Name of Project: **Establishing TMDLs to address wet weather flow impacts, pathogens, and NPDES program strategies in a priority urban watershed – Kaelepulu, Hawaii**

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Purpose

The purpose of this project is to conduct water quality research and extension activities that support Department of Health efforts to establish Total Maximum Daily Loads (TMDL) for inland waters in the Kaelepulu Watershed, Oahu. The focus of these activities is to quantify and explain pollutant loading and receiving water quality in the brackish waters of Kaelepulu pond, Kaelepulu canal and Hamakua canal, particularly with regard to nitrogen, phosphorus, sediment, enterococci, and chlorophyll a.

The project investigators were to assist the Department of Health in finalizing the existing draft Scoping Report (May 2005) and draft Sampling and Analysis Plan (June 2005) for Kaelepulu TMDL development. Based on these final documents, the contractor would collect and analyze water quality samples, and evaluate the data in order to develop appropriate numeric targets for pollutant loading limits, apportion the limited pollutant loads to the various sources, and calculate the pollutant load reductions required to meet the numeric targets and protect the designated uses of the receiving waters.

Since 2005, new data and information affecting the relationships between TMDLs, wet weather flows, pathogens, and the National Pollutant Discharge Elimination System (NPDES) strategies for the Kaelepulu Watershed have emerged. A revised Department of Health workplan (June 2008) that incorporated these recent developments forms the basis for this Scope of Services. Workplan completion will be assisted by this project through the incorporation of investigators and staff from the University of Hawaii College of Tropical Agriculture and Human Resources (Department of Molecular Biosciences and Bioengineering) and the University of Hawaii Water Resources Research Center. Specific objectives of the project are:

Project Objectives

Objective 1: Re-establish lines of communication within TMDL working group and articulate project status.

Objective 2: Finalize monitoring designs, sampling plans, and analytical routines for fairly allocating pollutant loads and for planning and documenting TMDL implementation

Objective 3: Identify the existing uses of the inland brackish waters and the occurrence, distribution, and life cycle status of existing biota in the inland brackish waters.

Objective 4: Determine the spatial, temporal and background variability of water quality in the Kaelepulu inland waters.

Objective 5: Summarize rainfall, runoff, and pollutant loading characteristics at various locations that impact the inland waters.

Objective 6: Produce workgroup outreach materials, project progress reports, and water quality data packages.

Project Workplan and Progress Towards Objectives

Objective 1: Re-establish lines of communication within TMDL working group and articulate project status.

Progress Towards Objectives: By the time of implementation of the project the work group participation has grown to include private wetland owners and an expanded group of State of Hawaii Department of Transportation (Highways Division) staff and contractors. The PI worked collaboratively with the DOH TMDL coordinator to reestablish communication with the various stakeholders and was provided with the names and contact info for the various participants. This proved to be problematic and it was not possible to meet with the entire group. Instead, a focused effort was made to engage the TMDL coordinator and Enchanted Lake Residents Association representative (Robert Bourke) and project engineer (Roger Babcock) and each of their respective networks in order to keep all groups informed of progress made.

On February 3, 2009 a preliminary scoping of temperature, DO, pH, turbidity was conducted with Bob Bourke (Enchanted Lake Residents Association). Measurements were made with a

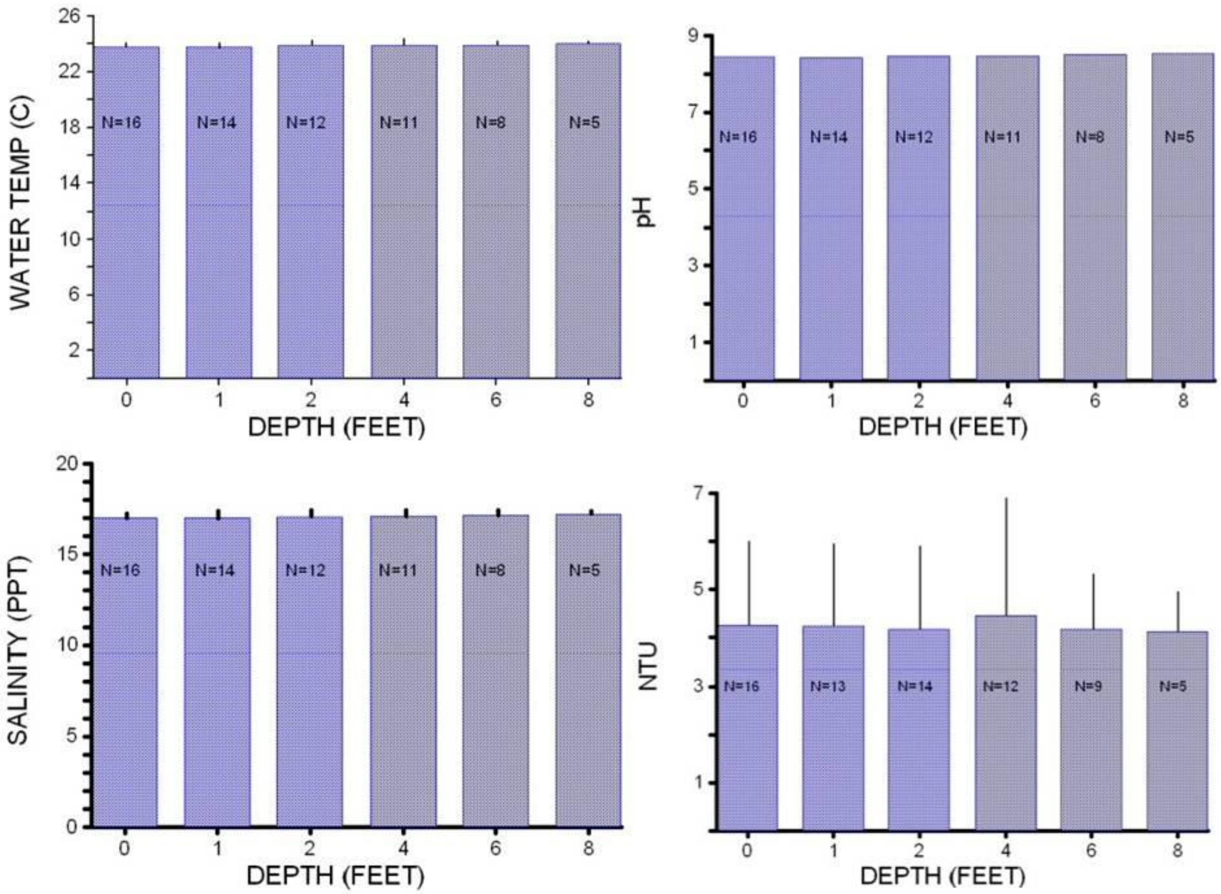

Figure 1. Summary of initial survey of Kaelepulu lake conducted in collaboration with Bob Bourke ERLA environmental coordinator.

YSI Sonde on loan from Oceanit Laboratories and a summary of the various water quality data is provided in Figure 1. The initial survey was done per request of Bob Bourke to familiarize the PI with the lake and adjoining tributaries and an indication of the interaction and collaboration of this particular stakeholder group. One striking feature of the data obtained was the uniformity of all parameters at various depths indicating that on this particular day the mixing of the lake was uniform. The data obtained supported the use of the sampling protocol that was presented in the sampling plan (see objective 2) and used throughout the reporting periods.

Objective 2: Finalize monitoring designs, sampling plans, and analytical routines for fairly allocating pollutant loads and for planning and documenting TMDL implementation

Progress Towards Objectives: A draft Scoping Report (May 2005) and a draft Sampling and Analysis Plan (June 2005 revised November 2009) were delivered by Roger Babcock (consulting engineer and Co-PI) to DOH. During the initial phases of the project the Scoping Report and Sampling and Analysis Plan were revised and submitted for approval. While the Sampling Plan was completed (Nov 2009) and documents submitted (see Appendix 1) because of timing issues sampling was initiated prior to receiving final approval.

Objective 3: Determine the spatial, temporal and background variability of water quality in the Kaelepulu inland waters. Identify the occurrence, distribution, and life cycle status of existing biota in the inland brackish waters.

- Task 3.0 Implement Sampling and Analysis Plan.

Progress Towards Objectives: Sampling of both the lake, tributaries and input sites were conducted on June 3-4, 2009, July 21, 2009, Aug. 12, Sept. 9, Oct. 6, Oct. 26, Nov. 17 and December 14, 2009 during the initial year of the project. During the extension phase samples were obtained on Feb. 3, March 11, April 28, May 26, Jun. 23 and Dec. 20 (storm event). Dissolved oxygen, salinity, pH were obtained at the same time the samples were obtained from the specific site. Water samples from the various sample sites were composited after collection as described in the sampling plan and then delivered to the Water Resources Laboratory at the University of Hawaii where they underwent analyses for other parameters (e.g., chlorophyll-a, turbidity, total suspended solids, nitrate-N, total nitrogen, ammonia, and Enterococci). Results of the various parameters are provided in separate spreadsheets in Appendix 2.

