PROJECT TITLE: Water Quality in Hilo Bay Under Base and Storm Flow Conditions

PRINCIPLE INVESTIGATOR: Dr. Tracy Wiegner

CONTACT INFORMATION:

ADDRESS: Marine Science Department, University of Hawaii at Hilo, 200 W. Kawili Street, Hilo, HI 96720

PHONE: 808-933-3904

E-MAIL: wiegner@hawaii.edu

FAX: 808-933-0423

WATER QUALITY IN HILO BAY
UNDER BASE AND STORM FLOW CONDITIONS

Overview: Hilo Bay waters have been known to exceed state water quality standards since the late 1970s and were formally included on the US Environmental Protection Agency's (USEPA) 303(d) list of impaired waterbodies in 1998 (Koch et al. 2004). Parameters exceeding standards include turbidity, nutrients, and fecal bacterial indicators. The listing of Hilo Bay for nutrients and sediment has been determined solely by means of visual assessment and not by direct measurements of these parameters.

Hawai`i County is committed to improving and restoring Hilo Bay's ecosystem and water quality. Correspondence from Mayor Harry Kim to the Army Corps of Engineers (ACOE), dated January 20, 2005, requests assistance to "improve the water quality and circulation of Hilo Bay." It was proposed that ACOE develop a computer circulation model to investigate whether modifications to the breakwater "or other alternatives will improve the water quality" of Hilo Bay. The ACOE is committed to developing a computer model to assess alternatives to improving water circulation within the Bay; however, their plans do not include measuring water quality parameters (turbidity, nutrients) within the Bay under different conditions (baseline vs. storm). University of Hawai`i at Hilo (UHH) Marine Science Department proposes to collaborate with Hawai`i County in conjunction with ACOE to collect essential water quality data to better understand the relationship between water quality and circulation within Hilo Bay and to use this data to accurately assess whether modifications to the breakwater will improve water quality.

It is assumed that if circulation within Hilo Bay is enhanced, water quality will improve; to date, the relationship between circulation and water quality has not been established. More importantly, the source of turbidity, nutrients, and fecal bacterial indicators within the Hilo Bay watershed, as well as, the response of the Bay to these pollutants under base and storm flow conditions are unknown. The potential effectiveness of remediation actions to improve the Hilo Bay's water quality, like modifying the breakwater, cannot be evaluated without knowledge about how the Bay functions. To understand how Hilo Bay functions as an ecosystem, water quality and circulation data are needed for the Bay, as well as water quality and discharge data for the river draining into the Bay. UHH proposes to collect the baseline data on sediment and nutrient inputs to the Bay, and to assess the response of the Bay to these inputs under base and storm flow conditions. This information along with ACOE circulation data will allow Hawai`i County to identify the best and most cost-effective remediation actions to improve Hilo Bay water quality.

Background: In Hawai`i, there is a tremendous economic reliance on the quality and health of coastlines. Hence, it is imperative that the fate and potential impacts of terrestrial inputs to coastal waters are quantified. Hilo Bay is an important wildlife and fishery area (HDOH 2000). It is also one of the longest, most accessible and least used sand beaches on the Island of Hawai`i (Hawai`i Island Journal 2004). Only 10% of the people who use this beach swim there (USEPA 2002), which stems from the fact that Hilo Bay is thought to suffer from high turbidity and excessive nutrients. In fact, Hilo Bay has been listed by HDOH and USEPA as one of the seven most troubled watersheds in the state of Hawai`i having water quality below state and federal standards. Clearly, more information on the water quality of the rivers draining into Hilo Bay, as well as, the Bay itself, are needed for better management of this ecosystem.

