Total Maximum Daily Loads (TMDLs) for Total Suspended Solids, Nitrogen and Phosphorus in Kaneohe Stream Kaneohe, Hawaii

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Executive Summary – State of Hawaii Department of Health
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The State of Hawaii Department of Health (DOH) proposes establishing Total Maximum Daily Loads (TMDLs) for Kaneohe Stream in the Kaneohe Bay watershed on the island of Oahu, Hawaii. TMDLs are required for pollutant –impaired waterbodies on the State's Clean Water Act (CWA) Section 303(d) list. The main objectives of the proposed TMDLs are to stimulate and guide action that will control sources of excessive nutrients and sediment, and to improve stream water quality so that the designated and existing uses of the stream network and its receiving waters will be protected and sustained. These uses include protection of native breeding stock, the support and propagation of aquatic life, recreation, aesthetic enjoyment, agricultural and industrial water supplies, and support fro traditional and customary native Hawaiian beliefs, values, and practices.

The Kaneohe Stream watershed (see Figure 1-1), located on the windward side of the island, covers about 3,655 acres (5.7 square miles) and flows into the southern portion of Kaneohe Bay. Early Hawaiians developed extensive irrigated pondfield and fishpond complexes along the streams and shoreline, remnants of which persist today. Two golf courses, a banana plantation, a botanical garden, and forest reserve lands occupy the upper watershed, bisected by three major highways and drained into a flood control reservoir. While much of the arable watershed land was devoted to agriculture through the early twentieth century, the lower portions of the southern Kaneohe Bay watershed have become one of the more heavily urbanized areas in the Koolaupoko region. Waikalualoko, situated between the mouths of Kaneohe and Kawa streams, is the only fishpond remaining, and no longer receives the freshwater input formerly delivered from these two streams and the irrigated pondfields long removed from the intervening delta. Among the few upland pondfields remaining is a spring-fed complex on the grounds of the Hawaii State Hospital (a DOH facility). Biological assessment of three locations within the stream network revealed "not supporting" to "partially supporting" habitat quality and "impaired" to "moderately impaired" biotic integrity when compared with high-quality reference stream conditions keyed to the presence of native fish, mollusks, and crustaceans (Burr 2003).

This TMDL decision rationale reviews existing conditions in the watershed and presents an analysis of pollutant load distributions and resulting water quality in Kaneohe and tributary streams. We provide calculations of waterbody pollutant loading capacities, and of their allocations to identified pollutant sources such that water quality standards for total suspended solids (TSS), total nitrogen (TN), nitrate + nitrite nitrogen (N+N), total phosphorus (TP), and turbidity in Kaneohe Stream, including the Kamooalii tributary, will be achieved as required. This analysis is based on the 2003 "Kaneohe Stream Total Maximum Daily Load Final Report" prepared by Oceanit Laboratories, Inc. and AECOS, Inc. for the State of DOH Environmental Planning Office (EPO), and additional information compiled and synthesized by EPO.

In southern Kaneohe Bay (the Class AA marine receiving water for Kaneohe Stream), nearshore waters at the mouths of Kaneohe and Kawa streams are currently listed under Sections 303(d) as water bodies in which water quality is impaired by excessive nutrients, turbidity, and suspended solids. Three water quality monitoring stations in the southern bay are also included on the list of impaired waters: Kaneohe Bay Southern Region, Beach Park, and Kokokahi Pier are listed for excessive nitrogen and turbidity; Beach Park and Kokokahi Pier are listed for excessive chlorophyll a; and Southern Region and Kokokahi Pier are listed for excessive *enterococcus* (bacterial indicator). Water quality in Kaneohe Stream, including its Kamooalii tributary, is impaired by elevated nutrients, turbidity, and dieldrin based on previous visual and numeric assessment by the DOH (Environmental Health Administration 2008, see excerpts from 2006 list in Appendix B).

The proposed TMDL decision (3 TMDLs) addresses a total of 8 listed waterbody/pollutant combinations – 4 in Kaneohe Stream and 4 four in the Kamooalii tributary. This is explained by our expectations that (1) implementing TMDLs calculated for TSS and nutrients will lead to the attainment of the turbidity criteria (TSS and nutrient concentrations as surrogate numeric targets for turbidity); (2) implementing TMDLs for total nitrogen and total phosphorous, and to a lesser extent TSS, sufficiently addresses the listed nutrient impairment (that was based solely on visual assessment results) and will lead to the attainment of the nitrate + nitrite nitrogen criteria; and (3) implementing TMDLs throughout the upper watershed (upstream from the Kamooalii tributary) and in the Kamooalii sub-basin (sub-basin 3) will lead to the attainment of water quality criteria within the Kamooalii tributary. Although TMDLs are not calculated or established for dieldrin, implementation of TSS TMDLs and other erosion and sediment management measures are expected to help reduce loading from legacy soil sources.

Baseline flow volumes and pollutant load contributions were calculated for individual land use areas during dry season (May-October) and wet season (November-April) conditions. Baseline flow volumes and total pollutant load contributions are roughly proportional to land use areas. However, sedimentation and nutrient uptake in the Waimaluhia Reservoir significantly affect downstream water quality, reducing loadings from the upper watershed area under baseline flow conditions by more than 90%. Baseline flow concentrations of total nitrogen exceed the TMDL water quality target upstream from the reservoir and in the Luluku Stream tributary during dry and wet seasons. Baseline flow concentrations of total suspended solids, total nitrogen, and total phosphorus are below targets for baseline flow conditions at all locations downstream from the Waimaluhia Reservoir.

Storm runoff, pollutant loads, stream flows, and concentrations of total suspended solids, nitrogen, and phosphorus were calculated for four 24-hour rainfall events: 0.35-inch (dry season 10% event), 1.27-inch (dry season 2% event), 0.70-inch (wet season 10% event), and 2.30-inch (wet season 2% event). From the 0.35-inch rainfall, very slight runoff (0.08 million cubic feet) occurs only from the 5% of the watershed that is highway, street or open water area. The TMDL water quality target for total phosphorus is exceeded in the urban tributary Kapunahala Stream but no other target is exceeded at any other location. As rainfall increases to the 2.30-inch event, runoff increases to 3.8 mcf. Pollutant loadings from the upper watershed area are reduced in the Waimaluhia Reservoir by 65% (TN) to about 85% (TSS, TP). Water quality targets for total nitrogen and total phosphorus are nevertheless exceeded in all stream segments.

Load capacities for TSS, TN, and TP were calculated as the maximum amount of pollutant loads that will be allowable without violating the water quality targets in each of the five Kaneohe stream segments. Allocations to individual land use areas were calculated as the lesser of the proportion of existing load to stream segment load capacity or the existing load from the area. This allocation procedure both recognizes the antidegradation policy in the water quality standards and provides a substantial margin of safety for achieving the numeric TMDL water quality targets. The summations of these thus calculated allocations for each pollutant are the TMDLs for TSS, TN, and TP for the Kaneohe Stream watershed.

The TMDL allocations for each land use area in each sub-basin are consolidated into wasteload allocations (WLAs) to identified NPDES permit service areas and load allocations (LAs) to the nonpoint source areas not directly regulated by Clean Water Act permit. Among the regulated point sources in the area, the only major facility WLAs are for the large, Phase 1 Municipal Separate Storm Sewer Systems (MS4s) operated by the State of Hawaii Department of Transportation, Highways Division (DOT) and by various departments of the City & County of Honolulu (CCH, led by the Department of Environmental Services, ENV). WLAs are also assigned to urban stormwater discharges from small, Phase 2 MS4 facilities operated by the State of Hawaii Department of Education (DOE), the State of Hawaii Department of Defense (DOD, permitting in progress), and the CCH Department of Parks and Recreation (Parks).

These consolidated allocations and the load reductions required for their achievement under critical dry season and wet season conditions are summarized in the tables below. Implementation of the required load reductions will result in attainment of the water quality standards for TSS, TN, and TP in Kaneohe Stream and other tributary streams in the Kaneohe watershed area. General permit coverage for stormwater associated with construction activities regulates more temporary activities that we expect to be controlled by shorter-term site-specific Best Management Practices (BMPs) and general permit standard conditions. Nonpoint sources include polluted runoff from urban, agricultural, and conservation lands, as well as diffuse pollution from groundwater sources that may be under the influence of human inputs (such as the leaching of fertilizers and wastewater).

Table ES-1: Consolidated Dry Season TMDL Allocations to Major Sources and Load Reductions Required to Achieve Kaneohe Stream TMDLs (Table 5.10)*

	Allocations			Existing Loads			Reductions Needed					
Wet Season Baseflow	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(%)	(kgd)	(%)	(kgd)	(%)
LA to Hawaii DOT	31	0.38	0.052	31	0.62	0.052	0	0	0.24	38	0	0
LA to Hawaii DOD	1.1	0.02	0.003	1.1	0.04	0.003	0	0	0.02	50	0	0
LA to Hawaii DOE	1.3	0.06	0.003	1.3	0.06	0.003	0	0	0	0	0	0
LA to Hawaii DOH	1.9	0.09	0.005	1.9	0.09	0.005	0	0	0	0	0	0
LA to CCH ENV	253	5.02	0.474	253	5.37	0.474	0	0	0.35	7	0	0
LA to UH WCC	1.5	0.07	0.004	1.5	0.08	0.004	0	0	0.00	5	0	0
LA to Other NPS	354	5.67	0.918	354	9.31	0.918	0	0	3.65	39	0	0
Totals:	643.7	11.31	1.458	644	15.58	1.458	0	0	4.26	27	0	0

	Allocations			Existing Loads			Reductions Needed					
Wet Season 10% Runoff	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(%)	(kg)	(%)	(kg)	(%)
WLA to Hawaii DOT	65	1.07	0.33	65	1.11	0.36	0	0	0.04	4	0.04	10
WLA to Hawaii DOD	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOE	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOH	0	0	0	0	0	0	0	0	0	0	0	0
WLA to CCH ENV	135	2.00	0.60	135	2.16	0.73	0	0	0.16	7	0.13	18
WLA to UH WCC	0	0	0	0	0	0	0	0	0	0	0	0
LA to NPS	0	0	0	0	0	0	0	0	0	0	0	0
Totals:	199	3.07	0.93	199	3.28	1.09	0	0	0.21	6	0.17	15

	Allocations			Existing Loads			Reductions Needed					
Wet Season 2% Runoff	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(%)	(kg)	(%)	(kg)	(%)
WLA to Hawaii DOT	784	8.06	1.64	784	14.6	4.56	0	0	6.56	45	2.92	64
WLA to Hawaii DOD	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOE	0.93	0.02	0.003	0.93	0.023	0.006	0	0	0	31	0.002	43
WLA to Hawaii DOH	1.42	0.02	0.003	1.42	0.036	0.009	0	0	0	0	0	0
WLA to CCH ENV	2,733	19.4	4.23	2733	33.7	10	0	0	14.3	42	6.11	59
WLA to UH WCC	1.15	0.02	0	1.15	0.029	0.007	0	0	0.01	45	0.005	68
LA to NPS	536	8.14	1.15	536	16.1	3.22	0	0	7.98	50	2.07	64
Totals:	4,056	35.7	7.03	4,056	64.6	18.1	0	0	28.9	45	11.1	61

*TMDL allocations in kg/day (kgd) are obtained by dividing total dry season kilograms (kg) by 184 days. Tabulated values are rounded to the nearest 0.01 kg, thus (a) "Totals" may be greater than the sum of WLA+LA and (b) values tabulated as 0 may be greater than 0.

Acronyms

TMDL = Total Maximum Daily Load
LA = Load Allocation
WLA = Waste Load Allocation
TSS = Total Suspended Solids
TN = Total Nitrogen
TP = Total Phosphorous

CCH = City and County of Honolulu
ENV = CCH Department of Environmental Services
DOT = State of Hawaii Department of Transportation
DOE = State of Hawaii Department of Education
DOD = State of Hawaii Department of Defense
Parks = CCH Department of Parks & Recreation

Table ES-2: Consolidated Wet Season TMDL Allocations to Major Sources and Load Reductions Required to Achieve Kaneohe Stream TMDLs (Table 5.11)*

Wet Season Baseflow	Allocations TSS (kgd)	Allocations TN (kgd)	Allocations TP (kgd)	Existing Loads TSS (kgd)	Existing Loads TN (kgd)	Existing Loads TP (kgd)	Reductions Needed TSS (kgd)	Reductions Needed TSS (%)	Reductions Needed TN (kgd)	Reductions Needed TN (%)	Reductions Needed TP (kgd)	Reductions Needed TP (%)
LA to Hawaii DOT	34	0.51	0.057	34	0.68	0.057	0	0	0.17	25	0	0
LA to Hawaii DOD	1	0.035	0.004	1	0.054	0.004	0	0	0.02	35	0	0
LA to Hawaii DOE	2	0.076	0.004	2	0.076	0.004	0	0	0	0	0	0
LA to Hawaii DOH	2	0.11	0.006	2	0.11	0.006	0	0	0	0	0	0
LA to CCH ENV	297	6.07	0.557	297	6.31	0.557	0	0	0.24	4	0	0
LA to UH WCC	2	0.090	0.004	2	0.090	0.004	0	0	0	0	0	0
LA to Other NPS	392	7.70	1.017	392	10.33	1.02	0	0	2.63	25	0	0
Totals:	729	14.59	1.648	729	17.65	1.648	0	0	3.07	17	0	0

Wet Season 10% Runoff	Allocations TSS (kg)	Allocations TN (kg)	Allocations TP (kg)	Existing Loads TSS (kg)	Existing Loads TN (kg)	Existing Loads TP (kg)	Reductions Needed TSS (kg)	Reductions Needed TSS (%)	Reductions Needed TN (kg)	Reductions Needed TN (%)	Reductions Needed TP (kg)	Reductions Needed TP (%)
WLA to Hawaii DOT	273	4.21	1.25	273	4.94	1.57	0	0	0.73	15	0.32	20
WLA to Hawaii DOD	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOE	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOH	0	0	0	0	0	0	0	0	0	0	0	0
WLA to CCH ENV	594	6.03	1.89	594	8.42	2.88	0	0	2.39	28	0.99	34
WLA to UH WCC	0	0	0	0	0	0	0	0	0	0	0	0
LA to NPS	0	0	0	0	0	0	0	0	0	0	0	0
Totals:	868	10.2	3.14	868	13.4	4.44	0	0	3.12	23	1.30	29

Wet Season 2% Runoff	Allocations TSS (kg)	Allocations TN (kg)	Allocations TP (kg)	Existing Loads TSS (kg)	Existing Loads TN (kg)	Existing Loads TP (kg)	Reductions Needed TSS (kg)	Reductions Needed TSS (%)	Reductions Needed TN (kg)	Reductions Needed TN (%)	Reductions Needed TP (kg)	Reductions Needed TP (%)
WLA to Hawaii DOT	1,834	14.5	4.21	1,834	34.5	10.7	0	0	20.0	58	6.50	61
WLA to Hawaii DOD	11.5	0.16	0.03	11.5	0.43	0.07	0	0	0.27	63	0.05	63
WLA to Hawaii DOE	30.0	0.51	0.11	30.0	0.75	0.19	0	0	0.24	32	0.07	39
WLA to Hawaii DOH	41.0	0.47	0.10	41.0	1.02	0.26	0	0	0	0	0	0
WLA to CCH ENV	11,672	88.8	22.1	11,672	148	41.0	0	0	59.7	40	18.9	46
WLA to UH WCC	33.1	0.38	0.08	33.1	0.83	0.21	0	0	0.45	54	0.12	60
LA to NPS	5,889	68.6	13.6	5,889	184	36.6	0	0	115	63	23.1	63
Totals:	19,511	173	40.2	19,511	369	89.0	0	0	196	53	48.8	55

*TMDL allocations in kg/day are obtained by dividing wet season kilograms (kg) by 181 days.
Tabulated values are rounded to the nearest 0.01 kg, thus (a) "Totals" may be greater than the sum of WLA+LA and (b) values tabulated as 0 may be greater than 0.

<u>Acronyms</u> – see previous table

In conjunction with TMDL development, the DOH Environmental Planning Office conducted a biological assessment that provides baseline information about stream habitat quality and biotic integrity (Burr 2003). This assessment provides an additional framework for tracking changes in stream conditions over time and for comparing conditions in Kaneohe Stream with conditions in other streams. Although the goals for restoring habitat quality and biotic integrity to the streams are not a subject for EPA approval, they can help guide TMDL implementation towards areas where pollutant load reduction and water quality improvement practices may best contribute to restoration efforts.

The proposed decision will affect water pollution control permits [NPDES (CWA Section 402) and Water Quality Certification (CWA Section 401)] and provide guidance for other planning and regulatory approvals (e.g. land use, zoning, and environmental management) and voluntary compliance efforts in the watershed. As required by the Code of Federal Regulations (C.F.R.) and Hawaii Administrative Rules (HAR), 40 C.F.R. sec. 122.44(d)(1)(vii)(B) and HAR sec. 1 1-55-19(a)(4)(C), and intended by Hawaii's Continuing Planning Process for Surface Water Pollution Control (approved by EPA June 14, 1976 and last reviewed by EPA in August 2001), upon approval of the TMDLs by EPA, any TMDL Waste Load Allocations (WLAs) are immediately effective to be applied in NPDES permits. NPDES permits issued by the DOH shall include limitations needed to implement the WLAs in TMDLs, and the DOH shall enforce these limits.

The State will assure implementation of the approved TMDL WLAs through the enforcement of NPDES permit conditions (HAR §11-55) and will pursue implementation of load allocations through 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 Management Plan (Hawaii Coastal Zone Management Program, 1996), and the State of Hawaii Water Pollution Control Revolving Fund Intended Use Plan (Clean Water State Revolving Fund Loan Program, 2008), all of which serve the State Water Quality Standards (HAR § 11-54). A “Koolaupoko Watershed Restoration Action Strategy” completed by the Kailua Bay Advisory Council in 2007 serves as a watershed based plan for polluted runoff control and an implementation plan for the nonpoint source load allocations in these TMDLs. Therefore implementation activities identified in that Plan and in the TMDL implementation framework discussed in this TMDL decision document are eligible to receive “incremental funds” via the CWA 319(h) grant program administered by the DOH. Specific measures for reducing pollutant loads in the Kaneohe watershed may also be found in the Ko’olaupoko Water Quality Action Plan (Kailua Bay Advisory Council), Kailua Waterways Strategic Implementation Plan and Kailua Waterways BMP Manual (Tetra Tech EM, Inc.).

While much of the pollutant loading to Kaneohe Stream is from non-urban nonpoint sources, monitoring and assessment results and conventional wisdom indicate that the additional loading and impact from nonpoint and point source urban stormwater is critically important to stream and watershed health. Thus management of the storm drainage systems and wastewater disposal systems in the Kaneohe urban core should be a focus for County and State polluted runoff control (nonpoint sources) and water pollution control (NPDES) implementation efforts.

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Chapter 1-Introduction

Total Maximum Daily Loads (TMDLs) for Total Suspended Solids, Nitrogen and Phosphorus in Kaneohe Stream, Kaneohe, Hawaii

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The State of Hawaii Department of Health (DOH) proposes establishing Total Maximum Daily Loads (TMDLs) for Kaneohe Stream in the Kaneohe Bay Watershed on the island of Oahu, Hawaii. TMDLs are required for pollutant-impaired water bodies on the State's Clean Water Act (CWA) Section 303(d) list. The primary objective of the proposed TMDLs is to stimulate and guide action that will control sources of excessive nutrients, sediment, and pathogens and improve the water quality of the streams so that the designated and existing uses of waterbodies throughout the Watershed will be protected and sustained. The proposed decision will affect water pollution control permits [NPDES (CWA Section 402) and Water Quality Certification (CWA Section 401)] and provide guidance for other planning and regulatory approvals (e.g. land use, zoning, and environmental management) and voluntary compliance efforts in the watershed.

TMDLs are a tool for implementing water quality standards, based on the relationship between point and nonpoint sources of pollutants and receiving water quality. The TMDLs must consider critical conditions, seasonal variations, future growth, and a margin of safety that accounts for uncertainty in the pollutant load calculations. EPA approval of TMDLs is based upon a checklist of elements (Appendix C) that must be satisfactorily addressed in the State’s TMDL decision. DOH uses these same elements as an organizing framework for responding to public review of the proposed decision (Appendix D). This TMDL decision rationale reviews existing conditions in the watershed and presents an analysis of pollutant load distributions and resulting water quality in Kaneohe and tributary streams. We provide calculations of waterbody pollutant loading capacities, and of their allocations to identified pollutant sources such that water quality standards for total suspended solids (TSS), total nitrogen (TN), nitrate + nitrite nitrogen (N+N), total phosphorus (TP), and turbidity in Kaneohe Stream, including the Kamooalii tributary, will be achieved as required. This analysis is based on the 2003 “Kaneohe Stream Total Maximum Daily Load Final Report,” (hereafter “2003 Report”) prepared by Oceanit Laboratories, Inc. and AECOS, Inc. for the DOH Environmental Planning Office (EPO), with additional information subsequently compiled and synthesized by EPO.

This rationale document was prepared by Jack D. Smith (DOH contractor); Alexandre Remnek, David C. Penn and Glen Fukunaga (DOH Environmental Planning Office); and Renee Kinchla (Research Corporation of the University of Hawaii). Technical assistance from Joanna Seto (DOH Clean Water Branch), Michael Wong (U.S. Army Corps of Engineers), Gerald Takayesu (City & County of Honolulu), and Robert Bourke (Oceanit Laboratories, Inc.) is gratefully acknowledged. This work was funded by the EPA through the Water Pollution Control program grants to DOH (Clean Water Act §106) and by State budgeting for staff positions and office support within DOH.

Within the Kaneohe Stream Watershed, our work was informed and facilitated by the gracious efforts of numerous individuals and organizations, including but not limited to:

- Koolau Golf
- City & County of Honolulu Department of Enterprise Services (Pali Golf Course)
- Hawaii Pacific University

- City & County of Honolulu Department of Parks & Recreation (Hoomaluhia Botanical Garden)
- Kailua Bay Advisory Council
- Halawa-Luluku Interpretive Development
- University of Hawaii School of Ocean & Earth Science Technology
- U.S. Geological Survey
- State of Hawaii Department of Land and Natural Resources (Office of Conservation and Coastal Lands)

The remainder of this chapter identifies and defines the TMDL problem and water quality objectives, and provides an overview of the watershed and stream environment, including references to previous studies and reports reviewed during the preparation of this document. Chapter 2, Setting, describes the physical and cultural context of the watershed; defines stream segments, tributary sub-basin areas, and pollutant sources (the organizational basis for the TMDL analysis and development); and characterizes the climatic conditions that express the seasonal variation and critical conditions addressed. Chapter 3, Water Quality Data, summarizes the available data used for the TMDL analysis. Chapter 4, Existing Conditions, develops the quantitative descriptions of hydrology and pollutant loads and presents the calculations of streamflow and existing water quality for critical dry season and wet season conditions. Chapter 5, TMDL Allocations, develops the numeric TMDL targets and the pollutant loading capacities for Kaneohe Stream for the seasonal and critical water quality conditions. Allocations of loading capacities to individual sources are then calculated and these allocations are consolidated into areas serviced by NPDES and other discharge permits.

Chapter 6 outlines a framework for ongoing TMDL implementation activities, Regulatory or other mechanisms through which the TMDL allocations will be implemented are described and the agencies that will be responsible for the implementation are identified. Chapter 7, Public Participation, contains an account of community initiative and activities relating to the TMDL process, and records of the public notice, public meeting, public comments, and DOH responses that are part of the administrative record of the DOH TMDL decision. Figures and tables are presented within the sections as they are introduced. A reference list (Section R), water quality data table (Appendix A), Technical Appendix (Appendix B, presenting the background data and mathematical relationships that are used to calculate runoff, pollutant loadings, streamflows, water quality, and TMDL allocations), and other supplementary information (Appendices C and D) follow the main text.

1.1 Location

Kaneohe Stream and its tributaries are located on the windward (northeast) side of the island of Oahu in the Hawaiian Islands. Among the many Kaneohe stream headwater sources in the Koolau mountain range, most flow into the Waimaluhia reservoir, then flow out of the reservoir together as Kamooalii Stream. This main stream is joined below the reservoir outlet with Luluku Stream and, further downstream in the town of Kaneohe, with the Kapunahala Stream tributary. From this confluence the combined streams become Kaneohe Stream, and continue downstream through Kaneohe town into the South Bay area of Kaneohe Bay.

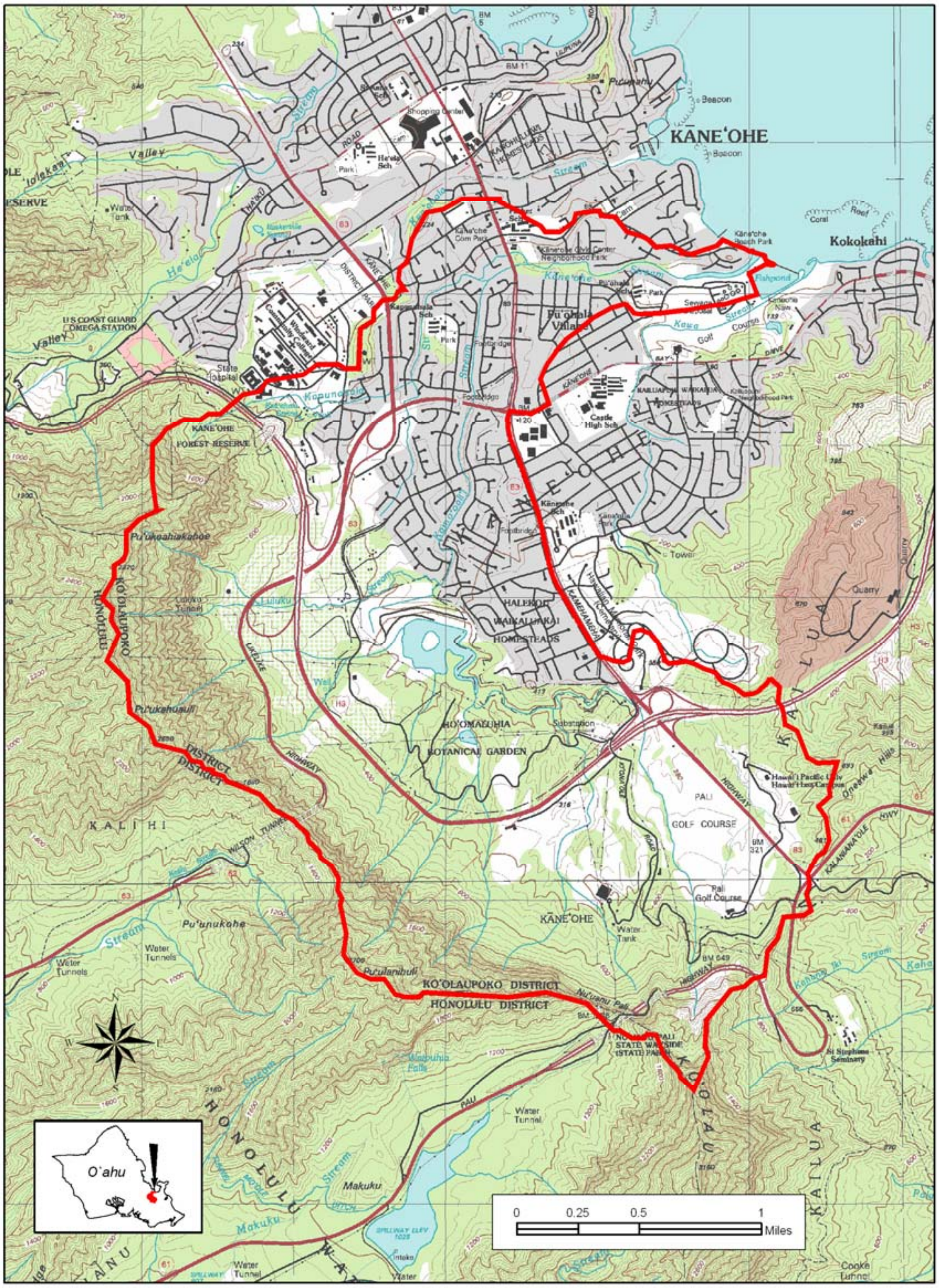


Figure 1-1. Kaneohe watershed location map.

The Kaneohe Stream watershed (Figure 1-1.) covers about 3,655 acres (5.7 square miles). Early Hawaiians developed extensive irrigated pondfield and fishpond complexes along the streams and shoreline (Handy & Handy 1972), remnants of which persist today. Two golf courses, a banana plantation, a botanical garden, and forest reserve lands occupy the upper watershed, bisected by three major highways and drained into a flood control reservoir. While much of the arable watershed land was devoted to agriculture through the early twentieth century, the lower portions of the southern Kaneohe Bay watershed have become one of the more heavily urbanized areas in the Koolaupoko region. Waikalualoko, situated between the mouths of Kaneohe and Kawa streams, is the only fishpond visibly remaining, and no longer receives the freshwater input formerly delivered from these two streams and the irrigated pondfields long removed from the intervening delta. Among the few upland pondfields remaining is a spring-fed complex on the grounds of the Hawaii State Hospital (a DOH facility). Similarly, wetland areas within the entire Kaneohe Bay watershed have been destroyed or damaged by heavy sediment loads, exotic vegetation, lowered water tables, and most importantly, by filling (Division of Ecological Services 1977).

1.2 Problem Statement - Water Quality Standards and Impaired Waters

Designated Uses

TMDLs are established to achieve and maintain 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. According to Hawaii classification of designated uses in the Hawaii Administrative Rule (HAR §11-54-3), the Kaneohe Stream network (inland freshwater) includes both Class 1 and Class 2 segments. Throughout all Class 1 waters, any conduct which results in a demonstrable increase in levels of point or nonpoint source contamination is prohibited.

In Class 1.b. segments in the headwaters of the tributary network (where the waters are within the Protective Subzone of the State Conservation District), uses to be protected 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. Although we have not assessed the attainment of protected uses in these remote segments, the protection of native breeding stock is perhaps the use most sensitive to threats and impairments posed by degraded water quality. Biological assessment in downstream Class 2 stream segments (Burr 2003) documented some presence of native fish and crustaceans, however ratings of “not supporting” to “partially supporting” habitat quality and “impaired” to “moderately impaired” biotic integrity (when compared with high-quality reference stream conditions keyed to the presence of native fish, mollusks, and crustaceans) for these segments suggest threats to the protection of native breeding stock in upstream Class 1 segments. These results reverberate with those from thirty years ago, when a comparative study of fish and crustacean populations in altered and unaltered Hawaiian streams “it appears that exotic animals which are able to withstand habitat alterations in streams are gradually replacing native stream animals which cannot tolerate changes in the habitat” (Nelson 1977), and the U.S Fish and Wildlife Service “suggested that stream channelization, competition with introduced species, extensive diversion of stream flows, decreased water quality and other urban impacts are contributing factors to the decline or elimination of native organisms” (Division of Ecological Services 1977).

One example of these factors is the detection of organochlorine pesticides in Kaneohe Stream bed sediment and fish tissue by the U.S. Geological Survey National Water Quality Assessment (NAWQA) (Brasher and Anthony 1998). At the NAWQA site in the lower reach of Kaneohe Stream, aldrin was detected in bed sediment, but not in fish tissue. Concentrations of its degradation product, dieldrin, exceeded the New York State Department of Environmental Conservation (NYSDEC) wildlife guideline for fish and the Canadian Sediment Quality Guideline (CSQG) probable effect level. Total chlordane in fish tissue approached the NYSDEC guidelines for the protection of fish-eating birds and mammals, and the CSQG chlordane guideline for the protection of aquatic life was exceeded in stream sediment. DDT was also detected in both the sediment and fish tissue, but not at levels deemed excessive by NYSDEC or CSQG.

The objectives of Class 2 waters are to protect uses for recreational purposes, the support and propagation of fish and other aquatic life, and agricultural and industrial water supplies. Uses to be protected include all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. Agricultural water supply was a major historical use of the stream and existing agricultural uses persist today. Existing uses throughout the stream also include support of recreational activities, aesthetic values, and traditional and customary native Hawaiian beliefs, values, and practices.

Numeric Water Quality Criteria

Specific water column criteria for Hawaii streams (Hawaii Administrative Rules Title 11, Department of Health Chapter 54 Water Quality Standards, HAR §11-54-5.2) first approximated their existing form in 1979 and were last revised in 2004 . Four parameters (temperature, pH, dissolved oxygen, salinity) have limits defined by specific upper or lower bounds. Nine other parameters, including turbidity, total nitrogen, total phosphorus, and total suspended solids in streams, are defined by three numeric criteria – a geometric mean and two exceedance values (10% and 2%) - for each of two seasons, wet and dry. The water quality criteria for these parameters are displayed in Table 1.1, where terms have the following meanings:

1. Geometric mean (GM). The geometric mean of all time-averaged samples should not exceed this value. The geometric mean is calculated as the *n*th root of the multiple of all samples, where *n* represents the total number of samples.
2. 10% exceedance value. No more than 10% of all time-averaged samples exceed this value.
3. 2% exceedance value. No more than 2% of all time-averaged samples exceed this value.

Table 1.1. Hawaii State Water Quality Standards for Streams

Parameter	Geometric mean not to exceed the given value (Wet Season/Dry Season[1])		Not to exceed the given value more than 10 percent of the time (Wet Season/Dry Season)		Not to exceed the given value more than 2 percent of the time (Wet Season/Dry Season)	
Total Suspended Solids (mg/L)	20	10	50	30	80	55
Nitrate + Nitrite as Nitrogen (µg/L)	70	30	180	90	300	170
Total Nitrogen (µg/L)	250	180	520	380	800	600
Total Phosphorus (µg/L)	50	30	100	60	150	80
Turbidity (NTU)	5.0	2.0	15.0	5.5	25.0	10.0

Notes:
From DOH Hawaii Administrative Rules Section 11-54-5.2(2)(b)
[1]The Wet Season is from November 1 through April 30 and Dry Season is from May 1 through October 31.
µg/L Micrograms per liter
mg/L Milligrams per liter
NTU Nephelometric turbidity units

One of the main purposes of TMDL decisions is to assure that these criteria are attained in waters of the state that have been listed under Clean Water Act §303(d) as "Impaired Waters."

Impaired Waters

The DOH, in its Final 2006 List of Impaired Waters in Hawaii prepared under Clean Water Act §303(d) (Environmental Health Administration 2008, see excerpts in Appendix C), identified water quality in Kaneohe Stream and the Kamooalii tributary as impaired due to elevated turbidity (based on numeric assessment) and sediment and nutrient levels (based on previous visual assessment, see Appendix C). Kaneohe Stream was also listed for excessive dieldrin levels based on the NAWQA results discussed above. Primary sources of these pollutants are thought to be the heavily urbanized and agricultural areas in the watershed. Other potential sources include a network of state and interstate highways traversing the watershed.

In southern Kaneohe Bay (the Class AA marine receiving water for Kaneohe Stream), nearshore waters at the mouths of Kaneohe and Kawa streams are currently listed under Clean Water Act §303(d) as water bodies in which water quality is impaired by excessive nutrients, turbidity, and suspended solids. Three water quality monitoring stations in the southern bay are also included on the list of impaired waters: Kaneohe Bay Southern Region, Beach Park, and Kokokahi Pier are listed for excessive nitrogen and turbidity; Beach Park and Kokokahi Pier are listed for excessive chlorophyll a; and Southern Region and Kokokahi Pier are listed for excessive *enterococcus* (bacterial indicator). Thus water pollutants in the Kaneohe watershed are a concern not only for the quality of Kaneohe and tributary streams but also for their detrimental impacts on the waters of Kaneohe Bay, particularly with regard to their designated use for the conservation of coral reefs, the objective "that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution of alteration of water quality from any human-caused sources or actions" [HAR 11-54-3(c)].

1.3 Pollutant Sources

Pollutants affecting water quality in Kaneohe Stream come from both point and nonpoint sources in the watershed. Point sources regulated by Clean Water Act permit area are primarily municipal separate storm sewer system (MS4) discharges, such as those from State highways, municipal streets and storm drain systems, public school areas, and State and City cemeteries and parks.

Stormwater discharges associated with construction activities are more temporary sources that we expect to be controlled by shorter-term site-specific Best Management Practices (BMPs) and general permit standard conditions. Nonpoint sources include polluted runoff from urban, agricultural, and conservation lands, as well as groundwater sources that may be under the influence of human inputs (such as the leaching of fertilizers and wastewater).

1.4 **Background and Concurrent Studies**

Kaneohe Bay and its drainage basins have been heavily studied and planned across a wide range of disciplines and timeframes. In the 1970s, the U.S. Army Corps of Engineers Kaneohe Bay Urban Water Resources Study thoroughly surveyed the area "with a view to recommending improvements in the interests of pollutions abatement, navigation, recreation, and overall bay development …" (Honolulu District, 1978). This Study concluded that "The results of water quality monitoring efforts along Kamooalii and Kaneohe streams have established that urbanized areas contribute substantially to the suspended sediments, nutrients, and debris entering Kaneohe Bay. Sources of these constituents include street dust and debris, erodible sites within the urbanized residential and commercial areas, wastewaters discharges to storm drains, and lawn fertilizers," and produced a classic "History of Change" in watershed characteristics and function (Devaney et al. 1982), as well as numerous unpublished reports on various aspects of the physical environment (see References). At the University of Hawaii, the Institute of Marine Biology (HIMB), Sea Grant Program, Water Resources Research Center, and Hawaii Environmental Simulation Laboratory all produced early studies related to various aspects of watershed hydrology, water quality, and ecosystem health that predate the positive and negative changes later wrought by the diversion of sewage effluent away from the Bay, the Waimaluhia flood control reservoir, and the H-3 Highway (e.g. Banner 1968; Banner & Bailey 1970; Bartram 1972; Bathen 1968; Cox et al. 1973; Dames & Moore 1977; Division of Ecological Services 1997; Dugan 1975 & 1977; Ekern 1975; Lau et al. 1976; Lopez and Dugan 1978; Quan et al 1970; Smith et al. 1973; Smith et al. 1979; Young et al. 1976;).

After the diversion of sewage effluent away from Kaneohe Bay in 1977, biological work focused on documenting the recovery of the Bay ecosystem (Coles & Ruddy 1995; Maragos et al. 1985; Smith 1979; Smith at al. 1981). The U.S. Geological Survey (USGS) helped monitor the impacts of H3 construction, and continues to produce technical reports addressing highway pollutant loading and reservoir sedimentation (Hill 1996; Wong, with various others, various years). Many decades of streamflow data from as many as four monitoring stations in the Kaneohe Stream watershed are archived by USGS, however, only one of these stations (16272200) was operative during the 2001-2002 period of the primary water quality data collection period for this TMDL decision.

From 1998-2001, HIMB initiated a long term project to monitor water quality and sediment processes in Kaneohe Bay, as part of a nationwide project cooperatively funded by EPA, NOAA and NASA, termed "CISNet" (Coastal Intensive Site Network). This was accompanied by HIMB participation in the Hawaii Coral Reef Initiative (also part of a nationwide program), and the establishment of coral reef assessment and monitoring program (CRAMP) sites and protocols. More recently, related work at the University of Hawaii School of Ocean and Earth Science Technology focused on the dispersion and effects of pollutant loading in Kaneohe Bay (DeCarlo et al. 2007; Hoover 2002; Ringuet 2003; Ringuet & Mackenzie 2005). Three previous DOH contractors investigated pollutant loading in the stream (Freeman 1993; Tomlinson & DeCarlo 2001; Oceanit Laboratories, Inc. & AECOS, Inc. 2003), with the Oceanit & AECOS effort serving as primary information source for the analysis presented in this TMDL decision.

Building on the classic efforts of Timbol & Maciolek (1978) and similar early work (Norton 1977; Division of Ecological Services 1977), various investigators with the U.S. Geological Survey, State of Hawaii Department of Land and Natural Resources, Bernice Pauahi Bishop Museum, and the State of Hawaii Department of Health are studying relationships between aquatic resources, streamflow regimes, hydromodification, and pollutant loading (Anthony et al. 2004; Brasher, with various others, various years; Burr 2003; Oki & Brasher 2003; Parham et al. 2008; Wolff 2005). While chronic sedimentation of stream bottoms appears to be a major cause of biological impairment (poor habitat quality and absence of key native organisms), sediment contamination and the bioaccumulation of toxins in fish are emerging as associated concerns. Any future work to repair stream habitat and restore stream biota should carefully consider the broader relationships between pollutant loading and the biological, chemical, and physical integrity of the receiving waters, including the adjoining brackish and marine waters.

Chapter 2 - Setting

Total Maximum Daily Loads (TMDLs) for Total Suspended Solids, Nitrogen and Phosphorus in Kaneohe Stream, Kaneohe, Hawaii

2.1 Overview

Early Hawaiians occupied the region of the Kaneohe watershed as long ago as ca. 500 AD. Early in the 16th century, each of the islands of Hawaii came to be divided into *moku*, or separate districts, each ruled by its individual chief. These *moku* were subdivided into smaller sections called *ahupua'a*, now the most commonly recognized of the early land divisions. *Moku* and *ahupua'a* of the island of Oahu are shown in Figure 2.1. As a fundamental unit of community subsistence and political organization, *ahupua'a* typically describes a section of land running *mauka makai*, from the mountain into the sea to the outer edge of the reef. Forests on the mountain provided wood for canoes, housing, implements, and fire. Taro and other foods and fiber grew in the valley's *lo'i kalo* (irrigated pondfields). Fish, salt, and *limu* (edible seaweed) were harvested from the sea. Through the center of the *ahupua'a* ran a stream, the most important and protected resource of the *ahupua'a*. The idea of TMDL, with allocations of resource protection obligations and watershed-based resource management, echoes the beliefs, values, and practices of early Hawaiian culture.

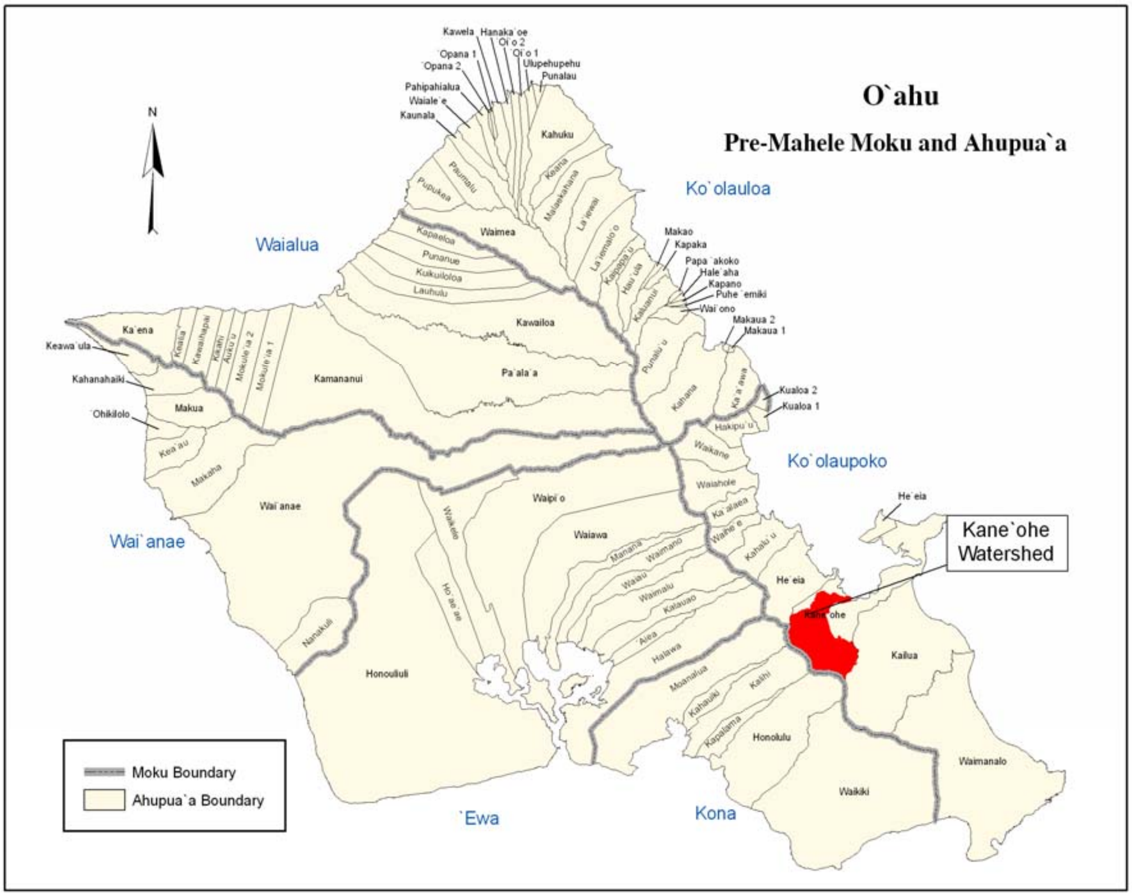


Figure 2-1. The *moku* and *ahupua'a* of Oahu

2.2 Geology and Landform

The windward side of Oahu is the inner edge of what was the caldera of the massive Ko'olau volcano. The Kaneohe watershed is one of the larger drainage systems within this ancient caldera. Based on Figure 2-1, the Kaneohe watershed, with the smaller adjacent Kawa and Kea'ahala watersheds, constitute the ancient Kaneohe *ahupua'a* that lies within the *moku* of Ko'olaupoko. The mountains and hills of the southern and southwestern boundaries of the watershed are composed of very dense rock formed within the caldera. The rocks are primarily of the Kailua Volcanic Series and are composed of massive basalt flows intruded by numerous vertical dikes (MacDonald 1990). These rocks have undergone hydrothermal action that has filled voids with secondary minerals, silica and calcite, making these rocks very dense and highly impermeable (Nance 2002). Overlaying this vertically stratified highly impermeable rock, is a layer of breccia, loosely stratified rocks of a variety of types varying in size from a few centimeters to over a meter in diameter (MacDonald 1990). Except for a narrow band of exposed rock along the Ko'olau mountain ridge, Kaneohe watershed soils overlying the breccia layer are assigned to NRCS hydrologic soil group B, deep or moderately deep and well drained to moderately well drained soils with a moderate rate of water transmission (NRCS 2001). This relatively permeable surface layer allows infiltration of rainfall and percolation into the less permeable dense rock below. The result is that vertical dikes within the surrounding mountains contain fresh ground water reserves that slowly feed Kaneohe watershed streams.

Headwaters of Kaneohe stream are a number of named and unnamed tributaries originating high (2,000 to 2,700 foot elevations) in the Ko'olau mountain range. The main branch of this tributary system is the upper reach of Kamooalii Stream, which was separated from its lower reaches by the construction of the Waimaluhia Reservoir (see below). Rainfall collected in the headwater streams tumbles down steep mountain cliff faces to 500-600 foot elevations within a half-mile distance. Stream slopes then flatten out and flow distance from here to its sea level discharge into Kaneohe Bay is about 4.5 miles. Streamflows in the main tributaries become perennial at elevations between 500 and 600 feet.

Figure 2-2. Windward face of the Pali showing uluhe fern dominating a colluvial deposit in the foreground and strong fluting of the cliff face by intermittent water flows in the background.

2.2 Watershed Sub-basins

The Kaneohe watershed is divided in this TMDL analysis into 6 sub-basin areas. Sub-basins 2 through 5 are essentially the same as sub-basins 2 through 5 in the 2003 Oceanit report. The area considered as Sub-basin 1 in the Oceanit report is subdivided in this analysis into new sub-basins 1.0 and 1.1. These sub-basin areas are delineated on the Kaneohe watershed map in Figure 2-3. The bulk of the remaining descriptive information, and all photographs in this chapter, are products of Oceanit and AECOS from their 2003 report to DOH.