- Task 3.1 Estimate changes in water depth at fixed locations (number to be determined) during:
    a. Spring tides when outlet is closed
    b. Spring tides when outlet is opened

Progress Towards Objectives: To accomplish this task the project work group enlisted the assistance of Dr. Mark Merrifield and Christopher P. Kontoes of the Oceanography Department at the School of Ocean Earth Science and Technology. They would loan a Sea Bird (SBE26) wave and tide recorder[1] to monitor depth changes in the lake. The gauge was installed on 5/30/2009 (Figure 2) at the following coordinates (21^{o} 22’27.58”N 157^{o} 44’19.22”W) which is adjacent to the residence of Hugo Defries. The rationale for location of the sensor was its proximity to a secure location as well as being close to an automated weather station that is located on the property of Hugo Defries. The changes in barometric pressure is needed to correct for the actual height of the water level being monitored and that data is being monitored by the weather station and available on line[2]. In addition, another automated tide gauge (HOBO U20[3]) was also loaned to the project work group and both gauges were set to record at 15 minute intervals. In this case the HOBO tide gauge was placed adjacent to the residence of Bob Bourke at the following coordinates (21^{o} 22’32.84”N 157^{o} 44’22.96”W). Both gauges

Figure 2. PI and Hugo Defries deploying automated tide sensor, May 30, 3009).

[1] http://www.ems-ocean.com/catalogue/Sea-Bird/sbe26/sbe26.pdf
[2] http://www.kaelepuluwetland.com/weather/reports/reports.html
[3] http://www.onsetcomp.com/products/data-loggers/u20-001-01

were retrieved on 10/22/2009 and the data downloaded and then redeployed the same day to monitor until the next reporting period. The data from both the Sea Bird and HOBO tide gauges can be downloaded as an Excel spreadsheet which can be combined and additional data added on to it. One additional type of data that can be added is rainfall which is being collected at similar frequencies as the tide gauges are recording at and all the information can then be visualized

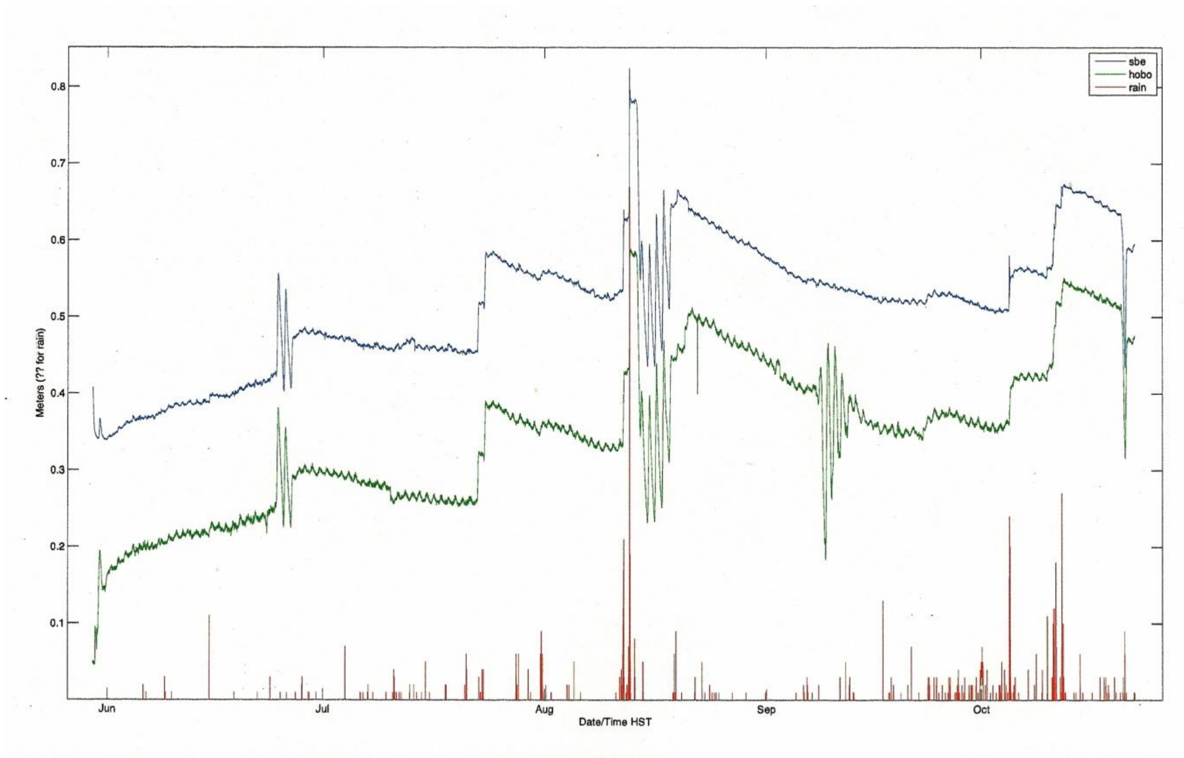

Figure 3. Graphic summary of the raw data from both SeaBird and HOBO automated tide gauges combined with rainfall between 05/30/2009 through 10/22/2009.

as seen in Figure 3. The data depicted is still in its raw form but can be viewed to give a first glimpse of the changes that are occurring with the opening of the birm and rainfall.   The initial data set has been corrected for water height but the remaining data set is still uncorrected and the raw data for both the Sea Bird and Hobo can be found in Appendix 3.

- Task 3.2 Obtain bathymetry data of Kaelepulu.

Progress Towards Objectives: By June of 2009 the project work group would benefit by the incorporation of Willis Motooka who kindly donated the use of his boat, trailer, electric motor (Figure 4) truck and his time to obtain samples

Figure 4. PI (left) with volunteer Willis Motooka (right) and his boat, motor and trailer that contributed to obtaining the samples for the investigation.

during the remainder of the project. His donation represented the largest of the in kind contribution ($14,400/year) towards the completion of the project. Tributaries still have to be traversed by kayak which represented additional contributions towards the project and a combination of both methods were used to conduct the obtaining of bathymetry values. The significance of the use of the motorized boat in combination with the kayak is that all depth measurements (n=80 sites) could be obtained over the course of approximately three hours. The raw data of the depth measurements for the bathymetry profile is presented in Appendix 1.

- Task 3.3 Using DOH's multiparameter water-quality sonde (YSI) estimate the diurnal variation in six parameters over a 24 hour period at fixed locations within the Kaelepulu watershed area.

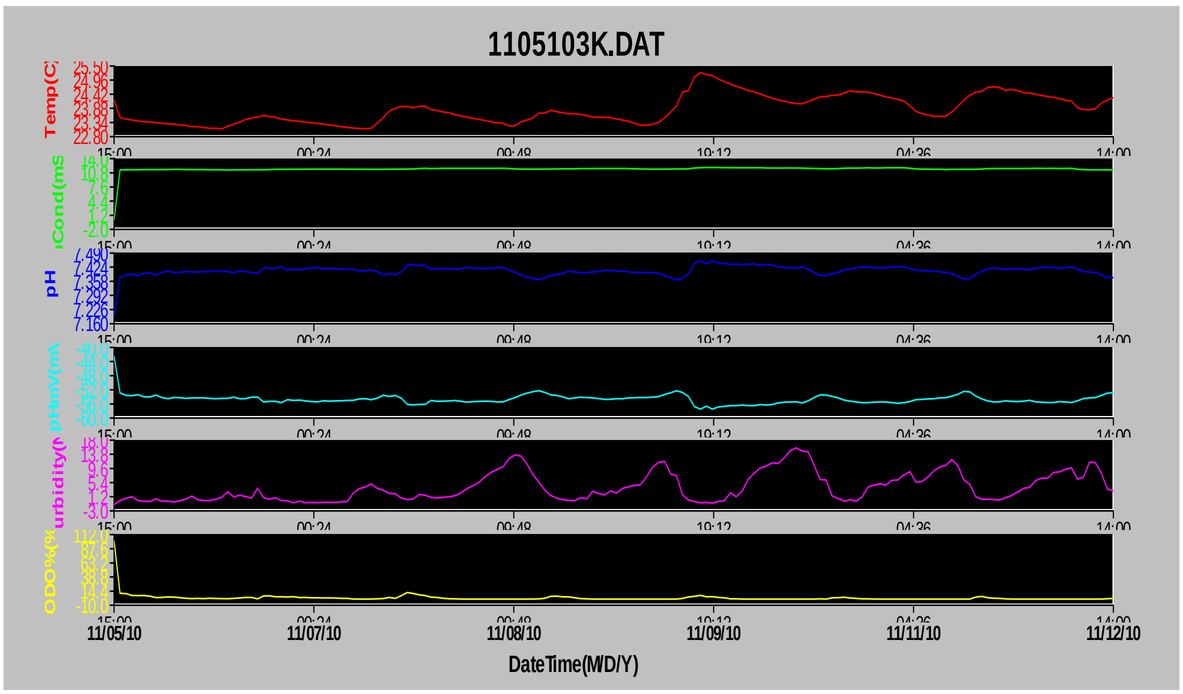

Figure 5. Temporal changes in six water quality parameters recorded by a YSI Sonde deployed at Site # 51 adjacent to Kaha park.

