	0.045	0:2	0%
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.019**	**0.010**	**0.010**	**0.057**	**0.010**	**0.019**	**0:11**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

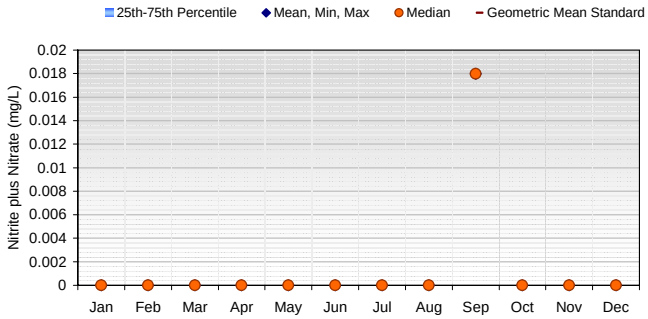
Figure A-46. Not-to-exceed nitrite plus nitrate analyses for Hanalei River

Wet Season Geometric Mean Analysis* (WQC = 0.070 mg/L)



Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	**Mean**	**Median**	**Min**	**Max**	**25th**	**75th**	**XS:Count**	**XS%**
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.041	0.041	0.041	0.041	0.041	0.041	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.030 mg/L)

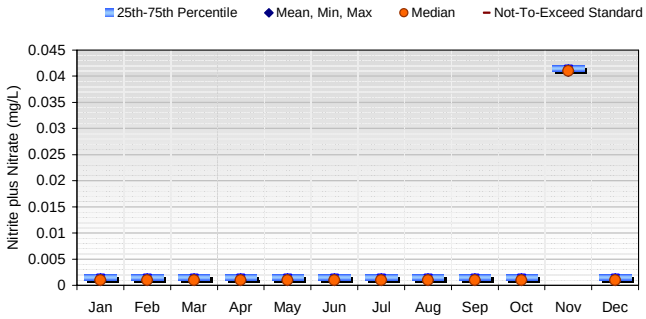


Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	**Mean**	**Median**	**Min**	**Max**	**25th**	**75th**	**XS:Count**	**XS%**
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.018	0.018	0.018	0.018	0.018	0.018	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.018**	**0.018**	**0.018**	**0.018**	**0.018**	**0.018**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

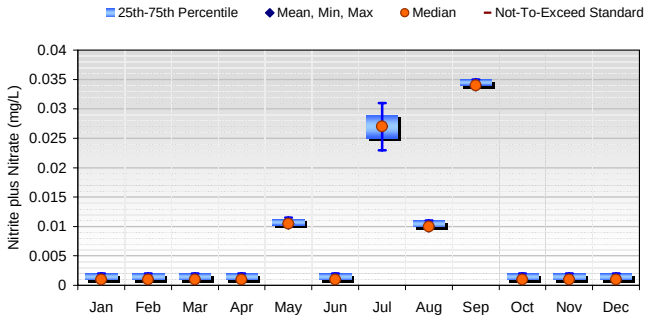
Figure A-47. Geometric mean nitrite plus nitrate analyses for Waioli Stream

Wet Season Not to Exceed 10% of the Time Analysis* (WQC = 0.180 mg/L)



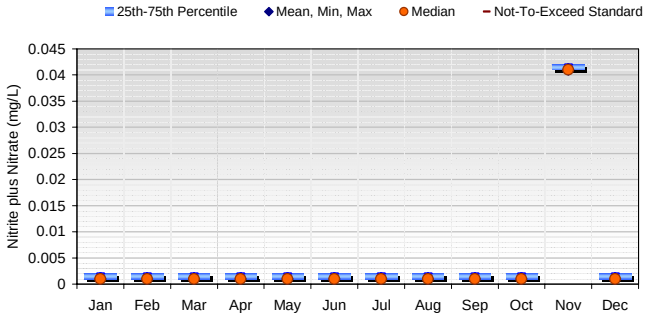
Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.041	0.041	0.041	0.041	0.041	0.041	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0:1**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 0.090 mg/L)



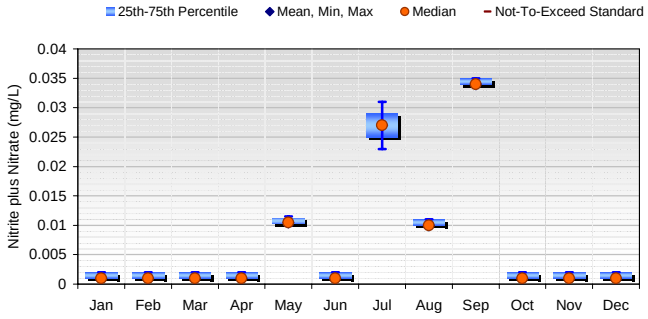
Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.011	0.011	0.010	0.011	0.010	0.011	0:2	0%
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.027	0.027	0.023	0.031	0.025	0.029	0:2	0%
Aug	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Sep	0.034	0.034	0.034	0.034	0.034	0.034	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.018**	**0.011**	**0.010**	**0.034**	**0.010**	**0.027**	**0:7**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 0.300 mg/L)



Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.041	0.041	0.041	0.041	0.041	0.041	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0.041**	**0:1**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.170 mg/L)

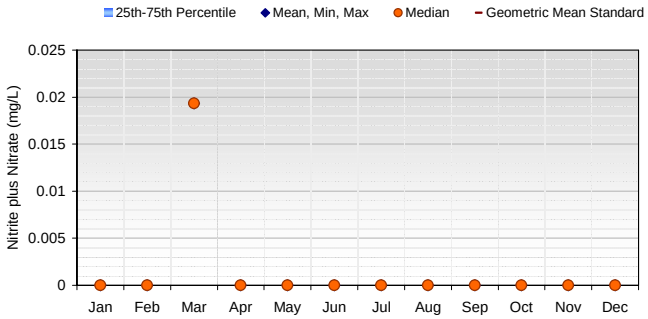


Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.011	0.011	0.010	0.011	0.010	0.011	0:2	0%
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.027	0.027	0.023	0.031	0.025	0.029	0:2	0%
Aug	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Sep	0.034	0.034	0.034	0.034	0.034	0.034	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.018**	**0.011**	**0.010**	**0.034**	**0.010**	**0.027**	**0:7**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

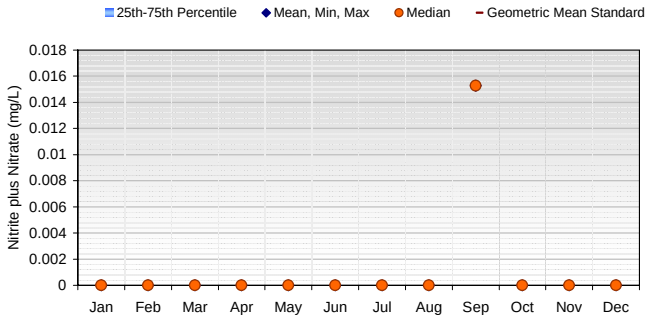
Figure A-48. Not-to-exceed nitrite plus nitrate analyses for Waioli Stream

Wet Season Geometric Mean Analysis* (WQC = 0.070 mg/L)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.019	0.019	0.019	0.019	0.019	0.019	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0.019**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.030 mg/L)

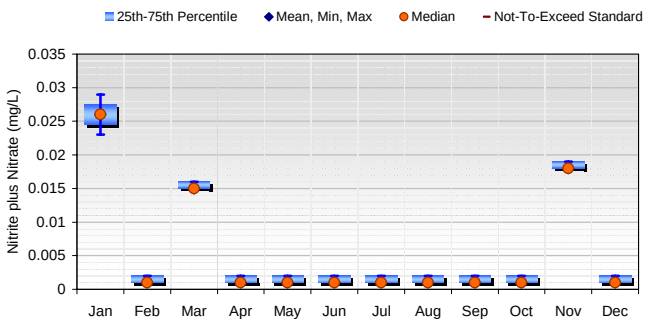


Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.015	0.015	0.015	0.015	0.015	0.015	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.015**	**0.015**	**0.015**	**0.015**	**0.015**	**0.015**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

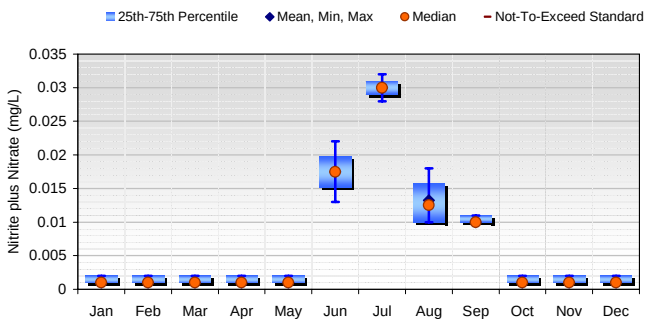
Figure A-49. Geometric mean nitrite plus nitrate analyses for Waipa Stream

Wet Season Not to Exceed 10% of the Time Analysis* (WQC = 0.180 mg/L)



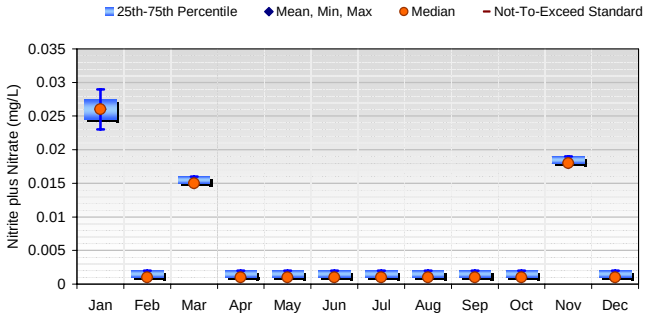
Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.026	0.026	0.023	0.029	0.025	0.028	0:2	0%
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.015	0.015	0.015	0.015	0.015	0.015	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.018	0.018	0.018	0.018	0.018	0.018	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.021**	**0.021**	**0.015**	**0.029**	**0.017**	**0.025**	**0:4**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 0.090 mg/L)



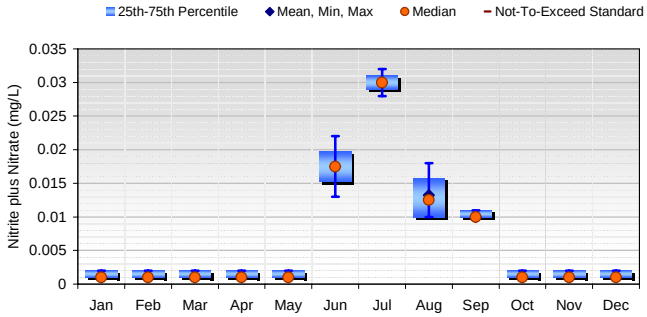
Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.018	0.018	0.013	0.022	0.015	0.020	0:2	0%
Jul	0.030	0.030	0.028	0.032	0.029	0.031	0:2	0%
Aug	0.013	0.013	0.010	0.018	0.010	0.016	0:4	0%
Sep	0.010	0.010	0.010	0.010	0.010	0.010	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.018**	**0.015**	**0.010**	**0.032**	**0.010**	**0.022**	**0:9**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 0.300 mg/L)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.026	0.026	0.023	0.029	0.025	0.028	0:2	0%
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.015	0.015	0.015	0.015	0.015	0.015	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.018	0.018	0.018	0.018	0.018	0.018	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.021**	**0.021**	**0.015**	**0.029**	**0.017**	**0.025**	**0:4**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.170 mg/L)

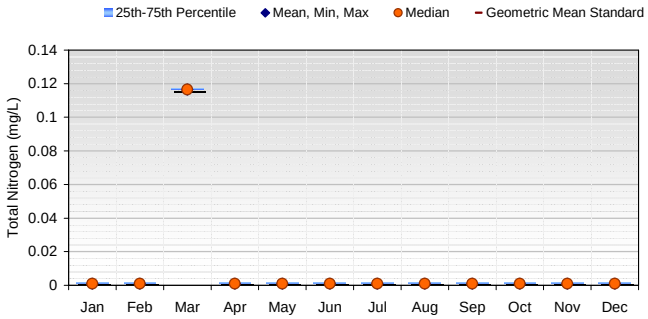


Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.018	0.018	0.013	0.022	0.015	0.020	0:2	0%
Jul	0.030	0.030	0.028	0.032	0.029	0.031	0:2	0%
Aug	0.013	0.013	0.010	0.018	0.010	0.016	0:4	0%
Sep	0.010	0.010	0.010	0.010	0.010	0.010	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.018**	**0.015**	**0.010**	**0.032**	**0.010**	**0.022**	**0:9**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

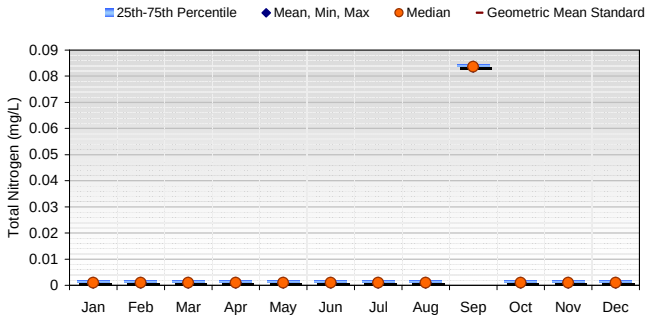
Figure A-50. Not-to-exceed nitrite plus nitrate analyses for Waipa Stream

Wet Season Geometric Mean Analysis* (WQC = 0.250 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.117	0.117	0.117	0.117	0.117	0.117	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0.117**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.180 mg/L)

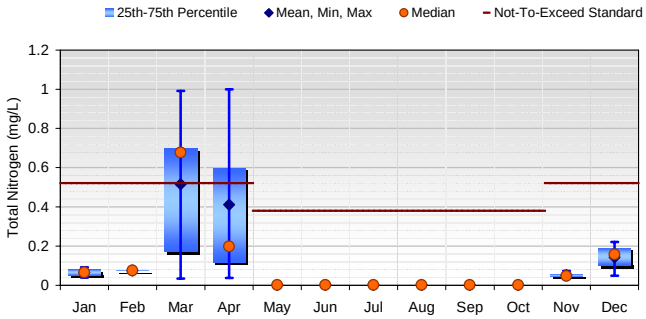


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.084	0.084	0.084	0.084	0.084	0.084	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.084**	**0.084**	**0.084**	**0.084**	**0.084**	**0.084**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

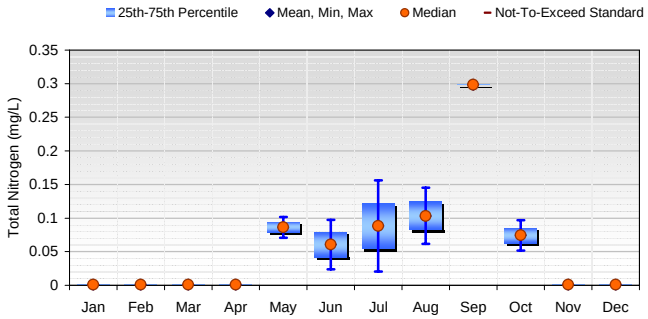
Figure A-51. Geometric mean total nitrogen analyses for Hanalei River

Wet Season Not to Exceed 10% of the Time Analysis (WQC = 0.520 mg/L)



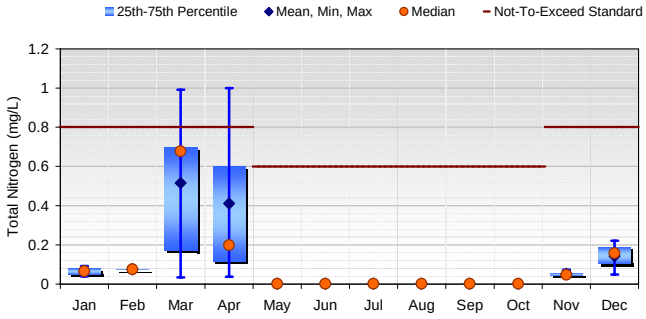
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.065	0.065	0.039	0.092	0.052	0.079	0:2	0%
Feb	0.075	0.075	0.074	0.075	0.074	0.075	0:2	0%
Mar	0.515	0.678	0.035	0.992	0.173	0.698	3:5	60%
Apr	0.411	0.197	0.037	1.000	0.117	0.599	0:3	0%
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.053	0.047	0.044	0.074	0.047	0.054	0:4	0%
Dec	0.142	0.158	0.049	0.221	0.103	0.189	0:3	0%
All Data	**0.249**	**0.075**	**0.035**	**1.000**	**0.047**	**0.209**	**3:19**	**16%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 0.380 mg/L)



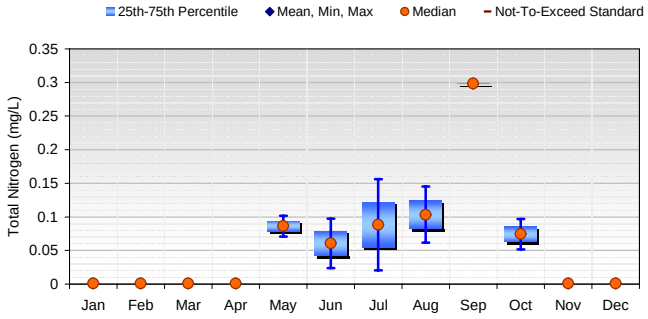
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.086	0.086	0.071	0.102	0.079	0.094	0:2	0%
Jun	0.061	0.061	0.024	0.098	0.042	0.079	0:2	0%
Jul	0.088	0.088	0.021	0.156	0.055	0.122	0:2	0%
Aug	0.103	0.103	0.062	0.145	0.082	0.124	0:2	0%
Sep	0.298	0.298	0.298	0.298	0.298	0.298	0:1	0%
Oct	0.074	0.074	0.052	0.097	0.063	0.085	0:2	0%
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.102**	**0.097**	**0.021**	**0.298**	**0.057**	**0.123**	**0:11**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis (WQC = 0.800 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.065	0.065	0.039	0.092	0.052	0.079	0:2	0%
Feb	0.075	0.075	0.074	0.075	0.074	0.075	0:2	0%
Mar	0.515	0.678	0.035	0.992	0.173	0.698	1:5	20%
Apr	0.411	0.197	0.037	1.000	0.117	0.599	0:3	0%
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.053	0.047	0.044	0.074	0.047	0.054	0:4	0%
Dec	0.142	0.158	0.049	0.221	0.103	0.189	0:3	0%
All Data	**0.249**	**0.075**	**0.035**	**1.000**	**0.047**	**0.209**	**1:19**	**5%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.600 mg/L)

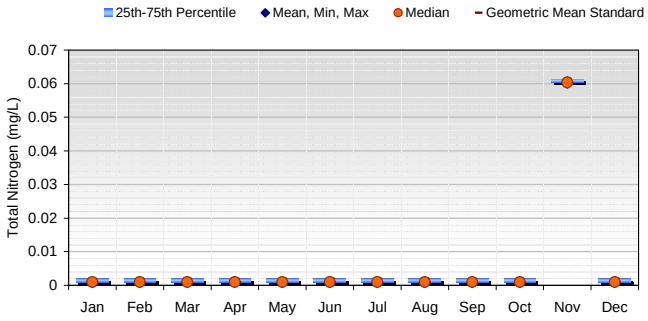


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.086	0.086	0.071	0.102	0.079	0.094	0:2	0%
Jun	0.061	0.061	0.024	0.098	0.042	0.079	0:2	0%
Jul	0.088	0.088	0.021	0.156	0.055	0.122	0:2	0%
Aug	0.103	0.103	0.062	0.145	0.082	0.124	0:2	0%
Sep	0.298	0.298	0.298	0.298	0.298	0.298	0:1	0%
Oct	0.074	0.074	0.052	0.097	0.063	0.085	0:2	0%
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.102**	**0.097**	**0.021**	**0.298**	**0.057**	**0.123**	**0:11**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

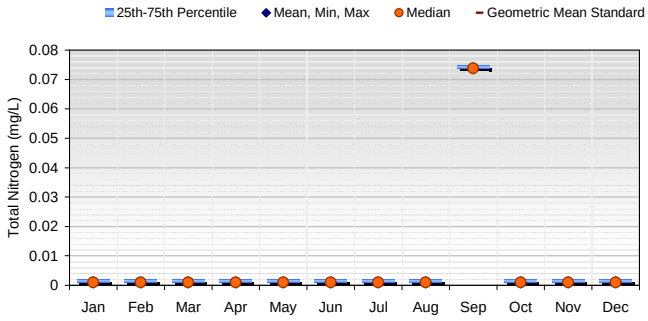
Figure A-52. Not-to-exceed total nitrogen analyses for Hanalei River

Wet Season Geometric Mean Analysis* (WQC = 0.250 mg/L)



Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.060	0.060	0.060	0.060	0.060	0.060	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0.060**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.180 mg/L)

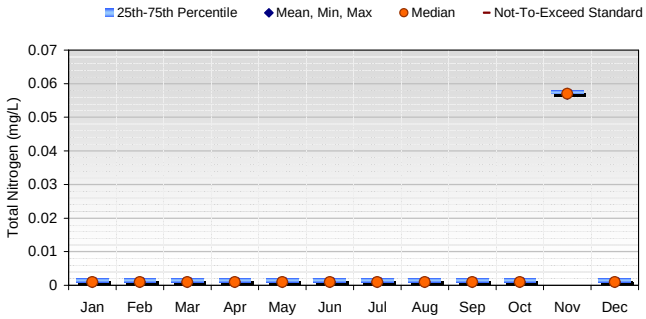


Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.074	0.074	0.074	0.074	0.074	0.074	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.074**	**0.074**	**0.074**	**0.074**	**0.074**	**0.074**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

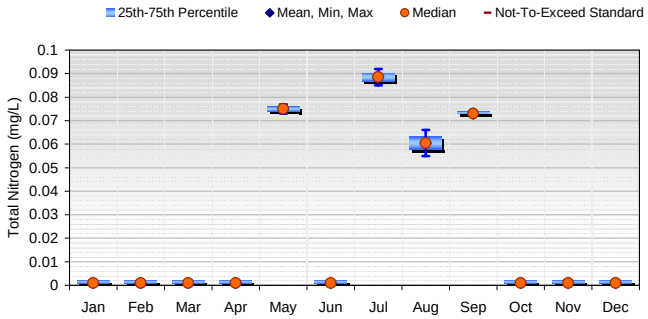
Figure A-53. Geometric mean total nitrogen analyses for Waioli Stream

Wet Season Not to Exceed 10% of the Time Analysis (WQC = 0.520 mg/L)



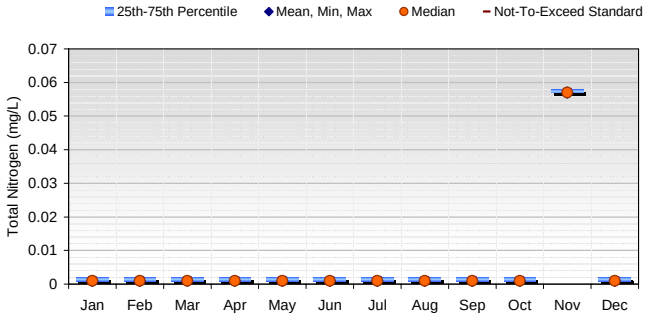
Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.057	0.057	0.057	0.057	0.057	0.057	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.057**	**0.057**	**0.057**	**0.057**	**0.057**	**0.057**	**0:1**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis (WQC = 0.380 mg/L)



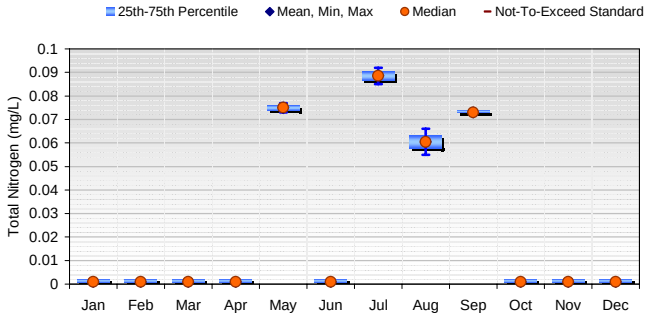
Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.075	0.075	0.073	0.077	0.074	0.076	0:2	0%
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.089	0.089	0.085	0.092	0.087	0.090	0:2	0%
Aug	0.061	0.061	0.055	0.066	0.058	0.063	0:2	0%
Sep	0.073	0.073	0.073	0.073	0.073	0.073	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.074**	**0.073**	**0.055**	**0.092**	**0.070**	**0.081**	**0:7**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 0.800 mg/L)



Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.057	0.057	0.057	0.057	0.057	0.057	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.057**	**0.057**	**0.057**	**0.057**	**0.057**	**0.057**	**0:1**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.600 mg/L)

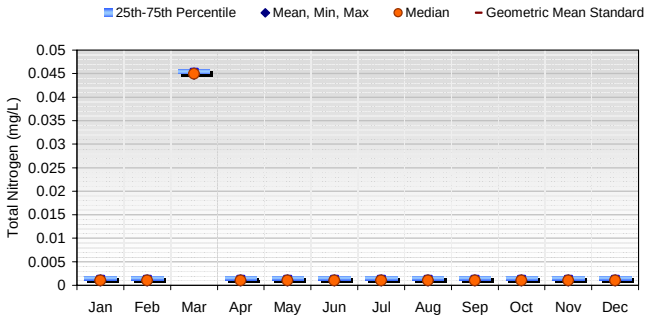


Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.075	0.075	0.073	0.077	0.074	0.076	0:2	0%
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.089	0.089	0.085	0.092	0.087	0.090	0:2	0%
Aug	0.061	0.061	0.055	0.066	0.058	0.063	0:2	0%
Sep	0.073	0.073	0.073	0.073	0.073	0.073	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.074**	**0.073**	**0.055**	**0.092**	**0.070**	**0.081**	**0:7**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

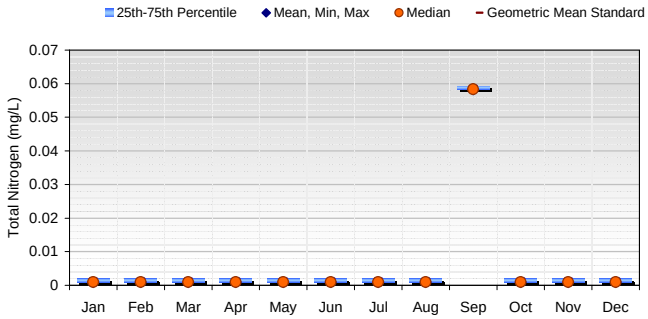
Figure A-54. Not-to-exceed total nitrogen analyses for Waioli Stream

Wet Season Geometric Mean Analysis* (WQC = 0.250 mg/L)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.045	0.045	0.045	0.045	0.045	0.045	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.045**	**0.045**	**0.045**	**0.045**	**0.045**	**0.045**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.180 mg/L)

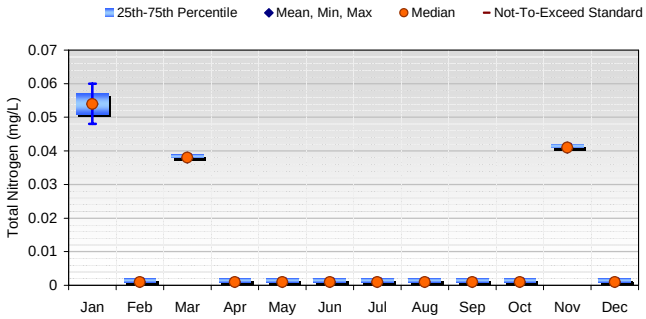


Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.058	0.058	0.058	0.058	0.058	0.058	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.058**	**0.058**	**0.058**	**0.058**	**0.058**	**0.058**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

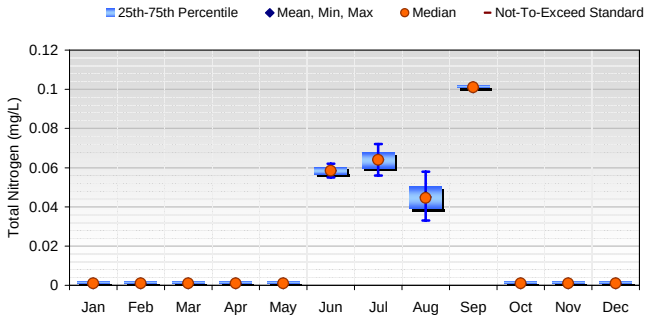
Figure A-55. Geometric mean total nitrogen analyses for Waipa Stream

Wet Season Not to Exceed 10% of the Time Analysis (WQC = 0.520 mg/L)



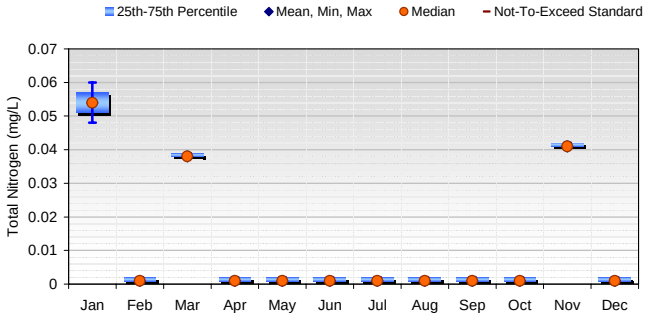
Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.054	0.054	0.048	0.060	0.051	0.057	0:2	0%
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.038	0.038	0.038	0.038	0.038	0.038	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.041	0.041	0.041	0.041	0.041	0.041	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.047**	**0.045**	**0.038**	**0.060**	**0.040**	**0.051**	**0:4**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis (WQC = 0.380 mg/L)



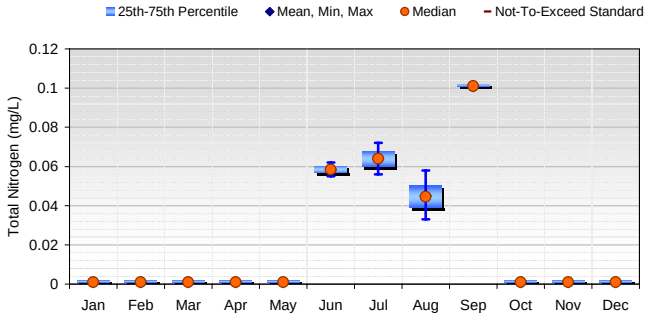
Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.059	0.059	0.055	0.062	0.057	0.060	0:2	0%
Jul	0.064	0.064	0.056	0.072	0.060	0.068	0:2	0%
Aug	0.045	0.045	0.033	0.058	0.039	0.051	0:4	0%
Sep	0.101	0.101	0.101	0.101	0.101	0.101	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.058**	**0.056**	**0.033**	**0.101**	**0.048**	**0.062**	**0:9**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 0.800 mg/L)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.054	0.054	0.048	0.060	0.051	0.057	0:2	0%
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.038	0.038	0.038	0.038	0.038	0.038	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.041	0.041	0.041	0.041	0.041	0.041	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.047**	**0.045**	**0.038**	**0.060**	**0.040**	**0.051**	**0:4**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.600 mg/L)

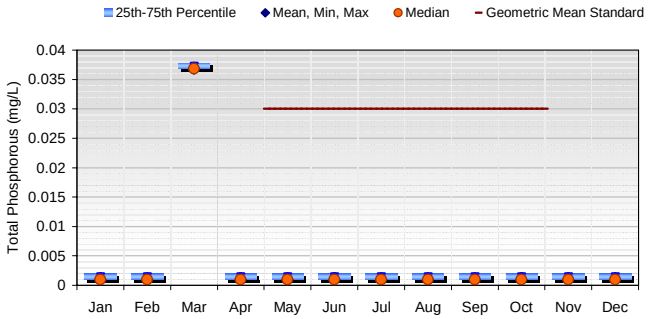


Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.059	0.059	0.055	0.062	0.057	0.060	0:2	0%
Jul	0.064	0.064	0.056	0.072	0.060	0.068	0:2	0%
Aug	0.045	0.045	0.033	0.058	0.039	0.051	0:4	0%
Sep	0.101	0.101	0.101	0.101	0.101	0.101	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.058**	**0.056**	**0.033**	**0.101**	**0.048**	**0.062**	**0:9**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

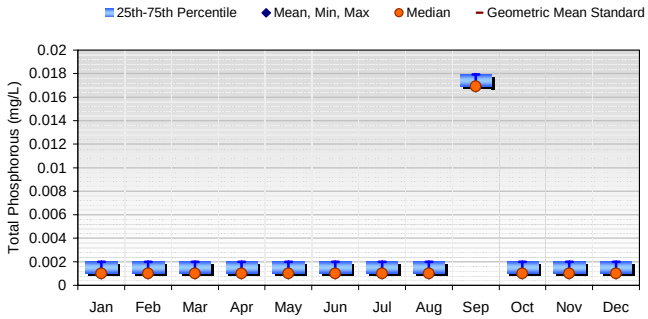
Figure A-56. Not-to-exceed total nitrogen analyses for Waipa Stream

Wet Season Geometric Mean Analysis* (WQC = 0.050 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.037	0.037	0.037	0.037	0.037	0.037	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.037**	**0.037**	**0.037**	**0.037**	**0.037**	**0.037**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.030 mg/L)

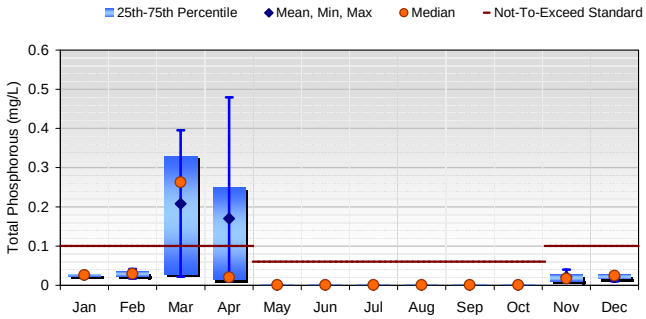


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.017	0.017	0.017	0.017	0.017	0.017	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.017**	**0.017**	**0.017**	**0.017**	**0.017**	**0.017**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

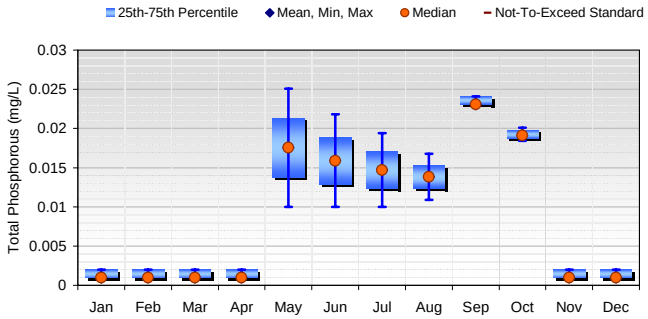
Figure A-57. Geometric mean total phosphorous analyses for Hanalei River

Wet Season Not to Exceed 10% of the Time Analysis (WQC = 0.100 mg/L)



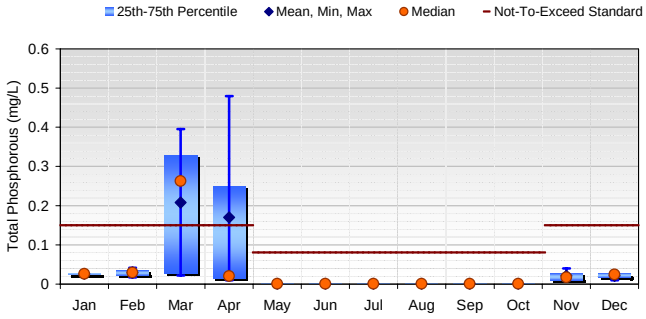
Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.026	0.026	0.022	0.031	0.024	0.029	0:2	0%
Feb	0.029	0.029	0.017	0.042	0.023	0.035	0:2	0%
Mar	0.208	0.263	0.022	0.395	0.029	0.330	3:5	60%
Apr	0.170	0.020	0.010	0.480	0.015	0.250	0:3	0%
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.021	0.017	0.010	0.040	0.010	0.028	0:4	0%
Dec	0.022	0.025	0.010	0.030	0.017	0.027	0:3	0%
All Data	**0.095**	**0.025**	**0.010**	**0.480**	**0.019**	**0.041**	**3:19**	**16%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 0.060 mg/L)



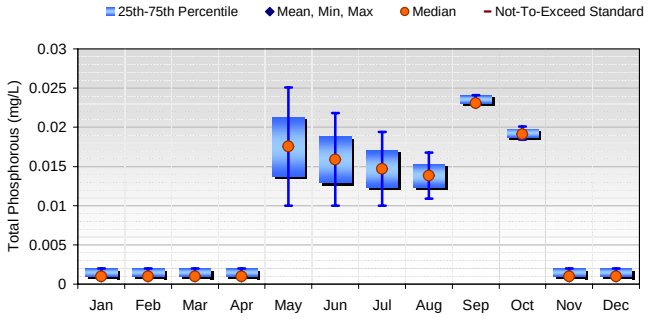
Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.018	0.018	0.010	0.025	0.014	0.021	0:2	0%
Jun	0.016	0.016	0.010	0.022	0.013	0.019	0:2	0%
Jul	0.015	0.015	0.010	0.019	0.012	0.017	0:2	0%
Aug	0.014	0.014	0.011	0.017	0.012	0.015	0:2	0%
Sep	0.023	0.023	0.023	0.023	0.023	0.023	0:1	0%
Oct	0.019	0.019	0.018	0.020	0.019	0.019	0:2	0%
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.017**	**0.018**	**0.010**	**0.025**	**0.010**	**0.021**	**0:11**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis (WQC = 0.150 mg/L)



Summary Statistics (Data: 11/5/2001 to 3/16/2006)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.026	0.026	0.022	0.031	0.024	0.029	0:2	0%
Feb	0.029	0.029	0.017	0.042	0.023	0.035	0:2	0%
Mar	0.208	0.263	0.022	0.395	0.029	0.330	3:5	60%
Apr	0.170	0.020	0.010	0.480	0.015	0.250	0:3	0%
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.021	0.017	0.010	0.040	0.010	0.028	0:4	0%
Dec	0.022	0.025	0.010	0.030	0.017	0.027	0:3	0%
All Data	**0.095**	**0.025**	**0.010**	**0.480**	**0.019**	**0.041**	**3:19**	**16%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.080 mg/L)

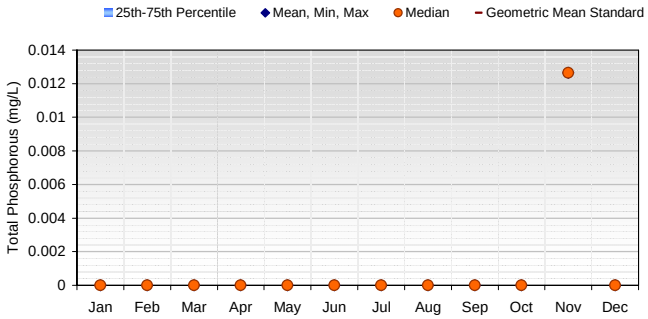


Summary Statistics (Data: 10/31/2003 to 9/21/2005)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.018	0.018	0.010	0.025	0.014	0.021	0:2	0%
Jun	0.016	0.016	0.010	0.022	0.013	0.019	0:2	0%
Jul	0.015	0.015	0.010	0.019	0.012	0.017	0:2	0%
Aug	0.014	0.014	0.011	0.017	0.012	0.015	0:2	0%
Sep	0.023	0.023	0.023	0.023	0.023	0.023	0:1	0%
Oct	0.019	0.019	0.018	0.020	0.019	0.019	0:2	0%
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.017**	**0.018**	**0.010**	**0.025**	**0.010**	**0.021**	**0:11**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

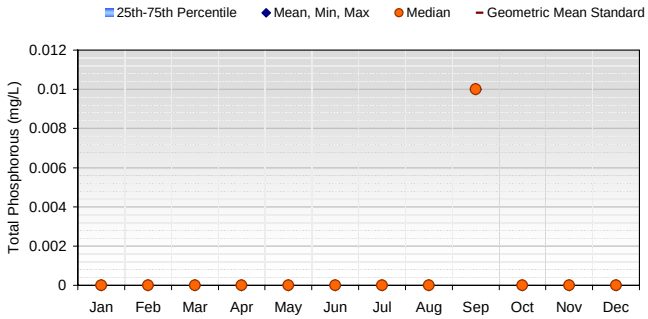
Figure A-58. Not-to-exceed total phosphorous analyses for Hanalei River

Wet Season Geometric Mean Analysis* (WQC = 0.050 mg/L)



Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.013	0.013	0.013	0.013	0.013	0.013	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.013**	**0.013**	**0.013**	**0.013**	**0.013**	**0.013**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.030 mg/L)

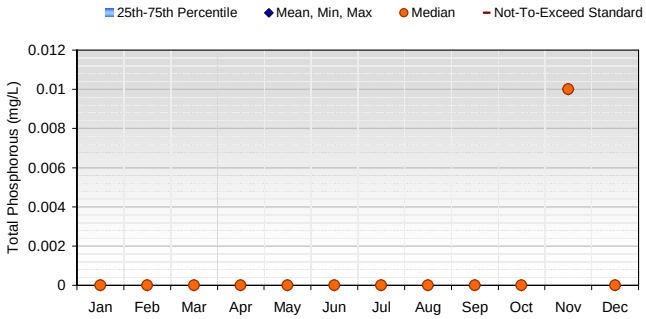


Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.010	0.010	0.010	0.010	0.010	0.010	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

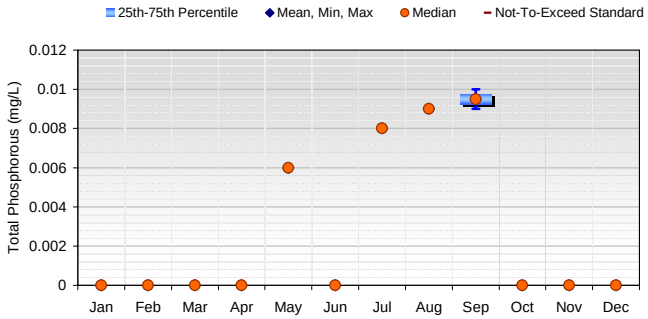
Figure A-59. Geometric mean total phosphorous analyses for Waioli Stream

Wet Season Not to Exceed 10% of the Time Analysis* (WQC = 0.100 mg/L)



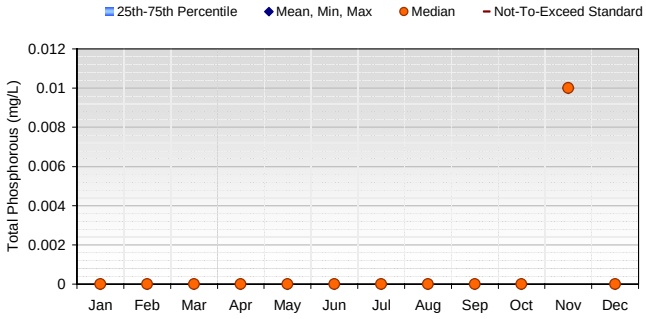
Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.010	0.010	0.010	0.010	0.010	0.010	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0:1**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis* (WQC = 0.060 mg/L)



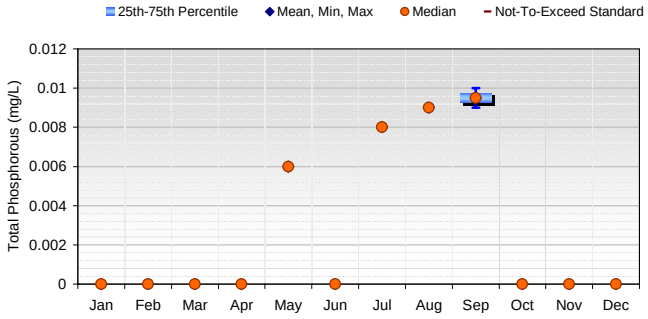
Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.006	0.006	0.006	0.006	0.006	0.006	0:2	0%
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.008	0.008	0.008	0.008	0.008	0.008	0:2	0%
Aug	0.009	0.009	0.009	0.009	0.009	0.009	0:2	0%
Sep	0.010	0.010	0.009	0.010	0.009	0.010	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.008**	**0.009**	**0.006**	**0.010**	**0.008**	**0.009**	**0:7**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 0.150 mg/L)



Summary Statistics (Data: 11/5/2001 to 11/5/2001)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.010	0.010	0.010	0.010	0.010	0.010	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0.010**	**0:1**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.080 mg/L)

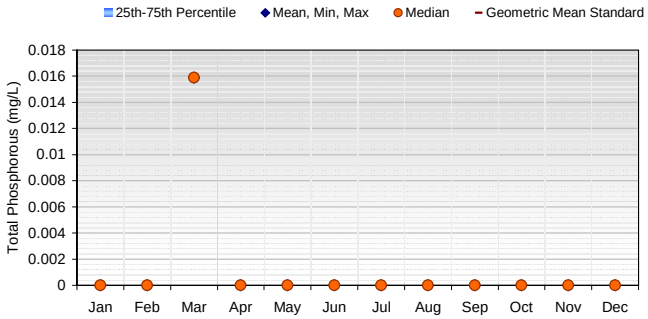


Summary Statistics (Data: 5/19/2003 to 9/22/2003)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.006	0.006	0.006	0.006	0.006	0.006	0:2	0%
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.008	0.008	0.008	0.008	0.008	0.008	0:2	0%
Aug	0.009	0.009	0.009	0.009	0.009	0.009	0:2	0%
Sep	0.010	0.010	0.009	0.010	0.009	0.010	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.008**	**0.009**	**0.006**	**0.010**	**0.008**	**0.009**	**0:7**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

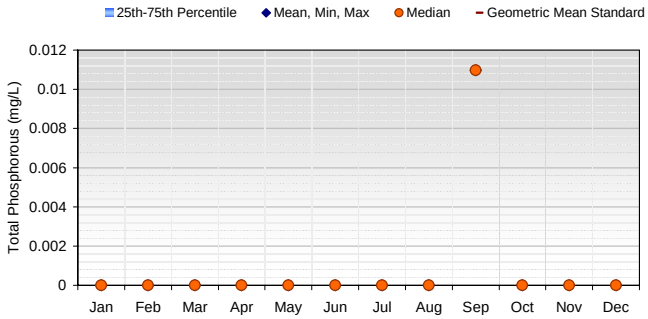
Figure A-60. Not-to-exceed total phosphorous analyses for Waioli Stream

Wet Season Geometric Mean Analysis* (WQC = 0.050 mg/L)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.016	0.016	0.016	0.016	0.016	0.016	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0.016**	**0:1**	**0%**

Dry Season Geometric Mean Analysis* (WQC = 0.030 mg/L)

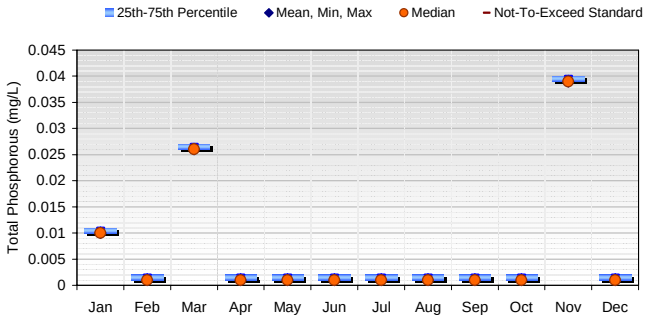


Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.011	0.011	0.011	0.011	0.011	0.011	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.011**	**0.011**	**0.011**	**0.011**	**0.011**	**0.011**	**0:1**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

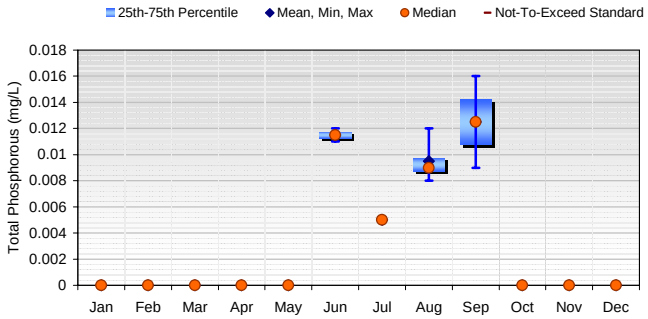
Figure A-61. Geometric mean total phosphorous analyses for Waipa Stream

Wet Season Not to Exceed 10% of the Time Analysis (WQC = 0.100 mg/L)



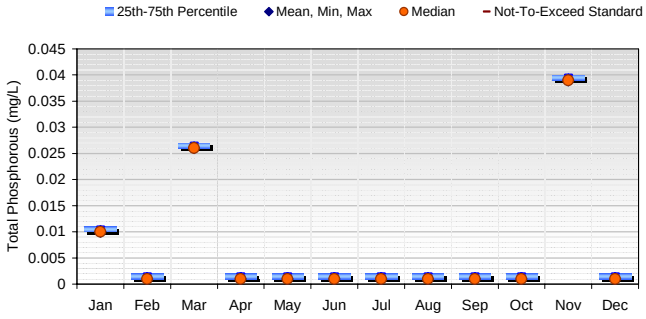
Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.026	0.026	0.026	0.026	0.026	0.026	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.039	0.039	0.039	0.039	0.039	0.039	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.021**	**0.018**	**0.010**	**0.039**	**0.010**	**0.029**	**0:4**	**0%**

Dry Season Not to Exceed 10% of the Time Analysis (WQC = 0.060 mg/L)



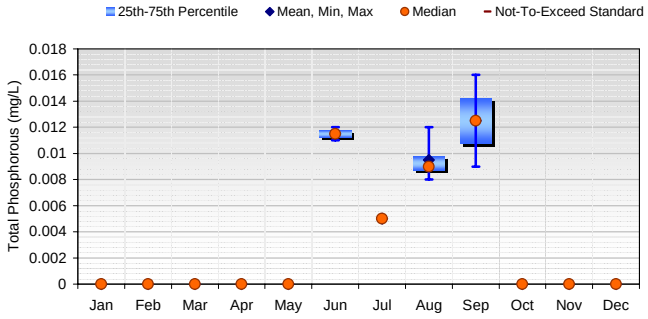
Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.012	0.012	0.011	0.012	0.011	0.012	0:2	0%
Jul	0.005	0.005	0.005	0.005	0.005	0.005	0:2	0%
Aug	0.010	0.009	0.008	0.012	0.009	0.010	0:4	0%
Sep	0.013	0.013	0.009	0.016	0.011	0.014	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.010**	**0.009**	**0.005**	**0.016**	**0.008**	**0.012**	**0:9**	**0%**

Wet Season Not to Exceed 2% of the Time Analysis* (WQC = 0.150 mg/L)



Summary Statistics (Data: 11/6/2001 to 3/9/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.010	0.010	0.010	0.010	0.010	0.010	0:2	0%
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.026	0.026	0.026	0.026	0.026	0.026	0:1	0%
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jul	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Aug	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Sep	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.039	0.039	0.039	0.039	0.039	0.039	0:1	0%
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.021**	**0.018**	**0.010**	**0.039**	**0.010**	**0.029**	**0:4**	**0%**

Dry Season Not to Exceed 2% of the Time Analysis* (WQC = 0.080 mg/L)



Summary Statistics (Data: 8/1/2003 to 9/20/2004)								
Month	Mean	Median	Min	Max	25th	75th	XS:Count	XS%
Jan	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Feb	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Mar	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Apr	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
May	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Jun	0.012	0.012	0.011	0.012	0.011	0.012	0:2	0%
Jul	0.005	0.005	0.005	0.005	0.005	0.005	0:2	0%
Aug	0.010	0.009	0.008	0.012	0.009	0.010	0:4	0%
Sep	0.013	0.013	0.009	0.016	0.011	0.014	0:1	0%
Oct	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Nov	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
Dec	0.000	0.000	0.000	0.000	0.000	0.000	0:0	n/a
All Data	**0.010**	**0.009**	**0.005**	**0.016**	**0.008**	**0.012**	**0:9**	**0%**

* Where the standard is missing from the graph, observed data are well below the water quality criteria.

Figure A-62. Not-to-exceed total phosphorous analyses for Waipa Stream

A-3. Streamflow Comparisons

Flow-Associated Trend Assessment

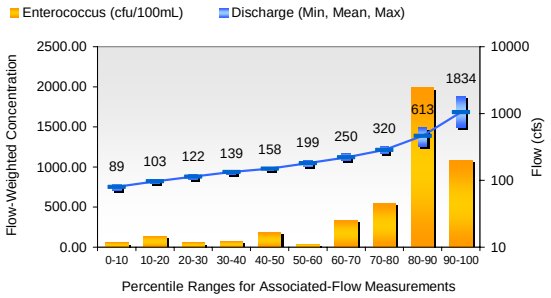
Location: USGS
Flow Gage: Discharge
Pollutant: Enterococcus (cfu/100mL)
Data from: 10/6/2003 to 5/18/2006 (138 Observations)

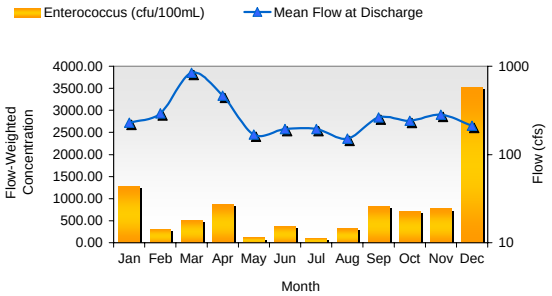
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	14	79.8	72.3	89.0	53.84	14.50	118.70
10-20	14	97.0	90.1	103.0	136.35	8.60	1119.90
20-30	14	113.3	104.0	122.0	53.31	2.00	166.40
30-40	13	133.2	124.0	139.0	71.66	3.10	222.20
40-50	14	149.8	140.0	158.0	184.34	1.00	1413.60
50-60	14	180.7	159.0	199.0	40.34	2.00	242.70
60-70	13	221.1	200.0	250.1	340.38	10.00	2419.60
70-80	14	285.8	254.0	320.0	549.90	29.20	2419.60
80-90	14	463.6	326.4	613.0	1989.52	8.60	24196.00
90-100	13	1046.7	630.1	1833.7	1081.34	13.20	2419.60

Seasonal Trend Assessment

Location: USGS
Flow Gage: Discharge
Pollutant: Enterococcus (cfu/100mL)
Data from: 10/6/2003 to 5/18/2006 (138 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	14	229.6	72.3	890.0	1287.45	10.40	2419.60
February	14	292.5	75.0	2150.0	311.64	4.10	1413.60
March	10	838.8	159.0	1833.7	513.92	13.20	1447.15
April	9	463.5	166.0	1170.0	868.83	2.00	2419.60
May	11	168.0	88.0	254.0	110.61	4.10	387.70
June	9	193.8	108.0	330.0	381.36	5.20	2419.60
July	10	194.5	103.0	493.0	91.09	1.00	307.60
August	11	150.7	74.0	387.0	325.13	2.00	980.40
September	9	262.9	148.0	387.0	824.14	38.40	2420.00
October	12	241.2	89.0	573.0	710.90	17.30	2419.60
November	15	283.1	92.9	851.0	773.26	8.60	1986.30
December	14	212.4	72.7	880.0	3517.48	2.00	24196.00





Monthly Flow Percentile Analysis

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Enterococcus (cfu/100mL)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (cfu/100mL)	64.1	385.5	40.5		275.5		50.4		115.3	2419.6	482.2
	Number of samples	3	3	3		1		1		1	2	14
February	Average concentration (cfu/100mL)	17.1	153.0	61.5	17.5	708.9	29.3	71.8	98.4		435.2	189.2
	Number of samples	1	2	3	1	2	1	2	1		1	14
March	Average concentration (cfu/100mL)						19.7	742.0	70.3	81.4	504.8	351.9
	Number of samples						1	1	1	2	5	10
April	Average concentration (cfu/100mL)						14.5	10.0		88.0	1594.8	381.5
	Number of samples						4	1		2	2	9
May	Average concentration (cfu/100mL)	51.2			87.1	12.7	13.1	216.5				92.1
	Number of samples	1			3	2	2	3				11
June	Average concentration (cfu/100mL)			54.8	52.0	121.3	5.2	2419.6	50.4	56.5		333.6
	Number of samples			1	1	3	1	1	1	1		9
July	Average concentration (cfu/100mL)		30.9	85.8	24.5	1.0			247.4	8.6		78.1
	Number of samples		1	2	3	1			2	1		10
August	Average concentration (cfu/100mL)	48.9		11.1	203.0		91.8	387.3		980.4		179.3
	Number of samples	4		2	1		2	1		1		11
September	Average concentration (cfu/100mL)					218.7		76.9	760.3	2420.0		656.7
	Number of samples					1		3	4	1		9
October	Average concentration (cfu/100mL)	44.3	40.5	153.9		17.3	242.7		1249.3	794.7		455.2
	Number of samples	1	3	1		1	1		2	3		12
November	Average concentration (cfu/100mL)		39.3	22.1	222.2	54.3	25.4	149.7	537.7		1307.5	379.9
	Number of samples		3	1	1	3	1	1	2		3	15
December	Average concentration (cfu/100mL)	66.0	68.4	27.2	34.8		2.0			12122.0	417.0	1799.7
	Number of samples	4	2	1	3		1			2	1	14
Flow Percentile Summary	Average concentration (cfu/100mL)	54.6	133.5	54.1	71.8	177.3	42.3	341.6	563.8	2182.0	1094.8	473.8
	Number of samples	14	14	14	13	14	14	14	13	14	14	138

Figure A-63. Flow versus *enterococcus* concentration at the USGS gage

Flow-Associated Trend Assessment

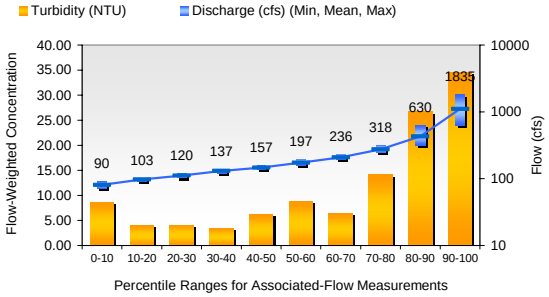
Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Turbidity (NTU)
Data from: 10/6/2003 to 5/18/2006 (156 Observations)

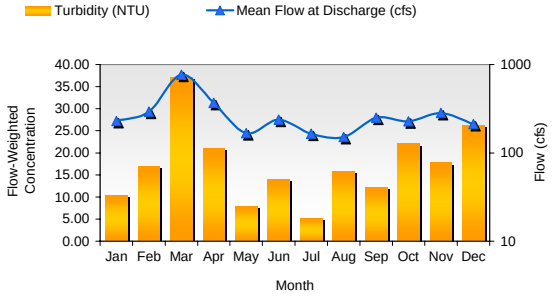
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	16	80.9	72.3	90.1	8.69	0.53	22.50
10-20	15	97.6	91.0	103.0	4.03	0.68	22.30
20-30	16	111.2	103.0	120.0	4.12	0.77	22.40
30-40	15	130.6	122.0	137.0	3.45	0.95	21.80
40-50	16	147.0	138.0	157.4	6.21	0.98	23.30
50-60	15	174.0	158.0	196.9	8.80	1.12	23.20
60-70	16	208.8	197.0	236.0	6.42	1.28	22.50
70-80	15	273.8	245.4	318.0	14.20	2.86	41.00
80-90	16	429.3	318.7	630.1	26.70	5.03	107.00
90-100	15	1104.7	638.0	1835.2	34.63	1.26	91.90

Seasonal Trend Assessment

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Turbidity (NTU)
Data from: 10/6/2003 to 5/18/2006 (156 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	14	229.6	72.3	890.0	10.36	0.53	22.40
February	14	292.5	75.0	2150.0	16.94	0.78	23.30
March	14	764.7	101.0	1835.2	37.14	0.77	91.90
April	14	367.5	105.0	1170.0	21.00	1.01	41.50
May	15	167.7	87.0	378.0	7.98	0.95	23.30
June	10	238.2	108.0	638.0	14.07	1.23	40.40
July	10	164.7	103.0	303.0	5.09	1.32	14.90
August	11	150.7	74.0	387.0	15.84	0.76	47.50
September	10	249.9	133.0	387.0	12.16	1.67	37.70
October	15	227.7	89.0	573.0	22.11	0.99	41.00
November	15	283.1	92.9	851.0	17.76	0.77	27.40
December	14	212.4	72.7	880.0	26.25	0.68	107.00





Monthly Flow Percentile Analysis

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Turbidity (NTU)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (NTU)	7.8	8.0	8.3			3.2	2.1		9.7	12.6	8.0
	Number of samples	*3*	*3*	*3*			*1*	*1*		*1*	*2*	*14*
February	Average concentration (NTU)	11.6	1.4	1.8	1.1	11.8	2.1	12.2	22.5		23.3	9.1
	Number of samples	*2*	*1*	*3*	*1*	*2*	*1*	*2*	*1*		*1*	*14*
March	Average concentration (NTU)		0.9		1.5		2.8	1.3	23.0		34.8	19.7
	Number of samples		*2*		*1*		*1*	*2*	*1*		*7*	*14*
April	Average concentration (NTU)			1.0	1.4	1.6	10.4		23.0	18.5	31.3	14.1
	Number of samples			*1*	*1*	*1*	*5*		*1*	*3*	*2*	*14*
May	Average concentration (NTU)	1.1	1.0	1.1	1.7	12.9	13.0	5.0	15.3	5.0		6.8
	Number of samples	*2*	*1*	*1*	*3*	*2*	*2*	*1*	*2*	*1*		*15*
June	Average concentration (NTU)			1.9	1.2	2.6	3.7	3.7	4.8	9.1	40.4	7.4
	Number of samples			*1*	*1*	*2*	*1*	*2*	*1*	*1*	*1*	*10*
July	Average concentration (NTU)		2.0	1.7	3.4	1.7	3.0		9.9			4.0
	Number of samples		*1*	*2*	*3*	*1*	*1*		*2*			*10*
August	Average concentration (NTU)	1.0		1.2		4.3	6.9	13.5		47.5		8.4
	Number of samples	*4*		*2*		*1*	*1*	*2*		*1*		*11*
September	Average concentration (NTU)				4.1	5.4		2.1	9.2	26.5		9.6
	Number of samples				*1*	*1*		*3*	*3*	*2*		*10*
October	Average concentration (NTU)	1.1	1.6	21.8		1.8	14.4	21.7	31.4	28.4		15.3
	Number of samples	*1*	*3*	*1*		*2*	*2*	*1*	*2*	*3*		*15*
November	Average concentration (NTU)		8.0	0.8	21.8	8.4	3.5		8.0	21.8	27.4	11.7
	Number of samples		*3*	*1*	*1*	*3*	*1*		*3*	*1*	*2*	*15*
December	Average concentration (NTU)	22.1	1.3		1.5			3.1		57.8	24.2	17.1
	Number of samples	*4*	*2*		*4*			*1*		*2*	*1*	*14*
Flow Percentile Summary	Average concentration (NTU)	8.9	3.8	4.2	3.3	6.4	8.3	6.7	14.9	26.8	29.6	11.3
	Number of samples	*16*	*16*	*15*	*16*	*15*	*16*	*15*	*16*	*15*	*16*	*156*

Figure A-64. Flow versus turbidity at the USGS gage

Flow-Associated Trend Assessment

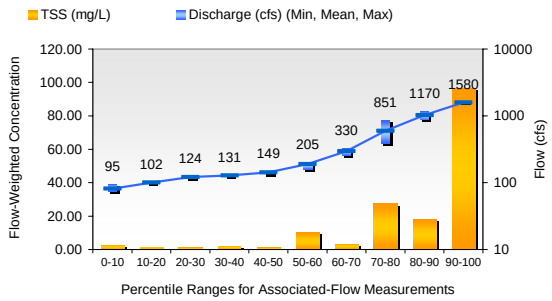
Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: TSS (mg/L)
Data from: 10/31/2003 to 3/16/2006 (25 Observations)

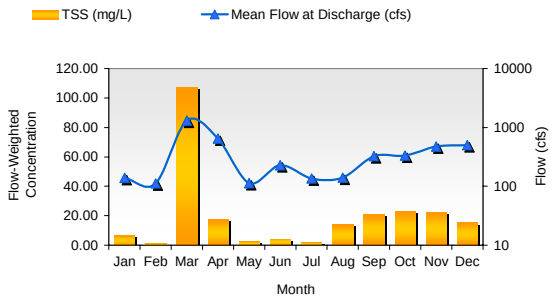
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	2.59	1.60	3.20
10-20	2	100.0	98.0	102.0	1.54	1.20	1.90
20-30	3	121.3	118.0	124.0	1.37	0.80	1.70
30-40	2	128.5	126.0	131.0	2.15	2.00	2.30
40-50	2	142.5	136.0	149.0	1.28	0.80	1.80
50-60	3	189.0	158.0	205.0	10.26	1.90	18.00
60-70	2	295.0	260.0	330.0	3.31	1.30	4.90
70-80	3	599.7	387.0	851.0	27.44	24.60	34.30
80-90	2	1025.0	880.0	1170.0	18.14	17.00	19.00
90-100	2	1579.4	1578.8	1580.0	96.47	25.00	168.00

Seasonal Trend Assessment

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: TSS (mg/L)
Data from: 10/31/2003 to 3/16/2006 (25 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	6.64	0.80	11.00
February	2	112.0	75.0	149.0	1.07	0.80	1.60
March	4	1299.1	204.0	1833.7	107.41	1.90	168.00
April	2	648.0	126.0	1170.0	17.35	2.00	19.00
May	2	113.0	95.0	131.0	2.55	2.30	2.90
June	2	227.0	124.0	330.0	4.03	1.70	4.90
July	1	136.0	136.0	136.0	1.80	1.80	1.80
August	2	139.5	74.0	205.0	14.07	3.20	18.00
September	2	323.5	260.0	387.0	21.04	1.30	34.30
October	2	331.5	102.0	561.0	23.03	1.20	27.00
November	2	474.5	98.0	851.0	22.26	1.90	24.60
December	2	501.0	122.0	880.0	15.12	1.60	17.00





Monthly Flow Percentile Analysis

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: TSS (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.8		11.0						5.9
	Number of samples			*1*		*1*						*2*
February	Average concentration (mg/L)	1.6				0.8						1.2
	Number of samples	*1*				*1*						*2*
March	Average concentration (mg/L)						1.9				110.3	83.2
	Number of samples						*1*				*3*	*4*
April	Average concentration (mg/L)				2.0					19.0		10.5
	Number of samples				*1*					*1*		*2*
May	Average concentration (mg/L)	2.9			2.3							2.6
	Number of samples	*1*			*1*							*2*
June	Average concentration (mg/L)			1.7				4.9				3.3
	Number of samples			*1*				*1*				*2*
July	Average concentration (mg/L)					1.8						1.8
	Number of samples					*1*						*1*
August	Average concentration (mg/L)	3.2					18.0					10.6
	Number of samples	*1*					*1*					*2*
September	Average concentration (mg/L)							1.3	34.3			17.8
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		1.2						27.0			14.1
	Number of samples		*1*						*1*			*2*
November	Average concentration (mg/L)		1.9						24.6			13.3
	Number of samples		*1*						*1*			*2*
December	Average concentration (mg/L)			1.6						17.0		9.3
	Number of samples			*1*						*1*		*2*
Flow Percentile Summary	Average concentration (mg/L)	2.6	1.6	1.4	2.2	4.5	10.0	3.1	28.6	18.0	110.3	20.5
	Number of samples	*3*	*2*	*3*	*2*	*3*	*2*	*2*	*3*	*2*	*3*	*25*

Figure A-65. Flow versus TSS concentration at the USGS gage

Flow-Associated Trend Assessment

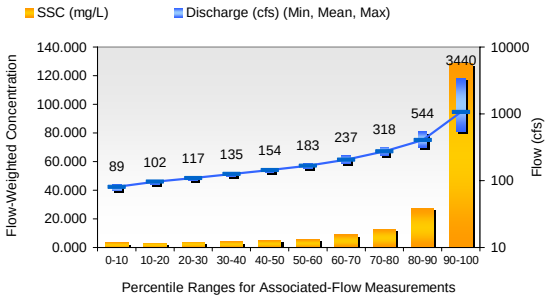
Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: SSC (mg/L)
Data from: 10/1/2003 to 3/21/2006 (813 Observations)

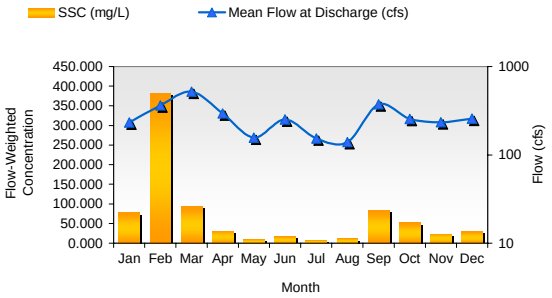
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	82	80.8	71.0	89.0	3.403	0.000	11.000
10-20	81	96.4	89.0	102.0	3.143	0.000	17.000
20-30	81	109.6	102.0	117.0	3.927	1.000	17.000
30-40	81	125.6	118.0	135.0	4.079	0.000	9.000
40-50	81	143.4	135.0	154.0	5.219	1.000	23.000
50-60	82	168.1	154.3	183.0	5.822	1.000	16.000
60-70	81	206.5	183.0	237.0	9.053	1.000	39.000
70-80	81	273.6	238.0	318.0	12.815	1.000	75.833
80-90	81	404.8	318.0	544.0	27.699	2.500	114.000
90-100	81	1068.9	549.0	3440.0	128.514	8.000	636.667

Seasonal Trend Assessment

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: SSC (mg/L)
Data from: 10/1/2003 to 3/21/2006 (813 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	80	232.8	72.1	2300.0	77.445	0.000	348.000
February	73	364.0	74.0	4273.2	381.627	0.000	1702.750
March	73	521.1	96.0	2932.2	94.357	1.000	636.667
April	60	295.2	97.0	1470.0	31.230	2.000	195.000
May	62	157.1	85.0	421.0	9.944	2.000	45.000
June	60	251.1	94.0	901.0	16.624	2.000	68.000
July	62	153.4	99.0	493.0	6.984	0.000	22.000
August	62	140.0	74.0	826.0	11.017	2.000	43.000
September	60	373.6	75.0	3210.0	82.816	2.000	324.000
October	69	255.2	71.0	1770.0	51.746	1.000	298.000
November	75	235.0	91.0	1210.0	23.273	1.000	98.000
December	77	257.3	71.6	1450.0	30.240	0.000	113.000





Monthly Flow Percentile Analysis

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: SSC (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)	3.0	3.5	5.4	4.7	6.4	7.8	18.8		32.7	118.8	18.1
	Number of samples	*16*	*13*	*19*	*3*	*5*	*5*	*4*		*8*	*7*	*80*
February	Average concentration (mg/L)	2.2	2.1	2.2	3.7	2.7	4.3	5.1	39.9	47.4	313.1	48.3
	Number of samples	*13*	*8*	*6*	*6*	*6*	*8*	*5*	*2*	*10*	*9*	*73*
March	Average concentration (mg/L)		3.6	3.7	6.3	8.9	6.6	7.5	12.3	12.7	81.3	32.0
	Number of samples		*5*	*10*	*4*	*2*	*5*	*7*	*9*	*7*	*24*	*73*
April	Average concentration (mg/L)		2.5	2.3	2.0	4.0	4.2	5.8	9.2	15.2	59.5	12.1
	Number of samples		*2*	*7*	*2*	*3*	*9*	*13*	*9*	*9*	*6*	*60*
May	Average concentration (mg/L)	2.7	2.3	4.2	5.3	3.9	5.6	10.1	15.6	33.5		6.9
	Number of samples	*7*	*14*	*5*	*5*	*7*	*5*	*10*	*7*	*2*		*62*
June	Average concentration (mg/L)		4.2	4.6	4.2	7.8	9.7	8.4	10.0	17.8	33.0	10.9
	Number of samples		*6*	*5*	*5*	*13*	*3*	*8*	*6*	*9*	*5*	*60*
July	Average concentration (mg/L)		4.3	4.2	3.2	4.6	6.3	12.3	12.2	15.0		5.7
	Number of samples		*4*	*15*	*12*	*12*	*9*	*4*	*5*	*1*		*62*
August	Average concentration (mg/L)	5.0	3.2	3.0	4.3	4.8	5.0	8.2	9.5	35.0	36.0	6.5
	Number of samples	*24*	*6*	*3*	*9*	*5*	*5*	*5*	*2*	*2*	*1*	*62*
September	Average concentration (mg/L)	6.3	8.7	3.0	6.0	8.0	4.2	11.0	11.3	21.5	93.9	22.0
	Number of samples	*4*	*3*	*1*	*2*	*3*	*9*	*7*	*13*	*10*	*8*	*60*
October	Average concentration (mg/L)	2.0	3.0	3.0	4.0	5.3	8.3	9.6	13.5	31.4	95.9	17.8
	Number of samples	*4*	*7*	*1*	*8*	*9*	*11*	*5*	*9*	*9*	*6*	*69*
November	Average concentration (mg/L)		2.3	2.8	4.1	4.5	5.3	12.3	13.3	33.6	48.9	11.9
	Number of samples		*6*	*5*	*15*	*11*	*8*	*6*	*13*	*5*	*6*	*75*
December	Average concentration (mg/L)	2.6	2.0	2.2	3.5	3.0	4.4	6.3	10.7	20.1	52.7	11.6
	Number of samples	*17*	*6*	*5*	*8*	*5*	*5*	*7*	*6*	*9*	*9*	*77*
Flow Percentile Summary	Average concentration (mg/L)	3.5	3.2	3.8	4.1	5.2	5.8	9.0	12.7	26.2	101.9	17.5
	Number of samples	*85*	*80*	*82*	*79*	*81*	*82*	*81*	*81*	*81*	*81*	*813*

Figure A-66. Flow versus suspended sediment concentration at the USGS gage

Flow-Associated Trend Assessment

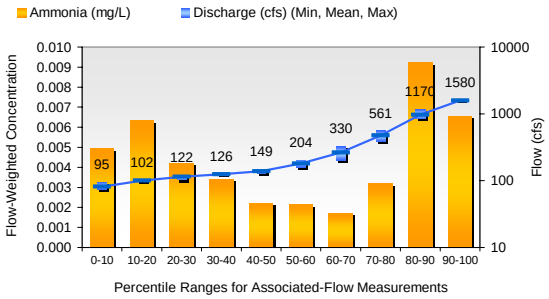
Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Ammonia (mg/L)
Data from: 10/31/2003 to 3/16/2006 (26 Observations)

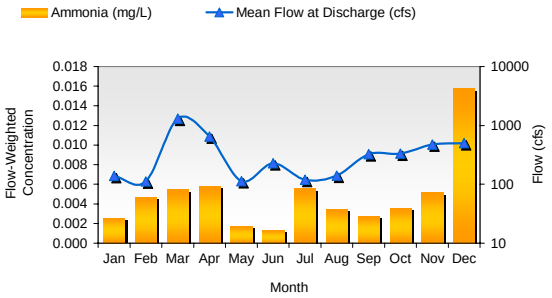
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	0.005	0.003	0.010
10-20	2	100.0	98.0	102.0	0.006	0.006	0.007
20-30	3	114.3	103.0	122.0	0.004	0.002	0.009
30-40	2	125.0	124.0	126.0	0.003	0.003	0.004
40-50	3	138.7	131.0	149.0	0.002	0.001	0.003
50-60	2	181.0	158.0	204.0	0.002	0.001	0.003
60-70	3	265.0	205.0	330.0	0.002	0.001	0.004
70-80	2	474.0	387.0	561.0	0.003	0.003	0.004
80-90	3	967.0	851.0	1170.0	0.009	0.005	0.018
90-100	2	1579.4	1578.8	1580.0	0.007	0.002	0.011

Seasonal Trend Assessment

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Ammonia (mg/L)
Data from: 10/31/2003 to 3/16/2006 (26 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	0.003	0.002	0.003
February	2	112.0	75.0	149.0	0.005	0.002	0.010
March	4	1299.1	204.0	1833.7	0.005	0.001	0.011
April	2	648.0	126.0	1170.0	0.006	0.004	0.006
May	2	113.0	95.0	131.0	0.002	0.001	0.003
June	2	227.0	124.0	330.0	0.001	0.001	0.003
July	2	119.5	103.0	136.0	0.006	0.003	0.009
August	2	139.5	74.0	205.0	0.003	0.003	0.004
September	2	323.5	260.0	387.0	0.003	0.002	0.004
October	2	331.5	102.0	561.0	0.004	0.003	0.007
November	2	474.5	98.0	851.0	0.005	0.005	0.006
December	2	501.0	122.0	880.0	0.016	0.003	0.018





Monthly Flow Percentile Analysis

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Ammonia (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.002			0.003					0.002
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	0.010				0.002						0.006
	Number of samples	*1*				*1*						*2*
March	Average concentration (mg/L)						0.001				0.006	0.005
	Number of samples						*1*				*3*	*4*
April	Average concentration (mg/L)				0.004					0.006		0.005
	Number of samples				*1*					*1*		*2*
May	Average concentration (mg/L)	0.003			0.001							0.002
	Number of samples	*1*			*1*							*2*
June	Average concentration (mg/L)				0.003			0.001				0.002
	Number of samples				*1*			*1*				*2*
July	Average concentration (mg/L)		0.009			0.003						0.006
	Number of samples		*1*			*1*						*2*
August	Average concentration (mg/L)	0.003					0.004					0.003
	Number of samples	*1*					*1*					*2*
September	Average concentration (mg/L)							0.002	0.004			0.003
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		0.007						0.003			0.005
	Number of samples		*1*						*1*			*2*
November	Average concentration (mg/L)		0.006						0.005			0.005
	Number of samples		*1*						*1*			*2*
December	Average concentration (mg/L)			0.003						0.018		0.010
	Number of samples			*1*						*1*		*2*
Flow Percentile Summary	Average concentration (mg/L)	0.005	0.007	0.002	0.003	0.003	0.003	0.001	0.004	0.012	0.006	0.005
	Number of samples	*3*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*26*

Figure A-67. Flow versus ammonia concentration at the USGS gage

Flow-Associated Trend Assessment

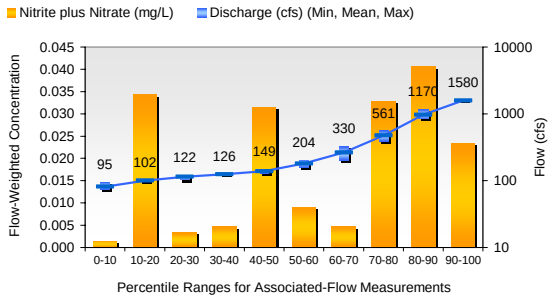
Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Nitrite plus Nitrate (mg/L)
Data from: 10/31/2003 to 3/16/2006 (26 Observations)

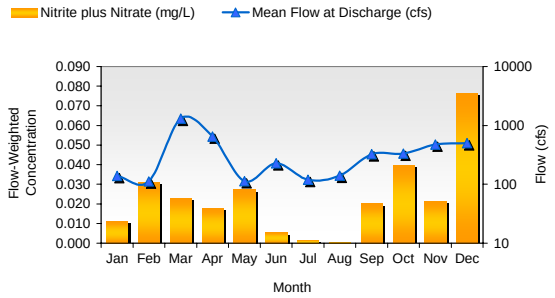
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	0.001	0.000	0.003
10-20	2	100.0	98.0	102.0	0.034	0.010	0.057
20-30	3	114.3	103.0	122.0	0.003	0.000	0.006
30-40	2	125.0	124.0	126.0	0.005	0.001	0.008
40-50	3	138.7	131.0	149.0	0.032	0.002	0.047
50-60	2	181.0	158.0	204.0	0.009	0.003	0.017
60-70	3	265.0	205.0	330.0	0.005	0.000	0.009
70-80	2	474.0	387.0	561.0	0.033	0.028	0.037
80-90	3	967.0	851.0	1170.0	0.041	0.019	0.086
90-100	2	1579.4	1578.8	1580.0	0.023	0.018	0.029

Seasonal Trend Assessment

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Nitrite plus Nitrate (mg/L)
Data from: 10/31/2003 to 3/16/2006 (26 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	0.011	0.004	0.017
February	2	112.0	75.0	149.0	0.031	0.000	0.047
March	4	1299.1	204.0	1833.7	0.023	0.003	0.029
April	2	648.0	126.0	1170.0	0.018	0.001	0.019
May	2	113.0	95.0	131.0	0.027	0.003	0.045
June	2	227.0	124.0	330.0	0.005	0.004	0.008
July	2	119.5	103.0	136.0	0.001	0.000	0.002
August	2	139.5	74.0	205.0	0.000	0.000	0.001
September	2	323.5	260.0	387.0	0.020	0.009	0.028
October	2	331.5	102.0	561.0	0.040	0.037	0.057
November	2	474.5	98.0	851.0	0.021	0.010	0.023
December	2	501.0	122.0	880.0	0.076	0.006	0.086





Monthly Flow Percentile Analysis

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Nitrite plus Nitrate (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.004			0.017					0.010
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	0.0001				0.047						0.023
	Number of samples	*1*				*1*						*2*
March	Average concentration (mg/L)						0.003				0.024	0.019
	Number of samples						*1*				*3*	*4*
April	Average concentration (mg/L)				0.001					0.019		0.010
	Number of samples				*1*					*1*		*2*
May	Average concentration (mg/L)	0.003			0.045							0.024
	Number of samples	*1*			*1*							*2*
June	Average concentration (mg/L)				0.008			0.004				0.006
	Number of samples				*1*			*1*				*2*
July	Average concentration (mg/L)		0.0003			0.002						0.001
	Number of samples		*1*			*1*						*2*
August	Average concentration (mg/L)	0.001					0.0001					0.001
	Number of samples	*1*					*1*					*2*
September	Average concentration (mg/L)							0.009	0.028			0.018
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		0.057						0.037			0.047
	Number of samples		*1*						*1*			*2*
November	Average concentration (mg/L)		0.010						0.023			0.016
	Number of samples		*1*						*1*			*2*
December	Average concentration (mg/L)			0.006						0.086		0.046
	Number of samples			*1*						*1*		*2*
Flow Percentile Summary	Average concentration (mg/L)	0.001	0.023	0.005	0.018	0.024	0.007	0.007	0.029	0.053	0.024	0.018
	Number of samples	*3*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*26*

Figure A-68. Flow versus nitrite plus nitrate concentration at the USGS gage

Flow-Associated Trend Assessment

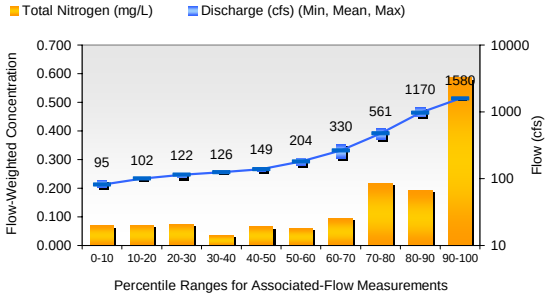
Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Total Nitrogen (mg/L)
Data from: 10/31/2003 to 3/16/2006 (26 Observations)

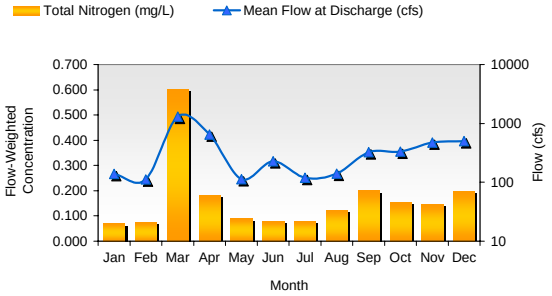
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	0.069	0.062	0.075
10-20	2	100.0	98.0	102.0	0.073	0.047	0.097
20-30	3	114.3	103.0	122.0	0.075	0.039	0.156
30-40	2	125.0	124.0	126.0	0.036	0.024	0.047
40-50	3	138.7	131.0	149.0	0.065	0.021	0.102
50-60	2	181.0	158.0	204.0	0.060	0.035	0.092
60-70	3	265.0	205.0	330.0	0.095	0.052	0.145
70-80	2	474.0	387.0	561.0	0.218	0.163	0.298
80-90	3	967.0	851.0	1170.0	0.193	0.158	0.221
90-100	2	1579.4	1578.8	1580.0	0.586	0.173	1.000

Seasonal Trend Assessment

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Total Nitrogen (mg/L)
Data from: 10/31/2003 to 3/16/2006 (26 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	0.069	0.039	0.092
February	2	112.0	75.0	149.0	0.075	0.074	0.075
March	4	1299.1	204.0	1833.7	0.604	0.035	1.000
April	2	648.0	126.0	1170.0	0.183	0.047	0.197
May	2	113.0	95.0	131.0	0.089	0.071	0.102
June	2	227.0	124.0	330.0	0.077	0.024	0.098
July	2	119.5	103.0	136.0	0.079	0.021	0.156
August	2	139.5	74.0	205.0	0.123	0.062	0.145
September	2	323.5	260.0	387.0	0.199	0.052	0.298
October	2	331.5	102.0	561.0	0.153	0.097	0.163
November	2	474.5	98.0	851.0	0.146	0.047	0.158
December	2	501.0	122.0	880.0	0.199	0.042	0.221





Monthly Flow Percentile Analysis

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Total Nitrogen (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.039			0.092					0.065
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	0.075				0.074						0.075
	Number of samples	*1*				*1*						*2*
March	Average concentration (mg/L)						0.035				0.624	0.476
	Number of samples						*1*				*3*	*4*
April	Average concentration (mg/L)				0.047					0.197		0.122
	Number of samples				*1*					*1*		*2*
May	Average concentration (mg/L)	0.071			0.102							0.086
	Number of samples	*1*			*1*							*2*
June	Average concentration (mg/L)				0.024			0.098				0.061
	Number of samples				*1*			*1*				*2*
July	Average concentration (mg/L)		0.156			0.021						0.088
	Number of samples		*1*			*1*						*2*
August	Average concentration (mg/L)	0.062					0.145					0.103
	Number of samples	*1*					*1*					*2*
September	Average concentration (mg/L)							0.052	0.298			0.175
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		0.097						0.163			0.130
	Number of samples		*1*						*1*			*2*
November	Average concentration (mg/L)		0.047						0.158			0.103
	Number of samples		*1*						*1*			*2*
December	Average concentration (mg/L)			0.042						0.221		0.131
	Number of samples			*1*						*1*		*2*
Flow Percentile Summary	Average concentration (mg/L)	0.069	0.100	0.040	0.058	0.047	0.091	0.075	0.206	0.209	0.624	0.161
	Number of samples	*3*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*26*

Figure A-69. Flow versus total nitrogen concentration at the USGS gage

Flow-Associated Trend Assessment

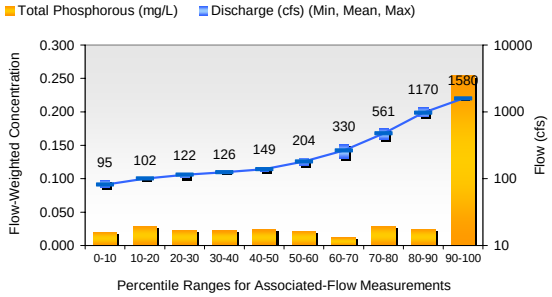
Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Total Phosphorous (mg/L)
Data from: 10/31/2003 to 3/16/2006 (26 Observations)

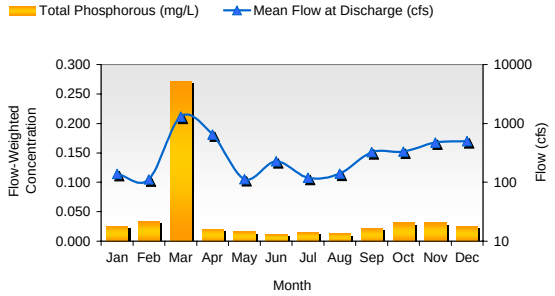
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	0.020	0.017	0.025
10-20	2	100.0	98.0	102.0	0.029	0.018	0.040
20-30	3	114.3	103.0	122.0	0.024	0.009	0.031
30-40	2	125.0	124.0	126.0	0.023	0.022	0.024
40-50	3	138.7	131.0	149.0	0.024	0.009	0.042
50-60	2	181.0	158.0	204.0	0.022	0.022	0.022
60-70	3	265.0	205.0	330.0	0.012	0.007	0.020
70-80	2	474.0	387.0	561.0	0.029	0.023	0.034
80-90	3	967.0	851.0	1170.0	0.025	0.020	0.030
90-100	2	1579.4	1578.8	1580.0	0.254	0.029	0.480