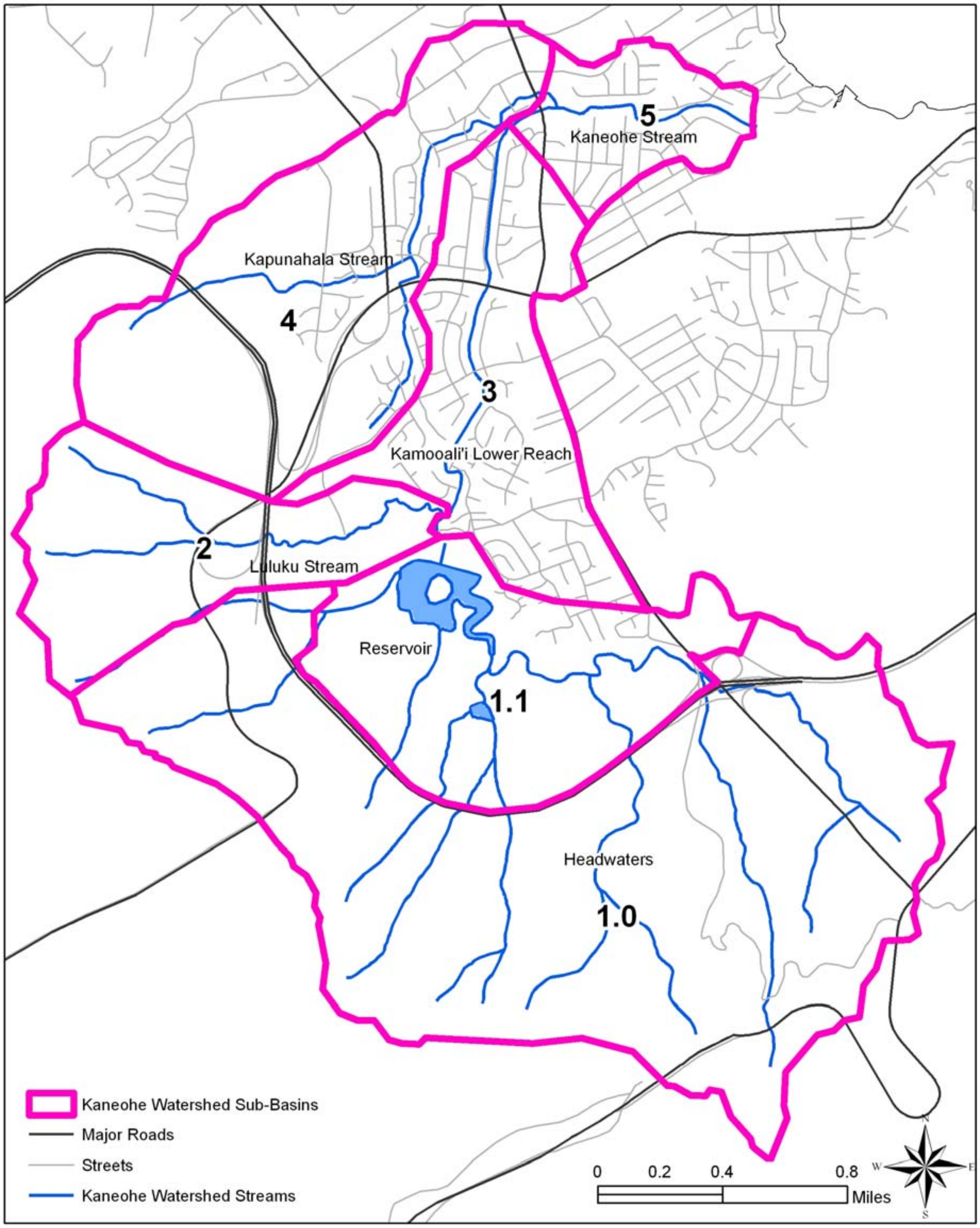


Figure 2-3. Kaneohe watershed streams and sub-basin drainage areas.

Sub-basin 1.0. Headwaters

This 2.4 square mile sub-basin is the area mauka from and including the interstate H-3 highway that is tributary to the Waimaluhia reservoir. About 65% of the area is forestland of the Kaneohe Forest Reserve. Below elevation 500 feet, 24% of the sub-basin area is devoted to the Koolau and Pali Golf Courses. The windward campus of Hawaii Pacific University and a portion of the Veterans Cemetery occupy about 4% of the area, banana plantations occupy another 4% . Portions of four major Oahu highways: Kamehameha, Pali, Likelike, and H-3, traverse the sub-basin.

Figure 2-4. Upper reaches of small streams that become the eastern branch of Kamo'oalii Stream, are here seen from Old Pali Road (now a foot trail). The high waterfall in the background drains one of several hanging valleys that feed into the narrow gulch of the stream.

Figure 2-5. Numerous small waterfalls flow down the face of the Nuuanu Pali during heavy rainfall. Waterfalls shown here converge into flows on and below the old roadway to become Kamo'oalii Stream flowing behind the Ko'olau Golf Course clubhouse building.

Steep colluvial deposits at the base of the rocky mountain face support dense growths of trees or monotypic stands of uluhe fern (*Dicranopteris linearis*). While many species of plants are found in the forested areas, trees particularly prevalent are common guava (*Psidium guajava*), mango (*Mangifera indica*), silky oak (*Grevillea robusta*), Molucca albizia (*Paraserianthus falcataria*), African tulip (*Spathodea campanulata*), and kukui (*Aleurites moluccana*). In places, native pandanus (*Pandanus tectorius*), ohia (*Metrosideros polymorpha*) and koa (*Acacia koa*) are still to be found. The steeper, higher slopes support grasses and shrub growth, regularly watered by cloud drip. Perennial flows develop in the streams from small springs in the rocky colluvium at elevations between 600 and 800 feet. Flows build rapidly downslope over beds of water rounded stones and boulders.

Sub-basin 1.1. Reservoir

This sub-basin, makai from H-3 highway, includes the 26-acre Waimaluhia Reservoir, and over 400-acres of Ho'omaluhia Botanical Garden that surround it. A small portion of Memorial Cemetery and some residential area from Kaneohe town extend into and occupy about 14% of the sub-basin.

Figure 2-6. Waimaluhia Reservoir surrounded by the Ho'omaluhia Botanical Garden, seen from the top of the dam and looking mauka towards the steep face of the Nuuanu Pali.

The earthen dam creating the Waimaluhia Reservoir was constructed by the Army Corps of Engineers after disastrous flooding of Keapuka subdivision in Kaneohe town in 1965 and 1969. The dam, originally named "Kaneohe-Kailua Dam," was dedicated in 1980. The Ho'omaluhia Recreation Area then surrounding the resulting lake on Kamo'oalii Stream has since become the Ho'omaluhia Botanical Garden. Normal water level in the reservoir is maintained at elevation 160 feet, with a flood overflow spillway at elevation 202 feet (Wong 2001). The confluence of Luluku Stream with Kamo'oalii Stream forming the beginning of the Kamo'oalii Lower Reach is immediately downstream from the reservoir outlet and spillway structure shown in Figures 2-7 and 2-8.

Figure 2-7. Outlet structure from Waimaluhia Reservoir at the base of the dam.

Figure 2-8. Flood overflow spillway channel shown where it empties into Kamo'oalii Stream beside the reservoir outlet structure.

Sub-basin 2. Luluku Stream

The 0.6 square mile Luluku Stream sub-basin is similar to the forested area of sub-basin 1.0. Approximately 73% of the area is forest and 25% is occupied by the banana plantation that extends from sub-basin 1.0 through sub-basin 2 and into sub-basin 4. The highest point in the sub-basin is the 2820 ft Puu Keahiakahoe in the Ko'olau mountain range. The eastern cliff face (pali) of the mountain descends steeply, in some places vertically, to around 800 feet and stream flow down this face is intermittent. Aprons of colluvium debris accumulated at the base of the cliffs tail out into the banana plantations and area traversed by the Likelike and H-3 highways.

Figure 2-9. Luluku Stream at Ho'omaluhia Botanical Garden access road bridge. USGS gauging station No. 16270900 (discontinued after 1998).

Figure 2-10. Luluku Stream (concrete culvert below house) joins outflow from Waimaluhia reservoir and continues downstream (far right) as Kamo'oalii Lower Reach in sub-basin 3.

Sub-basin 3. Kamo'oalii Lower Reach

The 0.7 square mile sub-basin 3 marks a sharp demarcation in land use cover from largely undeveloped and open space to the urban development of Kaneohe town. More than 93% of this sub-basin area is devoted to residential, business and associated municipal streets and highways. The remainder is mixed forest, agricultural, and park lands.

Figure 2-11. Beginning of Kamooalii Lower Reach. View from Waimaluhia reservoir dam shows Luluku Stream confluence culvert and downstream residential development.

The Kamo’oalii stream channel is highly modified in this lower reach. In some areas the channel is concrete lined or a box culvert (as beneath the Likelike Highway) but mostly the channel retains a "natural" bed and banks modified to resist erosion.

Figure 2-12. Kamo’oalii Lower Reach is confined between concrete or concrete-rock masonry (crm) walls. Herbicide spraying shown here is regularly used to control vegetation growth.

The Kamo’oalii lower reach flows north, passing under Likelike Highway, then makes a broad turn eastward to pass under Kamehameha Highway on its way to Kaneohe Bay (Figure 2-14). Near the beginning of that broad turn, Kamo’oalii Stream is joined by Kapunahala Stream entering through a closed conduit (Figure 2-16) and the combined flows from here to Kaneohe Bay are now named Kaneohe Stream.

Sub-basin 4. Kapunahala Stream

This 0.9 square mile sub-basin lies to the northeast of Puu Keahiakahoe. The uppermost steeply sloped area of the sub-basin is forest (37%) and agricultural (12%) land. The downstream portion of the sub-basin area (41%) is residential development, streets and highways, including 30 acres of parks. Most of the perennial flow in Kapunahala Stream comes from Kea'ahala Spring at around 280 feet elevation. Portions of this spring are diverted to *kalo loi* that are maintained by Hawaii State Hospital (and formerly by Windward Community College). The stream channel disappears into a wetland above Pookela Street in Castle Hills subdivision, reduced in size by construction activity in the 1990s. From this wetland, dominated by umbrella sedge (*Cyperus laevigatus*) and Job's tears (*Coix lachryma-jobi*), the stream re-emerges at a culvert under Pookela and then passes through residential areas of Kaneohe town. This segment of the channel, formerly documented as habitat for native *o'opu*, was heavily scoured and filled by gravel discharged from upstream construction sites (wetland fill) during storm events, and should be re-evaluated for its restoration potential. Just upstream from Kahekili highway, the stream enters a concrete-lined channel that continues downstream to its confluence with Kamo'oalii Stream.

Figure 2-13. Marsh above Pookela Street is dominated by Job's tears and umbrella sedge and surrounded in part by hau and banana.

A wetland similar to the one pictured in Figure 2-13 occupies an area between Luluku Road and Likelike Highway. This wetland area drains into Keapuka Stream, a southern tributary branch of Kapunahala. The confluence of the two branches is at the concrete channel of Kapunahala Stream where it passes under Keneke Street, about 600 feet downstream from Kahekili Highway.

Figure 2-14. Downstream from Kahekili Highway, Kapunahala Stream is confined to a concrete culvert with high vertical walls.

Sub-basin 5. Kaneohe Stream

Kaneohe Stream begins at the confluence of Kamo'oalii and Kapunahala Streams about 700 feet east of Kamehameha Highway. The sub-basin for this segment is one-third square mile of low elevation generally urban residential land beginning at the above confluence of streams to the estuary discharge in Kaneohe bay. Land use in the sub-basin is 87% residential, business and associated streets, and about 13% parks. Through most of its length, the stream channel has been modified by grading and shaping. Channel walls are concrete-rock masonry along the upper length of the segment and graded but natural soil banks in the lower estuarine length.

Figure 2-15. The beginning of Kaneohe Stream Segment 5. Kamo'oalii Stream flows over the concrete wall in the center background. Kapunahala Stream enters through the box culvert in the right background.

Figure 2-16. Kaneohe Stream beneath Kamehameha Highway (near the Kaneohe Library) is confined within a concrete and crm culvert structure.

Figure 2-17. Most of the lower reach of Kaneohe Stream is in a channel that is realigned, but lacks hardened, concrete bed or banks.

2.4 Climate

Sources of rainfall on the Kaneohe watershed are: trade wind showers; thermally induced trapping of moisture laden tradewinds against high mountain peaks (orographic lift); island wide storms fronts associated with North Pacific lows; subtropical (Kona) storms; and hurricanes. Subtropical storms and hurricanes are the most intense but also most infrequent of these sources, with return periods of about 1 and 10 years, respectively. Oahu typically receives about fifteen North Pacific frontal systems per year, of which four to eight produce an average of one to five inches of rain over a 1 to 3 day period.

Most of the rainfall on Kaneohe's upper watershed area is the result of daily orographic lift along the steep windward side of the Ko'olau mountain range. Annual rainfall along the mountain ridge averages 100 to 150 inches, compared to about 60 inches in the lower elevation area of Kaneohe town. Fog drip in the upper elevation forests is also a significant source of moisture in the upper watershed area. The majority of rainfall events in lower elevation areas of the Kaneohe watershed (sub-basins 3, 4, 5) are non-thermally induced tradewind showers. These showers tend to be most frequent in the morning and evening and are often intense, but have short duration and are spatially limited. A typical trade wind shower might have a diameter of 1 or 2 miles and be moving with the trade winds at 5 to 15 mph. From the perspective of a fixed point on land, the storm duration will be 4 to 20 minutes during which 0.1 to 0.5 inches of rain may fall (Oceanit 2003). Thus, there is considerable spatial and temporal variability in rainfall within the Kaneohe watershed area.

The climatic statistical model known as PRISM (parameter–elevation regressions on independent slopes model) developed at Oregon State University for USDA-NRCS and other agencies (Daly et al, 2002) has recently been extended by NRCS to all of the U.S. states including the islands of

Hawaii. The PRISM system provides 30-year (1961-1990) statistical regressions of annual and mean monthly rainfall distributions at 500m x 500m grid cell resolution for Oahu, including the Kaneohe watershed area. Seasonal distributions were obtained from summations of May-October (dry season) and November-April (wet season) monthly rainfall values. PRISM seasonal rainfall grids are overlaid on the Kaneohe watershed area in Figures 2-19 and 2-20 (rainfall in mm).

Data from the weather station at Pali Golf Course, located in sub-basin 1.0 of the Kaneohe watershed, provides a record of daily rainfall for the 30-year period of the PRISM statistical regressions. With the assumption that temporal rainfall distributions are similar across small watershed areas, then spatial distributions of rainfall for an individual event, e.g., 10% or 2% frequency storm, can be approximated from the PRISM seasonal distributions and the individual event data from a single reference monitoring station (Appendix A, Section A.2.0). For the 30-year Pali Golf Course record, rainfall was equal to or greater than 0.35-inch during 10% of the dry season days and equal to or greater than 0.70-inch during 10% of the wet season days. Rainfall was equal to or greater than 1.27-inch during 2% of the dry season days and equal to or greater than 2.30-inch during 2% of the wet season days. These rainfall statistics and the PRISM distributions provided the basis for approximations of Kaneohe watershed hydrology and pollutant load distributions.

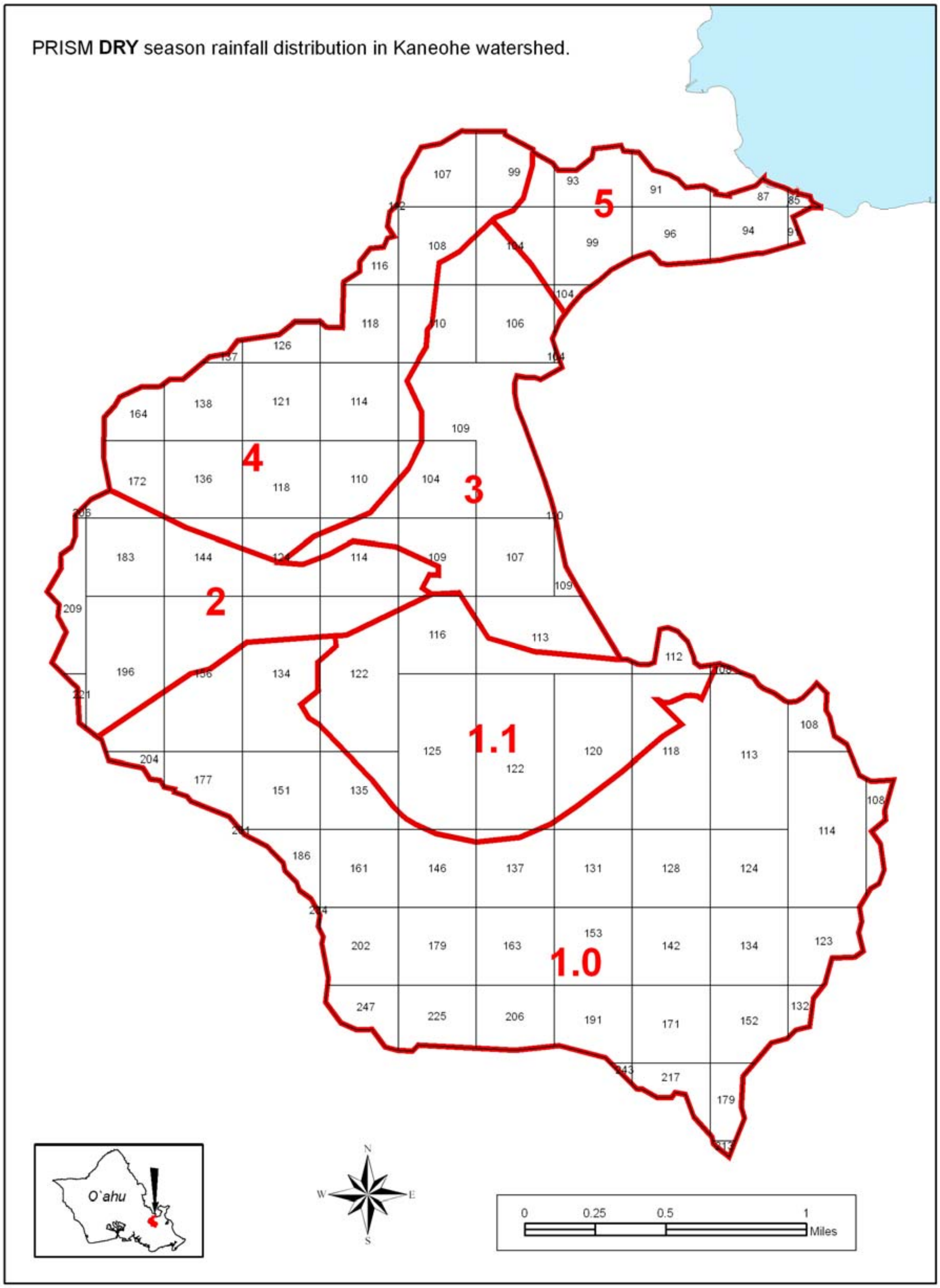


Figure 2-18. PRISM dry season rainfall distribution in Kaneohe watershed

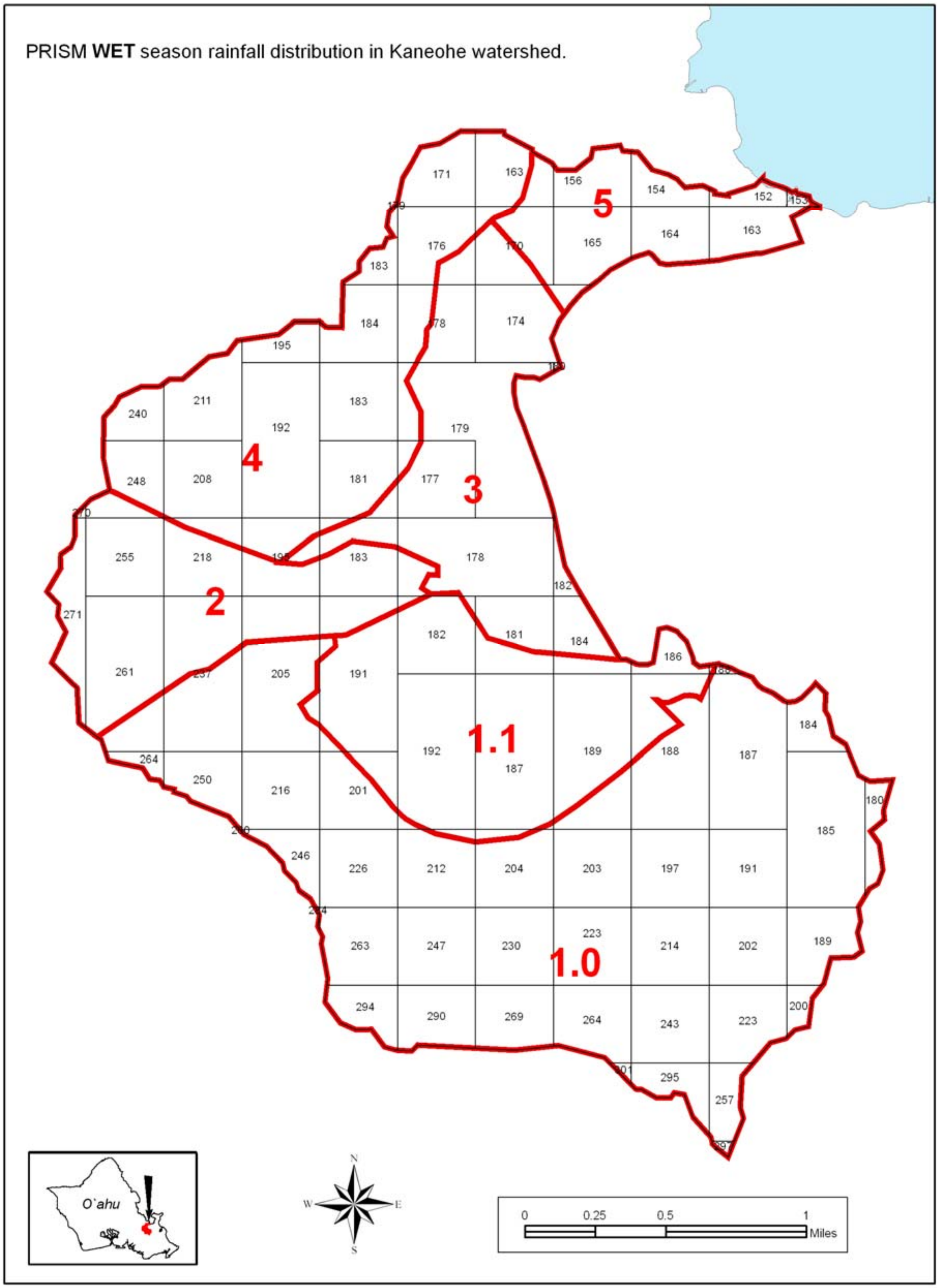


Figure 2-19. PRISM wet season rainfall distribution in Kaneohe watershed

3.1 Water Quality Sampling Campaigns

The assessment decisions and TMDL analysis for Kaneohe Stream use water quality data from sampling campaigns conducted in 2000-2002 by the Department of Health Clean Water Branch (DOH-CWB) and our contractors, Oceanit (OLI) and AECOS. Sampling stations are described in Tables 3.1 and displayed in Figure 3.1. The CWB campaign was limited to monthly grab sampling under baseline flow conditions (non-targeted). The Oceanit campaign focused on event-based automated sampling targeting storm flow conditions, and included opportunistic/diagnostic grab sampling across a range of flow conditions.

Table 3.1. Kaneohe Stream Water Quality Sampling Station Descriptions

CWB Station	OLI Station	Location (CWB-*OLI* names)	Latitude Deg	Latitude Min.00	Longitude Deg	Longitude Min.00	Elevation feet
5	1a	Hoomaluhia Dam-*Reservoir Outlet*	21°	23.509	157°	48.255	142
	1b	*-Pipe Outlet above Park Road*	21°	22.968	157°	48.368	264
6	1c	Kahua Lehua-*Lake inlet*	21°	23.149	157°	48.117	171
	1d	*-Lower Golf Course Stream*	21°	22.980	157°	47.745	219
	1e	*-Lower Pali Stream*	21°	23.063	157°	47.276	244
7	1f	Kamooalii Upper-*Koolau Golf Course Stream*	21°	22.457	157°	47.783	337
	1g	*-Upper Pali - Old Pali Road*	21°	22.067	157°	47.276	1010
	1h	*-Stream Inlet near dam*	21°	23.349	157°	48.439	185
4	2	Luluku Stream	21°	23.502	157°	48.558	213
3	3a	Kamooalii Lower-*East Kaneohe Stream*	21°	24.643	157°	48.059	36
	3b	*-Footbridge*	21°	24.441	157°	48.096	48
2	4a	West Kapunahala-*Kapunahala*	21°	24.649	157°	48.061	36
	4b	*-Kapunahala at Keneke St*	21°	24.300	157°	48.347	73
1	5	Wena Place-*Lower Kaneohe, Base Sta*	21°	24.674	157°	47.584	10
		Description/Access					
5	1a	Dam outlet structure, south side					
	1b	24" culvert above Hoomalahiu Park access road					
6	1c	Main inlet stream above wetland, access by pathway from Kahua Lehua camp ground					
	1d	Hoomaluhia Park bridge over stream					
	1e	Abandoned USGS Sta Near H-3 junction					
7	1f	Koolau Golf Course cart bridge behind clubhouse					
	1g	Intermittent waterfall from valley above old pali road 1/8th mi below lookout					
	1h	Footbridge over small stream, west side of dam					
4	2	Hoomaluhia Bridge just below USGS Station					
3	3a	Kamooalii Stream end above falls at junction with Kapunahala Stream, beginning of Kaneohe Stream					
	3b	Footbridge over stream apx. 1/3 mile above 3a, off Kukane St.					
2	4a	Inside culvert above waterfall at junction with Kamooalii/Kaneohe Stream					
	4b	Bridge over Kapunahala Stream					
1	5	Waikalua Place, through private residence					

CWB = DOH Clean Water Branch. OLI = Oceanit Laboratories, Inc.
Elevations are approximate from USGS quad map database. Latitude/Longitude data from USGS database WGS84 datum.

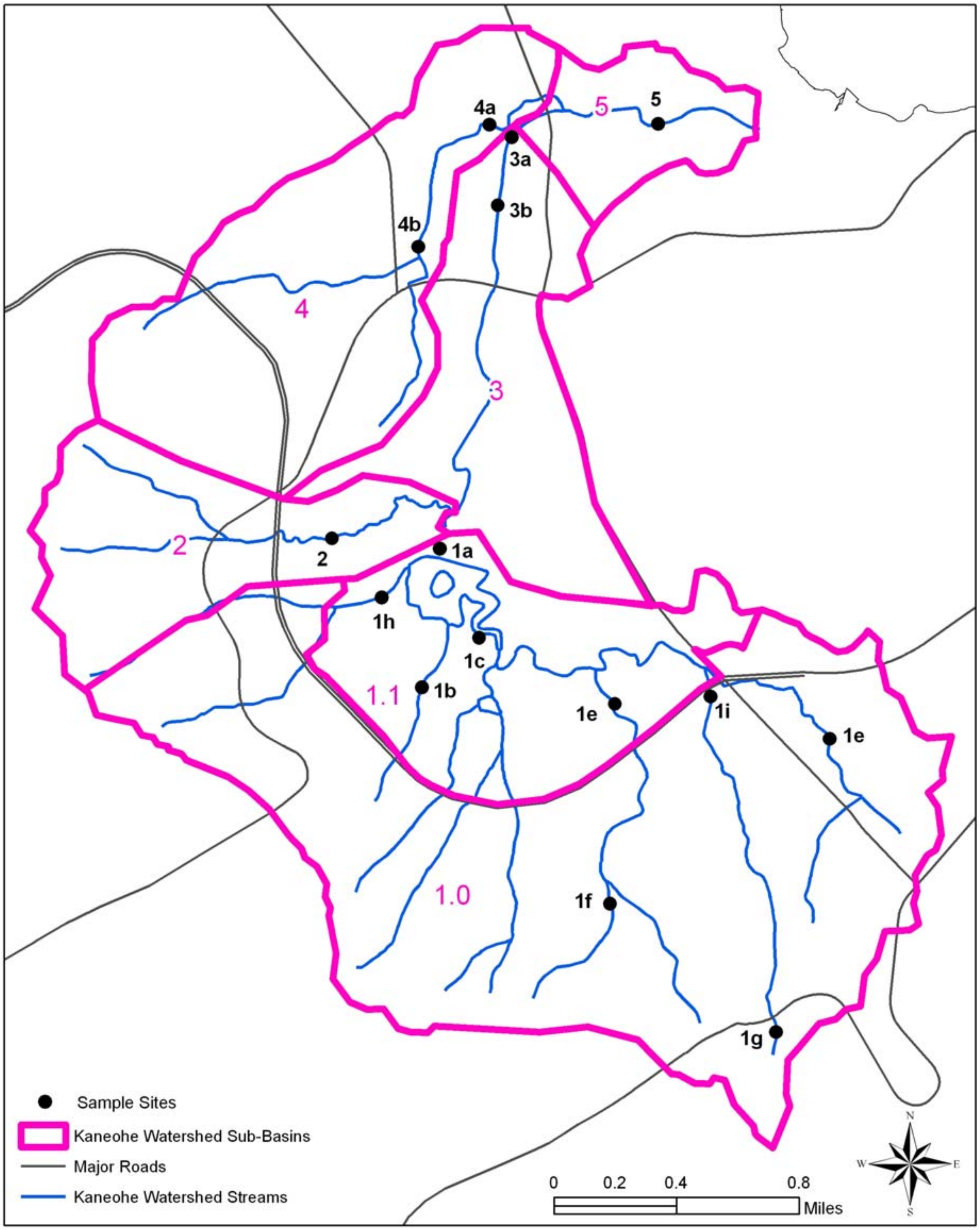


Figure 3-1. Water quality sampling station locations (as numbered by Oceanit)

Water quality data from both sampling campaigns is tabulated in Appendix A and summarized in the tables below. Baseline flow conditions measured in the field, using multiparameter water quality datasondes, included pH, temperature, conductivity, salinity, dissolved oxygen (DO), and turbidity. Ambient conditions including air temperature, weather, and stream flow were also recorded. All samples collected under both baseline and flow conditions were analyzed at the DOH lab or AECOS lab for the following parameters: turbidity, Total Dissolved Nitrogen (TDN), Total Nitrogen (TN), Total Dissolved Phosphorus (TDP), Total Phosphorus (TP), Nitrate+Nitrate Nitrogen (N+N), Ammonia (NH4), Total Suspended Solids (TSS), and Total Dissolved Silica. The suite of parameters analyzed for any particular sampling event differed depending upon the laboratory used, the volume of sample available, and the methods in use at the time of analysis.

3.2 Water Quality Sampling Results and Analysis

Tables 3.2 through 3.5 summarize the scope of the water quality sampling results, and the statistical analysis the data, for the parameters used in the impairment and TMDL analyses.

Table 3.2. Summary of Water Quality Sampling Results for Kaneohe Stream, Baseline Flow Conditions

Locations	Season	TSS (mg/L)		N + N (μg/L)		TDN (μg/L)*		TDP (μg/L)*		Turbidity (NTU)	
		GM	Exceed	GM	Exceed	GM	Exceed	GM	Exceed	GM	Exceed
Geomean Criterion	Wet	20		70		250 (TN)*		50 (TP)*		5	
	Dry	10		30		180 (TN)*		30 (TP)*		2	
Kamooalii Tributary											
1a to 1i	Wet	2.4	0 / 19	54	6 / 19	149	4 / 19	13	0 / 19	4.8	10 / 19
	Dry	3.1	1 / 19	24	7 / 19	124	3 / 19	18	3 / 19	**4.6**	17 / 21
1a (b. Dam)	Wet	1.0	0 / 6	50	2 / 6	177	1 / 6	11	0 / 6	2.4	1 / 6
	Dry	2.6	1 / 6	**34**	2 /6	**181**	1 / 6	21	1 / 6	**3.5**	2 / 6
1c	Wet	2.0	0 / 6	44	0 / 6	124	0 / 6	9	0 / 6	**8.8**	6 / 6
	Dry	4.1	0 / 6	22	2 / 6	95	1 / 6	14	1 / 6	**8.0**	6 / 6
1f	Wet	3.6	0 / 7	70	4 / 7	151	3 / 7	20	0 / 7	**5.2**	3 / 7
	Dry	2.9	0 / 7	19	3 / 7	112	1 / 7	21	1 / 7	**3.8**	9 / 9
2	Wet	3.5	1 / 7	**129**	7 / 13	182	1 / 7	34	1 / 7	**5.5**	3 / 7
	Dry	1.7	0 / 7	**66**	6 / 7	155	1 / 7	**40**	3 / 7	**2.9**	8 / 9
3	Wet	3.3	0 / 7	**208**	6 / 7	**422**	7 / 7	14	0 / 7	3.8	2 / 7
	Dry	6.2	1 / 7	**114**	6 / 7	**326**	6 / 7	21	1 / 7	**7.1**	9 / 9
All Data	Wet	2.8	1 / 33	87	19 / 33	194	12 / 33	16	1 / 33	4.7	15 / 33
	Dry	3.2	2 / 33	**41**	19 / 33	160	10 / 33	22	7 / 33	**4.6**	34 / 39
Kaneohe Stream											
4	Wet	7.2	0 / 6	**82**	4 / 6	170	1 / 6	21	0 / 6	**7.6**	5 / 6
	Dry	6.3	1 / 6	13	1 / 5	166	1 / 6	**34**	1 / 6	**7.2**	6 / 6
5	Wet	3.0	0 / 7	**218**	6 / 7	**383**	7 / 7	15	0 / 7	3.4	2 / 7
	Dry	6.3	1 / 7	**102**	6 / 7	**266**	3 / 7	25	1 / 7	**6.1**	9 / 9
All Data	Wet	4.5	0 / 13	**139**	10 / 13	**263**	8 / 13	17	0 / 13	4.9	7 / 13
	Dry	6.3	2 / 13	**44**	7 / 12	**214**	4 / 13	28	2 / 13	**6.5**	15 / 15

Notes: Bold font denotes exceedance of geomean criterion
TSS Total Suspended Solids
mg/L Milligrams per liter
N + N Nitrate + Nitrite
μg/L Micrograms per liter
*At the time of sampling, the DOH lab measured TDN (Total Dissolved Nitrogen) and TDP (Total Dissolved Phosphorus) only; this data was compared to the TN (Total Nitrogen) and TP (Total Phosphorus) criteria.
NTU Nephelometric Turbidity Units
GM Geometric Mean

Table 3.3. Summary of Water Quality Sampling Results for Kaneohe Stream, Storm Flow Conditions

Locations	TSS (mg/L)		Nitrate + Nitrite (μg/L)		TN (μg/L)		TP (μg/L)		Turbidity (NTU)	
	GM	**Exceed**	**GM**	**Exceed**	**GM**	**Exceed**	**GM**	**Exceed**	**GM**	**Exceed**
Wet Season Criterion										
10% NTE	50		180		520		100		15	
2% NTE	80		300		800		150		25	
Storm Geomean										
All Stations Combined										
Kamooalii	34.6	27 / 67	106	27 / 62	**1409**	44 / 57	**245**	50 / 56	**38.8**	45 / 66
Kaneohe	22.1	3 / 19	**325**	14 / 19	**1214**	10 / 17	**178**	14 / 17	**56.5**	14 / 19
Individual Stations										
Kamooalii Tributary										
1a to 1i	36.1	18 / 42	78.6	13 / 37	1501	25 / 34	**237**	29 / 33	**37.6**	26 / 41
1a	14.8	2 / 10	164	4 / 9	1502	6 / 8	**175**	6 / 8	**15.4**	4 / 9
1b	28.2	0 / 3	48.9	2 / 3	536	1 / 3	**151**	3 / 3	**24.3**	2 / 3
1h	**73.9**	3 / 4	**290**	1 / 1	485	0 / 1	**150**	1 / 1	**110**	4 / 4
1c-g + 1h	43.9	11 / 23	58.8	6 / 22	**1725**	16 / 20	**278**	17 / 19	**41.7**	14 / 23
2	38.2	6 / 13	101	5 / 13	**1896**	11 / 12	**300**	11 / 12	**47.6**	9 / 13
3a + 3b	26.7	3 / 12	145	9 / 12	**1622**	8 / 11	**199**	10 / 11	**34.7**	10 / 12
Kaneohe Stream										
4a + 4b	34.0	3 / 10	**338**	6 / 10	**2616**	9 / 9	**233**	7 / 9	**32.1**	7 / 10
5	13.7	0 / 9	**312**	8 / 9	512	1 / 8	131	7 / 8	**106**	7 / 9

Notes: Bold font denotes exceedance of NTE criterion
TSS Total Suspended Solids
mg/L Milligrams per liter
μg/L Micrograms per liter
TN (Total Nitrogen)
TP (Total Phosphorus)
NTU Nephelometric Turbidity Units
GM Geometric Mean
NTE Not to Exceed

3.3 Water Quality Impairment Analysis

The initial Clean Water Act Section 303(d) listings for these streams, in 2001, represent "legacy" assessment decisions that implied or stated the non-attainment of unspecified nutrient and sediment criteria under various streamflow regimes (and thus of various specific criteria including geomean, 10% NTE, and/or 2% NTE). The 2002-2006 process of validating and invalidating legacy assessment decisions solely on the basis of geomean criteria attainment means that a "delisting" of certain geomean criteria does not implicitly or explicitly delist legacy impairments tied to critical conditions. Thus the 2006 §303(d) listings for these streams pertain only to assessing the attainment of geomean criteria and/or legacy impairment listings that have yet to be re-evaluated with numeric assessments. Due to uncertainty about how to weigh dry-weather baseline samples, wet-weather baseline samples, and targeted storm samples (including auto-sampling of storm events and manual sampling of storm event recession) in assessing attainment of the 10% NTE and 2% NTE numeric criteria, only dry-weather and wet-weather baseline samples were used by DOH in developing the 2006 §303(d) list. In addition, listing decisions are based on the number of samples collected in wet and dry seasons, and consider whether photographs and visual assessments of the sampling locations and quality assurance documentation for the numeric data are available. Data from both upstream and downstream stations are aggregated to make listing decisions. More information on the §303(d) listing rationale, including a flow chart of the priority ranking and listing/delisting process for conventional pollutants, can be found in the 2006 Water Quality Monitoring and Assessment report (Environmental Health Administration 2008).

This TMDL analysis evaluated the water quality data with regard to the seasonal geomean (wet and dry) and wet season 10% NTE water quality criteria. Data used for evaluating geomean criteria included the data used in the 2006 §303(d) list plus dry-weather and wet-weather baseline grab samples that are scheduled without regard to flow conditions. For each stream, data from all stations were aggregated to determine compliance with water quality criteria.

Data from targeted sampling of stormflow conditions in 2001-2002 (see Appendix A) was intended to be used for addressing the critical conditions represented by the spectrum of 10% NTE and 2% NTE criteria, with the wet season 10% NTE criterion chosen for simplifying the endpoint at an intermediate critical condition. In addition, wet-weather baseline samples from May 7, 2002 were added to the storm flow dataset; these samples are identified as samples collected on days when either the daily or previous three-day precipitation total is greater than the corresponding 80^{th} percentile values. Two assumptions were made to support this analysis - the highest pollutant concentrations occurred during periods of high flow and high precipitation, and the geomean of the values greater than the 80^{th} percentile would be equivalent to the 90^{th} percentile value that is comparable to the 10% NTE value. This methodology was preferable to taking the 90^{th} percentile value of the current data set; the inclusion of each individual data point from targeted storm sampling data (which resulted in multiple samples collected during a daily storm event) would have skewed the results. Also, since there were few storm flow data collected during the dry season, it was more appropriate to aggregate and compare to the wet season 10% NTE standard; in addition the data was also compared to the wet season 2% NTE standard.

For this analysis, in the case of nutrient and sediment-related parameters, a waterbody is considered impaired by a pollutant if the statistical analysis of the data produces exceedance of any of the 3 decision endpoints: the dry season geomean, wet season geomean, or the wet season 10% NTE criterion. The results of this impairment analysis, and their influence on accompanying TMDL decisions, are summarized in Table 3.4. Note that these results are different from those in the 2006 Water Quality Monitoring and Assessment Report as follows:

1. TP impairments assigned to storm flow conditions in both streams, not to baseline flow conditions as in 2006.
2. Dieldrin impairment from 2006 is assumed to be ubiquitous in both streams, and is not included in the TMDL analysis for lack of sufficient data. However, we assume that implementation of nutrient and turbidity measures will include some controls on erosion. and sedimentation that will help to reduce future dieldrin loading. Dieldrin impairment will be revaluated in 2010 Water Quality Monitoring and Assessment Report.
3. Dissolved Oxygen and pH impairments are assigned to both streams under baseline flow conditions (see details in Table 3.5). These impairments are not addressed in the TMDL

analysis, and will be revaluated in the 2010 Water Quality Monitoring and Assessment Report.

4. TN and Turbidity impairments are assigned to both streams under storm flow conditions as well as baseline flow conditions.
5. NO3+NO2 impairments are assigned to Kaneohe Stream, and not to the Kamooalii tributary, under storm flow conditions as well as baseline flow conditions

Table 3.4. Waterbody Impairment Summary for Kaneohe Stream

	Kaneohe Stream		**Kamooalii Tributary**	
Geocode ID	3-2-10	3-2-10	3-2-10.01	3-2-10.01
Season	Dry	Wet	Dry	Wet
Impairment Analysis from 2006 §303(d) List (listed impairments in bold type)				
Enterococci	Unknown	Unknown	Unknown	Unknown
Total Nitrogen (TN)	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004
Nitrate+Nitrite Nitrogen (NO3+NO2)	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004
Total Phosphorus (TP)	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004	**Visual Listing** from 2001-2004
Turbidity	**Not Attained**	**Not Attained**	**Not Attained**	Unknown
Total Suspended Solids (TSS), Other Pollutants	TSS (Unknown), **Dieldrin**	TSS (Unknown), **Dieldrin**	TSS (Unknown)	TSS (Unknown)
Category	3, 5	3, 5	3, 5	3, 5
2006 Impairments	TN, NO3+NO2, TP, Turbidity, Dieldrin		TN, NO3+NO2, TP, Turbidity	
# of Impairments	5		4	
Impairments From TMDL Analysis				
Baseline Flow	TN, NO3+NO2, Turbidity	TN, NO3+NO2	NO3+NO2, Turbidity	NO3+NO2
	Dissolved Oxygen, pH[1]		Dissolved Oxygen, pH[1]	
Storm Flow[2]	TN, NO3+NO2, TP, Turbidity		TN, TP, Turbidity	
Flow-neutral	Dieldrin[3]		Dieldrin[3]	
# of Impairments	7		7	
# of TMDLs	**4**		**4**	
Total # of Impairments/TMDLs resolved in this decision document = 8				

Notes:

1 Dissolved oxygen and pH impairments are not addressed in the TMDL analysis, and will be revaluated in the 2010 Water Quality Monitoring and Assessment Report.

2 Storm analyses included 5/7/02 baseline flow data due to high flow conditions on that day; the wet 10% NTE was used as the criteria for the Storm Flow analysis.

3 Dieldrin impairment is not resolved by the TMDL analysis, and will be revaluated in 2010 Water Quality Monitoring and Assessment Report.

Table 3.5. Summary of Dissolved Oxygen and pH Sampling Results for Kaneohe Stream

Locations	**Dissolved Oxygen (Percent Saturation)**		**pH**	
Criterion	Less Than 80%		Less than 5.5 or Greater than 8.0	
Season	Wet	Dry	Wet	Dry
Kamooalii Tributary				
1a to 1i	1 / 20	8 / 21	8 / 20	6 / 20
1a (b. Dam)	0 / 6	2 / 6	2 / 6	0 / 6
1c	0 / 6	3 / 6	0 / 6	0 / 5
1f	1 / 8	3 / 9	6 / 8	6 / 9
2	0 / 9	2 / 9	4 / 9	2 / 9
3	0 / 9	1 / 9	8 / 9	8 / 9
All Kamooalii	1 / 38	11 / 39	20 / 38	16 / 38
Kaneohe Stream				
4	0 / 6	1 / 6	6 / 6	6 / 6
5	0 / 9	2 / 9	5 / 9	8 / 9
All Kaneohe	0 / 15	3 / 15	11 / 15	14 / 15

4.1 Calculation Methods

The principal objective of calculation methods in this analysis is to relate stream flows and pollutant concentrations to individual contributions from identified sources of baseflow volumes, storm runoff, and pollutant loadings. Sources in each sub-basin are identified as land use categories, e.g., forest, agriculture, residential, etc. These methods are a series of mass balance calculations described in mathematical detail in Appendix B and summarized in the following.

Dry Weather Baseflows

Dry weather seasonal baseflows are determined from a flow recession model developed for the adjacent Kawa Stream watershed (Environmental Planning Office, 2005). In this model, baseflow is a direct function of accessible soil/ground water storage. Soil water volume increases with infiltration of precipitation and is depleted by discharge to baseflow, evapotranspiration, and percolation to deep groundwater. Infiltration and evapotranspiration are both curtailed by impervious surfaces. Infiltration is further reduced by the fraction of impervious surface that is connected directly to a storm sewer collection system. Thus the primary properties that determine baseflow volume contributions from each source are the source area, impervious fraction, and connected fraction of the impervious area. Also part of the calculation is geography as precipitation (thus infiltration) varies with location in the watershed in accord with PRISM seasonal rainfall distributions.

Characteristic soil water concentrations of TSS, TN, and TP are estimated for each land use category, based first on reported groundwater concentration data and then adjusted to reflect observed dry weather Kaneohe Stream concentrations. Baseflow pollutant load contributions from each source are then the products of the categorical soil water concentrations and the baseflow volume contribution from the source. Sub-basin baseflow volume and pollutant load contributions are the sum of individual contributions from each land use category source in the sub-basin.

Wet Weather Storm Flows

Runoff volumes for individual storm events are determined from the well established SCS runoff formulation (USDA 1986) where the hydrologic effects of land use, cover, imperviousness, and soil properties are conjoined in a single curve number (CN) value for each individual source. Rainfall distributions among source locations for individual storm events are considered to be proportional, on average, to PRISM seasonal rainfall distributions.

Characteristic storm runoff concentrations of TSS, TN, and TP are estimated for each land use category, based first on reported stormwater runoff data and then adjusted to reflect observed wet weather Kaneohe Stream concentrations. Storm flow pollutant load contributions from each source are then the products of the categorical runoff concentrations and the storm runoff volume contribution from the source. Sub-basin runoff volume and pollutant load contributions are the sum of individual contributions from each land use category source in the sub-basin. For the storm event, net sub-basin contributions are the sum of runoff contributions and seasonal baseflow contributions.

Streamflows and Water Quality

Streamflows in and pollutant loadings to each stream segment are the sum of inflows from its tributary sub-basin and outflows from the immediately upstream segment(s).
Portions of the inflowing pollutant loadings are considered to be assimilated within the segment by sedimentation and/or biological uptake. By either mechanism, assimilation is proportional to the stream segment surface area and to pollutant concentration.

Dry weather conditions are regarded as steady state. Stream segment outflows are equal to total inflows. Pollutant load outflows are equal to total inflowing loads less the assimilation within the segment. For a storm event condition, streamflow is considered to increase over a "time of concentration" from baseflow to an event-maximum level that remains for the event duration and then declines back to the baseflow level. Event mean streamflows and pollutant concentrations for the event are calculated as their averages over an event period of rainfall duration plus the estimated "time of concentration." These calculation procedures are diagrammed in Figure 4-1(a) and (b).

4.2 Source Area Distributions

Within the Kaneohe watershed, politically-derived State Land Use District Boundaries, Conservation District Subzone boundaries, and County Zoning dictate legally-permissible uses of private and public property (Figure 4-2). The Conservation District Subzone boundaries also dictate the location of Class 1.b. stream segments (Figure 4-4). Scientifically-derived land cover classes indicate the physical characteristics of this property (Figure 4-3 and Table 4.1), and human activity may ignore legal permissions and alter physical characteristics.

There are no public or industrial treatment facility discharges in the Kaneohe Stream watershed. The identified sources of pollutants in this watershed are therefore land use areas contributing baseflows and storm runoff to the stream. The distributions of these areas within each sub-basin of the watershed are displayed in Figure 4-2 and tabulated in Table 4.1 below. The land use areas are divided into forest, agriculture, parks, golf courses, cemeteries, institutional (schools and hospitals), residential, commercial, and City and County of Honolulu streets and DOT highways (both separated into roadways with curbs and those with swales).

