REVISIONS TO
TOTAL MAXIMUM DAILY LOADS FOR
THE ALA WAI CANAL
- ISLAND OF OAHU, HAWAII -

TOTAL NITROGEN
TOTAL PHOSPHORUS

Adopted by Hawaii Department of Health

Prepared by U. S. Environmental Protection Agency, Region 9
and Hawaii Department of Health

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Executive Summary

Ala Wai Canal, a 2 mile-long man-made canal located in the Honolulu area of the island of Oahu, Hawaii, is an impaired waterbody. Nutrients, sediments, and several toxic pollutants from the watershed enter the canal from 3 major and several minor tributary streams at a rate faster than they can be assimilated and recycled. As a result, Ala Wai Canal is not meeting the State of Hawaii water quality criteria, and its beneficial uses are not being maintained. This report addresses nutrient loadings (total nitrogen and total phosphorus) to Ala Wai Canal; additional pollutants contributing to the canal's water quality problems will be addressed at a later date.

These Total Maximum Daily Loads (TMDLs) are calculations of the maximum amount of total nitrogen and total phosphorus that can enter Ala Wai Canal without violating the State's Water Quality Standards, which are compiled in the Hawaii Administrative Rules, Chapter 11-54. Determining the TMDLs is a process required by the federal Clean Water Act to ensure that surface waters support a balanced aquatic community and are safe for recreational uses.

The Hawaii State Department of Health (HIDOH) completed TMDLs for total nitrogen and total phosphorus in 1995 which identified nutrient loading reductions needed at a watershed scale to meet water quality standards. Since 1995, implementation actions designed to restore streams in the watershed and improve water quality in the canal have been initiated by a local watershed group, the City and County of Honolulu (CCH), and HIDOH. Meanwhile, HIDOH, CCH, and other researchers have collected substantial water quality data for Ala Wai Canal and its tributaries. Pursuant to the implementation timeframe identified in the 1995 TMDLs, the TMDLs are now being revised to provide more detailed load and wasteload allocations in order to assist in identifying other implementation needs.

The revised TMDLs and allocations are based on analysis of water quality data for the watershed collected during the past 5 years; information in the Ala Wai Canal Watershed Management and Implementation Plan, Mamala Bay Study, and other reports; and the existing TMDLs and supporting documentation to determine the revised TMDLs and allocations for Ala Wai Canal. The revised TMDLs identify allowable nutrient loads by nutrient source category as well as the estimated percent reductions in nutrient loading from different source categories which would be necessary to meet the TMDLs and State Water Quality Standards. In combination with stream restoration and Canal maintenance activities being planned by the watershed group and CCH, TMDL implementation should result in attainment of State Water Quality Standards in the Canal.

Approximately half of the watershed land area is comprised of conservation lands and half of urban lands. The TMDL Report estimates nitrogen and phosphorus loadings and associated allocations for four source categories: non-urban land (which includes conservation lands), urban lands, groundwater sources, and cesspools. Table 1 summarizes estimated loads for each source category and in total, and the associated allocations and total allowable loads for nitrogen and phosphorous. It appears that aggressive actions to reduce nutrient loadings from both urban and non-urban areas will be necessary to implement the allocations. We expect that management practices designed to address erosion prevention and control will assist in attaining the nutrient allocations. Phosphorous loadings, in particular, appear to be closely associated with sediment loadings to the watershed. Actions to ensure that cesspool loadings are effectively eliminated appear necessary to implement the nitrogen allocations.

The TMDL analysis does not directly account for the benefits of proposed Canal dredging and stream channel restoration projects in its analysis of the Canal's capacity to receive and assimilate nutrient loadings without violating water quality standards. However, we expect that both canal dredging and stream restoration projects will have the beneficial effect of increasing the watershed's capacity to assimilate nutrient loadings due to the filtering effects of restored streambank vegetation, improvements in Canal water mixing, and removal of existing nutrient reservoirs in Canal sediments.

Table 1: Summary of Load Estimates and Major Allocations (see Table 7 for details)

Source	Est. Load (kg/day)	% total load	Allocation (kg/day)	% reduction needed
Total Nitrogen				
non-urban lands	30	38-51%	13	57%
urban lands	6-26	10-33%	6	63%*
groundwater	4	5-7%	2	50%
cesspools	19	24-32%	1	95%
unallocated reserve			3	
Total	59-79	100%	25	
Total Phosphorus				
non-urban lands	8	38-48%	4	50%
urban lands	6-10	35-48%	4	~50%*
groundwater	2	10-12%	1	50%
cesspools	5	5-6%	0	>90%
unallocated reserve			1	
Total	21-25	100%	10	

* estimated percent reductions are based on the midpoint loading estimate for this source category
Source: Analysis of data reported in Freeman, 1993 and CCH, 1999 and 2000

Aggressive best management practices (BMPs) appear necessary for land uses and activities that potentially introduce pollutants into the Ala Wai Canal watershed. BMP programs which should be considered by land management agencies, private landowners, and watershed stakeholders include:

- management of invasive species and erosion sources in conservation land areas,
- fertilizer application practices in parks, golf courses and other landscaped areas,
- stormwater management practices including stormwater retention and filtering practices,
- programs to control and reduce littering, illegal dumping, and animal waste discharges to water courses,
- programs to upgrade or eliminate use of cesspools for sewage disposal, and
- programs to ensure that boat wastes are disposed of in pump-out facilities.

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Introduction

The Hawaii State Department of Health (HIDOH) is adopting revised Total Maximum Daily Loads (TMDLs) for total nitrogen and total phosphorus for Ala Wai Canal. The revised TMDLs were prepared by staff from U.S. Environmental Protection Agency (EPA) and HIDOH. The TMDLs are based upon an analysis of monitoring data collected by several agencies, existing stormwater and watershed management plans, and the existing TMDLs for Ala Wai Canal nutrients. These TMDLs constitute formal revisions to the Ala Wai Canal nutrient TMDLs adopted by HIDOH in 1995 and approved by EPA in 1996. The 1995 TMDLs provided general guidance concerning the levels of nutrient reduction from different sources needed to meet standards in the Canal. The TMDLs indicated that HIDOH intended to review available data and information and, if necessary, revise the TMDLs within about 5 years. A great deal of monitoring, analysis, and planning activity has been directed toward the Ala Wai watershed over the past 5 years by the HIDOH, the City and County of Honolulu, U.S. Geological Survey (USGS), the local watershed association, and many researchers.

Development of these revised, more detailed TMDLs is intended to use the more recent data and information to help support, guide, and complement efforts by local watershed land managers and stakeholders to implement effective actions to address Ala Wai Canal water quality problems. The goal of the TMDLs and associated implementation actions is to reduce pollutant loadings such that the Canal meets the criteria, objectives, and protected uses set forth in the Hawaii Administrative Rules (HAR), Chapter 11-54, Water Quality Standards (WQS).

Section 303(d) of the Federal Clean Water Act (CWA) [33 U.S.C. Section 1313(d), see also 40 CFR 130.7] requires states to adopt a water quality standards-based approach to controlling sources of pollution in instances where application of technology-based standards has failed to bring State surface waters into compliance with State Water Quality Standards. The first step required of states under CWA Section 303(d) is development of the CWA Section 303(d) List of Water Quality-Limited Segments (List), which must be submitted to the U.S. Environmental Protection Agency (EPA) for approval in successive even-numbered years (except for the year 2000, in which a list revision was not required by EPA). TMDLs must be prepared for all waters on the List and approved by EPA. Federal regulations (40 CFR 130.6) and national policy (Perciasepe policy, August 1997) indicate that TMDLs should be implemented through a mixture of regulatory and voluntary implementation approaches.

Methods for estimating TMDLs add another dimension, that of surface flows, to the usual practice of evaluating water quality by measuring pollutant concentrations in water samples. The phrase “Total Maximum Daily Load” means that the amount of a pollutant entering an impaired waterbody per unit of time (the daily load) is limited to that load that the waterbody can accept and still meet WQS (the maximum daily load). The “total” acceptable pollutant load must be allocated among contributing sources, whether point or nonpoint sources or a combination of both. Next, load reductions are implemented where needed through a combination of permit conditions and voluntary practices (known as best management practices or BMPs), and monitoring data are collected to determine if the TMDL for a pollutant is being met. Several iterations of BMP implementation and TMDL monitoring may be needed to track changes in pollutant loading and transport over time; consequently, an adaptive management approach should be applied to TMDL implementation. The revised TMDLs for Ala Wai Canal nutrients constitute the second phase in the TMDL process for this watershed, and are intended to provide additional detail concerning source contributions and allocations to assist in targeting nutrient control and watershed restoration projects.

Ala Wai Canal, the subject of the present TMDLs, is listed as an impaired waterbody on Hawaii's 1998 EPA-approved CWA 303(d) List due to several pollutants including nitrogen, phosphorus, sediment, metals, pathogens, and pesticides (HIDOH, 1998). Substantial water quality monitoring and modeling have been conducted to assess water quality problems and pollutant sources in the Ala Wai Canal watershed. In order to prepare the revised nutrient TMDLs for Ala Wai Canal, HIDOH and EPA staff analyzed existing monitoring data, modeling results, watershed management plans and stormwater management plans. Key information and data sources consulted in the preparation of the revised TMDLs are listed in the reference section of the report and all sources considered are maintained in the administrative record for this action.

Estimates of nutrient loads from significant loading sources were derived and linked to receiving water conditions in order to derive estimates of pollutant loading capacity-- the capacity of Ala Wai Canal to receive pollutant loads without exceeding applicable water quality standards. Specific wasteload allocations for nutrient sources subject to NPDES permitting requirements and load allocations for other nutrient sources were identified and summed to comprise the total allowable loads of total nitrogen and total phosphorus-- i.e., the TMDLs. The TMDL Report describes analytical steps followed to develop these estimates. The Report also describes sources of uncertainty in the analysis and assumptions used to account for analytical uncertainty-- thereby providing the margin of safety required by the CWA. The TMDL Report also discusses seasonal variations in pollutant loads and effects and shows how the TMDL calculations account for these seasonal variations.