Seasonal Trend Assessment

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Total Phosphorous (mg/L)
Data from: 10/31/2003 to 3/16/2006 (26 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	0.026	0.022	0.031
February	2	112.0	75.0	149.0	0.033	0.017	0.042
March	4	1299.1	204.0	1833.7	0.272	0.022	0.480
April	2	648.0	126.0	1170.0	0.021	0.020	0.024
May	2	113.0	95.0	131.0	0.016	0.009	0.025
June	2	227.0	124.0	330.0	0.011	0.007	0.022
July	2	119.5	103.0	136.0	0.015	0.009	0.019
August	2	139.5	74.0	205.0	0.012	0.011	0.017
September	2	323.5	260.0	387.0	0.022	0.020	0.023
October	2	331.5	102.0	561.0	0.031	0.018	0.034
November	2	474.5	98.0	851.0	0.031	0.030	0.040
December	2	501.0	122.0	880.0	0.025	0.025	0.029





Monthly Flow Percentile Analysis

Location: USGS
Flow Gage: Discharge (cfs)
Pollutant: Total Phosphorous (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.031			0.022					0.026
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	0.017				0.042						0.029
	Number of samples	*1*				*1*						*2*
March	Average concentration (mg/L)						0.022				0.280	0.215
	Number of samples						*1*				*3*	*4*
April	Average concentration (mg/L)				0.024					0.020		0.022
	Number of samples				*1*					*1*		*2*
May	Average concentration (mg/L)	0.025			0.009							0.017
	Number of samples	*1*			*1*							*2*
June	Average concentration (mg/L)				0.022			0.007				0.015
	Number of samples				*1*			*1*				*2*
July	Average concentration (mg/L)		0.009			0.019						0.014
	Number of samples		*1*			*1*						*2*
August	Average concentration (mg/L)	0.017					0.011					0.014
	Number of samples	*1*					*1*					*2*
September	Average concentration (mg/L)							0.020	0.023			0.021
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		0.018						0.034			0.026
	Number of samples		*1*						*1*			*2*
November	Average concentration (mg/L)		0.040						0.030			0.035
	Number of samples		*1*						*1*			*2*
December	Average concentration (mg/L)			0.029						0.025		0.027
	Number of samples			*1*						*1*		*2*
Flow Percentile Summary	Average concentration (mg/L)	0.020	0.022	0.030	0.018	0.031	0.018	0.014	0.029	0.022	0.280	0.052
	Number of samples	*3*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*2*	*3*	*26*

Figure A-70. Flow versus total phosphorous concentration at the USGS gage

Flow-Associated Trend Assessment

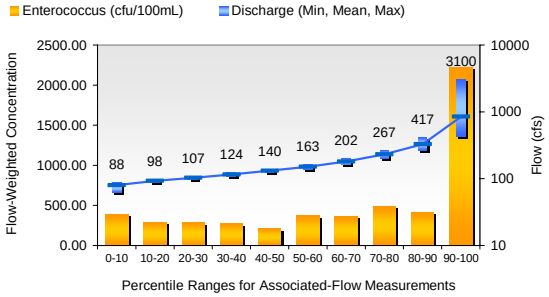
Location: Weke
Flow Gage: Discharge
Pollutant: Enterococcus (cfu/100mL)
Data from: 1/9/1995 to 5/18/2006 (776 Observations)

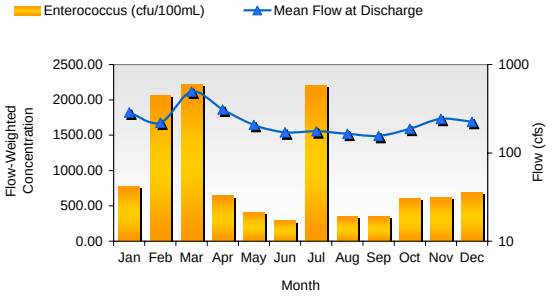
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	78	79.5	63.0	88.0	391.16	10.00	7270.00
10-20	77	93.2	88.0	98.0	293.14	5.60	1529.00
20-30	78	103.4	98.1	107.0	284.70	6.20	3076.00
30-40	77	116.1	108.0	124.0	275.66	8.10	1483.00
40-50	78	131.6	124.9	140.0	210.43	6.30	1297.60
50-60	77	150.8	140.0	163.0	374.88	10.00	2723.00
60-70	78	181.3	163.0	202.0	365.37	1.00	5012.00
70-80	77	230.8	202.0	267.0	491.82	10.00	10112.00
80-90	78	329.4	267.0	417.0	411.84	10.00	2382.00
90-100	77	850.5	430.0	3100.0	2226.37	10.00	24196.00

Seasonal Trend Assessment

Location: Weke
Flow Gage: Discharge
Pollutant: Enterococcus (cfu/100mL)
Data from: 1/9/1995 to 5/18/2006 (776 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	51	286.5	72.1	3100.0	781.76	60.00	4038.50
February	59	219.0	75.0	2150.0	2071.75	10.00	10112.00
March	66	493.3	67.0	4880.0	2227.35	10.00	24196.00
April	60	311.0	94.0	1170.0	644.04	10.00	5012.00
May	57	206.9	83.0	1530.0	414.28	5.60	3654.00
June	69	170.9	63.0	638.0	288.42	10.00	1011.10
July	71	176.0	67.0	1960.0	2208.24	1.00	12996.50
August	82	165.0	74.0	565.0	348.54	6.30	7270.00
September	77	155.5	63.0	462.0	347.98	10.00	1664.00
October	70	187.9	75.0	774.0	610.71	41.00	2419.20
November	62	243.3	77.0	1530.0	621.24	28.60	2723.00
December	52	224.4	72.0	880.0	689.51	30.00	2900.00





Monthly Flow Percentile Analysis

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Enterococcus (cfu/100mL)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (cfu/100mL)	454.1	429.8	968.5	495.8		1088.3	290.0	2165.3	557.7	771.9	669.5
	Number of samples	*17*	*7*	*2*	*5*		*6*	*1*	*2*	*3*	*8*	*51*
February	Average concentration (cfu/100mL)	79.8	269.6	714.7	301.5	219.5	604.0	475.0	2359.4	388.0	2622.6	795.0
	Number of samples	*4*	*5*	*7*	*10*	*6*	*8*	*5*	*5*	*3*	*6*	*59*
March	Average concentration (cfu/100mL)	160.2	100.0	180.7	117.8	392.0	876.4	316.3	202.1	273.8	2276.3	931.9
	Number of samples	*5*	*2*	*3*	*4*	*5*	*5*	*4*	*8*	*9*	*21*	*66*
April	Average concentration (cfu/100mL)		111.5	74.5	151.0	71.0	65.5	464.5	189.4	205.1	957.3	382.1
	Number of samples		*2*	*2*	*2*	*2*	*2*	*17*	*13*	*10*	*10*	*60*
May	Average concentration (cfu/100mL)	521.7	271.2	159.9	207.8	149.4	133.2	278.5	814.5	139.4	510.3	297.0
	Number of samples	*3*	*6*	*8*	*5*	*7*	*6*	*7*	*6*	*5*	*4*	*57*
June	Average concentration (cfu/100mL)	256.9	243.8	130.3	106.8	213.9	79.5	174.6	651.9	201.5	779.0	215.7
	Number of samples	*7*	*5*	*15*	*4*	*8*	*10*	*5*	*3*	*9*	*3*	*69*
July	Average concentration (cfu/100mL)	195.6	166.0	129.1	134.8	143.9	39.1	64.6	137.5	503.3	4442.1	352.1
	Number of samples	*9*	*7*	*10*	*12*	*13*	*2*	*5*	*4*	*6*	*3*	*71*
August	Average concentration (cfu/100mL)	949.5	258.9	258.7	223.1	205.5	389.6	214.7	396.5	328.3	644.0	370.5
	Number of samples	*11*	*6*	*6*	*15*	*12*	*4*	*7*	*11*	*9*	*1*	*82*
September	Average concentration (cfu/100mL)	231.2	256.0	324.8	374.3	221.5	372.0	177.9	304.7	666.9	250.0	307.3
	Number of samples	*14*	*7*	*10*	*7*	*8*	*5*	*10*	*8*	*7*	*1*	*77*
October	Average concentration (cfu/100mL)	274.8	296.2	429.7	514.4	303.6	422.9	996.7	269.5	869.9	948.8	475.9
	Number of samples	*8*	*11*	*8*	*6*	*8*	*8*	*3*	*6*	*6*	*6*	*70*
November	Average concentration (cfu/100mL)	254.9	409.6	145.5	896.0	169.8	304.8	337.1	262.6	669.0	1077.3	432.1
	Number of samples	*5*	*6*	*4*	*2*	*6*	*12*	*5*	*7*	*9*	*6*	*62*
December	Average concentration (cfu/100mL)	598.0	442.8	227.2	304.0	311.1	403.7	346.4	353.4	555.5	1116.4	481.1
	Number of samples	*5*	*4*	*5*	*3*	*7*	*5*	*9*	*4*	*3*	*7*	*52*
Flow Percentile Summary	Average concentration (cfu/100mL)	387.6	288.5	276.4	281.4	218.4	411.3	333.9	510.0	422.9	1550.7	465.8
	Number of samples	*88*	*68*	*80*	*75*	*82*	*73*	*78*	*77*	*79*	*76*	*776*

Figure A-71. Flow versus *enterococcus* concentration at Weke Road

Flow-Associated Trend Assessment

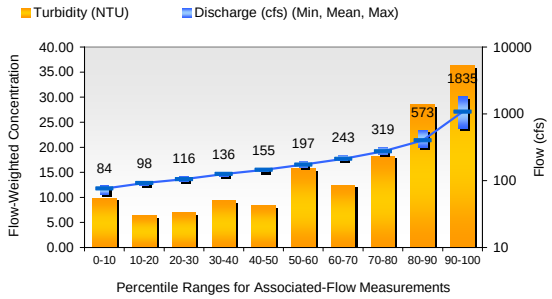
Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Turbidity (NTU)
Data from: 4/12/2003 to 5/24/2006 (205 Observations)

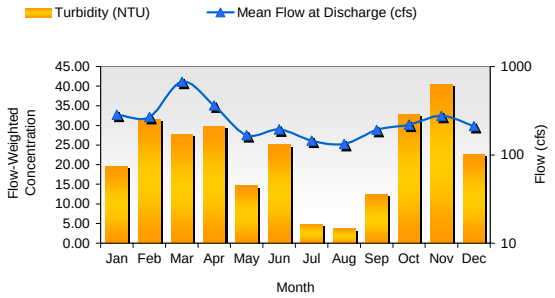
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	21	76.5	63.0	84.0	9.81	2.78	24.30
10-20	20	92.2	86.0	98.0	6.38	2.11	24.90
20-30	21	105.5	98.0	116.0	6.96	2.31	26.20
30-40	20	126.5	116.0	136.0	9.38	2.82	25.00
40-50	20	145.0	136.0	155.0	8.41	2.98	28.40
50-60	21	174.1	157.4	197.0	15.73	3.07	61.40
60-70	20	212.4	198.0	242.8	12.46	2.67	28.10
70-80	21	274.3	244.0	318.7	18.30	2.11	35.50
80-90	20	401.1	320.0	573.0	28.53	2.92	71.30
90-100	20	1079.7	613.0	1835.2	36.27	3.97	131.00

Seasonal Trend Assessment

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Turbidity (NTU)
Data from: 4/12/2003 to 5/24/2006 (205 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	15	283.7	72.1	993.1	19.50	2.89	39.30
February	18	267.8	75.0	2150.0	31.68	2.89	51.20
March	22	675.5	101.0	1835.2	27.70	2.31	77.80
April	22	364.4	105.0	1170.0	29.74	2.80	69.20
May	23	166.8	87.0	378.0	14.59	2.87	28.40
June	15	194.9	79.0	638.0	25.05	3.10	86.60
July	14	145.1	72.0	303.0	4.93	2.59	10.90
August	15	132.9	73.0	387.0	3.66	2.67	7.96
September	15	192.1	63.0	387.0	12.34	3.41	35.50
October	16	219.9	89.0	573.0	32.82	2.57	71.30
November	16	275.8	92.9	851.0	40.45	2.11	131.00
December	14	212.3	72.0	880.0	22.59	3.40	38.70





Monthly Flow Percentile Analysis

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Turbidity (NTU)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (NTU)	13.7	14.5	10.2	3.8		15.0	28.1		39.3	17.7	16.6
	Number of samples	4	2	1	1		2	1		1	3	15
February	Average concentration (NTU)	2.9	14.4	9.9	17.8	14.2	4.3	15.2	25.2	25.1	51.2	16.1
	Number of samples	1	2	4	3	2	1	2	1	1	1	18
March	Average concentration (NTU)			2.8	4.1		9.1	12.8	25.9	26.0	27.4	20.8
	Number of samples			2	1		1	3	3	4	8	22
April	Average concentration (NTU)			2.8	3.8	4.6	13.1	9.1	27.2	23.1	38.8	19.5
	Number of samples			1	1	2	5	2	3	4	4	22
May	Average concentration (NTU)		4.1	2.9	6.7	18.1	20.4	18.8	23.9	2.9		13.2
	Number of samples		5	1	3	4	3	4	2	1		23
June	Average concentration (NTU)	4.0	3.5	3.6	4.7	3.6	3.9	8.1	7.3	22.8	86.6	11.4
	Number of samples	1	1	3	1	2	2	2	1	1	1	15
July	Average concentration (NTU)	3.2		2.9	6.8	3.7	10.5		4.4			4.7
	Number of samples	2		4	3	2	1		2			14
August	Average concentration (NTU)	4.3	3.4	2.9	3.5	3.3	3.1	2.7		4.8		3.6
	Number of samples	5	3	1	1	1	1	2		1		15
September	Average concentration (NTU)	5.0	4.0		5.1	9.2		4.2	19.9	16.5		9.6
	Number of samples	4	1		1	1		3	3	2		15
October	Average concentration (NTU)		8.2	11.7	23.7	3.9	42.5	23.5	14.9	48.3		22.9
	Number of samples		2	3	1	2	2	1	2	3		16
November	Average concentration (NTU)		11.0	3.7	24.0	12.5	15.4		13.3		63.2	22.4
	Number of samples		3	1	1	3	2		3		3	16
December	Average concentration (NTU)	24.2	4.0		6.8	6.2		3.6		33.4	28.8	16.5
	Number of samples	4	2		3	1		1		2	1	14
Flow Percentile Summary	Average concentration (NTU)	9.8	7.3	6.0	9.3	9.4	15.4	12.0	18.9	26.8	37.3	15.2
	Number of samples	21	21	21	20	20	20	21	20	20	21	205

Figure A-72. Flow versus turbidity at the Weke Road

Flow-Associated Trend Assessment

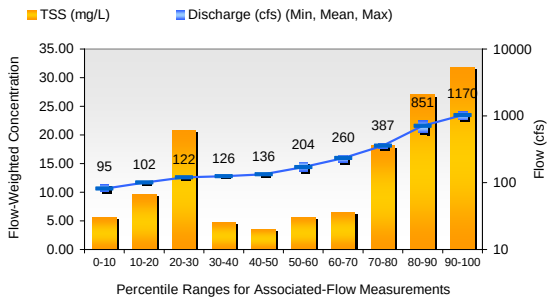
Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: TSS (mg/L)
Data from: 10/31/2003 to 9/21/2005 (23 Observations)

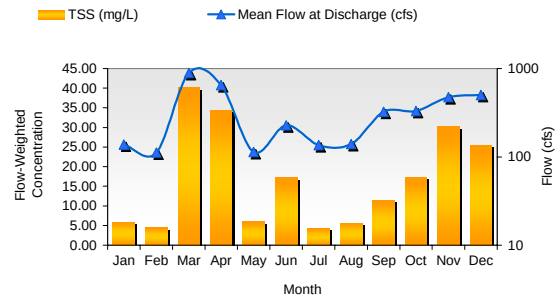
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	5.64	2.30	10.00
10-20	2	100.0	98.0	102.0	9.65	4.90	14.60
20-30	2	120.0	118.0	122.0	20.80	5.70	35.40
30-40	2	125.0	124.0	126.0	4.75	4.60	4.90
40-50	2	133.5	131.0	136.0	3.61	3.00	4.20
50-60	3	170.3	149.0	204.0	5.68	4.90	6.00
60-70	2	232.5	205.0	260.0	6.52	6.30	6.80
70-80	2	358.5	330.0	387.0	18.13	15.00	21.80
80-90	2	706.0	561.0	851.0	27.03	19.50	32.00
90-100	2	1025.0	880.0	1170.0	31.82	24.00	37.70

Seasonal Trend Assessment

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: TSS (mg/L)
Data from: 10/31/2003 to 9/21/2005 (23 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	5.87	5.70	6.00
February	2	112.0	75.0	149.0	4.40	3.40	4.90
March	2	892.0	204.0	1580.0	40.19	6.00	44.60
April	2	648.0	126.0	1170.0	34.48	4.60	37.70
May	2	113.0	95.0	131.0	5.94	3.00	10.00
June	2	227.0	124.0	330.0	17.18	4.90	21.80
July	1	136.0	136.0	136.0	4.20	4.20	4.20
August	2	139.5	74.0	205.0	5.61	2.30	6.80
September	2	323.5	260.0	387.0	11.50	6.30	15.00
October	2	331.5	102.0	561.0	17.25	4.90	19.50
November	2	474.5	98.0	851.0	30.20	14.60	32.00
December	2	501.0	122.0	880.0	25.39	24.00	35.40





Monthly Flow Percentile Analysis

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: TSS (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			5.7			6.0					5.9
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	3.4				4.9						4.2
	Number of samples	*1*				*1*						*2*
March	Average concentration (mg/L)						6.0				44.6	25.3
	Number of samples						*1*				*1*	*2*
April	Average concentration (mg/L)				4.6						37.7	21.2
	Number of samples				*1*						*1*	*2*
May	Average concentration (mg/L)	10.0				3.0						6.5
	Number of samples	*1*				*1*						*2*
June	Average concentration (mg/L)				4.9				21.8			13.4
	Number of samples				*1*				*1*			*2*
July	Average concentration (mg/L)					4.2						4.2
	Number of samples					*1*						*1*
August	Average concentration (mg/L)	2.3						6.8				4.6
	Number of samples	*1*						*1*				*2*
September	Average concentration (mg/L)							6.3	15.0			10.7
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		4.9							19.5		12.2
	Number of samples		*1*							*1*		*2*
November	Average concentration (mg/L)		14.6							32.0		23.3
	Number of samples		*1*							*1*		*2*
December	Average concentration (mg/L)			35.4							24.0	29.7
	Number of samples			*1*							*1*	*2*
Flow Percentile Summary	Average concentration (mg/L)	5.2	9.8	20.6	4.8	4.0	6.0	6.6	18.4	25.8	35.4	13.8
	Number of samples	*3*	*2*	*2*	*2*	*3*	*2*	*2*	*2*	*2*	*3*	*23*

Figure A-73. Flow versus TSS concentration at the Weke Road

Flow-Associated Trend Assessment

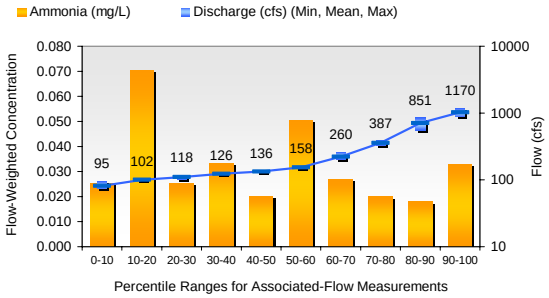
Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Ammonia (mg/L)
Data from: 10/31/2003 to 9/21/2005 (24 Observations)

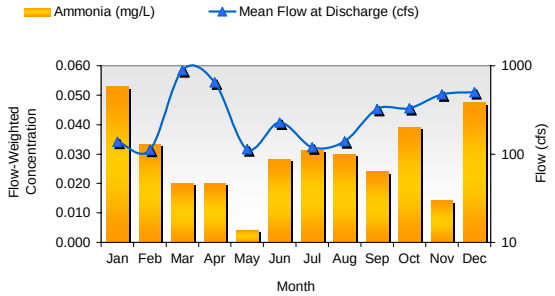
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	0.025	0.010	0.040
10-20	2	100.0	98.0	102.0	0.070	0.050	0.090
20-30	2	110.5	103.0	118.0	0.025	0.020	0.030
30-40	3	124.0	122.0	126.0	0.033	0.020	0.050
40-50	2	133.5	131.0	136.0	0.020	0.000	0.040
50-60	2	153.5	149.0	158.0	0.051	0.030	0.070
60-70	3	223.0	204.0	260.0	0.027	0.020	0.030
70-80	2	358.5	330.0	387.0	0.020	0.020	0.020
80-90	2	706.0	561.0	851.0	0.018	0.010	0.030
90-100	2	1025.0	880.0	1170.0	0.033	0.020	0.050

Seasonal Trend Assessment

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Ammonia (mg/L)
Data from: 10/31/2003 to 9/21/2005 (24 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	0.053	0.030	0.070
February	2	112.0	75.0	149.0	0.033	0.030	0.040
March	2	892.0	204.0	1580.0	0.020	0.020	0.020
April	2	648.0	126.0	1170.0	0.020	0.020	0.020
May	2	113.0	95.0	131.0	0.004	0.000	0.010
June	2	227.0	124.0	330.0	0.028	0.020	0.050
July	2	119.5	103.0	136.0	0.031	0.020	0.040
August	2	139.5	74.0	205.0	0.030	0.030	0.030
September	2	323.5	260.0	387.0	0.024	0.020	0.030
October	2	331.5	102.0	561.0	0.039	0.030	0.090
November	2	474.5	98.0	851.0	0.014	0.010	0.050
December	2	501.0	122.0	880.0	0.048	0.030	0.050





Monthly Flow Percentile Analysis

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Ammonia (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.030			0.070					0.050
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	0.040					0.030					0.035
	Number of samples	*1*					*1*					*2*
March	Average concentration (mg/L)							0.020			0.020	0.020
	Number of samples							*1*			*1*	*2*
April	Average concentration (mg/L)				0.020						0.020	0.020
	Number of samples				*1*						*1*	*2*
May	Average concentration (mg/L)	0.010				0.000						0.005
	Number of samples	*1*				*1*						*2*
June	Average concentration (mg/L)				0.050				0.020			0.035
	Number of samples				*1*				*1*			*2*
July	Average concentration (mg/L)			0.020		0.040						0.030
	Number of samples			*1*		*1*						*2*
August	Average concentration (mg/L)	0.030						0.030				0.030
	Number of samples	*1*						*1*				*2*
September	Average concentration (mg/L)							0.030	0.020			0.025
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		0.090							0.030		0.060
	Number of samples		*1*							*1*		*2*
November	Average concentration (mg/L)		0.050							0.010		0.030
	Number of samples		*1*							*1*		*2*
December	Average concentration (mg/L)				0.030						0.050	0.040
	Number of samples				*1*						*1*	*2*
Flow Percentile Summary	Average concentration (mg/L)	0.027	0.070	0.025	0.033	0.020	0.050	0.027	0.020	0.020	0.030	0.032
	Number of samples	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*24*

Figure A-74. Flow versus ammonia concentration at the Weke Road

Flow-Associated Trend Assessment

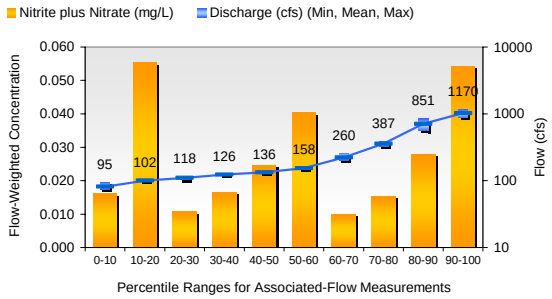
Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Nitrite plus Nitrate (mg/L)
Data from: 10/31/2003 to 9/21/2005 (24 Observations)

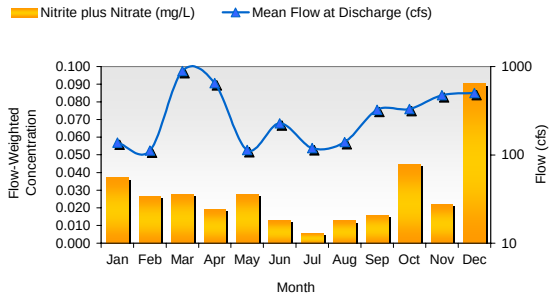
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	0.016	0.010	0.020
10-20	2	100.0	98.0	102.0	0.055	0.040	0.070
20-30	2	110.5	103.0	118.0	0.011	0.000	0.020
30-40	3	124.0	122.0	126.0	0.017	0.010	0.020
40-50	2	133.5	131.0	136.0	0.025	0.010	0.040
50-60	2	153.5	149.0	158.0	0.040	0.030	0.050
60-70	3	223.0	204.0	260.0	0.010	0.010	0.010
70-80	2	358.5	330.0	387.0	0.015	0.010	0.020
80-90	2	706.0	561.0	851.0	0.028	0.020	0.040
90-100	2	1025.0	880.0	1170.0	0.054	0.020	0.100

Seasonal Trend Assessment

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Nitrite plus Nitrate (mg/L)
Data from: 10/31/2003 to 9/21/2005 (24 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	0.037	0.020	0.050
February	2	112.0	75.0	149.0	0.027	0.020	0.030
March	2	892.0	204.0	1580.0	0.028	0.010	0.030
April	2	648.0	126.0	1170.0	0.019	0.010	0.020
May	2	113.0	95.0	131.0	0.027	0.010	0.040
June	2	227.0	124.0	330.0	0.013	0.010	0.020
July	2	119.5	103.0	136.0	0.006	0.000	0.010
August	2	139.5	74.0	205.0	0.013	0.010	0.020
September	2	323.5	260.0	387.0	0.016	0.010	0.020
October	2	331.5	102.0	561.0	0.045	0.040	0.070
November	2	474.5	98.0	851.0	0.022	0.020	0.040
December	2	501.0	122.0	880.0	0.090	0.020	0.100





Monthly Flow Percentile Analysis

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Nitrite plus Nitrate (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.020			0.050					0.035
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	0.020					0.030					0.025
	Number of samples	*1*					*1*					*2*
March	Average concentration (mg/L)							0.010			0.030	0.020
	Number of samples							*1*			*1*	*2*
April	Average concentration (mg/L)				0.010						0.020	0.015
	Number of samples				*1*						*1*	*2*
May	Average concentration (mg/L)	0.010				0.040						0.025
	Number of samples	*1*				*1*						*2*
June	Average concentration (mg/L)				0.020				0.010			0.015
	Number of samples				*1*				*1*			*2*
July	Average concentration (mg/L)			0.000		0.010						0.005
	Number of samples			*1*		*1*						*2*
August	Average concentration (mg/L)	0.020						0.010				0.015
	Number of samples	*1*						*1*				*2*
September	Average concentration (mg/L)							0.010	0.020			0.015
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		0.070							0.040		0.055
	Number of samples		*1*							*1*		*2*
November	Average concentration (mg/L)		0.040							0.020		0.030
	Number of samples		*1*							*1*		*2*
December	Average concentration (mg/L)				0.020						0.100	0.060
	Number of samples				*1*						*1*	*2*
Flow Percentile Summary	Average concentration (mg/L)	0.017	0.055	0.010	0.017	0.025	0.040	0.010	0.015	0.030	0.050	0.026
	Number of samples	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*24*

Figure A-75. Flow versus nitrite plus nitrate concentration at the Weke Road

Flow-Associated Trend Assessment

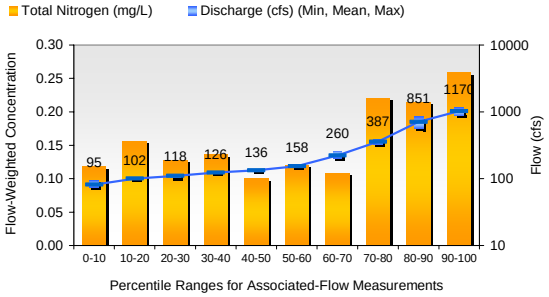
Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Total Nitrogen (mg/L)
Data from: 10/31/2003 to 9/21/2005 (24 Observations)

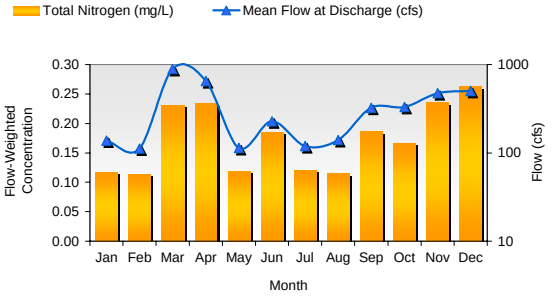
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	0.12	0.10	0.13
10-20	2	100.0	98.0	102.0	0.16	0.11	0.20
20-30	2	110.5	103.0	118.0	0.13	0.10	0.16
30-40	3	124.0	122.0	126.0	0.14	0.08	0.21
40-50	2	133.5	131.0	136.0	0.10	0.09	0.11
50-60	2	153.5	149.0	158.0	0.12	0.11	0.13
60-70	3	223.0	204.0	260.0	0.11	0.08	0.12
70-80	2	358.5	330.0	387.0	0.22	0.21	0.23
80-90	2	706.0	561.0	851.0	0.21	0.16	0.25
90-100	2	1025.0	880.0	1170.0	0.26	0.25	0.27

Seasonal Trend Assessment

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Total Nitrogen (mg/L)
Data from: 10/31/2003 to 9/21/2005 (24 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	0.12	0.10	0.13
February	2	112.0	75.0	149.0	0.11	0.11	0.12
March	2	892.0	204.0	1580.0	0.23	0.08	0.25
April	2	648.0	126.0	1170.0	0.23	0.08	0.25
May	2	113.0	95.0	131.0	0.12	0.11	0.13
June	2	227.0	124.0	330.0	0.19	0.12	0.21
July	2	119.5	103.0	136.0	0.12	0.09	0.16
August	2	139.5	74.0	205.0	0.11	0.10	0.12
September	2	323.5	260.0	387.0	0.19	0.12	0.23
October	2	331.5	102.0	561.0	0.17	0.16	0.20
November	2	474.5	98.0	851.0	0.24	0.11	0.25
December	2	501.0	122.0	880.0	0.26	0.21	0.27





Monthly Flow Percentile Analysis

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Total Nitrogen (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.100			0.130					0.115
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	0.120					0.110					0.115
	Number of samples	*1*					*1*					*2*
March	Average concentration (mg/L)							0.080			0.250	0.165
	Number of samples							*1*			*1*	*2*
April	Average concentration (mg/L)				0.080						0.250	0.165
	Number of samples				*1*						*1*	*2*
May	Average concentration (mg/L)	0.130				0.110						0.120
	Number of samples	*1*				*1*						*2*
June	Average concentration (mg/L)				0.120				0.210			0.165
	Number of samples				*1*				*1*			*2*
July	Average concentration (mg/L)			0.160		0.090						0.125
	Number of samples			*1*		*1*						*2*
August	Average concentration (mg/L)	0.100						0.120				0.110
	Number of samples	*1*						*1*				*2*
September	Average concentration (mg/L)							0.120	0.230			0.175
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		0.200							0.160		0.180
	Number of samples		*1*							*1*		*2*
November	Average concentration (mg/L)		0.110							0.250		0.180
	Number of samples		*1*							*1*		*2*
December	Average concentration (mg/L)				0.210						0.270	0.240
	Number of samples				*1*						*1*	*2*
Flow Percentile Summary	Average concentration (mg/L)	0.117	0.155	0.130	0.137	0.100	0.120	0.107	0.220	0.205	0.257	0.155
	Number of samples	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*24*

Figure A-76. Flow versus total nitrogen concentration at the Weke Road

Flow-Associated Trend Assessment

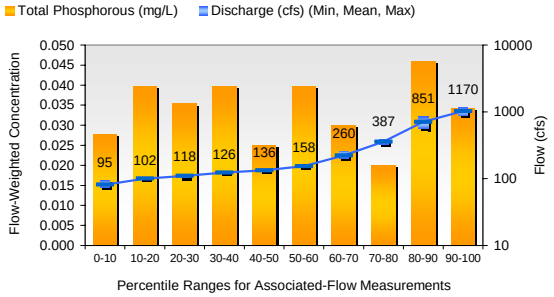
Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Total Phosphorous (mg/L)
Data from: 10/31/2003 to 9/21/2005 (24 Observations)

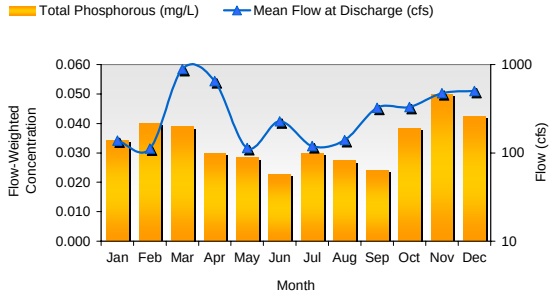
Flow Range	# Obs	Associated Flow			Pollutant Concentration		
Percentile	Count	Mean	Min	Max	Mean	Min	Max
0-10	3	81.3	74.0	95.0	0.028	0.020	0.040
10-20	2	100.0	98.0	102.0	0.040	0.030	0.050
20-30	2	110.5	103.0	118.0	0.035	0.030	0.040
30-40	3	124.0	122.0	126.0	0.040	0.030	0.060
40-50	2	133.5	131.0	136.0	0.025	0.020	0.030
50-60	2	153.5	149.0	158.0	0.040	0.030	0.050
60-70	3	223.0	204.0	260.0	0.030	0.030	0.030
70-80	2	358.5	330.0	387.0	0.020	0.020	0.020
80-90	2	706.0	561.0	851.0	0.046	0.040	0.050
90-100	2	1025.0	880.0	1170.0	0.034	0.030	0.040

Seasonal Trend Assessment

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Total Phosphorous (mg/L)
Data from: 10/31/2003 to 9/21/2005 (24 Observations)

Time Period	# Obs	Associated Flow			Pollutant Concentration		
Month	Count	Mean	Min	Max	Mean	Min	Max
January	2	138.0	118.0	158.0	0.034	0.030	0.040
February	2	112.0	75.0	149.0	0.040	0.020	0.050
March	2	892.0	204.0	1580.0	0.039	0.030	0.040
April	2	648.0	126.0	1170.0	0.030	0.030	0.030
May	2	113.0	95.0	131.0	0.028	0.020	0.040
June	2	227.0	124.0	330.0	0.023	0.020	0.030
July	2	119.5	103.0	136.0	0.030	0.030	0.030
August	2	139.5	74.0	205.0	0.027	0.020	0.030
September	2	323.5	260.0	387.0	0.024	0.020	0.030
October	2	331.5	102.0	561.0	0.038	0.030	0.040
November	2	474.5	98.0	851.0	0.050	0.050	0.050
December	2	501.0	122.0	880.0	0.042	0.040	0.060





Monthly Flow Percentile Analysis

Location: Weke
Flow Gage: Discharge (cfs)
Pollutant: Total Phosphorous (mg/L)

Month	Data Type	Flow Percentile Range (based on entire dataset)										Monthly Summary
		0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	
January	Average concentration (mg/L)			0.040			0.030					0.035
	Number of samples			*1*			*1*					*2*
February	Average concentration (mg/L)	0.020					0.050					0.035
	Number of samples	*1*					*1*					*2*
March	Average concentration (mg/L)							0.030			0.040	0.035
	Number of samples							*1*			*1*	*2*
April	Average concentration (mg/L)				0.030						0.030	0.030
	Number of samples				*1*						*1*	*2*
May	Average concentration (mg/L)	0.040				0.020						0.030
	Number of samples	*1*				*1*						*2*
June	Average concentration (mg/L)				0.030				0.020			0.025
	Number of samples				*1*				*1*			*2*
July	Average concentration (mg/L)			0.030		0.030						0.030
	Number of samples			*1*		*1*						*2*
August	Average concentration (mg/L)	0.020						0.030				0.025
	Number of samples	*1*						*1*				*2*
September	Average concentration (mg/L)							0.030	0.020			0.025
	Number of samples							*1*	*1*			*2*
October	Average concentration (mg/L)		0.030							0.040		0.035
	Number of samples		*1*							*1*		*2*
November	Average concentration (mg/L)		0.050							0.050		0.050
	Number of samples		*1*							*1*		*2*
December	Average concentration (mg/L)				0.060						0.040	0.050
	Number of samples				*1*						*1*	*2*
Flow Percentile Summary	Average concentration (mg/L)	0.027	0.040	0.035	0.040	0.025	0.040	0.030	0.020	0.045	0.037	0.034
	Number of samples	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*2*	*2*	*3*	*24*

Figure A-77. Flow versus total phosphorous concentration at the Weke Road

Appendix B:
Hanalei Bay Watershed Bacteria, Nutrients, and Sediment Model Development and Application

Prepared for:
USEPA Region 9
Hawai'i Department of Health

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Contents

EXECUTIVE SUMMARY V

B-1. INTRODUCTION 1

B-2. WATERSHED LOADING MODEL – LSPC 3

B-2.1. MODEL CONFIGURATION 3
B-2.1.1. Watershed Delineation 4
B-2.1.2. Meteorological Data 4
B-2.1.3. Land Cover Representation 8
B-2.1.4. Soils 12
B-2.1.5. Reach Characteristics 15
B-2.1.6. Point Source Discharges 15
B-2.1.7. Hydrology Representation 17
B-2.1.8. Watershed Runoff Pollutant Representation 18
B-2.2. MODEL CALIBRATION AND VALIDATION 20
B-2.2.1. Hydrology Simulations 22
B-2.2.1.1. Hydrology Calibration 23
B-2.2.1.2. Hydrology Validation 27
B-2.2.2. Water Quality Simulations 32
B-2.2.2.1. Calibration Methodology 33
B-2.2.2.2. Calibration and Validation Results 35
B-2.3. LINK TO RECEIVING WATER MODEL 39

B-3. RECEIVING WATER MODEL – EFDC 40

B-3.1. EFDC MODELING FRAMEWORK 40
B-3.2. MODEL CONFIGURATION 40
B-3.2.1. Model Dimensions and Grid Generation 41
B-3.2.2. Constituent Configuration 41
B-3.2.3. Boundary Conditions 42
B-3.2.3.1. Open Ocean Boundary Conditions 42
B-3.2.3.2. Lateral Boundary Conditions 43
B-3.2.3.3. Meteorological Boundary Conditions 44
B-3.2.3.4. Initial Conditions 45
B-3.3. HYDRODYNAMIC MODEL CALIBRATION AND VALIDATION 46
B-3.3.1. Hydrodynamic Calibration 46
B-3.3.2. Hydrodynamic Validation 51
B-3.4. WATER QUALITY MODEL CALIBRATION AND VALIDATION 53
B-3.4.1. Water Quality Calibration 53
B-3.4.2. Water Quality Validation 54

B-4. MODEL ASSUMPTIONS 56

B-5. MODEL APPLICATION 59

B-6. REFERENCES 60

List of Tables

Table B-1. Hanalei Bay Subwatershed Areas 5
Table B-2. Precipitation Datasets Used for the Hanalei Bay Watershed Model 7
Table B-3. Land Cover Areas (acres) by Subwatershed 11
Table B-4. Slope and Assigned Soil Category by Subwatershed 14
Table B-5. Stream Characteristics 16
Table B-6. LSPC Monitoring Station Information 21
Table B-7. Volumes and Relative Error of Modeled Verses Observed Flows During Calibration 27
Table B-8. Volumes and Relative Error of Modeled Verses Observed Flows During Validation 31
Table B-9. Summary of the TSS Water Quality Data 35
Table B-10. Summary of the *Enterococcus* Water Quality Data 35
Table B-11. Summary of the Ammonia Water Quality Data 36
Table B-12. Summary of the Nitrite Plus Nitrate Water Quality Data 36
Table B-13. Summary of the Total Nitrogen Water Quality Data 37
Table B-14. Summary of the Total Phosphorous Water Quality Data 37
Table B-15. Cloud Cover Conversions 45
Table B-16. EFDC Monitoring Station Information 46

List of Figures

Figure B-1. Model domain for the Hanalei Bay watershed 2
Figure B-2. Location of weather stations and rainfall distribution 6
Figure B-3. Land cover distribution 10
Figure B-4. Average slope 13
Figure B-5. Hanalei National Wildlife Refuge wetland impoundments and taro pondfields 17
Figure B-6. Relationships between sediment and nutrients 20
Figure B-7. Monitoring stations used for LSPC model calibration and validation 22
Figure B-8. Comparison of modeled and observed daily flows during calibration 24
Figure B-9. Comparison of modeled and observed average monthly flows during calibration 24
Figure B-10. Regression analysis of modeled and observed average monthly flows during calibration 25
Figure B-11. Seasonal variation of median modeled and observed flows during calibration 25
Figure B-12. Seasonal variation of average modeled and observed flows during calibration 26
Figure B-13. Regression analysis of modeled and observed seasonal variation during calibration 26
Figure B-14. Comparison of modeled and observed daily flows during validation 28
Figure B-15. Comparison of modeled and observed average monthly flows during validation 28
Figure B-16. Regression analysis of modeled and observed average monthly flows during validation 29
Figure B-17. Seasonal variation of median modeled and observed flows during validation 29
Figure B-18. Seasonal variation of average modeled and observed flows during validation 30
Figure B-19. Regression analysis of modeled and observed seasonal variation during validation 30
Figure B-20. LSPC inflows to the EFDC model 44
Figure B-21. Monitoring stations used for EFDC model calibration and validation 47
Figure B-22. Modeled and observed water surface elevation at the Offshore Wall station 48
Figure B-23. Modeled and observed salinity at the Offshore Wall station during calibration 48
Figure B-24. Modeled and observed temperature at the Offshore Wall station during calibration 49
Figure B-25. Modeled and observed salinity at various stations during calibration 50
Figure B-26. Modeled and observed temperature at various stations during calibration 51
Figure B-27. Modeled and observed salinity at various stations during validation 52
Figure B-28. Modeled and observed temperature at various stations during validation 53

List of Acronyms

ACQOP	Accumulation rate for the watershed model
BRH	Bed Roughness Height
C-CAP	Coastal Change Analysis Program
COOPS	Center for Operational Oceanographic Products and Services
DEM	Digital Elevation Model
DOP	Dissolved Organic Phosphorous
EFDC	Environmental Fluids Dynamic Code
EIA	Effective Impervious Area
GIS	Geographic Information System
HSPF	Hydrologic Simulation Program – Fortran
IWATER	Water budget simulation for impervious land segments
LSPC	Loading Simulation Program in C++
NCDC	National Climatic Data Center
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWR	National Wildlife Refuge
PET	Potential Evapotranspiration
PO_4	Ortho-phosphate
POTFW	Wash-off potency factor for the watershed model
PWATER	Water budget simulation for pervious land segments
SQOLIM	Maximum storage for the watershed model
STATSGO	State Soil Geographic Database
TMDL	Total Maximum Daily Load
Toolbox	TMDL Modeling Toolbox
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Executive Summary

This report presents the configuration, calibration, and validation of a customized modeling framework developed to support *enterococcus* and turbidity TMDLs and nutrient load reduction targets for several waterbodies in the Hanalei Bay watershed. This framework is divided into two major components: a series of watershed models and a receiving water model. The watershed models predicted pollutant loadings for each of the four primary watersheds draining to Hanalei Bay, while the receiving water model of the estuaries and Hanalei Bay simulated water circulation and pollutant transport in the tidally-influenced waterbodies.

The Hanalei Bay watershed includes the Hanalei River, Waioli, Waipa, and Waikoko watersheds. Each freshwater segment drains to an estuary before discharging into Hanalei Bay. All land area draining to either a freshwater segment or an estuary was represented using a Loading Simulation Program in C++ (LSPC) watershed model. These watersheds were delineated into 41 subbasins for LSPC modeling. The loads from LSPC model were incorporated into a receiving water model based on the Environmental Fluids Dynamic Code (EFDC) of the tidally-influenced waterbodies, including the Hanalei River Estuary, Waioli Stream Estuary, Waipa Stream Estuary, Waikoko Stream Estuary, and the Hanalei Bay.

Model configuration involved identifying and formatting key datasets used to represent hydrology, hydrodynamics, and land practices in the Hanalei Bay watershed. These datasets, which include watershed boundaries, meteorological data, land cover, soils, reach characteristics, water quality data, bathymetry, and circulation and tidal data, were incorporated into the LSPC or EFDC models during model setup. The LSPC model was then calibrated and validated for both hydrology and water quality for May 2001 – May 2006. Model results were compared to flow and water quality data during this process. Similarly, the EFDC model was calibrated and validated for hydrodynamics and water quality for 2004-2005 by comparing the model results to observed data. Both the LSPC and EFDC models achieved good fit between modeled and observed results.

Output from the LSPC and EFDC models were used to determine nutrient load reduction targets as well as existing loads and TMDLs for the *enterococcus* and turbidity impaired waterbodies in the Hanalei Bay watershed. The TMDL values were compared against existing loads to determine the load reductions necessary to meet the water quality criteria. LSPC model output was also used to assess land cover-specific contributions to the total existing watershed load for each pollutant, which may be helpful during TMDL implementation.

B-1. Introduction

Water quality modeling can be used to establish the quantitative understanding necessary to develop scientifically justifiable Total Maximum Daily Loads (TMDLs) for a waterbody. A water quality model that is customized for a specific waterbody can simulate the major physical, chemical, and biological processes that occur in the system, and thus provide quantitative relationships between the water quality response and external forcing functions. A customized modeling framework was developed to support *enterococcus*, TSS (as surrogate for turbidity), and nutrient TMDLs and load targets for several waterbodies in the Hanalei Bay watershed.

The modeling framework used in this study can be divided into two major components, which represent the processes essential for accurately modeling hydrology, hydrodynamics, and water quality in the Hanalei Bay watershed. The first component of the modeling system is a series of watershed models developed to predict pollutant loadings for each of the four primary watersheds draining to Hanalei Bay. The second component is a receiving water model of the estuaries and Hanalei Bay used to simulate water circulation and pollutant transport in the tidally-influenced waterbodies. The Loading System Program in C++ (LSPC) was selected to simulate the watershed loadings (Shen et al., 2004; USEPA, 2003a), and the estuaries and Bay were represented by the Environmental Fluid Dynamics Code (EFDC) (Hamrick, 1992).

Both models selected are components of the United States Environmental Protection Agency's (USEPA) TMDL Modeling Toolbox (Toolbox), which has been developed through a joint effort between USEPA and Tetra Tech, Inc. (USEPA, 2003b). The Toolbox is a collection of models, modeling tools, and databases that have been utilized over the past decade in the determination of TMDLs for impaired waters. It takes these proven technologies and provides the capability to more readily apply the models, analyze the results, and integrate watershed and detailed hydrodynamic and water quality receiving water applications. The Toolbox provides exchange of information between the models through common databases; therefore, the results from the LSPC model were easily incorporated into the EFDC water quality model.

The Hanalei Bay watershed, which includes the Hanalei River, Waioli, Waipa, and Waikoko watersheds, was delineated into 41 subbasins (Figure B-1) for LSPC modeling. The EFDC model framework simulates the tidally-influenced waterbodies, including the Hanalei River Estuary, Waioli Stream Estuary, Waipa Stream Estuary, Waikoko Stream Estuary, and the Hanalei Bay (Figure B-1), using a multi-dimensional grid. The EFDC receiving water model was linked to the LSPC model to incorporate watershed loads from each of the subwatersheds draining to an estuary. This modeling report is intended to accompany a TMDL report and provide a more detailed discussion on the models used for the TMDL analyses, including model configuration, calibration and validation, and assumptions. Specifically, Section B-2 describes the watershed model, Section B-3 discusses the receiving water model, Section B-4 identifies assumptions used during

model configuration and application, Section B-5 describes the model application to TMDL development, and Section B-6 lists the applicable references.

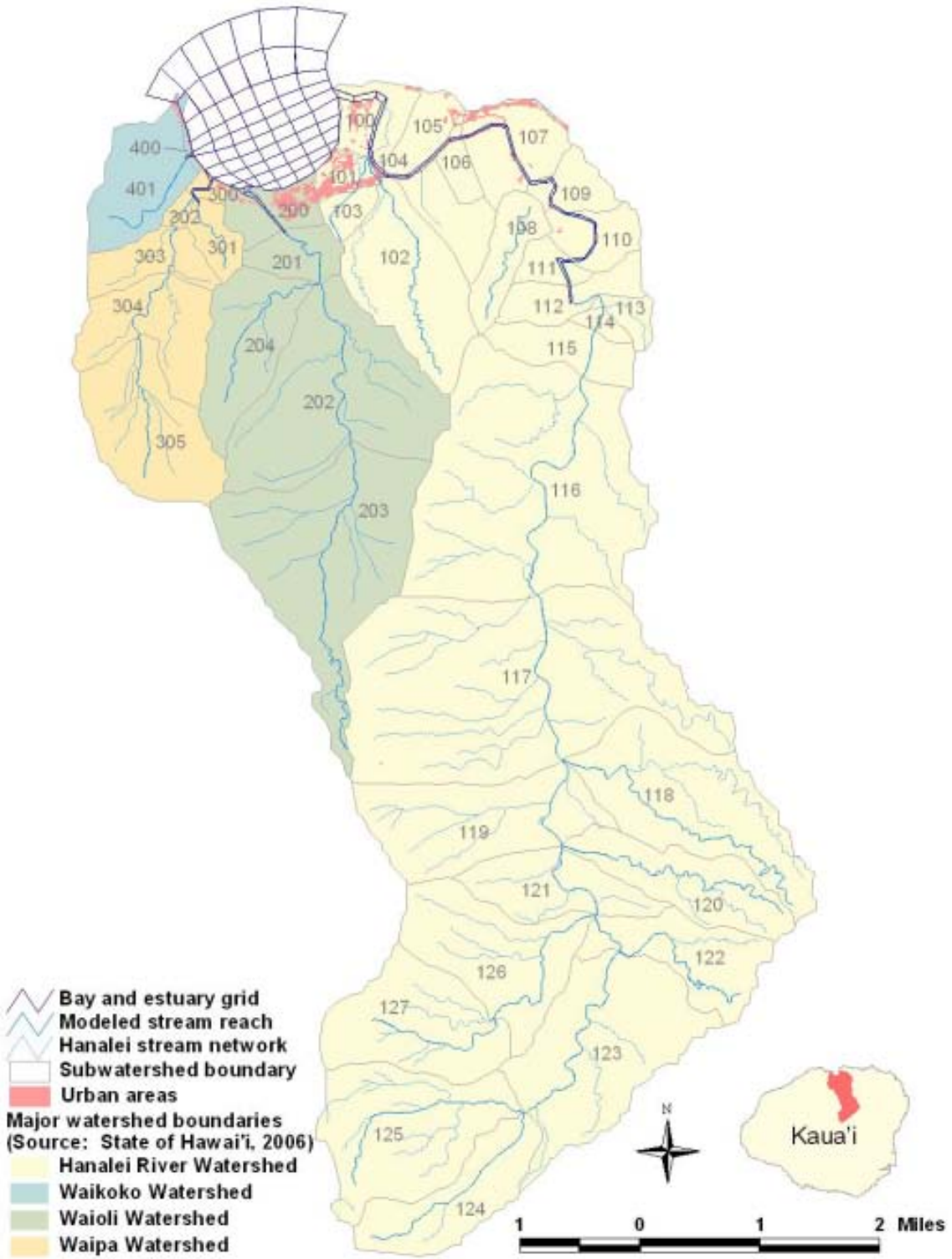

Figure B-1. Model domain for the Hanalei Bay watershed

B-2. Watershed Loading Model – LSPC

Pollutants that influence water quality are often derived from the land surface. They may accumulate on the land surface and be directly related to use of the land, or they may be naturally bound to soils. In either case, during rainy periods, these pollutants, including bacteria, nutrients, and sediment itself, are delivered to receiving waterbodies through creeks, canals, and other transport mechanisms. To assess the link between sources of bacteria, sediment, and nutrients and the impaired waters in the Hanalei Bay watershed, a modeling system may be utilized that simulates land-use based sources of pollutants and the hydrologic and hydraulic processes that affect delivery. Understanding and modeling of these processes provides the necessary decision support for TMDL development and allocation of loads to sources.

The USEPA LSPC model (Shen et al., 2004; USEPA, 2003a) was used to represent the hydrologic and water quality conditions in the Hanalei Bay watershed. LSPC is a component of the TMDL Modeling Toolbox (USEPA, 2003b). It integrates a geographical information system (GIS), comprehensive data storage and management capabilities, a dynamic watershed model (a re-coded version of USEPA's Hydrological Simulation Program – FORTRAN [HSPF] [Bicknell et al., 2001]), and a data analysis/post-processing system into a convenient PC-based windows interface that dictates no software requirements. LSPC is capable of representing loading and both flow and water quality from non-point and point sources as well as simulating in-stream processes. Because it is a deterministic model, it requires specific input data, such as weather, soils, land cover, and topography. LSPC can simulate flow, sediment, metals, nutrients, pesticides, and other conventional pollutant contributions from specific source areas (e.g., subwatershed or land cover areas). For the Hanalei Bay watershed, LSPC was used to simulate bacteria (*enterococcus*), sediment (total suspended solids [TSS]), and nutrients (total phosphorous, organic nitrogen, ammonia as nitrogen, and nitrite plus nitrate as nitrogen) for TMDL development.

B-2.1. Model Configuration

LSPC represented the variability of non-point source contributions through dynamic representation of hydrology and land practices. It included all point and non-point source contributions. Key components of the watershed modeling are discussed below:

- Watershed delineation
- Meteorological data
- Land cover representation
- Soils
- Reach characteristics
- Point source discharges
- Hydrology representation
- Pollutant representation

B-2.1.1. Watershed Delineation

To evaluate sources contributing to the impaired waterbodies and to represent the spatial variability of these sources, the contributing drainage area was represented by a series of subwatersheds. This subdivision was primarily based on the stream networks and topographic variability, and secondarily on the locations of flow and water quality monitoring stations, consistency of hydrologic factors, and land cover consistency. The 32.3 square-mile Hanalei Bay watershed was divided into 41 subwatersheds for appropriate hydrologic connectivity and representation. These subwatersheds are distributed among four areas draining to Hanalei Bay: Hanalei River watershed (28 subwatersheds), Waioli watershed (five subwatersheds), Waipa watershed (six subwatersheds), and Waikoko watershed (two subwatersheds). Figure B-1 illustrates the subwatershed locations and numbers. The subwatershed drainage areas and the waterbody they contribute to are presented in Table B-1 along with the total area for the Hanalei River, Waioli, Waipa, and Waikoko watersheds and their percentage of the Hanalei Bay land area.

B-2.1.2. Meteorological Data

Meteorological data are a critical component of the watershed model. LSPC requires appropriate representation of precipitation and potential evapotranspiration (PET). In general, hourly or sub-hourly precipitation data are recommended for nonpoint source modeling. Continuous flow data for the Hanalei River were evaluated to determine the necessary precipitation interval. This analysis suggested that during most storm events, it takes hours or days for the storm to move through the system, which indicates that an hourly time interval is sufficient for modeling. Therefore, only weather stations with hourly-recorded precipitation data were considered in the data selection process. Rainfall-runoff processes for each subwatershed were driven by precipitation data from the most representative station. These data provide necessary input to LSPC algorithms for hydrologic and water quality representation.

The Hanalei Bay watershed has an incredibly wide distribution of rainfall, as depicted in Figure B-2. The headwaters are near Mount Wai’ale’ale, which receives over 450 inches of rainfall annually and is one of the rainiest places on earth, and the coastal areas near the mouth of the watersheds (less than 10 miles from Mount Wai’ale’ale) receive less than 100 inches of rain per year. Because of this extreme variability and its impact on stream flows, it was important to accurately represent the rainfall distribution in the model using appropriate rainfall gages.

Table B-1. Hanalei Bay Subwatershed Areas

Subwatershed Identification Number	Contributing Waterbody	Subwatershed Area (acres)	Subwatershed Area (square miles)
Hanalei River Watershed			
100	Hanalei River Estuary	220.5	0.34
101	Hanalei River Estuary	100.0	0.16
102	Hanalei River Estuary	709.9	1.11
103	Hanalei River Estuary	88.4	0.14
104	Hanalei River Estuary	6.0	0.01
105	Hanalei River Estuary	402.9	0.63
106	Hanalei River Estuary	93.2	0.15
107	Hanalei River Estuary	352.1	0.55
108	Hanalei River Estuary	235.8	0.37
109	Hanalei River Estuary	158.3	0.25
110	Hanalei River	206.3	0.32
111	Hanalei River	102.9	0.16
112	Hanalei River	226.0	0.35
113	Hanalei River	85.1	0.13
114	Hanalei River	48.9	0.08
115	Hanalei River	264.7	0.41
116	Hanalei River	2,120.1	3.31
117	Hanalei River	2,423.0	3.79
118	Hanalei River	1,003.2	1.57
119	Hanalei River	826.2	1.29
120	Hanalei River	524.7	0.82
121	Hanalei River	432.5	0.68
122	Hanalei River	480.8	0.75
123	Hanalei River	1,093.6	1.71
124	Hanalei River	516.2	0.81
125	Hanalei River	917.4	1.43
126	Hanalei River	755.9	1.18
127	Hanalei River	730.9	1.14
Total Area for the Hanalei River Watershed		*15,125.5*	*23.63*
Percentage of the Hanalei Bay Watershed Area		*73.2%*	
Waioli Watershed			
200	Waioli Stream Estuary	201.1	0.31
201	Waioli Stream	184.9	0.29
202	Waioli Stream	1,223.3	1.91
203	Waioli Stream	1,352.1	2.11
204	Waioli Stream	521.3	0.81
Total Area for the Waioli Watershed		*3,482.7*	*5.44*
Percentage of the Hanalei Bay Watershed Area		*16.9%*	
Waipa Watershed			
300	Waipa Stream Estuary	40.4	0.06
301	Waipa Stream Estuary	127.1	0.20
302	Waipa Stream	31.9	0.05
303	Waipa Stream	244.3	0.38
304	Waipa Stream	473.9	0.74
305	Waipa Stream	674.1	1.05
Total Area for the Waipa Watershed		*1,591.8*	*2.49*
Percentage of the Hanalei Bay Watershed Area		*7.7%*	
Waikoko Watershed			
400	Waikoko Stream Estuary	14.4	0.02
401	Waikoko Stream	443.6	0.69
Total Area for the Waikoko Watershed		*458.0*	*0.72*
Percentage of the Hanalei Bay Watershed Area		*2.2%*	
Hanalei Bay Watershed			
Grand Total Area for the Hanalei Bay Watershed		*20,658.0*	*32.28*

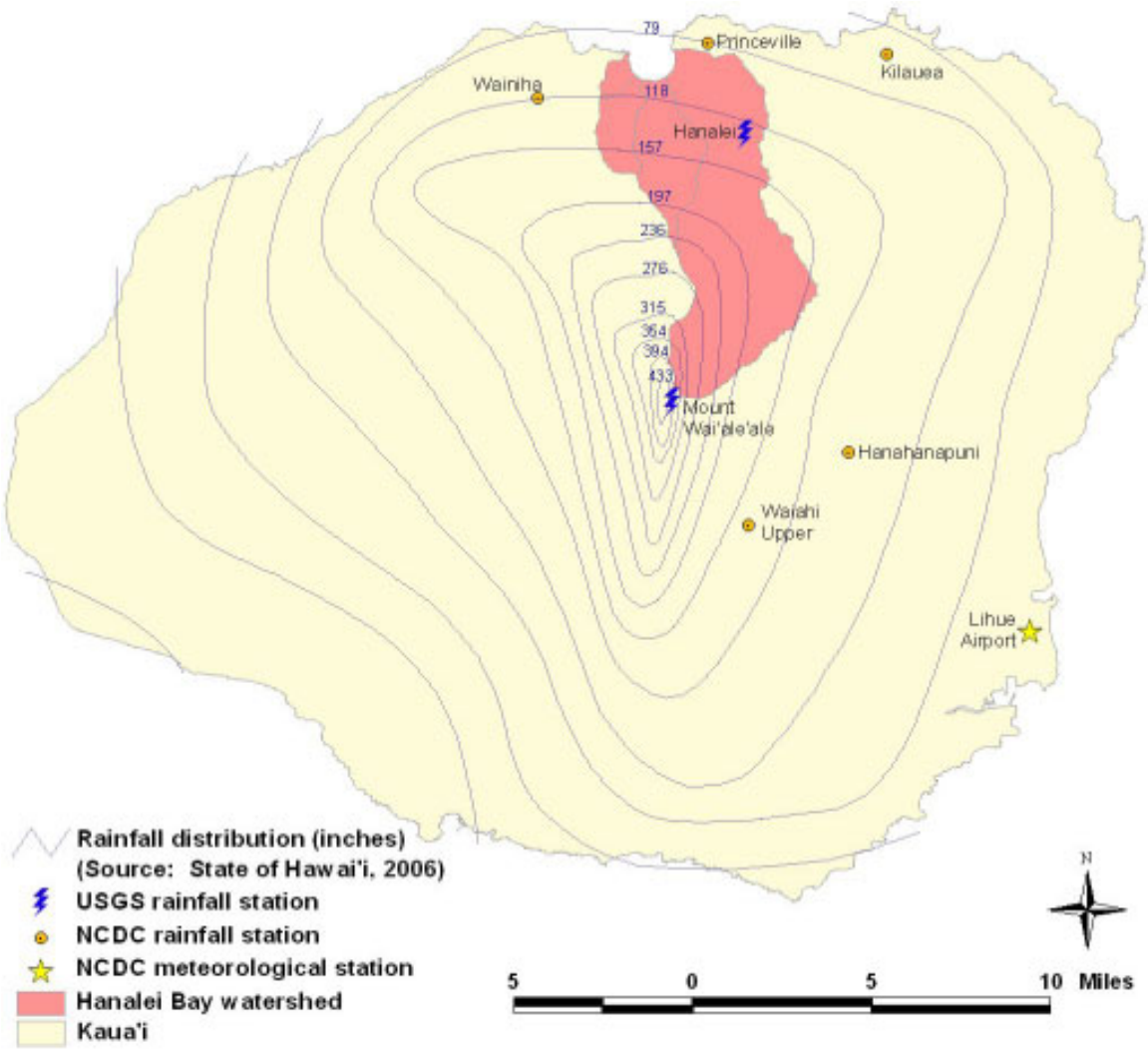

Figure B-2. Location of weather stations and rainfall distribution

United States Geological Survey (USGS) and National Climatic Data Center (NCDC) precipitation data were reviewed based on geographic location, rainfall distribution, period of record, and missing data to determine the most appropriate meteorological stations. Hourly rainfall data were obtained from two USGS rainfall stations located near the Hanalei Bay watershed (Table B-2 and Figure B-2): Mount Wai'ale'ale and Hanalei.

The Mount Wai'ale'ale and Hanalei USGS rainfall stations were the primary stations used in the LSPC model. Data for these stations were obtained from USGS for May 1, 2001 through May 31, 2006. Because rainfall gages are not always in operation and accurately recording data, the resulting datasets may contain various intervals of missing data. The data gaps for the Hanalei and Mount Wai'ale'ale stations are identified in Table B-2. To address the incomplete portions of each dataset, it was necessary to patch the rainfall data with information from nearby gages.

Table B-2. Precipitation Datasets Used for the Hanalei Bay Watershed Model

Station Number	Station Name	Elevation (feet)	Notes
Primary Rainfall Stations			
221101159280801	Hanalei	60	Data Gaps: 5/1/01-5/7/01; 7/25/02-8/6/02
220427159300201	Mount Wai'ale'ale	5,150	Data Gaps: 1/3/02-7/30/02
Stations Used for Patching			
HI8165	Princeville	217	Used to patch Hanalei and Mount Wai'ale'ale; Data Gaps: many periods of sporadic data gaps
HI4561	Kilauea	320	Used to patch Princeville
HI8155	Waihina	101	Used to patch Princeville
HI8966	Upper Waiahi	780	Used to patch Wai'ale'ale
HI1140	Hanahanapuni	600	Used to patch Wai'ale'ale

Specifically, to address days with the missing intervals, the normal-ratio method (Dunne & Leopold, 1978) was applied. The normal-ratio method estimates a missing rainfall value using a weighted average from surrounding stations with similar rainfall patterns according to the relationship presented in Equation B-1:

$$P_A = \frac{1}{n}\left(\sum_{i=1}^{n} \frac{N_A}{N_i} P_i\right) \qquad \text{Equation B-1}$$

where P_A is the impaired precipitation value at station A, n is the number of surrounding stations with unimpaired data at the same point in time, N_A is the long term average precipitation at station A, N_i is the long term average precipitation at nearby station i, and P_i is the observed precipitation at nearby station i. For each impaired data record at station A, n consists of only the surrounding stations with unimpaired data. When no precipitation is available at the surrounding stations, zero precipitation is assumed at station A. The United States Weather Bureau has a long established practice of using the long-term average rainfall as the precipitation normal. Since the normal ratio considers the long-term average rainfall as the weighting factor, this method is adaptable to regions where there is large orographic variation in precipitation; therefore, elevation differences will not bias the predictive capability of the method.

To address the data gaps for the Hanalei station, data from the NCDC Princeville station were applied. Unfortunately, the Princeville station had many sporadic data gaps. Therefore, the Kilauea and Waihina NCDC stations were used to estimate the missing rainfall at Princeville using the normal-ratio method. Similarly, to address the data gaps at Wai'ale'ale, the patched Princeville dataset along with data from the Upper Waiahi and Hanahanapuni NCDC stations were used to estimate the missing rainfall. The location of each rainfall station is illustrated in Figure B-2, while Table B-2 identifies the station numbers and elevation.

Hourly PET data were calculated using data from the Lihue Airport NCDC station (Figure B-2). Specifically, the Hamon method (1961) was used to compute PET using air temperature data. Equation B-2 describes the Hamon formula:

$$PET = CTS \times DYL \times VDSAT \qquad \text{Equation B-2}$$

where *PET* is the daily potential evapotranspiration in inches, *CTS* is the monthly variable coefficient (a value of 0.0055 is suggested), *DYL* is the possible hours of sunshine in units of 12 hours computed as a function of latitude and time of year, and *VDSAT* is the saturated water vapor density (absolute humidity) at the daily mean air temperature in grams per cubic meter (g/cm^3). Equation B-3 is used to compute *VDSAT*:

$$VDSAT = \frac{216.7 \times VPSAT}{TAVC + 273.3} \qquad \text{Equation B-3}$$

where *VPSAT* is the saturated vapor pressure at the air temperature and *TAVC* is the mean daily temperature (deg C). *VPSAT* is calculated by Equation B-4:

$$VPSAT = 6.108 \times \exp\left(\frac{17.26939 \times TAVC}{TAVC + 273.3}\right) \qquad \text{Equation B-4}$$

The calculated daily *PET* values were disaggregated to an hourly time series using a standard sine wave equation over the daylight hours (*DYL*), which reaches its peak at noon of each day.

The hourly rainfall data were combined with the calculated PET values and formatted into model weather files for each rainfall gage. The individual weather files were expanded to include solar radiation, wind speed, cloud cover, air temperature, and dew point from Lihue Airport. These additional meteorological data were incorporated to run the LSPC temperature module and provide the necessary inputs to the EFDC model of the estuaries and Bay.

B-2.1.3. Land Cover Representation

The watershed model requires a basis for distributing hydrologic and pollutant loading parameters. This is necessary to appropriately represent hydrologic variability throughout the basin, which is influenced by land surface and subsurface characteristics. It is also necessary to represent variability in pollutant loading, which is highly correlated with land practices. The basis for this distribution was provided by the land activity coverage of the Hanalei Bay watershed. The National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover image from a remote sensing study in 2000 (NOAA, 2000) was used to represent land cover in the watersheds.

There were originally thirteen C-CAP land cover categories present in the Hanalei Bay watershed. To simplify model parameterization, land categories that share hydrologic or pollutant loading characteristics were grouped, resulting in ten categories for modeling. Specifically, the unconsolidated shore and bare land cover types were grouped into a single bare land category, the unclassified cover type was merged into the scrub/shrub category because most of the unclassified lands were located within areas that were predominantly scrub/shrub, and the palustrine forest and palustrine scrub/shrub land covers were combined into a single category. The model land cover categories are illustrated in Figure B-3. Land cover areas by subwatershed and percentages for each watershed draining to Hanalei Bay are presented in Table B-3. The location of taro pondfields located in the watershed closely overlap with the cultivated lands cover type; therefore, this cover type was used to represent taro agriculture in the model. Similarly, the palustrine emergent cover type generally overlapped with the location of wetland impoundments, especially near the Hanalei River Estuary; therefore this category was used to represent wetland or bird impoundments in the model.

LSPC algorithms require that land cover categories be divided into separate pervious and impervious land units for modeling. The division of the two urban land cover categories identified above to represent impervious and pervious areas in the model was based on impervious percentages in the C-CAP land cover descriptions (NOAA, 2000). This division resulted in twelve land cover categories in the Hanalei Bay watershed. The low intensity developed land cover was assumed to have 15% impervious cover. This value is slightly lower than the 25% impervious cover from the land cover descriptions. The lower value is used to represent effective impervious area (EIA) in which EIA is the portion of the total impervious area directly connected to the drainage system. Especially in urban areas with lower density, EIA is less than the total impervious area because impervious runoff that first drains to pervious areas can infiltrate (Bicknell et al., 2001). The high intensity developed land category was assigned 75% impervious cover, which is the same value as the land cover descriptions since in highly urbanized areas, EIA and total impervious areas are often similar (Bicknell et al., 2001).

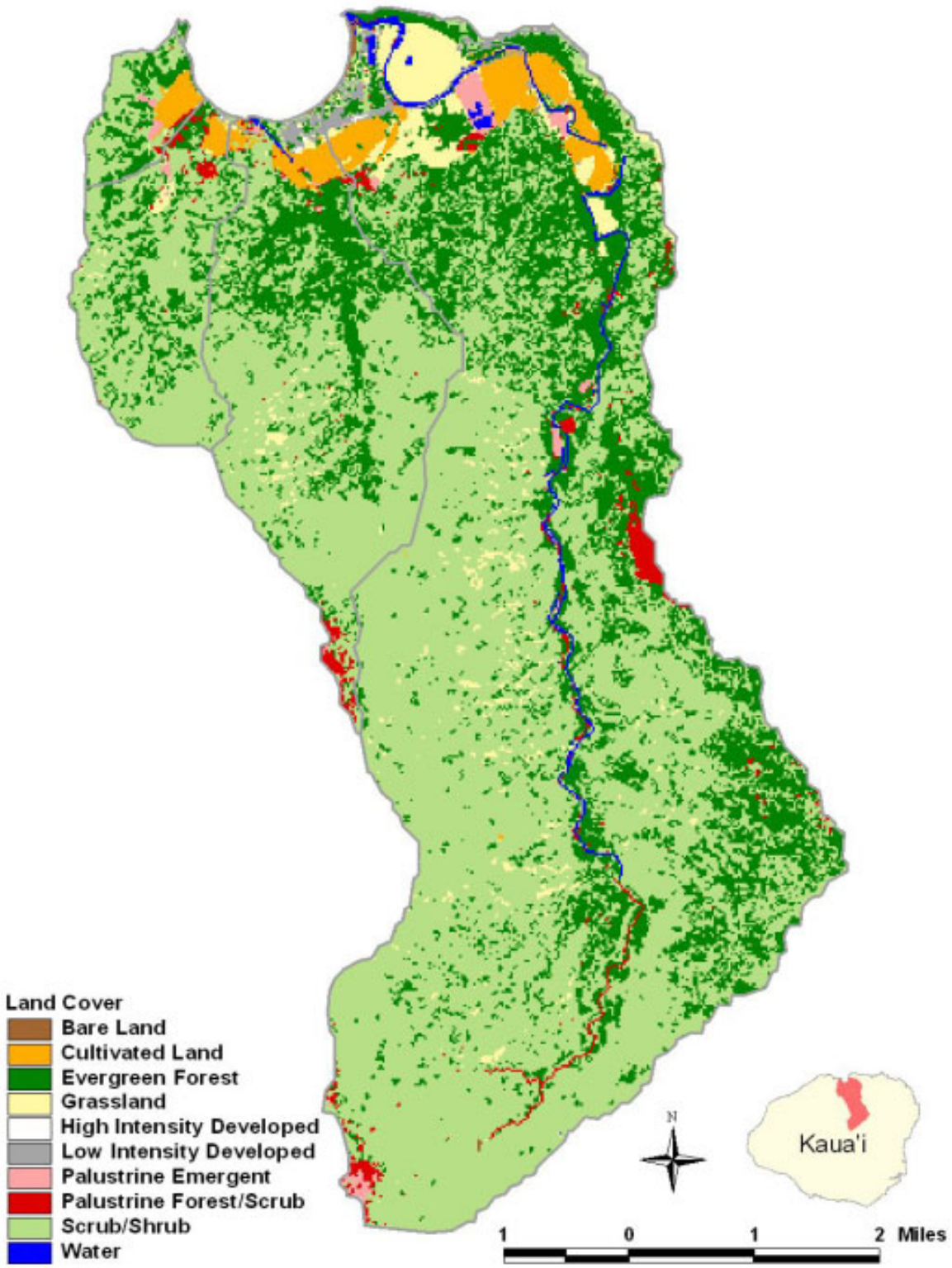

Figure B-3. Land cover distribution

Table B-3. Land Cover Areas (acres) by Subwatershed

Subwatershed Identification Number	Area (in Acres) for Each Land Cover Category									
	Bare Land	Cultivated Land	Evergreen Forest	Grassland	High Intensity Developed	Low Intensity Developed	Palustrine Emergent	Palustrine Forest/Scrub	Scrub/ Shrub	Water
Hanalei River Watershed										
100	11.3	0.0	49.8	87.2	0.0	19.6	0.9	2.2	11.3	37.8
101	2.2	0.9	28.5	5.1	2.0	42.7	0.4	0.7	16.9	0.2
102	0.0	16.5	320.5	74.9	0.0	0.4	4.9	13.6	279.5	0.0
103	0.0	73.6	3.8	7.8	0.0	0.2	0.7	0.2	2.0	0.0
104	0.0	0.0	1.1	0.4	0.0	2.7	0.2	0.2	0.2	1.1
105	0.0	0.7	151.9	163.9	0.0	11.1	0.0	10.5	56.3	8.5
106	0.0	4.4	7.3	8.7	0.0	4.7	45.6	1.3	2.4	18.7
107	0.2	164.6	84.5	15.6	0.2	34.2	0.7	0.0	41.8	11.6
108	0.0	0.4	142.6	2.0	0.0	0.0	0.0	0.4	90.5	0.0
109	0.0	27.4	66.1	15.6	0.0	0.0	13.8	1.8	27.4	6.4
110	0.0	54.3	65.6	30.5	0.0	0.7	0.0	2.4	44.7	8.5
111	0.0	0.2	64.3	11.8	0.0	0.0	0.0	0.2	23.4	2.7
112	0.0	0.0	135.9	21.3	0.0	0.0	0.0	0.7	63.6	4.4
113	0.0	0.0	46.7	3.6	0.0	0.0	0.0	5.1	28.2	2.2
114	0.0	0.0	27.1	2.7	0.0	0.0	0.0	0.9	16.2	2.0
115	0.0	0.0	147.2	0.2	0.0	0.0	0.0	4.2	107.2	4.9
116	0.0	0.0	677.0	32.0	0.0	0.0	14.0	52.7	1,311.5	32.5
117	0.4	0.4	420.8	73.6	0.0	0.2	1.6	54.7	1,850.1	22.5
118	0.0	0.0	364.3	8.0	0.0	0.0	0.0	10.0	621.4	0.4
119	0.0	0.0	100.3	15.1	0.0	0.0	0.4	3.6	695.9	12.0
120	0.2	0.0	178.4	4.7	0.0	0.0	0.0	0.4	338.7	0.7
121	0.2	0.7	83.2	14.0	0.0	0.0	0.0	3.8	320.9	9.1
122	0.0	0.0	183.9	0.0	0.0	0.0	0.0	4.9	290.4	0.0
123	0.0	0.0	242.4	4.0	0.0	0.0	0.0	21.8	824.6	0.2
124	1.3	0.0	11.6	0.9	0.0	0.0	1.1	13.6	489.0	0.0
125	0.0	0.0	38.3	8.5	0.0	0.0	20.7	41.6	805.5	0.0
126	0.0	0.0	112.8	21.6	0.0	0.0	0.0	1.1	622.5	0.0
127	0.0	0.0	57.4	4.9	0.0	0.0	0.0	0.4	668.1	0.0
Hanalei River Watershed Area	*16.0*	*344.0*	*3,813.0*	*638.5*	*2.2*	*116.5*	*105.0*	*253.1*	*9,650.4*	*186.4*
Percentage of Total Area	*0.1%*	*2.3%*	*25.2%*	*4.2%*	*0.0%*	*0.8%*	*0.7%*	*1.7%*	*63.8%*	*1.2%*
Waioli Watershed										
200	2.0	48.9	24.7	11.3	2.7	35.6	2.4	6.4	60.7	6.4
201	0.0	52.3	72.5	2.2	0.0	0.0	4.4	8.2	44.5	0.2
202	0.2	0.0	375.6	16.7	0.0	0.0	0.0	0.9	830.4	0.0
203	0.0	0.0	186.6	27.6	0.0	0.0	3.1	42.7	1,091.7	0.0
204	0.0	0.0	213.9	1.3	0.0	0.0	0.0	0.0	305.8	0.0
Waioli Watershed Area	*2.2*	*101.2*	*873.3*	*59.2*	*2.7*	*35.6*	*10.0*	*58.3*	*2,333.1*	*6.7*
Percentage of Total Area	*0.1%*	*2.9%*	*25.1%*	*1.7%*	*0.1%*	*1.0%*	*0.3%*	*1.7%*	*67.0%*	*0.2%*
Waipa Watershed										
300	0.0	11.1	12.2	2.2	0.2	2.9	0.0	5.1	7.1	0.0
301	0.0	20.5	28.0	0.9	0.0	0.0	0.0	14.5	62.7	0.0
302	0.0	0.0	13.6	0.2	0.0	0.0	0.0	6.7	11.3	0.0
303	0.0	0.0	73.6	12.2	0.0	0.0	6.0	3.6	149.4	0.0
304	0.0	0.0	115.0	8.9	0.0	0.0	0.0	0.9	349.4	0.0
305	0.2	0.0	132.3	0.9	0.0	0.0	0.2	0.2	541.3	0.0
Waipa Watershed Area	*0.2*	*31.6*	*374.7*	*25.4*	*0.2*	*2.9*	*6.2*	*30.9*	*1,121.3*	*0.0*
Percentage of Total Area	*0.0%*	*2.0%*	*23.5%*	*1.6%*	*0.0%*	*0.2%*	*0.4%*	*1.9%*	*70.4%*	*0.0%*
Waikoko Watershed										
400	0.7	5.8	4.0	0.0	0.0	3.1	0.0	0.0	1.3	0.0
401	1.3	56.3	137.7	2.2	0.0	4.2	12.7	8.2	220.8	0.0
Waikoko Watershed Area	*2.0*	*62.0*	*141.7*	*2.2*	*0.0*	*7.3*	*12.7*	*8.2*	*222.2*	*0.0*
Percentage of Total Area	*0.4%*	*13.5%*	*30.9%*	*0.5%*	*0.0%*	*1.6%*	*2.8%*	*1.8%*	*48.5%*	*0.0%*
Hanalei Bay Watershed										
Total Area – Hanalei Bay Watershed	*20.5*	*538.9*	*5,202.7*	*725.2*	*5.1*	*162.3*	*133.9*	*350.5*	*13,327.0*	*193.0*
Percentage of Total Area	*0.1%*	*2.6%*	*25.2%*	*3.5%*	*0.0%*	*0.8%*	*0.6%*	*1.7%*	*64.5%*	*0.9%*

B-2.1.4. Soils

Soil data for the watershed were obtained from the State Soil Geographic (STATSGO) Database (USDA, 2006). There are four main Hydrologic Soil Groups (Groups A, B, C, and D). These groups, which are described below, range from soils with low runoff potential to soils with high runoff potential (USDA, 1986).

Group A Soils have low runoff potential and high infiltration rates even when wet. They consist chiefly of sand and gravel and are well drained to excessively-drained.

Group B Soils have moderate infiltration rates when wet and consist chiefly of soils that are moderately-deep to deep, moderately- to well-drained, and moderately coarse textures.

Group C Soils have low infiltration rates when wet and consist chiefly of soils having a layer that impedes downward movement of water with moderately-fine to fine texture.

Group D Soils have high runoff potential, very low infiltration rates and consist chiefly of clay soils. These soils also include urban areas.

The Hanalei Bay watershed only contains Group B and Group C soils. The total area associated with each specific soil type was determined for all 41 subwatersheds. The representative soil group for each model subwatershed was based on the dominant soil type found in that subwatershed. Because steep slopes have the potential to contribute larger amounts of sediment than areas with gentler slopes, these areas were assigned to a separate soil group so they could be parameterized accordingly. To identify the subwatersheds with steep slopes, the Digital Elevation Model (DEM) was used to determine slopes throughout each subwatershed (Figure B-4). The mean slope for each subwatershed was then calculated and the subwatersheds with a mean slope greater than one standard deviation above the mean watershed slope were assigned to a separate category.

Steep slope subwatersheds were only located in areas with Soil Group B; therefore, three soil categories were used to represent the Hanalei Bay watershed: Group B, Group C, and Group B – Steep. Table B-4 identifies the mean slope and final soil group for each model subwatershed.

In addition to these hydrologic properties of the soil, regression analyses were performed to determine the pollutant makeup of the soil. Of the pollutants analyzed, only total phosphorous and total nitrogen concentrations had a strong relationship with sediment concentrations. The R^2 value was 0.8345 for the total phosphorous analysis and 0.7293 for the total nitrogen analysis (sample size was 181 for each regression).

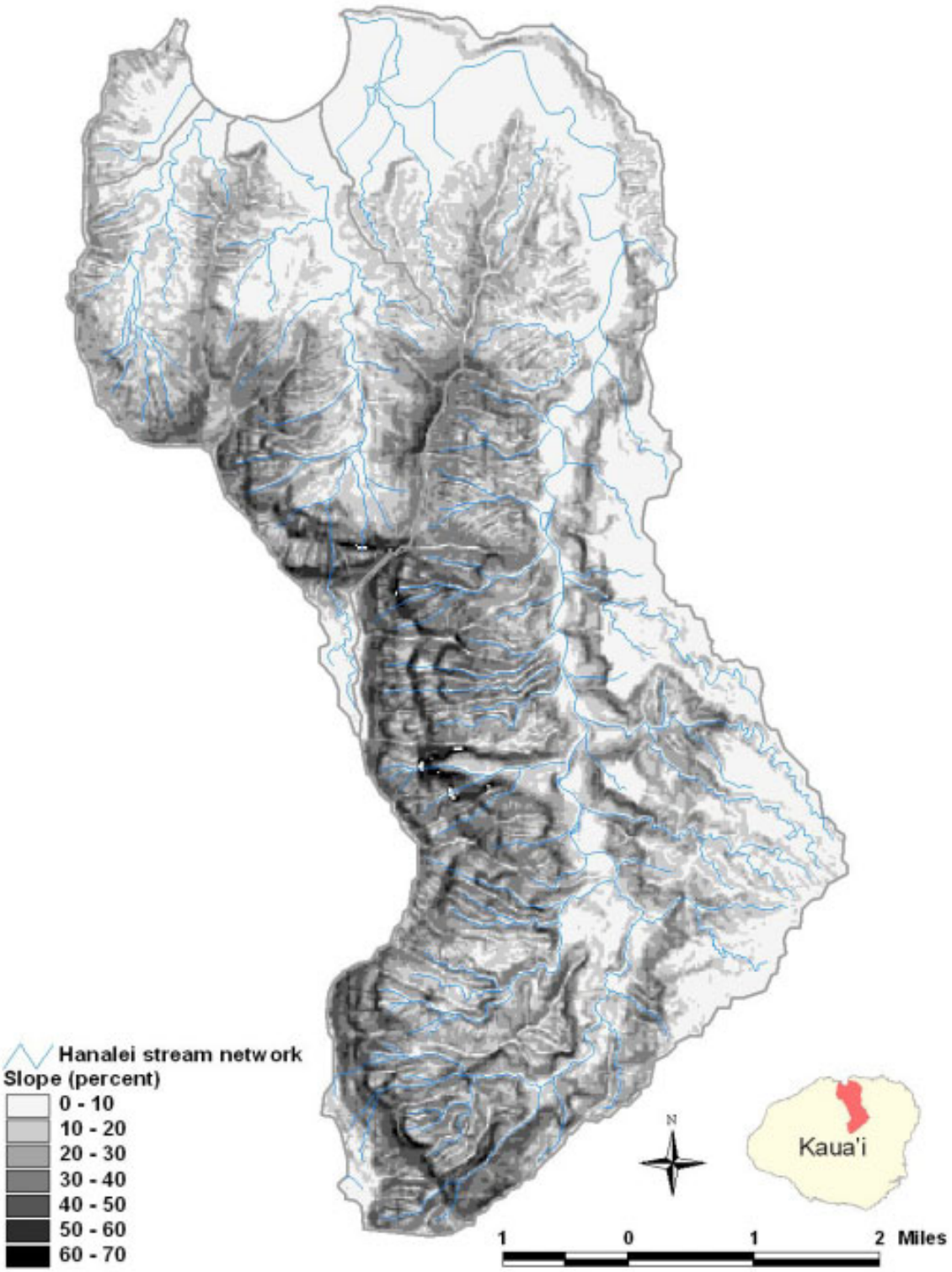

Figure B-4. Average slope

Table B-4. Slope and Assigned Soil Category by Subwatershed

Subwatershed Identification Number	Mean Watershed Slope	Model Soil Category
Hanalei River Watershed		
100	3.13	C
101	0.20	C
102	15.90	B
103	0.23	C
104	1.78	C
105	7.38	C
106	1.76	C
107	7.10	B
108	17.74	B
109	10.07	B
110	9.49	B
111	11.99	C
112	15.14	B
113	13.38	B
114	14.78	B
115	16.80	B
116	22.52	B
117	28.82	B - Steep
118	18.93	C
119	34.70	B - Steep
120	19.45	C
121	27.37	B - Steep
122	17.05	C
123	23.40	B
124	38.10	B - Steep
125	34.12	B - Steep
126	29.97	B - Steep
127	32.02	B - Steep
Waioli Watershed		
200	6.56	C
201	8.19	C
202	24.05	B
203	30.95	B - Steep
204	20.93	B
Waipa Watershed		
300	0.99	C
301	16.19	B
302	1.80	C
303	16.83	B
304	20.74	B
305	27.47	B - Steep
Waikoko Watershed		
400	4.20	C
401	15.40	B
Summary		
Watershed-wide Mean Slope	16.28	
Standard Deviation	10.65	

B-2.1.5. Reach Characteristics

Each delineated subwatershed was represented with a single stream assumed to be a completely mixed, one-dimensional segment with a trapezoidal cross-section. The stream reach network from the Hawai'i Statewide GIS Program (State of Hawai'i, Office of Planning, 2006) was used to determine the representative stream reach for each subwatershed. Once the representative reach was identified, slopes were calculated based on DEM data and stream lengths measured from the stream coverage. Similar to other watershed modeling studies, headwater streams were assigned a value equal to 70 percent of the length from the stream coverage since they tend not to extend the entire length of their respective subwatersheds (Tetra Tech, Inc., 2004a, 2004b).