Progress Towards Objectives: The sonde's to be used for this task required repair and servicing and were not available during 2009. After servicing the sondes were deployed on 9/17/2010, 9/28/2010, 10/9/2010, 11/5/2010 and 11/20/2010 at various locations and also at various depths. In all cases the units were set to record over the course of seven days and at 15 minute intervals. The raw data for all recordings are provided in the Appendix. An example of the temporal changes in water temperature, conductivity, pH, dissolved oxygen and turbidity is presented in Figure 5. This particular sonde unit was deployed in the upper reaches of the tributary that must be entered from Kaha Park. While there are some clear diurnal patterns in some of the water quality parameters (e.g., temperature, turbidity) many parameters remain relatively stable over the course of the sampling period. A remarkable finding at this location was the very low dissolved oxygen level that does not fluctuate indicating a severely impacted segment of the study area. The only kinds of fish species that are able to tolerate these levels is tilapia and not surprising they are the only species present in this segment of the estuary.

Interestingly, turbidity was observed to rise and fall in a recurring pattern to the point of being diurnal in nature. Further investigation is required to determine the reason that turbidity should be varying in such a fashion. One possible explanation is changes in phytoplankton density and clearly requires further examination.

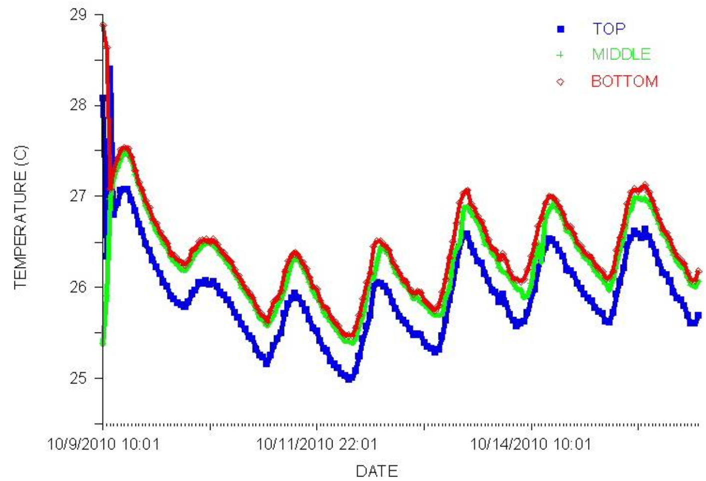

Figure 6. Recorded **t**emporal changes in water temperature at three depths located at sampling Site #24 .

One of the reasons for deploying the sonde's was to obtain profiles to indicate stratification taking place or spatial differences in basic water parameters being recorded by the sonde units. At site #24 located in the the deepest portion of the lake three sonde's were deployed at different depths and allowed to record for a week interval. The resulting temperature profile from the three units are summarized in Figure 6. Some thermal stratification was observed with the coolest water temperatures being recorded closest to the surface and the warmest values were obtained close to the bottom of the lake. There is also a clear diurnal pattern in the change of water temperature at all depths with the coolest temperatures being recorded during dawn hours at all depths. While there are clear patterns emerging the differences between the diurnal variation at each depth is just over one degree C. The differences in water temperatures between the different depths is less than a degree C and indicates that at this sample location the water temperatures are relatively uniform in distribution.

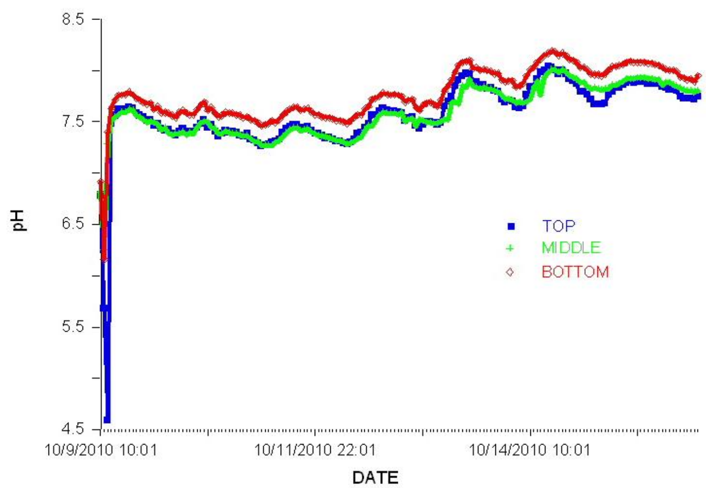

Figure 7. Recorded temporal changes in pH recorded at various depths at Site #24.

Recorded values of pH, a second physical parameter is summarized in Figure 7. This particular water quality parameter like water temperature was found to be very consistent at the three depths. A similar situation was also recorded with conductivity and together these physical parameters indicate a uniformly distributed water column at this location. This is also consistent with the data presented if Figure 1 which was obtained over the main expanse of the lake.

While some of the physical water quality parameters are apparently uniformly distributed there are considerable differences in other parameters such as turbidity. The profile of turbidity recorded in the same sample location and at the same three depths is summarized in Figure 8. Clearly there is a stratification that has taken place with the top water layer recording values that were over 150 times greater than that which was recorded at depth. The lowest values were recorded from the sonde nearest the bottom of the lake. In addition, a diurnal variation in turbidity is observed in the surface waters and as with temperature the lowest values coincide with the hours prior to dawn. The diurnal pattern does not appear at deeper reaches of the lake. The most reasonable explanation for such a difference in turbidity is the abundance of phytoplankton that is present in the surface layers. In the following section chlorophyl a values tha exceed current standards will be reported. The data also indicates a large amount of phytoplankton being present. From the data recorded it is apparent that during the recording period the water column is stable. As to be seen in the following sections there is also ample nutrients in the water column that would support a large succession of phytoplankton.

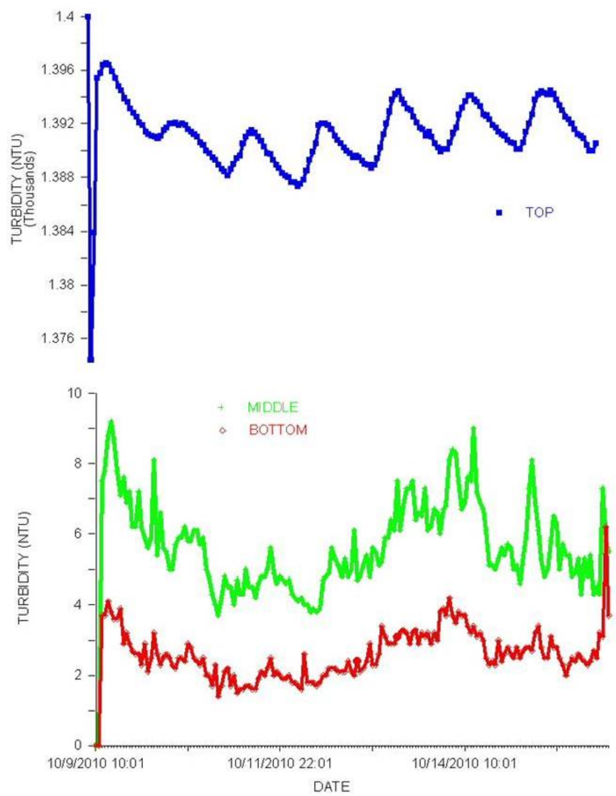

Figure 8. Temporal changes in turbidity recorded at three depths at Sample Site #24. Note the difference in scale for the top graph.

Sondes were also deployed at different locations throughout the sampling sites and set to record during the same seven day period. This would provide an estimate of the spatial variation of water quality parameters that occurs among the various locations. Water temperature data is summarized (Figure 9) for three sample sites (i.e., #45, #47, and #51) which span the Hamakua canal that begins at Kaha park (Site #51). Clearly there are significant differences in water temperatures recorded for each of the different sites. Water temperatures as high as 33 C were recorded from Site #51 which is the highest recorded for any sampling site throughout the study area and study period. Although temperatures have the beginnings of a diurnal cycle at this location it does not have the regularity seen for the other two sample sites. The decrease in water temperatures and increase in the regularity of the diurnal fluctuations in water temperature are coincident with an increase in water depth and also decrease in distance from the main tributary feeding the lake.

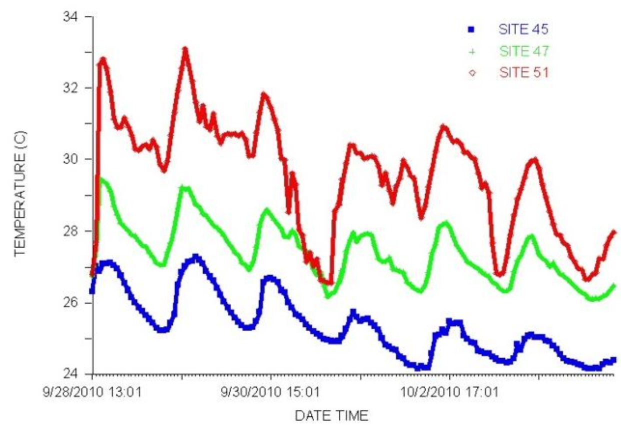

Figure 9. Temporal and spatial differences in water temperature at three sampling sites.

A summary of the recorded pH during the same time period is presented in Figure 10. Diurnal variations as well as spatial differences in recorded pH are clearly evident. It should not be surprising that the data indicate that different locations of the sampling areas are spatially differentiated with regard to physical water quality parameters.