Table 4.1. Kaneohe Watershed Land Use Areas

LAND USE AREAS (Acres)									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	994	60	0	359	20	35		0	0	0	0	60	1527
1.1	10	0	382	0	25	36	37	0	2	6	0	0	498
2	271	93	0	0	0	0	0	0	0	0	0	8	372
3	14	5	4	0	0	10	343	29	25	7	7	0	444
4	250	82	30	0	0	47	208	15	11	9	10	17	678
5	0	0	22	0	0	7	118	1	7	12	1	0	168
Totals	1538	241	437	359	45	135	706	45	45	33	18	85	3686

Notes:
Basin 1.0 Golf Course = 216 ac Pali G.C. + 143 ac Koolau G.C.
Basin 1.1 Parks = 357.56 ac Botanical Garden + 26 ac Reservoir
Basin 4 Institutional = 26 ac DOH Hospital + 21 ac UH Windward Community College

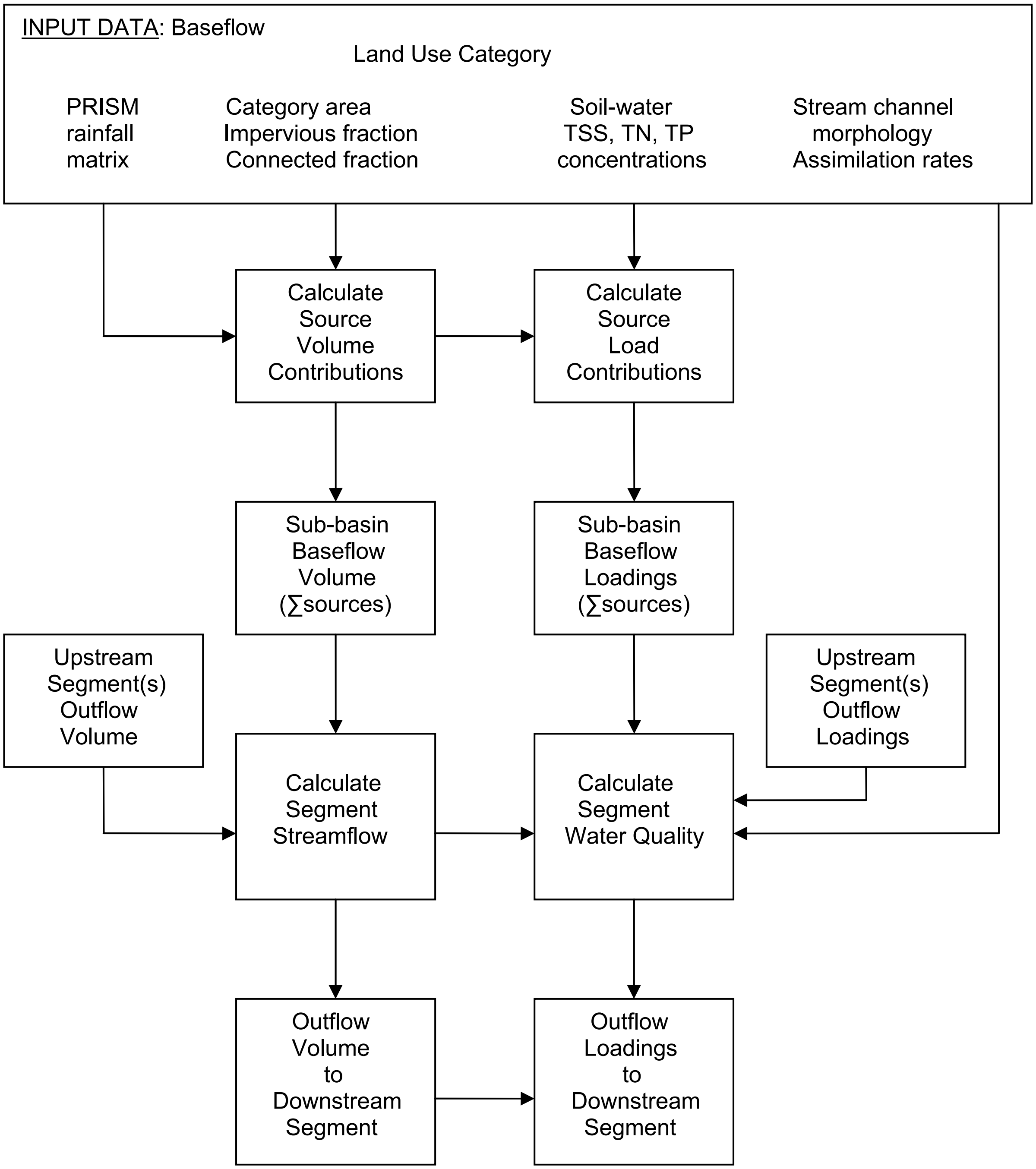


Figure 4-1. ***(a)*** Kaneohe baseflow calculation schematic

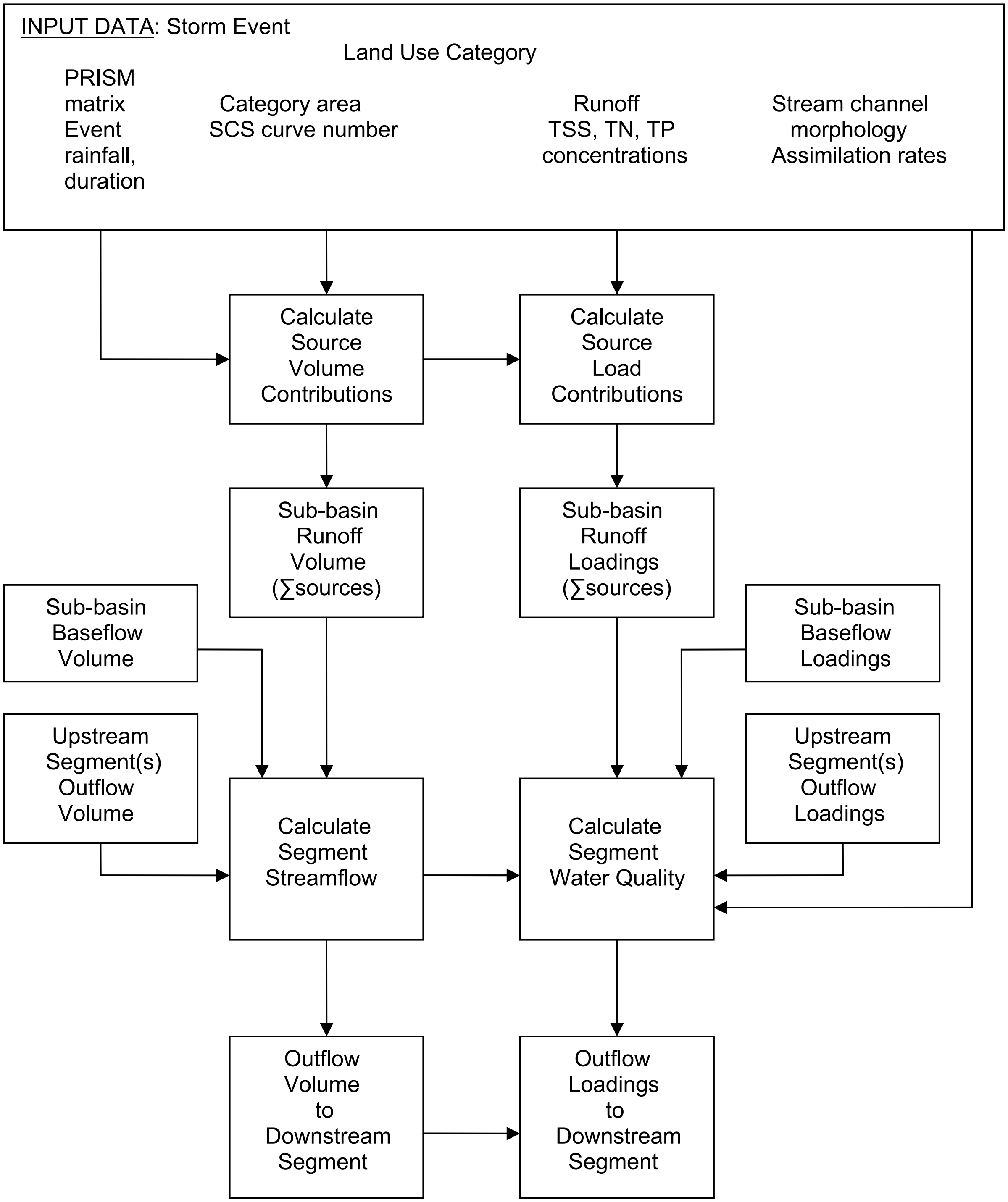


Figure 4-1. (b) Kaneohe storm event calculation schematic

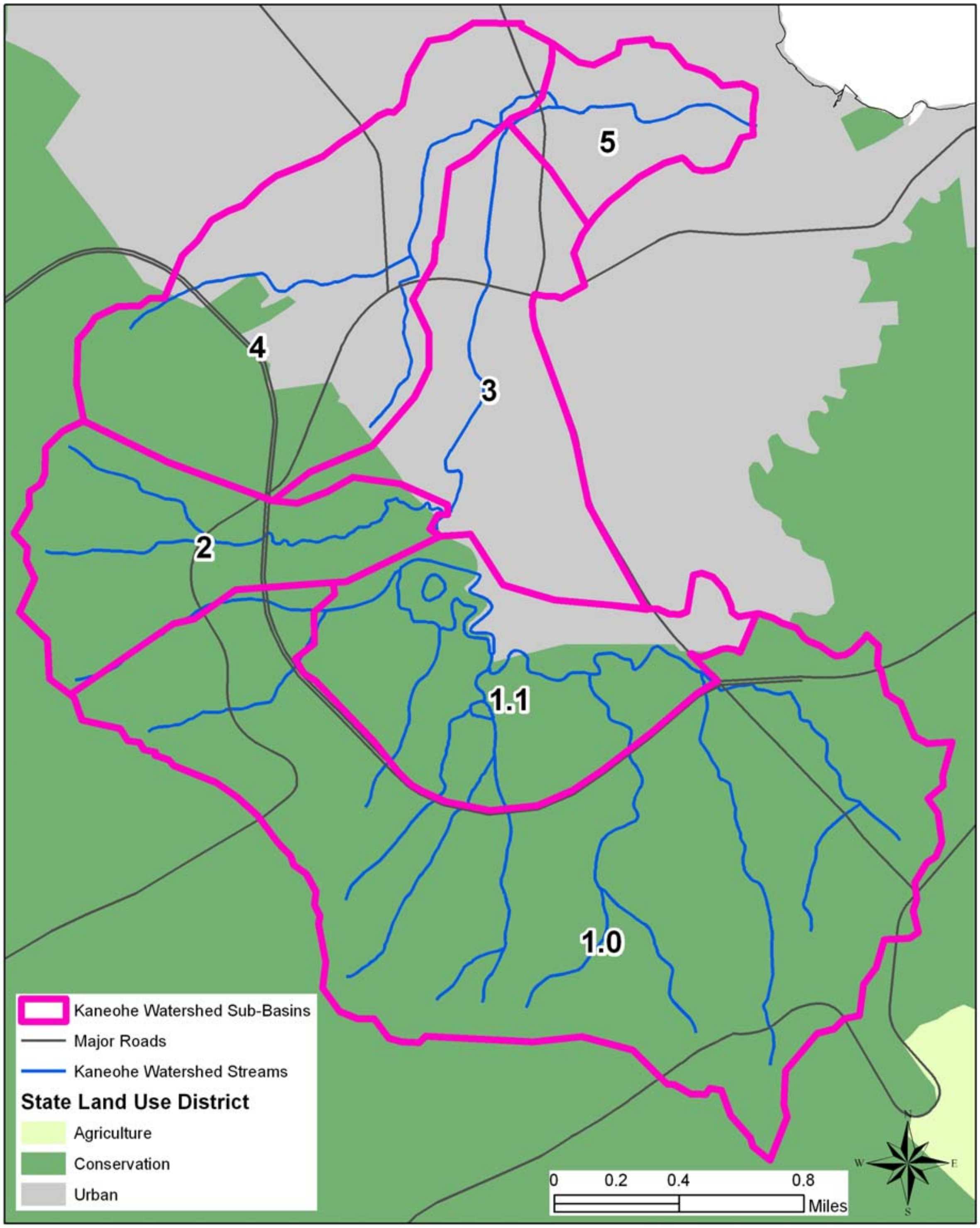


Figure 4-2. State land use classifications in the Kaneohe watershed

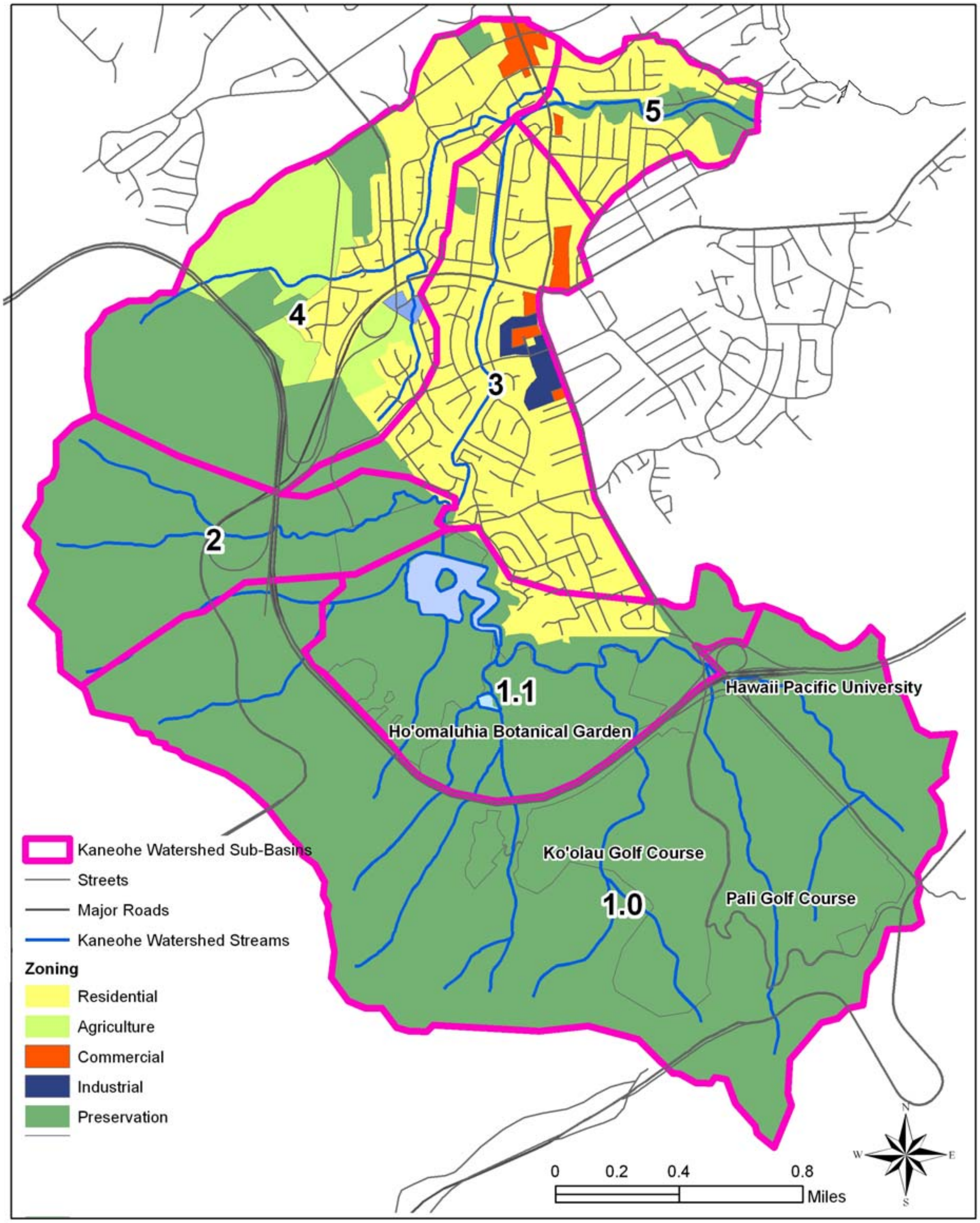


Figure 4-3. Land use distribution in Kaneohe watershed

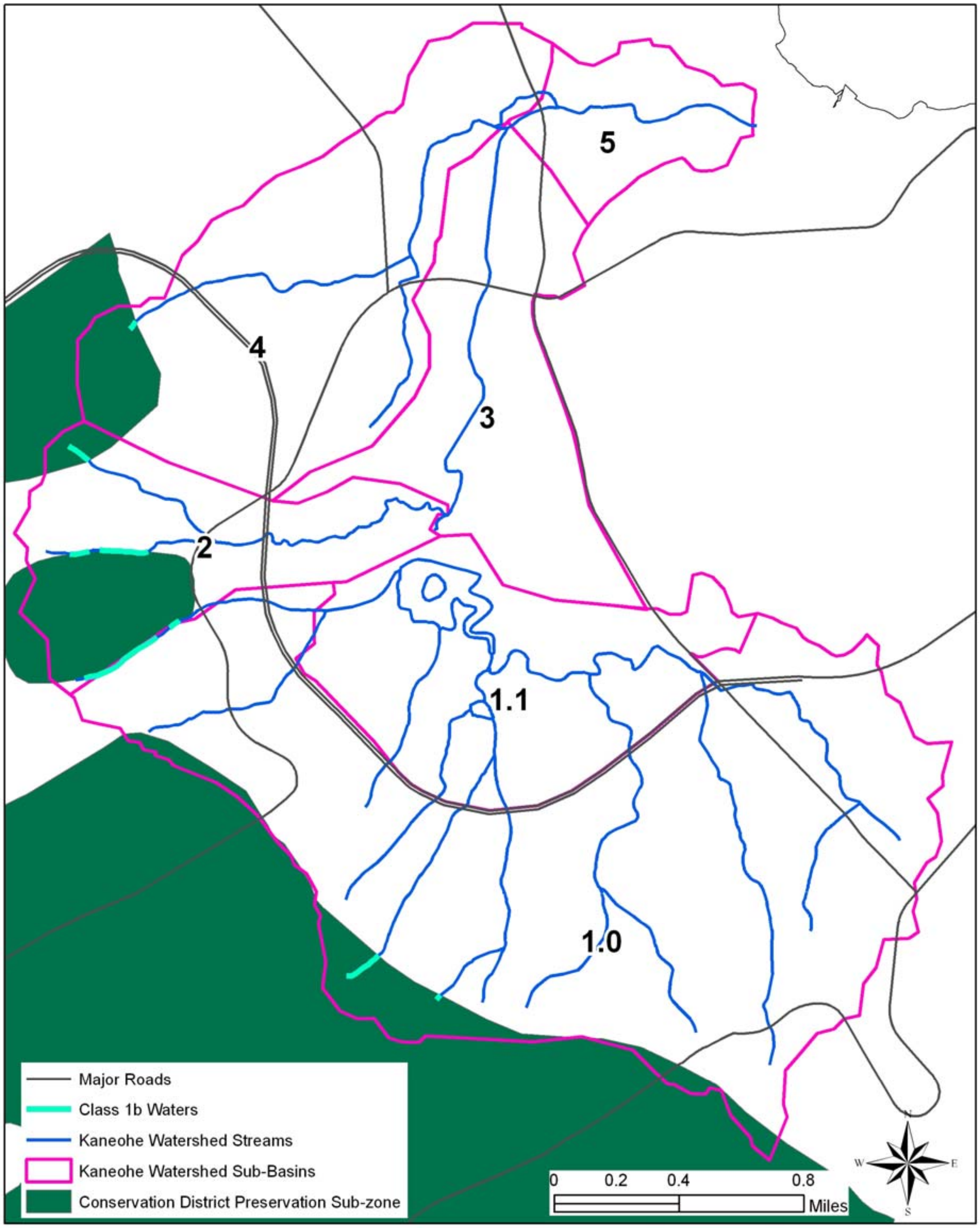
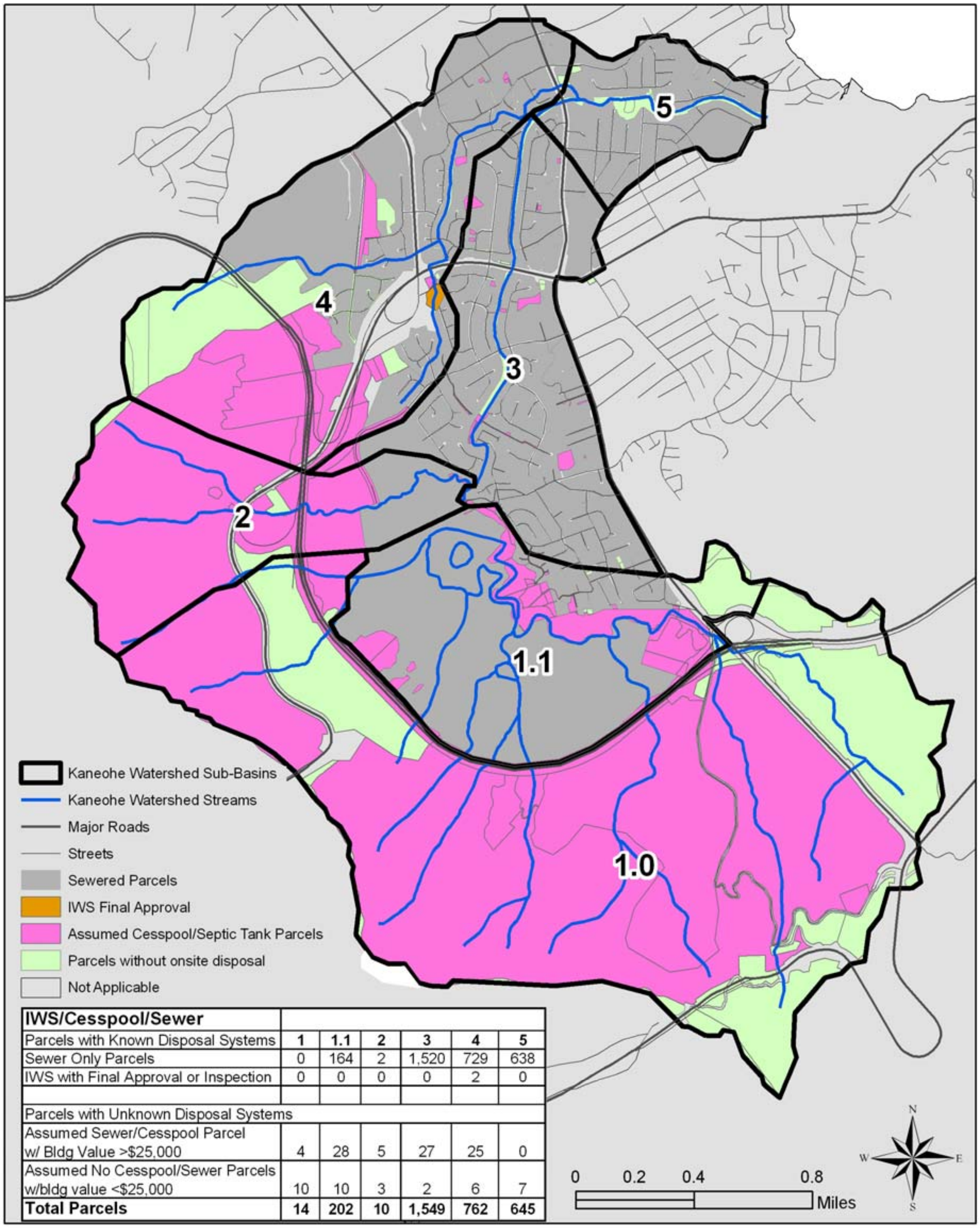


Figure 4-4. Class 1-b Waters and Conservation District sub-zone in the Kaneohe watershed

Outside of areas served by a sewer system, waste disposal is through onsite septic and cesspool systems, including large capacity cesspools at schools and at public parks (see Figure 4-5). Although the construction of cesspools has been restricted since August 1991, and large capacity cesspools were ordered closed in 2003, many older residences and facilities may still be using cesspools as their wastewater disposal method. Problems with cesspools may include, but are not limited to, failure due to improper operation and lack of maintenance, and seepage, which may cause contamination of coastal waters, streams, and perhaps even potable groundwater (Whittier et al. 2004). The subsurface flow of wastewater from cesspool pits cannot be easily traced, but since the flow of subsurface water is toward streams, we can reasonably conclude that wastewater from cesspools into streams will contribute to nitrogen and phosphorus loadings.

The State of Hawaii Department of Health Wastewater Branch (DOH-WWB) maintains a database that includes information about cesspool and septic tank plan (IWS) approvals and construction inspections. Planned IWS are not always constructed, and planned systems may be operating without final approval or inspection. Thus our identification of "IWS with Final Approval" may be a conservative estimate the total number of operating IWS potentially known to DOH. Data below is current as of 2006, and may not reflect newer construction projects.

Parcels with a Building Value Greater than $25,000 appear to have structures on them due to their layout, zoning, dwelling unit data, and building value. For the purposes of this report, parcels with these attributes were assumed to have a bathroom and a cesspool for disposal, as they are beyond sewer service areas. Google Earth Satellite photos, personal information, and newspaper accounts of home sales were used to verify these structures. Parcels with low to no building value, no obvious road access, no satellite photo evidence and no personal verification were assumed to have no buildings and no cesspools.



IWS/Cesspool/Sewer						
Parcels with Known Disposal Systems	**1**	**1.1**	**2**	**3**	**4**	**5**
Sewer Only Parcels	0	164	2	1,520	729	638
IWS with Final Approval or Inspection	0	0	0	0	2	0
Parcels with Unknown Disposal Systems						
Assumed Sewer/Cesspool Parcel w/ Bldg Value >$25,000	4	28	5	27	25	0
Assumed No Cesspool/Sewer Parcels w/bldg value <$25,000	10	10	3	2	6	7
Total Parcels	**14**	**202**	**10**	**1,549**	**762**	**645**

Figure 4-5. Kaneohe Watershed Waste Disposal

4.3 Hydrologic Properties

As described above and in Appendix B, baseflow contributions from the Kaneohe Stream watershed are determined by impervious and storm sewer connected areas. Storm runoff contributions are determined by SCS curve number (CN) values. These important hydrologic properties for the existing Kaneohe Stream watershed are summarized in Table 4.2 and are based on Kaneohe hydrologic soil groups presented in Figure 4-6.

Table 4.2. Hydrologic Properties of Kaneohe Stream Watershed.

a. IMPERVIOUS AREA FRACTIONS

									CCH Streets		DOT Highways	
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales
1.0	0.4	0.02	0.05	0.1	0.05	0.2	0.37	0.8	1	0.8	0.85	0.75
1.1	0	0.03	0.05	0.1	0.05	0.2	0.37	0.8	1	0.8	0.85	0.75
2	0.64	0.03	0.05	0.1	0.05	0.2	0.37	0.8	1	0.8	0.85	0.75
3	0	0.03	0.05	0.1	0.05	0.2	0.37	0.8	1	0.8	0.85	0.75
4	0.37	0.05	0.05	0.1	0.05	0.2	0.37	0.8	1	0.8	0.85	0.75
5	0	0.03	0.05	0.1	0.05	0.2	0.37	0.8	1	0.8	0.85	0.75

b. CONNECTED IMPERVIOUS FRACTIONS

									CCH Streets		DOT Highways	
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales
1.0	0	0	0	0	0.5	0.4	0.43	1	1	0.5	1	0.5
1.1	0	0	0	0	0.5	0.4	0.43	1	1	0.5	1	0.5
2	0	0	0	0	0.5	0.4	0.43	1	1	0.5	1	0.5
3	0	0	0	0	0.5	0.4	0.43	1	1	0.5	1	0.5
4	0	0	0	0	0.5	0.4	0.43	1	1	0.5	1	0.5
5	0	0	0	0	0.5	0.4	0.43	1	1	0.5	1	0.5

c. SCS CURVE NUMBERS

									CCH Streets		DOT Highways	
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales
1.0	61	61	61	61	61	68	80	92	98	89	98	89
1.1	48	61	61	61	61	68	80	92	98	89	98	89
2	67	61	61	61	61	68	80	92	98	89	98	89
3	48	61	61	61	61	68	80	92	98	89	98	89
4	61	61	61	61	61	68	80	92	98	89	98	89
5	48	61	61	61	61	68	80	92	98	89	98	89

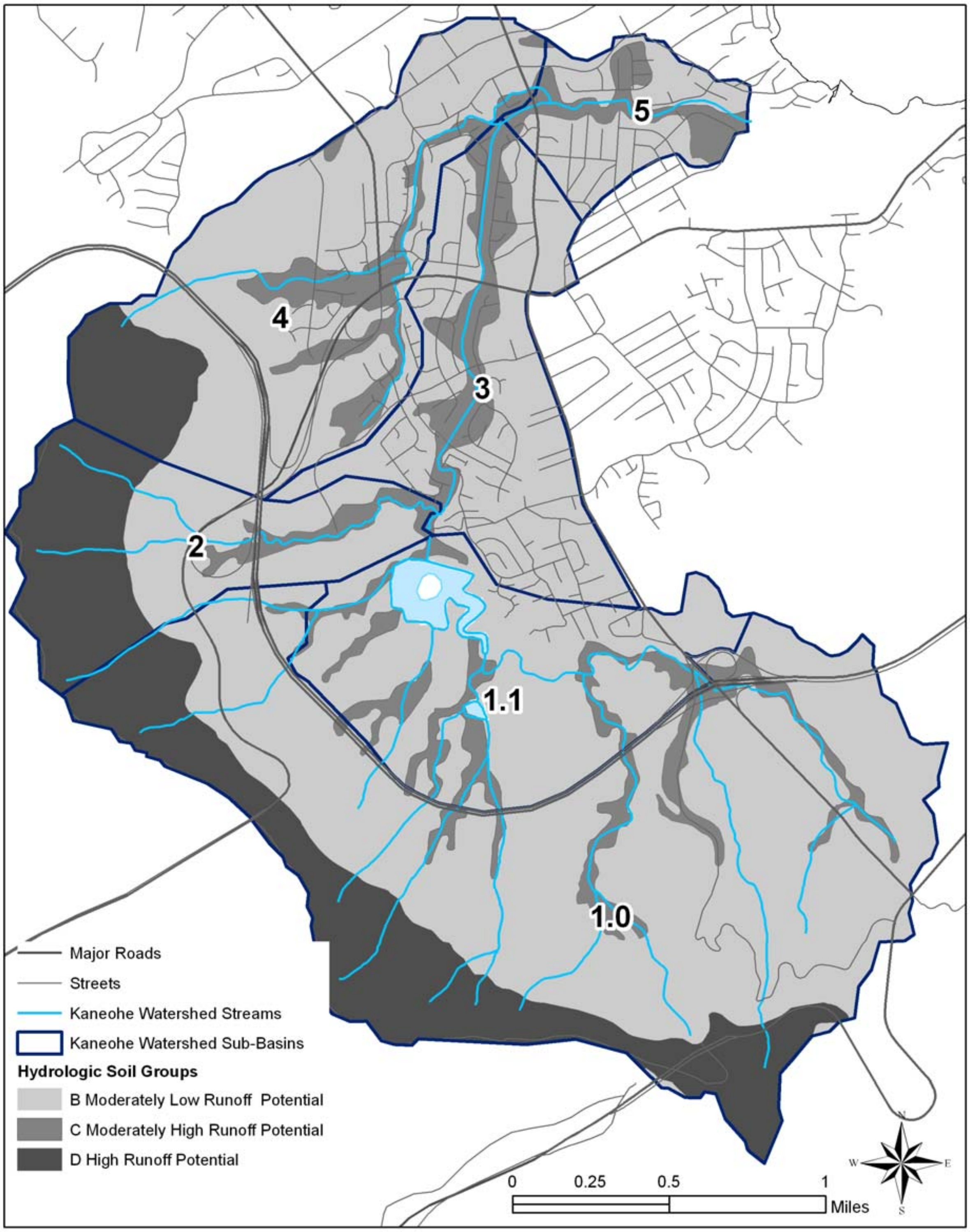


Figure 4-6. Kaneohe Watershed Hydrologic Soil Groups

4.4 Pollutant Source Concentrations

Pollutant concentrations that are associated in this analysis with land use sources are presented in Table 4.3. Baseflow concentrations were initially developed from reported mean USGS NAWQA groundwater concentrations (Hunt 2004) and then adjusted according to 2001-2002 baseline water quality data and stream assimilation rates assumed in this analysis. Storm runoff concentrations were initially developed from event mean concentration (EMC) data reported by EPA's National Urban Runoff Program (EPA 1983, Pitt et al 2003) and other estimates of nonpoint source pollutant loading rates (Shannon and Brezonik 1972, Uttermark et al 1974). These initial estimates were then adjusted according to the wet weather water quality data and the calibrated stream assimilation rates. Stream assimilation rates are represented as sedimentation velocities and their calibrated values are also included in Table 4.3.

Table 4.3. Pollutant Source Concentrations and Assimilation Rates

a. BASEFLOW CONCENTRATIONS (mg/l)									CCH Streets		DOT Highways	
Const.	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales
TSS	20	30	20	20	20	20	60	60	60	60	60	60
TN	0.5	1	0.5	0.5	0.75	1	1.2	1.2	1.2	1.2	1.2	1.2
TP	0.05	0.1	0.05	0.05	0.05	0.05	0.1	0.1	0.1	0.1	0.1	0.1
b. RUNOFF CONCENTRATIONS (mg/l)									CCH Streets		DOT Highways	
Const.	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales
TSS	100	150	100	80	80	80	180	150	180	120	180	100
TN	3	6	2	3	3	2	2	1.5	3	1	3	2
TP	0.6	1.2	0.5	0.5	0.5	0.5	0.5	0.6	1	0.6	1	0.6
c. ASSIMILATION RATES (ft/sec)				TSS		TN	TP					
				0.0003		5E-05	0.0001					

4.5 Stream Channel Hydraulics

Streamflow hydraulics in Kaneohe Stream segments are functions of morphological properties of the segments. The channel properties assumed for this analysis are summarized in Table 4.4.

Table 4.4. Kaneohe Stream Segment Channel Morphology

STREAM CHANNEL MORPHOLOGY									
		from	to	Length	Width	Slope	Manning	Tconc	Sediment
Seg	Description	River Mile	River Mile	(ft)	(ft)	(ft/ft)	n	(hr)	Efficiency
1.0	Upper Kamooalii	4.38	2.68	9,000	12	0.038	0.04	2	1
1.1	Reservoir	2.68	2.21	2,500	454	0	0.04	1	0.5
2	Luluku Stream	3.15	2.21	5,000	10	0.048	0.04	1	1
3	Lower Kamooalii	2.21	0.88	7,000	20	0.016	0.04	2	1
4	Kapunahala Str.	2.25	0.88	7,250	20	0.048	0.04	2	1
5.0	Kaneohe Stream	0.88	0.30	4,650	100	0.009	0.04	2	1
5.1	Kaneohe Estuary	0.30	0.00	1,600	120	0.0013	0.04	1	1

4.6 Existing Dry Season Conditions

Dry Season Baseflow. The highest CN-value for the land use categories in the Kaneohe watershed is 98 (streets/highways with curbs). This value translates into a minimum rainfall of 0.04-inch before runoff will occur. During an average 58% of the dry season days, rainfall at the Pali Golf Course weather station will be less than this minimum rainfall amount and baseflow conditions should prevail. Calculated baseflow and pollutant load contributions for this 58% time period are summarized in Table 4.5. Calculated base streamflow and water quality along the mainstem length of the Kaneohe Stream system are displayed in Figure 4-7. Diamond symbols on this and subsequent figures represent stream flows and pollutant concentrations of segments 2 (Luluku Stream) and 4 (Kapunahala Stream). TMDL target concentrations are also displayed in Figure 4-7 and subsequent figures.

Dry Season 10% Rainfall Event. Rainfall at Pali Golf Course is equal to or greater than 0.35-inch during an average 10% of the dry season days. Calculated runoff and pollutant load contributions for this 0.35-inch rainfall event are summarized in Table 4.6. Calculations of streamflow and water quality for this 10% rainfall event are displayed in Figure 4-8.

Dry Season 2% Rainfall Event. Rainfall at Pali Golf Course is equal to or greater than 1.27-inch during an average 2% of the dry season days. Calculated runoff and pollutant load contributions for this 1.27-inch rainfall event are summarized in Table 4.7. Calculations of streamflow and water quality for this 2% rainfall event are displayed in Figure 4-9.

Table 4.5. Existing Dry Seasonal Baseflow and Pollutant Load Contributions

a. Dry Season Baseflow Sources (cfs)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	3.94	0.14	0.00	0.80	0.02	0.05	0.00	0.00	0.00	0.00	0.00	0.14	5.09
1.1	0.02	0.00	0.74	0.00	0.03	0.05	0.07	0.00	0.00	0.01	0.00	0.00	0.92
2	1.18	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	1.41
3	0.02	0.01	0.01	0.00	0.00	0.02	0.58	0.02	0.01	0.01	0.00	0.00	0.69
4	0.85	0.17	0.04	0.00	0.00	0.07	0.36	0.01	0.01	0.02	0.01	0.04	1.57
5	0.00	0.00	0.02	0.00	0.00	0.01	0.16	0.00	0.00	0.02	0.00	0.00	0.22
Totals:	6.01	0.53	0.81	0.80	0.05	0.19	1.17	0.03	0.02	0.06	0.01	0.20	9.89

b. Dry Season Baseflow TSS Loads (kg/day)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	192.71	10.04	0.00	39.22	1.10	2.28	0.00	0.00	0.00	0.00	0.00	20.63	265.97
1.1	0.97	0.00	36.37	0.00	1.41	2.34	10.10	0.00	0.14	1.75	0.00	0.00	53.08
2	57.61	15.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.23	76.39
3	0.99	0.75	0.27	0.00	0.00	0.76	85.61	2.91	2.00	1.94	0.71	0.00	95.94
4	41.69	12.32	2.01	0.00	0.00	3.38	53.07	1.30	0.87	2.50	1.04	5.33	123.52
5	0.00	0.00	1.18	0.00	0.00	0.51	23.53	0.10	0.50	2.83	0.12	0.00	28.76
Totals:	293.97	38.66	39.83	39.22	2.51	9.27	172.30	4.31	3.51	9.02	1.87	29.19	643.66

c. Dry Season Baseflow TN Loads (kg/day)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	4.82	0.33	0.00	0.98	0.04	0.11	0.00	0.00	0.00	0.00	0.00	0.41	6.70
1.1	0.02	0.00	0.91	0.00	0.05	0.12	0.20	0.00	0.00	0.04	0.00	0.00	1.34
2	1.44	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	2.02
3	0.02	0.02	0.01	0.00	0.00	0.04	1.71	0.06	0.04	0.04	0.01	0.00	1.96
4	1.04	0.41	0.05	0.00	0.00	0.17	1.06	0.03	0.02	0.05	0.02	0.11	2.95
5	0.00	0.00	0.03	0.00	0.00	0.03	0.47	0.00	0.01	0.06	0.00	0.00	0.60
Totals:	7.35	1.29	1.00	0.98	0.09	0.46	3.45	0.09	0.07	0.18	0.04	0.58	15.58

d. Dry Season Baseflow TP Loads (kg/day)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0.48	0.03	0.00	0.10	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.66
1.1	0.00	0.00	0.09	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.12
2	0.14	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.20
3	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.16
4	0.10	0.04	0.01	0.00	0.00	0.01	0.09	0.00	0.00	0.00	0.00	0.01	0.27
5	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.05
Totals:	0.73	0.13	0.10	0.10	0.01	0.02	0.29	0.01	0.01	0.02	0.00	0.05	1.46

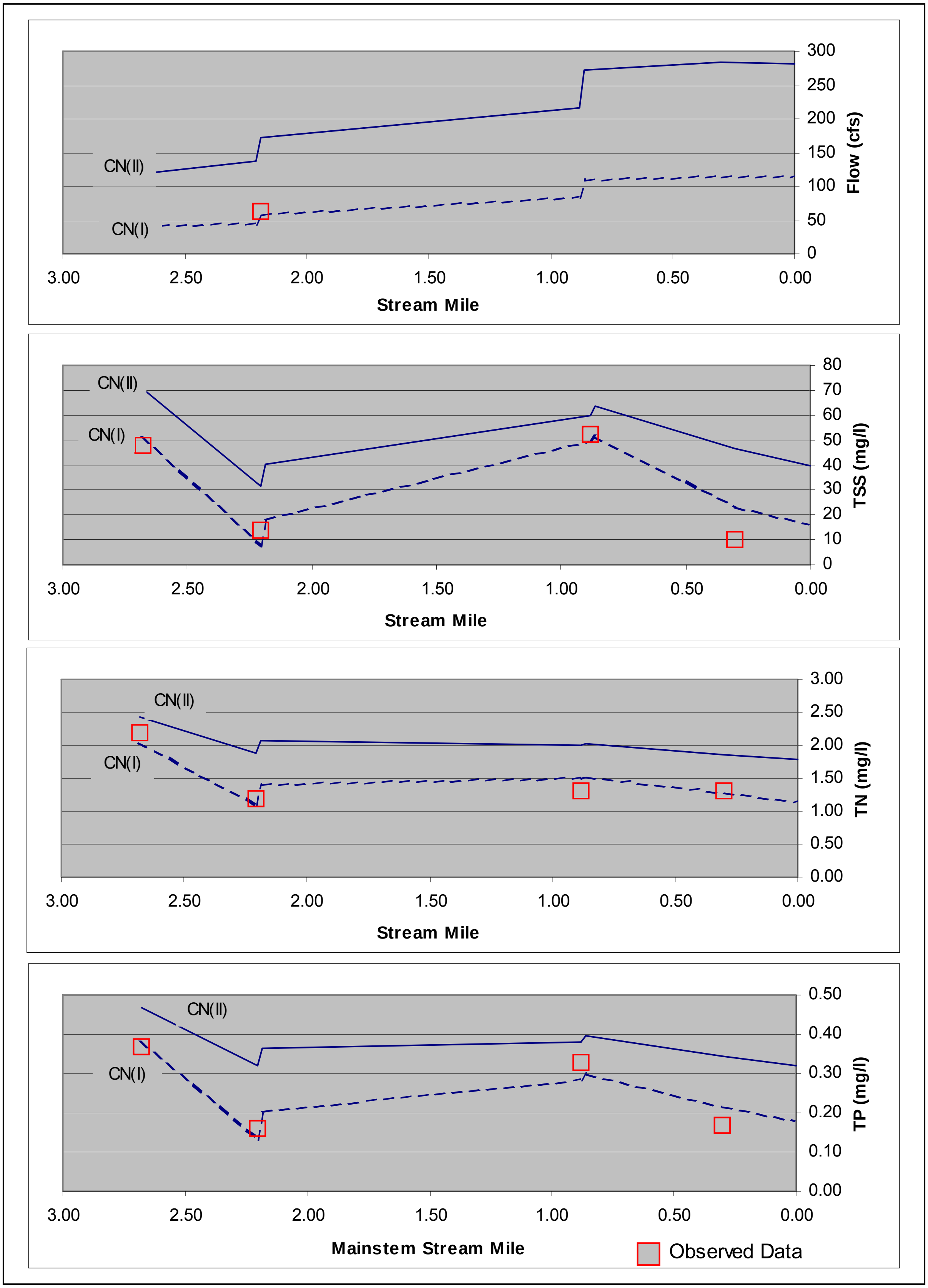


Figure 4-7. Existing dry season baseflow and water quality

Table 4.6. Existing Dry Season 10% Event Runoff and Pollutant Load Contributions

a. Dry Season 10% Event Runoff Sources (mcf)

P = 0.35inch td = 4hours

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	0.003	0.0027
1.1	0	0	0	0	0	0	0	0	0.001	0.0001	0	0	0.0011
2	0	0	0	0	0	0	0	0	0	0	0	0.0007	0.0007
3	0	0	0	0	0	0	0	0.0017	0.014	0.0001	0.004	0	0.0196
4	0	0	0	0	0	0	0	0.0006	0.006	0.0001	0.006	0.0005	0.0133
5	0	0	0	0	0	0	0	0.0001	0.003	0.00002	0.0007	0	0.0039
Totals:	0	0	0	0	0	0	0	0.0024	0.0242	0.0003	0.0105	0.0039	0.041

b. Dry Season 10% Event TSS Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	7.5	7.5
1.1	0	0	0	0	0	0	0	0	5.2	0.31	0	0	5.5
2	0	0	0	0	0	0	0	0	0	0	0	2.0	2.0
3	0	0	0	0	0	0	0	7.4	70	0.23	21	0	98.5
4	0	0	0	0	0	0	0	2.7	32	0.39	30	1.5	66.0
5	0	0	0	0	0	0	0	0.28	16	0.075	3.4	0	19.6
Totals:	0	0	0	0	0	0	0	10.4	123	1.00	53.5	11.1	199

c. Dry Season 10% Event TN Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	0.15	0.15
1.1	0	0	0	0	0	0	0	0	0.086	0.003	0	0	0.089
2	0	0	0	0	0	0	0	0	0	0	0	0	0.040
3	0	0	0	0	0	0	0	0.074	1.17	0.002	0.34	0	1.59
4	0	0	0	0	0	0	0	0.027	0.53	0.003	0.49	0.031	1.08
5	0	0	0	0	0	0	0	0.003	0.26	0.001	0.056	0	0.32
Totals:	0	0	0	0	0	0	0	0.10	2.05	0.008	0.89	0.22	3.28

d. Dry Season 10% Event TP Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	0.045	0.045
1.1	0	0	0	0	0	0	0	0	0.029	0.002	0	0	0.030
2	0	0	0	0	0	0	0	0	0	0	0	0.012	0.012
3	0	0	0	0	0	0	0	0.030	0.39	0.001	0.11	0	0.54
4	0	0	0	0	0	0	0	0.011	0.18	0.002	0.16	0.009	0.36
5	0	0	0	0	0	0	0	0.001	0.088	0.0004	0.019	0	0.11
Totals:	0	0	0	0	0	0	0	0.042	0.68	0.005	0.30	0.066	1.09

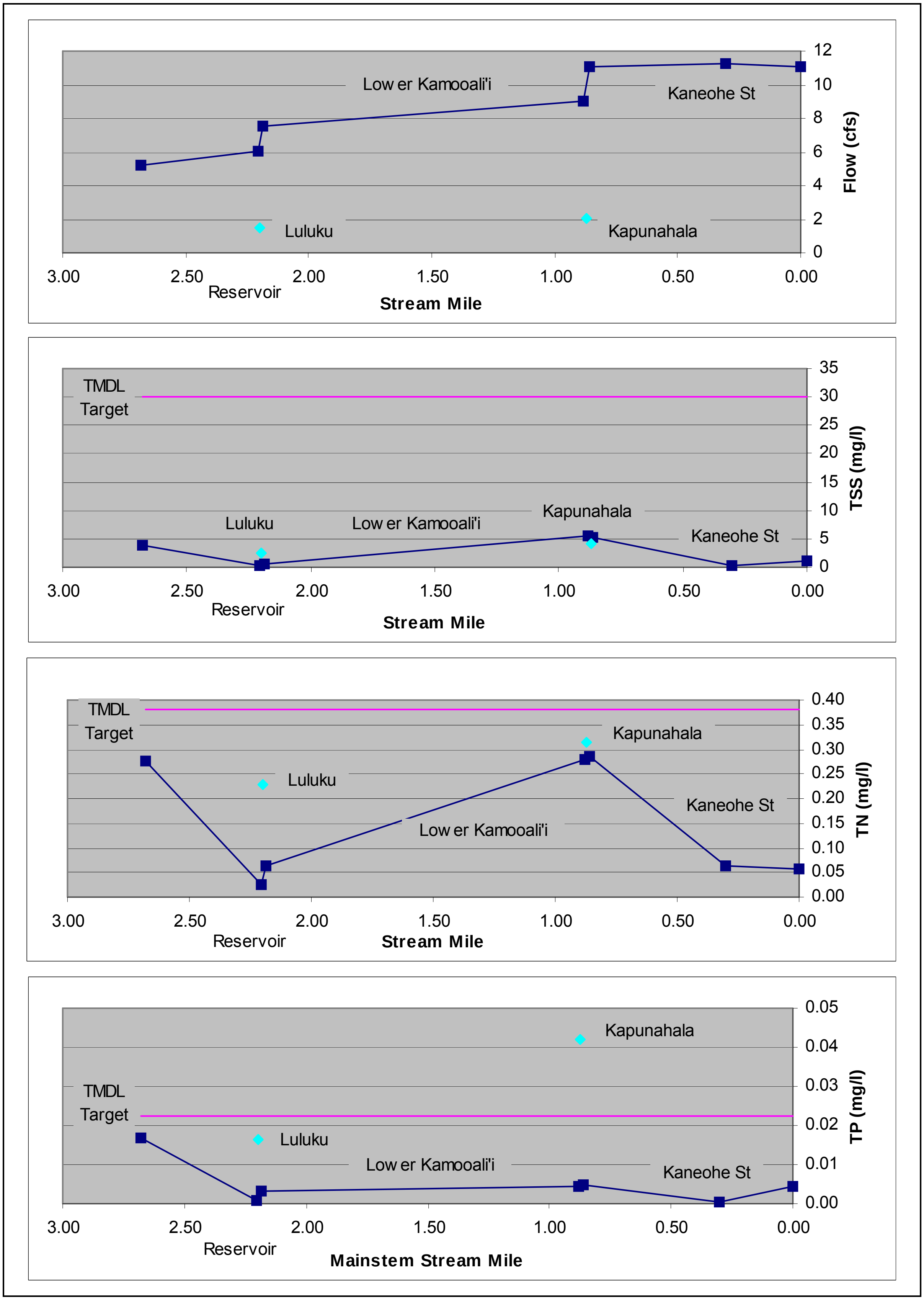


Figure 4-8. Existing dry season 10% event streamflow and water quality.