In addition to stream slope and length, mean depths and channel widths are required to route flow and pollutants through the hydrologically connected subwatersheds. Mean stream depth and channel width were estimated using regression curves that relate upstream drainage area to stream dimensions. Table B-5 presents the stream characteristics for each representative reach. An estimated Manning's roughness coefficient of 0.02 was also applied to each representative stream reach, which is associated with a smooth, natural stream.

B-2.1.6. Point Source Discharges

There are no National Pollutant Discharge Elimination System (NPDES) dischargers that are major point sources of flow or pollutants in the Hanalei Bay watershed. To address the flow diversions to wetland impoundments and taro pondfields at the Hanalei National Wildlife Refuge (NWR), a constant withdrawal from the irrigation ditch system was incorporated into the model. Specifically, an average flow of 34 cubic feet per second (cfs) was withdrawn from the Hanalei River near the southern end of the Hanalei NWR (USFWS, 2005). It was estimated that 65 percent of the inflows return to the Hanalei River because consumptive use is lower than the inflow requirements (USFWS, 2005). To address these return flows, 22.1 cfs (which is 65 percent of the 34 cfs withdrawal) was distributed among four model subwatersheds in the Hanalei NWR based on their wetland impoundments and taro pondfields land area (represented by the palustrine emergent and cultivated lands cover types, respectively).

Table B-5. Stream Characteristics

Subwatershed/Reach Identification Number	Reach Length (miles)	Reach Depth (feet)	Reach Width (feet)	Reach Slope
Hanalei River Watershed				
100	1.03	3.68	51.33	0.00
101	0.58	1.65	16.59	0.00
102	1.49	1.54	15.10	0.08
103	0.36	0.85	6.56	0.00
104	0.11	3.60	49.78	0.00
105	0.66	3.60	49.77	0.00
106	0.13	3.57	49.19	0.00
107	0.93	3.56	49.05	0.00
108	0.9	1.13	9.72	0.18
109	0.58	3.52	48.19	0.00
110	0.72	3.50	47.95	0.00
111	0.31	3.49	47.64	0.01
112	0.37	3.48	47.48	0.01
113	0.12	3.46	47.13	0.02
114	0.21	3.46	47.00	0.02
115	0.41	3.45	46.93	0.02
116	2.41	3.43	46.51	0.01
117	1.53	3.24	42.98	0.02
118	2.27	1.70	17.35	0.14
119	0.85	2.87	36.10	0.03
120	1.81	1.42	13.36	0.16
121	0.85	2.68	32.77	0.04
122	2.18	2.33	26.89	0.11
123	2.04	2.21	25.08	0.05
124	1.29	1.41	13.31	0.46
125	1.41	1.66	16.71	0.46
126	1.6	1.90	20.31	0.06
127	0.91	1.56	15.28	0.21
Waioli Watershed				
200	0.49	2.42	28.53	0.01
201	0.76	2.38	27.85	0.01
202	1.62	2.23	25.28	0.04
203	2.23	1.85	19.54	0.34
204	1.09	1.41	13.34	0.19
Waipa Watershed				
300	0.35	1.94	20.87	0.01
301	0.54	0.95	7.57	0.14
302	0.35	1.88	19.96	0.01
303	0.46	1.87	19.78	0.04
304	0.76	1.77	18.31	0.08
305	0.87	1.52	14.80	0.35
Waikoko Watershed				
400	0.05	1.36	12.68	0.00
401	0.75	1.35	12.51	0.05

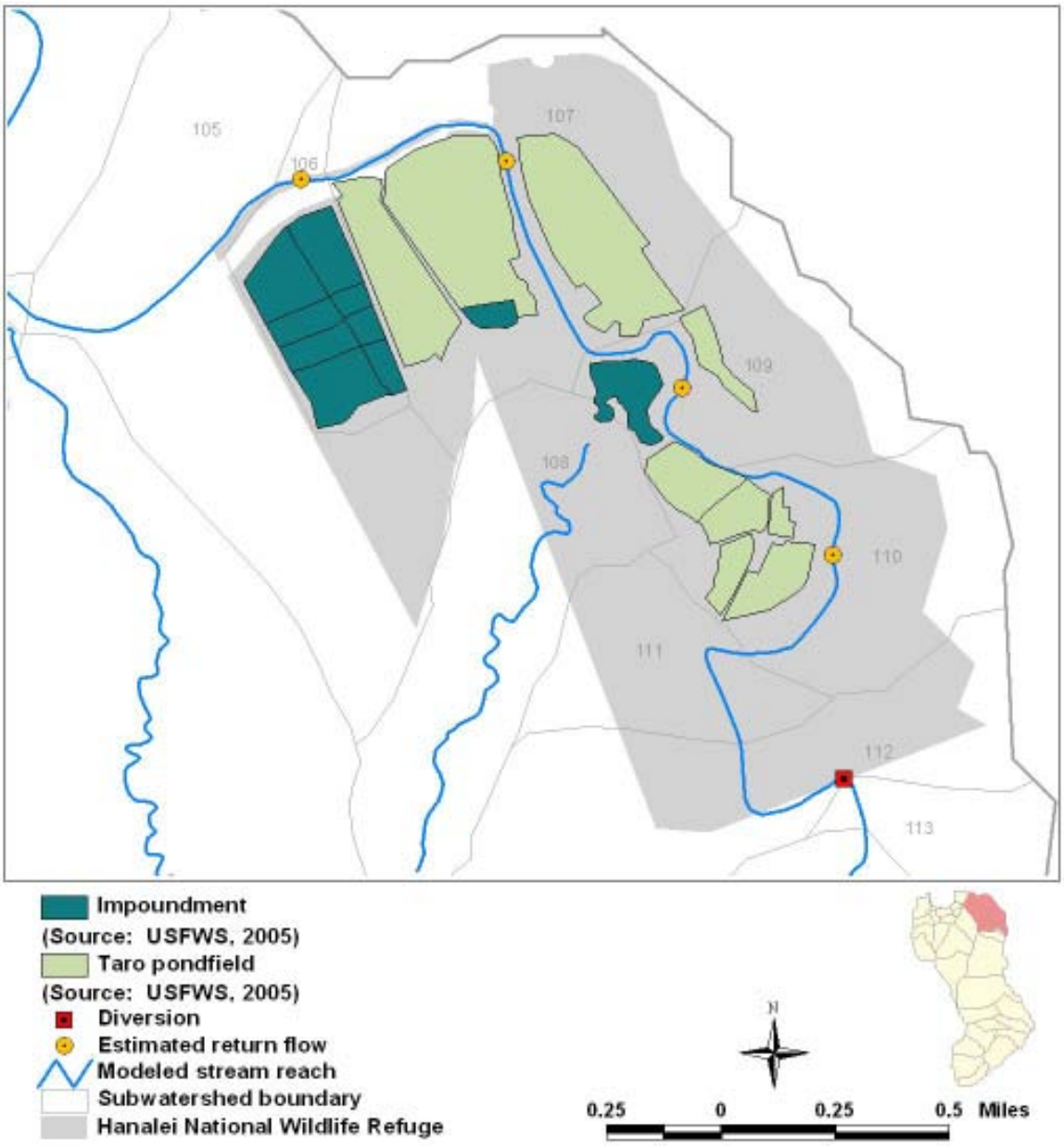

Figure B-5. Hanalei National Wildlife Refuge wetland impoundments and taro pondfields

B-2.1.7. Hydrology Representation

Watershed hydrology plays an important role in the determination of nonpoint source flow and ultimately nonpoint source loadings to a waterbody. The watershed model must appropriately represent the spatial and temporal variability of hydrologic characteristics within a watershed. Key hydrologic characteristics include interception storage capacities, infiltration properties, evaporation and transpiration rates, and watershed slope and roughness. LSPC's algorithms are identical to those in HSPF. The LSPC/HSPF modules used to represent watershed hydrology for TMDL development included

PWATER (water budget simulation for pervious land units) and IWATER (water budget simulation for impervious land units). A detailed description of relevant hydrological algorithms is presented in the HSPF User's Manual (Bicknell et al., 2001).

Key hydrologic parameters in the PWATER and IWATER modules are infiltration, groundwater flow, and overland flow. USDA's STATSGO Soils Database served as a starting point for designation of infiltration and groundwater flow parameters. For parameter values not easily derived from these sources, documentation on past HSPF or LSPC applications was accessed. Starting values were refined through the hydrologic calibration and validation process (described in Section B-2.2.1).

B-2.1.8. Watershed Runoff Pollutant Representation

The pollutants simulated for the Hanalei Bay watershed are associated with both natural and anthropogenic activities. 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 NWR have increased over the past thirty years (Asquith and Melgar, 1999) and introduced mammals such as feral cats, dogs, and rats on the Hanalei NWR are considered problem species (Berg et al., 1997). These wildlife populations are also potential sources contributing to elevated bacteria concentrations in the watershed. Further downstream from the Hanalei NWR, there are pastures with bison ranching (Berg et al., 1997) along with the town of Hanalei, which has no centralized waste treatment. Waste disposal is through onsite septic & cesspool systems except for small treatment plants that serve the commercial centers (Fujimoto, 1977; Griffin, 2000). All of these sources have the potential to contribute to the elevated *enterococcus* concentrations measured throughout the watershed.

Sediment concentrations are also associated with both natural and anthropogenic activities. Although there are occasionally high erosion rates due to high precipitation and steep slopes in the headwaters, sediment loads from the headwaters are also associated with alteration of the forest landscape due to human inhabitation, introduction of feral livestock (pigs and goats), and alien tree and plant species (Griffin, 2000). Based on the evaluation of turbidity and suspended sediment data, sediment yields increase in the more downstream portions of the watershed (Berg et al., 1997). Specifically, sediment yields double through the Hanalei NWR and turbidity values increase as well (Berg et al., 1997). While sediment plumes have been observed in return flows to the Hanalei River, the total sediment load may be minor compared to the sediment generated during natural flood events (the Hanalei River load was estimated at 30-80 times the load from ditches and impoundments) (Berg et al., 1997).

Nutrients are also associated with a variety of land-based activities. The presence of wildlife in wetlands, grasslands, and forested areas, fertilization of agricultural areas, and various activities in urban areas are all potential sources of nutrients (Berg, 1995; Berg et al., 1997; USEPA, 2005; Schueler and Holland, 2000). Nutrients in the agricultural areas

of the Hanalei River watershed have been previously studied by Berg (Berg et al., 1997; Berg, 1995). These studies concluded that due to fertilization of taro ponds, or lo'i, nitrogen loads in return waters were 4-40 times higher when compared to inflow waters on the Hanalei NWR (Berg et al., 1997). Other potential sources of nutrients, such as wildlife and urban activities (poor sewage treatment, residential fertilization, pet waste, etc.), are not quantified in the Hanalei Bay watershed; however, they are well documented sources of nutrient (USEPA, 2005; Schueler and Holland, 2000). These land cover associations were taken into consideration during parameterization of the bacteria, sediment, and nutrient water quality constituents.

Because of the different properties associated with each of these pollutants, they were incorporated into the LSPC model using different assumptions. Loading processes for *enterococcus*, ammonia, and nitrite plus nitrate were represented for each land unit using build-up/wash-off functions. Specifically, these pollutants accumulated on the land surface during dry periods and were washed off during storm events. Starting values for parameters relating to land cover-specific accumulation rates (ACQOP) and build up limits (SQOLIM) were adjusted during model calibration and validation of *enterococcus*, ammonia, and nitrite plus nitrate (see Section B-2.2.2).

Observed data indicate that total phosphorous and total nitrogen concentrations have a strong relationship with sediment concentrations due to their sorptive properties (R^2 = 0.8345 and 0.7293, respectively); however, ammonia and nitrite plus nitrate did not have a strong correlation (R^2 = 0.0001 and 0.0033, respectively; Figure B-6). Because ammonia and nitrite plus nitrate did not exhibit a relationship to sediment, it was assumed that organic nitrogen was causing the strong correlation; therefore, both organic nitrogen and total phosphorous were represented in the model through their association with sediment. In order to simulate sediment contributions, the sediment modules were implemented.

These modules simulate the production and removal of sediment from all pervious and impervious land segments in the model. The removal of sediment by water is simulated as wash-off of available sediment (pervious and impervious lands) and scour of the soil matrix (pervious only). Both processes are highly dependent on land-based activities. Wash-off depends on both the amount of detached sediment available to be carried away by the overland flow and the transport capacity of the overland flow. The amount of detached sediment available to be transported depends primarily on the rainfall intensity. The transport capacity of the overland flow depends on surface water storage and surface water flow. Once the sediment is transported to the stream channel by overland flow, transport, deposition, and scour of sediment in the stream channels can also be simulated. These processes depend primarily on sediment characteristics, e.g. settling velocity, critical shear stress for deposition, critical shear stress for resuspension, and predicted bottom shear stresses.

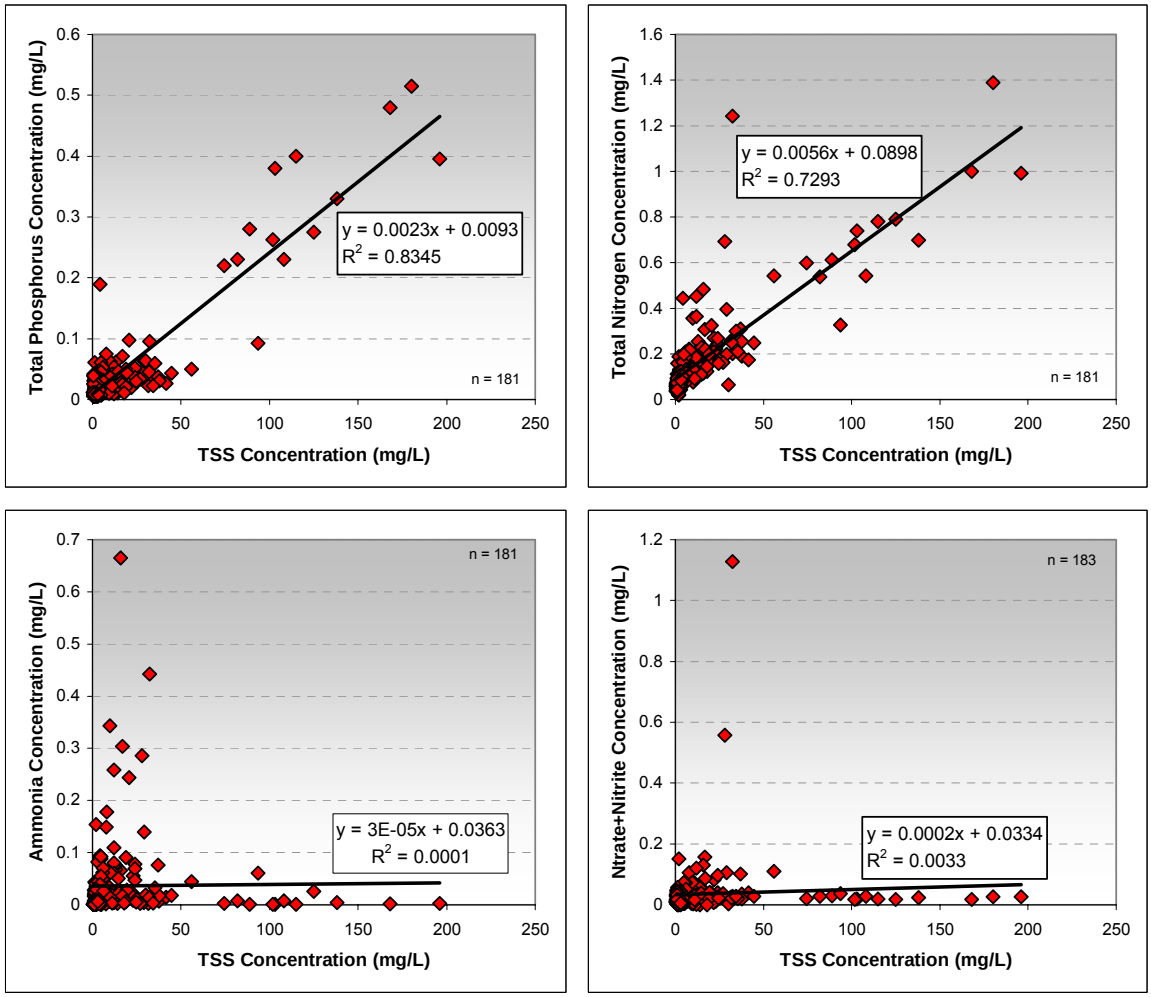

Figure B-6. Relationships between sediment and nutrients

After using the sediment modules to simulate total suspended solids (TSS), total phosphorous and organic nitrogen associated with sediment were simulated using the LSPC water quality module. The relationships between sediment and these nutrients were primarily simulated using the POTFW parameter. POTFW is the wash-off potency factor or the ratio of constituent yield to sediment outflow. A unique value for POTFW was assigned for each constituent and these values varied by land cover type. A detailed discussion of the water quality parameters is provided in Section B-2.2.2.

B-2.2. Model Calibration and Validation

After the model was configured, model calibration and validation were performed. This is generally a two-phase process, with hydrology calibration and validation completed before repeating the process for water quality. Upon completion of the calibration and

validation at selected locations, a calibrated dataset containing parameter values for each modeled land cover type and pollutant was developed.

Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. The calibration was performed for different LSPC modules at multiple locations throughout the watershed. This approach ensured that heterogeneities were accurately represented. Subsequently, model validation was performed to test the calibrated parameters at different locations for different time periods, without further adjustment.

Nine flow and/or water quality monitoring stations for the simulation period were identified and are illustrated in Figure B-7. The majority of these stations were used for both water quality and hydrology calibration and/or validation; however, only the USGS flow gage on the Hanalei River (Station 16103000) contained continuous flow data for robust hydrology calibration and validation. Information about each monitoring station, including outflow subwatershed, the responsible agency, and identification of model calibration and/or validation, is presented in Table B-6, and their locations are illustrated in Figure B-7.

Table B-6. LSPC Monitoring Station Information

Station Name	Subwatershed Identification Number	Data Collecting Agency*	Use in Watershed Model Simulations			
			Hydrology		Water Quality	
			Calibration	Validation	Calibration	Validation
Hanalei Upper	112	DOH		●		●
Upper ISCO	110	Hui/Tt		●		●
Snapshot - gage	113	Hui				●
Convergence	112	Hui				●
USGS gage	116	Hui; Hui/Tt	●	●	●	
Waioli Lower	201	DOH		●		●
Waioli Upper	202	DOH		●		●
Waipa Lower	303	DOH		●		●
Waipa Upper	304	DOH		●		●

*Key:
DOH = Hawai'i Department of Health
Hui = Hanalei Watershed Hui
Hui/Tt = Joint monitoring effort conducted by the Hanalei Watershed Hui and Tetra Tech, Inc.

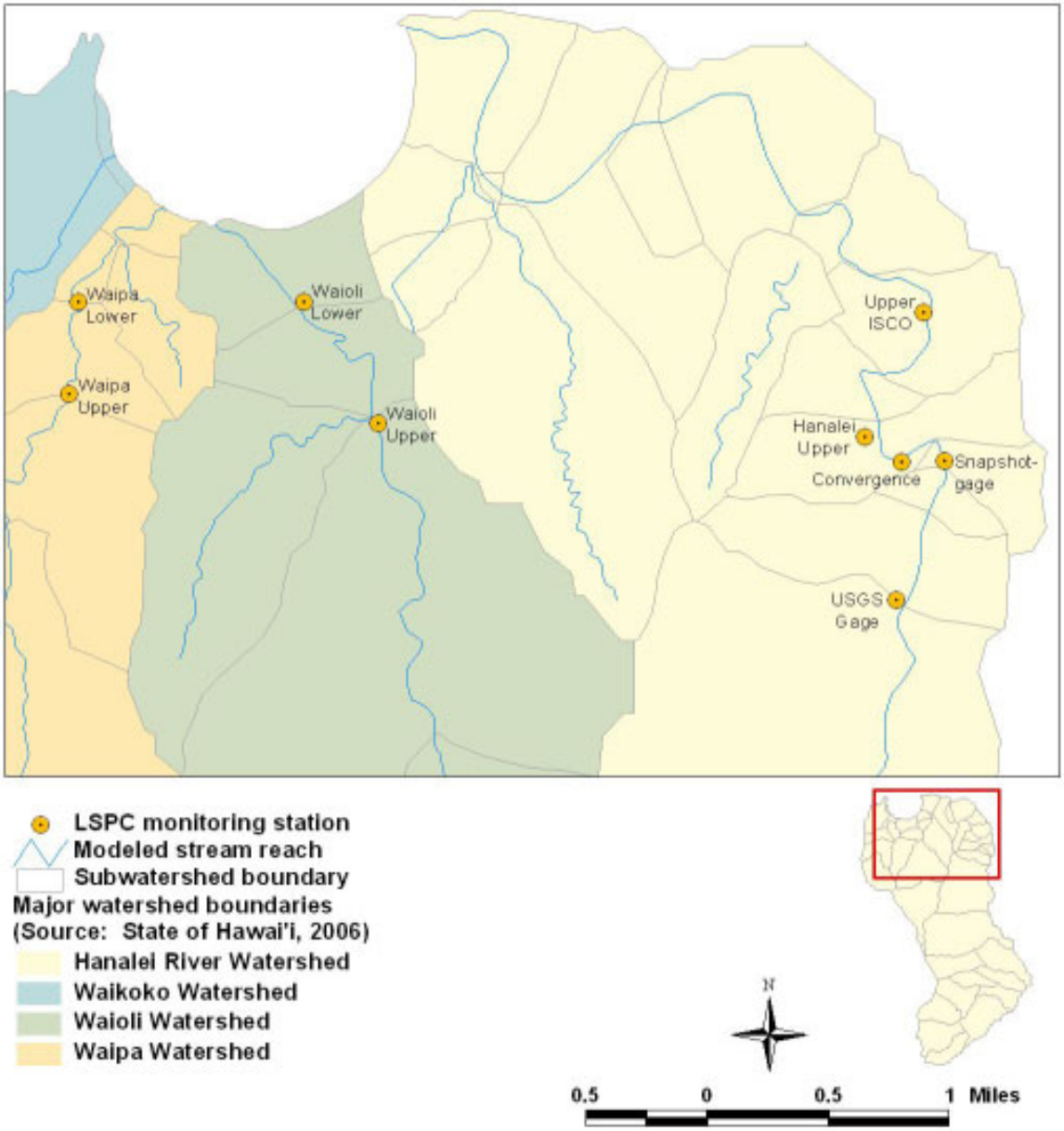

Figure B-7. Monitoring stations used for LSPC model calibration and validation

B-2.2.1. Hydrology Simulations

Hydrology is the first model component calibrated because estimation of pollutant loadings relies heavily on flow prediction. The hydrology calibration involves a comparison of model results to in-stream flow observations at available locations. After comparing the results, key hydrologic parameters were adjusted and additional model simulations were performed. This iterative process was repeated until the simulated results closely represented the system and reproduced observed flow patterns and magnitudes. To ensure that an appropriate amount of precipitation was delivered to the

system, the weather station(s) initially assigned to certain subwatersheds were adjusted along with the weighting factors used to distribute the rainfall if more than one station was assigned per subwatershed. To ensure that the model results are as current as possible and to provide for a range of hydrologic conditions, May 2001 through May 2006 was selected as the hydrology simulation period.

The USGS stream gage (located in subwatershed 116) was the only continuous flow monitoring station available in the Hanalei Bay watershed (Figure B-7). This station is upstream of nearly all development in the watershed; although some of the land draining to this station was historically used for agriculture or grazing (Griffin, 2000). The calibration period was June 1, 2003 through May 31, 2006 and the validation period was May 1, 2001 through May 31, 2003.

Key considerations in the hydrology calibration included the overall water balance, the high-flow/low-flow distribution, stormflows, and seasonal variation. Model evaluation was performed through graphical comparison, regression analyses, and the relative error method. The model's accuracy was primarily assessed through interpretation of the time-variable plots. Time-variable plots of observed versus modeled flow provided insight into the model's representation of storm hydrographs, baseflow recession, time distributions, seasonal variation and other pertinent factors often overlooked by statistical comparisons. In addition, regression analysis was used to provide a measure of model accuracy.

To supplement the analyses described above, error analysis was performed using modeled and observed volumes. The most important factor in assessment of model performance and applicability in TMDL development is the volume of water transported through the system. Since loading is directly related to volume, accurate estimates of storm volumes are essential. For the hydrology calibration and validation analyses, an assessment was performed to determine the relative error of model-predicted storm volumes with various hydrologic and time-variable considerations. Relative errors in model performance under each condition were compared to recommended criteria to assess the accuracy of the model (Lumb et al., 1994). The following two sections describe the model calibration and validation results.

B-2.2.1.1. Hydrology Calibration

Hydrology calibration was performed at the USGS gage (located in subwatershed 116) for June 1, 2003 through May 31, 2006. Figure B-8 through Figure B-13 show the graphical comparisons used to assess model performance. Figure B-8 depicts a time-series plot of modeled and observed daily flows for one year of the calibration period. This time series provides a good overview of model performance and shows that the model captures the observed daily frequency and magnitude well. However this daily plot does not allow quantitative comparison or measure of accuracy. For a quantitative comparison, modeled and observed flows and rainfall were summarized by average monthly values over the simulation period. Comparison of average monthly conditions is

depicted graphically in Figure B-9. It should be noted that the USGS flow data from October 2005 through May 2006 is provisional and is subject to revision upon final review. The model closely matches the observed data during this time period.

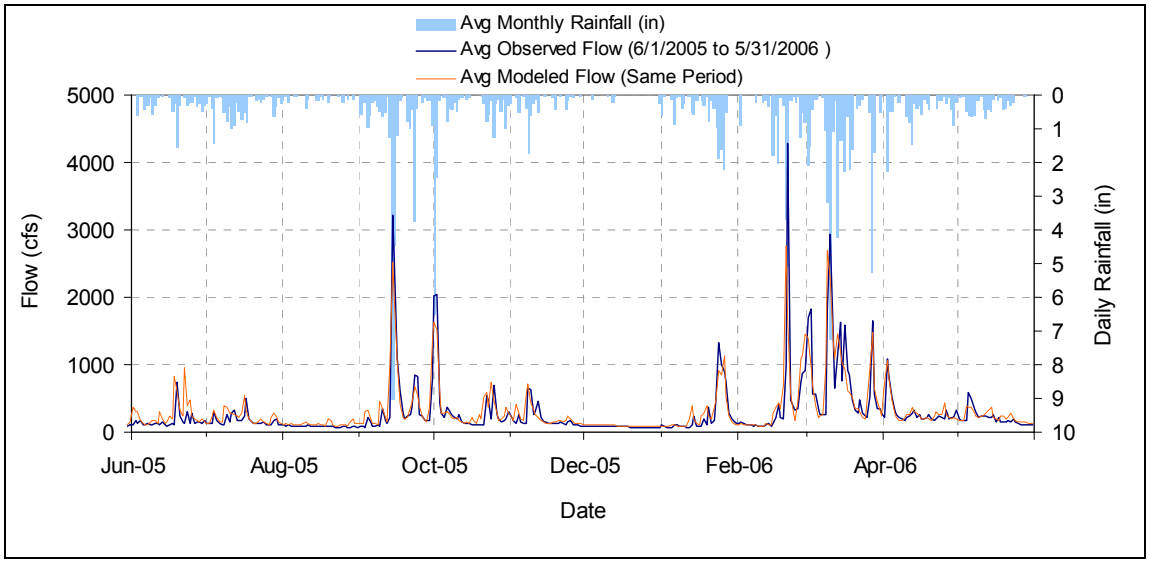

Figure B-8. Comparison of modeled and observed daily flows during calibration

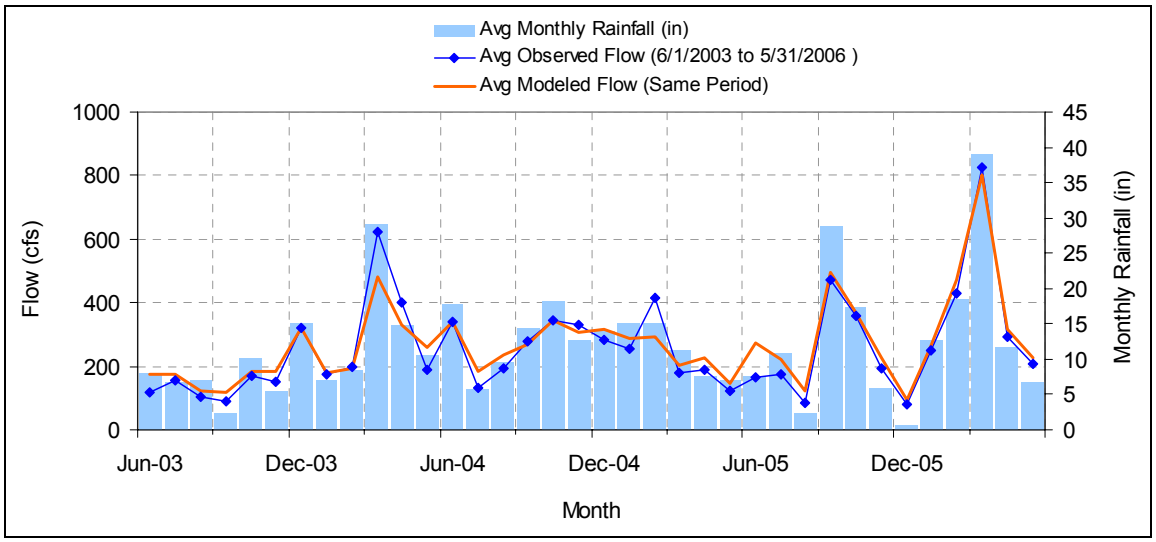

Figure B-9. Comparison of modeled and observed average monthly flows during calibration

To provide a measure of model accuracy, average monthly model-predicted and observed flows were compared through a regression analysis shown in Figure B-10. The regression line shows a good fit between modeled and observed average monthly flow ($R^2 = 0.92$). Certain months have been over- or under-predicted, but overall the model appears to predict stream flow at a frequency and magnitude similar to the observed data.

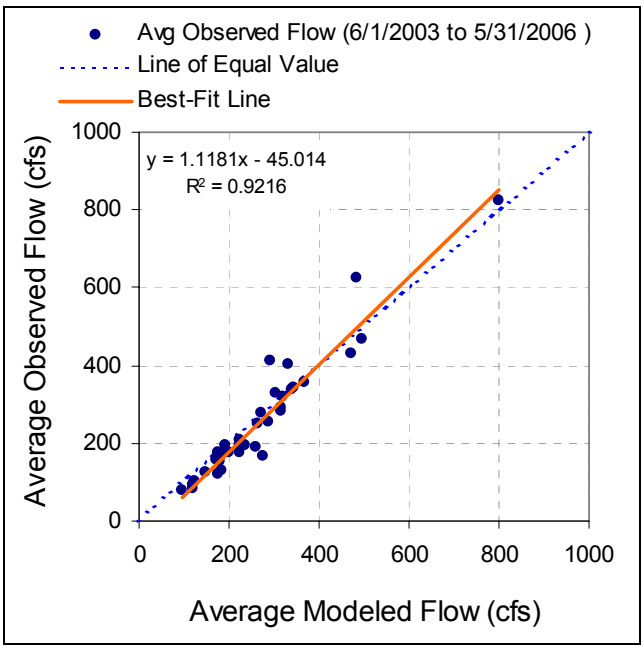

Figure B-10. Regression analysis of modeled and observed average monthly flows during calibration

Another useful measure is an evaluation of model performance with respect to seasonal variations. Figure B-11 depicts the model's median monthly performance for the entire simulation period and Figure B-12 illustrates the average annual performance by month. These graphs indicate that the model slightly over-predicts stream flow during the summer months; however, the regression analysis (Figure B-13) shows a strong correlation for seasonal variation between modeled and observed flows with an R^2 of 0.98.

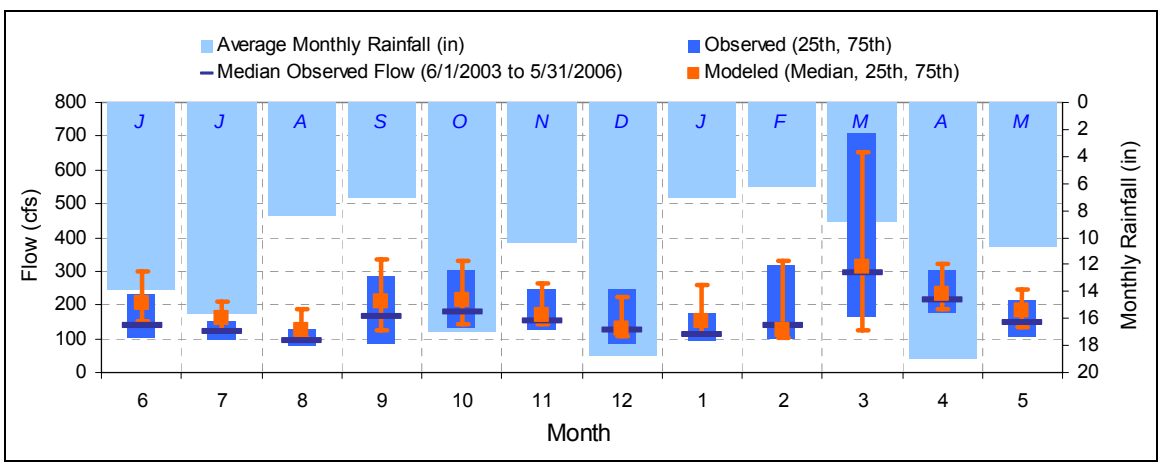

Figure B-11. Seasonal variation of median modeled and observed flows during calibration

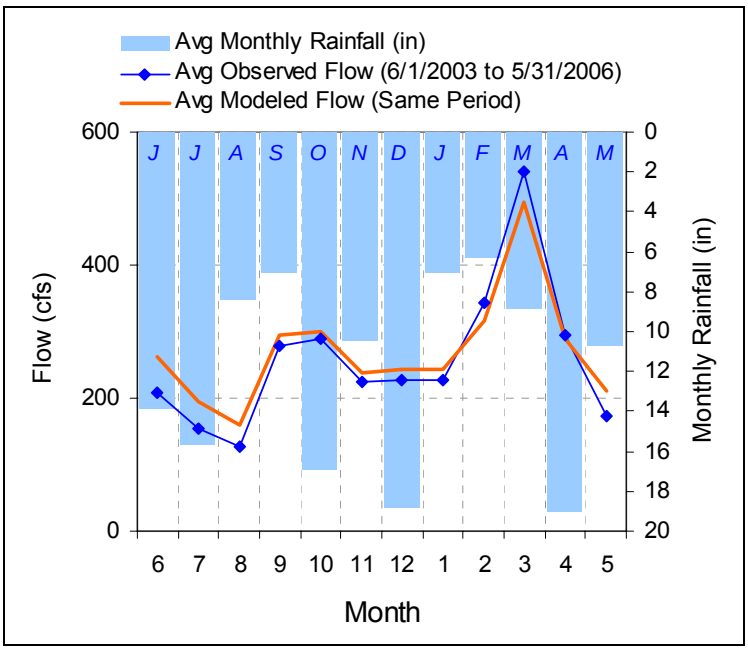

Figure B-12. Seasonal variation of average modeled and observed flows during calibration

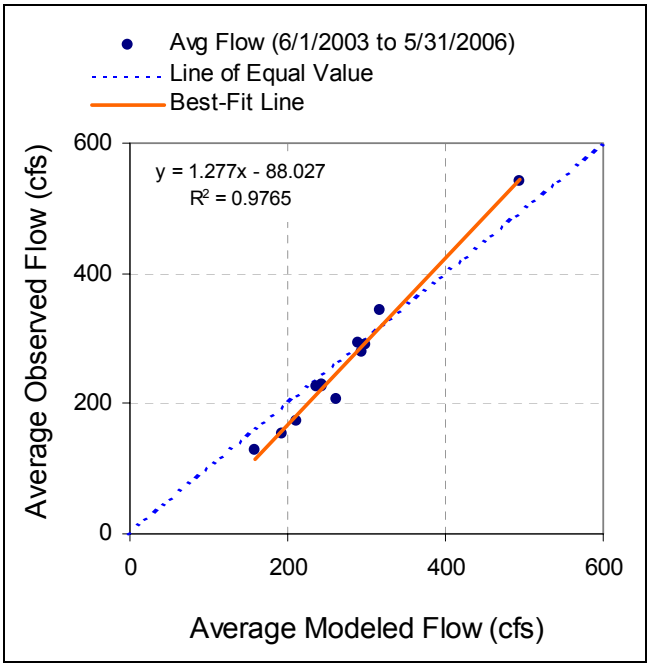

Figure B-13. Regression analysis of modeled and observed seasonal variation during calibration

One of the most important factors in assessment of model performance and applicability in TMDL development is the volume of water transported through the system. For the

hydrology calibration analysis, an assessment was performed to determine the relative error of model-predicted storm volumes with various hydrologic and time-variable considerations. Table B-7 reports the results of the analysis performed during model calibration. Specifically, volumes were compared under different flow regimes and seasonal periods. For higher flows (highest 10%), the model performs well in predicting storm volumes, with an error of –11.62%. The model over-predicts lower flows (lowest 50%), with an error of 19.66%. The overall error in volume is 5.16%. The overall accuracy of the model was determined by comparing these relative errors in model performance to recommended criteria (Lumb et al., 1994). In all cases except for the lowest flows, the errors were well within the recommended criteria, thus indicating the model is predicting flow and volumes well during various hydrologic and seasonal conditions. Since the runoff and resulting streamflow are highly dependent on rainfall, occasional storms were over-predicted or under-predicted depending on the spatial variability of the meteorologic and gage stations.

Table B-7. Volumes and Relative Error of Modeled Verses Observed Flows During Calibration

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 116 3-Year Analysis Period: 6/1/2003 - 5/31/2006 Flow volumes are (inches/year) for upstream drainage area		**USGS 16103000 Hanalei River nr Hanalei, Kauai, HI**	
Total Simulated In-stream Flow:	**196.42**	Total Observed In-stream Flow:	**186.79**
Total of simulated highest 10% flows:	**68.30**	Total of Observed highest 10% flows:	**77.27**
Total of Simulated lowest 50% flows:	**45.37**	Total of Observed Lowest 50% flows:	**37.92**
Simulated Summer Flow Volume (months 7-9):	**39.36**	Observed Summer Flow Volume (7-9):	**34.06**
Simulated Fall Flow Volume (months 10-12):	**47.67**	Observed Fall Flow Volume (10-12):	**45.34**
Simulated Winter Flow Volume (months 1-3):	**63.35**	Observed Winter Flow Volume (1-3):	**66.82**
Simulated Spring Flow Volume (months 4-6):	**46.05**	Observed Spring Flow Volume (4-6):	**40.57**
Total Simulated Storm Volume:	**85.09**	Total Observed Storm Volume:	**87.99**
Simulated Summer Storm Volume (7-9):	**15.57**	Observed Summer Storm Volume (7-9):	**13.97**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	5.16	10	
Error in 50% lowest flows:	19.66	10	
Error in 10% highest flows:	-11.62	15	
Seasonal volume error - Summer:	15.54	30	
Seasonal volume error - Fall:	5.14	30	
Seasonal volume error - Winter:	-5.19	30	
Seasonal volume error - Spring:	13.49	30	
Error in storm volumes:	-3.29	20	
Error in summer storm volumes:	11.43	50	

B-2.2.1.2. Hydrology Validation

After calibrating hydrology, a validation of these hydrologic parameters was made through a comparison of model output to a different period (May 1, 2001 through May 31, 2003) at the USGS gage (which is located in subwatershed 116). Model validation essentially confirmed the applicability of the watershed-based hydrologic parameters derived during the calibration process. Validation results were assessed in a similar

manner to calibration: graphical comparison, regression analysis, and relative error in volume of model results and observed data. Figure B-14 through Figure B-19 present the daily, average monthly, and seasonal variation graphs and regression analyses for the validation time period.

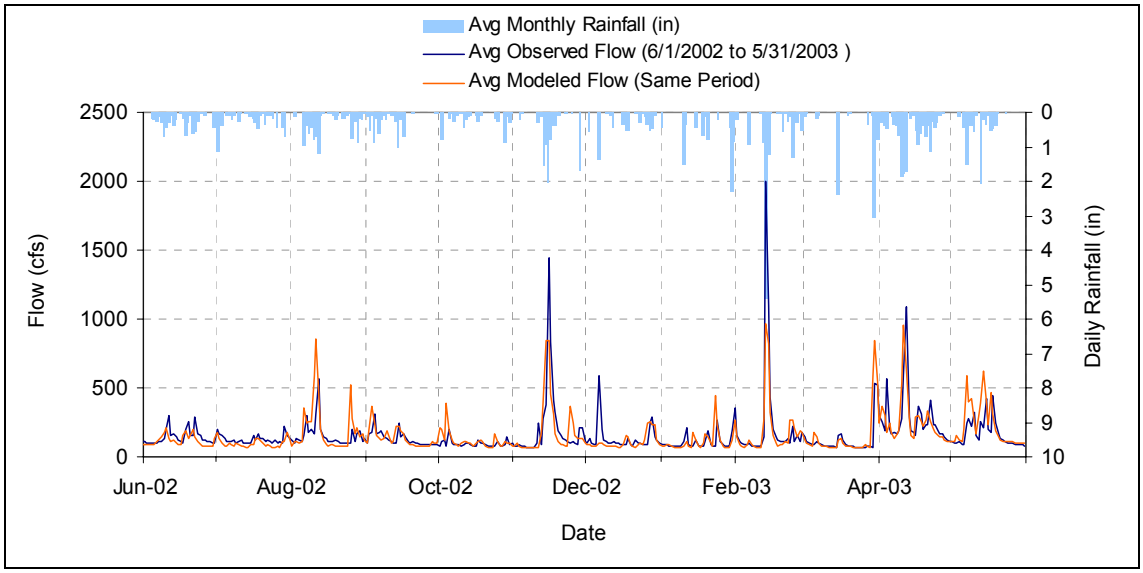

Figure B-14. Comparison of modeled and observed daily flows during validation

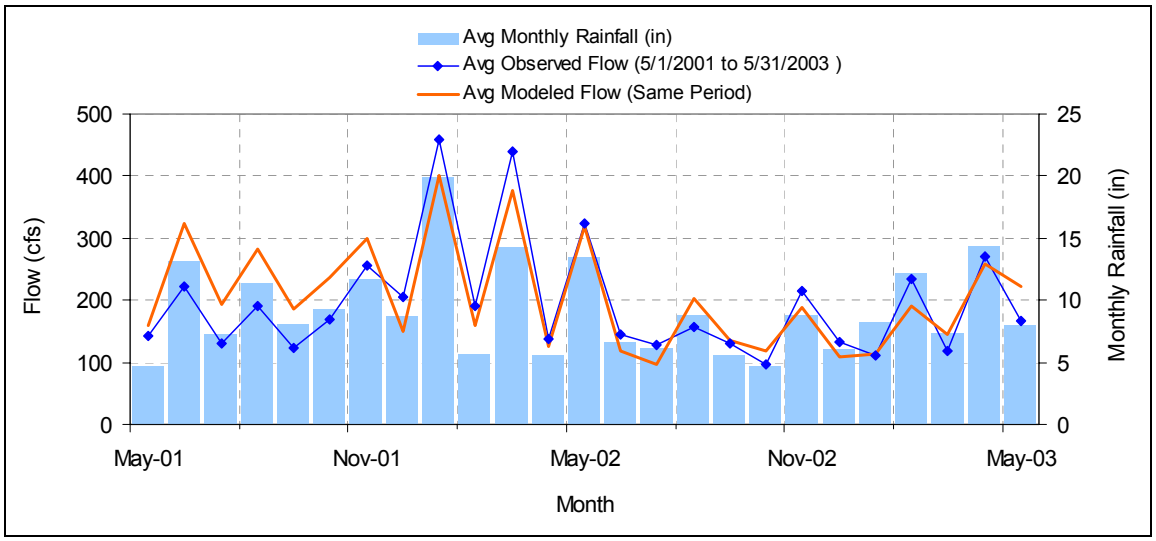

Figure B-15. Comparison of modeled and observed average monthly flows during validation

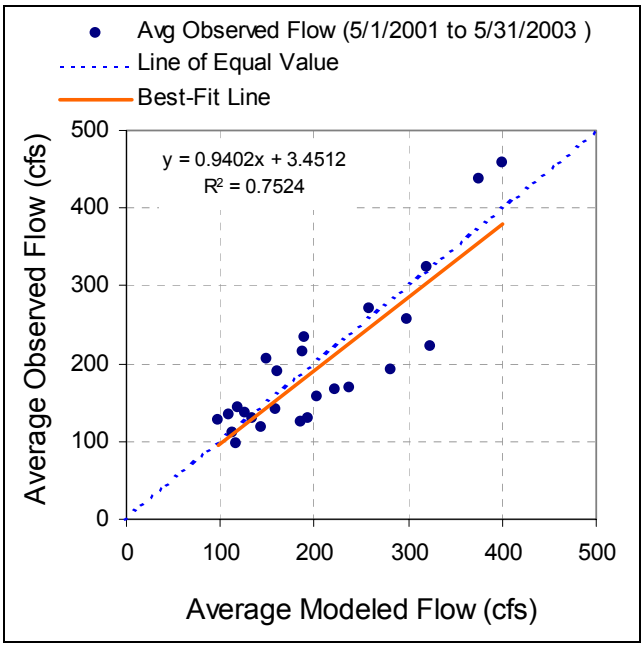

Figure B-16. Regression analysis of modeled and observed average monthly flows during validation

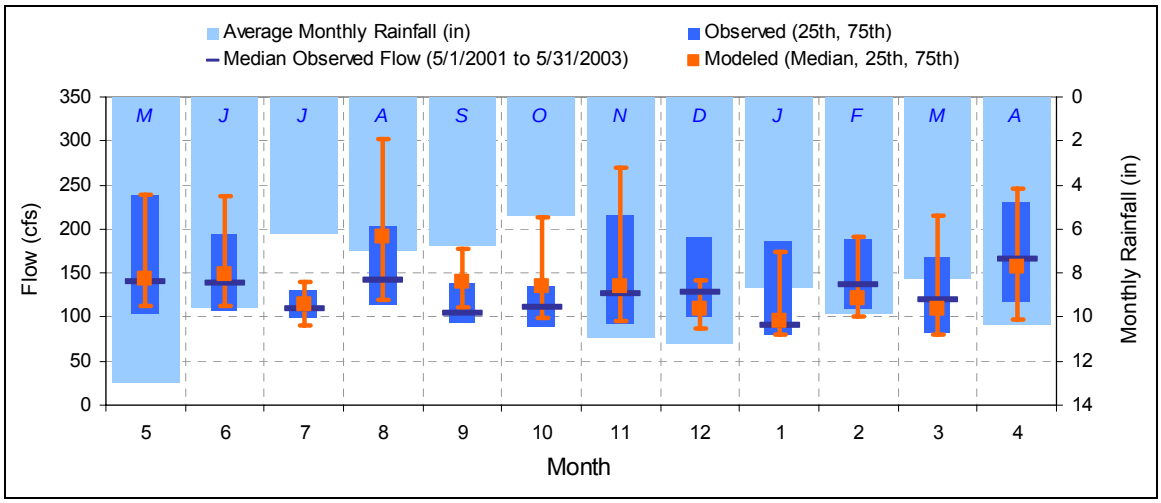

Figure B-17. Seasonal variation of median modeled and observed flows during validation

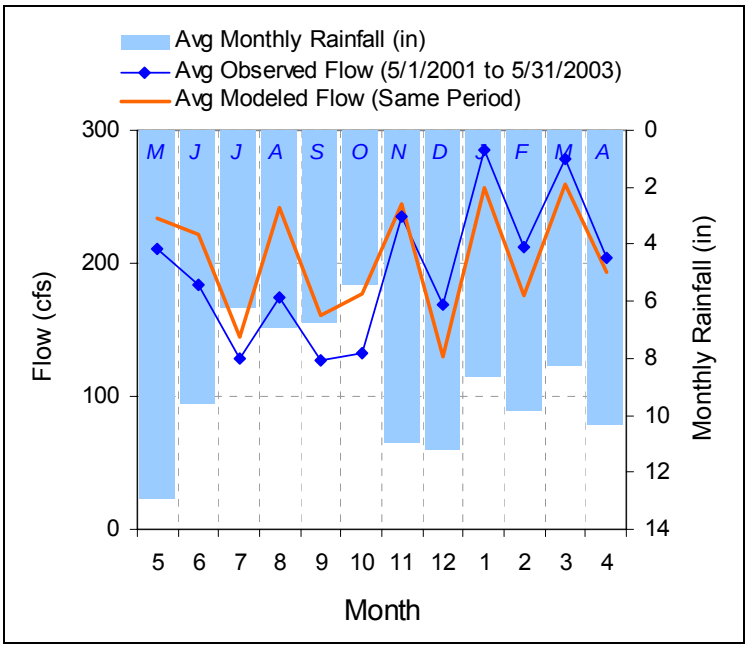

Figure B-18. Seasonal variation of average modeled and observed flows during validation

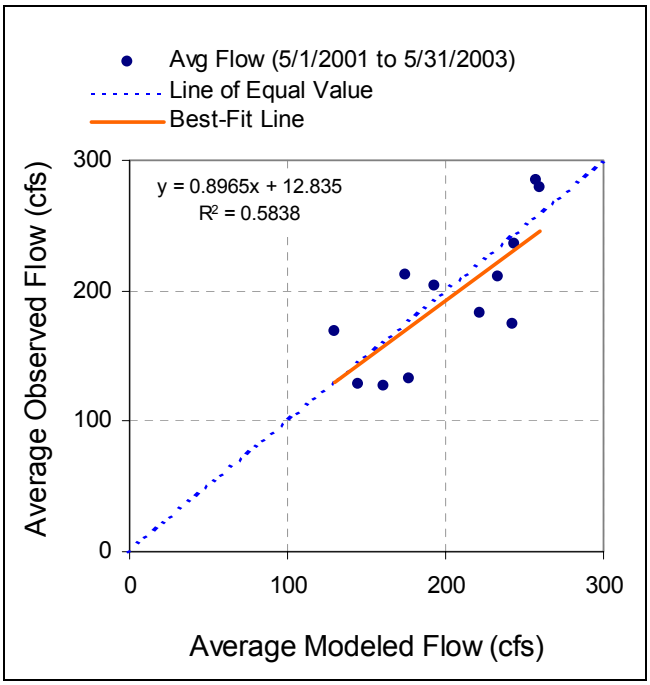

Figure B-19. Regression analysis of modeled and observed seasonal variation during validation

Similar to the calibration results, the model generally predicts flow frequency and magnitudes within the observed range. The correlations presented in the validation regression analyses are not as strong as those for model calibration (R^2 = 0.75 for average monthly flows and R^2 = 0.58 for seasonal variation). However, when combined with the

other measures of model performance (graphical comparisons and relative error statistics) these reduced correlations are considered acceptable.

Table B-8 presents the relative error analyses for the validation period. For the highest 10% of flows, the model performs well in predicting storm volumes with an error of –0.95%. The model performs similarly for lower flows (lowest 50%), with an error of –0.98%. The overall error in volume is 4.63%. With the exception of error in summer storm volumes, in which the model is over-predicting, these values are all well within the recommended criteria, thus indicating the model is predicting flow and volumes well during various hydrologic and seasonal conditions (Lumb et al., 1994). Overall, the validation results are very similar to the calibration results, thus confirming the applicability of the watershed-based hydrologic parameters derived during the calibration process. Some measurements are over-predicted during calibration and under-predicted during validation (and vice versa); therefore, it was important to strike a balance and best represent the system for the entire modeling period. As described in Section B-3.3, the EFDC model predicts hydrodynamics well, thus further confirming that the LSPC simulated flows, which are inflows to the EFDC model, are representative of the hydrologic conditions in the Hanalei Bay watershed.

Table B-8. Volumes and Relative Error of Modeled Verses Observed Flows During Validation

LSPC Simulated Flow		**Observed Flow Gage**	
REACH OUTFLOW FROM SUBBASIN 114 2.08-Year Analysis Period: 5/1/2001 - 5/31/2003 Flow volumes are (inches/year) for upstream drainage area		**USGS 16103000 Hanalei River nr Hanalei, Kauai, HI**	
Total Simulated In-stream Flow:	**148.72**		**142.14**
Total of simulated highest 10% flows:	**53.72**	Total of Observed highest 10% flows:	**54.23**
Total of Simulated lowest 50% flows:	**35.07**	Total of Observed Lowest 50% flows:	**35.42**
Simulated Summer Flow Volume (months 7-9):	**32.13**	Observed Summer Flow Volume (7-9):	**25.27**
Simulated Fall Flow Volume (months 10-12):	**32.17**	Observed Fall Flow Volume (10-12):	**31.36**
Simulated Winter Flow Volume (months 1-3):	**39.96**	Observed Winter Flow Volume (1-3):	**44.65**
Simulated Spring Flow Volume (months 4-6):	**44.46**	Observed Spring Flow Volume (4-6):	**40.86**
Total Simulated Storm Volume:	**66.87**	Total Observed Storm Volume:	**61.71**
Simulated Summer Storm Volume (7-9):	**11.59**	Observed Summer Storm Volume (7-9):	**6.77**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	4.63	10	
Error in 50% lowest flows:	-0.98	10	
Error in 10% highest flows:	-0.95	15	
Seasonal volume error - Summer:	27.12	30	
Seasonal volume error - Fall:	2.59	30	
Seasonal volume error - Winter:	-10.50	30	
Seasonal volume error - Spring:	8.82	30	
Error in storm volumes:	8.37	20	
Error in summer storm volumes:	71.09	50	

To further validate the hydrologic parameters, hourly model output was compared to discrete flow measurements at several sampling stations throughout the Hanalei Bay watershed, including two stations in both the Waipa and Waioli watersheds (see Figure

B-7 for station locations and Figures D-1 through D-5 of Appendix D for graphical comparisons of modeled and observed flow). This comparison is important because it tests parameter values calibrated and validated in the Hanalei River watershed in two additional watersheds draining to Hanalei Bay.

The observed measurements were not collected during storm events; therefore, this comparison addresses background flow conditions. Figures D-1 through D-5 of Appendix D illustrate that the model closely matches the observed flow on the days sampled. Although these comparisons are not as robust as the calibration and validation performed using continuous stream flow measurements, they confirm the applicability of the hydrologic parameters throughout the Hanalei Bay watershed.

Two storm events were sampled during the spring of 2006 at an ISCO® automatic sampler located above the head of tide in the Hanalei River: March 9, 2006 and March 16, 2006. Along with water quality samples, stage data were collected; however, a site-specific rating curve was not available to determine stream flow at the sampler location (in subwatershed 110). Since modeled and observed stream flow at the sampler could not be compared, observed sub-hourly flow at the USGS gage (subwatershed 116) was used as a surrogate for the ISCO® flow to obtain a general idea about model fit during storm events.

Figures D-6 and D-7 of Appendix D show the flow results for the two storm events. While the exact hydrograph is not captured for the March 9, 2006 storm, the model is predicting flow at a similar magnitude during the storm (Figure D-6 of Appendix D). The March 16, 2006 storm is more difficult to interpret since the model is not predicting peaks in flow during the sampled storm event (Figure D-7 of Appendix D). Figure D-8 of Appendix D illustrates the entire week surrounding the March 16, 2006 storm. This graph indicates that the model is following the expected flow pattern based on the available precipitation data; therefore, this discrepancy between modeled and observed storm flows is considered acceptable.

As stated previously, because runoff and resulting streamflow are highly dependent on rainfall, occasional storms were over-predicted or under-predicted depending on the spatial variability of the meteorologic and gage stations. These discrepancies are expected in a modeling study. Their magnitude and frequency in the current study are determined to be acceptable. Overall, the model performed well at predicting stream flow and volume under a variety of hydrologic and seasonal conditions and the calibrated hydrologic parameters are considered applicable throughout the Hanalei Bay watershed.

B-2.2.2. Water Quality Simulations

After the model was calibrated and validated for hydrology, water quality simulations were performed for May 2001 through May 2006. Sediment, *enterococcus*, and nutrients were modeled using the approaches described in Section B-2.1.8. The USGS location (located in subwatershed 116) was used as the water quality calibration station because it

had the most robust dataset of the freshwater stations. The other water quality monitoring stations presented in Figure B-7 and Table B-6 were used for model validation.

Key considerations in the water quality simulations included the frequency and magnitude of the predicted constituents. Model evaluation was performed through interpretation of the time-variable plots. Time-variable plots of observed versus modeled concentrations provided insight into the model's representation of the frequency and magnitude of each constituent. The following sections describe the methodology used to adjust the water quality parameters and the model calibration and validation results, including a summary of the observed data used for comparison.

B-2.2.2.1. Calibration Methodology

As described in Section B-2.1.8, *enterococcus*, ammonia, and nitrite plus nitrate were simulated using build-up/wash-off processes and total phosphorous and organic nitrogen were modeled as sediment-associated constituents. These two methodologies are described below.

B-2.2.2.1.1. Build-up/Wash-off Water Quality Simulations

The build-up/wash-off modeling process included identifying starting values for parameters relating to land cover-specific accumulation rates (ACQOP) and buildup limits (SQOLIM) for *enterococcus*, ammonia, and nitrite plus nitrate. These starting values were used to perform the initial simulations. To assess model fit with available data, the time series model output was graphically compared to the observed data. Model calibration consisted of adjusting the ACQOP and SQOLIM parameter values for *enterococcus*, ammonia, and nitrite plus nitrate for the different land covers to minimize the difference between model output and the observed data at the USGS gage, while ensuring that the parameter values remain realistic. Once the model had a similar frequency and magnitude when compared to observed data, model simulations were performed for validation of the calibrated parameters at the validation stations identified in Figure B-7 and Table B-6. This iterative process of modifying the ACQOP and SQOLIM parameter values and comparing the results with observed data was repeated until a reasonable fit was achieved for the calibration and validation stations. Calibration and validation results are presented in Section B-2.2.2.2.

B-2.2.2.1.2. Sediment Associated Water Quality Simulations

The sediment-associated modeling process initially involved the simulation of TSS, followed by total phosphorous and organic nitrogen. TSS was simulated using the sediment modules in LSPC. Several parameters are associated with these modules and the key parameters adjusted during calibration are identified below:

- *KRER* is the coefficient in the soil detachment equation
- *JRER* is the exponent in the soil detachment equation
- *KSER* is the coefficient in the detached sediment wash-off equation
- *JSER* is the exponent in the detached sediment wash-off equation
- *ACCSDP* is the rate at which solids accumulate on the land surface (used in impervious land)
- *REMSDP* is the fraction of solids storage which is removed each day when there is no runoff, for example, because of street sweeping (used in impervious land)

These parameters have land-use-specific values and were also varied by soil category since the steep-slope soil type has the potential to contribute greater sediment loads to the watershed. Initial parameter values were obtained from previous modeling studies and were used to perform the baseline simulations. The modeled TSS values were graphically compared with observed data at the calibration station. The initial parameter values were then adjusted to more closely match the frequency and magnitude of observed TSS, while ensuring that the parameter values remained realistic. After the model achieved a good fit with observed TSS at the calibration station, simulations were performed to compare model results with observed data at the validation stations (identified in Figure B-7 and Table B-6). Similar to the build-up/wash-off methodology, this iterative process was repeated until a good fit was obtained between modeled and observed TSS at the calibration and validation stations. Calibration and validation results for TSS are presented in Section B-2.2.2.2.

After TSS was calibrated and validated, the sediment-associated parameters were simulated. Several parameters are associated with the sediment-associated general quality processes and the key parameters adjusted during calibration are identified below:

- *POTFW* is the wash-off potency factor
- *POTFC* is the background concentration potency factor
- *IOQC* is the concentration of constituent in interflow outflow
- *AOQC* is the concentration of constituent in groundwater outflow

Similar to the other parameters, land-use-specific values for total phosphorous and organic nitrogen were used for most of these parameters to represent the properties associated with different land cover types. Initial parameter values were input from previous studies and baseline simulations were subsequently performed. The modeled total phosphorous and organic nitrogen values were graphically compared to observed data at the USGS calibration station. Organic nitrogen data were not available for comparison with modeled results; therefore, the simulated organic nitrogen, ammonia, and nitrite plus nitrate were summed and compared to the observed total nitrogen values during calibration and validation. The initial parameters were adjusted to obtain a good fit between modeled and observed concentrations. Once the model followed the frequency and magnitude of observed total phosphorous and nitrogen, simulations were performed to compare model results with observed data at the validation stations (Figure B-7 and Table B-6). This process was repeated until a good fit was obtained between

modeled and observed concentrations at both the calibration and validation stations. Results are presented in Section B-2.2.2.2.

B-2.2.2.2. Calibration and Validation Results

The model was calibrated and validated by comparing hourly model output with observed data. The vast majority of the observed data were grab samples collected at nine stations throughout the Hanalei Bay watershed (Figure B-7 and Table B-6). One freshwater location, the Upper ISCO station, had data for three samples during a storm event. The datasets used for TSS, *enterococcus*, ammonia, nitrite plus nitrate, total nitrogen, and total phosphorous calibration and validation are summarized in Table B-9 through Table B-14, respectively.

Table B-9. Summary of the TSS Water Quality Data

Station Name	Subwatershed Identification Number	Sampling Period	Number of Samples	Summary Statistics (mg/L)				
				Minimum	Maximum	Mean	Geometric Mean	Median
Hanalei Upper	112	11/5/01-12/16/02	4	0.50	3.00	1.63	1.32	1.50
Upper ISCO	110	3/9/06-3/16/06	2	101.75	196.00	148.88	141.22	148.88
USGS	116	10/31/03-3/16/06	25	0.80	168.00	20.47	5.60	2.90
Waioli Lower	201	11/5/01-9/22/03	5	0.50	3.00	1.30	1.08	1.00
Waioli Upper	202	11/5/01-9/22/03	5	0.50	2.00	1.10	1.00	1.00
Waipa Lower	303	11/6/01-9/20/04	8	0.50	4.00	1.36	1.14	1.00
Waipa Upper	304	8/1/03-9/20/04	7	0.20	3.00	1.17	0.84	1.00

Table B-10. Summary of the *Enterococcus* Water Quality Data

Station Name	Subwatershed Identification Number	Sampling Period	Number of Samples	Summary Statistics (#/100mL)				
				Minimum	Maximum	Mean	Geometric Mean	Median
Convergence	112	5/5/01-5/3/03	9	6.3	251.0	106.9	60.3	93.3
Snapshot - Gage	113	5/5/01-5/3/03	7	10.0	374.0	108.8	62.2	56.5
Upper ISCO	110	3/9/06-3/16/06	2	573.0	993.0	783.0	754.3	783.0
USGS	116	10/6/03-5/18/06	138	1.0	24196.0	473.8	75.5	55.6

Table B-11. Summary of the Ammonia Water Quality Data

Station Name	Subwatershed Identification Number	Sampling Period	Number of Samples	Summary Statistics (mg/L)				
				Minimum	Maximum	Mean	Geometric Mean	Median
Hanalei Upper	112	11/5/01-12/16/02	4	0.001	0.004	0.002	0.001	0.001
Upper ISCO	110	3/9/06-3/16/06	2	0.001	0.002	0.002	0.002	0.002
USGS	116	10/31/03-3/16/06	26	0.001	0.018	0.005	0.003	0.003
Waioli Lower	201	11/5/01-8/4/03	4	0.001	0.006	0.004	0.003	0.004
Waioli Upper	202	11/5/01-8/4/03	4	0.001	0.009	0.006	0.004	0.006
Waipa Lower	303	11/6/01-9/20/04	8	0.001	0.003	0.002	0.001	0.002
Waipa Upper	304	8/1/03-9/20/04	7	0.001	0.006	0.002	0.002	0.001

Table B-12. Summary of the Nitrite Plus Nitrate Water Quality Data

Station Name	Subwatershed Identification Number	Sampling Period	Number of Samples	Summary Statistics (mg/L)				
				Minimum	Maximum	Mean	Geometric Mean	Median
Hanalei Upper	112	11/5/01-12/16/02	4	0.002	0.007	0.005	0.004	0.005
Upper ISCO	110	3/9/06-3/16/06	2	0.018	0.026	0.022	0.022	0.022
USGS	116	10/31/03-3/16/06	26	0.000	0.086	0.018	0.007	0.010
Waioli Lower	201	11/5/01-9/22/03	5	0.007	0.042	0.023	0.017	0.023
Waioli Upper	202	11/5/01-9/22/03	5	0.009	0.041	0.027	0.022	0.031
Waipa Lower	303	11/6/01-9/20/04	8	0.004	0.028	0.015	0.012	0.015
Waipa Upper	304	8/1/03-9/20/04	7	0.006	0.032	0.019	0.017	0.018

Table B-13. Summary of the Total Nitrogen Water Quality Data

Station Name	Subwatershed Identification Number	Sampling Period	Number of Samples	Summary Statistics (mg/L)				
				Minimum	Maximum	Mean	Geometric Mean	Median
Hanalei Upper	112	11/5/01-12/16/02	4	0.037	0.074	0.051	0.049	0.047
Upper ISCO	110	3/9/06-3/16/06	2	0.678	0.992	0.835	0.820	0.835
USGS	116	10/31/03-3/16/06	26	0.021	1.000	0.161	0.098	0.094
Waioli Lower	201	11/5/01-9/22/03	5	0.055	0.085	0.071	0.070	0.073
Waioli Upper	202	11/5/01-9/22/03	5	0.057	0.092	0.073	0.072	0.073
Waipa Lower	303	11/6/01-9/20/04	8	0.033	0.101	0.054	0.051	0.052
Waipa Upper	304	8/1/03-9/20/04	7	0.041	0.087	0.058	0.056	0.058

Table B-14. Summary of the Total Phosphorous Water Quality Data

Station Name	Subwatershed Identification Number	Sampling Period	Number of Samples	Summary Statistics (mg/L)				
				Minimum	Maximum	Mean	Geometric Mean	Median
Hanalei Upper	112	11/5/01-12/16/02	4	0.005	0.008	0.006	0.006	0.006
Upper ISCO	110	3/9/06-3/16/06	2	0.263	0.395	0.329	0.322	0.329
USGS	116	10/31/03-3/16/06	26	0.007	0.480	0.052	0.026	0.023
Waioli Lower	201	11/5/01-9/22/03	5	0.006	0.016	0.010	0.009	0.009
Waioli Upper	202	11/5/01-9/22/03	5	0.006	0.010	0.008	0.008	0.008
Waipa Lower	303	11/6/01-9/20/04	8	0.005	0.026	0.011	0.010	0.009
Waipa Upper	304	8/1/03-9/20/04	7	0.005	0.039	0.013	0.011	0.009

To assess the predictive capability of the model, the output was graphically compared to observed data. Appendix E presents the results of the water quality calibration and validation by constituent. Specifically, Figures E-1 through E-6 of Appendix E present the calibration results for each pollutant at the USGS station. Figures E-7 to E-39 of Appendix E represent the validation results for each subwatershed containing a validation station (Table B-6). The calibration results indicate that the model is predicting observed water quality constituents within the range of observed data (ranges are presented in Table B-9 through Table B-14) and at a similar frequency. The validation results support

this conclusion; however, it often appears that the model is generally over-predicting the water quality concentrations during validation. This is due to the fact that most of the grab samples used for comparison were not obtained during storm peaks. In addition, the temporal scale of the graphs in Appendix E does not portray the hour-to-hour model results that include a range of concentrations. The model more closely matches the observed patterns in the subwatersheds with more observed data for comparison (as evident in the calibration plots), indicating that the calibrated parameters accurately represent the overall conditions in the watershed.

Figures E-40 and E-41 of Appendix E present modeled pollutographs and observed data for TSS, ammonia, nitrite plus nitrate, total nitrogen, and total phosphorous, along with their associated hydrographs for the March 9, 2006 and March 16, 2006 storm events sampled at the Upper ISCO station (Figure B-7). These pollutographs indicate that the model generally under-predicts the sediment-associated constituents (TSS, total nitrogen, and total phosphorous) and over-predicts the ammonia and nitrite plus nitrate. For the March 16, 2006 storm event, the observed rainfall does not correspond with the observed flow for this event; therefore, the model does not respond similar to the observed data. Figure D-8 of Appendix D illustrates that the model is following the expected patterns based on the available precipitation data.

The observed TSS, total nitrogen, and total phosphorous results during these events were much higher than other observed data in the watershed, as illustrated by Figures E-2, E-5, and E-6 of Appendix E for subwatershed 116 and Figures E-10, E-28, and E-34 of Appendix E for subwatershed 110 (which contains the Upper ISCO sampling station). There are several possible explanations for these higher values:

- All other measurements may have been taken during low flow conditions and therefore their sediment (and corresponding total nitrogen and total phosphorous) levels are much lower than the storm samples collected in March 2006;
- There is an unusual condition in the watershed, which was excluded as an input to the model, that may have contributed to the high sediment loadings; or
- The high values may be due to sampling or laboratory error.

Box plot graphs were developed as additional tools to evaluate water quality calibration and validation. These graphs show the minimum, mean, and maximum modeled values for the dates with corresponding observed data. Figures E-42 through E-47 of Appendix E illustrate these results for each constituent at the USGS gage station during model calibration and Figures E-48 through E-80 of Appendix E represent the validation results for each pollutant at each subwatershed. These plots support the conclusions from the time-series graphs presented in Figures E-1 through E-39 of Appendix E and indicate that the model is generally predicting TSS, *enterococcus*, ammonia, nitrite plus nitrate, total nitrogen, and total phosphorous concentrations within the range of observed data. Some measurements are over- or under-predicted depending on the available rainfall.

Overall, the model appears to reproduce the magnitude of observed data well. Deviations from the observed data may be caused by localized storms that resulted in higher or lower

loadings, which are determined by the associated modeled flow. This flow is dependent on the proximity of the storm to the meteorological station and model subwatersheds.

B-2.3. Link to Receiving Water Model

After completing model calibration and validation for hydrology and water quality, the model was applied to obtain hourly flow and water quality concentrations from January 1, 2004 through December 31, 2005 for all of the subwatersheds draining to an estuary or the Hanalei Bay. These model results were incorporated into the receiving water model of the Hanalei River Estuary, Waioli Stream Estuary, Waipa Stream Estuary, Waikoko Stream Estuary, and Hanalei Bay. The calibration and validation of the hydrodynamic and water quality portions of the receiving water model are discussed in Section B-3.

B-3. Receiving Water Model – EFDC

B-3.1. EFDC Modeling Framework

The purpose of the hydrodynamic and water quality model for Hanalei Bay and its estuaries is to mathematically simulate water circulation and the fate and transport of nutrients, TSS, and *enterococcus* in the concerned waters. The model was developed using the Environmental Fluids Dynamic Code (EFDC).

EFDC is a general purpose modeling package for simulating one-, two-, and three-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 at the Virginia Institute of Marine Science for estuarine and coastal applications. This model is now being supported by USEPA 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 sub-model, (2) a water quality sub-model, (3) a sediment transport sub-model, and (4) a toxics sub-model. 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. In this study, only the hydrodynamic and water quality sub-models were applied to simulate Hanalei Bay and its estuaries for TMDL development.

B-3.2. Model Configuration

Configuration of the EFDC model involved identifying and processing bathymetric data, developing model grids, defining boundary and initial conditions, and linkage to the LSPC models for lateral inputs. Three types of boundary conditions were applied to the model: open ocean boundary conditions, lateral flux boundary conditions representing watershed contributions, and meteorological boundary conditions. Open ocean boundaries consist of time-variable tidal water levels, temperature, salinity, and water quality concentrations. The lateral flux boundary conditions include the inflow of water and associated temperature and water quality concentration. The spatial representation of these inflow boundary conditions was determined by mapping the geographical

coordinates of the watershed outlets to the model grid. The meteorological boundary condition is represented using time-variable weather conditions including solar radiation, wind speed and direction, air temperature, atmospheric pressure, relative humidity, and cloud cover conditions.

In hydrodynamic and water quality modeling, initial conditions provide a starting point for the model to march forward through time. An initial temperature, salinity, flow velocity, and water depth were specified for the entire domain. It should be noted that for the time period simulated, the overall model performance was not sensitive to the initial conditions.

The following discussion provides specific details regarding configuration and application of EFDC to Hanalei Bay and the estuaries.

B-3.2.1. Model Dimensions and Grid Generation

The computational domain for the Hanalei Bay and estuaries model includes the entire Bay and the four attached estuaries: Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream. Although EFDC is capable of simulating a system in three dimensions, a vertically-integrated 2-dimensional EFDC model was developed for Hanalei Bay and the estuaries. This was deemed appropriate because insufficient vertical profile data are available to fully characterize the system and support 3-dimensional simulation. Thus, the model grid extends 51 cells longitudinally, 18 laterally, and is represented by a single layer in the vertical plane. It consists of 113 total computational cells (see Figure B-1).

Bathymetry data used in the model for the Bay was based on survey data obtained from the USGS. Currently no bathymetric information is available to accurately characterize the estuaries. Estuarine channel widths were therefore obtained from available GIS data for the region (i.e., stream network), and depths were obtained by extrapolating from the USGS data. These estuarine representations were then refined through the hydrodynamic model calibration process (described in Section B-3.3).

The period of simulation was 2004 and 2005, which was selected based on data availability and consistency with the LSPC model. Specifically, 2005 was identified as the calibration year since it is the only year for which surface water elevation data are available. Additionally, it represents the most complete salinity, temperature, and water quality data for model calibration. The year 2004, another year with significant data, was selected for model validation.

B-3.2.2. Constituent Configuration

For the hydrodynamic model, salinity and temperature were configured to simulate thermodynamics, salt transport, and mass balance in the system. For the water quality

model, the following constituents were simulated to meet the needs for nutrient and bacteria TMDL development:

- Phytoplankton
- Dissolved Organic Phosphorus (DOP)
- Ortho-phosphate (PO_4)
- Dissolved Organic Nitrogen
- Ammonia
- Nitrite plus nitrate
- Bacteria (*enterococcus*)

Since turbidity is not a physical variable that can be directly simulated in the EFDC model, TSS was simulated as a surrogate. TSS and turbidity are highly correlated at lower values (generally associated with lower flows), but their relationship is less predictable at higher values (generally associated with higher flows). These relationships are discussed further in Section B-5. The transport of TSS was simulated using a simplified formulation where only the settling velocity was parameterized to represent lumped interaction between the water column and the channel bed. Full EFDC sediment transport modeling was not feasible due to insufficient data in the estuaries (particularly for geometry, bank and bed composition, etc.).

B-3.2.3. Boundary Conditions

B-3.2.3.1. Open Ocean Boundary Conditions

Hanalei Bay opens to the Pacific Ocean. Its open ocean boundary was represented using seven grid cells in the model (represented by the seven outermost [or northern-most] cells in Figure B-1). This boundary was assigned time-series water levels, temperature, salinity, and water quality concentrations. Ideally, the open ocean boundary condition would be developed using observed tidal data for Hanalei Bay; however, this information was not available for model development. It was indicated on the NOAA- Center for Operational Oceanographic Products and Services (COOPS) website that the tidal conditions at station 1611400 (Nawiliwili) are similar to those in Hanalei Bay, with a phase shift of about 1 hour and an amplitude difference of about 7%. Therefore, the real-time hourly water level data for station 1611400 (Nawiliwili) were used to configure the open boundary condition and represent tidal forces. Phase and amplitude were further refined through the calibration process.

There are no temperature data available in 2004 or 2005 for configuring the open boundary condition, so historical data from 2000 to 2003 at the Pavilion station were used. The Pavilion station data were used because this station is not significantly impacted by watershed flow, as indicated by the salinity data. The temperature open boundary condition was represented on a monthly basis. First, the monthly average temperature for each year was calculated based on the measured data at the Pavilion.

Then the monthly average temperatures of each year were averaged over the four years to derive monthly average temperature.

For the salinity open boundary condition, it was assumed that there is no significant seasonal or day-to-day fluctuation in the ocean salinity. Therefore, a salinity concentration of 35 parts per thousand (ppt) was estimated for the open boundary condition, and this is close to the maximum observed values at the Pavilion and Pinetrees stations.

No water quality data were available for configuring the water quality open ocean boundary conditions. Therefore, a nominal value of 0.001 mg/L was set for all the nutrient concentrations, 0.1 mg/L for TSS, and 10 #/100mL for e*nterococcus*. These values are close to the magnitude of the minimum values observed in the shallow bay areas and are therefore assumed to reasonably represent background ocean levels.

B-3.2.3.2. Lateral Boundary Conditions

Seventeen of the 41subwatersheds were identified as feeding directly into Hanalei Bay and the estuaries (Figure B-20). The flows, temperature, TSS, e*nterococcus*, and nutrient concentrations simulated by the calibrated LSPC watershed model were used to configure their corresponding lateral boundary conditions. Salinity concentrations were set to 0.0 ppt for all watershed flows since they represent freshwater contributions. It should be noted that the nutrient constituents in the LSPC model are not exactly the same as those in the EFDC model. Specifically, the LSPC model simulates organic nitrogen, total phosphorus, ammonia, and nitrite plus nitrate.

In reality, organic nitrogen and phosphorus are composed of both particulate and dissolved portions. However, no data are available to derive a ratio to partition the LSPC simulated organic nitrogen into particulate and dissolved components; therefore, it was conservatively assumed that all the organic nitrogen takes the dissolved form (i.e. dissolved organic nitrogen(EFDC) = organic nitrogen(LSPC)). Another assumption is that the phosphorous:nitrogen ratio for the organic matter follows the Redfield Ratio, i.e., 0.139 (Chapra, 1997). Based on this ratio, the DOP in EFDC can be derived as: DOP(EFDC) = organic nitrogen(LSPC)*0.139. Consequently, PO_4(EFDC) = total phosphorous(LSPC) – DOP(EFDC). Using these assumptions and formulas, the lateral water quality boundary conditions were derived based on the LSPC model results.

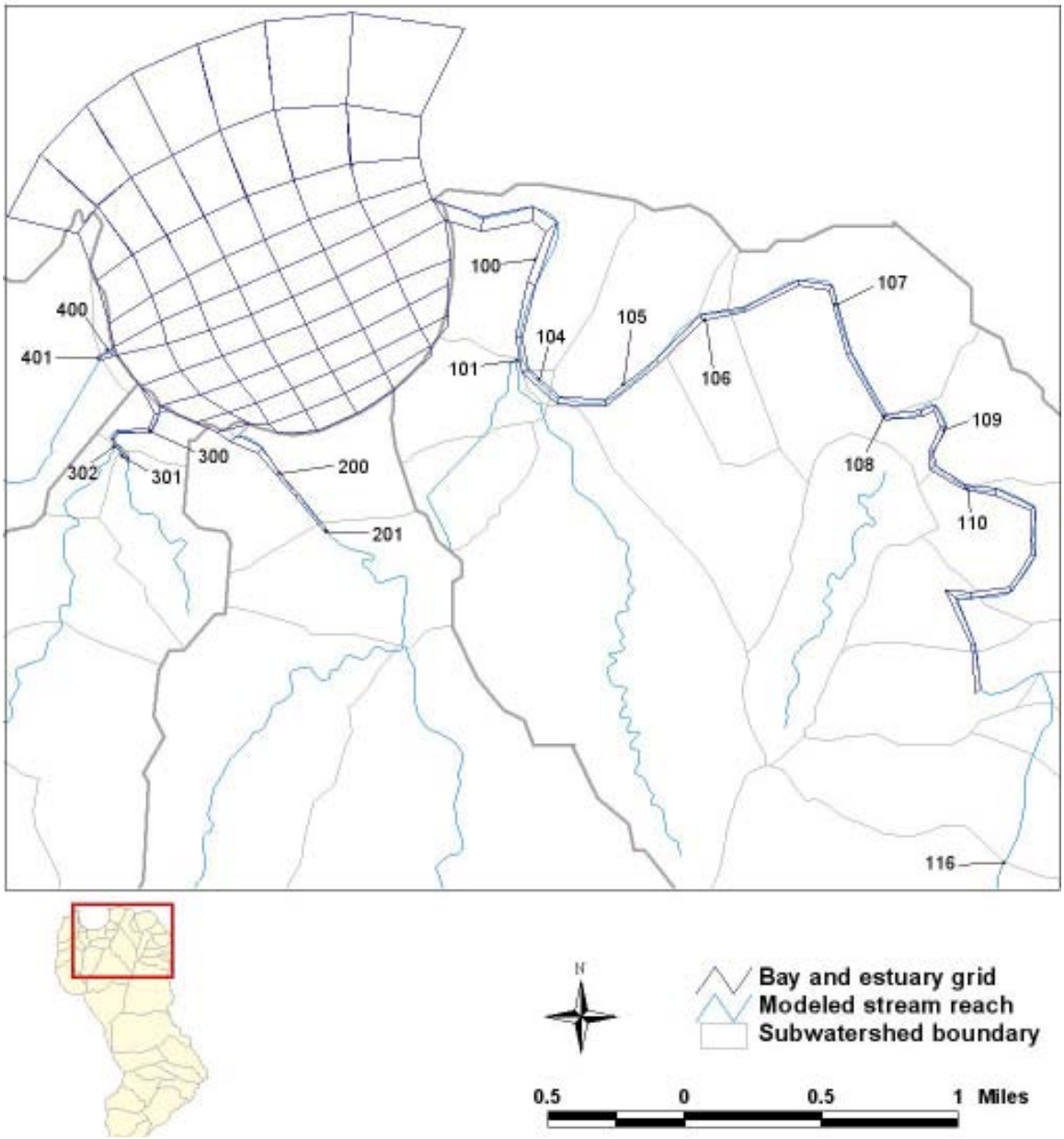

Figure B-20. LSPC inflows to the EFDC model

B-3.2.3.3. Meteorological Boundary Conditions

The Hanalei and Wai'ale'ale precipitation stations used in the LSPC modeling did not record the necessary meteorological parameters for EFDC modeling; therefore additional meteorological stations were identified. There were two surface airway stations from Kaua'i that were in close proximity to Hanalei Bay. These stations were Barking Sands (WBAN 22501) and the Lihue Airport (WBAN 22536). The stations were evaluated based on their proximity to the modeling domain, period of record, parameters measured, and completeness of data. Based on the evaluation, it was found that the Barking Sands

station had significant data gaps for all parameters. Therefore, the Lihue Airport was selected for creating the meteorological file (Figure B-2). Data for 2004 to 2005 were downloaded from the NCDC online site. This station had data for most of the required parameters and provided the most complete temporal data record for model application. It is the closest station to Hanalei Bay that recorded the necessary data for EFDC simulations. Data for dry and wet bulb temperature, dew point temperature, relative humidity, wind speed, wind direction, sea level pressure, and sky conditions for the years 2004 to 2005 were obtained. Sky condition was represented as a fraction of cloud cover derived from the NCDC data. Cloud cover was estimated based on the descriptive sky condition reported in the NCDC data for the meteorological station. The conversions used to represent cloud cover into a scale that conforms to the EFDC format are presented in Table B-15.

Table B-15. Cloud Cover Conversions

Cloud Cover Condition (from NCDC dataset)	Fractional Cloud Cover (for conversion to EFDC format)
CLR: Clear Below 12,000 ft	0.05
FEW: Few	0.25
SCT: Scattered	0.50
BKN: Broken	0.75
VV: Indefinite Ceiling	0.90
OVC: Overcast	0.95

Solar radiation was estimated by calculating the clear sky solar radiation using latitude and longitude, and then adjusting the values based on the estimated cloud cover. The Princeville Ranch 1117 (HI8165) NCDC hourly rain gage (Figure B-2) was used to represent hourly precipitation data for the EFDC model because this station was closer in proximity to the Hanalei Bay than the precipitation station selected for the LSPC model.

B-3.2.3.4. Initial Conditions

A uniform temperature of 22°C and salinity of 34 ppt were specified as the initial condition throughout the water column. The initial water velocity for the entire computation domain was set to 0.0 m/s and water surface elevation was set to 0.0 feet. Sensitivity analysis showed that the model performance is not sensitive to the initial conditions due to the highly dynamic features of the Hanalei Bay-Estuary system.

B-3.3. Hydrodynamic Model Calibration and Validation

B-3.3.1. Hydrodynamic Calibration

Calibration of the EFDC hydrodynamic model was performed through a comparison of model predictions with various observed data, including observed tidal fluctuation, temperature, and salinity in the Hanalei Bay and estuary system. The year 2005 was selected for calibration, because it is the only year for which all data are available. Tidal fluctuation, salinity, and temperature data were available at the Offshore Wall station from the USGS. Data for this station were only available for 76 days in 2005, which does not cover the entire calibration year; therefore, this station could not be used as the open ocean boundary condition. Alternatively, this station was used as a calibration station, thus adding more reliability to the model. In addition, salinity and temperature were also available in other stations distributed throughout the system. In this study, seven stations were identified to have the most complete data set for conducting a model calibration for both hydrodynamics and water quality (in both the bay and the estuaries). These stations are: DU Pond and Weke Road along the Hanalei River Estuary; the Landing, Pinetrees, and the Pavilion stations within the Bay; and the Waioli mouth and Waikoko mouth stations located at the Waioli and Waikoko Stream Estuaries (Table B-16 and Figure B-21).

