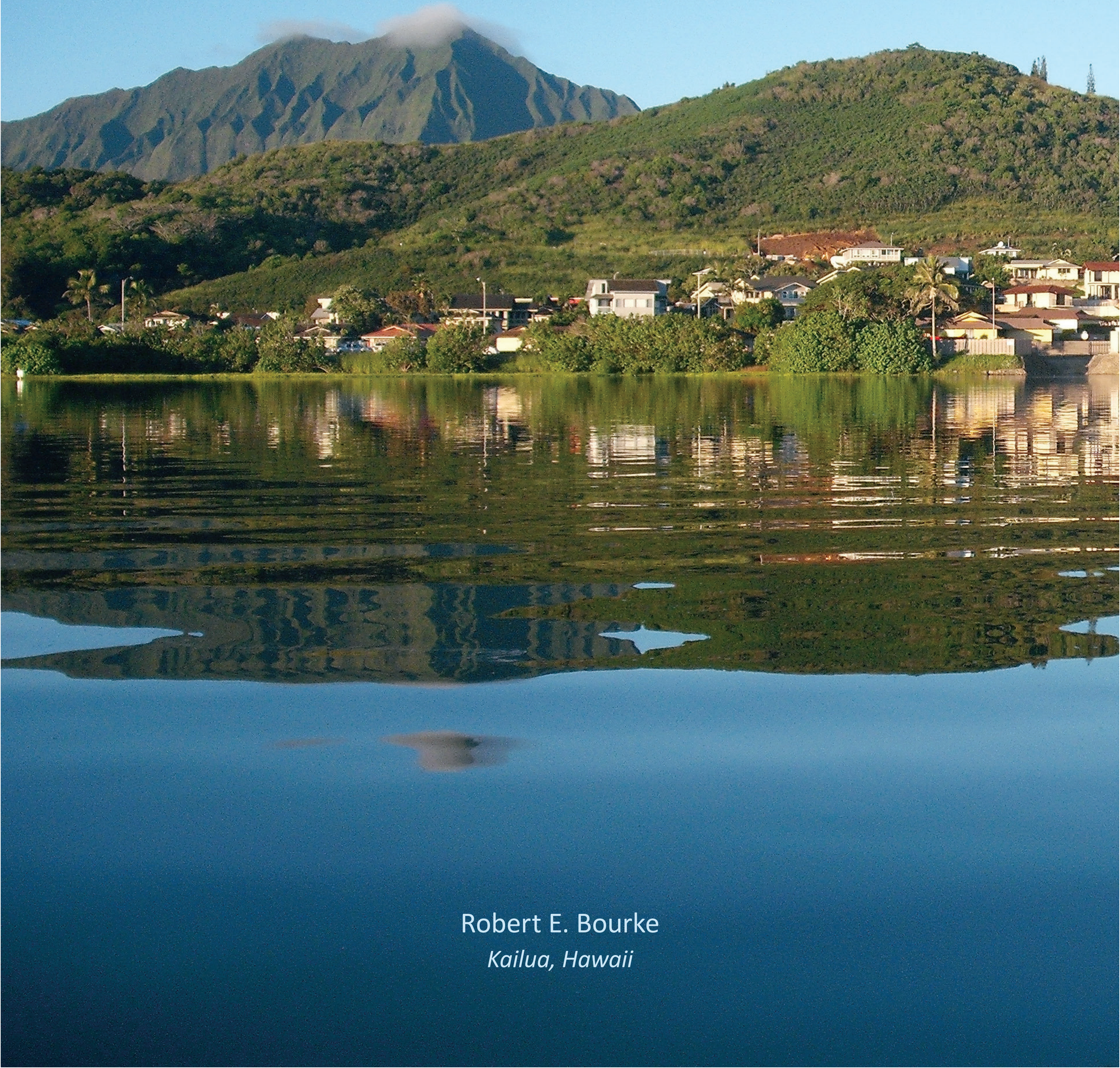
Natural History, Hydrology & Water Quality of Kaelepulu Pond

The Urbanized Estuary of Enchanted Lake



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Kailua, Hawaii

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ABSTRACT

The Kaelepulu watershed once incorporated all of the present day Kawainui (7,175 acres) and Kaelepulu (3,450 acres) watersheds. With only one natural outlet, large storm events would commonly cause flooding across the low elevation sand dune separating the waterbodies from Kailua Bay. In response to the growth of Kailua Town across the sand dune, the USACE constructed the Oneawa Canal (1952) to drain the marsh to the west end of Kailua Bay, and in 1966 completed building the Kawainui Levee. The levee protected Kailua Town from flooding but also separated Kaelepulu Stream from its primary water source of 10 to 15 cubic feet per second. Also in the late 1960s, the 190-acre Kaelepulu Pond, surrounded by an additional 90 acres of marsh, was dredged and filled around its perimeter to create the urban community of Enchanted Lake. This resulted in the 90-acre pond that we see now. The Enchanted Lake Residents Association (ELRA) purchased 79 acres of the pond from Bishop Estate and has managed it since 1989. The City and County of Honolulu (City) owns the storm drains leading into the lake and the main channels of the Kaelepulu Stream, and Kawainui Stream. These water bodies receive storm drain flow from most of Kailua and channel this flow to the Kaelepulu Stream mouth at the east end of Kailua Bay.

The area of the Kawainui and Kaelepulu streams, pond, and wetlands totals about 135 acres currently. The estuary has a maximum depth of 9.5 feet (at 1.5 ft LMLLW) and a volume of 30 million cubic feet (MCF), with the Kaelepulu stream containing 5.5 MCF, the Kawainui Stream containing 2 MCF, with the balance contained in the pond. A rise or fall of the 135 acre surface by 2 inches requires 1 MCF of water exchange.

The pond and streams are brackish, receiving flow both from rainfall/runoff and from ocean flow, and are more correctly termed to be an estuary. Rainfall averages 41-inches per year varying seasonally from a 1.5-inch per month in the summer to 6-inches per month in the winter. Runoff typically results in a rise in lake elevation about three times the rainfall amount, although intense or large storms may result in a 1:4 rise ratio. Because evaporative losses from the system total about 7.5-inches per month, water levels in the lake typically fall during months that do not have at least 2.5 inches of rainfall.

The City opens the mouth of the stream at Kailua Beach six to ten times per year to promote circulation and minimize flood threat from water impounded by the beach sand berm. Water surface elevations higher than 3.3 ft LMLLW cause the stream to overflow to adjacent residential areas. The number of days the stream remains open to tidal flow is directly dependent upon the height of the stream, the depth (not width) of the initial opening, and the length of time of the initial outflow until the rising tide flows back into the stream. The presence of high surf on the beach also appears to shorten the period of time the stream is open by increasing the quantity of sand pushed into the channel by wave action. The quantity of water exchange from the ocean is typically several times larger than the quantity of water entering the system from rainfall runoff. In most estuaries this salinity difference promotes

mixing and maximizes exchange with the ocean. However, the Kaelepulu Stream has a shallow area that blocks the flow of salt water to the pond and greatly decreases the circulation efficiency.

During rainfall events, runoff enters the estuary through 55 City storm drains and canals. The quality of the water entering the system is a function of the size and present land use of the sub-watershed serviced by each drain. The greatest contribution of sediment turbidity (cloudiness) and nutrients is from construction projects with open soil, particularly if these bare graded lands are on steep hill slopes. Turbid water entering the pond from construction sites will drop half (50%) of its sediment load within 100 minutes, but it takes about a week for 90% of the sediment to settle out of the water. During large storm events the brown water entering the Ocean through the stream mouth likely represents only a very small fraction of the sediment and nutrient load entering the pond from the upland pollutant source.

Drainages from City streets and canals also provide pollutant loads to the pond in the form of road gravel, trash, and green-waste and garbage discarded into open, and primarily hardened, channels. The 57.5 miles of City roads in the pond's watershed contribute about 200 cubic yards of road gravel and tar residue to the pond each year — the equivalent of 20 large dumpsters of gravel every year.

Following every significant rain and runoff event, the storm drains introduce large quantities of debris to the pond, a portion of which floats on the surface and collects on windward shores of the pond. Floating debris is removed on a monthly basis by the ELRA clean-up crew. Typically, about half of the material removed is vegetative matter (primarily tree trimmings and coconuts) and half is floating plastics and cans. Each of the five open channels draining to the pond transports an abundance of yard cuttings and garbage to the pond.

Mangroves have been successfully removed from the Kaelepulu wetland, pond, and stream but these areas are continually re-seeded from mature mangrove colonies along the banks of the upper Kawai Nui Stream. A pending State/City project should soon (2016) remove the large quantity of mangrove along the upper Kawai Nui Stream. The mangroves increase the chance of flooding, overgrow native flora and fauna habitats, provide roosting for non-native birds, and result in water with low dissolved oxygen, low pH, high turbidity, and high tannin content. Permanent removal of the mangroves is seen as a necessary positive management action to protect the estuary ecosystem.

Sewage inflow to the system has been a concern in the past. Prior to completion of the Kailua Waste Water Treatment Plant (1966), secondary treated sewage flowed directly into Kaelepulu Pond. Repair and re-lining of the community sewers in the early 2000s is believed to have sealed leaky pipes that may have contributed to groundwater pollution. A sewage pump station located on the bank of Kaelepulu Pond discharged raw sewerage to the pond numerous times in the 1990s and early 2000s during heavy rainstorm events when stormwater entering the sanitary sewer system overwhelmed the capacity of the pumping system. City improvements to control stormwater inflow to the sanitary sewer system and upgrades to the lift-pump station have limited the overflow to a single occurrence in the past 5 years.

A number of studies conducted over the last three decades by the University of Hawaii, USGS, the City, and the Department of Health have searched unsuccessfully for chemical and sewage pollutants within the estuary system.

The primary challenges facing the estuary and their proposed solutions are six-fold:

1. PROBLEM: Loss of historical flow from the Kawainui headwaters has caused the Kawainui Stream branch of the estuary to become stagnant.
   SOLUTION: Permanent flow should be established from Kawainui Marsh to the ITT wetland and Kawainui Stream should be established by installation of a drain pipe around the southern end of the Kawainui levee.
2. PROBLEM: Poor coordination of stream mouth openings contributes to the lack of water exchange within the system
   SOLUTION: The City needs to make a written commitment to open the stream mouth on a monthly basis synchronized appropriately with the ocean tides.
3. PROBLEM: Overgrowth by mangroves results in poor water quality, displaced native species, and increased flood risk.
   SOLUTION: The City, Alexander and Baldwin, and private entities along the banks of the Kailua Waterways need to coordinate their efforts to remove ALL mangrove from the system.
4. PROBLEM: Ineffective controls of erosion and sediment transport from construction sites, particularly those on hillsides, contribute extremely large quantities of sediments and nutrients to the system.
   SOLUTION: The community, primarily the ELRA and Neighborhood Board, need to take responsibility for notifying developers of their erosion control responsibilities, and compel the City and State DOH inspectors to inforce existing regulations.
5. PROBLEM: A lack of gross filters on storm drains and storm channels allows large quantities of road gravel, trash, and vegetation trimmings to enter the pond.
   SOLUTION: Compel the City to meet its existing storm water NPDES commitments in the Kaelepulu watershed.
6. PROBLEM: A buildup of sediments in one portion of the Kaelepulu Stream prevents the effective flow of ocean saltwater all the way into the pond.
   SOLUTION: The ELRA is in the process of permitting to conduct necessary dredging.

The systematic solution to each of the above problems will greatly contribute to the restoration of the Kaelepulu and Kawainui Stream ecosystem, improve water quality, enhance fisheries and increase the level of ecosystem functions and services provided by the estuary to the surrounding community and nearshore waters of Kailua Bay.

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PROLOGUE

This paper has been produced as a means to assemble a wide variety of information concerning the Kaelepulu estuary in Kailua, Oahu, Hawaii to help managers understand how the estuary works, to help make wise stewardship decisions, and to guide others in future investigations of this estuary.

Every natural system is the product of multiple factors working together to produce a unique ecosystem. But some factors in each ecosystem play more important roles than others, and shoulder a disproportionate effect on the way the system functions. To effectively manage a natural system it is important to identify the key factors of control, and understand how they may be manipulated to both avoid ecosystem catastrophes and direct the production of valued ecosystem functions and services to the community.

"Nature to be Commanded Must be Obeyed" (Bacon ~1600)

I first met this estuary over 30 years ago, in 1983 when I helped Mark Brooks gather a dozen gunny sacks of ogo, (*Gracilaria tikvayhae,* the same species that dominates the estuary today*)* to be used as seed stock for an aquaculture venture at Heeia fishpond. The ogo was collected from the shallow wetland end of the lake in patches between the oyster beds that covered half of the substrate, and in the afternoon shadows of the 50-foot tall mangroves that lined the western shore of the pond along Keolu Drive. Like most people in the community, I'd driven past "The Lake" hundreds of times without appreciating the value of the estuary, only decrying the foul odor downwind of the mangroves every summer. In the early 1990s I was approached by Mr. Dixon Yamamoto, who had purchased land along Keolu from Jimmy Lee. Mr. Lee had gotten rid of the mangroves and filled the land (and was cited by the USACE for it), before selling the property to Mr. Yamamoto. But the rotten egg smell attributed to the mangroves persisted, and Mr. Yamamoto was worried it would lower his land value. He need not have worried, as the Japanese economic bubble popped before he could sell his developed lots, and they were eventually sold for only about half of his original asking price. In 1999 I purchased one of the improved but undeveloped lots, built a house, and therein began the persistent journey trying to understand how this estuary works, how to protect it, and what needs to be done to improve it for future generations.

ALOHA

Bob Bourke

1. Historical Context

1.1. Kaelepulu Pond – Pre Human Contact

Pre-historically, the Oahu Koolau caldera collapsed about 1 million years ago leaving the Pali and Koolau escarpments to mark the edge of the caldera. The embayment resulting from the collapse was subject to sea level changes both higher and lower than the present elevation. About 10,000 to 15,000 years ago when the sea level was about 100 feet lower than present, both valleys drained to the sea through a common stream channel, the likely remnant of which can be seen as a river of sand in the middle of Kailua Bay in 80-90 feet of water. 4,000 to 6,000 years ago, when the sea level was near its present stage, waves washed up onto Oahu's shoreline at the mauka edge of both Kaelepulu and Kawainui bays. The bays became isolated from the ocean by sand bar and beach accretion across the embayment mouth that slowly isolated the system from the ocean. Marine bivalve shells are commonly found in shallow excavations in the Kaelepulu wetlands, and beach sands containing shark tooth fragments have been found in deposits 20 feet beneath the surface at the mauka edge of Kawainui Marsh.

1.2. Kaelepulu Pond – Pre-1964

Kaelepulu is the Hawaiian name given both to the wetland pond and to the watershed, including Kawai Nui, that it once drained. The literal translation of Kaelepulu, "the moist darkness" attests to its likely long history as a shallow, probably highly organic, wetland pond. Legend describes the pond as a source for Ama ama, or mullet, which could be caught in the waters and taken by runner to chiefs across the island. The historical presence of mullet within the pond attests to at least some brackish influence to the pond and may explain why, in the early 20th century, sugar plantations preferred obtaining their irrigation water from Kawai Nui – the headwaters of Kaelepulu. The 1883 map by Alexander shows rice being cultivated in the flow from Kawainui to Kaelepulu, but not around the perimeter of the pond, again attesting to its likely brackish nature. In contrast, the artifacts and heiau found around the perimeter of Kawainui and many legends and stories declare that this was an open fresh or brackish water body at the time when the Hawaiians arrived about 1,600 years ago and was maintained as an open fish pond through the reign of King Kamehameha (~1820), becoming covered by vegetation by 1900.

The oldest available nautical map of Kailua shows the mouth of Kaelepulu Stream about 1,000 feet west of its present location adjacent to the "Kailua Tavern" near the present location of Kalapawai Store. Examination of present day aerial photos show the presence of a sand channel through the shallow nearshore reef at that same location (Figure 29). Other original maps of Kailua (#1345 Jackson1884, #1026 Alexander 1884, and #1434 Bishop 1888) show Kaelepulu pond as an open water pond surrounded with a 200-300 foot wide band of wetland. The Alexander map, surveyed in February of 1884, shows an open water area of about 190 acres. All three maps indicate slightly different locations for the stream mouth (although all three show it open to flow) and the presence of multiple oxbow lakes on the Kaelepulu Stream boundary indicating the likely lack of stability of the stream channel.

Pre-1964 photos and maps of the pond depict a black-water pond with an indistinct shoreline of reeds or grasses. There is no evidence that the pond was actively managed as a fish pond, but rather it was actively maintained as a natural fishery. Hawaii Fish and Game pamphlets from the 1930s describe large flocks of Hawaiian Coots (now an endangered species nesting in the system's wetlands) with the warning that the catch limit of 20 birds per day being was enforced.

In 1921, the Waimanalo Sugar Company began plans to obtain water from Maunawili through a series of ditches and tunnels (Waimanalo Sugar Company annual reports). In 1923, the Waimanalo Sugar Company obtained an 18-year lease of rice fields and water rights from Kaneohe Ranch which allowed them to displace the rice farmers, and use a 175 HP pump to extract 120 MCF to 244 MCF per year from Kawainui Marsh and pump it to an elevation of 180 feet from which it flowed in a series of ditches and tunnels to the Waimanalo Reservoir at an elevation of 160 feet. In 1926 Waimanalo Sugar Company excavated a 1,970-foot long by 15-foot wide ditch within the marsh to improve the flow of water to the pump. This ditch is clearly seen in the 1928 USGS map of Kailua (Figure 4). Combined water extraction from Kawainui Marsh and flow from upper Maunawili to the Waimanalo Sugar fields varied from an annual average of 4 CFS (123 MCF/yr) to 7.7 CFS (244 MCF/yr) between the years of 1926 and 1946. In 1944, a 36" diameter slotted pipe was driven and excavated to a depth of 57 feet in the marsh in an unsuccessful attempt to increase flow rates. In 1945 and 1946, which were considered to be drought years, the water extraction drained Kawainui Marsh completely dry by June. Pumping stopped in late 1946 when Waimanalo Sugar Company ceased operations. The Maunawili ditch still transfers water from upper Maunawili to the agriculture fields of Waimanalo, but at a much lower rate estimated to vary from 1 to 2 cfs.

Beginning in the 1930s, the USACE was asked to find a solution to the relatively frequent flooding of portions of Kailua from the Kawai Nui Marsh. By 1952, the USACE had completed construction of the Oneawa channel, forming a new outlet from the north-east extent of the marsh to the ocean just beyond the north end of Kailua Beach (Figure 1). The channel appears to have been named as an extension of the Oneawa Stream noted on early maps as the lower extension of the Kapaa Stream. This new outlet lessened, but did not completely stop the incidence of flooding, and by 1966 the USACE had constructed a flood control levee from Kailua Road to the head of the Oneawa channel. In the process of constructing the levee, the bed of Kawainui Stream was enlarged and extended the length of the levee to within a few feet of, but not connected to, the Oneawa channel. The levee blocked all flow (10-16 cfs) from the marsh to Kawai Nui Stream. The Kawai Nui Stream became a 1.6-mile long channel running behind Kailua Town and fed only by groundwater and City stormwater drains to its junction with the Kaelepulu Stream below Kaelepulu Pond. The average flow to the marsh (as measured from USGS gauges on Manuwili and Kohanaiki Streams is about 9.75 cfs, with a mean flow of about 3 cfs. This does not include any groundwater flow to the marsh. In 1989, on New Year's Eve, the levee overtopped and inundated several hundred homes in the Coconut Grove area of Kailua. Following this event, the USACE raised the levee to its present 13-foot elevation (at station 15:00) and topped it with a 4-foot tall concrete wall.

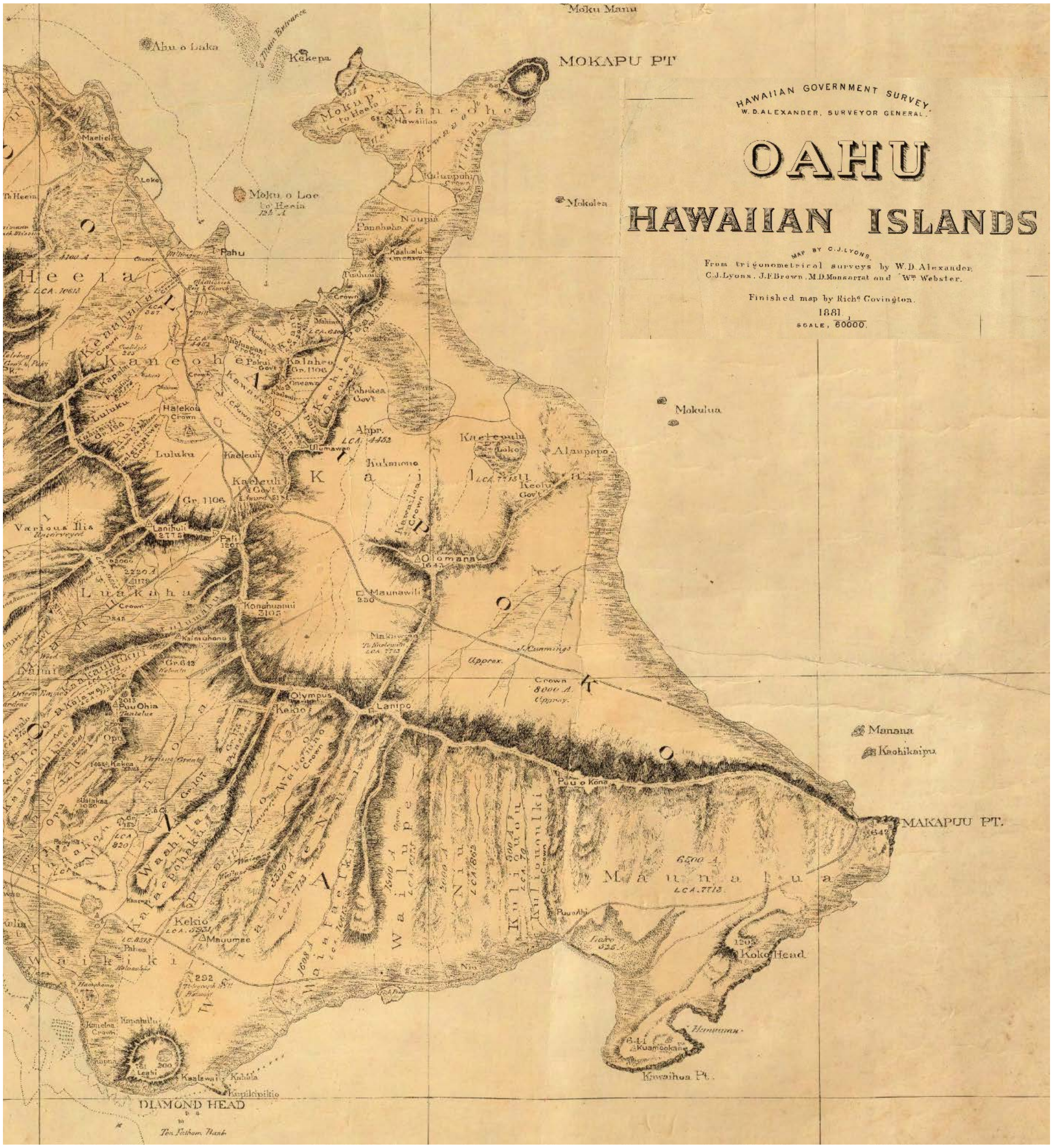


Figure 1. Section of Oahu map of 1881 by Rich Covington showing mouth of Kaelepulu Stream about 1,000 feet west of its present location

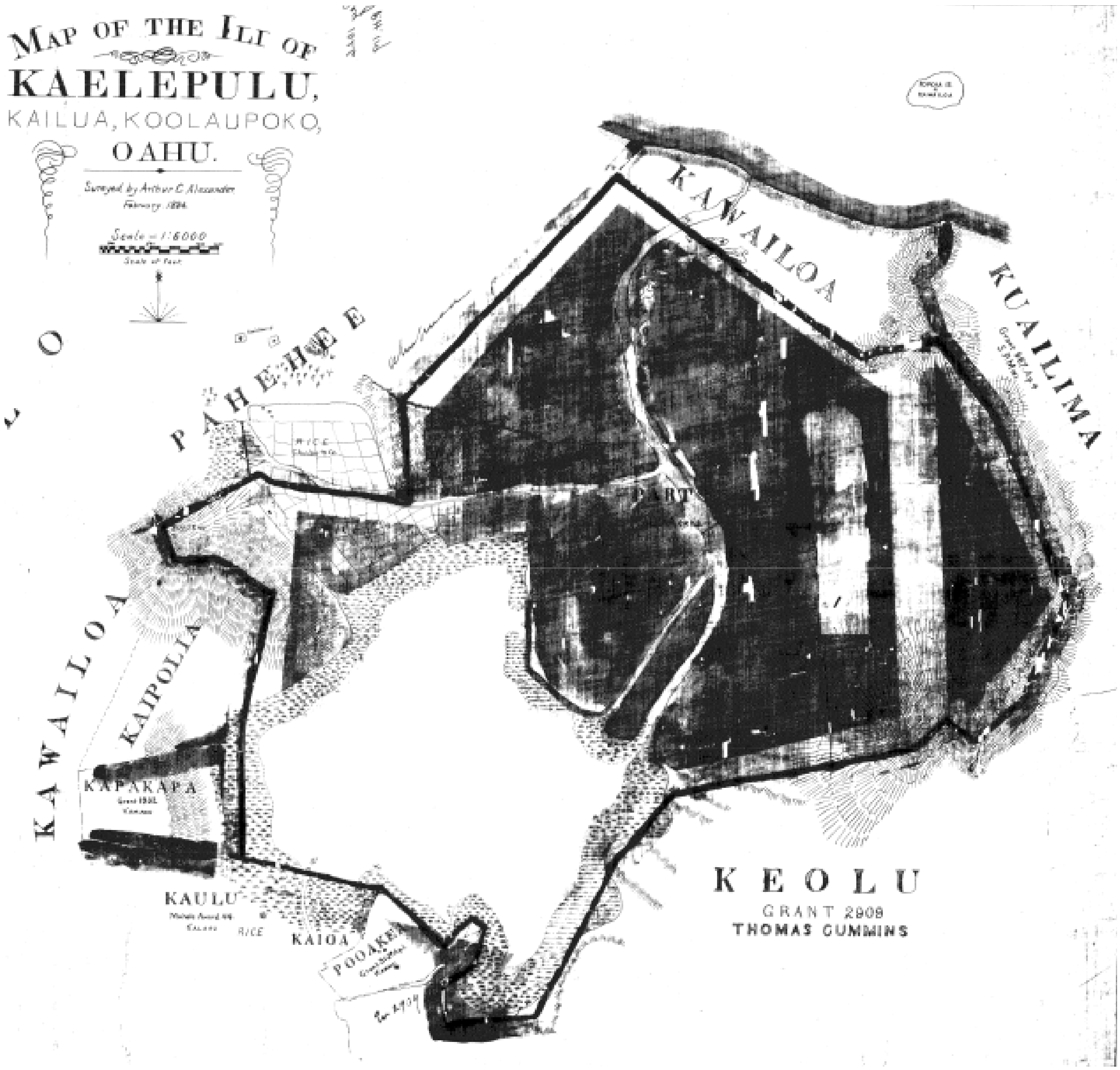
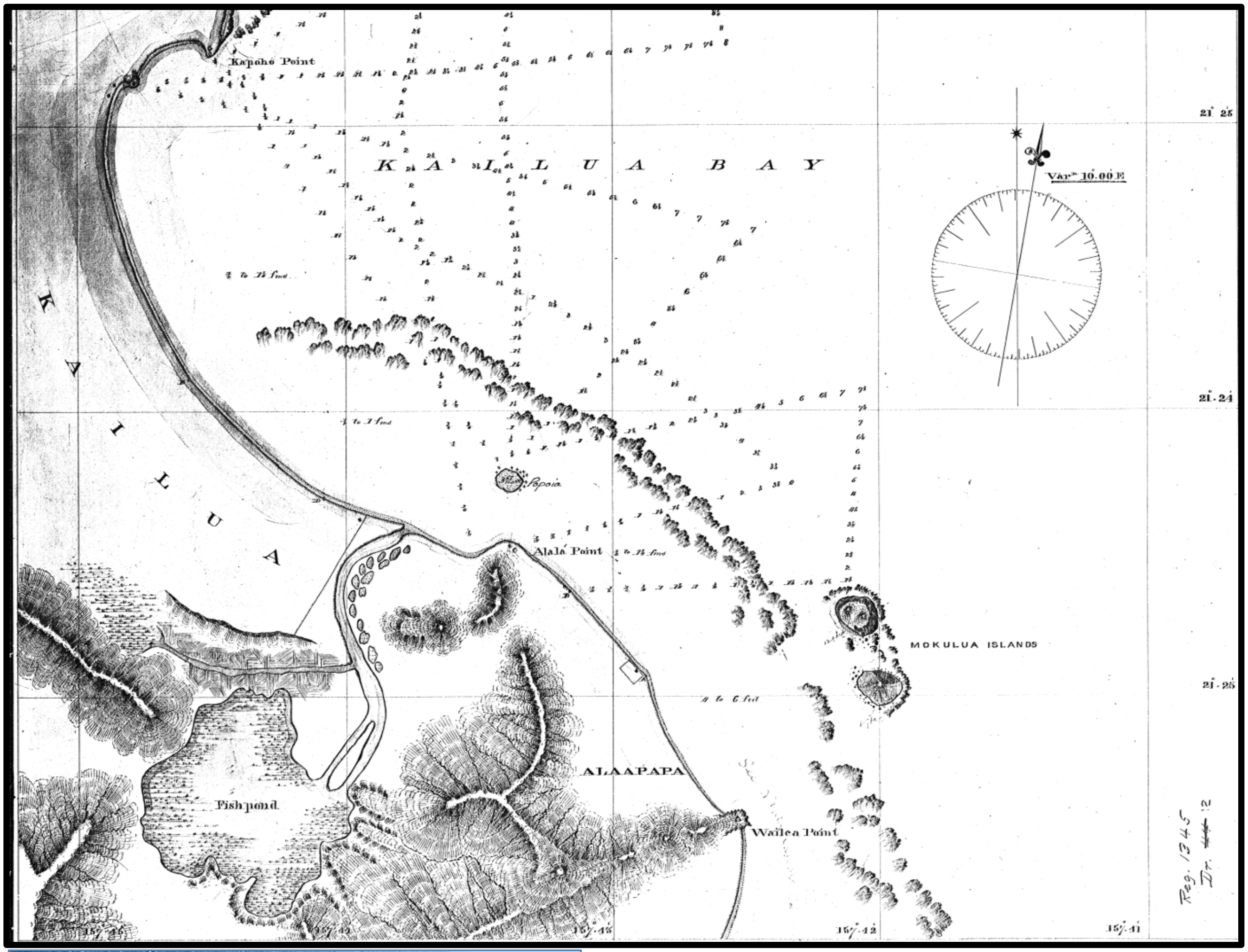