Table 4.7. Existing Dry Season 2% Event Runoff and Pollutant Load Contributions

a. Dry Season 2% Event Runoff Sources (mcf)

P = 1.27inch td = 8hours

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0.094	0.0004	0	0.0003	0	0.0002	0	0	0	0	0	0.12	0.21
1.1	0	0	0	0	0	0.0002	0.019	0	0.006	0.008	0	0	0.034
2	0.086	0.0005	0	0	0	0	0	0	0	0	0	0.020	0.11
3	0	0	0	0	0	0.0002	0.15	0.050	0.083	0.009	0.024	0	0.31
4	0.008	0	0	0	0	0.001	0.099	0.022	0.037	0.012	0.034	0.029	0.24
5	0	0	0	0	0	0.0002	0.034	0.002	0.020	0.012	0.004	0	0.072
Totals:	0.19	0.0009	0.00	0.0003	0.00	0.002	0.30	0.074	0.15	0.041	0.062	0.17	0.98

b. Dry Season 2% Event TSS Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	267	1.5	0	0.60	0	0.53	0	0	0	0	0	327	597
1.1	0	0	0	0	0	0.55	97	0	30	29	0	0	157
2	242	2.3	0	0	0	0	0	0	0	0	0	58	302
3	0	0	0	0	0	0.53	759	212	421	30	123	0	1545
4	21	0.08	0	0	0	2.6	507	95	188	41	173	83	1110
5	0	0	0	0	0	0.40	175	7.6	100	40	21	0	344
Totals:	531	3.9	0	0.60	0	4.6	1538	315	740	140	316	468	4056

c. Dry Season 2% Event TN Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	8.0	0.061	0	0.02	0	0.013	0	0	0	0	0	6.5	15
1.1	0	0	0	0	0	0.014	1.1	0	0.50	0.24	0	0	1.8
2	7.3	0.09	0	0	0	0	0	0	0	0	0	1.2	8.5
3	0	0	0	0	0	0.013	8.4	2.1	7.0	0.25	2.0	0	20
4	0.64	0.003	0	0	0	0.064	5.6	0.95	3.1	0.34	2.9	1.7	15
5	0	0	0	0	0	0.010	1.9	0.08	1.7	0.33	0.34	0	4.4
Totals:	16	0.2	0	0.02	0	0.11	17	3.1	12	1.2	5.3	9.4	65

d. Dry Season 2% Event TP Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	1.6	0.012	0	0.004	0	0.003	0	0	0	0	0	2.0	3.6
1.1	0	0	0	0	0	0.003	0.27	0	0.17	0.14	0	0	0.59
2	1.5	0.018	0	0	0	0	0	0	0	0	0	0.35	1.8
3	0	0	0	0	0	0.003	2.1	0.85	2.3	0.15	0.68	0	6.1
4	0.13	0.001	0	0	0	0.016	1.4	0.38	1.0	0.20	0.96	0.50	4.6
5	0	0	0	0	0	0.002	0.49	0.03	0.56	0.20	0.11	0	1.4
Totals:	3.2	0.031	0	0.004	0	0.029	4.3	1.3	4.1	0.70	1.8	2.8	18

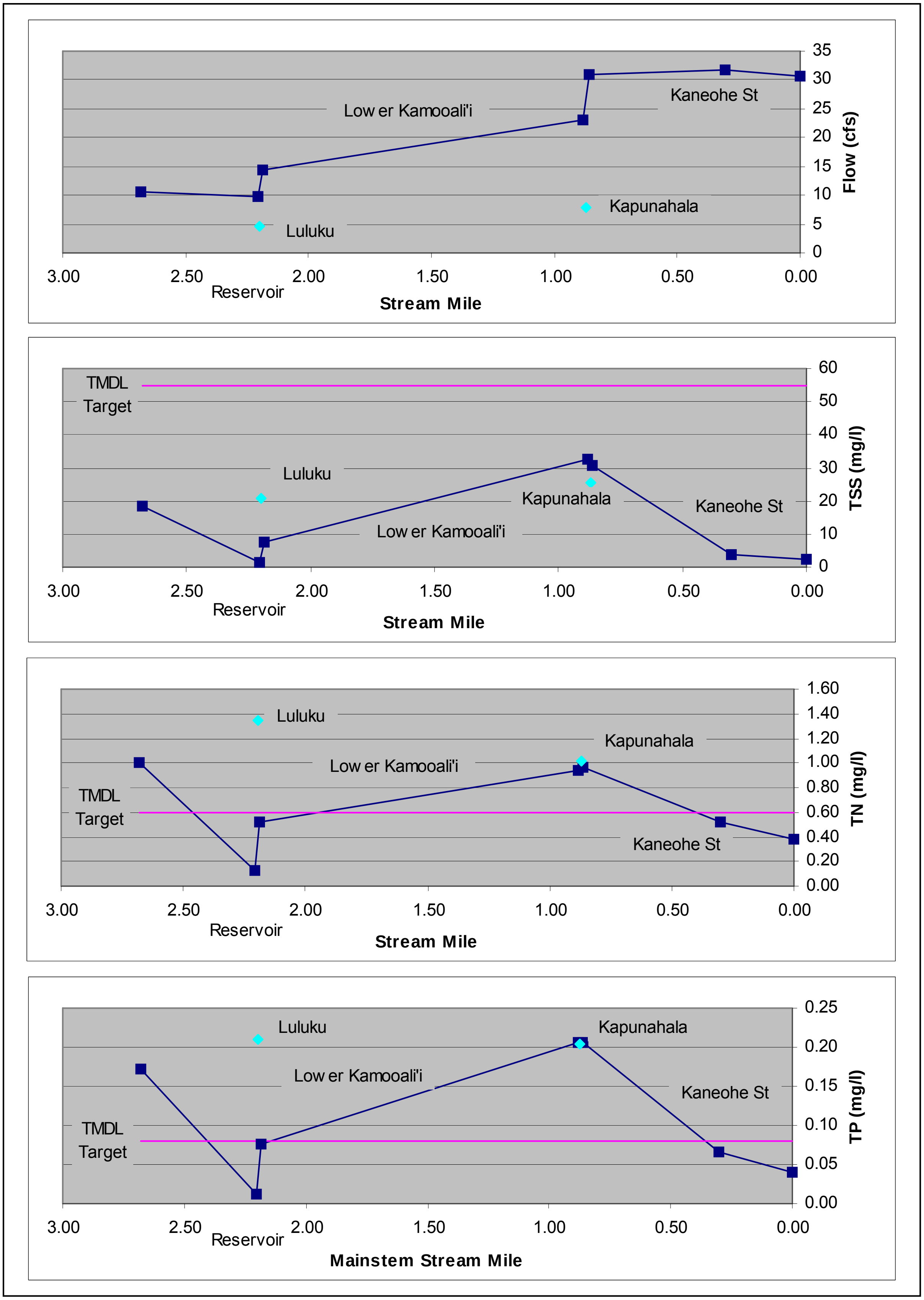


Figure 4-9. Existing dry season 2% event streamflow and water quality.

4.7 Existing Wet Season Conditions

Wet Season Baseflow. During an average 55% of the wet season days, rainfall at the Pali Golf Course weather station will be less than the minimum 0.04-inch necessary to induce runoff. Calculations of baseflow and pollutant load contributions for this 55% time period are summarized in Table 4.8. Calculated wet seasonal baseflow and water quality along the mainstem length of the Kaneohe Stream system are displayed in Figure 4-10. Diamond symbols on this and subsequent figures represent stream flows and pollutant concentrations of segments 2 (Luluku Stream) and 4 (Kapunahala Stream). TMDL target concentrations are also displayed in Figure 4-10 and subsequent figures.

Wet Season 10% Rainfall Event. Rainfall at Pali Golf Course is equal to or greater than 0.70-inch during an average 10% of the wet season days. Calculated runoff and pollutant load contributions for this 0.70-inch rainfall event are summarized in Table 4.9. Calculations of streamflow and water quality for this 10% rainfall event are displayed in Figure 4-11.

Wet Season 2% Rainfall Event. Rainfall at Pali Golf Course is equal to or greater than 2.30-inch during an average 2% of the wet season days. Calculated runoff and pollutant load contributions for this 2.30-inch rainfall event are summarized in Table 4.10. Calculations of streamflow and water quality for this 2% rainfall event are displayed in Figure 4-12.

Table 4.8. Existing Wet Seasonal Baseflow and Pollutant Load Contributions

a. Wet Season Baseflow Sources (cfs)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	4.3	0.16	0	0.93	0.029	0.058	0	0	0	0	0	0.15	5.6
1.1	0.023	0	0.881	0	0.037	0.059	0.080	0	0.001	0.013	0	0	1.1
2	1.3	0.25	0	0	0	0	0	0	0	0	0	0.02	1.5
3	0.025	0.012	0.007	0	0	0.019	0.69	0.023	0.015	0.015	0.005	0	0.80826
4	0.94	0.20	0.051	0	0	0.082	0.42	0.010	0.006	0.019	0.008	0.040	1.8
5	0	0	0.032	0	0	0.012	0.19	0.001	0.004	0.022	0.001	0	0.27
Totals:	6.6	0.62	0.97	0.93	0.07	0.23	1.4	0.034	0.026	0.068	0.014	0.22	11.1

b. Wet Season Baseflow TSS Loads (kg/day)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	210	12	0	46	1.4	2.8	0	0	0	0	0	23	294
1.1	1.1	0	43	0	1.8	2.9	12	0	0.152	1.9	0	0	63
2	62	18	0	0	0	0	0	0	0	0	0	3.5	84
3	1.2	0.92	0.34	0	0	0.92	101	3.4	2.2	2.2	0.81	0	113
4	46	14	2.5	0	0	4.0	62	1.5	0.94	2.8	1.2	5.8	141
5	0	0	1.6	0	0	0.60	29	0.12	0.54	3.2	0.14	0	35
Totals:	321	45	47	46	3.3	11	203	5.0	3.8	10	2.1	32	729

c. Wet Season Baseflow TN Loads (kg/day)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	5.3	0.39	0	1.1	0.054	0.14	0	0	0	0	0	0.45	7.4
1.1	0.028	0	1.1	0	0.069	0.15	0.23	0	0.003	0.039	0	0	1.6
2	1.6	0.60	0	0	0	0	0	0	0	0	0	0.069	2.2
3	0.031	0.031	0.008	0	0	0.046	2.0	0.067	0.043	0.043	0.016	0	2.3
4	1.2	0.48	0.062	0	0	0.20	1.2	0.030	0.019	0.055	0.024	0.12	3.4
5	0	0	0.039	0	0	0.030	0.57	0.002	0.011	0.063	0.003	0	0.72
Totals:	8.0	1.5	1.2	1.1	0.12	0.56	4.1	0.1	0.08	0.20	0.043	0.64	18

d. Wet Season Baseflow TP Loads (kg/day)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0.53	0.039	0	0.11	0.004	0.007	0	0	0	0	0	0.038	0.73
1.1	0.003	0	0.11	0	0.005	0.007	0.020	0	0.000	0.003	0	0	0.15
2	0.16	0.060	0	0	0	0	0	0	0	0	0	0.006	0.22
3	0.003	0.003	0.001	0	0	0.002	0.17	0.006	0.004	0.004	0.001	0	0.19
4	0.12	0.048	0.006	0	0	0.010	0.10	0.003	0.002	0.005	0.002	0.010	0.30
5	0	0	0.004	0	0	0.002	0.048	0.0002	0.001	0.005	0.0002	0	0.060
Totals:	0.80	0.15	0.12	0.11	0.008	0.028	0.34	0.008	0.006	0.017	0.004	0.053	1.6

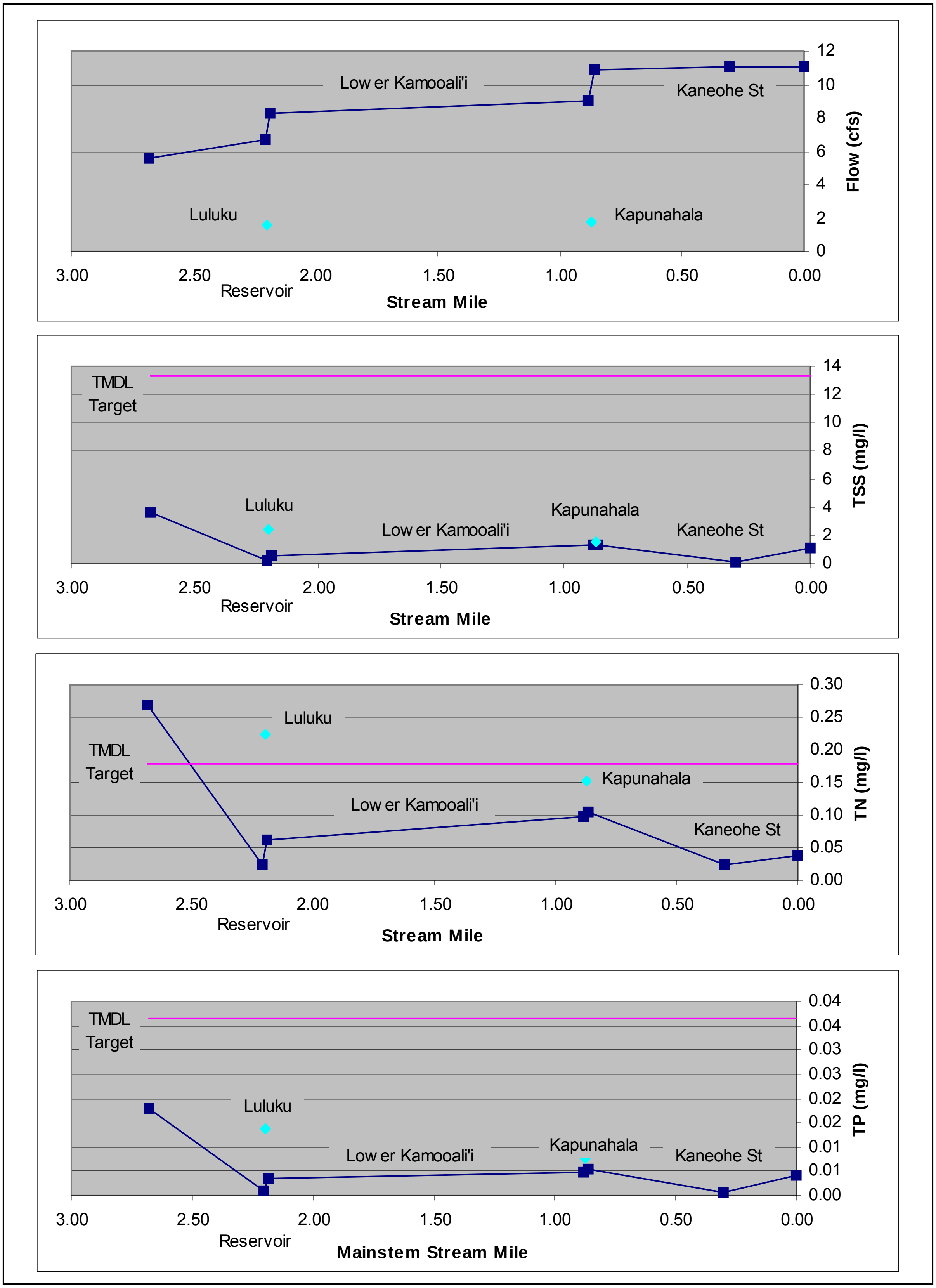


Figure 4-10. Existing wet season baseflow and water quality.

Table 4.9. Existing Wet Season 10% Event Runoff and Pollutant Load Contributions

a. Wet Season 10% Event Runoff Sources (mcf)

P = 0.70inch td = 6hours

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	0.029	0.029
1.1	0	0	0	0	0	0	0.001	0	0.003	0.002	0	0	0.006
2	0	0	0	0	0	0	0	0	0	0	0	0.005	0.005
3	0	0	0	0	0	0	0.009	0.017	0.041	0.002	0.012	0	0.081
4	0	0	0	0	0	0	0.005	0.007	0.018	0.003	0.017	0.007	0.057
5	0	0	0	0	0	0	0.001	0.001	0.010	0.003	0.002	0	0.017
Totals:	0	0	0	0	0	0	0.017	0.024	0.072	0.011	0.031	0.041	0.196

b. Wet Season 10% Event TSS Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	83	83
1.1	0	0	0	0	0	0	6.6	0	15	7.6	0	0	29
2	0	0	0	0	0	0	0	0	0	0	0	13	13
3	0	0	0	0	0	0	48	70	210	8.1	60	0	396
4	0	0	0	0	0	0	28	30	90	10	87	19	265
5	0	0	0	0	0	0	6.4	2.3	51	10	10	0	80
Totals:	0	0	0	0	0	0	89	103	366	36	157	116	868

c. Wet Season 10% Event TN Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	1.7	1.7
1.1	0	0	0	0	0	0	0.073	0	0.25	0.063	0	0	0.38
2	0	0	0	0	0	0	0	0	0	0	0	0.26	0.26
3	0	0	0	0	0	0	0.53	0.70	3.5	0.068	1.00	0	5.8
4	0	0	0	0	0	0	0.31	0.30	1.5	0.085	1.5	0.39	4.0
5	0	0	0	0	0	0	0.071	0.023	0.85	0.087	0.17	0	1.2
Totals:	0	0	0	0	0	0	0.99	1.0	6.1	0.30	2.6	2.3	13.4

d. Wet Season 10% Event TP Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	0.50	0.50
1.1	0	0	0	0	0	0	0.018	0	0.082	0.038	0	0	0.14
2	0	0	0	0	0	0	0	0	0	0	0	0.078	0.078
3	0	0	0	0	0	0	0.13	0.28	1.2	0.041	0.33	0	2.0
4	0	0	0	0	0	0	0.078	0.12	0.50	0.051	0.48	0.12	1.4
5	0	0	0	0	0	0	0.018	0.009	0.28	0.052	0.057	0	0.42
Totals:	0	0	0	0	0	0	0.25	0.41	2.0	0.18	0.87	0.70	4.4

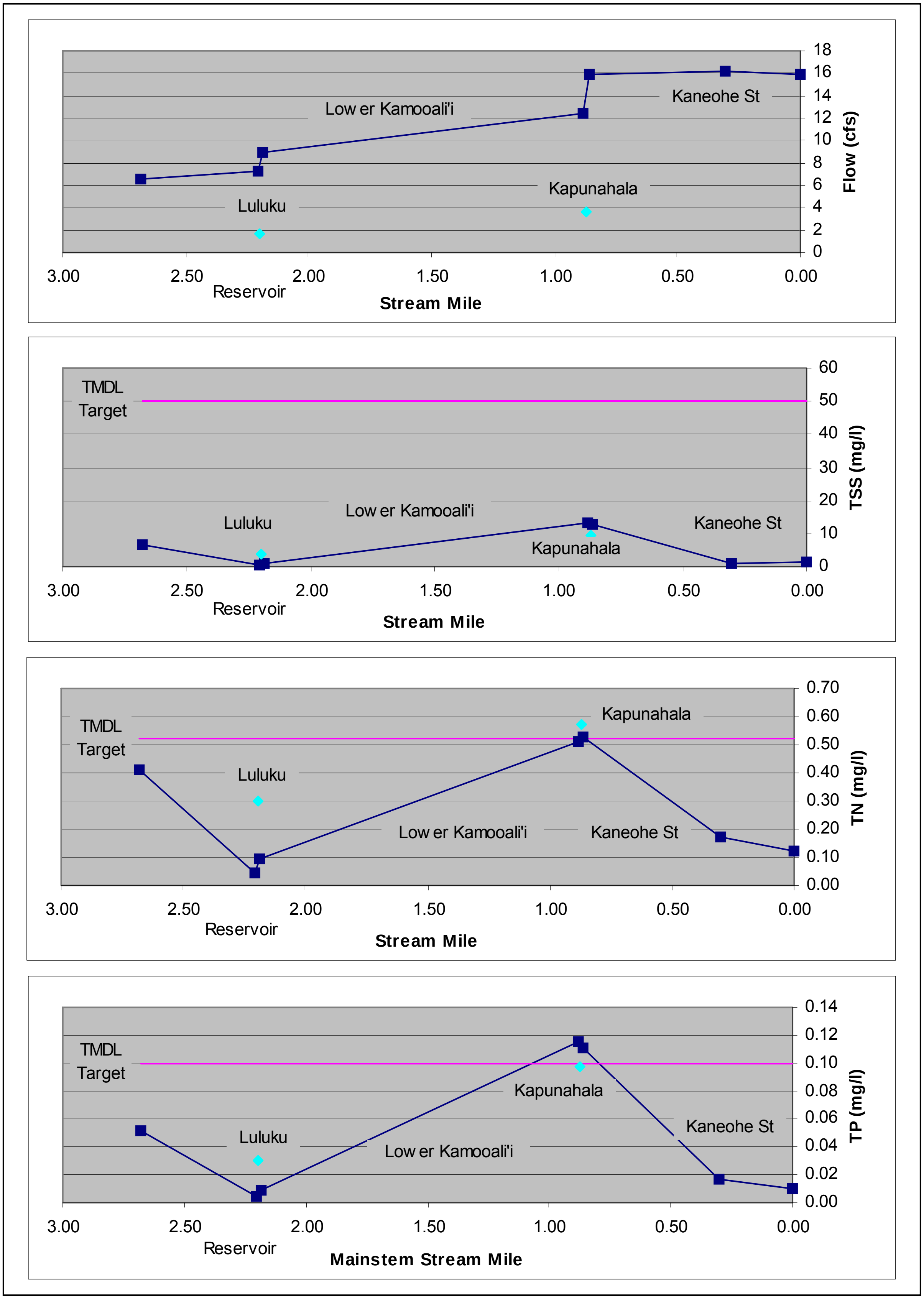


Figure 4-11. Existing wet season 10% event streamflow and water quality.

Table 4.10. Existing Wet Season 2% Event Runoff and Pollutant Load Contributions

a. Wet Season 2% Event Runoff Sources (mcf)

P = 2.30inch td = 15hours

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	1.1	0.039	0	0.20	0.005	0.024	0	0	0	0	0	0.30	1.6
1.1	0	0	0.19	0	0.006	0.025	0.090	0	0.012	0.025	0	0	0.35
2	0.47	0.059	0	0	0	0	0	0	0	0	0	0.044	0.58
3	0	0.003	0.001	0	0	0.008	0.78	0.14	0.17	0.028	0.049	0	1.2
4	0.22	0.042	0.008	0	0	0.033	0.47	0.063	0.074	0.035	0.071	0.075	1.1
5	0	0	0.005	0	0	0.005	0.22	0.005	0.043	0.041	0.008	0	0.33
Totals:	1.8	0.14	0.20	0.20	0.012	0.095	1.6	0.20	0.30	0.13	0.13	0.42	5.2

b. Wet Season 2% Event TSS Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	3034	166	0	460	11	55	0	0	0	0	0	841	4568
1.1	0.066	0	527	0	0	57	461	0	61	86	0	0	1191
2	1343	249	0	0	0	0	0	0	0	0	0	125	1718
3	0	13	4	0	0	19	3992	579	883	95	251	0	5836
4	610	179	23	0	0	74	2393	268	378	120	361	212	4619
5	0	0	14	0	0	11	1135	20	219	138	43	0	1580
Totals:	4987	606	568	460	11	216	7981	867	1541	439	655	1178	19511

c. Wet Season 2% Event TN Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	91	6.7	0	17	0.4298	1.4	0	0	0	0	0	17	134
1.1	0.002	0	11	0	0	1.4	5.1	0	1.0	0.71	0	0	19
2	40	10	0	0	0	0	0	0	0	0	0	2.5	53
3	0	0.50	0.072	0	0	0.47	44	5.8	15	0.79	4.2	0	71
4	18	7.1	0.47	0	0	1.9	27	2.7	6.3	1.0	6.0	4.2	75
5	0	0	0.29	0	0	0.28	13	0.20	3.6	1.2	0.72	0	19
Totals:	150	24	11	17	0.43	5.4	89	8.7	26	3.7	11	23.6	369

d. Wet Season 2% Event TP Loads (kg)

									CCH Streets		DOT Highways		
Basin	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	18	1.3	0	2.9	0.072	0.34	0	0	0	0	0	5.0	28
1.1	0.0004	0	2.6	0	0	0.35	1.3	0	0.34	0.43	0	0	5.0
2	8.1	2.0	0	0	0	0	0	0	0	0	0	0.75	11
3	0	0.10	0.018	0	0	0.12	11	2.3	4.9	0.48	1.4	0	20
4	3.7	1.4	0.12	0	0	0.46	6.6	1.1	2.1	0.60	2.0	1.3	19
5	0	0	0.072	0	0	0.069	3.2	0.078	1.2	0.69	0.24	0	5.5
Totals:	30	4.9	2.8	2.9	0.07	1.3	22	3.5	8.6	2.2	3.6	7.1	89

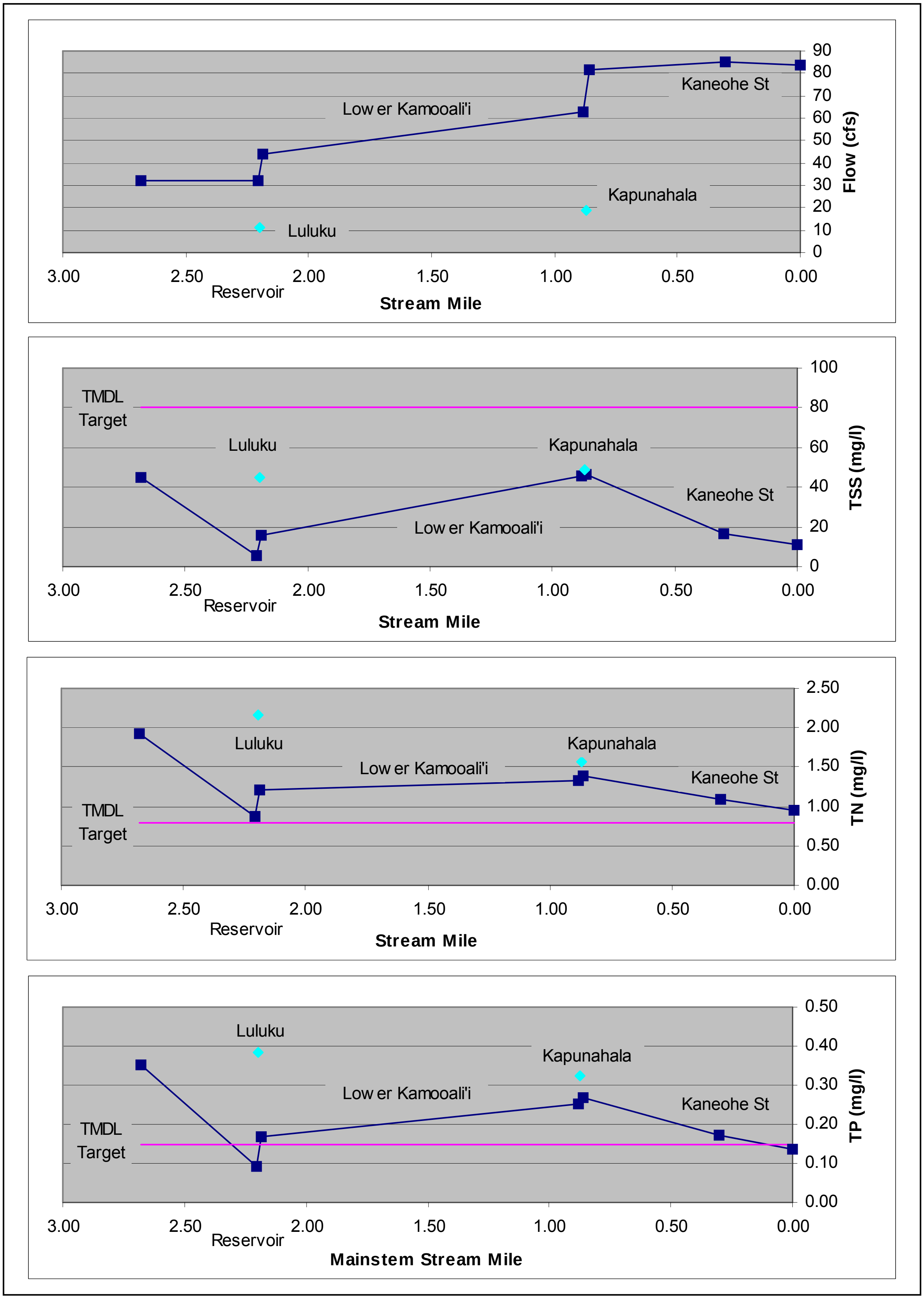


Figure 4-12. Existing wet season 2% event streamflow and water quality.

4.8 Summary Observations

Existing baseflow contributions from individual land use categories are roughly proportional to the areas of those categories, with 83% of baseflow originating in the unsewered 75% of the watershed that is forest, agriculture, parks, and open area. Total baseflow pollutant loading contributions similarly are roughly proportional to land use areas, with 64% of TSS, 70% of TN, and 73% of TP contributions associated with the forest, agriculture, parks, and open areas that are 75% of the watershed. This is an incomplete picture of the water quality impacts of these pollutant loading contributions. More than 60% of the total baseflow volume and 50% of the baseflow TSS, TN, and TP loading contributions originate in the 55% of watershed area that is tributary to the Waimaluhia Reservoir. However, these upstream baseflow loadings are reduced by more than 90% in the reservoir. Thus, the net baseflow loading contributions to downstream waters from 55% of the watershed area are reduced in the reservoir to less than 5% of the original total. That is, while more than 60% of the Kaneohe Stream baseflow volume is derived from infiltration in the upper watershed area, water quality downstream from the Waimaluhia Reservoir is almost entirely determined by the 45% of watershed area downstream from the reservoir.

The water quality influence of the Waimaluhia Reservoir is similar and magnified for the storm event conditions considered. For all four events (0.35 to 2.30-inch rainfall) more than one-third of the total storm runoff comes from the 55% of total watershed area that is upstream from the reservoir. Pollutant loading contributions from this upper watershed area are about 7% of the total loadings for all parameters for the 0.35-inch rainfall event, increasing to 27, 35, and 34% of the total runoff loadings of TSS, TN, and TP, respectively, for the 2.30-inch event. Loading reductions in the reservoir are more than 90% for all parameters for the 0.35-inch event and decline to about 87, 65, and 83%, respectively, for TSS, TN, and TP for the 2.30-inch event. Thus, for the largest rainfall condition, wet season 2% event, runoff loadings of TSS, TN, and TP from the upper watershed area are reduced by the reservoir to 4, 12, and 6%, respectively, of the original totals or 5, 16, and 8% of the total reduced loadings to the waters downstream from the reservoir. For rainfall up to 2.30-inches, water quality downstream from the Waimaluhia Reservoir is mostly determined by runoff loadings from the watershed area downstream from the reservoir.

Chapter 5 -TMDL Allocations

Total Maximum Daily Loads (TMDLs) for Total Suspended Solids, Nitrogen and Phosphorus in Kaneohe Stream, Kaneohe, Hawaii

5.1 Conditions and Criteria

The TMDLs in this analysis were developed for the six conditions: baseflow, 10% storm event, and 2% storm event for both dry and wet weather seasons. Baseflow (non-runoff) conditions apply during an average 58% of the 184 dry season days. Rainfall (Pali Golf Course weather station) is equal to or greater than 0.35-inch during 10% and 1.27-inch during 2% of the dry season days. Average rainfall durations were estimated as 4 and 8 hours, respectively, for the 10% and 2% dry season rainfall events.

Baseflow conditions apply during an average 55% of the 181 wet season days. Rainfall is equal to or greater than 0.70-inch during 10% and 2.30-inch during 2% of the dry season days. Average rainfall durations were estimated as 6 and 15 hours, respectively, for the 10% and 2% wet season rainfall events.

Water quality criteria for the 10% and 2% rainfall events are the water quality standards not to be exceeded during more than 10% and 2% of the time, respectively. The criteria for baseflow conditions are calculated to satisfy the geometric mean water quality standard for the season. The numerical targets for these criteria are summarized in Table 5.1.

Table 5.1. TMDL Criteria

TMDL Criteria (Water Quality Targets)	TSS (mg/l)	TN (mg/l)	TP (mg/l)
Dry Season: Baseflow	6	0.130	0.022
10% Storm Event	30	0.380	0.060
2% Storm Event	55	0.600	0.080
Wet Season: Baseflow	13	0.179	0.036
10% Storm Event	50	0.520	0.100
2% Storm Event	80	0.800	0.150

Loading capacities and their allocations developed for baseflow conditions are geometric mean values not to be exceeded during the 58% and 55% of the dry season and wet season days, respectively, when seasonal baseflow conditions prevail. Loading capacities and allocations developed for the 10% storm events are intended as values to be exceeded no more than 10% of the time. Loading capacities and allocations developed for the 2% storm events are intended as values to be exceeded no more than 2% of the time. Associations of the wet weather TMDLs with explicit (critical) rainfall conditions, along with the spreadsheet format of this analysis, are intended to provide some design insight for TMDL implementing authorities.

5.2 Loading Capacity Calculations

Loading capacities were calculated for each Kaneohe Stream segment as the maximum segment pollutant loadings that will meet the Table 5.1 water quality targets for each of the six TMDL conditions. These loading capacities for the dry season conditions are tabulated in Table 5.2 and for the wet season conditions in Table 5.3. Calculated loading capacities are compared in these tables to existing loadings for each stream segment.

Table 5.2. Dry Season Kaneohe Stream Loading Capacities

a. Dry Season Baseflow Loading Capacities (kg/day)

	Flow		TSS		TN		TP	
Seg	(cfs)		LC	Exist	LC	Exist	LC	Exist
1.0	5.1		497	266	3.3	6.7	0.87	0.66
1.1	6.0		2,213	53	9.4	1.3	3.17	0.12
2	1.4		216	76	1.2	2.0	0.35	0.20
3	8.1		553	96	2.5	2.0	0.81	0.16
4	1.6		586	124	2.8	3.0	0.88	0.27
5	9.9		1,805	29	7.5	0.6	2.57	0.05
		Totals:	5,869	644	26.7	15.6	8.66	1.46

b. Dry Season 10% Event Loading Capacities (kg) (for 4 hour event, 0.35" rainfall)

	Flow		TSS		TN		TP	
Seg	(cfs)		LC	Exist	LC	Exist	LC	Exist
1.0	5.2		467	7.5	1.6	0.15	0.37	0.05
1.1	6.1		1,724	5.5	3.7	0.09	1.11	0.03
2	1.4		168	2.0	0.5	0.04	0.12	0.01
3	9.0		533	98	1.4	1.59	0.37	0.54
4	2.1		559	66	1.5	1.08	0.39	0.36
5	11.3		1,690	20	3.6	0.32	1.08	0.11
		Totals:	5,141	199	12.4	3.28	3.44	1.09

c. Dry Season 2% Event Loading Capacities (kg) (for 8 hour event, 1.27" rainfall)

	Flow		TSS		TN		TP	
Seg	(cfs)		LC	Exist	LC	Exist	LC	Exist
1.0	10.6		1,920	597	8.6	14.6	1.4	3.6
1.1	9.8		6,430	157	13.2	1.8	3.1	0.6
2	4.6		787	302	3.5	8.5	0.6	1.8
3	23.0		2,261	1,545	9.0	19.9	1.6	6.1
4	7.9		2,254	1,110	8.3	15.3	1.5	4.6
5	31.6		5,891	344	12.5	4.4	2.9	1.4
		Totals:	19,543	4,056	55.1	64.6	11.1	18.2

Table 5.3. Wet Season Kaneohe Stream Loading Capacities

a. Wet Season Baseflow Loading Capacities (kg/day)

	Flow		TSS		TN		TP	
Seg	(cfs)		LC	Exist	LC	Exist	LC	Exist
1.0	5.6		1,061	294	4.8	7.4	1.46	0.73
1.1	6.7		4,650	63	12.9	1.6	5.15	0.15
2	1.5		457	84	1.8	2.2	0.58	0.22
3	9.1		1,165	113	3.4	2.3	1.32	0.19
4	1.8		1,237	141	3.9	3.4	1.45	0.30
5	11.1		3,789	35	10.3	0.7	4.16	0.06
		Totals:	12,358	729	37.1	17.7	14.1	1.6

b. Wet Season 10% Event Loading Capacities (kg) (for 6 hour event, 0.70" rainfall)

	Flow		TSS		TN		TP	
Seg	(cfs)		LC	Exist	LC	Exist	LC	Exist
1.0	6.6		1,019	83	3.50	1.67	0.94	0.50
1.1	7.3		3,755	29	7.27	0.38	2.65	0.14
2	1.7		374	13	1.05	0.26	0.31	0.08
3	12.4		1,187	396	3.37	5.81	1.00	1.96
4	3.6		1,220	265	3.36	4.04	1.01	1.35
5	16.2		3,513	80	6.79	1.20	2.48	0.42
		Totals:	11,068	868	25.4	13.4	8.4	4.4

c. Wet Season 2% Event Loading Capacities (kg) (for 15 hour event, 2.30" rainfall)

	Flow		TSS		TN		TP	
Seg	(cfs)		LC	Exist	LC	Exist	LC	Exist
1.0	31.8		7,488	4,568	49.0	133.6	10.2	27.9
1.1	32.4		16,340	1,191	37.7	18.8	12.2	5.0
2	11.4		2,835	1,718	17.2	52.8	3.7	10.8
3	62.8		6,820	5,836	35.2	70.9	7.9	20.4
4	19.1		6,858	4,619	34.3	74.6	7.8	19.4
5	85.4		14,218	1,580	32.8	18.9	10.6	5.5
		Totals:	54,560	19,511	206.2	369.5	52.4	89.0

5.3 Allocation Calculations

The calculated load capacities for each stream segment were allocated to each of the tributary sub-basin sources in proportion to the existing load from the source. Where the existing loads were less than the allocated load capacity, the assigned source allocation was the existing load. This approach conforms to the non-degradation policy in Hawaii's water quality standards. The resulting source allocations for the six TMDL conditions are presented in the following Tables 5.4 through 5.9.

Table 5.4. Dry Season Baseflow Source Allocations

a. Dry Season Baseflow TSS Allocations (kg/day)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	193	10	0	39	1.1	2.3	0	0	0	0	0	21	266
1.1	0.97	0	36	0	1.4	2.3	10	0	0.14	1.8	0	0	53
2	58	16	0	0	0	0	0	0	0	0	0	3.2	76
3	0.99	0.75	0.27	0	0	0.76	86	2.9	2.0	1.9	0.71	0	96
4	42	12	2.0	0	0	3.4	53	1.3	0.87	2.5	1.0	5.3	124
5	0	0	1.2	0	0	0.51	24	0.10	0.50	2.8	0.12	0	29
Totals:	294	39	40	39	2.5	9.3	172	4.3	3.5	9.0	1.9	29	644

b. Dry Season Baseflow TN Allocations (kg/day)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	2.41	0.17	0	0.49	0.021	0.057	0	0	0	0	0	0.21	3.35
1.1	0.024	0	0.91	0	0.053	0.12	0.20	0	0.003	0.035	0	0	1.34
2	0.89	0.32	0	0	0	0	0	0	0	0	0	0.040	1.25
3	0.025	0.025	0.007	0	0	0.038	1.7	0.058	0.040	0.039	0.014	0	1.96
4	0.99	0.39	0.048	0	0	0.16	1.0	0.025	0.017	0.048	0.020	0.10	2.82
5	0	0	0.030	0	0	0.025	0.47	0.002	0.010	0.057	0.002	0	0.60
Totals:	4.34	0.90	0.99	0.49	0.073	0.40	3.40	0.085	0.069	0.18	0.036	0.35	11.31

c. Dry Season Baseflow TP Allocations (kg/day)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0.48	0.033	0	0.10	0.003	0.006	0	0	0	0	0	0.034	0.66
1.1	0.002	0	0.091	0	0.004	0.006	0.017	0	0.0002	0.003	0	0	0.12
2	0.14	0.052	0	0	0	0	0	0	0	0	0	0.005	0.20
3	0.002	0.002	0.001	0	0	0.002	0.14	0.005	0.003	0.003	0.001	0	0.16
4	0.10	0.041	0.005	0	0	0.008	0.088	0.002	0.001	0.004	0.002	0.009	0.27
5	0	0	0.003	0	0	0.001	0.039	0.000	0.001	0.005	0.0002	0	0.05
Totals:	0.73	0.13	0.10	0.10	0.006	0.023	0.29	0.007	0.006	0.015	0.003	0.049	1.46

Table 5.5. Dry Season Source Allocations for 10% Storm Event Runoff

a. Dry Season 10% Event Runoff TSS Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	7.5	7.5
1.1	0	0	0	0	0	0	0	0	5.2	0.31	0	0	5.5
2	0	0	0	0	0	0	0	0	0	0	0	2.0	2.0
3	0	0	0	0	0	0	0	7.4	70	0.23	21	0	98
4	0	0	0	0	0	0	0	2.7	32	0.39	30	1.5	66
5	0	0	0	0	0	0	0	0.28	16	0.07	3.4	0	20
Totals:	0	0	0	0	0	0	0	10	123	1.00	53	11	199

b. Dry Season 10% Event Runoff TN Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	0.15	0.15
1.1	0	0	0	0	0	0	0	0	0.09	0.00	0	0	0.09
2	0	0	0	0	0	0	0	0	0	0	0	0.04	0.04
3	0	0	0	0	0	0	0	0.06	1.02	0.00	0.30	0	1.38
4	0	0	0	0	0	0	0	0.03	0.53	0.00	0.49	0.03	1.08
5	0	0	0	0.00	0.00	0	0	0.00	0.26	0.00	0.06	0	0.32
Totals:	0	0	0	0.00	0.00	0	0	0.09	1.90	0.01	0.85	0.22	3.07

c. Dry Season 10% Event Runoff TP Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1	0	0	0	0	0	0	0	0	0	0	0	0.05	0.05
1.1	0	0	0	0	0	0	0	0	0.03	0.00	0	0	0.03
2	0	0	0	0	0	0	0	0	0	0	0	0.01	0.01
3	0	0	0	0	0	0	0	0.02	0.27	0.00	0.08	0	0.37
4	0	0	0	0	0	0	0	0.01	0.18	0.00	0.16	0.01	0.36
5	0	0	0	0.00	0.00	0	0	0.00	0.09	0.00	0.02	0	0.11
Totals:	0	0	0	0.00	0.00	0	0	0.03	0.56	0.00	0.26	0.07	0.93

Table 5.6. Dry Season Source Allocations for 2% Storm Event Runoff

a. Dry Season 2% Event Runoff TSS Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	267	1.5	0	0.60	0	0.53	0	0	0	0	0	327	597
1.1	0	0	0	0	0	0.55	97	0	30	29	0	0	157
2	242	2.3	0	0	0	0	0	0	0	0	0	58	302
3	0	0	0	0	0	0.53	759	212	421	30	123	0	1545
4	21	0.08	0	0	0	2.6	507	95	188	41	173	83	1110
5	0	0	0	0	0	0.40	175	7.6	100	40	21	0	344
Totals:	531	3.9	0	0.6	0	4.6	1538	315	740	140	316	468	4056

b. Dry Season 2% Event Runoff TN Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	4.703	0.04	0.00	0.013	0	0.008	0	0	0	0	0	3.84	8.60
1.1	0	0	0	0	0	0.014	1.08	0	0.50	0.24	0	0	1.84
2	2.982	0.04	0	0	0	0	0	0	0	0	0	0.48	3.50
3	0	0	0	0	0	0.01	3.83	0.96	3.19	0.11	0.93	0	9.02
4	0.349	0.00	0	0	0	0.035	3.07	0.52	1.71	0.19	1.57	0.90	8.34
5	0	0	0	0.00	0.00	0.01	1.95	0.08	1.67	0.33	0.34	0	4.38
Totals:	8.035	0.07	0.00	0.01	0.00	0.07	9.93	1.56	7.07	0.87	2.84	5.22	35.7

c. Dry Season 2% Event Runoff TP Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0.63	0.005	0	0.0015	0	0.001	0	0	0	0	0	0.77	1.41
1.1	0	0	0	0	0	0.003	0.27	0	0.17	0.14	0	0	0.59
2	0.46	0.006	0	0	0	0	0	0	0	0	0	0.11	0.58
3	0	0	0	0	0	0.001	0.54	0.22	0.60	0.039	0.18	0	1.57
4	0.041	0.0002	0	0	0	0.005	0.45	0.12	0.34	0.066	0.31	0.16	1.49
5	0	0	0	0	0	0.002	0.49	0.030	0.56	0.20	0.11	0	1.39
Totals:	1.134	0.01	0.00	0.0015	0.00	0.01	1.75	0.37	1.66	0.45	0.60	1.04	7.03

Table 5.7. Wet Season Baseflow Source Allocations

a. Wet Season Baseflow TSS Allocations (kg/day)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	210	12	0	46	1.4	2.8	0	0	0	0	0	23	294
1.1	1.1	0	43	0	1.8	2.9	12	0	0.15	1.9	0	0	63
2	62	18	0	0	0	0	0	0	0	0	0	3.5	84
3	1.2	0.92	0.34	0	0	0.92	101	3.4	2.2	2.2	0.81	0	113
4	46	14	2.5	0	0	4.0	62	1.5	0.94	2.8	1.2	5.8	141
5	0	0	1.6	0	0	0.60	29	0.12	0.54	3.2	0.14	0	35
Totals:	321	45	47	46	3.3	11	203	5.0	3.8	10	2.1	32	729

b. Wet Season Baseflow TN Allocations (kg/day)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	3.4	0.25	0	0.74	0.035	0.092	0	0	0	0	0	0.29	4.8
1.1	0.028	0	1.1	0	0.069	0.15	0.23	0	0.003	0.039	0	0	1.6
2	1.2	0.48	0	0	0	0	0	0	0	0	0	0.055	1.8
3	0.031	0.031	0.008	0	0	0.046	2.0	0.067	0.043	0.043	0.016	0	2.3
4	1.2	0.48	0.062	0	0	0.20	1.2	0.030	0.019	0.055	0.024	0.12	3.4
5	0	0	0.039	0	0	0.030	0.57	0.002	0.011	0.063	0.003	0	0.72
Totals:	5.86	1.24	1.19	0.74	0.10	0.51	4.06	0.10	0.08	0.20	0.04	0.46	14.6

c. Wet Season Baseflow TP Allocations (kg/day)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0.53	0.039	0	0.11	0.0036	0.007	0	0	0	0	0	0.038	0.73
1.1	0.003	0	0.11	0	0.0046	0.007	0.020	0	0.0003	0.003	0	0	0.15
2	0.16	0.060	0	0	0	0	0	0	0	0	0	0.006	0.22
3	0.003	0.0031	0.001	0	0	0.002	0.17	0.006	0.004	0.004	0.001	0	0.19
4	0.12	0.048	0.006	0	0	0.010	0.10	0.003	0.002	0.005	0.002	0.010	0.30
5	0	0	0.004	0	0	0.002	0.05	0.0002	0.001	0.005	0.0002	0	0.06
Totals:	0.802	0.151	0.119	0.114	0.008	0.028	0.338	0.008	0.006	0.017	0.004	0.053	1.648

Table 5.8. Wet Season Source Allocations for 10% Storm Event Runoff

a. Wet Season 10% Event Runoff TSS Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	83	83
1.1	0	0	0	0	0	0	6.6	0	15	7.6	0	0	29
2	0	0	0	0	0	0	0	0	0	0	0	13	13
3	0	0	0	0	0	0	48	70	210	8	60	0	396
4	0	0	0	0	0	0	28	30	90	10	87	19	265
5	0	0	0	0	0	0	6.4	2.3	51	10	10	0	80
Totals:	0	0	0	0	0	0	89	103	366	36	157	116	868

b. Wet Season 10% Event Runoff TN Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	1.7	1.7
1.1	0	0	0	0	0	0	0.07	0	0.25	0.06	0	0	0.38
2	0	0	0	0	0	0	0	0	0	0	0	0.26	0.26
3	0	0	0	0	0	0	0.31	0.41	2.0	0.04	0.58	0	3.4
4	0	0	0	0	0	0	0.26	0.25	1.2	0.07	1.2	0.32	3.4
5	0	0	0	0	0	0	0.07	0.02	0.85	0.09	0.17	0	1.2
Totals:	0	0	0	0.0	0.0	0	0.71	0.68	4.4	0.26	2.0	2.3	10.2

c. Wet Season 10% Event Runoff TP Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	0	0	0	0	0	0	0	0	0	0	0	0.50	0.50
1.1	0	0	0	0	0	0	0.02	0	0.08	0.04	0	0	0.14
2	0	0	0	0	0	0	0	0	0	0	0	0.08	0.08
3	0	0	0	0	0	0	0.07	0.14	0.60	0.02	0.17	0	1.00
4	0	0	0	0	0	0	0.06	0.09	0.37	0.04	0.36	0.09	1.01
5	0	0	0	0	0	0	0.02	0.01	0.28	0.05	0.06	0	0.42
Totals:	0	0	0	0	0	0	0.16	0.24	1.34	0.15	0.59	0.67	3.14

Table 5.9. Wet Season Source Allocations for 2% Storm Event Runoff

a. Wet Season 2% Event Runoff TSS Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	3,034	166	0	460	11	55	0	0	0	0	0	841	4,568
1.1	0	0	527	0	0	57	461	0	61	86	0	0	1,191
2	1,343	249	0	0	0	0	0	0	0	0	0	125	1,718
3	0	13	4	0	0	19	3,992	579	883	95	251	0	5,836
4	610	179	23	0	0	74	2,393	268	378	120	361	212	4,619
5	0	0	14	0	0	11	1,135	20	219	138	43	0	1,580
Totals:	4,987	606	568	460	11	216	7,981	867	1,541	439	655	1,178	19,511

b. Wet Season 2% Event Runoff TN Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	33.4	2.4	0.0	6.3	0.2	0.51	0	0	0	0	0	6.2	49.0
1.1	0.002	0	10.5	0	0	1.42	5.1	0	1.0	0.7	0	0	18.8
2	13.1	3.2	0	0	0	0	0	0	0	0	0	0.8	17.2
3	0	0.2	0.0	0	0	0.24	22.0	2.9	7.3	0.4	2.1	0	35.2
4	8.4	3.3	0.2	0	0	0.85	12.2	1.2	2.9	0.5	2.8	2.0	34.3
5	0	0.0	0.3	0.0	0.0	0.3	12.6	0.2	3.6	1.2	0.7	0	18.9
Totals:	55.0	9.2	11.1	6.3	0.2	3.3	52.0	4.3	14.9	2.7	5.6	8.9	173.4

c. Wet Season 2% Event Runoff TP Allocations (kg)

									CCH Streets		DOT Highways		
Seg	Forest	Agricul.	Parks	Golf C.	Cem.	Inst.	Resid.	Comm.	curbs	swales	curbs	swales	Totals
1.0	6.66	0.49	0.00	1.05	0.03	0.13	0	0	0	0	0	1.85	10.20
1.1	4E-04	0	2.63	0	0	0.35	1.28	0	0.34	0.43	0	0	5.04
2	2.73	0.68	0	0	0	0	0	0	0	0	0	0.26	3.66
3	0	0.04	0.01	0	0	0.05	4.31	0.90	1.91	0.19	0.54	0	7.94
4	1.48	0.58	0.05	0	0	0.19	2.68	0.43	0.85	0.24	0.81	0.51	7.82
5	0	0.00	0.07	0.00	0.00	0.07	3.15	0.08	1.22	0.69	0.24	0	5.52
Totals:	10.88	1.78	2.76	1.05	0.03	0.78	11.43	1.41	4.31	1.55	1.59	2.62	40.18

5.4 Margin of Safety

There are significant margins of safety implicit in the calculations of load capacities and their allocations. For example, the critical 10% and 2% rainfall events were determined from the 24-hour days of recorded rainfall. However, the actual durations of rainfall, runoff, increased streamflow and pollutant loadings are for all the thus-determined events less than a full 24 hours, usually significantly less. The actual times of exceeding the respective 10% and 2% water quality criteria are thereby substantially less (40 to 80%) than assumed.