Surprisingly, very little water quality data are available for Hilo Bay in contrast to other Hawaiian estuaries like Kaneohe, Hanalei, and Nawiliwili Bays. Reports are scarce and only one peer-reviewed paper exists for Hilo Bay (Silvius et al. 2005). Most water quality data for Hilo Bay are from consultant reports for Environmental Assessments (EA) and Environmental Impact Statements (EIS) from ACOE evaluations, and Hawai`i Department of Health (HDOH) and the United States Geological Survey (USGS) monitoring (Silvius et al. 2005). However, these studies were not designed to evaluate how Hilo Bay operates under different conditions (i.e. baseflow vs. storms).

<u>State of knowledge on Hilo Bay</u> – Hilo Bay is considered a salt wedge estuary that is stratified with a freshwater surface layer existing up to a mile offshore (Dudley & Hallacher 1991). This stratification is most pronounced during wet season when surface runoff to Hilo Bay is high. The dense saline layer moves offshore at depth with the tide and the upper freshwater layer is pushed shorewards by easterly and northeasterly trade winds. There is minimal mixing between freshwaters and saltwater layers inside the breakwater because wave energy is low. Low wave energy also allows sediments carried by the rivers to settle out into the lower salty layer, where they may be transported back into the Bay with the incoming tide. Tidal velocities are probably too low to re-suspend bottom sediments, but suspended sediments will move in and out of Hilo Bay with the tide.

The Hilo Bay watershed has one of the highest precipitation rates on the Hawaiian Islands, ranging from 3 meters on the coast to 6 meters at the upper elevations annually (Juvik & Juvik 1998). Hence, it is no surprise that the amount of freshwater entering Hilo Bay is far greater than any other Hawaiian estuary. Surface waters are primarily discharged into Hilo Bay from the Wailoa and Wailuku Rivers. Wailoa River is a groundwater-fed flood-control channel that discharges into Waiakea Pond prior to entering Hilo Bay. Waiakea Pond is the single largest source of groundwater into Hilo Bay (M & E Pacific 1980). It is estimated that and 1.8 million cubic meters of groundwater enters the Bay in this area (M & E Pacific 1980). The Wailuku River is the largest perennial river in the state and the largest source of surface water to Hilo Bay. The average flow of water from the Wailuku River into Hilo Bay is 1 million cubic meters (range: 40 thousand -7 billion cubic meters; M & E Pacific 1980). Surprisingly, little is known about the inputs of sediments and nutrients from these rivers. Currently, HDOH, in collaboration with USGS, are quantifying storm inputs of sediments and nutrients from Waiakea and Alenio gulches (both feed into Wailoa River) to Hilo Bay as a part of HDOH total daily maximum load (TMDL) program. Inputs of sediments and nutrients from the Wailuku River are currently being measured by UHH (Dr. Tracy Wiegner, Marine Science) and US Department of Agriculture Forest Service (Dr. Richard MacKenzie). Response of Hilo Bay to these inputs is unknown.

Much of the concern surrounding Hilo Bay's water quality stems from the fact that Hilo Bay's waters are not clear. High-relief drainage and intense rainfall in Hilo Bay's watershed may contribute to naturally high sediment loads observed in the rivers during storms. It is suspected that the Wailuku River delivers the majority of sediments to Hilo Bay during storms and is the reason behind the poor water clarity in the Bay.

Preliminary data from UHH has found that turbidity is 10 times higher in Wailuku River than Wailoa River during recent storms in October and November 2005 (Figure 1). Currently, it is not known how long the Bay's waters stay turbid following a storm and whether these sediment inputs impact the ecosystem.

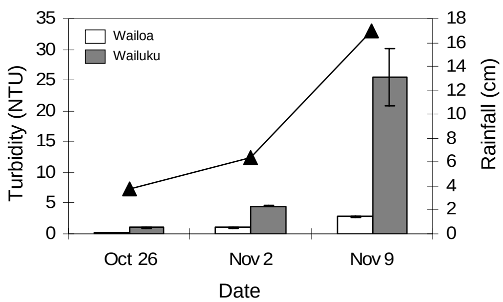

Figure 1. Comparison of average (±SD) turbidity values in the Wailoa and Wailuku Rivers in Hilo, HI over different rainfall amounts. Rainfall data was obtained from http://www.prh.noaa.gov/hnl/pages/hiclimate.php. Rainfall amounts were calculated using data from two days prior to sampling. Turbidity data were collected during MARE 350 class during Fall 2005 semester.