Figure 2. February 1884 map (reg.# 1026) of Kaelepulu by Alexander



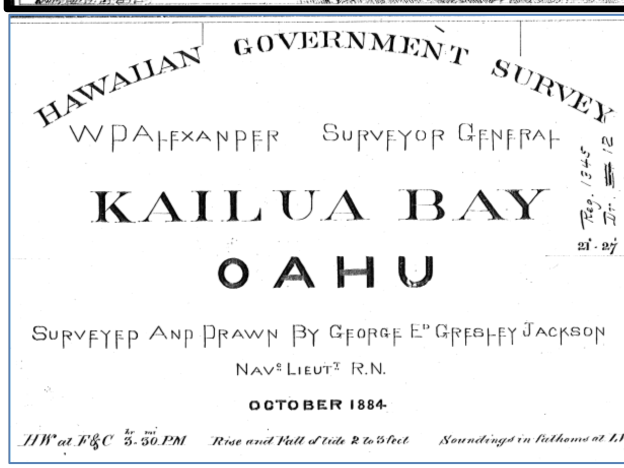


Figure 3. 1884 Map of Kailua by Jackson

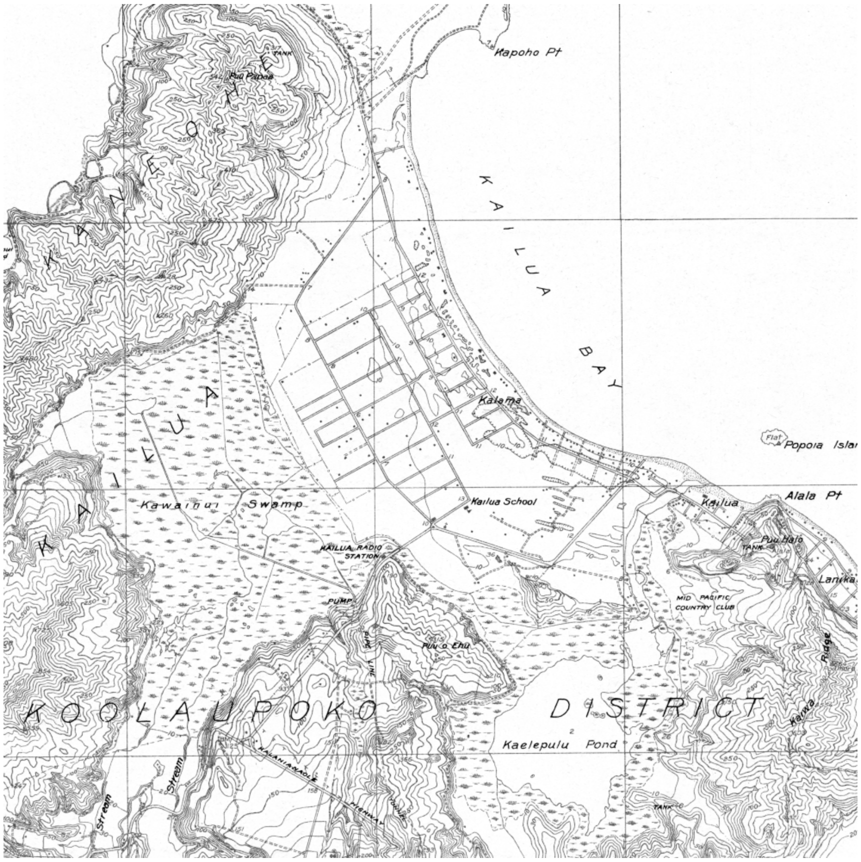


Figure 4 Portion of USGS Kailua 1928 map quadrangle showing beginnings of urban growth. Note the1,000-ft ditch dug in the swamp by Waimanalo sugar to channel irrigation water to their pumps.

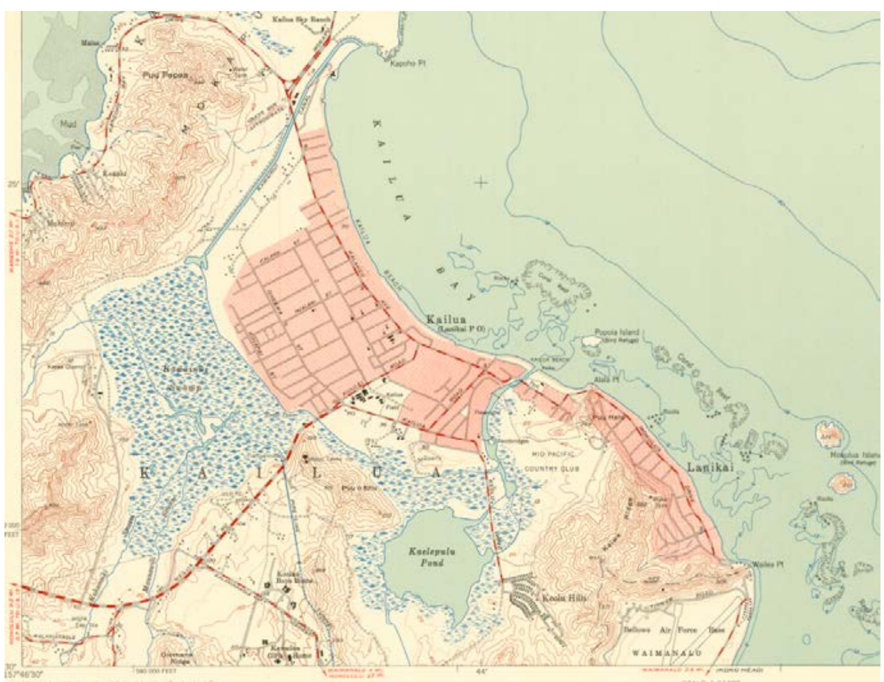


Figure 5 Portion of USGS 1952 Kailua Quadrangle showing completed Oneawa drainage canal.

Between 1952 when the Oneawa canal was completed, and 1966 when the levee was finished, the Kawainui Stream still drained the marsh and the flow to the ocean through the Kaelepulu Stream mouth was significant. Consistent with the oldest maps, statements from Kailua residents prior to 1966 consistently describe the mouth of the Kaelepulu Stream at Kailua Beach as flowing over the sandbar on a regular basis as compared to after the construction of the levee (Figure 29) (Turner, personal communication, Morely, personal communication).

1.3. 1964: The Creation of "Enchanted Lake"

In 1964 the Bishop Estate Trust (now Kamehameha Schools) reached agreement with Lone Star Hawaii developers headed by Joe Pau, Scarfoni, and other partners to develop the lands surrounding Kaelepulu Pond. Mr. Scarfoni was the owner of an 80-foot tall hill in the middle of Kailua. This hill was mined to develop fast lands and a shoreline around the pond. Remnants of the hill are visible in the 1963 aerial photo shown in Figure 6 as the lite unvegetated area just north of Kawainui Stream. The pond was

Figure 6. 1963 aerial photo of Enchanted Lake under construction. Note lack of Kawainui levee and presence of berm across stream exit from pond with heavy silt load entering from Hele Channel inlet (enlarged inset) where the stream channel is still very shallow. USGS: EKM-2CC-246, 1-14-63.

dredged to provide the balance of the fill material. A 1963 USGS aerial photo (No. 4289) shows most of the lake dredged with silt pouring in from the Hele channel and what appears to be a dam preventing flow from the stream back into the newly created lake (Figure 6).

The dredging and filling resulted in a water body of about 90 acres, 79 of which was within the original lease grant from Bishop Estate, and 11 acres at the upper, south, end of the pond owned by one the original Lone Star Development partners. The pond is connected to the ocean through a mile-long sea-level channel, Kaelepulu Stream, which is intersected by the Kawainui Stream about halfway to the ocean. As a permit condition, the developers were also required to dredge the Kaelepulu Stream. The estimated 200,000 cubic yards of material dredged was used to fill the adjacent links of the MidPacific Golf course. The surface area of these two streams is about 33 acres, plus an additional 12 acres of adjacent wetlands, yielding a total water surface area of about 135 acres to the estuary. As the community was constructed, each successive group of shoreline home lots was brought into the "Enchanted Lake Association" (ELA) for a total of 136 private home owners. An additional 37 home lots abut the Kaelepulu wetland which, as it was outside the initial Bishop Estate properties leased to Lone Star, are not obligatory members of the community association (ELRA) who now own the lake. The present configuration of the pond has little resemblance to its historical footprint (Figure 7, Figure 8).

Figure 7 Outline of the 1926 Kaelepulu Pond superimposed over present day Enchanted Lake.

As part of the development agreement the storm drain system was deeded to the City which was granted a drainage easement for storm water to be "discharged into Kaelepuu Pond, and therefrom to the sea." Bishop Estate owned the water area of the pond until 1989 when they sold it for $1 to the newly re-organized Enchanted Lake Residents Association (ELRA). Bishop Estate also owned the lease hold of the Kukilakila Condominiums (110 units) who were initially incorporated into the ELA membership through their lease requirements. The Kukilakila individual owners are no longer required to be obligatory members of the ELRA.

In 1966, a pumping station began operation adjacent to Enchanted Lake to pump the sewage to the newly constructed Kailua waste water treatment plant. However, rumors of very leaky sewers surrounding the lake persisted until about 2003, when all of the main trunk sewer transfer lines were renovated (lined) or replaced, thereby ensuring no contamination of the pond with groundwater containing sewage from leaky pipes. The sewage pump station is located on an inlet to the pond and can by-pass sewage to the pond in case of pump failure or overwhelming flow due to inflow during intense rainfall events.

After the completion of the home lots on the relatively level lands surrounding the pond, the hillsides were next developed. The majority of the Keolu hillsides to the east of the pond were populated with home lots by the mid 1970s, followed by the development of several hundred homes as part of "The Bluffs" on the hills to the south of the pond beginning in the late 1970s. During the initial grading phase the developer, Lone-Star, used upper margins of the Kaelepulu Pond for stockpile and fill. Along this south-east boundary of the pond mangroves had taken root and formed a mangle with a 100-foot wide swath of 50-foot tall trees extending a quarter mile along Keolu Drive. The mangle was a favored roost for egrets and other birds, but often developed a very strong odor which resulted in numerous complaints.

Figure 8 1998 Aerial of Kaelepulu and Kawainui watersheds.

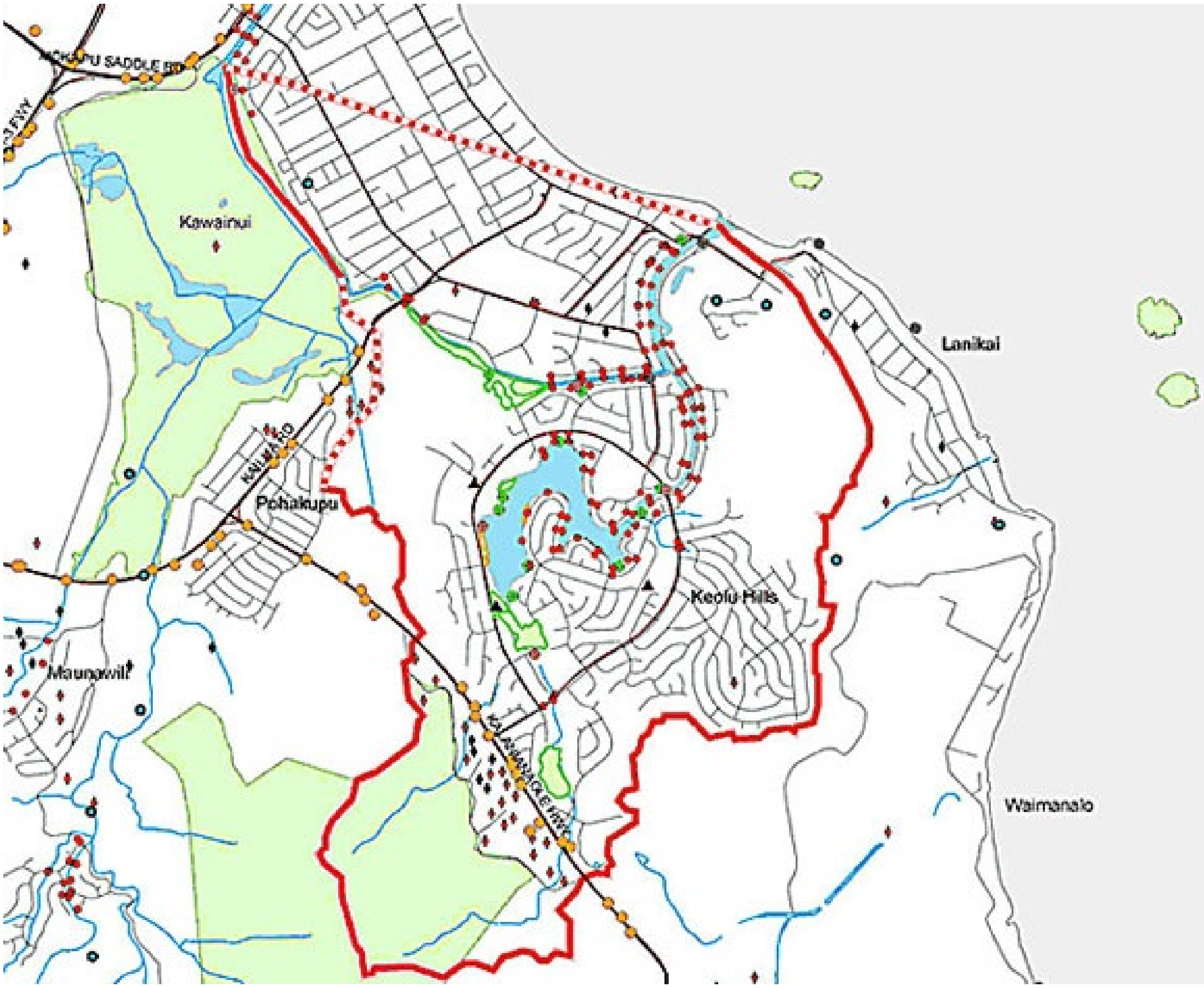


Figure 9 Present day map with Kaelepulu watershed boundary and effluent points from City storm drains.

Lone-Star was cited by the USACE in 1978 for illegally filling this property, and a decade later sold it to one of its partners, James Lee of LECI Corp. Purportedly in response to the community odor problem, Mr. Lee removed the mangroves, constructed a retention wall and filled the land in a 110-foot wide buffer between Keolu Drive and the pond to prevent the mangroves from growing back. The filled land was sold to another developer (D. Yamamoto) who developed 22 residential lots, but not before the USACE again demanded mitigation for the un-permitted fill to about 2-acres of wetland.   As a condition of the consent decree the balance of Mr. Lee's holding (~11 acres of pond and wetland plus 2 acres of "fast" land) was converted to conservation land, with seven bird islands designed (and almost constructed) within the wetland area, and 6 acres of the property designated as a permanent wetland preserve. As the seven constructed bird islands were nearly completed, but not yet stabilized by vegetation, a large storm event struck and reconfigured the multiple islands into one large contiguous island. The property was subsequently sold in 2003 and is now well-managed by the de Vries family who constructed a home on the 2-acres of fast land in 2006.

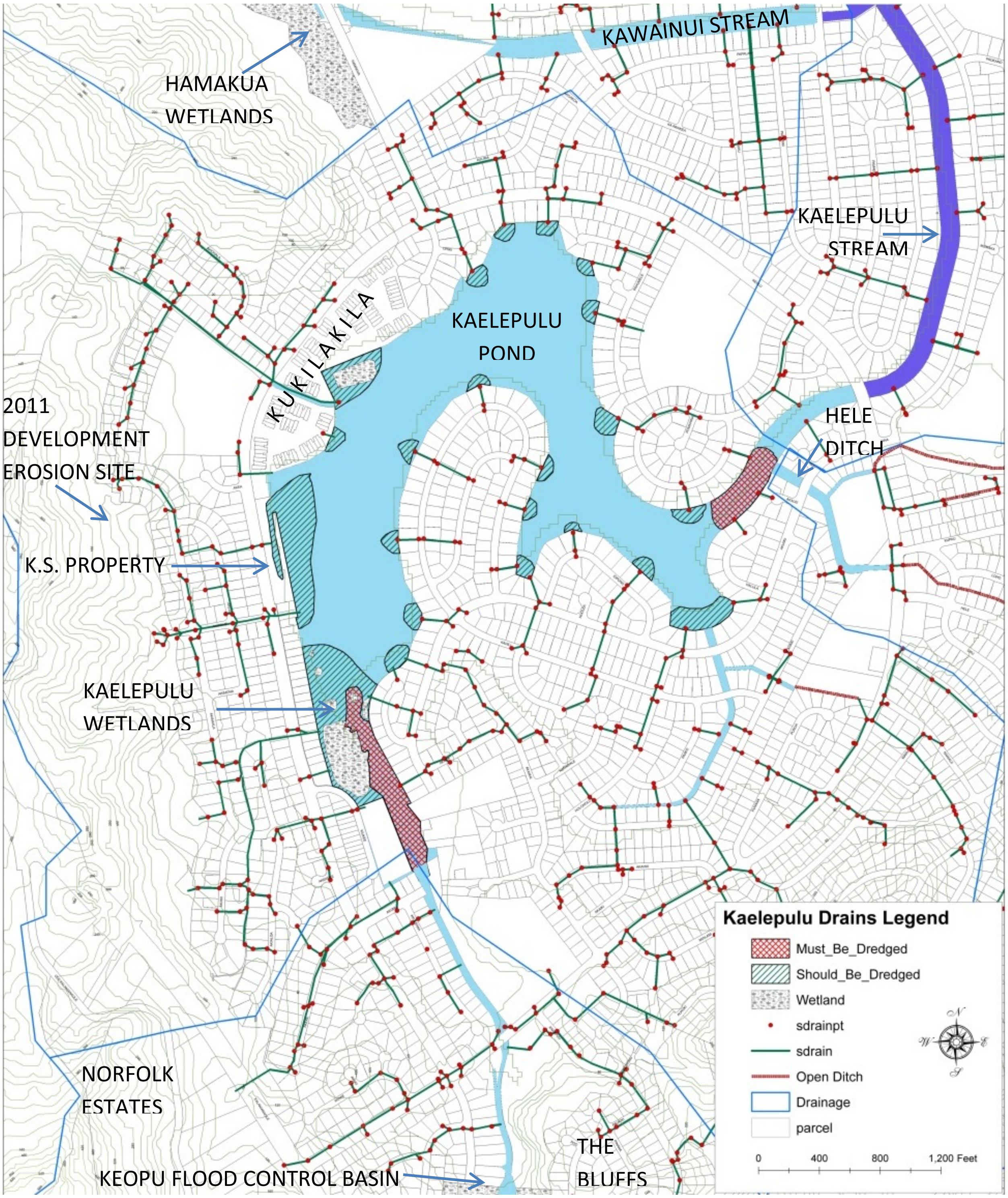


Figure 10 City storm drain map of Kaelepulu Pond showing areas with sediment buildup at mouths of drain outlets.

Development of “The Bluffs” included construction of the Keopu storm control basin on the upper reach of Kaelepulu Stream, at the head of the half-mile long 20-foot wide 10-foot deep box culvert originally constructed as part of the Enchanted Lake development. Also during the 1990s the former fallow lands on the foothills of Mt. Olomana were converted to 2 to 5-acre “gentleman farm” lots in the Norfolk development. Each of the above development phases yielded extremely large sediment loads to the pond as a result of grading practices that lacked adequate erosion control.

At some point, likely prior to 1980 and with some degree of regularity in the 1990s, the City began taking responsibility for opening of the stream mouth through the sand bar at Kailua Beach. The regular openings were in response to flooding that resulted if the sand beach was allowed to build up too high prior to any significant rainfall event. During heavy rainfall events the pond would rise above flood elevation (3.3 ft LMLLW) prior to overtopping the sand berm of Kailua Beach. On many occasions neighborhood residents from the impacted homes would physically dig a trench through the sand dune to help the canal open itself prior to the arrival of the City’s bulldozer. Over the past decade better records have been kept of the opening schedule and methods and since about 2012 the City sporadically began following a suggested opening schedule coordinated with peak monthly tides. Results were much improved when they followed the schedule. The long term practice of moving the sand out of the stream ben and piling it up on the sand dunes (out of the active beach cell) has likely contributed to the documented erosion of this section of beach, even though all of the rest of Kailua Beach has been accreting over the past 80 years.

2. Ecosystem Driving Factors

2.1. Rainfall

The Kaelepulu watershed is located on the windward side of Oahu and is subject to trade wind bourn showers as well as the larger typical central Pacific weather systems and occasional “Kona” storms erupting from the south. The majority of the watershed is separated from the Koolau Mountain ridge and is therefore not typically subject to diurnal orographic rainfall or to the intense rainfall associated with the uplift of the Kona storm systems as they meet this mountain range. The closest official rain gauge (HI24 / OFSH1) is about 1 mile mauka of Kaelepulu Pond at the Olomana fire station. Six-hour accumulated data is available in graphical format on line by month from 2005 to the present (http://www.prh.noaa.gov/hnl/hydro/pages/rra_graphs.php?station=OFSH1). 15-minute data is available (http://www.prh.noaa.gov/hnl/hydro/hydronet/hydronet-data.php) for this site.

Rainfall statistics (Giambelluca et al, 2012 - http://rainfall.geography.hawaii.edu/ and NOAA Rainfall Atlas) indicate that a 24 hour storm with a return period of 10 years has a total rainfall of about 8.7-inches, whereas the average annual 24-hour storm has a total rainfall of about 4.9 inches (Figure 11). Annual rainfall averages 41.2 inches. The annual rainfall is not distributed evenly during the year (Figure 12, Figure 13) and there is a large variance by month between years (Figure 14).

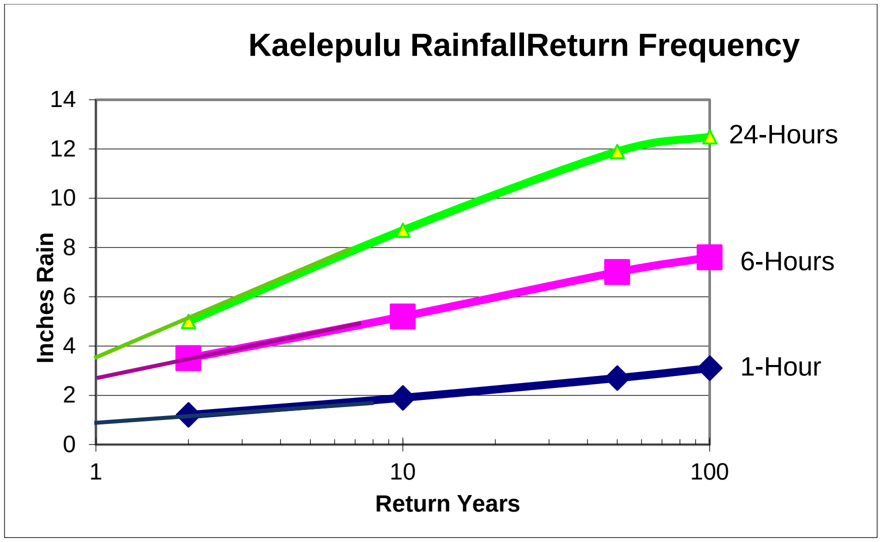
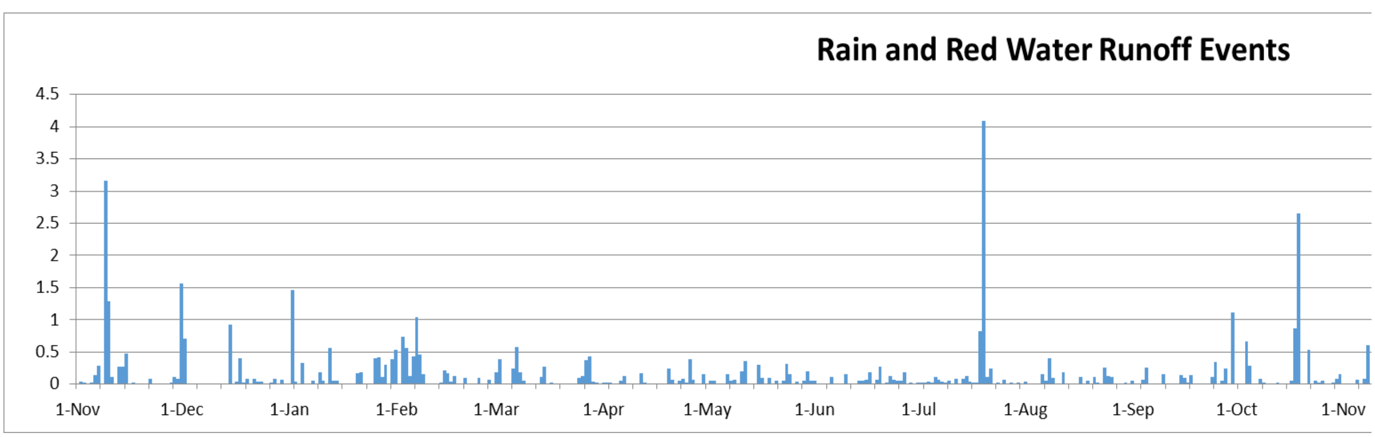


Figure 11 Rainfall long term expected incidence of large storm events at Kaelepulu. Derived from Gaimbelluca et al. 2013

Figure 12 (Below and next page) Daily rainfall at Kaelepulu for 2-year period from November 2013 to November 2015



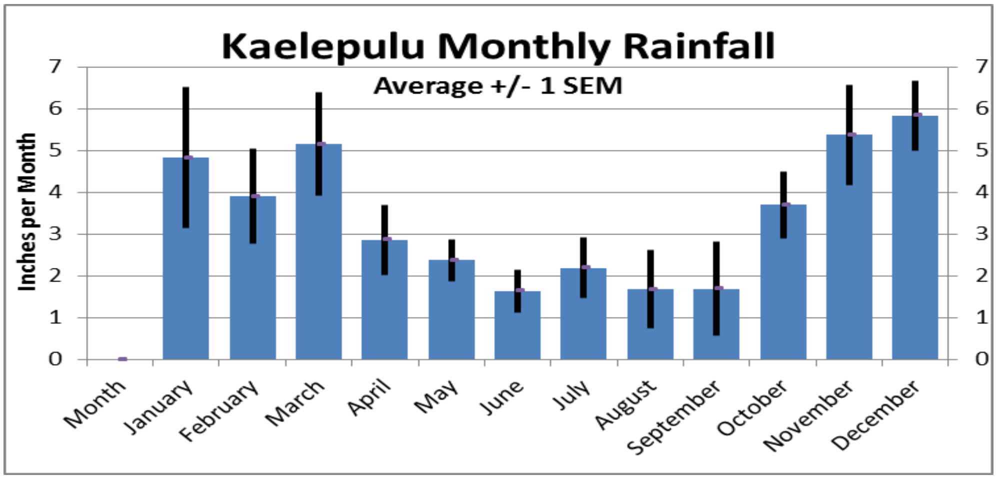


Figure 13 Monthly average rainfall (+/- 1 Standard Error of Mean)

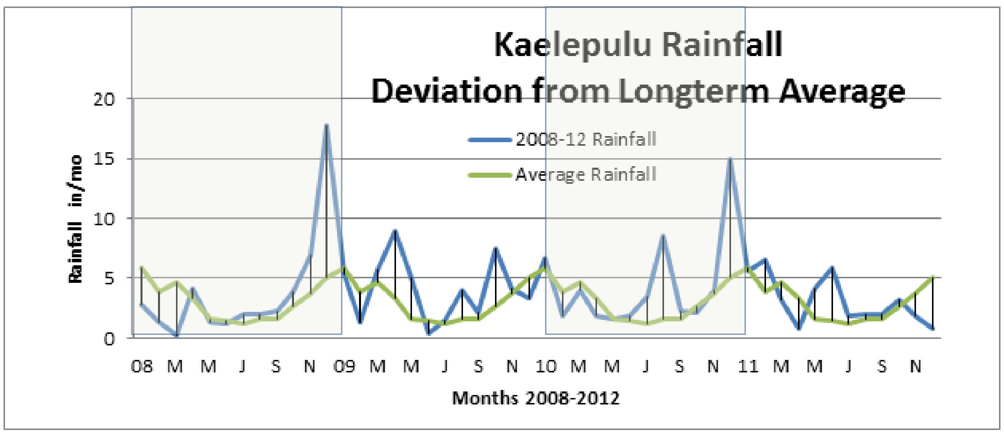
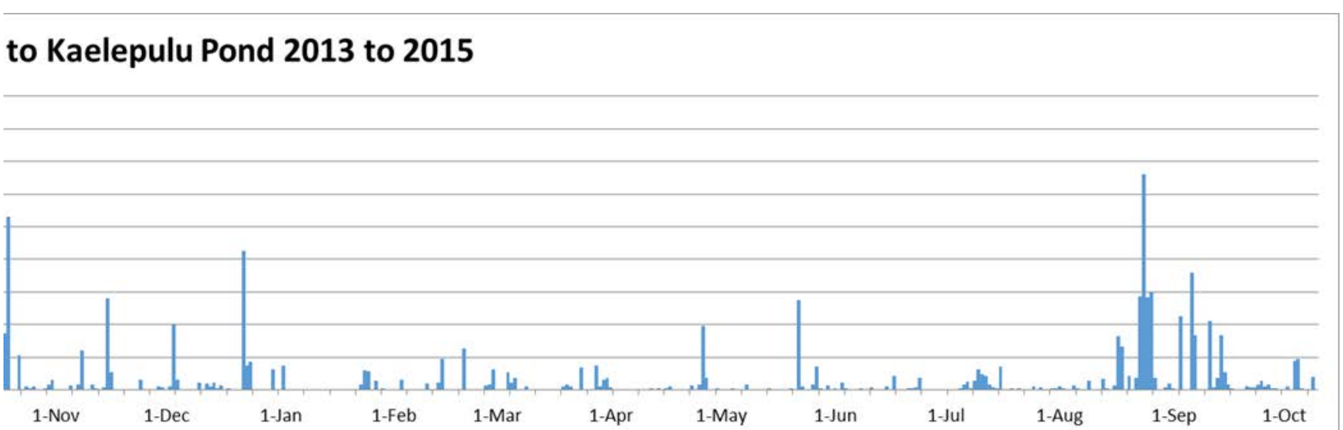


Figure 14 Actual monthly rainfall for 2-year period showing deviation from expected average.