Table B-16. EFDC Monitoring Station Information

Station Name	Data Collecting Agency	Use in Receiving Water Model Simulations			
		Hydrodynamics		Water Quality	
		Calibration	Validation	Calibration	Validation
DU Pond	Hui	●	●	●	●
Weke Road	DOH; Hui	●	●	●	●
Landing	DOH; Hui	●	●	●	●
Pinetrees	DOH; Hui	●	●	●	●
Pavilion	DOH; Hui	●	●	●	●
Waioli Mouth	Hui	●	●		
Waikoko Mouth	Hui	●	●	●	●
Offshore Wall	USGS	●			

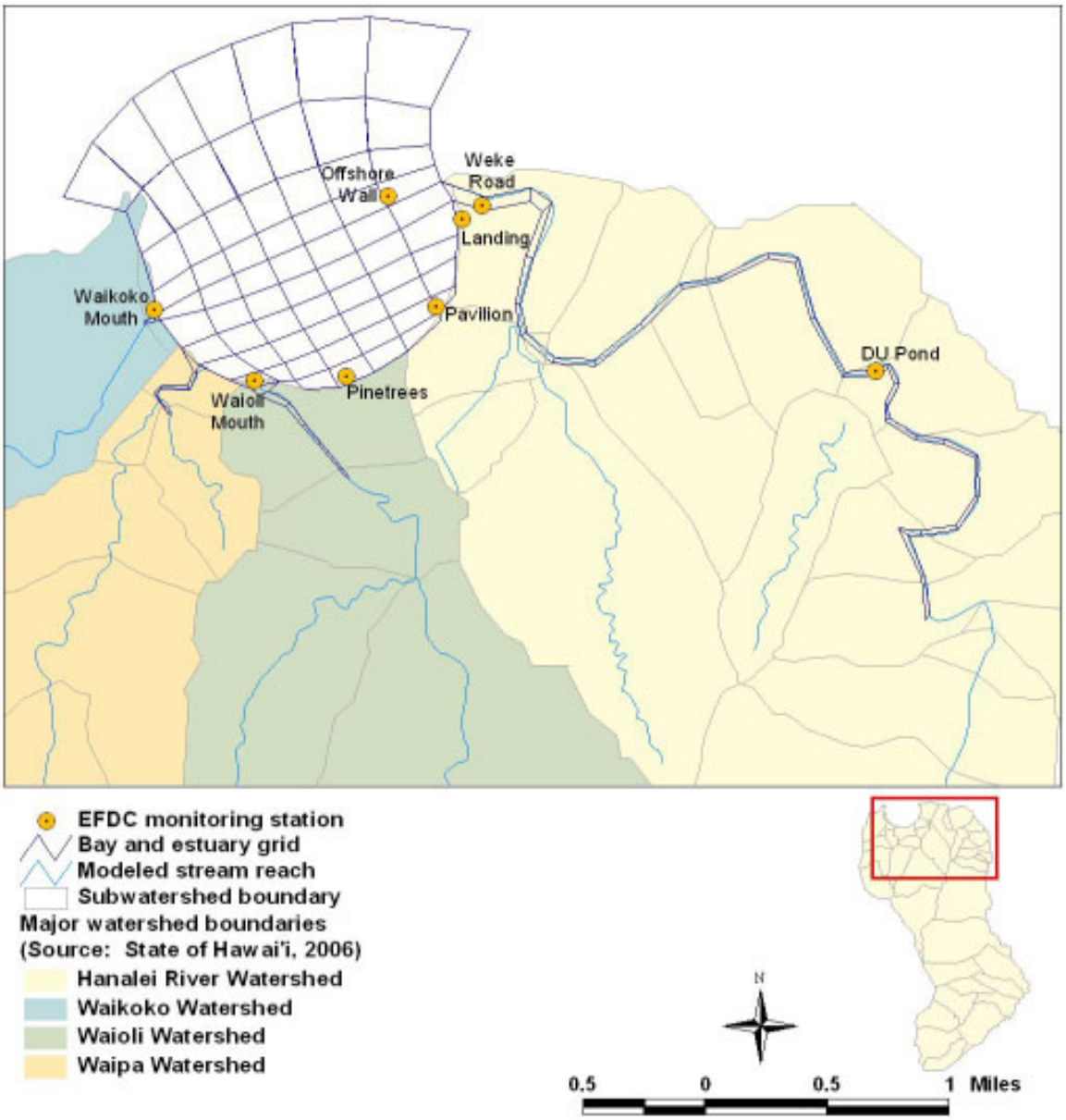

Figure B-21. Monitoring stations used for EFDC model calibration and validation

The hydrodynamic model was configured and run for January 1, 2005 to December 31, 2005, and the simulation results were compared with observed data. The model calibration was conducted by adjusting appropriate parameters until the model predicted the observed data reasonably well. The major parameters that were considered in the calibration include the bed roughness height (BRH), the bathymetry of the estuary channels, and the tidal adjustment factors. The initial configuration of the model included a BRH=0.01 meters, zero tidal adjustment, and channel bathymetry obtained through Bay survey data extrapolation. The model-computed hourly water surface elevations were compared with real-time data (at 4 to 5 minute intervals) from the USGS

measurement located at the Offshore Wall station. Figure B-22 illustrates the model-data comparison for tidal elevations in 2005. As shown, the model captures the general magnitude and temporal pattern of the observed data well. Therefore, no further adjustment to tidal data was considered necessary. Figure B-23 and Figure B-24 illustrate the salinity and temperature results at the Offshore Wall station. The simulated salinity at the Weke Road, Waioli mouth, and Waikoko mouth stations initially deviated from the observed value significantly, indicating that other parameters needed refinement.

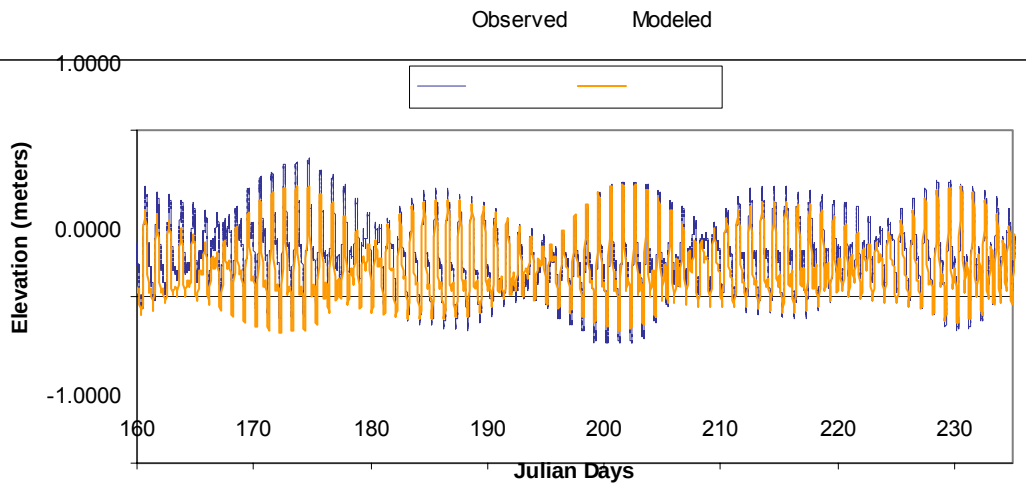

Figure B-22. Modeled and observed water surface elevation at the Offshore Wall station

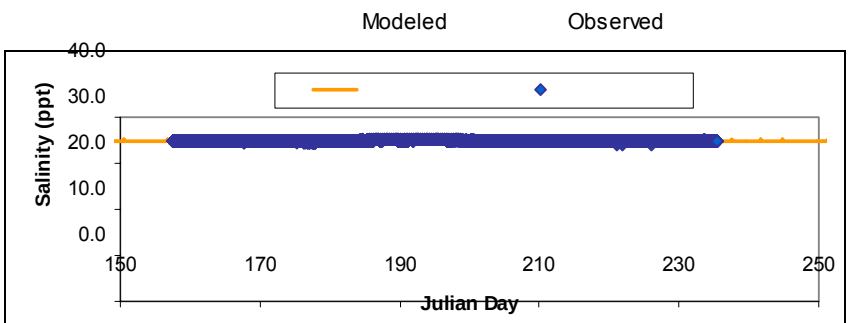

Figure B-23. Modeled and observed salinity at the Offshore Wall station during calibration

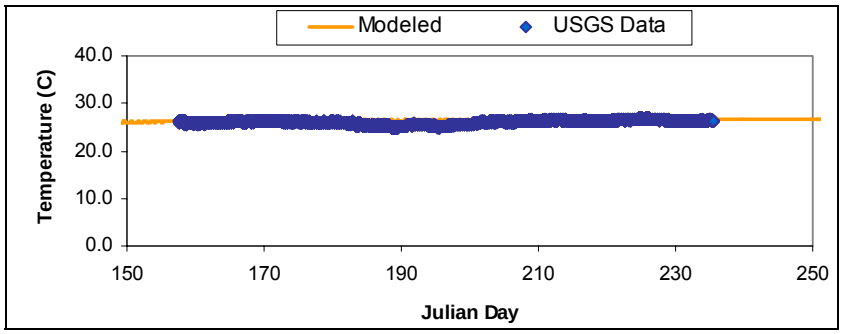

Figure B-24. Modeled and observed temperature at the Offshore Wall station during calibration

Several sensitivity analyses were conducted, and it was determined that the salinity at these locations was insensitive to changes in BRH. Therefore, BRH was fixed at 0.01 m. As discussed in the model configuration section, the major uncertainty associated with the model configuration was the channel depth, since no data were available for these estuaries. Therefore, the bathymetry of these river channels was gradually adjusted to achieve a better match between the simulated and observed salinity. Figure B-25 shows the model-data comparison for salinity after a number of iterations in bathymetry adjustment. As shown in these graphs, the model is able to simulate the general trends and magnitude of the observed data. In addition, the model-simulated temperature was compared with observed data in Figure B-26. All of these figures show that the model has reproduced the main hydrodynamic parameters including surface elevation, salinity, and water temperature well.

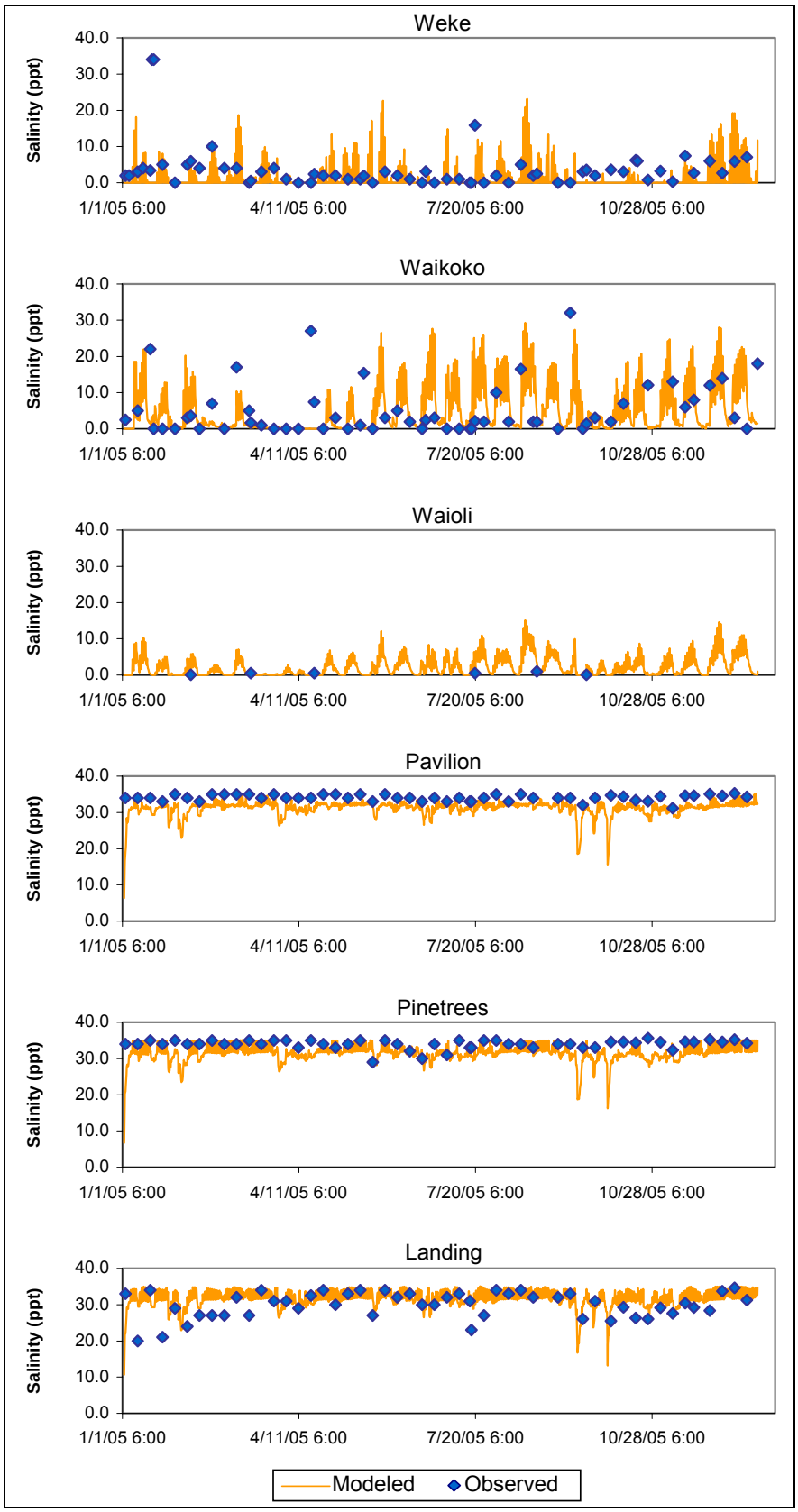

Figure B-25. Modeled and observed salinity at various stations during calibration

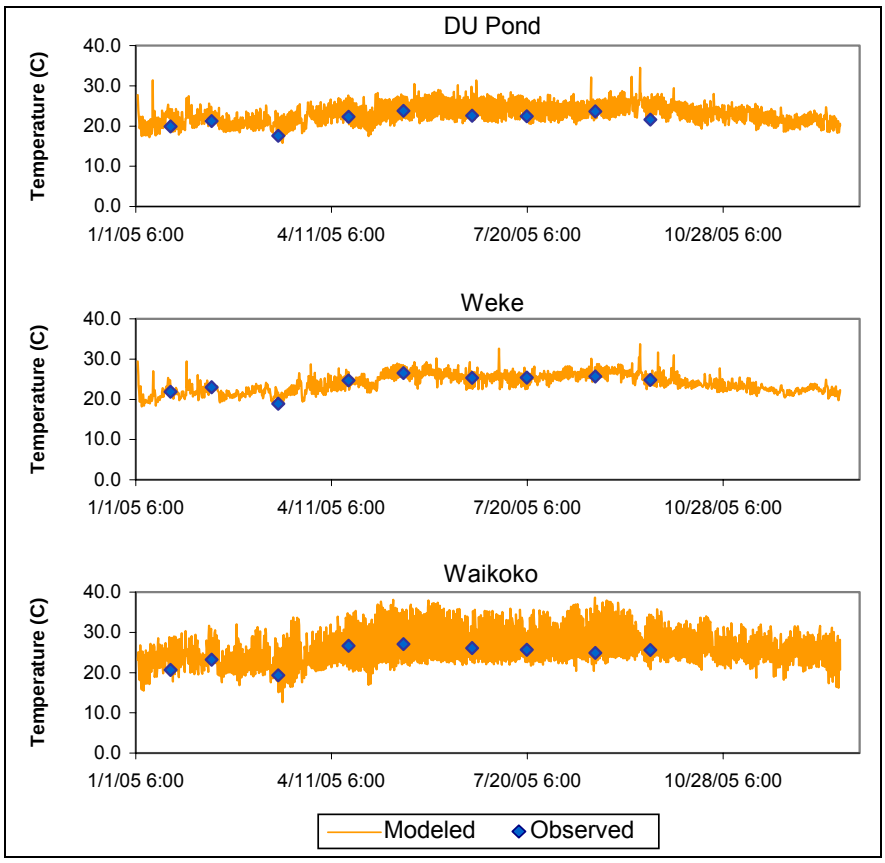

Figure B-26. Modeled and observed temperature at various stations during calibration

B-3.3.2. Hydrodynamic Validation

Model validation was conducted to corroborate the model calibration. The hydrodynamic model that was calibrated using 2005 data was directly applied to the year 2004, which has a fairly good quantity of data, which can be used to evaluate model performance. The model was configured using the tidal, meteorological, and watershed inflows of 2004, with all other parameters identical to those in the calibration run. Model simulations were performed and the results were directly compared with observed data in 2004. Figure B-27 and Figure B-28 show the model-data comparison for salinity and temperature, respectively. As shown, the model performs similarly to the calibration run and is therefore considered calibrated and validated for hydrodynamics.

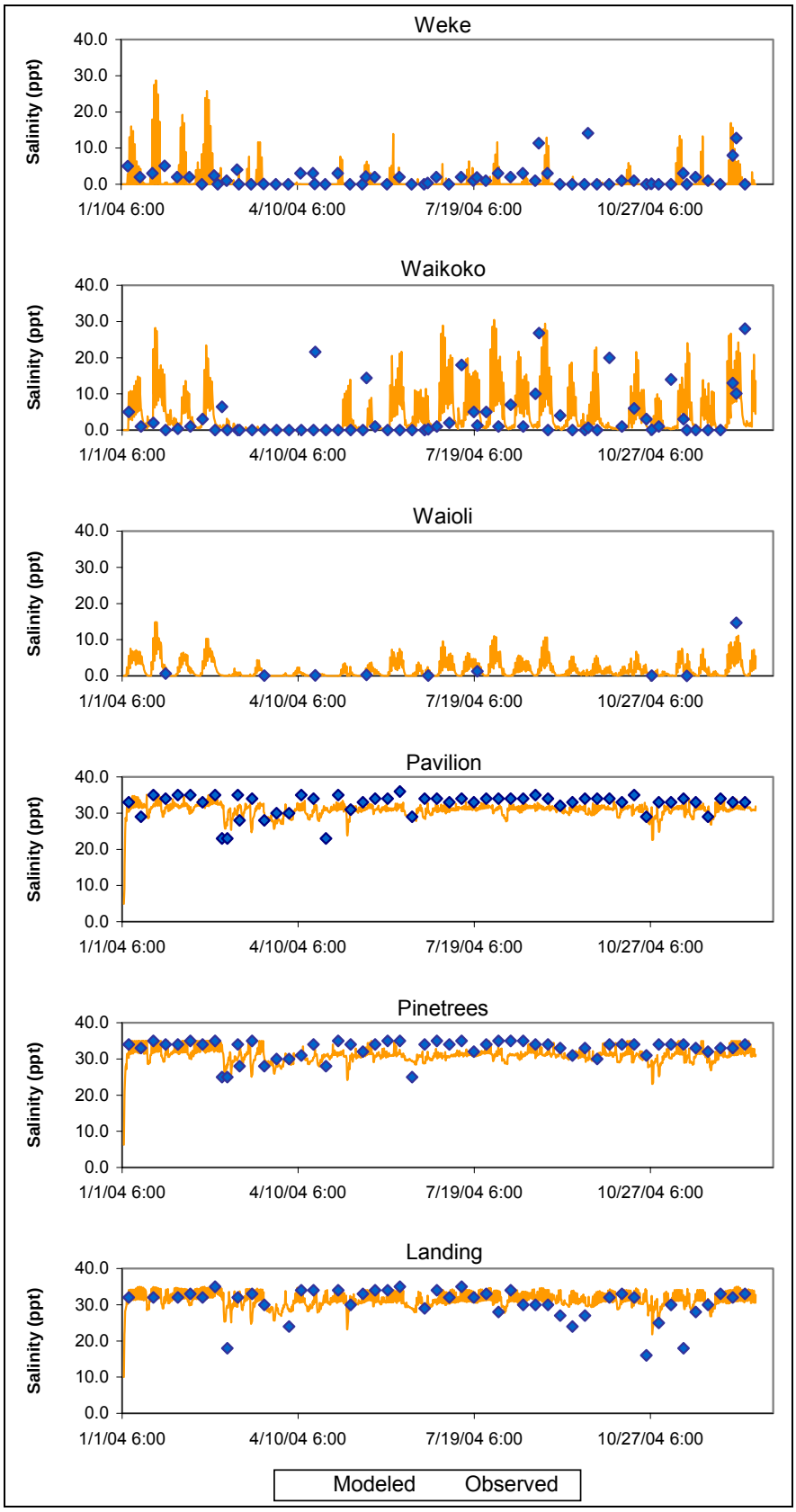

Figure B-27. Modeled and observed salinity at various stations during validation

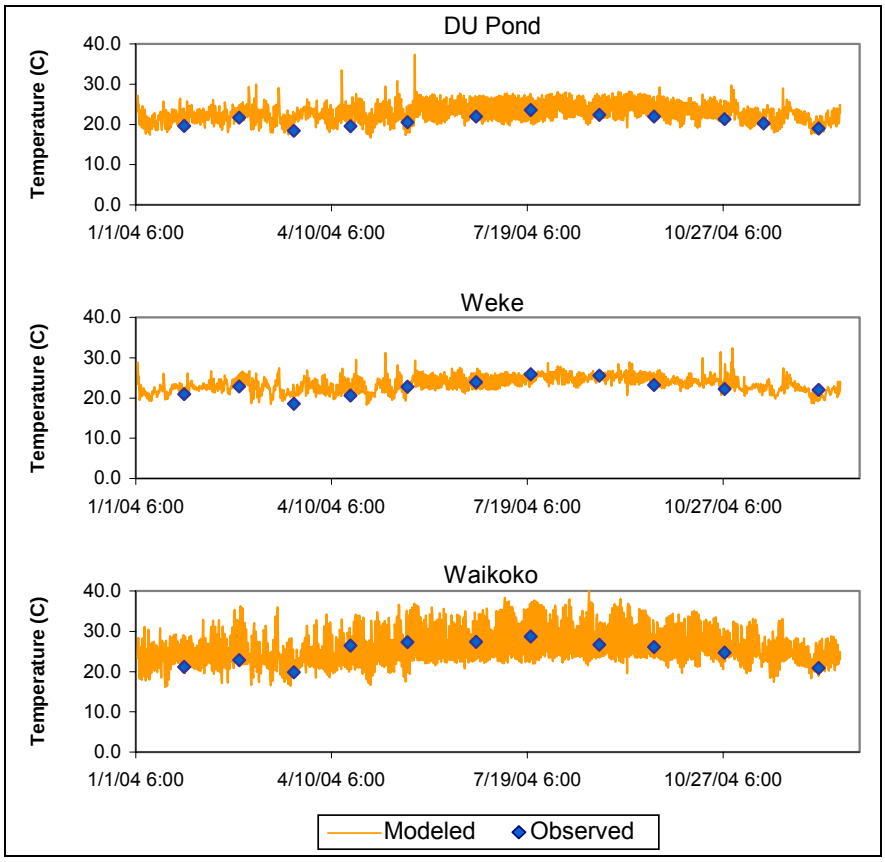

Figure B-28. Modeled and observed temperature at various stations during validation

B-3.4. Water Quality Model Calibration and Validation

B-3.4.1. Water Quality Calibration

Water quality calibration was performed for the same period as the hydrodynamic calibration, which involved an iterative process of adjusting key model kinetic parameters to achieve a reasonable match between model predictions and observed concentrations. Initially, the EFDC water quality model was configured using the loading rates generated by the calibrated LSPC watershed model, and model simulations were performed from January 1, 2005 to December 31, 2005. The model-simulated organic nitrogen, DOP, PO_4, ammonia, nitrite plus nitrate, TSS, and *enterococcus* concentrations were compared with the observed data. It was found that the model was able to reproduce the TSS and *enterococcus* with this initial setup; however, the model significantly under-predicted the nutrient concentrations. Therefore, model calibration focused on the nutrient components.

Simulated nutrient concentrations appeared to be insensitive to the corresponding kinetic parameters when the values of these parameters were set within a reasonable range. This

can be explained by the fact that the Hanalei Bay and estuary system is a small, but highly dynamic system. The retention time for water quality constituents is too short for kinetic processes to generate significant impacts on water quality. The key driving force on water quality is the loading rate and dynamic transport processes (hydrodynamics) in the estuaries and Bay. Since hydrodynamics were well-represented, the primary focus was on refining LSPC loading estimates to the Bay and estuaries. This coupled-calibration process was necessary and justified due to limited data for LSPC model calibration in the most downstream watersheds. The water quality results presented in Appendices E and F for LSPC and EFDC, respectively, reflect the final calibration results for each model.

The EFDC water quality calibration results are presented in Figures F-1 through F-7 of Appendix F. In general, the simulated water quality concentrations show significant temporal and spatial variability, matching the trends shown in the data. For TSS, the model simulated very high peak values following each storm at the stations in the estuaries due to the high contribution from the watershed inflows, and predicted relatively low concentration during non-storm period. Although there are no data available during the storm periods corresponding to those simulated peak values, the model-simulated TSS concentration does match the data for the corresponding period, indicating that the model has represented the source-response relationship for TSS well.

The model also generally reproduced the observed *enterococcus* well, mimicking the spatial and temporal variability. The only significant deviation of the model prediction from the data occurred at the mouth of Waikoko. As shown, the simulated *enterococcus* concentration at the mouth of Waikoko missed several peak values during the last two months of 2005. This can be attributed to the uncertainty in the watershed model (e.g., due to the absence of actual storms in the meteorological data used) or unknown (and thus unsimulated) local impacts.

The comparison of simulated nutrient concentrations and observed data shows that the model has reproduced the general magnitude and trends in the observed data well. The model not only mimics the temporal fluctuation in nutrient concentrations in response to storms, but it also simulates the spatial variability in nutrient concentrations observed in the data. The nutrient concentrations are generally higher at the Waikoko mouth station than at the DU Pond and Weke Road stations, and this is confirmed by the data.

B-3.4.2. Water Quality Validation

To further evaluate the model's predictive capability, the parameters set for the 2005 period were applied to January 1 to December 31, 2004. The water quality model was directly applied to the validation period without further change in model parameters. The boundary conditions, as simulated by the LSPC watershed model for 2004, were incorporated into the model as boundary conditions, with all the other boundary conditions kept the same as in the 2004 hydrodynamic validation run.

Without any further changes, the simulated water quality concentrations, including TSS, *enterococcus*, ammonia, organic nitrogen, DOP, PO_4, and nitrite plus nitrate were compared with the observed data, and good agreement between the model and data was demonstrated (as seen in Figures F-8 through F-14 of Appendix F).

The water quality model's performance for both calibration and validation simulations demonstrates that it is accurately representing the cause and effect response in the Hanalei Bay and estuary system. This is because the estuary-bay model is the recipient of watershed model predictions. Its ability to accurately predict observed values suggests that the linkage to watershed processes is sound (and that watershed model predictions are accurate). During storm events, increased flow and pollutant loading in the Hanalei River, Waioli Stream, Waipa Stream, and Waikoko Stream (due to increased rainfall over the watersheds) result in increased flow and concentrations in the estuaries and bay. The model's predictive ability suggests that it can be used as a scientific tool for analyzing watershed management scenarios and developing TMDLs to protect the water quality in this system.

B-4. Model Assumptions

Assumptions are inherent to the modeling process as the model user attempts to represent the natural system as accurately as possible. The assumptions associated with the LSPC model and its algorithms are described in the HSPF User's Manual (Bicknell et al., 2001). There were several additional modeling assumptions used in the models of the Hanalei Bay watershed, which are described below.

- Land cover practices are consistent for all that fall within a given category and associated modeling parameters are transferable among subwatersheds. Although there may be localized differences in hydrology and/or pollutant conveyance characteristics, detailed data are not available to fully characterize these variations in the model. Thus, the model assumes larger-scale representative conditions. Variability in land cover representation would increase spatial variability of loading estimates.
- Urban land covers in the watershed model consisted of low intensity developed and high intensity developed. The low intensity developed land cover category was assumed to have15 percent effective impervious area, while the high intensity developed consisted of 75 percent impervious cover. These assumptions influence the rate and volume at which water is conveyed to the streams, estuaries, and Bay. Consequently, they also influence pollutant loading characteristics.
- Subwatersheds with a mean slope greater than one standard deviation above the watershed-wide mean slope were assigned to a high-slope soil group and parameterized accordingly in the LSPC model. This increases precision in both hydrology and pollutant loading simulation.
- The agriculture diversion was represented simplistically in LSPC based on an average constant withdrawal of 34 cfs (USFWS, 2005) and 65% of this flow eventually returned to the Hanalei River through the impoundments and taro pondfields (USFWS, 2005; Berg et al., 1997).
- Sediment wash-off from pervious areas occurred via detachment of the soil matrix. This process was considered uniform in the watershed model regardless of the land cover type or season. Though detachment may vary spatially, insufficient data are available to add more resolution to this prediction. Variability in detachment representation would increase spatial variability of loading estimates.
- Sediment in the watershed consisted of 15% sand and 85% finer sediment particles (such as silt and clay). This assumption is consistent with particle size measurements collected in the Hanalei River by the USGS (Penn, 2006).
- Total phosphorous and organic nitrogen were linearly related to TSS. Analysis of available data supports this assumption, as illustrated in Figure B-6. Because nitrite plus nitrate and ammonia were not correlated with sediment, it is assumed that the presence of organic nitrogen is driving the strong relationship between total nitrogen and TSS.
- Total phosphorous and organic nitrogen were bound to a particle during wash off until they dissociated upon reaching the receiving waterbody in the watershed model.

- The weather station assignments and weighting factors, which were adjusted during LSPC hydrology calibration and validation, are assumed representative of the rainfall patterns in the watershed. Precipitation data are a driving factor in the watershed model; therefore, the flow predictions are largely dependent on the rainfall representation.
- Gaps in the precipitation records were patched with nearby stations, as described in Section B-2.1.2. The stations available for patching were assumed to represent the Hanalei Bay watershed well. As described above, precipitation data are a critical component to the watershed model. Accurate rainfall representation is necessary for accurate flow predictions.
- The locational information for the Upper and Lower Waipa stations sampled by the Hawai'i Department of Health Clean Water Branch did not plot near Waipa Stream. For model calibration and validation, these stations were assumed to be located along Waipa Stream closest to where the coordinates originally plotted. Because the actual sampling location and the estimated location are likely in the same subwatershed, this assumption has minimal impact on the water quality calibration and validation.
- The upper extent of the Waioli, Waipa, and Waikoko Estuaries were estimated from the DEM and other waterbody polygon GIS files. These estimates can be refined in future model runs. The location of the upper boundaries impacts the overall flow and pollutant loading characteristics because these parameters are predicted at the bottom of each subwatershed.

Assumptions associated with EFDC modeling of the estuaries and Bay include the following:

- It was assumed that phytoplankton and periphyton are not important contributors to water quality in the Hanalei Bay and estuaries (supported by data); therefore, no additional data collection or model calibration for these two parameters were deemed necessary. This assumption is not expected to significantly influence model results, because available data show that algal activity in the estuary and bay is limited.
- The tidal conditions were assumed to be uniform along the open boundary location. This assumption is not expected to have a significant impact on the water quality simulation due to the relatively small scale of modeling domain. If a larger domain is simulated spatially-variable tidal and current information is desirable.
- It was assumed that there was no significant seasonal or day-to-day variability in ocean salinity outside of Hanalei Bay; therefore a constant salinity was set at the ocean open boundary. This was assumed due to data limitations, however it is not expected to significantly impact model results.
- It was assumed that the water temperature at the Pavilion station was a good approximation of that of the open ocean, thus the open ocean temperature boundary condition was derived based on this data. This assumption is justified through a series of numerical experiments that were performed. They demonstrated that the temperature at the Pavilion is very similar to that at the open boundary.
- It was assumed that the water quality concentrations, including nutrients, bacteria, and TSS, were low in the ocean for all seasons; therefore low background concentrations of these constituents were set at the ocean open boundary. Available

data do not indicate significant off-shore contributions. Both data and model results support the assumption that the primary load contributor to the bay is the watershed.

- It was assumed that a barotropic hydrodynamic current instead of wave action drives the transport processes in the bay and estuaries (an inherent assumption for all hydrodynamic and water quality models). This assumption can result in less dilution of water quality parameters. This is a conservative assumption for TMDL development.
- All organic matters were assumed to be dissolved in the EFDC model due to limited data. This assumption can result in an overestimate of the organic nitrogen and phosphorus in the estuary and bay since the settling loss of particulate organic matter is not represented. This is a conservative assumption for TMDL development.

Many of the assumptions described above are associated with the how the natural system is represented by the models. Significant data are required as model inputs. In some cases, these data are not available and/or not detailed enough to represent all conditions in the watersheds; therefore, assumptions are used to fill the data gaps. Conservative assumptions are used, where possible, in these cases to ensure that the models are protective of environmental conditions. Other assumptions above relate to the models themselves. These are also concerned with how the system is represented, but they are associated with the models, not the data. These assumptions are generally a function of the type of model selected.

B-5. Model Application

The LSPC and EFDC models were used to determine nutrient load reduction targets as well as existing loads and TMDLs for the *enterococcus* and turbidity impaired waterbodies in the Hanalei Bay watershed. The *enterococcus*, TSS (as a surrogate for turbidity), and nutrients existing loads were output for the subwatersheds of interest from both of the models and summarized for the critical TMDL time period of 2004. Subsequently, water quality parameters were reduced in the LSPC model and a series of simulations were performed. These results were incorporated into the EFDC model of the estuaries as lateral boundary conditions until the water quality criteria were achieved in the estuaries. Once the water quality criteria were reached, the associated estuary loadings were output from the model and summarized. These values are the TMDLs. The percent reductions were then calculated by comparing the difference between the existing loads and the TMDLs.

Similar analyses were performed to address the stream TMDLs. Specifically, the water quality parameters were reduced in the LSPC model until the water quality criteria were met. The loadings associated with these model runs were output from the model and summarized to calculate the TMDLs. The existing loads were compared with these values to calculate percent reductions for each pollutant.

Because most of the water quality criteria in the estuary are more stringent than the stream criteria, meeting the estuary criteria will generally ensure that the stream criteria are achieved. If a pollutant was listed in the estuary and the stream, the lower water quality criteria was used to ensure that the waterbody meets the most stringent criteria at all times. This process is described in further detail in the TMDL Report for the Hanalei Bay watershed. In addition, LSPC model output was used to assess land cover-specific contributions to the total existing watershed load for each pollutant, which may be helpful during TMDL implementation. All of these results are presented in the TMDL Report for the Hanalei Bay watershed.

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Appendix C:
Relative Land Cover Loadings

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Hawai'i Department of Health

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Introduction

The charts presented below illustrate the relative pollutant loads by land cover type (i.e. load for Land Cover A divided by the watershed-wide load) for the Hanalei River, Waioli, Waipa, and Waikoko watersheds. These loadings are based on LSPC model output by pollutant for existing conditions in each watershed (see Appendix B for a detailed discussion of the modeling approach and results). The land cover data were obtained from the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program (C-CAP) land cover image from a remote sensing study in 2000 (NOAA, 2000).

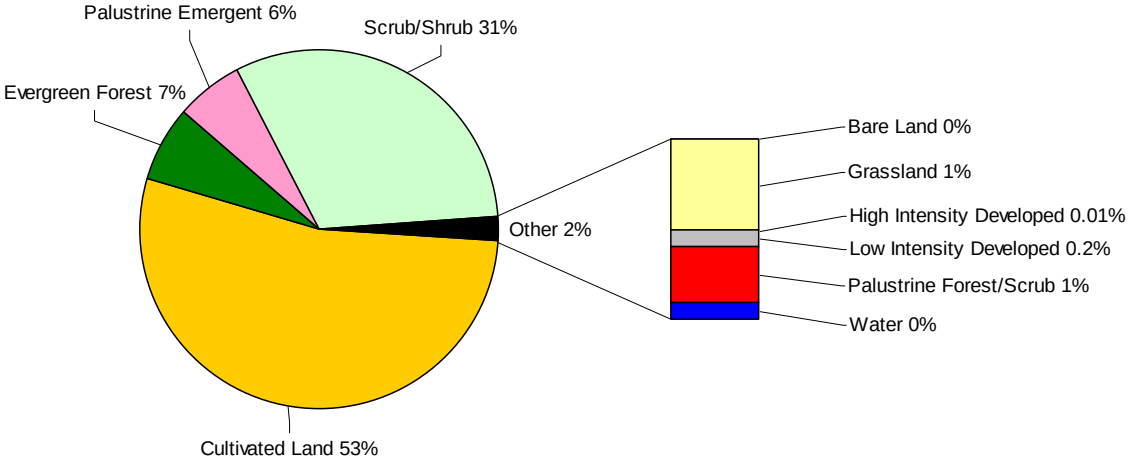

Figure C-1. Relative ammonia land cover loadings for the Hanalei River watershed

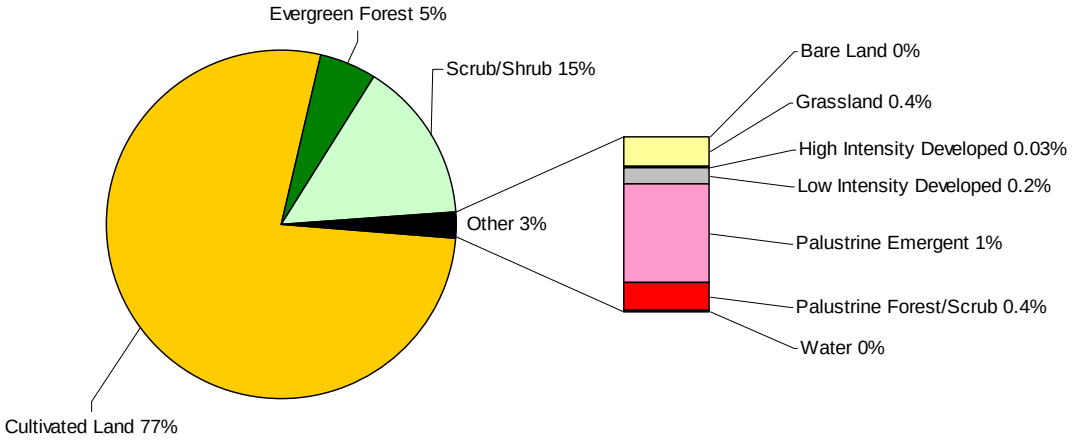

Figure C-2. Relative ammonia land cover loadings for the Waioli watershed

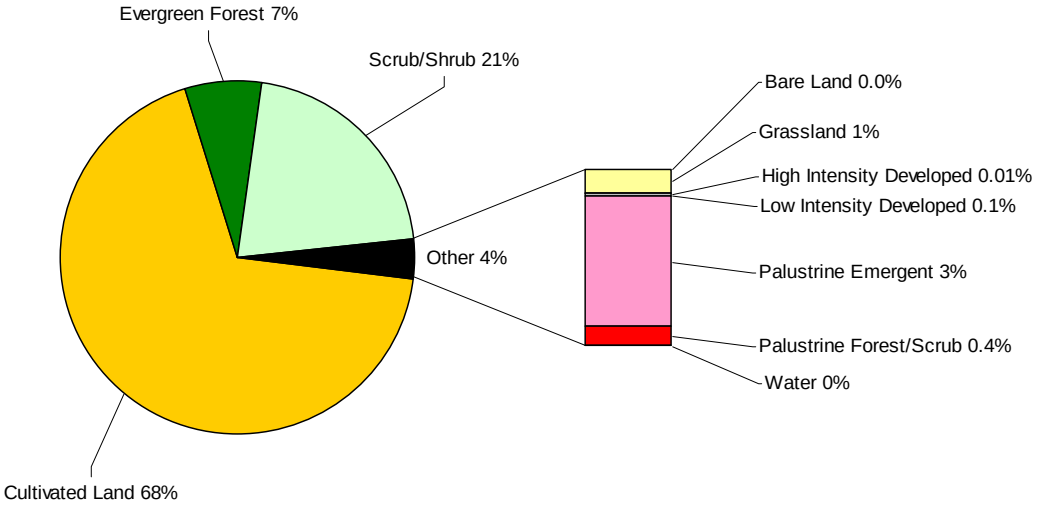

Figure C-3. Relative ammonia land cover loadings for the Waipa watershed

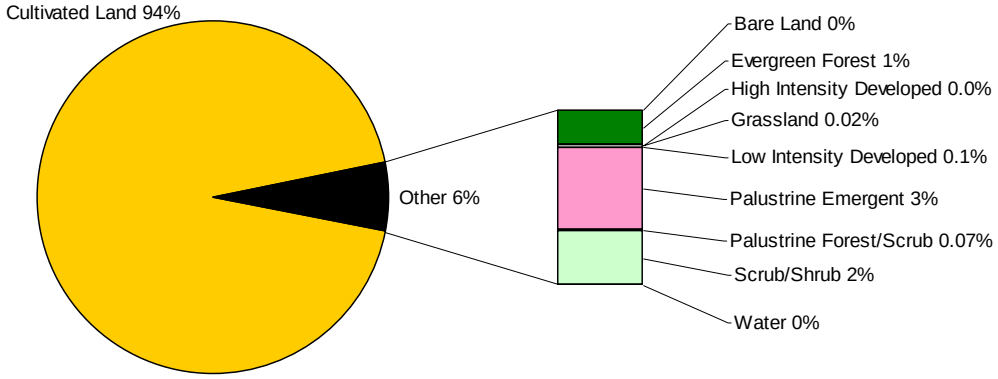

Figure C-4. Relative ammonia land cover loadings for the Waikoko watershed

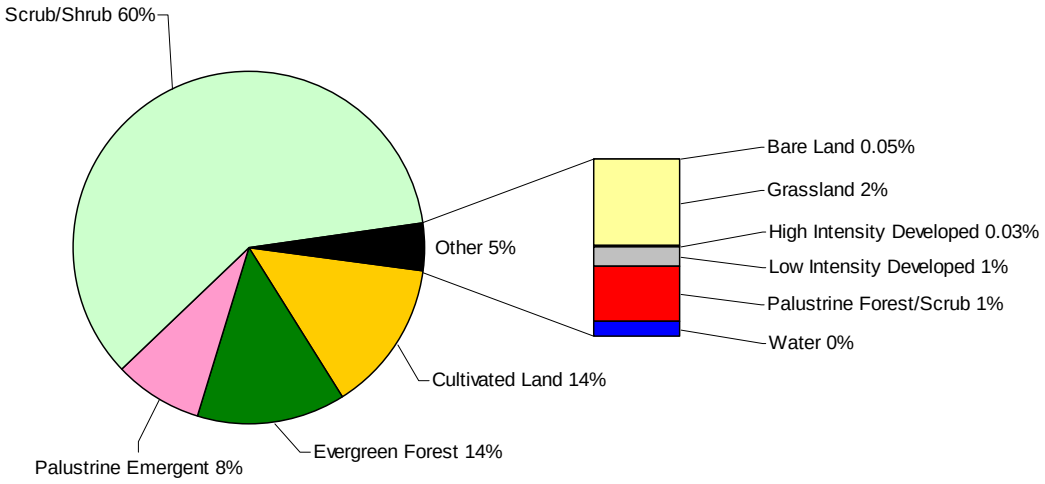

Figure C-5. Relative nitrate plus nitrite land cover loadings for the Hanalei River watershed

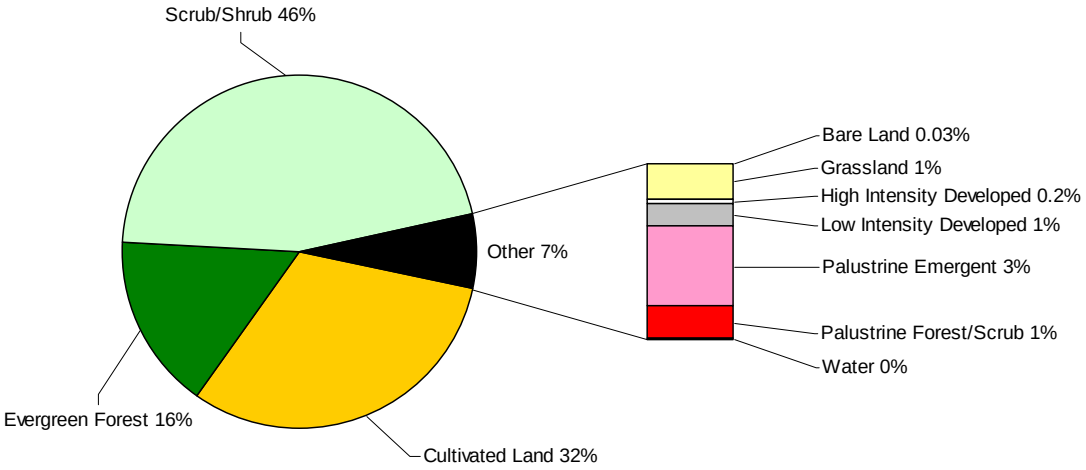

Figure C-6. Relative nitrate plus nitrite land cover loadings for the Waioli watershed

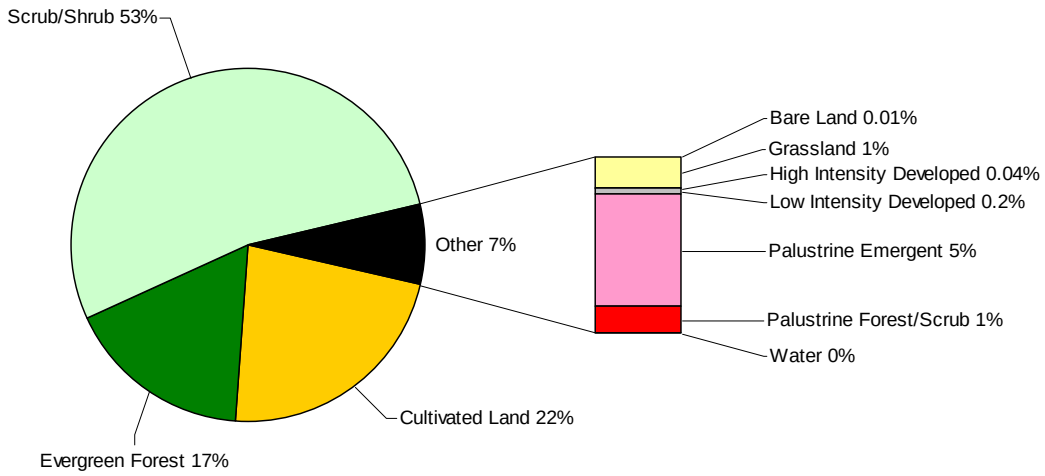

Figure C-7. Relative nitrate plus nitrite land cover loadings for the Waipa watershed

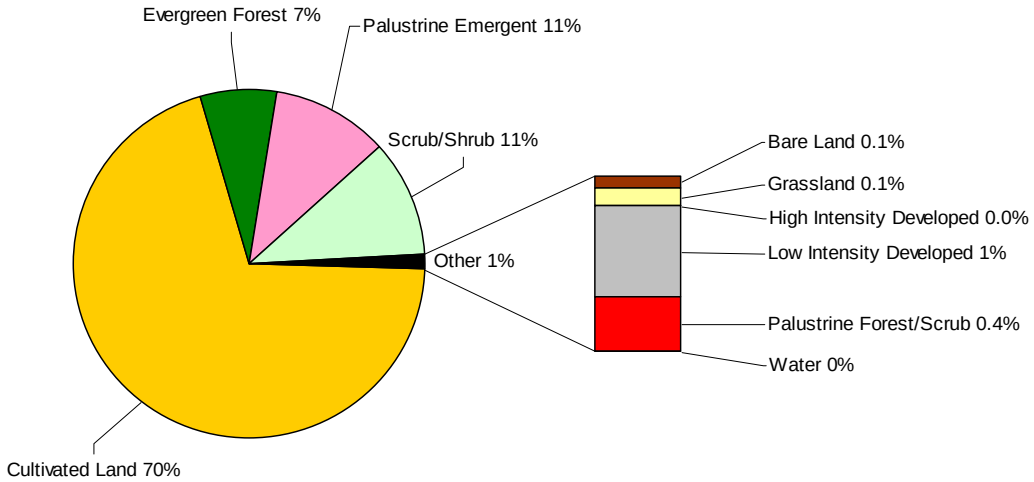

Figure C-8. Relative nitrate plus nitrite land cover loadings for the Waikoko watershed

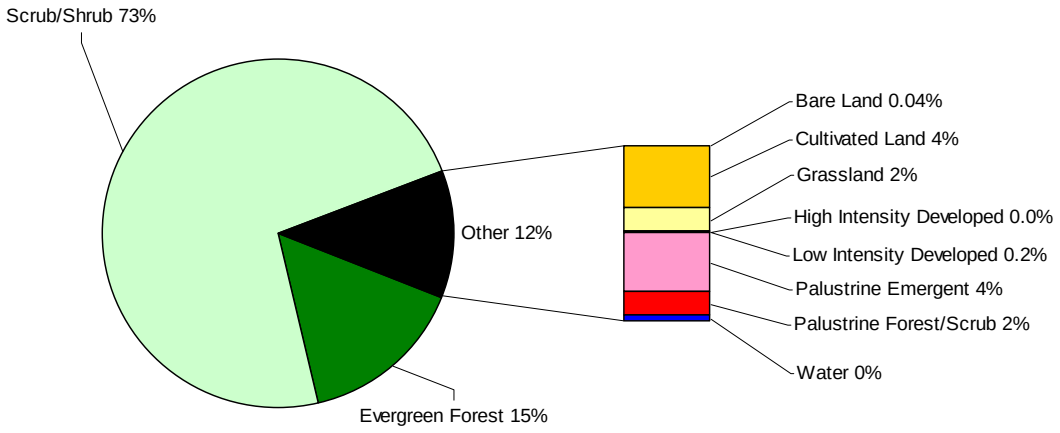

Figure C-9. Relative total nitrogen land cover loadings for the Hanalei River watershed

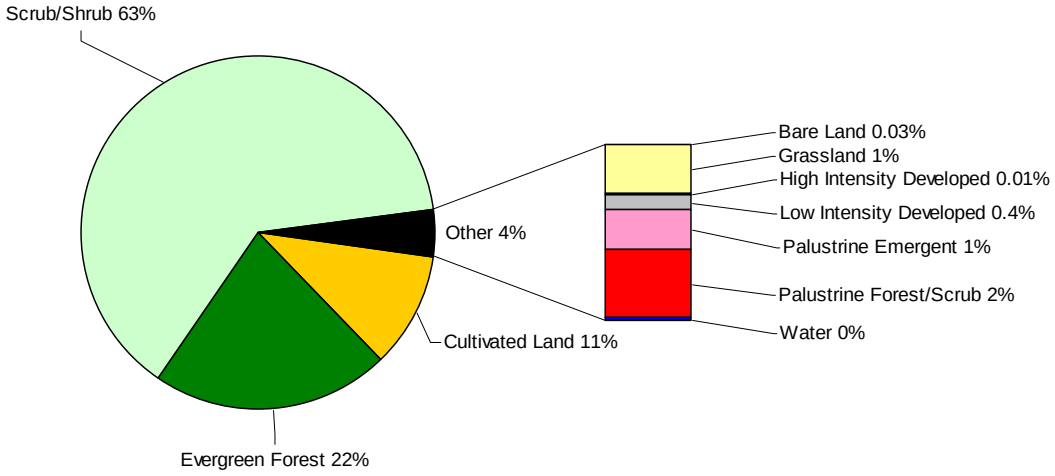

Figure C-10. Relative total nitrogen land cover loadings for the Waioli watershed

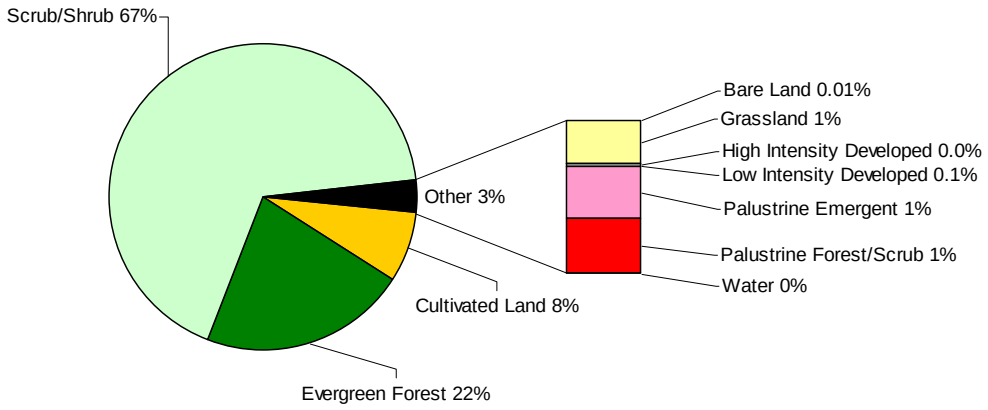

Figure C-11. Relative total nitrogen land cover loadings for the Waipa watershed

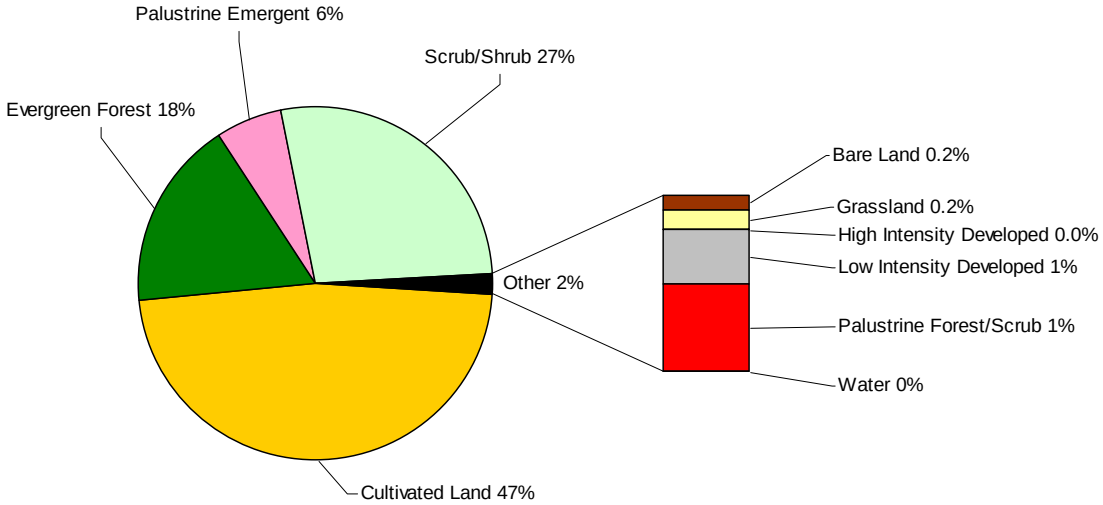

Figure C-12. Relative total nitrogen land cover loadings for the Waikoko watershed

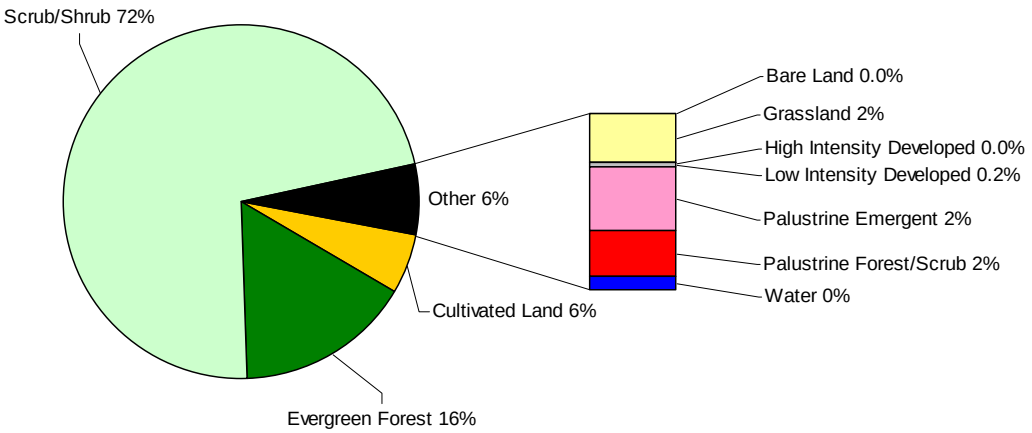

Figure C-13. Relative total phosphorus land cover loadings for the Hanalei River watershed

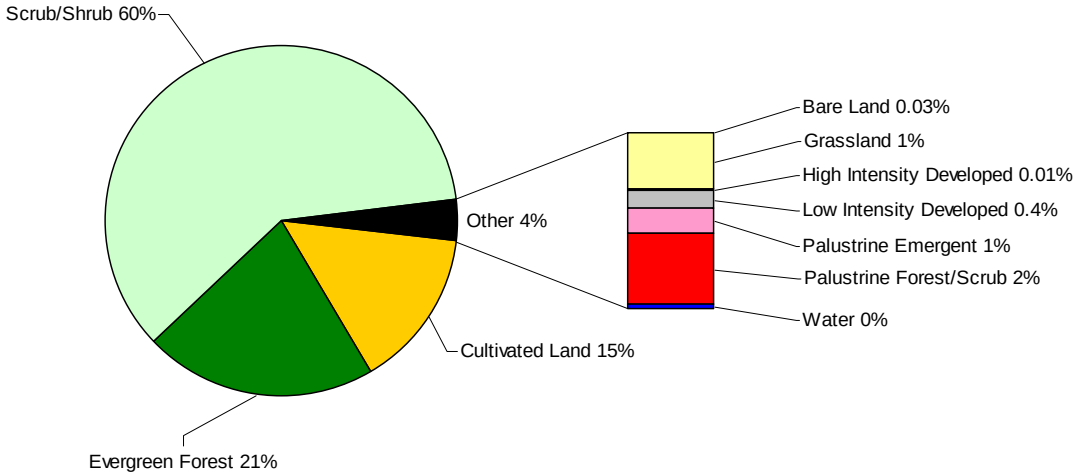

Figure C-14. Relative total phosphorus land cover loadings for the Waioli watershed

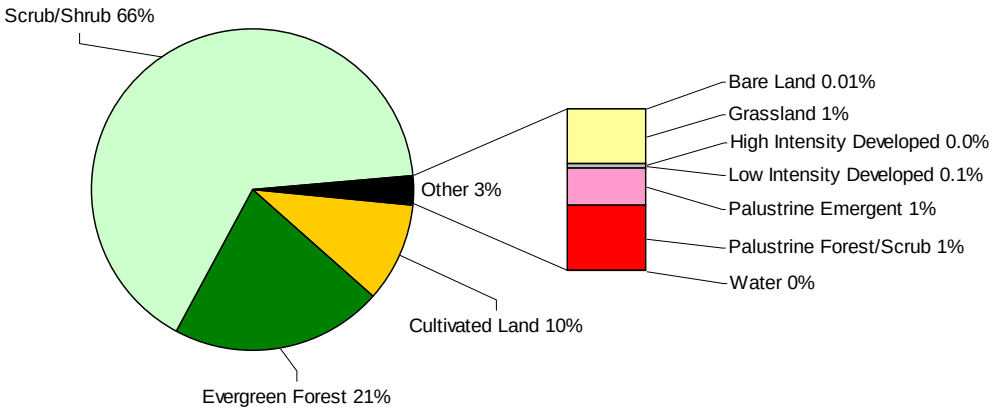

Figure C-15. Relative total phosphorus land cover loadings for the Waipa watershed

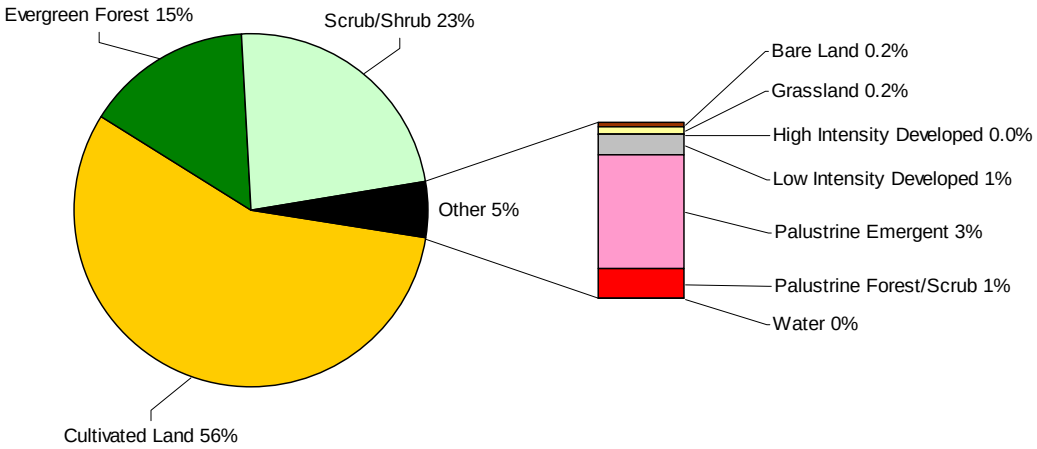

Figure C-16. Relative total phosphorus land cover loadings for the Waikoko watershed

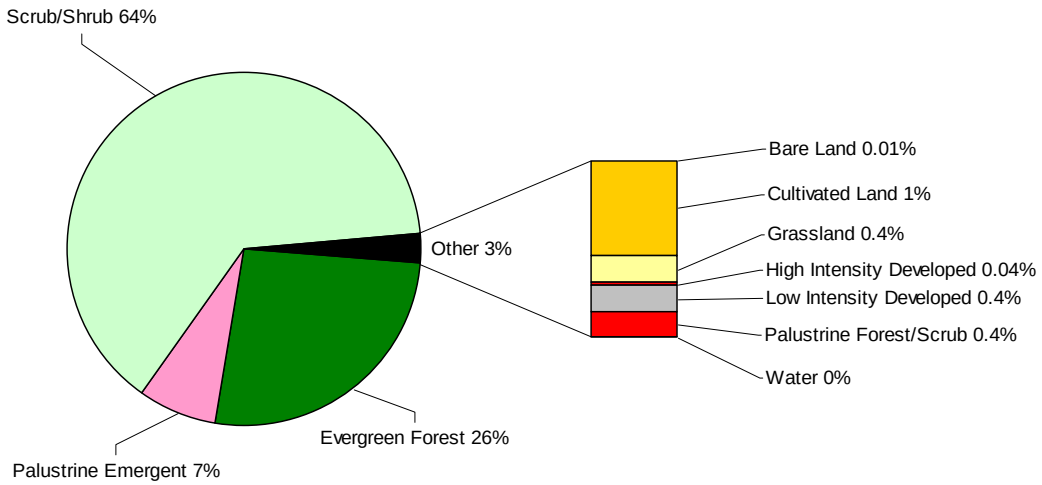

Figure C-17. Relative enterococci land cover loadings for the Hanalei River watershed

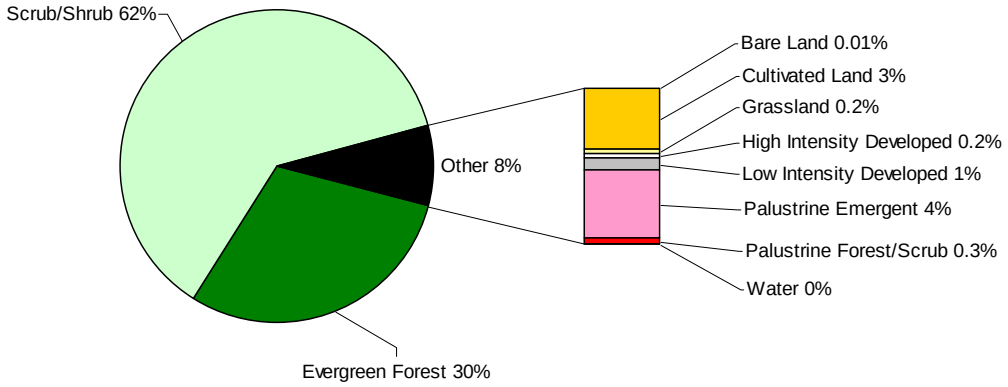

Figure C-18. Relative enterococci land cover loadings for the Waioli watershed

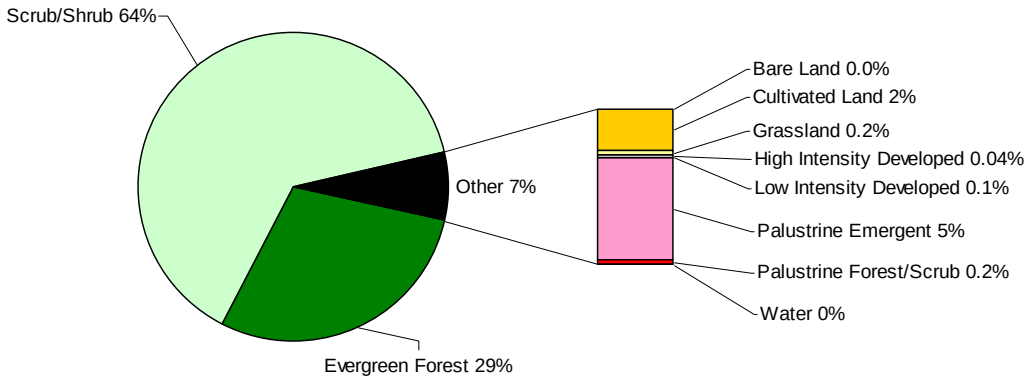

Figure C-19. Relative enterococci land cover loadings for the Waipa watershed

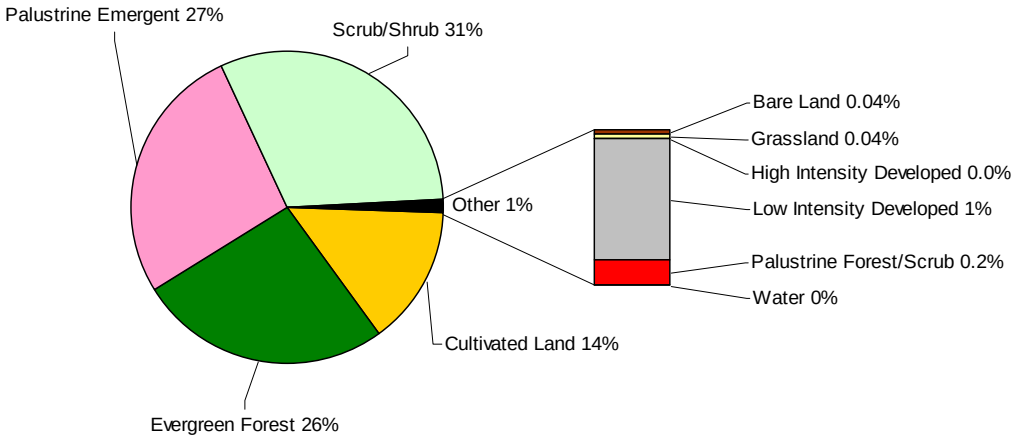

Figure C-20. Relative enterococci land cover loadings for the Waikoko watershed

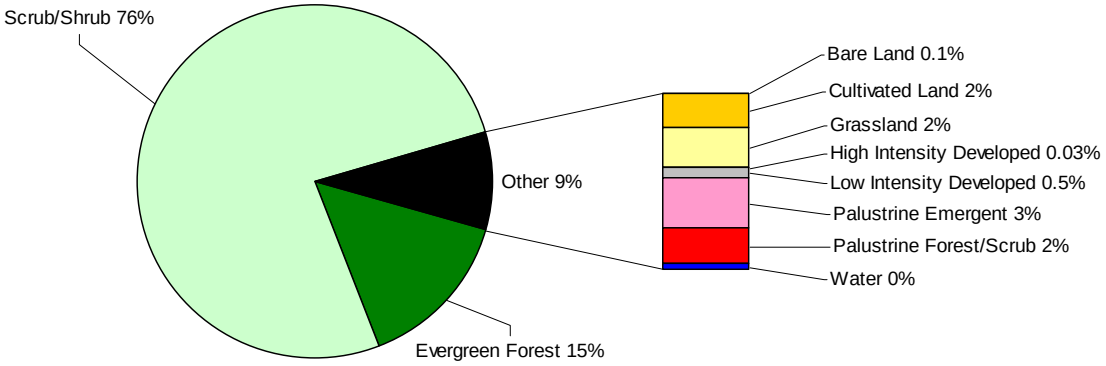

Figure C-21. Relative total suspended solids/turbidity land cover loadings for the Hanalei River watershed

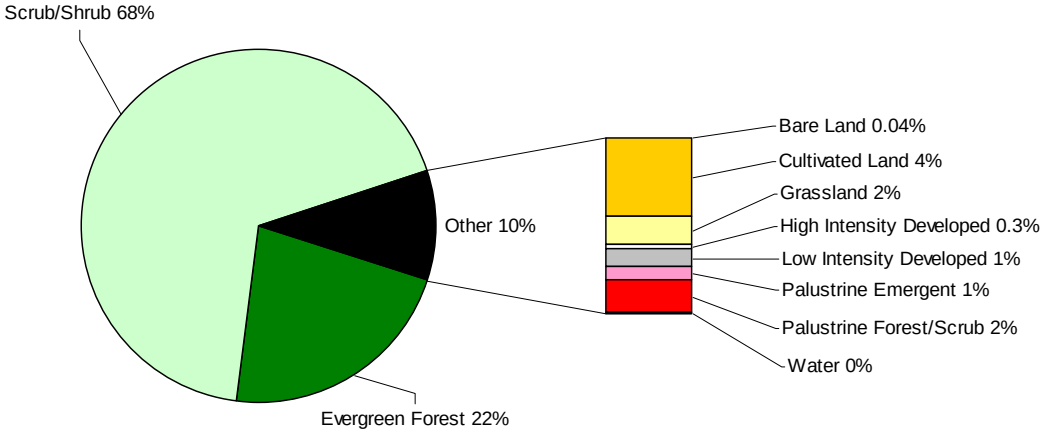

Figure C-22. Relative total suspended solids/turbidity land cover loadings for the Waioli watershed

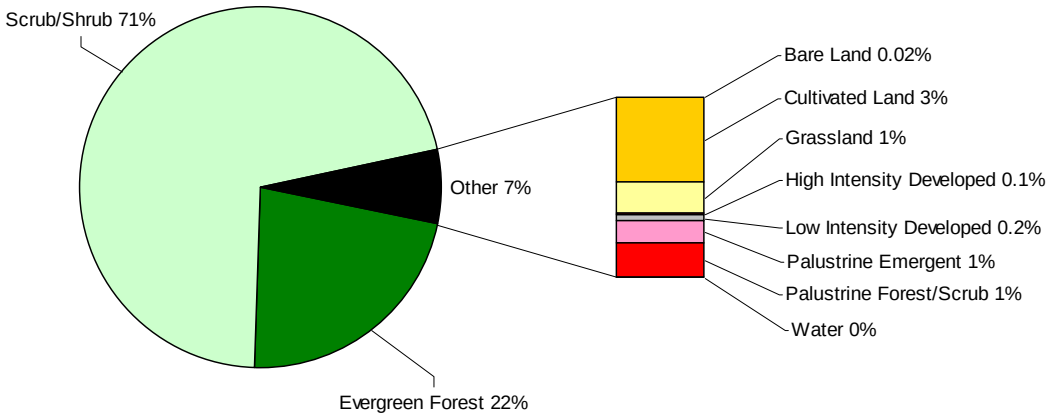

Figure C-23. Relative total suspended solids/turbidity land cover loadings for the Waipa watershed

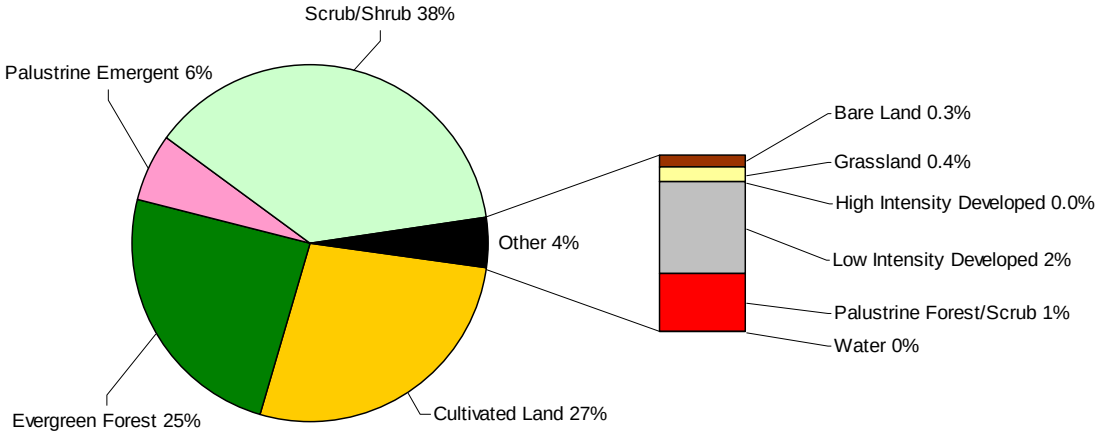

Figure C-24. Relative total suspended solids/turbidity land cover loadings for the Waikoko watershed

Appendix D: Additional LSPC Hydrology Validation Results

Prepared for:
USEPA Region 9
Hawai'i Department of Health

Prepared by:
Tetra Tech, Inc.
1230 Columbia Street, Suite 520
San Diego, California 92101

Introduction

The graphs presented below in Sections D.1 and D.2 provide further validation of the hydrology parameters used in the LSPC modeling (see Appendix B for a detailed discussion of the modeling approach and results). Specifically, for the graphs in Section D.1, hourly model flow output was compared with discrete flow measurements at several sampling stations throughout the Hanalei Bay watershed, including two stations in both the Waipa and Waioli watersheds. This comparison is important because it tests parameter values calibrated and validated using continuous flow data at the USGS gage in the Hanalei River watershed in two additional watersheds draining to Hanalei Bay. In Section D.2, hourly model flow output was compared with sub-hourly flow at the USGS gage during two storm events to obtain a general idea about model fit during storm events. Additional details regarding the hydrology simulations and results are discussed in Appendix B.

D-1. Hydrology Validation: Discrete Measurement Comparisons

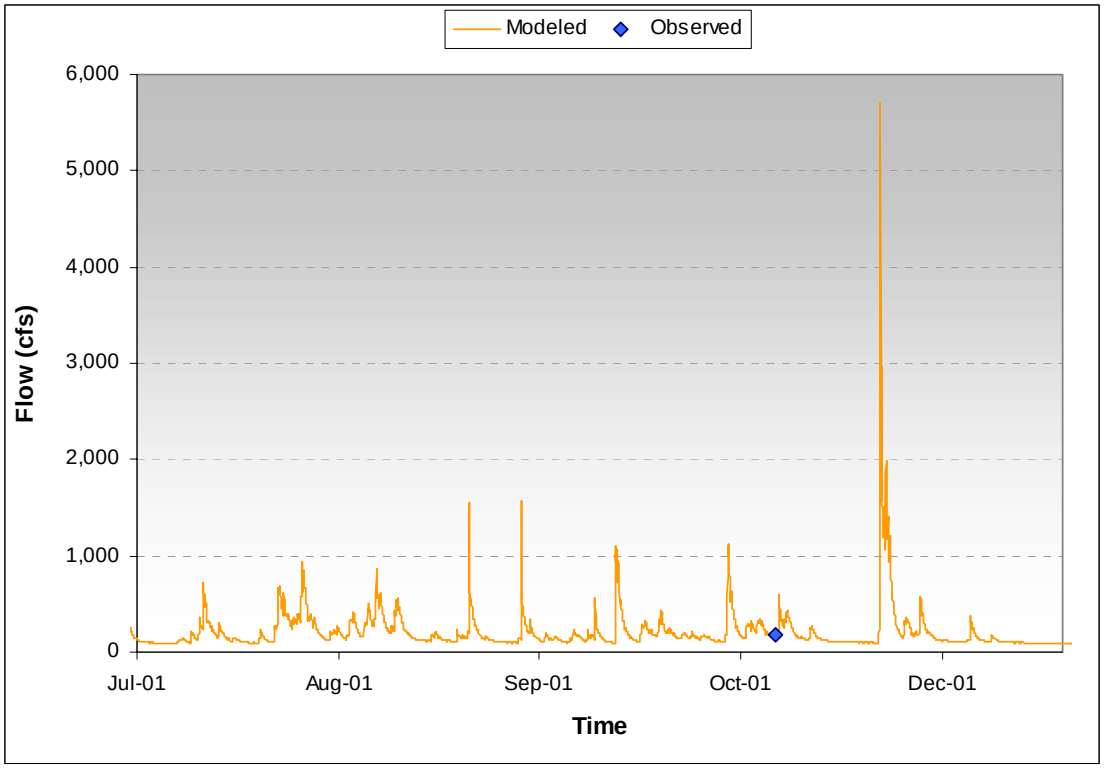

Figure D-1. Modeled and observed discrete flow measurements at subwatershed 112

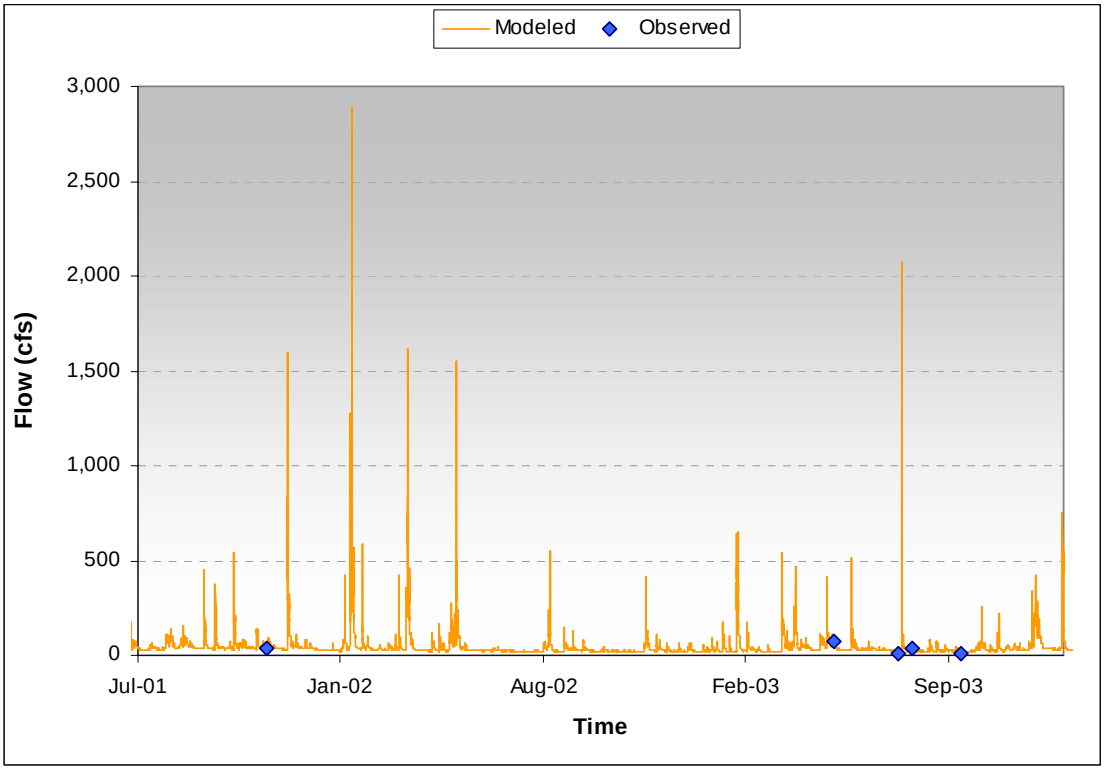

Figure D-2. Modeled and observed discrete flow measurements at subwatershed 201

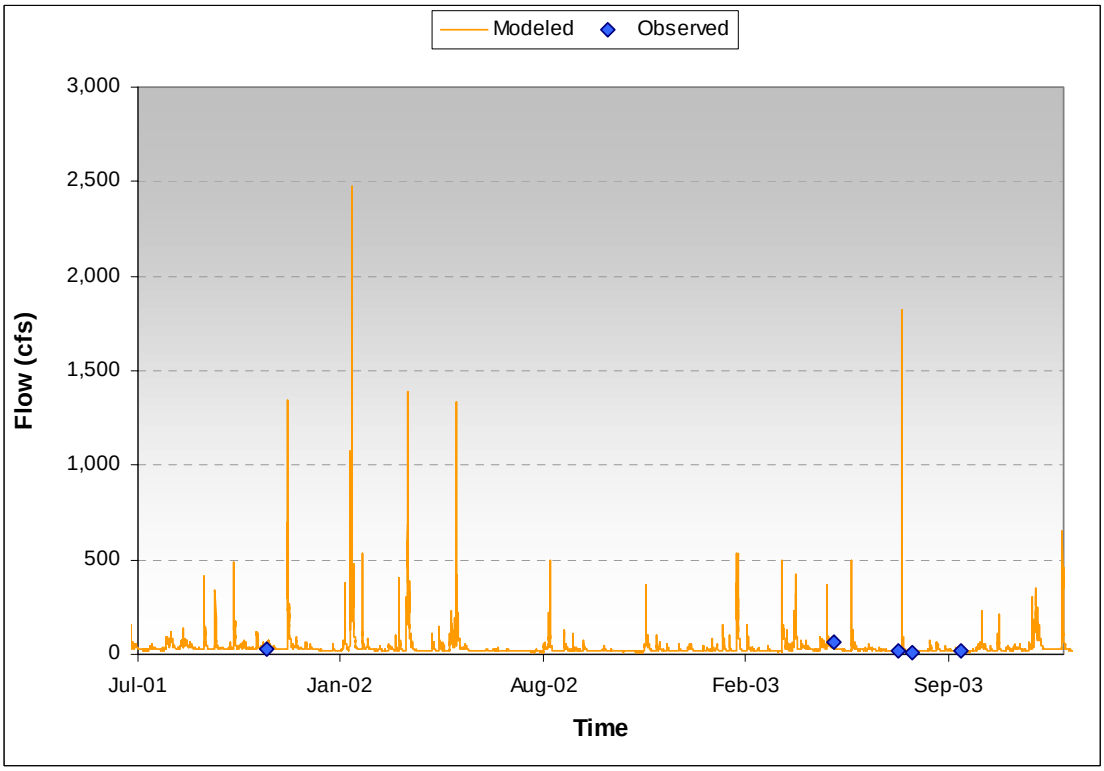

Figure D-3. Modeled and observed discrete flow measurements at subwatershed 202

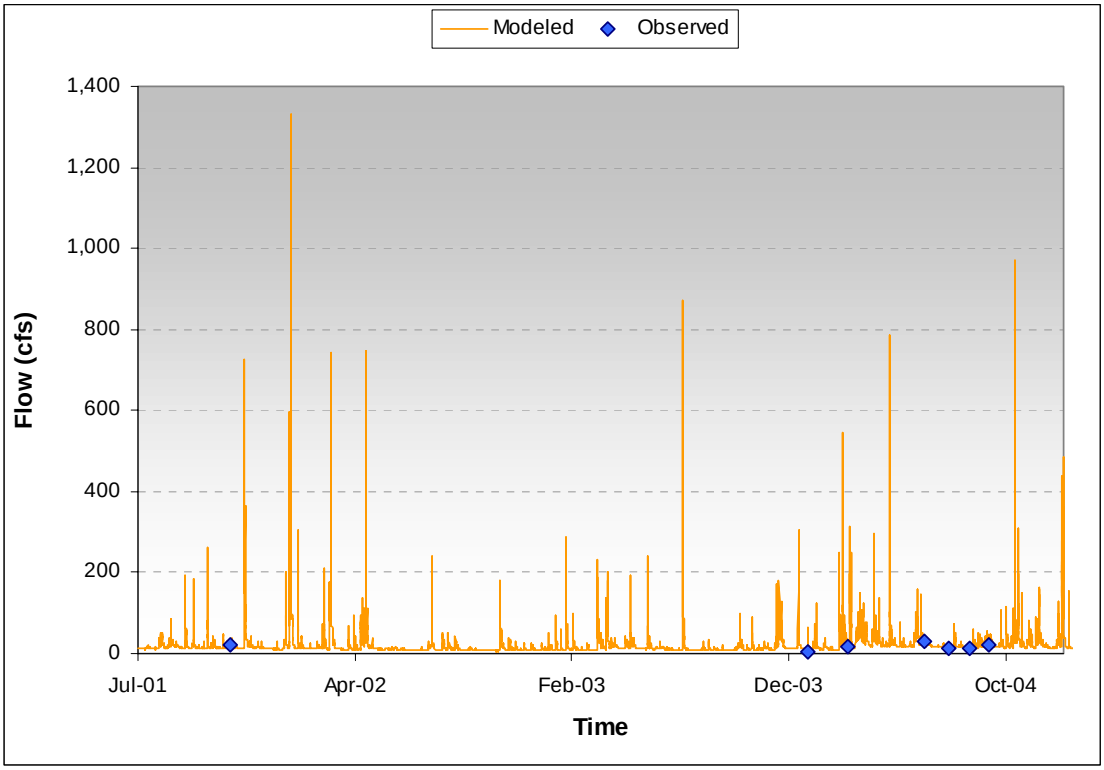

Figure D-4. Modeled and observed discrete flow measurements at subwatershed 303

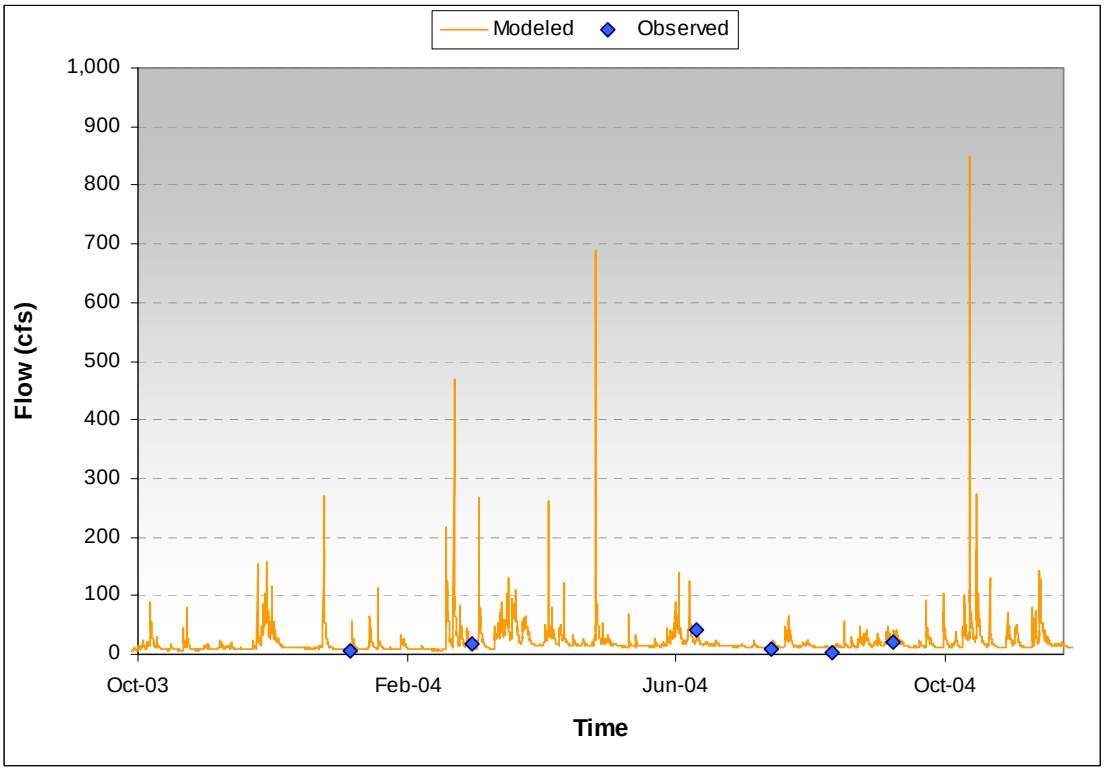

Figure D-5. Modeled and observed discrete flow measurements at subwatershed 304

D-2. Hydrology Validation: Automatic Sampler Comparisons

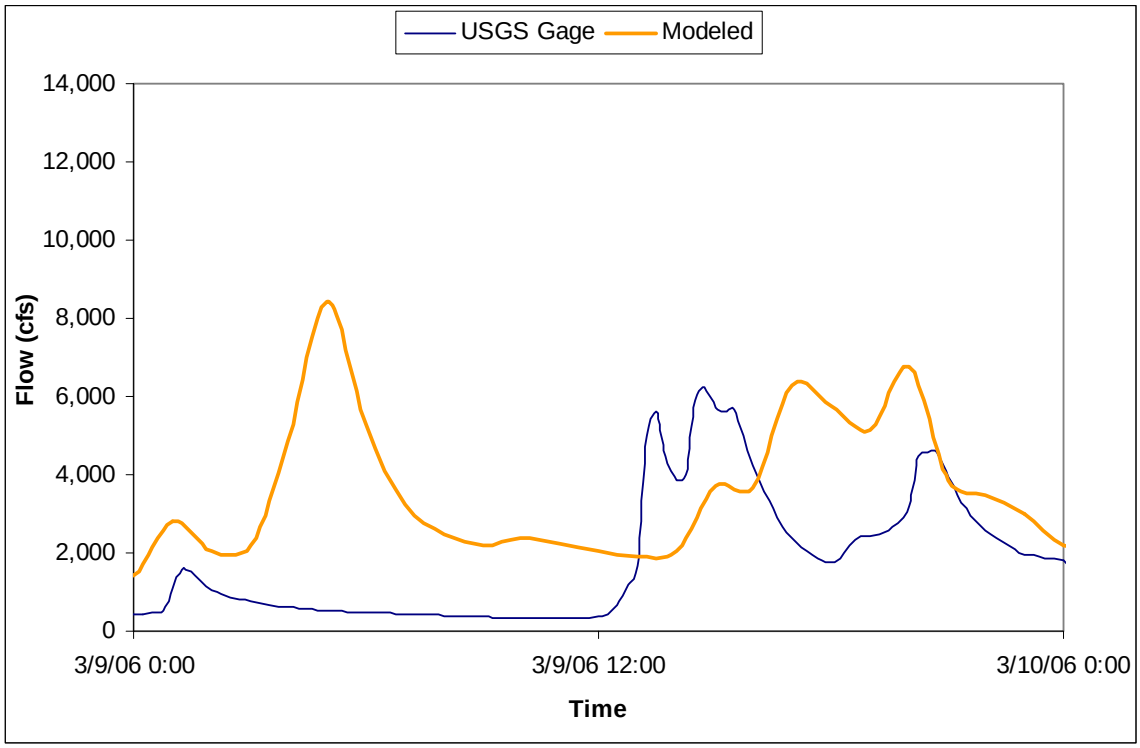

Figure D-6. Modeled flow at the automatic sampler location (subwatershed 110) and observed flow at the USGS gage (subwatershed 116) – March 9, 2006 storm

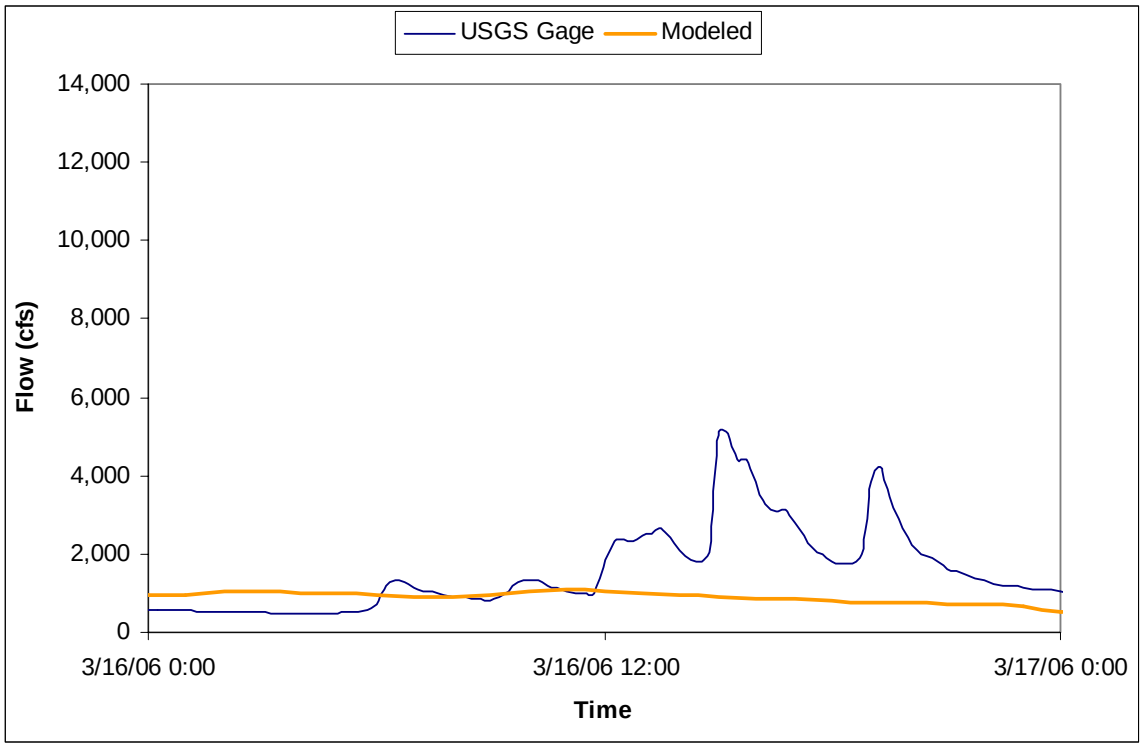

Figure D-7. Modeled flow at the automatic sampler location (subwatershed 110) and observed flow at the USGS gage (subwatershed 116) – March 16, 2006 storm

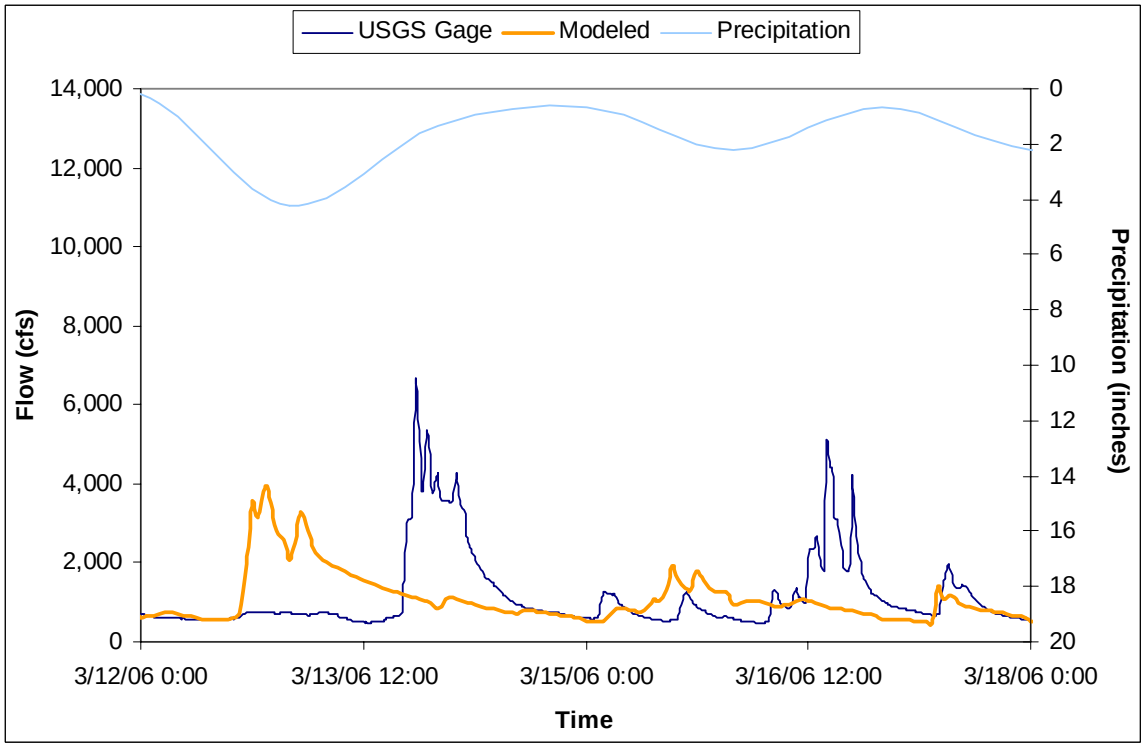

Figure D-8. Modeled flow at the automatic sampler location (subwatershed 110) and observed flow at the USGS gage (subwatershed 116) – *week of* March 16, 2006 storm

Appendix E: LSPC Water Quality Calibration and Validation Results

Prepared for:
USEPA Region 9
Hawai'i Department of Health

Prepared by:
Tetra Tech, Inc.
1230 Columbia Street, Suite 520
San Diego, California 92101

Introduction

The graphs presented below in Sections E.1 through E.5 provide water quality calibration and validation results by constituent for the LSPC modeling (see Appendix B for a detailed discussion of the modeling approach and results). Specifically, the graphs in Section E.1 present the hourly model output compared to the observed data for each parameter at the USGS station, which was used for model calibration. Similarly, Section E.2 provides the same comparisons at all other stations in the Hanalei Bay watershed, which were used for model validation. Table B-6 of Appendix B identifies the calibration and validation stations. Section E.3 presents the hourly LSPC model results for each pollutant compared against the observed data collected throughout two storm events using an automatic sampler. Further LSPC model calibration and validation are provided in Sections E.4 and E.5, respectively. These sections present box plot graphs that illustrate the minimum, mean, and maximum modeled values for the dates corresponding with observed data. Additional details regarding the LSPC water quality simulations and results are discussed in Appendix B.