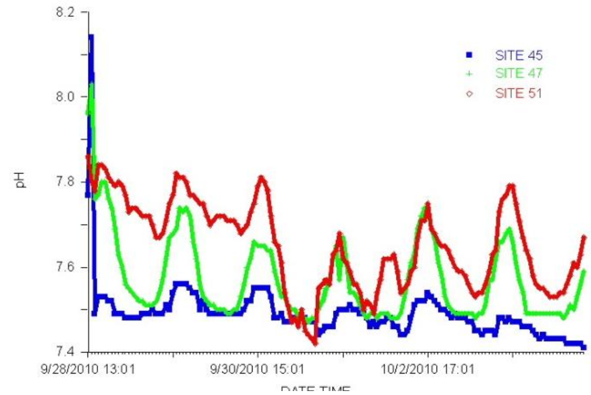

Figure 10. Temporal and spatial differences in pH at three sampling sites.

When various physical water quality parameters (e.g., conductivity, pH, dissolved oxygen) obtained during a single sampling period is plotted against the latitude of the sampling sites (Figure 11) it reveals that the spatial distribution occurs in a gradient fashion such as in the Hamakua Canal. This section of the study area is one of the most impacted with the most westerly sample sites situated in what is essentially a cul-de-sac with little or no ongoing circulation. Clearly such areas need to be considered as discrete segments rather than considering the water as one continuous water body.

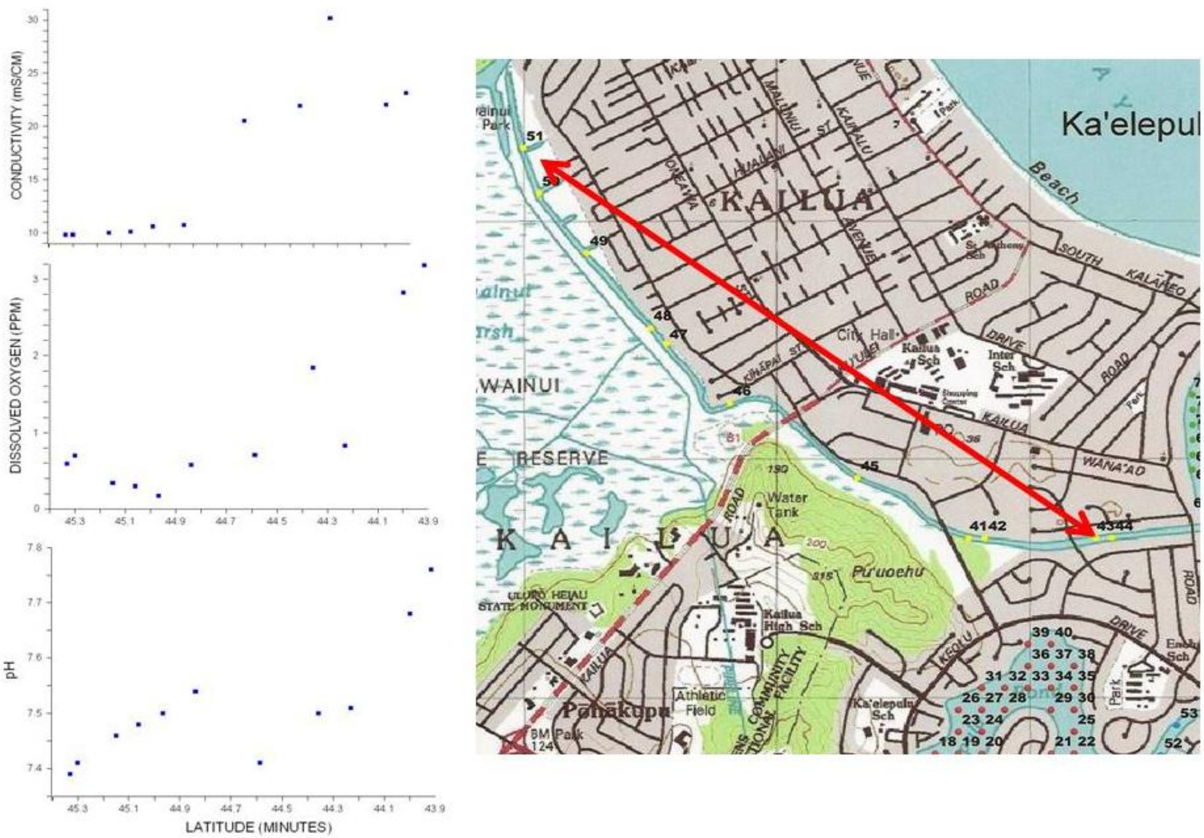

Figure 11. Physical water quality parameters recorded at various sampling sites along the Hamakua Canal taken on February 3, 2010.

Progress Towards Objectives: A total of 14 sampling efforts that took place between June 3, 2009 to June 24, 2010 was completed over the course of the project. Raw data for all of the samples (includes input, pond and tributary sites) is provided in Appendix 2. That samples were obtained over the course of a single year and formed the rationale for requesting an extension of the project. The data has been analyzed and an overall summary of the data is provided in Table 1.

Table 1. Summary of water quality parameters from the pond obtained between June 3, 2009 through June 24, 2010.

						# of times
	Std	Data	10% Std	% Data	Detects	exceed
Species	Pond	Pond	Pond	Pond	Pond	89
Total N (ug/L)	200	176	350	32	63 of 168	
Nitrate + Nitrite N (ug/L)	8	12	25	7	12 of 168	
Ammonia N (ug/L)	6	30	10	18	32 of 168	
Total P (ug/L)	25	16	50	9	41 of 168	
TSS (mg/L)	NS	NS	NS	NS	NS	
Chlorophyll a (ug/L)	2.0	30.3	5	94	168 of 168	
Turbidity (NTU)	1.5	4.1	3	58	168 of 168	
Enterococcus (CFU/100mL)	33	4	NS	NS	76 of 168	16
Red means standard not met				supposed to be less than 10%		supposed to be zero

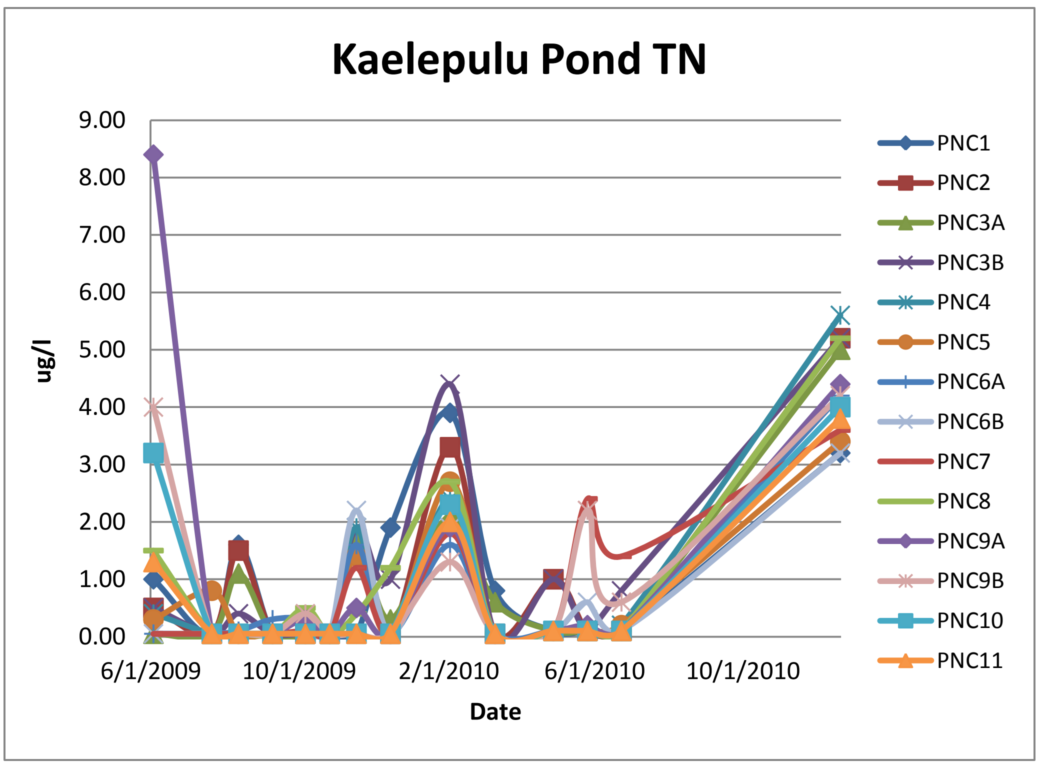

Figure 12. Summary of Total N obtained over the course of the study period.

The water quality data were compared to the current standards using "specific criteria for recreational area" (HAR 11-54-5.2 and 11-54-8) and several parameters did not meet current standards in various categories and those have been marked in red. Using the geometric mean criteria, ammonia, chlorophyll a and turbidity exceeded the prescribed standard. When using the "not to exceed the given value more than 10% of the time" criteria total N, ammonia, chlorophyll a and turbidity were found to be non-compliant. The temporal changes in total N obtained from the pond over the course of the sampling period is summarized in Figure 12 to illustrate the variability that occurred during the study period. Interestingly when the geometric mean criteria is used for Enterococcus the value was found to be compliant with current water quality standards. However, when using the "no single sample shall exceed the maximum of 89 CFU/100ml" criteria there were 16 instances in which the pond was found to be non-compliant. Inputs were found to contain the most Enterococcus with an average of 2,712 CFU/100ml (range: 1 – 52,000 CFU/100ml) per sample site whereas an average of 162 CFU/100ml (range: 1 – 3,040 CFU/100ml) and 292 CFU/100ml (range: 1 – 2,140 CFU/100ml) were found for the Kaelepulu pond and Hamakua + Kaelepulu canals, respectively.