2.2.Runoff Sources and Quantity

The contributing area of the Kaelepulu watershed is about 3,450 acres (Figure 9), or roughly 25-times the water surface area of the estuary. Significant rainfall events (0.5 to 2-inch/24 hours) typically result in an average rise in pond elevation at a ratio of about 1:3. For small rainfall events or for rainfall events without significant antecedent rainfall the rates are often as low as a 1:2 rise. Large or intense rainfall events often display a rain:rise ratio of 1:4. During a single exceptionally intense event, in the presence of significant antecedent rain (12/31/07, measured at 7.9 inches over 6 hours), the rain:rise ratio was about 1:4.5 with the lake surface reaching an elevation of almost 4 ft LMLLW and requiring the fire department to open the sand berm by hand to lower flood waters (Figure 15).

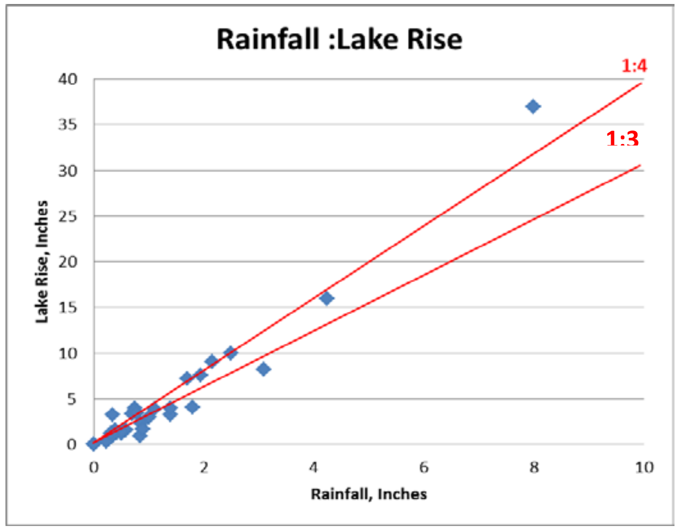


Figure 15. Typical rainfall events result in a rain:rise ratio of about 1:3. In intense, or large rainfall events the rain:rise ratio is often closer to 1:4.

Evaporation in the absence of rainfall results in an average .25-inch elevation drop in the system per day (7.5 inch/month)(Figure 16). Over the 135-acre area of the waterbody, this is equal to an evaporation rate of about 1.4 cubic feet per second (40L/s or 10 gal/sec) During the months of May through September when the average monthly rainfall is not sufficient (less than 2.5 inches per month) to offset the monthly evaporation (7.5-in/mo), the water surface elevation of the pond often falls to near mean sea level (1.2 ft LMLLW). below this elevation the rate of surface drop is much slower than 0.25-inch/day, likely due to the inflow of surrounding groundwater. Evaporation loss rates from the pond have been measured as high as 0.33-inch per day during dry periods with strong trade winds, and as low as 0.2 inches per day in the presence of humid weather and low wind speeds.

The large majority of flow enters the estuary through the City's storm drain system most of which consists of buried drain pipes emptying directly into the pond. Much of the storm drain system was constructed by the original developer in the 1960s and deeded to the City for operation and maintenance. An agreement between Bishop Estate, the ELA (now ELRA), and the City states that the pond owner grants the City use of the lake in perpetuity as a stormwater effluent easement from its drains into Kaelepulu Pond and from there to the sea. Note, however, that this agreement was made prior to the Federal Clean Water Act, and while the City may have permission to drain storm water into Kaelepulu, they do not have the right to allow these waters to carry pollutant loads into the pond. The agreement does stipulate that the City will maintain and repair, including necessary dredging and keep open, all inlets to Kaelepulu Pond and the outlet from said pond (Drainage Agreement, 1963). There are 5 channelized flows and 35 buried culverts (with over 500 curb drain inlets) entering the main body and wetland portion of Kaelepulu Pond (Figure 10) with the balance (55 total) entering the Kawainui and Kaelepulu stream channels.

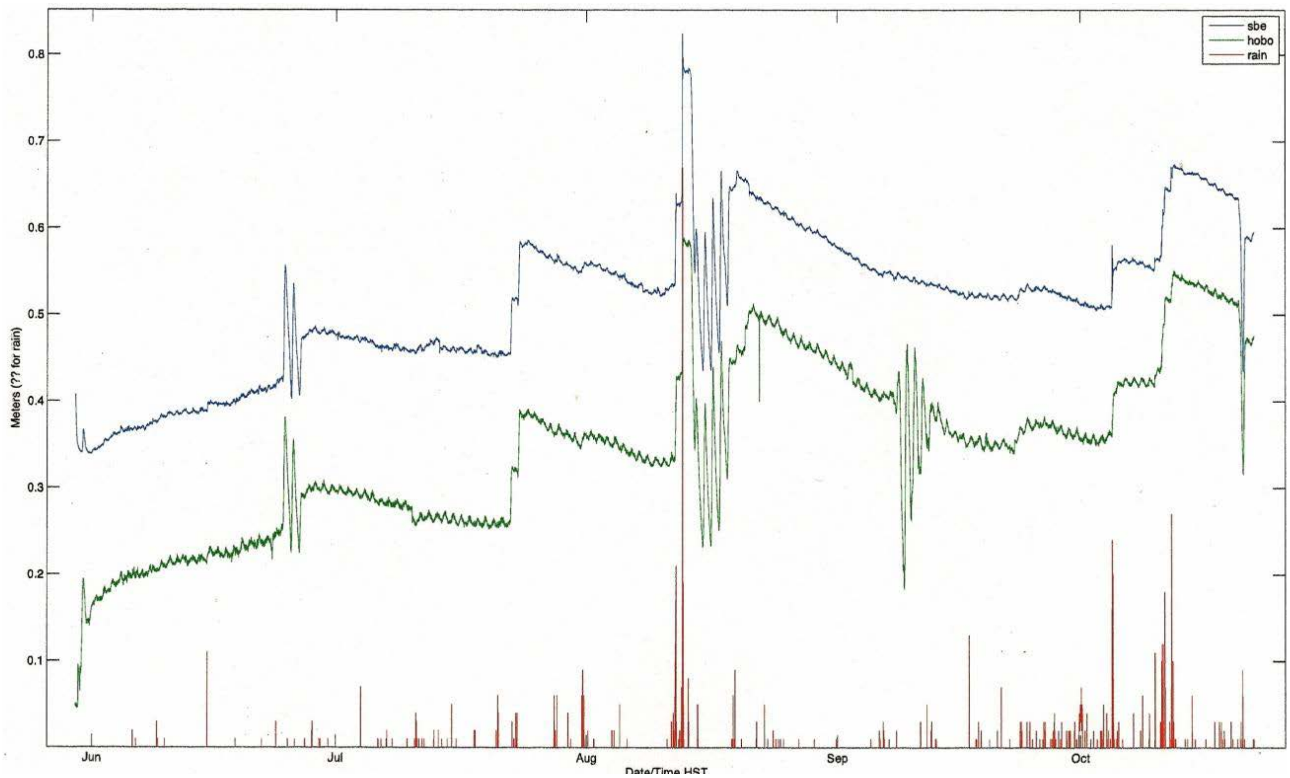


Figure 16 Typical pond water surface elevation patterns associated with rainfall, evaporation, and stream mouth berm opening events as recorded 5/30/09 through 10/22/09. Evaporation rate in the absence of rainfall is about ¼-inch per day (From: Babcock & Tamura, 2010).

2.3.Estuary Bathymetry and Volume

Prior to 2000, no one had measured the depth of the pond. The son of one of the dredge operators remarked that he had been told that the lake had been dredged to a depth of "two to three fathoms" (12-18 feet), which seems reasonable given the equipment used for the operation. Today, at a typical water surface elevation of 1.5-ft LMLLW the maximum depth of the pond is about 9.5 feet. The bottom consists of very fine soft black sediments. As a curiosity I once took a 20-foot length ¾-inch rod to test the consistency of the sediments. At most locations that were not near drain outlets, the rod could very easily be pushed down to the water surface level, indicating the presence of at least 10 feet of soft unconsolidated sediments. Near drain outlets, sediments were coarser, often mixed with debris and pipe penetration was typically limited to less than a couple of feet.

During these initial investigations it was noted that many of the storm drain openings appeared to have accumulated sediment and debris, actually forming small vegetated peninsulas fronting some outfalls (Figure 10). One extreme area of shoaling occurs at the mouth of the pond where it enters Kaelepulu Stream and is joined by the City's Hele drainage channel. At this location the depth of the channel shoals to about 1-foot (@1.5' LMLLW)(Figure 17). Assuming a design depth of 8-feet for this channel, the estimated volume of sediment necessary to fill the channel to these contour lines is approximately

15,000 cubic yards. There are two possible sources for this large quantity of fill partially blocking the mouth of Kaelepulu Stream out of Kaelepulu Pond. As the Hele ditch drains much of the upper hill slopes of the Enchanted Lake community, it is likely that a great deal of sediment entered the lake in the early 1970s as the hillside lots were being developed with little or no erosion or runoff controls (See Figure 6). During the development of Enchanted Lake, the contractor was also said to have constructed a land bridge near this location (also visible in Figure 6) which may not have been completely removed.

The estuary has a volume of about 26.5 Million cubic feet (MCF), at 1.5 ft LMLLW with the Kaelepulu stream containing about 4 MCF, the Kawainui stream containing about 1 MCF, with the balance contained in the pond (Figure 17). A rise or fall of the 135 acre surface by 2-inches requires 1 MCF of water exchange. A 6-inch rise or fall represents about 10% of the volume of the estuary.

For a period of 3 months during the summer of 2015 an experiment was conducted (Oceanit. 2015) in which about 2 CFS flow was restored from Kawainui Marsh over the Levee and into Kawainui Stream. In the absence of rainfall, this flow was shown to be sufficient to more than balance evaporative losses and raise the elevation of the system by about .125 to .25-inch per day. Fresh water entering the upper reach of Kawainui Stream did not displace the salt water within the reach, but spread out on the surface maintaining a surface gradient throughout the entire lower estuary. The report calculated mass balance average monthly flow rates for the system before and after construction of the Kawainui Levee, and after construction of a presumed flow restoration structure allowing 2 CFS to flow from the marsh to the stream (Figure 18)

A NOTE CONCERNING WATER SURFACE ELEVATIONS

Water surface elevation measurements in this document are fixed to a locally established Local apparent Mean Lower Low Water (LMLLW) tide as marked with a tide staff affixed to the Lanikai Pedestrian Bridge. The nearest NOAA tide gauge providing real-time water surface elevation (to MLLW) and deviation from predicted tide is the Mokuoloe Gauge in Kaneohe Bay. We assume that our tides follow the Waimanalo predicted tide pattern with deviations from predicted being the same as that measured at Kaneohe. To determine the elevation a temporary staff gage was established at the Lanikai pedestrian bridge in 2006, and over the course of a year on 10 separate occasions when the stream was open to tidal flow, elevations and times were noted when the water within the stream reached slack tide – when the ocean and the stream were at equal elevations. The “true” elevation at the slack tide was taken to be the predicted elevation for the Waimanalo tide plus the deviation at that time as recorded by the Kaneohe tide gauge. All ten measurements were in agreement to a common base to within 0.1 foot. A second staff gage was established on a pile in the Kaelepulu wetland at this same datum. Since 2006, we have noted that predicted flows associated with tidal elevations have agreed well with our locally established measurement of mean lower low tide. The City affixed a staff gage on a piling of the Lanikai automobile bridge in 2008. The City’s gage elevations are tied to the City’s MSL survey base which was established at Honolulu Harbor and is 0.26 feet higher than our LMLLW. Our LMLLW gauge reads 0.26 feet when the City’s MSL gauge reads 0.0.

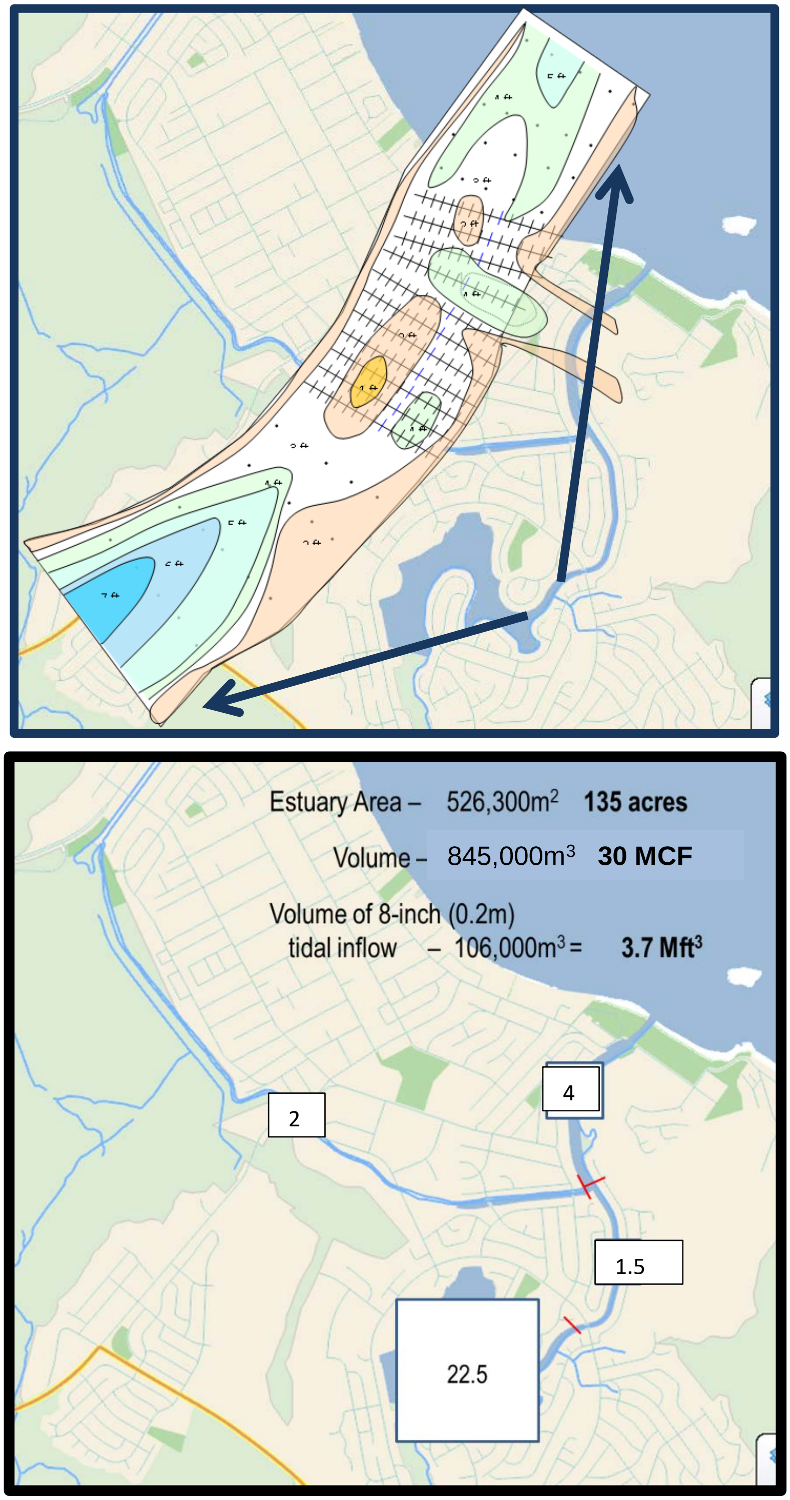


Figure 17. Top: The mouth of Kaelepulu Stream as it exits the pond is shoaled to within a foot of the surface and dramatically impacts circulation between the stream and the pond. Bottom map graphically depicts the estimated relative volume of water in each section of the estuary as represented by cubes with a base as shown

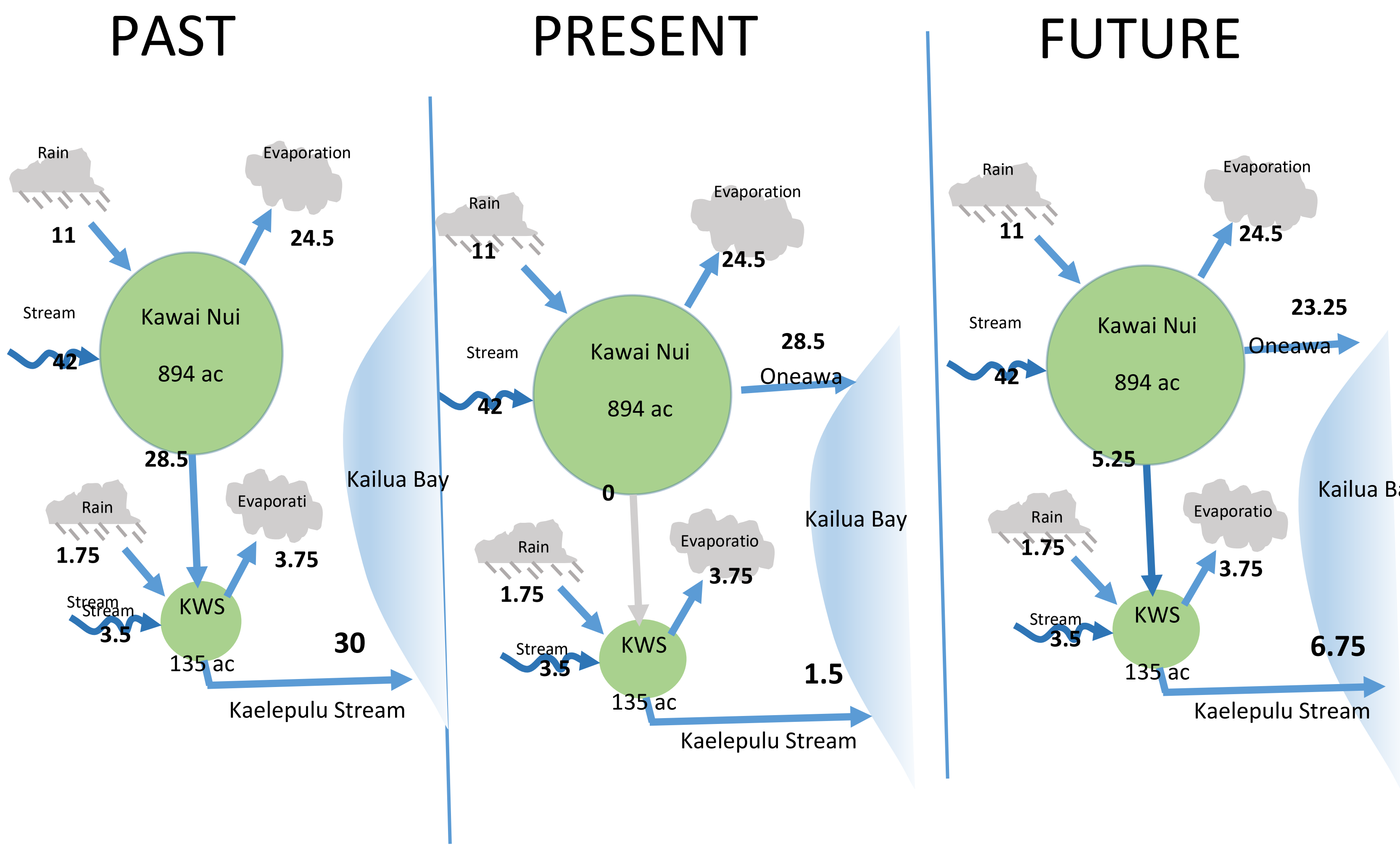


Figure 18 Average monthly mass balance water flow for Kawainui and Kaelepulu Systems before and after construction of the Kawainui Levee, and after proposed flow restoration (From: Oceanit, 2016)

2.4. Water Quality Impacts of Runoff

During rainfall events, each of the City's outfalls to the pond displays different water quality depending upon the size of the area drained and land use activities at the time of the rainfall (Figure 19). The greatest predictor of high turbidity is the presence of construction activities with exposed soils. As the estuary pond will commonly display a salinity of about half sea water (15-18 ppt) the freshwater runoff tends to spread across the top of the denser high salinity waters (Figure 23). If the stream mouth is open at the ocean, this low salinity water is the first to leave the system and can carry significant loads of the finest suspended or dissolved pollutants to the ocean (Figure 20). Estimates of the quantity of sediment entering the pond from any storm drain can be made by measuring the flow volume (cross sectional area times velocity) and the dry weight quantity of sediment suspended in a sample of the water obtained from the flow. In the flow pictured in the upper right photo of Figure 20 the upper reach of Kaelepulu storm drain channel was estimated to be delivering 1 ton of sediment containing 2.5 kg of nitrogen and 0.75 kg phosphorous fertilizer into the pond every 6 minutes. If the stream mouth is closed at the beach, then sediment and pollutant load slowly precipitates out over a period of minutes to several days (Figure 22) and therefore remains in the estuary.

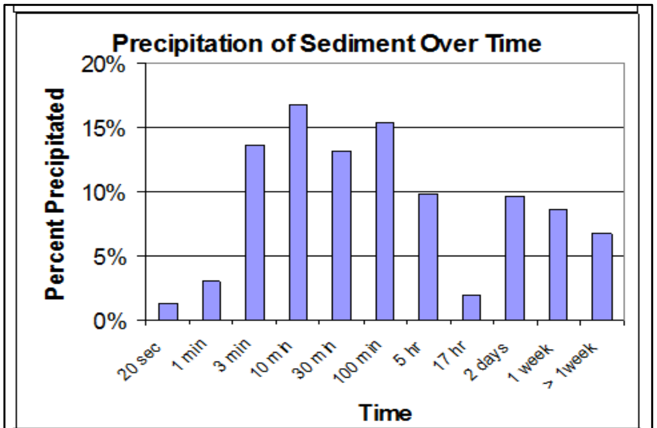
Figure 19 Water quality samples from pond inlets obtained during a single runoff event (3/19/06) distinguish between drainages that have active construction grading projects and those that do not.

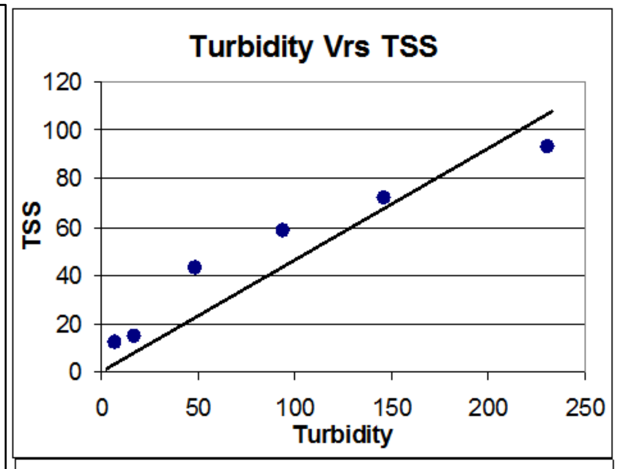
The most obvious source of pollutants to the system is sediment in runoff from construction sites with inadequate erosion and runoff controls. The samples depicted in Figure 19 were taken during a single storm event from inlets all around the pond. The inlets influenced by construction sites are obvious.

To better understand the fate of sediments entering the lake through storm drains, a controlled laboratory test was conducted. A highly turbid 2-liter sample of stormwater entering the lake was collected from a City storm drain that was receiving runoff from a large hillside construction site. The sample was kept agitated until it was poured into a 50-cm deep funnel cone with a valve at the bottom. At various intervals, the valve was opened to remove that portion of the sediments which had settled to the bottom. These sediments were then individually dried and weighed. Roughly 25% of the sediments settled within 10 minutes and half had settled after about an hour. However it required two days for an additional 25% (75% total) to settle, and after one week, 10% of the settleable solids still remained in solution. These results are graphically displayed in Figure 22. From a practical perspective this means that even if the stream mouth is open during a heavy storm event that at least 50% of all sediments entering the lake, settles within the lake. It is likely that well in excess of 90% of solids entering the lake remain there.

Figure 20 Construction activities (A) have the greatest impact upon delivery of sediment and nutrient turbidity to the pond (B) and into the ocean (C) when the stream mouth is open.

Figure 21 Poorly implemented BMPs at construction sites (A) or intentional by-passing of required BMPs (B) result in significant plumes of turbid water entering the pond (C) and deposition of fine mud throughout the estuary (D). The high iron content of the soil colors the pond bright orange for several days following major rainfall events when land is being graded in the watershed.





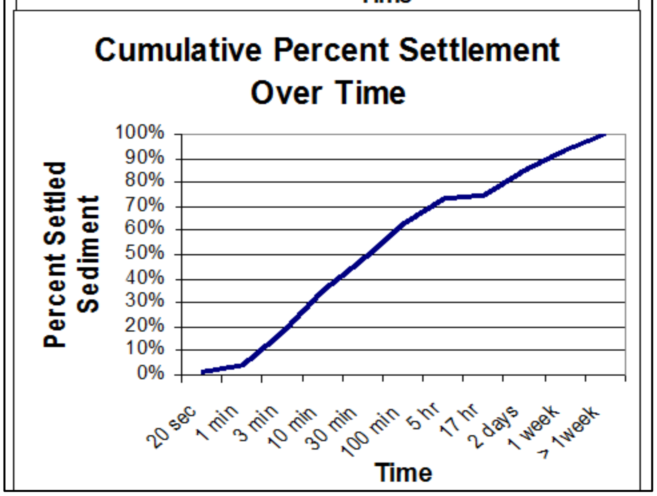
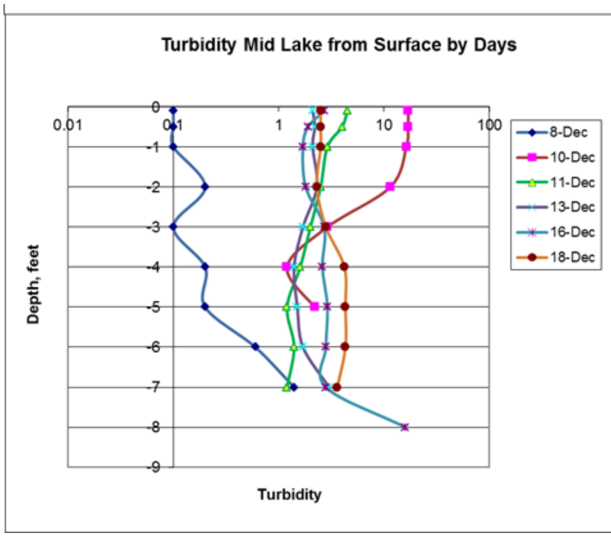
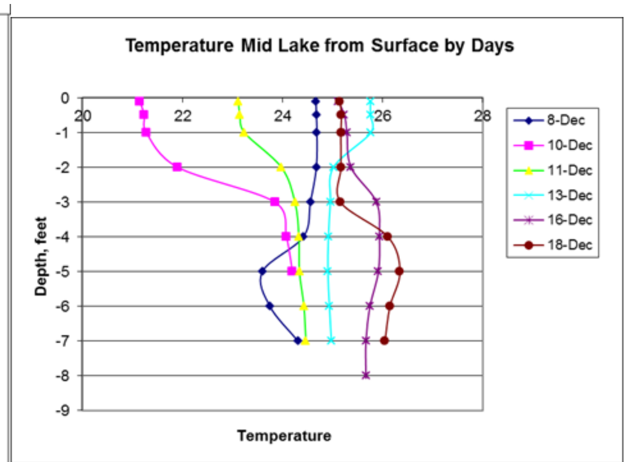


Figure 22. Laboratory results showing the relationship between turbidity and total suspended sediments over time in a water sample. Two graphs on the left depict results of a laboratory test and display the length of time required for erosive sediments to precipitate out of a 50 cm (20-inch) water column. Above graph is from one event taken at increasing distances from the storm water outfall to the opposite side of the pond.