E-1. Water Quality Calibration: Grab Sample Comparisons

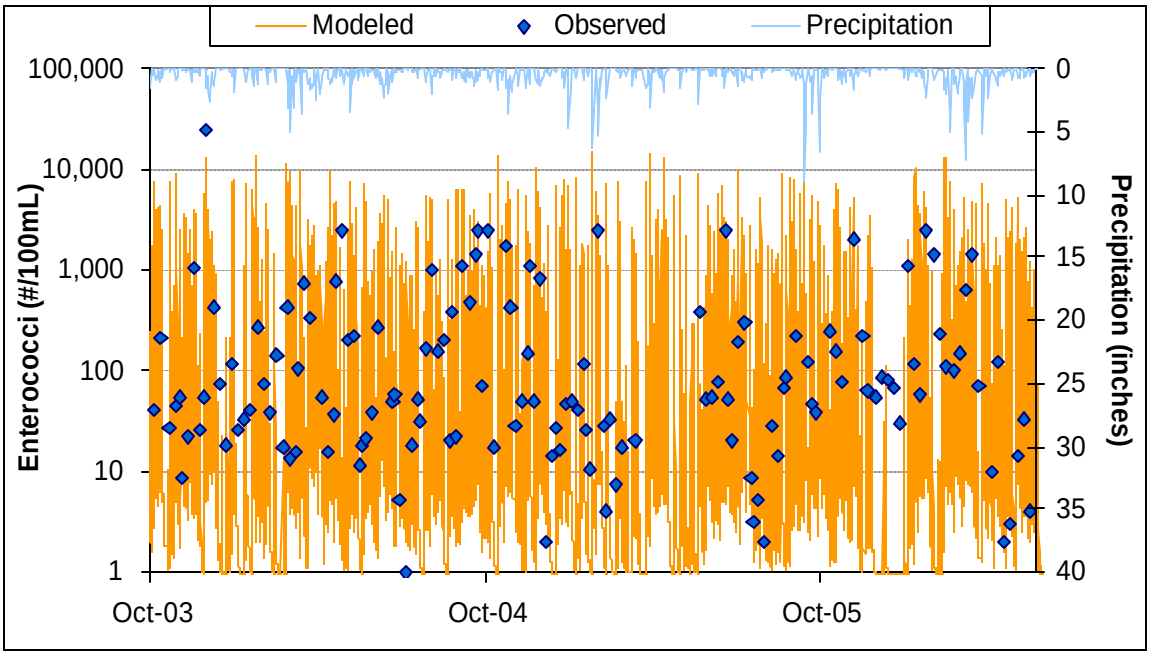

Figure E-1. Modeled and observed *enterococcus* concentrations at subwatershed 116

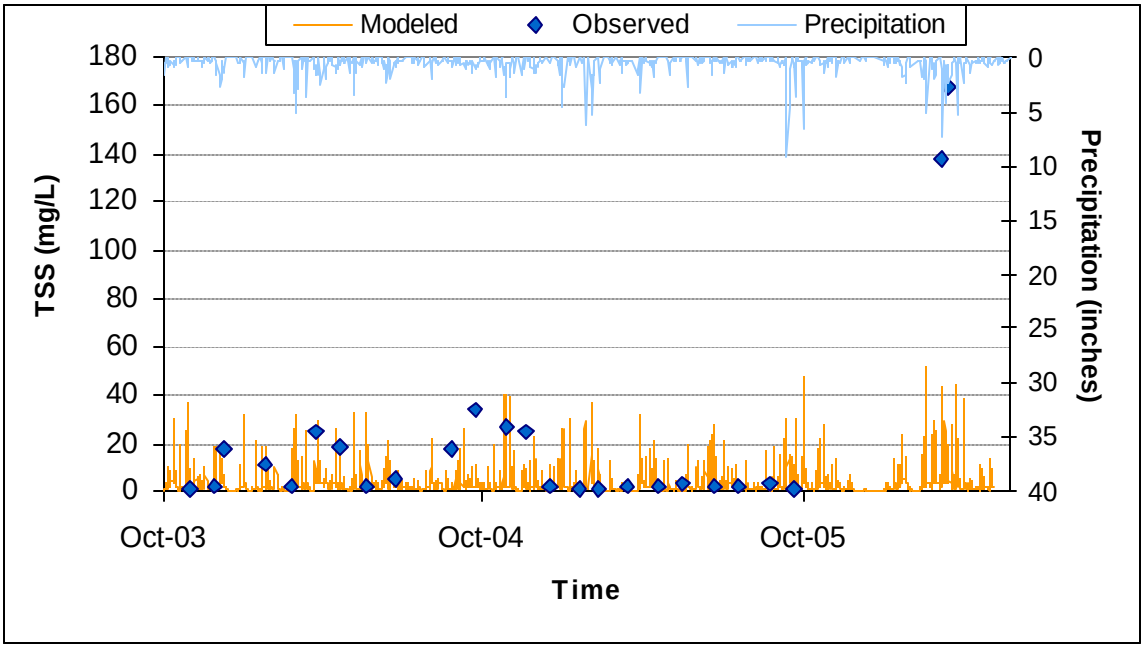

Figure E-2. Modeled and observed TSS concentrations at subwatershed 116

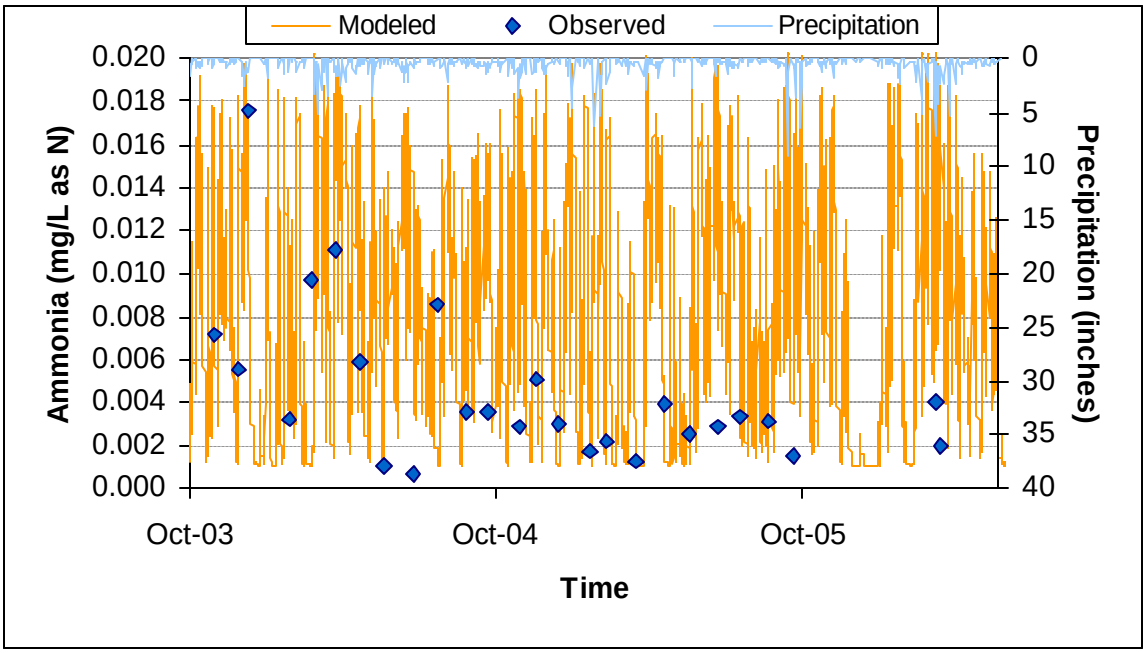

Figure E-3. Modeled and observed ammonia concentrations at subwatershed 116

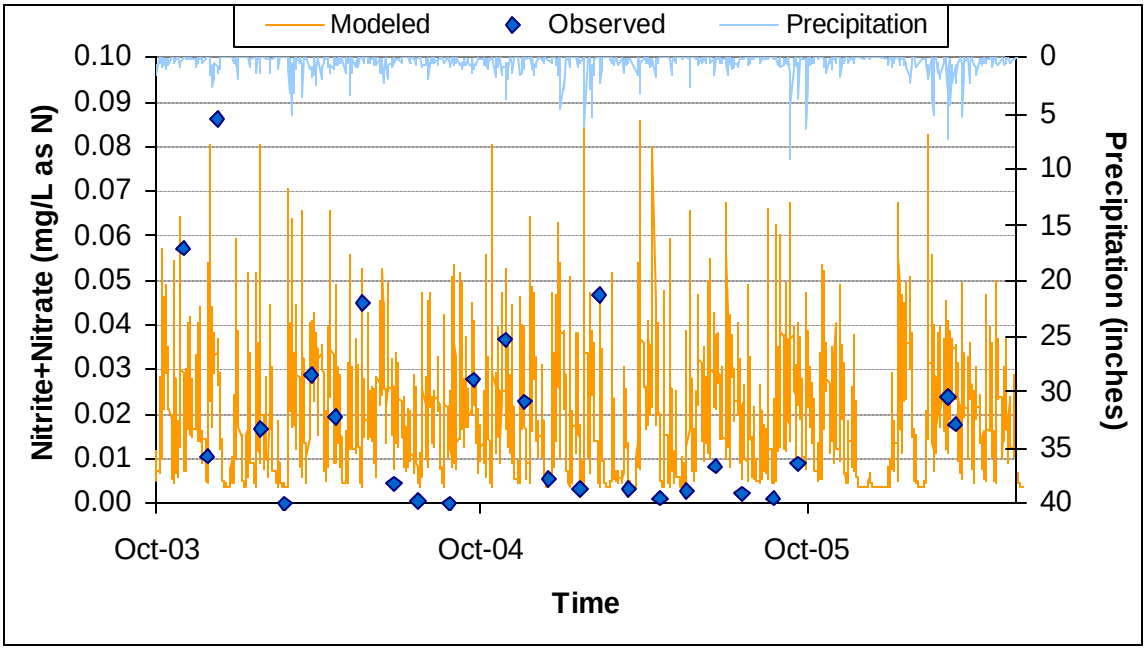

Figure E-4. Modeled and observed nitrite plus nitrate concentrations at subwatershed 116

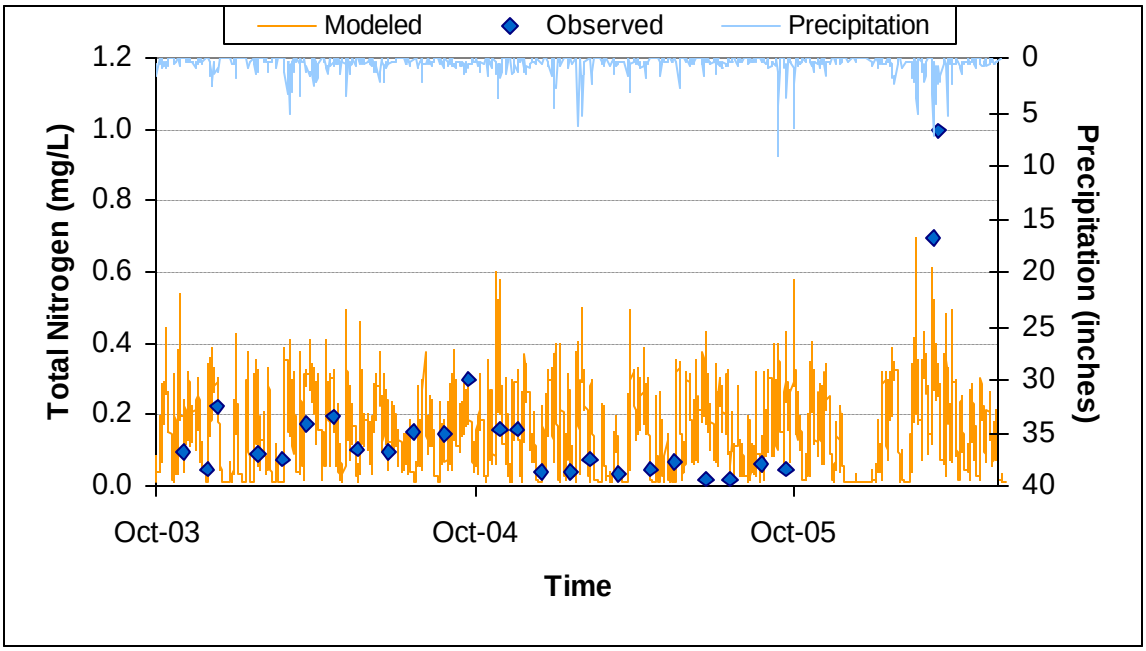

Figure E-5. Modeled and observed total nitrogen concentrations at subwatershed 116

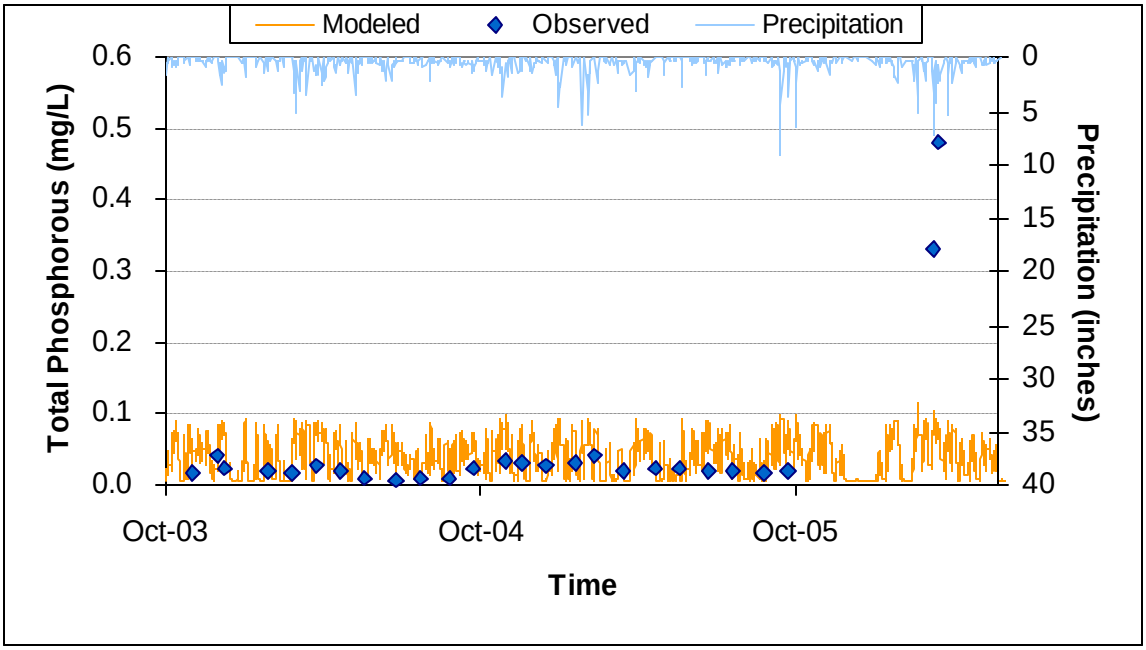

Figure E-6. Modeled and observed total phosphorous concentrations at subwatershed 116

E-2. Water Quality Validation: Grab Sample Comparisons

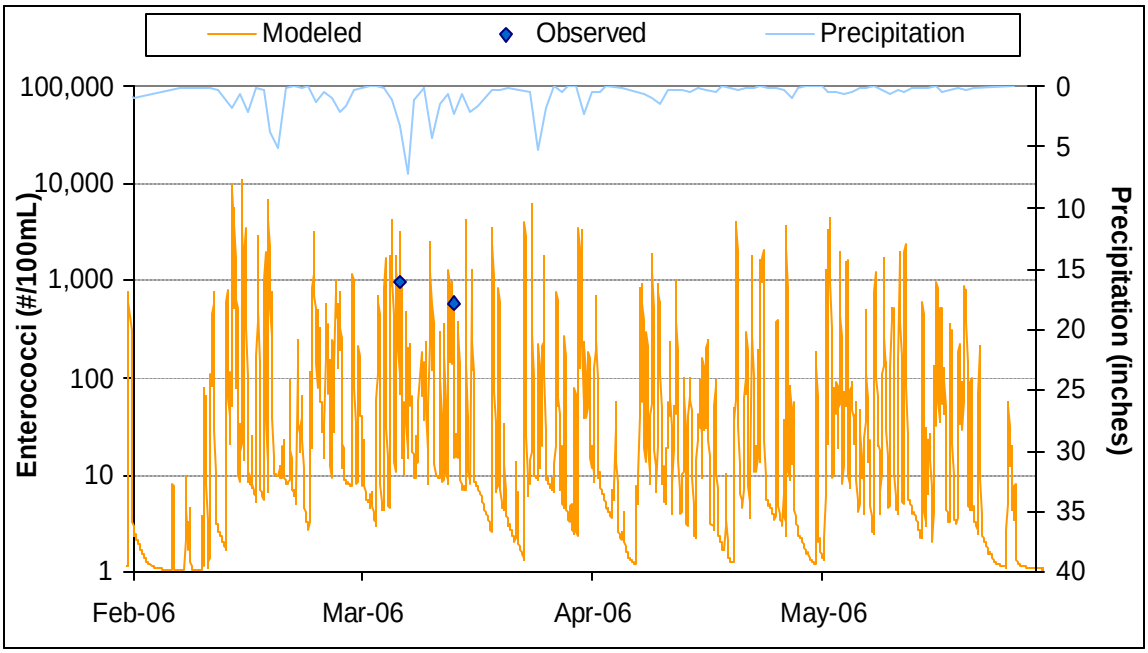

Figure E-7. Modeled and observed *enterococcus* concentrations at subwatershed 110

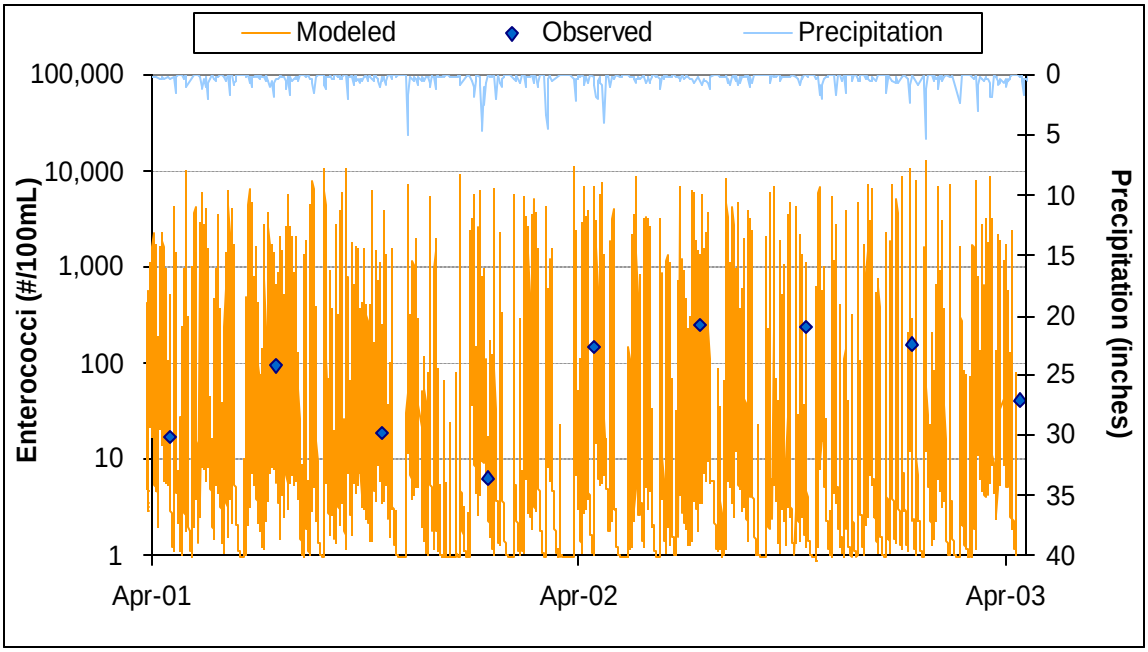

Figure E-8. Modeled and observed *enterococcus* concentrations at subwatershed 112

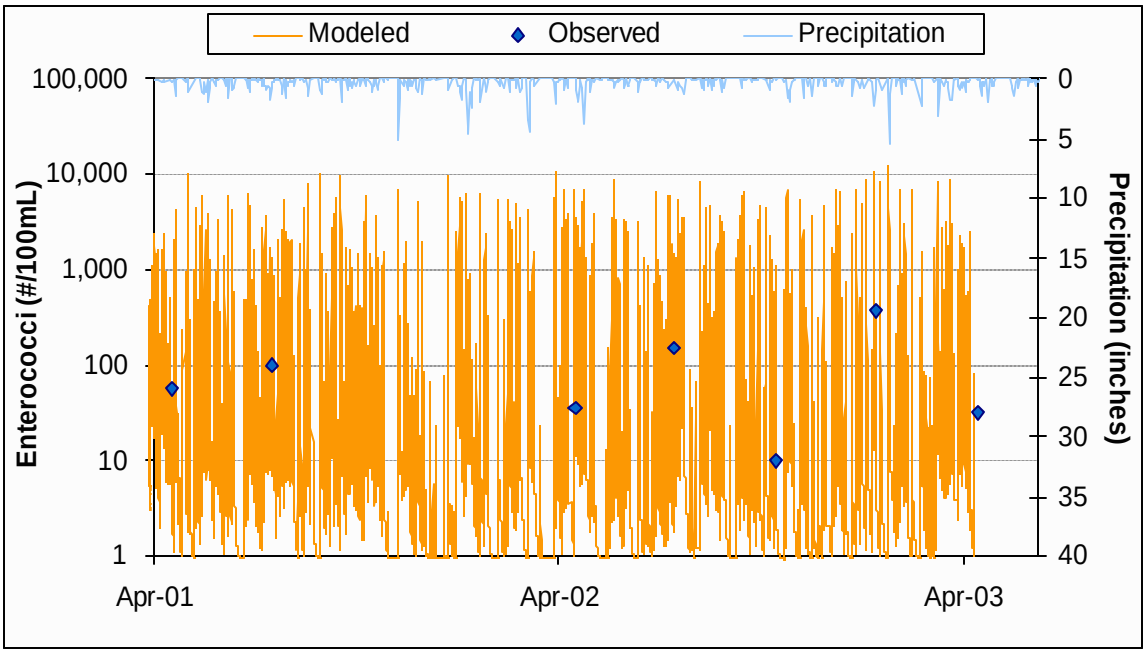

Figure E-9. Modeled and observed *enterococcus* concentrations at subwatershed 113

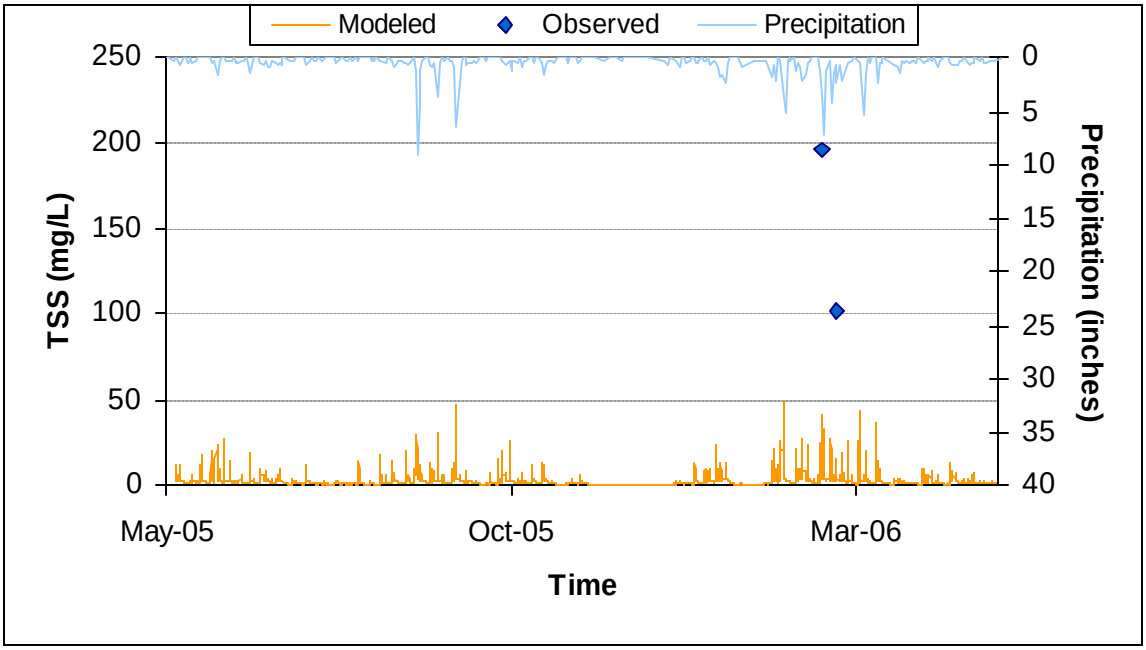

Figure E-10. Modeled and observed TSS concentrations at subwatershed 110

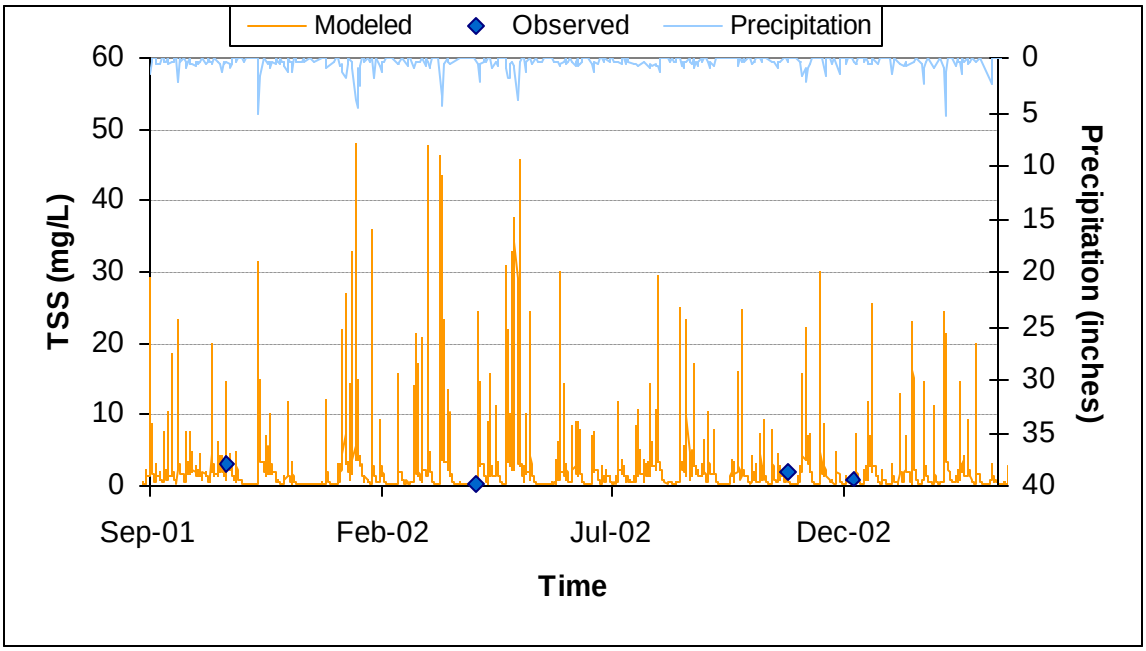

Figure E-11. Modeled and observed TSS concentrations at subwatershed 112

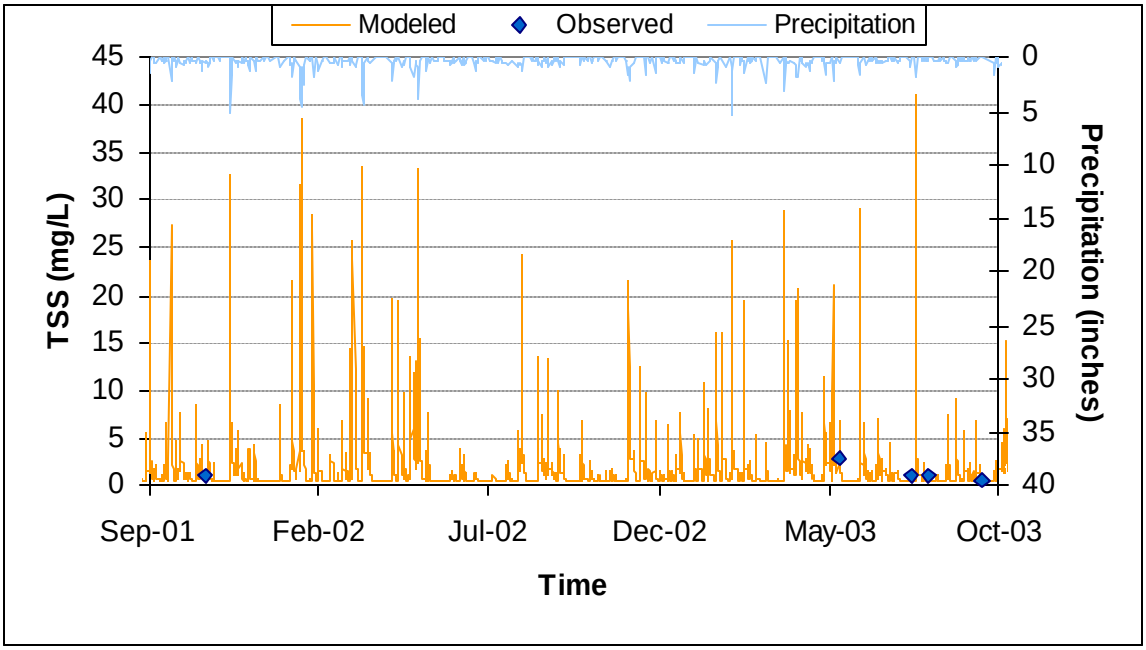

Figure E-12. Modeled and observed TSS concentrations at subwatershed 201

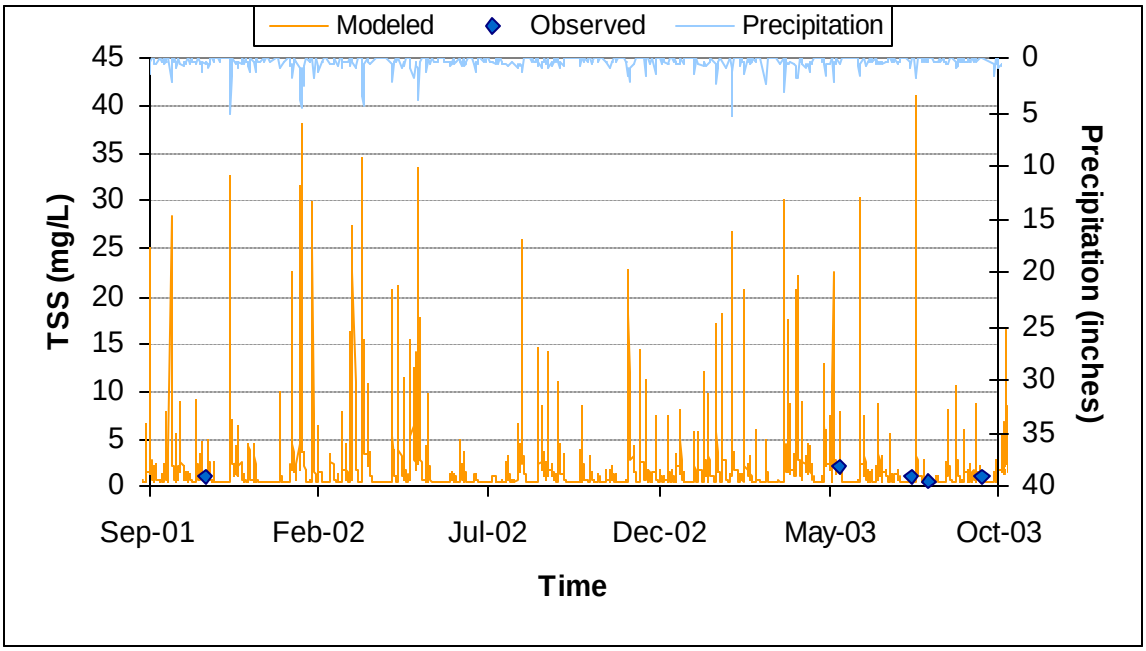

Figure E-13. Modeled and observed TSS concentrations at subwatershed 202

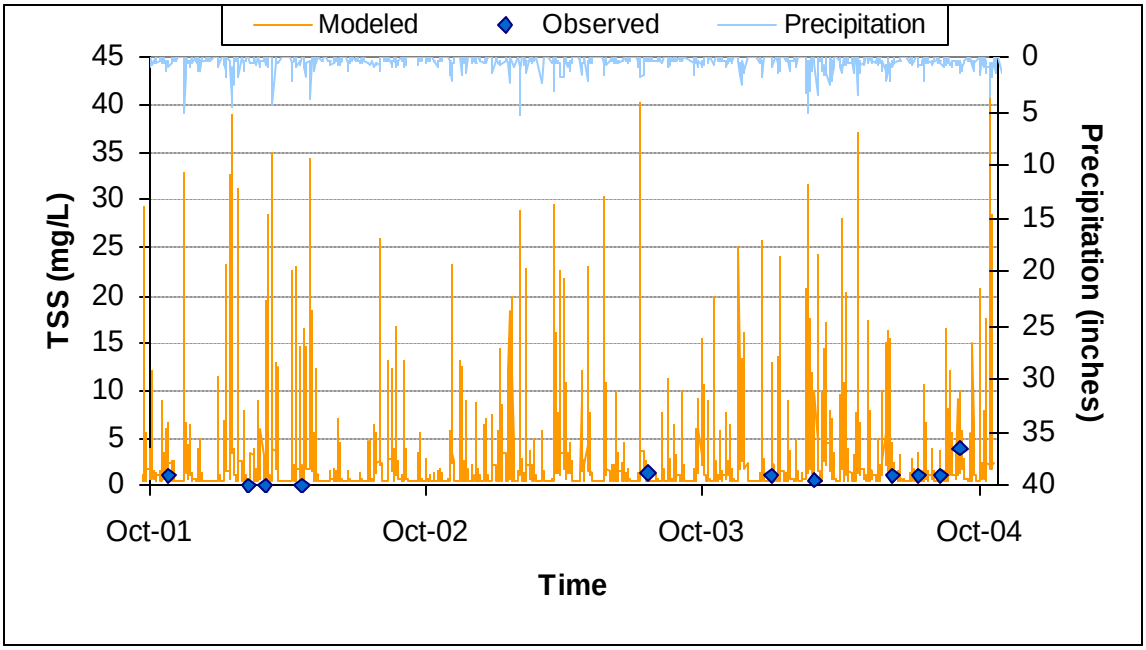

Figure E-14. Modeled and observed TSS concentrations at subwatershed 303

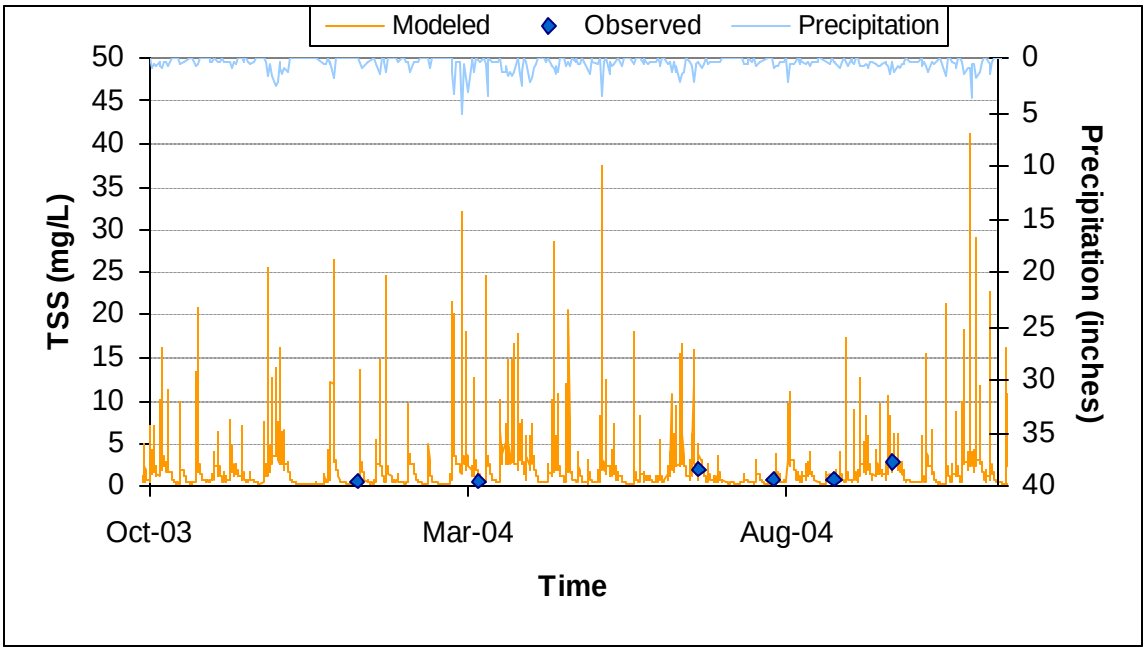

Figure E-15. Modeled and observed TSS concentrations at subwatershed 304

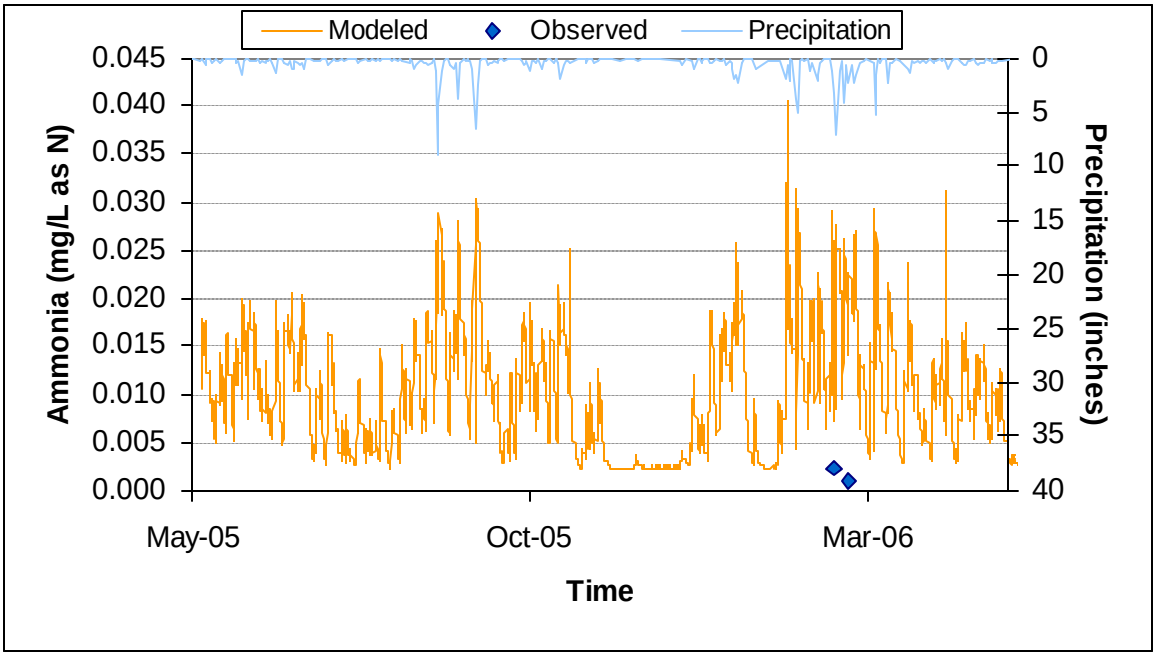

Figure E-16. Modeled and observed ammonia concentrations at subwatershed 110

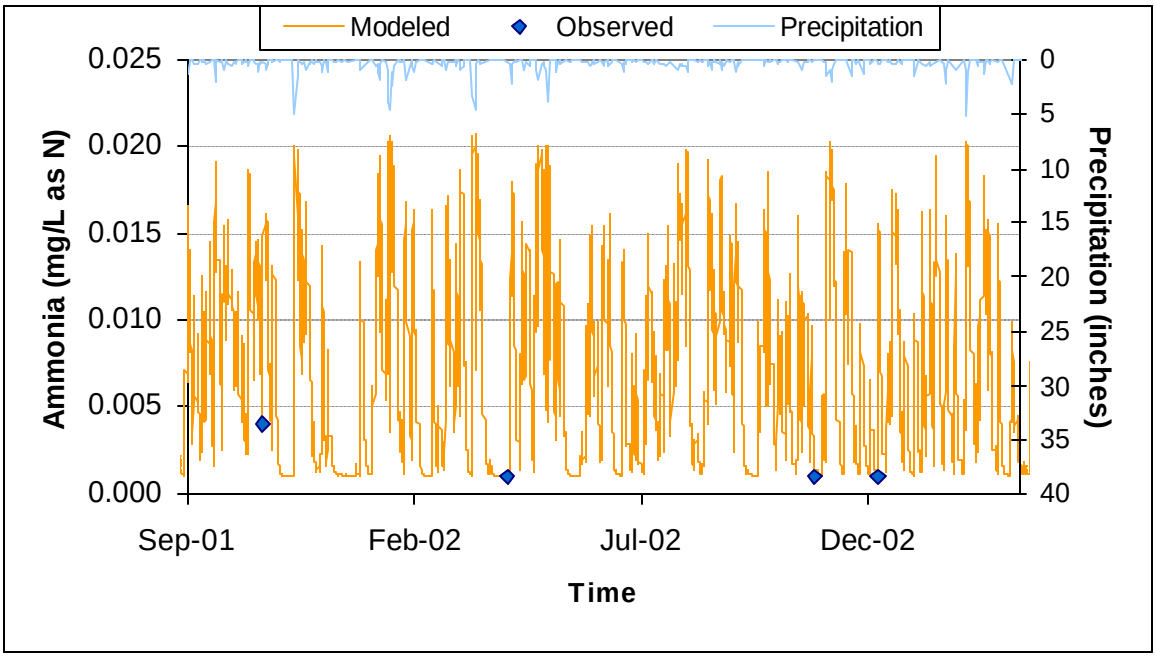

Figure E-17. Modeled and observed ammonia concentrations at subwatershed 112

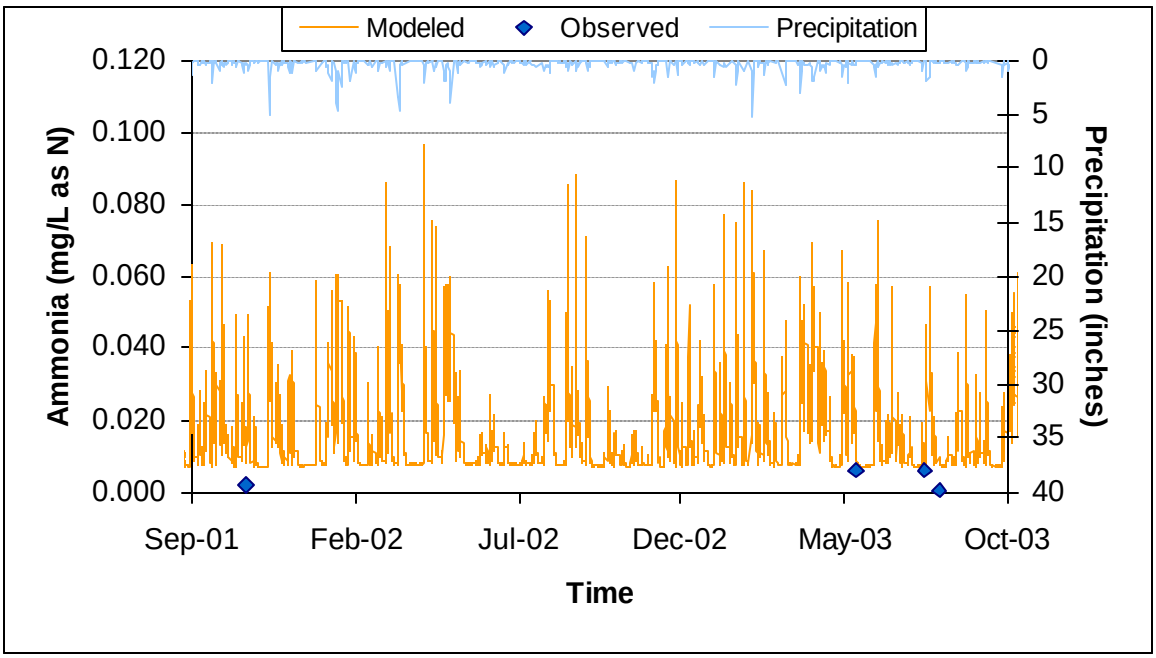

Figure E-18. Modeled and observed ammonia concentrations at subwatershed 201

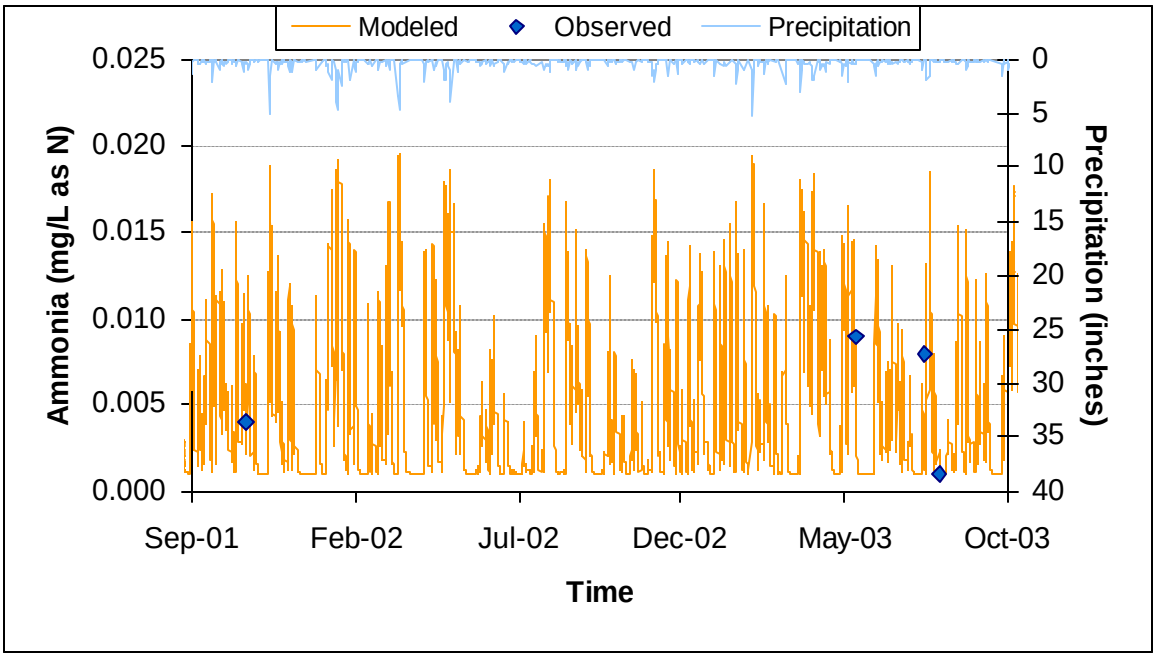

Figure E-19. Modeled and observed ammonia concentrations at subwatershed 202

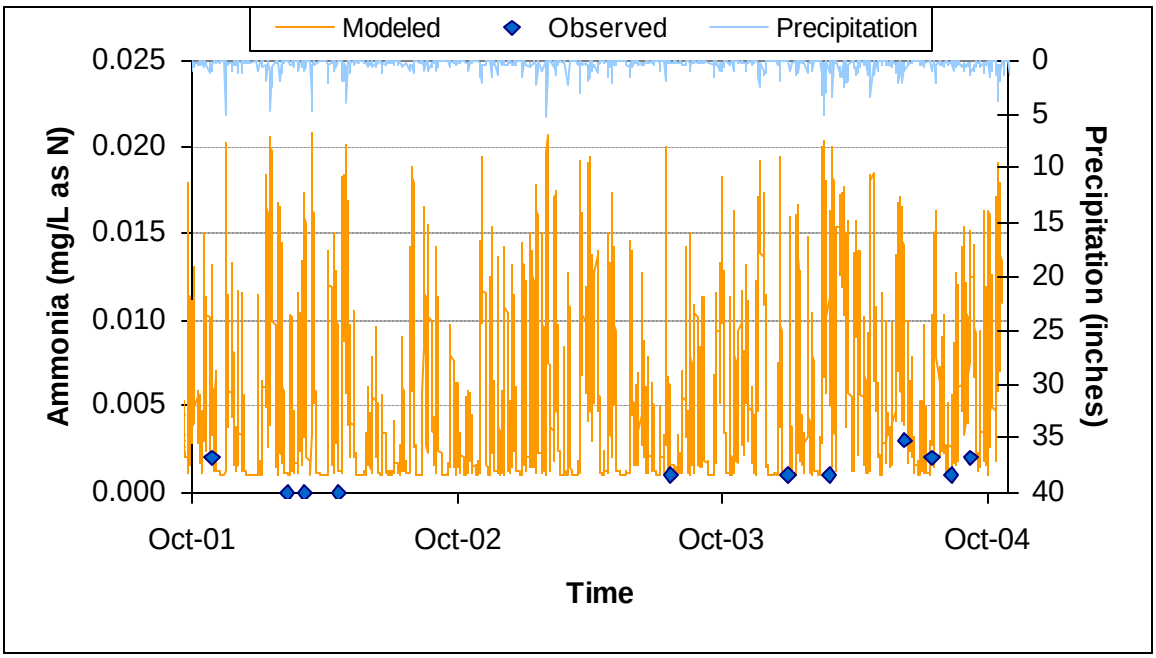

Figure E-20. Modeled and observed ammonia concentrations at subwatershed 303

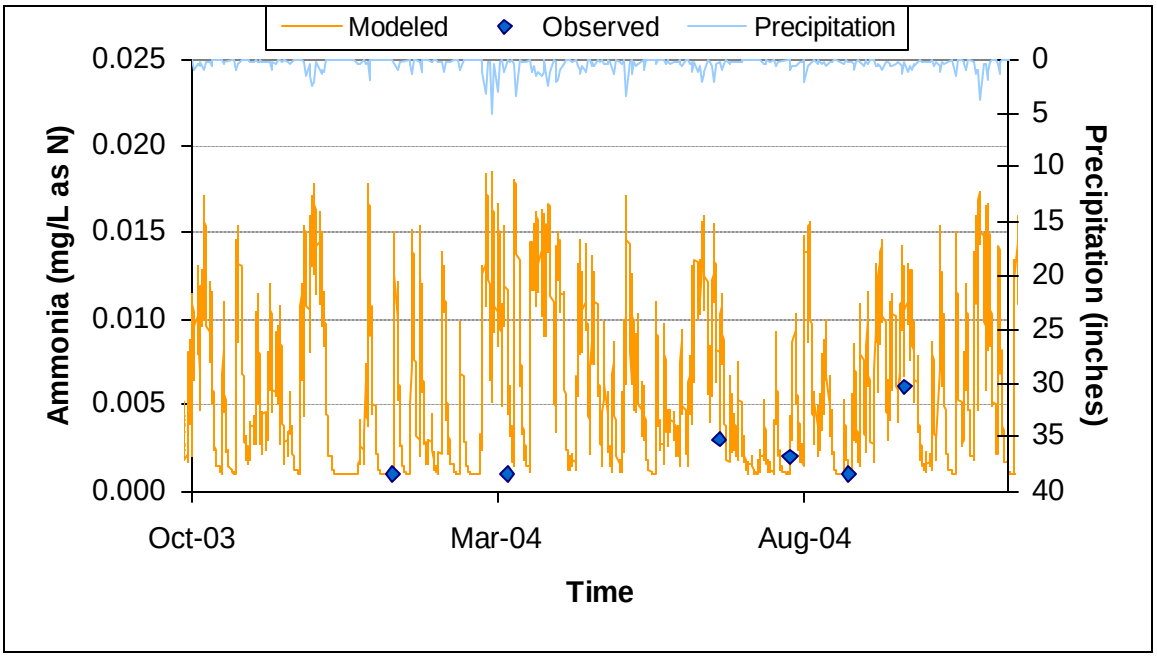

Figure E-21. Modeled and observed ammonia concentrations at subwatershed 304

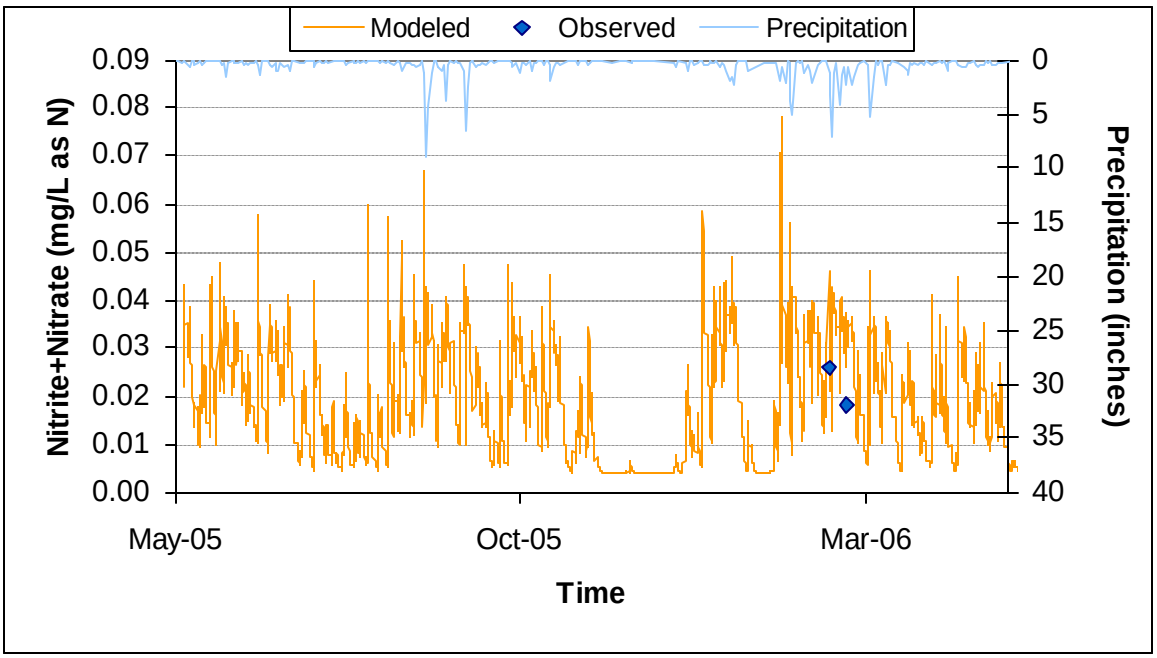

Figure E-22. Modeled and observed nitrite plus nitrate concentrations at subwatershed 110

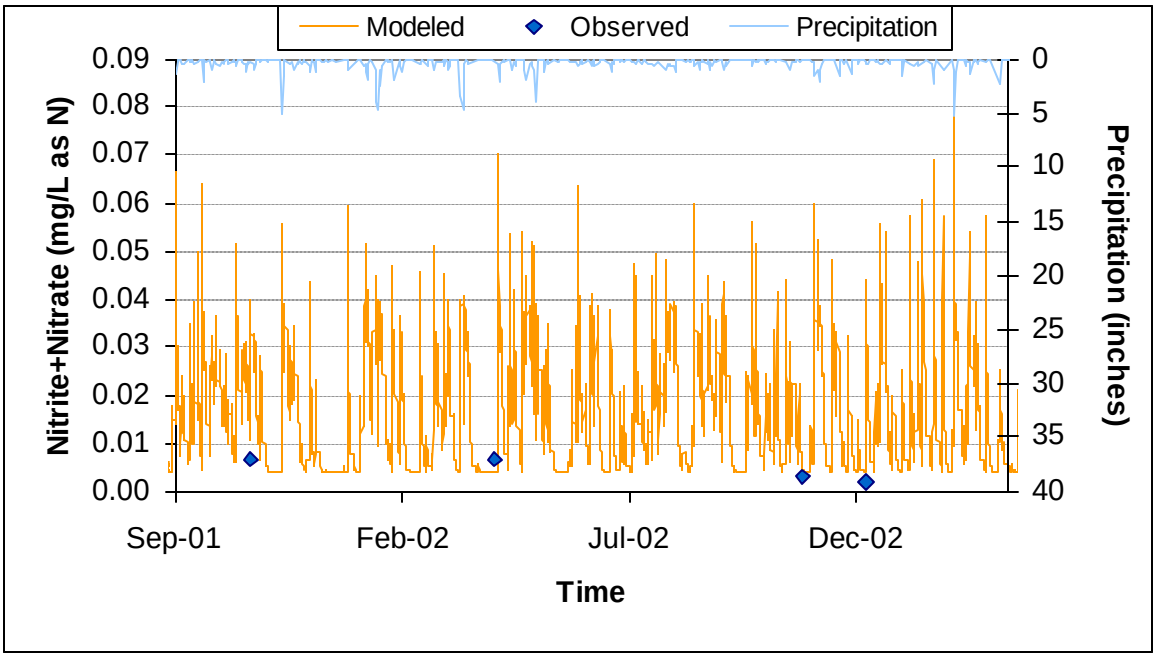

Figure E-23. Modeled and observed nitrite plus nitrate concentrations at subwatershed 112

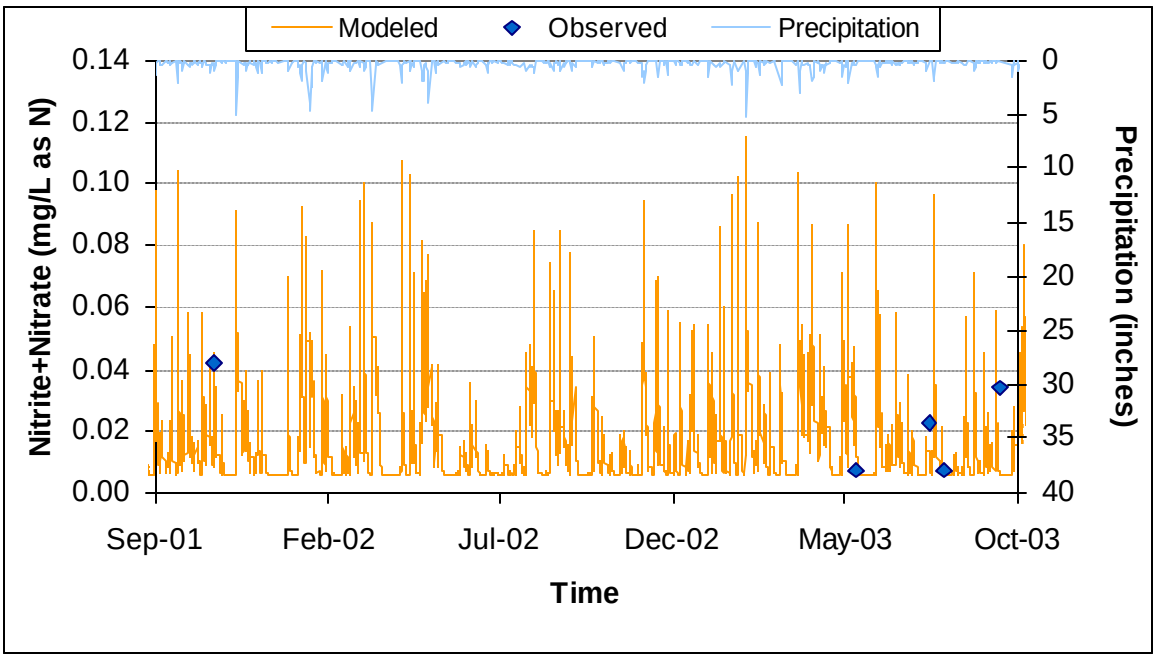

Figure E-24. Modeled and observed nitrite plus nitrate concentrations at subwatershed 201

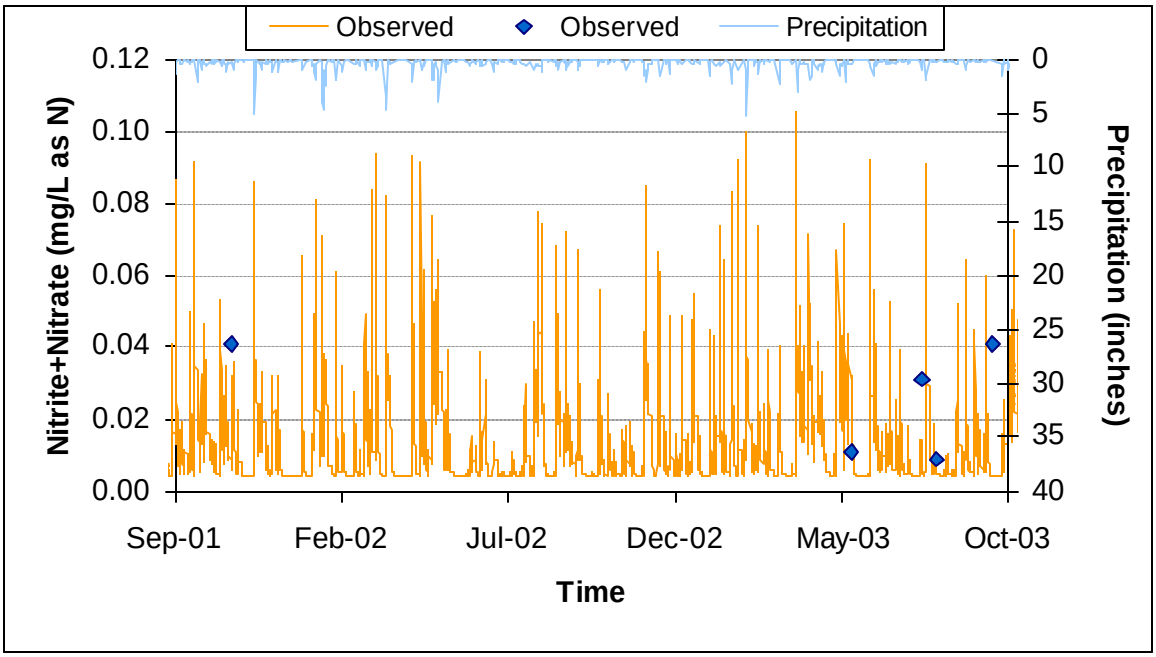

Figure E-25. Modeled and observed nitrite plus nitrate concentrations at subwatershed 202

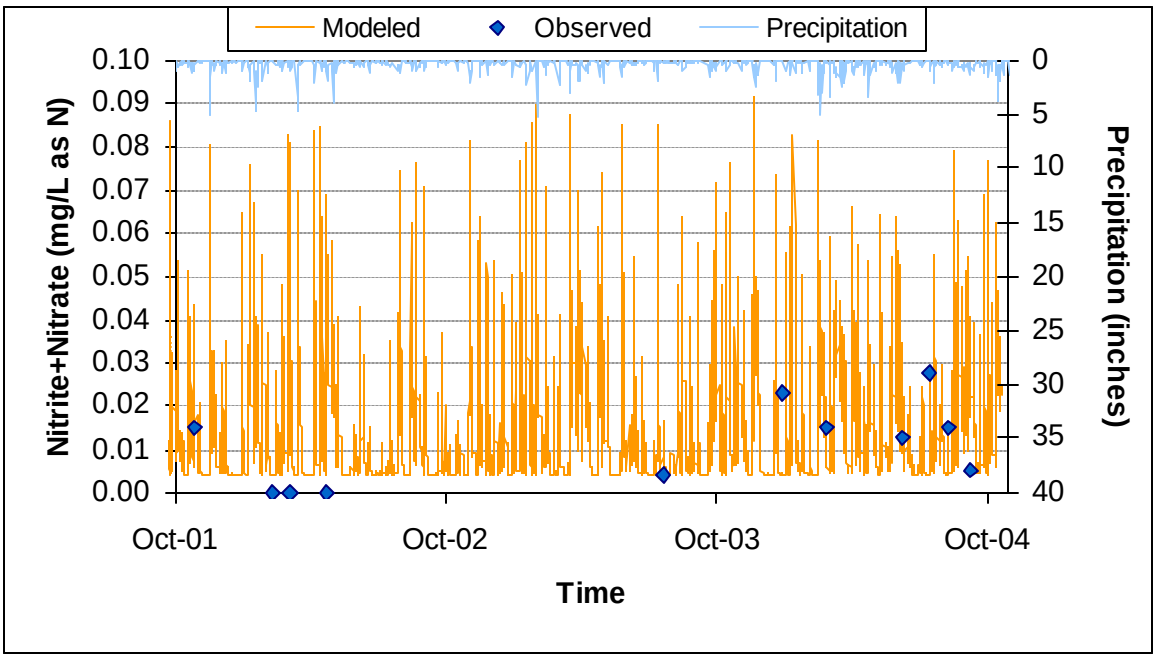

Figure E-26. Modeled and observed nitrite plus nitrate concentrations at subwatershed 303

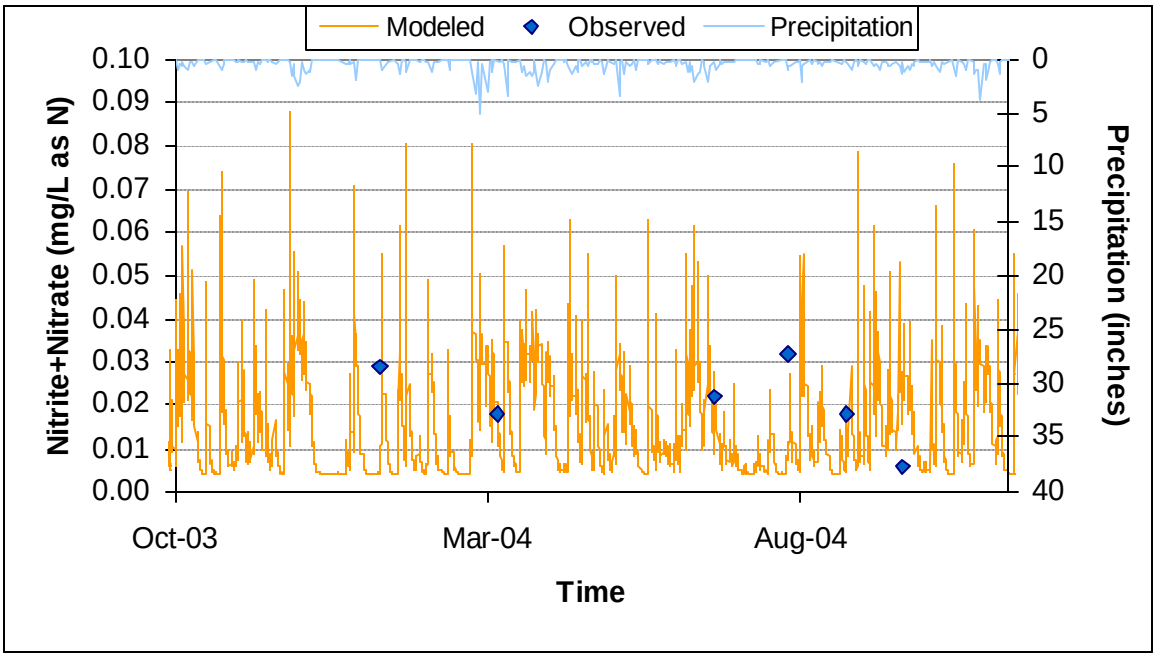

Figure E-27. Modeled and observed nitrite plus nitrate concentrations at subwatershed 304

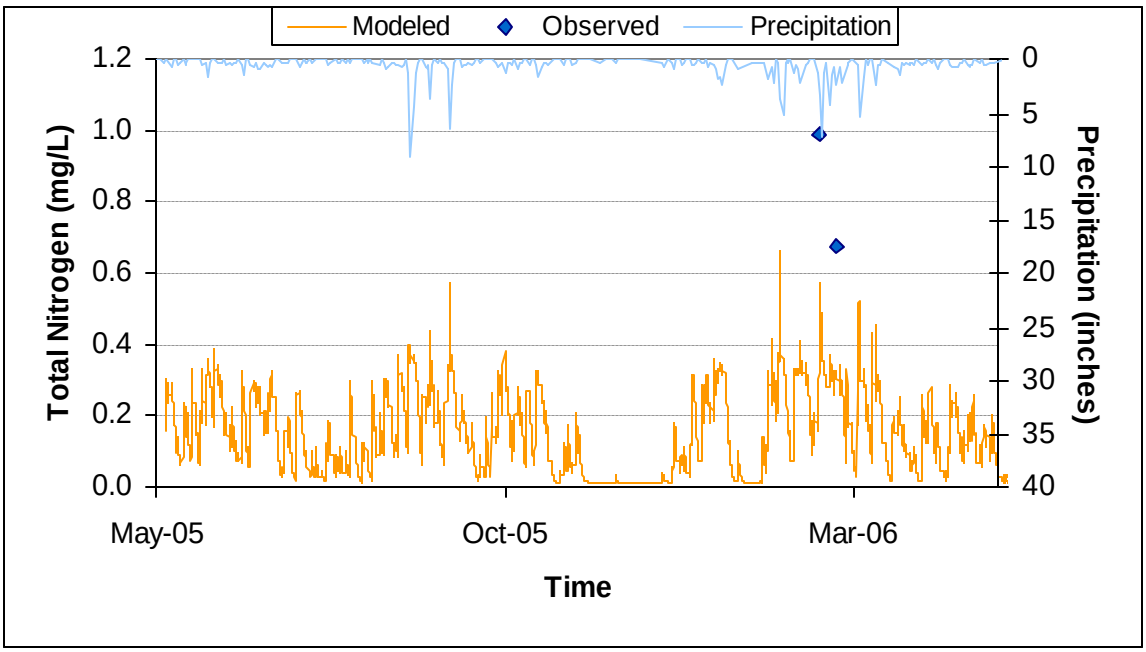

Figure E-28. Modeled and observed total nitrogen concentrations at subwatershed 110

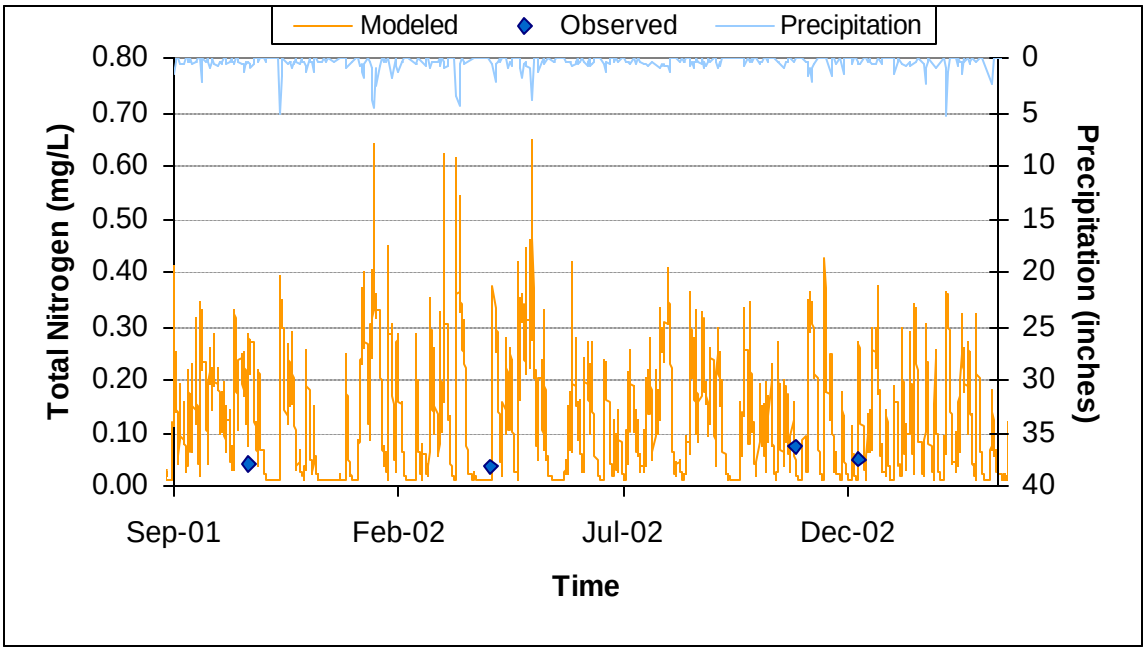

Figure E-29. Modeled and observed total nitrogen concentrations at subwatershed 112

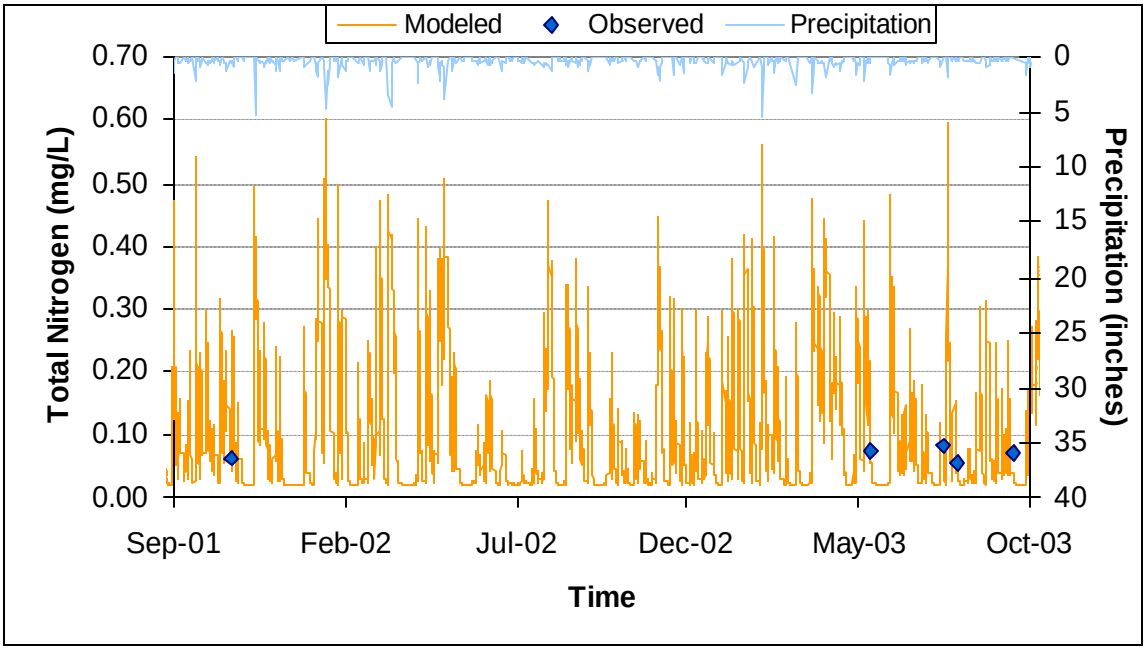

Figure E-30. Modeled and observed total nitrogen concentrations at subwatershed 201

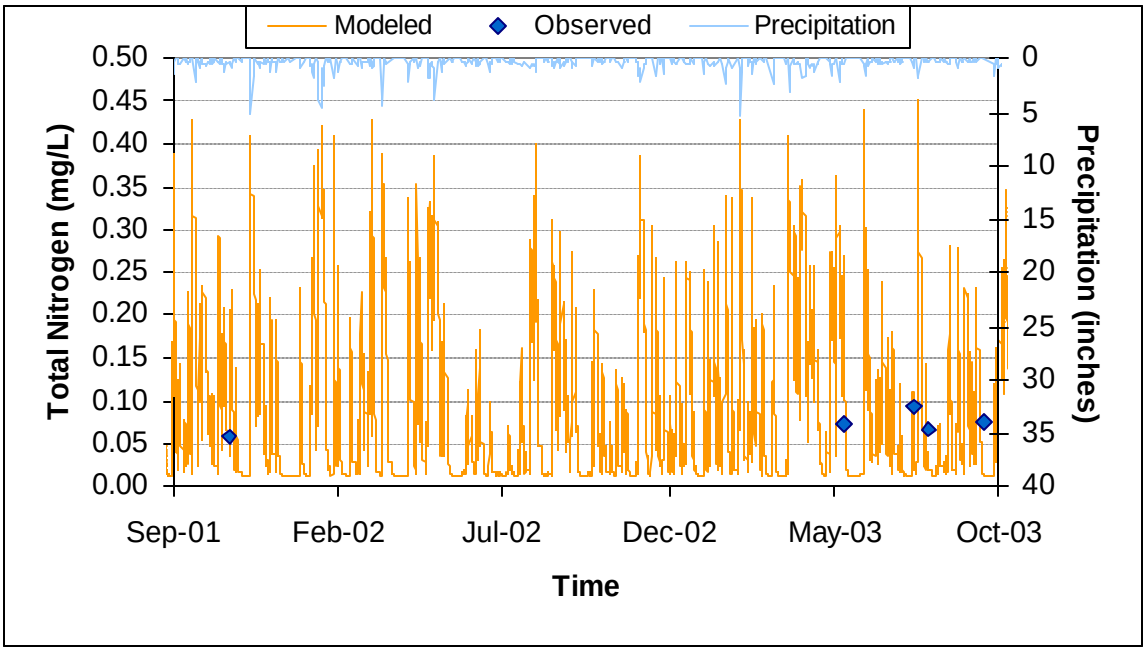

Figure E-31. Modeled and observed total nitrogen concentrations at subwatershed 202

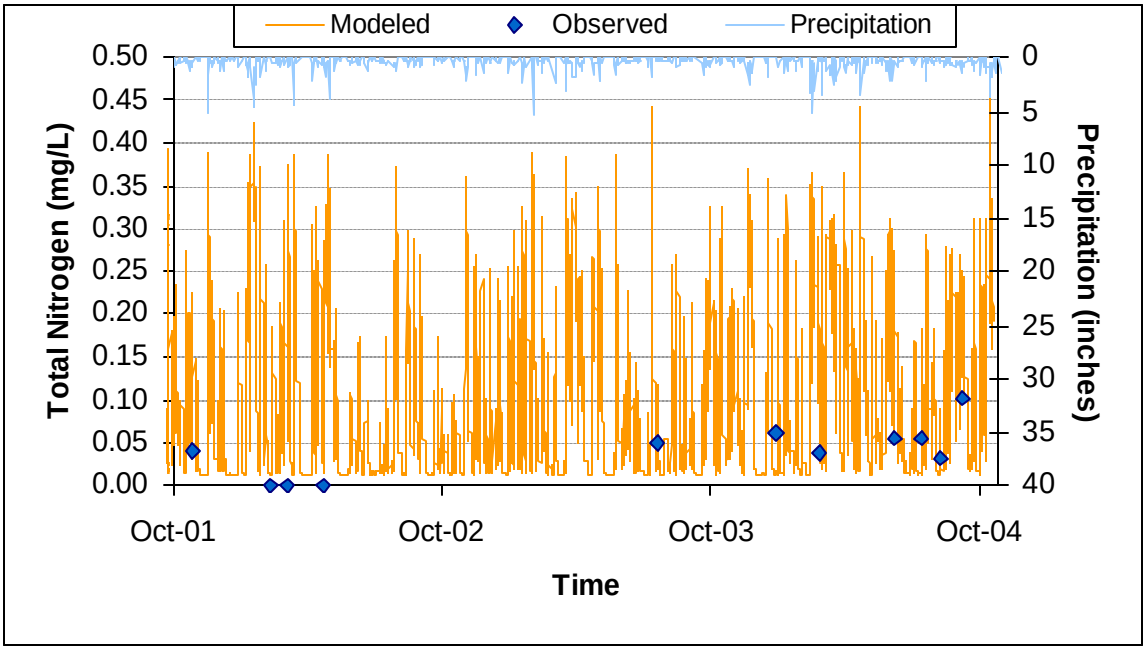

Figure E-32. Modeled and observed total nitrogen concentrations at subwatershed 303