The revised Ala Wai Canal TMDLs and associated wasteload and load allocations are expressed in terms of average mass loads per day of total nitrogen and total phosphorus which can be discharged and assimilated in the Canal without exceeding water quality standards. An average daily loading time-step was judged to be appropriate for the Ala Wai Canal TMDLs based on our analysis of water quality standards violations in the Canal and its tributaries, the hydraulic characteristics of the Canal, the apparent patterns of pollutant loading in the watershed, and the methods through which the water quality standards are expressed.

WQS extend beyond simple requirements to meet chemical criteria-- the standards also set designated uses and objectives with respect to habitat and aquatic life that must be met. The functions and values of the chemical, physical, and biological aspects of streams are interdependent. The Ala Wai Canal is a man-made waterbody in a highly urbanized area. In addition to water quality impacts associated with loadings of nutrients and other pollutants, Ala Wai Canal also appears to be affected by hydrologic modifications including dredging, flow management and diversions, and damaged streambank and channel conditions in tributary streams. Although pollutant loadings should be reduced pursuant to the TMDL, it may be necessary to also implement other actions to ensure that WQS are fully attained.

Minimum TMDL Elements

The following are eight minimum TMDL elements, consistent with EPA guidance.

1. **Problem Definition**: Identify the waterbody, pollutants causing impairment, applicable WQS, and describe the environmental problem.

2. **Numeric Target Definition**: Identify quantitative targets or endpoints for the waterbody which interpret and apply applicable water quality standards and are used to calculate the TMDLs. Discuss how the stream can assimilate the Total Maximum Daily Load (TMDL) of pollutants

3. **Source Analysis and Estimation**: Estimate pollutant loads discharged into the waterbody from all sources, including natural background sources as well as land uses (i.e., agriculture and urban).

4. **Linkage Analysis and TMDL Calculation**: Estimate the capacity of the waterbody to receive pollutants without exceeding WQS. This amount equals the TMDL.

5. **Partition the loads among the contributing sources**: Allocate the available pollutant loading identified by the TMDL among significant contributing sources.

6. **Margin of Safety Analysis:** Discuss explicit and/or implicit margins of safety in the TMDL calculations and discuss sources of uncertainty in the data collection methods and computations.

7. **Account for Seasonal Variations and Critical Conditions**: Discuss seasonal variations in pollutant loadings and discuss how the TMDLs are sensitive to seasonal waterbody conditions, such that the TMDL will meet WQS in all seasons and under all critical conditions.

8. **Conduct a Public Participation Process**: Provide for public review and comment on proposed TMDLs. Normally, this involves issuance of a public notice, an opportunity for the public to provide written comments on the TMDL, and preparation of responses to comments. One or more public information meetings may also be held.

For Ala Wai Canal, each element is addressed below along with implementation recommendations.

1. Problem Definition

Ala Wai Canal is an artificial estuary constructed in the 1920s to drain the marshy areas around Waikiki. The two mile long Canal receives inflows from three major tributaries, Manoa, Palolo, and Makiki Streams, and several urban tributaries. The Canal flows into Mamala Bay. Ala Wai Canal is very stagnant because it receives relatively little freshwater inflow except during substantial storms, and the upper half of the Canal has no major freshwater tributaries at all. Moreover, seawater mixes poorly with Canal waters because the Canal is relatively narrow (including in the area where it joins Mamala Bay). As a result of the limited circulation within the Canal, nutrients, sediments, and other pollutants tend to build up in the stagnant waters and settle to the bottom of the Canal.

The watershed draining into the Ala Wai Canal is 10,515 acres in size. Land use in the watershed is divided between forested conservation lands (46%) located in the higher elevations of the watershed and urban land uses (approximately 53%) at lower elevations. Single family and multi-unit residential housing make up the bulk of the urbanized areas of the watershed; the watershed also includes much of the highly developed Waikiki area and University of Hawaii campus. The conservation lands are managed by the Hawaii Department of Land and Natural Resources. The more urbanized areas of the watershed are within the jurisdiction of the City and County of Honolulu. Agriculture is not a significant land use in the watershed.

The upper part of the Ala Wai basin experiences periodically intense rainstorms and receives more than 3500 mm/year in rainfall on average (Freeman, 1993). The lower parts of the basin receive less than 1000 mm/year in rainfall. A majority of rainfall occurs during the winter months although substantial rainfall has been recorded throughout the year.

Ala Wai Canal water quality is impaired by nitrogen, phosphorous, sediments, pathogens, metals, and pesticides. The Canal is listed on Hawaii's 1998 Section 303(d) list for these pollutants. Applicable standards for the Canal are summarized below.

Water quality standards for total nitrogen and total phosphorus for Ala Wai Canal are listed in H.A.R. Chapter 11-54-05.2. and summarized below:

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten per cent of the time	Not to exceed the given value more than two per cent of the time
Total Nitrogen (µg N/L)	200.0	350.0	500.0
Total Phosphorus (µg P/L)	25.0	50.0	75.0 \

For the purposes of the TMDL program, "time" is defined as one year.

L = Liter

µg = microgram or 0.000001 grams

Ala Wai Canal is classified in State water quality standards as a Class 2 inland water. Beneficial uses of the Canal are designated in State standards at H.A.R. Chapter 11-54-03(b)(2) as follows:

"Class 2.

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

No new industrial discharges shall be permitted within estuaries, with the exception of:

(A) Acceptable non-contact thermal and drydock or marine railway discharges within Pearl Harbor, Oahu;

(B) Stormwater discharges associated with industrial activities (defined in 40 C.F.R. Section 122.26(b)(14)) which meet, at the minimum, the basic water quality criteria applicable to all waters as specified in section 11-54-04(a), and all applicable requirements specified in chapter 11-55, titled "Water Pollution Control; and

(C) Discharges covered by a National Pollutant Discharge Elimination System general permit, approved by the U.S. Environmental Protection Agency and issued by the Department in accordance with 40 C.F.R. Section 122.28 and all applicable requirements specified in chapter 11-55, titled "Water Pollution Control.". "

An analysis of data collected by HIDOH in 1996-97, the City and County of Honolulu (CCH) between 1995-2000, and USGS between 1999-2001 indicated that the Canal and its tributaries often exceed applicable Hawaii water quality standards for total nitrogen and total phosphorus (HIDOH, 1997; CCH 2000, USGS, 2001). Table 2 summarizes HIDOH's findings from its 1996-97 study regarding exceedances of water quality standards in three areas of the Canal for total nitrogen and total phosphorus. Data were collected at sampling sites at the eastern end, middle, and western ends of the Canal. Because Hawaii's standards are expressed in terms of levels not to be exceeded (geometric mean, 10% and 2% exceedance frequencies), the table identifies the percentage of samples in violation of the different standards for the geometric mean and 2% standards. For example, no more than 50% of samples may exceed the geometric mean standard of 200 ug/l and no more than 2% of samples can exceed the less stringent standard of 500 ug/l.

Table 2: Frequency of Nutrient Standards Exceedances in Ala Wai Canal

Site	Parameter	Percent Exceeding Geometric Mean WQS	Percent Exceeding 2 % Standard
Kapahulu Library (eastern end)	Total Nitrogen	97%	85%
Manoa/Palolo Stream Mouth (middle)	Total Nitrogen	98.5%	50%

Table 2: Continued

Ala Moana Street Bridge (western end)	Total Nitrogen	77%	28%
Kapahulu Library (eastern end)	Total Phosphorus	86%	21%
Manoa/Palolo Stream Mouth (middle)	Total Phosphorus	83%	1%
Ala Moana Street Bridge (western end)	Total Phosphorus	76%	10%

Source: HIDOH, 1997.

In the 1996-97 study, HIDOH found that in Ala Wai Canal, mean total nitrogen concentrations exceeded State standards by nearly six times and total phosphorus by nearly twice the standard. HIDOH also found that total nitrogen levels in Makiki, Manoa, and Palolo Streams regularly exceeded State freshwater stream standards, and that total phosphorus levels in Makiki Stream regularly exceeded State freshwater standards. This finding is underscored by the analysis of CCH data for nutrient levels in the Manoa Stream tributary, which indicates that the applicable water quality standards for freshwater streams are violated most often for total nitrogen (100% of values between 1995-2000, n=56) and nearly as often for total phosphorus (92% of values between 1995-2000, n=56) (HIDOH analysis of data reported in CCH, 2000). These results are consistent with data recently published by USGS for Manoa Stream for the 1999-2001 period. The USGS data indicate that the TP WQS were exceeded in 95% of samples and the nitrogen standards exceeded in at least 71% of samples (n=38)[11]

The HIDOH study of the Canal found that the geometric mean standards for nitrogen and phosphorus were exceeded significantly more frequently than the 2% standard, indicating that nutrient problems in the Canal are virtually continuous. An analogous comparison of CCH data for Manoa Stream with freshwater geometric mean and 2% standards also found that the geometric mean standards are violated much more often than the 2% standards. Due to the low flow and water exchange rates within the Canal and the stagnant conditions that result, large nutrient loads associated with large storms may remain in the Canal system as dissolved nutrients or become bound up with Canal sediments for lengthy periods following those storms. As a result, an ongoing reservoir of nutrients may be built up over time which becomes available when Canal sediments are mobilized by tidal or high flow conditions.

There is some evidence that nutrient loads are higher during periodic high intensity storms in the watershed. The 2001 USGS data for the period 1999-2001 indicated a fairly strong relationship between flows and pollutant concentrations (USGS, 2001). As illustrated in Figures 3 and 4, both nitrogen and phosphorous concentrations were substantially higher during high flow events associated with storms than during lower flow events. The combination of higher flows and concentrations would yield substantially higher daily nutrient loads in response to storms and the runoff which occurs in response to storms. The 1997 HIDOH study reported measurements of water quality during one large storm in March 1997. Phosphorus concentrations in Makiki Stream during this storm were greater than 2 mg/l total phosphorus--approximately 10 times higher than the levels reported in the neighboring tributary streams during the same period (HIDOH, 1997). Laws, et al. (1993) also reported a large increase in phosphorus

1 The USGS did not report total nitrogen results for each sampling event; therefore, we reviewed other nitrogen measures reported by USGS in preparing this analysis.

concentrations following rainfall based on measurements taken at Makiki Stream. No data were identified for this analysis which relate nutrient levels in Ala Wai Canal to rainfall-related runoff and nutrient concentrations in its tributaries.