The most visible sign of pollutant loads to the pond is the turbidity caused by suspended sediment load. The relationship between turbidity and sediment load from a construction site is shown in the top right graphic of Figure 22. The most common source of these sediments has been from grading activities on construction sites. As a first estimate the quantity of sediment as measured in milligrams per liter (mg/L) is half the turbidity NTU reading. The graphic (Figure 22) shows the relationship between turbidity and TSS as measured in a set of samples from a single storm event, adjacent to the plume inlet drain (230 NTU) to the opposite side of the pond (15 NTU).





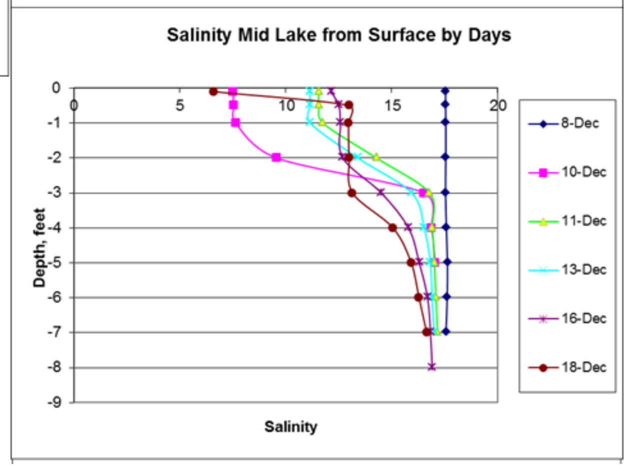


Figure 23. Turbidity, temperature and salinity cross section data from mid-lake taken one day prior and on several days following a large runoff event associated with hillside construction runoff from above the lake.

Following a rainfall runoff event, the estuary displays distinct stratification that slowly mixes over a period of several days to weeks depending upon the magnitude of wind waves. Just prior to and following a significant rainfall event (12/9/2010) water quality profiles of temperature, salinity and turbidity were measured near the center of the lake (Figure 23). The graphics clearly show a well mixed un-stratified waterbody on Dec. 10, transformed by storm water inflow to produce a 2-foot thick layer of low salinity, low temperature, high turbidity (11-17 NTU) water on the top of the estuary. Profiles taken over the course of the following week show the stratification slowly dissipating through mixing but resulting in a generally more turbid pond. Typically the turbidity in the pond following a runoff event involves sequential blooms of phytoplankton and zooplankton over a period of one to several weeks. Note that while the salinity profile appears to take one to two weeks to become un-stratified, the sediment carried in with the fresh water lens as measured by turbidity, disappears within about a day. This is consistent with the laboratory results that show a 75% reduction in TSS within 24 hours (Figure 23).

During one very large rainfall event (9-inches on 12/19/10) the water surface of the 135 acre estuary rose from 1.73 feet to 3.4 feet LMLLW before the sand berm was over-topped and the water began to flow to the ocean (Figure 24). A YSI water quality data sonde on the Lanikai Bridge at the mouth of Kaelepulu Stream recorded a turbidity of about 80 NTU as the estuary fell to an elevation of 0.9 feet (Figure 24). 2.5 feet of water drop across the 135 acre estuary represents about 5.59 x10^9 liters of water. If a turbidity of 80 ntu is equal to a TSS of 40 mg/l (Figure 22) then a first order calculation would suggest that about 22 metric tons of sediment was carried to Kailua Bay during the first period of stream outflow following this storm.

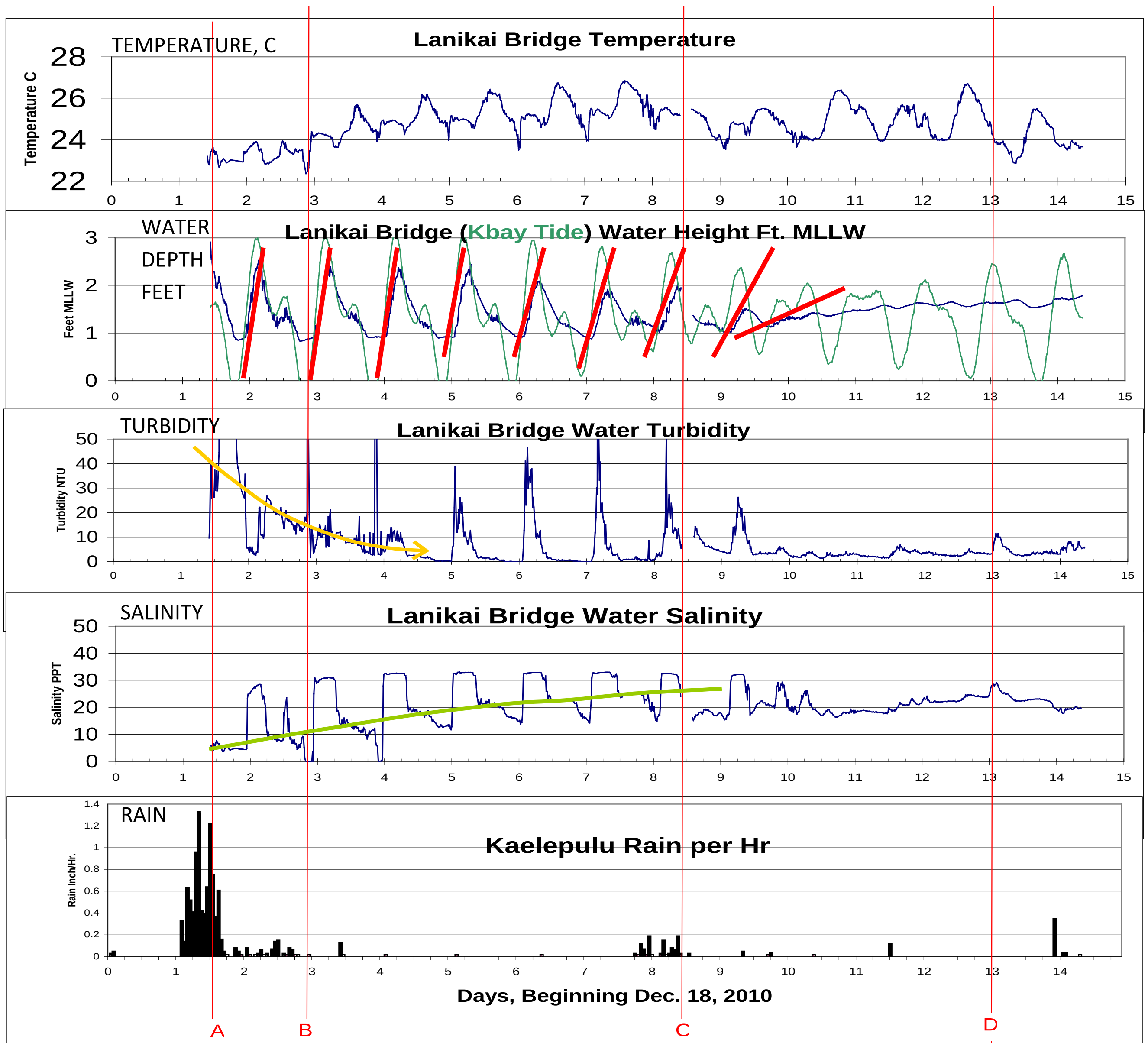


Figure 24. Dynamics of water quality during stream opening following December 18, 2010, 9-inch rainfall event as measured at Lanikai Bridge using a YSI water quality sonde.

In Figure 24 temperature fluctuates with both diurnal and tidal cycles. Water level in stream (blue=stream, green=ocean tide) breached the sand berm and fell to meet high tide (A), then began responding directly to tidal flow through a broad (100ft) opening to the ocean. The rate at which sand re-fills and eventually stops flow is mirrored by the inflow rate as shown by the red lines. Turbidity of the outflowing water was initially 80 NTU and then fell on subsequent tide flows to background levels within about 3 days. Spikes in turbidity during tidal inflow are attributed to entrained bubbles and particulates from breaking waves. Salinity of inflowing water is always near 33 ppt, whereas the salinity of the outflowing water gradually increases over time as the outflowing surface water becomes mixed with the inflowing salt water. The lower graphic shows rainfall during the period of measurement.

The magnitude of sediment that is carried to Kaelepulu Pond as a result of inadequate sediment and runoff controls at construction sites cannot be overemphasized. The difficulty arises because when the sediment is in transit, it is difficult to quantify, and when it is in the pond it is dispersed and out of view. Contractors, when confronted with evidence of a plume in the pond inevitably transition through several standard responses:

- Oh, no, we didn't have any significant runoff from our site. Must be from somewhere else. [Response: Would you like to look at this series of photos showing the runoff coming from your site?]
- You can't say all of that sediment is from our construction site. [Response: Yes, we can. Would you like to see the photos we took in adjacent drainages with clear runoff during the storm?]
- Well, it's really not all that much sediment. [Response: We have taken samples and made runoff volume calculations and can estimate the total quantity as about X tons.]
- No way that's accurate. Besides, everyone knows that lake has been polluted forever, so what's the big deal?

At this point the dialogue diverges differing between the socially responsible and the socially irresponsible contractors, with one dialogue leading to erosion control upgrades and cooperation, the other leading towards legal action.

In the runoff event displayed in Figure 24 we estimate that 22 tons of sediment were washed into Kailua Bay, but we know from sediment settlement calculations (Figure 22) that it is likely that upwards of 90% of the sediment (200 tons) remained in the pond and stream channels. When construction sites have large quantities of land open and inadequately protected from erosion, the quantity of material that is transported to the pond and from there to Kailua Beach over the period of several storms can be highly significant.

In the spring of 2004, a lot owner was conducting filling and grading of a steep parcel. The main drain from the parcel empties at the back of the "wetland" property owned by the de Vries family, who had been in the process of excavating the drainage easement between the end of the drain pipe and the Kaelepulu Stream. The two photos (Figure 25) show the result of a single 4-inch rainfall event that transported and deposited the estimated (8x30x120 ft) 1,000 cubic yards of sand gravel and rock into the excavation. Note that all of the fines, which typically represent at least half of the total quantity, were all washed into the stream and wetland.

Figure 25. Before (left) and after(right) sediment from a City storm drain filled this swale during a single storm. The staff is a 16-foot survey rod.

2.5.Keopa Flood Control Basin

The Keopa flood control basin (TMK 42004048) was constructed (1971-1972?) as part of the Kailua Bluffs development in the early 1970s and the dam deeded to the City for maintenance. The structure intercepts most of the runoff from the upper portion of the watershed and conveys it into Kaelepulu Pond through a concrete lined Kaelepulu Stream (Figure 20, upper right). In a very large (100 year 6 hour) storm the basin may receive runoff as high as 2,322 cfs (almost half of the total flow to Kaelepulu Pond) but limits the outflow to only 397 cfs (ParEn, 1993). In even larger storms when inflow may be as high as 3,665 cfs, the structure will overflow, but still limits the discharge to “only” 2,560 cfs. Although the dam is owned and maintained by the City, the actual basin is privately owned. Within the basin and about 100-feet back from the inner dam- face is a dirt mound (access easement) that is raised two or three feet above the basin floor and running across the width of the basin. This mound serves as an internal retention basin and likely was very effective as a silting basin to capture sediments during runoff events. Unfortunately, a lack of maintenance (this is within the privately owned section of the property) has allowed the formation of two erosional gullies through the mound which negates the effectiveness of this structure to capture sediment. This portion of the basin is also listed as a wetland on the City’s GIS map site, which could greatly complicate the permit process to make repairs to this berm. With minimal alterations to the internal configuration of the Keopa Basin, this structure could be greatly improved to act as an effective sedimentation basin for the watershed.

Figure 26. Top: Looking down the inside Keopu dam face as muddy water pours through the two erosional channels cut through the internal raised berm. Bottom: Inside the basin looking at the back of the dam face with the muddy water flowing into the two flow control structures beneath the dam.

2.6.City Streets as a Source of Physical Pollutants to Lake

Many of the inlets into the pond are fronted by a shallow area of built up sediment. When digging in these areas one often comes across deposits of fine gravel similar to the type used in asphalt. When Keolu Drive was re-surfaced in 2010, measurements of the eroded street surface were made prior to re-surfacing. One square meter of road surface was found to have eroded at least 3 liters of material of which 325 cc's of sand and gravel still remained indicating 2.675 L of erosion. Given that there are 57.5 miles of City roadways in the watershed, the total area of all roads (assumed average width of 34 ft) is about 1-million square meters and the total eroded material is about 2,675 cubic meters of material. This is equal to about 3,000 cubic yards, or 200 ten-yard dump trucks. Assuming this erosion took place over a period of 15 years yields an annual erosion rate from City Roads of about 200 yd^3/year.

Road surfaces are often considered to be sources of heavy metals like Chromium, Lead, and Cadmium due primarily from automobile engine and brake wear. Samples of gravel from the lake below a storm drain after a big storm, another of fresh (hot!) asphalt, and the third sample of 325 cc vacuumed from the road surface all tested at below detection limits for arsenic, cadmium, chromium, lead, mercury, selenium and silver.

Figure 27 Testing for quantity and quality of material eroded from City road surfaces.

2.7.Storm Drain Inflow as a Source of Pollutants to the System

In 2001 Kaelepulu was included in the State of Hawaii's listing of water quality limited segments based upon visual assessment for excessive nutrients, turbidity, and bacterial loads. A TMDL (Total Maximum Daily Load) assessment was initiated in 2004. The effort resulted in several preliminary reports by the University of Hawaii (Babcock, 2004; Babcock 2005), a sewage tracking study by the USGS (Hunt, 2008), a legislative summary by DOH (Penn, 2008) and a water quality sampling study (Babcock and Tamaru, 2012 unpublished). The water sampling effort collected samples and analyzed physical water quality parameters (T,pH, NTU) from 80 surface water sites within the estuary and up to 31 samples from inflows during 14 sample events between 10/26/2009 and 12/20/2010. The surface samples were then composited (~4 samples per composites, 11 samples from within the pond and wetland, and 11 samples from the Kawainui and Kaelepulu Streams) and analyzed for nutrient and bacterial concentrations.. The final report was never accepted by the DOH due to unspecified violations of QAQC protocols. However a copy of the report and data was obtained by ELRA and subsequent analyses conducted on the database. Correlation between variables and GIS spatial analyses (see appendix) provided interesting information but did not greatly assist in understanding the causes of or solutions for decreased water quality within the system. The clearest information was produced by aggregating the whole database (596 samples) by general locations within the system. Figure 28 clearly indicates that City storm drain inlets are a major source of nutrient, bacterial, and total suspended sediment loads to the estuary.

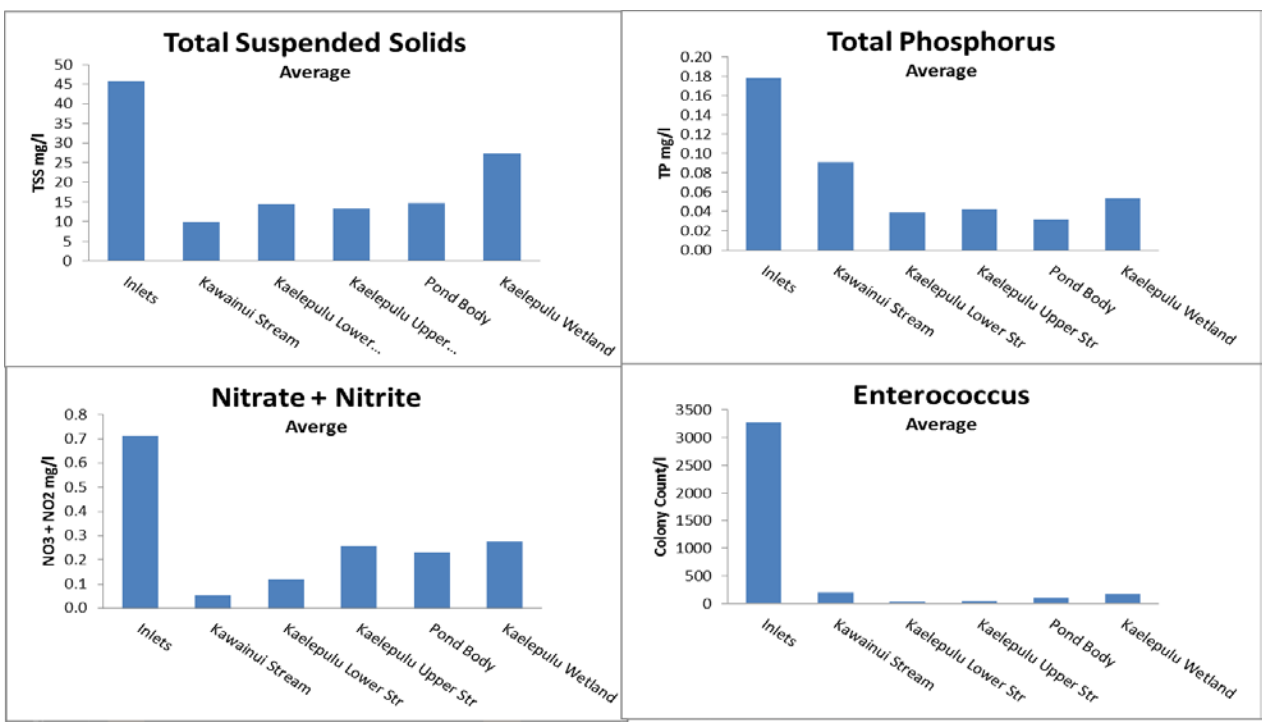


Figure 28 TMDL data summarized by general location within the estuary clearly shows that inlets to the system (City storm drains) are the primary source of nutrients, bacteria, and turbidity to the system.

2.8. Stream Mouth Openings

2.8.1. Why the stream mouth needs to be manually opened

Figure 29 The City uses heavy equipment to open the stream mouth about nine times per year.

The necessity for the City to artificially open the stream mouth likely began shortly following completion of the initial Kawainui Levee in 1966 which deprived Kaelepulu Stream of the flow volume necessary to push sand out of the stream mouth across the beach and into the ocean. Clearing of the stream mouth using heavy equipment often involved merely pushing the sand up and out of the stream to either side, or out into the ocean, although there are persistent rumors that sand may also have been trucked off to other locations such as City golf course sand traps and Waikiki beach. Present day permit requirements stemming from the Clean Water Act prevent the City from pushing the sand into the ocean (as the stream would naturally do) and decree that the sand must be placed above the high water mark. In the 1960s there was little or no dune formation on the beach fronting the stream mouth with residents able to see the horizon and the ocean from Kawailoa Road. Today the sand dunes are 10-15 feet high on both sides of the stream channel. Kailua Beach has historically been accreting sand, growing seaward at a rate of about 1 foot per year – except for the section of beach adjacent to the Kaelepulu Stream mouth which has undergone historical erosion (see UH Coastal Geology, 2016)

Figure 30 1963 aerial (USGS EKM-2CC-246) dated 1-14-63 prior to construction of Kawainui Levee. Note stream flowing across sand beach (a), and wide sand beach continuous around Aala Point and into Lanikai (b). Location of historic stream mouth channel (~1850 nautical chart) can be seen ~1,000 feet to the west (c).

The stream must be manually opened because the deprivation of head-water flow resulting from construction of the Kawainui Levee has not left sufficient natural flow to keep the channel open across the dynamic sand beach. Prior to construction of the levee, the average monthly flow through the stream mouth was about 30 MCF, but since the levee was constructed the flow has only been about 1.5 MCF per month (Figure 18). The channel that evolved to carry 30 MCF is now only carrying about 5% of its average flow. This lower flow rate is not sufficient to offset the quantity of surf-suspended sand that builds up in and quickly closes the channel.

2.8.2. Three functions of stream mouth openings

Artificial opening of the stream mouth serves three essential functions: 1) it decreases flood threat to the community, 2) promotes exchange between Kaelepulu and the ocean and improved water quality in the estuary, and 3) supports fishery resources dependent upon estuary exchange (specifically mullet, and awa that must spend part of their lifecycle in brackish water).

The Park Engineering study (1993) estimated that a 100-year storm would generate flood elevations in the lower Kaelepulu stream of about 3.8 feet MSL (~4.1 ft LMLLW) and that this flood elevation would inundate the ground floors of several house lots located along Wanaao and Kawailoa Roads. More recent observation sets a flood inundation level of 3.3 feet LMLLW based upon bank overflow immediately upstream of the Lanikai Bridge at this elevation. If the sand berm at Kailua Beach is kept lower than 3.3 feet LMLLW then it will overtop and erode away before a flood elevation can be reached.

The secondary reason to breach the sand berm on a regular basis is to improve circulation and exchange within the stream, estuary, and associated wetlands. In summer months when evaporation exceeds inflow, exchange with the ocean at high tide is the only mechanism that will keep the wetlands wet, and prevent odoriferous mud flats from being exposed. Seawater inflow during a stream mouth opening can exchange much more water through the estuary than even very large storms. A 1-year rainfall event of 4.5 inches will raise the elevation of the estuary by 1 to 1.5 feet representing about a third of the entire estuary volume. But if the stream mouth is kept open through eight days at two tide cycles per day (such as occurred February, 2015,Figure 34), the accumulated volume of seawater inflow is 5.5-feet which exceeds the volume of the entire estuary. Of course, much of this water is merely mixed and then flows out on the next outgoing tide (Figure 24) but the effect is still quite positive.

The positive impact of estuary exchange upon local nearshore fisheries is an often overlooked impact of stream mouth openings. In addition to acting as a filter, preventing most of the land-based sediments and nutrients from reaching the nearshore coral reef habitats, the estuary also acts to transform these same nutrients into biological material of importance to the broader aquatic ecosystem. Following a runoff event nutrients are quickly absorbed by fast-growing phytoplankton and macro-algae in the pond. Visible blooms of phytoplankton often begin within days after runoff events or ocean exchange events, and are quickly followed by blooms of zooplankton (primarily copepods and rotifers) feeding off of the phytoplankton. These zooplankton are the primary feed for many larval fish and invertebrates. Larvae of ocean fish that find their way in through the stream mouth (kaku, papio, ama’ama, awa, lae, aholehole, and others) find plentiful food within the estuary. When the estuary is in the midst of a zooplankton bloom and the stream mouth is opened to flow, the feast of copepods and rotifers broadcast out into the bay definitely supports the broader community of larval fish in the bay.

2.8.3. Hydrologic influences that impact stream opening effectiveness

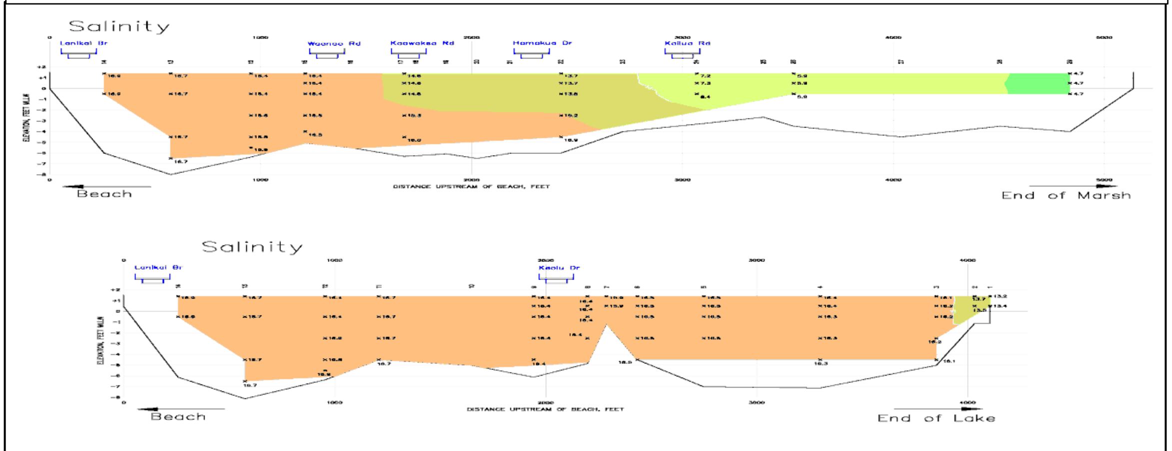
At a water surface elevation of 1.5 ft the system has a total area of about 135 acres and a volume of about 30 million cubic feet (MCF) of water, most of which (22.5 MCF, 90 ac) is contained within the Kaelepulu Pond and wetland (Figure 17).

When the stream mouth is open to the ocean at the beach, low salinity water from the surface of the stream flows out to sea whenever the stream water surface elevation is higher than the ocean. The rate of flow is determined by the size of the channel and the hydraulic gradient (head difference) between the stream and the ocean. The effluent plume from the stream spreads out on the surface of the nearshore waters and is transported either to the left (west) towards the center of the beach, or to the right (east) towards the boat ramp and Lanikai by nearshore currents. On the rising tide the water flowing into the estuary commonly has a salinity of 33-35 ppt – essentially full strength sea water. As it flows into the stream this salt water tends to sink beneath the lower salinity water in the estuary and flow upstream as a classic estuary salt wedge. However, the progress of the salt wedge is blocked at the entrance to the pond by the shallow shoaled channel adjacent to the City's Hele drainage channel (Figure 17) (Figure 33). As this flow is blocked, the Kaelepulu stream channel tends to fill up with higher salinity water, pushing the low salinity water back up and into the body of the pond. This submerged berm in the stream channel greatly reduces the efficiency of water exchange and circulation within the body of the pond.

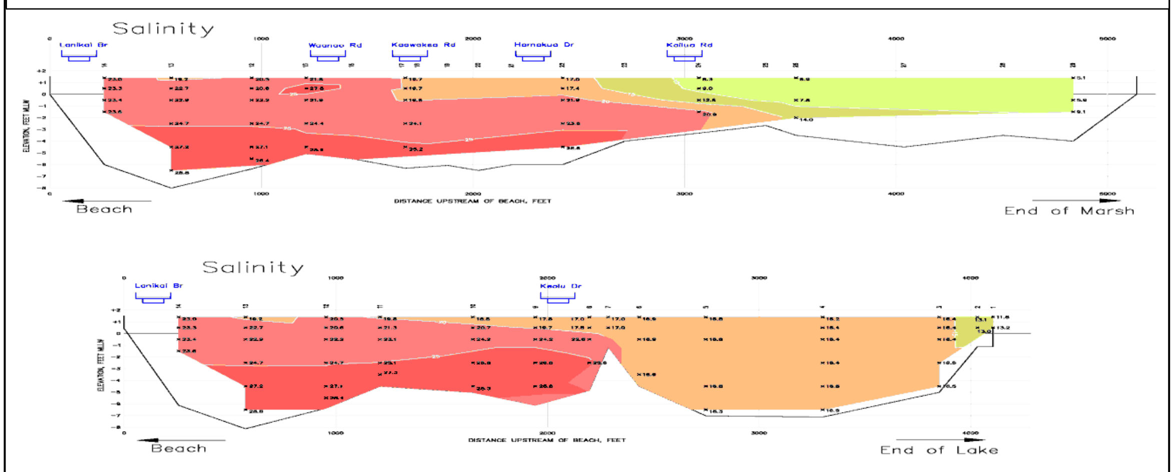
The impact of this submerged berm upon water circulation is demonstrated in Figure 33. The figure shows salinity cross sections through the Kawainui (top) and Kaelepulu (bottom) branches of the estuary. The top pair of cross sections represents a period of time without significant rainfall to the well mixed estuary. In the middle figure the stream mouth has been opened allowing ocean water (red) to flood into and across the floor of the estuary. Note how the water of high salinity is stopped by the submerged berm and does not enter the main portion of the pond. In the lower pair of cross sections, the stream mouth is closed at the beach, but rainfall has lowered the salinity of the surface waters and depressed the salt wedge in the estuary.

As the denser seawater slowly fills the fresh and brackish water stream channels, it eventually overtops the submerged berm at the mouth of Kaelepulu Pond and then falls into the bottom pond basin. The volume of the streams (at 1.5 ft elevation) is roughly 7.5 MCF. Assuming the stream channels need to be half full of dense sea water to overtop the submerged berm and flow into the main body of the pond, this would be a volume of 4 MCF, or equal to about a 8-inch (20 cm) rise in water surface elevation from a tidal inflow. Any inflow events less than 8-inches are not likely to effectively pump sea water into the body of the pond. Figure 35 shows a cross section of the estuary showing the percent exchange from a typical opening event (top) and the desired modified flow and exchange pattern expected following removal of the shallow berm in the Kaelepulu Stream channel.

Before opening event, well mixed water profiles. Top: Kawainui Stream Bottom: Kaelepulu



After minor opening event the flow of the salt wedge to the pond is blocked by shoal



Rainfall runoff forms a new stratification within the estuary.