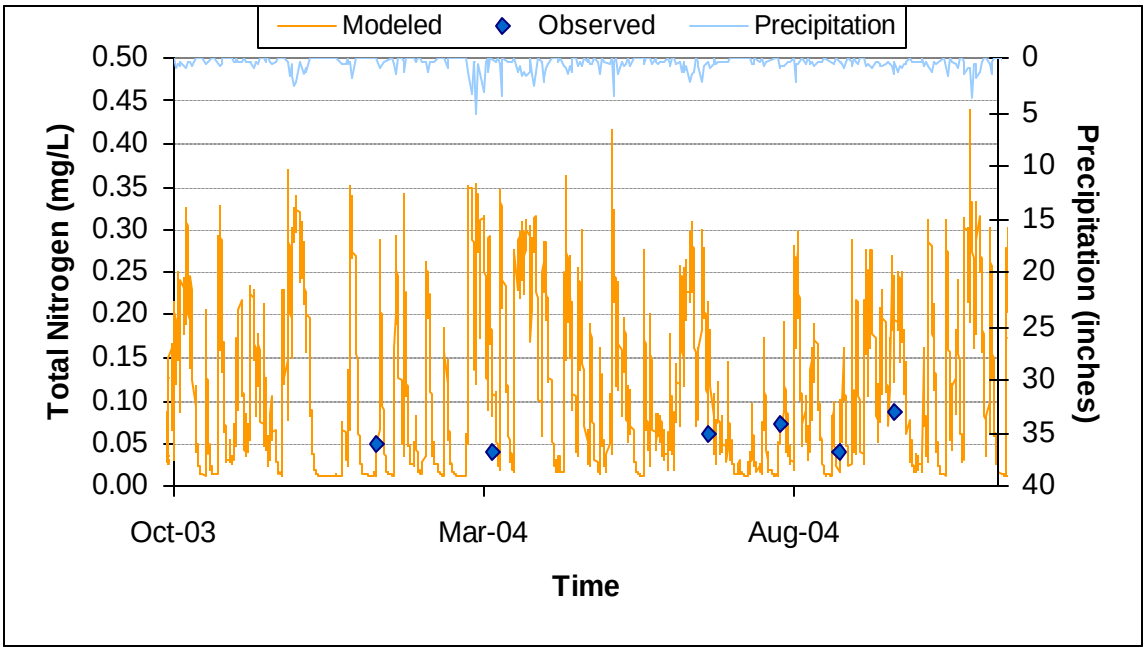

Figure E-33. Modeled and observed total nitrogen concentrations at subwatershed 304

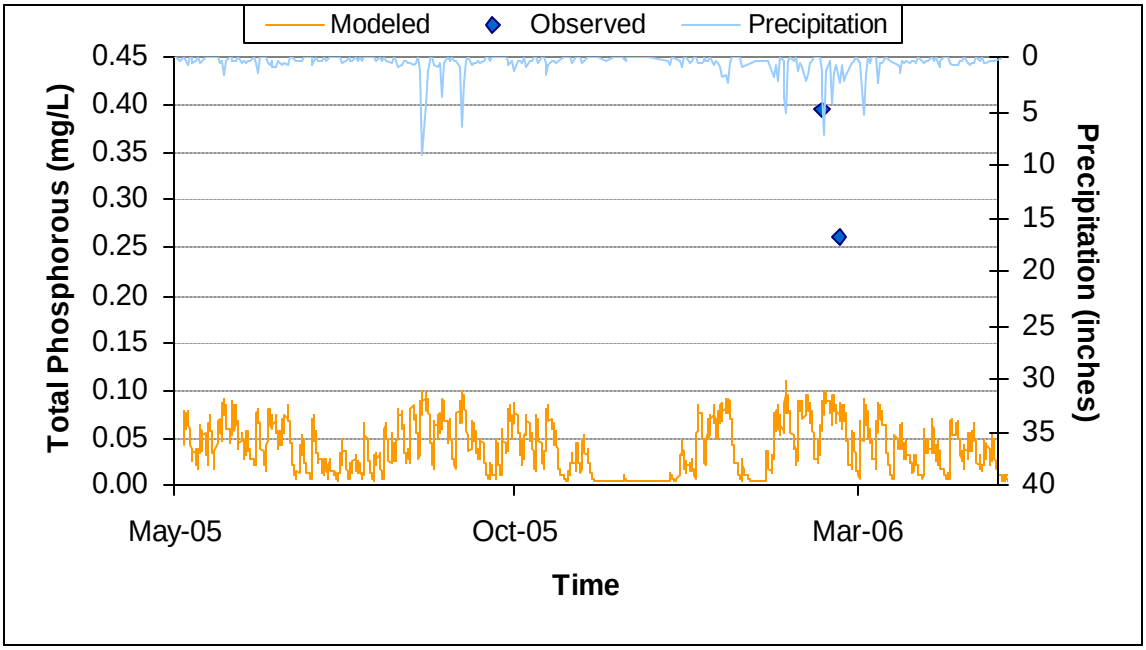

Figure E-34. Modeled and observed total phosphorous concentrations at subwatershed 110

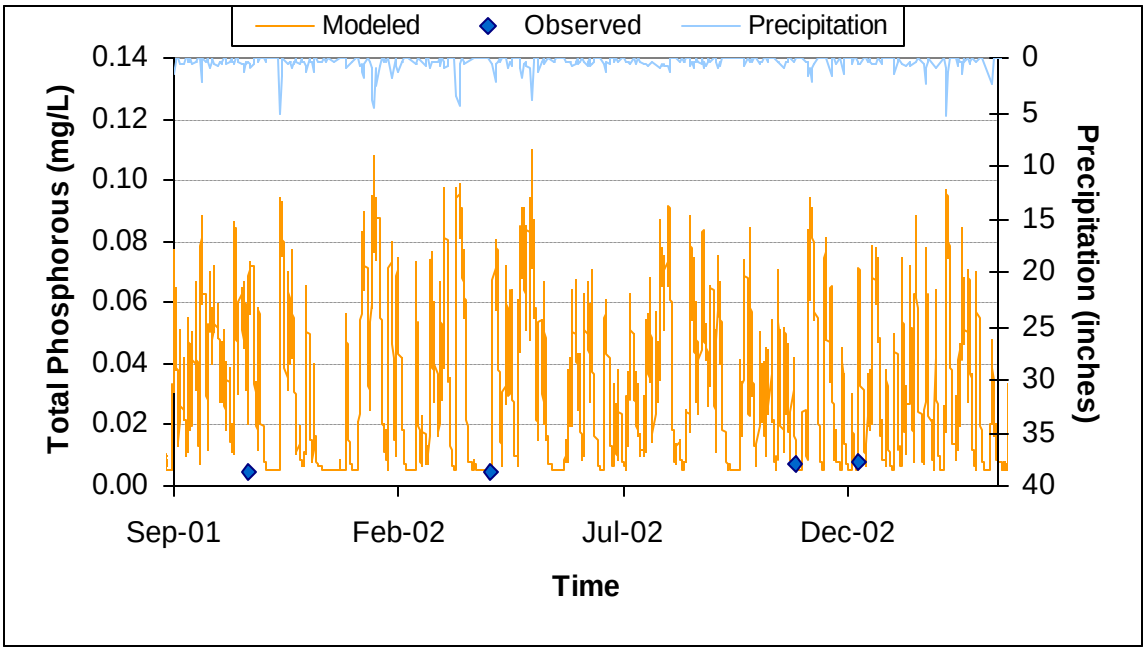

Figure E-35. Modeled and observed total phosphorous concentrations at subwatershed 112

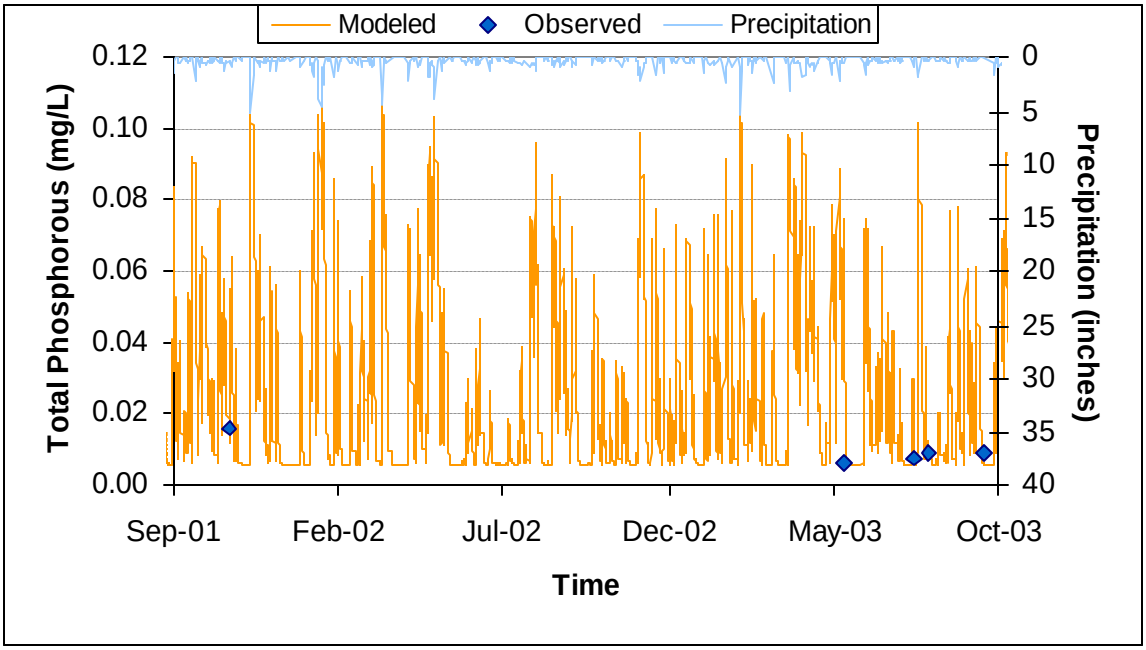

Figure E-36. Modeled and observed total phosphorous concentrations at subwatershed 201

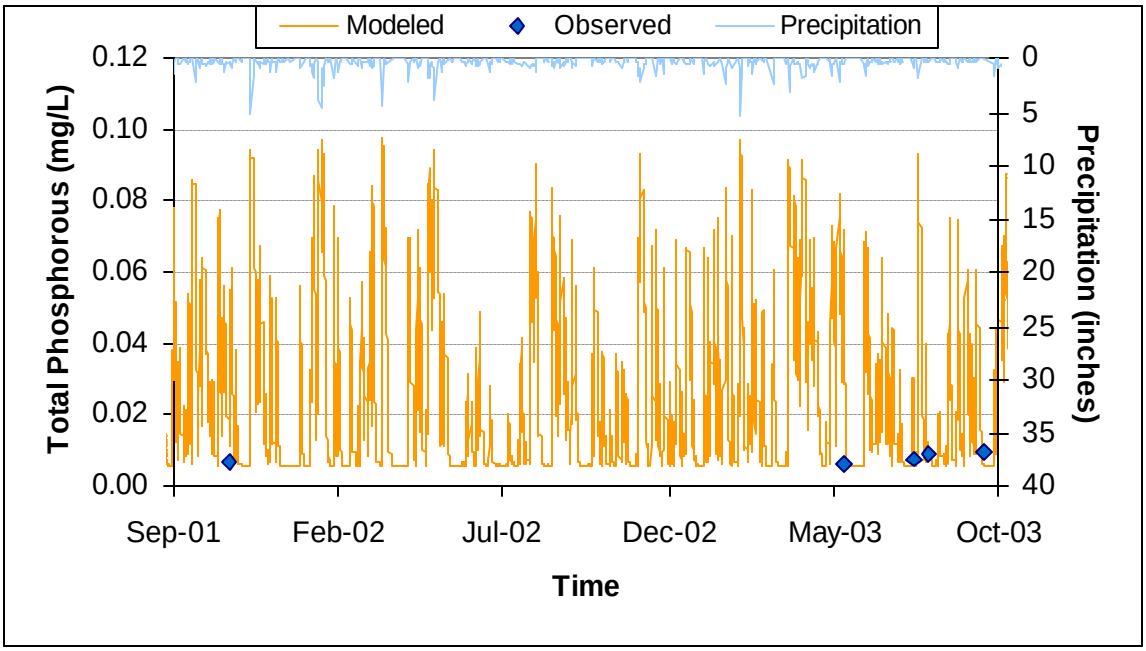

Figure E-37. Modeled and observed total phosphorous concentrations at subwatershed 202

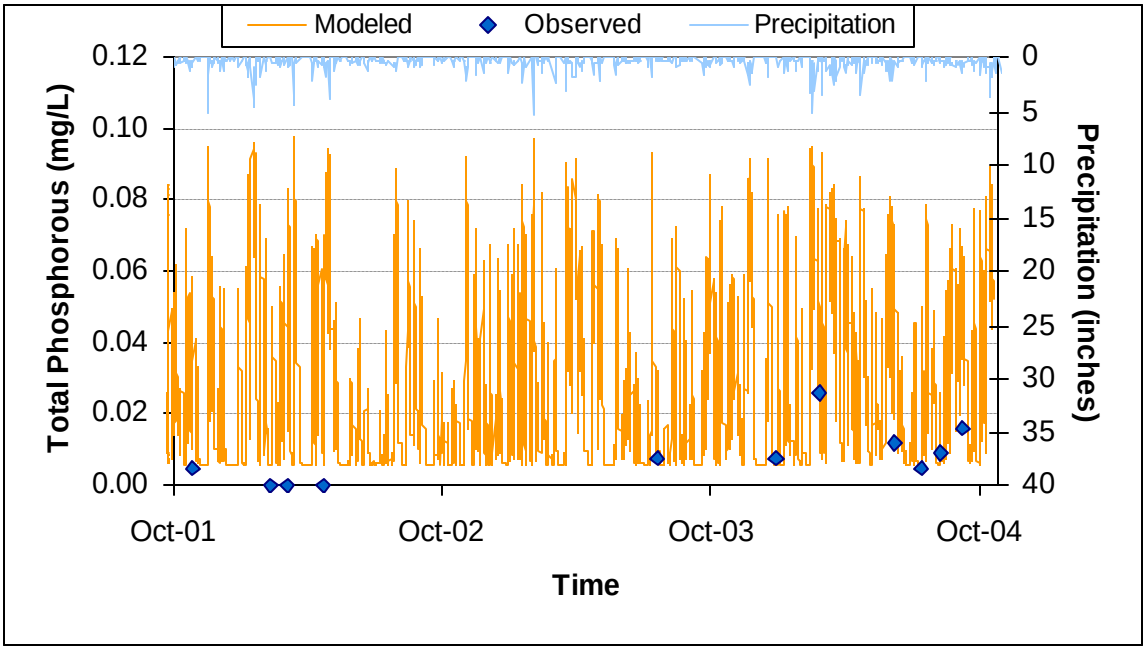

Figure E-38. Modeled and observed total phosphorous concentrations at subwatershed 303

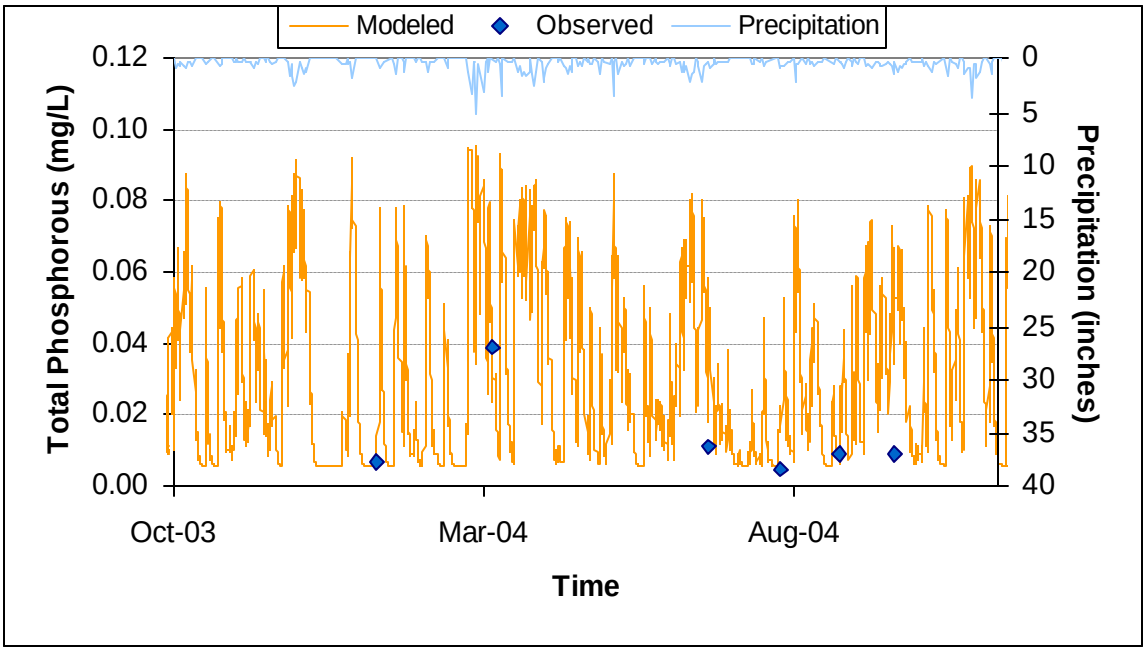

Figure E-39. Modeled and observed total phosphorous concentrations at subwatershed 304

E-3. Water Quality Validation: Automatic Sampler Comparisons

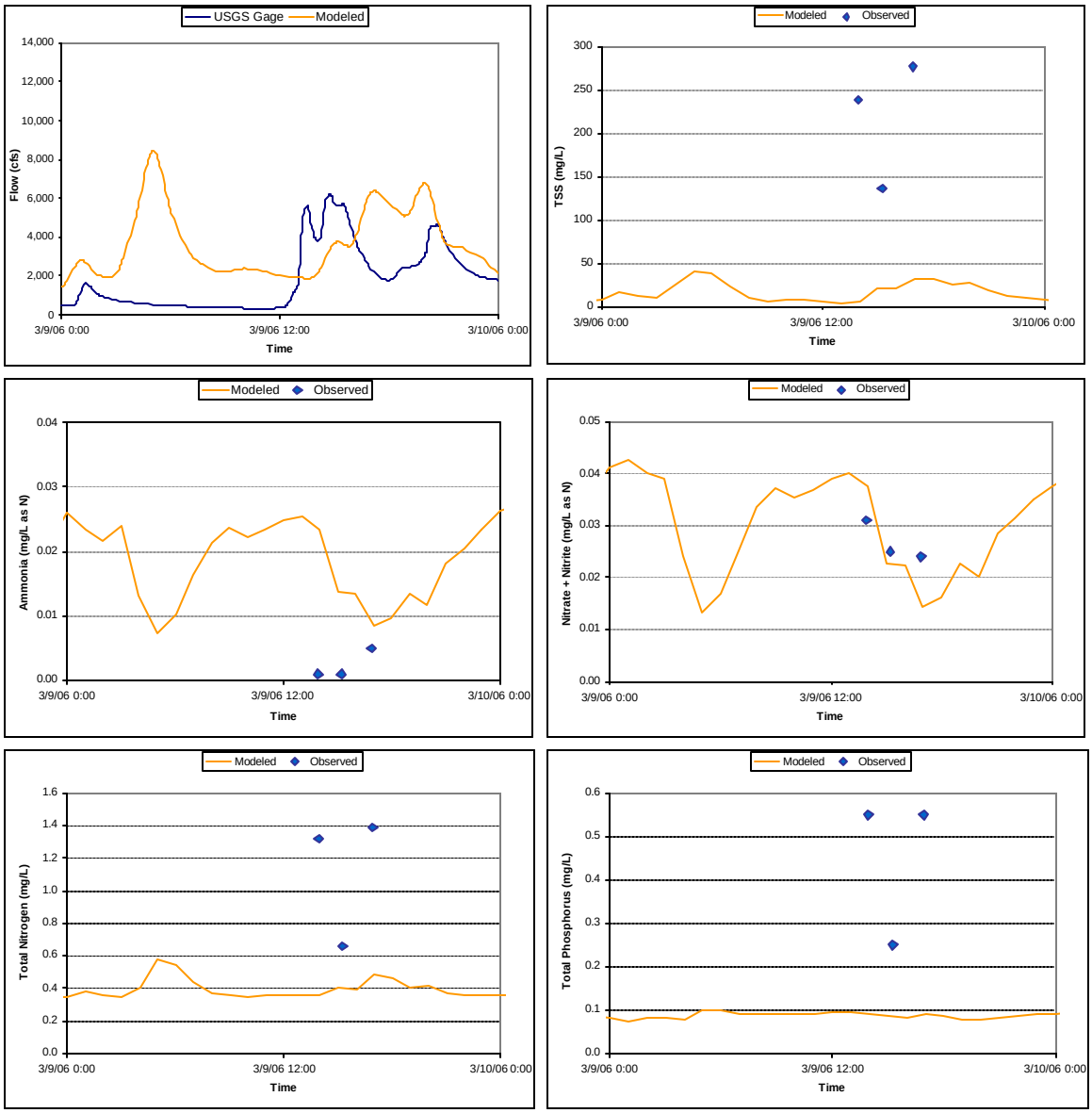

Figure E-40. Modeled and observed results at the Upper ISCO station – March 9, 2006 storm

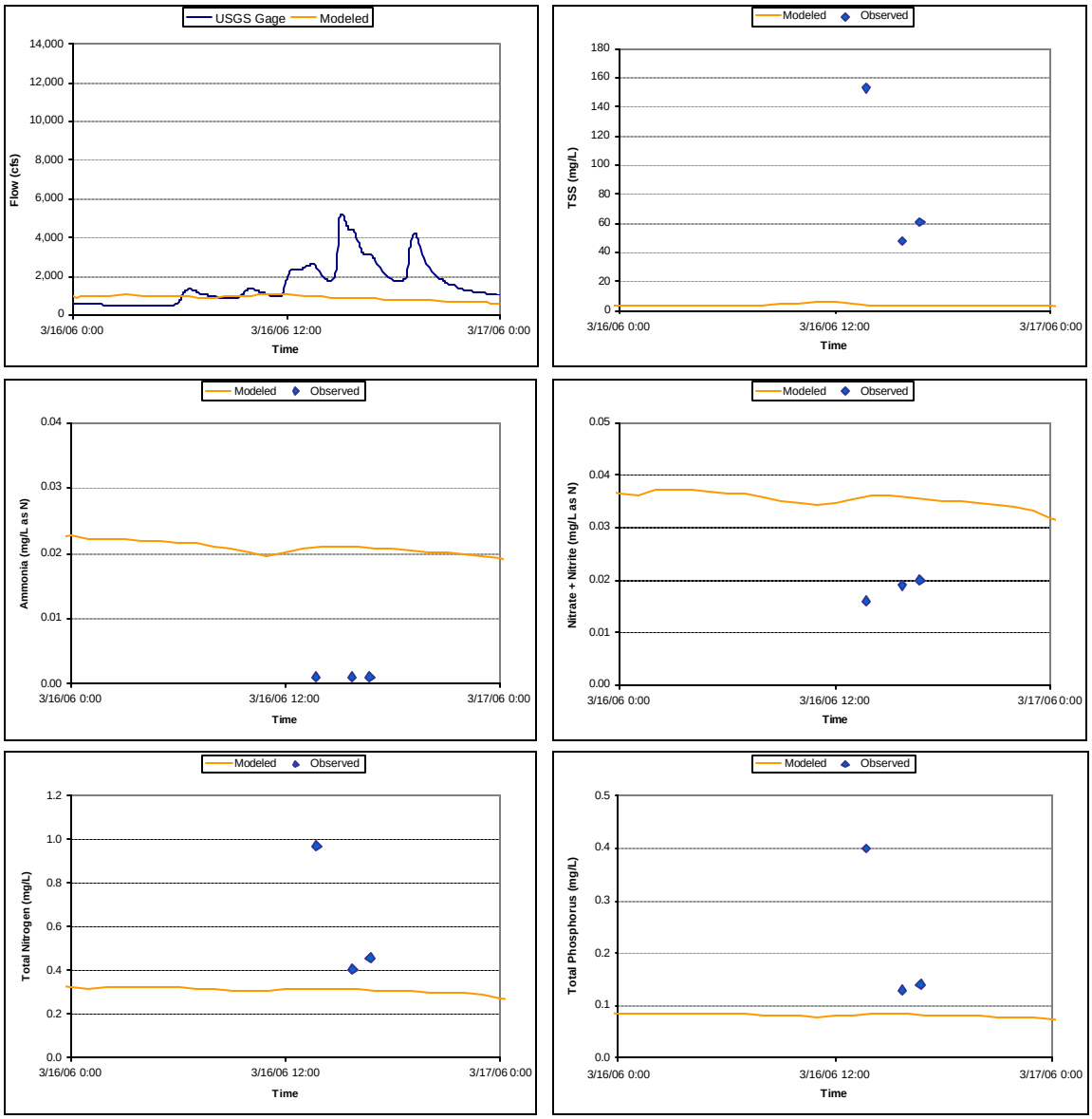

Figure E-41. Modeled and observed results at the Upper ISCO station – March 16, 2006 storm

E-4. Water Quality Calibration: Daily Comparisons

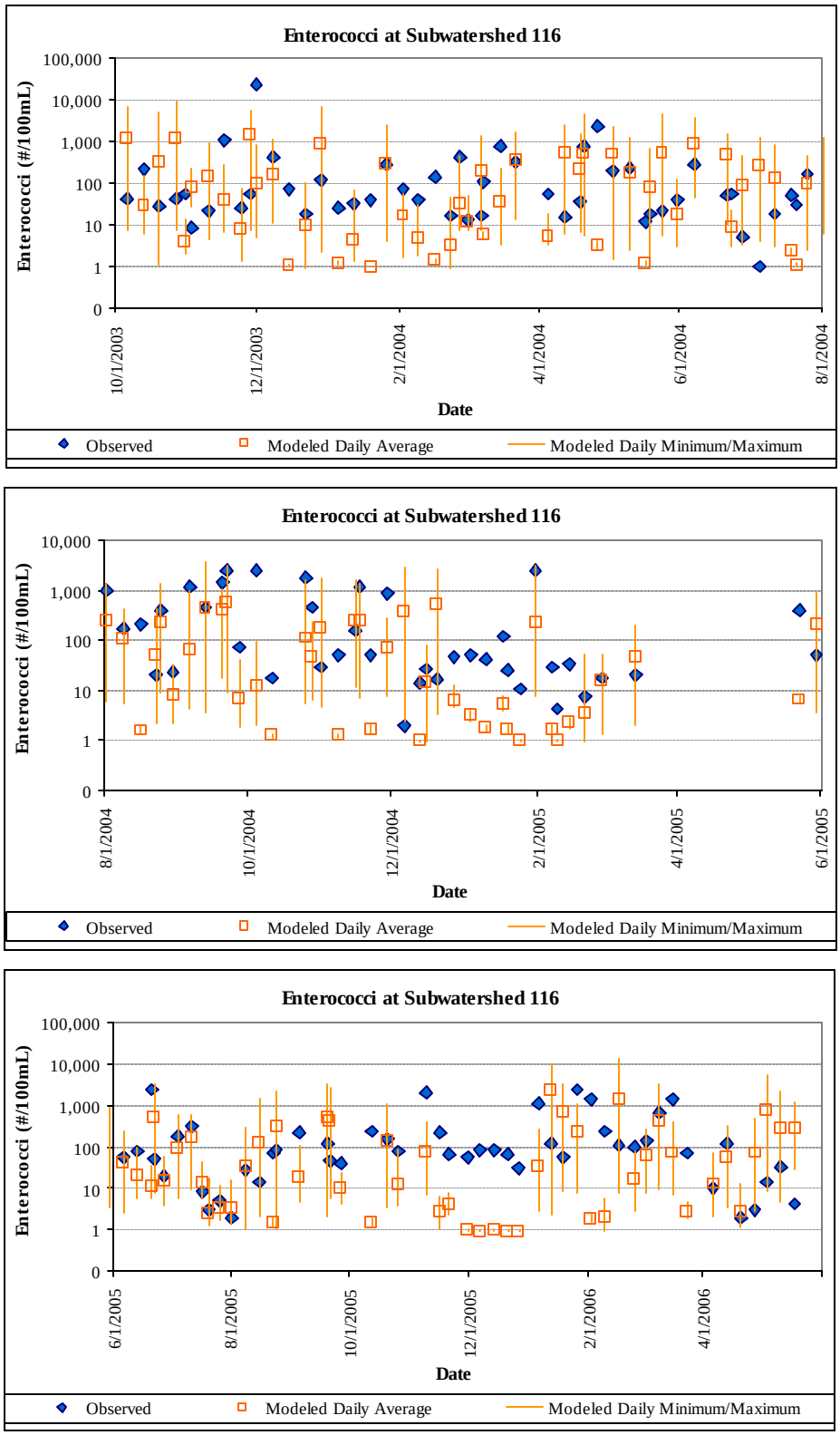

Figure E-42. Box plot comparisons of modeled and observed *enterococcus* at subwatershed 116

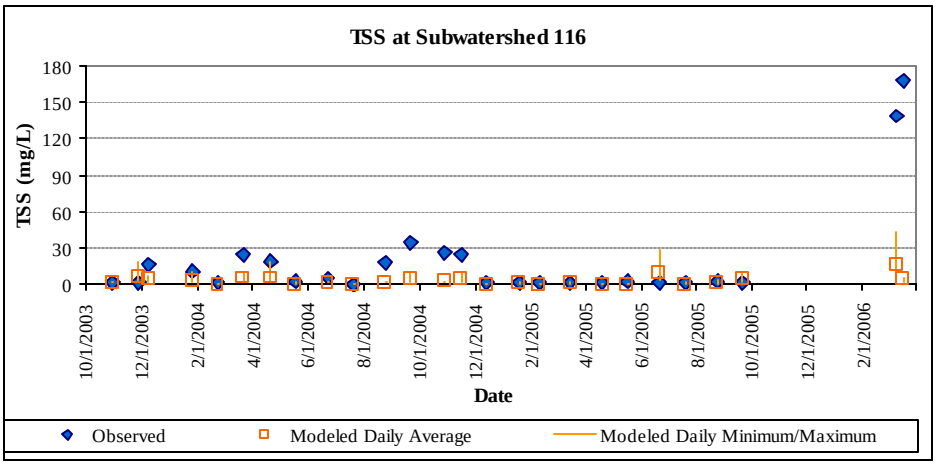

Figure E-43. Box plot comparisons of modeled and observed TSS at subwatershed 116

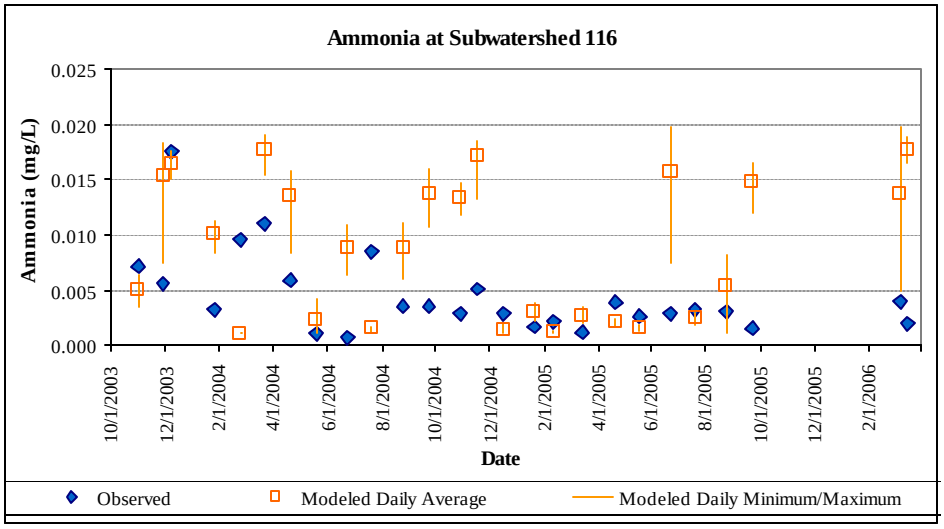

Figure E-44. Box plot comparisons of modeled and observed ammonia at subwatershed 116

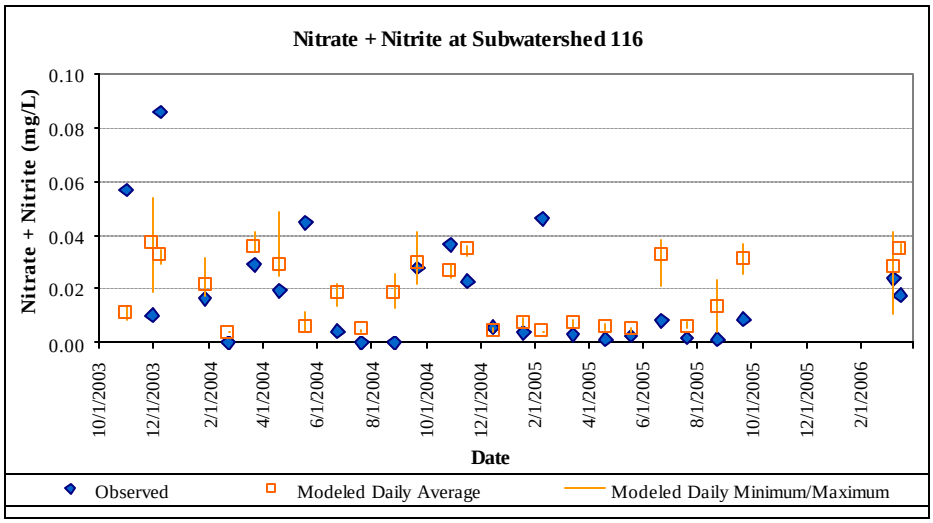

Figure E-45. Box plot comparisons of modeled and observed nitrite plus nitrate at subwatershed 116

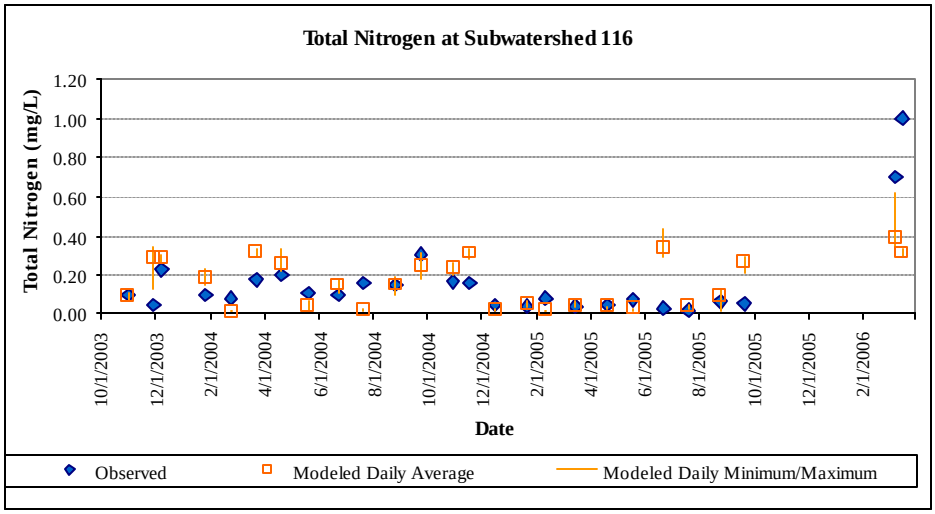

Figure E-46. Box plot comparisons of modeled and observed total nitrogen at subwatershed 116

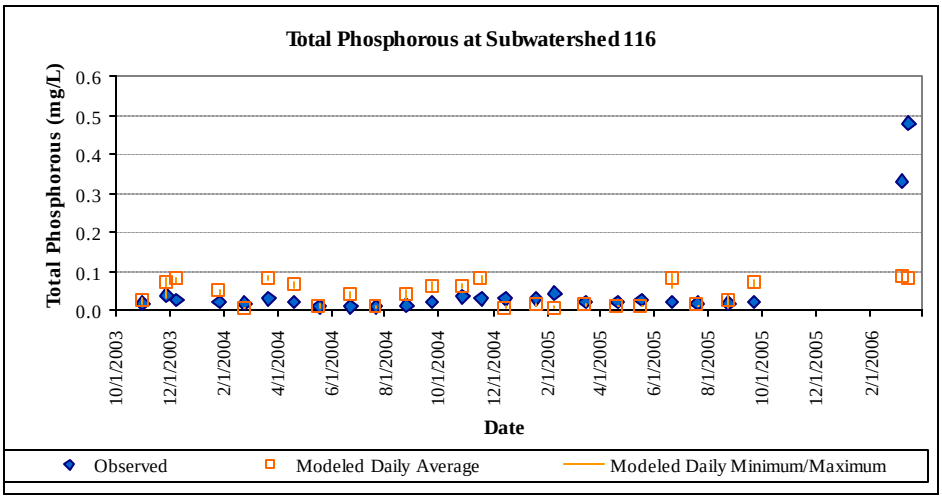

Figure E-47. Box plot comparisons of modeled and observed total phosphorous at subwatershed 116

E-5. Water Quality Validation: Daily Comparisons

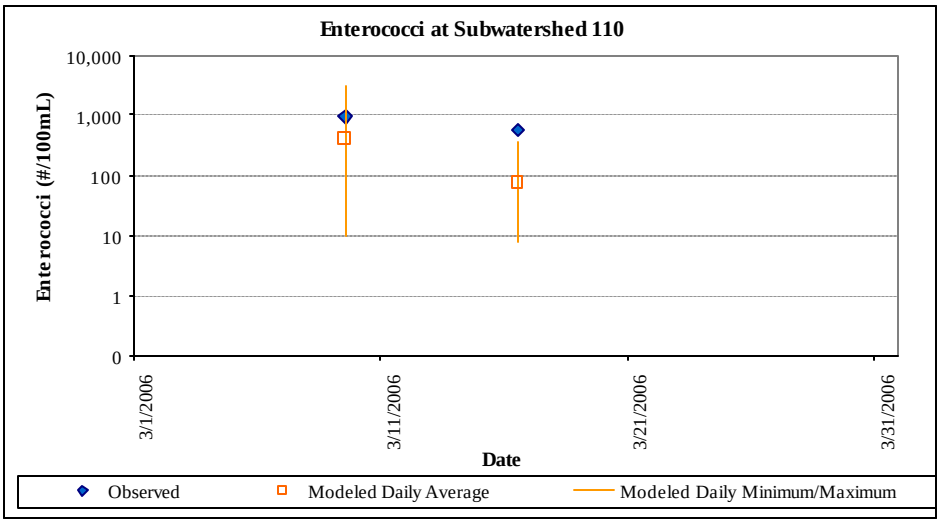

Figure E-48. Box plot comparisons of modeled and observed *enterococcus* at subwatershed 110

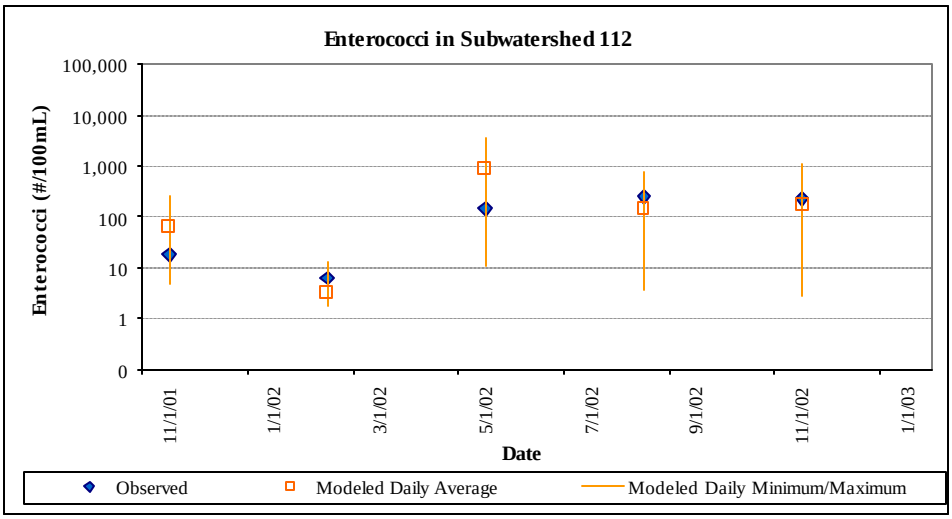

Figure E-49. Box plot comparisons of modeled and observed *enterococcus* at subwatershed 112

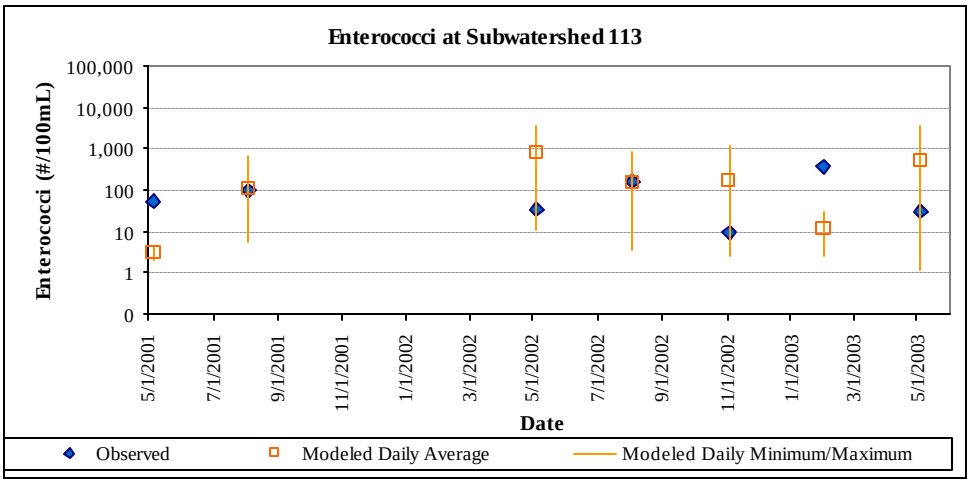

Figure E-50. Box plot comparisons of modeled and observed *enterococcus* at subwatershed 113

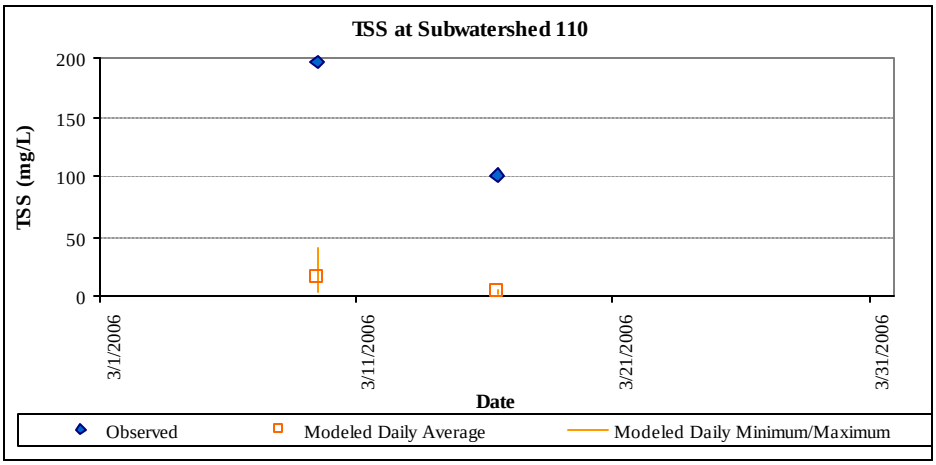

Figure E-51. Box plot comparisons of modeled and observed TSS at subwatershed 110

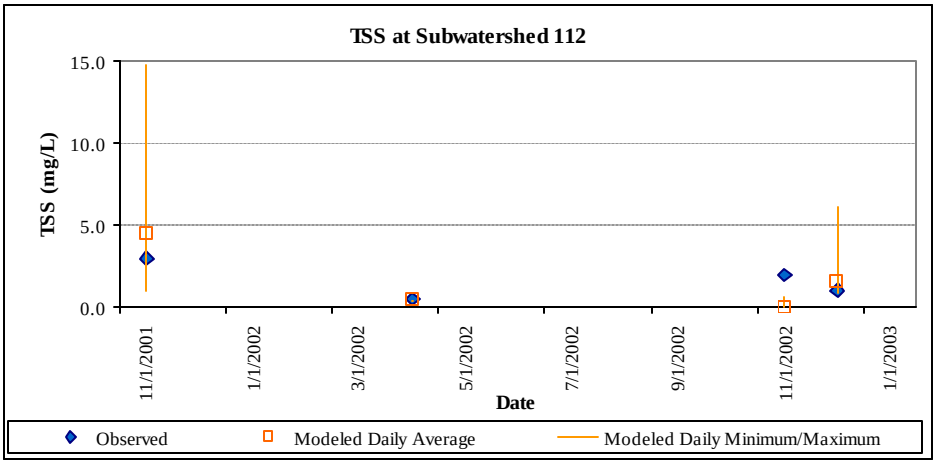

Figure E-52. Box plot comparisons of modeled and observed TSS at subwatershed 112

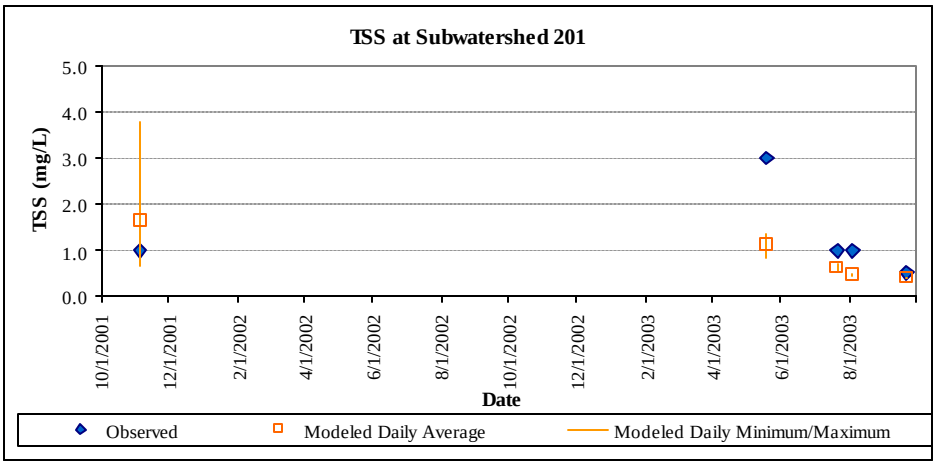

Figure E-53. Box plot comparisons of modeled and observed TSS at subwatershed 201

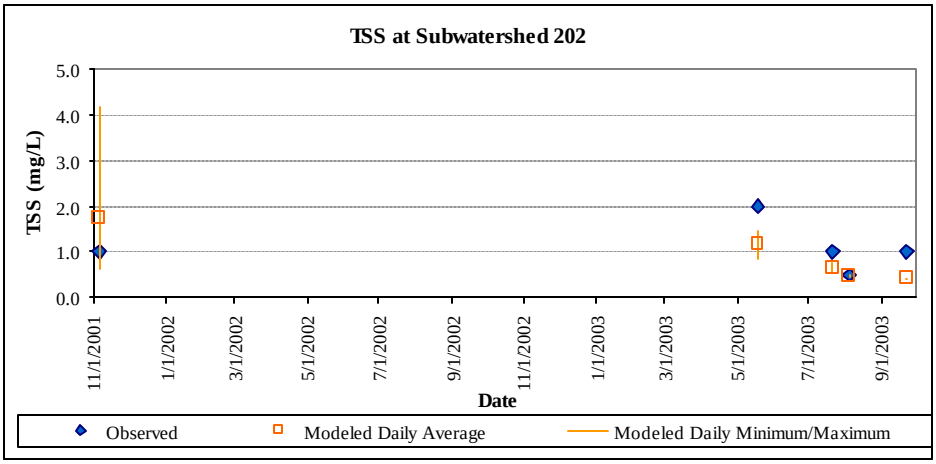

Figure E-54. Box plot comparisons of modeled and observed TSS at subwatershed 202

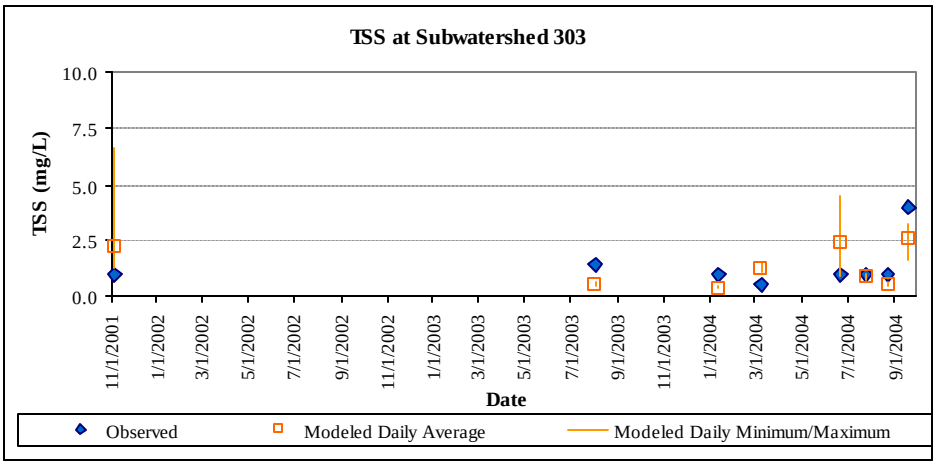

Figure E-55. Box plot comparisons of modeled and observed TSS at subwatershed 303

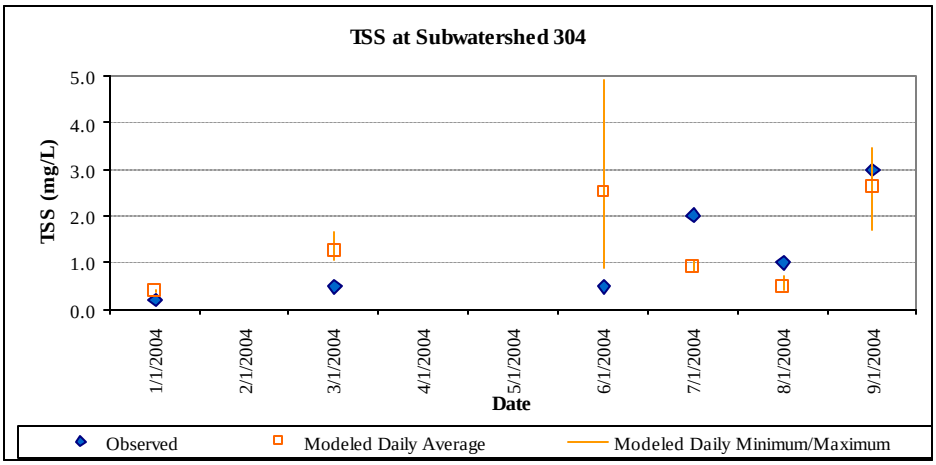

Figure E-56. Box plot comparisons of modeled and observed TSS at subwatershed 304

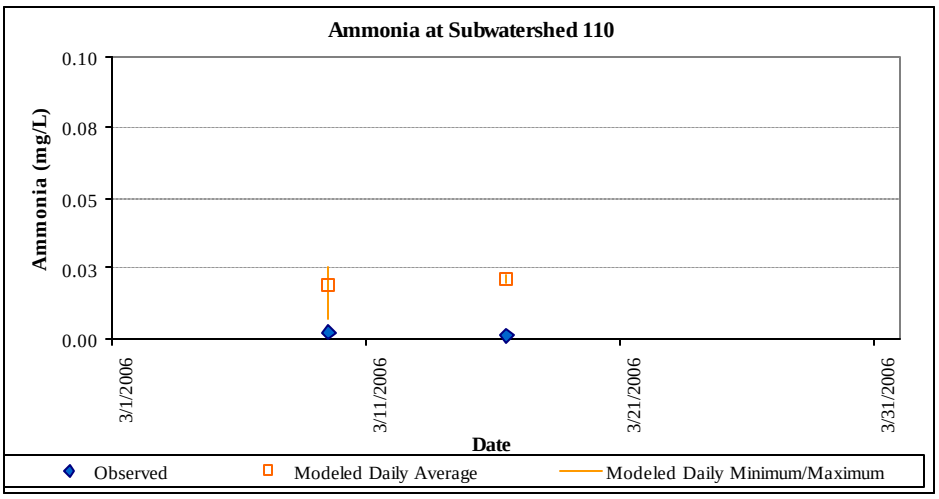

Figure E-57. Box plot comparisons of modeled and observed ammonia at subwatershed 110

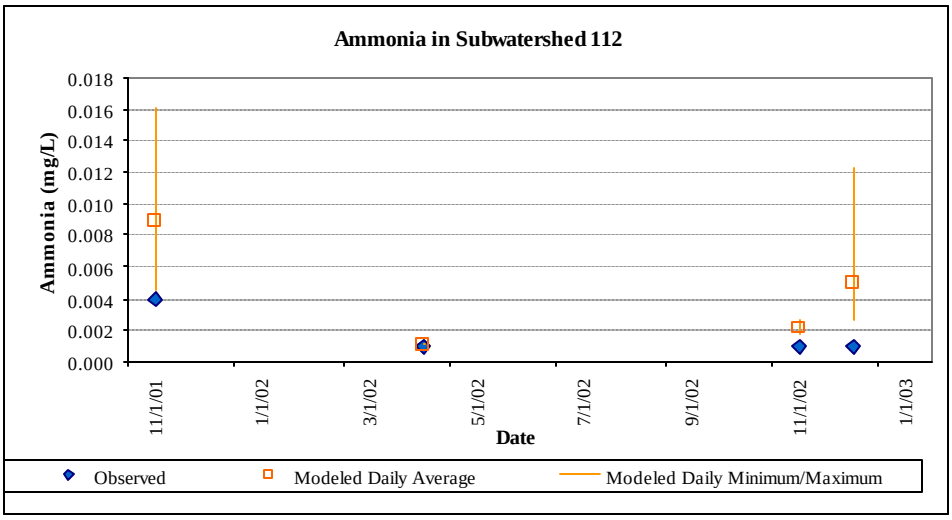

Figure E-58. Box plot comparisons of modeled and observed ammonia at subwatershed 112

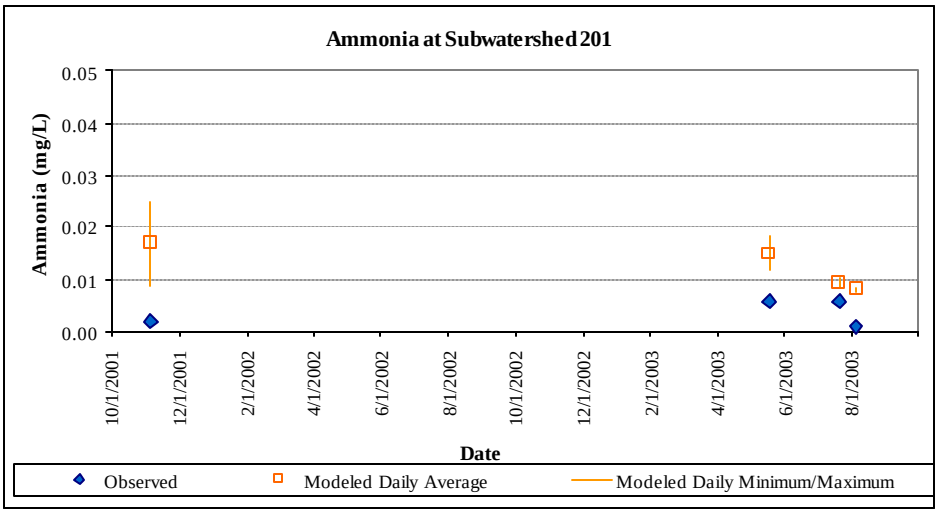

Figure E-59. Box plot comparisons of modeled and observed ammonia at subwatershed 201

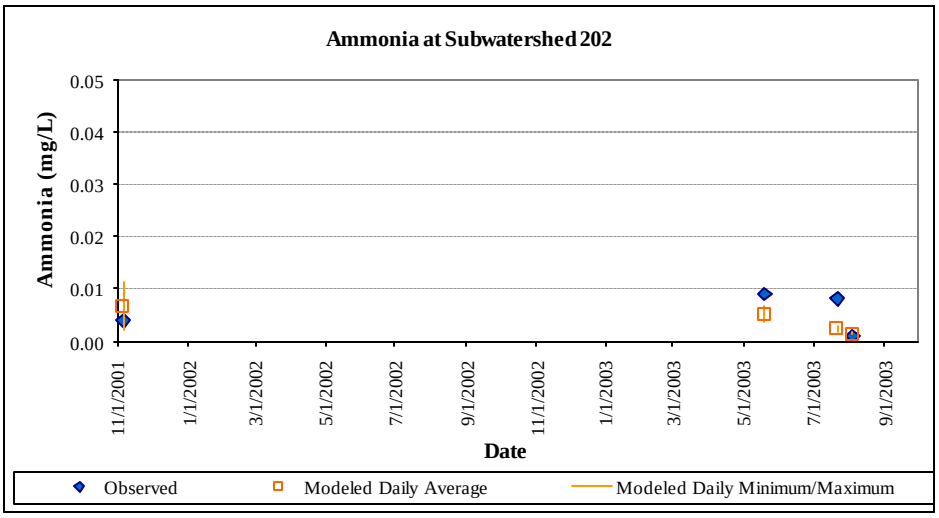

Figure E-60. Box plot comparisons of modeled and observed ammonia at subwatershed 202

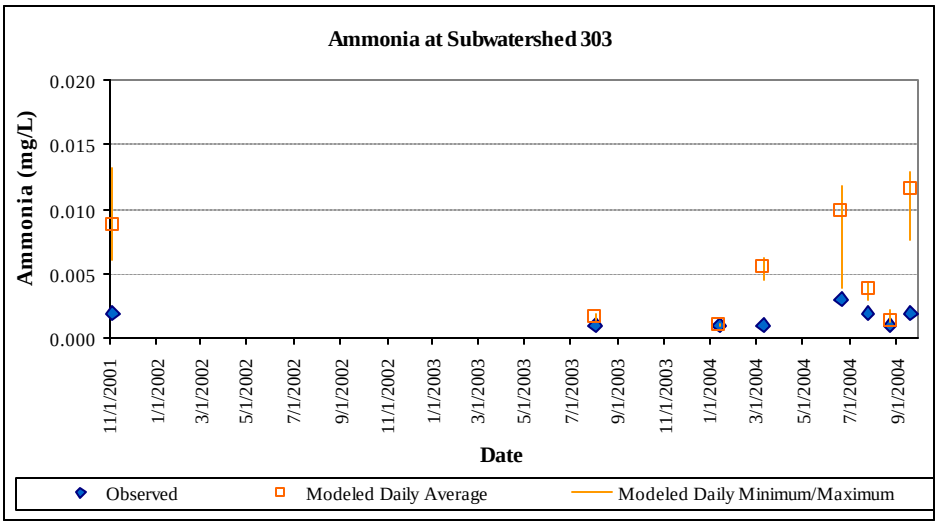

Figure E-61. Box plot comparisons of modeled and observed ammonia at subwatershed 303

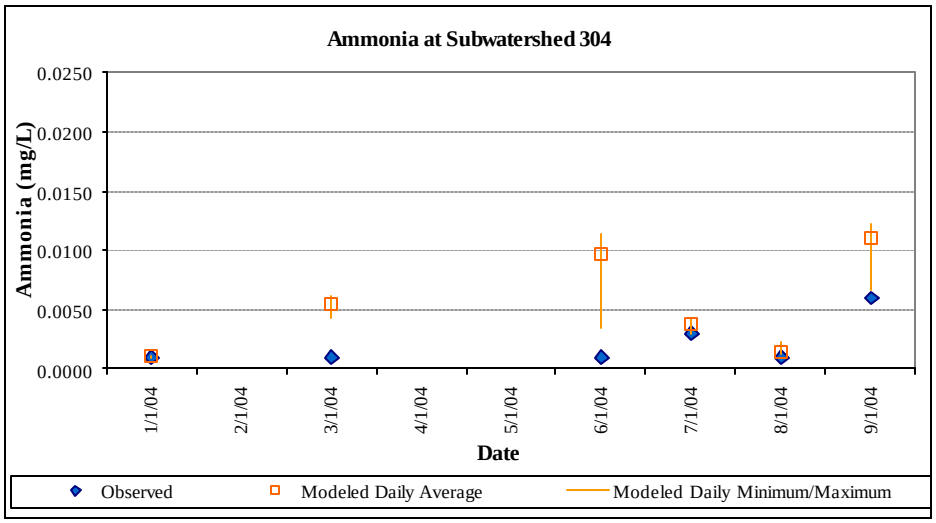

Figure E-62. Box plot comparisons of modeled and observed ammonia at subwatershed 304

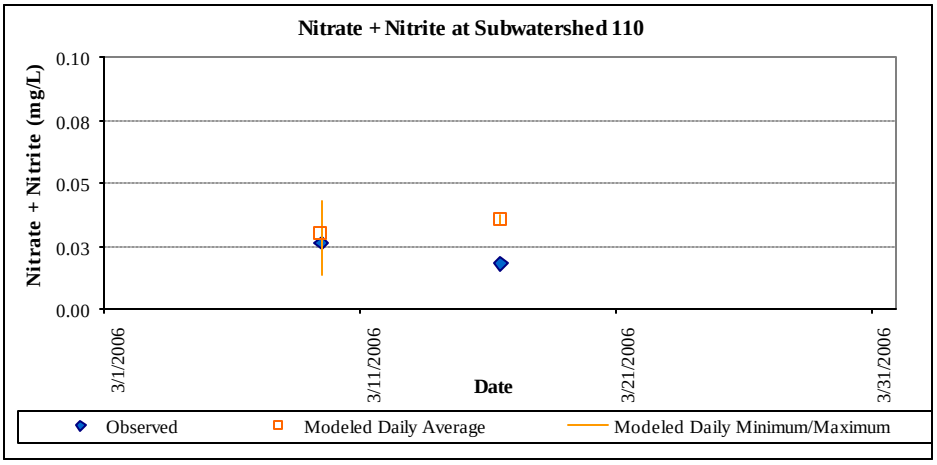

Figure E-63. Box plot comparisons of modeled and observed nitrite plus nitrate at subwatershed 110

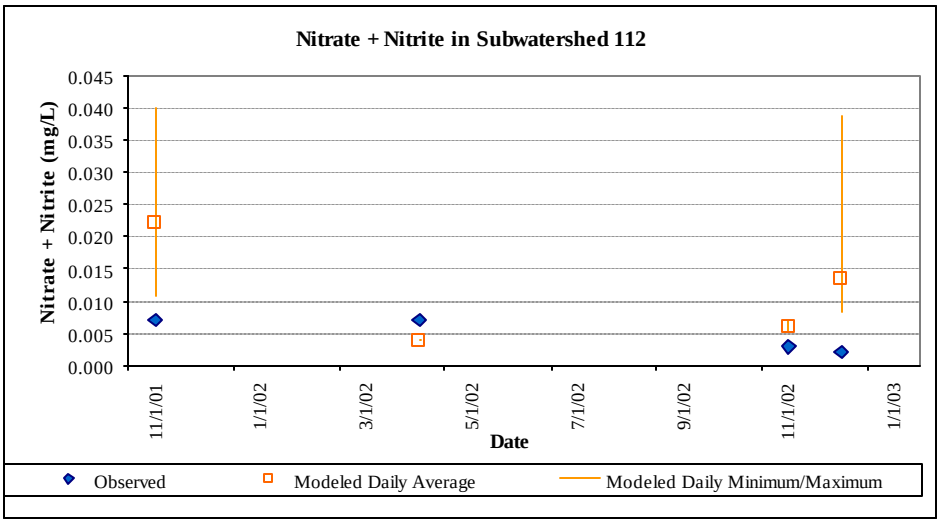

Figure E-64. Box plot comparisons of modeled and observed nitrite plus nitrate at subwatershed 112

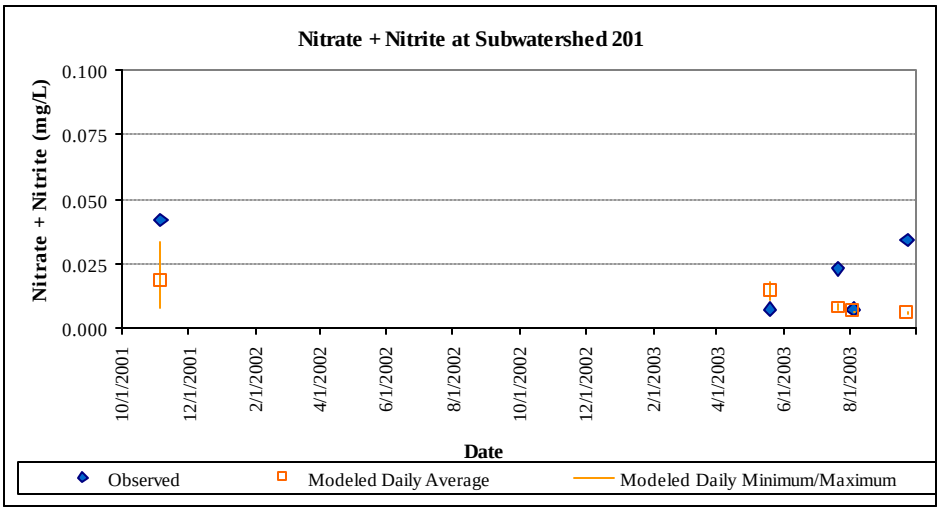

Figure E-65. Box plot comparisons of modeled and observed nitrite plus nitrate at subwatershed 201

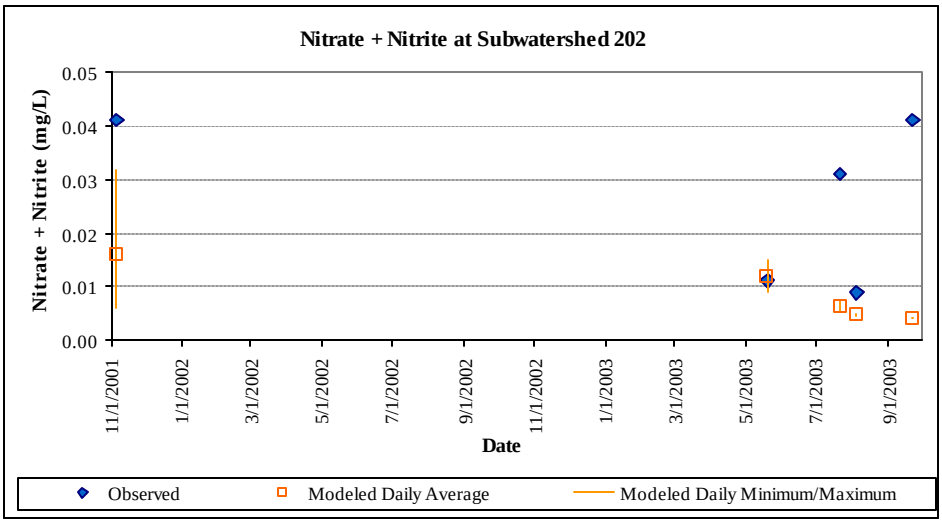

Figure E-66. Box plot comparisons of modeled and observed nitrite plus nitrate at subwatershed 202

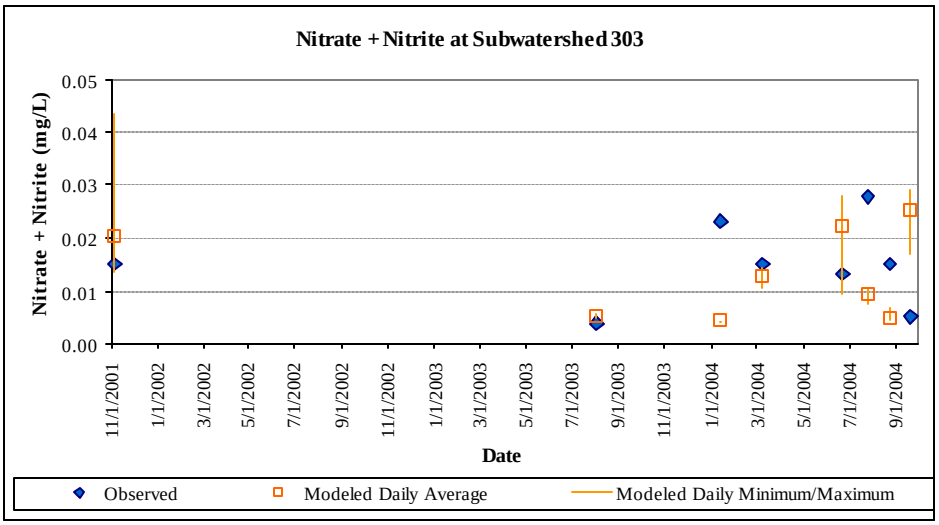

Figure E-67. Box plot comparisons of modeled and observed nitrite plus nitrate at subwatershed 303

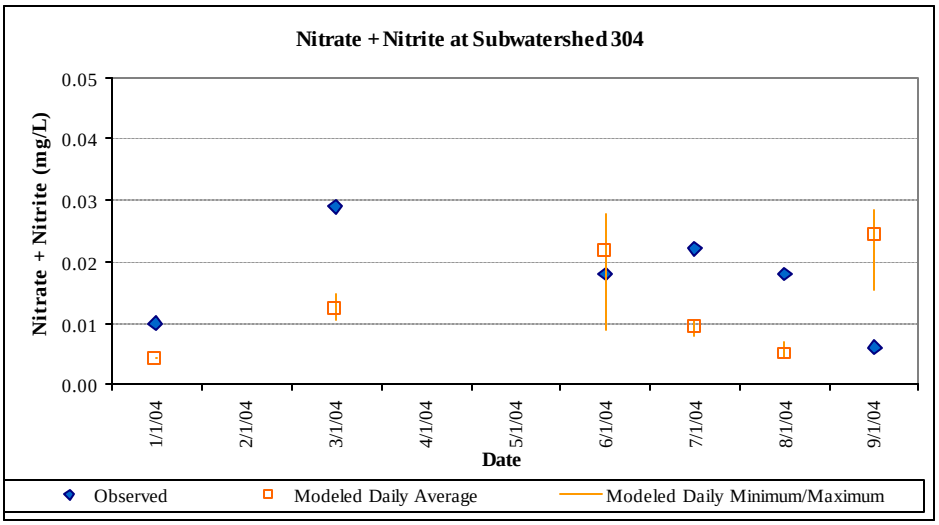

Figure E-68. Box plot comparisons of modeled and observed nitrite plus nitrate at subwatershed 304

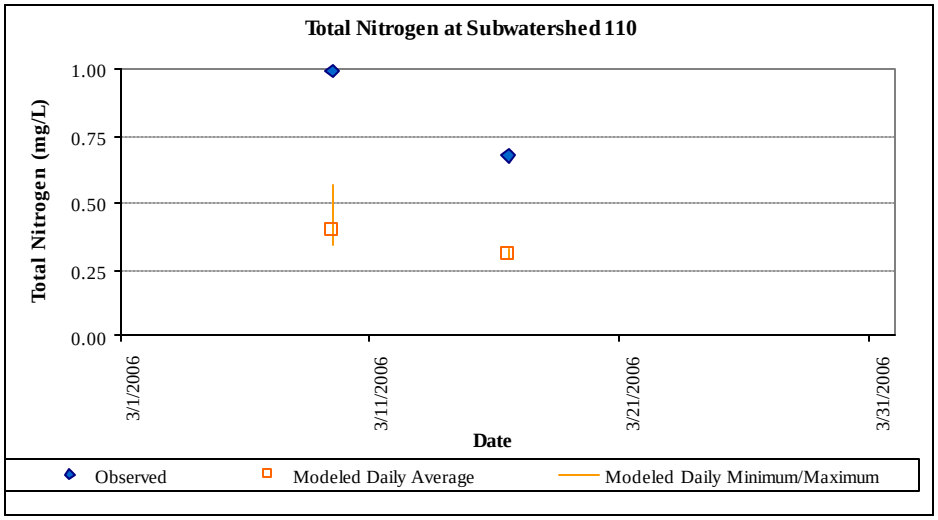

Figure E-69. Box plot comparisons of modeled and observed total nitrogen at subwatershed 110

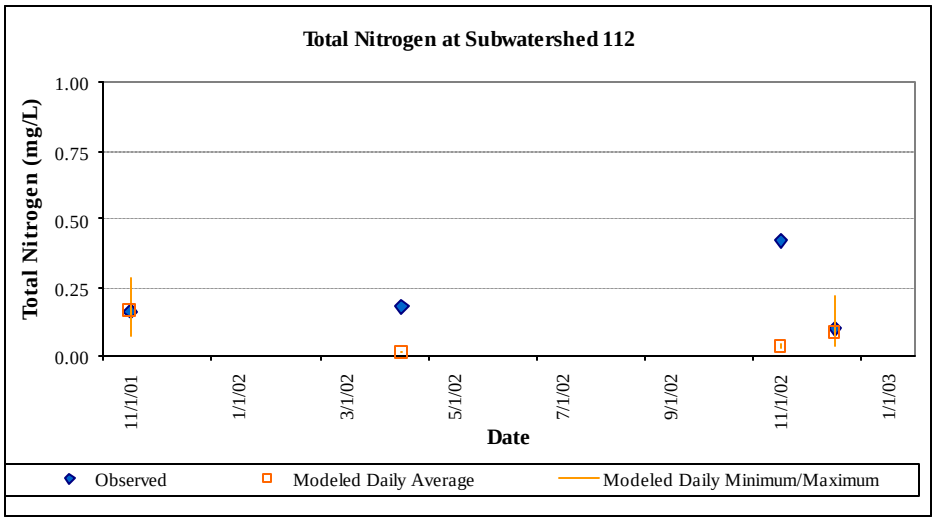

Figure E-70. Box plot comparisons of modeled and observed total nitrogen at subwatershed 112

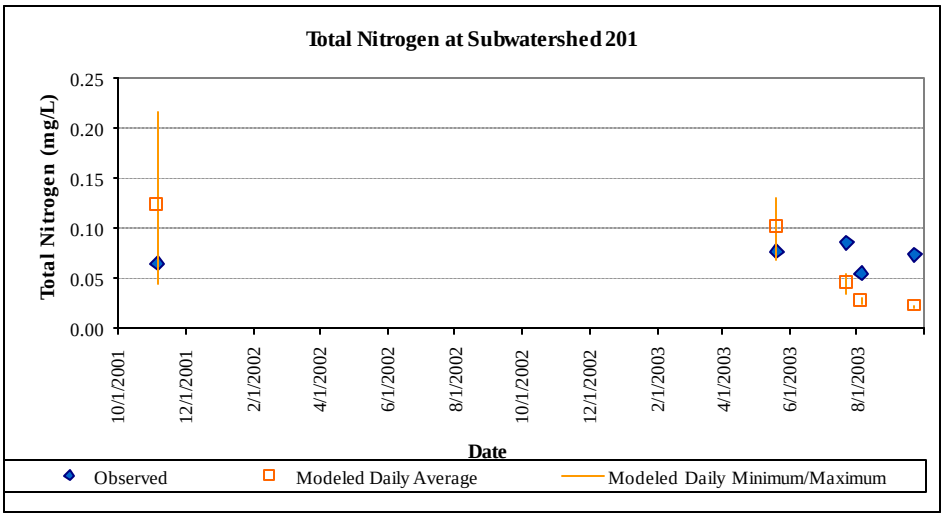

Figure E-71. Box plot comparisons of modeled and observed total nitrogen at subwatershed 201

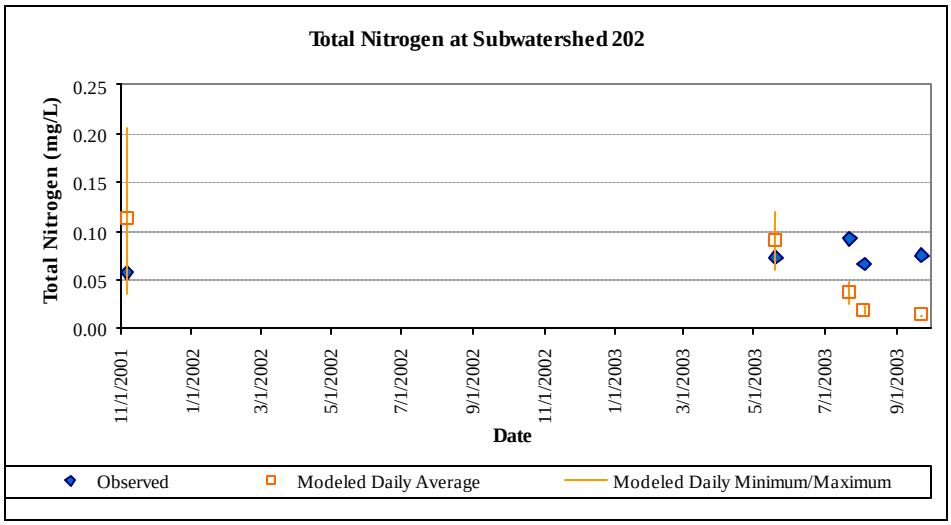

Figure E-72. Box plot comparisons of modeled and observed total nitrogen at subwatershed 202

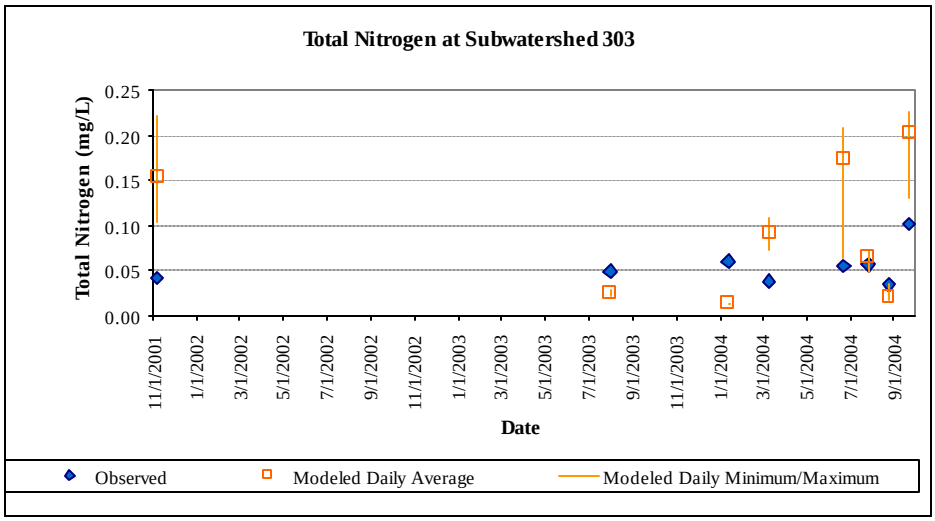

Figure E-73. Box plot comparisons of modeled and observed total nitrogen at subwatershed 303

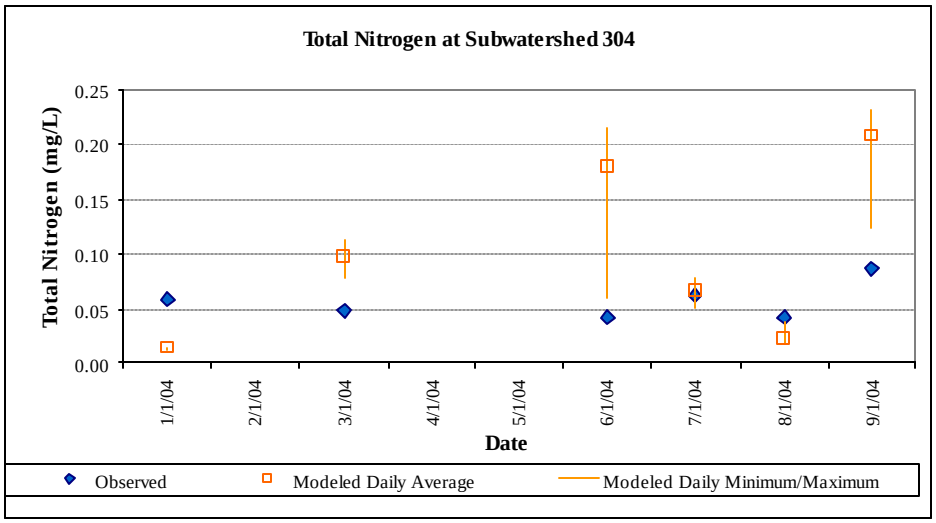

Figure E-74. Box plot comparisons of modeled and observed total nitrogen at subwatershed 304

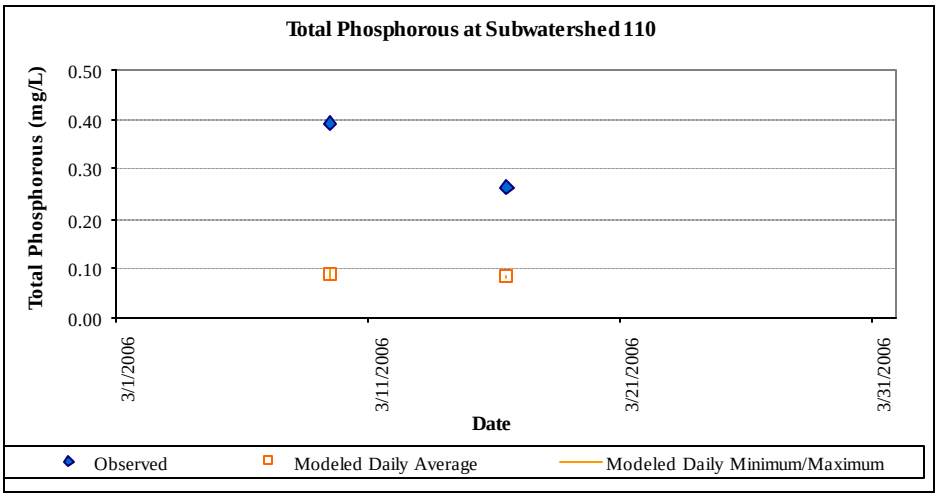

Figure E-75. Box plot comparisons of modeled and observed total phosphorous at subwatershed 110

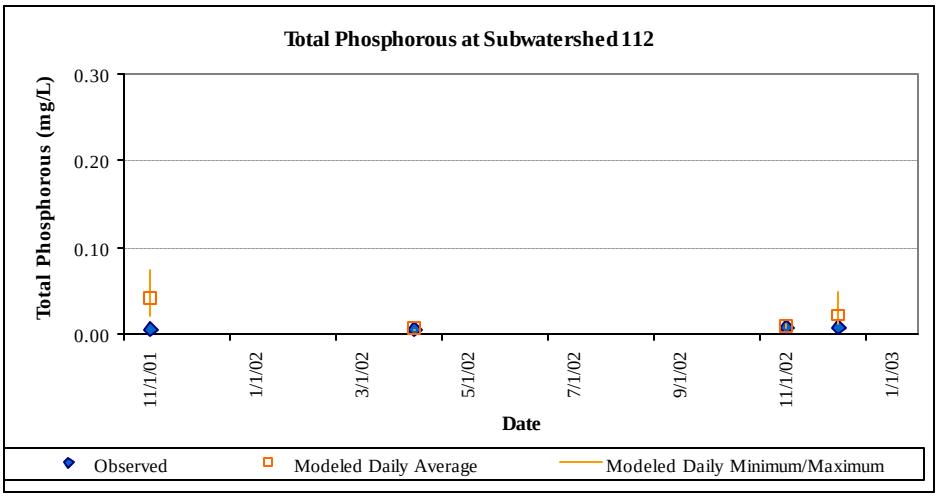

Figure E-76. Box plot comparisons of modeled and observed total phosphorous at subwatershed 112

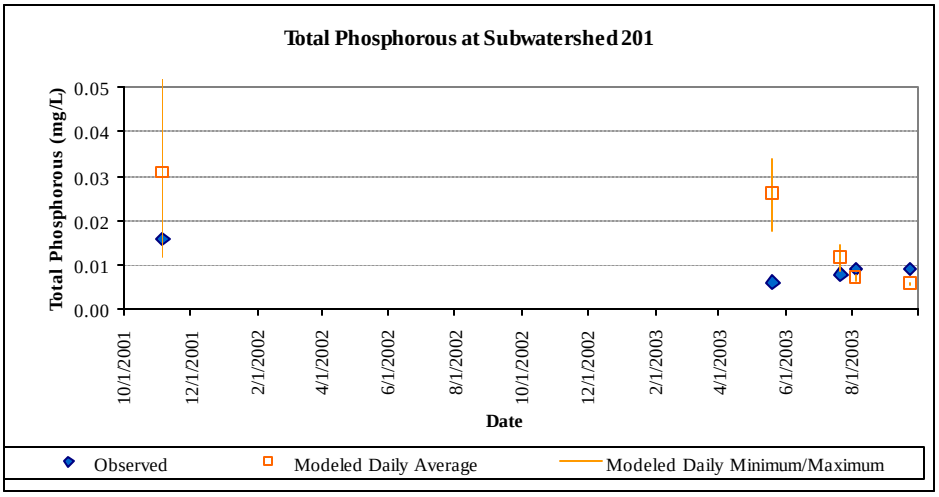

Figure E-77. Box plot comparisons of modeled and observed total phosphorous at subwatershed 201

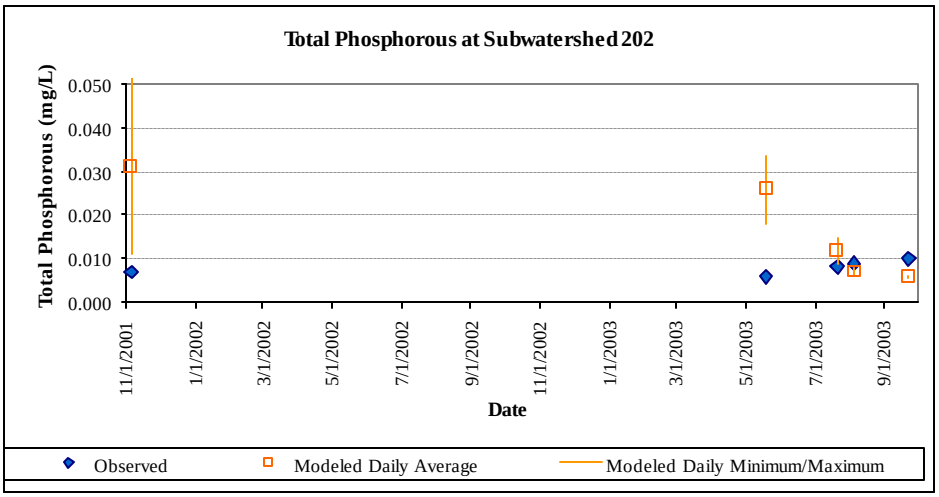

Figure E-78. Box plot comparisons of modeled and observed total phosphorous at subwatershed 202

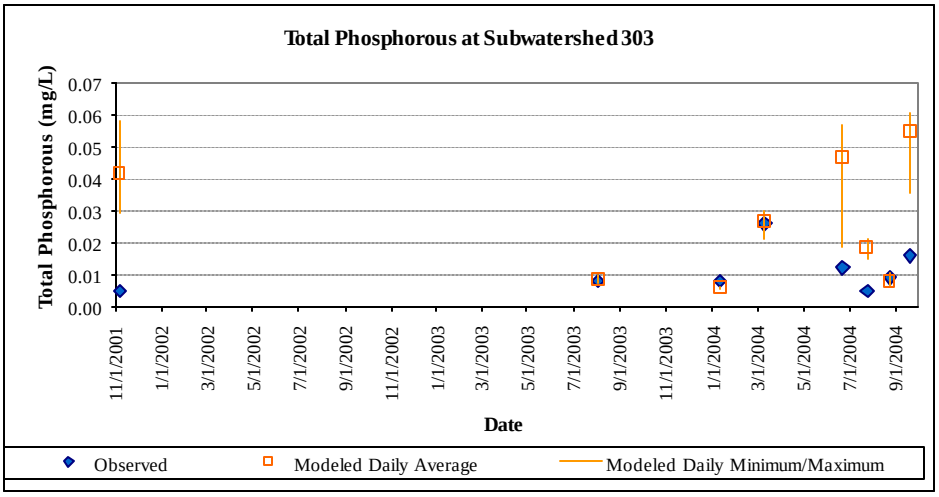

Figure E-79. Box plot comparisons of modeled and observed total phosphorous at subwatershed 303

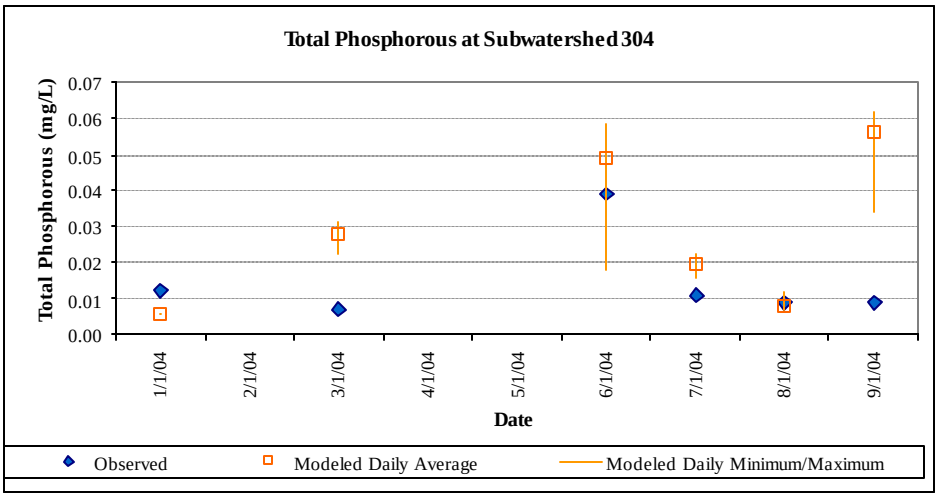

Figure E-80. Box plot comparisons of modeled and observed total phosphorous at subwatershed 304

Appendix F: EFDC Water Quality Calibration and Validation Results

Prepared for:
USEPA Region 9
Hawai'i Department of Health

Prepared by:
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Introduction

The graphs presented below in Sections F.1 and F.2 provide water quality calibration and validation results by constituent for the EFDC modeling (see Appendix B for a detailed discussion of the modeling approach and results). Specifically, the graphs in Section F.1 present the hourly model output compared to the observed data for each parameter at each station (Table B-16 of Appendix B) during 2005, which was used for model calibration. Similarly, Section F.2 provides the same comparisons during 2004, which were used for model validation. Additional details regarding the EFDC water quality simulations and results are discussed in Appendix B.