Water quality standards were also compared with values obtained from the stream sections of the study area and they are summarized in Table 2. In this case the dry standard is being compared and total N, TSS and Turbidity were found to exceed the geometric mean criteria. The temporal changes in TSS over the course of the study period is summarized in Figure 13. As with the pond situation when using the geometric mean criteria for Enterococcus the water quality standard was met. However, on 23 instances the steam sections failed to meet the single sample criteria.

Table 2. Summary of water quality parameters from the stream obtained between June 3 2009 through June 24, 2010.

Species	Dry Std Streams	Data Streams	Dry Detects Pond	# of times exceed 89
Total N (ug/L)	180	218	48 of 98	
Nitrate + Nitrite N (ug/L)	30	10.1	2 of 98	
Ammonia N (ug/L)	NS	NS	NS	
Total P (ug/L)	30	18	29 of 98	
TSS (mg/L)	10	13.5	98 of 98	
Chlorophyll a (ug/L)	NS	NS	NS	
Turbidity (NTU)	2	3.5	98 of 98	
Enterococcus (CFU/100mL)	33	6	42 of 70	23
Red means standard not met				supposed to be zero

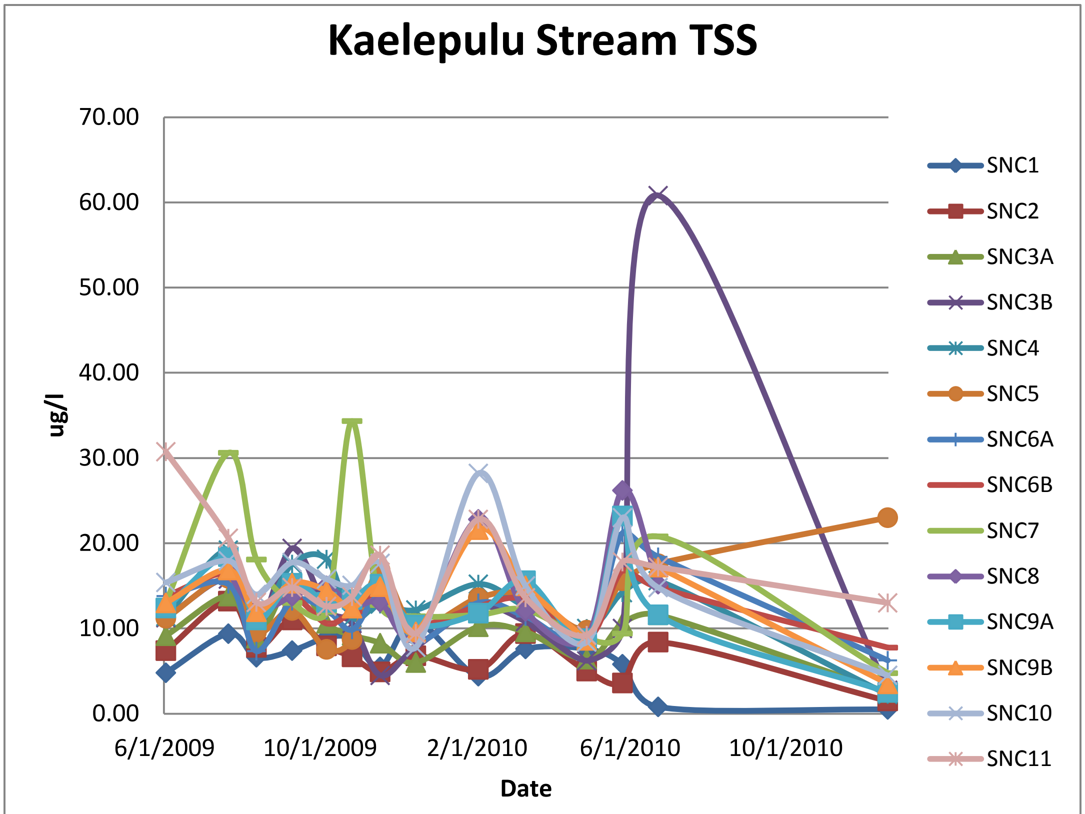

Figure 13. Summary of TSS in the stream section obtained over the course of the study period

Table 3. Comparison of Wet water quality parameters from the stream obtained between June 3 2009 through June 24, 2010.

						# of times
	Wet Std	Wet Data	10% Std	% Data	Detects	exceed
Species	Streams	Streams	Streams	Streams	Streams	89
Total N (ug/L)	250	312	520	39	63 of 168	
Nitrate + Nitrite N (ug/L)	70	< 10	180	0	0 of 70	
Ammonia N (ug/L)	NS	NS	NS	NS	NS	
Total P (ug/L)	50	27	100	20	29 of 70	
TSS (mg/L)	20	10.6	50	20	70 of 70	
Chlorophyll a (ug/L)	NS	NS	NS	NS	NS	
Turbidity (NTU)	5	2.8	15	0	168 of 168	
Enterococcus (CFU/100mL)	33	6	NS	NS	76 of 168	12
Red means standard not met				supposed to be less than 10%		supposed to be zero

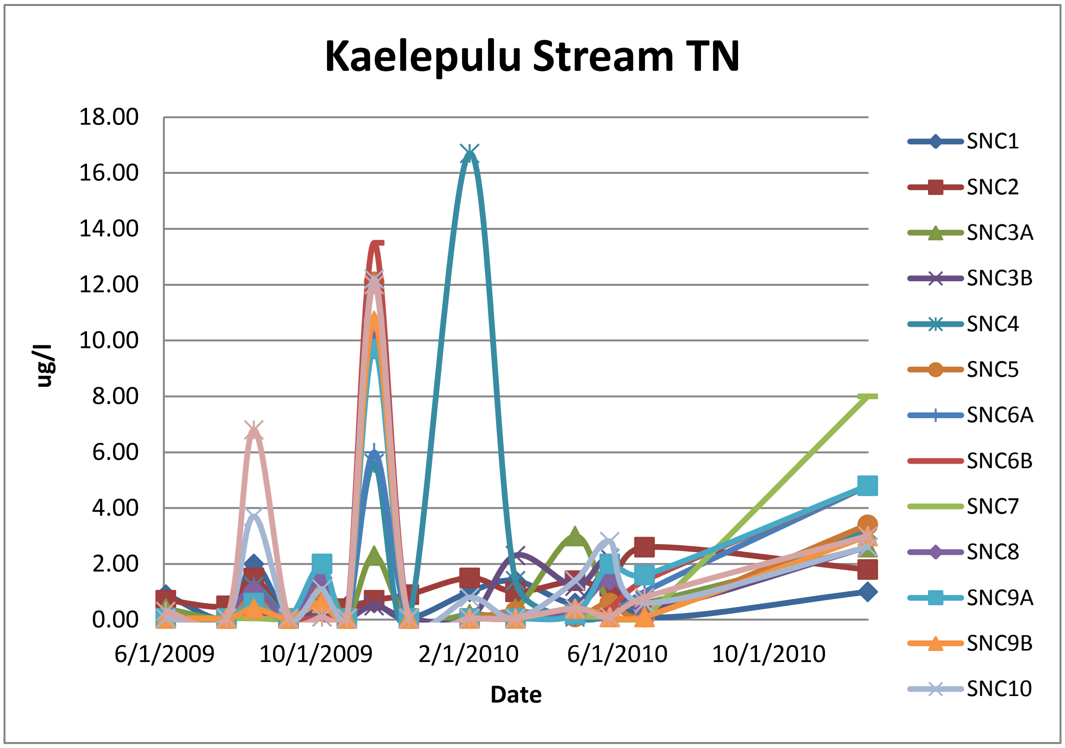

Figure 14. Temporal changes in Total N observed over the course of the study period.

Stream data was compared to "Wet" water quality standards and the results are summarized in Table 3. Total N was the only parameter found to exceed the geometric mean criteria whereas Total N, Total P and TSS were found to exceed the not less than 10% criteria using the wet standard. As with the other situations presented Enterococcus met the geometric mean standard but was found to exceed the single maximum sample on 12 occasions. A summary of the temporal variation in Total N values obtained over the course of the study period is presented in Figure 14. The spreadsheet of the compiled data for all samples is provided in Appendix 2 under the spreadsheet titled (Compiled_Kaelepulu_TMDL_data_w_summary_(YL)(1).xls).

Physical parameters such as temperature, dissolved oxygen, pH, and conductivity were also measured with each sampling activity and the raw data is provided in Appendix 2 sample DO_PH_SAL during the two years of sampling. For each sampling event 40 samples were obtained from the pond and 40 samples were obtained for the stream and a scatter plot of observed water temperature at each location is summarized in Figure 15 for samples taken on April 30, 2010. The latitude is used as a means to indentify the sample site and is plotted on the X axis.