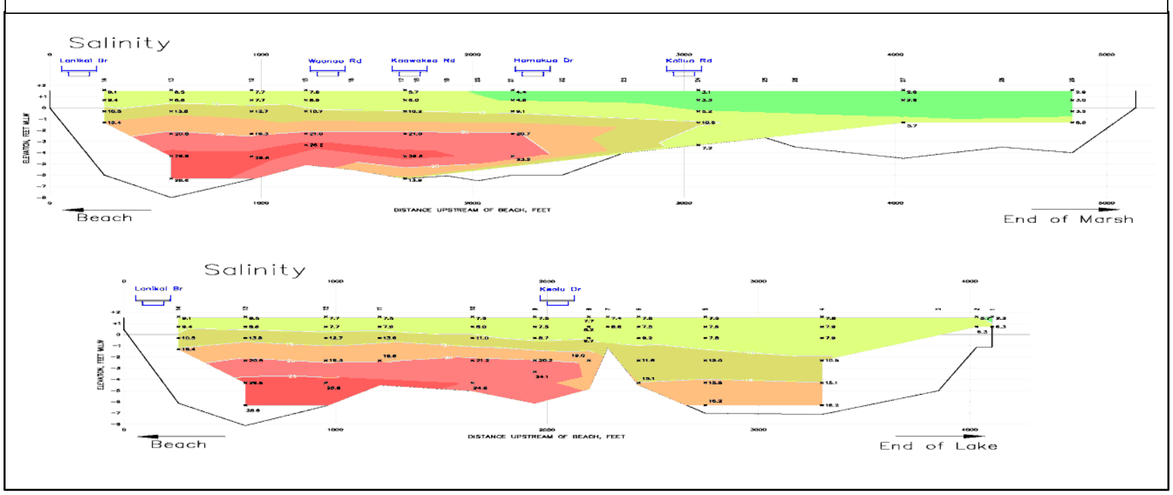


Figure 31 Water quality cross sections of Kawainui (top, each pair) and Kaelepulu (bottom of each pair) before (top) and after stream mouth opening (middle), followed by inflow from rainfall (bottom).

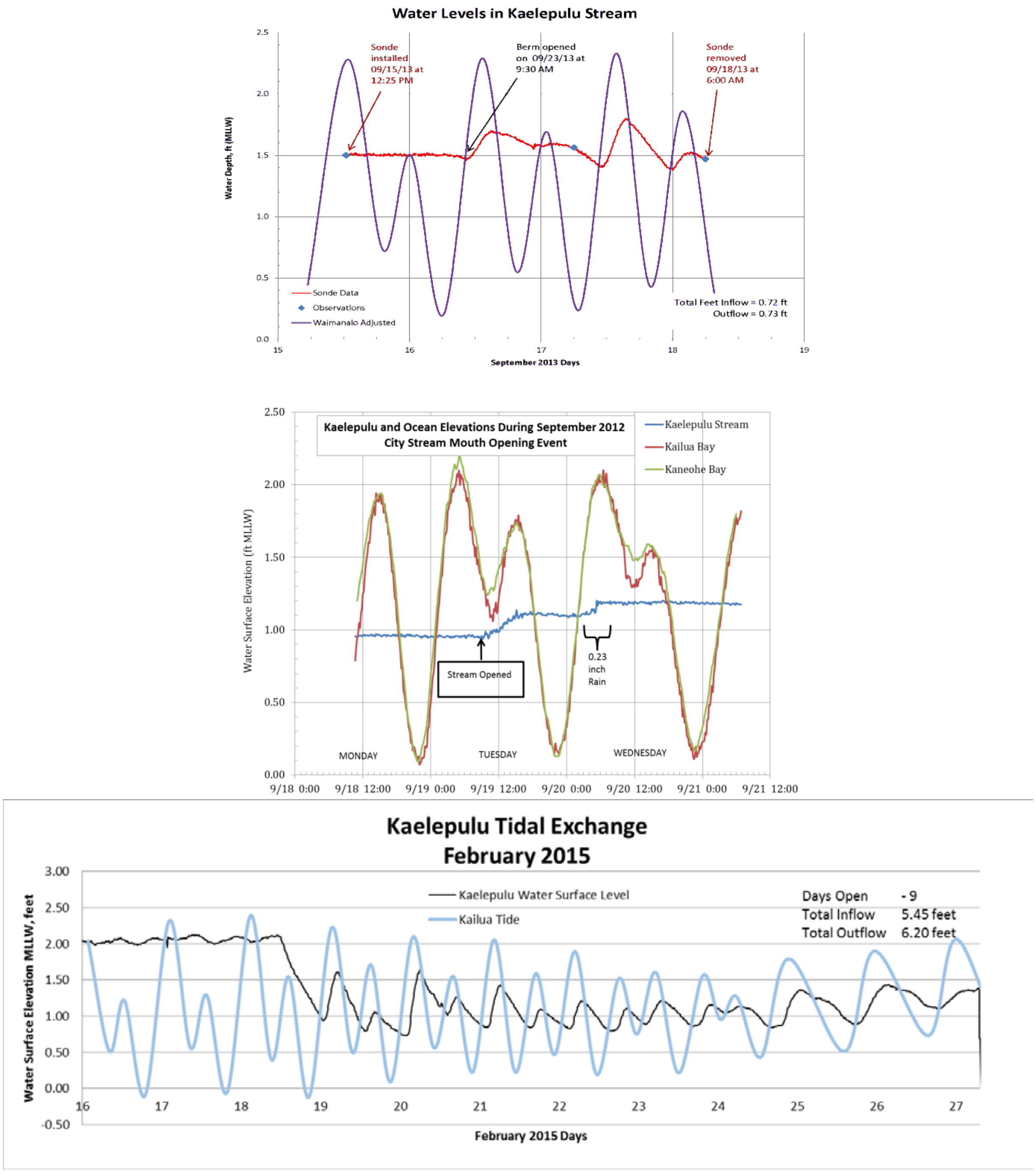


Figure 32. Stream mouth openings initiated by City heavy equipment operators vary greatly in the quantity of resulting exchange. Openings made with only a short outflow period until the incoming tide (top) or those openings made when the sea level were higher than the stream (middle) were not effective. Openings that produce greater exchange are the result of a high initial water surface elevation, high amplitude tides, and the timing of the openings to produce a long period of initial draw down. It is presumed that the long period of initial drawdown served to erode a larger channel through the beach which then requires more time to close over several tidal cycles.

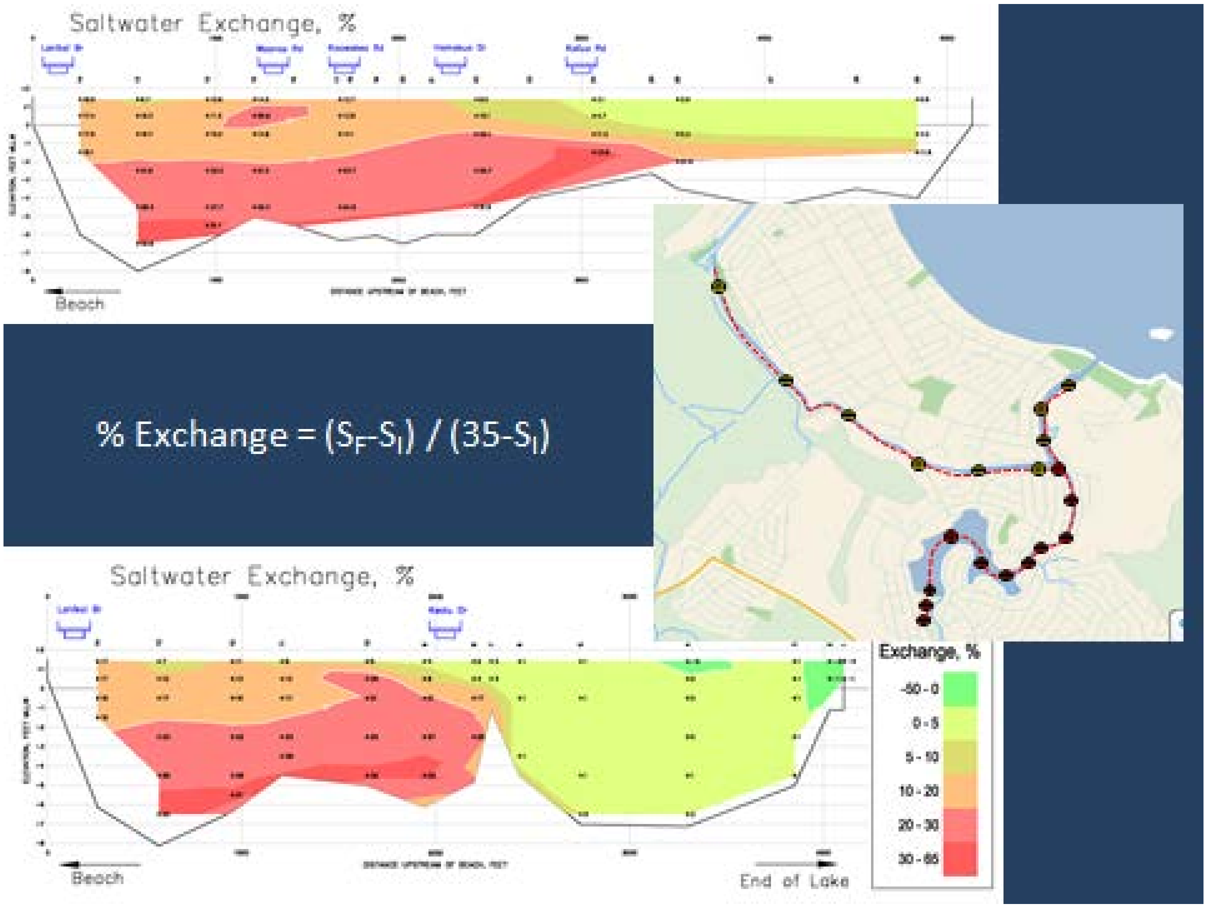
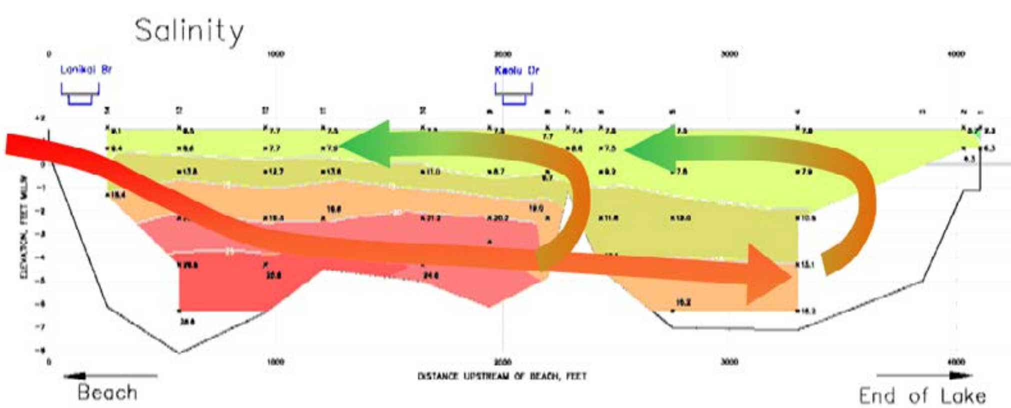


Figure 33 Top: Results of percent exchange calculations, based upon salinity changes following one stream mouth opening event. As expected the greatest exchange occurs nearest the stream mouth, however it is also evident that the shallow area in Kaelepulu Stream (lower graphic) is a significant block to effective water exchange. Bottom: Removal of this obstruction by dredging will allow the inflowing salt water to penetrate all the way into the body of the pond, greatly improving total circulation.



During periods when the stream mouth is open to flow, channel erosion and widening occurs if the water flow speed exceeds about 3 feet per second. At speeds above about 5 feet per second there is significant fluidization of the sand bed and very rapid erosion and channel widening occur. The rate at which the channel closes itself is dependent upon the size of the initial opening at the end of the initial draw down, the size of waves generating suspended sand particles in the stream mouth surf zone, and the height of the incoming tides governing flow speed through the channel. Flow speeds less than about 3 ft/sec allow suspended sand to precipitate and fill the channel. Experience has demonstrated that the best time for the City to open the stream channel is on a low low falling tide several days prior to the highest tides of the month. If done properly, this maximizes the initial water head and duration of outflow and allows the outflowing water to erode a channel of significant width and depth. This wide and deep channel then stays open on subsequent inflow events if the inflow velocity remains near or above 3 feet per second across the sand bar. The eroded sand stays in the Kailua Bay system and is eventually re-deposited on the beach. The series of photos in Figure 30 show an initial 15-foot wide, 1 foot deep channel created by the City's bulldozer widening to a 30 foot wide 3 foot deep channel in about an hour and fifteen minutes. A half hour after the final photo the channel was 50 feet wide. The City had attempted to open the stream four hours prior (10 am) and were not successful because of a high tide. Timing openings with the tide is very important.

The City has assumed responsibility for opening the stream mouth sand berm since at least the early 1970's. While the City maintains that they conduct these openings primarily as a flood threat reduction measure, the City's storm water agreement with Bishop Estate clearly states that the City will be responsible for maintaining the drainage "to the sea" and will "keep open, all inlets to Kaelepulu Pond and the outlet from said pond."(Kaelepulu Pond Drainage Agreement Liber 4506 pg 95-96).

Figure 34. October 2014 the City responded to a high water surface in the pond and an impending rainstorm to conduct an "emergency" opening of the stream mouth. Flow established in a 1-foot deep 15 foot wide channel completed at 16:15 developed into a 30-foot wide 3 foot deep channel in about an hour and fifteen minutes. Within minutes of the last photo the cameraman had to abandon his location as the bank was eroding from beneath his feet.

2.9. Long Term Tidal Sea Level Changes Impact to Pond Elevations

Over the years the elevation of the pond when the stream mouth closes to the sea has varied from as low as 1.05 feet to as high as 2.00 feet, MLLW. Much of this variation is likely due to tide, wind, and wave characteristics specific to the opening event, however, there appears to be a longer term trend based upon decadal variations in sea surface levels as documented by Thompson and Marrifield (2015). This trend will have long term management impacts as during the 5-year period when sea level is low (next 2019-2024) when the pond will tend to fill to just over the 1-foot MLLW elevation. At this elevation, much of the wetlands are dry and odoriferous mud banks tend to be exposed. The average monthly sea level as measured in Kaneohe Bay from 1990 until 2017 is shown below at the top of Figure 35. The lower portion of the figure demonstrates the tide much higher (0.5 to 1.1 foot) than predicted during a stream mouth opening event in May, 2017. During the event the pond elevation started at 3.2 feet and ended 13 days later at 2.0 feet. Beginning around 2019, the opposite effect could be seen with actual tides much lower than predicted filling the lake to unacceptably low water surface elevations.

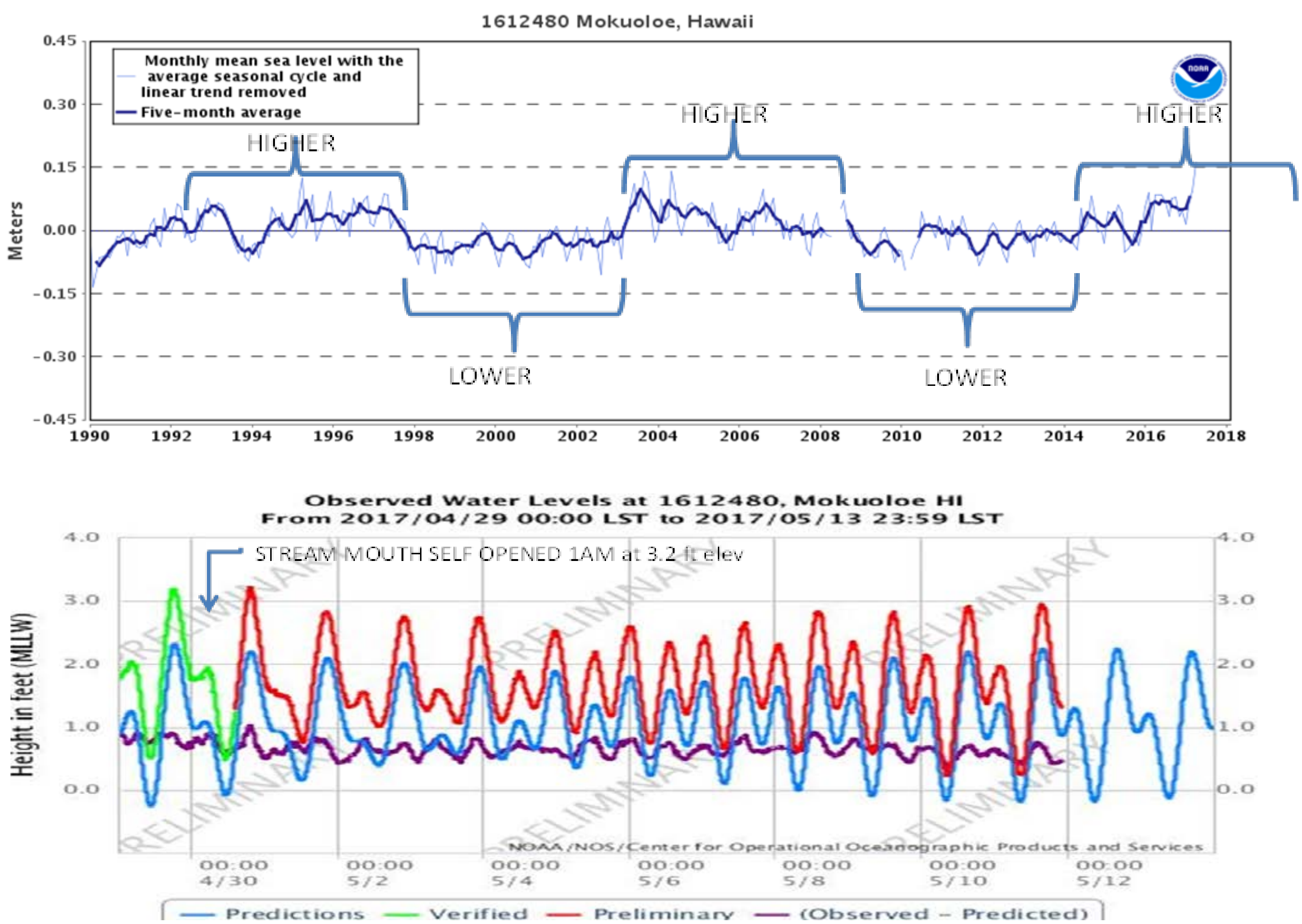


Figure 35. Long term variations in average sea level (top) can result in sea levels very much different from what is anticipated. Lower graphic predicted tide is in blue, with measured in red and green.

2.10. Mangrove Removal from Kaelepulu Pond and Stream

Beginning in 2000, work began towards the removal of the many hundreds of seedling mangroves beginning to grow in the shallows of the Kaelepulu Wetland. The area had been cleared of mangrove during construction of the mitigation wetland and adjacent homes but was rapidly being re-seeded from adjacent mature mangle within the pond. The seedlings were the result of two major (and numerous minor) mangle patches in the pond covering an area of about 2.5 acres. In 2003 the ELRA received a 319-grant from the Department of Health to remove mangrove from the pond. The bulk of the money was spent to hire two separate companies to physically remove the two large mangle forests from the pond. As the largest mangle was growing on the last remaining undeveloped shoreline, still owned by Kamehameha Schools, they also contributed to the cost of the removal, and have since maintained their 2-acre wetland parcel free of mangroves. Over a period of about two years volunteer work crews removed the balance of mangrove growth around the perimeter of the pond and re-trimmed the thousands of seedlings that sprouted from the remnant roots of the removed mangle.

In 2008 the ELRA and Kailua Canoe Club were joint recipients of a grant from the Hawaii Community Foundation and Kaneohe Ranch to clear mangroves from the mile-long Kaelepulu Stream between the lake and the ocean, and from the lower 1/3rd mile length of Kawainui Stream above its junction with Kaelepulu. Upon completion of this task, the canoe club was awarded a new racing canoe valued at about $20,000 (Figure 35).

Figure 36. Mangrove removal from Kaelepulu and Kawainui Streams by the Kailua Canoe Club earned them a new racing canoe from the Harold Castle Foundation

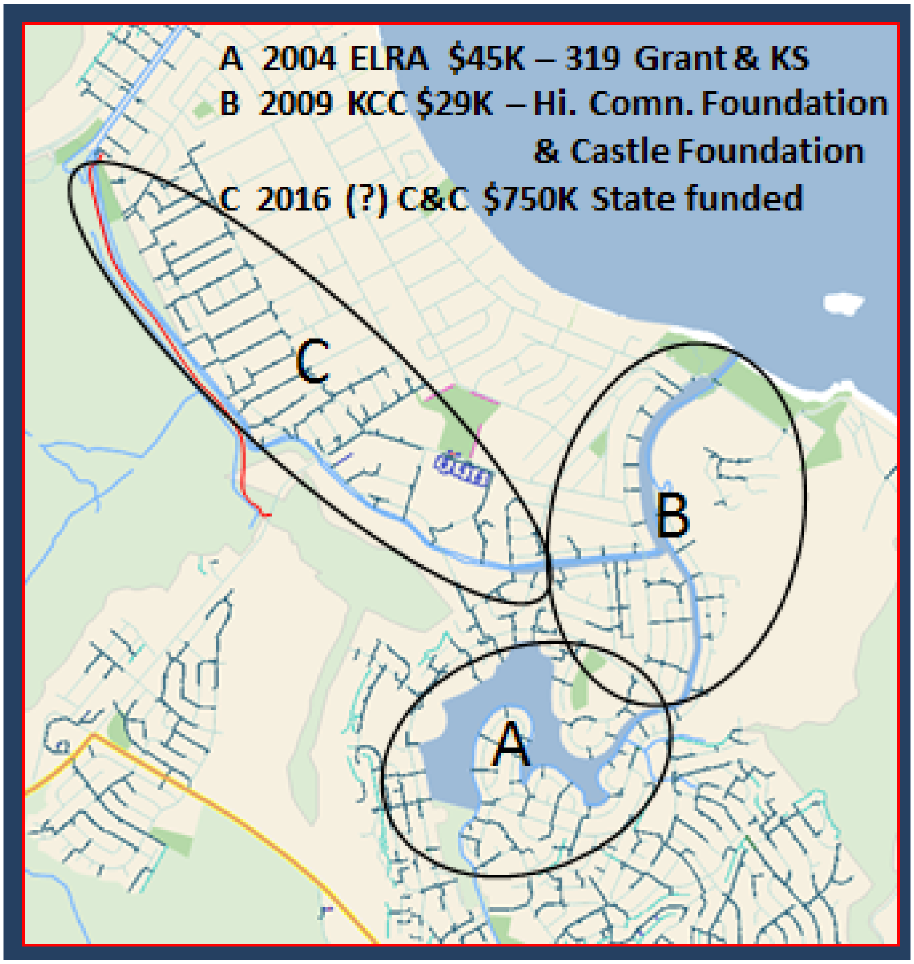
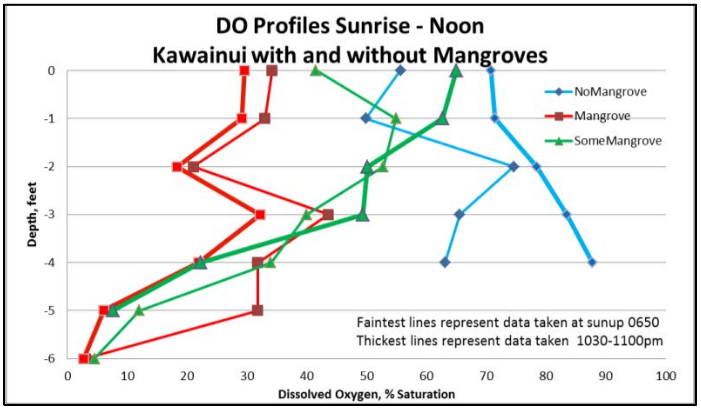


Figure 37 Mangrove removal efforts in the pond, the lower reaches of Kaelepulu and Kawainui Streams have been conducted with grant funds and a good deal of community effort. Removal of the large mangle in the upper Kawainui reach is pending funding from the State and City and is anticipated to be completed in 2017.

In 2010 as the Kailua Canoe Club removal of mangrove in the lower Kaelepulu was being completed, it became clear that the very large stands of mature mangrove clogging the upper Kawainui Stream were rapidly reseeding the estuary and were much too large to be removed through community effort. During the following State Legislature session $750,000 in State funding was obtained to pass through to the City to allow them to remove the mangrove. As of March, 2017 bids to remove mangrove from about half of Area C have already exhausted available funds and an additional $800,000 has been allocated by the City Council to address this problem.

The adverse impact of mangrove upon water quality is clear. The impact upon dissolved oxygen and pH was demonstrated along a short reach of Kawainui Stream where the stream transitions from open water, to a section recently (2 years) cleared of mangrove, to a section completely overgrown with mangrove. Depth profiles of dissolved oxygen and pH taken in the early morning and again at noon show the persistence of low oxygen and pH within the mangle (Figure 37). The poor water quality in the area recently cleared of mangrove is attributed to the persistence of the roots and trunk systems that remain below water for several years following removal of the aerial portion of the plant. In addition, the mangle shades and crowds out native flora and fauna and provides roosts for non-native birds, in particular large flocks of cattle egrets. Fecal material deposited within the mangrove fuels anaerobic conditions and a number of these non-native birds prey upon endangered native water birds dependent upon adjacent wetlands.



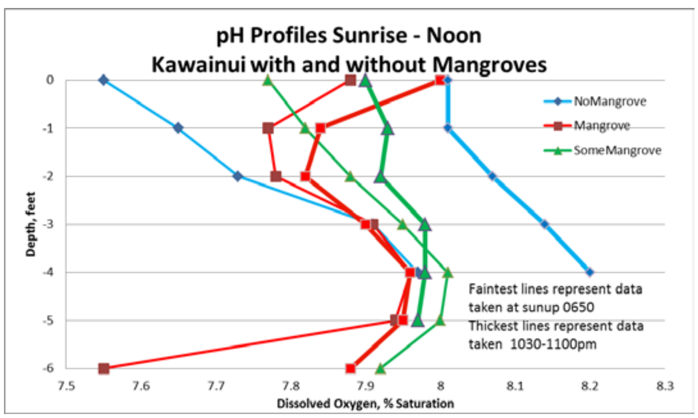


Figure 38 Dissolved oxygen and pH profiles obtained in Kawainui channel at dawn and again at noon at three locations 1) in the midst of mature mangrove growth, 2) in an area where mangrove had been removed two-years prior, and 3) in an area with no mangroves. These graphics depict the adverse impact of mangroves upon dissolved oxygen and pH. Consistent with similar results obtained in Pearl Harbor, the ability of mangroves to adversely impact oxygen and pH water quality exists long after their removal, likely due to the presence of the massive root systems which are not typically removed when the trees are cut.

3. Fisheries

The pond supports populations, in rough order of prevalence, of tilapia, gobies, milkfish, mullet, barracuda, papio, and lae. The papio (*Caranx ignobilis*) is a recent addition, first noted in the late summer of 2013 as small (4-6") juveniles, and presently (4/2017) as (12-24"") 10-lb+ adults. The milkfish (Awa, *Chanos chanos*) occur in schools of 10's to a few hundred sub-adults (12-24") grazing on the macro-algae beds of Gracilaria (Figure 40) in shallow water. When the stream m outh is open, these Awa awa are targeted by throw-net fishermen near Lanikai Bridge. Barracuda are plentiful in the lake and are avidly sought by fishermen, most of whom release their catch. Sizes typically range from 24-39", but individuals approaching 72" have been reported (and personally seen by the author). The large barracuda in Figure 38 were all killed by a low oxygen event associated with overgrowth of macro-algae in the pond. The macro algae growth was likely stimulated by the inflow of sediments and associated nutrients from an upslope development grading project.

Figure 39 Recreational fishing, often catch and release, is popular in Kaelepulu Pond

Figure 40 Large barracuda are common the in pond, these died due to an algae bloom. Awa awa schools feed almost exclusively on the macro *algae Gracilaria tikvayahe* as seen in the right hand photo.

Figure 41. The use of gill nets is prohibited in the ELRA and Kaelepulu Wetland portions of the estuary. The 10-pound Awa in the top photo provides a good rationale for this prohibition. Samoan crabs can reach sizable dimensions in the estuary. Since 2014, papio have been becoming more prevalent in the pond. By 2017 these papio had reached ulua (10 lb) size within the system.

Gobies (o'opu akupa, *Eleotris sandwicensis)* are abundant, but not often observed in the pond. They are commonly caught by net in the shallows. On one occasion (11/25/05)., during what appeared to be an algae bloom low-oxygen event, thousands of gobies were seen at the surface and many hundreds died.

Nutrients entering the system from the surrounding watershed coupled with the inflow of ocean water fuels the growth of phytoplankton and zooplankton which, if they don't result in low-oxygen fish die-offs, fuel the growth and reproduction of an impressive crop of fish within the pond. The crowds of pole fishermen, throw-netters, and (illegal) gill netters that vie with each other for the fish leaving the pond on every stream mouth opening are testament to the vitality of the fishery.

4. Conclusion and Recommendations

The Kailua Waterways, consisting of the truncated branch of the Kawainui Stream, the Hamakua Wetlands, the Kaelepulu Stream, Kaelepulu Pond, and Kaelepulu Wetland, are a much modified but vibrant ecosystem innervating the communities of Kailua and Enchanted Lake. Over the past century, both systems transitioned from bountiful open water fish ponds, to irrigation sources for taro, rice, and sugar farmers, and by the mid-twentieth century into swamps choked with alien vegetation acting as receptors for sewage. The watershed was cut in half by construction of the Kawainui levee, and then the area of Kaelepulu Pond was halved by filling the perimeter of the pond for home lots. Yet, both systems retain ecosystems that support recreation, wildlife and fisheries. With the advent of the Clean Water Act and recognition of the value these systems bring to the broader community, a number of studies and projects have pointed the way for the restoration of these ecosystems.