As described above, DOH did not find significant differences between median wet season and dry season concentrations of total nitrogen and total phosphorus in the Maikiki watershed (DOH, 1997). When the CCH data for Manoa Stream are stratified between wet and dry seasons from 1995-2000, there is no obvious difference between wet and dry season concentrations during this period (see figures 2 and 3). When the USGS data for Manoa Stream are stratified between wet and dry seasons from 1999-2001, the seasonal mean nutrient concentrations are virtually identical (wet season means were 1.22 mg/L TN and 0.379 mg/L TP compared with dry season means of 1.49 mg/L TN and 0.376 mg/L TP, n = 38). These studies of Ala Wai tributaries may suggest that although individual storms contribute large, short term nutrient loads, no significant difference between mean wet and dry season nutrient concentrations in the tributaries was observed based on analysis of available data.

Nutrient impacts reported in Ala Wai Canal include elevated turbidity, excessive algae growth, and odors which impair recreational use of the canal and may also affect the health of aquatic life. Nutrient loading, and phosphorus loading in particular, are associated with excessive sediment loading due to erosion from conservation lands, some urban areas, and streambanks.

The Ala Wai Canal landscape and streams have been substantially altered over time. The conservation areas have experienced substantial adverse impacts due to introduction of non-native animal and plant species and construction of roads and trails. The urbanized areas have been heavily developed. As a result, a high percentage of the watershed is occupied by impervious surfaces which build up and discharge nutrients and other pollutants, and concentrate storm runoff receiving waters. Source of nitrogen and phosphorus in the watershed include animal wastes (from domestic, feral, and wild animals), fertilizers, automobile exhausts, food waste and other garbage, and rotting vegetation. In addition, sewage is believed to contribute substantial amounts of nitrogen and, to a lesser extent, phosphorus to the watershed. Up to approximately 500 homes use cesspools to dispose of sewage, and these cesspools may be substantial sources of nutrient loading to streams in the watershed (CCH, 2002). It is also possible, but unverified, that sewage from improperly functioning septic tanks and leaks in the sanitary sewers is reaching surface water through groundwater inflows. Stream channels in the urbanized areas of the watershed have been heavily modified over time by a variety of flood control projects. Some tributary channels experience substantial erosion and destruction of riparian vegetation during storm flows, which may contribute significant amounts of nutrients to the Canal. Removal of riparian vegetation from stream channels also reduces the capacity of the tributaries to assimilate nutrients prior to their entry into the Ala Wai Canal. Finally, illicit discharges of sewage from boats may be a significant source of nutrient loading.

Ala Wai Canal has been dredged periodically to address turbidity and other adverse water quality conditions. Another round of dredging is planned for 2002, which may help to improve water quality in the long run by increasing circulation and channel depth, and by removing built-up deposits of nutrients, sediment, pesticides, and metals. In the short run, however, dredging may cause releases of pollutants present in dredged material. Several alternative methods for enhancing Canal quality are currently under consideration, including discharge of salt water or brackish well water into the eastern end of the Canal to improve circulation and mixing, and flush sediments and associated pollutants into nearshore coastal waters, where they may be more readily dispersed by tidal currents.

2. Numeric Target Definition

Numeric targets are water quality endpoints which identify the receiving water goals the TMDL is designed to meet, which also represent attainment of applicable State water quality standards for the pollutants in question. The numeric targets for the revised Ala Wai Canal nitrogen and phosphorus TMDLs are the applicable Hawaii Water Quality Standards for total nitrogen and total phosphorus listed above. In particular, the TMDL was designed to meet the geometric mean standards since the review of available water quality data indicated that these standards were being exceeded most frequently in the Canal and its tributary streams. The geometric mean standard is the most stringent standard in effect from the standpoint of allowed nutrient concentrations. Moreover, the water quality data analysis did not indicate any strong seasonal variation in receiving water quality conditions which might suggest a need to focus upon shorter time steps in the TMDL analysis. Finally, the hydrologic characteristics of the Ala Wai Canal suggest that it is appropriate to focus on nutrient loadings and conditions over a lengthy period as the Canal is poorly mixed, has long water retention times, and may build up a reservoir of nutrients in sediments.

The purpose of the Ala Wai Canal TMDL revision is to more accurately identify the magnitude and location of nutrient loads entering Ala Wai Canal in excess of those allowed by the WQS and accompanying antidegradation policy. The end result of the process is a set of allowable pollutant loads, that, when met, will put Ala Wai Canal in compliance with the Water Quality Standards and restore the designated uses.

3. Source Analysis and Estimation

Key nutrient loading sources of concern in the Ala Wai watershed include urban runoff, runoff from non-urban lands (principally conservation lands), construction of roads and trails, nutrient inputs from groundwater into stream baseflow, nutrient inputs from stream side vegetation, sewage disposed of in cesspools, injection wells, sewage from boats, nutrients from ocean waters which enter the Canal through tidal action, and naturally occurring nitrogen and phosphorus compounds present in eroded soil and rock.

Sufficient information is provided in Freeman, 1993 to estimate nutrient inputs from conservation lands, urban areas, groundwater/base flow, and cesspools. These estimates are discussed in more detail below.

Very limited information about ocean water quality was available; therefore it is conservatively assumed that ocean water entering the Canal is at the applicable open ocean water quality standards of 150 ug/l total nitrogen and 20 ug/l total phosphorus.

Insufficient information was available to estimate nutrient loads associated with streamside vegetation, injection wells, boat discharges, and natural soil and rock. Based on a review of the Ala Wai Watershed Water Quality Improvement Project (1998) and discussions with local watershed stakeholders, it is believed that substantial amounts of rotted vegetation build up in the stream channels and are dislodged and transported to the Canal by high magnitude storms. This vegetation could represent a significant source of nutrient loading to the Canal, but further characterization of this source was infeasible for the TMDL analysis. Little information about injection wells was obtained, but we believe relatively few home owners in the watershed dispose of household wastes through this means. Nutrient and pathogen loading associated with illegal discharges of boat wastes may be significant since approximately 800 boats use the Ala Wai Boat Harbor, but few boaters use pump out stations (Harleman, et al., 1996). The amount of boat waste disposed of in the Canal as opposed to ocean waters is unknown.

Pollutant loading sources may be divided between point sources (sources regulated by NPDES permits) and nonpoint sources (other sources not regulated under NPDES). Point sources present in the Ala Wai Canal include:

- City and County of Honolulu (stormwater discharges from its stormwater collection system)
- Hawaii Department of Transportation (stormwater discharges from State highway stormwater system)
- Ala Wai Marine, Ltd. (industrial discharger of wash water and stormwater from a marine railway facility)
- Yacht Harbor Towers (condominium discharger of air conditioning cooling water).

The CCH and DOT stormwater discharges may contribute significant sources of nutrients to the watershed, but insufficient information is available to distinguish among them. These sources would be considered together in the urban land use category reported by Freeman.

The discharges from Ala Wai Marine and Yacht Harbor Towers are not believed to contribute significant amounts of nutrients to the Canal (analysis of information in Stevenson, et al., 1995). Ala Wai Marine does not appear to discharge regularly, and the Yacht Harbor Towers discharge is composed of cooling water discharges that have not been documented to carry significant nutrients. Each of the other sources of interest in the watershed is classified as a nonpoint source.

Three existing studies which report estimates of nutrient loadings to the Ala Wai Canal watershed were evaluated to develop the source analysis estimates for the TMDL. The scope and methods used in each of these studies are briefly summarized, and source analysis results are then reported and compared.

Freeman's 1993 Load Estimates

Pollutant loadings were estimated based on results of a modeling study completed by Pacific Environmental Research in 1993 (Freeman, 1993, chapter 2 and Appendix A). The ALAWAT model provides daily estimates of pollutant loadings from different land uses based on estimates of runoff, stream flow, sediment loads and pollutant loads. The model uses a version of the SCS rainfall-runoff model to estimate pollutant loads for different land use areas. The pollutant loading model, including calibration and validation steps, is described in detail in Freeman, 1993. This loading study was used during the development of the existing nutrient TMDLs for Ala Wai Canal.

The model first characterizes watershed hydrology (Freeman, pp. 2-5 - 2-14). The model estimates average annual rainfall in the watershed based on an analysis of 10 years of local rainfall data. Next, the model estimates runoff from four sources: direct runoff from land, bank storage and seepage, stream baseflow and spring/basal flow, and direct rainfall to the receiving waterbody. In this step, the model accounts for movement of water from one source to another (e.g., from direct runoff to short term storage in stream banks and perched groundwater), and accounts for evaporation loss from the system. The model yields estimates of stream flow for the three major tributaries in the Ala Wai watershed.

The model provides estimates of sediment loading from different erosion sources. Three separate methods are used and compared to estimate sediment loading from urbanized areas (Freeman, 2-18 – 2-23). Sediment loads from construction and non-urban areas are estimated based on application of the Universal Soil Loss Equation (Freeman, pp. 2-24 - 2-29). Estimates of sediment loading were used, in part, to estimate nutrient loadings as described below.

The model next provides estimates of nutrient loads from significant loading source categories present in the watershed. Loading estimates are provided for total nitrogen and total phosphorus for four land use categories:

- urban NPS runoff (developed areas, mostly in the City of Honolulu)
- non-urban NPS runoff (principally conservation lands)
- spring/basal loads from groundwater
- cesspool loads

The model estimates nutrient loads for the first three land use categories based on analysis of the relationship between suspended sediment loads and nutrient loads measured in the Manoa Stream watershed (Freeman, pp. 2-29 - 2-30). The model uses results from the hydrologic and sediment loading analyses discussed above to estimate nutrient loads for the entire watershed for these three land use categories. Estimates of nutrient loading associated with cesspools in the watershed are based on a 1990 study by Department of Public Works and Department of Health (reported in Freeman, 1993). The model provides average annual daily loading information based on estimates of long term average annual rainfall-runoff and associated pollutant loading estimates. For purposes of the TMDLs, annual nutrient loading estimates reported as annual loading estimates in the Freeman report (pp. 3-4 - 3-8) were converted to average daily loads in order to facilitate comparison with the total loading capacity estimates provided in the following chapter. Table 3 reports loadings of total nitrogen, and Table 4 report loadings of total phosphorus.