Another possible factor contributing to the low water clarity in Hilo Bay are algal blooms. Algal blooms result when nutrients are prevalent and their presence gives coastal waters a greenish tint. As previously mentioned, the USEPA 303(d) impaired listing for Hilo Bay for excessive nutrients was based solely on visual assessment. From these assessments, it was assumed that Hilo Bay had high nutrient concentrations because the water had "a greenish tint", resulting from suspected algal blooms (Silvius et al. 2005). Actual nutrient and chlorophyll *a* (chl *a*) data for Hilo Bay are scarce. Preliminary data from UHH indicates that nutrient concentrations are five times greater in the Wailoa than the Wailuku River (Figure 2), suggesting that Wailoa may be the primary surface water source of nutrients to Hilo Bay (MARE 350 unpublished data). The effect of these nutrient inputs to Hilo Bay has not been assessed to date.

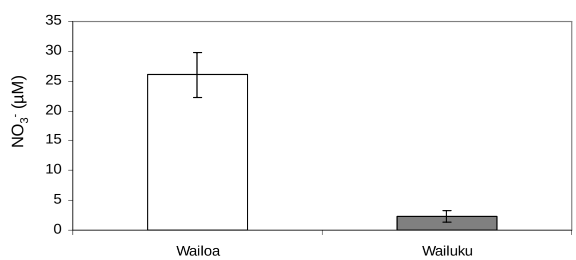

Figure 2. Comparison of average (±SD) nitrate concentrations in the Wailoa and Wailuku Rivers, Hilo, HI over October 19, October 26, November 2, and November 9. Data were collected by the MARE 350 class during Fall 2005 semester.

The temporal scale over which the few turbidity and nutrient samples were collected is inadequate to characterize the range of conditions experienced in Hilo Bay. It is assumed that inputs of sediments and nutrients to Hilo Bay are high during storms; however, these events have not been historically targeted. Current research efforts by UHH, HDOH, and USGS are beginning to quantify storm inputs of sediments and nutrients into Hilo Bay from the Wailuku River, Alenio Gulch, and Waiakea Gulch. Information on how Hilo Bay responds to storms over temporal and spatial scales is not known. Storm inputs of nutrients are thought to stimulate algal blooms; however, no direct measurements have verified this. Additionally, the importance of these algal blooms as a food source to higher trophic levels, like commercially and recreationally important fish, is unknown.

Overall, the Hilo Bay Restoration Plan recommends (Silvius et al. 2005):

- Identifying sources of sediments and nutrients to Hilo Bay from surface waters under base and storm flow conditions

- Collection of baseline chemical and ecological data to substantiate visual assessment of nutrients (making direct measurements of nutrient and chl *a* concentrations)
- Examining the response of algae in Hilo Bay to base and storm flow conditions
- "Scientific coordination to ensure that samples are continuously and constantly gathered, without interruptions or changes in protocols, and with much better spatial coverage than provided by" previous studies.

The study proposed below by UHH will begin to collect critical baseline data for Hilo Bay that is: 1) essential for understanding how the Bay functions under baseflow and storm conditions, 2) recommended by the Hilo Bay Restoration Plan, 3) needed to develop a successful and cost effective restoration plan, and 4) required to evaluate whether modification of the breakwater by ACOE will improve Hilo Bay water quality.

Proposed UHH Study

Experimental Design: This study will specifically examine how storms affect water quality (sediments, nutrients, chl *a*) in Hilo Bay by comparing conditions in the Bay before and following a storm event over a one-year period. A similar design has been successfully used by Ringuet & Mackenzie (2005) to evaluate the effects of storms on water quality and algae in Southern Kaneohe Bay, Oahu.