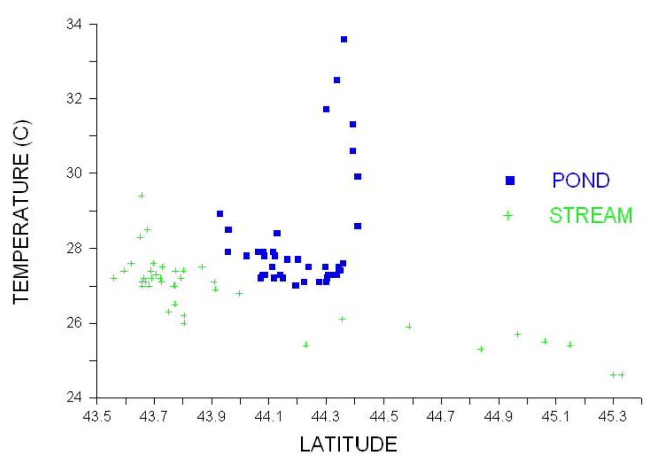

Figure 15. Distribution of water temperature over the study area obtained on April 30, 2010.

When presented in this fashion it can be clearly seen that there are some clear spatial differences that make up the study area. Although the data is not taken all at the same time there is also a difference of 9 C within the study area on the same day. The high temperatures are associated with areas of shallow depth and recorded at mid day results in these skewed values but none the less indicate the variation that is to be expected across the study area.

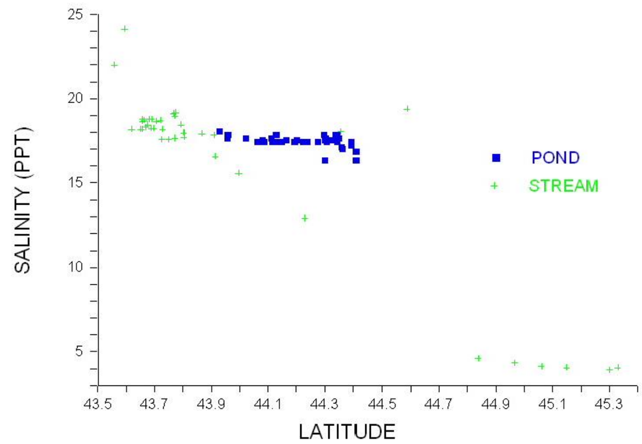

Figure 16. Summary of the distribution of salinity across the study area obtained on April 30, 2010.

A scatter plot of the observed salinity across the study area is presented in Figure 16 and reveals the variation observed among the various locations. The average salinity was calculated at 16.8 ppt but was also accompanied by a considerable range (3.9 – 24.1 ppt). The low salinity values were recorded at the most westerly sites located in the Hamakua canal that have also been reported on previously (Figure 11). Interestingly while there is no physical connection between Kawainui Marsh and this section of the study area the low salinity indicates some seepage across the man made berm that currently separates the two water bodies.

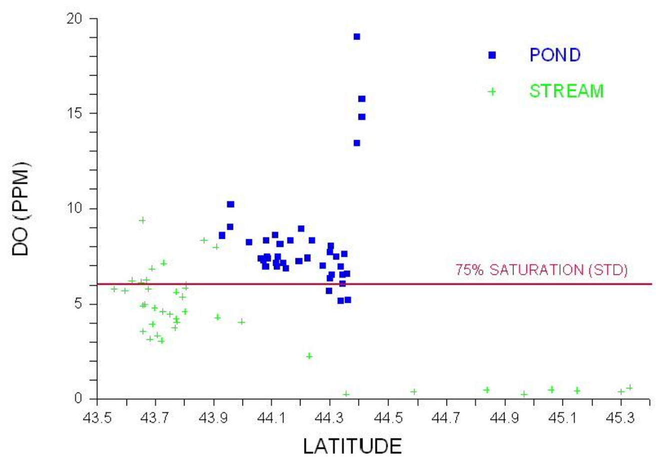

Figure 17. Summary of the distribution of dissolved oxygen across the study area obtained on April 30, 2010.

A similar scatter plot is presented for dissolved oxygen in Figure 17. The average dissolved oxygen for the entire study area was calculated at 6.2 ppm (range: 0.2 – 19.0 ppm). There are clearly areas of the study area that do not meet the must be above 75% saturation criteria and the majority of these sites are located in the Hamakua and Kaelepulu canals. The very high dissolved oxygen values are obtained in the shallowest section of the pond that is also accompanied with a substantial amount of macroalgal growth. As mentioned previously when obtaining the dissolved oxygen values these were done at mid day.

A scatter plot of the observed pH obtained at the same time and sample sites as those for temperature, salinity and dissolved oxygen is summarized in Figure 18. In addition to the data the “not to exceed” 8.6 pH standard is also provided. On this particular day there were three sample sites in which that standard was exceeded. These sites are again located in the shallowest section of the pond and has a high concentration of macro algae. As mentioned previously these sites also had the high temperatures and extraordinarily high values in dissolved oxygen which indicates a high rate of photosynthesis taking place. It is widely known that in aquatic systems a high rate of photosynthesis depletes the CO_2 in solution as it is taken up by the macroalgae. The removal of CO_2 results in reducing the amount of carbonic acid that is normally present resulting in a rise in pH. Such a condition is one possible explanation of the higher pH values occurring in these particular sites as opposed to the other locations in the study area. As mentioned previously the raw data for each sampling date and for each sample site is presented in the Appendix for use in developing the TMDL.

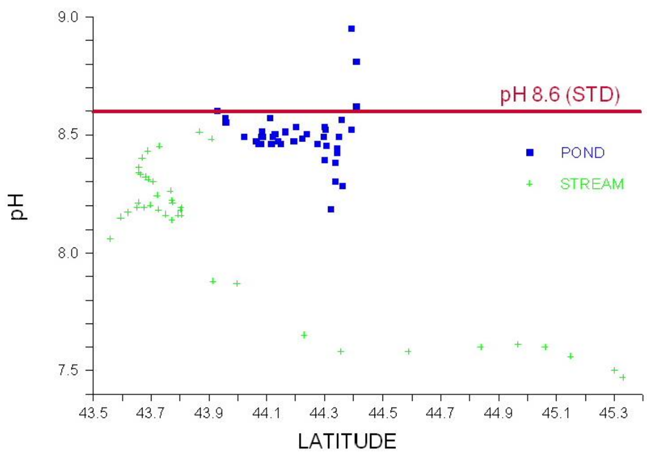

Figure 18. Distribution of pH values across the various sample sites of the study area obtained on April 30, 2010.

Objective 4: Identify the existing uses of the inland brackish waters. Identify the occurrence, distribution, and life cycle status of existing biota in the inland brackish waters.

- Task 4.0 Collaborate with TMDL workgroup to establish survey to be used to assess current uses of Kaelepulu inland waters.

Progress Towards Objectives: A photographic survey of activities ongoing on the inland waters were taken utilizing the sample sites (n=80) as a makeshift transect line on two separate occasions (06/20/2009 and 07/20/2009). As seen in the photos the major activities that occur are kayaking, canoeing, paddle-boarding and fishing. Fishing consist of both netting (e.g., hand net, throw net, lay net) as well as pole fishing. No attempt was made at addressing frequency at this point in time. One clear result is that the amount of use of the inland waters is restricted to the waterways that extend between site 80 and 65 (Figure 19). On both occasions no activity was observed along the entire

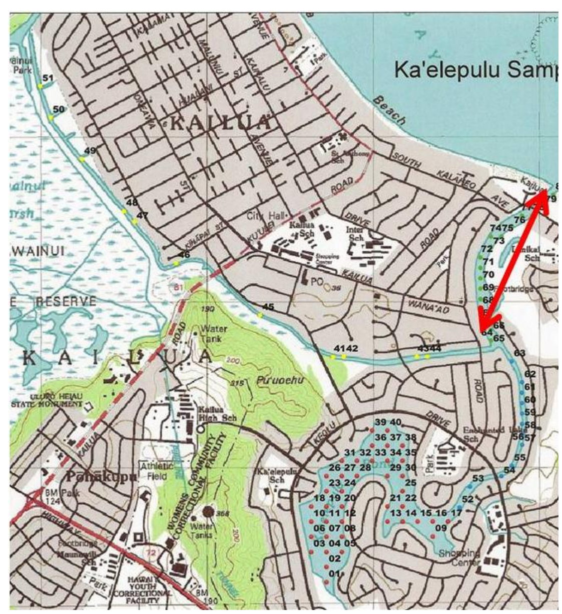

Figure 19. Red arrow indicates location where the majority of activities take place.

length of the Hamakua canal or on the lake itself. That is not to say that there is no activity ongoing as there are numerous launching areas and floating docks along the banks of the lake.

- Task 4.1 Conduct survey of stakeholder groups and summarize results.

No progress made during the reporting period regarding the survey and one will need to be completed and will be responsibility of the PI to deliver. However, during the initial survey conducted in June and July it became evident that some focus on the large amount of macro algae that is present in the pond would also need to be addressed. Samples were submitted to the Agricultural Diagnostics laboratory during the reporting period to assess the macro and micro-nutrient makeup of the algae. Anecdotal information suggests that macroalgae from Hawaiian fishponds maybe a suitable compost material and is currently being used by taro farmers in their taro loi as well as being tested for composting material[4]. A summary of the results obtained from thee separate samples obtained from Kaelepulu Lake on Feb 2. 2010 is summarized in Table 4.