Some nutrients discharged to Ala Wai watershed tributaries do not make it all the way to the Ala Wai Canal because some nutrients are stored in instream sediments and plants or removed from the system (e.g., nitrogen gas may be released from certain nitrogen-containing compounds by denitrifying bacteria). Because a portion of nutrient loads are effectively removed from the system prior to reaching the Ala Wai Canal, the level of nutrient loading reductions needed to meet water quality standards in the Canal may be less than would be the case if nutrients were conservative (i.e., all transported to the Canal).

Table 3: Nitrogen Loading Estimates by Land Use Category

Land Use Category	Loadings (kg/day)	% of Total Loadings
Urban nonpoint source	6-26	10-33
Non-urban nonpoint source	30	38-51
Spring/basal groundwater	4	5-7
Cesspools	19	24-32
TOTAL LOADS	59-79	100

Source: Freeman, p. 3-7

Table 4: Phosphorus Loading Estimates by Land Use Category

Land Use Category	Loadings (kg/day)	% of Total Loadings
Urban nonpoint source	6-10	35-48
Non-urban nonpoint source	8	38-48
Spring/basal groundwater	2	10-12
Cesspools	1	5-6
TOTAL LOADS	31.0	100

Source: Freeman, p. 3-8

Stevenson, et al's Nutrient Load Estimates

Stevenson, et al (1995) developed pollutant loading estimates for all Mamala Bay tributaries and for all point sources as part of the Mamala Bay Study (1996). Estimates were not reported for individual land uses or tributaries, so the estimates are somewhat less useful for TMDL development. The nonpoint source loadings were estimated using computer models which estimated (1) average annual loads using Camp Dresser McKee's Watershed Management Model (WMM), and (2) loadings from critical precipitation events using the HEC-STORM model developed by the Army Corps of Engineers. Both models use local land use information and pollutant loading factors based on land use-specific event mean concentrations (EMCs) from U.S. EPA's National Urban Runoff Program. After land uses in the watershed were defined, precipitation patterns, impervious surface areas, and base stream flows were estimated. Next, EMC data were selected from local and national data sets. Annual pollutant loads were estimated at the watershed scale using the WMM model. Finally, the HEC-STORM continuous simulation model was run for a one year period (actually a hybrid year representing January-June 1994 and July- December 1985) which was believed to be representative. Model calibration and validation steps are not discussed in the report in detail; therefore, it was not possible to review the accuracy of the models used. The methods used are described in more detail in Stevenson, et al., Section 3. The nutrient loading results are reported in Table 5 below.

CCH's Nutrient Load Estimates for Urban Areas of Ala Wai Watershed

As part of its stormwater monitoring program, CCH developed estimates of pollutant loads for the urbanized portion of the Ala Wai watershed in 1999. The CCH estimates were based on an EMC approach similar to that used by Stevenson, et al. to generate annual loading amounts which are summarized in Table 5. The CCH method generated loading estimates based on a simple equation which factors in median annual rainfall in the watershed, amount of impervious area, estimated pollutant runoff coefficients, and estimated pollutant concentrations on the land. It does not appear that CCH did any validation analysis to determine the accuracy of its loading estimates. CCH's methods are discussed in more detail in CCH, 1999, Appendix B. CCH also reported nutrient loading by land use category. The nutrient loading results by land use category are reported in table 5 below, and the total loading estimates are reported in table 6 below.

Table 5: Estimated Annual Nutrient Loading in Urban Areas of Ala Wai Watershed

Land Use	Area (ac)	%	TN (lbs)	%	TP (lbs)	%
Residential	3795	68	5225	56	1140	52
Industrial	31	<1	183	2	44	2
Commercial	629	11	2618	14	707	32
School/Park	1138	20	1336	14	291	13
Urban Total	5593		9362		2182	
Nonurban Total	10515					

source: CCH, 1999.

Comparison of Loading Estimates

As illustrated in Table 6, the three nutrient loading estimates reviewed for the TMDL yielded significantly different estimates of pollutant loading based on three different methods. The Freeman estimates for total nitrogen loading are lower than those generated by Stevenson, et al. and CCH, and higher for total phosphorus loading. The accuracy of each estimate is unknown, and we would expect there to be significant potential error in each of the estimates. Each estimation method has its own advantages and disadvantages.

Table 6: Comparison of Recent Nutrient Loading Estimates for Ala Wai Canal (kg/year)

Pollutant/ Land Use Category	Freeman (1993)	Stevenson, et al (1996)	City and County of Honolulu (1999)
Total Nitrogen			
Total Ala Wai Canal	25,330	60,900	NR
Urban Areas	2230	NR	9362
Non-Urban Areas	14,700	NR	NR
Groundwater/Baseflow	1570	NR	NR
Cesspools	6830	NR	NR

Table 6: Continued

Total Phosphorus			
Total Ala Wai Canal	12922	7818	NR
Urban Areas	3650	NR	2182
Non-Urban Areas	6930	NR	NR
Groundwater/Baseflow	552	NR	NR
Cesspools	1790	NR	NR

NR - not relevant

The Freeman estimates have the advantage of using a 10 year rainfall record to generate long term loading estimates for a period which includes wide variation in actual rainfall conditions, and at a relatively fine geographic scale. The Freeman estimates area also reported by major land use which facilitates division of loads into allocations. The disadvantage of the Freeman estimates is that the accuracy of the load estimation methods is uncertain.

The Stevenson, et al. estimates have the advantage of including a simulation of nutrient loads associated with storm runoff as well as an average annual loading estimate. However, this storm-load simulation is based on a very limited period of time. In addition, the results of these two modeling methods are not distinguished in the report and loadings by land use category are not reported. This method relies upon the possibly questionable assumption that EMCs for individual land uses taken from the National Urban Runoff Program studies are representative of Hawaiian conditions. Stevenson, et al. do not report loads by land uses, which inhibits division of allowable loads into load allocations.

The CCH estimates are based on a very simple method of unknown accuracy. This method does not account for shorter duration high magnitude storms as do the Freeman and Stevenson, et al. methods. Loads are not estimated for the non-urban portion of the watershed.

These TMDLs are calculated using the loading estimates developed by Freeman for four main reasons:

- Freeman analyzed the longest period of precipitation records in deriving the estimates, increasing the chances of effectively accounting for interannual variations in precipitation.

- Freeman's analysis divides the watershed into much smaller units of analysis, thereby more accurately accounting for differences in local land uses.

- Freeman reports loads by key land use categories, which facilitates allocation analysis.

- Overall, it appears the Freeman estimates are not widely off the mark. The Freeman nitrogen loading estimates are lower than the other two studies, but are within the same order of magnitude, indicating that they are roughly comparable. The Freeman phosphorus loading estimates are higher than the other two studies but are within the same order of magnitude.

4. Linkage Analysis and Computation of TMDLs

The next step in determining the TMDLs is to link the analysis of allowable pollutant amounts in the Canal (as represented by the numeric targets) with the analysis of pollutant loadings (provided by the source analysis) to determine the mass loads of nutrients which can be present in the Canal without exceeding water quality standards. This amount, also known as the loading capacity, equals the TMDL for each pollutant. To determine the revised nitrogen and phosphorus TMDLs, the 1995 TMDLs were reviewed and compared with potential TMDLs based on different calculation factors. This section:

- summarizes the 1995 TMDLs and the methods used to calculated them,
- restates the 1995 TMDLs as allowable mass loads to facilitate comparison with other methods and allocation among sources,
- presents an alternative method for calculating the TMDLs,
- compares the 1995 TMDLs with the results derived through the alternative method, and
- identifies the selected values for this TMDL revision

Summary of 1995 TMDLs

The TMDLs adopted by HIDOH in 1995 were calculated based on analysis presented in Freeman, 1993. Freeman calculated the TMDLs based on consideration of 6 main factors:

1. the numeric targets for the TMDL which, in this case, were the State's numeric water quality standards.
2. the volume of water contained in the Canal basin, which is reported in Freeman, 1993, p. 3-46.
3. the residence time of water in the Canal basin, which is reported in Freeman, 1993, p. 3-46.
4. background concentrations of nutrients in ocean waters (assumed by Freeman to equal the coastal waters water quality standard)
5. the amount of excess nutrients loaded into the watershed (based on the ALAWAT model, reported in Freeman, 1993, p. 3-46).
6. the ambient water quality conditions in the Canal (reported in Freeman, 1993, p. 3-47)

Freeman described the TMDLs in the 1993 analysis in terms of necessary nutrient load <u>reductions</u> on a daily basis. Freeman calculated necessary nutrient load reductions through the use of two calculation methods which are summarized here and described in more detail in Freeman, 1993, pp. 3-43- 3-48. The first method was based on nutrient loading data generated by Freeman's ALAWAT pollutant loading model. The estimated average daily nutrient loads to the Canal estimated with the ALAWAT model were converted to a per liter basis as TN = 182 ug/l and TP = 74 ug/l. Background loadings from the ocean were taken into account by assuming that ocean water is at the applicable ocean water quality standards of TN = 150 ug/l and TP = 20 ug/l. Allowable concentrations are the State water quality standards, 200 ug/l for nitrogen and 25 ug/l for phosphorus. Therefore the excess load beyond the Canal's loading capacity based on Freeman's first method was estimated as:

Average excess nutrient concentration (ug/l) =

[Average inputs from watershed (ug/l) + Background ocean concentration (ug/l)] -

Allowable concentration (ug/l)

Excess daily nitrogen concentration = [182 ug/l + 150 ug/l] - 200 ug/l

= 132 ug/l

Excess daily phosphorous concentration = [74 ug/l + 20 ug/l] - 25 ug/l

= 69 ug/l

Freeman's second method for estimating excess loading capacity relied upon an analysis of Ala Wai Canal water quality data (OI Consultants, reported in Freeman, 1993), taking into account an assumed freshwater water residence time of 3 days. Water residence time was considered because considerable amounts of dissolved and suspended nutrients remain in the Canal after they are discharged from freshwater or stormwater tributaries. As a result, the daily assimilative capacity of the Canal for new nutrient discharges is reduced because of the lag time in the movement of nutrient laden freshwater into ocean waters. Therefore, the TMDL analysis considered how long, on average, it takes for freshwater discharged into the Canal to reach the ocean waters of Mamala Bay. The TMDL assumes average freshwater residence time of 3 days based on the results of a dye study which found average water residence time of 40-60 hours (reported in Freeman, 1993, p. 3-46).