F-1. Water Quality Calibration

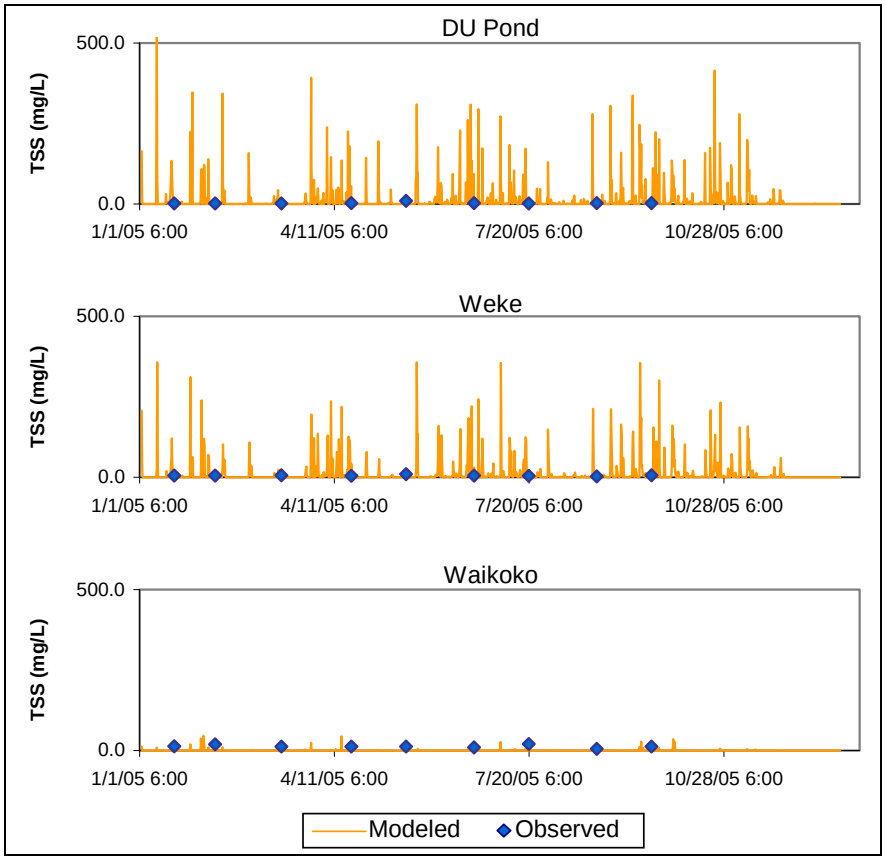

Figure F-1. Modeled and observed TSS concentrations for calibration

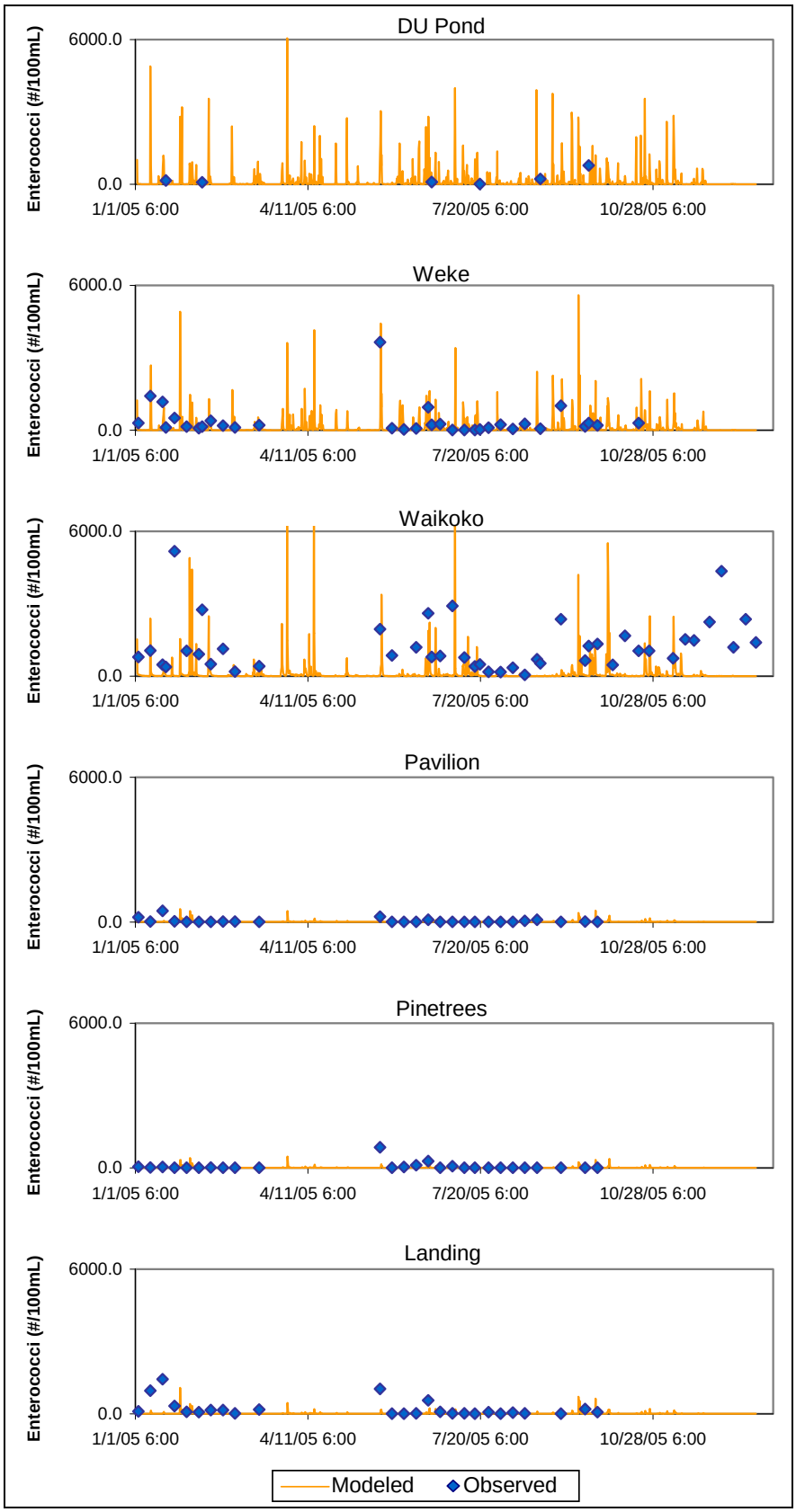

Figure F-2. Modeled and observed *enterococcus* concentrations for calibration

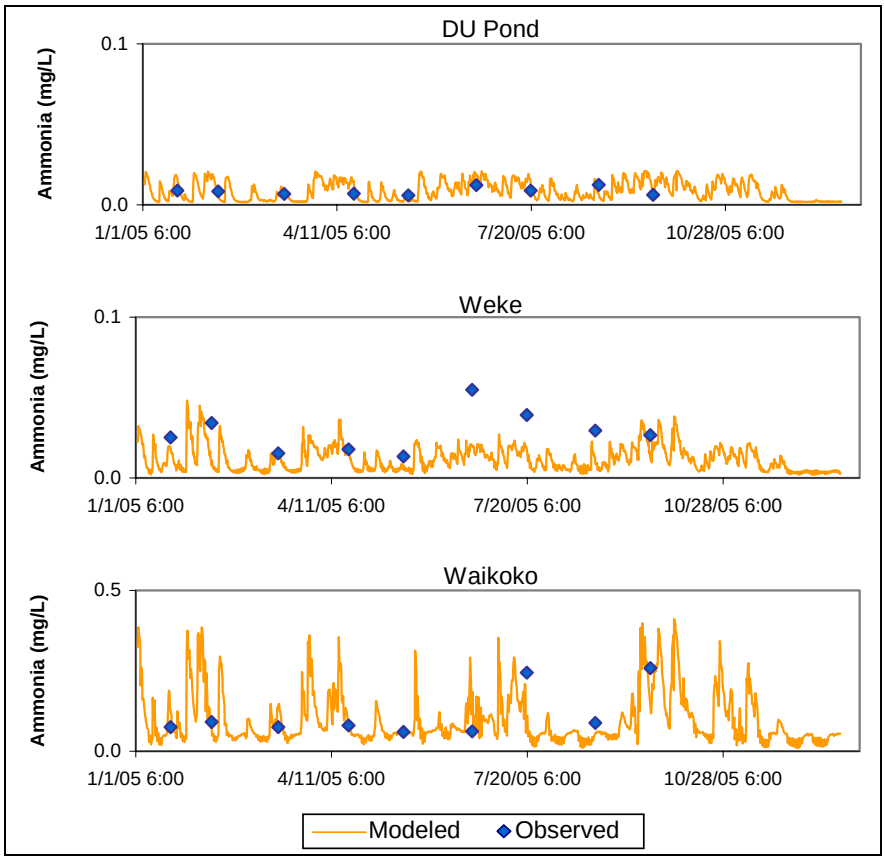

Figure F-3. Modeled and observed ammonia concentrations for calibration

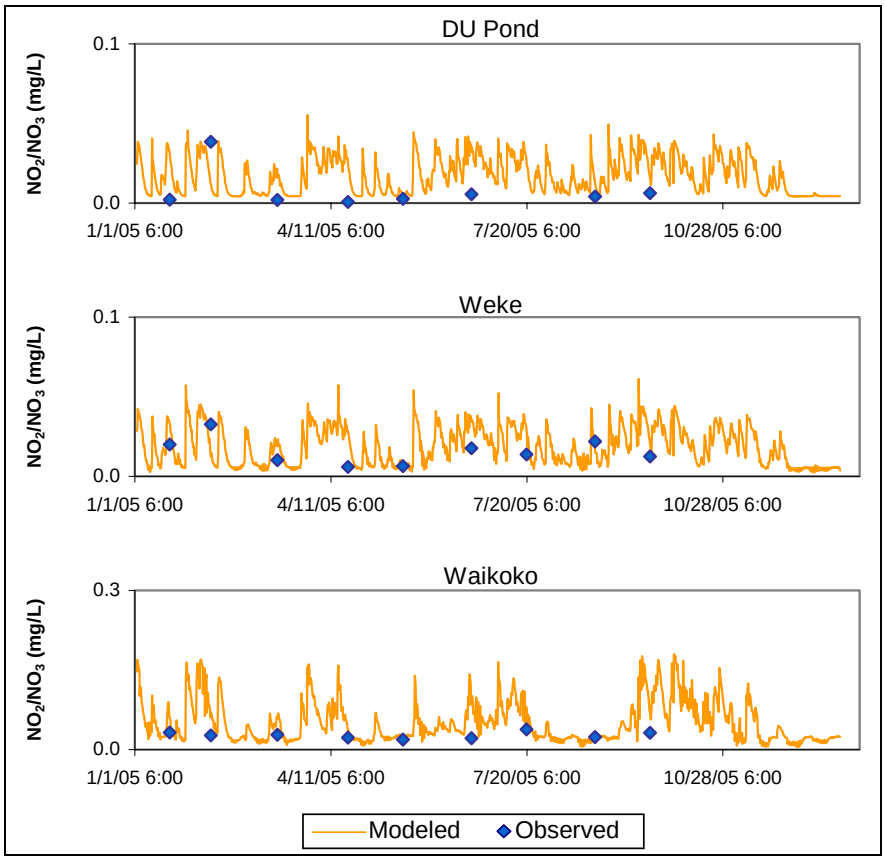

Figure F-4. Modeled and observed nitrite plus nitrate concentrations for calibration

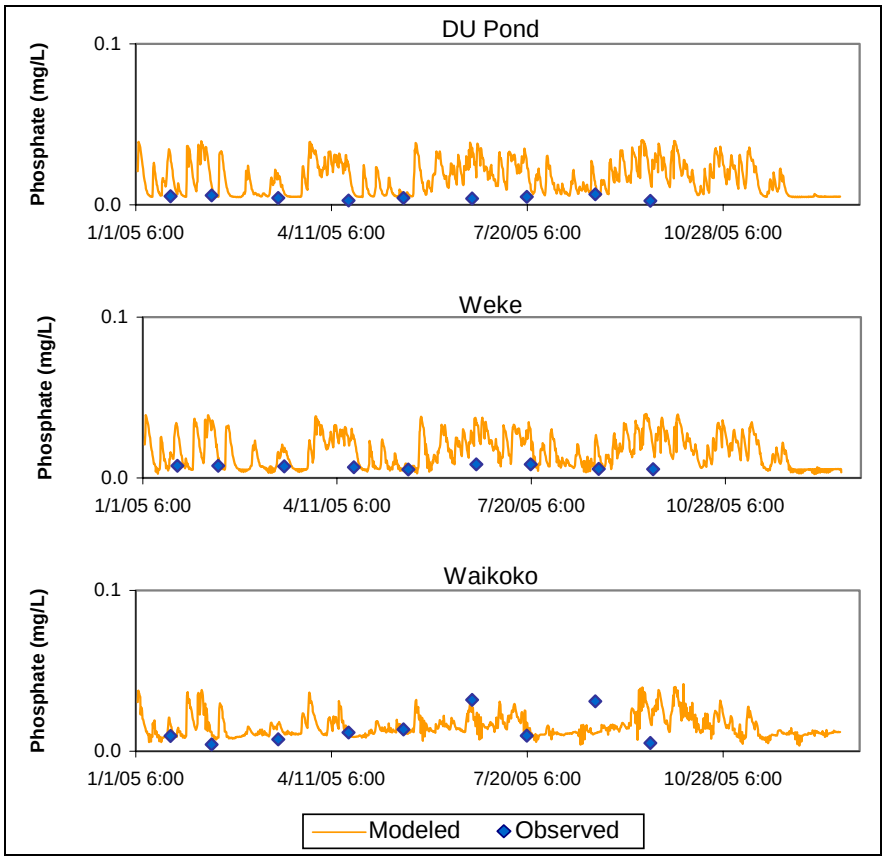

Figure F-5. Modeled and observed phosphate concentrations for calibration

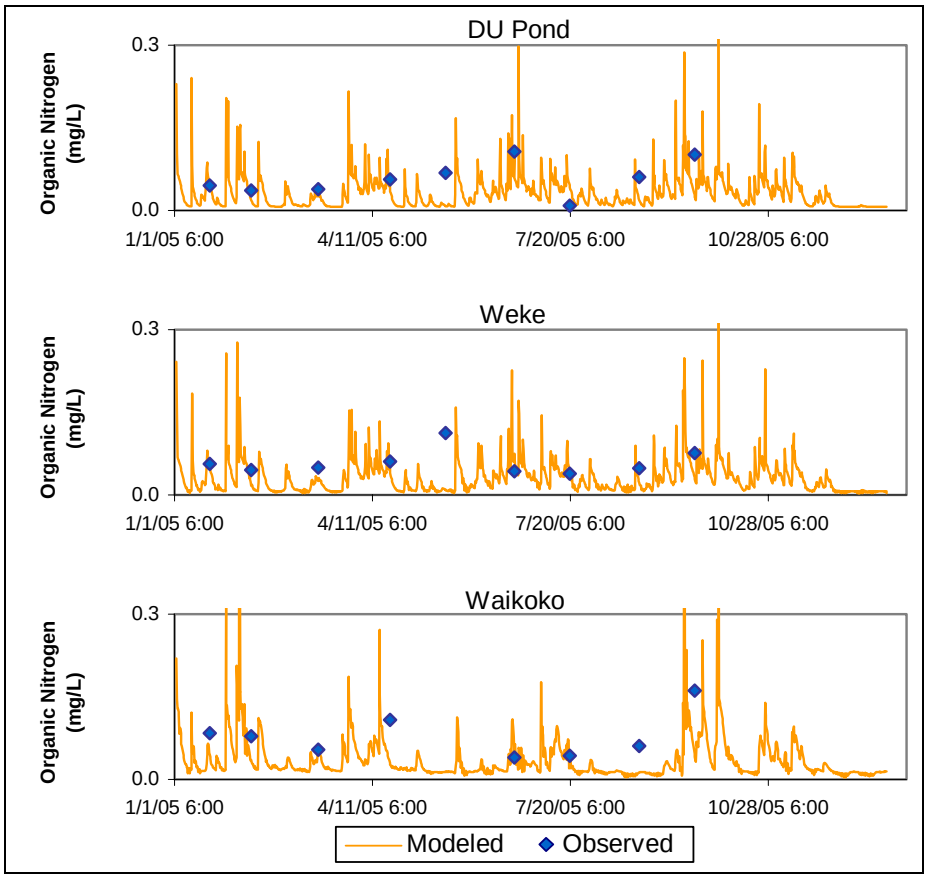

Figure F-6. Modeled and observed organic nitrogen concentrations for calibration

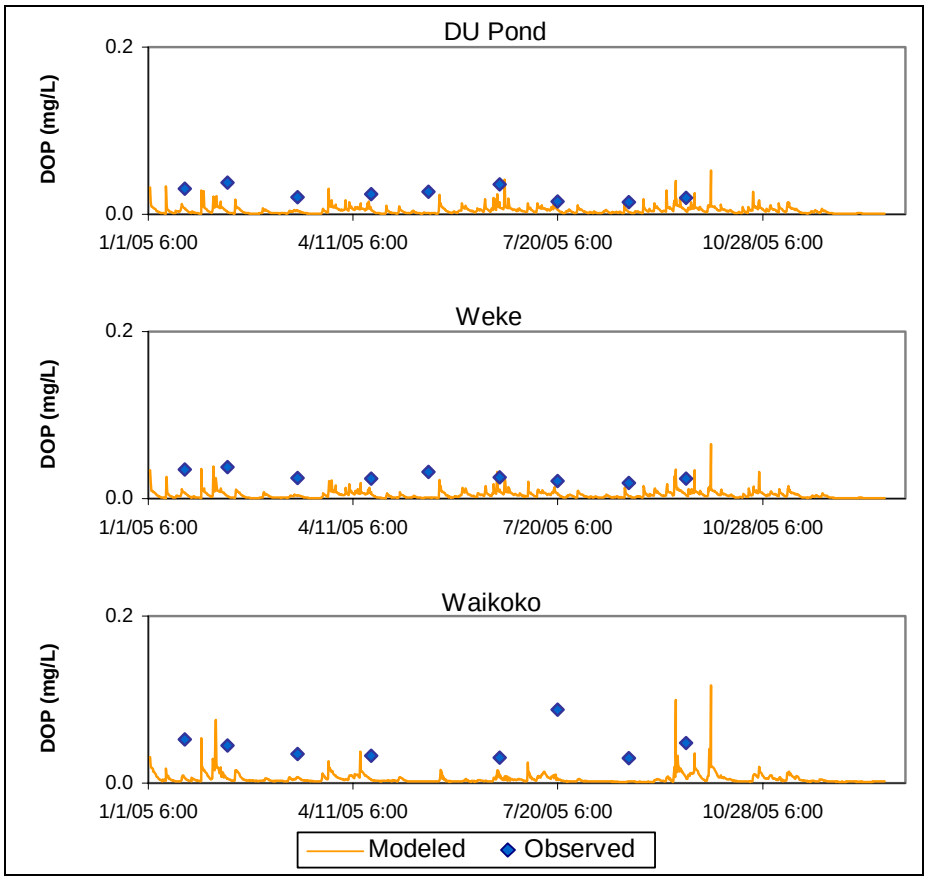

Figure F-7. Modeled and observed dissolved organic phosphorous concentrations for calibration

F-2. Water Quality Validation

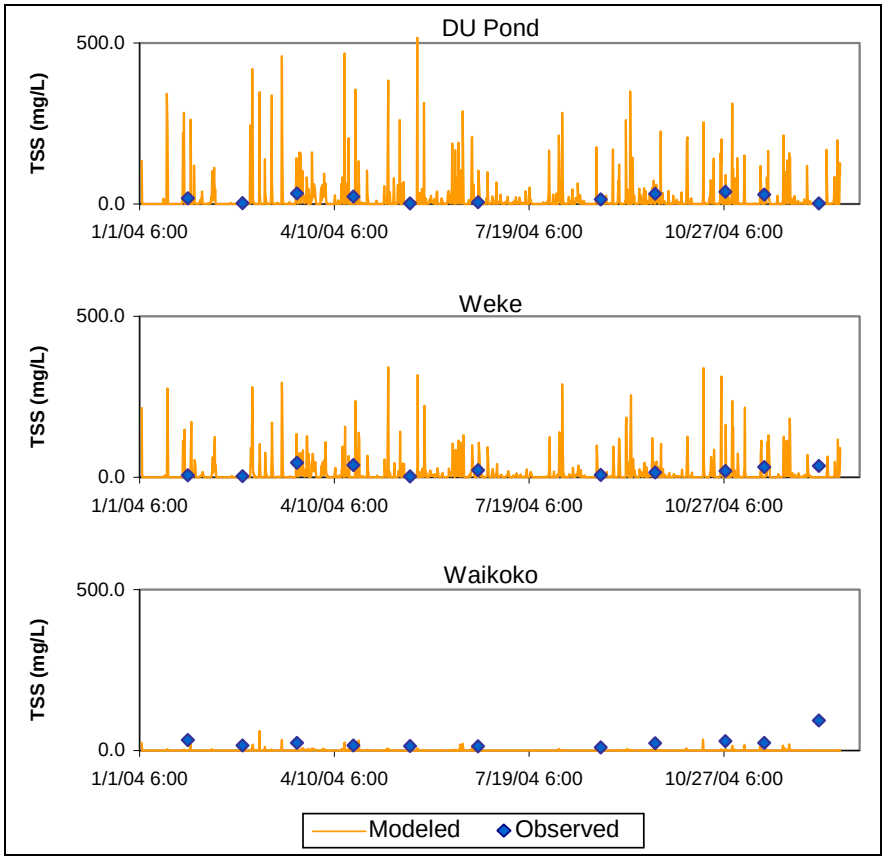

Figure F-8. Modeled and observed TSS concentrations for validation

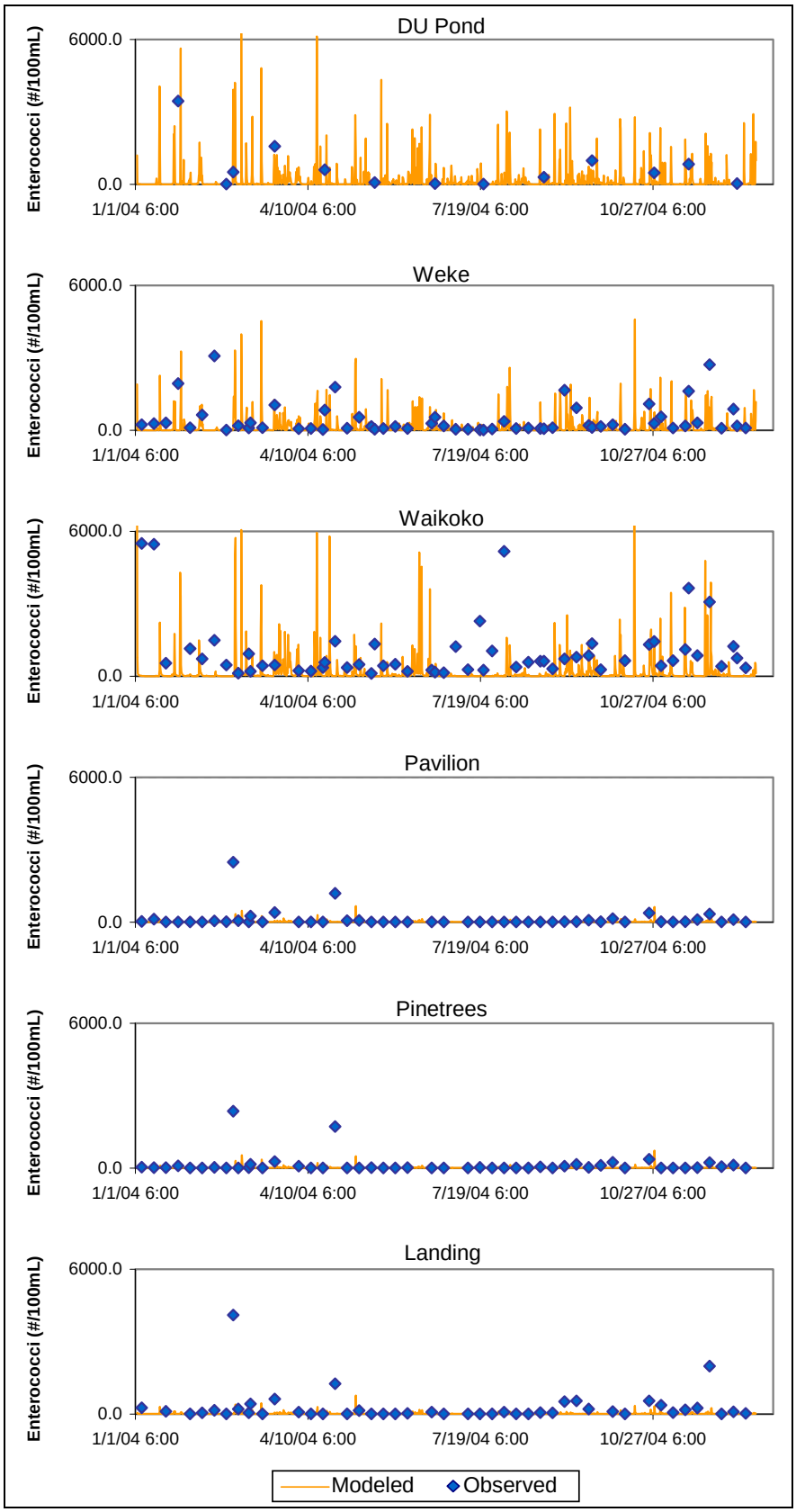

Figure F-9. Modeled and observed *enterococcus* concentrations for validation

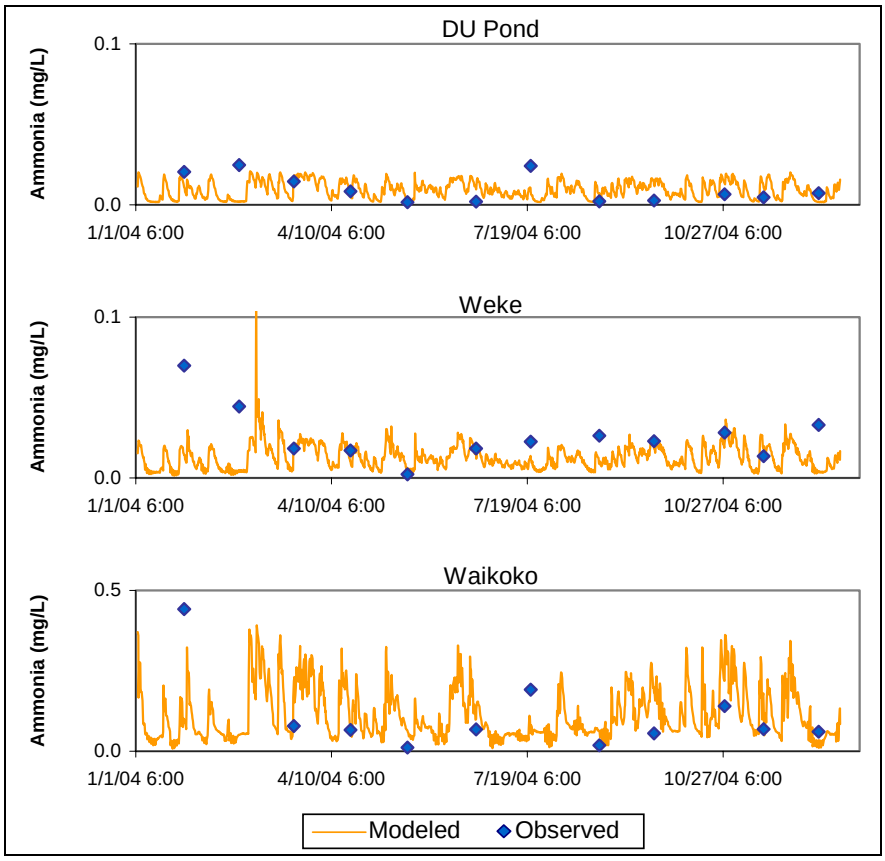

Figure F-10. Modeled and observed ammonia concentrations for validation

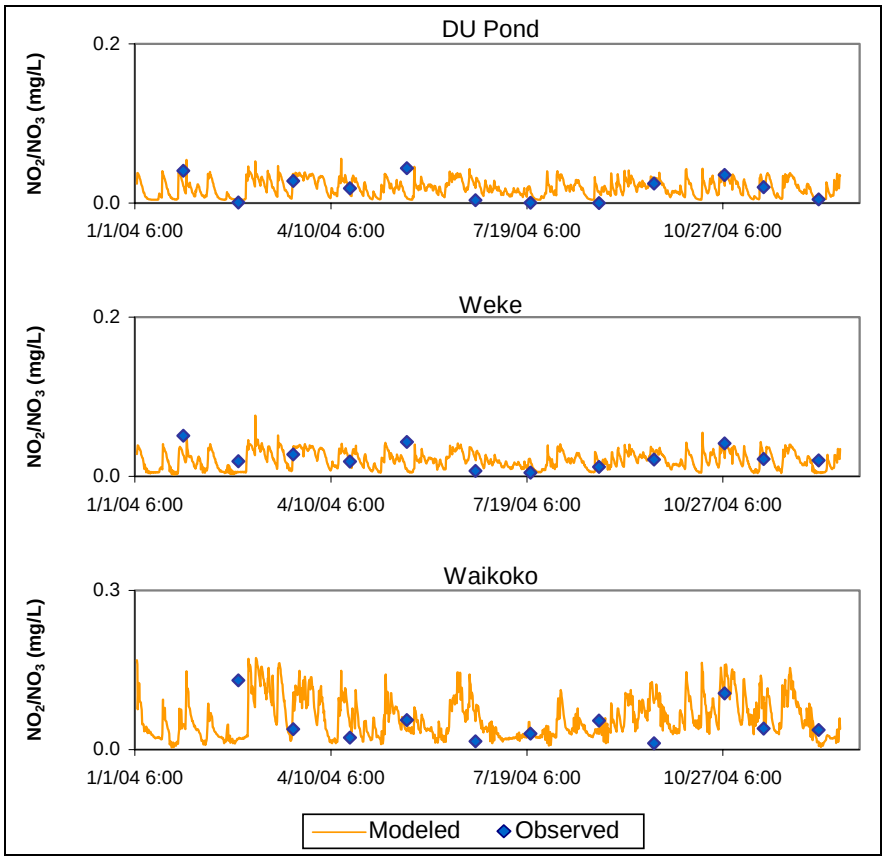

Figure F-11. Modeled and observed nitrite plus nitrate concentrations for validation

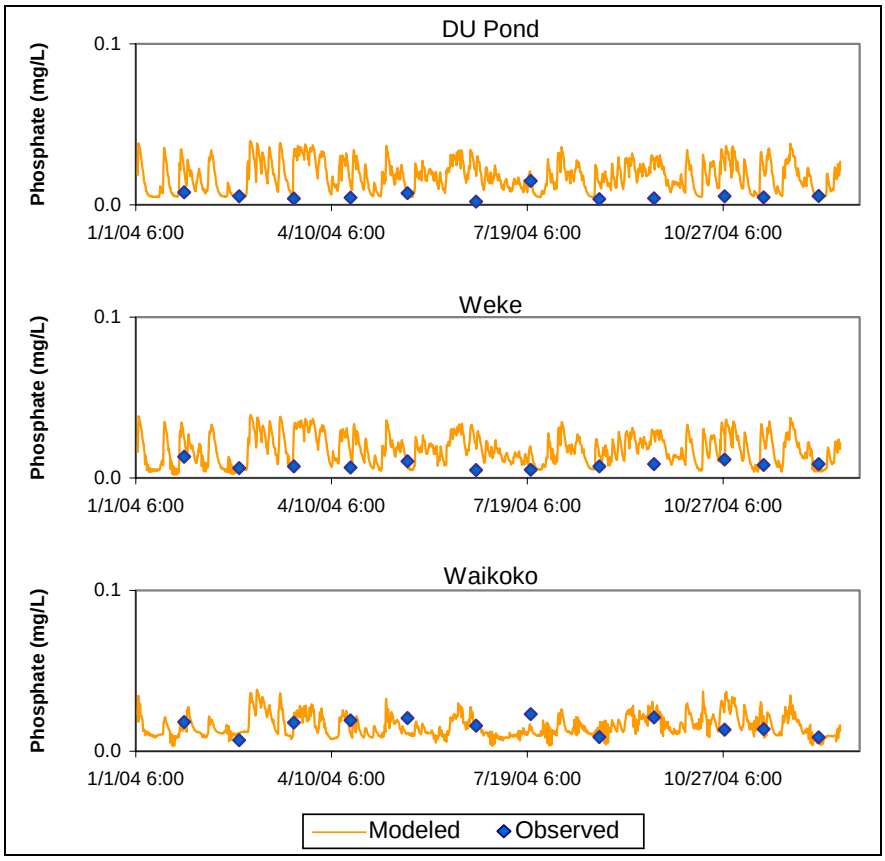

Figure F-12. Modeled and observed phosphate concentrations for validation

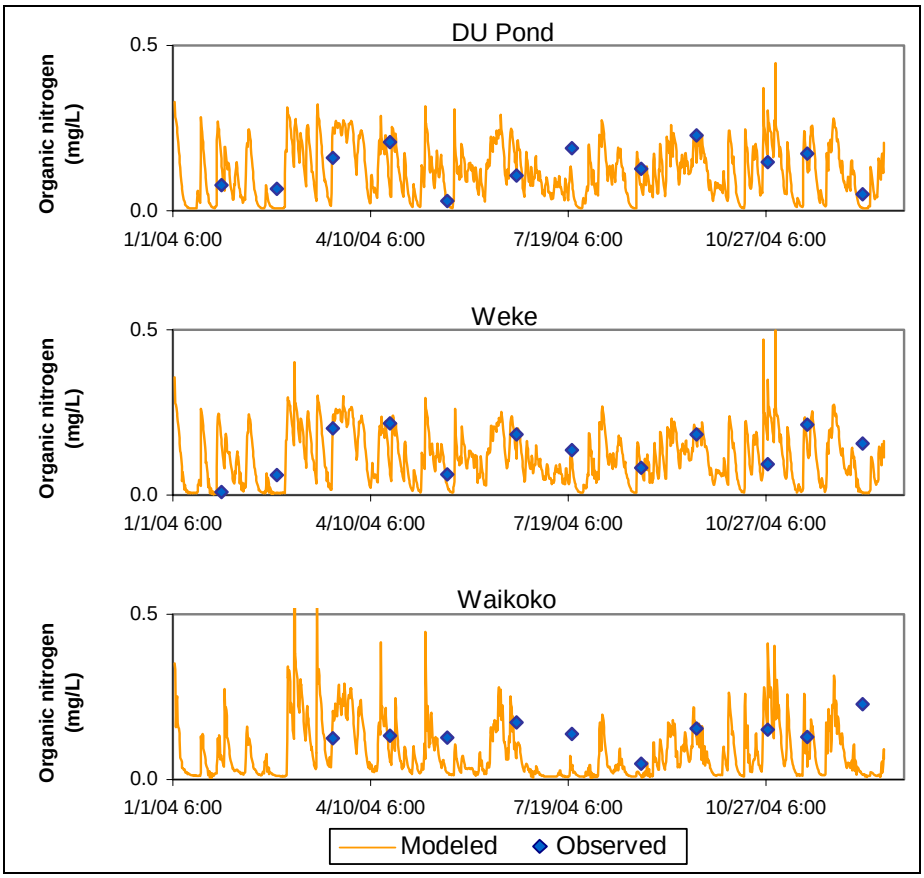

Figure F-13. Modeled and observed organic nitrogen concentrations for validation

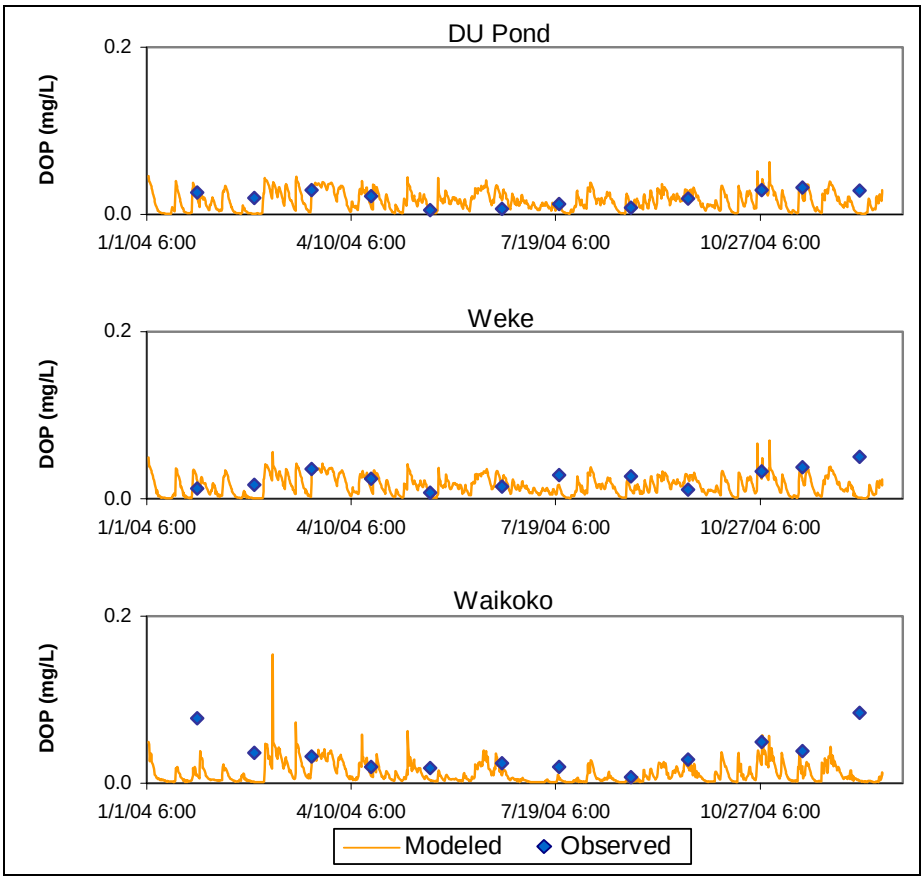

Figure F-14. Modeled and observed dissolved organic phosphorous concentrations for validation

APPENDIX G – DOH WATERBODY ASSESSMENT SHEETS, 2006 303(d) LIST, AND EPA TMDL APPROVAL CHECKLIST

Waterbody Information Sheet: Streams

Stream Name & Location: Hanalei River, Kauai

Inspected By: Gary Wolinsky

Date: 08-12-96

I. RESEARCH
1. Why is this stream being inspected? (choose all that apply) **Public Nomination**, Watershed Target, Other (explain)
2. What land use zoning areas are within this stream's watershed? (choose all that apply) **Urban**, Rural, **Agriculture, Conservation**
3. Is there water quality data available for this stream? Yes **No**
3a. Is there evidence of criteria violations? Yes **No** (If "yes," list pollutants.)
4. Has this stream ever been subject to fish consumption advisories, or health warnings (excluding leptospiroses)? Yes **No** (If "yes," describe the action and attach documentation to this sheet.)
5. Has this stream ever suffered any fish kills? Yes **No** (If "yes," list their date and magnitude, and attach documentation to this sheet.)
II. FIELD ASSESSMENT
1. If there are criteria violations for this stream, are the sources of these pollutants readily apparent? Yes **No** Discuss.
2. Is this stream being impaired by point source discharges? Yes **No** (If "yes," discuss.)
3. Are any of the following activities occurring in the watershed: **agriculture, commercial enterprise, construction, or residential development**?(choose all that apply)
4. If so, are any of these activities occurring on such a scale as to be significant pollutant sources for this waterbody? **Yes** No (If "yes," discuss, listing pollutants and transport mechanisms.) Taro farming may contribute some nutrient and sediment load
5. Is there evidence of nutrient enrichment, including algal blooms or excessive amounts of nuisance vegetation? Yes **No**

6. Is there a significant amount of debris or litter? Yes **No**
7. Has the stream channel been channelized with concrete or substantially modified or straightened? **Yes** No
8. Has the riparian area been cleared of vegetation? **Yes** No In some areas.
9. Is there evidence of significant erosion in the stream channel? Yes **No**
10.Evaluate the visual water quality. Muddy -- heavy sediment load
11. How is this water used, and by whom? Aquatic life, recreational/canoeig, kayaking
12. Comments All streams on the Windward side carry heavy sediment loads
13. Is this stream of high enough quality that it should not be considered impaired? Discuss. The heavy sediment loadings to the Hanalei and other Windward streams probably only occurs in resposne to storms and may intensify on a seasonal basis.

2006 Waterbody Assessment Decisions [Integrated 303(d) List/305(b) Report for Hawaii]

- New 303(d) listing are shaded, **bold** and ***italicized*** in the table, as are any changes for previously listed waters. 2004 303(d) listings are **blue and bold**.
- **Stream codes:** EN = Entire Network, EE = Entire Estuary, ER = Entire Reservoir, EW = Entire Wetland, EL = Entire Lake.
- **Marine Codes:** B = Bay (as specified within HAR 11-54-6), C = Open Coastal (fronting areas within 1000' and 100 fathoms of specified area), E = Estuary, K = Kona (All marine waters of Hawaii Island from Loa Point, South Kona District, clockwise to Malae Point, North Kona District, excluding Kawaihae Harbor and Honokohau Harbor, and for all areas from the shoreline at mean lower low water to a distance 1000m seaward (see HAR 11-54-6), P = Pearl Harbor; * = Listings from previous reporting cycles which, at that time, were then listed as separate entities from similar named sampling stations, convention continued for this cycle.
- **Decision Codes:** ? = unknown, N = not attained, A = Attained, Ac = Attained (with combined season data), Nc = Not attained (with combined season data), N1 = not attained (by 2 times the standard), N1c = not attained (by combined data, 2 times the standard), V = visual listing from 2001-2004, L = previous listing from 1998 or earlier.
- **Parameter Codes:** Total N = total nitrogen; NO3+NO2 = nitrite+nitrate nitrogen; Total P = total phosphorus; TURB = turbidity; TSS = total suspended solids; chl-a = chlorophyll a; NH4 = ammonium nitrogen.
- **TMDL Priority Codes:** High (H), Medium (M), and Low (L) priority for initiating TMDL development within the current monitoring and assessment cycle (through April 15, 2008), based on the prioritization criteria described in the Integrated Report and on current and projected resource availability for completing the TMDL development process. IP = TMDL development in progress.
- **Notes:** Assessment results for enterococci microbiological sampling in embayments and open coastal waters are only applicable within the 300 meter (one thousand feet) boundary from the shoreline (HRS 11-54-8(b)).
- For this report, assessed water bodies were sorted by island (north to south), then into the streams category (salinity below 0.5 ppt) or the coastal category (salinity above 0.5 ppt).

KAUAI Stream Waters												
Assessed Waterbody	**Waterbody Type**	**Scope of Assessment**	**Geocode ID**	**Season**	**enterococci**	**Total N**	**NO_3+NO_2**	**Total P**	**TURB**	**Other Pollutants**	**Category**	TMDL Priority
Hanakapiai	Stream	EN	2-1-10		?	?	?	?	?	TSS (?)	2, 3	
Limahuli	***Stream***	***EN***	***2-1-12***	***Dry***	?	A	***N***	A	?	TSS (A)	2, 3, ***5***	***L***
Limahuli	Stream	EN	2-1-12	Wet	?	?	?	?	Ac	TSS (?)	2, 3	
Manoa	***Stream***	***EN***	***2-1-13***	***Dry***	?	Ac	Ac	Ac	***N1***	TSS (Ac)	3, ***5***	***L***
Manoa	***Stream***	***EN***	***2-1-13***	***Wet***	?	Ac	Ac	Ac	***Nc***	TSS (Ac)	3, ***5***	***L***
Wainiha	Stream	EN	2-1-14	Dry	?	Ac	Ac	Ac	Ac	TSS (Ac)	2, 3	
Wainiha	Stream	EN	2-1-14	Wet		Ac	Ac	Ac	Ac	TSS (Ac)	2, 3	
Lumahai	Stream	EN	2-1-15		?	?	?	?	?	TSS (?)	3	
Waipa	***Stream***	***EN***	***2-1-17***	***Dry***	?	A	A	A	***N***	TSS (A)	3, ***5***	***H***
Waipa	Stream	EN	2-1-17	Wet	?	?	?	?	?	TSS (?)	3	
Waioli	Stream	EN	2-1-18	Dry	?	A	A	A	A	TSS (A)	2, 3	
Waioli	Stream	EN	2-1-18	Wet	?	?	?	?	?	TSS (?)	3	
Hanalei	~~River~~***Stream***	**EN**	**2-1-19**	**Dry**	***N***	A	A	A	~~**V**~~ **N**	TSS (A)	3, **5**	**H (IP)**
Hanalei	***Stream***	***EN***	***2-1-19***	***Wet***	***N***	A	A	A	A	TSS (A)	3, ***5***	***H* (IP)**
Kalihiwai	Stream	EN	2-1-25		?	?	?	?	?	TSS (?)	3	
Kilauea	***Stream***	***EN***	***2-1-28***	***Dry***	?	A	A	A	***N***	TSS (A)	3, ***5***	***L***
Kilauea	**Stream**	**EN**	**2-1-28**	**Wet**	?	Ac	Ac	Ac	**N**	TSS (Ac)	3, **5**	**L**
Moloaa	***Stream***	***EN***	***2-1-34***	***Dry***	?	A	A	A	***N***	TSS (A)	3, ***5***	***L***
Moloaa	***Stream***	***EN***	***2-1-34***	***Wet***	?	?	?	?	***N***	TSS (?)	3, ***5***	***L***
Papaa	***Stream***	***EN***	***2-1-35***	***Dry***	?	***N1***	***N1***	Ac	***N1***	TSS (Ac)	3, ***5***	***L***
Papaa	Stream	EN	2-1-35	Wet	?	?	?	?	?	TSS (?)	3	
Aliomanu	Stream	EN	2-1-36		?	?	?	?	?	TSS (?)	3	
Anahola	***Stream***	***EN***	***2-2-01***	***Dry***	?	Ac	A	A	***N***	TSS (A)	3, ***5***	***L***
Anahola	***Stream***	***EN***	***2-2-01***	***Wet***	?	Ac	Ac	Ac	***N***	TSS (Ac)	3, ***5***	***L***
Kapaa	**Stream**	**EN**	**2-2-04**	**Dry**	?	A	A	A	~~**V**~~ **N**	TSS (A)	3, **5**	~~**M**~~ ***L***
Kapaa	**Stream**	**EN**	**2-2-04**	**Wet**	?	A	A	A	**N**	TSS (A)	3, **5**	~~**M**~~ ***L***
Wailua	***Stream***	***EN***	***2-2-08***	***Dry***	?	Ac	Ac	Ac	***N***	TSS (Ac)	3, ***5***	***L***
Wailua	Stream	EN	2-2-08	Wet	?	A	A	A	A	TSS (A)	3	
Hanamaulu	***Stream***	***EN***	***2-2-12***	***Dry***	?	?	?	?	***N***	TSS (?)	3, ***5***	***L***
Hanamaulu	**Stream**	**EN**	**2-2-12**	**Wet**	?	?	?	?	**N**	TSS (?)	3, **5**	~~**M**~~ ***L***

KAUAI Marine Waters											
Waterbody Type	Scope of Assessment	Geocode ID	Season	enterococci	Total N	NO_3+NO_2	Total P	TURB	Other Pollutants	Category	TMDL Priority
C	Aliomanu Beach	HI710019	wet	?	?	?	?	?		3	
C	Anahola Beach	HI823433	wet	A	?	?	?	?		2,3	
C	Anahola Beach	HI270737	wet	?	?	?	?	?		3	
C	Anini Beach	HI338804	wet	?	?	?	?	?		3	
C	**Anini Beach Park**	HI418744	***wet***	A	?	?	?	**N**		***2,3,5***	**L**
C	Beach House Beach	HI156238	dry	A	?	?	?	?		2,3	
C	Brennecke Beach	HI166521	dry	A	?	?	?	?		2,3	
C	Donkey Park	HI853903	wet	?	?	?	?	?		3	
C	Gillin's Beach	HI976083	dry	?	?	?	?	?		3	
C	Glass Beach	HI949505	wet	?	?	?	?	?		3	
C	***Haena Beach Park***	***HI554189***	***wet***	***A***	***?***	***?***	***?***	***N***		***2,3,5***	***L***
C	Hanakapi'ai Beach	HI797414	wet	?	?	?	?	?		3	
B	**Hanalei Bay (Landing)**	***HIW00093***	wet	**N**	?	?	?	**N**		***3,5***	**H (IP)**
B	**Hanalei Bay (Pavilion)**	***HIW00092***	wet	**N**	?	?	?	***N***		***3,5***	**H**
B	**Hanalei Bay Mooring station***	***HIW00157***	wet	**N**	?	?	?	?		***3,5***	**H**
E	**Hanalei Bay upstream of Dolphin***	***HIW00160***	wet	?	?	?	?	**N**		***3,5***	**H (IP)**
B	**Hanalei Bay (Waioli Beach)**	***HIW00091***	***wet***	***~~N~~ A***	***?***	***?***	***?***	***N***		***2,3,5***	***H***
E	**Hanalei River**	***HI385259***	wet	**N**	?	?	?	**N**		***3,5***	**H (IP)**
B	**Hanama'ulu Bay (Beach)**	***HIW00094***	wet	**N**	?	?	?	?		***3,5***	
B	**Hanama'ulu Bay**	***HIW00063***	wet	?	?	?	?	**N**		***3,5***	**L**
B	Hanapepe Bay	HIW00095	wet	?	?	?	?	?		3	
B	**Hanapepe Bay- from breakwater to shore and nearshore waters to 30' from Puolo Point to Paakehi Point**	HIW00048	wet	?	**L**	**L**	**L**	?	**nutrients**	***3,5***	**L**
C	Haula Beach	HI277808	dry	?	?	?	?	?		3	
C	Kahili Beach	HI533519	wet	?	?	?	?	?		3	
C	Kalalau Beach	HI908803	wet	?	?	?	?	?		3	

KAUAI Marine Waters											
Waterbody Type	Scope of Assessment	Geocode ID	Season	enterococci	Total N	NO_3+NO_2	Total P	TURB	Other Pollutants	Category	TMDL Priority
C	Nukolii Beach Park	HI502794	wet	A	?	?	?	?		2,3	
C	Pacific Missile Range Facility	HI176480	dry	?	?	?	?	?		3	
C	Pakala (Makaweli)	HI468251	wet	?	?	?	?	?		3	
C	Palama Beach (Nomilu)	HI665178	wet	?	?	?	?	?		3	
C	Papa'a Bay	HI130639	wet	?	?	?	?	?		3	
C	Pila'a Beach	HI363048	wet	?	?	?	?	?		3	
C	***Po'ipu Beach Co. Park***	***HI396850***	***dry***	***N***	***?***	***?***	***?***	***?***		***3,5***	***L***
C	Polihale State Park	HI247403	dry	A	?	?	?	?		2,3	
B	**Port Allen Boat Harbor (Port Allen Pier)**	***HIW00026***	wet	?	**N**	?	?	**N**	**chl-a(N)**	***3,5***	**L**
B	Port Allen Boat Harbor	HIW00120	wet	?	?	?	?	?		3	
C	Prince Kuhio Park	HI742228	dry	?	?	?	?	?		3	
C	Princeville	HI520271	wet	?	?	?	?	?		3	
C	***Salt Pond Beach Co. Park***	***HI701008***	***wet***	***N***	***?***	***?***	***?***	***?***		***3,5***	***L***
C	Sheraton Beach	HI542569	dry	?	?	?	?	?		3	
C	Shipwreck Beach	HI358435	dry	?	?	?	?	?		3	
C	Spouting Horn Beach Co. Park	HI951651	dry	?	?	?	?	?		3	
C	Tunnels Beach	HI936087	wet	?	?	?	?	?		3	
C	Wahiawa Bay	HIW00121	wet	?	?	?	?	?		3	
C	Waiakalua Iki Beach	HI505816	wet	?	?	?	?	?		3	
C	Waiakalua Nui Beach	HI371632	wet	?	?	?	?	?		3	
E	**Waikoko Estuary**	***HIW00162***	wet	?	?	?	?	**N**		***3,5***	**H (IP)**
E	**Wailua (Wailua River Station)**	***HI606168***	wet	**N**	?	?	?	?		***3,5***	~~**M**~~ ***L***
C	**Waimea Bay Beach- nearshore waters to 18' from Kekaha Oomano Pt. - 1.5 miles SE of Mahinaui Stream**	***HIW00057***	wet	?	?	?	?	**L**	**susp. solids**	***3,5***	~~**M**~~ ***L***
C	Waimea Rec. Pier St. Pk.	HI245235	dry	?	?	?	?	?		3	
C	Wainiha Bay	HI417823	wet	?	?	?	?	?		3	
C	Wai'ohai Beach	HI392082	dry	?	?	?	?	?		3	
E	**Waioli Stream Estuary**	***HIW00163***	wet	?	?	?	?	**N**		***3,5***	~~**M**~~ ***H*** **(IP)**
E	**Waipa Stream Estuary**	***HIW00164***	wet	?	?	?	?	**N**		***3,5***	**H (IP)**
C	Waipouli Beach	HI682678	wet	A	?	?	?	?		2,3	

EPA Region 9 TMDL Review Checklist

EPA Region 9 uses this checklist to review TMDLs submitted for EPA Region 9 approval to ensure that the TMDLs meet all the requirements of the Clean Water Act and EPA's regulations concerning TMDL content. Because many TMDL submissions from California and other states also include TMDL implementation measures pursuant to EPA's regulatory requirements at 40 CFR 130.6, the checklist also includes review criteria for TMDL implementation measures. EPA regulations do not require the submission of implementation measures at the same time as TMDLs are submitted.

State: Waterbodies:
Pollutant(s): Date of State Submission:
Date Received By EPA: EPA Reviewer:

TMDL Review Criteria (per Clean Water Act Section 303(d) and 40 CFR 130.2 and 130.7)	**Approved**	**Comments**
1. Submittal Letter: State submittal letter indicates final TMDL(s) for specific water(s)/pollutant(s) were adopted by state and submitted to EPA for approval under 303(d).		
2. Water Quality Standards Attainment: TMDL and associated allocations are set at levels adequate to result in attainment of applicable water quality standards.		
3. Numeric Target(s): Submission describes applicable water quality standards, including beneficial uses, applicable numeric and/or narrative criteria. Numeric water quality target(s) for TMDL identified, and adequate basis for target(s) as interpretation of water quality standards is provided.		
4. Source Analysis: Point, nonpoint, and background sources of pollutants of concern are described, including the magnitude and location of sources. Submittal demonstrates all significant sources have been considered.		
5. Allocations: Submittal identifies appropriate wasteload allocations for point sources and load allocations for nonpoint sources. If no point sources are present, wasteload allocations are zero. If no nonpoint sources are present, load allocations are zero.		
6. Link Between Numeric Target(s) and Pollutant(s) of Concern: Submittal describes relationship between numeric target(s) and identified pollutant sources. For each pollutant, describes analytical basis for conclusion that sum of wasteload allocations, load allocations, and margin of safety does not exceed the loading capacity of the receiving water(s).		
7. Margin of Safety: Submission describes explicit and/or implicit margin of safety for each pollutant.		
8. Seasonal Variations and Critical Conditions: Submission describes method for accounting for seasonal variations and critical conditions in the TMDL(s)		

9. Public Participation: Submission documents provision of public notice and public comment opportunity; and explains how public comments were considered in the final TMDL(s).		
10. Technical Analysis: Submission provides appropriate level of technical analysis supporting TMDL elements.		
Note: **The following criteria do not apply to all TMDLs, but must be applied in the situations noted.**		
11. Monitoring Plan for TMDLs Under Phased Approach (where phased approach is used): TMDLs developed under phased approach identify implementation actions, monitoring plan and schedule for considering revisions to TMDL.		
12. Reasonable Assurances (for waters affected by both point and nonpoint sources): Where point source(s) receive less stringent wasteload allocations because nonpoint source reductions are expected and reflected in load allocations, implementation plan provides reasonable assurances that nonpoint implementation actions are sufficient to result in attainment of load allocations in a reasonable period of time. Reasonable assurances may be provided through use of regulatory, non-regulatory, or incentive based implementation mechanisms as appropriate.		
Implementation Plan Review Criteria (per Clean Water Act Section 303(e) and 40 CFR 130.6)		
13. Clear Implementation Plan: Submittal describes planned implementation actions or, where appropriate, specific process and schedule for determining future implementation actions **.** Plan is sufficient to implement all wasteload and load allocations in reasonable period of time. TMDL(s) and implementation measures are incorporated into the water quality management plan. Water quality management plan revisions are consistent with other existing provisions of the water quality management plan.		

APPENDIX H – DOCUMENTATION OF PUBLIC PARTICIPATION PROCESS

- Classified Ad and Affidavit of Publication-Notice of Public Information Meeting – The Garden Island Newspaper, February 04, 2007
- Classified Ad and Affidavit of Publication -Notice of Public Information Meeting – Honolulu Star-Bulletin, February 04, 2007
- List of Addresses Receiving Direct Notice of Draft TMDL and Public Information Meeting
- Hanalei TMDL Fact Sheet for Public Information Meeting
- Hanalei TMDL Public Information Meeting Sign-In Sheet
- Public Comments from:
    - Ching Young Village Shopping Center
    - Mowry, Bill
    - East Kauai Soil & Water Conservation District
    - Imparato, Carl
    - Fujikawa, Clyde
    - Alexander & Baldwin, Inc.
    - Department of Public Works (County of Kauai)
    - Hanalei Watershed Hui
    - Hawaii Agriculture Research Center
    - Hawaii Farm Bureau Federation
    - Kauai Taro Growers Association
    - Young, Thomas
    - Kauai National Wildlife Refuge Complex (U.S. Department of the Interior, Fish and Wildlife Service)
- DOH Consolidated Response to Public Comments

State of Hawaii
County of Kauai

IN THE MATTER OF }
Hanalei Bay Watershed }

AFFIDAVIT OF PUBLICATION

NOTICE OF PUBLIC COMMENT PERIOD AND PUBLIC INFORMATION MEETING-TOTAL MAXIMUM DAILY LOADS (TMDLs) FOR HANALEI BAY WATERSHED, ISLAND OF KAUAI, HAWAII

The proposed decision will affect water pollution control permits and provide guidance for other planning and regulatory approvals (e.g. land use and environmental management) within the Hanalei Bay watershed.

Under §303(d) and §303(e) of the Federal Clean Water Act, 33 U.S.C. §1313(d) and §1313(e), and 40 CFR §130.7 and §130.5, the State of Hawaii Department of Health (DOH) requests public comments on proposed total maximum daily loads (TMDLs) of total suspended solids in four estuaries (Hanalei, Waioli, Waipa, and Waikoko) and one stream (Hanalei) and of indicator bacteria (enterococci) in Hanalei Estuary. The proposed decision divides each of these six TMDLs into load allocations (LAs) for various sources of polluted runoff (nonpoint sources) in the Hanalei Bay watershed. It also provides a framework for future wasteload allocations (WLAs) for point sources of these pollutants (point sources are facilities regulated by National Pollutant Discharge Elimination System, or NPDES, permits). NPDES-permitted facilities within the Hanalei Bay watershed are currently limited to those operating under general permit coverage and no WLAs are assigned to them by the proposed TMDLs.

DOH also calculated loading capacities and nonpoint source load targets for numerous pollutant/waterbody combinations in the Hanalei Bay watershed that currently do not require TMDLs. As more water quality information becomes available, if additional TMDLs are required then these loading capacities and load targets provide a basis for fulfilling the requirements.

The proposed TMDLs, LAs, loading capacities and load targets are presented in a draft report titled "Total Maximum Daily Loads and Load Targets for the Hanalei Bay Watershed." This draft report is available for public inspection Monday through Friday between 7:45 am and 4:30 pm in the Environmental Planning Office (EPO), DOH, 919 Ala Moana Boulevard, Room 312, Honolulu, Hawaii and in the Kauai District Health Office, DOH, 3040 Umi Street Lihue, Hawaii 96766. For a copy of the draft report (including a technical appendix), please phone the EPO at (808) 586-4337, fax the EPO at (808) 586-4370, send e-mail to barbara.matsunaga@doh.hawaii.gov, visit our web site at http://www.hawaii.gov/health/epo, or mail a request to the EPO postal address below.

In order to be considered in the decisionmaking process, all comments on the proposed decision must be received in writing (fax and e-mail acceptable) no later than 4:30 PM on Monday, March 12, 2007, except that comments postmarked or shipped by this deadline will also be accepted. Send comments to the Program Manager, Environmental Planning Office, State of Hawaii Department of Health, 919 Ala Moana Boulevard, Third Floor, Honolulu, HI 96814; kelvin.sunada@doh.hawaii.gov; or fax to (808) 586-4370. Public comments and the DOH response will be used to revise the draft report, as necessary, for final EPA approval of the proposed TMDLs.

A public information meeting on the proposed TMDLs is scheduled for Tuesday, February 20, 2007, from 6:30 – 8:30 PM in the Hale Halawai Ohana o Hanalei (Community Center), Hanalei, Hawaii 96714. The purpose of the meeting is to explain why the TMDLs are being established, the methods used to calculate the allocations, and the results of these calculations, and to discuss the relationships between these TMDLs, efforts to improve water quality in the Hanalei Bay watershed, and the State's water quality management planning process in general.

If you require special assistance or auxiliary aids or services to participate in the meeting (i.e. sign language interpreter, wheelchair accessibility, or parking designated for the disabled), please contact EPO (at the numbers/addresses shown above) no later than February 09, 2007 so that arrangements can be made.

Chiyome L. Fukino, M.D.
Director of Health

(February 4, 2007)

STATE OF HAWAII }
COUNTY OF KAUAI} SS.

Clorinda Brede, being duly sworn, deposes and says, that she is an employee of "The Garden Island," a newspaper published in Lihue, County of Kauai, State of Hawaii; that the NOTICE in the above entitled matter of which the annexed is a true and correct printed copy, was published one time in "The Garden Island" aforesaid, on the 4th of February, 2007 and that this affiant is not a party to or in any way interested in the above entitled matter.

Clorinda Brede

Subscribed and sworn to before me this
~~8th~~ 2nd day of March, 2007.

Carmencita P. Centeno

CARMENCITA P. CENTENO
Notary Public, Fifth Judicial Circuit,
State of Hawaii

My Commission Expires
Jul 25, 2008

IN THE MATTER OF
NOTICE OF PUBLIC COMMENT PERIOD AND PUBLIC INFORMATION MEETING TOTAL MAXIMUM DAILY LOADS (TMDSs) FOR HANALEI BAY WATERSHED, ISLAND OF KAUAI, HAWAII

AFFIDAVIT OF PUBLICATION

STATE OF HAWAII)
) **SS.**
City and County of Honolulu)

Carrie Asuncion being duly sworn, deposes and says that she is a clerk, duly authorized to execute this affidavit of MidWeek Printing, Inc., publisher of MidWeek and the Honolulu Star-Bulletin, that said newspapers are newspapers of general circulation in the State of Hawaii, and that the attached notice is true notice as was published in the aforementioned newspapers as follows:

MidWeek _____ times on _____

Honolulu Star-Bulletin 1 times on 02/04/2007

And that affiant is not a party to or in any way interested in the above entitled matter.

C. Asuncion

Subscribed to and sworn before me this 6th day of February A.D. 20 07

Patricia K. Rose

Notary Public of the First Judicial Circuit
State of Hawaii

My commission expires October 07, 2010

Ad# 05527310

NOTICE OF PUBLIC COMMENT PERIOD AND PUBLIC INFORMATION MEETING-TOTAL MAXIMUM DAILY LOADS (TMDLs) FOR HANALEI BAY WATERSHED, ISLAND OF KAUAI, HAWAII

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If you require special assistance or auxiliary aids or services to participate in the meeting (i.e. sign language interpreter, wheelchair accessibility, or parking designated for the disabled), please contact EPO (at the numbers/addresses shown above) no later than February 09, 2007 so that arrangements can be made.

Chiyome L. Fukino, M.D.
Director of Health

(SB05527310 2/4/07)

Addressees receiving personalized notice letters about the "availability of a draft water quality planning report a proposed water quality decision concerning 'Total Maximum Daily Loads and Load Targets for the Hanalei Bay Watershed'" (with the public notice enclosed)

M. Ben-Dor Diamonds Family Trust P.O. Box 526 Hanalei, Hawaii 96714	Ching Young Village Limited Partnership P.O. Box 1217 Hanalei, Hawaii 96714
Mr. Alvin Kyono, Kauai Branch Manager State of Hawaii Department of Land and Natural Resources Division of Forestry and Wildlife 3060 Elwa Street, Rm. 306 Lihue, Hawaii 96766	Mr. Steven Kyono, Kauai District Engineer State of Hawaii Department of Transportation Highways Division 1720 Haleukana Street Lihue, Hawaii 96766
Mr. Ted Inouye, Chair East Kauai Soil and Water Conservation District P.O. Box 278 Hanamaulu, Hawaii 96715	Mr. Nathan Aiwohi, Principal Hanalei Elementary School 5-5415 Kuhio Highway Hanalei, Hawaii 96714
Kapaa 382 LLC 4569 Kukui St., Suite 200 Kapaa. Hawaii 96746	Mr. Ian Costa, Director County of Kauai, Planning Department 4444 Rice Street, Suite 473 Lihue, Hawaii 96766
Mr. Donald Fujimoto, Director County of Kauai, Department of Public Works 4444 Rice Street, Suite 275 Lihue, Hawaii 96766	Mr. Gilbert Kea, President Garden Island Resource Conservation and Development, Inc. c/o Laurie Ho, NRCS RC&D Coordinator 3083 Akahi Street, Suite 204 Lihue, Hawaii 96766-1102
Christine Kobayashi et al. P.O. Box 44 Hanalei, Hawaii 96714	Kalani Fronda, Kauai Land Manager Kamehameha Schools P.O. Box 3466 Honolulu, Hawaii 96801
Martha J. Mowry Trust 404 E. Highway 246 Buellon, California 93427	Princeville Development LLC Princeville Agricultural LLC P.O. Box 223040 Princeville, Hawaii 96722-3040
Patricia W. Sheehan Trust P.O. Box 81 Hanalei, Hawaii 96714	Kauai Taro Growers Association P.O. Box 427 Hanalei, Hawaii 96714
Mr. Mike Hawkes, Refuge Manager Hanalei National Wildlife Refuge U.S. Fish and Wildlife Service P.O. Box 1128 Kilauea, Hawaii 96754	Waikoko Land Corporation c/o Samuel W. Pratt P.O. Box 3974 Lihue, Hawaii 96766

Waioli Corporation P.O. Box 1631 Lihue, Hawaii 96766	Waipa Foundation P.O. Box 1816 Hanalei, Hawaii 96714
Gaylord and Carol Wilcox Family Limited Partnership 111 Royal Circle Honolulu, Hawaii 96816	

Hanalei TMDL Update (February 20, 2007)

What is the TMDL Process, State of Hawaii Department of Health (DOH)?

- identify activities that help reduce pollutant loads, improve water quality, and increase our ability to support legally-protected uses (such as recreation, aesthetic enjoyment, ecosystem protection, and native breeding).
- these activities may be favored to receive funding from DOH [Clean Water Act Section 319(h) grants] and may also qualify for funding from other sources.
- the process starts with identifying places where water quality is "limited" or "impaired."

Why is Hanalei part of this process?

- Visual inspections (1996) and later information identified six Hanalei waterbodies where water quality is "limited" or "impaired." The limitations/impairments are:
- Excessive turbidity (usually caused by sediment) in Hanalei Stream, Estuary, and Embayment and in Waioli, Waipa, and Waikoko estuaries.
- Excessive indicator levels for bacteria in Hanalei Estuary and Hanalei Embayment.

The complete statewide list of impaired waters and supporting information can be viewed online at www.hawaii.gov/health/environmental/env-planning/wqm/303dpcfinal.pdf or requested from DOH (see contact information on the other side of this flyer).

What happens next?

- To satisfy federal Clean Water Act requirements, the U.S. Environmental Protection Agency (EPA), DOH, and TetraTech, Inc. conduct a federally-funded water quality planning process for inland waters (streams and estuaries) that flow into Hanalei Bay.
- Based on calculations of existing pollutant loads and their relationship with State water quality standards, we suggest how pollutants, pollutant source areas, and stream environments could be managed to achieve necessary water quality improvements.
- We submit Total Maximum Daily Loads (TMDLs), which establish the maximum rate at which these waters can receive certain pollutants (in this case, bacterial indicators and sediments) without exceeding the State's water quality standards, for EPA approval after the public review process is completed.
- **Hanalei was recently selected by EPA and DOH as one of three priority areas statewide for achieving measurable water quality improvements within the next ten years.** Thus DOH will continue working with the watershed community to plan actions for reducing pollutant loads, improving water quality, and supporting protected uses in specific problem areas.
- This "TMDL Implementation Plan" can be a big part of the community's prescription for watershed health, and ideally will be part of a bigger "Watershed-Based Plan" that includes nine components specified by EPA guidance (www.epa.gov/fedrgstr/EPA-WATER/2003/October/Day-23/w26755.htm).
- The actions identified in both plans may be prioritized to receive funding from the Department of Health [Clean Water Act Section 319(h) grants] and may also qualify for funding from other sources.
- DOH just applied for federal funding to complete TMDL development for Hanalei Bay.

Where do we get more information about this project? next page>

Hanalei TMDL Update (February 20, 2007)

Who is responsible for this project?

- The Total Maximum Daily Load (TMDL) Program is a cooperative effort of the U.S. Environmental Protection Agency (EPA) and the State of Hawaii Department of Health (DOH).
- The program is coordinated by the DOH Environmental Planning Office with technical assistance from the DOH Clean Water Branch and the DOH State Laboratories Division.
- The Hanalei Watershed Hui and other community interests help us identify water pollution problems and create water quality solutions in the Hanalei Bay watershed.

Department of Health Contact Information

State of Hawaii Department of Health (Chiyome Leinaala Fukino, M.D., Director)
Environmental Health Administration (Laurence K. Lau, Deputy Director)
Environmental Planning Office (Kelvin H. Sunada, Program Manager)
919 Ala Moana Boulevard, Third Floor
Honolulu, HI 96814
PHONE (808) 586-4337 **271-3141+ 64337** **TOLL-FREE FROM KAUAI**
FAX (808) 586-4370 **271-3141+ 64370** **TOLL-FREE FROM KAUAI**
David Penn, Total Maximum Daily Load Coordinator **david.penn@doh.hawaii.gov**
Linda Koch, Assessment Coordinator linda.koch@doh.hawaii.gov

Where do we get more information about TMDLs?

National TMDL program information **www.epa.gov/owow/tmdl**
The DOH Environmental Planning Office website at
www.hawaii.gov/health/environmental/env-planning/wqm/wqm.html includes:

- TMDL technical reports and implementation plans
- stream biological assessment reports
- Statewide Clean Water Act §303(d) list of Impaired Waters
- Various Water Quality Standards information and water quality reports

The DOH Clean Water Branch website at
www.hawaii.gov/health/environmental/water/cleanwater/index.html includes:

- Monitoring and Analysis Program information (including Current Warnings, Advisories, and Closures)
- Water Pollution Control Permit information
- Polluted Runoff Control Program information [Clean Water Act Section 319(h) grants]

What about enforcement?

Federal, state, and local law do not require nonpoint source TMDL implementation and nonpoint source TMDLs are not enforced by federal, state, and local authorities. EPA and DOH enforce ambient water quality standards, water pollution control permit conditions, and water pollution control permitting requirements.

State of Hawaii Department of Health

ATTENDANCE SHEET

Environmental Planning Office
919 Ala Moana Blvd., Rm. 312
Honolulu, HI 96814 Ph. (808) 586-4337 FAX: (808) 586-4370

Date: February 20, 2007
Time: 6:30-8:30 PM
Purpose: Hanalei TMDL Public Information Meeting
Location: Hale Halawai Ohana o Hanalei (Community Center), Hanalei, Hawaii 96714

Name:	Affiliation or Address:	Ph./FAX:
Cathy Hau Gong	Box 232 Hanalei	
Carl Berg	HWH	
Charlos Spencer	BOX 98 HANALE	
Gary Hunten	DOH - CWB Kauai	
Geoff Culverhouse	Cheng Young Village	
Makaala Kaawaawa	HWH	
Rodney Hamaguchi	Kauai Taro Growers Assn.	
Irwin Hamaguchi	" " " "	
CLYDE FUJIKAWA	KTGA - HFD	
Miguel Legaspi	" "	
Gary Masako Koga	" "	
Jamie Cate	Kailua, HI	
CARL IMPARATO	BOX 1102, HANALEI	

ATTENDANCE SHEET

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Name:	Affiliation or Address:	Ph./FAX:
Chris Kobayashi	(KTGA) PO Box 135 Hanalei 96714	826-7836
Wendy Wilfre	EPA	541-2752
Hedouin Laetitia	HIPYB	639 1279
Kathy Chaston	UH-CTAHR MANOA	956-4065
Paul Pedone	NRCS	503-414-3249
Abby Bak	KTGA	639 2199
Matt Rosener	HWH	639 2640
Michael Lee	PO Box 223040 Princeville 96722	826-3310
Ed Tschupp	County Wastewater	241 6610
Dwight Morishige	Hanalei	826-1106
Rich Copeland	HWH	
Wilbert Tai Hook	Hanalei	652-3387

ATTENDANCE SHEET

Environmental Planning Office
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Honolulu, HI 96814 Ph. (808) 586-4337 FAX: (808) 586-4370

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Time: 6:30-8:30 PM
Purpose: Hanalei TMDL Public Information Meeting
Location: Hale Halawai Ohana o Hanalei (Community Center), Hanalei, Hawaii 96714

Name:	Affiliation or Address:	Ph./FAX:
Monika Mira	EKSWCP 9334 Rice St #104 Lih 96766	245-9014 x 117
Steve Kyono	DOT-HWY-K 1720 Haleukana St Lihue	241-3000
Samson Mahenikiji JR	P.O Box 861 Hanalei Hi 96714	
Mike Mitchell	Hanalei NWR P.O. Box 1128 Kilauea 96722	828-6641/828-6634
Keith Wong	Hanalei P.O. Box 148 Hanalei	8269941
Bobby Watson	Hanalei, P.O. 38	
Stacy Sproat-Beck	Waipa Foundation, Box 1189, Hanalei	639-1815
DL West Warren	PO Box 772 Hanalei	

23 FEB 2007

CHING YOUNG VILLAGE
Shopping Center

"The Heart of Hanalei"
P.O. Box 1217 Hanalei, Kauai, Hawaii 96714
Telephone (808) 826-7222 • Fax (808) 826-7635
WWW.CHINGYOUNGVILLAGE.COM
E-Mail: chingyvsc@hawaiian.net

February 22, 2007

Mr. Kelvin Sunada
Program Manager
Environmental Planning Office
State of Hawaii Department of Health
919 Ala Moana Blvd., Third Floor
Honolulu, HI 96814

Subject : TMDL & Load Targets for Hanalei Bay Watershed

Dear Mr. Sunada :

I was fortunate enough to attend the recent meeting in Hanalei regarding the proposed TMDL loading for the Bay.

The meeting was well attended and the presentation was very professional. However , I did feel that the base line for measurements was possibly taken during the wrong year. 2006 was a year of extreme rainfall for the entire Kauai island; and also the entire state.

With that said, we must move ahead and analyze the plan for the next 10 years. I did spend sometime, prior to the meeting , reading the report and it would appear that the majority of the turbidity and TSS comes from the shrub/scrub land which makes up 90% of the watershed (see Page 48 & Page 66). It would therefore be fair to say , a more concerned effort should be placed on reducing pollution from the 90% culprit and later address the final 10% which is urban and cultivated lands.

I did get the impression from the meeting that a few participants wished to point the blame at the farming and urban areas, and turn a blind eye to pollution from wildlife and reserve areas.

1-1320

How do we reduce pollution from uncultivated lands where wild life is prevalent? Not easy ! Maybe organized hunting to reduce the feral pig population. Install more fences to control location of wildlife ? Possible but we still have to address ground water runoff which is not held back by fences. Unfortunately, I do not have any words of wisdom with this problem and my only comment would be ; The levels of pollution from the 90% land cover area MUST have always been a fixed variable fluctuating only by an increase in Feral Pig population and increase in wildlife due to installation of Wildlife Sanctuaries.

The cultivated and urban areas pose a different problem. We must take into account people's lively hood, tourist trade and requirements. From the graphs on Pages 38 and 43, we try to get a possible correlation between farming and ammonia/nitrates levels. There does appear to be an increase in these levels but the gauges used are some 10 miles apart so an accurate comparison is hard to realize. We do know that fertilizers will impart some pollution but how much is the question? A more detailed study in conjunction with the farming community should be implemented, to possibly offer less hazardous products for fertilization; if such an item is available.

One interesting item came to note at the presentation was a picture showing a storm drain flowing directly into the river. Is it perhaps better to allow the runoff to filter through the land thereby offering some form of filtering prior to entering the river or bay ? This would be similar to using wetland sewage removal.

Investigate the possibility of having a sewage treatment facility for the North Shore. Where does the money come from ? is it possible to install the infrastructure necessary to connect all houses ? Where do we pump the effluent after treatment ?

Ensure all businesses and residences are using proper sewage disposal either treatment plants , cesspools or septic tanks. This requires proper enforcement and follow-up.

This is only a brief outline of possible actions to be taken and I look forward to reading the final report and any further meetings on this subject.

Very truly yours
Ching Young Village

Geoffrey M. Culverhouse
Manager & Partner

J. Ronald Miner, Ph D, P.E.
3131 N W Norwood Place
Corvallis, Oregon 97330-1150
Home (503) 757-8949
Office (503) 737-6295

January 21, 1992

Mr. Bill Mowry
Hanalei Garden Farms
P.O. Box 929
Hanalei, Hawaii 96714

Dear Mr. Mowry:

As a life long researcher and teacher specializing in the environmental impacts of livestock production on water quality, I have been fascinated by the challenge of estimating the potential impact of your operation. I am currently a professor in the Department of Bioresource Engineering at Oregon State University and have been involved in livestock production - water quality research and teaching for the past twenty years. Prior to that I was involved in similar research for five years at Iowa State University and three years at Kansas State University. I have published over a hundred professional papers and one book on this topic. Thus, I consider myself appropriate to comment on this topic.

During the past ten years, a portion of my work has been involved directly in investigating the impact of grazing animals on streams. There are two constituents of livestock manure that require most frequent consideration with regard to stream pollution; nitrogen and enteric bacteria. The major pathway by which either of these can enter a stream is direct deposition when the animals have access to the stream as a source of drinking water. When the animals are fenced out of the stream and are provided an alternate source of drinking water away from the stream, this pathway is completely excluded. Thus, in the case of your operation, in which the bison are kept out of the stream there would be no opportunity for manure to be deposited directly into the river.

The second pathway for nitrogen and microorganisms to enter a stream is due to runoff from the pasture land transporting these materials. So long as a vegetative cover is maintained on the pasture area, data indicate that this is not a major source of either of these materials entering the stream. There are two causes: (1) the first part of a rainfall event is the part that picks up the soluble nitrogen and dislodges the bacteria and this enters the soil profile, (2) the portion of the precipitation that runs across the land surface is filtered by the standing vegetation

and the vegetative debris on the ground surface. This latter phenomenon is often referred to as a vegetative filter. Vegetative filters have been demonstrated to be highly effective in removing microorganisms and in reducing any other transported particulate material.

One final consideration is the quantity of nitrogen that is deposited on the land surface. The data available to me suggests that we would expect each bison to defecate about 0.8 pounds of nitrogen per day. As deposited by the animals, approximately fifty percent would be volatilized. Thus the effective nitrogen application from 200 bison would be approximately 29,200 pounds per year. Spread over 200 acres, this would be 146 pounds of nitrogen per acre. This fertilization rate would be less than that consumed by the growing grass, hence less than would be necessary to be applied as chemical fertilizer to achieve the same level of productivity.

In consideration of the above analyses it would be my professional opinion that it would not be possible to measure an adverse impact of the bison ranch on the nearby river based on either nitrogen or enteric bacteria. Furthermore, I know of no other constituent of the bison ranch effluent that could be detected in the river in concentrations that could be considered deleterious to its overall quality.

I hope this analysis is helpful to you. If you or the local government officials have additional questions or if I can be of further assistance, I will be happy to provide detailed research data supporting these observations.

Yours truly,

J. Ronald Miner

J. Ronald Miner, Ph D, P.E.

Baseline Studies of the Hanalei River Estuary and Other North Shore Rivers, Kauai

Final Report

by

Environmental Center, University of Hawaii
John T. Harrison

Department of Zoology, University of Hawaii
Robert A. Kinzie III
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Prepared for
The State of Hawaii
Board of Land and Natural Resources

By Agreement with
The University of Hawaii Environmental Center

Contract No. 25853

June 30, 1991

8 MAR 2007

East Kauai
Soil & Water Conservation District

March 2, 2007

Kelvin Sunada
Hawaii State Department of Health
Environmental Planning Office
919 Ala Moana Blvd, Room 312
Honolulu, HI 9814

Re: Hanalei TMDL Comments

Aloha Mr. Sunada:

The East Kauai Soil & Water Conservation District would like to submit the following comments regarding the Hanalei TMDLs. Being that the Conservation District is conservation based organization, we would like to support the Department of Health's efforts in the implementation of the Hanalei TMDLs. At the same time we would like to ensure that HIDOH is willing to address the farmers' concerns about the load reductions that are called for in the TMDLs. The Conservation Districts will partner with the farmers to help them implement BMPs, provide technical assistance, act as a sponsor for Federal grants and provide additional assistance that would help them to receive cost share funding from NRCS programs such as WHIP and EQIP.

Mahalo,

Ted Inouye

Ted Inouye
EKSWCD Chair
East Kauai Soil & Water Conservation Districts
4334 Rice Street, Suite 104
Lihue, HI 96766

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13 MAR 2007

March 11, 2007

Mr. David Penn, Total Maximum Daily Load Coordinator
State of Hawaii Department of Health, Environmental Planning Office
919 Ala Moana Boulevard, Third Floor
Honolulu, HI 96814

Re: January 2007 Draft of "TMDL and Load Targets for the Hanalei Bay Watershed"

Aloha Dave,

The draft TMDL report is an important step forward in understanding the water quality problems of the Hanalei Bay watershed. However, I am very concerned about suggestions that we should now move on to implementation plans (for reducing pollutant loads, improving water quality, or repairing the integrity of aquatic ecosystems), when it appears that we still do not have the answers to several key questions.

First: *what types* of pollutant loads should we be concerned about, and *why* should we care?

- For example, it seems clear to me that we should be concerned if biological pathogens are found in dangerous concentrations in the water *in places where people would be exposed to such pathogens and at times when rational people would be exposed to such pathogens* (that is, in the waters of the bay, during periods when the waster isn't brown and clearly inappropriate for swimming). But if such pathogens exist at dangerous levels only a few days of the year, or in locations where humans would not normally be exposed to them, it may not be prudent to undertake costly efforts to reduce or eliminate those pathogens.

- Is it equally important that we be concerned about pathogens, turbidity/suspended solids, and/or nutrients? Has a case been made that major costs - whether they be monetary costs or impositions on taro farmers - should be incurred to reduce concentrations of any or all of these substances? The research results that were presented at the two-day conference at the Princeville Hotel last month seemed to be very inconclusive.

Second: for those pollutants that are determined to have significance to the community and the watershed, we need to know the extent to which each of the five *controllable* sources (pig/goat populations, cattle/horse/buffalo grazing, bird sanctuaries, taro farming, and residential sewage) contributes to the problem, and how much - under realistic mitigation strategies - each of these contributions could be reduced.

- Neither the TMDL report nor any of the research discussed at the aforementioned conference appears to have measured or modeled the impacts of the controllable sources.

- Page 66 of the TMDL report notes that "the bulk of bacterial source areas appear to include wildlands and wetlands in the larger watersheds... and cultivated lands in Waikoko." Further, Figure 6 (page 27) call into question whether either agriculture or the lack of a central sewage system are major sources of the high enterococcus levels.

Third: any action plan should be limited to only those measures that can be realistically expected to produce *meaningful* benefits. Implementation measures that would simply

T-1350

reduce levels of pollutants but not result in *tangible benefits* should generally be eliminated from consideration.

- For example, Table 18 (page 74) shows that 99.4% - 99.7% reductions in enterococcus loads would be required to meet single sample maximum targets. I.e., existing levels are 156 to 284 times the standard. So measures that might reduce the loads by even 20% would still leave enterococcus loads at 125 to 227 times the standard. Why bother?

"A problem well stated is a problem half solved."

Until the issues outlined above have been fully addressed, I believe that it would be imprudent to undertake *any* implementation actions. Instead, I believe that the next step should be to conduct focused research directed at answering the questions that need to be resolved in order to create a justifiable implementation plan. These questions include:

- What are the pathogen counts where people are exposed (i.e., in the bay, during normal swimming conditions, not when the water isn't brown with heavy runoff)?

- The use of enterococcus as a surrogate for fecal bacteria may have been appropriate for the preliminary studies done to date; but before proceeding to implementation, we need to determine the levels of actual pathogens and identify the extent to which the sources of such pathogens are human, domesticated livestock, wild animals, birds, or farming.

- What are the specific negative impacts of fecal bacteria, suspended solids, and nutrients on the public and on the ecosystem, and would those impacts be *meaningfully* reduced through realistic implementation measures?

- Modeling should be done to determine what percentages of each of the problems are caused by each of the following: taro farming, livestock pasturage, wild ungulates, the bird sanctuary, inadequate sewage system(s), and other (uncontrollable/natural) causes.