The primary challenges facing the Kaelepulu estuary are six-fold:

1) restoring partial flow to the Kawainui Stream from Kawainui Marsh,
2) maximizing ocean exchange through the stream mouth through monthly openings, scheduled to coincide with appropriate tides,
3) riding the estuary of <u>all</u> invasive mangroves,
4) effecting control over sediment loads from construction sites,
5) improving penetration of the salt wedge circulation into the main pond by dredging a short section of Kaelepulu Canal near the mouth of the pond, and
6) retrofitting the City storm drains to prevent introduction of gross pollutants into the pond.

Loss of historical flow from the Kawainui watershed has caused the Kawainui Stream branch to become stagnant. Prior to the levee construction, 1966, this stream carried an average of 28.5 MCF per month to the Kaelepulu Stream and out into Kailua Bay. Under present conditions, unless there is active rainfall, the flow is essentially zero. Trial restoration of 2 CFS flow (Oceanit, 2016) demonstrated the positive ecological impact of restored flow and the absence of any measurable increase to flood threat.

The City has periodically opened the Kaelepulu Stream mouth through the sand berm at Kailua Beach because, according to its drainage agreement with the pond owner, it is responsible for maintaining the drainage of Kaelepulu Pond to the sea and because it is a good flood threat minimization measure to keep the top of the berm lower than the flood elevation. Observations made of numerous opening events show a broad range of both effort and effectiveness of the openings. The most effective openings tend to be a few days before peak tides (new or full moon), a few hours after high tide when the level of the ocean drops below the level of the stream. This allows both a long period of outflow and the highest hydraulic gradient as the ocean falls to its low-low tide. Narrow deep openings are more effective than wide shallow openings. The most effective openings are accomplished by excavation of a relatively deep (~3 ft) narrow (~10 ft) channel. This maximizes the hydraulic radius of the initial opening and allows the subsequent stream flow to erode the bulk of the sand into the nearshore ocean where it re-deposits upon the adjacent beach. To minimize flood threat, it is not necessary to open the stream mouth to flow, but merely to lower the sand dune level a few inches below the 3.3 ft MLLW (3.0 ft MSL) flood elevation.

Mangroves have proven to have very negative impacts upon nearshore ecosystems in Hawaii. Removal of mangroves from the Kaelepulu portion of the estuary resulted in marked improvement to ecosystem quality and decreases in the incidence of malodorous events. It is critical that ALL of the mangroves are removed from the system to eliminate the constant source of re-seeding from existing mature trees.

Silt loads from construction sites with open grading have been highly significant sources of pollution to the system over the past two decades. The nitrogen and phosphorus carried in 1 pound of top soil is sufficient to grow 100 pounds of algae in the pond. Most construction sites have only minimal BMPs designated in their permits, and most do not even follow these. Even when BMPs are followed, however, there is still a very significant (many tons) of sediment that often makes its way off the construction site into City storm drains and into the estuary. The Keopu flood control basin used to act as an effective silt trap but has been allowed to degrade to a point where it no longer serves this function. It is not right that the owners of the pond must pay for the inability of contractors to control their sediment loads. If the City can't force contractors to keep sediments on their construction sites, then it is likely that this issue will be raised on future federal NPDES permit applications.

Because of the shallowing of the Kaelepulu stream near Hele Channel and its junction with the pond body, the dense salt water entering from the ocean does not typically flow all the way into the pond, but mixes within the canal and flows out again on subsequent outgoing tides. This shallow spot has likely been in existence since 1963. Removal of this shallow sill by dredging will allow the inflowing water to enter and fall to the bottom of the main pond, with less saline surface water draining out to the ocean on subsequent outgoing tides. This would both greatly improve the actual exchange and increase the salinity of the pond – likely to the point where it will again support oyster growth to improve water quality and more robust fisheries.

In the final analyses, most of the water entering the system does so through the City storm water drain system, which operates under the Federal non-point source discharge elimination system (NPDES) permit and is subject to Federal Clean Water Act and State Department of Health water quality regulations. While much of the pollutants originate from non-City sources (with the major exception of road surfaces), the City is still responsible for the pollution loads that come out of the end of the pipe into the estuary. The State began a total maximum daily load (TMDL) study of Kaelepulu in 2003, and funded a number of studies up through 2010 but has never completed the process. The City conducted a storm water BMP study (AECom, 2008) and then rejected the key BMP recommendations of the report to filter gross pollutants from several of the major open channels entering the system. Completion of the State TMDL will very likely put pressure on the City to upgrade its drainage system. It is imperitive that the City complies with the terms of its existing NPDES permit (2016-2020). This permit has many requirements for improved pollution prevention including a gross pollutant (trash and particulates) reduction limit of 50% by 2024 and 100% reduction by 2030.

The systematic solution to each of the above problems will greatly contribute to the restoration of the Kaelepulu and Kawainui Stream ecosystem, improve water quality, enhance fisheries and increase the level of ecosystem functions and services provided to the surrounding community and nearshore waters of Kailua Bay.

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Appendix A
Summary of Previous Studies

1. Park Engineering Flood Study 1992

Park Engineering completed a flood study in 1992, three years following the 1989 flood event that overtopped the Kawainui flood levee. The study concluded that the Kaelepulu Pond acted as a flood detention basin with a flood elevation of 3.8 ft MSL impacting homes in low lying areas nearest the shoreline. The presence of mangrove along the channels was noted to decrease the flood flow capacity of both the Kaelepulu and Kawainui streams and had resulted in significant shallowing of the Kawainui Branch. The only shallow portion of the Kaelepulu branch was the submerged berm at the entrance to Kaelepulu Pond.

As part of the preparation for proposed dredging of the Kawainui Stream behind Kailua AECOs in 1991 sampled five surface water stations between Kailua Bridge and the Kaawakea Bridge in the Kawainui Stream adjacent to Hamakua Wetland as part of an environmental assessment involving development of these lands for housing. One set of samples was during dry weather and the other following rain events.

2. University of Hawaii – Water quality & Bacteriology, Fujioka et al.

A series of studies were conducted by the University of Hawaii in the early 1990s in response to public outcry concerning potential pollution of Kailua Bay from the Kailua Waste Water Treatment Facility ocean outfall. These studies include works by Anuna and Fujioka, 1993; Roll and Fujioka, 1993; Moravcik and Heitz, 1993; Krock and Fujioka, 1993, and Fujioka, Wu, and Fujioka, 1993) Conclusions of these studies where they touched upon Kaelepulu Stream include:

- Recreational water quality standards in Kailua Bay are exceeded when Kaelepulu Stream is open to flow.
- Kaelepulu Stream salinity is subject to ocean water inflow and should be considered as an estuary, not a stream system.
- Water quality standards for streams were always exceeded in the Kaelepulu Stream and Pond.
- The primary source of indicator bacteria were sewage discharges and duck feces, with lesser input from source waters, soil and storm drain runoff.
- Nutrient loading was suspected in the Hele ditch, in the Kawainui Stream, and in the pond adjacent to the City sewage pump station on Akumu Street.

3. University of Hawaii TMDL Studies Tamaru & Babcock

The Department of Health allocated funds to UH for the performance of several studies including

- Kaelepulu TMDL Scoping Study, 2005 in which previous reports are reviewed and an overall analyses of the watershed conducted to better understand the scope of work necessary to be completed to achieve a TMDL
- Kaelepulu TMDL Sampling and Analyses Plan (Draft,2005; Final 2009).

- Kaelepulu TMDL Progress Report, 2011.
- Kaelepulu TMDL Water Quality Monitoring Report. 2012 A compilation of over a year of monthly sampling events, rainfall monitoring and water surface elevation measurements from sites spread across the entire water body. Report was rejected by DOH for alleged mis-handling of sample quality control. The data from the almost 600 nutrient and bacteriological analyses were obtained from the authors and is included at the end of this report. Date reduction showed little correlation between variables. GIS graphical analyses of the data proved intriguing, but did not yield significant insights. The simplest analyses, graphing the data grouped by general location proved to be the most insightful and demonstrated that the large majority of nutrients, sediments, and bacterial loadings were simply entering the estuary through storm drain outfalls. This graphic is shown at the end of the TMDL data set in the back of the report (pg 69).

4. Kailua Bay Advisory Task Force – KBAC – 2003 Draft Kailua Waterways Improvement Plan

5. Kailua Bay Advisory Task Force - KBAC – 2007 Koolaupoko Watershed Restoration Action Strategy.

6. University of Hawaii PCB study – 2003

Funded by KBAC, the University of Hawaii was tasked to describe the bathymetry and currents within Kaelepulu Pond, and to investigate the potential buildup of PCB contaminants in fish within the estuary. A single bathymetry cross section was conducted through the pond and salinity profiles conducted along the transect identified both the shallow sill at the pond entrance as well as its effect in blocking the salt wedge penetration into the pond. Sufficient quantities and sizes of fish were not able to be captured to conduct most of the tissue studies planned. PCB analyses conducted on the limited samples obtained (1 barracuda) showed levels of PCBs in the fish tissue with extremely low concentrations – about the same as can be detected in butter obtained from any grocery store. The UH report, purporting to have documented the presence of contaminated fish within the estuary, was reviewed and rejected by the State Department of Health (DOH).

7. DOH Legislative Report 2006-2008

The State DOH listed the Kailua Waterways (Kaelepulu + Kawainui Stream) as “water quality limited segments” in 2002 and began the TMDL study in 2004. This report authored by D. Penn reviewed the findings of the first several years of effort by the DOH and provides a good summary of the challenges involved.

8. TEC sediment cores – for City drainage study.

The City conducted a planning study of the watershed to determine the best approach for management of effluent through the drain system into the pond and associated streams (AECom, 2008). This study identified the four channelized drains to the pond as likely candidates for the installation of physical best management practice devices. A follow-up study is being conducted to better understand runoff and pollutant loading characteristics of the storm sewer system and to develop plans for physical BMPs

9. USGS Sewage Tracer Study – 2006 Bill Hunt

Hunt, 2008 with the USGS on contract to the State DOH as part of the TMDL program collected a series of samples at 41 stations throughout the watershed and measured 71 trace contaminants typically linked to sewage contamination. As part of the investigation, water quality nutrient sampling was also conducted at seven stations along the Kaelepulu Stream, eight stations along the Kawainui Stream, eight stations within the main body of Kaelepulu Pond and four stations within the Kaelepulu wetland. The only contaminant detected above laboratory analyses detection limits was caffeine, at three locations as depicted in Figure 40

Figure 42 Sample sites where caffeine was detected in surface waters, with overlay of local coffee houses.

10. Kailua Waterways. Report to the 24th State of Hawaii Legislature (2008).

A very thorough, but highly biased, report authored by Dr. Penn as (then) the head of the State of Hawaii DOH TMDL program. The 2006 legislature, perceiving a lack of progress on the TMDL study of the watershed initiated in 2002, the 2006 requested summarizing information from previous reports and studies related to the Kailua waterways (Kawainui Stream, Kaelepulu Stream and Pond). The report incorrectly assumes that Kaelepulu is a pollutant source (not as an estuary ecosystem) and focuses upon the multiple potential sources of pollutants to the system and theoretical ways to control these pollutant sources. The report then goes into great detail concerning the State water quality standards, the types of systems to which these apply, and how the Kailua Waterways do not meet these standards.

One of the recommendations of the report is to evaluate the possibility of restoring flow from Kawainui Marsh to Kawainui Stream.

11. Summary of Previous Water Quality Nutrient Studies

Previous investigations of water quality within the Kailua Waterways have been conducted by

- Fujioka and Roll, 1993 primarily measured bacterial loads, but also collected nutrient samples in the Kaelepulu and Kawainui systems.
- AECOS, in 1994 collected water quality data from the Kawainui Stream adjacent to Hamakua wetland for an EA to develop
- Bourke, in 2004-2006 primarily collected turbidity and TSS data, with limited nutrient data, associated with multiple drainages entering the Kaelepulu system
- Hunt, in 2006 as part of the USGS study funded by the DOH TMDL program (nutrient data included below)
- Tamaru, in 2009-2010 as part of the State DOH's TMDL program for Kaelepulu compiled monthly samples from over 40 surface water stations spread throughout the estuary.

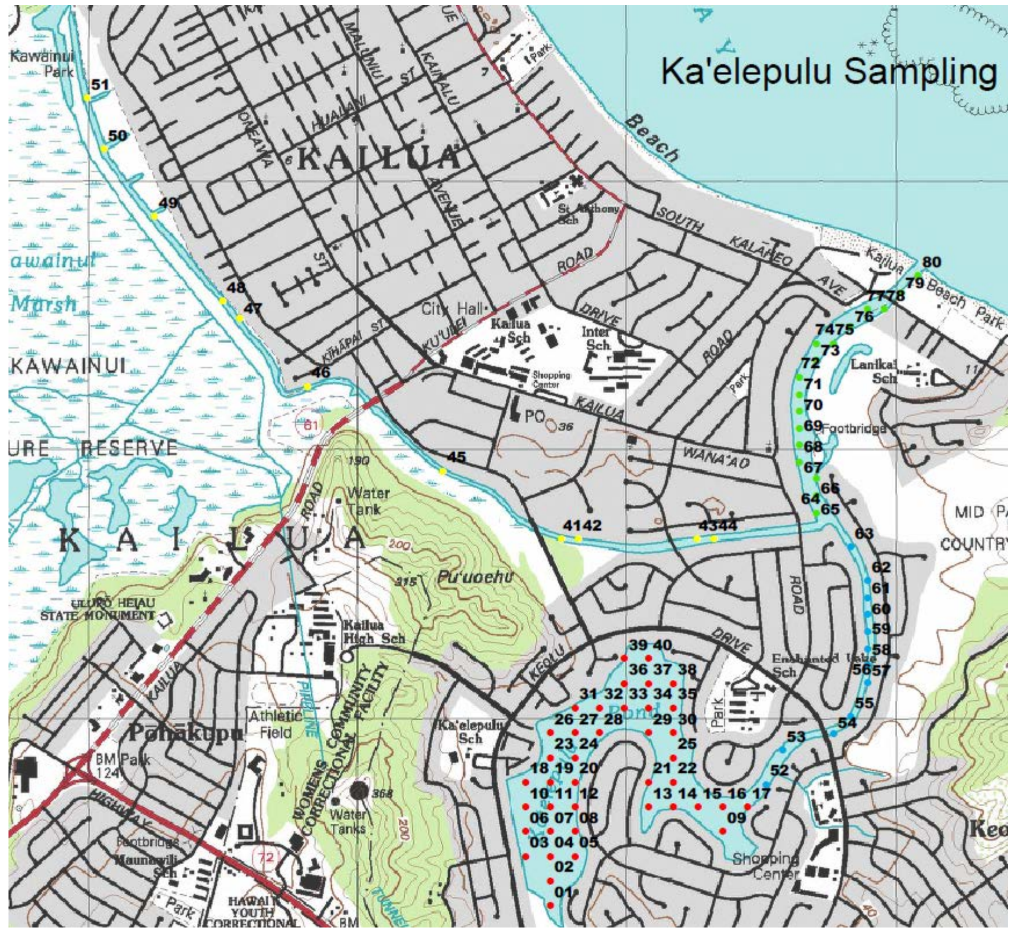
Location Sorted Data from USGS 2008

	System	Descriptor	site_no	sample_dt	sample_tm	p00095 Conductivity	mg/L Ammonia N	p00608 Ammonia N	Ammonia NH4	p71846 Ammonia NH4	mg/L N03+NO2 as N	p00631 N03+NO2 as N	mg/L Phosphorus PO4	p00660 Phosphorus PO4	mg/L Phosphorus p	p00671 Phosphorus p
Kaelepulu Below Junction						31425	0.105	<0.1	0.12	0.11	0.008	0.008	0.015	0.015	0.005	
	Kaelepulu Stream	at Lanikai bridge	212300157440914	7/24/2008	14:00	32100	0.12	< 0.240			0.008	< 0.016	0.016	E 0.016	0.005	E 0.005
	Kaelepulu Stream	End of golf course above Lanikai Br	212300157440928	7/24/2008	13:50	30800	0.088	E 0.088	0.11	E 0.11	0.008	< 0.016	0.015	E 0.015	0.005	E 0.005
	Kaelepulu Stream	Mid golf course	212300157440913	7/24/2008	13:42	31900	0.12	< 0.240			0.008	< 0.016	0.015	E 0.015	0.005	E 0.005
	Kaelepulu Stream	at golf island	212300157440927	7/24/2008	13:31	30900	0.091	E 0.091	0.12	E 0.12	0.008	< 0.016	0.013	E 0.013	0.004	E 0.004
Kaelepulu Above Junction						29867	0.093	<0.1	0.14	0.11	0.009	<0.016	0.013	0.015	0.004	
	Kaelepulu Stream	Just above Kawainui St junction	212300157440926	7/24/2008	13:22	29500	0.05	< 0.100			0.011	E 0.011	0.014	E 0.014	0.005	E 0.005
	Kaelepulu Stream	500 feet above Kawainui Junction	212300157440912	7/24/2008	13:16	30100	0.12	< 0.240			0.008	< 0.016	0.013	E 0.013	0.004	E 0.004
	Kaelepulu Stream	Near Golf Course Side channel	212300157440925	7/24/2008	13:09	30000	0.108	0.108	0.14	0.14	0.008	< 0.016	0.011	E 0.011	0.004	E 0.004
Lower Kawainui Stream						24450	0.364	0.364	0.468	0.468	0.033	0.034	0.073	0.015	0.024	0.024
	Kawainui Stream	Below Kaawakea Br	212300157440924	7/24/2008	12:46	28400	0.146	0.146	0.19	0.19	0.048	0.048	0.025	0.025	0.008	0.008
	Kawainui Stream	below Hamakua Bridge - mangroves	212300157440904	7/24/2008	12:00	27000	0.329	0.329	0.42	0.42	0.067	0.067	0.049	0.049	0.016	0.016
	Kawainui Stream	Hamakua Wetland	212300157440923	7/24/2008	11:46	23700	0.427	0.427	0.55	0.55	0.008	E 0.008	0.053	0.053	0.017	0.017
	Kawainui Stream	above Kailua Bridge	212300157440903	7/24/2008	11:25	18700	0.553	0.553	0.71	0.71	0.008	< 0.016	0.165	0.165	0.054	0.054
Upper Kawainui Stream						17025	0.355	0.355	0.455	0.455	0.0083	<0.016	0.084	0.015	0.027	0.027
	Kawainui Stream	1/3 way above Kailua Bridge to Kaha	212300157440911	7/24/2008	11:02	16800	0.423	0.423	0.54	0.54	0.009	E 0.009	0.092	0.092	0.030	0.030
	Kawainui Stream	Above Kailua Br. 1/2 way to Kaha	212300157440922	7/24/2008	10:50	16900	0.415	0.415	0.53	0.53	0.008	< 0.016	0.084	0.084	0.027	0.027
	Kawainui Stream	Below Kaha park at side channel	212300157440921	7/24/2008	10:34	16700	0.334	0.334	0.43	0.43	0.008	< 0.016	0.081	0.081	0.026	0.026
	Kawainui Stream	at Kaha Park 1st side channel	212300157440902	7/24/2008	10:20	17700	0.248	0.248	0.32	0.32	0.008	< 0.016	0.078	0.078	0.025	0.025
Main Pond Body						36663	0.053	<0.1	0.08	0.08	0.008	<0.016	0.032	0.032	0.010	0.010
	Pond	KS Lot lagoon	212300157440907	7/28/2008	10:45	37600	0.05	< 0.100			0.008	< 0.016	0.070	0.070	0.023	0.023
	Pond	North west near Clemmer's	212300157440917	7/28/2008	12:15	36900	0.05	< 0.100			0.008	< 0.016	0.019	0.019	0.006	0.006
	Pond	East side - edge of wetland	212300157440930	7/28/2008	11:45	36800	0.062	E 0.062	0.08	E 0.08	0.008	< 0.016	0.026	0.026	0.009	0.009
	Pond	md pond - off KS lot below wetland	212300157440931	7/28/2008	11:30	36500	0.05	< 0.100			0.008	< 0.016	0.027	0.027	0.009	0.009
	Pond	Kukilakila Pennensula end	212300157440932	7/28/2008	12:30	36000	0.065	E 0.065	0.08	E 0.08	0.008	< 0.016	0.028	0.028	0.009	0.009
	Pond	Bevar's house shoreline	212300157440933	7/28/2008	11:55	36300	0.05	< 0.100			0.008	< 0.016	0.031	0.031	0.010	0.010
	Pond	North shore	212300157440936	7/28/2008	12:10	36400	0.05	< 0.100			0.008	< 0.016	0.023	0.023	0.007	0.007
	Pond	North west shore	212300157440934	7/28/2008	12:25	36800	0.05	< 0.100			0.008	< 0.016	0.032	0.032	0.010	0.010
Inlets to Pond						17750	0.358	0.358	0.460	0.460	0.015	<0.016	0.337	0.337	0.11	0.11
	Pond Inlet	Keopa Channel by Kaelepulu Elem	212300157440901	7/24/2008	10:30	17000	0.475	0.475	0.61	0.61	0.009	E 0.009	0.43	0.43	0.140	0.140
	Pond Inlet to wetland	Kaelepulu Stream mouth at wetland	212300157440905	7/28/2008	9:30	18500	0.241	0.241	0.31	0.31	0.02	0.02	0.244	0.244	0.080	0.080
Pond wetland						26775	0.105	0.105	0.135	0.19	0.0143	<0.016	0.091	0.091	0.030	0.030
	Pond Wetland	Channel on west side	212300157440906	7/28/2008	9:48	13600	0.185	0.185	0.24	0.24	0.033	0.033	0.216	0.216	0.070	0.070
	Pond Wetland	West side - edge of open water	212300157440915	7/28/2008	10:30	32500	0.057	0.057	0.07	E 0.07	0.008	< 0.016	0.039	0.039	0.013	0.013
	Pond Wetland	East Side - edge of open water	212300157440916	7/28/2008	11:40	30300	0.111	0.111	0.14	0.14	0.008	< 0.016	0.059	0.059	0.019	0.019
	Pond Wetland	Center - edge of open water	212300157440929	7/28/2008	10:20	30700	0.068	0.068	0.09	E 0.09	0.008	< 0.016	0.05	0.05	0.016	0.016
Untested (?) Samples																
	Pond	Northshore - Kellys'	212300157440918													
	Pond	Junction with exit channel	212300157440919													
	Kaelepulu Stream	Below Keolu Br	212300157440920													
	Pond	Center main lake	212300157440937													
	Pond	East shore	212300157440938													
	Pond	Center off Mike's	212300157440939													
	Pond	East Lake - across from Maosi's	212300157440940													
	Pond Inlet	by kukilakila boatramp	212300157440941													
	Pond	Kemo's cove	212300157440908													
	Pond Inlet	Channel to Maosi's cove	212300157440909													
	Pond Inlet	Dead Dog Creek by shallows	212300157440910													

# P00095	- Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius
# P00608	- Ammonia, water, filtered, milligrams per liter as nitrogen
# P00631	- Nitrate plus nitrite, water, filtered, milligrams per liter as nitrogen
# P00660	- Orthophosphate, water, filtered, milligrams per liter
# P00671	- Orthophosphate, water, filtered, milligrams per liter as phosphorus

TMDL data made available through Dr. R. Babcock and Dr. C. Tamaru, University of Hawaii. The following dataset was not accepted by the Hawaii Department of Health for unspecified "violations of QAQC protocol." Samples were obtained during 14 field excursions at roughly 1-month intervals between 6/3/09, and 12/20/2010 and include two storm events (10/26/09 and 12/20/2010). Physical water quality measurements were made and samples taken from 80 locations on the water surface and from up to 31 inlet locations when there was flow. Adjacent surface samples were combined (~4 samples per composite) into 11 samples within the Kawainui and Kaelepulu channels, 11 samples within the pond and wetland, and up to 31 samples from inlets, all subjected to nutrient analyses (594 analyses total).

Sample site	Code	Location
1,2,3	PNC1	Wetland
4,5,8	PNC2	Wetland
6,7,10	PNC3	Wetland
11,12,20	PNC4	Pond
18,19,23,24	PNC5	Pond
26,27,28,31	PNC6	Pond
32,33,34,29	PNC7	Pond
39,40,36,37	PNC8	Pond
38,35,30,25	PNC9	Pond
21,22,13,14	PNC10	Pond
15,16,17,9	PNC11	Pond
51,50,49	SNC1	Kawainui
48,47,46	SNC2	Kawainui
45,41,42	SNC3	Kawainui
43,44,65	SNC4	Kawainui
52,53,54,55	SNC5	Upper Kaelepulu
56,51,58,59	SNC6	Upper Kaelepulu
60,61,62,63	SNC7	Upper Kaelepulu
64,66,67,68	SNC8	Low Kaelepulu
69,70,71,72	SNC9	Low Kaelepulu
76,75,74,73	SNC10	Low Kaelepulu
80,79,78,77	SNC11	Low Kaelepulu
1 through 31	IN	Storm drain inlets



Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
IN1	1	12/20/2010	15.5000	5.2100	5.4000	0.3000	1.0000	0.0050	510	37.2	488
IN1	2	6/23/2010	8.0000	0.0090	0.8000	0.4000	225.0000	0.0250		7.1	1250
IN1	3	5/26/2010	5.8000	0.0520	1.0000	0.5500	67.0000	0.3215	7100	4.4	1486
IN1	4	4/28/2010	4.0000	0.0400	0.4000	0.2500	108.0000	0.1300	8450		
IN1	5	3/11/2010	6.0000	0.3726	0.4000	0.1100	22.0000	0.0250	9600	3.9	1240
IN1	6	2/2/2010	13.8000	2.2936	2.2000	0.2300	10.0000	0.0250	1000	15.2	896
IN1	7	12/15/2009	15.0000	0.0889	0.6000	0.2000	382.0000	0.2620	150	6.0	
IN1	8	11/17/2009	20.0000	0.2103	1.7000	0.0250	193.0000	0.2775	2667	11.1	15500
IN1	9	10/26/2009	31.6000	0.0100	0.0500	0.1500	205.0000	0.1480	400	11.3	19900
IN1	10	10/6/2009	33.7255	0.1751	1.4000	0.1000	16.0000	0.3200	13400	16.6	7700
IN1	11	9/9/2009	20.8000	0.0100	0.1000	0.3000	203.0000	0.0250	5267	12.4	1290
IN1	12	8/12/2009	35.9184	0.7441	5.5000	0.3700	271.0000	0.0396	36800	28.4	1010
IN1	13	7/21/2009	21.0000	0.0100	0.0500	0.1500	153.7500	0.2070	440	13.9	1520
IN1	14	6/3/2009	17.4000	0.3082	2.5000	0.1800	57.6190	0.0410	1	9.0	1190
IN2	1	12/20/2010	10.0000	5.7900	7.6000	0.1500	22.0000	0.0050	5	12.9	787
IN3	6	2/2/2010	13.0000	0.1133	0.7000	0.1600	10.0000	0.0250	1200	33.8	199
IN4	1	12/20/2010	9.2500	7.7300	8.2000	0.2000	1.0000	0.0050	260	27.1	375
IN4	2	6/23/2010	4.8000	0.0100	1.2000	0.3000	128.0000	0.0250		3.4	755
IN4	3	5/26/2010	2.2000	0.0226	0.6000	0.5500	68.0000	0.0250	2250	4.4	853
IN4	4	4/28/2010	4.4000	0.0100	0.2000	0.2500	60.0000	0.1400	28900		
IN4	5	3/11/2010	4.4000	0.0100	0.8000	0.0800	24.0000	0.0565	31200	2.2	740
IN4	6	2/2/2010	8.4000	0.1826	0.8000	0.1700	18.0000	0.0700	2600	16.3	279
IN4	7	12/15/2009	7.1154	0.0670	0.0500	0.6500	304.0000	0.2800	150	2.8	
IN4	8	11/17/2009	3.4000	0.1008	1.4000	0.0250	31.0000	0.1230	2334	2.4	1290
IN4	9	10/26/2009	5.8824	0.0418	0.5000	0.2500	166.2500	0.0500	4800	3.9	1900
IN4	10	10/6/2009	6.7347	0.0384	0.8000	0.0250	13.3333	0.0600	9200	3.9	853
IN4	11	9/9/2009	5.6000	0.0100	0.2000	0.2000	138.0000	0.0250	4400	2.9	706
IN4	12	8/12/2009	4.1237	0.4595	1.3000	0.3200	100.0000	0.0150	11400	5.4	698
IN4	13	7/21/2009	1.0417	0.0100	0.0500	0.2600	105.0000	0.0320	1100	2.8	819
IN5	1	12/20/2010	4.2500	2.1400	3.0000	0.6000	18.0000	0.0050	870	50.4	340
IN5	2	6/23/2010	1.2000	0.0316	2.0000	0.2000	6.0000	0.3945		2.6	572
IN5	3	5/26/2010	2.2000	0.0271	0.6000	0.2000	12.0000	0.3965	10	3.3	691
IN5	4	4/28/2010	3.2000	0.0900	0.8000	0.0250	0.0001	0.4100	10		
IN5	5	3/11/2010	4.0000	0.0341	0.6000	0.1400	0.0001	0.4115	10	4.4	611
IN5	6	2/2/2010	5.4000	0.6015	1.5000	0.2400	6.0000	0.0500	200	11.1	563
IN5	7	12/15/2009	5.0000	0.3927	0.7000	0.4000	24.0000	0.3950	150	15.4	
IN5	8	11/17/2009	2.5490	0.2048	0.0500	0.0250	23.0000	0.1335	150	3.9	803
IN5	9	10/26/2009	1.8000	0.1330	0.2000	0.2500	26.0000	0.3020	10	4.4	895
IN5	10	10/6/2009	2.5000	0.3918	1.0000	0.0250	11.0000	0.2700	2600	4.3	528
IN5	11	9/9/2009	2.0000	0.0931	0.0500	0.3500	38.0000	0.4150	1000	4.7	645
IN5	12	8/12/2009	3.4615	0.9026	2.2000	0.2300	7.0000	0.5260	4000	6.3	542
IN6	1	12/20/2010	60.0000	5.5800	6.4000	0.0250	26.7000	0.0050	5	116.0	262
IN6	2	6/23/2010	9.2000	0.0100	2.4000	0.2500	88.0000	0.0250		4.6	653
IN6	3	5/26/2010	7.8000	0.0113	1.6000	0.4500	58.0000	0.0250	3400	7.4	707
IN6	4	4/28/2010	6.2000	0.0100	0.8000	0.2000	18.0000	0.1600	1700		
IN6	5	3/11/2010	6.0000	0.0100	1.3000	0.1100	20.0000	0.0250	2800	1.9	620
IN6	6	2/2/2010	4.8000	0.1112	0.2000	0.1400	0.0001	0.0250	2400	4.8	685
IN6	7	12/15/2009	9.7917	0.0100	1.8000	0.2500	146.0000	0.3290	667	4.9	
IN6	8	11/17/2009	13.6735	0.0100	1.2000	0.0500	65.0000	0.1775	3667	6.8	4340
IN6	9	10/26/2009	5.2000	0.0100	0.0500	0.1000	60.0000	0.0250	2600	1.9	1370
IN6	10	10/6/2009	2.0000	0.0295	0.2000	0.0500	17.0000	0.0700	200	1.8	594
IN6	11	9/9/2009	2.2000	0.0100	0.0500	0.4000	105.0000	0.0250	400	2.0	645
IN6	12	8/12/2009	7.0784	0.2489	1.1000	0.2100	50.0000	0.0150	3900	7.0	729
IN6	13	7/21/2009	13.1373	0.0100	0.0500	0.2600	168.7500	0.0542	540	10.6	678
IN7	1	12/20/2010	23.7500	0.0050	5.2000	0.0500	50.0000	0.0050	450	77.4	221
IN7	6	2/2/2010	15.2000	0.0598	0.5000	0.1700	16.0000	0.0250	1000	29.3	322
IN7	12	8/12/2009	6.3918	0.4986	2.5000	0.2500	0.1000	0.2610	38000	9.9	351
IN7	14	6/3/2009	12.4138	0.0010	1.7000	0.1100	2.8750	0.2520	308	10.0	381