The excess load beyond the Canal's loading capacity based on the second method was estimated as:

$$\frac{\text{[Average nutrient concentrations in water column (ug/l) - Ala Wai Canal WQS (ug/l)]}}{\text{average water residence time (days)}}$$

$$\text{Excess daily nitrogen} = \frac{612 \text{ ug/l} - 200 \text{ ug/l}}{3}$$

Excess daily nitrogen = 137 ug/l

$$\text{Excess daily phosphorus} = \frac{57 \text{ ug/l} - 25 \text{ ug/l}}{3}$$

Excess daily phosphorus = 11 ug/l

Freeman averaged the results from the two methods because he concluded that neither method was clearly preferable, and because use of both methods provides additional analytical rigor. The estimated average excess daily nutrient levels expressed as concentrations were as follows:

Average excess daily nitrogen = (132 + 137)/2

Average excess daily nitrogen= 134 ug/l

Average excess daily phosphorus = (69 + 11)/2

Average excess daily phosphorus= 40 ug/l

Freeman then converted these average excess concentrations to average excess mass loads by multiplying the concentrations by the estimated volume of water in the Ala Wai Canal at mean lower low water level (Freeman, 1993, p. 3-46).

Average excess daily load (kg) =

average excess daily concentration (ug/l) * water volume (m3) * unit correction factor

Average excess daily nitrogen load = 134 ug/l * 324,464 m3 * 0.000001

= 43.5 kg/day

Average excess daily phosphorus load = 40 ug/l * 324,464 m3 * 0.000001

= 13.0 kg/day

Converting to daily loads, the excess daily nitrogen load was 44 kg/day and excess daily phosphorus load is 13 kg/day (values were rounded to nearest whole numbers). These amounts were presented as the TMDLs by HIDOH in 1995.

Restatement of 1995 TMDLs as Allowable Mass Loads

To assist in comparison with potential TMDLs calculated through other methods and in calculation of more precise allocations, the excess loads for nitrogen and phosphorus identified in the 1995 TMDLs were subtracted from the actual estimated loads to identify the allowable loading capacity (also known as the TMDL) for Ala Wai Canal. As discussed in the source analysis and presented in Tables 3 and 4, annual estimated loads are presented as a range of possible loads to reflect different estimates in loading from urban areas. To calculate the TMDL, we select the midpoint in the range of estimated loads ((69 kg/day for TN and 19 kg/day for TP), and subtract the excess loads from these midpoint estimated loads. The midpoint estimate of average daily nitrogen loads is 69 kg/day, and the midpoint estimate of average daily phosphorus loads is 23 kg/day.

The loading capacities/TMDLs are calculated by:

TMDL = Average total estimated daily load - average total excess load

Nitrogen TMDL = 69 kg/day - 44 kg/day

Nitrogen TMDL = 25 kg/day

Phosphorus TMDL = 23 kg/day - 13 kg/day

Phosphorus TMDL = 10 kg/day

Potential Alternative Method for Calculating the TMDLs and Loads Available for Allocation

Alternative methods for calculating the TMDLs were evaluated for this TMDL revision. We are unaware of any newer water quality fate and transport modeling which has been completed for the Canal since the 1995 TMDLs were adopted which might facilitate completion of more sophisticated TMDL analysis. However, in order to facilitate a review of the 1995 TMDLs, a simplified method for calculating the TMDLs was developed for this report. The nutrient TMDLs for Ala Wai Canal could be calculated based solely on consideration of 3 factors:

1. the numeric targets for the TMDL which, in this case, are the State's numeric water quality standards.
2. the volume of water contained in the Canal basin, which is reported in Freeman, 1993, p. 3-46.
3. background concentrations of nutrients in ocean waters (assumed to equal the ocean standards)

The TMDL would be expressed by the following equation:

TMDL (kg) = WQS (ug/l) * water volume at MLLW level (m3) * units correction factor

For total nitrogen,

TMDL = 200 ug/l * 324,464 m3 * 0.000001

TMDL= 65 kg/day

For total phosphorus,

TMDL = 25 ug/l * 324,464 m3 * 0.000001

TMDL = 8 kg/day

The amount of nitrogen and phosphorus available for allocation to watershed sources could be less than the TMDLs suggest because there are background levels of nutrients which would be present in the Canal even if there were no human-caused nutrient loads. However, insufficient data were located for this analysis to support an estimate of background loading levels which would be present in the Canal.

Comparison of 1995 TMDLs with Values Calculated Based Simplified Method

The nitrogen TMDL based on the 1995 method is approximately 38% of the TMDL calculated through the simplified method presented above. In contrast, the 1995 TMDL for total phosphorus is very close to the TMDL based on the simplified method. Because this comparison involves analysis of results derived through very different methods, it is difficult to evaluate potential sources of uncertainty in both the 1995 TMDLs and the amounts calculated through the simplified method.   The method used in the 1995 TMDLs is more complex than the simplified method because it considers local water quality data and more influences on Canal water quality (including background loading levels and water residence time). Federal regulations recommend that States should use site-specific information where feasible to calculate TMDLs (40 CFR 130.7(c)(1)). For these reasons, the 1995 TMDL method is preferable in the absence of a much more sophisticated pollutant fate and transport modeling capability.

Revised TMDL Conclusions

The 1995 TMDLs have been revised to be expressed in terms of average daily mass loads which can be present in the Canal without exceeding the applicable water quality standards. This method of expressing the TMDL is more useful in terms of allocation planning and comparison to future estimates of pollutant loading in the watershed. The basic results of the 1995 TMDLs are not being changed, even though the way in which they are expressed is being changed. However, in order to account for the uncertainties inherent in this method, the allocations for both the TN and TP TMDLs are being written to include a 10% unallocated reserve to provide an explicit margin of safety in the TMDLs. Therefore, the TMDLs for Ala Wai Canal are as follows:

Total nitrogen TMDL = 25 kg/day

Total phosphorus TMDL = 10 kg/day

The TMDLs are expressed as daily average loads, to be averaged over a one year period. When implemented in conjunction with other actions to restore the Canal's functions, the TMDLs will reduce the amount of nutrients being discharged to Ala Wai Canal to a level such that the Water Quality Standards are met. Full implementation of the TMDLs will most likely require both a reduction in the concentration of pollutants entering the Canal, physical management of the Canal (e.g., dredging), and possibly flow augmentation to improve Canal circulation.

5. Partitioning of the Loads Among Contributing Sources

The 1995 TMDLs provided a load allocation to all nonpoint sources, consistent with the provision in Federal regulations that load allocations can be expressed as "gross allotments" (40 CFR 130.2). The revised TMDL provides refined allocations which take into account information concerning the relative contributions of nutrients from different land uses and the regulation of stormwater discharges as point sources since the initial TMDL was completed.

As discussed in the Source Analysis section above, Freeman provided estimates of nutrient loading from urban and non-urban (principally conservation) land uses, baseflow/groundwater, and cesspools. In this revised TMDL, wasteload allocations for point sources and load allocations for nonpoint sources are provided based on land uses. No specific mass based allocations are provided for the Ala Wai Marine, Ltd. and Yacht Harbor Towers discharges; however, concentration-based waste load allocations equal to the applicable Ala Wai Canal water quality standards are being established as a precautionary measure.

The wasteload and load allocations are calculated based principally on the feasibility of implementing the load reduction levels needed to meet the allocation. The importance of each discharge category as a mass loading source was also considered. We determined that each source category was a significant source of nitrogen and phosphorus loadings and that allocations to each category were necessary for both nitrogen and phosphorus.

Our conclusions concerning the feasibility of reducing nutrient loadings through structural and nonstructural best management practices are based on a review of readily available literature (e.g., EPA, 1993). The estimated effectiveness of several potential practices is summarized in Table 7.

Based on the review of these materials, we have concluded that a range of structural and nonstructural BMPs are available which used in combination with each other as BMP systems can yield nutrient control levels exceeding 40-70% in urban land uses. Many of these practices would require substantial capital investments and annual maintenance.

Table 7: Probable Range of Effectiveness of BMPs for Nutrient Removal (%)

Practice	TN Removal Efficiency	TP Removal Efficiency
Infiltration Basin	50-80	50-80
Vegetated Filter Strips	50-90	50-90
Grass Swales	20-60	30-80
Porous Pavement	60-90	60-90
Extended Detention Dry Ponds	20-60	10-60
Extended Detention Wet Ponds	10-90	50-90
Constructed Wetlands	0-40	0-80
Stream Buffer Areas	30-40	30-40
Septic Tank Limits	30-40	30-40
Fertilizer Application Practices	30-40	30-40
Septic Maintenance	30-40	30-40

Source: EPA, 1993

The potential effectiveness of practices and actions to prevent nutrient loading in nonurban areas, and particularly in conservation land areas, is less well understood. However, there is substantial interest within the watershed in addressing soil erosion sites, restoring damaged stream channels, and reforesting denuded areas of the conservation lands of the Ala Wai watershed. Moreover, practices to reduce the impacts of invasive species (e.g., fencing to reduce feral animal movement has been shown to be effective in reducing erosion. Therefore, we believe there is significant potential to address nutrient sources in the non-urban areas of the watershed as well. The effectiveness of erosion control practices is currently being tested in the watershed by CCH and the Ala Wai Watershed Committee through demonstration projects.

Up to 500 homes in the watershed still use cesspools to dispose of household wastes. Given the relatively porous geology of the watershed, the TMDL makes the conservative assumption that cesspool wastes eventually reach surface water sources. Because there are readily available, though expensive, alternatives to cesspools in most locations such as properly designed septic systems and connections to municipal sewers, the TMDL analysis assumes this source can be virtually eliminated. It is the goal of the Department that use of cesspools for domestic waste disposal [must] be phased out.

Significant nutrient loading is estimated to come from groundwater, which enters Ala Wai stream channels as baseflow. These loads are estimated to be less significant than loadings from the other land use categories. Actions to reduce nutrient loading from surface sources should eventually result in decreases in groundwater loading; however, the lag time before those groundwater loading reductions occur is unknown but could be several decades.