Table 4. Macro and micronutrients of gracilaria samples obtained from Kaelepulu lake.

Sample	%	%	%	%	%	%	%	ug/g	ug/g	ug/g	ug/g	ug/g
	N	C	P	K	Ca	Mg	Na	Fe	Mn	Zn	Cu	B
Lake1	0.76	17.52	0.08	15.77	0.26	0.66	3.51	13867	177	23	14	331
Lake2	0.74	17.42	0.09	16.76	.034	0.66	3.60	14748	194	23	13	327
Lake3	0.79	17.42	0.08	17.96	.028	0.64	3.66	16958	189	24	14	337

While the macronutrients are not particularly high, the micronutrients, particularly iron (Fe) should be of major interest as this is an essential micronutrient for growing plants. It is certainly understandable why there is much interest in using macro algae for composting based on this result. The results also points to an opportunity for use of the macroalgae present in the lake and to view the situation of having so much algae as an opportunity rather than a problem. It will also become important to understand why there is such a high concentration of Fe in the macro algae present but goes beyond the scope of the current project.

Algae samples were also submitted to the laboratory of Dr. Florence Thomas where the metal content of macroalgae samples were analyzed from reef flat surrounding HIMB, Gracillaria sp in Kaelepulu pond and Gracilaria salicornia from Waikalua fishpond in Kaneohe Bay. Results are summarized in Table 5 and the high concentration of Fe was again observed but only in samples from algae obtained from the two Hawaiian fishponds. This was also observed for Mn and to a much lesser extent for the other metals that were analyzed. Clearly, the fishpond environment is resulting in a higher concentrations of key micronutrients that surely promote primary productivity.

[4] http://www.ctahr.hawaii.edu/sustainag/news/articles/V5-Malama-limu.pdf

Table 5. Metals found in macroalgae collected from different locations on the Windward Coast of Oahu

Sample	Ag	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Se	V	Zn
HIMB	0.07	6.72	0.00	0.38	0.44	1.88	202	37.16	0.96	0.21	0.16	3.99	19.80
Kaelepulu	0.02	5.53	0.22	1.93	3.38	7.36	1448	785.85	4.18	0.69	0.45	8.92	13.96
Waikalua	0.04	5.63	0.05	2.03	6.92	5.36	3199	117.48	4.13	1.00	0.14	11.19	19.28

A major shortfall is that the assessment of biological diversity is still not completed and will need to be finished to complete this project.

During the initial survey it was also evident that the black chin tilapia, *Sarotherodon melanotheron* is dominating the vertebrate biota in the estuary. Samples of tilapia from Kaelepulu were submitted to the University of Hawaii's Agricultural Diagnostics Center to undergo proximate analyses to assess crude protein and fat content and will be compared to those being cultured in an aquaculture setting. The tilapia will also be sampled and tested for total mercury, selenium and fatty acid profiles, under the auspices of a NOAA supported project that is focusing on a comparison of the food safety value of wild versus cultured tilapia.

Figure 20. Before and after photos trash fish being consumed by black soldier fly larvae.

An initial attempt was made to address what would be an alternative use of this highly invasive species and did distract from completing the biological survey. However, this one species is so dominant in the watershed that any assessment would need to also include some effort to address remediation effort(s) and were felt to be warranted by the PI.

Conversion of organic material by saprophages has gained in popularity over the last decade and larvae of the black soldier fly (BSL) *Hermetia illucens* have been shown to be capable of converting large amounts of organic waste into protein rich biomass (Figure 20). The grubs reportedly can serve as a substitute for fishmeal or use directly as a fish or chicken food. During the reporting period three Biopods™ were stocked with feral tilapia collected exclusively from Kaelepulu over the course of three months to assess the food conversion ratio from fish to grubs. Average input for the three bipods was 16.5 ± 0.5 kg wet weight and average output of live grubs was 0.64 ± 0.1 kg resulting in a 3.9 ± 0.7% FCR. The low recovery value is attributed to the large amount of indigestible matter (e.g., bones, scales) that remain. While the output of grubs was low they do represent a readily available source of feed that have the potential to be used as a feed directly for either fish or chickens.

- Task 4.2 Obtain historical aerial photos showing change in watershed growth and diversification

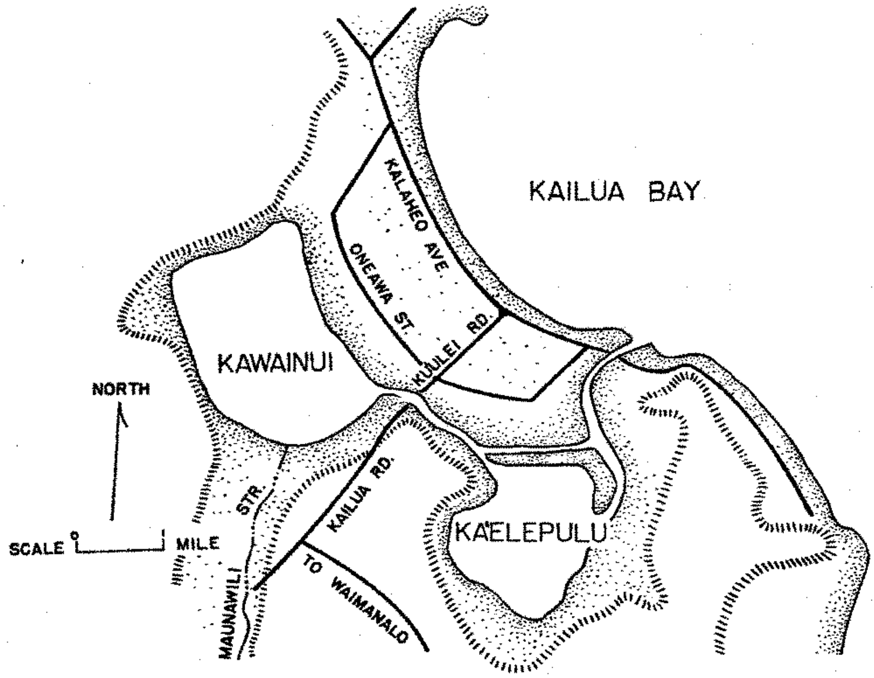

Figure 21. Kawainui and Kaelepulu Ponds, Circa 1930 (Sterling and Summers, 1978)

Progress Towards Objectives: A drawing of the two major fishponds that make up the Kailua watershed basin is provided in Figure 21 and a starting point for showing change in the watershed growth. The Aerial Photography Single Frame Records collection was surveyed to obtain historical aerial photos. The data base is a large and diverse group of imagery acquired by Federal organizations from 1937 to the present. Over 6.4 million frames of photographic images are available for download as medium and high resolution digital products. Individual photographs vary in scale, size, film type, quality, and coverage and is accessible through the USGS website: http://edcsns17.cr.usgs.gov/NewEarthExplorer/. The search for aerial photographs using coordinates that blanketed the sampling sites was conducted using 10 year intervals beginning in 1937. In addition to the Single Frame Records both aerial mosaics and airplane scanners data bases were used for searching for appropriate photographs of the target area. Unfortunately, the number of photographs detected was very low and a summary of those that were found is provided the Appendices (Enchanted Lake Aerials). Aerial photos taken in 1978 and 1985 were the only ones detected using the USGS website and Google Earth Images for 2001 and 2006 were also included to update the aerial images.

Objective 5: Summarize rainfall, runoff, and pollutant loading characteristics at various locations that impact Kaelepulu inland waters.

Progress Towards Objectives: Rain gauges that would impact the Kaelepulu Pond were identified with the assistance of Kevin Kodama, Senior Hydrologist with the

National Weather Service (NOAA). The raw data of all rain gauges on Oahu between 2006 and part of 2011 were obtained and is provided in Appendix 6. The rainfall data is recorded on a daily basis for each gauge site and have been placed in a spreadsheet from which data can easily be extracted and summarized for individual gauges such as for the Olomana Fire Station which is presented in Figure 22. This illustration shows the total rainfall for each month between 2006 -2010. Plotted in this form it is easy to determine the onset of the wet periods for each year and the variation of rainfall for each year.

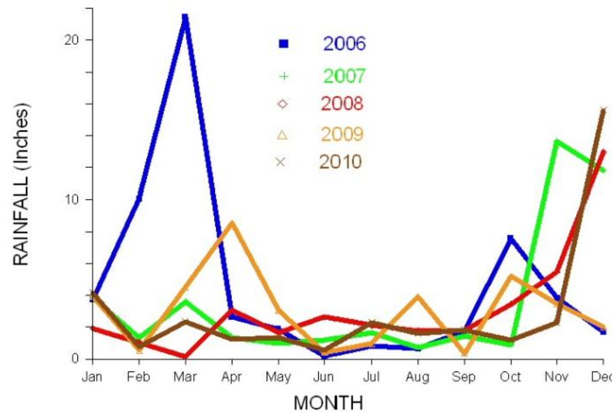

Figure 22. Monthly total rainfall recorded over five years at the rain gauge located at the Olomana Fire Station.