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
IN8	1	12/20/2010	12.0000	0.0200	0.0100	0.0250	1.0000	0.0050	80	6.5	84
IN9	1	12/20/2010	12.5000	0.3900	2.6000	0.0250	38.0000	0.0050	270	62.6	89
IN10	1	12/20/2010	4.2500	0.0500	1.4000	0.0250	1.0000	0.0050	210	21.7	72
IN11	1	12/20/2010	13.7500	0.4000	1.6000	0.0250	62.0000	0.0050	40	22.0	55
IN12	1	12/20/2010	13.0000	1.0300	3.2000	0.1000	22.0000	0.0050	950	27.0	201
IN13	1	12/20/2010	6.0000	3.8800	15.8000	0.0500	32.0000	0.0050	90	107.0	253
IN14	1	12/20/2010	62.7500	5.8900	8.6000	0.0250	1.0000	0.0050	490	73.5	318
IN14	2	6/23/2010	4747.0588	0.2915	10.4000	>13.0	1230.0000	1.5900		5410.0	697
IN14	6	2/2/2010	15.4000	2.0702	2.1000	0.1700	6.0000	0.0250	1600	28.1	666
IN14	7	12/15/2009	1.6000	0.7376	0.2000	0.1500	14.0000	0.0620	334	3.2	
IN14	8	11/17/2009	13.7500	0.6049	0.1000	0.0250	49.0000	0.0600	1667	6.7	956
IN14	9	10/26/2009	0.9434	0.6367	0.2000	0.1000	26.6667	0.0250	3800	1.2	846
IN14	10	10/6/2009	2.0000	1.0026	1.5000	0.0250	10.0000	0.0600	400	3.9	454
IN14	11	9/9/2009	3.4000	0.2476	0.3000	0.2000	63.0000	0.0250	1400	4.2	491
IN14	12	8/12/2009	13.5294	2.1368	3.3000	0.3600	0.1000	0.0150	8500	31.5	488
IN14	13	7/21/2009	49.0909	0.1949	3.7000	0.5800	105.0000	0.2170	9100	10.0	715
IN15	1	12/20/2010	39.5000	0.9600	3.2000	0.3500	16.7000	0.0050	560	78.7	154
IN15	6	2/2/2010	5.6000	0.1299	0.4000	0.1700	0.0001	0.0250	800	26.9	354
IN15	12	8/12/2009	5.8824	0.3061	1.5000	0.2200	0.1000	0.0150	13200	15.4	458
IN15	13	7/21/2009	6.3265	0.0100	0.4000	0.2000	13.7500	0.0150	900	12.9	274
IN16	3	5/26/2010	4.0000	0.5017	2.4000	0.7000	0.0000	0.0250	10	9.8	431
IN16	6	2/2/2010	1.0000	2.1159	2.1000	0.2700	14.7000	0.0250	10	3.4	390
IN16	7	12/15/2009	10.0000	1.9357	0.0500	1.1500	12.0000	0.0250	334	6.7	
IN16	9	10/26/2009	6.6667	2.4754	2.9000	0.4000	22.6667	0.1155	600	4.7	583
IN16	10	10/6/2009	2.0000	4.3070	4.4000	0.2000	9.0000	0.0700	3	1.4	315
IN16	12	8/12/2009	5.0980	4.8807	7.7000	0.3000	0.1000	0.0150	1800	3.2	401
IN18	1	12/20/2010	29.0000	0.0300	1.0000	0.0250	6.0000	0.0050	560	14.8	15
IN19	1	12/20/2010	41.2500	5.5900	4.6000	0.0250	1.0000	0.0050	370	71.9	406
IN19	12	8/12/2009	0.2000	1.9928	3.3000	0.1900	0.1000	0.0150	1600	2.2	458
IN20	1	12/20/2010	11.2500	4.0700	4.4000	0.0250	1.0000	0.0050	1020	30.4	659
IN20	2	6/23/2010	32.0000	0.0100	2.2000	0.4500	446.0000	0.0250		13.5	14760
IN20	3	5/26/2010	13.2000	0.0100	0.1000	0.0500	158.0000	0.1185	1400	10.6	11000
IN20	4	4/28/2010	17.0000	0.0100	0.4000	0.0500	72.0000	0.2500	1400		
IN20	5	3/11/2010	11.0000	0.0100	0.2000	0.0050	26.0000	0.0905	1000	5.3	15090
IN20	6	2/2/2010	17.0000	1.2624	1.1000	0.5900	16.0000	0.0500	10800	3.4	1570
IN20	7	12/15/2009	12.9412	0.1582	0.0500	0.2000	16.0000	0.7050	1333	4.5	
IN20	8	11/17/2009	18.0000	0.0100	0.0500	0.0250	42.0000	0.1440	2000	7.0	20500
IN20	9	10/26/2009	17.4081	0.0100	0.0500	0.1000	96.0000	0.1165	1000	8.9	23800
IN20	10	10/6/2009	13.4615	0.0100	0.0500	0.0250	16.0000	0.1300	400	7.1	17300
IN20	11	9/9/2009	23.0612	0.0100	0.0500	0.1500	131.0000	0.0250	270	5.3	19900
IN20	12	8/12/2009	9.4000	0.5300	1.7000	0.1800	2.6667	0.0699	52000	8.6	9420
IN20	13	7/21/2009	16.2500	0.0100	0.9000	0.1200	206.2500	0.0150	160	8.4	18700
IN20	14	6/3/2009	23.6000	0.5805	2.0000	0.3200	15.6000	0.1110	1	16.9	3860
IN21	1	12/20/2010	4.2500	1.3200	14.8000	0.0250	48.0000	0.0050	890	2.4	1244
IN22	1	12/20/2010	13.5000	3.8000	3.6000	0.1000	32.0000	0.0050	5	36.2	625
IN22	2	6/23/2010	7.6000	0.0100	0.1000	0.0250	37.0000	0.0250		2.2	19470
IN22	3	5/26/2010	11.8000	0.0100	0.1000	0.0250	12.0000	0.0250	10	3.0	21600
IN22	4	4/28/2010	17.4000	0.0100	1.0000	0.1000	20.0000	0.1100	10		
IN22	5	3/11/2010	17.2000	0.0100	0.0500	0.0050	6.0000	0.0555	10	5.3	17770
IN22	6	2/2/2010	15.2000	0.2061	0.3000	0.0050	13.0000	0.2500	400	16.4	10000
IN22	7	12/15/2009	13.2692	0.0100	0.0500	0.2500	52.0000	0.2430	334	6.1	
IN22	8	11/17/2009	13.8000	0.0100	0.0500	0.0250	0.0001	0.1175	150	4.0	21000
IN22	9	10/26/2009	14.2857	0.0100	0.0500	0.0250	34.6667	0.0300	10	6.0	24500
IN22	10	10/6/2009	15.4000	0.0100	0.0500	0.0250	16.0000	0.0600	3	5.7	19900
IN22	11	9/9/2009	20.0000	0.0100	0.0500	0.1000	74.0000	0.0250	3	7.8	20600
IN22	12	8/12/2009	12.0000	0.2233	1.3000	0.0050	0.0001	0.0241	12400	7.9	12300
IN22	13	7/21/2009	13.4694	0.0100	0.7000	0.0400	61.5000	0.0150	260	5.5	21600
IN22	14	6/3/2009	25.2381	0.0010	1.4000	0.0050	18.7500	0.1000	1	12.8	15200
IN23	1	12/20/2010	28.2500	7.6100	9.4000	0.0250	33.3000	0.0050	5	25.3	302

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
IN23	12	8/12/2009	44.8000	0.0100	2.1000	0.0050	183.0000	0.2220	5200	26.5	23800
IN23	14	6/3/2009	17.0000	0.0010	3.1000	0.0050	13.7662	0.0200	1	10.5	20300
IN24	1	12/20/2010	11.0000	0.6300	2.6000	0.2000	94.0000	0.2200	5	9.1	3101
IN24	2	6/23/2010	5.6000	0.0100	0.4000	0.2500	294.0000	0.3945		3.2	9946
IN24	3	5/26/2010	12.6000	0.0100	0.8000	0.1500	276.0000	0.4700	5800	4.4	11830
IN24	4	4/28/2010	10.6000	0.0100	0.4000	0.2000	120.0000	0.5600	5500		
IN24	5	3/11/2010	16.2000	0.0100	1.5000	0.0050	222.7000	0.2280	6000	4.4	9014
IN24	6	2/2/2010	38.6000	0.0392	1.3000	0.2800	42.0000	0.3200	14400	53.0	4339
IN24	7	12/15/2009	15.0980	0.0100	0.0500	0.1500	54.0000	0.5090	150	4.1	
IN24	8	11/17/2009	7.2549	0.0100	0.9000	0.0500	62.0000	0.6300	667	2.5	14300
IN24	9	10/26/2009	7.7895	0.0100	0.0500	0.1500	230.6667	0.1965	10	2.5	16200
IN24	10	10/6/2009	8.5294	0.0100	0.8000	0.0250	46.6667	0.3900	400	3.3	12400
IN24	11	9/9/2009	13.5000	0.1260	0.0500	0.2500	245.0000	0.4015	667	5.3	13500
IN24	12	8/12/2009	12.2857	0.0100	1.2000	0.0600	129.4118	0.2100	3700	5.0	13600
IN24	13	7/21/2009	18.8000	0.0100	0.0500	0.0900	340.5000	0.0150	22	10.1	18600
IN25	1	12/20/2010	8.2500	0.2800	2.6000	0.0250	46.0000	0.2500	820	7.2	1837
IN25	2	6/23/2010	5.6000	0.0100	1.0000	0.2000	205.0000	0.3180		5.8	13540
IN25	3	5/26/2010	21.0000	0.0100	0.1000	0.0250	184.0000	0.3985	10	4.6	15080
IN25	4	4/28/2010	8.2000	0.0100	0.6000	0.7000	76.0000	0.5100	10		
IN25	5	3/11/2010	17.2000	0.0100	1.7000	0.0050	97.0000	0.2340	10	3.0	10410
IN25	6	2/2/2010	14.0000	0.0853	1.8000	0.0050	22.0000	0.7800	1600	11.9	10160
IN25	7	12/15/2009	8.6000	0.0100	2.9000	0.3000	102.0000	0.4350	150	2.4	
IN25	8	11/17/2009	7.5510	0.0100	0.8000	0.0500	32.0000	0.6650	150	1.2	14800
IN25	9	10/26/2009	10.1961	0.0100	0.0500	0.1000	449.3333	0.1850	10	2.5	17700
IN25	10	10/6/2009	8.2000	0.0100	1.2000	0.0250	67.0000	0.4300	200	3.2	11300
IN25	11	9/9/2009	10.6000	0.0100	0.0500	0.2000	261.0000	0.4065	3	3.4	15300
IN25	12	8/12/2009	7.3469	0.0100	1.0000	0.0500	98.0000	0.2050	1700	3.8	14900
IN25	13	7/21/2009	10.4082	0.0100	1.0000	0.1000	226.0000	0.2630	100	7.3	17500
IN26	1	12/20/2010	36.6700	9.9900	10.6000	0.0250	53.3000	0.0050	5	47.7	358
IN26	2	6/23/2010	0.0001	0.0045	0.2000	0.4000	7.0000	0.2060		0.8	768
IN26	3	5/26/2010	1.4000	0.0023	0.1000	0.2500	2.0000	0.1950	10	1.0	1156
IN26	4	4/28/2010	0.2000	0.0100	1.4000	0.5500	0.0001	0.1800	10		
IN26	5	3/11/2010	1.4000	0.0100	1.7000	0.1900	0.0001	0.1795	10	0.9	1020
IN26	6	2/2/2010	4.6000	0.2081	0.0500	0.1600	11.6000	0.0500	4000	5.1	176
IN26	7	12/15/2009	0.1961	0.0364	0.0500	0.3000	28.0000	0.1860	150	0.5	
IN26	8	11/17/2009	1.9608	0.0397	0.0500	0.0250	5.0000	0.1370	150	0.8	2040
IN26	9	10/26/2009	5.6000	0.0429	0.0500	0.2000	32.0000	0.1375	10	0.7	1890
IN26	11	9/9/2009	2.6000	0.0380	0.0500	0.3500	52.0000	0.1495	3	1.5	1490
IN26	12	8/12/2009	8.0412	0.8972	2.9000	0.1200	95.0000	0.2410	1600	5.5	1230
IN26	13	7/21/2009	9.0196	0.0100	1.9000	0.2000	101.0000	0.4870	1900	12.3	12900
IN26	14	6/3/2009	18.0000	0.0010	1.4000	0.0050	10.5833	0.0608	62	6.3	11300
IN27	1	12/20/2010	39.5000	4.0700	7.6000	0.0250	63.3000	0.0050	5	61.8	519
IN27	2	6/23/2010	23.2000	0.0723	0.4000	0.4000	19.0000	0.3865		20.4	844
IN27	3	5/26/2010	71.2000	0.0113	0.6000	0.8000	60.0000	0.4480	600	65.3	956
IN27	4	4/28/2010	20.6000	0.0100	0.1000	0.3500	22.0000	0.3600	10		
IN27	5	3/11/2010	9.4000	0.0695	1.7000	0.3500	4.0000	0.3335	400	3.4	2117
IN27	6	2/2/2010	7.4000	0.2024	1.2000	0.2300	0.1500	0.1500	238	5.2	834
IN27	7	12/15/2009	15.0000	0.0100	0.0500	0.1500	52.0000	0.1010	150	5.4	
IN27	8	11/17/2009	15.8974	0.1344	10.4000	0.0250	54.0000	0.2385	150	3.1	15100
IN27	9	10/26/2009	10.9259	0.0100	0.0500	0.2000	81.3333	0.2950	3	2.9	19600
IN27	10	10/6/2009	6.2745	0.0100	0.4000	0.2000	59.0000	0.3600	3	3.4	15200
IN27	11	9/9/2009	22.3077	0.0100	0.0500	0.2000	196.0000	0.4415	3	9.4	11300
IN27	12	8/12/2009	12.3077	0.4519	2.2000	0.1100	126.0000	0.2310	126	7.3	10600
IN27	13	7/21/2009	115.0000	0.2283	3.9000	0.6900	130.0000	0.4450	1260	94.6	1320
IN29	1	12/20/2010	17.5000	2.9000	3.8000	0.0250	46.0000	0.0050	170	27.1	448
IN29	4	4/28/2010	2.4000	0.1000	0.6000	0.8500	36.0000	0.1700	280		
IN29	6	2/2/2010	6.8000	0.3063	0.0500	0.1900	0.0001	0.0100	10400	12.9	280
IN29	7	12/15/2009	13.3333	0.0427	0.0500	0.4500	32.0000	2.1700	150	6.2	
IN29	12	8/12/2009	2.4490	0.7937	2.4000	0.1300	0.1000	0.1310	4200	4.0	564

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
IN1	1	12/20/2010	15.5000	5.2100	5.4000	0.3000	1.0000	0.0050	510	37.2	488
IN1	2	6/23/2010	8.0000	0.0090	0.8000	0.4000	225.0000	0.0250		7.1	1250
IN1	3	5/26/2010	5.8000	0.0520	1.0000	0.5500	67.0000	0.3215	7100	4.4	1486
IN1	4	4/28/2010	4.0000	0.0400	0.4000	0.2500	108.0000	0.1300	8450		
IN1	5	3/11/2010	6.0000	0.3726	0.4000	0.1100	22.0000	0.0250	9600	3.9	1240
IN1	6	2/2/2010	13.8000	2.2936	2.2000	0.2300	10.0000	0.0250	1000	15.2	896
IN1	7	12/15/2009	15.0000	0.0889	0.6000	0.2000	382.0000	0.2620	150	6.0	
IN1	8	11/17/2009	20.0000	0.2103	1.7000	0.0250	193.0000	0.2775	2667	11.1	15500
IN1	9	10/26/2009	31.6000	0.0100	0.0500	0.1500	205.0000	0.1480	400	11.3	19900
IN1	10	10/6/2009	33.7255	0.1751	1.4000	0.1000	16.0000	0.3200	13400	16.6	7700
IN1	11	9/9/2009	20.8000	0.0100	0.1000	0.3000	203.0000	0.0250	5267	12.4	1290
IN1	12	8/12/2009	35.9184	0.7441	5.5000	0.3700	271.0000	0.0396	36800	28.4	1010
IN1	13	7/21/2009	21.0000	0.0100	0.0500	0.1500	153.7500	0.2070	440	13.9	1520
IN1	14	6/3/2009	17.4000	0.3082	2.5000	0.1800	57.6190	0.0410	1	9.0	1190
IN2	1	12/20/2010	10.0000	5.7900	7.6000	0.1500	22.0000	0.0050	5	12.9	787
IN3	6	2/2/2010	13.0000	0.1133	0.7000	0.1600	10.0000	0.0250	1200	33.8	199
IN4	1	12/20/2010	9.2500	7.7300	8.2000	0.2000	1.0000	0.0050	260	27.1	375
IN4	2	6/23/2010	4.8000	0.0100	1.2000	0.3000	128.0000	0.0250		3.4	755
IN4	3	5/26/2010	2.2000	0.0226	0.6000	0.5500	68.0000	0.0250	2250	4.4	853
IN4	4	4/28/2010	4.4000	0.0100	0.2000	0.2500	60.0000	0.1400	28900		
IN4	5	3/11/2010	4.4000	0.0100	0.8000	0.0800	24.0000	0.0565	31200	2.2	740
IN4	6	2/2/2010	8.4000	0.1826	0.8000	0.1700	18.0000	0.0700	2600	16.3	279
IN4	7	12/15/2009	7.1154	0.0670	0.0500	0.6500	304.0000	0.2800	150	2.8	
IN4	8	11/17/2009	3.4000	0.1008	1.4000	0.0250	31.0000	0.1230	2334	2.4	1290
IN4	9	10/26/2009	5.8824	0.0418	0.5000	0.2500	166.2500	0.0500	4800	3.9	1900
IN4	10	10/6/2009	6.7347	0.0384	0.8000	0.0250	13.3333	0.0600	9200	3.9	853
IN4	11	9/9/2009	5.6000	0.0100	0.2000	0.2000	138.0000	0.0250	4400	2.9	706
IN4	12	8/12/2009	4.1237	0.4595	1.3000	0.3200	100.0000	0.0150	11400	5.4	698
IN4	13	7/21/2009	1.0417	0.0100	0.0500	0.2600	105.0000	0.0320	1100	2.8	819
IN5	1	12/20/2010	4.2500	2.1400	3.0000	0.6000	18.0000	0.0050	870	50.4	340
IN5	2	6/23/2010	1.2000	0.0316	2.0000	0.2000	6.0000	0.3945		2.6	572
IN5	3	5/26/2010	2.2000	0.0271	0.6000	0.2000	12.0000	0.3965	10	3.3	691
IN5	4	4/28/2010	3.2000	0.0900	0.8000	0.0250	0.0001	0.4100	10		
IN5	5	3/11/2010	4.0000	0.0341	0.6000	0.1400	0.0001	0.4115	10	4.4	611
IN5	6	2/2/2010	5.4000	0.6015	1.5000	0.2400	6.0000	0.0500	200	11.1	563
IN5	7	12/15/2009	5.0000	0.3927	0.7000	0.4000	24.0000	0.3950	150	15.4	
IN5	8	11/17/2009	2.5490	0.2048	0.0500	0.0250	23.0000	0.1335	150	3.9	803
IN5	9	10/26/2009	1.8000	0.1330	0.2000	0.2500	26.0000	0.3020	10	4.4	895
IN5	10	10/6/2009	2.5000	0.3918	1.0000	0.0250	11.0000	0.2700	2600	4.3	528
IN5	11	9/9/2009	2.0000	0.0931	0.0500	0.3500	38.0000	0.4150	1000	4.7	645
IN5	12	8/12/2009	3.4615	0.9026	2.2000	0.2300	7.0000	0.5260	4000	6.3	542
IN6	1	12/20/2010	60.0000	5.5800	6.4000	0.0250	26.7000	0.0050	5	116.0	262
IN6	2	6/23/2010	9.2000	0.0100	2.4000	0.2500	88.0000	0.0250		4.6	653
IN6	3	5/26/2010	7.8000	0.0113	1.6000	0.4500	58.0000	0.0250	3400	7.4	707
IN6	4	4/28/2010	6.2000	0.0100	0.8000	0.2000	18.0000	0.1600	1700		
IN6	5	3/11/2010	6.0000	0.0100	1.3000	0.1100	20.0000	0.0250	2800	1.9	620
IN6	6	2/2/2010	4.8000	0.1112	0.2000	0.1400	0.0001	0.0250	2400	4.8	685
IN6	7	12/15/2009	9.7917	0.0100	1.8000	0.2500	146.0000	0.3290	667	4.9	
IN6	8	11/17/2009	13.6735	0.0100	1.2000	0.0500	65.0000	0.1775	3667	6.8	4340
IN6	9	10/26/2009	5.2000	0.0100	0.0500	0.1000	60.0000	0.0250	2600	1.9	1370
IN6	10	10/6/2009	2.0000	0.0295	0.2000	0.0500	17.0000	0.0700	200	1.8	594
IN6	11	9/9/2009	2.2000	0.0100	0.0500	0.4000	105.0000	0.0250	400	2.0	645
IN6	12	8/12/2009	7.0784	0.2489	1.1000	0.2100	50.0000	0.0150	3900	7.0	729
IN6	13	7/21/2009	13.1373	0.0100	0.0500	0.2600	168.7500	0.0542	540	10.6	678
IN7	1	12/20/2010	23.7500	0.0050	5.2000	0.0500	50.0000	0.0050	450	77.4	221
IN7	6	2/2/2010	15.2000	0.0598	0.5000	0.1700	16.0000	0.0250	1000	29.3	322
IN7	12	8/12/2009	6.3918	0.4986	2.5000	0.2500	0.1000	0.2610	38000	9.9	351
IN7	14	6/3/2009	12.4138	0.0010	1.7000	0.1100	2.8750	0.2520	308	10.0	381

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
IN8	1	12/20/2010	12.0000	0.0200	0.0100	0.0250	1.0000	0.0050	80	6.5	84
IN9	1	12/20/2010	12.5000	0.3900	2.6000	0.0250	38.0000	0.0050	270	62.6	89
IN10	1	12/20/2010	4.2500	0.0500	1.4000	0.0250	1.0000	0.0050	210	21.7	72
IN11	1	12/20/2010	13.7500	0.4000	1.6000	0.0250	62.0000	0.0050	40	22.0	55
IN12	1	12/20/2010	13.0000	1.0300	3.2000	0.1000	22.0000	0.0050	950	27.0	201
IN13	1	12/20/2010	6.0000	3.8800	15.8000	0.0500	32.0000	0.0050	90	107.0	253
IN14	1	12/20/2010	62.7500	5.8900	8.6000	0.0250	1.0000	0.0050	490	73.5	318
IN14	2	6/23/2010	4747.0588	0.2915	10.4000	>13.0	1230.0000	1.5900		5410.0	697
IN14	6	2/2/2010	15.4000	2.0702	2.1000	0.1700	6.0000	0.0250	1600	28.1	666
IN14	7	12/15/2009	1.6000	0.7376	0.2000	0.1500	14.0000	0.0620	334	3.2	
IN14	8	11/17/2009	13.7500	0.6049	0.1000	0.0250	49.0000	0.0600	1667	6.7	956
IN14	9	10/26/2009	0.9434	0.6367	0.2000	0.1000	26.6667	0.0250	3800	1.2	846
IN14	10	10/6/2009	2.0000	1.0026	1.5000	0.0250	10.0000	0.0600	400	3.9	454
IN14	11	9/9/2009	3.4000	0.2476	0.3000	0.2000	63.0000	0.0250	1400	4.2	491
IN14	12	8/12/2009	13.5294	2.1368	3.3000	0.3600	0.1000	0.0150	8500	31.5	488
IN14	13	7/21/2009	49.0909	0.1949	3.7000	0.5800	105.0000	0.2170	9100	10.0	715
IN15	1	12/20/2010	39.5000	0.9600	3.2000	0.3500	16.7000	0.0050	560	78.7	154
IN15	6	2/2/2010	5.6000	0.1299	0.4000	0.1700	0.0001	0.0250	800	26.9	354
IN15	12	8/12/2009	5.8824	0.3061	1.5000	0.2200	0.1000	0.0150	13200	15.4	458
IN15	13	7/21/2009	6.3265	0.0100	0.4000	0.2000	13.7500	0.0150	900	12.9	274
IN16	3	5/26/2010	4.0000	0.5017	2.4000	0.7000	0.0000	0.0250	10	9.8	431
IN16	6	2/2/2010	1.0000	2.1159	2.1000	0.2700	14.7000	0.0250	10	3.4	390
IN16	7	12/15/2009	10.0000	1.9357	0.0500	1.1500	12.0000	0.0250	334	6.7	
IN16	9	10/26/2009	6.6667	2.4754	2.9000	0.4000	22.6667	0.1155	600	4.7	583
IN16	10	10/6/2009	2.0000	4.3070	4.4000	0.2000	9.0000	0.0700	3	1.4	315
IN16	12	8/12/2009	5.0980	4.8807	7.7000	0.3000	0.1000	0.0150	1800	3.2	401
IN18	1	12/20/2010	29.0000	0.0300	1.0000	0.0250	6.0000	0.0050	560	14.8	15
IN19	1	12/20/2010	41.2500	5.5900	4.6000	0.0250	1.0000	0.0050	370	71.9	406
IN19	12	8/12/2009	0.2000	1.9928	3.3000	0.1900	0.1000	0.0150	1600	2.2	458
IN20	1	12/20/2010	11.2500	4.0700	4.4000	0.0250	1.0000	0.0050	1020	30.4	659
IN20	2	6/23/2010	32.0000	0.0100	2.2000	0.4500	446.0000	0.0250		13.5	14760
IN20	3	5/26/2010	13.2000	0.0100	0.1000	0.0500	158.0000	0.1185	1400	10.6	11000
IN20	4	4/28/2010	17.0000	0.0100	0.4000	0.0500	72.0000	0.2500	1400		
IN20	5	3/11/2010	11.0000	0.0100	0.2000	0.0050	26.0000	0.0905	1000	5.3	15090
IN20	6	2/2/2010	17.0000	1.2624	1.1000	0.5900	16.0000	0.0500	10800	3.4	1570
IN20	7	12/15/2009	12.9412	0.1582	0.0500	0.2000	16.0000	0.7050	1333	4.5	
IN20	8	11/17/2009	18.0000	0.0100	0.0500	0.0250	42.0000	0.1440	2000	7.0	20500
IN20	9	10/26/2009	17.4081	0.0100	0.0500	0.1000	96.0000	0.1165	1000	8.9	23800
IN20	10	10/6/2009	13.4615	0.0100	0.0500	0.0250	16.0000	0.1300	400	7.1	17300
IN20	11	9/9/2009	23.0612	0.0100	0.0500	0.1500	131.0000	0.0250	270	5.3	19900
IN20	12	8/12/2009	9.4000	0.5300	1.7000	0.1800	2.6667	0.0699	52000	8.6	9420
IN20	13	7/21/2009	16.2500	0.0100	0.9000	0.1200	206.2500	0.0150	160	8.4	18700
IN20	14	6/3/2009	23.6000	0.5805	2.0000	0.3200	15.6000	0.1110	1	16.9	3860
IN21	1	12/20/2010	4.2500	1.3200	14.8000	0.0250	48.0000	0.0050	890	2.4	1244
IN22	1	12/20/2010	13.5000	3.8000	3.6000	0.1000	32.0000	0.0050	5	36.2	625
IN22	2	6/23/2010	7.6000	0.0100	0.1000	0.0250	37.0000	0.0250		2.2	19470
IN22	3	5/26/2010	11.8000	0.0100	0.1000	0.0250	12.0000	0.0250	10	3.0	21600
IN22	4	4/28/2010	17.4000	0.0100	1.0000	0.1000	20.0000	0.1100	10		
IN22	5	3/11/2010	17.2000	0.0100	0.0500	0.0050	6.0000	0.0555	10	5.3	17770
IN22	6	2/2/2010	15.2000	0.2061	0.3000	0.0050	13.0000	0.2500	400	16.4	10000
IN22	7	12/15/2009	13.2692	0.0100	0.0500	0.2500	52.0000	0.2430	334	6.1	
IN22	8	11/17/2009	13.8000	0.0100	0.0500	0.0250	0.0001	0.1175	150	4.0	21000
IN22	9	10/26/2009	14.2857	0.0100	0.0500	0.0250	34.6667	0.0300	10	6.0	24500
IN22	10	10/6/2009	15.4000	0.0100	0.0500	0.0250	16.0000	0.0600	3	5.7	19900
IN22	11	9/9/2009	20.0000	0.0100	0.0500	0.1000	74.0000	0.0250	3	7.8	20600
IN22	12	8/12/2009	12.0000	0.2233	1.3000	0.0050	0.0001	0.0241	12400	7.9	12300
IN22	13	7/21/2009	13.4694	0.0100	0.7000	0.0400	61.5000	0.0150	260	5.5	21600
IN22	14	6/3/2009	25.2381	0.0010	1.4000	0.0050	18.7500	0.1000	1	12.8	15200
IN23	1	12/20/2010	28.2500	7.6100	9.4000	0.0250	33.3000	0.0050	5	25.3	302