For another example, in the storm event runoff calculations, SCS curve numbers for average soil moisture conditions, CN(II), are assumed. In fact, for a significant number of the 10% and 2% rainfall events, dry soil moisture conditions appear more likely to be the case and smaller curve numbers, CN(I), would better represent these conditions. For these events, the smaller CN-values would translate into less runoff volumes and stream flows, smaller pollutant loadings and stream concentrations (see the calculations calibration for the November 27, 2001 rainfall event in Appendix B), and ultimately smaller load reductions than are calculated to achieve TMDL allocations.

Finally, the assignment of existing loads as allocations instead of load capacity based allocations where the existing sub-basin load is less than the individual segment load capacity provides large margins of safety for the total watershed TMDLs.

5.5 Consolidation of Major Sources

Load source categories and their allocations have been consolidated into existing loads from and allocations to areas that are serviced by agencies that hold or should hold NPDES permits (industrial or MS4 permits) and those areas that remain nonpoint sources of pollutants. Large MS4 permit holders in the Kaneohe Watershed area are Hawaii Department of Transportation (DOT) and City & County of Honolulu Department of Environmental Services (CCH ENV). The service area for the Hawaii DOT MS4 permit is represented by the consolidation of all DOT highway areas in the watershed. The service area for the CCH ENV MS4 permit is the consolidation of all neighborhood parks, residential, commercial, and municipal street areas in the watershed. Small MS4 permit holders are Hawaii Department of Defense (DOD), Department of Education (DOE), and Honolulu Department of Parks & Recreation (CCH Parks). The DOD permit service area is that portion of the Veteran's Cemetery that lies in the Kaneohe watershed area. The DOE permit service area is the consolidation of all public school facility properties in the watershed. The CCH Parks permit service area is the Pali Golf Course and Ho'omaluhia Botanical Garden. Small neighborhood park areas in the watershed do not appear to require a separate MS4 permit and are therefore included in the CCH ENV large MS4 permit. Nonpoint pollution sources are the forest, agriculture, and open water areas, Koolau Golf Course, and the portion of Memorial Cemetery that lies in the Kaneohe watershed. All areas are considered as nonpoint sources of baseflow volume and quality. Consolidations of dry season TMDL allocations, existing loads, and reductions needed are presented in Table 5.10. The same consolidations for the wet season period are displayed in Table 5.11.

Implementation of the required load reductions will result in attainment of the water quality standards for total suspended solids, total nitrogen, and total phosphorus in Kaneohe Stream.

Table 5.10. Consolidated Dry Season TMDL Allocations to Major Sources

Dry Season Baseflow	Allocations			Existing Loads			Reductions Needed					
	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(%)	(kgd)	(%)	(kgd)	(%)
LA to Hawaii DOT	31	0.38	0.052	31	0.62	0.052	0	0	0.24	38	0	0
LA to Hawaii DOD	1.1	0.02	0.003	1.1	0.04	0.003	0	0	0.02	50	0	0
LA to Hawaii DOE	1.3	0.06	0.003	1.3	0.06	0.003	0	0	0	0	0	0
LA to Hawaii DOH	1.9	0.09	0.005	1.9	0.09	0.005	0	0	0	0	0	0
LA to CCH ENV	253	5.02	0.474	253	5.37	0.474	0	0	0.35	7	0	0
LA to UH WCC	1.5	0.07	0.004	1.5	0.08	0.004	0	0	0.00	5	0	0
LA to Other NPS	354	5.67	0.918	354	9.31	0.918	0	0	3.65	39	0	0
Totals:	643.7	11.31	1.458	644	15.58	1.458	0	0	4.26	27	0	0

Dry Season 10% Runoff	Allocations			Existing Loads			Reductions Needed					
	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(%)	(kg)	(%)	(kg)	(%)
WLA to Hawaii DOT	65	1.07	0.33	65	1.11	0.36	0	0	0.04	4	0.04	10
WLA to Hawaii DOD	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOE	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOH	0	0	0	0	0	0	0	0	0	0	0	0
WLA to CCH ENV	135	2.00	0.60	135	2.16	0.73	0	0	0.16	7	0.13	18
WLA to UH WCC	0	0	0	0	0	0	0	0	0	0	0	0
LA to NPS	0	0	0	0	0	0	0	0	0	0	0	0
Totals:	199	3.07	0.93	199	3.28	1.09	0	0	0.21	6	0.17	15

Dry Season 2% Runoff	Allocations			Existing Loads			Reductions Needed					
	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(%)	(kg)	(%)	(kg)	(%)
WLA to Hawaii DOT	784	8.06	1.64	784	14.6	4.56	0	0	6.56	45	2.92	64
WLA to Hawaii DOD	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOE	0.93	0.02	0.003	0.93	0.023	0.006	0	0	0	31	0.002	43
WLA to Hawaii DOH	1.42	0.02	0.003	1.42	0.036	0.009	0	0	0	0	0	0
WLA to CCH ENV	2,733	19.4	4.23	2733	33.7	10	0	0	14.3	42	6.11	59
WLA to UH WCC	1.15	0.02	0	1.15	0.029	0.007	0	0	0.01	45	0.005	68
LA to NPS	536	8.14	1.15	536	16.1	3.22	0	0	7.98	50	2.07	64
Totals:	4,056	35.7	7.03	4,056	64.6	18.1	0	0	28.9	45	11.1	61

Table 5.11. Consolidated Wet Season TMDL Allocations to Major Sources

Wet Season Baseflow	Allocations			Existing Loads			Reductions Needed					
	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(kgd)	(%)	(kgd)	(%)	(kgd)	(%)
LA to Hawaii DOT	34	0.51	0.057	34	0.68	0.057	0	0	0.17	25	0	0
LA to Hawaii DOD	1	0.035	0.004	1	0.054	0.004	0	0	0.02	35	0	0
LA to Hawaii DOE	2	0.076	0.004	2	0.076	0.004	0	0	0	0	0	0
LA to Hawaii DOH	2	0.11	0.006	2	0.11	0.006	0	0	0	0	0	0
LA to CCH ENV	297	6.07	0.557	297	6.31	0.557	0	0	0.24	4	0	0
LA to UH WCC	2	0.090	0.004	2	0.090	0.004	0	0	0	0	0	0
LA to Other NPS	392	7.70	1.017	392	10.33	1.02	0	0	2.63	25	0	0
Totals:	729	14.59	1.648	729	17.65	1.648	0	0	3.07	17	0	0

Wet Season 10% Runoff	Allocations			Existing Loads			Reductions Needed					
	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(%)	(kg)	(%)	(kg)	(%)
WLA to Hawaii DOT	273	4.21	1.25	273	4.94	1.57	0	0	0.73	15	0.32	20
WLA to Hawaii DOD	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOE	0	0	0	0	0	0	0	0	0	0	0	0
WLA to Hawaii DOH	0	0	0	0	0	0	0	0	0	0	0	0
WLA to CCH ENV	594	6.03	1.89	594	8.42	2.88	0	0	2.39	28	0.99	34
WLA to UH WCC	0	0	0	0	0	0	0	0	0	0	0	0
LA to NPS	0	0	0	0	0	0	0	0	0	0	0	0
Totals:	868	10.2	3.14	868	13.4	4.44	0	0	3.12	23	1.30	29

Wet Season 2% Runoff	Allocations			Existing Loads			Reductions Needed					
	TSS	TN	TP	TSS	TN	TP	TSS		TN		TP	
	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(kg)	(%)	(kg)	(%)	(kg)	(%)
WLA to Hawaii DOT	1,834	14.5	4.21	1,834	34.5	10.7	0	0	20.0	58	6.50	61
WLA to Hawaii DOD	11.5	0.16	0.03	11.5	0.43	0.07	0	0	0.27	63	0.05	63
WLA to Hawaii DOE	30.0	0.51	0.11	30.0	0.75	0.19	0	0	0.24	32	0.07	39
WLA to Hawaii DOH	41.0	0.47	0.10	41.0	1.02	0.26	0	0	0	0	0	0
WLA to CCH ENV	11,672	88.8	22.1	11,672	148	41.0	0	0	59.7	40	18.9	46
WLA to UH WCC	33.1	0.38	0.08	33.1	0.83	0.21	0	0	0.45	54	0.12	60
LA to NPS	5,889	68.6	13.6	5,889	184	36.6	0	0	115	63	23.1	63
Totals:	19,511	173	40.2	19,511	369	89.0	0	0	196	53	48.8	55

5.6 Implementation Assurance

The large facility MS4 wasteload allocations (WLAs) to the City & County of Honolulu (CCH ENV) and Hawaii Department of Transportation (DOT) will be implemented through NPDES permits for those agencies. These revised permits call for the respective permittees to develop implementation and monitoring plans for each of the WLAs in Tables 5.10 and 5.11 above. The WLA implementation plans shall identify specific actions targeted to achieving the needed reductions of total suspended solids, total nitrogen, and total phosphorus. The monitoring plans shall specify the water quality monitoring and activity tracking necessary to demonstrate compliance with the WLAs assigned to the permittees.

Implementation of WLAs for small MS4 facilities will be assisted by the submittal of information and the development of stormwater management plans for public facilities required under NPDES Phase II (small facility MS4 permits). All public facilities on Oahu with more than one building and an underground drainage system (as indicated by an inlet/outlet that leads to/from a subsurface conveyance structure) are required to apply for permit coverage. The Small MS4 permit issued to Hawaii DOE (No. HI S000003), with a compliance date of January 28, 2006, includes three public elementary schools – Kapunahala, Benjamin Parker, and Puohala – within the Kaneohe watershed area. Each of these schools has complied with the requirement to submit a Storm Water pollution Control Plan and is in the process of implementing said plan. The Hawaii Veterans Cemetery requires a Small MS4 permit and Hawaii DOD is currently preparing application for this permit with DOH. The Pali Golf Course is one of many facilities covered by the CCH ENV large MS4, and other City facilities currently regulated by Small MS4s (such as parks), and facilities that should have been regulated under Small MS4s (including Ho’omaluhia Botanical Garden) are expected to be incorporated under this large MS4 permit for the next permit cycle.

The nonpoint source load allocations (LAs) for the Kaneohe watershed area may be implemented through a variety of voluntary approaches to polluted runoff control. A more detailed discussion of the implementation framework for both point sources (WLAs) and nonpoint sources (LAs) follows in Chapter 6.

Wasteload Allocations (WLAs) for the Kaneohe Stream TMDLs will be implemented through compliance with NPDES permit conditions and by following the stormwater management plans associated with those permits (Table 6.1). It will be necessary to revise most of these permits to include effluent limitations consistent with the approved WLAs, as required by federal regulations at 40 CFR 122.44(d)(1). Updating the permit schedules, planning requirements, compliance information, and monitoring requirements, and making these updates more readily available for agency and public use, is an important ongoing implementation task.

The large MS4 NPDES permits issued to the City & County of Honolulu (CCH MS4) and State of Hawaii Department of Transportation Highways Division (HDOT) require the respective permittees to develop WLA implementation and monitoring plans for at least one newly approved TMDL submittal per year, and to promptly begin implementing these plans. These WLA implementation plans shall identify specific actions targeted to achieving the needed reductions of total suspended solids, total nitrogen, and total phosphorus. The WLA monitoring plans shall specify the water quality monitoring and activity tracking necessary to demonstrate compliance with the WLAs assigned to the permittees. Similar conditions exist for non-MS4 permits (existing and new), requiring individual, site-specific implementation and monitoring plans sufficient to implement the specific WLAs, followed by specific action to reduce pollutant loading.

Implementation of WLAs to the NPDES Phase II small facility stormwater discharge permits (small MS4), such as those issued to the Department of Education for public schools, will be assisted by the submittal of information and development of stormwater management plans that are required under these permits. All public facilities on Oahu with more than one building and an underground drainage system (as indicated by an inlet/outlet that leads to/from a subsurface conveyance structure) are required to apply for permit coverage. However, although this decision for Kaneohe Stream assigns WLAs to small MS4s for specific City & County of Honolulu Parks facilities, the City and DOH will likely incorporate most or all of these facilities into the existing large MS4 permit coverage when the large MS4 permit is reissued on 2009.

Load Allocations (LAs) -The nonpoint source load allocations (LAs) for the Kaneohe watershed area may be implemented through a variety of voluntary approaches to polluted runoff and diffuse pollution control, including those described in 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. Although it was established thirty years ago that "the tenor of formulating management actions for non-point source pollution sources is directed toward source control. This direction is supported by the fact the pollution control is most effective and least expensive at the source" (Honolulu District 1978), there appears to be a long way remaining to go in this direction.

Table 6.1. NPDES Permits controlling discharges to Kaneohe Stream

Permit Type[1]	Permittee/Facility	Permit Number	Issued / Expires	Plan Dates[2]	Date of Last Inspection[3]	Date of Last Violation[4]	Discharge Monitoring Required?[5]
Phase 1 MS4	State of Hawaii Department of Transportation, Highways Division/MS4	HI S000001	02/28/2006 09/08/2009	SWMP 03//2007	August 2008 (C)	10/10/2000 NAV	No
Phase 1 MS4	City & County of Honolulu, Departments of Environmental Services, Facilities Maintenance, Design & Construction, Planning & Permitting/MS4	HI S000002	02/28/2006 09/08/2009	SWMP 03/31/2007	August 2008 (C)		No
Phase 2 MS4	State of Hawaii Department of Education (Ben Parker Elementary, Kapunahala Elementary, Puohala Elementary)	HI S000003	01/13/2005 12/31/2009	SWPCP 12/15/2006			No
Phase 2 MS4	State of Hawaii Department of Defense Hawaii Veterans Cemetery (also discharges to Kawa Stream)	pending	pending	SWPCP			
NGPC-C	Gentry Homes, Ltd. Mahinui Place	R10B792	5/7/2008 10/21/2012				
NOXP	Ohana Architectural Precast, LLC	07BC959	10/29/2007 10/28/2012				
NGPC	Various	Various	Future				
?	Windward Community College Assumed receiving water is Keaahala Stream, unless otherwise determined during permit reissuance	H107KC937	Expired?				No
Phase 2 MS4	State of Hawaii Department of Health Hawaii State Hospital	pending	pending	Assumed receiving water is Keaahala Stream, unless otherwise determined during processing of the permit application			

[1]Key to Permit Types:
MS4 = Municipal Separate Storm Sewer System (Phase 1 = large, Phase 2 = Small)
NGPC = Notice of General Permit Coverage (Appendices B-L)
C = Construction Stormwater
NOXP = Conditional No Exposure Exclusion

[2]Key to Plan Types
SWMP = Storm Water Management Plan
BMPP = Best Management Practices Plan
SWPCP = Storm Water Pollution Control Plan

[3]Key to inspection Types: C = Compliance, J = Complaint
[4]Key to ViolationTypes: NAV = Notice of Apparent Violation

[5]Key to Discharge Monitoring Requirements (for discharges to Kaneohe Stream):
N = None
R = Report occurrence of discharge
M = Report measurements of discharge constituents

An initial review of the land parcels within the Kaneohe Stream watershed (Table 6.2) suggests that there are no large capacity cesspools present, and that the individual wastewater systems (IWS) used for sewage and other wastewater disposal are not completely inventoried, inspected, or approved for use on about 89 parcels. Completing a review of these parcels and their IWS status is a narrowly-defined implementation task could lead to further inspection, discovery, and rectification of wastewater treatment and disposal problems and to potential nonpoint source pollutant load reductions. Ongoing repair and maintenance of the sewer collection system (Fukunaga & Associates 1999) and storm drainage system is also important in this regard. specific improvements to the collection, treatment, and disposal system in the Kailua-Kaneohe-Kahaluu region are addressed in the City's Wastewater Facilities Plan (Wilson Okamoto & Associates 2000).

Table 6.2. Wastewater Disposal Systems in Kaneohe Stream Sub-basins

IWS/Cesspool/Sewer	**Sub-Basins**						
Parcels with Known Disposal Systems	**1**	**1.1**	**2**	**3**	**4**	**5**	**Total**
Sewer Only Parcels	0	164	2	1520	725	664	3,075
IWS with Final Approval or Inspection	0	0	0	0	2	0	2
Parcels with Unknown Disposal Systems							
Assumed Sewer/Cesspool*	4	28	5	27	25	0	89
Assumed No Cesspool/Sewer*	10	10	3	2	6	18	49

* Assumes that Parcels w/ Bldg Value >$25,000, and no disposal system record, have an IWS, and the Parcels w/bldg value <$25,000, and no disposal system record, do not.

When IWS problems are discovered, they may be addressed by connecting the problem facility to conventional sanitary sewer collection or by improving and upgrading the design and construction of new and existing individual wastewater systems. A recently published Onsite Wastewater Treatment Survey and Assessment (Water Resources Research Center and Engineering Solutions, Inc., 2008) provides guidance as to the various treatment and disposal systems that are currently available and to describe their advantages and constraints so that those involved in the selection, design, construction, operation, maintenance, and permitting of these facilities can make informed decisions.

Watershed Based Plan

Specific measures for reducing pollutant loads in the Kaneohe watershed are identified in the Ko'olaupoko Water Quality Action Plan (Kailua Bay Advisory Council, 2002) and the Kailua Waterways Improvement Plan, Strategic Implementation Plan, and BMP Manual (Tetra Tech EM, Inc., 2003), as well as the Koolaupoko Watershed Restoration Action Strategy (Kailua Bay Advisory Council, 2007, see below). By addressing the nine elements required by EPA guidance and incorporating the LA objectives from Tables 6.1 and 6.2 above, this Action Strategy unlocks the door to additional Clean Water Act §319(h) incremental funds for water quality improvement projects. Such projects may also qualify for the DOH Clean Water State Revolving Fund Program, which provides low interest loans for the construction of point source and non-point source water pollution control projects.

The Watershed Restoration Action's management recommendations for South Kaneohe focus on riparian preservation and restoration, homeowner education, upland restoration, street sweeping, and stormwater catchment and recycling. Results from a Precision Riparian Buffer Model suggest the potential to preserve over 22 acres of riparian habitat owned by large landowners in the basin. The plan also recommends establishing a South Kaneohe Watershed Council that would seek acknowledgement from local Neighborhood Boards as a lead community entity into the planning process of watershed restoration and natural resource management.

In 1994, the State Legislature created the Kaneohe Bay Regional Council (administratively attached to DLNR) to serve as a central coordinative clearinghouse of public and private activities in the Bay, and as a repository and disseminator of information, and to facilitate productive interaction between users of the bay and the general public in order to develop a common vision and make recommendations for public policy. The Kaneohe Bay Master Planning Task Force, created by the Legislature in 1990, produced a 1992 Master Plan that led to the establishment of the Regional Council ("to provide a forum for future issues affecting the bay and advise County and State agencies") and recognized "an urgent need to address pollution of the bay originating in the watershed." In order to address this need, the Task Force stated the following positions on land use issues:

- Preserve in their natural state existing wetlands, natural riparian zones, and hillsides with slopes of 20% or more.
- Restrict development in the watershed in accordance with the City & County of Honolulu Koolaupoko Development Plan.
- Limit development where a sewage collection system does not exist, and restrict use of septic and individual waste water systems to residential lots with sufficient size (15,000 ft^2 or more) for disposal.
- Delay northward extension of the sewage collection system until existing infrastructure deficiencies are rectified.
- Repair and upgrade the existing sewage collection system to prevent by-passes of raw or partially treated sewage effluent into the bay and to prevent sewage infiltration through groundwater to the bay.
- Preserve and procure existing open space to increase present and future public access.
- Provide stable legislative support for a comprehensive water quality monitoring program for the Bay and its major streams.
- Establish and promote the use of cost-free hazardous waste collection sites.

For upslope areas, activities undertaken within the State Conservation District may require various levels of DLNR approval, including management plan development and implementation. Addressing water quality goals and objectives in these approvals, in consultation with the Regional Council, could be fertile ground for invigorating communications between DLNR upland, lowland, and marine management efforts and the wider community.

This Task Force/Master Plan platform provides useful baseline for ongoing efforts, and points to a lead role for the Regional Council in implementing the Watershed Restoration Action Strategy and TMDLs. To help address the monitoring needs outlined in the Action Strategy, all parties may consider focusing on a Master Plan recommendation to "institute a research program coordinated by HIMB [the Hawaii Institute of Marine Biology] to ascertain current levels of pollutant input into the bay, and determine the causes of deteriorating Bay water quality, and determine the impacts of fishing and water quality degradation on fish abundance, complementary to ongoing DLNR studies, evaluate the impacts of recreational uses of the Bay."

Sources of Additional information and Assistance for Polluted Runoff Control Implementation

The effectiveness and efficiency of many Best Management Practices (BMPs) for reducing pollutant loads are not necessarily tested under Hawaii conditions, and final selection of BMPs must also consider site-specific conditions. Sources of additional information and assistance are listed below. Technical assistance for agricultural producers is available from various organizations, primarily the U.S. Department of Agriculture (Natural Resources Conservation Service) and the University of Hawaii College of Tropical Agriculture and Human Resources.

Oahu Resource Conservation& Development works to improve the quality of life on O'ahu by encouraging and assisting local leadership to develop and carry out activities that conserve and sustain our natural, human, cultural and economic resources.
http://www.pacrimrcd.org/SectionIndex.asp?SectionID=72

U.S. Department of Agriculture, Natural Resources Conservation Service provides technical assistance with conservation planning (Aiea Service Center), cost-sharing for plan implementation (Farm Bill programs), and related information (technical guide and technical notes).
http://www.hi.nrcs.usda.gov/programs/

University of Hawaii College of Tropical Agriculture and Human Resources – Water Quality Extension Program: Includes Conservation System Guides for Pacific Basin Beginning and Limited Resource Farmers and Ranchers; The HAPPI (Hawaii's Pollution Prevention Information) Home Series and Farm Series informational worksheets and assessment materials developed to address different water pollution issues; and publications on various topics by the Regional Water Quality Program.
http://www.ctahr.hawaii.edu/wq/publications/publications.htm

State of Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife
http://www.dofaw.net/
Forestry Best Management Practices   http://www.state.hi.us/dlnr/dofaw/wmp/bmps.htm

The Koolau Mountains Watershed Partnership (KMWP) is part of the Hawaii Association of watershed Partnerships (HAWP). KWP is a voluntary alliance of public and private landowners and concerned parties who have banded together to manage forested upland watershed areas of the Ko'olau mountains on O'ahu and ensure fresh water supplies for future generations.
http://hawp.org/SectionView.php?SubSite=05
http://www.state.hi.us/dlnr/dofaw/wmp/koolau/default.htm
http://hawp.org/AboutHAWP.php

Hawaii Low Impact Development Guide (produced by CZM, 2006)
http://www.hawaii.gov/dbedt/czm/initiative/lid_pdf/lid_guide_2006.pdf

EPA Green Infrastructure: Covers everything from conservation easements and Transfer of Development Rights to pervious pavements and green roofs.
http://cfpub.epa.gov/npdes/home.cfm?program_id=298
Stormwater BMP menu (green infrastructure link accesses some of this information)
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm

Green Roof Information
www.greenroofs.org (click on 'About Green Roofs' and scroll down for runoff information)
http://www.caseytrees.org/programs/planning-design/gbo.html (Green Build Out Model)

http://www.greeninfrastructure.net/

Guam/CNMI stormwater management plan link
http://new.deq.gov.mp/artdoc/Sec6art55ID136.pdf

Center for Watershed Protection (www.cwp.org)

Codes & Ordinances Worksheet

The Codes & Ordinances Worksheet, or COW, is a simple worksheet that you can use to see how the local development rules in your community stack up against the model development principles outlined in Better Site Design. Answer the questions and see how environmentally-friendly your community is!
http://www.cwp.org/COW_worksheet.htm

Watershed Protection Audit

One of the most important tasks in establishing a watershed baseline is to conduct an audit of local watershed protection capabilities. The audit establishes a baseline of current strategies and practices within the watershed. By understanding the current state of development, watershed groups can assess strategies, practices, strengths and weaknesses can better plan future efforts. This document can help watershed organizations conduct an audit of the watershed protection tools currently available in their watershed.
http://www.cwp.org/Community_Watersheds/Watershed_Protection_Audit2.pdf

Stormwater Center
http://www.stormwatercenter.net/

Hawaii Coastal Nonpoint Pollution Control Program information

Program Documents

http://www.hawaii.gov/dbedt/czm/initiative/nonpoint.shtml
http://www.hawaii.gov/health/environmental/water/cleanwater/prc/implan-index.html

Management Measures

Urban (similar to the stormwater site but slightly different focus)
http://www.epa.gov/owow/nps/urbanmm/index.html

Agriculture
http://www.epa.gov/owow/nps/agriculture.html
http://www.epa.gov/owow/nps/agmm/index.html

Forestry
http://www.epa.gov/owow/nps/forestrymgmt/

Hydromodification
http://www.epa.gov/owow/nps/hydromod/index.htm

Marinas and Recreational Boating
http://www.epa.gov/owow/nps/mmsp/index.html

OTHER IMPLEMENTATION CONSIDERATIONS AND PRIORITIES

The watershed area covered by the Koolaupoko Watershed Restoration Action Strategy (Kailua Bay Advisory Council 2007) extends beyond the boundaries of the contributing areas for Kaneohe stream. Given that water quality impairments in the Kaneohe Bay watershed extend into the brackish and marine receiving waters for Kaneohe and Kawa streams, any implementation activities completed within the larger watershed area are expected to benefit these receiving waters, and should be considered part of the TMDL implementation framework.

In order to best organize the information used in this TMDL analysis, perpetuate its value, and link it with existing and new information as such becomes available, the ongoing delineation of waterbody segments and their contributing area boundaries should be incorporated into a new, local-resolution National Hydrography Dataset (NHD) for Hawaii. The DOH 2006 Water Quality Monitoring and Assessment Report (EHA 2008) outlines a tiered approach to defining and georeferencing attainment decision units, waterbody segments, and NHD reaches to represent a combination of hydrologic and regulatory truth.

While much of the pollutant loading to Kaneohe streams is from non-urban nonpoint sources, biological surveys and assessments indicate that the additional loading and impact from nonpoint and point source urban stormwater in these sub-basins is critically important to stream and watershed health. Thus management of the storm drainage systems in the Kaneohe urban core should be a focus for County and State polluted runoff control (nonpoint sources) and water pollution control (NPDES) implementation efforts. Approaches to consider include:

- Employing a watershed approach to county and state permitting, particularly with regard to the cumulative impacts of concurrent county grading permit and NPDES general permit coverage issuance for widespread land disturbance tied to construction activities;
- Further facilitating cross-program access to permitting and compliance databases for DOH TMDL staff; and
- Including TMDL staff in internal, pre-public notice review of proposed NPDES permit issuance.

EPA Source Water Assessment Program (SWAP) efforts for Oahu conducted by the DOH and the University of Hawaii Water Resources Research Center (Whittier et al. 2004) included the delineation of capture zones for potable groundwater wellheads and the identification potential contaminating activities (PCAs) within each capture zone. Acquiring the PCA inventory and linking it with surface water management program activities is another cross-program objective for DOH, along with developing a similar capture zone and PCA inventory approach for all groundwater that is a potential source of surface water quality impairments (non-potable and potable shallow and deep aquifers). The PCAs identified in the SWAP efforts include individual wastewater systems (IWS) and underground injection wells regulated by the EPA/State underground injection control program (UIC). Improving access to and the utility of IWS and UIC databases would be help support for TMDL development and implementation.

While chronic sedimentation of stream bottoms appears to be a major cause of biological impairment (poor habitat quality and absence of key native organisms), sediment contamination and the bioaccumulation of toxins in fish are emerging as associated concerns. Any future work to repair stream habitat and restore stream biota should carefully consider the broader relationships between pollutant loading and the biological, chemical, and physical integrity of the receiving waters, including the adjoining brackish and marine waters. Also, given that stream diversions and groundwater wells have altered the hydrologic regime and reduced streamflows (Takasaki et al. 1969), flow restoration also deserves consideration as a means to increase stream assimilative capacity and transport capacity for pollutants and to improve habitat for stream biota.

From a hydrocultural perspective, two more implementation frameworks deserve particular attention - the guidebook produced by the Kaneohe-Kahaluu Stream Restoration and Maintenance Project (Wilson Okamoto Corp. 2004) as part of a City & County of Honolulu visioning process, and the 2006 Strategic Plan (http://www.oha.org/pdf/hlid/SPfinalJan2006.pdf) and 2008 Preliminary Draft Interpretive Plan (http://www.hlid.org/pdf/IDP_Draft_080122.pdf) for the Halawa Luluku Interpretive Development Project, a joint effort of the Federal Highways Administration, State of Hawaii Department of Transportation, and State of Hawaii Office of Hawaiian Affairs. Public comments on this program include a call to “transform the Luluku agricultural complex into a viable farm to grow food for us to eat and stimulate our economy” (R. Kealoha Kaliko in *Ka Wai Ola O OHA – The Living Water of OHA* 22(7): 03, Iulai 2005, http://www.oha.org/pdf/kwo05/0507/3.pdf).

Chapter 7 – Public Participation

Total Maximum Daily Loads (TMDLs) for Total Suspended Solids, Nitrogen and Phosphorus in Kaneohe Stream, Kaneohe, Hawaii

TMDL development in the Kaneohe Bay watershed is an outcome of many years of public participation in initiating and sustaining environmental protection programs. Public nominations and watershed targeting by EPA and DOH led to numerous waterbody assessment in the Kaneohe bay watershed, including Kamooalii and Kaneohe streams, in 1996. The results of these assessments formed the basis for adding these two waters to the State's 303(d) list in 2001. Kawa Stream (in an adjacent watershed), and Waimanalo Stream (in the same region) were added to the list in 1998. Kawa Stream and Waimanalo TMDL development was already in progress by 2000, and included some preliminary scoping of Kaneohe Stream TMDLs and biological assessment of the stream.

During that time, various other scientific, educational, and political programs were also addressing water pollution problems and concerns. The DOH TMDL program built on its existing experience with Kawa Stream and these other programs to begin water quality sampling directed at Kaneohe Stream TMDL development (with the DOH Clean Water Branch, Oceanit, Inc., and AECOS, Inc.). Other programs involved during this period included the Kaneohe-Kahaluu Stream Advisory Committee (City and County of Honolulu Vision Community #7), which conducted a Kaneohe-Kahaluu Stream Restoration and Maintenance Project that produced a community guidebook (Wilson Okamoto Corp. 2004); the Halawa Luluku Interpretive Development Project, whose mission is to establish an interpretive development plan for areas affected by the construction of H-3 that will preserve and interpret the history, culture and traditions of these lands in perpetuity (see Chapter 6, Other Implementation Considerations and Priorities), and the Kailua Bay Advisory Council (KBAC).

DOH participated in the development of KBAC's Water Quality Action Plan (2002) and the Kailua Waterways Improvement Plan, Strategic Implementation Plan, and BMP Manual (Tetra Tech EM, Inc., 2003). At a January 2003 Koolaupoko Watershed Community Workshop, DOH presented an overview of our water pollution control/water quality improvement programs and, with KBAC, led participants in water quality improvement exercises to reinforce their understanding of these programs and begin developing an Implementation Plan for Kaneohe Stream. Later in 2003, DOH participated in a Stream Fair organized by the Kaneohe-Kahaluu Community Vision Team. Most recently, DOH funded KBAC's completion of the Koolaupoko Watershed Restoration Action Strategy (2007) through Clean Water Act §319(h), which now serves as a "Watershed Based Plan" that may attract priority funding for actions from this plan that reduce pollutant loading, improve water quality, repair habitat quality, and restore ecosystem integrity.

During the TMDL development process, Oceanit, Inc., AECOS, Inc., Jack D. Smith, and DOH-EPO staff discussed the TMDLs with various other interested parties and sources of information, including:

- State of Hawai'i Department of Health (Clean Water Branch, Wastewater Branch, Safe Drinking Water Branch, Office of Hazard Evaluation and Emergency Response)

- U.S. Environmental Protection Agency (Region 9)
- University of Hawai'i (Sea Grant Extension Program, Center for Conservation Research and Training, College of Tropical Agriculture and Human Resources, Water Resources Research Center)
- City & County of Honolulu (Department of Environmental Services, Department of Facilities Maintenance, Department of Design and Construction, Department of Planning, Board of Water Supply)
- State of Hawaii Department of Transportation (Highways Divisions)
- State of Hawaii Department of Education
- Hawaii State Hospital (State of Hawaii Department of Health)
- Hoomaluhia Botanical Garden (City and County of Honolulu Department of Parks and Recreation)
- Pali Golf Course ((City and County of Honolulu Department of Enterprise Services)
- Windward Oahu Soil and Water Conservation District
- Kaneohe Neighborhood Board # 30 (City & County of Honolulu)
- Kaneohe Bay Regional Council (State of Hawaii Department of Land and Natural Resources, Division of Boating and Ocean Recreation)
- State of Hawaii Department of Land and Natural Resources (Division of Aquatic Resources, Division of Forestry and Wildlife, Commission on Water Resource Management)
- Windward Community College
- WaikaluaLoko Fishpond Preservation Society
- HalawaLuluku Interpretive Development Project (State of Hawaii Department of Transportation and Office of Hawaiian Affairs)
- Ahupuaa Action Alliance
- Kaneohe Community Family Center
- Kaneohe Businesses Group
- Private land owners and property managers, and in particular Koolau Golf Course (Rob Nelson), Hope Chapel Kaneohe, Hawaii Pacific University, Kaneohe Shopping Center
- U.S. Geological Survey (Pacific Water Science Center)
- Hawaii Farm Bureau Federation (East Oahu County)

After internal review and preliminary DOH approval, a draft TMDL submittal was published for public review on August 15, 2008 (with direct notice to interested parties, and public notice). Thirteen people attended a public information meeting held on August 28, 2008 to present and discuss the results. Follow-up discussions and meetings with interested parties were held as requested. We received written comments on the draft decision document from the City and County of Honolulu (Department of Environmental Services and Department of Parks and Recreation), the State of Hawaii Department of Defense (Office of Veteran's Services), and Oceanit, Inc., and responded to each. Appendix D includes these responses to comments, the comments received, the public notice (with direct notice information), and the public information meeting sign-in sheet.

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APPENDIX A – Kaneohe Stream Water Quality Data

Table A.1. Kaneohe Stream Water Quality Data – Baseline Flow Conditions
*OLI station numbers are used throughout, Station Name is that given by the party conducting the sampling (OLI or CWB) for that sampling event (see Chapter 3).

OLI Station*	Name*	Date	Time	Temp (C)	DO%	DO (mg/L)	ORP (mV)	Sal (PPT)	Cond (mS/cm)	HyTurb (NTU)	HaTurb (NTU)	pH
Kamooalii Tributary - Wet Season												
1a	Ho'omaluhia Dam	11/6/2001	0914	22.90	99.7	8.57	259	0.08	0.18	1.30	1.52	8.70
1a	Ho'omaluhia Dam	12/4/2001	0840	21.93	96.4	8.39	312	0.17	0.17	1.70	2.06	7.89
1a	Ho'omaluhia Dam	1/8/2002	0850	21.19	91.9	8.09	319	0.09	0.19	1.20	1.58	8.10
1a	Ho'omaluhia Dam	2/5/2002	0857	20.78	106.6	9.52	330	0.09	0.19	17.10	13.10	7.44
1a	Ho'omaluhia Dam	3/5/2002	1200	20.82	90.8	8.07	297	0.10	0.21	41.30	2.44	7.79
1a	Ho'omaluhia Dam	4/2/2002	0800	20.26	102.3	9.20	335	0.08	0.18	2.10	1.36	7.94
1c	Kahua Lehua	11/6/2001	0940	22.02	84.5	7.36	249	0.09	0.20	6.70	6.68	7.87
1c	Kahua Lehua	12/4/2001	0858	21.54	92.9	8.08	209	0.11	0.23	4.90	5.04	7.72
1c	Kahua Lehua	1/8/2002	0912	20.78	92.9	8.26	224	0.10	0.22	8.00	7.37	7.78
1c	Kahua Lehua	2/5/2002	0920	20.65	102.0	9.10	308	0.05	0.09	20.90	20.40	7.36
1c	Kahua Lehua	3/5/2002	1225	20.07	88.4	8.02	311	0.10	0.21	18.60	10.50	7.53
1c	Kahua Lehua	4/2/2002	0810	18.74	94.0	9.76	326	0.10	0.21	7.20	8.53	7.60
1f	Kamooalii U	3/6/2001	1015	18.55	85.9	8.08	359	0.09		8.40	4.02	7.92
1f	Kamooalii U	3/27/2001	0845	23.50	76.6	6.86	342	0.08		11.60		8.20
1f	Ko'olau G.C.	11/6/2001	1020	20.62	96.6	8.58	271	0.09	0.20	11.60	9.21	8.34
1f	Ko'olau G.C.	12/4/2001	0926	20.58	99.2	8.84	294	0.09	0.21	4.90	3.43	8.38
1f	Ko'olau G.C.	1/8/2002	0940	20.18	98.5	8.80	298	0.09	0.19	3.80	3.57	8.28
1f	Ko'olau G.C.	2/5/2002	0950	19.40	103.9	9.56	306	0.09	0.20	15.60	5.23	7.96
1f	Ko'olau G.C.	3/5/2002	1250	19.42	91.7	8.41	291	0.09	0.19	8.20	8.97	8.07
1f	Ko'olau G.C.	4/2/2002	0830	17.76	106.1	10.03	338	0.08	0.19	6.40	4.53	8.19
2	Luluku	12/13/2000	0945	19.11	94.0	8.71	302	0.06		19.10		8.00
2	Luluku	3/6/2001	0930	18.56	92.1	8.64	358	0.06		7.30	2.01	7.92
2	Luluku	3/27/2001	0900	19.30	81.5	7.06	335	0.06		7.50		8.13
2	Luluku Stream	11/6/2001	0903	20.22	101.0	9.14	263	0.06	0.14	49.30	26.70	8.40
2	Luluku Stream	12/4/2001	0827	20.18	103.0	9.23	294	0.13	0.13	4.30	2.61	8.32
2	Luluku Stream	1/8/2002	0835	19.33	90.0	8.02	322	0.05	0.13	2.90	3.74	8.20
2	Luluku Stream	2/5/2002	0847	19.50	109.7	9.95	326	0.08	0.18	8.10	8.62	7.59
2	Luluku Stream	3/5/2002	1145	19.66	94.8	8.62	294	0.08	0.16	11.80	10.10	7.88
2	Luluku Stream	4/2/2002	0745	17.65	104.6	9.88	326	0.07	0.15	4.10	3.49	7.87

OLI Station*	Name*	Date	Time	Temp (C)	DO%	DO (mg/L)	ORP (mV)	Sal (PPT)	Cond (mS/cm)	HyTurb (NTU)	HaTurb (NTU)	pH
3a	Kamooalii L	12/13/2000	0920	21.40	98.5	9.35	305	0.09		8.30		8.24
3a	Kamooalii L	3/6/2001	0900	20.72	97.3	8.85	360	0.08		9.80	4.74	8.15
3a	Kamooalii L	3/27/2001	0820	22.80	87.5	7.41	335	0.09		9.50		8.40
3a	East Kaneohe	11/6/2001	0834	22.19	97.5	8.49	256	0.08	0.19	27.80	9.63	8.54
3a	East Kaneohe	12/4/2001	0805	22.17	97.3	8.47	294	0.06	0.19	2.90	2.13	8.35
3a	East Kaneohe	1/8/2002	0810	20.64	100.4	8.89	315	0.09	0.20	3.80	3.44	8.31
3a	East Kaneohe	2/5/2002	0825	20.64	103.0	9.18	325	0.10	0.21	8.50	7.17	7.90
3a	East Kaneohe	3/5/2002	1120	21.48	95.6	8.42	281	0.10	0.21	4.90	2.40	8.70
3a	East Kaneohe	4/2/2002	0730	18.50	109.1	10.08	328	0.09	0.20	3.00	2.14	8.10
Kamooalii Tributary - Dry Season												
1a	Ho'omaluhia Dam	5/7/2002	1011	21.12	93.9	8.32	372	0.04	0.10	146.80	129.00	7.39
1a	Ho'omaluhia Dam	6/4/2002	0910	26.25	87.4	7.05	302	0.10	0.22	4.40	1.74	7.84
1a	Ho'omaluhia Dam	7/9/2002	0945	23.99	92.8	7.72	324	0.10	0.21	1.30	1.50	7.71
1a	Ho'omaluhia Dam	8/6/2002	1010	26.14	75.5	5.95	394	0.10	0.21	0.90	2.04	7.71
1a	Ho'omaluhia Dam	9/10/2002	0900	26.33	100.3	8.15	337	0.09	0.20	0.50	1.62	7.72
1a	Ho'omaluhia Dam	10/8/2002	0900	25.10	69.6	5.73	356	0.09	0.19	1.70	1.53	7.71
1c	Kahua Lehua	5/7/2002	1037	21.05	91.9	8.17	264	0.08	0.17	18.10	13.80	
1c	Kahua Lehua	6/4/2002	0920	24.54	72.4	6.01	299	0.10	0.21	9.00	7.37	7.49
1c	Kahua Lehua	7/9/2002	1000	23.54	84.3	7.23	304	0.09	0.20	7.70	9.59	7.46
1c	Kahua Lehua	8/6/2002	1026	24.92	76.2	6.14	395	0.09	0.20	5.40	7.58	7.45
1c	Kahua Lehua	9/10/2002	0915	24.03	84.3	7.04	331	0.08	0.19	5.30	7.15	7.33
1c	Kahua Lehua	10/8/2002	0919	23.56	59.9	5.12	355	0.08	0.19	5.30	5.00	7.32
1f	Kamooalii U	6/13/2001	0909	20.73	92.7	8.22	354	0.10	0.22	10.40	8.38	8.28
1f	Kamooalii U	9/10/2001	0840	22.25	79.9	6.92	331	0.10	0.21	3.90	5.49	8.01
1f	Kamooalii U	9/26/2001	1130	22.17	70.6	6.15	280	0.10	0.21		4.22	8.17
1f	Ko'olau G.C.	5/7/2002	1107	20.30	102.3	9.26	324	0.13	0.25	18.90	5.17	8.06
1f	Ko'olau G.C.	6/4/2002	0935	22.22	91.8	7.93	313	0.09	0.20	6.00	3.70	8.06
1f	Ko'olau G.C.	7/9/2002	1030	21.15	97.4	8.69	307	0.09	0.20	2.90	3.37	8.01
1f	Ko'olau G.C.	8/6/2002	1050	24.21	87.5	7.16	394	0.08	0.18	1.50	2.54	7.95
1f	Ko'olau G.C.	9/10/2002	0946	22.33	98.8	8.57	328	0.09	0.19	2.70	2.39	7.89
1f	Ko'olau G.C.	10/8/2002	0950	22.18	70.5	6.08	356	0.09	0.20	2.80	2.23	7.87

OLI Station*	Name*	Date	Time	Temp (C)	DO%	DO (mg/L)	ORP (mV)	Sal (PPT)	Cond (mS/cm)	HyTurb (NTU)	HaTurb (NTU)	pH
2	Luluku	6/13/2001	0927	20.09	95.6	8.57	327	0.06	0.15	5.40	5.39	8.17
2	Luluku	9/10/2001	0910	21.33	83.4	7.40	310	0.06	0.13	1.00	3.31	7.92
2	Luluku	9/26/2001	1110	21.47	70.4	6.14	270	0.06	0.14		3.82	8.58
2	Luluku Stream	5/7/2002	1000	20.36	99.3	9.08	375	0.08	0.18	15.20	3.77	7.62
2	Luluku Stream	6/4/2002	0900	22.27	85.9	7.50	316	0.07	0.17	3.40	1.38	7.74
2	Luluku Stream	7/9/2002	0930	21.17	105.1	9.27	326	0.06	0.15	2.60	3.78	7.99
2	Luluku Stream	8/6/2002	0957	22.55	90.9	7.66	385	0.06	0.15	1.50	2.30	7.93
2	Luluku Stream	9/10/2002	0847	21.72	96.0	8.49	329	0.06	0.13	2.40	2.05	7.66
2	Luluku Stream	10/8/2002	0845	21.62	69.0	6.02	353	0.06	0.13	2.70	2.42	7.64
3a	Kamooalii L	6/13/2001	0840	23.70	99.8	8.32	317	0.08	0.18	12.80	12.20	8.51
3a	Kamooalii L	9/10/2001	0815	24.67	86.7	7.20	302	0.09	0.20	2.30	6.49	8.21
3a	Kamooalii L	9/26/2001	1100	27.50	83.5	6.58	268	0.09	0.19		8.92	8.82
3a	East Kaneohe	5/7/2002	0950	21.54	100.9	9.08	394	0.05	0.12	124.10	104.10	7.75
3a	East Kaneohe	6/4/2002	0840	25.49	95.5	7.84	309	0.10	0.22	5.80	4.97	8.53
3a	East Kaneohe	7/9/2002	915	25.69	103.7	8.59	345	0.09	0.20	5.50	3.77	8.64
3a	East Kaneohe	8/6/2002	0950	26.92	90.4	7.09	367	0.09	0.20	1.70	2.51	8.84
3a	East Kaneohe	9/10/2002	0835	25.28	104.2	8.60	317	0.09	0.19	2.60	2.83	8.39
3a	East Kaneohe	10/8/2002	0830	24.39	75.4	6.23	343	0.09	0.19	3.10	4.66	8.81