The load and wasteload allocations were calculated by multiplying the estimated loads from each source category (as presented in the source analysis section above) by an estimate of feasible loading reductions for that category. The remainder from this calculation is the load allocation. The estimated of feasible loading reductions is based on staff review of the ranges of BMP effectiveness presented in table 6 above and discussions with staff in EPA's nonpoint source program. For example, the load allocation for urban areas for total nitrogen is:

Load Allocation (urban areas) = Midpoint of estimated load - [Estimated loads * controllable percentage]

= 16 kg/day - [16 kg/day * .65]

= 2.1 kg/day

As discussed in the preceding section, a portion of the both the phosphorus and nitrogen TMDLs is being reserved (i.e., not allocated) to help account for the possibility that the phosphorus is under-protective. Staff have determined that 10% of the available TMDL will be reserved[2] . It is expected that future analysis of the Canal may yield a better understanding of the degree to which the Canal is impaired due to excessive phosphorus loadings. Based on future analysis, it may be reasonable to revisit the phosphorous allocations and actually allocate all or part of this 10% reserve.

Table 8 presents the Wasteload and Load Allocations for the Ala Wai Canal watershed, along with the estimated levels of nutrient reduction needed to implement the allocations and meet the TMDLs. Clearly, substantial reductions would be needed to meet the TMDLs and water quality standards. It is also clear that reductions would be needed from both the urban and non-urban portions of the basin.

Table 8: TMDLs, Wasteload Allocations, and Load Allocations for Ala Wai Canal Watershed

Source/Allocation	Est. Load (kg/day)	% total load	Allocations (kg/day)	% reduction needed
Total Nitrogen				
Non-urban source load allocation	30	38-51%	13	55%
Urban source wasteload allocation: City and County of Honolulu Department of Transportation	6-26	10-33%	6	~65%
Groundwater/Baseflow load allocation	4	5-7%	2	50%
Cesspools load allocation	19	24-32%	1	95%
Hawaii Marine Ltd. WLA			note 1	
Yacht Harbor Towers WLA			note 1	
Unallocated 10% reserve			3	
Total/TMDL	**69.4**	**100%**	**25.4**	

Table 8 continued

Source/Allocation	Est. Load (kg/day)	% total load	Allocations (kg/day)	% reduction needed
Total Phosphorus				
Non-urban lands load allocation	8	38-48%	4	50%
Urban source wasteload allocation: City and County of Honolulu Department of Transportation	6-10	35-48%	4	-50%
Groundwater/baseflow load allocation	2	5-6%	1	50%
Cesspools load allocation	1	5-6%	0	>95%
Super Hawaii Marine WLA			note 2	
Yacht Harbor Towers WLA			note 2	
Unallocated reserve			1	
Total/TMDL	**21-25**	**100%**	**10**	

All figures have been rounded to the closest whole number in response to a comment concerning the lack of precision in the analytical methods used for the TMDLs.

Note 1: WLA = 150 ug/l total nitrogen

Note 2: WLA = 20 ug/l total phosphorus

Source: Analysis of Freeman, 1993 and CCH, 1999

6. Margin of Safety Analysis

Federal regulations require TMDLs to provide a margin of safety to account for uncertainty in the analysis (40 CFR 130.7). The margin of safety may be provided implicitly, through the use of conservative analytical assumptions, or explicitly, by reserving and not allocating a portion of available loading capacity. A substantial margin of safety was built into each of the TMDLs through several conservative assumptions that are environmentally protective for Ala Wai Canal.

1. The TMDL analysis of water residence time in the Canal assumed the residence time was 3 days or 72 hours, which appears to be more conservative than the 40-60 hours estimated in the study quoted in Freeman, 1993. This results in a lower estimate of daily capacity to assimilate nutrient inputs.
2. The TMDL analysis assumes nutrients discharged actually reach waterbodies and are transported to the Canal. A less conservative assumption would have been to estimate a nutrient delivery ratio and assume significant amounts of discharged nutrients never reach water courses. Limited available information indicates that perhaps 15-25% of estimated nutrient loads do not reach the Canal (Freeman, 1993)
3. The TMDL analysis assumes nitrogen and phosphorus are conservative pollutants in the environment (i.e., a unit of nitrogen discharged remains a full unit in the receiving water). A less conservative assumption would have been to assume or calculate nutrient removal from the system, either through plant uptake (a common fate of nitrogen in the environment) or deposition of nutrients on soil particles which are not as bioavailable (a common fate of phosphorus).
4. The TMDL analysis of Canal assimilative capacity was based on an estimate of water volume at mean lower low water (MLLW) (Freeman, 1993). This is a relatively low water volume which is exceeded during much of the day. As a result, the estimate of assimilative capacity is lower than would be the case if average or median water volumes present in the Canal were used.
5. The TMDL analysis of background conditions assumes that ocean water entering the Canal is at the ocean water quality standard despite the absence of data indicating that ocean nutrient levels are that high. A less conservative assumption would have been to use ambient ocean conditions in the near shore area as a basis for the background loading assumption. However, insufficient local data were available to support this approach.
6. The TMDLs for both TN and TP incorporate a 10% unallocated reserve to help account for analytical uncertainty.

Despite these known sources of uncertainty, setting TMDLs with this method represents a reasonable starting point for implementation. Subsequent monitoring during the implementation phase may be used to refine the TMDLs and should indicate whether or not BMPs are helping achieve better water quality. The present TMDLs should be regarded as the second phase in a continuing assessment, planning and implementation process.

7. Seasonal Variations and Critical Condition

Clean Water Act Section 303(d) requires the consideration of "seasonal variations" in the establishment of TMDLs. In addition, federal regulations at 40 CFR 130.7 state that TMDLs must take into account critical conditions for stream flow, loading, and water quality parameters. As discussed in the source analysis, a review of available data for the Canal and its tributaries did not indicate that water quality conditions vary substantially between the wet and dry seasons. Standards appear to be exceeded much of the time throughout the year. There is some evidence that periodic high intensity storms contribute large slugs of nutrient loads to the Canal. The Canal appears to retain nutrient loads for substantial time periods due to its poor circulation patterns.

No information was found in the development of the TMDL which indicates that the aquatic life or recreational uses are more or less sensitive during particular seasons of the year. Hawaii water quality standards for the Canal make no provision for seasonal differences. Therefore, the TMDL is based on the assumption that the beneficial uses must be protected to the same level at all times.

Based on these factors, we conclude that there is no strong seasonal or short term variability in pollutant loads or effects in the Ala Wai Canal (although we do recognize a disproportionate share of nutrient loads appear to be associated with sporadic, high magnitude storms which may occur at any time of the year). Similarly, we found no basis for identifying a single critical condition which the TMDL must address. Instead, available information suggests that long term mass loadings to the Canal appear to be most important in determining the Canal's ability to meet water quality standards. Therefore, the TMDL is based on average daily loads.

The annual average daily timestep is appropriate for the Ala Wai Canal nutrient TMDLs for several reasons. First, the structure and hydrology of the Canal cause water to remain fairly stagnant. Water flow velocities are very low and water residence times are relatively lengthy. As a result, the chemical and biological processes active in the Canal which affect the processing of nutrient loads to the Canal resemble processes active in lakes or reservoirs with slow water exchange rates. Nutrients are more likely to remain in the system longer than would be the case in waters with faster flows. In waters with these characteristics, the long term average mass loading of nutrients appears to be a more important influence on water quality standards exceedances than shorter term loadings associated, for example, with individual storm events. It is appropriate to apply longer averaging periods for nutrient TMDLs for waters with these characteristics. Second, although there is some seasonal variability in rainfall and runoff in the watershed, there is no strong evidence that nutrient related problems in the Canal (e.g., algae growth) are more prevalent in some seasons more than others. Several key factors which influence nutrient productivity such as water level, temperature and salinity do not vary substantially across seasons. Third, a review of available data do not indicate that water quality standards exceedances are isolated to specific seasons or times of the year .

For these reasons, it is appropriate to focus on the average annual timestep, expressed on an average daily basis, in calculating the TMDLs.

8. Public Participation Process

The public was afforded the opportunity to review and comment on the proposed TMDLs. A public meeting was held on June 7, 2001 to discuss the TMDL with community members and answer questions. The Department issued a public notice soliciting official comments on this report, then prepared responses to comments and a final TMDL submittal for EPA approval. The final TMDL report and the comments received during the public notice period will be instrumental in developing future implementation plans and in designing analytical methods to address remaining pollutants of concern in the watershed.

9. Implementation Expectations

As discussed above, it appears that substantial nutrient loading reductions from urban, non-urban, and cesspool sources will be needed to implement the TMDLs. Because phosphorus loading, in particular, appears to be closely associated with sediment loading, practices to prevent and control erosion sources will also probably assist in nutrient control. HIDOH intends to work with the local community, watershed groups, and the regulated community to identify implementation actions to achieve the TMDLs' objectives in coordination with watershed restoration action planning. To begin this process, the Department is recommending that four key stakeholders prepare proposed action plans within 9 months to implement the allocations:

- City and County of Honolulu should identify actions necessary to implement its WLA, with the intent that these actions will be incorporated in the NPDES permit when it is reissued in 2004. The CCH plan should specifically identify both implementation and monitoring actions that will be carried out to reduce nutrient loading and measure the effectiveness of these actions in meeting the WLAs and the associated water quality standards.
- Hawaii Department of Transportation should identify actions necessary to implement its WLA, with the intent that these actions will be incorporated in the NPDES permit when it is reissued in 2004. The DOT plan should specifically identify both implementation and monitoring actions that will be carried out to reduce nutrient loading and measure the effectiveness of these actions in meeting the WLAs and the associated water quality standards.
- Ala Wai Watershed Association should identify specific approaches it intends to take in targeting currently available or future funding to implement projects that will result in reduction of erosion and nutrient loading in the watershed, consistent with the allocations in the TMDLs. The AWWA plan should specifically identify both implementation and monitoring actions that will be carried out to reduce nutrient loading and measure the effectiveness of these actions in meeting the WLAs and the associated water quality standards.
- The Hawaii Department of Land and Natural Resources should prepare a plan which explains how it will implement projects to control erosion, nutrient loading and invasive species in order to carry out the nutrient reductions required by the load allocations for non-urban areas of the watershed. DLNR is responsible for taking actions to control nonpoint sources of pollution on lands it manages pursuant to the Hawaii coastal nonpoint source management plan. DLNR provides funding and technical assistance to facilitate design and implementation of projects to protect water quality. The DLNR plan

should identify specific actions it will take to implement and monitor necessary practices and restoration projects in the conservation land areas of the Ala Wai Canal watershed.