Site Description: For this project, eight stations will be sampled for sediments, nutrients, and chl *a* (Figure 3). Two stations will be located in the freshwater portion of the Wailoa and Wailuku Rivers. These stations will be used to determine the amount of sediments and nutrients entering the Bay from surface waters. Four stations will be located inside of Hilo Bay. Two Hilo Bay stations will be located along a transect following the Wailoa River plume (Figure 3). The other two Hilo Bay stations will be located along a transect following the Wailuku River plume (Figure 3). This transect will be on a slight angle to the northwest of the river's mouth because previous studies have shown that the Wailuku River plume is deflected northwest in Hilo Bay (Dudley & Hallacher 1991). Two control sites will be located outside of the Hilo Bay breakwater (Figure 3). Plumes from either river should not affect these control sites. Most of the proposed stations have been previous sampled by UHH through research and class projects (data shown in Figures 1 and 2).

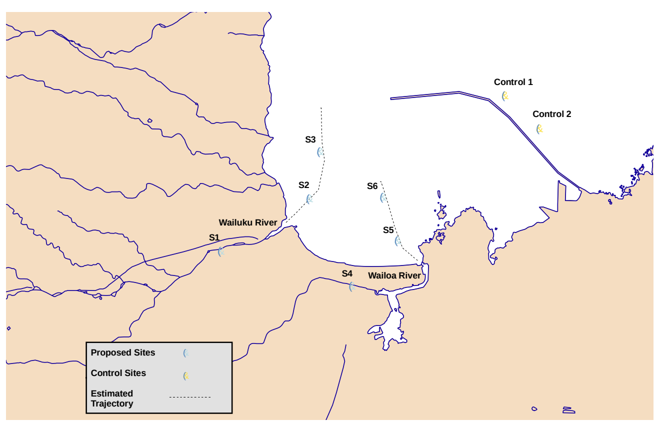

Figure 3. Proposed sampling stations in Hilo Bay.

Sampling Strategy: Water samples from the river and bay stations will be collected under base and storm flow conditions during the wet and dry season over a one-year period. Each station will be sampled for suspended sediments, nutrients, and chl *a* for five days during each season, under both base and storm flow conditions. This time frame was selected based on previous findings from Kaneohe Bay, where algae bloomed after three to five days following a storm (Ringuet & Mackenzie 2005). Because the focus of this study is to evaluate water quality in Hilo Bay before and after a storm, water samples will be collected from surface waters where river sediments and algae are most likely concentrated due to the Bay's stratification. For this study, storm conditions will be defined as when Hilo receives more than 5 cm of rain in 24 hours. This rainfall amount is based on current research Dr. Wiegner, who has found that 5 cm of rain corresponds to a rise in the Wailuku River by 1 m, which is the average stage height for a storm event based on historical USGS data. Rainfall data for Hilo Bay will be obtained from a NOAA website (http://www.prh.noaa.gov/hln/pages/hiclimate.php). Following a storm, all stations will be sampled for five consecutive days. Baseflow conditions will be defined as when Hilo receives less than 5 cm of rain over a period of five days prior to collection (Ringuet & Mackenzie 2005)

To estimate sediment and nutrient inputs to Hilo Bay from the Wailoa and Wailuku Rivers, water samples will be collected at the two river stations during base and storm flow conditions. For the Wailoa station, a depth integrated sampler will be used to collect all samples. Stage height and discharge for the Wailoa River will be measured using a staff gage and velocity meter, respectively. For the Wailuku River, a depth-integrated sampler will be used to collect water under base flow conditions and an automated storm sampler will be used to collect water during storms. A storm sampler has been installed on the Wailuku River near the USGS gage for current UHH research. Discharge for the Wailuku River will be calculated using stage height measured at the USGS gaging station and stage height-discharge relationship previously established by this agency. Concentration and discharge data will be used to calculate sediment and nutrient fluxes from the Wailoa and Wailuku Rivers to Hilo Bay under base and storm flow conditions.