OLI Station*	Name*	Date	Time	Temp (C)	DO%	DO (mg/L)	ORP (mV)	Sal (PPT)	Cond (mS/cm)	HyTurb (NTU)	HaTurb (NTU)	pH
Kaneohe Stream - Wet Season												
4a	West Kapunahala	11/6/2001	0834	21.79	109.4	9.59	256	0.07	0.17	25.90	25.60	8.64
4a	West Kapunahala	12/4/2001	0800	21.47	89.7	7.84	293	0.09	0.20	2.20	4.29	8.53
4a	West Kapunahala	1/8/2002	0805	20.71	102.5	9.19	317	0.09	0.19	8.50	6.57	8.40
4a	West Kapunahala	2/5/2002	0820	20.57	107.3	9.65	325	0.11	0.24	7.20	5.38	8.05
4a	West Kapunahala	3/5/2002	1115	21.43	102.3	9.07	274	0.10	0.20	8.70	7.52	9.15
4a	West Kapunahala	4/2/2002	0720	18.16	103.8	9.78	321	0.09	0.19	7.00	6.36	8.24
5	Kaneohe	12/13/2000	0855	21.64	94.7	8.41	305	0.11		11.00		8.11
5	Kaneohe	3/6/2001	0800	20.23	100.7	9.27	359	0.09		13.00	4.94	7.92
5	Kaneohe	3/27/2001	0807	22.40	85.6	7.24	343	0.10		8.00		8.50
5	Wena Pl.	11/6/2001	0745	21.71	86.8	7.62	244	0.09	0.20	35.80	5.51	8.16
5	Wena Pl.	12/4/2001	0725	21.85	95.5	8.34	270	0.10	0.21	2.40	1.76	8.16
5	Wena Pl.	1/8/2002	0725	20.40	91.2	7.89	310	0.10	0.21	2.10	2.18	8.21
5	Wena Pl.	2/5/2002	0750	20.41	105.3	9.60	323	0.10	0.22	7.88	7.38	7.80
5	Wena Pl.	3/5/2002	1035	20.97	90.7	7.98	292	0.11	0.22	24.80	3.32	7.97
5	Wena Pl.	4/2/2002	0700	18.14	106.4	9.89	335	0.10	0.21	2.30	1.90	7.90
Kaneohe Stream - Dry Season												
4a	West Kapunahala	5/7/2002	0941	21.83	102.9	8.89	354	0.17	0.35	19.40	7.89	8.05
4a	West Kapunahala	6/4/2002	0830	24.19	105.6	8.83	307	0.09	0.20	9.00	6.10	8.80
4a	West Kapunahala	7/9/2002	0900	23.65	109.1	9.22	337	0.08	0.18	9.10	7.49	8.95
4a	West Kapunahala	8/6/2002	0938	25.90	100.1	8.04	364	0.08	0.18	4.70	6.32	8.98
4a	West Kapunahala	9/10/2002	0828	23.58	101.8	8.36	312	0.08	0.17	8.50	7.61	8.50
4a	West Kapunahala	10/8/2002	0815	22.74	66.7	5.68	335	0.08	0.17	7.50	7.76	8.48
5	Kaneohe	6/13/2001	0827	22.84	86.9	7.79	312	0.07	0.16	10.70	12.50	8.56
5	Kaneohe	9/10/2001	0740	24.22	91.2	7.67	294	0.09	0.20	0.60	2.28	8.28
5	Kaneohe	9/26/2001	1054	26.53	78.2	6.25	246	0.09	0.19		9.04	8.74
5	Wena Pl.	5/7/2002	0905	21.75	105.5	8.99	311	0.02	0.06	70.20	54.60	7.38
5	Wena Pl.	6/4/2002	0815	25.82	104.0	8.46	303	0.06	0.14	6.50	3.90	8.63
5	Wena Pl.	7/9/2002	0840	24.00	111.8	9.38	310	0.09	0.20	7.30	4.62	8.63
5	Wena Pl.	8/6/2002	0915	25.23	98.9	8.13	363	0.09	0.20	14.60	3.71	8.87
5	Wena Pl.	9/10/2002	0747	25.25	101.2	8.06	314	0.09	0.19	4.80	2.96	8.04
5	Wena Pl.	10/8/2002	0735	24.07	68.7	6.06	335	0.08	0.18	3.10	3.99	8.22

OLI Station*	Name*	Date	TSS (mg/L)	NH_4 (µg/L)	NO_3+NO_2 (µg/L)	TDN (µg/L)	TDP (µg/L)	Chl 'a' (µg/L)	Si (mg/L)	2-day Rain (inch)	Comments
Kamooalii Tributary - Wet Season											
1a	Ho'omaluhia Dam	11/6/2001	0.50	12	77	173	11		5.00	0.08	
1a	Ho'omaluhia Dam	12/4/2001	1.00	8	39	163	11		4.80	0.09	
1a	Ho'omaluhia Dam	1/8/2002	0.50	4	18	143	10		7.50	0.03	
1a	Ho'omaluhia Dam	2/5/2002	3.00	13	166	295	19		7.30	1.00	
1a	Ho'omaluhia Dam	3/5/2002	1.00	8	41	156	11		6.60	0.97	
1a	Ho'omaluhia Dam	4/2/2002	1.00	5	43	167	9		5.40	0	
1c	Kahua Lehua	11/6/2001	1.00	9	54	118	15		11.80	0.08	
1c	Kahua Lehua	12/4/2001	1.00	13	67	116	6		11.50	0.09	
1c	Kahua Lehua	1/8/2002	1.00	8	38	116	5		12.40	0.03	
1c	Kahua Lehua	2/5/2002	8.00	5	59	202	11		7.90	1.00	
1c	Kahua Lehua	3/5/2002	4.00	4	31	108	12		10.60	0.97	
1c	Kahua Lehua	4/2/2002	2.00	5	30	105	9		10.00	0	
1f	Kamooalii U	3/6/2001	3.00	0	90	130	20	0.16	8.10		Upper station started later than others
1f	Kamooalii U	3/27/2001									
1f	Ko'olau G.C.	11/6/2001	15.00	9	6	79	22		8.70	0.08	
1f	Ko'olau G.C.	12/4/2001	5.00	2	39	58	14		7.80	0.09	
1f	Ko'olau G.C.	1/8/2002	4.00	2	51	155	19		8.30	0.03	
1f	Ko'olau G.C.	2/5/2002	5.00	1	196	255	20		8.80	1.00	
1f	Ko'olau G.C.	3/5/2002	9.00	2	205	279	23		7.70	0.97	
1f	Ko'olau G.C.	4/2/2002	7.00	1	186	269	25		7.20	0	
2	Luluku	12/13/2000									
2	Luluku	3/6/2001	1.00	20	110	140	30	0.53	12.00		
2	Luluku	3/27/2001									Lower station only (short stream)
2	Luluku Stream	11/6/2001	33.00	8	71	107	53		12.10	0.08	
2	Luluku Stream	12/4/2001	1.00	2	118	143	31		11.00	0.09	
2	Luluku Stream	1/8/2002	3.00	4	97	186	33		12.20	0.03	
2	Luluku Stream	2/5/2002	5.00	1	331	405	31		13.90	1.00	
2	Luluku Stream	3/5/2002	7.00	3	140	202	38		11.20	0.97	
2	Luluku Stream	4/2/2002	2.00	2	138	197	24		10.80	0	
3	Kamooalii L	12/13/2000									
3	Kamooalii L	3/6/2001	5.00	20	220	380	10	3.50	9.00		
3	Kamooalii L	3/27/2001									

OLI Station*	Name*	Date	TSS (mg/L)	NH_4 (µg/L)	NO_3+NO_2 (µg/L)	TDN (µg/L)	TDP (µg/L)	Chl 'a' (µg/L)	Si (mg/L)	2-day Rain (inch)	Comments
3	East Kaneohe	11/6/2001	12.00	13	35	338	16		5.80	0.08	
3	East Kaneohe	12/4/2001	2.00	10	373	594	14		5.50	0.09	TNH4 .08
3	East Kaneohe	1/8/2002	3.00	11	307	536	13		7.60	0.03	TNH4 .12
3	East Kaneohe	2/5/2002	3.00	4	376	485	19		9.20	1.00	
3	East Kaneohe	3/5/2002	2.00	10	202	314	13		8.20	0.97	
3	East Kaneohe	4/2/2002	2.00	6	247	385	10		6.10	0	
Kamooalii Tributary - Dry Season											
1a	Ho'omaluhia Dam	5/7/2002	53.00	32	129	272	19		4.30	3.36	Storm Event
1a	Ho'omaluhia Dam	6/4/2002	1.00	22	22	88	234		7.90	0	
1a	Ho'omaluhia Dam	7/9/2002	1.00	15	43	188	11		8.10	0.37	
1a	Ho'omaluhia Dam	8/6/2002	1.00	16	17	194	12		8.30	0.10	
1a	Ho'omaluhia Dam	9/10/2002	1.00	34	24	207	13		8.10	0.23	
1a	Ho'omaluhia Dam	10/8/2002	6.00	23	30	194	12		9.00	0.05	
1c	Kahua Lehua	5/7/2002	5.00	13	72	324	12		9.10	3.36	Storm Event
1c	Kahua Lehua	6/4/2002	2.00	5	5	23	96		11.40	0	
1c	Kahua Lehua	7/9/2002	4.00	6	31	107	11		11.50	0.37	
1c	Kahua Lehua	8/6/2002	4.00	1	24	92	6		10.30	0.10	
1c	Kahua Lehua	9/10/2002	4.00	5	16	92	11		10.80	0.23	
1c	Kahua Lehua	10/8/2002	7.00	2	29	109	10		11.80	0.05	
1f	Kamooalii U	6/13/2001									
1f	Kamooalii U	9/10/2001	3.00	0	10	50	10	0.17	9.60		
1f	Kamooalii U	9/26/2001									No Hydrolab Turb. Reading
1f	Ko'olau G.C.	5/7/2002	5.00	1	214	353	17		8.30	3.36	Storm Event
1f	Ko'olau G.C.	6/4/2002	3.00	1	1	153	210		8.20	0	
1f	Ko'olau G.C.	7/9/2002	3.00	1	116	177	14		8.20	0.37	
1f	Ko'olau G.C.	8/6/2002	2.00	1	75	111	12		7.50	0.10	
1f	Ko'olau G.C.	9/10/2002	2.00	2	18	66	14		7.90	0.23	
1f	Ko'olau G.C.	10/8/2002	3.00	1	6	66	14		8.60	0.05	
2	Luluku	6/13/2001									
2	Luluku	9/10/2001	3.00	10	50	80	30	3.25	13.40		NO NH4 Reading
2	Luluku	9/26/2001									No Hydrolab Turb Readings

OLI Station*	Name*	Date	TSS (mg/L)	NH_4 (µg/L)	NO_3+NO_2 (µg/L)	TDN (µg/L)	TDP (µg/L)	Chl 'a' (µg/L)	Si (mg/L)	2-day Rain (inch)	Comments
2	Luluku Stream	5/7/2002	2.00	1	474	599	26		11.20	3.36	Storm Event
2	Luluku Stream	6/4/2002	1.00	3	3	134	172		12.10	0	
2	Luluku Stream	7/9/2002	1.00	1	100	129	27		12.30	0.37	
2	Luluku Stream	8/6/2002	2.00	1	91	138	27		11.90	0.10	
2	Luluku Stream	9/10/2002	1.00	7	87	124	31		11.10	0.23	
2	Luluku Stream	10/8/2002	3.00	1	102	149	51		12.20	0.05	
3	Kamooalii L	6/13/2001									
3	Kamooalii L	9/10/2001	7.00	20	190	370	10	3.36	7.20		NO NH4 Reading
3	Kamooalii L	9/26/2001									No Hydrolab Turb & NH4 Readings
3	East Kaneohe	5/7/2002	38.00	22	335	601	19		4.80	3.36	Storm Event
3	East Kaneohe	6/4/2002	5.00	10	10	209	309		7.80	0	
3	East Kaneohe	7/9/2002	6.00	17	124	323	12		8.20	0.37	
3	East Kaneohe	8/6/2002	3.00	8	113	259	9		8.40	0.10	
3	East Kaneohe	9/10/2002	3.00	17	142	295	12		10.20	0.23	
3	East Kaneohe	10/8/2002	5.00	14	191	343	21		9.00	0.05	

OLI Station*	Name*	Date	TSS (mg/L)	NH_4 (μg/L)	NO_3+NO_2 (μg/L)	TDN (μg/L)	TDP (μg/L)	Chl 'a' (μg/L)	Si (mg/L)	2-day Rain (inch)	Comments
Kaneohe Stream - Wet Season											
4	West Kapunahala	11/6/2001	17.00	4	72	129	23		12.20	0.08	
4	West Kapunahala	12/4/2001	4.00	3	62	102	17		11.20	0.09	
4	West Kapunahala	1/8/2002	10.00	21	118	238	14		12.40	0.03	
4	West Kapunahala	2/5/2002	5.00	1	231	308	20		13.30	1.00	
4	West Kapunahala	3/5/2002	7.00	5	75	187	33		13.60	0.97	
4	West Kapunahala	4/2/2002	6.00	2	34	132	23		10.00	0	
5	Kaneohe	12/13/2000									
5	Kaneohe	3/6/2001	7.00	0	200	320	10	6.79	10.30		
5	Kaneohe	3/27/2001									
5	Wena Pl.	11/6/2001	9.00	14	50	290	18		9.60	0.08	Rain
5	Wena Pl.	12/4/2001	1.00	8	330	442	14		7.40	0.09	
5	Wena Pl.	1/8/2002	2.00	15	289	426	13		9.70	0.03	
5	Wena Pl.	2/5/2002	4.00	4	363	465	19		10.10	1.00	
5	Wena Pl.	3/5/2002	2.00	17	258	395	17		8.60	0.97	
5	Wena Pl.	4/2/2002	2.00	10	270	376	11		7.90	0	
Kaneohe Stream - Dry Season											
4	West Kapunahala	5/7/2002	5.00	4	1120	1230	20		9.90	3.36	Storm Event
4	West Kapunahala	6/4/2002	8.00	3	3	39	154		13.70	0	high algae growth
4	West Kapunahala	7/9/2002	4.00	5	18	161	28		13.70	0.37	
4	West Kapunahala	8/6/2002	6.00	1	7	201	22		12.30	0.10	
4	West Kapunahala	9/10/2002	6.00	4	1	110	26		13.40	0.23	
4	West Kapunahala	10/8/2002	11.00	1	n/a	123	29		12.20	0.05	
5	Kaneohe	6/13/2001									
5	Kaneohe	9/10/2001	6.00	10	130	260	10	3.53	8.50		NO NH4 Reading
5	Kaneohe	9/26/2001									No Hydrolab Turb & NH4 Readings
5	Wena Pl.	5/7/2002	34.00	20	568	1020	24		7.20	3.36	Storm Event
5	Wena Pl.	6/4/2002	6.00	13	13	172	254		9.80	0	high algae growth
5	Wena Pl.	7/9/2002	4.00	10	97	246	14		9.80	0.37	
5	Wena Pl.	8/6/2002	4.00	13	59	214	13		8.90	0.10	
5	Wena Pl.	9/10/2002	4.00	18	132	267	16		10.40	0.23	
5	Wena Pl.	10/8/2002	5.00	90	156	149	25		11.20	0.05	

Table A.2. Kaneohe Stream Water Quality Data – Storm Flow Conditions

OLI Station*	Name*	Date	Time	HaTurb (NTU)	TSS (mg/L)	NO_3+NO_2 (μg/L)	TN (μg/L)	TP (μg/L)	Sample Type
Kamooalii Tributary									
1a	KS 04B	11/27/2001	230	9.89	8	1170	3170	179	pager
1a	KS 04C	11/27/2001	1315	17	9.4	60	274	98	grab
1a	KS 04A	11/27/2001	0001	14.5	39.6	678	1990	228	level
1a	Kane'ohe 5	12/13/2001	640	18.2	18	620	4000	150	pager
1a	Kane'ohe 5	12/13/2001	1300	2.08	1.2	112	246	200	grab
1a	Kane'ohe 04B	1/29/2002	130	11.7	10	211	3800	90	pager
1a	Ho'omaluhia Overflow	1/29/2002	1340		38.5	163	542	210	
1a	Kane'ohe 04A	1/29/2002	0001	101	84	6	7400	390	level
1a	R1 Reservoir Outlet	4/23/2002	1515	3.5	4.6				grab
1a	Ho'omaluhia Dam	5/7/2002	1011	129	53	129			
1b	Pipe	11/27/2001	900	34.4	34.7	217	682	106	grab
1b	Kane'ohe 8 pipe	12/13/2001	1150	29.7	45	2	508	250	grab
1b	Ho'omaluhia 24" culvert	1/29/2002	1510	14	14.4	269	445	130	
1c	KS 14B	11/27/2001	230	11.4	8	53	3790	120	pager
1c	Upper Park	11/27/2001	900	144	62.7	311	1000	220	grab
1c	KS 14C	11/27/2001	1245	20.6	12.6	131	440	140	grab
1c	KS 14A	11/27/2001	0001	764	873	2	14400	5150	level
1c	Kane'ohe 6	12/13/2001	640	7.86	188	1	3700	175	pager
1c	Kane'ohe 6	12/13/2001	1145	8.04	3.6	50	118	175	grab
1c	Kane'ohe 14B	1/29/2002	130	79.6	60	26	8500	260	pager
1c	Ho'omaluhia Stream	1/29/2002	1445	14.3	7.7	128	302	100	
1c	Kane'ohe 14A	1/29/2002	0001	51	57	57	5400	190	level
1c	Kahua Lehua	5/7/2002	1037	13.8	5	72			
1d	G1 Golf Course Stream	4/23/2002	1530	377	380				grab
1e	HPU	1/29/2002	400	166	49	80	700	410	grab
1f	KS 09B	11/27/2001	230	93.4	124	230	4090	400	pager
1f	KS 09C	11/27/2001	1212	12.4	41	246	521	175	grab
1f	KS 09A	11/27/2001	0001	863	730	99	13600	2500	level
1f	Kane'ohe 7	12/13/2001	640	4.73	7.3	1	1480	175	pager
1f	Ko'olau Golf Course	1/26/2002	1730	62	824	62	17500	1750	
1f	Ko'olau Golf Course	1/26/2002	2030	263	74.5	263	3980	240	pager
1f	Ko'olau Golf Course	1/29/2002	1250	14.8	12.6	304	575	110	
1f	Kane'ohe 09A	1/29/2002	0001	51.5	60.3	101	1020	230	level
1f	Ko'olau G.C.	5/7/2002	1107	5.17	5.00	214			
1g	Pali	11/27/2001	800	45.7	46.5	60	717	69	grab
1g	Station 1--Kaneohe	12/13/2001	1020	16.2	22.1	100	426		grab
1h	Ko'olau B	1/29/2002	1425	29.4	19.6	290	485	150	
1h	S2-sml str R. Fork	4/23/2002	1505	224	214				grab
1h	G2 Grass Swale	4/23/2002	1507	139	79				grab
1h	S1-sml str L. Fork	4/23/2002	1508	160	90				grab
1i	Lower Pali Stream	11/27/2001	910	197	120	146	1250	339	grab
1i	Station 2--Kaneohe	12/13/2001	1050	97.4	102	36	7510	552	grab
2	KS 06B	11/27/2001	230	69.4	75.2	90	1750	318	pager
2	KS 06C	11/27/2001	1345	10.8	9	338	526	150	grab

OLI Station*	Name*	Date	Time	HaTurb (NTU)	TSS (mg/L)	NO_3+NO_2 (µg/L)	TN (µg/L)	TP (µg/L)	Sample Type
2	KS 06A	11/27/2001	0001	158	189	146	2160	212	level
2	Kane'ohe 4	12/13/2001	640	206	3.6	14	3960	425	pager
2	Kane'ohe 4	12/13/2001	1330	29.9	25.3	185	392	275	grab
2	Ho'omaluhia USGS	1/26/2002	1730	10	376	10	9430	269	
2	Ho'omaluhia USGS	1/26/2002	2030	122	41.5	122	5370	367	pager
2	Kane'ohe 06B	1/29/2002	130	52.2	96	116	1420	350	pager
2	USGS Site	1/29/2002	1315	10.8	13	409	680	130	
2	Kane'ohe 06A	1/29/2002	0001	155	154	56	3300	520	level
2	USGS #1	4/23/2002	1503	686	374	202	7800	1950	grab
2	Luluku Stream	5/7/2002	1000	3.77	2	474			
2a	USGS Roadside	4/23/2002	1500	31.9	14.2	32	554	99	grab
3a	KS 07B	11/27/2001	230	45.8	50	190	1080	350	pager
3a	KS 07C	11/27/2001	1445	16.5	10.4	290	458	110	grab
3a	KS 07A	11/27/2001	0001	150	265	198	4030	950	level
3a	Kane'ohe 2R	12/13/2001	640	3.25	3.6	276	4940	125	pager
3a	Kane'ohe 2L	12/13/2001	0001	76.8	120	2	7900	450	level
3a	Rt branch	1/26/2002	2030	313	3	5200	60		pager
3a	Rt branch	1/26/2002	0001	35	189	6010	370		level
3a	Kane'ohe R Branch	1/29/2002	1600	70.2	28.5	374	708	210	
3a	Kane'ohe 07A	1/29/2002	0001	18.7	22.5	280	768	140	level
3	East Kaneohe	5/7/2002	0950	104.1	38.0	335			
3b	Kane'ohe Strm @ ft brdge	1/29/2002	510	30.5	18	271	482	120	grab
3c	Kane'ohe Street Runoff	1/29/2002	500	2.4	9	138	320	120	grab
Kaneohe Stream									
4a	KS 13B	11/27/2001	230	28.8	35.7	281	2240	225	pager
4a	KS 13C	11/27/2001	1450	7.62	6	2130	2360	100	grab
4a	KS 13A	11/27/2001	0001	122	363	135	3560	1000	level
4a	Kane'ohe 3	12/13/2001	640	32.3	36.5	108	5480	175	pager
4a	Kane'ohe 3	12/13/2001	0001	112	137	60	6350	475	level
4a	Kane'ohe 13B	1/29/2002	130	45.2	47.6	192	1420	190	pager
4a	Kane'ohe L Branch	1/29/2002	1600	10.9	9.6	1530	1710	100	
4	West Kapunahala	5/7/2002	0941	7.89	5	1120			
4b	Keneke Street	1/29/2002	505	37.4	21.5	685	1030	170	grab
4c	Kane'ohe 13A	1/29/2002	0001	83.6	109	167	3500	340	level
5	KS lower	11/27/2001	1500	12.3	9.7	941	1300	171	grab
5	Kane'ohe 1	12/13/2001	1400	10.4	13.4	219	399	150	
5	Kane'ohe Main Strm #1	1/26/2002	2100	156	13.4	156	447	120	isco
5	Kane'ohe Main Strm #1	1/26/2002	2300		17.8				isco
5	Kane'ohe Main Strm #1	1/27/2002	100		14.6				isco
5	Kane'ohe Main Strm #1	1/27/2002	300	253	11.6	253	421	138	isco
5	Kane'ohe Main Strm #1	1/27/2002	500	308	11.6	308	468	110	isco
5	Kane'ohe Main Strm #1	1/27/2002	700	329	8.2	329	457	90	isco
5	Composite 1	1/27/2002		248		248	511	163	
5	Composite 2	1/27/2002		239		239	443	130	
5	Wena Pl.	5/7/2002	0905	54.6	34	568			

B.1.0 Purpose.

The TMDL allocation process needs to disaggregate watershed-scale observations of stream flow and stream quality to contributions from individual sub-basins in the watershed and from identified land use areas, i.e., pollutant sources, in each sub basin during both dry weather and wet weather conditions. The elements of a systematic and technically consistent procedure for this disaggregation in the Kaneohe Stream watershed are described in this Appendix.

B.2.0 Rainfall Distribution.

Local climatic patterns are influenced by a number of local factors: topography, terrain features, and proximity to coastal moisture sources. The climatic statistical regression model known as PRISM (parameter–elevation regressions on independent slopes model) incorporates these factors in a GIS-based climatic mapping system developed at Oregon State University for USDA-NRCS and other agencies (Daly et al, 2002). PRISM climatic mapping has now been extended by NRCS to all of the U.S. states including the islands of Hawaii. This system provides 30-year (1961-1990) statistical regressions of annual and mean monthly rainfall distributions at 500m x 500m grid cell resolution for Oahu, including the Kaneohe watershed area. Seasonal distributions are obtained from summations of May-October (dry season) and November-April (wet season) monthly rainfall values. If temporal rainfall distributions are assumed similar across small watershed areas, then spatial distributions of rainfall for an individual event, e.g., 10% or 2% frequency storm, can be approximated:

$$P_j = \frac{P_{Zj}}{P_{ZR}} P_R \qquad (2\text{-}1)$$

Where:

P_j = event rainfall at watershed location j
P_{Zj} = seasonal PRISM rainfall at location j
P_{ZR} = seasonal PRISM rainfall at reference location
P_R = event rainfall at reference meteorological station in or near watershed area.

B.3.0 Evaporation.

Pan-evaporation data from Hawaii have been correlated inversely with annual rainfall (Takasaki et al, 1969). Rainfall can evidently be an effective surrogate for a combination of parameters (solar incidence, vapor pressure, cloud cover) normally found in calculations of evaporation and evapotranspiration. The form of the regression equation developed by Takasaki et al, $\log_{10}E = 1.9387 - 0.0035P$, is computationally awkward for

TMDL disaggregation purposes. Figure B1 is a replotting of the Oahu evaporation data from Takasaki et al (Table 4) in a more convenient linear form:

$$E_v = E_0 - (e_v)P \qquad (3\text{-}1)$$

Where:

E_v = estimated median annual pan evaporation, inch
P = median annual rainfall, inch
E_0 = intercept of linear evaporation v. rainfall regression line, inch
e_v = slope of linear evaporation v. rainfall regression line, inch/inch.

For the linear regression equation ($r^2 = 0.948$) in Figure B1, E_0 is 78.39 and e_v is 0.341.

Baseflow data for Kawa Stream (see section B.5.0) indicates that the intercept of 78.39 for equation *3-1* may overstate actual evapotranspiration rates. Evapotranspiration, at least during conditions of limited soil moisture, is likely to be less than pan evaporation measurements.

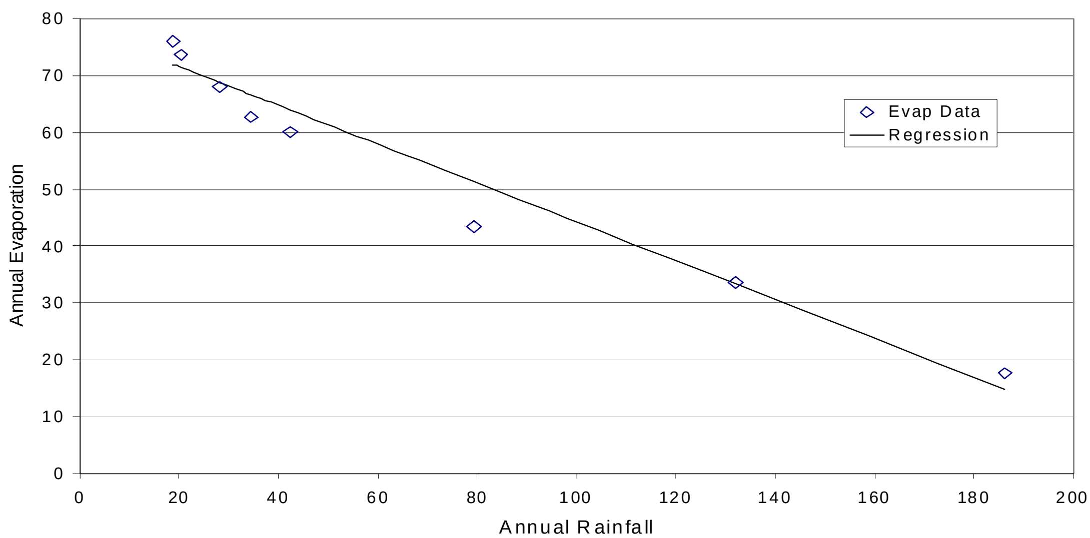


Figure B1. Correlation of Evaporation with Rainfall, Oahu Stations

B.4.0 Stormwater Runoff.

Of the several approaches used to simulate stormwater runoff, two relatively simple models are useful for the scale and purposes of TMDL development. For individual events, i.e., design storms, the SCS runoff formulation (USDA 1985, 1986) has found wide application:

$$R = \frac{(P - 0.2S)^2}{(P - 0.2S) + S} \qquad (4\text{-}1a)$$

$$S = \frac{1000}{CN} - 10 \qquad (4\text{-}1b)$$

Where:

R = event runoff, inch
P = event rainfall, inch
S = potential maximum retention after runoff begins, inch
CN = SCS curve number, $0 < CN < 100$.

The major factors that determine *CN* are the hydrologic soil group (*HSG*), land use, cover, and conservation practice. *CN* values are tabulated in the USDA technical release TR-55, Urban Hydrology for Small Watersheds (USDA 1986). *HSG* classifications (Table K1) for Hawaii soils, along with detailed soil maps and other information, can be found in NRCS soil survey reports (http://www.ctahr.hawaii.edu/soilsurvey/soils.htm).

The runoff volume (ft^3) contributed by the jth individual land use parcel A_j (acres) is:

$$(V_R)_j = \frac{(43{,}560\ ft^3/acre)}{(12\ in/ft)} \frac{\left(P_R \frac{P_{Zj}}{P_{ZR}} - 0.2S_j\right)^2}{P_R \frac{P_{Zj}}{P_{ZR}} + 0.8S_j} A_j \qquad (4\text{-}2)$$

For multiple event periods, e.g., seasonal or annual, an empirical rational formula runoff expression has been commonly used. Estimates of annual pollutant loads in the Honolulu City & County MS4 permit application are based on such a runoff expression (CCH 1992):

$$R = (P)(p_r)(R_v) \qquad (4\text{-}3a)$$

$$R_v = 0.05(1\text{-}f_I) + 0.95f_I \qquad (4\text{-}3b)$$

Where:

p_r = fraction of rainfall that produces runoff (0.9 used by Honolulu)
R_v = mean runoff coefficient
f_I = impervious fraction of area.

Equation *4-3b* considers 95% of rainfall on the impervious area fraction to runoff directly to the storm sewer drainage system that discharges to the stream and only 5% of rainfall on the pervious area fraction runs off to the stream (i.e., 95% of pervious area rainfall infiltrates into the soil). Where not all of the impervious area is connected to a storm sewer system, only the runoff from the connected fraction, f_C, of the impervious area flows to the storm sewer system and the remainder (1-f_C) of the impervious area runoff is directed to the pervious area where 95% infiltrates. For this case the runoff coefficient expression can be adjusted to recognize the connected area fraction, f_C, and:

$$R_v = 0.05(1\text{-}f_I) + (0.05)(0.95)f_I\,(1\text{-}f_C) + 0.95f_If_C \qquad (4\text{-}3c)$$

$$= 0.05 - 0.05(1\text{-}0.95)f_I + 0.95(1\text{-}0.05)f_If_C$$

In the application of equation *4-3*, *P* is the mean annual or seasonal rainfall and *R* is the corresponding mean annual or seasonal runoff.

The runoff volume (ft^3) contributed by an individual land use parcel *j* is:

$$(V_R)_j = \frac{43{,}560}{12} P_R \frac{P_{Zj}}{P_{ZR}} (p_r R_v)_j A_j \qquad (4\text{-}4)$$

For either runoff expression, the load (kg) of pollutant *k* in the runoff from land parcel *j* is:

$$L_{jk} = \frac{(28.32\,L/ft^3)}{(10^6\ mg/kg)} (V_R)_j\, C_{jk} \qquad (4\text{-}5)$$

Where:

C_{jk} = concentration of pollutant *k* in runoff from land use category *j*, mg/l.

B.5.0 <u>Stream Baseflow</u>.

A water balance developed for watershed soils connected hydraulically to the watershed surface streams will include recharge of soil water storage by infiltration (I) from rainfall events (and irrigation of agricultural soils) and depletion of the storage by evapotranspiration (E), other losses by percolation to underlying aquifers or at the watershed boundaries (L), and baseflow seepage to the watershed streams (Q_B). The dynamics of a monthly water balance can be expressed.

$$\frac{\partial S_G}{\partial t} = (I - E - L)A - Q_B \tag{5-1}$$

Where:

S_G = soil water storage, acre-inch
I = monthly infiltration, inch/month
E = monthly evapotranspiration, inch/month
L = other losses, inch/month
A = watershed area, acres
Q_B = baseflow volume, acre-inch/month

In equation *5-1*, the infiltration, evapotranspiration (occurring only from the pervious area fraction), and other losses can be assumed to be represented:

$$I = P - R = (1 - p_r R_v)P \tag{5-2a}$$
$$E = (E_0 - e_v P)(1 - f_I) \tag{5-2b}$$
$$L = (I - E)f_L \tag{5-2c}$$

Where f_L = fractional losses, assumed as a fraction of net soil inflow.

Thus, $$(I - E - L) = \{(1 - p_r R_v + e_v(1 - f_I))P - E_0(1 - f_I)\}\{1 - f_L\} \tag{5-2d}$$

Baseflow can be related to available soil water storage through a recession coefficient:

$$\alpha \equiv \frac{\partial Q_B}{\partial S_G} \tag{5-3}$$

The above two expressions can be combined with equation *5-1* to provide a dynamic baseflow function expressed in largely determinable terms of weather.

$$\frac{1}{\alpha}\frac{\partial Q_B}{\partial t} + Q_B = \{(1 - p_r R_v + e_v(1 - f_I))P - E_0(1 - f_I)\}\{1 - f_L\}A \qquad (5\text{-}4)$$

Where:

α = baseflow recession coefficient, month^{-1}
P = monthly rainfall, inch/month
E_0 = intercept of evapotranspiration equation, inch/month

The recession coefficient (α) is a technical function encompassing soil or aquifer hydraulic properties and watershed topography, stream density, and geology. A calculation of this recession coefficient may be developed from an appropriate expression of these watershed properties, i.e., through a mechanistic groundwater baseflow model. Alternatively, an operational value of the coefficient may be developed empirically, from available dry weather streamflow data, without committing to any particular groundwater model or mechanism beyond the thermodynamic demand of the water balance.

From equation *5-4,* the simplified empirical expression can be derived:

$$\frac{1}{\alpha}\frac{\partial Q_B}{\partial t} + Q_B = (bP - c) \qquad (5\text{-}5)$$

Where:

$$b = (\beta_1 + \beta_2 f_I - \beta_3 f_I f_c)A$$
$$c = \gamma_{ev}(1 - f_I)A$$

And the following identities are developed from equations *5-4* and *4-3c*:

$$\beta_1 \equiv (1 - 0.05p_r + e_v)(1 - f_L)$$
$$\beta_2 \equiv [0.05(1 - 0.95)p_r - e_v](1 - f_L)$$
$$\beta_3 \equiv 0.95(1 - 0.05)p_r(1 - f_L)$$
$$\gamma_{ev} \equiv E_0(1 - f_L)$$

The integral of equation *5-5* expresses current baseflow in terms of its history.

$$(Q_B)_t = (Q_B)_0 \exp(-\alpha\Delta t) + d[bP - c]_{\Delta t}[1 - \exp(-\alpha\Delta t)] \quad (5\text{-}6a)$$

or

$$(Q_B)_t = (Q_B)_0(1 - a) + ad[bP - c]_{\Delta t} \quad (5\text{-}6b)$$

For monthly mean flow, $(\overline{Q}_B)_{\Delta t} \cong (\overline{Q}_B)_0(1 - a) + a\,d[bP - c]_{\Delta t}$ *(5-6c)*

Where:

a = $[1 - \exp(-\alpha\Delta t)]$, if $\alpha\Delta t < 0.2$, $a \approx \alpha\Delta t$
d = conversion of flow from acre-inch/month to cfs,
$(43{,}560/12)/(30\text{x}86{,}400) = 1.4 \text{ x } 10^{-3}$.

The relative contribution to the watershed or sub basin area baseflow from an individual land use parcel *j* can be approximated through the *bP–c* term from equation *5-6*.

The equation *5-6c* baseflow model was empirically tested against available rainfall and baseflow data from the adjacent Kawa Stream watershed. A regression-analysis fit of 1997-98 monthly mean baseflow measurements for Kawa Stream (Nance 1999) with monthly baseflows computed with equation *5-6c* and contemporaneous local rainfall data (Kaneohe station 838.1) is shown in Figure B2. The regression equation coefficients in this figure,

$$Q_M = 0.781Q_0 + 0.135P - 0.223 \quad (r^2 = 0.956).$$

Where:

Q_M = monthly baseflow volume, acre-inch/month
Q_O = previous month baseflow volume, acre-inch/month

This corresponds to values of 0.22, 0.76, and 1.25 for the parameters *a*, *b*, and *c*, respectively, in equation *5-6c*, with 723 acres and 0.20 effective impervious fraction f_I in the watershed area tributary to Nance's upper streamflow monitoring gauge. The regression value for *b* (0.76) in the Kawa Stream analysis is only about half the *b*-value theoretically derived in equation *5-5* and the regression value for *c* (1.25) is only about 1/5 the *c*-value theoretically derived from equation *5-5* and the pan evaporation data in Figure B1. This may be because 1998 was a very dry rainfall-year and pan evaporation will overstate the evapotranspiration losses under extended dry soil conditions. The empirical regression coefficients can be reproduced for the Kawa Stream watershed if actual evapotranspiration, *E*, is assumed to be 27% of the Figure B1 pan evaporation and the other losses, *L*, in equation *5-2* are 32% of the resulting *I-E*.

For the 30-year weather record considered in the Kaneohe Stream TMDL analysis, the longer-term equation *3-1* parameters E_0 and e_v are reduced by one-third from their Figure B1 regression values and other losses (f_L) are assumed to be 50% of *I-E*.

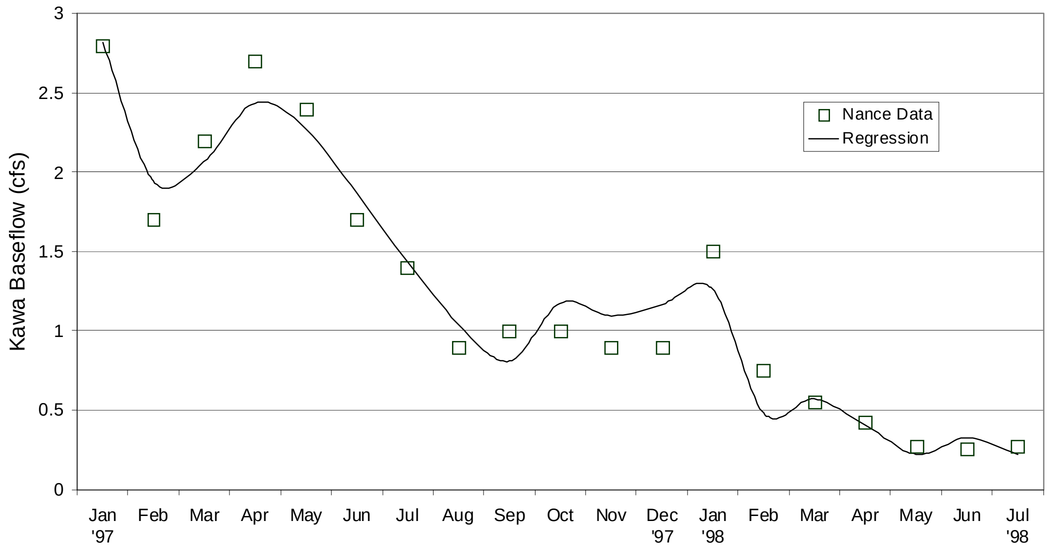


Figure B2. Kawa Stream Baseflow (1997-98)

If long term average baseflow is approximated as a pseudo-steady seasonal cycle, then mean wet and dry seasonal baseflows can be derived from the time-averaged integration of equation *5-6* with seasonal mean rainfall values, P_W and P_D:

From equation *5-6,* monthly wet and dry seasonal baseflows are expressed:

$$(Q_B)_W = (Q_B)_0 \exp(-\alpha t) + B_W(1 - \exp(-\alpha t)) \qquad 0 < t \leq 6 \qquad (5\text{-}7a)$$

$$(Q_B)_D = (Q_B)_6 \exp(-\alpha(t-6)) + B_D(1 - \exp(-\alpha(t-6))) \qquad 6 < t \leq 12 \qquad (5\text{-}7b)$$

Where:

$$B_W = d\,\frac{bP_W - c}{6}$$

$$B_D = d\,\frac{bP_D - c}{6}$$

And:

P_W, P_D = respectively, wet and dry season rainfall totals, inch

c = seasonal evapotranspiration basis calculation.

The cyclical steady-state assumption requires:

$$(Q_B)_0 = (Q_B)_{12} = (Q_B)_6 \exp(-\alpha 6) + B_D (1 - \exp(-\alpha 6)) \qquad (5\text{-}7c)$$

Then by replacing $(Q_B)_0$ in equation (5-7a):

$$(Q_B)_6 = [(Q_B)_W]_{t=6} = [(Q_B)_6 \exp(-\alpha 6) + B_D (1 - \exp(-\alpha 6))] \exp(-\alpha 6) + B_W (1 - \exp(-\alpha 6))$$

Or: $$(Q_B)_6 (1 - \exp(-\alpha 12)) = (B_D \exp(-\alpha 6) + B_W)(1 - \exp(-\alpha 6))$$

And because $$(1 - \exp(-\alpha 12)) = (1 - \exp(-\alpha 6))(1 + \exp(-\alpha 6))$$

$$(Q_B)_6 = \frac{B_D \exp(-\alpha 6) + B_W}{1 + \exp(-\alpha 6)} \qquad (5\text{-}8a)$$

By similar calculation by replacing $(Q_B)_6$ in equation (5-7c):

$$(Q_B)_0 = \frac{B_D + B_W \exp(-\alpha 6)}{1 + \exp(-\alpha 6)} \qquad (5\text{-}8b)$$

Average baseflow for the wet season is derived from the time-averaged integral of equation *5-7a*:

$$\overline{Q}_W = \frac{\int_{t=0}^{6} (Q_B)_W \, \partial t}{\Delta t} = (Q_B)_0 \left(\frac{1 - \exp(-\alpha 6)}{\alpha 6} \right) + B_W \left(1 - \frac{1 - \exp(-\alpha 6)}{\alpha 6} \right) \qquad (5\text{-}9)$$

Substituting equation *5-8b* for $(Q_B)_0$ into equation *5-9* and simplifying:

$$\overline{Q}_W = B_D F_6 + B_W (1 - F_6) \qquad (5\text{-}10a)$$

The similar calculation of average baseflow for the dry season by time-averaged integration of equation *5-7b* and substitution of equation *5-8a* for $(Q_B)_6$ yields:

$$\overline{Q}_D = B_D (1 - F_6) + B_W F_6 \qquad (5\text{-}10b)$$

Where in both equations (*5-10*):

$$F_6 = \frac{1 - \exp(-6\alpha)}{6\alpha (1 + \exp(-6\alpha))}$$

This seasonal averaging model allows negative seasonal B_D values, i.e., wet season replenishing of dry season storage depletion, while still providing positive dry season baseflow. However, when the net seasonal Q_D or Q_W is negative for the sub basin or stream segment tributary area, this may indicate that the segment is losing rather than gaining streamflow. It may also mean that the constant evapotranspiration loss term is overstated in the model; in reality, evapotranspiration should decrease as soil moisture is depleted.

The dry seasonal mean baseflow load contribution (kg/day) of pollutant *k* from land use parcel *j* is:

$$(L_{BD})_{jk} = 2.447\,(\overline{Q}_D)_j\,(C_B)_{jk}\,, \quad \overline{Q}_D \geq 0$$

$$(L_{BD})_{jk} = 0\,, \quad \overline{Q}_D < 0 \qquad (5\text{-}11a)$$

And:

$$(L_{BW})_{jk} = 2.447\,(\overline{Q}_W)_j\,(C_B)_{jk}\,, \quad \overline{Q}_W \geq 0$$

$$(L_{BW})_{jk} = 0\,, \quad \overline{Q}_W < 0 \qquad (5\text{-}11b)$$

Where:

$(C_B)_{jk}$ = baseflow concentration of pollutant *k* from land use category *j*, mg/l
2.447 = conversion of the (Q)(C) units of (ft^3/sec)(mg/l) to kg/day.

If the baseflow contribution from a land use parcel is not positive, no load is contributed from that parcel.

These expressions for volume and pollutant load contributions to baseflow are used in the Kaneohe Stream TMDL allocation process to disaggregate watershed baseflow volumes and loads to individual land use parcels.

B.6.0 Streamflow and Water Quality

Streamflow and water quality in this TMDL analysis are calculated as seasonal mean values (for baseflow conditions) or as event mean values (for storm event conditions). Streamflow at the end of segment *j* is the sum of the flow at the beginning of the segment $(Q_0)_j$ and dispersed baseflow $(Q_B)_j$ and storm runoff $(Q_R)_j$ inflows along the length of the segment. Flow at the beginning of the segment is the sum of any point source discharges at the head of the segment *j* and inflow from the immediately upstream segment(s) *j-1*.

$$Q_j = (Q_0)_j + (Q_B)_j + (Q_R)_j \qquad (6\text{-}1)$$

$$(Q_0)_j = (Q_{PS})_j + Q_{j-1}$$

During the individual storm event, streamflow is developed from the dynamic storage and Manning expressions:

$$A_s \frac{\partial y}{\partial t} = Q_{in} - Q \qquad (6\text{-}2a)$$

$$Q = \frac{1.49}{n} s^{1/2}\, w\, y^{5/3}$$

Or: $(6\text{-}2b)$

$$y = \left(\frac{Q\, n}{1.49\, s^{1/2} w} \right)^{3/5}$$

Where Q_{in} is inflow from upstream and along the stream segment length, A_s is stream segment surface area (width x length), w is the mean stream segment width, y is stream segment depth, and $w >> y$.

A streamflow expression for the left hand side of equation *6-2a* can be obtained from differentiating the y-expression of equation *6-2b*:

$$A_s \frac{\partial y}{\partial t} = \frac{3 A_s}{5 \overline{Q}^{2/5}} \left(\frac{n}{1.49\, s^{1/2} w} \right)^{3/5} \frac{\partial Q}{\partial t} \qquad (6\text{-}3a)$$

For the stream depth increasing period of the idealized storm event hydrograph, let the mean stream segment flow be approximated by the segment baseflow plus half of all the upstream and in-segment runoff flow:

$$\overline{Q}_j \cong Q_{Base} + \frac{1}{2} \sum_{k=0}^{j} (Q_R)_k \qquad (6\text{-}3b)$$

For this period, equation *6-2a* can then be rewritten:

$$\frac{1}{\alpha} \frac{\partial Q}{\partial t} + Q = Q_{in} \qquad (6\text{-}4a)$$

$$\alpha \equiv \frac{5 \overline{Q}^{2/5}}{3 A_s} \left(\frac{1.49\, s^{1/2} w}{n} \right)^{3/5} \qquad (6\text{-}4b)$$

Integration of equation *6-4* provides the streamflow from segment *j* during the storm event:

$$(Q_t)_j = (Q_0)_j \exp(-\alpha_j t) + (\overline{Q}_{in})_j (1 - \exp(-\alpha_j t)) \qquad (6\text{-}5)$$

And the event mean streamflow from segment *j* is the time integrated average of equation *6-5* over the period of the storm runoff duration:

$$(\overline{Q}_{\Delta t})_j = \frac{\int_0^t (Q_t)_j \, dt}{t} \qquad (6\text{-}6a)$$

$$(\overline{Q}_{\Delta t})_j = (Q_0)_j \left(\frac{1 - \exp(-\alpha_j t)}{\alpha_j t}\right) + (\overline{Q}_{in})_j \left(1 - \frac{1 - \exp(-\alpha_j t)}{\alpha_j t}\right) \qquad (6\text{-}6b)$$

$$(\overline{Q}_{in})_j = (\overline{Q}_{\Delta t})_{j-1} + (Q_{PS})_j + (Q_B)_j + (Q_R)_j \qquad (6\text{-}6c)$$

Time-averaged pollutant concentrations increase along the segment length by dispersed baseflow and storm runoff loads and are reduced by instream sedimentation. Instream assimilation rates for phosphorus and nitrogen, as well as suspended solids, are expressed in this analysis as a particle settling velocity but other chemical transformation or biological assimilation mechanisms are equivalently described by the same first-order sediment decay expression.

$$Q \frac{\partial C}{\partial x} + \left(\frac{Q_B + Q_R}{l} + v_s w \in\right) C = \frac{L_B + L_R}{2.447\, l} \qquad (6\text{-}7)$$

Where:

v_s = settling velocity, ft/sec
ϵ = sedimentation efficiency
w = stream width, feet
l = stream segment length, feet
L = baseflow or storm runoff pollutant load, kg/day.