- Ala Wai Marine, Ltd. should monitor its discharges for nutrient input into the Canal, report results of these monitoring efforts to HIDOH, and, if nutrient levels exceed applicable State water quality standards, include specific provisions in its next NPDES permit application which ensure compliance with the WLAs established in these TMDLs.
- Yacht Harbor Towers should monitor its discharges for nutrient input into the Canal, report results of these monitoring efforts to HIDOH, and, if nutrient levels exceed applicable State water quality standards, include specific provisions in its next NPDES permit application which ensure compliance with the WLAs established in these TMDLs.

In addition, the Department recommends that the U.S. Army Corps of Engineers and DLNR specifically consider the TMDLs and associate allocations as part of the ongoing Ala Wai Canal Project Feasibility Study. The feasibility study should include the identification and analysis of possible options for reducing nutrient and sediment discharges to the Canal and its tributary streams.

The wasteload allocations for each of the NPDES discharges will need to be considered when the permits are next considered for reissuance in order to ensure that the revised permits are consistent with the wasteload allocations, as required by 40 CFR 122.44(d). The dischargers should work with HIDOH to determine the appropriate mechanisms for ensuring that the permits and wasteload allocations are consistent with each other, as required by federal regulations. The recommended plans from the dischargers are the first step in the process of identifying protective measures to be incorporated in the permits.

BMP programs which should be considered by land management agencies, private landowners, and watershed stakeholders include:

1. Conservation Land Management: Conservation lands in the watershed should be carefully managed to address trail use and management issues (including overuse and misuse), and to address invasive plant and animal species which contribute unnatural nutrient loads and increase vulnerability of steep areas to erosion. Erosion site categories which warrant increased attention include trails, roads, bare and landslide areas, and damaged stream courses.

2. Fertilizer Use Practices: Improved practices to reduce fertilizer application in parks, golf courses and other landscaped areas would probably be effective in reducing runoff of excess fertilizer applications.

3. Urban Runoff Control Practices: The City and County of Honolulu, Department of Transportation, the University of Hawaii, and other institutions should improve structural and non structural stormwater management practices to reduce potential for nutrients to enter stormwater (e.g. through better housekeeping practices and/or structures to intercept or filter runoff before it reaches stormdrains), reduce the volume of stormwater entering the Canal (e.g., through retention and detention basins and perhaps constructed wetlands), and reduce the amount of nutrients reaching the Canal (e.g., through trash booms at storm drain outfalls). Practices to eliminate streambank vegetation through use of herbicides should be reconsidered because they probably contribute to streambank erosion which, in turn, contributes to nutrient loading and reduced nutrient filtering.

4. Litter and Animal Waste Control Practices: The City and County of Honolulu, in concert with local watershed stakeholders, should consider improved litter prevention and collection programs, increased surveillance to address illegal trash dumping in stream courses, and improved practices to prevent animal

wastes from entering water courses.

5. Reduced Use of Cesspools and Other Ineffective Sewage Management Methods: The watershed community should enhance its efforts to eliminate use of cesspools for sewage disposal, and promote conversion to well-designed septic systems and municipal sewage connections where feasible. The Department intends to work with the County Building Department to identify cesspools in operation and work with land owners to expedite the transition to other methods of wastewater management. It is the Department's goal that cesspools no longer be used for household waste disposal.

6. Boat Waste Management Programs: DLNR, which manages the Boat Harbor, should improve practices to ensure that boat wastes are disposed of in pump-out facilities. For example, programs to add dyes to waste storage tanks aboard boats have been effective in Southern California in making it easier to detect illegal discharges, and deterring illegal discharges as a result (Harleman, et al., 1996).

Proposed actions to dredge the Canal, restore streambanks of key tributaries, remove trash from stream courses, and enhance flushing flows within the Canal are likely to reduce the stored quantity of previously discharged nutrients, filter nutrients from runoff, and/or increase the assimilative capacity of the Canal for nutrient inputs. By themselves, these practices appear insufficient to address the nutrient problems in the Canal; however, they will help address a difficult pollutant problem. In addition, efforts to flush pollutants from the Canal may simply move the pollutants into the Ala Wai Boat Harbor, Mamala Bay, and nearby beach areas. The TMDLs should be implemented and shown to be effective as part of any strategy to address other causes of water quality problems in the watershed.

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http://wwwdhihnl.wr.usgs.gov/nawqa/