The total annual rainfall recorded for gauges in Waimanalo, Maunawilli, Kailua Fire Station and Olomana Fire Station were summarized between 2006 -2010. A graphic example of the results recorded for all five years is presented in Figure 23. The gauge located in Maunawilli consistently records the highest amount of rainfall annually and indicates one area that can substantially impact the study area. However, the contributions by the Waimanalo and Olomana watersheds as represented by total rainfall recorded when combined represent the largest contribution of freshwater to the study area.

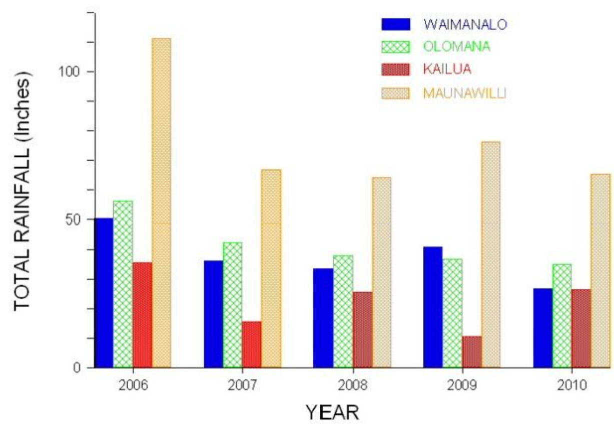

Figure 23. Total annual rainfall recorded over a five year period for gauges at four locations surrounding the study area.

Using the 2009 monthly rainfall data recorded for all four gauges (Figure 24) it appears that even though the amount of rainfall varies at each location they are all apparently recording the same rain event. This pattern was consistently observed for all five years of which data was obtained and indicates that all of these systems will contribute water into Kaelepulu system to some degree during a single rain event.

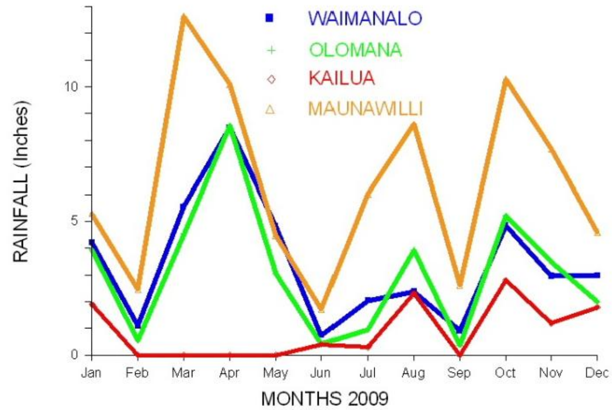

Figure 24. Total monthly rainfall at four gauges recorded during 2009.

Table 6. Summary of estimated flow rates of four inputs into Kaelepulu Lake (2009 – 2010).

Site Number	Longitude	Latitude	Average Flow (L/Min)	Range (L/Min)
4	21 22.544N	157 44.416W	1.4	0.2 – 6.0
5	21 22.350N	157 44.246W	2.3	0.2 – 10.0
6	21 22.364N	157 44.252W	29.0	10 – 180
31	21 22.158N	157 44.174W	8.2	5 - 20

Estimated flow data for all input sources that were sampled have been recorded in the raw data of the various input sites over the course of the year long sampling. That raw data is provided in Appendix 2 under the file: Input Sites_DO_PH_SAL_2009 and 2010 . Of the 31 input sites that were visited during each of the sampling activities only four were found to have water flowing to some degree on all occasions visited and the information has been summarized in Table 6.

Input Sites 5 and 31 (Figure 25) are actual point sources of freshwater inputs that flow into a drainage canal that enters into the eastern end of Kaelepulu pond. The canal contains several small inputs similar to what is seen at Site 31 but not to the degree that they can be measured easily. The flow that is recorded at Site 6 is the collection of all of the minor inputs into the canal as the estimate of the flow is obtained at the base where all of the effluent merges into one short channel. The estimated 29.0 L/min (460 gallons per hour or 11,040 gallons per day) is the average flow rate from all 11 visits that is draining from this particular system. As can be seen in the table the range in flow rates on any given day from this canal can be very large. This input represents the main input of freshwater into Kaelepulu pond.

Figure 25. Photographs of main input sites of freshwater.

Input site 4 is also a drainage canal that is totally separate from that previously described. While it contained water at each sampling the amount of flow is relatively low (1.4 L/min or 22 gph or 548 gpd).

Normal rainfall data (storm events are removed) was correlated with several water quality parameters and a positive correlation between rainfall and enterococcus values was detected. Figure 26 depicts the correlation between the rainfall data from the Maunawilli rain gauge and enterococcus values that were obtained from the pond over the course of the study period.

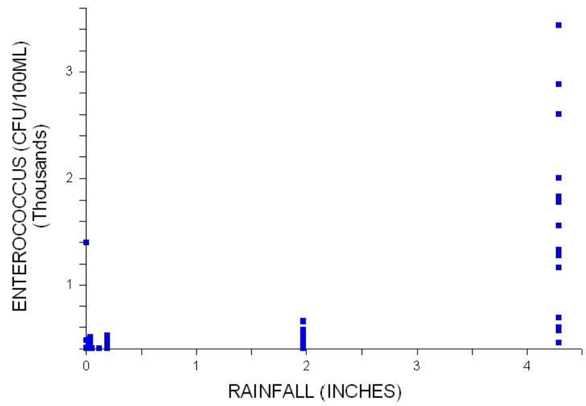

Figure 26. Correlation between rainfall from the Maunawilli rain gauge versus enterococcus found in the pond.

Surprisingly, other parameters such as turbidity (Figure 27), conductivity, TSS, TPP, chlorophyl a, nitrate, and ammonia did not show any correlation between the amount of rainfall and values present in Kaelepulu pond. Summary graphs are available in the Appendix for rainfall data as is the raw data in an excel spreadsheet.

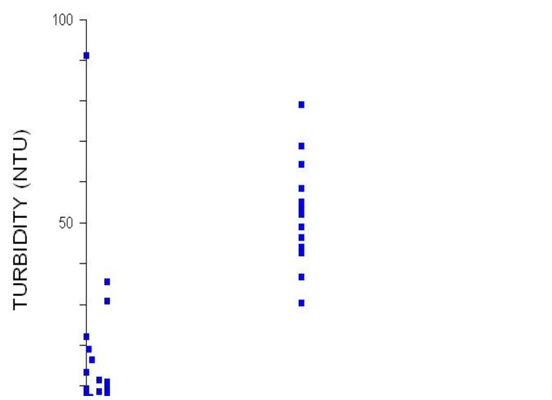

Figure 27. Correlation between turbidity values in Kaelepulu pond and rainfall data from the Maunawilli rain gauge.

Objective 6: Produce progress reports summarizing data obtained.

- Task 6.1 Produce quarterly progress reports consistent with those required for reporting to the granting agency (EPA).

Progress Towards Objectives: Only two annual reports were submitted to the Enviromental planning office and the reporting largely was done through monthly updates in the sampling process. This combination of factors was used by the planning office as an arena for re-evaluating the project in light of the last four years of TMDL and NPDES program development, and for establishing milestones for project completion. Project completion was to be assisted by the recent increase in Environmental Planning Office staff resources (one water quality assessment specialist and one environmental engineer with expertise in water quality modelling), our recent agreement with the University of Hawaii Water Resources Research Center for laboratory analytical services, and ongoing work by NPDES permittees, watershed landowners, and community groups. However, major changes in staffing at DOH have taken place and some guidance and assistance will be solicited with the current personnel to complete the project. However, prior to the reorganization the Major upcoming milestones for the TMDL process included:

- confirming within DOH the classification of Kaelepulu Pond, Kaelepulu Canal, and Hamakua Canal as Class 1 and Class 2 inland brackish waters that include a mosaic of saline lakes, wetlands, drainage ditches, and canals. This inland brackish water system does not have the "continual or seasonal surface connection to the ocean" that defines estuaries. Therefore only the "basic water quality criteria applicable to all waters" and "specific criteria for recreational areas" would be directly applicable to these waters, and the TMDL process would have to establish numeric targets for use in nutrient and sediment loading calculations.
- identifying the existing uses of these inland brackish waters. This determination hinges upon historic documentation of both the physical characteristics of the waterbodies and the institutional arrangements governing their management, and drives the establishment of the numeric targets.
- completing a watershed sanitary survey that examines the actual and potential sources of fecal contamination in the waterbody, and includes recommendations for managing their effects.
- reassessing the extent to which recreational uses of the waterbodies are impaired by excessive bacterial indicator concentrations, given the effects of wet weather flows and wildlife sources,
- establishing the appropriate numeric targets to meet water quality objectives that protect designated beneficial uses in these inland brackish waters.
- calculating pollutant loads that will result in the achievement of these numeric targets (TMDLs).
- allocating these pollutant loads among NPDES permits (WLAs) and nonpoint sources (LAs).

Objective 6: Produce workgroup outreach materials, project progress reports, and water quality data packages.

Progress Towards Objectives: Two presentations providing updates were made to the Enchanted Lake Residents Association at their annual meetings in November of 2009 and again in 2011. Copies of the presentations are provided in the Appendices. It is envisioned that the PI will be making at least one more presentation after the project is completed.