To summarize, I believe that it would be premature, inappropriate and pointless to spend any money or effort on implementation plans that would not have reasonably-predictable *significant and beneficial* impacts on total pollutant loads - particularly if it appears that such implementation plans might be costly or might impose substantial impacts on local agriculture (by increasing the cost of taro production) or on local residents (through the costs of a centralized sewage treatment system). Instead, the logical next steps are to: (i) define meaningful objectives that are supported by science and by the community, and (ii) to obtain the key missing information that is needed in order to produce a worthwhile implementation plan.

Thank you for considering these comments.

Carl F. Imparato
P.O. Box 1102, Hanalei HI 96714
carl.imparato@juno.com

Penn, David C

From: william schulman [chapelcal@yahoo.com]
Sent: Monday, March 12, 2007 11:46 AM
To: Penn, David C
Subject: TMDL

To: David Penn - TMDL Coordinator- DOH

From: Clyde Fujikawa - Taro Farmer
808- 826-4708

Date: March 11, 2007

Topic: Comments on Hanalei Watershed TMDL

In review of the "Hanalei Bay Watershed TMDL" the initial results suggest that the main pollutant sources are open areas with natural occurring phenomenon such as heavy collections of sediment and bacteria after rain fall. Understanding that these are the main sources of our pollution it would be better to do a "Use Attainability Analysis" and seek to have the optimum water quality standard that allows for farming, wildlife and human economics and tradition in balance.

At this time an "economic study" should also be done before proceeding further with this TMDL. With many farmers already applying best management practices through the NRCS and other soil agencies any further restrictions would seriously hamper taro farmers from farming.

As we are all aware of , Taro farming is both supported under the State of Hawaii and it statues and legislature as well as amendments of the clean water act in relation to traditional kalo growing and farming.

We as the people of Kauai and the State of Hawaii need to re-evaluate what is happening here so that we do not throw the baby out with the bathwater and destroy "OUR WAY OF LIFE."

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1 2 MAR 2007

ALEXANDER & BALDWIN, INC.

March 12, 2007

State of Hawaii Department of Health
Environmental Planning Office
Attention: Mr. Kelvin Sunada
919 Ala Moana Boulevard, Third Floor
Honolulu, HI 96814

Subject: **Total Maximum Daily Loads and Load Targets for Hanalei Bay Watershed**

Dear Mr. Sunada:

Alexander and Baldwin, Inc. (A&B) is pleased to provide comments regarding the draft report entitled *Total Maximum Daily Loads and Load Targets for the Hanalei Bay Watershed.* While we recognize that there may well be water quality issues in the Hanalei Bay Watershed that should be addressed, A&B has serious concerns regarding the potentially devastating impact of the draft TMDL on agriculture within the watershed. We also feel that the methodology used in developing the Hanalei TMDL will prove to be a fatally flawed template for the ongoing and future development of TMDLs required for other water bodies included on Hawaii's list of impaired waters (commonly known as "the 303(d) list").

Draft TMDL Does Not Pass the "Common Sense" Test

A brief review of the draft report raises the obvious question regarding whether the load reductions called for make sense, much less are attainable. In several cases, load reductions approaching 100 % are called for by the TMDL, while similarly high reductions are "suggested" by many of the Load Target Allocations (including a remarkable 99.7 % reduction in Waikoko Stream *enterococcus* levels). Such reductions do not seem reasonable given that there are clearly inputs from natural sources within the watershed that cannot be reduced. While we understand that inputs from natural (background) sources are required to be included in the load allocations, we strongly believe that certain of the water quality standards upon which the TMDLs are based (particularly the turbidity standards) ought to take into account natural background conditions. Of particular concern are the reductions required in total suspended solids (TSS) loads (up to 97.8 %) despite the fact that none of the affected water bodies is currently listed as impaired for TSS. As discussed in more detail below, we believe that these overstated, and clearly unachievable, load reductions have resulted from a combination of an inappropriate approach to development of the TMDLs, unreliable data, and flawed water quality standards for turbidity that are overdue for a careful review and revision. We urge the Department to carefully scrutinize each of these issues and to re-evaluate whether the approach to TMDL development is appropriate in light of what appear to be obvious problems with the results.

Inclusion of Load Targets in the Draft TMDL Report is Inappropriate

In addition to the six water body-pollutant combinations addressed by TMDLs for turbidity and *enterococcus* in the draft report, the Department has chosen to include a far greater number of

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L-1358

"load target allocations" for water bodies "threatened" by various pollutants (including *enterococcus*, total suspended solids, and nutrients). It should be noted that none of the water bodies for which load targets have been developed has been determined to be impaired by any of these pollutants (none appear on the draft 303(d) list prepared by the Department in December 2006). In fact, for several of these water body-pollutant combinations, monitoring results appear to show attainment with water quality standards.[1] While these load target allocations are not technically TMDLs, it is likely that this distinction will be lost on parties, potentially including state and local regulatory agencies and landowners, who eventually seek to implement the TMDL through land use policies and other means. In essence, these load target allocations are *de facto* TMDLs and will almost certainly be implemented as such, essentially circumventing the listing process that so-called impaired waters are supposed to undergo. A crucial element of this process is the data review and quality control process and the "weight of evidence" approach which specifies exactly when listing is supported and when it is not. Based on the draft 2006 303(d) list, listing is clearly not supported for these water body-pollutant combinations at this time, and therefore development of TMDLs, including these *de facto* TMDLs, is wholly inappropriate. While we support efforts to improve water quality in these water bodies that may be necessary to prevent future impairment listings, we believe that application of the TMDL program should be restricted, as intended, to water designated as impaired, and that such efforts should occur in coordination with, but outside of, the TMDL program. As the Department is surely aware, the TMDL program, while not itself a "regulatory program", is intended to encourage regulatory and other mandatory implementation mechanisms. Given the severe impact on agriculture that these clearly unachievable load target allocations, if implemented, are likely to have, we believe it is imperative that water quality problems, where they exist, be confirmed through the existing listing process before potentially draconian measures are implemented to address them. We therefore strongly encourage that the Department delete all load target allocations from the draft TMDL document, and that the scope of the document be limited to those water body-pollutant combinations for which impairment has been demonstrated.

Water Quality Standards for Total Suspended Solids and Turbidity are Inconsistent
To address impairment of the Hanalei Bay Watershed estuaries and Hanalei River for turbidity, TMDLs were developed using total suspended solids (TSS) as a surrogate for turbidity. According to the draft report, "TSS was used as a surrogate for turbidity during TMDL and load target analyses because turbidity is not mass-based and therefore cannot be used to calculate loads. However, stream and estuary turbidity WQC were incorporated into the TMDL analyses to ensure attainment of WQC in the estuaries (where no TSS WQC exists). Correlative analyses confirm the relationship between TSS and turbidity (R^2 value of 0.7175), as described below in Section 4.3.2.3 and illustrated in Figure 13), further justifying this approach." Figure 13 shows a correlation indicating that TSS concentration (y) is equal to 1.1 times turbidity (x) (that is, for example, a turbidity of 5.0 NTU is equal to a TSS concentration of 5.5 mg/L). While this approach to developing a "turbidity TMDL" is not unique to Hawaii, it unfortunately leads to the absurd result that the TMDL requires up a 77 % reduction in total suspended solids in the Hanalei River Estuary and in the Hanalei River itself even though available TSS data (as

[1] For example, Part 4 of the Department's *Draft 2006 Integrated Report of Assessed Waters in Hawaii Prepared Under Clean Water Act §303(d) and §305(b)* indicates that water quality standards for nutrients are attained in Hanalei River during the wet and dry season, that standards for nutrients and TSS are attained in Waipa and Waioli Streams during the dry season, and that there is insufficient data to make attainment determinations for other water body-pollutant combinations within the watershed.

referenced in the draft 303(d) list) shows attainment of the TSS standard in the river (there is no TSS standard for estuaries). Similarly large reductions are called for in Waipa and Waioli Streams, where attainment of the TSS standard is also indicated by the draft 303(d) list. A comparison of the water quality standards for turbidity and total suspended solids in streams provides an understanding for this result.

Assuming for the moment that the correlation between TSS and turbidity is accurate, the table below shows the TSS concentration corresponding to the various turbidity standards for streams and the associated TSS standards.

	Turbidity Standard (NTU)	Corresponding TSS (mg/l)	TSS Standard (mg/l)
Geometric Mean			
Dry	2.0	2.2	10.0
Wet	5.0	5.5	20.0
Not to Exceed 10%			
Dry	5.5	6.05	30.0
Wet	15.0	16.5	50.0
Not to Exceed 2%			
Dry	10.0	11.0	55.0
Wet	25.0	27.5	80.0

As can be seen by the table, the TSS standard can be as much as five times higher than the TSS concentration necessary to show compliance with the turbidity standard. As a result, the draft report calculates huge reductions in TSS loads as being necessary to attain the applicable turbidity standards in the watershed. Turbidity standards for estuaries are even lower than those for streams (ranging from 1.5 to 5.0 NTU), indicating an even lower TSS loading necessary for attainment of the turbidity standard. The TMDLs therefore provide a valuable indication that the current turbidity standards may not be appropriate measures of water quality, and that the development of turbidity standards that are more consistent with the TSS standards may be appropriate.

To support consideration of whether the present turbidity standards are appropriate for evaluating water quality in Hawaii, we have enclosed and incorporated by reference our previous comments to the Department regarding the state's water quality standards for turbidity, which were submitted in response to the draft 303(d) lists prepared in 2004 and in 2006[2]. These turbidity standards were set arbitrarily without consideration of background levels typical of streams and other waterways. The large amount of water quality data that has now been collected in Hawaii, and particularly the large number of streams that have been designated as impaired solely due to turbidity, provides a strong indication that some accounting for natural background levels of turbidity needs to be incorporated into the State's water quality standards. The fact that, according to the draft TMDLs and load allocations, the present turbidity standards cannot possibly be attained without almost entirely removing *all* inputs of suspended solids (including those from natural erosion processes in undisturbed areas of upper watershed) speaks strongly to the fact that a review and revision of the State's water quality standards for turbidity is long overdue.

A&B would also like to comment in general on the use of TSS as a surrogate for turbidity in the development of TMDLs. It is unclear in the report whether TSS and turbidity data from each water body were considered and evaluated separately, or whether all TSS and turbidity data pairs were grouped together and evaluated as a whole. We suspect that the latter is the case, since only one turbidity/TSS relationship is presented in the draft report. As noted above, this correlation has been utilized by other states in developing their "turbidity TMDLs". Neverthless, it has become recognized that relationships between turbidity and TSS can vary significantly between watersheds, water body types, seasons, and flow regimes. Among the effects contributing to this variation are the differences in particle size distribution between, for example, streams (where fast flows may tend to keep large particles suspended) and bays or estuaries (where smaller, slower settling particles are more likely to predominate); as a result, turbidity readings may vary significantly between the two water bodies even when TSS levels are comparable. The use of a single correlation between turbidity and TSS for all water bodies, seasons, and flow regimes may well be a source of error in the TMDL analysis.

Impairment Decisions Inconsistent between Draft TMDL and Draft 303(d) List
Table 10 of the draft report provides a summary of listings and exceedances of water quality criteria that is inconsistent with conclusions in the *Draft 2006 Integrated Report of Assessed Waters in Hawaii Prepared Under Clean Water Act §303(d) and §305(b)* (2006 draft 303(d) list). Specifically, the table indicates that water quality criteria for a number of pollutants are exceeded where the draft 303(d) list indicates that they are not. While the source of this discrepancy is unclear, it appears that either water quality data which was used in the development of the TMDL was not available or was for some other reason not used in the preparation of the draft 303(d) list, or that decision-making processes for determining whether water quality criteria are being met differ between the development of the 303(d) list and development of the TMDL. We strongly believe that there should be consistency in data evaluation, quality assurance and quality control, and decision making between the two processes, and request that the Department provide clarification regarding the apparently differing conclusions being drawn in the two documents. We believe that there is a significant problem with the draft TMDL if data sets that were determined to be unacceptable for the purposes of developing the draft 303(d) list have been used in the development of the TMDLs, and particularly in the calibration of the models. We urge the Department to carefully review this issue.

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[2] A large number of streams included on the 2006 proposed 303(d) list are listed either solely or partly due to reported impairment by turbidity; many based on visual assessments only. The current numerical water quality standard for turbidity (2.0 NTU dry season/5.0 NTU wet season), which applies to all streams in the state, is as strict or stricter than the turbidity standard for drinking water and does not consider the normal background turbidity present in streams, particularly during storm events (when turbidity greater than 200 NTU is common), irrespective of any inputs from human sources. As a result, many streams are currently listed as impaired, and many more will undoubtedly be listed as more data is collected, based on turbidity data that is wholly consistent with healthy Hawaiian streams (according to EPA, low turbidity streams and rivers – those typically located at the upper reaches of an undeveloped watershed – are those with turbidities less than 20 NTU – *four to ten times the Hawaii standard*). In comparison, roughly two-thirds of the states which have a numerical turbidity standard at all employ a relative criteria based on background turbidity levels (typically establishing their WQS at 5-10 NTU *above background*). We believe strongly that a review and revision of the State WQS for turbidity is necessary in order to prevent the continued listing of streams for turbidity levels that exceed the current standard but are in fact not indicative of actual water quality impairment.

Consider Consequences of the TMDL

While the TMDL program is purported to be non-regulatory in nature (i.e., it does not, by itself, impose load reductions to achieve improvements in water quality), it is undeniable that implementation of TMDLs can and will have far reaching regulatory impacts. The draft Hanalei TMDL is therefore of particular concern, given that that load reductions of nearly 100 % are called for in some cases. Given the constraints on land uses within the watershed that would need to be imposed in order for these load reductions to even be approached, and the corresponding potential impacts on those who depend upon agriculture for their livelihoods, the TMDL should be subject to the utmost scientific scrutiny to ensure that identified water quality problems are real, and that the need for and extent of corrective actions is well supported. We urge the Department to give these needs careful consideration as it moves forward with this and other TMDLs.

A&B appreciates the opportunity to provide comments on the draft TMDL, and would welcome the opportunity to discuss any of our comments with DOH-EPO staff.

Sincerely,

Sean M. O'Keefe
Director, Environmental Affairs
Alexander & Baldwin, Inc.

cc: G.S. Holaday, HC&S
D. Heafey, HC&S
M. Ching, A&B
J. Ashman, HARC

15 MAR 2007

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March 12, 2007

Program Manager, Environmental Planning Office
State of Hawaii, Department of Health
919 Ala Moana Boulevard, Third Floor
Honolulu, Hawaii 96814
Attn: Mr. Kelvin Sunada

SUBJECT: PROPOSED TOTAL MAXIMUM DAILY LOADS (TMDLs), HANALEI BAY WATERSHED, KAUAI, HAWAII

Dear Mr. Sunada:

The County of Kauai Department of Public Works Wastewater Management Division appreciates the opportunity to comment on the subject Proposed TMDLs for the watersheds tributary to Hanalei Bay, Kauai, Hawaii. The public meeting conducted by the State of Hawaii Department of Health (DOH) on February 20, 2007 was very helpful for the County and the public to understand the TMDL program. The proposed TMDLs are based on extensive analysis of existing conditions in the watersheds along with stream biological assessments and documentation of the present conditions of the stream habitat and ecology.

The issues involved with the proposed TMDL's are complex, and there is potential for the TMDL program to have widespread impact on land use and development within affected area. Because the vast majority of the watershed area is either undeveloped or used for various agricultural activities including livestock, and there are essentially no activities that are presently regulated for point-source water quality discharges under the National Pollutant Discharge Elimination System (NPDES), the predominant pollutant loadings are from non-point-source activities that are difficult to regulate or control. This raises the concern that the few activities that can be regulated in some fashion, such as agricultural practices, may be saddled with an economically unacceptable burden in an effort to make a minor incremental improvement in water quality.

Ultimately, the TMDL analysis and data can be one element of a framework for evaluation of water quality improvements resulting from projects such as development of a sewer system for the Hanalei community. It is important that such projects be evaluated based on consideration of costs and benefits for the community and the environment, and that the TMDLs should not be

L-1360

MAR 14 2007

used to either mandate or undermine the assessment of water quality projects or public policies regarding land use decisions.

We encourage the DOH to expand your public outreach efforts to foster further understanding of the proposed TMDLs and their implications. For example, workshops could be sponsored to educate the public and potentially affected County agencies such as the Office of the Mayor, the County Council, the Planning Department, the Planning Commission and various divisions of the County Public Works Department.

Thank you for the opportunity to provide our comments. If you have any questions, please contact us at (808) 241-6610.

Very truly yours,

EDWARD TSCHUPP, P.E.
Chief, Wastewater Management Division

CONCUR:

DONALD M. FUJIMOTO
County Engineer

cc: Engineering Division
Planning Department

12 MAR 2007

Hanalei Watershed Hui

Post-it® Fax Note 7671	Date 3.12.07	# of pages ▶ 2
To Dave Penn	From Makaala	
Co./Dept. DOH	Co. Hanalei Watershed Hui	
Phone # 808.586.4370	Phone # 808.826.1985	
Fax #	Fax # 808.826.1985	

March 12, 2007

David C. Penn, Ph.D.
Total Maximum Daily Load (TMDL) Coordinator
State of Hawaii Department of Health
Environmental Health Administration
Environmental Planning Office
919 Ala Moana Boulevard, Third Floor
Honolulu, HI 96814

Re: Hanalei TMDL Report Comments

Aloha Dave,

The Hanalei Watershed Hui thanks you for your efforts to bring the information in the Hanalei TMDL Report to the community. We appreciate your thorough presentation of the results of the Tetra Tech work.

On March 10, 2007, The Hanalei Watershed Hui convened a meeting to discuss the community response to the report. Organizations represented at this meeting included the Hanalei Watershed Hui, the Hanalei-Ha'ena Community Association, Hui Maka'ainana 'o Makana, Hui Ho'omalu i ka 'Aina and the Hanalei Roads Committee. These organizations represent nearly forty years of experience advocating for community issues on the North Shore of Kaua'i.

This meeting focused on how to provide community leadership in the development of the plan to address the water quality issues identified in the TMDL report. The Hanalei Watershed Hui was originally organized to provide community leadership and support to implement a community directed Hanalei Watershed Action Plan. From this work, the TMDL study was initiated. The Hanalei community is committed to a collaborative process that identifies community participation as a prerequisite for successful planning and remediation of the water quality issues in our community. This community has valuable experience and an impressive record of leadership, participation, consensus-building and results.

We believe that more information is needed to identify the sources of much of the pollution discussed in the TMDL report; but we also believe that specific community directed projects could be undertaken to address specific impacts to our water quality. There is consensus in the

E malama kumu wai ~ Protect the source
5299C Kuhio Hwy, P.O. Box 1285, Hanalei, Kaua'i, HI 96714
Telephone/Facsimile (808) 826-1985 Email: hanaleiriver@hawaiian.net

community that agricultural best management practices would likely produce improved water quality. There is also interest in organizing local hunters to address the overpopulation of feral pigs. The focus of both of these measures needs to be "locally directed and implemented".

The Hanalei Watershed Hui suggests that the next step is to convene a meeting in Hanalei to discuss the development of a Hanalei Community Water Quality Plan. This meeting would produce a process for such a plan to be written. Any plan for Hanalei must include the culture, traditions and history of this place. The Hanalei Watershed Hui can provide the community collaboration and the educational components of such a plan, the public outreach required to address the water quality issues of this watershed, and a model for other watersheds in our region.

The success of any implementation plan depends on the community involvement in the plan. Therefore the implementation of a Hanalei TMDL Water Quality Action Plan must begin with the community of Hanalei.

The process begins with the community, we must take the lead.

Sincerely,

Makaala Kaaumoana
Executive Director
Hanalei Watershed Hui

Jeffery T. Chandler
President
Hui Maka'ainana 'o Makana

Carl Imparato
President
Hanalei-Ha'ena Community Association

Jeffery T. Chandler
Chair
Hui Ho'omalu i ka 'Aina

Barbara Robeson
Co-Chair
Hanalei Roads Committee

1 2 MAR 2007

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March 12, 2007

Program Manager
Environmental Planning Office
State of Hawaii Department of Health
919 Ala Moana Blvd
Third Floor
Honolulu, HI 96814

Subject: **Proposed Total Maximum Daily Loads for Hanalei Bay Watershed**

Dear Mr. Sunada:

The Hawaii Agriculture Research Center (HARC) is frustrated and discouraged by the proposed TMDLs for the Hanalei Bay Watershed. Although it is unclear exactly how this document will be used and what its ramifications will be, it is clear that taro growers are being targeted for massive and unrealistic reductions in suspended solids, enterococcus, nitrite, nitrate, nitrogen, phosphorous, and ammonia based on speculation, inadequate data, and tenuous application of that data.

The draft report amounts to a complex scientific study of the interplay between land uses, natural phenomena (run-off, erosion), and water quality within the Hanalei watershed. As the Department and anyone who has attempted to decipher the document can appreciate, it is difficult for even those with a scientific and/or regulatory background to understand, interpret, and evaluate the implications of the report. Furthermore, the appropriateness of the complex modeling applications presented in the report (in many cases without sufficient supporting information and data) is impossible to assess for those without the necessary highly specialized background. **Given the technical complexity of the document, HARC strongly believes that the Hanalei watershed TMDL, and TMDLs in general, should be subject to third party peer review, as would any scientific study prior to publication. This is particularly important for this study and other TMDLs which are likely to have far-reaching consequences for agriculture and other land uses within the affected watersheds.** Absent such a review, the State runs a high risk of making both poor and extremely costly (monetarily, socially, and culturally) land use decisions based on "junk science".

For years, HARC and others have questioned the validity and practicality of the State water quality standards, especially the turbidity standard. Because the current turbidity standard was originally set without consideration of natural background levels, it is not a reasonable standard upon which to base impairment decisions, 303(d) listings, or TMDLs. The current numerical turbidity standards were established in the late 1970s and were set somewhat arbitrarily, based on a general perception of what acceptable turbidity levels should be for each water body type. Prior to that, the State's standards for turbidity, among other parameters, were defined in reference to natural conditions. Due to the paucity of water quality data available at the time, these standards were deemed "ambiguously defined and unenforceable", since it was not possible to determine a numerical value for "natural conditions" (although it was at least recognized that turbidity readings greater than 200 NTU- which is eight to 100 times the current standard - are "common" in streams during storm runoffs). Conversely, there is now sufficient data to suggest that turbidity levels observed in water bodies statewide may be more reflective of natural background conditions than of "impairment". We therefore reiterate our previous recommendation that the Department of Health review its turbidity standard and consider whether a revision to reflect natural background turbidity levels in healthy aquatic ecosystems is appropriate. Failure to do so will result in continued misdirection of resources identifying and attempting to address water quality "problems" that in fact may not exist.

HARC is particularly concerned that the proposed TMDL covers a far broader range of pollutant combinations than even the most recent draft of the 303(d) list and imposes load allocations and load targets for pollutants for which impairment has not been demonstrated, and in some cases, where data demonstrate attainment of water quality standards. The report should be restricted to addressing water quality issues that have been identified through the 303(d) listing process. This process helps to assure that impairment decisions are based upon robust data sets meeting minimum quality assurance and quality control standards. All load *targets* proposed by the document should be deleted in their entirety unless and until such time as valid impairment decisions dictate the need for TMDL development.

HARC appreciates the opportunity to comment on the proposed TMDL for the Hanalei Watershed and sincerely hopes that our comments are seriously considered before the agency finalizes its document. The draft report is precedent setting and may well forever change the face of farming not only in the Hanalei Valley, but state-wide. Given these far-reaching ramifications, it is absolutely essential that the Department "get it right" and we implore you to take whatever measures necessary to do so.

Sincerely,

Stephanie A. Whalen

Stephanie A. Whalen
President and Director of Research

Hawaii Farm Bureau
FEDERATION
2343 Rose Street, Honolulu, HI 96819
PH: (808)848-2074; Fax: (808) 848-1921
e-mail hfbf@hfbf.org

12 MAR 2007

March 12, 2007

Program Manager
Environmental Planning Office
State of Hawaii Department of Health
919 Ala Moana Blvd
Third Floor
Honolulu, HI 96814

Subject: **Proposed Total Maximum Daily Loads for Hanalei Bay Watershed, Island of Kauai**

Dear Mr. Sunada:

The Hawaii Farm Bureau Federation (HFBF), a non-profit, voluntary organization working in support of farmers, ranchers, horticulture, aquaculture, forestry and other agricultural producers, offers the following comments regarding the proposed Total Maximum Daily Loads (TMDLs) for Hanalei Bay Watershed.

We are extremely concerned about the ramifications to taro farmers of the proposed TMDLs. **Our main concern is that if the proposed TMDLs and Load Targets are implemented it will force taro farmers to go out of business**. Our further comments are as follows:

- Farmers were not solicited to be active participants in this process and were led to believe that the focus of this project was reduction in bacteria, which would not affect their operations.
- Farmers have been told not to worry, that any activities stemming from this project would be voluntary in nature. Considering the statements on page 64 and 65 regarding implementation of TMDLs through lease conditions, among other tactics, farmers have been misled about DOH's intentions.

See Sections 7.5.2 Land Ownership and 7.5.3 Regulatory and Management Authority
Initial analysis from this perspective suggests that the State of Hawai'i Department of Land and Natural Resources (DLNR), Princeville corporations, U.S. Fish and Wildlife Service (USFWS), Kamehameha Schools, and Waikoko Land Corp. are the most critical landowners for supporting implementation activities.

Had farmers been made aware of the potentially devastating impact on them, they would have been more involved in the process. It is impossible at this point to read, comprehend, and comment on a document of this magnitude and complexity, much less garner the resources to do the rigorous scientific analysis necessary to justify the draconian measures called for in the document.

1-1259

- Taro farmers were not given answers to their questions at the one public information session held at the end of February and asked for a session specific to them. The March 9 meeting resulted in more questions from farmers but still no answers. The Public/stakeholder outreach appears to be merely a formality that has not accomplished the intent of an "information/education component, which the state will use to enhance public understanding of the project and encourage public involvement ....".

- **HFBF can hardly believe the seriousness of the tables regarding load allocations and load reductions required to achieve TMDLs. The percentage reductions (some as much as 97.8%) required are clearly not feasible.**

- The idea that this TMDL will be used as a template for future TMDLs around the State is just plain frightening. Among other things, we call into question the validity of the data and the huge assumptions and speculations made to come up with these allocations. If data is to be used for regulatory/enforcement purposes, that data must be scientifically sound and relevant to the purpose for which it is used.

- Farmers are now being told that this document will enable them to receive funding to better stream water quality through various projects. We believe that CWA section 319(h) is the principal authority for EPA funding dedicated to nonpoint source pollution control and that funding is competitive and requires matching. In other words, funding for projects beneficial to the farmer or that may be required by the ramifications of this document are certainly not guaranteed.

Taro is sacred to Native Hawaiians and is an integral part of the Native Hawaiian culture. Taro is a culturally significant plant to the kanaka maoli, Hawaii's indigenous people. Taro holds great cultural, religious, and historic meaning to Native Hawaiians and is highly respected and revered. There has been a steady overall decline in taro cultivation over the years; Hawaii lost 60 small taro farms between 1994 and 2004, bringing the total down to about 130. At the same time, the amount of land planted with taro plummeted from 550 to 370 acres. Farmers and agricultural experts blame the decline on skyrocketing land values and stagnant commodity prices that haven't kept pace with rising farming costs.

Kauai is where approximately 70 percent of Hawaii's taro is grown. It takes 14 months for taro to grow and come to market. Farmers battle with everything from pocket rot disease to insatiable apple snails to leaf blight which can wipe out most of the crop. However, this proposed TMDL is one additional burden that farmers will not be able to overcome.

It is extremely ironic that while the 2007 Hawaii State Legislature is moving towards the adoption of a law to recognize the importance of the kalo in the heritage of the State by adopting, establishing, and designating the kalo plant as the official state plant, the State DOH is moving to adopt a proposal that is causing taro farmers to throw up their arms in dismay and talk about shutting down because they will not be able to meet the load reductions that will be required.

HFBF urges you to reconsider this proposed TMDL and work with the taro farmers towards a cooperative solution to any problems DOH perceives.

Sincerely,

Alan Takemoto Alan Takemoto

Executive Director

KAUA'I TARO GROWERS ASSOCIATION

March 12, 2007

Mr. Kelvin Sunada
Manager
Environmental Planning Office
State of Hawaii, Dept of Health
919 Ala Moana Boulevard, 3rd Floor
Honolulu, Hawaii 96814

Re: TMDL Hanalei Bay Watershed

Dear Mr. Sunada,

On behalf of the taro farmers of the Kauai Taro Growers Association, we are submitting this letter to request for a time extension to review the Draft report of January 2007. We did not receive a copy of this report until March and were not able to have a KTGA meeting for the farmers to review. We would also like to have clear and simple explanations of the report, charts and results.

Although we did have a meeting with David Penn, there were many questions that were unanswered and need more information. When we attended the first information meeting with Carl Berg years ago, he explained that the testing that he was going to do was to only test for bacteria and would focus on the cesspools and animal waste. He also stated that it would not be affecting the taro farmers in anyway. However, we briefly scanned the report and found that it is focusing also on sedimentation, turbidity and nutrients from agriculture and water bird impoundments. The report also seems to encourage land owners to impose restrictions on farmers in their agricultural leases. We would like further explanation on how, when and over what duration the results were attained, and what impact we can expect TMDL implementation to have on taro farming. Is the focus just on bacteria? The amount of reductions for nutrients that is recommended seems extremely high and judging from the farmers that walked out of the meeting, the information was not sufficient.

Taro farming is already on the decline due to the many challenges from weather, diseases, invasive apple snails, labor shortages, irrigation repairs, etc. that this may be the "straw that breaks the camel's back" and many farmers will leave taro farming for other opportunities. Government should be looking for ways that would encourage the taro farmers to continue and not push them to give up taro farming that is culturally significant to Hawaii and is a way of life, its "staff of life."

Mahalo nui loa,

Rodney Haraguchi
President

Post Office Box 427, Hanalei, Kaua'i, Hawai'i 96714

2 7 MAR 2007

Environmental Planning Office
Hawaii State Department of Health
919 Ala Moana Blvd. Rm 312
Honolulu, Hawaii 96814
Email: kelvin.sunada@doh.hawaii.gov

Thank you for this opportunity to provide comment on the current Total Maximum Daily Loads and Load Targets for the Hanalei Bay Watershed

As a long time member of Hamakua Soil and Water Conservation District, I have had the opportunity to work with the State Department of Health, Clean water Branch in a collaborative manner. As a District we try to work within a partnership of Federal, State and local Government to provide voluntary solutions to erosion and environmental problems of non-point source pollution.

The Hanalei Bay Watershed is a complex ecosystem with many challenges. The top of the system is the wettest area on Earth; the geology of Kauai is the oldest and some of the most degraded in the State. The river systems create a very unique landscape that in its self have provided for the early Hawaiian sustenance and survival till today. The taro growing culture along with the wetland ecosystem is fed by the profuse nutrient loading of sediments delivered to this near shore environment. This it what happens to the natural environment of volcanic islands in the Pacific.

The executive summary mentions "pollutant load capacities (based on water quality standards)" This will be a brief diversion from the subject matter of TMDLs. The water quality standards for turbidity and nutrients needs to be revisited based on the numbers provided for this watershed. For this writer, I find it impossible to believe that any reasonable person would believe that voluntary implementation of best management practices would bring these two constituents into compliance. Page 62 details the ongoing planning and implementation efforts of many agencies with the goals of reducing these problem areas. The soil and water conservation district has been active for the last fifty years and yet the amounts to be reduced are beyond anything attainable by normal means.

Bringing the Hanalei Bay into compliance will destroy the unique taro culture along with the unique near shore ecosystem. These systems require the nutrient and TSS loading to remain as they are. The tourist economy depends on the States preservation of areas such as Hanalei Bay watershed with its taro farms and rustic life styles.

The matter of indicator bacteria is a separate problem. As stated in the text, the high numbers are associated with high rainfall events. The endemic nature of these indicator bacteria needs to be separate from the pathogen agents. Dr Berg has stated on several occasions that the study of the pathogens is necessary. If the correlation between indicators and pathogens are not on target then we need different methods.

It is obvious there is a need to control sewage in this environment.

1-1391

Early water Quality Standards Chapter 37-A

Section 3. Classification of water Uses

1. Class AA Waters

    2. Kauai (a) Class AA Waters

        The near shore waters between Hikinoe Valley and Puu Poa Point, including Wainiha Bay and Hanalei Bay

B. Classification of Fresh Water Uses

Fresh waters are classified in accordance with the uses to be protected

1. Class 1 waters

    The uses to be protected in this class of waters are drinking water supply and food processing

    It is the objective of this class of waters that they remain as nearly the natural state as possible with an absolute minimum of pollution from any source.

2. Class 2 Waters

    The uses to be protected in this class of waters are bathing, swimming, recreation, growth and propagation of fish and other aquatic life and agricultural and industrial water supply.

    It is the objective for this class of waters that their use for recreational purposes, propagation of fish and other aquatic life and agriculture and industrial water supply not be limited in any way. Such waters shall be kept clean of trash, solid materials or oils and shall not act as receiving waters for any effluent which has not received the best practicable treatment compatible with the standards established for this class

At some point of time a new set of water quality standards were written. Chapter §11-54 (Aug/31/2004) This document has two similar sections §11-54-3 (2) (c) Marine waters and (1) Class AA Along with §1-54-3(b) inland waters (1) class 1 and (2) class 2

After careful search of government documents and questions to key DOH staff I have been unable to determine when and if an appropriate process was used to change these existing uses. A State planning process along with public notification should have been done. Class 1 uses were eliminated (drinking water) and many others added to Class 2

In the area of marine waters a whole subset to Class AA waters has been added (ii), (iii), and (IV) The inclusion of these waters adds a new dimension to the areas protected. In fact the EPO recommendation is to add one class A area that is sandwiched between two Class AA. If the proper notification and public participation process was not provided to the public then the lower water shed should revert to Class A in the marine environment and the streams should be Class 2

The waters of Hanalei should have had a use attainability Analysis to determine if the uses are attainable. It is obvious that given the load reduction numbers that it will be a very costly to achieve the load reductions as required

I am recommending that the state planning process be utilized. And that a local watershed plan be developed and implemented in stead of implementation of this TMDL.

Further more the Water quality Standards need to come into line with the ever evident reality of what is happening in the environment.

Thank You for the opportunity to comment

Thomas Young
Vice Chair
Hamakua Soil and Water Conservation District
529 Kukuau St.
Hilo Hawaii 96720

16 MAR 2007

U.S. DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

KAUAI NATIONAL WILDLIFE REFUGE COMPLEX
KILAUEA POINT
P.O. BOX 1128
KILAUEA, HAWAII 96754
808/828-1413, FAX 808/828-6634

March 12, 2007

Dear Mr. Penn,

The U.S. Fish and Wildlife Service (Service) appreciates the opportunity to review and comment on the draft Total Maximum Daily Load (TMDL) Report for the Hanalei Bay Watershed. As a major landowner within the Hanalei Valley watershed, the Service believes it has a responsibility to take a leadership role to improve Hanalei River water quality. The Service is committed to this leadership role while meeting our legal mandates for management of Hanalei National Wildlife Refuge (Refuge).

The refuge was established in 1972 under the authority of the Endangered Species Act of 1973 for protecting and promoting the recovery of four endangered Hawaiian waterbirds: the Hawaiian Duck, Hawaiian Coot, Hawaiian Moorhen, and Hawaiian Stilt. This conservation action was deemed necessary due to loss of wetlands and the introduction of non-native predators. At one time, Hawaii contained an estimated 58,974 acres of wetlands. Because the remaining wetlands cover less than 3% of Hawaii's surface area, they are extremely important in supporting both plant and animal species endemic to the Hawaiian Islands. The remaining quality wetland habitat is restricted to a few small federal national wildlife refuges and state wildlife areas.

Protection, restoration, and management of Hawaii's remaining wetlands are essential to the recovery of endemic waterbirds, as well as the survival of migrant waterfowl and shorebirds that visit the islands. Kauai is second only to Oahu in terms of wetland acreage in the Hawaiian archipelago. Additionally, Kauai is important for rare ground nesting birds because it lacks the Indian mongoose. The island's relatively extensive wetlands and undeveloped areas provide the last stronghold for the endangered Hawaiian Duck.

The State's TMDL findings along with research conducted in the Hanalei watershed identify three areas where the Service may be able to implement BMPs to contribute toward improving water quality in the Hanalei River.

1) Pathogens (Enterococcus) – Cesspools associated with four residences located on the refuge are likely contributors to this problem. Therefore, the refuge will continue to work with the Hanalei Hui to convert refuge residences from their outdated cesspools to the more efficient septic tank systems. One such septic conversion was recently completed, but there are 4 additional systems to upgrade. The Service is actively seeking funds needed to complete these sewage conversions and may offer in-kind contributions (e.g., equipment, operators, other materials, as needed).

L1270

2) Sediment – Reduction of the chronic, "low flow condition" sediment loading from the refuge to the Hanalei River is important to the Service. With adequate funding, the Service proposes to coordinate with the Hanalei Hui to install an additional 4 check gates at strategic locations in refuge drains, along with the 3 check gates currently in-place, to reduce sediment loading from both the taro loi and the refuge managed wetlands drainage ditches. Regular maintenance dredging of the "up stream area" of the check gates will help to minimize the amount of sediment accumulated which then can be washed from these areas during flood events. Contingent upon adequate funding, monitoring will be implemented, with the help of the Hanalei Hui, to validate the effectiveness of these check gates. Preliminary data from the Hanalei Hui indicate that one check gate can reduce the sediment load in that drainage ditch up to 10%. In addition, the Refuge staff will work with refuge taro farmers to explore and implement alternative methods of taro loi cultivation to reduce that contribution to the low water sediment load.

3) Nutrients – The Refuge staff will work with refuge taro farmers over the next few months to identify potential BMPs. For example, the amount of sediment-bound fertilizer being washed off taro loi may be reduced by changing water application rates, stricter enforcement of the 30-day wet fallow requirement of the farmer's Special Use Permit, and by investigating ways to facilitate conversion to organic farming or the use of "slow release" fertilizers. Effective implementation of BMPs will take considerable time and coordination, but it would likely provide a substantial contribution to reducing the nutrient loads to the Hanalei River from the refuge. In addition, converting cesspools to upgraded septic tanks will also help reduce nutrient (e.g., ammonia) input to the river from refuge lands.

By implementing BMPs on HNWR, the Service anticipates making a substantial contribution to improve water quality to help achieve the goals of the TMDL. Furthermore, the Service hopes to take an active role in facilitating work on the watershed action plan being prepared to implement the objectives of the TMDL.

Sincerely,

Michael M. Hawkes

Michael M. Hawkes
Refuge Manager

LINDA LINGLE
GOVERNOR OF HAWAII

CHIYOME L. FUKINO, M.D.
DIRECTOR OF HEALTH

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. Box 3378
HONOLULU, HAWAII 96801-3378

In reply, please refer to:

EPO-0425

September 29, 2008

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Clyde Fujikawa chapelcal@yahoo.com	Rodney Haraguchi, President Kauai Taro Growers Association P.O. Box 427 Hanalei, Hawaii 96714
Michael Hawkes, Refuge Manager Kauai National Wildlife Refuge Complex Fish and Wildlife Service U.S. Department of Interior P.O. Box 128 Kilauea, Hawaii 96754	Carl F. Imparato P.O. Box 1102 Hanalei, Hawaii 96714
Ted Inouye, Chair East Kauai Soil & Water Conservation District 4334 Rice Street, Suite 104 Lihue, Hawaii 96766	Makaala Kaaumoana, Executive Director Hanalei Watershed Hui P.O. Box 1285 Hanalei, Hawaii 96714
Martha J. Mowry Trust 404 E. Highway 246 Buellon, California 93427 c/o Sharon Pait FAX TO: (808) 826-9208	Sean M. O'Keefe Director, Environmental Affairs Alexander & Baldwin, Inc. P.O. Box 266 Puunene, Hawaii 976784
Alan Takemoto, Executive Director Hawaii Farm Bureau Federation 2343 Rose Street Honolulu, Hawaii 96819	Edward Tschupp, P.E. Chief, Wastewater Management Division Donald M. Fujimoto, County Engineer Department of Public Works, County of Kauai 4444 Rice Street, Suite 275 Lihue, Hawaii 96766-1340
Stephanie Whalen President and Director of Research Hawaii Agriculture Research Center 99-193 Aiea Heights Drive, Suite 300 Aiea, Hawaii 96701	Thomas Young 529 Kukuau St. Hilo, Hawaii 96720

Subject: Response to Public Comments on Draft Total Maximum Daily Loads and Loads Targets for the Hanalei Bay Watershed

Thank you all for submitting comments on the Draft Total Maximum Daily Loads and Load Targets for the Hanalei Bay Watershed. Our consolidated response to these comments (enclosed) is organized to correspond with the U.S. Environmental Protection Agency (EPA) Region 9 TMDL Review Checklist elements and to address additional concerns related specifically to the Hanalei Bay watershed and generally to State water pollution control and water quality management programs, particularly with regard to TMDL implementation, TMDL development approaches, and water quality standards. The complete text of each comment letter, and a copy of this response, are included in Appendix H of the Department of Health (DOH) TMDL submittal to EPA. After EPA approval of the TMDL submittal, the entire submittal package will be published on the DOH Environmental Planning Office website (http://www.hawaii.gov/health/epo).

The TMDL process repeatedly touches other issues that complicate our water pollution control efforts. The draft Hanalei TMDLs generated considerable criticism from some quarters and raised nagging questions about the validity of the underlying standards, the feasibility of load allocations, the role of common sense, and the threat of mandatory TMDL implementation. Although we can't resolve all of these important concerns in a single TMDL decision, we will seek to address them in this response, associated revisions to the Hanalei TMDL decision document, and ongoing efforts to improve the TMDL process.

To reach the current TMDL decision, EPA and DOH employed some of the nation's leading TMDL practitioners to incorporate an extensive set of hydrologic and water quality data [obtained through cooperative field efforts with the U.S. Geological Survey (USGS) Pacific Islands Water Science Center, the U.S. Fish and Wildlife Service, and the Hanalei Watershed Hui] into the loading analysis. This analysis used well-established and thoroughly-documented modeling procedures to estimate the maximum loadings of pollutants that would still accommodate the attainment of water quality criteria. However, due to the difficulty of drawing precise links between nonpoint sources (including natural background, endangered waterbirds, wildlife, livestock, and wetland farming) and waterbody impairment in the Hanalei Bay Watershed, we propose employing a phased approach to the development and implementation of these TMDL load allocations. 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. While resolving questions about standards is not the role of TMDL decisions, our phased approach should also give us information about feasibility of implementation that will help us to move beyond persistent challenges to turbidity and enterococcus standards.

The next phase, which is currently underway through an EPA contract with Tetra Tech, Inc., will refine the stream and estuary TMDLs as necessary in the process of establishing TMDLs for the embayment receiving waters (Hanalei Bay). This provides a context for using new information to improve our understanding and management of pollutant loading and water quality dynamics throughout the watershed, including new hydrologic, water quality, and oceanographic data

obtained from taro farmers, the USGS Pacific Water Science Center, the USGS Western Coastal and Marine Geology Program, Stanford University, DOH, and the Hanalei Watershed Hui. This phase also expects to benefit from the concurrent development of a Watershed Based Plan for polluted runoff control, to be led by the Hanalei Watershed Hui through a contract with DOH. Over the coming year, we invite all of you to join us in these efforts, which we recognize must include more frequent and direct communication between DOH and the entire community.

During the development of the TMDLs there were a number of concerns expressed about potential implementation mandates, costs, societal impacts, and environmental effectiveness. Because the TMDL does not set any waste load allocations for point sources, our TMDL implementation framework and the upcoming Watershed Based Plan are intended 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. Although we believe it is our civic duty to fully identify potential implementation mandates (including those largely beyond DOH control, such as legislation, approval and permitting conditions, lease conditions, and third-party lawsuits), DOH is not recommending any particular mandates in Hanalei at this time. Instead, we advocate a community-driven adaptive approach to implementing nonpoint source load allocations based on TMDL decisions, other watershed planning results, and local knowledge and experience.

This TMDL decision is a starting point for nonpoint source implementation activities that can be adapted as new information becomes available, and that are intended to include ongoing review and future revision of the TMDL decision. If you have any questions about our responses, please contact David Penn, TMDL Coordinator, at 586-4337.

Sincerely,

Kelvin Sunada, Program Manager
Environmental Planning Office

Enclosure

Response to Public Comments on Draft Total Maximum Daily Loads and Load Targets for the Hanalei Bay Watershed
State of Hawaii Department of Health, Environmental Health Administration, Environmental Planning Office
919 Ala Moana Boulevard, Room 312
Honolulu, HI 96814
September 2008

1. Index to Public Comments Received

Commenting Organization/Individual*	Signatories	Date of Comments	Identifier used in DOH response	TMDL Elements addressed[1]
Alexander & Baldwin, Inc.	Sean M. O'Keefe, Director, Environmental Affairs	03/12/2007	A&B	1, 3, 6, 10, 13
Ching Young Village Shopping Center*	Geoffrey M. Culverhouse, Manager & Partner	02/22/2007	CYVSC	4, 13
Department of Public Works (County of Kaua'i)*	Edward Tschupp, P.E. Chief, Wastewater Management Division	03/12/2007	COK-DPW	9, 13
East Kaua'i Soil & Water Conservation District	Ted Inouye, Chair	03/02/2007	EKSWCD	13
Fujikawa, Clyde*	Clyde Fujikawa, Taro Farmer	03/12/2007	CF	9, 13
Hanalei Watershed Hui*	Makaala Kaaumoana Executive Director, Hanalei Watershed Hui Jeffrey T. Chandler President, Hui Maka'ainana 'o Makana Chair, Hui Ho'omalu i ka 'Aina Carl Imparato, President Hanalei-Ha'ena Community Association Barbara Robeson, Co-Chair Hanalei Roads Committee	03/12/2007	HWH	4, 13
Hawaii Agriculture Research Center	Stephanie A. Whalen President & Director of Research	03/12/2007	HARC	1, 10, 13
Hawaii Farm Bureau Federation*	Alan Takemoto, Executive Director	03/12/2007	HFBF	6, 9, 10, 13
Imparato, Carl F.*	Carl F. Imparato	03/11/2007	CFI	13
Kauai National Wildlife Refuge Complex (U.S. Department of the Interior, Fish and Wildlife Service)*	Michael M. Hawkes Refuge Manager	03/12/2007	KNWRC	13
Kauai Taro Growers Association*	Rodney Haraguchi, President	03/12/2007	KTGA	1, 9, 10, 13
Mowry, Bill	Bill Mowry	03/01/2007	BM	4
Young, Thomas	Thomas Young	03/12/2007	TY	4, 5, 13

*Individual, group representative(s), or group member(s) attended public information meeting, based on sign-in sheet or DOH observations.
[1]See Key to TMDL Elements Addressed on next page. All except Element 1 correspond to numbered items on the EPA Region 9 TMDL Review Checklist (see Appendix G in TMDL submittal to EPA).

2. Key to TMDL Elements Addressed

Element 1 - Problem Statement[1]
Element 2 - Water Quality Standards Attainment
Element 3 - Numeric Target Definition
Element 4 - Source Analysis and Estimation
Element 5 - Partition the Loads Among the Contributing Sources (Allocations)
Element 6 - Linkage Analysis and TMDL Calculation (Loading Capacity)
Element 7 - Margin of Safety
Element 8 - Seasonal Variations and Critical Conditions
Element 9 - Public Participation
Element 10 - Technical Analysis
Element 11 - Monitoring and Review Plan for Phased TMDLs
Element 12 - Reasonable Assurances (for waters affected by both point and nonpoint sources)[2]
Element 13 - Implementation Plan[3]

[1]For purposes of this response, substitutes for the "Submittal Letter" element found on the EPA Review Checklist (see Appendix G of TMDL decision rationale document)
[2]Not applicable to Hanalei, which is not affected by point sources.
[3]EPA expectations for this element are applicable to other Region 9 states, such as California, where State law requires that implementation plans be included in approved TMDLs. Although this is not required for Hawaii, under this element we address comments received about various aspects of TMDL implementation.

3. Response to Public Comments

Element 1 - Problem Statement

Description of the watershed setting

- See various comments and responses below.

Impairment Overview

- Is the focus just on bacteria? (KTGA)
- Because the current turbidity standard was originally set without consideration of natural background levels, it is not a reasonable standard upon which to base impairment decisions. (HARC)
- The report should be restricted to addressing water quality issues that have been identified through the 303(d) listing process. This process helps to assure that decisions are based on robust data sets meeting minimum quality assurance and quality control standards. All load *targets* proposed by the document should be deleted in their entirety unless and until such time as valid impairment decisions dictate the need for TMDL development. (HARC)
- Table 10 of the draft [TMDL] report … indicates that water quality criteria for a number of pollutants are exceeded where the draft 303(d) list indicates that they are not… we request that the Department provide clarification regarding the apparently differing conclusions being drawn in the two documents. (A&B)
- …we believe that the application of the TMDL program should be restricted, as intended, to water designated as impaired, and that such efforts should occur in coordination with, but outside of, the TMDL program. (A&B)

Response: TMDLs may deal with water quality impairments confirmed by data collected outside of the §303(d) listing process, as EPA has affirmed in numerous TMDL approvals. However, for clarification (and in conjunction with our phased TMDL approach), at this time we are only requesting EPA approval of the TMDLs that directly address the eight (8) impairments confirmed by the EPA-approved 2006 §303(d) list. In subsequent phases of Hanalei TMDL development, we will continue evaluating all readily-available data from the watershed to reassess water quality impairments, especially additional data specifically collected in conjunction with the TMDL development process.

TMDL development and the designation of impaired waters go hand-in-hand under Clean Water Act (CWA) §303(d) and EPA regulations, policy, and practice. Given the disparate timelines of water quality monitoring and assessment cycles, §303(d) list approval, and TMDL development, it is common for States to develop TMDLs for waterbodies that are on the cusp of impairment ("threatened") or that are likely to meet impairment decision criteria if monitoring trends observed in currently limited datasets continue ("Informative TMDLs"), and to re-evaluate and revise impairment decisions for specific waterbodies and pollutants during TMDL development. As TMDL development frequently involves new data collection, it often contributes to more complete assessment of current waterbody impairment. For Hanalei, as for other TMDLs, DOH believes (and EPA has confirmed) that such approaches are reasonable and consistent with the requirements of CWA §303(d).

In response to these comments, DOH revised pertinent tables and related discussions to incorporate the more recent and currently applicable 2006 §303(d) list information and clarify the terminology used. Pending completion of the next phase of TMDL development (underway), including another careful review of the data, we are labeling most allocations not directly tied to 2006-listed waterbody/pollutant combinations as "Informative TMDLs" as suggested by EPA. The few remaining "Load Targets" are calculated only for ammonia concentrations in streams, based on the assumption that achieving the estuary ammonia criteria in streams (where it is not an explicit part of the standards, otherwise these would be Informative TMDLs) would be protective of stream nitrogen and turbidity standards. However, it remains important to note that these "Informative TMDLs" and "Load Targets" provide additional tools for polluted runoff control planning and for measuring conformance with antidegradation requirements. Also, implementation of these allocations would be protective of related standards for other pollutants, and may contribute to the achievement of water quality standards for §303(d) listed impairments in the same waterbody (e.g. reducing nutrient loadings can also help to achieve turbidity criteria, and reducing TSS loadings can also help to reduce nutrient and enterococcus loadings) and in down-gradient receiving waters.

The focus of the TMDL process is on sources of pathogens, sediment, and nutrients that contribute to water quality impairment and threats in the Hanalei Bay watershed. According to the Report of the Technical Committee on Water Quality Standards (Department of Health 1977), the current turbidity standard (which emerged from the Committee recommendations and has been in effect since 1979) is ecosystem-based and was originally set with consideration of natural background levels. While we agree that review of the turbidity criteria is in order, we note that they are also validated by their measured attainment in numerous waterbodies for the current and previous monitoring and assessment reporting cycles. Although the current standard

is the legally-required standard upon which to base impairment decisions, these TMDLs are part of a phased approach and can be revised in the future if modifications are made to the water quality standards. Please see additional response under Additional Concerns – Water Quality Standards below.

Element 2 – Water Quality Standards Attainment
No comments received.

Element 3 - Numeric Target Definition

- It is unclear…whether TSS and turbidity data from each water body were considered and evaluated separately, or whether all TSS and turbidity data pairs were grouped together and evaluated as a whole. The use of a single correlation between turbidity and TSS for all water bodies, seasons, and flow regimes may well be a source of error in the TMDL analysis…this approach to developing a "turbidity TMDL"… leads to the absurd result that the TMDL requires … large reductions [in TSS] … where attainment of the TSS standards is also indicated by the draft 303(d) list. (A&B)
- Figure 13 shows a correlation indicating that TSS concentration (y) is equal to 1.1 times turbidity (x). … While this approach to developing a "turbidity TMDL" is not unique to Hawaii, it unfortunately leads to the absurd result that … the TSS standard can be as much as five times higher than the TSS concentration necessary to show compliance with the turbidity standard. As a result, the draft report calculated huge reductions in TSS loads as being necessary to attain the applicable turbidity standards in the watershed. … The TMDLs therefore provide a valuable indication that the current turbidity standards may not be appropriate measures of water quality, and that the development of turbidity standards that are more consistent with the TSS standards may be appropriate. (A&B)

Response: The TMDLs require significant reductions in total suspended solids to achieve the turbidity standards based on a scientifically defensible relationship. Our goal is to be protective of water quality throughout the Hanalei Bay watershed - therefore the most stringent of the TSS and turbidity criteria are applied to a large dataset to return statistically significant correlation results.

The TSS and turbidity data were evaluated several different ways and, as the comment suggests, all paired data were combined for the final analyses presented in the TMDL report. The combined R^2 value indicates a fairly strong relationship between TSS and turbidity that is well within the range observed in other TMDLs. The table below presents the various analytical results, including the combined data as well as the variability between watersheds, waterbody types, and seasons. Although these results show 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.

Analytical Group		Number of Samples	R^2	Equation	Corresponding TSS value (mg/L) *(if x = 5)*
All paired data		183	0.7175	y = 1.10x	5.5
Watershed Comparison	Hanalei	91	0.7196	y = 1.17x	5.85
	Waikoko	23	0.5525	y = 0.96x	4.8
	Waioli	33	0.8917	y = 0.71x	3.55
	Waipa	36	0.5529	y = 0.75x	3.75
Waterbody Type Comparison	Estuary	129	0.6817	y = 1.02x	5.1
	Stream	54	0.783	y = 1.27x	6.35
Seasonal Comparison	Wet	100	0.7277	y = 1.17x	5.85
	Dry	83	0.5634	y = 0.65x	3.25

Note: Flow comparisons were not performed due to lack of measured flow data for most waterbodies.

The current turbidity standards must be achieved to ensure compliance with these TMDLs. While the comment indicates that perhaps the turbidity standard should be increased to maintain consistency with the TSS standards, the alternative scenario (decreasing the current TSS standard to maintain consistency with the turbidity standards) may also be a viable option.

Based on the comments received, we revised the discussion of the Correlative Analyses (Section 4.3.2.3) to note that careful reevaluation of the numeric targets for turbidity endpoints, including more robust multivariate analysis of turbidity and TSS correlations, will be conducted during the next phase of TMDL development, with subsequent changes to the loading analysis as necessary in future revisions of the TMDL decision.

Element 4 - Source Analysis and Estimation

- We believe that more information is needed to identify the sources of much of the pollution discussed in the TMDL report ...(HWH)
- … the baseline for measurements was possibly taken during the wrong year. 2006 was a year of extreme rainfall for the entire Kauai island … (CYVSC)
- the levels of pollution from the 90% land cover area MUST have always been a fixed variable fluctuating only by an increase in feral pig population and increase in wildlife due to installation of wildlife sanctuaries. (CYVSC)
- it would not be possible to measure an adverse impact of the bison ranch on the nearby river based on either nitrogen or enteric bacteria. Furthermore, I know of no other constituent of the bison ranch effluent that could be detected in the river in concentrations that would be considered deleterious to its overall quality. (BM)
- the effective nitrogen application from 200 bison would be … 146 pounds of nitrogen per acre per year. (BM)
- It is obvious there is a need to control sewage in this environment. (TY)

Response: Obtaining more information to identify sources of pollution is a key objective of the phased TMDL approach and the upcoming watershed based plan. The baseline for measurements was take during the years in which funding was available to support monitoring activities. If these happened to be years of extreme rainfall then the information could represent scenarios of both heavier wet weather loading (under stormflow conditions) and lower dry weather concentrations (greater dilution by higher baseflow). Loading from the 90% land cover area is affected by many factors (including but not limited to wildlife), and is being analyzed

through joint U.S. Department of Agriculture, U.S. Geological Survey, and University of Hawaii measurement and modelling of the upper watershed.

As discussed in public meetings, clarification of which farms may be more or less responsible for increasing the conveyance of high TSS discharge to the stream and estuaries, and how, is a potential activity for phased development and adaptive implementation of the TMDLs. Although bison ranch impacts could also be addressed in this effort, we understand that most, if not the entire herd has been removed. Nonetheless, we would appreciate receiving any additional information you may have acquired from Dr. Miner (now deceased).

With regard to the need to control sewage, DOH added the following language to the TMDL executive summary:

> In general DOH 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 DOH on-site disposal system strategy and water quality monitoring strategies, any implementation activities conducted should first focus on inventory and inspection of sanitary sewer collection systems and individual wastewater systems; repairing and upgrading failing and sub-standard systems (as indicated by inspection results); and completing watershed sanitary surveys and wastewater source tracking to complement information obtained from system inventory/inspection and ambient receiving water monitoring.

Element 5 - Partition the Loads Among the Contributing Sources (Allocations)

- These systems [unique taro culture along with the unique near shore ecosystem] require the nutrient and TSS loading to remain as they are. (TY)

<u>Response:</u> We agree that nutrient and TSS loading into taro pondfield and near shore ecosystems are important components of ecosystem function, but we have limited information available about how the inputs to and outputs from these systems combine to affect their overall environmental health status. In the first phase of TMDL development, our objective in this regard to estimate the maximum loading from nonpoint sources (including taro pondfields) that allows attainment of the nutrient, TSS, and bacterial indicator criteria in receiving streams and estuaries (inland waters). In subsequent phases of TMDL development (already underway), our goals are to estimate the maximum loading from inland waters and coastal nonpoint sources to near shore ecosystems that allows attainment of the turbidity and bacterial indicator criteria in receiving embayment waters, and to refine the first phase results based on new data and implementation experience. We suggest that any scientific information you have about relationships between nutrient and TSS input and output and taro pondfield and nearshore ecosystem health be shared with the Hanalei community and DOH for consideration in the next phases of TMDL development.

Element 6 - Linkage Analysis and TMDL Calculation (Loading Capacity)

- HFBF can hardly believe the seriousness of the tables regarding load allocations and load reductions required to achieve TMDLs. (HFBF)
- Such reductions do not seem reasonable given that there are clearly inputs from natural sources within the watershed that cannot be reduced. (A&B)

Response: The basis for the load allocations and load reductions required are the stream and estuary water quality objectives (standards) and the pollutant concentrations measured throughout the watershed. The TMDL calculations are based on well-understood physical, chemical, and biological principles. Various monitoring efforts will be required and recommended as components of ongoing, phased adaptive implementation of the TMDLs. As new data become available, both the implementation measures and the TMDLs themselves can be adapted and revised as necessary. The definition of and approach to "natural sources" can also be addressed in future phases of TMDL development. However, depending upon this definition and approach, loading from "natural sources" is not necessarily irreducible, and is still required to result in full achievement of the water quality standards.

Element 7 - Margin of Safety Analysis
No comments received.

Element 8 - Account for Seasonal Variations and Critical Conditions
No comments received.

Element 9 - Conduct a Public Participation Process

- We would also like to have a clear and simple explanation of the report, charts and results. (KTGA)
- Taro farmers were not given answers to their questions at the one public information session held at the end of February and asked for a session specific to them. The March 9 meeting resulted in more questions from farmers but still no answers. (HFBF)
- Request for a time extension to review the draft report (KTGA, CF).
- Farmers were not solicited to be active participants in this process and were led to believe that the focus of this project was reduction in bacteria, which would not affect their operations. The public/stakeholder outreach appears to be merely a formality that has not accomplished the intent of an "information/education component, which the state will use to enhance public understanding of the project and encourage public involvement." Had farmers been made aware of the potentially devastating impact on them, they would have been more involved in the process. It is impossible at this point to read, comprehend, and comment on a document of this magnitude and complexity, much less garner the resources to do the rigorous scientific analysis necessary to justify the draconian measures called for in the document. (HFBF)
- We encourage the DOH to expand your public outreach efforts to foster further understanding of the proposed TMDLs and their implications (COK-DPW)

Response: Expanded discussion and documentation of the public participation process is provided (now Section 9) in the revised TMDL decision document. TMDL development began largely due to the efforts of the Hanalei Watershed Hui (HWH), and DOH relied on HWH to lead the public participation process. In order for all us to achieve water quality success in future phases of TMDL development and implementation, improved communication among all parties will be needed.

The public comment period for this TMDL was the same as that regularly provided for all proposed DOH TMDL decisions, with DOH meeting all federal requirements and fulfilling all EPA Region 9 review criteria for TMDL public participation. Although DOH did not extend the time available for reviewing the draft report, our decision to establish these TMDLs as "phased TMDLs" in the EPA submittal means that DOH is committed to ongoing involvement with the Hanalei community to explain and review the focus and results of plans for implementing the State's water quality standards.

Element 10 – Technical Analysis

- … there should be consistency in data evaluation, quality assurance and quality control, and decision making between the two processes, and [we] request that the Department provide clarification regarding the apparently differing conclusions being drawn in the two documents…. there is a significant problem with the draft TMDL if data sets that were determined to be unacceptable for the 303(d) list have been used for the purposes of developing the TMDLs, and particularly in calibration of the models. (A&B)
- We would like further explanation on how, when, and over what duration results were attained …? (KTGA)
- … taro growers are being targeted for massive and unrealistic reductions, … based on speculation, inadequate data, and tenuous application of that data (HARC)
- … we call into question the validity of the data and the huge assumptions and load reductions required to achieve the TMDLs. If data is to be used for regulatory/enforcement purposes, that data must be scientifically sound and relevant to the purpose for which it is used. (HFBF)
- ... the TMDL should be subject to the utmost scientific scrutiny to ensure that identified water quality problems are real, and that the need for and extent of corrective actions is well supported. (A&B)
- Given the technical complexity of the document …TMDLs in general should be subject to third party peer review, as would any scientific study prior to publication. (HARC)

Response: We agree that there are discrepancies between the results of impairment assessments appearing in the draft TMDLs and impairment decisions appearing in the draft 2006 §303(d) lists. This is not uncommon, and conforms with EPA regulations and policy, as mentioned in the response in **Element 1, *Impairment Overview***. Also, as explained below, it can be expected that impairment assessments may change in the process of finalizing draft TMDLs, and impairment decisions may change in the process of finalizing draft §303(d) lists. Although the Hanalei TMDL document submitted for EPA approval may reflect different assessment conclusions than those appearing in the EPA-approved 2006 §303(d) list, the proposed TMDL decision is based on the latter, and any differences between the two will be

further explained and resolved during subsequent phases of TMDL development and in future §303(d) decisions.

One source of discrepancy is the disparate timelines of water quality monitoring and assessment cycles, §303(d) list drafting and approvals, and TMDL development, as discussed in our response above (under **Element 1, *Impairment Overview***). For example, the final 2006 §303(d) list, approved by EPA, incorporated data that were not used for the draft 2006 §303(d) decisions. As our response to comments on the Hanalei decisions in the final 2006 §303(d) list notes, "After discussion, both the microbiological and Hach turbidity data have been included in the assessment. The tables now reflect the additional data."

Another source of discrepancy, as suggested by the comments, is using data for TMDL development that has not yet been accepted (but has not been terminally rejected) for the §303(d) list. In the response to comments on the 2006 §303(d) list, DOH stated "… the Hydrolab and nutrient data [submitted by the Hanalei Watershed Hui, or HWH] will not be completely tossed out; only not used for this reporting cycle… These data would be reevaluated for the next cycle, and there is a possibility that it may be used for the next report." HWH Hydrolab data are not used in the TMDL analysis, and EPO examination of the HWH nutrient data led us to conclude that it is of known and acceptable quality for TMDL development purposes. This examination included discussions about the nutrient data with the HWH (source of data) and DOH Clean Water Branch (author of DOH response quoted above), neither of which indicated any specific problem with the manner in which the nutrient samples were collected, handled, or analyzed. If problems are discovered in the re-evaluation for the next §303(d) listing cycle, the utility of the data for TMDL development will be further addressed in subsequent TMDL development phases.

To reach the current TMDL decision, EPA and DOH employed some of the nation's leading TMDL practitioners to incorporate an extensive set of valid hydrologic and water quality data [obtained through cooperative field efforts with the U.S. Geological Survey (USGS) Pacific Islands Water Science Center, the U.S. Fish and Wildlife Service, and the Hanalei Watershed Hui] into the loading analysis. In response to comments, we revised Section 4 (Data Inventory and Analysis) to clarify the explanation of our data collection efforts.

This analysis used scientifically-sound and problem-relevant modeling procedures to estimate the maximum loadings of pollutants that would still accommodate the attainment of water quality criteria. However, due to the difficulty of drawing precise links between nonpoint sources (including natural background, endangered waterbirds, wildlife, livestock, and wetland farming) and waterbody impairment in the Hanalei Bay Watershed, we propose employing a phased approach to the development and implementation of these TMDL load allocations. 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.

Not all scientific studies are subjected to third party peer review prior to publication, but studies published in peer-reviewed publications are commonly accorded higher status within the

scientific community and the world at large, as further conditioned by the relative prestige of the sponsoring publication and its editors and reviewers. We believe that the level of review currently provided by the TMDL process is adequate, and encourages rather than excludes third-party experts from providing their input. Also, our ability to subject TMDLs to the "utmost scientific scrutiny" must be balanced against the resources currently available to conduct the TMDL process and fulfill our obligations to EPA and to the public in a timely manner.

Element 11 - Monitoring and Review Plan for Phased TMDLs
No comments received.

Element 12 – Reasonable Assurances
Not applicable.

Element 13 - Implementation

Numerous comments expressed concerns about the feasibility of TMDL implementation given the seemingly extreme load reductions required and the accompanying threat of potentially damaging implementation mandates, costs, and societal impacts. Although we are not responding in detail to all of these concerns (most of which are itemized below) at this time, we are committed to continue addressing them in the context of ongoing phased TMDL development, watershed based planning, and other DOH water pollution control and water quality management program activities in Hanalei. DOH would like to reiterate that our TMDL implementation framework and the upcoming Watershed Based Plan are intended 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. Although we believe it is our duty to fully identify potential implementation mandates (including those largely beyond DOH control, such as legislation, approval and permitting conditions by other agencies, lease conditions, and third-party lawsuits), DOH is not recommending any particular mandates in Hanalei at this time. Instead, we advocate a community-driven adaptive approach to implementing nonpoint source load allocations based on TMDL decisions, other watershed planning results, and local knowledge and experience.

This TMDL decision is a starting point for nonpoint source implementation activities that can be adapted as new information becomes available, and that are intended to include ongoing review and future revision of the TMDL decision. The responses below are intended to highlight some of the more important or potentially fruitful areas for this effort.

Comments on Wildland sources

- … a more concerned effort should be placed on reducing pollution from the 90% culprit [shrub/scrub land] and later address the final 10% which is urban and cultivated lands. (CYVSC)
- There is also interest in organizing local hunters to address the overpopulation of feral pigs. (HWH)

Comments on Wastewater disposal

- Investigate the possibility of having a sewage treatment facility for the North Shore. (CYVSC)
- Ensure all businesses and residences are using proper sewage disposal, either treatment plants, cesspools or septic tanks. This requires proper enforcement and follow-up. (CYVSC)

Comments on Agricultural sources

- There is consensus in the community that agricultural best management practices could likely produce improved water quality. (HWH)
- … funding for projects beneficial to the farmer or that may be required by the ramifications of this document are certainly not guaranteed. (HFBF)
- The amount of reductions for nutrients that is recommended seems extremely high and judging from the farmers that walked out of the meeting, the information was not sufficient. (KTGA)
- … we would like to ensure that HIDOH is willing to address the farmer's concerns about the load reductions that are called for in the TMDLs. (EKSWCD)
- … taro growers are being targeted for massive and unrealistic reductions … (HARC)
- The percentage reductions … required are clearly not feasible. (HFBF)
- Concern that the few activities that can be regulated in some fashion, such as agricultural practices, may be saddled with an economically unacceptable burden in an effort to make a minor incremental improvement in water quality. (COK-DPW)
- A&B has serious concerns regarding the potentially devastating impact of the draft TMDL on agriculture within the watershed. (A&B)
- …if the proposed TMDLs and Load Targets are implemented it will force taro farmers to go out of business … (HFBF)
- this may be the "straw that breaks the camel's back" and many farmers will leave taro farming for other opportunities. (KTGA)
- … this proposed TMDL is one additional burden that farmers will not be able to overcome. (HFBF)
- an "economic study" should also be done before proceeding further with this TMDL. With many farmers already applying best management practices through the NRCS and other soil agencies any further restrictions would seriously hamper taro farmers from farming. (CF)
- … what impact can we expect TMDL implementation to have on taro farming? (KTGA)
- The report seems to encourage landowners to impose restrictions on farmers in their agricultural leases. (KTGA)
- Farmers have been told not to worry, that any activities stemming from this project would be voluntary in nature. Considering the statements on page 64 and 65 regarding implementation of TMDLs through lease conditions, among other tactics, farmers have been misled about DOH's intentions. (HFBF)

General Comments on TMDL Implementation

- Bringing the Hanalei Bay into compliance will destroy the unique taro culture along with the unique near shore ecosystem. (TY)
- I find it impossible to believe that that any reasonable person would believe that voluntary implementation of best management practices would bring these two constituents [turbidity and nutrients] into compliance. The soil and water conservation district has been active for the last fifty years and yet the amounts to be reduced are beyond anything attainable by normal means. (TY)
- … it would be premature, inappropriate, and pointless to spend any money or effort on implementation plans that would not have reasonably-predictable *significant and beneficial* impacts on total pollutant loads – particularly f it appears that such implementation plans might be costly or might impose substantial impacts on local agriculture … or on local residents. Instead, the next logical steps are to: (i) define meaningful objectives that are supported by science and the community, and (ii) to obtain the key missing information that is needed on order to produce a worthwhile implementation plan. (CFI)
- we also believe that specific community directed projects could be undertaken to address specific impacts to our water quality. (HWH)
- The focus of both of these measures [agricultural best management practices and addressing the overpopulation of feral pigs) needs to be "locally directed and implemented." (HWH)
- The Hanalei Watershed Hui suggests that the next step is to convene a meeting in Hanalei to discuss the development of a Hanalei Community Water Quality Plan. This meeting would produce a process for such a plan to be written. Any plan for Hanalei must include the culture, traditions and history of this place. (HWH)
- By implementing BMPs on the NWR, the Service anticipates making a substantial contribution to improve water quality to help achieve the goals of the TMDL. Furthermore, the Service hopes to take an active role in facilitating work on the watershed action plan being prepared to implement the objectives of the TMDL. (KNWRC)

<u>Response:</u> DOH expects that specific implementation suggestions (e.g. *Comments on Wildland sources* and *Comments on Wastewater disposal* above) will be considered in the upcoming development of a locally directed watershed based plan, and that this plan will also help identify and assess the extent and impact of historic and ongoing conservation efforts; obtain additional scientific information to gain a better understanding of pollutant sources and their relative contributions to total pollutant loads; and use this information to select for future action specific implementation measures that are economically feasible and socially acceptable. Specifically, we 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.

Based on comments received, we revised the Implementation Framework (now Section 8.0 in the TMDL document) to further emphasize that DOH is neither encouraging nor discouraging landowners from imposing restrictions on farmers in their agricultural leases. A multitude of public and private landowners and their tenants; other public and private watershed users; and

various local, state, and federal regulatory authorities are all responsible for achieving the State's water quality goals. The purpose of our Implementation Framework is to identify all the responsible parties, their relationships with each other, and the possible ways they could affect and effect TMDL implementation. It is not to pass judgment on how they should or should not conduct these relationships, which is more appropriately the role and responsibility of community-driven TMDL implementation planning. However, please note that we also retained our suggestion from the draft TMDL that "factors for prioritizing implementation activities throughout the watershed should also emphasize habitat quality, biotic integrity, and related existing uses [such as support for traditional and customary native Hawaiian beliefs, values, and practices and for other 'reasonable and beneficial uses' and in-stream uses protected under the State Water Code (Hawai'i Revised Statutes Chapter 174C; State of Hawai'i, 2004).]"

Finally, providing more information and explanation concerning the scientific basis of the load reductions, and other aspects of the TMDL process, is an important objective of the upcoming TMDL development phases. We realize the need for more frequent and direct communication with the entire community, and ask you to let us know whenever there is a need or opportunity to do so. For our part, we will spend more time and effort reaching out to the Hanalei community, in accordance with the selection of Hanalei by DOH and EPA as one of three areas in the state where water quality improvements may be possible and multiple clean water program tools may be applied to help make these improvements.

Additional Concerns

- These overstated, and clearly unachievable, load reductions have resulted from a combination of an inappropriate approach to development of the TMDLs, unreliable data, and flawed water quality standards for turbidity that are overdue for a careful review and revision. We urge the Department to carefully scrutinize each of these issues and to re-evaluate whether the approach to TMDL development is appropriate in light of what appear to be obvious problems with the results. (A&B)

<u>Response:</u> To reach the current TMDL decision, EPA and DOH employed some of the nation's leading TMDL practitioners to incorporate an extensive set of reliable hydrologic and water quality data into the loading analysis. This analysis used well-established, conceptually-sound, and thoroughly-documented modeling procedures to estimate the maximum loadings of pollutants that would still accommodate the attainment of water quality criteria. However, due to the difficulty of drawing precise links between nonpoint sources (including natural background, endangered waterbirds, wildlife, livestock, and wetland farming) and waterbody impairment in the Hanalei Bay Watershed, we propose employing a phased approach to the development and implementation of these TMDL load allocations. 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. While resolving questions about standards is not the role of TMDL decisions, our phased approach should also give us information about feasibility of implementation that will help us to move beyond persistent challenges to turbidity and enterococcus standards.

Comments on Programmatic Elements

- It is unclear exactly how this document will be used and what its ramifications will be … (HARC)
- The idea that this TMDL will be used as a template for future TMDLs around the State is just plain frightening. (HFBF)
- …the methodology used in developing the Hanalei TMDL will prove to be a fatally flawed template for the ongoing and future development of TMDLs required for other water bodies …(A&B)
- It is important that such projects [the development of a sewer system for the Hanalei community] be evaluated based on consideration of costs and benefits for the community and for the environment, and that the TMDLs should not be used to either mandate or undermine the assessment of water quality projects or public policies regarding land use decisions. (COK-DPW)
- … it is undeniable that implementation of the TMDLs can and will have far reaching regulatory impacts. (A&B)
- I'm recommending that the state planning process be utilized. And that a local watershed plan be developed and implemented instead of implementation of this TMDL. (TY)
- When we attended the first information meeting with Carl Berg years ago, he explained that the testing he was going to do was to only test for bacteria and would focus on the cesspools and animal waste. He also stated that it would not be affecting the taro farmers in any way. However, we briefly scanned the report and found that it is focusing also on sedimentation, turbidity, and nutrients from agriculture and water bird impoundments. (KTGA)
- … the State DOH is moving to adopt a proposal that is causing taro farmers to throw up their arms in dismay and talk about shutting down because they will not be able to meet the load reductions that are required. HFBF urges you to reconsider this proposed TMDL and work with taro the taro farmers towards a cooperative solution to any problems DOH perceives. (HFBF)

<u>Response:</u> This TMDL decision document will be used as a starting point for nonpoint source implementation activities that can be adapted as new information becomes available, and that are intended to include ongoing review and future revision of the TMDL decision. The idea that this TMDL will be used as a template for future TMDLs around the State is not introduced in the TMDL documents or in any other program materials. However, future TMDLs will continue to use the best available information, applicable water quality standards, conceptually-sound methodologies, and reasonable approaches to ensure that the TMDLs meet all the requirements of the Clean Water Act and EPA's regulations and follow EPA guidance concerning TMDL content, and are protective of the beneficial uses of the waterbodies in the watershed.

At this stage in the TMDL implementation process, DOH's role is mainly to identify a wide range of implementation alternatives, not necessarily to select them.

As implementation proceeds, we recognize that county governments have a special role in setting public policy for land uses. We note that water quality standards also embody an important public policy, to protect the designated uses of state waters, and standards-based TMDLs are a

required vehicle for implementing this statewide policy. Given that both state and county governments have public trust duties to protect state waters, TMDLs should be an important tool and consideration in water quality project assessment and land use decisionmaking. We look forward to future discussions that include the county, and to county land use decisions and other decisions that protect state waters.

The extent to which TMDL implementation actually has regulatory impacts varies markedly between point sources and polluted runoff (non-point sources), and depends heavily on parties beyond DOH control. We advocate 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.

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The TMDL program is a technically-based state planning process for implementing the State Water Quality Standards, one that frequently overlaps with and is hard to distinguish from other water-quality related programs and projects, such as the EPA Targeted Watershed Initiative Grant and other Hanalei Watershed Hui projects explained years ago by Carl Berg. Despite our efforts to clarify these distinctions, it appears that more frequent and direct communication between DOH and the entire community is needed. We regret any misrepresentation of the TMDL process that occurred and encourage citizens to take an active role in creating new opportunities that help the state to enhance public understanding, generate public involvement, and work towards cooperative solutions to water quality problems.

We understand that the high percentage reductions proposed in the TMDL have alarmed readers, particularly farmers. We invite taro farmers to lower their arms from dismay and help us find ways to use the TMDL process to achieve environmental results in a reasonable manner. Towards that end, we believe that our decision to employ a phased approach to Hanalei TMDL development and implementation, including the development of a local watershed based plan, is the best way to respond to your immediate concerns.

Comments on Water Quality Standards

- These turbidity standards were set arbitrarily without consideration of the background levels typical of streams and other waterways. (A&B)
- We therefore reiterate our previous recommendation that the Department of Health review its turbidity standard and consider whether a revision to reflect natural background turbidity levels in healthy aquatic ecosystems is appropriate. (HARC)
- The water quality standards for turbidity and nutrients needs to be revisited based on the numbers provided for this watershed. (TY)
- The TMDLs therefore provide a valuable indication that the current turbidity standards may not be appropriate measures of water quality, and the development of turbidity standards that are more consistent with the TSS standards may be appropriate. The fact that according to the draft TMDLs and load allocations, the present turbidity standards cannot possibly be attained without almost entirely removing all inputs of suspended solids speaks strongly to the fact that a review of the State's water quality standards for turbidity is long overdue. (A&B)

- To support consideration of whether the present turbidity standards are appropriate for evaluating water quality in Hawaii, we have enclosed and incorporated by reference our previous comments submitted in response to the draft 303(d) lists prepared in 2004 and in 2006. (A&B)
- … I have been unable to determine when and if an appropriate process was used to change these existing uses. A State planning process along with public notification should have been done. Class 1 [fresh water] uses were eliminated (drinking water) and many other uses added to Class 2. (TY)
- In the area of marine waters a whole subset to Class AA waters has been added. In fact the EPO recommendation is to add one Class A area that is sandwiched between two Class AA. (TY)
- The endemic nature of these indicator bacteria needs to be separate from the pathogen agents. If the correlation between indicators and pathogens are not on target then we need different methods. (TY)
- The waters of Hanalei should have had a use attainability Analysis to determine of the uses are attainable. (TY)
- It would be better to do a use attainability analysis and seek to have the optimum water quality standard that allows for farming, wildlife and human economics and tradition in balance. (CF)

Response:

Turbidity and Nutrient Criteria

The Department of Health water quality standards for turbidity and nutrients are ecosystem-based, consider and reflect natural background levels in healthy aquatic ecosystems, and are constructed using statistical distribution functions that can be related to flow frequency. The turbidity standards were not set arbitrarily, and according to the 1977 Technical Committee Report "The proposed standards for inland water are based on analysis of existing data. Numerical values are developed mainly for streams where the information base is considered to be the strongest." Complete responses to HARC's account of the history of the turbidity standard (paragraph 1, page 2 of HARC comment letter), TY's account of and questions about the history of waterbody classes and uses (page 2 of TY comment letter), and A&B's enclosure and incorporation by reference of their previous comments submitted in response to the draft 303(d) lists prepared in 2004 and 2006 are beyond the scope of this response to TMDL concerns, although previous DOH responses to A&B comments on the draft 303(d) lists remain instructive. However, in order to prepare more comprehensive responses about the history of these standards, DOH requests that HARC provide references to the documents quoted in its account. It appears that TY quotes from the 1974 version of the "Early water Quality Standards Chapter 37-A," which was amended in 1979. Since these contemporary standards (Chapter 37-A of the State Public Health Regulations effective 1979) were written (based on the recommendations of the 1977 Technical Committee, see DOH Response above under **Element 1 - Problem Statement, *Impairment Overview***), they were re-promulgated once (in 1982 as HAR-11-54) and subsequently amended six times, culminating in the current 2004 version (which is the only version legally applicable for DOH regulatory purposes, including TMDL development).

DOH is currently revising the specific water quality criteria for marine recreational waters and was recently petitioned by the City and County of Honolulu to update chlordane and dieldrin water quality standards for fish consumption. We agree that the turbidity and nutrient numbers provided for the Hanalei watershed by the TMDL process are now part of larger datasets that could be used to revisit the water quality standards. However, DOH cannot determine when any formal review of the turbidity and nutrient standards might be conducted and when the appropriateness of revisions to these standards might be considered until:

- the current, public health-related criteria revisions and standards petition are resolved,
- the long-vacant water quality standards specialist position in EPO is staffed, and
- long-term priorities and strategies for the water quality standards are re-evaluated.

Waterbody Uses and Classes

The only process for changing the definition or protection "existing uses" is amending the Clean Water Act and associated federal regulations, which are independent of and superior to a State planning process, and which follow federal procedural requirements. The Clean Water Act sets November 28, 1975 as the date for determining existing uses.

At the State level, we believe that all state procedural requirements have been met. Changes to the water quality standards are governed by Hawaii Revised Statutes (HRS) Chapter 91, Administrative Procedure, and Hawaii Administrative Rules (HAR) Chapter 11-1, Department of Health Rules of Practice and Procedure. We are not aware and have no evidence of any non-compliance with these laws and regulations in any past amendment of the State Water Quality Standards. Class 1 waters and their uses, as they appear in the 1974 standards quoted by TY, were sub-divided into Class 1.a and Class 1.b waters and uses by the subsequent 1979 amendment, with no further changes to date. Although the uses to be protected in Class 1.a waters do not explicitly include drinking water supply, this use of Class 1.a. waters is protected when it qualifies as an "other nondegrading use which is compatible with the protection of ecosystems associated with this class" [HAR 11-54-3(b)(1)(A)]. The uses to be protected in Class 1.b. waters include "domestic water supplies" [HAR 11-54-3(b)(1)(B)].

Although amending the water quality standards is the only process that can be used to change the overall structure and mechanics of waterbody class designations (as in the subdivision example above), it is just one of many processes that can be used to change the specific class designation of a particular area, and most of these processes are beyond DOH authority and control. For example, whereas Class 1 waters in 1974 were restricted to "all sources of fresh surface waters … used for domestic, culinary, or food processing purposes," in 1979 the designation of Class 1.a. and Class 1.b. waters become controlled by the underlying land use districting and protected status assigned by other State and Federal authorities and processes.

As quoted by TY, the near shore waters of Hanalei Bay were designated Class AA waters in the 1974 version of the Water Quality Standards (Public Health Regulations Chapter 37-A), and this designation has not changed in the last 34 years. Thus in the Hanalei TMDL and other TMDL decision documents, EPO identifies the Classes associated with different areas as defined since 1974, modified in 1979 by the State Water Quality Standards, and subsequently controlled by

non-DOH agency decisions (particularly of the U.S. Department of the Interior, U.S. Department of Commerce, and State Board of Land and Natural Resources).

DOH did not recommend adding "one class A area that is sandwiched between two Class AA areas" in Hanalei. We added Figure 19 to the Implementation Framework (Section 8.0 in the new document) to help clarify the discussion of relationships between waterbody Class and implementation responsibilities and alternatives. With regard to TY's suggestion that perhaps "the lower watershed should revert to Class A in the marine environment and streams should be Class 2":

- there never was Class A in the marine environment to revert to,
- depending on existing uses between 1974 and 1979, there may or may not be Class 2 streams to revert to, and
- proper notification and public participation process was provided to the public in accordance with the laws governing the amendment of the 1974 standards in 1979.

Pathogens

We agree that separating the endemic nature of the enterococcus indicator bacterium from pathogen agents and using different methods to better quantify the presence of human pathogenic organisms in surface waters could improve our ability to assess public health risks. However, irrespective of ongoing efforts by EPA, DOH, the University of Hawaii, and the global scientific community to help make these kinds of improvements, enterococcus units are the current water quality criteria upon which our regulatory decisions must be based. Nonetheless, in recognition of the difficulty in using these criteria, DOH added the following language to the TMDL document (e.g. Executive Summary):

> In general DOH 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 DOH on-site disposal system strategy and water quality monitoring strategies, any implementation activities conducted should first focus on inventory and inspection of sanitary sewer collection systems and individual wastewater systems; repairing and upgrading failing and sub-standard systems (as indicated by inspection results); and completing watershed sanitary surveys and wastewater source tracking to complement information obtained from system inventory/inspection and ambient receiving water monitoring.

Use Attainability Analysis

Use Attainability Analysis (UAA) is not a required component of the TMDL process and is only required under the Clean Water Act when States wish to remove or revise specific designated uses for state waters that were previously established in the State Water Quality Standards. DOH is obligated to submit Hanalei TMDLs for EPA approval but has no current obligation to submit

any UAAs for EPA approval, and we are unclear about which designated uses, if any, are proposed for removal or revision in the public comments received. The results of any UAA approved by EPA would still have to be processed through an amendment to the State Water Quality Standards in order for any associated changes in designated uses to take effect.

The practical benefits of a UAA are uncertain. Even if DOH successfully removed or revised designated uses in particular waters based on the results of an approved UAA, those waters would still be considered state waters and would still be regulated by the pertinent water quality criteria, anti-degradation policy, and water quality certification requirements established by the State Water Quality Standards (HAR §11-54) and by NPDES permit requirements (HAR §11-55). Moreover, the pollutant loads that they carry to receiving waters would still be subject to TMDL load allocations [Clean Water Act §303(d)]. Although the UAA process could eventually lead to the development of site-specific water quality criteria for Hanalei – an approach that might represent a preferred pathway to more optimal balance between farming, wildlife, and human economics and traditions - DOH believes that phased TMDL development with adaptive TMDL implementation provides a more immediate and efficient framework for working together to achieve community socioeconomic goals while reducing pollutant loads, improving water quality, and protecting and restoring aquatic ecosystem integrity. Based on the following assumptions and factors:

- Developing approvable UAAs is generally more difficult than developing approvable TMDLs, given EPA's history;
- DOH capacity for completing complex amendments to the water quality standards is more limited than its capacity for completing TMDLs;
- It is uncertain whether actual TMDL implementation will cause significant socioeconomic harm, and whether that potential harm can be softened or avoided by removing or revising designated uses in the water quality standards through a UAA; and
- There is considerable uncertainty surrounding the relative significance of ecosystem, water pollution, or water quality benefits that would result from a UAA process versus a TMDL process;

we prefer to pursue TMDL development and implementation rather than conducting a UAA for Hanalei.