<u>Measurements</u>: Parameters regulated by HDOH for estuarine water quality will be targeted for this study (HDOH 2004). Nutrients [total nitrogen (TN), ammonium (NH_4^+), nitrate (NO_3^-), total phosphorus (TP), phosphate (PO_4^{3-}), dissolved silicon (H_4SiO_4)], pH, turbidity, total suspended sediments (TSS), and chl *a* will be measured during the wet and dry season under base and storm flow conditions. Additionally, dissolved organic carbon (DOC) and particulate carbon (PC) will be measured at the request of ACOE for their eutrophication model. NH_4^+ (USGS I-2525), NO_3^- (USEPA 353.4), TP (USGS I-4650-03), PO_4^{3-} (USEPA 365.5), and H_4SiO_4 (USEPA 366) will be measured using standard autoanalyzer methods. TN and DOC will be measured on a Shimadzu TOC-V CSH, TNM-1 following the recommendations by Sharp et al 2002. Turbidity will be measured on a Hach 2100P Turbidimeter. TSS will be measured using standard methods (APHA et al. 1995). PC will be analyzed on a CHN analyzer (Costech Analytical Technologies). Chl *a* will be measured using USEPA method 445.0. To characterize the conditions at each station when sampling, physiochemical parameters (salinity, conductivity, temperature, dissolved oxygen concentration, dissolved oxygen percent saturation, light penetration) will be measured using a YSI multi-parameter meter and a Li-Cor light meter, respectively. At the request of ACOE, depth profiles for these physiochemical parameters will be measured at the six Hilo Bay stations. Meteorological data (rainfall, winds, waves, and tides) will also be obtained for the sampling dates.

Projected Outcomes: This project will bring together researchers from UHH and ACOE to help Hawai`i County decide on appropriate remediation actions to improve water quality in Hilo Bay. Specifically, essential baseline water quality data for Hilo Bay will be collected to complement circulation data being collected by ACOE. This information will allow for a greater understanding of how Hilo Bay functions. With this understanding, appropriate restoration actions can be developed and implemented to improve Hilo Bay water quality.

This project will also provide a mechanism for involving the local community in the Hilo Bay ahupua'a. This project will train undergraduate and Master's students at UHH. Additionally, this project will support the new analytical facility at the UHH built with National Science Foundation funds to expand the University's research capacity.

Results from this research will be made available to a wide audience. Scientists will be targeted through peer-reviewed articles in scientific journals and presentations at local and international scientific meetings. Our results will also be made available to managers and the general public through presentations at local watershed advisory meetings.

Projected Deliverables: The following deliverables will be provided by UHH to the Honolulu District of the U.S. Army Corps of Engineers (USACE):

1. Nutrient sample data in formats compatible with input to the proposed USACE water quality numerical models.
2. Draft and final report documenting nutrient sample collection, meteorological data for the sample collection periods (to include at a minimum rainfall, winds, waves and tides), description of sample concentration trends for each collection period, and summary/conclusion of sampling results.
3. Final deliverables will be provided to Honolulu District personnel within 12 months from the date of the notice to proceed.