Figure 1: Map of Ala Wai Canal Watershed

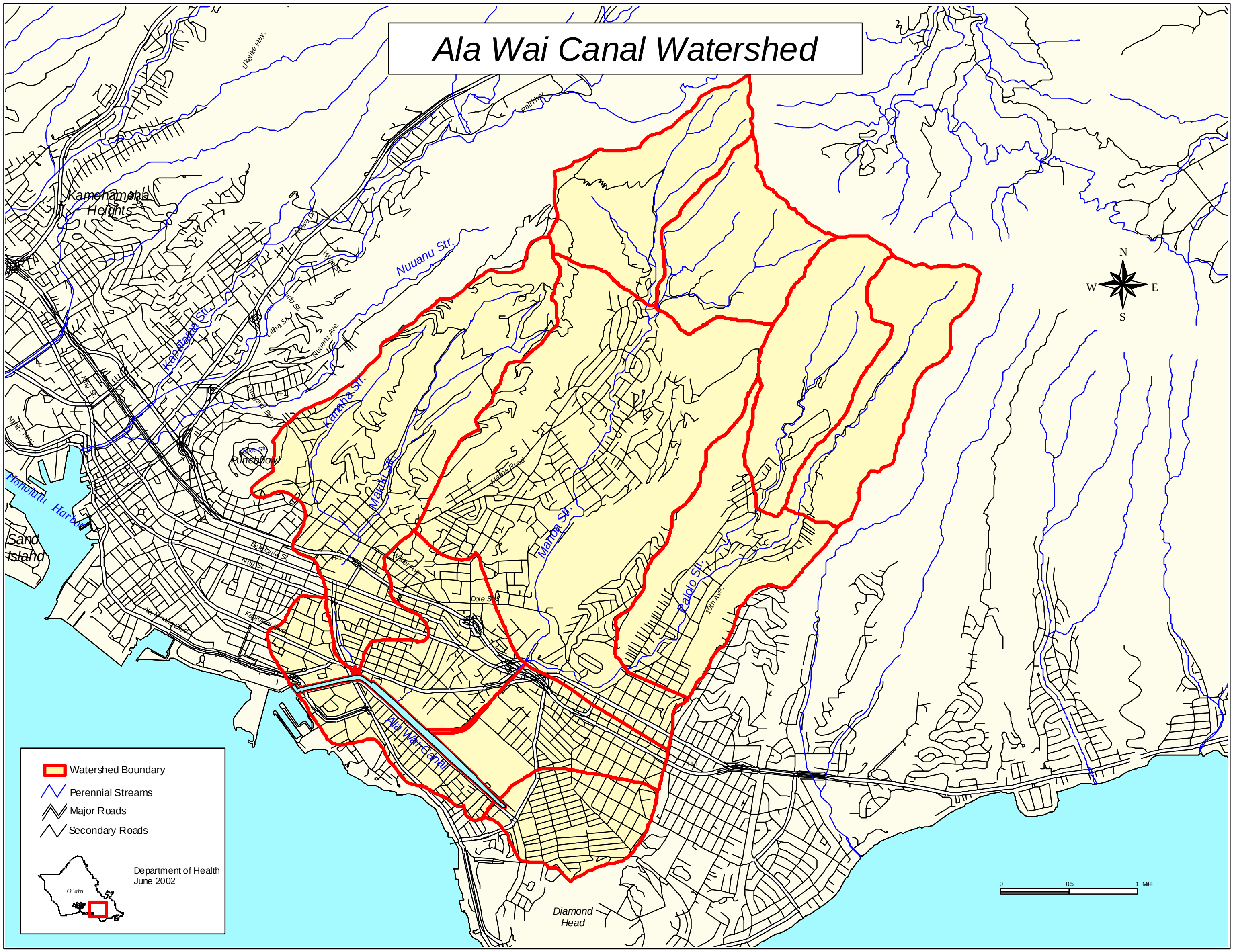

Figure 2: Comparison of Manoa Stream Total Nitrogen Data: Wet and Dry Seasons

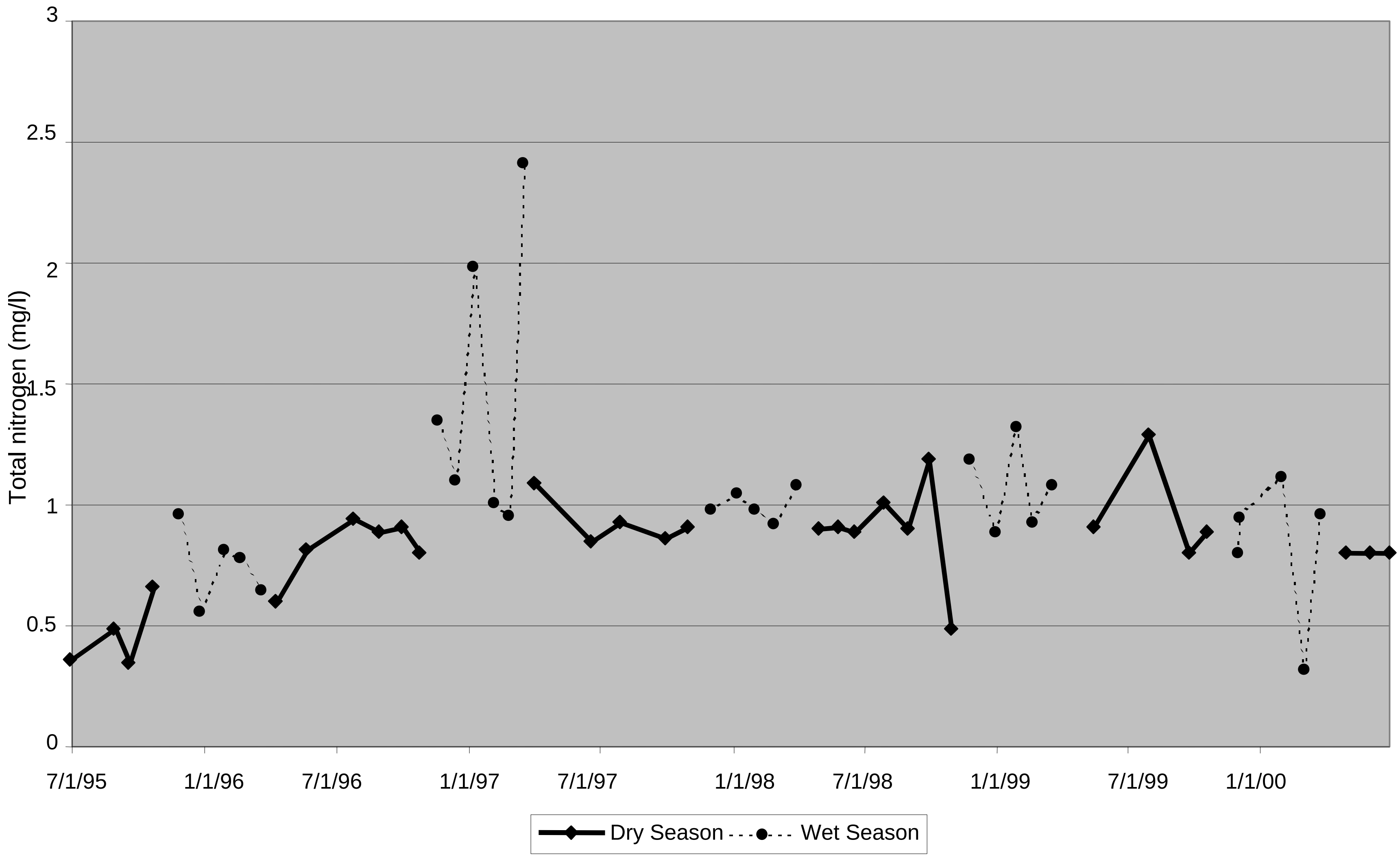

Figure 3: Comparison of Manoa Stream Total Phosphorous Data: Wet and Dry Seasons

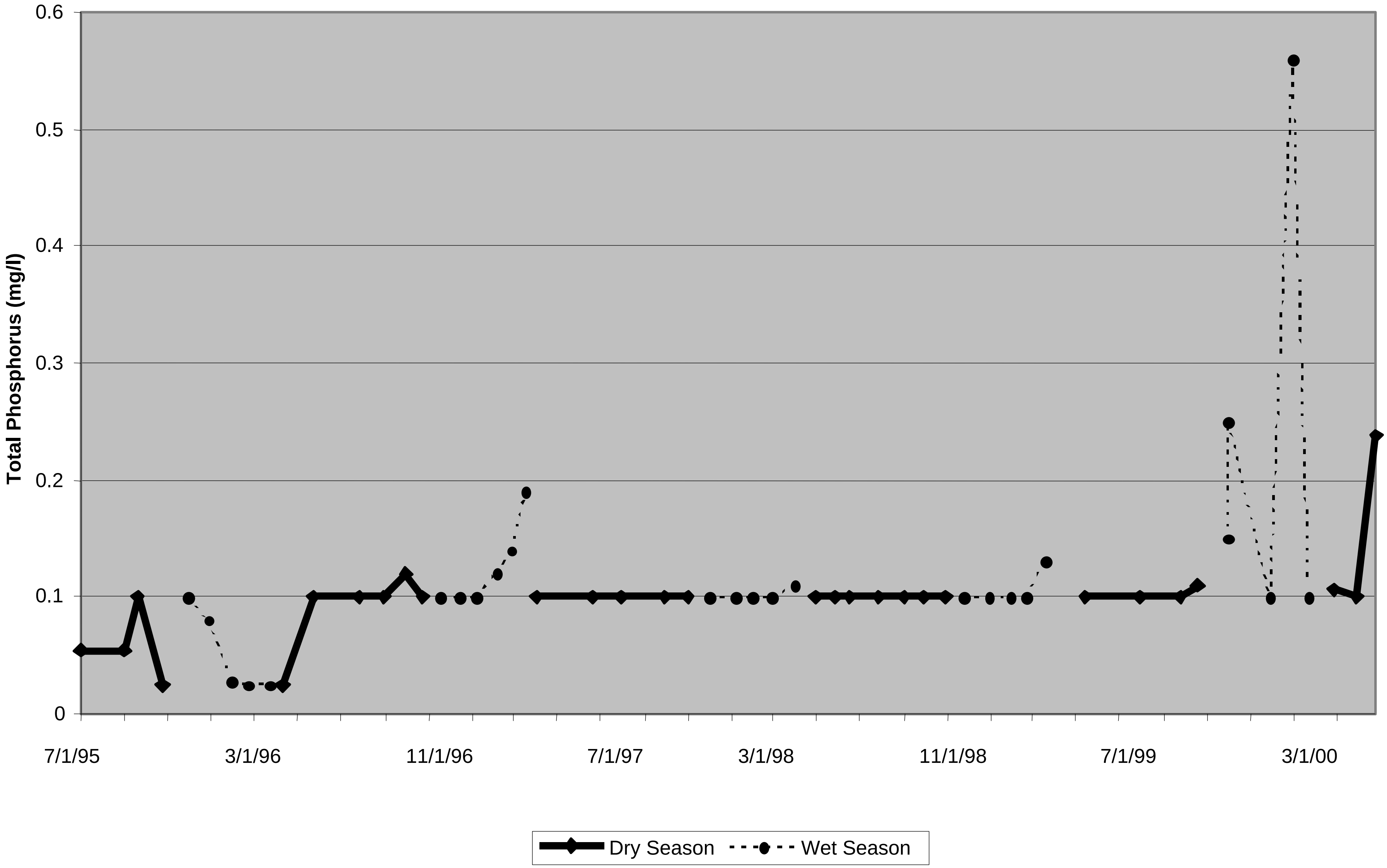

Figure 4: Comparison of Manoa Stream USGS Data: Nitrogen and Flow
Manoa Stream at Kanewai Field (3/99-6/01)
Source: USGS 2001

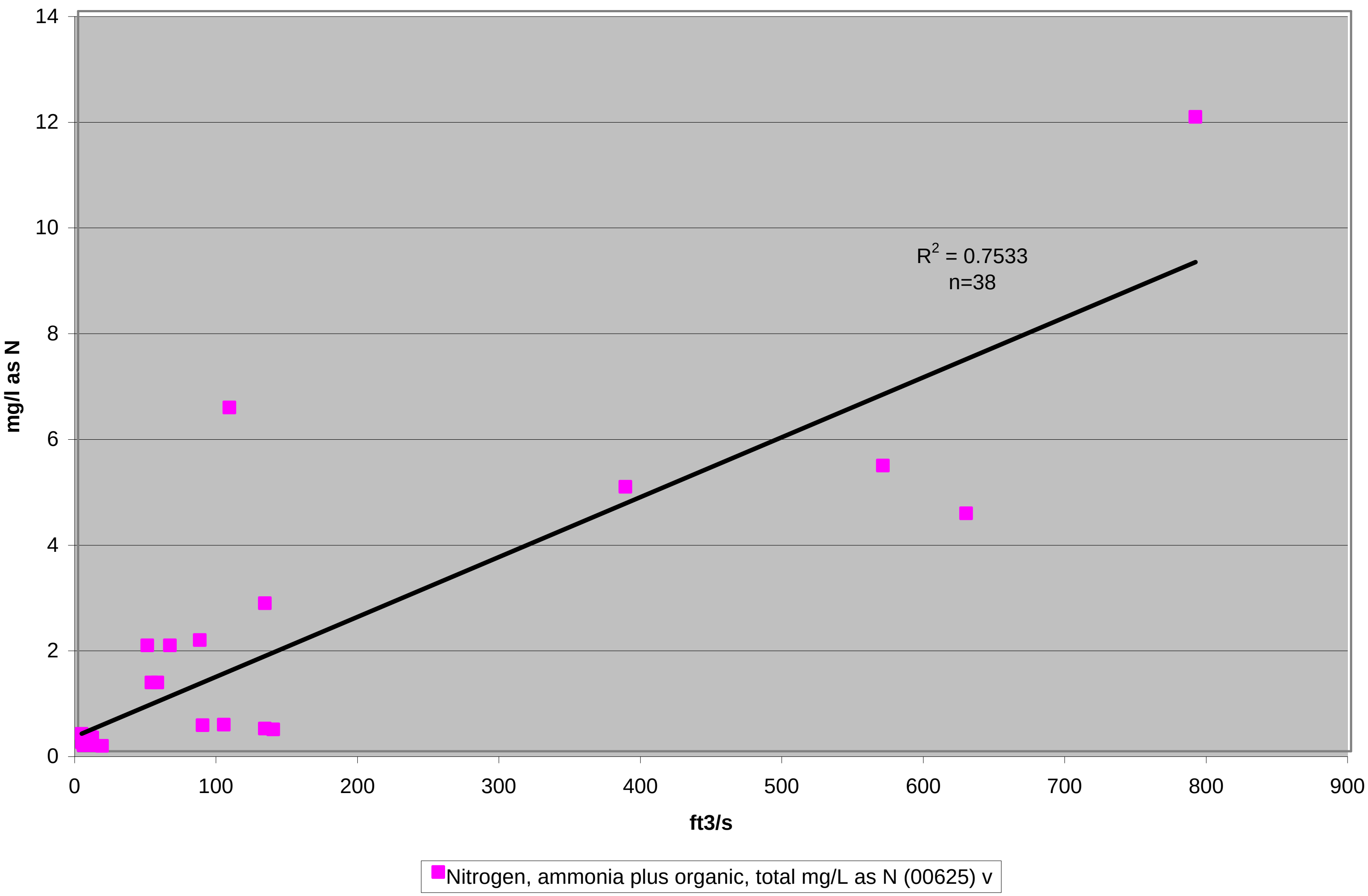

Figure 5: Comparison of Manoa Stream USGS Data: Total Phosphorus and Flow: Manoa Stream at Kanewai Field (3/99-6/01) Source USGS 2001