The integral of equation *6-7* provides the end-of-segment concentration:

$$C_j = (C_0)_j \exp(-\beta_j) + \frac{(L_B + L_R)_j}{2.447\overline{Q}} \left(\frac{1-\exp(-\beta_j)}{\beta_j}\right) \tag{6-8a}$$

$$\beta_j \equiv \frac{(Q_B + Q_R + v_s A_s \in)_j}{\overline{Q}_j} \tag{6-8b}$$

$$\overline{Q}_j \equiv \frac{(Q_0)_j + Q_j}{2} \tag{6-8c}$$

B.7.0 Reservoir

The multiple Kaneohe headwater streams flow into the Waimaluhia reservoir within the Ho'omaluhia Botanical Garden. The stage-discharge relationship for the low flow outlet structure at this reservoir is (ACOE 1981):

$$Q_r = 105.3\, H^{3/2} \tag{7-1}$$

Where H = reservoir depth above elevation 160 (msl).

Reservoir outflow dynamics are developed in a way analogous to equations *6-4* :

$$A_s \frac{\partial H}{\partial t} = Q_{in} - Q_r \tag{7-2a}$$

$$A_s \frac{\partial H}{\partial t} = \frac{2\, A_s}{3(105.3)^{2/3}\, \overline{Q}_r^{1/3}} \frac{\partial Q_r}{\partial t} \tag{7-2b}$$

And: $$\frac{1}{\alpha_r} \frac{\partial Q_r}{\partial t} + Q_r = Q_{in} \tag{7-2c}$$

Where: $$\alpha_r \equiv \frac{3\overline{Q}_r^{\,1/3}}{2\, A_s} (105.3)^{2/3} \tag{7-2d}$$

Reservoir outflow during the storm event follows from integration of equation *7-2c*:

$$(Q_t)_r = (Q_0)_r \exp(-\alpha_r t) + (\overline{Q}_{in})_r (1 - \exp(-\alpha_r t)) \qquad (7\text{-}3)$$

And the event mean reservoir outflow is:

$$(\overline{Q}_{\Delta t})_r = \frac{\int_0^t (Q_t)_r \, dt}{t} \qquad (7\text{-}4a)$$

$$(\overline{Q}_{\Delta t})_r = (Q_0)_r \left(\frac{1 - \exp(-\alpha_r t)}{\alpha_r t}\right) + (\overline{Q}_{in})_r \left(1 - \frac{1 - \exp(-\alpha_r t)}{\alpha_r t}\right) \qquad (7\text{-}4b)$$

Time-averaged outflow pollutant concentrations for the reservoir are calculated by the same expression (equation *6-8*) as for other stream segments, with a reduced reservoir sedimentation efficiency ϵ because of flow short-circuiting and incomplete mixing.

B.8.0 Model Calibration.

Data from the November 27, 2001 storm event were used to calibrate the Kaneohe Stream water quality model described above. Total rainfall (Pali Golf Course) for this event was 5.83 inches for the 24 hour event duration. Calculated event mean streamflow and water quality – concentrations of total suspended solids, total nitrogen, and total phosphorus – are displayed as functions of mainstem stream mile in Figure B3. Available data for November 27, 2001 are displayed as the open squares in this figure. Streamflow is the average flow at USGS station 16272200 on Kamo'oalii Stream below Luluku. Water quality data are geometric mean concentrations for November 27, 2001 samples from Oceanit stations 1c and 1a (combined), 3, and 5, respectively. The SCS runoff model in this TMDL analysis uses the CN(II) curve numbers for average soil moisture conditions. However, November 27, 2001 was preceded by a 13 day period with a total rainfall of only 0.07 inch. It is therefore likely that the more appropriate curve numbers for this particular event should be the CN(I) values for a dry soil condition. Recalculated streamflow and water quality values for this condition are also displayed as the dashed lines in Figure B3.

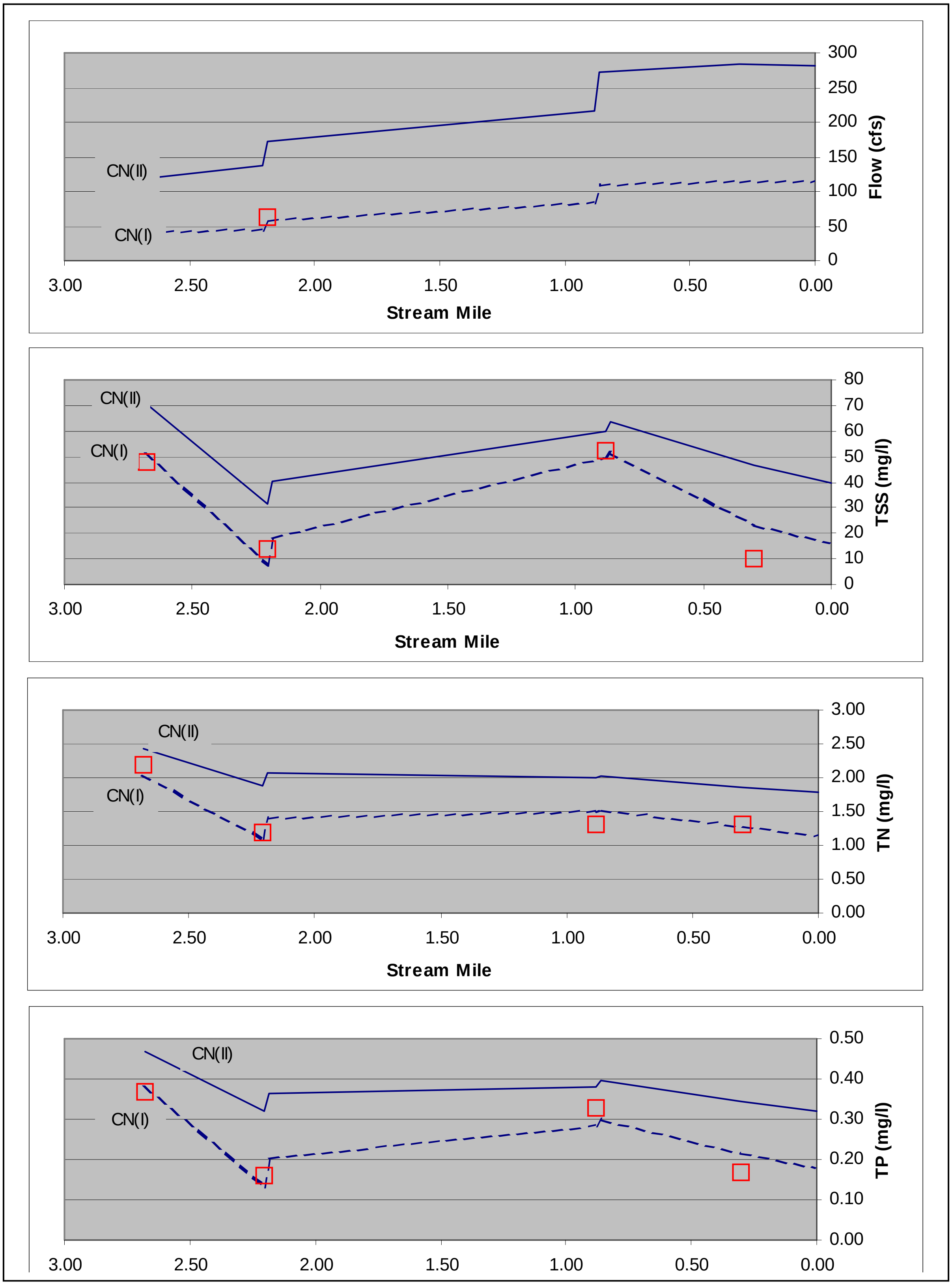


Figure B3. Kaneohe Stream Flow and Water Quality: November 27, 2001

B.9.0 Water Quality Targets.

Hawaii's water quality standards for concentrations of conventional pollutants are expressed as a three term probabilistic function:

a) The geometric mean concentration shall not exceed a designated value (C_G),
b) Concentrations shall not exceed a value (C_{10}) more than 10% of the time, and
c) Concentrations shall not exceed a value (C_2) more than 2% of the time.

A proposed interpretation of this standard for TMDL purposes is the following. The geometric mean criterion can be expressed:

$$p\ln(C_d) + (0.9 - p)\ln(C_{w9}) + 0.08\ln(C_8) + 0.02\ln(C_2) \le \ln(C_G) \qquad (9\text{-}1)$$

Where:

C_2 = geometric mean of the highest 2% of daily concentrations
C_8 = geometric mean of the next highest 8% of daily concentrations
C_{w9} = geometric mean of concentrations during remaining days of stormwater runoff
C_d = geometric mean of concentrations during days without stormwater runoff
p = fraction of days without stormwater runoff

And if the geometric mean concentration of a fractional interval can be estimated as the geometric mean of the concentration extremes of the interval:

$C_{w9} \approx (C_d \bullet C_{10})^{1/2}$
$C_8 \approx (C_{10} \bullet C_2)^{1/2}$
$C_2 \approx (C_2 \bullet mC_2)^{1/2}$
mC_2 = highest concentration occurring.

With these approximations, equation *9-1* can be rewritten in terms of the standard:

$$(0.45 + \frac{p}{2})\ln(C_d) + (0.49 - \frac{p}{2})\ln(C_{10}) + 0.06\ln(C_2) + 0.01\ln(m) \le \ln(C_G) \qquad (9\text{-}2)$$

Equation *9-2* is rearranged to define a geometric mean concentration (C_d) for dry-weather conditions in terms of the water quality standard:

$$\ln(C_d) \le \frac{\ln(C_G) - (0.49 - \frac{p}{2})\ln(C_{10}) - 0.06\ln(C_2) - 0.01\ln(m)}{(0.45 + \frac{p}{2})} \qquad (9\text{-}3)$$

The *m*-term will reduce the value of C_d by about 1 or 2 percent for values of $m<10$. It is an identifiable component of the TMDL margin of safety.

Two sets of TMDLs can be developed, for each of the different wet and dry season conditions and standards, that satisfy the C_2 criterion for the 2% return frequency storm event, the C_{10} criterion for the 10% return frequency event, and the C_d criterion for dry-weather baseflow. These TMDLs will achieve the Hawaii water quality standards and account for both critical conditions and seasonal variations. Furthermore, the association of each TMDL with a defined storm event or baseflow condition will provide explicit design guidance for TMDL implementing authorities.

In some cases, concentrations of some pollutants, e.g., nitrogen, herbicides, can be higher during dry weather periods than during stormwater runoff. In these cases the water quality standards not to be exceeded more than 2% or 10% of the time will apply to dry weather baseflow rather than to stormwater runoff conditions and the geometric mean criterion would be expressed:

$$0.02\ln(C_2) + 0.08\ln(C_8) + (p-0.1)\ln(C_{d9}) + (1-p)\ln(C_w) \le \ln(C_G)$$

And: (9-4)

$$(1-p)\ln(C_w) + p\ln(C_d) = \ln(C_G)$$

$$C_{d9} \approx (C_G \bullet C_{10})^{1/2}$$
$$C_8 \approx (C_{10} \bullet C_2)^{1/2}$$
$$C_2 \approx (C_2 \bullet mC_2)^{1/2}$$
mC_2 = highest concentration occurring.

By the same substitution and rearranging of terms outlined above, wet weather and then dry weather concentration criteria can be developed:

$$\ln(C_w) \le \frac{(1.05-\frac{p}{2})\ln(C_G) - (\frac{p}{2}-0.01)\ln(C_{10}) - 0.06\ln(C_2) - 0.01\ln(m)}{(1-p)} \qquad (9\text{-}5)$$

$$\ln(C_d) \le \frac{(\frac{p}{2}-0.05)\ln(C_G) + (\frac{p}{2}-0.01)\ln(C_{10}) + 0.06\ln(C_2) + 0.01\ln(m)}{p} \qquad 9\text{-}6)$$

Where C_d is the geometric mean of dry weather concentrations and C_w is the geometric mean of concentrations during days of stormwater runoff.

B.10.0 Loading Capacities and Allocations.

Loading capacity is "the greatest amount of (pollutant) loading that a water can receive without violating water quality standards." (40 CFR 130.2(f)). The greatest amount of loading occurs when water quality concentrations at all locations are equal to the numerical water quality standard or other target concentration for the TMDL process. For this condition, $C_j = (C_0)_j = C_d$ (or C_{10} or C_2 for storm events).

Baseflow load capacities (kg/day) are developed from equation (*6-8*):

$$C_d\,(1-\exp(-\beta_j)) \;=\; \frac{(LC_B)_j}{2.447\overline{Q}}\left(\frac{1-\exp(-\beta_j)}{\beta_j}\right)$$

And:

$$\overline{Q}_j \beta_j = (Q_B + v_s A_s \in)_j$$

So:

$$(LC_B)_j = 2.447\,(Q_B + v_s A_s \in)_j\, C_d \qquad (10\text{-}1)$$

Load capacities (kg) for the 10% frequency storm event are similarly developed:

$$(LC_R)_j = \left[2.447\,(Q_B + Q_R + v_s A_s \in)_j\,(C_{10}) - (LC_B)_j\right]\frac{t_d + t_c}{24} \qquad (10\text{-}2a)$$

And load capacities (kg) for the 2% frequency event are:

$$(LC_R)_j = \left[2.447\,(Q_B + Q_R + v_s A_s \in)_j\,(C_2) - (LC_B)_j\right]\frac{t_d + t_c}{24} \qquad (10\text{-}2b)$$

$$Q_R = \frac{V_R}{3600(t_d + t_c)} \qquad (10\text{-}2c)$$

Where:

V_R = runoff volume, ft^3
t_d = rainfall duration, hours
t_c = time of runoff concentration, hours.

Where the existing segment load is greater than the segment load capacity, the allocations of load capacity to individual sources are:

$$(Allocation)_{ij} = LC_j\,\frac{L_{ij}}{L_j} \qquad (10\text{-}3)$$

Where the existing segment load is less than or equal to the segment load capacity, the allocations to individual sources are the existing loads (non-degradation policy).

APPENDIX C – DOH WATERBODY ASSESSMENT SHEETS, 2006 303(d) LIST, AND EPA TMDL APPROVAL CHECKLIST

Waterbody Information Sheet: Streams

Stream Name & Location: Kaneohe Stream, Oahu

Inspected By: Gary Wolinsky

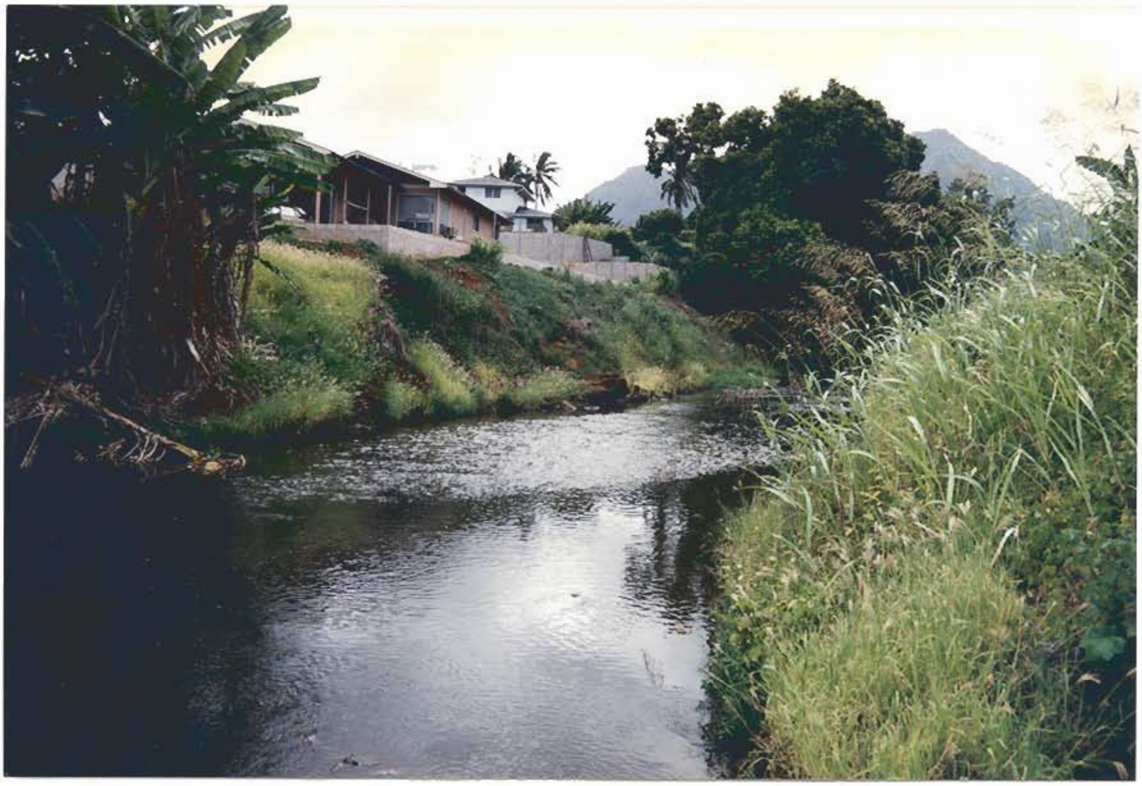
Date: 08-16-96

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.) The document "Soil, Sediment, and Water Quality Monitoring, Bayview Golf Course," prepared by AECOS, Inc., describes water quality data for Kaneohe Stream for a one year period from 1991 through 1992. Two stations were monitored: one above Bayview Golf Course (KAN1), and one at the stream mouth (KAN2). Both stations recorded violations of the turbidity criterion, with a compiled geometric mean of 5.63 NTU for KAN1 and 5.57 NTU for KAN2. (Criteria are 5 NTU in wet season, 2 in dry season.) Violations of nitrogen criteria are very pronounced. The annual geometric mean for nitrate +nitrite nitrogen at KAN1 was 339 ug/L, and 292 ug/l at KAN2. This compares to a criterion of 70 ug/L. Total nitrogen was similarly elevated. Annual geometric mean values for KAN1 and KAN 2, respectively, were 571 ug/L and 532 ug/L. The wet season criterion is 250 ug/L. No violations of the total phosphorus criterion were recorded.
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.) Current earthwork at Bay View Golf Course
5. Is there evidence of nutrient enrichment, including algal blooms or excessive amounts of nuisance vegetation? **Yes** No Excessive algal growth noted
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
9. Is there evidence of significant erosion in the stream channel? Yes **No**
10.Evaluate the visual water quality. Brown/green turbid water and algal growth noted
11. How is this water used, and by whom? Aquatic life, flood control
12. Comments The excessive algal growth corresponds to the water quality data. Note that this data was taken before expansion/improvements at Bay View Golf Course.

13. Is this stream of high enough quality that it should not be considered impaired? Discuss.

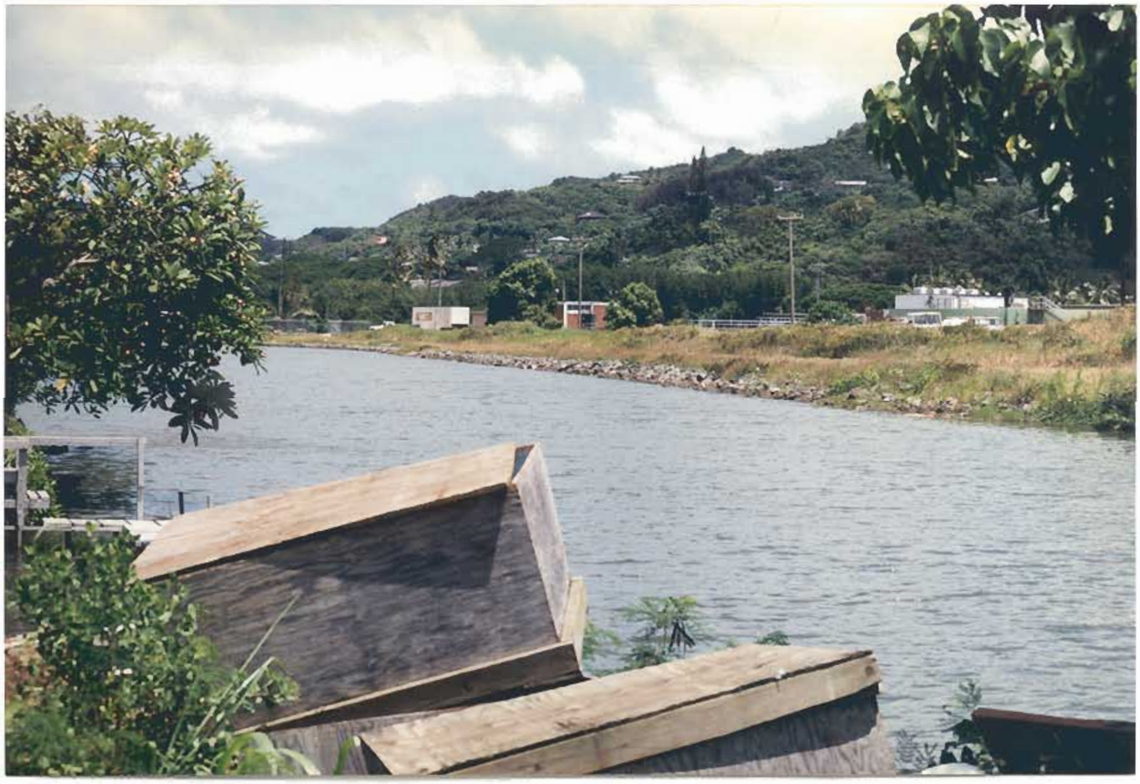
No. This stream is running turbid and has excessive algal growth. Near coastal waters are extremely muddy at the mouth of Kaneohe stream. Some turbidity may be attributed to the earthwork at Bay View Golf Course and may be temporary.



018/16/1996 Kaneohe Stream @ Waikalua Pl/Waikalua Wy

08/16/1996 Kaneohe Stream
End of Holowai Pl behind Bayview Golf Course
Note turbid, green water

08/16/1996 Kaneohe Stream
Waikalua Pl/Waikalua Wy
Note eroded bank



08/16/1996 Kaneohe Stream
Behind Bayview Golf Course
End of Holowai Pl

08/16/1996 Kaneohe Stream
Waikalua Pl/Waikalua Wy
Note salty-bottom deposit

08/15/1996 Kaneohe Stream & nearshore @ end of Kulauli St
Note turbid conditions in stream & near shore waters

Waterbody Information Sheet: Streams

Stream Name & Location: Kamooalii Stream (below confluence w/Luluku Stream and Flood Control Reservoir/Botanical Gardens), Kaneohe

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.) Residential area runoff. Observed resident rinsing materials to storm drain -- see photo

5. Is there evidence of nutrient enrichment, including algal blooms or excessive amounts of nuisance vegetation? **Yes** No

Noted algal growth in stream

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

9. Is there evidence of significant erosion in the stream channel? **Yes** No

10.Evaluate the visual water quality.

Turbid

11. How is this water used, and by whom?

Aquatic life, drain for residential area

12. Comments

13. Is this stream of high enough quality that it should not be considered impaired? Discuss.

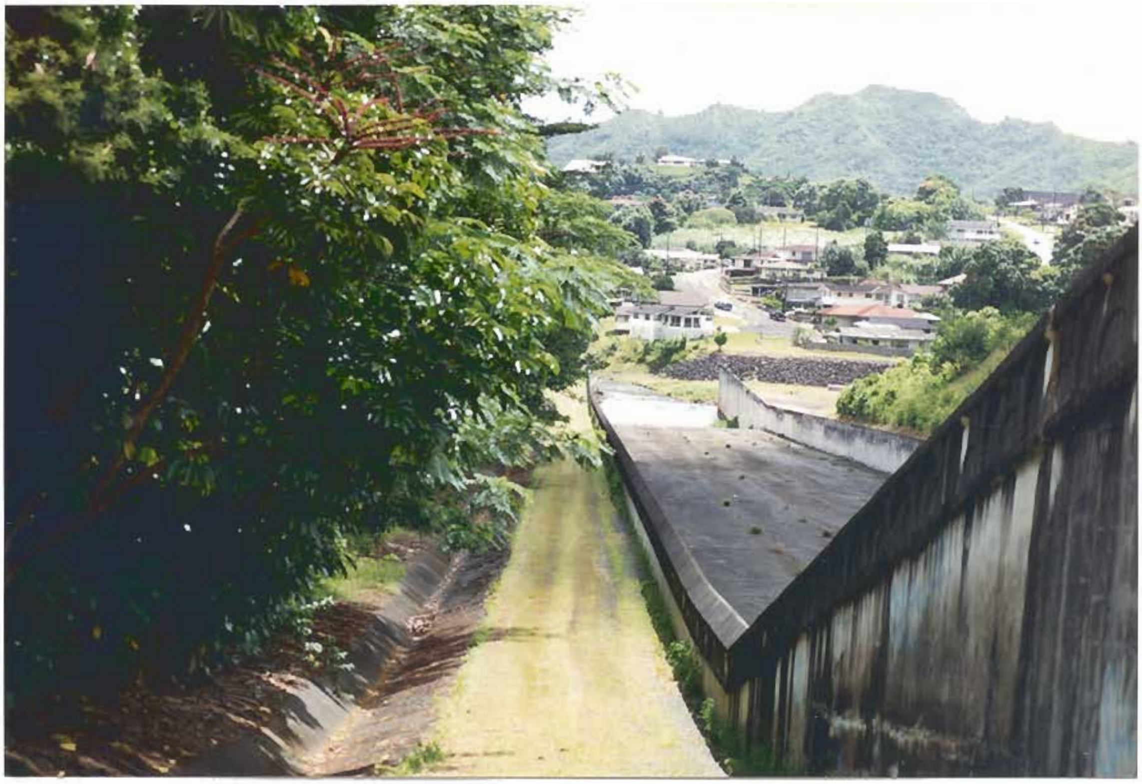
No. This stream suffers turbid conditions and moderate algal growth

Kamooalii Stream below Moku Moo Reservoir - Dam in background @ Liula & Kamooalii St
algae, turbid

Kamooalii Stream @ Liula & Kamooalii
algae, turbid

Kamooalii Stream @ Liula & Kamooalii St
Note turbidity/algae

Residential Storm Drain Use - Kamooalii Stream



08/14/1996 Moku Moo - Kaneohe Reservoir

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).

OAHU 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
Kaneohe	Stream	EN	3-2-10	Dry	?	V	V	V	*N*	TSS (?), Dieldrin	3, 5	H (IP)
Kaneohe	Stream	EN	3-2-10	Wet	?	V	V	V	N	TSS (?), Dieldrin	3, 5	H (IP)
Kamooalii (Trib to Kaneohe Stream)	Stream	Kamooalii Trib	3-2-10.01	Dry	?	V	V	V	N	TSS (?)	3, 5	H (IP)
Kamooalii (Trib to Kaneohe Stream)	Stream	Kamooalii Trib	3-2-10.01	Wet	?	V	V	V	?	TSS (?)	3, 5	H (IP)
Kawa	Stream	EN	3-2-11		?	L	L	L	L	TSS (L)	3, 4a	TMDLs approved 2002, *2005*
Kapaa	Stream	EN	3-2-13-*Kapaa*		?	L	L	L	L	TSS, Metals (L); *Lead*	3, 4a, 5	~~H~~ *M* (nutrient & sediment TMDLs approved 2007)
Kawainui Marsh	*Wetland*	*EW*	3-2-13-*W*		?	?	?	?	?	TSS (?)	3, 5	~~H~~ *M*
Kawainui	*Stream*	*EN*	3-2-13		?	?	?	?	?	TSS (?)	3, 5	~~H~~ *M*
Maunawili	Stream	EN	3-2-13.*01*		?	V	V	V	V	TSS (?), Trash	3, 5	M
Kaelepulu	Stream	EN	3-2-14		?	V	V	V	V	TSS (?)	3, 5	H (IP)
Waimanalo	Stream	EN	3-2-15		?	L	L	L	L	TSS (?)	3, 4a	TMDLs approved 2001
Palolo	Stream	EN	3-3-07.*01.1*		?	?	?	?	?	TSS (?), Trash	3, 5	~~M~~ *L*
Manoa	Stream	EN	3-3-07.01		?	V	V	V	V	TSS (?), Dieldrin, Chlordane	3, 5	~~M~~ *L*
Makiki	Stream	EN	ALWS06	Dry	?	N	?	N	?	TSS (?)	3, 5	~~M~~ *L*
Nuuanu	Stream	EN	3-3-09	Dry	?	N	*N*	*N*	~~V~~ *N*	*TSS (N)*, Trash, Dieldrin, Chlordane	3, 5	~~H~~ *M*
Nuuanu	Stream	EN	3-3-09	Wet	?	N	N	A	~~V~~ *N*	TSS (A), Trash, Dieldrin, Chlordane	3, 5	~~H~~ *M*
Kapalama	Stream	EN	3-3-10		?	V	V	V	V	Trash	3, 5	~~M~~ *L*
Kalihi	Stream	EN	3-3-11	Dry	?	?	N	A	N	TSS (A), Trash	3, 5	H
Kalihi	Stream	EN	3-3-11	Wet	?	N	N	A	A	TSS (A), Trash	3, 5	H
Moanalua	Stream	EN	3-3-12.01	*Dry*	?	*Nc*	Ac	Ac	*N1*	TSS (Ac), Trash	3, 5	~~M~~ *L*
Moanalua	Stream	EN	3-3-12.01	*Wet*	?	*Nc*	Ac	Ac	Ac	TSS (Ac), Trash	3, 5	~~M~~ *L*
Salt Lake	Lake	EL	3-3-12-SaltLake		?	?	?	?	N	Trash	3, 5	~~M~~ *L*
Halawa	Stream	EN	3-4-02		?	V	V	V	V	TSS (?)	3, 5	H (IP)

OAHU 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	Kahanamoku Beach	HI366432	wet	N	?	?	?	?		3,5	L
C	Kahanamoku Lagoon	HIW00003	wet	N	?	?	?	?		3,5	L
C	Kahe Pt. Beach Co. Pk.	HI548986	dry	?	?	?	?	?		3	
E	Kahuku Golf Course	HI989341	na	?	?	?	?	?		3	
B	Waialua/Kaiaka Bays Nearshore waters to 60' from Puaena Point to a point 1.5 miles W of Kaiaka Pt.	HIW00083		?	L	L	L	N	nutrients, susp. Solids (L)	3,5	L
B	Kaiaka Bay	HIW00106	wet	~~N~~ A	N	N	?	N	chl-a(N), NH4(N)	2,3,5	L
C	Kaihalulu Beach	HI668562	dry	?	?	?	?	?		3	
C	Kailua Beach Park	HI482719	wet	~~N~~ A	N	?	N	N	chl-a(N)	2,3,5	L
C	Kaiona Beach	HI234342	dry	N	?	?	?	?		3,5	L
C	Kaipapa'u Beach	HI787959	dry	?	?	?	?	?		3	
C	Kakaako Waterfront	HI302297	wet	?	?	?	?	?		3	
C	Kalae oio Beach Park	HI860454	wet	?	?	?	?	?		3	
C	Kalama Beach	HI071892	dry	A	?	?	?	?		2,3	
C	Kaloko (Queens) Beach	HI353985	dry	?	?	?	?	?		3	
C	Kaluanui Beach	HI410842	dry	?	?	?	?	?		3	
C	Kanenelu Beach	HI196120	wet	?	?	?	?	?		3	
B	Kaneohe Bay-nearshore waters at mouths of Kaneohe and Kawa streams	HIW00054	wet	?	L	L	L	N	nutrients, susp. Solids (L)	3,5	~~H~~ L
B	Kaneohe Bay (Central Region)	HIW00013	dry	?	N	N	?	N	NH4(N)	3,5	L
B	Kaneohe Bay (Northern Region)	HIW00012	dry	?	N	N	?	N	NH4(N)	3,5	L
B	Kaneohe Bay (Southern Region)	HIW00011	dry	N	N	N	?	N	NH4(N)	3,5	L
B	Kaneohe Bay (Beach Park)	HIW00004	wet	?	N	?	N	N	chl-a(N)	3,5	L
B	Kaneohe Bay (Kokokahi Pier)	HIW00005	wet	N	N	?	N	N	chl-a(N)	3,5	L
C	Kapaeloa Beach	HI904851	wet	?	?	?	?	?		3	
C	Kapi'olani Park	HI733929	wet	?	?	?	?	?		3	
C	Kaunala Beach	HI622160	dry	?	?	?	?	?		3	
C	Kaupo Beach Co. Park	HI791127	dry	?	?	?	?	?		3	
C	Kawaiku'i Beach Park	HI304424	dry	N	?	?	?	?		3,5	L
C	Kawailoa Beach	HI312049	wet	?	?	?	?	?		3	
C	Kawela Bay	HI698581	dry	N	N	?	N	N	chl-a(N)	3,5	L
C	Kea'au Beach Co. Park	HI730738	dry	?	?	?	?	?		3	

APPENDIX D – Public Notice, Public Meeting, Public Comments, and DOH Response

NOTICE OF PUBLIC COMMENT PERIOD AND PUBLIC INFORMATION MEETING - TOTAL MAXIMUM DAILY LOADS (TMDLs) FOR KANEOHE STREAM, ISLAND OF OAHU, 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 Kaneohe Stream 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, total nitrogen, and total phosphorus in Kaneohe Stream (including the Kamooalii tributary), Koolaupoko, Oahu. The proposed decision divides each of these three TMDLs (each TMDL addresses a single waterbody-pollutant combination) into load allocations (LAs) for various sources of polluted runoff and diffuse pollution (nonpoint sources), and wasteload allocations (WLAs) for point sources of these pollutants (point sources are facilities regulated by National Pollutant Discharge Elimination System, or NPDES, permits). The WLAs proposed involve stormwater discharges from municipal separate storm sewer systems (MS4) operated by the State of Hawaii Department of Transportation (Highways Division), the State of Hawaii Department of Education (public school campuses), the State of Hawaii Department of Defense (Veteran's Cemetery), and the City and County of Honolulu (various departments and facilities).

The proposed TMDLs, LAs, and WLAs are presented in a draft decision document entitled "Total Maximum Daily Loads (TMDLs) for Total Suspended Solids, Nitrogen and Phosphorus in Kaneohe Stream Kaneohe, Hawaii." This draft document 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 96814, and in the Kaneohe Public Library, 45-829 Kamehameha Highway, Kaneohe, Hawaii 96744 during regular library hours. For a copy of the draft document, 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, September 15, 2008, 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, Room 312, 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 decision document, as necessary, for final EPA approval of the proposed TMDLs.

A public information meeting on the proposed TMDLs is scheduled for Thursday, August 28, 2008, from 6:30 – 8:30 PM in the Kaneohe Community Park located at 45-529 Keaahala Road, Kaneohe, Hawaii 96744. 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 Kaneohe 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 August 24, 2008 so that arrangements can be made.

Chiyome L. Fukino, M.D.
Director of Health

IN THE MATTER OF

Public Notice

AFFIDAVIT OF PUBLICATION

STATE OF HAWAII } SS.
City and County of Honolulu

Doc. Date: August 15, 2008 # Pages: 1
Notary Name: Patricia K. Reese First Judicial Circuit
Doc. Description: Affidavit of Publication

Notary Signature 08/15/08 Date

PATRICIA K. REESE NOTARY PUBLIC Comm. No. 86-467 STATE OF HAWAII

Rose Mae Rosales being duly sworn, deposes and says that she is a clerk, duly authorized to execute this affidiavit 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:

Honolulu Star-Bulletin 1 times on:
08/15/2008

Midweek Wed. 0 times on:

Midweek Fri. 0 times on:

_______ times on:

And that affiant is not a party to or in any way interested in the above entitled matter.

Rose Mae Rosales

Subscribed to and sworn before me this 15th day

of August A.D. 20 08

Patricia K. Reese, Notary Public of the First Judicial Circuit, State of Hawaii

My commission expires: October 07, 2010

Ad # 0000059896

NOTICE OF PUBLIC COMMENT PERIOD AND PUBLIC INFORMATION MEETING - TOTAL MAXIMUM DAILY LOADS (TMDLs) FOR KANEOHE STREAM, ISLAND OF OAHU, 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 August 24, 2008 so that arrangements can be made.

Chiyome L. Fukino, M.D.
Director of Health
(SB59896 8/15/08)

PATRICIA K. REESE NOTARY PUBLIC Comm. No. 86-467 STATE OF HAWAII

LN: ________

ATTENDANCE SHEET (of)

Environmental Planning Office
919 Ala Moana Blvd., Third Floor
Honolulu, HI 96814 Ph. (808) 586-4337 FAX: (808) 586-4370

Date: August 28, 2008
Time: 18:30-20:30
Location: Kaneohe Community Park, 45-529 Keaahala Rd., Honolulu, HI 96744
Purpose: Public Information meeting - Total Maximum Daily Load (TMDL), Kaneohe Stream, Oahu

Name	Affiliation/Mailing Address	Phone/FAX	email
Grant Hamachi	East County Farm Bureau	259-7085	
Lisa Schofield	Oahu Soil + Water Cons Dist.	483-8600 x119	melissa.schofield@ verizon.net
Chris Corley	PB Americas	371-5762	Corley@pbworld.com
Yanling Li	PB	489-7271	LiYan@pbworld.com
Yi Mei	Community	206-1077	maymeggie@hotmail.com
Mery Apple	UH	551-6613	mery@hawaii.edu
Gene Dashiell	ENVR Plng Svcs	593-8330	dashiell.e@hawaiiantel.net
Gerald Takayesu	City ENV	768-3257	gtakayesu@ honolulu.gov
Bob Shin	SDOT	831-6705	
Kent Morimoto	Austin Tsutsumi & Assoc.	533-3646	kmorimoto@atahawaii.com
Bob Bourke	Oceanit	531 3017	RBOURKE@OCEANIT.COM
~~Gerald Takayesu~~	~~City DES~~		
Jaime Saavedra	PB	531-7094	

Ken Tentsch State DOT 831-6703

LINDA LINGLE
GOVERNOR

ROBERT G.F. LEE
MAJOR GENERAL
ADJUTANT GENERAL

MARK S. MOSES
MAJOR, USMC, RETIRED
DIRECTOR

STATE OF HAWAII
DEPARTMENT OF DEFENSE
OFFICE OF VETERANS' SERVICES
459 PATTERSON ROAD, E-WING, ROOM 1-A103
HONOLULU, HAWAII 96819-1522
Telephone Number 433-0420

September 10, 2008

Mr. David Penn
State of Hawaii, Department of Health
P.O. Box 3378
Honolulu, HI 96801-3378

Dear Mr. Penn:

SUBJECT: Departmental Comments Regarding Draft Document – Total Maximum Daily Loads for Kaneohe Stream

We, at the Office of Veteran Services, are concerned about the environment and will make every effort to minimize our impact on it. The following comments are submitted in response to the subject document.

The Hawaii State Veteran's Cemetery sits on the side of a hill with natural contours that drain into Kawa stream by an existing drainage easement through private properties on Kumakua Place. Runoff from both the Veteran's Cemetery and Hawaiian Memorial Park drain into this drainage channel. During heavy rainstorms, the channel is prone to flooding due to the amount of runoff from both properties.

In the short term, we are currently in the process of correcting one of the slopes on the Veteran's Cemetery property that our design engineers have said will decrease the amount of runoff by 7%. In addition, we are exploring better ways of applying fertilizers to minimize its dilution in heavy runoff. However, we also recognize that these efforts may not be enough to meet the decrease in load and waste load requirements demanded in your draft document.

We estimate that it may take up to six months to determine whether the actions we are taking today will indeed reduce our TMDL to the acceptable limit. If it does not, we may need to make major modifications to the cemetery. Therefore, we ask that you give us two years to meet the Total Maximum Daily Load (TMDL) allocations, rather than making it effective immediately upon approval of the draft document. This time is required in order for us to measure the load after the current slope modification and short term fixes are completed, obtain legislative funding, and to plan, design, and construct remediation measures to further correct the problem if any is still required.

Sincerely,

Mark Moses

Mark Moses
Director

LINDA LINGLE
GOVERNOR OF HAWAII

CHIYOME L. FUKINO, M.D.
DIRECTOR OF HEALTH

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HI 96801-3378

In reply, please refer to:
File:
EPO-0541

September 25, 2009

Mr. Mark Moses, Director
Department of Defense
Office of Veterans' Services
459 Patterson Road, E-Wing, Room 1-A103
Honolulu, Hawaii 96819-1522

Dear Mr. Moses:

Subject: Total Maximum Daily Loads for Kaneohe Stream, Oahu, Hawaii

Thank you for the Office of Veterans' Services comments on the draft Total Maximum Daily Loads (TMDLs) for Kaneohe Stream, Oahu, Hawaii, along with new information about slope correction, runoff management, and fertilizer applications at the Hawaii Veteran's Cemetery. The Department of Health Environmental Planning Office (EPO) has prepared the following response to these comments.

According to our analysis, the Hawaii State Veteran's Cemetery drains into both Kaneohe Stream and Kawa Stream. The Kaneohe Stream TMDLs and the Revised Kawa Stream TMDLs each assign waste load allocations (WLAs) to the Cemetery. The Revised Kawa Stream TMDLs were approved by the U.S. Environmental Protection Agency (EPA) in September 2005, and EPA approval is pending for the Kaneohe Stream TMDLs. Although the WLAs in these TMDLs are effective immediately upon EPA approval for National Pollutant Discharge Elimination System (NPDES) permitting purposes, the time given by the Department of Health (DOH) for a permittee to meet the WLAs is decided when the permit is issued. We have no record of the Office of Veterans' Services application for the NPDES Small MS4 (Municipal Separate Storm Sewer System) permit that will regulate the Cemetery facility, and we expect that this permit, when issued, will include conditions for assuring implementation of the Cemetery WLAs assigned by the Kawa Stream and Kaneohe Stream TMDLs.

Slope correction to decrease runoff, as noted in your comments, can be an effective way to meet load reduction requirements. However, although decreasing the amount of runoff from the property is one way to reduce downstream pollutant loading, it can also deprive the downstream receiving waters of vital components of their flow regime. This alteration of streamflow dynamics can negatively affect channel form and hydraulic function, habitat availability and suitability for aquatic organisms, water supply, and waterbody assimilative capacity and nutrient/trophic status. We urge the Office of Veterans' Services, when designing pollutant load reduction measures, to carefully examine the trade-offs between runoff reduction/retention and the environmental hydrology and ecological health of downstream receiving waters.

The Cemetery's current efforts to minimize and quantify polluted runoff and drainage impacts to Kawa and Kaneohe streams are the same kinds of measures that would be included in a WLA implementation plan and WLA implementation monitoring plan submitted to DOH to fulfill the conditions of an NPDES MS4 permit. We encourage the Office of Veteran's Services to continue these efforts and apply for this permit.

We wish to thank the Office of Veterans' Services for its participation in the TMDL development process and look forward to future cooperative efforts. If you have any questions about this letter, please contact Mr. Dave Penn at (808) 586-4337 or at david.penn@doh.hawaii.gov.

Sincerely,

KARL K. MOTOYAMA, ACTING MANAGER
Environmental Planning Office

DEPARTMENT OF ENVIRONMENTAL SERVICES
CITY AND COUNTY OF HONOLULU
DOH-EPO 1000 ULUOHIA STREET, SUITE 308 • KAPOLEI, HAWAII 96707
RECEIVED PHONE: (808) 768-3486 • FAX: (808) 768-3487 • Website: http://envhonolulu.org

MUFI HANNEMANN
Mayor

'08 SEP 15 P2:23

ERIC S. TAKAMURA, Ph.D., P.E.
Director

KENNETH A. SHIMIZU
Deputy Director

ROSS S. TANIMOTO, P.E.
Deputy Director

SWQ 08-287

September 15, 2008

Mr. Kelvin Sunada, Program Manager
Environmental Planning Office
State Department of Health
919 Ala Moana Boulevard, Room 312
Honolulu, Hawaii 96814

Dear Mr. Sunada:

Subject: Comments on the Proposed Total Maximum Daily Loads (TMDLs) <u>Kaneohe Stream, Island of Oahu, Hawaii</u>

Please find attached our comments on the proposed TMDLs for Kaneohe Stream. This is in response to the "Notice of Public Comment Period and Public Information Meeting – Total Maximum Daily Loads (TMDLs) for Kaneohe Stream, Island of Oahu, Hawaii."

If you have any questions, please contact Gerald Takayesu of our Storm Water Quality Branch, Division of Environmental Quality at 768-3287.

Sincerely,

fr Eric S. Takamura, Ph.D., P.E.
Director

Attachment: Consolidated Comments

L-229

Consolidated ENV, DES, DPR, DFM Comments on the
Total Maximum Daily Loads (TMDLs) for Total Suspended Solids, Nitrogren and Phosphorus in Kaneohe Stream – Draft for Public Review August 2008
September 15, 2008

We share concerns for improving water quality in Kaneohe Stream and Kaneohe Bay and continue to address reducing the targeted pollutants TSS, nitrogen and phosphorous through updates to our storm water management plan. We request a time extension to submit comments as we need more detailed explanation of the methodology and rationale for developing the TMDLs and wasteload allocations. Additional comments include the following:

- 1 Methodology is not clear. Need more explanation on how the TMDLs and wasteload allocations were developed especially the process for calculating loads for MS4 permit holders vs. other non point sources
- 2 Are the reductions and WLA/LA based on end-of-pipe (including upstream) or reductions along conveyance system or drainage system?
- 3 There is not enough reference to the number of samples taken during wet weather events. Provide additional details into the water quality monitoring program
- 4 Need to change designations. Change DES to ENV on page iv and elsewhere. City's departmental abbreviations are DES – Department of Enterprise Services, responsible for the City's golf courses; DPR – Department of Parks and Recreation, responsible for Hoomaluhia; and ENV, Department of Environmental Services, lead agency responsible for administering the City's MS4 permit.
- 5 What is the rationale for including Hoomaluhia Botanical Gardens and the Pali Golf Course together as one WLA? In Kapa'a TMDL all City sources had separate WLAs. Also other TMDL reports list Golf as separate Source Allocation. Also note Pali Golf Course is not part of CCH Department of Parks and Recreation as is implied in Section 5.5 Sentence 8 of Draft Kaneohe TMDL
- 6 Why is the CCH MS4 listed as CCH DES? In Kapa'a TMDL the CCH MS4 is listed as CCH MS4 (see Kapa'a TMDL Tables 6.10 and 6.11 vs Draft Kaneohe TMDL Tables 5.10 and 5.11)
- 7 Allocations should refer to land area, land use, and ownership
- 8 Are residential areas excluding streets (houses, retail establishments, etc) along CCH MS4 considered Nonpoint Source during baseflow, 10% Runoff, and/or 2% Runoff
- 9 Verify applicability of the SCS curve number method to the extremely steep rocky slopes of the Koolaus.
- 10 Verify impervious area fractions as described in Table 4.2, "Hydrologic Properties of Kaneohe Stream Watershed. For instance, a) the impervious area fractions for "forest" is listed a "0" even though the Koolaus have rock outcroppings, which are fairly impervious; and b) City streets with curbs is listed as "1" even though many of the streets do not have sidewalks and the property owners are responsible to and do maintain grassed areas adjacent to their properties.

11 • Inconsistency in Allocation of Major Sources from past TMDL reports as compared to Kaneohe TMDL – previous TMDL reports separated golf, landfill, etc.

12 • Koolau Golf Course may need NPDES General Permit for industrial discharge – for vehicle/equipment fleet maintenance. They then would be point discharge and have an assigned WLA. Please explain reasoning behind not creating a separate designation for the Koolau golf course as opposed to isolating the City's golf course and park facilities.

13 • Following is a summary of land uses and percentages from 4.1 "Kaneohe Watershed Land Use Areas."

Forest	1,516 acres	41.5 %
Agriculture	255	7.0
Parks	702	19.2
Open Space	267	7.3
Schools	25	0.6
Residential	675	18.5
Commercial	43	1.1
City Streets	76	2.1
DOT Highways	97	2.7
Total	3,656	100.0

TMDL needs to address how DOH will enforce on stakeholders that do not have NPDES permits (e.g. State Department of Land and Natural Resources and Koolau Golf Course) that do not implement measures to reduce pollutants.

Wild pigs and alien plant species such as Miconia have done significant damage to forested areas. Nearly half of the watershed area is in conservation, how does DOH plan to get DLNR and other non-permitted stakeholders to reduce their pollutant sources?