Budget Justification: Funds are requested for 1 month of summer salary plus fringe (June 2006 & June 2007) for Dr. Tracy Wiegner. The anticipated salary increases have been taken into account in the budget (5% increase as of July 2005). Dr. Wiegner will be the P.I. on this project, overseeing its overall design, sample collection and processing, data analysis, and final presentation in written reports/manuscripts and presentations at local and international meetings. She will collaborate with ACOE and mentor both Masters and undergraduate students on this project. Her UHH appointment is 9 months and does not cover salary during the summer. Funds are also requested to support one graduate-level student research assistant in the Tropical Conservation Biology and Environmental Science Program at UHH. Graduate-level student research assistants are funded to work 20 hrs per week with benefits (30%). Support is also requested for an undergraduate-level student research assistant (10 days/season; 12hours/day) at an hourly wage of $8.85 (A3-1 level) and fringe rate of 12%. It is estimated that 1920 nutrient samples (triplicate samples; comparable sampling scheme for proposed Hawaii Sea Grant project on similar topic) will be generated at a cost of $3.00 to $10.00 per sample (UHH Analytical Laboratory fees for UHH faculty). Funds for supplies are estimated at $7005 for the entire project. During the project, supply monies will be used to purchase YSI and velocity meters, as well as a freezer to store samples. To collect samples in Hilo Bay, a boat is needed. UHH Marine Science Department has a 20' aluminum Larson outboard skiff at the cost of $125/day. It is estimated that $3,400 will be needed to cover the boat fees. Travel back and forth from UHH Marine Science Department to the Wailoa River Boat Ramp is approximately 5 miles. UHH Marine Science Department charges $0.50/mile to use their vehicles. Funds are requested to cover overhead at a rate of 3.5% of 'modified' direct costs.

Budget	**Cost**
Personnel	
P.I. summer salary (1 month; June 2006)	$5,065
P.I. summer salary (1 month; June 2007)	$5,318
Fringe (2.6%; June 2006 & 2007)	$270
Research Assistant salary (graduate-level)	$17,000
Fringe (30%)	$5,100
Research Assistant (undergraduate-level)	$2,124
Fringe (12%)	$255
Laboratory Fess	
Nutrient Analysis	$18,240
Field Equipment & Supplies	
Supplies	$7,005
Boat Fee	$2,500
Vehicle Fee	$100
Boat Rental Fee for ACOE (6 days)	$900
University Overhead (3.5%)	$2,236
Total	$66,113

References:

APHA, AWWA, and WEF. 1995. Total solids dried at 103-105 C. In: Eaton, A.D., L.S., Clesceri, and A.E. Greenberg (eds.), Standard Methods for the Examination of Water and Water Water, 19th edition. American Public Health Association, Washington, D.C.

Dudley, W.C. Jr and L. E. Hallacher. 1991. Distribution and dispersion of sewerage pollution in Hilo Bay and contiguous waters. Final report. County of Hawai`i Department of Public Works.

HDOH. 2000. Hawai`i's implementation plan for polluted runoff control.

HDOH. 2004. Amendment and compilation of chapter 11-54. Hawai`i administrative rules. http://www.Hawai`i.gov/health/about/rules/11-54.pdf

Hawai`i Island Journal. 2004. What's wrong with Hilo Bay?

Juvik, J, and S. Juvik. 1998. Atlas of Hawai`i. Department of Geography. University of Hawai`i Press. Hilo, Hawai`i.

Koch, L., J. Harrigan-Lum, and K. Henderson. 2004. 2004 List of impaired waters in Hawai`i prepared under Clean Water Act Section 303(d). HDOH Environmental Planning Office.

M & E Pacific. 1980 Hilo area comprehensive study—Geological, biological and water quality investigations of Hilo Bay. US ACOE, Honolulu District.

Ringuet, S. and F. T. Mackenzie. 2005. Controls on nutrient and phytoplankton dynamics during normal flow and storm runoff conditions, southern Kaneohe Bay, Hawai`i. Estuaries 28(3): 327-337.

Sharp, S.H., et al. 2002. A preliminary method comparison for measurement of dissolved organic nitrogen in seawater. Marine Chemistry 78: 171-184.

Silvius, K., P. Moravcik, and M. James. 2005. Hilo Bay watershed-based restoration plan. Submitted to HDOH, Polluted Runoff Control.

USEPA. 2002. National health protection survey of beaches-2001 swimming season. http://yosemite.epa.gov/water/beach2002.nsf