14 • The City requests for a listing of all upcoming TMDL studies for Oahu based on priority and schedule to better prepare themselves for anticipated modifications to the City's Storm Water Management program and NPDES permit requirements. It will also aid in preparing future budget requests, monitoring plans, and overall program management planning documents.

DEPARTMENT OF PARKS AND RECREATION
CITY AND COUNTY OF HONOLULU
KAPOLEI HALE • 1000 ULUOHIA STREET, SUITE 309 • KAPOLEI, HAWAII 96707
TELEPHONE: (808) 768-3003 • FAX: (808) 768-7053 • INTERNET: www.honolulu.gov

DOH-EPO
RECEIVED
'08 SEP -5 A8:34

MUFI HANNEMANN
MAYOR

LESTER K.C. CHANG
DIRECTOR

GAIL Y. HARAGUCHI
DEPUTY DIRECTOR

September 3, 2008

Mr. Kelvin H. Sunada, Manager
Environmental Planning Office
State of Hawaii
Department of Health
P.O. Box 3378
Honolulu, Hawaii 96801

Dear Mr. Sunada:

Subject: Total Maximum Daily Loads for Kaneohe Stream

Thank you for informing us as to the availability of the draft rationale for a proposed water quality decision concerning "Total Maximum Daily Loads for Kaneohe Stream".

The Department of Environmental Services will be responding to your request on behalf of this department for any ideas and priorities for specific activities that could reduce pollutant loads, improve water quality and repair the integrity of aquatic ecosystems.

Should you have any questions, please contact Mr. John Reid, Planner, at 768-3017.

LESTER K. C. CHANG
Director

LKCC:jr
(275823)

cc: Mr. Gerald Takayesu, Department of Environmental Services

J-2277

LINDA LINGLE
GOVERNOR OF HAWAII

CHIYOME L. FUKINO, M.D.
DIRECTOR OF HEALTH

STATE OF HAWAII
DEPARTMENT OF HEALTH
P. O. BOX 3378
HONOLULU, HI 96801-3378

In reply, please refer to:
File:
EPO-0540

September 25, 2009

Mr. Timothy E. Steinberger, Director
City and County of Honolulu
Department of Environmental Services
1000 Uluohia Street, Suite 308
Kapolei, Hawaii 96707

Dear Mr. Steinberger:

Subject: Total Maximum Daily Loads for Kaneohe Stream, Oahu, Hawaii

We thank the Department of Environmental Services (ENV) for submitting comments, dated September 15, 2008, on the draft Total Maximum Daily Loads (TMDLs) for Kaneohe Stream, Oahu, Hawaii. We appreciate ENV's attention to the draft document and offer the following responses to concerns about the methodology and rationale for developing the TMDLs and waste load allocations. Although we denied ENV's request to extend the public comment period, we did meet thereafter to discuss our revisions to the document, and remain committed to using the TMDL decision as a starting point for implementation activities that can be adapted as new information becomes available, including, if warranted, future revision of the TMDL decision. Department of Health (DOH) capacity for TMDL development is limited by available resources and information, and we welcome any support that can be provided for boosting TMDL program capacity and increasing data availability.

For reference purposes, as shown in the attached annotated copy of ENV's comments, we numbered the City's bulleted comments from 1 to 14.

Comment 1. Methodology is not clear. Need more explanation on how the TMDLs and wasteload allocations were developed especially the process for calculating loads for MS4 permit holders vs. other non point sources.

Response. Appendix A, Technical Methods, has been extensively revised and supplemented to make the technical calculation methods more clear, and appears as Appendix B in the revised document. The processes for calculating loads (and allocations) for MS4 permit holders and for other non point sources are the same. Loads are calculated for the individual land areas for each source (MS4 and other NPS) in each sub-basin for each of the TMDL conditions (season, baseflow, 10% or 2% storm event).

Results of these load calculations for each source in each sub-basin are presented in Tables 4.5 through 4.10. Load capacities for each stream segment and the allocations of that load capacity to each of the land area sources in that segment's sub-basin are calculated as described in Appendix B, Section B.10.0. These allocations to each land area source are presented in Tables 5.4 through 5.9. Loads from all of the land area sources (from all the sub-basins) for which an individual MS4 permit holder is responsible are then summed (consolidated) into the total "existing loads" for that permit holder. Likewise, the individual waste load and load allocations are consolidated into the total "allocations" for each MS4 permit holder. These consolidated waste load and load allocations and existing loads are presented in Tables 5.10 and 5.11.

Comment 2. Are the reductions and WLA/LA based on end-of-pipe (including upstream) or reductions along conveyance system or drainage system?

Response. Reductions and WLA/LA calculations are based on end-of-pipe discharges to the stream segment of runoff from the sub-basin areas draining to the pipe. In some cases (e.g., pervious areas, streets with open swale drainage), estimates of existing loads have implicitly assumed some internal reductions along the overland or swale conveyance systems prior to the end-of-pipe discharge. The reductions and WLA/LA in Tables 5.10 and 5.11 are therefore beyond and in addition to any internal reductions that may have existed along the sub-basin drainage or conveyance system.

Comment 3. There is not enough reference to the number of samples taken during wet weather events. Provide additional details into the water quality monitoring program.

Response. In the revised TMDL document, we included a new Appendix A that provides the suggested information.

Comment 4. Need to change designations. Change DES to ENV on page iv and elsewhere. City's departmental abbreviations are DES – Department of Enterprise Services, responsible for the City's golf courses; DPR – Department of Parks and Recreation, responsible for Hoomaluhia; and ENV, Department of Environmental Services, lead agency responsible for administering the City's MS4 permit.

Response. These changes recommended by the City are adopted in the revised TMDL document.

Comment 5. What is the rationale for including Hoomaluhia Botanical Gardens and the Pali Golf Course together as one WLA? In Kapa'a TMDL all City sources had separate WLAs. Also other TMDL reports list Golf as separate Source Allocation. Also note Pali Golf Course is not part of CCH Department of Parks and Recreation as is implied in Section 5.5 Sentence 8 of Draft Kaneohe TMDL.

Response. The distributions of consolidated loads and allocations in Tables 5.10 and 5.11 in the public review draft of the Kaneohe TMDL document (and in previous TMDL documents) reflected the understanding by the DOH Environmental Planning Office (EPO) at the time of preparation of the document(s) of the intended MS4 permit assignments by the DOH Clean Water Branch (CWB) to CCH administrative departments. It is the subsequent understanding of EPO that all of the CCH runoff sources (streets, residential and commercial land areas, Hoomaluhia Botanical Gardens, municipal parks, and Pali Golf Course) will be included in a single MS4 permit issued to the Department of Environmental Services (ENV). Thus, the existing loads and respective allocations for all of these sources are now consolidated for each of the TMDL conditions in the revised Kaneohe TMDL document into a single LA (for baseflow) or WLA (for storm runoff) assigned to CCH ENV.

Comment 6. Why is the CCH MS4 listed as CCH DES? In Kapa'a TMDL the CCH MS4 is listed as CCH MS4 (see Kapa'a TMDL Tables 6.10 and 6.11 vs. Draft Kaneohe TMDL Tables 5.10 and 5.11).

Response. Please see the above responses to Comments 4. and 5.

Comment 7. Allocations should refer to land area, land use, and ownership.

Response. Consolidated allocations (Tables 5.10 and 5.11) are to NPDES-permitted or otherwise responsible agencies. Individual components of the consolidations are the allocations to individual land use areas to be found in Tables 5.4 through 5.9. We believe this is a reasonable and acceptable allocation approach. As discussed with and communicated to the City on numerous occasions, there are no federal or state requirements that load allocations refer to specific land area, land use, and ownership. However, the TMDL methodology can be applied to pursue different allocation arrangements that facilitate TMDL implementation, and these different arrangements can always be proposed as future TMDL revisions.

Comment 8. Are residential areas excluding streets (houses, retail establishments, etc.) along CCH MS4 considered Nonpoint Source during baseflow, 10% Runoff, and/or 2% Runoff?

Response. Residential areas are considered as nonpoint source contributors during baseline flow conditions and as point source contributors of MS4 runoff during storm events (10% Runoff, and/or 2% Runoff).

Comment 9. Verify applicability of the SCS curve number method to the extremely steep rocky slopes of the Koolau.

Response. Slope and soil (or rock) characteristics are accounted for in the hydrologic soil grouping (HSG) in the SCS curve number method. The steep rocky Koolau slopes at the head of the Kaneohe watershed, for example, are classed as "rock land" (rRK) and "rock outcrop" (rRO) in the NRCS Soil Survey of the State of Hawaii. Both "soil" classes are HSG D, largely impermeable soils with relatively high SCS curve numbers. The SCS curve number method calculates that a large fraction of the rainfall will run off from these areas, as is the common observation.

Comment 10. Verify impervious area fractions as described in Table 4.2, "Hydrologic Properties of Kaneohe Stream Watershed." For instance, a) the impervious area fractions for "forest" is listed a "0" even though the Koolaus have rock outcroppings, which are fairly impervious; and b) City streets with curbs is listed as "1" even though many of the streets do not have sidewalks and the property owners are responsible to and do maintain grassed areas adjacent to their properties.

Response. Table 4.2 and calculations based on this table have been modified to reflect this point made by the City.

a) For the upland "forest" areas in sub-basins 1.0, 2, and 4, the fractions that are soil class rRK or rRO (HSG D) are in the revised TMDL document now considered as impervious area fractions: 0.4 for sub-basin 1.0; 0.64 for sub-basin 2; 0.37 for sub-basin 4. However, the connected impervious fraction for each of the forest areas remains "0".

b) The street area estimations, following the SCS protocol in NRCS TR-55, Table 2-2a, are considered to be curb-to-curb street surfaces only for City streets with curbs (thus the impervious fraction of "1"), but the full ROW (Right-of-Way) widths and areas are considered for streets without curbs (i.e., with swale drainage).

Comment 11. Inconsistency in Allocation of Major Sources from past TMDL reports as compared to Kaneohe TMDL – previous DMDL reports separated golf, landfill, etc.

Response. Please see the above responses to Comments 5. and 7.

Comment 12. Koolau Golf Course may need NPDES General Permit for industrial discharge – for vehicle/equipment fleet maintenance. They then would be point discharge and have an assigned WFLA. Please explain reasoning behind not creating a separate designation for the Koolau golf course as opposed to isolating the City's golf course and park facilities.

Response. Table 4.1 and subsequent tables and calculations have been revised in the revised TMDL document to, among other things, provide for a separate designation for Koolau Golf Course. (Also see the above response to Comment 5.) If the Golf Course facility requires NPDES permit coverage, we can revise the TMDLs to assign a WLA to the facility, and to reduce the nonpoint source load allocations accordingly.

Comment 13. Following is a summary of land uses and percentages from 4.1 "Kaneohe Watershed Land Use Areas."

Forest	*1,516*	*Acres*	*41.5*	*%*
Agriculture	*255*		*7.0*	
Parks	*702*		*19.2*	
Open Space	*267*		*7.3*	
Schools	*25*		*0.6*	
Residential	*675*		*18.5*	
Commercial	*43*		*1.1*	
City Streets	*76*		*2.1*	
DOT Highways	*97*		*2.7*	
Total	*3,656*		*100.0*	

TMDL needs to address how DOH will enforce on stakeholders that do not have NPDES permits (e.g. State Department of Land and Natural Resources and Koolau Golf Course) that do not implement measures to reduce pollutants.

Wild pigs and alien plant species such as Miconia have done significant damage to forested areas. Nearly half of the watershed area is in conservation, how does DOH plan to get DLNR and other non-permitted stakeholders to reduce their pollutant sources?

Response. DOH supports a voluntary approach to obtaining compliance with State water quality standards from nonpoint source polluters, and provides funding to help design, install, and evaluate appropriate management practices. DOH pursuit of enforcement actions against nonpoint source polluters is based on establishing a body of evidence that demonstrates how a polluter caused or contributed to a violation of the State water quality standards. The water quality standards do not explicitly require that nonpoint source stakeholders implement measures to reduce pollutants, but we view all parties as having a duty not to cause violation of the standards. Depending upon the circumstances of any particular nonpoint source pollution event, the extent to which such measures are or are not implemented may or may not become a component of an enforcement action.

The DLNR has a vested interest in assuring that water quality in Hawaiian waterbodies meet water quality standards. Specific implementation measures could be determined in a watershed management plan developed in collaboration with other watershed stakeholders; the TMDL only provides load and wasteload allocations and an implementation framework. The DLNR and a number of non-profit organizations have been involved in ecosystem restoration in the Ko'olaupoko region, we hope that their efforts continue and are aided with funding for watershed improvements.

Comment 14. The City requests for a listing of all upcoming TMDL studies for Oahu based on priority and schedule to better prepare themselves for anticipated modifications to the City's Storm Water Management program and NPDES permit requirements. It will also aid in preparing future budget requests, monitoring plans, and overall program management planning documents.

Response. We welcome the City's interest in closer collaboration on TMDL development and storm water management. A list of current TMDL development efforts is maintained on the EPO website at www.hawaii.gov/health/epo, and TMDL development priorities are indicated in the current Water Quality Monitoring and Assessment Report that is posted on the same website. The current TMDL development schedule for Oahu, in approximate priority order, includes Waikele and Kapakahi streams, other streams in the Pearl Harbor basin, Kaelepulu inland waters, and Kalihi and Nuuanu streams. Although TMDL development priorities are established in conjunction with the Hawaii Clean Water Act Section 303(d) list, priorities may change as needed due to a variety of administrative, logistical, and financial concerns.

We wish to thank the City and County of Honolulu for its participation in the TMDL development process and look forward to future cooperative efforts. If you have any questions about this letter, please contact Mr. Dave Penn at (808) 586-4337 or at david.penn@doh.hawaii.gov.

Sincerely,

KARL K. MOTOYAMA, ACTING MANAGER
Environmental Planning Office

cc: Lester K. C. Chang, City & County of Honolulu, Department of Parks & Recreation

oceanit.
innovation through engineering & scientific excellence

DOH-EPO
RECEIVED

September 15, 2008

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Kelvin Sunada, Program Manager
Environmental Planning Office,
State of Hawaii Department of Health,
919 Ala Moana Boulevard, Room 312,
Honolulu, HI 96814

Subject: Comments Regarding Draft Kaneohe Stream TMDL

Mr. Sunada;

Thank you for the opportunity to review the draft document. We fully understand the difficulty in developing these TMDLs and appreciate both the effort and complexities involved in making the necessary assumptions and calculations. This comment letter only touches upon broad issues within the draft document. We have attached a PDF copy of the draft report with hand written comments of minor or editorial value for your review.

In 2002, when Oceanit collected water quality data for this report and reviewed data collected by others, we attempted to develop the TMDL estimates based upon a HEC-HMS model of the watershed. In the cyclical repetitive process of reviewing the model results and modifying the input parameters and variables we remained unsatisfied with the lack of correlation between model results and actual field data. Our resulting TMDL calculations were therefore based upon a simple spreadsheet method using measured flows and measured (or sometimes estimated) pollutant loads to calculate and distribute existing pollutant loads. This purely descriptive approach avoided the use of runoff and infiltration constants and pollutant loading constants developed for non-Hawaiian topographies. While this method obviously still had its problems, we felt it was the most straight forward descriptive approach available.

The approach in this draft of the TMDL uses a simple SCS runoff formulation with pollutant loadings apparently derived from the City's 1992 NPDES permit application and constants (C_{jk}, C_{Bjk}).for which we could not determine the referenced source. We absolutely support any simple method that can be reproduced from one watershed to the next in Hawaii. However, as with our earlier attempt at using HEC-RAS, examination of the tables and associated Figures 4-3 through 4-8 does not give us confidence that the model truly represents what is happening in the watershed. It is likely that the difficulties in using this method lay within the limitations of the SCS method in high slopes and the imprecise nature of the pollutant constants available for use in Hawaii. Obviously efforts on the part of the DOH, UH, and others to derive simple runoff and pollutant constants specific to Hawaii would be of great value to future TMDL efforts.

Executive Summary

This section is entirely too long, too convoluted, and contains too much extraneous information to be of use to either public administrators or the public at large. It appears that the summary was cobbled together with paragraphs copied directly from the main body of the report rather than edited for content and brevity. The lack of any stated conclusions or future direction and generally vague language leaves the reader at a loss.

Chapter 1 - Introduction

1.1 Make sure that references to the appendices are specific and that the appendices are well marked making them easy to locate. Are there 3 appendices (A, B, C) or appendices A through I ?

1.2 TMDL's can rapidly become too complicated if the focus is allowed to drift away from central issues. Discussion of extraneous issues, such as organochlorine, dieldrin, chlordane or other pesticides, while important from a watershed perspective, should not be included in the TMDL for solids, nitrogen, and phosphorous.

1.3 The section of pollutant sources is entirely too brief. Without knowledge of probable pollutant sources specified, it will be very difficult to decide where and how to limit loadings.

1.4 The discussion of background and concurrent studies seems dis-organized and does not serve to bring the reader up-to-date on the issues in a logical or sequential basis.

1.5 This section might be a good place to discuss the source of the loading constants used in the hydraulic and pollutant loading calculations.

Chapter 2 Setting

2.1 The assumption that temporal rainfall distributions are similar across small watershed areas is not likely to be true in this watershed.

2.2 Tables 2-19 and 2-19 need units.

Chapter 3 – Water Quality Data

3.1 Need to clarify that the DOH monthly sample locations were the same as the key Oceanit storm sample locations. For the purpose of the report, only one station name should be used per site for clarity, and units between all tables should be the same. It is curious in the DOH data set that the high rain volume in May appears to be correlated with high pollutant loads during the following month. Is this correct, or a typo? Some comment should be made to explain this apparent anomaly.

3.2 Because the DOH data set appears to be used for the "baseline" (non-storm) dataset, would it not be appropriate to delete data for the single day when they sampled during a storm?

3.3 In the Oceanit data set, the data for NO3 + NO2 appears to be missing

Chapter 4 – Existing Conditions

4.1 The dry weather base flow recession model should be based upon Kaneohe flow and rainfall data – not Kawa watershed. The topography and geology of the two watersheds, 4.1 although physically adjacent, are totally different from one another. There should be adequate flow and rainfall data to develop an independent flow model.

4.2 It does not make sense to categorize the Koolau Golf course as "Open" (equilavent to the lake surface!?!), but the Pali Golf Course as a park.

4.3 The physical boundary of the watershed appears to be larger than the one Ocean used, but the calculated total square miles is smaller. This probable bears double-checking.

4.4 There is discussion of assimilation or up-take within a stream (or lake) reach, but this is not shown on the schematic in Figure 4-1 or 4-2.

4.5 What are the units in Table 4.2. If they are "Area Fractions", shouldn't they add up to 1.00?

4.6 The source for the runoff concentration coefficients in Table 4.3 should be clearly stated and referenced as they are THE key factors in determining exceedance.

4.7 Please be clear in Figure 4-3 that the modeled line represents the Q or pollutant concentration in the main stream while the diamonds represent the Q or concentration in the in-feeding branches. Perhaps adding measured data points to this graphic would clarify how the model relates to known conditions.

4.8 The values used in Table 4.4 appear to be gross estimates, which is a sure way to generate poor model results with the SCS method. The Manning coefficients are not likely to be the same for all reaches. The Sedimentation efficiency for the Reservoir was earlier stated to be 0.71 (USGS ref.), so this number (not 0.5) should be used. In this method, I believe, that the "width" refers to the wetted surface width, and not some arbitrary estimate. We presume that a "user generated" storm was used, and not the Type-I or Type-II storms that come with the model as these often give erroneous results in Hawaiian environments.

4.9 Estimation of the relation between base-flow and rainfall is probably better made empirically from existing data.

4.10 With rainfall so strongly stratified across the watershed it is difficult to see how existing baseflow contributions from individual land use categories are proportional only to the areas of those categories. Only TSS is reduced by 90% (or 71%?) in the reservoir. TN and TP have different reduction coef. In the lake.

4.11 It is not clear how the various land use types used in Table 4.5 correlates with the various NPDES holders listed in Chapter 7. Since control appears to be focused upon permit holders, this would seem to be an important factor.

Chapter 5 – TMDL allocations

5.1 Table 5.1 outlines a good approach to segregating the events by GM 10%nte and 2%nte in parallel with the way the State WQ standards were created. In Appendix Section 9.9 these are correctly apportioned out into FOUR categories

Baseflow	0	<	x	<	0.04"	58% of Dry Days
C_8	0.04	<	x	<	0.35	35% of Dry Days

10%	0.35	<	x	<	1.27	8% of Dry Days
2%	1.27	<	x			2% of Dry Days

5.1 The calculation method outlined in Ch 5 appears to neglect runoff from the 35% light-rain days.

5.2 How is the Loading Capacity calculated in Table 5.2? Make note in the table that the "Existing" loads are derived from Tables 4.5, 4.6, and 4.7.

5.3 In Table 5.10, need to explain in the body of the text that when the "Existing Loads" are lower than allowed by State Standards, they have been artificially increased equal to the Allocations so as to prevent arithmetic negative number loadings from appearing in the table.

5.4 In Table 5.11, some of the allocations stretch believability. How is it, for example, that the WLA to CCH DES grossly exceeds the LA to NPS during 10% and 2% runoff events? In reality we know that during intense storms the muddy water comes from the mountains (NPS) not from City storm drains.

Chapters 6 and 7

6&7.1 These chapters contain lots of boiler plate and quotes, but little of substance. The first statement under "Watershed Based Plan" appears to recommend following the Ko`olaupoko Water Quality Action Plan, and Action Strategy, both written by a private group (KBAC). If that's the case, then why did we do a TMDL? All of the KBAC plans, while containing notable community input, are essentially the result of a series of popular votes conducted by their board of directors, with little or no basis in scientific fact. Assuming that the TMDLs can be met by addressing only the permit holders listed in Table 6.1 and cesspools listed in Table 6.2 is a gross oversimplification of the problem and takes little or no advantage of the sampling and modeling that were conducted as part of the TMDL.

6&7.2 From the perspective of a regulated NPDES holder, the TMDL does little to direct where (in what sub-basin) pollutant loads are greatest, or where they can be most easily addressed. The TMDL and other studies leading up to this work have compiled a good deal of information, which in combination with a decent GIS database and knowledge of the watershed should provide some excellent first suggestions as to where reduction loads could be found.

APPENDIX A

A.1 It is not likely valid to assume that temporal rainfall distributions are similar across small watershed areas or that spatial distributions follow these variations.

A.2 The evaporation model developed is valid, but it is not clear that a straight line regression is appropriate. It is not clear where this information is used in the following calculations

A.3 It is not clear where the constants (C_{jk}, C_{Bjk}) come from or if they are valid for this watershed.

A.4 Deriving a baseflow equation from the adjacent watershed is not a valid method as both the topography and geology are very different between watersheds. There should be enough data to derive an empirical equation.

A.5 It is not clear that settling velocity (v_s) is valid to use in conditions of turbulent flow. This section could benefit greatly from a few sample calculations showing where the numbers generated fit into the tables within the body of the report.

Watershed issues are, by their very nature, complex. A TMDL should, in our opinion, make an attempt to somewhat simplify pollution issues by focusing clearly on the specific problem pollutant, defining its sources within the watershed, and then showing were excessive sources may exist and may thereby be controlled. In general the Kaneohe TMDL draft report presents an overly complex view of the watershed not likely to be easily understood by the public and without definition of the actual sources of the pollutant loads. While it does address all of the existing and likely future NPDES permit holders, it does not explain specifically how their individual load assessments were calculated. While the general methods were made excruciating clear in the appendix, the values and sources of values for the various constants was not clear. While it is clear from the closing chapters that the focus of pollutant control will be on the NPDES permit holders, there is no evidence shown that these sources are indeed the primary sources or that they are the most effective to control.

Review of this TMDL reasserts the need for better runoff models specific to Hawaii with pollutant loading coefficients specific to individual land types and uses.

Thank your for the opportunity to review the document. We hope that the comments provided will result in an improved TMDL that will prove to be a valuable aide in the improvement of water quality and restoration of the Kaneohe watershed.

Sincerely,

Robert E. Bourke, Environmental Scientist
Oceanit
828 Fort Street Mall, Suite 600
Honolulu, Hawaii 96813

LINDA LINGLE
GOVERNOR OF HAWAII

CHIYOME L. FUKINO, M.D.
DIRECTOR OF HEALTH

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In reply, please refer to:
File:
EPO-0542

September 25, 2009

Mr. Robert E. Bourke
Oceanit, Inc.
Oceanit Center
828 Fort Street Mall, Suite 600
Honolulu, Hawaii 96813

Dear Mr. Bourke:

Subject: Total Maximum Daily Loads for Kaneohe Stream, Oahu, Hawaii

Thank you for your comments on the draft Total Maximum Daily Loads (TMDLs) for Kaneohe Stream, Oahu, Hawaii. The Department of Health Environmental Planning Office (EPO) has prepared the following response to these comments, which is limited to responding to those comments that appear in the body of your letter. Given that the annotated PDF copy of the draft document that was attached to these comments is "of minor or editorial value only," we did not open it. For reference purposes, as shown in the attached annotated copy of your comments, we numbered the comments from 1.1 (beginning at Introduction) to A.5 (settling velocity).

We acknowledge that all models have limitations and believe that our model is useful for its purpose. We provided a detailed description of the watershed so readers could judge this for themselves. In response to the last page of your letter, and as further explained in our responses below, we believe that the revised TMDL document explains specifically how the individual NPDES load assessments and nonpoint source load allocations were calculated, clearly identifies the values and sources of values for the various constants, and provides evidence that the contributing areas associated with permitted sources are primary sources under certain seasonal and critical conditions. The question of which sources are the most effective to control is perhaps the most difficult to answer, and we hope the answers will be advanced by information developed during TMDL implementation.

Executive Summary

Comment. This section is entirely too long, too convoluted, and contains too much extraneous information to be of use to either public administrators or the public at large. It appears that the summary was cobbled together with paragraphs copied directly from the main body of the report rather than edited for content and brevity. The lack of any stated conclusions or future direction and generally vague language leaves the reader at a loss.

Response. The most important conclusions stated in the Executive Summary are (1) the tabulated summary of "consolidated allocation and the load reductions required for their achievement . . ." (Tables ES-1 and ES-2) and (2) the linked premise that "Implementation of the required load reductions will result in the attainment of water quality standards . . ." (p. iii). The most important future directions stated are (1) "management of the storm drainage systems and wastewater disposal systems in the Kaneohe urban core should be a focus for County and State . . . implementation efforts" (p. vi) and (2) "the goals for restoring habitat quality and biotic integrity to the streams . . . can help guide TMDL implementation towards areas where . . . practices may best contribute to restoration efforts" (pp. v-vi). The Executive Summary progresses to these conclusions and future directions by first introducing the water quality problem, then describing the technical approach used to produce the required regulatory decision, and finally explaining how the problem could be solved and will be addressed. Organizing the Executive Summary around key paragraphs from the main body of the document is a stylistic choice; we don't expect everyone to agree with it.

Chapter 1 – Introduction

Comment 1.1. Make sure that references to the appendices are specific and that the appendices are well marked making them easy to locate. Are there 3 appendices (A, B, C) or appendices A through I ?

Response. In the draft TMDL document, there are three appendices: A, B, and C. In the revised TMDL document, there are four, also lettered sequentially. We corrected Chapter 1 and other pages that referred to Appendices A-I or otherwise complicated their reference.

Comment 1.2. TMDL's can rapidly become too complicated if the focus is allowed to drift away from central issues. Discussion of extraneous issues, such as organochlorine, dieldrin, chlordane or other pesticides, while important from a watershed perspective, should not be included in the TMDL for solids, nitrogen, and phosphorous(sic).

Response. The single paragraph referring to organochlorine pesticides in the document is, as described in the document, presented as an example of the factors considered by the Department in its assessment of the biotic integrity and habitat quality of Kaneohe

Stream. The TMDL is a technically-based plan and regulatory decision for achieving water quality standards, and is presented from a watershed perspective in order to guide water pollutant load reductions, water quality improvements, and aquatic ecosystem repairs that all contribute to a healthier watershed. Pesticide issues are not extraneous to this purpose, especially given that Kaneohe Stream continues to be listed on the Clean Water Act Section 303(d) list as a waterbody where water quality is impaired by excessive dieldrin levels.

Comment 1.3. The section of pollutant sources is entirely too brief. Without knowledge of probable pollutant sources specified, it will be very difficult to decide where and how to limit loadings.

Response. In the revised TMDL document, more detailed descriptions of pollutant sources, their probable amounts, and locations are provided in Chapter 4 – Existing Conditions.

Comment 1.4. The discussion of background and concurrent studies seems dis-organized and does not serve to bring the reader up-to-date on the issues in a logical or sequential basis.

Response. The discussion of background studies in the document is presented in the chronological order of significant water quality impacting events or concerns of their respective times. Most recent or concurrent studies are described in terms of likely interest to present and future TMDL or other water quality management planning efforts, e.g., chronic sedimentation of stream bottoms. We believe this forms both a logical and sequential basis for the discussion.

Comment 1.5. This section might be a good place to discuss the source of the loading constants used in the hydraulic and pollutant loading calculations.

Response. Discussion of the source of loading constants used in the hydraulic and pollutant loading calculations is more appropriately presented in Chapter 4 - Existing Conditions, and in Appendix A in the context of descriptions of the calculations which employ the referenced constants.

Chapter 2 – Setting

Comment 2.1. The assumption that temporal rainfall distributions are similar across small watershed areas is not likely to be true in this watershed.

Response. We agree that this assumption of temporal similarity is a relatively crude approximation over the length and elevation changes in the Kaneohe watershed. However, the PRISM model used in this document is a distinct advance beyond earlier TMDL models (e.g., by Oceanit) that ignored the much greater spatial variability of rainfall distribution. (See also response to Comment A.1).

Comment 2.2. Tables 2-19 and 2-19(sic) *need units.*

Response. Correct. The units for Figures 2-18 and 2-19 are "average monthly mm of rainfall" for the season depicted, as is now shown in the revised TMDL document.

Chapter 3 – Water Quality Data

Comment 3.1. Need to clarify that the DOH monthly sample locations were the same as the key Oceanit storm sample locations. For the purpose of the report, only one station name should be used per site for clarity, and units between all tables should be the same. It is curious in the DOH data set that the high rain volume in May appears to be correlated with high pollutant loads during the following month. Is this correct, or a typo? Some comment should be made to explain this apparent anomaly.

Response. Much of this lack of clarity arose from the labeling in portions of the 2002 Oceanit report that were used as a template for the draft TMDL document. In the revised TMDL document, we consolidated the information in Chapter 3, and added a new Appendix A, to clarify sample locations and units of measure. We agree that the concentrations of NH4 and TDP were curiously high for the June 4, 2002 sampling event in the DOH data set. In the revised TMDL document, this data set is incorporated into Appendix A, where we corrected the transcription error in the NH4 values. The erroneous NH4 values were not used in any impairment analysis or TMDL calculation, thus this error had no bearing on the TMDL decision. We rechecked the TDP values, which correctly match the values in the archival DOH data.

Comment 3.2. Because the DOH data set appears to be used for the "baseline" (non-storm) dataset, would it not be appropriate to delete data for the single day when they sampled during a storm?

Response. Not necessarily. As noted in Chapter 3 of the revised TMDL document, there are occasions when the calendrically-scheduled baseline sampling happened to coincide with a storm event. In such cases, the data may be accepted for use in storm flow calculations. The purpose of the baseline sampling is to avoid over-representation of storm flow data in the dataset used to calculate a geometric mean for comparison with geometric mean criteria, not to prevent it altogether. Thus data from the non-targeted baseline sampling may also be accepted for use in these calculations

Comment 3.3. In the Oceanit data set, the data for NO3 + NO2 appears to be missing.

Response. In the revised TMDL document, we included the missing data in the new Appendix A.

Chapter 4 – Existing Conditions

Comment 4.1. The dry weather base flow recession model should be based upon Kaneohe flow and rainfall data – not Kawa watershed. The topography and geology of the two watersheds although physically adjacent, are totally different from one another. There should be adequate flow and rainfall data to develop an independent flow model.

Response. The dry weather baseflow recession model for Kaneohe watershed is in fact based upon Kaneohe flow and rainfall data. The general model was originally developed for TMDL application in the Kawa watershed; its calibration for that watershed was used for illustration in Appendix A of the draft Kaneohe TMDL document as an indication of its general applicability. However, the Kaneohe version of the model is based upon Kaneohe watershed characteristics: stream drainage network, land use distribution, rainfall, topography, geology, etc. (See also the response to Comment A.4.)

Comment 4.2. It does not make sense to categorize the Koolau Golf course as "Open" (equivalent to the lake surface!?!), but the Pali Golf Course as a park.

Response. Land use categories in the public review draft of the TMDL document were originally restricted in number because of publication space limitations (numbers of spreadsheet columns). Some land use areas were therefore forced into initially inappropriate categories for document presentation but subsequently applied to the appropriate regulatory category in the consolidation of sources in Tables 5.10 and 5.11. This unfortunately confusing procedure has been corrected in the revised TMDL document and both Pali and Koolau Golf Courses are now displayed throughout the document under the new category of "Golf Course."

Comment 4.3. The physical boundary of the watershed appears to be larger than the one Ocean(sic) *used, but the calculated total square miles is smaller. This probable*(sic) *bears double-checking.*

Response. The Kaneohe Stream watershed boundary in the public review draft of the TMDL document is expanded slightly in the vicinity of the intersection of Kaneohe Bay Drive and Kamehameha Highway to coincide with the Kawa Stream watershed boundary in the Kawa Stream TMDL, and is contracted slightly in the vicinity of Windward Community College, to reflect the municipal separate storm sewer drainage of the local area. In the final TMDL document, the lower area of the watershed adjacent to Kaneohe Bay is reduced further in order to exclude the estuarine segment of the stream and the lands tributary to this segment. The Oceanit watershed delineations were imported from older sources that were derived from digital elevation modeling of topographic data, and these delineations did not consider ground-based hydrologic truth or DOH regulatory boundaries. In order to improve the accuracy and applicability of TMDL analysis, we adjusted the older sources of watershed delineation data to incorporate newer ground verification and standard regulatory information.

Comment 4.4. There is discussion of assimilation or up-take within a stream (or lake) reach, but this is not shown on the schematic in Figure 4-1 or 4-2(sic).

Response. The assimilation of pollutant loadings is mathematically described in Appendix A, Section A.6.0. Streamflow and Water Quality. This assimilation is implicit in the Figure 4-1(a) and 4-1(b) calculation steps labeled "Calculate Segment Water Quality."

Comment 4.5. What are the units in Table 4.2. If they are "Area Fractions", shouldn't they add up to 1.00?

Response. All values in Table 4.2 are dimensionless, i.e., without units. The impervious area fraction (4.2a) is the fraction of the individual land use area that is impervious (as opposed to "pervious"). The connected impervious fraction (4.2b) is the fraction of the impervious area that is connected directly to a storm sewer drainage system. In neither case do these individually independent fractions add up to any meaningful total.

Comment 4.6. The source for the runoff concentration coefficients in Table 4.3 should be clearly stated and referenced as they are THE key factors in determining exceedance.

Response. Runoff (and baseflow) concentration coefficients in Table 4.3 are primary calibration parameters for the TMDL model(s). Initial values for these coefficients were obtained from the references cited in Section 4.4 of the TMDL document. The initial values were then adjusted in the model calibration process to provide an acceptable fit between water quality values calculated by the model(s) and Kaneohe stream data collected by Oceanit during the November 27, 2001 calibration event (See Appendix A, Figure A3.) It is the final calibrated values of these coefficients that are listed in Table 4.3.

Comment 4.7. Please be clear in Figure 4-3 that the modeled line represents the Q or pollutant concentration in the main stream while the diamonds represent the Q or concentration in the in-feeding branches. Perhaps adding measured data points to this graphic would clarify how the model relates to known conditions.

Response. Modeled line and diamond symbol representations in Figure 4-3 (and subsequent figures) are described in the first paragraph of Section 4.6 of the TMDL document.

Comment 4.8. The values used in Table 4.4 appear to be gross estimates, which is a sure way to generate poor model results with the SCS method. The Manning coefficients are not likely to be the same for all reaches. The Sedimentation efficiency for the Reservoir was earlier stated to be 0.71 (USGS ref.), so this number (not 0.5) should be used. In this method, I believe, that the "width" refers to the wetted surface width, and not some arbitrary estimate. We presume that a "user generated" storm was used, and not the Type-I or Type-II storms that come with the model as these often give erroneous results in Hawaiian environments.

Response. Values used in Table 4.4 are estimated from on-site visits. No parameter in this table is used in the SCS runoff method. There is likely more variation among Manning coefficient values than is shown in this table. However, the relatively rapid achievement of steady streamflow assumed in the TMDL calculations (for the selected 10% and 2% storm event conditions) leaves any differences in event mean streamflow due to Manning coefficient variance fairly insignificant. Granted, the depth of flow in the stream channel will be significantly affected by the Manning coefficient value, but depth of flow does not appear in any of the TMDL calculations (See Appendix A).

"Sedimentation efficiencies" in Table 4.4 and in the USGS ref. are entirely different entities. The 0.71 value in the USGS ref. is the fraction of the annual incoming sediment load that is deposited (removed) in the Waimaluhia reservoir. The 0.5 value in Table 4.4 is the fraction of total reservoir, or stream segment, surface area that is "effectively" represented by the uniform assimilation (sedimentation) model in the water quality and load capacity calculations (See Appendix A). The "sediment efficiency" in Table 4.4 is a measure of the lateral mixing or, conversely, hydraulic short-circuiting in the segment and not the ultimate sediment removal. Wetted perimeter is the appropriate measure dividing the cross-sectional flow area in the hydraulic radius used in Manning equation flow velocity calculations. The "width" in Table 4.4 is the mean flow surface width in the segment. It is multiplied by segment length to provide the segment surface area used in the assimilation component in the water quality model (Section 6.0 of technical appendix).

Comment 4.9. Estimation of the relation between base-flow and rainfall is probably better made empirically from existing data.

Response. If base-flow were the only objective, this might perhaps be true (although attempts at exactly this for another nearby watershed area indicate this is not so straightforward either). However, the primary objective of the otherwise tedious mathematics of the baseflow model development is to connect the observed baseflow in the stream segment back to individual flow contributions from the land use areas tributary to the segment, and the observed water quality in the stream segment back to dry weather pollutant load contributions related to those individual land use areas, in a systematic and mechanistically defensible way.

Comment 4.10. With rainfall so strongly stratified across the watershed, it is difficult to see how existing baseflow contributions from individual land use categories are proportional only to the areas of those categories. Only TSS is reduced by 90% (or 71%) in the reservoir. TN and TP have different reduction coef. in the lake.

Response. Baseflow contributions from individual land use categories are functions of individual land use characteristics (impervious and connected area fractions, soil water quality) and local rainfall (See Appendix A, Section A.5.0) the net results of which are only then multiplied by the areas of the categories. TN and TP are both calculated to be reduced by about 90% in the reservoir during baseflow conditions, TSS by more than 90%.

Comment 4.11. It is not clear how the various land use types used in Table 4.5 correlates(sic) *with the various NPDES holders listed in Chapter 7*(sic). *Since control appears to be focused upon permit holders, this would seem to be an important factor.*

Response. Correlations between the land use types in Table 4.5, and subsequent other tables, and the NPDES permit holders listed in Chapter 5 is admittedly not clear in the public review draft of the TMDL document. Land use categories and permit holder responsibilities have both been adjusted in the revised TMDL document to more clearly (and accurately) display the land use and regulatory category connections. (See also the response to Comment 4.2 above.)

Chapter 5 – TMDL Allocations

Comment 5.1. Table 5.1 outlines a good approach to segregating the events by GM 10%nte and 2%nte in parallel with the way the State WQ standards were created. In Appendix Section 9.9 these are correctly apportioned out into FOUR categories

Baseflow	*0*	<	*x*	<	*0.04"*	*58% of Dry Days*
C_8	*0.04*	<	*x*	<	*0.35"*	*35% of Dry Days*
10%	*0.35*	<	*x*	<	*1.27"*	*8% of Dry Days*
2%	*1.27*	<	*x*			*2% of Dry Days*

The calculation method outlined in Ch 5 appears to neglect runoff from the 35% light-rain days.

Response. A more accurate categorical apportionment for the dry season baseflow illustration would be:

Baseflow	0	<	x	<	0.04"	58% of Dry Days
C_{w9}	0.04	<	x	<	0.35"	32% of Dry Days
8%	0.35	<	x	<	1.27"	8% of Dry Days
2%	1.27	<	x			2% of Dry Days

						100% of Dry Days

The calculation method outlined in Appendix A, Section A.9.0, includes all of the days.

Comment 5.2. How is the Loading Capacity calculated in Table 5.2? Make note in the table that the "Existing" loads are derived from Tables 4.5, 4.6, and 4.7.

Response. Loading Capacity (LC) calculations were described in Appendix A, Section A.10.0 (renamed Appendix B in the revised TMDL document). The revised TMDL document includes the note for Table 5.2 as suggested.

Comment 5.3. In Table 5.10, need to explain in the body of the text that when the "Existing Loads" are lower than allowed by State Standards, they have been artificially increased equal to the Allocations so as to prevent arithmetic negative number loadings from appearing in the table.

Response. In all tables in the TMDL document, "Existing Loads" are calculated by the methods and equations described in Appendix A, Sections A.4.0 (for stormwater runoff) and A.5.0 (for baseflow), without regard to State Standards or Allocations. In Tables 5.4 through 5.9, for those segments where the existing sub-basin load is less than the calculated load capacity for the segment, the allocation assigned to each individual source is reduced to the existing load from the source so as to comply with the non-degradation policy in Hawaii's water quality standards. These reduced individual source allocations are carried into the consolidations of allocations that are presented in Table 5.10 and Table 5.11.

Comment 5.4. In Table 5.11, some of the allocations stretch believability. How is it, for example, that the WLA to CCH DES grossly exceeds the LA to NPS during 10% and 2% runoff events? In reality we know that during intense storms the muddy water comes from the mountains (NPS) not from City storm drains.

Response. In the TMDL calculations, allocations are generally proportional to existing loads. Existing loads from the CCH municipal storm sewer system are calculated to largely exceed the loads from NPS during the 10% and 2% runoff events. Please note that a 24-hour, 2.30-inch rainfall (wet season 2% event) is not a very intense storm in the normal experience of the upper Kaneohe watershed (reference rainfall station is at Pali Golf Course). The 1.27-inch and 0.35-inch rainfall amounts (dry season 2% and 10% events) are even less intense. For these storm events of less-than-extreme intensity, most of the rainfall in the upper watershed NPS areas infiltrates while most of the rainfall in the lower watershed developed area becomes runoff to the municipal separate storm sewer system. Furthermore, runoff from most of the NPS area flows through the Waimaluhia reservoir, where inflowing pollutant loads are greatly reduced. The most extreme storms that bring down the muddy water from the mountains occur less frequently than the 10% or 2% runoff events that are the focus of the TMDL calculations in this document as dictated by the water quality criteria. For better or for worse, the reality of the TMDL requirements is more tied to the water quality standards than to our experiential knowledge of storm intensity.

Chapters 6 and 7

Comment 6&7.1. These chapters contain lots of boiler plate and quotes, but little of substance. The first statement under "Watershed Based Plan" appears to recommend following the Ko'olaupoko Water Quality Action Plan, and Action Strategy, both written by a private group (KBAC). If that's the case, then why did we do a TMDL? All of the KBAC plans, while containing notable community input, are essentially the result of a series of popular votes conducted by their board of directors, with little or no basis in scientific fact. Assuming that the TMDLs can be met by addressing only the permit holders listed in Table 6.1 and cesspools listed in Table 6.2 is a gross oversimplification of the problem and takes little or no advantage of the sampling and modeling that were conducted as part of the TMDL.

Response. We did a TMDL because the Kaneohe Stream was assigned a high priority for TMDL development on the Clean Water Act Section 303(d) list. The information presented in Chapters 6 and 7 is intended to assist with figuring out how to meet the TMDLs, not to provide or dictate any final answers. What the first statement under "Watershed Based Plan" actually says is quite more discrete than what you say it appears to recommend. When DOH provides references to documents that identify specific measures for reducing pollutant loads, it does not mean that DOH recommends those measures or documents. All it means is that they are sources of information that are available to people who may be developing the recommendations themselves. In Chapters 6 and 7, there is no statement that "DOH assumes the TMDLs can be met by addressing only the permit holders listed in Table 6.1 and cesspools listed in Table 6.2." Information about permit holders and cesspools is provided so that people active in TMDL implementation can make use of it as they see fit.

Comment 6&7.2. From the perspective of a regulated NPDES holder, the TMDL does little to direct where (in what sub-basin) pollutant loads are greatest, or where they can be most easily addressed. The TMDL and other studies leading up to this work have compiled a good deal of information, which in combination with a decent GIS database and knowledge of the watershed should provide some excellent first suggestions as to where reduction loads could be found.

Response. Actually, the tabulations of existing loads in Tables 4.5 through 4.10 provide a great deal of information about exactly where (in what sub-basin) and for which land use areas and by how much the pollutant loads are greatest.

APPENDIX A
Please note that Appendix A in the draft TMDL document is renamed Appendix B in the revised TMDL document.

Comment A.1. It is not likely valid to assume that temporal rainfall distributions are similar across small watershed areas or that spatial distributions follow these variations.

Response. With long-term (i.e., 20 to 30 years) records of hourly, or even daily, rainfall available from few weather stations in a given watershed area, alternatives to the temporal similarity assumption are not readily at hand. A rainfall distribution analysis using two-station statistical records is being examined for application in Kalihi and Nuuanu Stream TMDL development, but testing of this method is not yet completed. Differences in daily rainfall records from two stations at extreme watershed locations and elevations should in theory provide some insight into the temporal variations of rainfall across the watershed area. In any case, spatial distributions of rainfall are not assumed to follow temporal distributions, but are obtained directly from PRISM model calculations. (Also see the response to Comment 2.1).

Comment A.2. The evaporation model developed is valid, but it is not clear that a straight line regression is appropriate. It is not clear where this information is used in the following calculations.

Response. As noted in Section 3.0 of the Appendix, the linear regression is less than the ideal form but is adopted for mathematical convenience. The information is used in the calculation of net inflow (infiltration minus evaporation and other losses) to watershed soils that is part of the ultimate calculation of baseflow contributions. In the revised TMDL document, Appendix B (formerly Appendix A) has been substantially amended to provide greater detail and clarity about the TMDL calculation methods.

Comment A.3. It is not clear where the constants (C_{jk}, C_{Bjk}) come from or if they are valid for this watershed.

Response. The C_{jk} and C_{Bjk} constants are primary calibration parameters developed specifically to fit the general TMDL calculations to the specific Kaneohe watershed data. Initial values for these constants were obtained from the references cited in Section 4.4 of the TMDL document. These initial values were then adjusted in the model calibration process to provide an acceptable fit between water quality values calculated by the model(s) and Kaneohe stream data collected by Oceanit during the November 2001 calibration event. (See also the response to Comment 4.6.)

Comment A.4. Deriving a baseflow equation from the adjacent watershed is not a valid method as both the topography and geology are very different between watersheds. There should be enough data to derive an empirical equation.

Response. See the responses to Comments 4.1 and 4.9.

Comment A.5. It is not clear that settling velocity (v_s) is valid to use in conditions of turbulent flow. This section could benefit greatly from a few sample calculations showing where the numbers generated fit into the tables within the body of the report.

Response. Even in generally turbulent flow conditions, there are interfacial boundary films through which entities migrate at determinable velocities. The "settling velocity" used in the empirically calibrated concentration calculation(s) described in Section 6.0 of the Appendix should not be viewed so much as a literal physical settling velocity but more as a mathematical rate constant convenience for what likely are several different physical, chemical, and biological assimilation mechanisms, all of which will also as likely be ultimately limited by some form of first-order kinetics. In any of the likely assimilation mechanisms then, the first-order transport rate of mass or energy across a boundary or along a path will be proportional to the cross-sectional area of the path and the velocity along the path or across the boundary. Thus the in-stream assimilation rate component in the Section 6.0 water quality equations is expressed as a product of the stream segment surface area (through which solids must physically settle or solar energy for biological uptake must pass) and an empirically determined "velocity" of transport.

We wish to thank Oceanit for its participation in the TMDL development process. If you have any questions about this letter, please contact Mr. Dave Penn at (808) 586-4337 or at david.penn@doh.hawaii.gov.

Sincerely,

KARL K. MOTOYAMA, ACTING MANAGER
Environmental Planning Office

C: Jan N. Sullivan
Dayan Vithanage