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
IN23	12	8/12/2009	44.8000	0.0100	2.1000	0.0050	183.0000	0.2220	5200	26.5	23800
IN23	14	6/3/2009	17.0000	0.0010	3.1000	0.0050	13.7662	0.0200	1	10.5	20300
IN24	1	12/20/2010	11.0000	0.6300	2.6000	0.2000	94.0000	0.2200	5	9.1	3101
IN24	2	6/23/2010	5.6000	0.0100	0.4000	0.2500	294.0000	0.3945		3.2	9946
IN24	3	5/26/2010	12.6000	0.0100	0.8000	0.1500	276.0000	0.4700	5800	4.4	11830
IN24	4	4/28/2010	10.6000	0.0100	0.4000	0.2000	120.0000	0.5600	5500		
IN24	5	3/11/2010	16.2000	0.0100	1.5000	0.0050	222.7000	0.2280	6000	4.4	9014
IN24	6	2/2/2010	38.6000	0.0392	1.3000	0.2800	42.0000	0.3200	14400	53.0	4339
IN24	7	12/15/2009	15.0980	0.0100	0.0500	0.1500	54.0000	0.5090	150	4.1	
IN24	8	11/17/2009	7.2549	0.0100	0.9000	0.0500	62.0000	0.6300	667	2.5	14300
IN24	9	10/26/2009	7.7895	0.0100	0.0500	0.1500	230.6667	0.1965	10	2.5	16200
IN24	10	10/6/2009	8.5294	0.0100	0.8000	0.0250	46.6667	0.3900	400	3.3	12400
IN24	11	9/9/2009	13.5000	0.1260	0.0500	0.2500	245.0000	0.4015	667	5.3	13500
IN24	12	8/12/2009	12.2857	0.0100	1.2000	0.0600	129.4118	0.2100	3700	5.0	13600
IN24	13	7/21/2009	18.8000	0.0100	0.0500	0.0900	340.5000	0.0150	22	10.1	18600
IN25	1	12/20/2010	8.2500	0.2800	2.6000	0.0250	46.0000	0.2500	820	7.2	1837
IN25	2	6/23/2010	5.6000	0.0100	1.0000	0.2000	205.0000	0.3180		5.8	13540
IN25	3	5/26/2010	21.0000	0.0100	0.1000	0.0250	184.0000	0.3985	10	4.6	15080
IN25	4	4/28/2010	8.2000	0.0100	0.6000	0.7000	76.0000	0.5100	10		
IN25	5	3/11/2010	17.2000	0.0100	1.7000	0.0050	97.0000	0.2340	10	3.0	10410
IN25	6	2/2/2010	14.0000	0.0853	1.8000	0.0050	22.0000	0.7800	1600	11.9	10160
IN25	7	12/15/2009	8.6000	0.0100	2.9000	0.3000	102.0000	0.4350	150	2.4	
IN25	8	11/17/2009	7.5510	0.0100	0.8000	0.0500	32.0000	0.6650	150	1.2	14800
IN25	9	10/26/2009	10.1961	0.0100	0.0500	0.1000	449.3333	0.1850	10	2.5	17700
IN25	10	10/6/2009	8.2000	0.0100	1.2000	0.0250	67.0000	0.4300	200	3.2	11300
IN25	11	9/9/2009	10.6000	0.0100	0.0500	0.2000	261.0000	0.4065	3	3.4	15300
IN25	12	8/12/2009	7.3469	0.0100	1.0000	0.0500	98.0000	0.2050	1700	3.8	14900
IN25	13	7/21/2009	10.4082	0.0100	1.0000	0.1000	226.0000	0.2630	100	7.3	17500
IN26	1	12/20/2010	36.6700	9.9900	10.6000	0.0250	53.3000	0.0050	5	47.7	358
IN26	2	6/23/2010	0.0001	0.0045	0.2000	0.4000	7.0000	0.2060		0.8	768
IN26	3	5/26/2010	1.4000	0.0023	0.1000	0.2500	2.0000	0.1950	10	1.0	1156
IN26	4	4/28/2010	0.2000	0.0100	1.4000	0.5500	0.0001	0.1800	10		
IN26	5	3/11/2010	1.4000	0.0100	1.7000	0.1900	0.0001	0.1795	10	0.9	1020
IN26	6	2/2/2010	4.6000	0.2081	0.0500	0.1600	11.6000	0.0500	4000	5.1	176
IN26	7	12/15/2009	0.1961	0.0364	0.0500	0.3000	28.0000	0.1860	150	0.5	
IN26	8	11/17/2009	1.9608	0.0397	0.0500	0.0250	5.0000	0.1370	150	0.8	2040
IN26	9	10/26/2009	5.6000	0.0429	0.0500	0.2000	32.0000	0.1375	10	0.7	1890
IN26	11	9/9/2009	2.6000	0.0380	0.0500	0.3500	52.0000	0.1495	3	1.5	1490
IN26	12	8/12/2009	8.0412	0.8972	2.9000	0.1200	95.0000	0.2410	1600	5.5	1230
IN26	13	7/21/2009	9.0196	0.0100	1.9000	0.2000	101.0000	0.4870	1900	12.3	12900
IN26	14	6/3/2009	18.0000	0.0010	1.4000	0.0050	10.5833	0.0608	62	6.3	11300
IN27	1	12/20/2010	39.5000	4.0700	7.6000	0.0250	63.3000	0.0050	5	61.8	519
IN27	2	6/23/2010	23.2000	0.0723	0.4000	0.4000	19.0000	0.3865		20.4	844
IN27	3	5/26/2010	71.2000	0.0113	0.6000	0.8000	60.0000	0.4480	600	65.3	956
IN27	4	4/28/2010	20.6000	0.0100	0.1000	0.3500	22.0000	0.3600	10		
IN27	5	3/11/2010	9.4000	0.0695	1.7000	0.3500	4.0000	0.3335	400	3.4	2117
IN27	6	2/2/2010	7.4000	0.2024	1.2000	0.2300	0.1500	0.1500	238	5.2	834
IN27	7	12/15/2009	15.0000	0.0100	0.0500	0.1500	52.0000	0.1010	150	5.4	
IN27	8	11/17/2009	15.8974	0.1344	10.4000	0.0250	54.0000	0.2385	150	3.1	15100
IN27	9	10/26/2009	10.9259	0.0100	0.0500	0.2000	81.3333	0.2950	3	2.9	19600
IN27	10	10/6/2009	6.2745	0.0100	0.4000	0.2000	59.0000	0.3600	3	3.4	15200
IN27	11	9/9/2009	22.3077	0.0100	0.0500	0.2000	196.0000	0.4415	3	9.4	11300
IN27	12	8/12/2009	12.3077	0.4519	2.2000	0.1100	126.0000	0.2310	126	7.3	10600
IN27	13	7/21/2009	115.0000	0.2283	3.9000	0.6900	130.0000	0.4450	1260	94.6	1320
IN29	1	12/20/2010	17.5000	2.9000	3.8000	0.0250	46.0000	0.0050	170	27.1	448
IN29	4	4/28/2010	2.4000	0.1000	0.6000	0.8500	36.0000	0.1700	280		
IN29	6	2/2/2010	6.8000	0.3063	0.0500	0.1900	0.0001	0.0100	10400	12.9	280
IN29	7	12/15/2009	13.3333	0.0427	0.0500	0.4500	32.0000	2.1700	150	6.2	
IN29	12	8/12/2009	2.4490	0.7937	2.4000	0.1300	0.1000	0.1310	4200	4.0	564

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
IN29	14	6/3/2009	60.5405	0.2250	2.7000	0.3400	331.0000	0.0100	60	19.1	1010
IN30	1	12/20/2010	20.7500	5.9100	5.6000	0.2000	1.0000	0.0050	440	104.0	273
IN30	2	6/23/2010	1.2000	0.0023	0.1000	0.6000	32.0000	0.1260		3.2	664
IN30	3	5/26/2010	5.2000	0.0100	0.4000	0.1500	38.0000	0.0250	10	4.6	764
IN30	4	4/28/2010	1.4000	0.0100	0.1000	0.6500	2.0000	0.0250	10		
IN30	5	3/11/2010	7.8000	0.0100	1.7000	0.1400	0.0001	0.1940	10	3.9	1190
IN30	6	2/2/2010	13.2000	0.1196	0.0500	0.1400	8.0000	0.0700	1600	10.0	623
IN30	7	12/15/2009	6.3462	0.0100	0.0500	0.4000	42.0000	0.3770	150	3.7	
IN30	8	11/17/2009	8.0000	0.0100	0.6000	0.1000	34.0000	0.2930	1334	4.1	8510
IN30	9	10/26/2009	4.6316	0.0100	0.0500	0.1500	116.0000	0.2500	10	2.2	9380
IN30	10	10/6/2009	16.5385	0.2012	0.8000	0.0500	31.0000	0.1600	2440	9.4	1290
IN30	11	9/9/2009	5.4000	0.0100	0.0500	0.2500	129.0000	0.2355	185	3.5	4270
IN30	12	8/12/2009	26.0784	0.6593	2.7000	0.2200	154.0000	0.1770	34400	17.7	508
IN30	13	7/21/2009	15.5769	0.0100	2.9000	0.1700	102.0000	0.1250	460	10.2	728
IN31	1	12/20/2010	5.7500	1.2700	10.8000	0.1000	22.0000	0.0050	980	24.6	223
IN31	2	6/23/2010	0.8000	0.0100	0.1000	0.1500	2.0000	0.0250		0.2	598
IN31	3	5/26/2010	34.4000	0.0023	0.1000	0.3000	10.0000	0.0250	1900	1.2	687
IN31	4	4/28/2010	3.0000	0.0100	3.4000	0.0250	8.0000	0.0250	2100		
IN31	5	3/11/2010	2.0000	0.0377	0.9000	0.1600	0.0001	0.0250	2000	0.7	601
IN31	6	2/2/2010	0.6000	0.0814	0.0500	0.1400	0.0001	0.0250	10	0.5	725
IN31	7	12/15/2009	0.4000	0.0652	0.0500	0.2000	12.0000	0.0250	150	0.4	
IN31	8	11/17/2009	0.5479	0.0652	0.9000	0.1000	0.0000	0.0250	150	0.4	1150
IN31	9	10/26/2009	0.0000	0.0859	0.2000	0.1500	8.0000	0.0250	10	0.3	1070
IN31	10	10/6/2009	0.7843	0.0964	0.5000	0.0250	7.0000	0.0500	3	0.4	684
IN31	11	9/9/2009	0.0000	0.1231	0.0500	0.2000	14.0000	0.0505	3	0.3	794
INNEW	12	8/12/2009	0.7692	0.2505	0.5000	0.1700	0.1000		15	0.8	798
INNEW	13	7/21/2009	0.0001	0.2272	1.9000	0.1800	0.1000	0.0420	1	0.6	806
PNC1	1	12/20/2010	12.0000	3.5200	3.2000	0.1500	9.3000	0.1100	1	30.2	1345
PNC1	2	6/23/2010	21.2000	0.0100	0.1000	0.0250	151.0000	0.0250		2.9	23380
PNC1	3	5/26/2010	60.6000	0.0100	0.1000	0.0250	45.0000	0.0250	10	18.9	22780
PNC1	4	4/28/2010	38.0000	0.0100	0.1000	0.0250	48.0000	0.0800	16		
PNC1	5	3/11/2010	64.8000	0.0100	0.8000	0.0050	70.7000	0.0900	10	30.8	19900
PNC1	6	2/2/2010	219.0000	0.0100	3.9000	0.0300	238.0000	0.0250	1000	91.2	17520
PNC1	7	12/15/2009	38.5714	0.0100	1.9000	0.0500	94.0000	0.0845	3	22.0	
PNC1	8	11/17/2009	31.5534	0.0100	0.0500	0.0250	80.0000	0.0250	3	13.2	18000
PNC1	9	10/26/2009	15.8824	0.0100	0.0500	0.1000	121.3333	0.0250	3	8.6	23100
PNC1	10	10/6/2009	35.0000	0.0100	0.0500	0.0500	68.0000	0.0250	3	16.2	24300
PNC1	11	9/9/2009	16.2500	0.0100	0.0500	0.0050	146.0000	0.0250	1	5.1	18400
PNC1	12	8/12/2009	13.2000	0.1864	1.6000	0.0600	53.0000	0.1440	880	9.9	12700
PNC1	13	7/21/2009	94.2857	0.0100	0.0500	0.0500	162.5000	0.0150	1	35.4	21200
PNC1	14	6/3/2009	18.4000	0.0010	1.0000	0.0050	53.0500	0.1250	2	11.1	10800
PNC2	1	12/20/2010	14.7500	3.4400	5.2000	0.0250	8.0000	0.3220	116	36.6	2018
PNC2	2	6/23/2010	12.8000	0.0100	0.1000	0.0250	38.0000	0.0250		1.3	22910
PNC2	3	5/26/2010	11.2000	0.0100	0.1000	0.0250	35.0000	0.0250	24	1.8	23660
PNC2	4	4/28/2010	10.6000	0.0100	1.0000	0.0250	32.0000	0.0800	22		
PNC2	5	3/11/2010	22.2000	0.0100	0.0500	0.0050	14.7000	0.0600	34	6.3	19190
PNC2	6	2/2/2010	33.2000	0.0100	3.3000	0.0050	3.0000	0.0250	1	5.8	21060
PNC2	7	12/15/2009	10.6000	0.0100	0.0500	0.3000	68.0000	0.0480	3	3.4	
PNC2	8	11/17/2009	11.8343	0.0100	1.7000	0.0250	60.0000	0.0250	3	3.4	18500
PNC2	9	10/26/2009	13.6622	0.0100	0.0500	0.0500	52.0000	0.0250	3	3.9	22900
PNC2	10	10/6/2009	14.0000	0.0100	0.0500	0.0250	39.0000	0.0250	3	4.5	24400
PNC2	11	9/9/2009	16.3107	0.0100	0.0500	0.0050	88.0000	0.0250	1	4.1	19000
PNC2	12	8/12/2009	12.9964	0.1190	1.5000	0.0400	106.0000	0.0150	930	9.1	13600
PNC2	13	7/21/2009	25.1282	0.0100	0.0500	0.0050	112.5000	0.0150	1	9.9	21400
PNC2	14	6/3/2009	9.2000	0.0010	0.5000	0.0050	5.2778	0.0050	2	4.0	19600
PNC3A	1	12/20/2010	16.3300	3.8500	5.0000	0.9000	38.0000	0.1670	180	46.5	1800
PNC3A	2	6/23/2010	20.4000	0.0100	0.1000	0.0250	49.0000	0.0250		2.3	23400
PNC3A	3	5/26/2010	10.2000	0.0100	0.1000	0.0250	40.0000	0.0250	1	2.0	23660
PNC3A	4	4/28/2010	44.6000	0.0100	0.1000	0.0250	40.0000	0.0250	1		

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
PNC3A	5	3/11/2010	191.6000	0.0100	0.6000	0.0050	38.7000	0.0500	1	4.9	19350
PNC3A	6	2/2/2010	26.2000	0.0100	2.1000	0.0050	0.0001	0.0250	1	2.1	21900
PNC3A	7	12/15/2009	9.8077	0.0100	0.3000	0.0500	56.0000	0.0390	3	2.4	
PNC3A	8	11/17/2009	10.3846	0.0100	1.7000	0.0250	54.0000	0.0250	3	4.2	18000
PNC3A	9	10/26/2009	12.8302	0.0100	0.0500	0.0250	62.6667	0.0250	3	4.1	22200
PNC3A	10	10/6/2009	13.0000	0.0100	0.0500	0.0250	40.0000	0.0250	3	5.1	24300
PNC3A	11	9/9/2009	8.5106	0.0100	0.0500	0.0050	64.0000	0.0250	1	2.5	19400
PNC3A	12	8/12/2009	12.8834	0.1979	1.1000	0.0500	86.0000	0.0150	3040	9.5	12800
PNC3A	13	7/21/2009	28.0000	0.0100	0.0500	0.0050	83.7500	0.0150	1	10.4	21700
PNC3A	14	6/3/2009	15.4000	0.0010	0.0500	0.0050	13.4000	0.0050	2	6.1	15000
PNC3B	1	12/20/2010	17.2500	3.4500	5.2000	0.1500	32.0000	0.1970	260	44.0	1854
PNC3B	2	6/23/2010	18.4000	0.0100	0.8000	0.0250	43.0000	0.0250		1.8	23570
PNC3B	3	5/26/2010	11.4000	0.0100	0.1000	0.0250	12.0000	0.0250	6	1.5	23660
PNC3B	4	4/28/2010	8.8000	0.0100	1.0000	0.0250	24.0000	0.0250	4		
PNC3B	5	3/11/2010	9.0000	0.0100	0.0500	0.0050	0.0001	0.0250	2	4.5	19320
PNC3B	6	2/2/2010	23.4000	0.0100	4.4000	0.0050	0.0001	0.0250	1	2.5	21930
PNC3B	7	12/15/2009	10.2000	0.0100	1.0000	0.1500	68.0000	0.0406	3	2.3	
PNC3B	8	11/17/2009	11.1765	0.0100	1.9000	0.0250	66.0000	0.0250	3	4.9	18300
PNC3B	9	10/26/2009	11.7647	0.0100	0.0500	0.0250	88.0000	0.0250	3	3.8	22400
PNC3B	10	10/6/2009	15.3061	0.0100	0.0500	0.1000	29.0000	0.0250	3	5.2	24300
PNC3B	11	9/9/2009	13.8000	0.0100	0.0500	0.0050	40.0000	0.0250	1	2.5	19100
PNC3B	12	8/12/2009	10.9731	0.1795	0.4000	0.0900	84.0000	0.0150	2480	9.2	12800
PNC3B	13	7/21/2009	27.0588	0.0100	0.0500	0.0050	82.5000	0.0150	1	9.4	21500
PNC3B	14	6/3/2009	17.4000	0.0010	0.5000	0.0050	16.3333	0.0050	2	8.4	16600
PNC4	1	12/20/2010	19.0000	4.1800	5.6000	0.0250	4.0000	0.1235	100	79.0	1666
PNC4	2	6/23/2010	14.0000	0.0100	0.2000	0.0250	28.0000	0.0250		2.0	23120
PNC4	3	5/26/2010	9.8000	0.0100	0.1000	0.0250	22.6700	0.0250	4	1.6	23990
PNC4	4	4/28/2010	9.0000	0.0100	0.1000	0.0250	24.0000	0.0250	3		
PNC4	5	3/11/2010	10.4000	0.0100	0.0500	0.0050	12.0000	0.0250	2	5.1	19760
PNC4	6	2/2/2010	15.4000	0.0100	2.4000	0.0050	0.0001	0.0250	8	2.6	22350
PNC4	7	12/15/2009	10.6000	0.0100	0.0500	0.0500	36.0000	0.0434	3	3.0	
PNC4	8	11/17/2009	11.5094	0.0100	1.9000	0.0250	90.0000	0.0250	3	2.5	18600
PNC4	9	10/26/2009	12.1569	0.0100	0.0500	0.0250	61.3333	0.0250	3	2.9	23600
PNC4	10	10/6/2009	12.5490	0.0100	0.0500	0.1500	24.0000	0.0250	3	3.1	24500
PNC4	11	9/9/2009	14.4000	0.0100	0.0500	0.0050	38.0000	0.0250	1	2.4	19000
PNC4	12	8/12/2009	13.8462	0.0100	0.0500	0.0500	120.0000	0.0100	1600	9.3	15000
PNC4	13	7/21/2009	18.1818	0.0100	0.0500	0.0050	47.5000	0.0150	1	6.2	21500
PNC4	14	6/3/2009	10.2000	0.0010	0.4000	0.0050	9.2143	0.0050	2	4.7	16100
PNC5	1	12/20/2010	30.2500	3.4400	3.4000	0.0500	6.0000	0.1470	150	68.8	1924
PNC5	2	6/23/2010	14.8000	0.0100	0.2000	0.0250	31.0000	0.0250		2.2	21960
PNC5	3	5/26/2010	19.4000	0.0100	0.1000	0.0250	10.6700	0.0250	4	2.1	24100
PNC5	4	4/28/2010	9.6000	0.0100	0.1000	0.0250	58.0000	0.0600	4		
PNC5	5	3/11/2010	13.2000	0.0100	0.0500	0.0050	10.7000	0.0250	6	3.4	20070
PNC5	6	2/2/2010	16.0000	0.0100	2.7000	0.0050	0.0250	0.0250	2	2.5	22220
PNC5	7	12/15/2009	9.8077	0.0100	0.0500	0.0250	30.0000	0.0584	3	2.7	
PNC5	8	11/17/2009	14.9020	0.0100	1.4000	0.0250	113.0000	0.0250	3	2.6	18500
PNC5	9	10/26/2009	10.4000	0.0100	0.0500	0.0500	45.3333	0.0250	3	3.0	23100
PNC5	10	10/6/2009	10.0000	0.0100	0.0500	0.1000	23.0000	0.0250	3	2.8	24900
PNC5	11	9/9/2009	11.6000	0.0100	0.0500	0.0050	67.0000	0.0250	1	2.3	19000
PNC5	12	8/12/2009	11.1765	0.1187	0.0500	0.0600	54.0000	0.0150	1430	9.4	13800
PNC5	13	7/21/2009	17.8788	0.0100	0.8000	0.0050	52.5000	0.0150	1	4.1	21700
PNC5	14	6/3/2009	6.2000	0.0010	0.3000	0.0050	8.2500	0.0050	2	3.6	17000
PNC6A	1	12/20/2010	32.7500	3.2200	4.2000	0.0250	1.0000	0.1410	134	64.3	2586
PNC6A	2	6/23/2010	17.6000	0.0100	0.1000	0.0250	32.0000	0.0250		3.8	23210
PNC6A	3	5/26/2010	10.8000	0.0100	0.1000	0.0250	21.3300	0.0250	60	2.7	24810
PNC6A	4	4/28/2010	9.2000	0.0100	0.1000	0.0250	68.0000	0.0250	35		
PNC6A	5	3/11/2010	13.0000	0.0100	0.0500	0.0050	18.7000	0.0250	44	4.0	19830
PNC6A	6	2/2/2010	21.4000	0.0100	1.6000	0.0050	18.0000	0.0250	4	1.8	23380
PNC6A	7	12/15/2009	11.2000	0.0100	0.0500	0.0500	68.0000	0.0501	3	3.1	

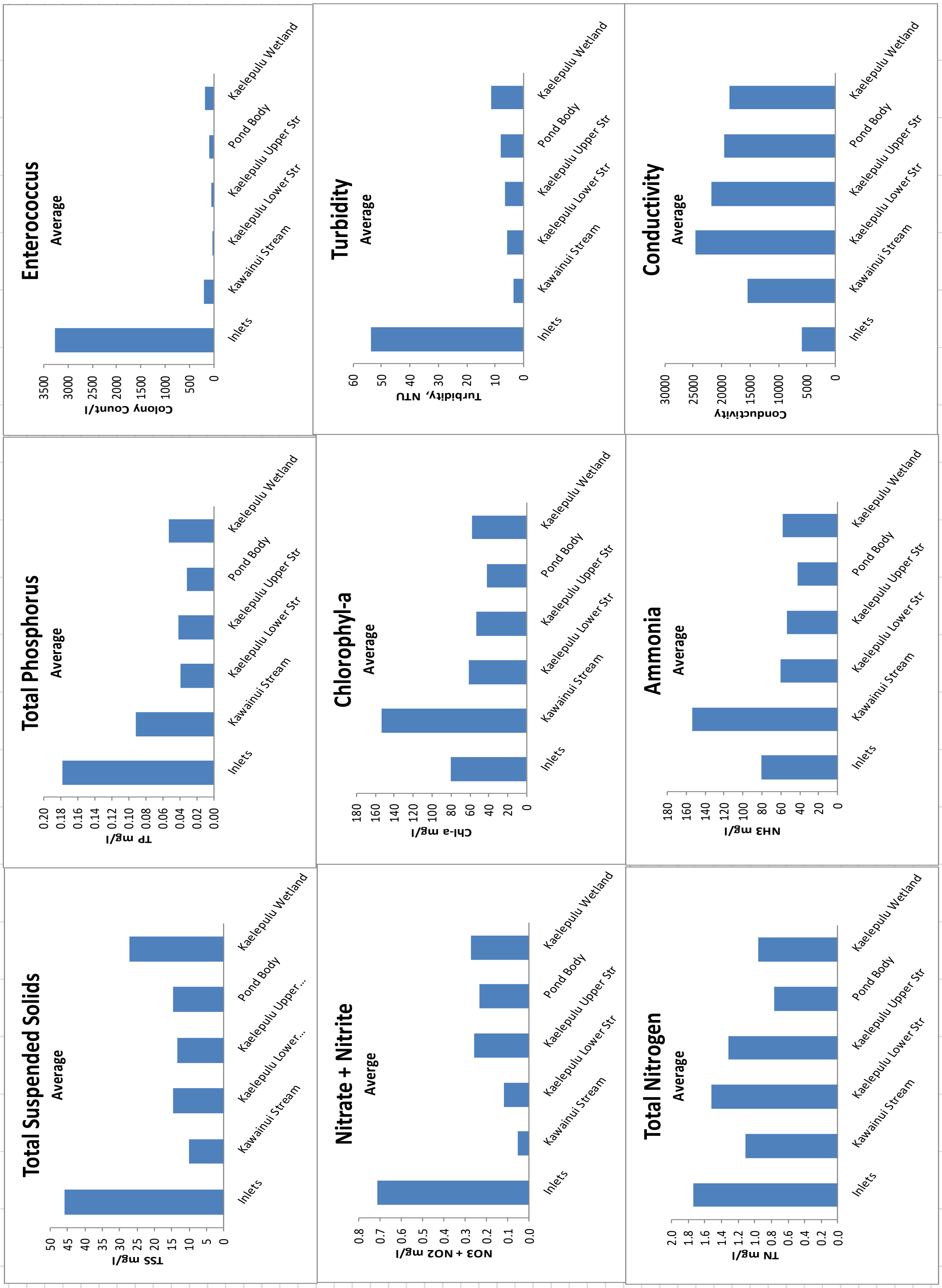
Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
PNC6A	8	11/17/2009	18.1132	0.0100	1.6000	0.0250	118.0000	0.0250	3	5.7	18800
PNC6A	9	10/26/2009	11.8095	0.0100	0.0500	0.0500	61.3333	0.0250	3	2.7	24300
PNC6A	10	10/6/2009	10.5769	0.0100	0.3000	0.1000	32.0000	0.0250	3	2.4	24900
PNC6A	11	9/9/2009	13.6538	0.0100	0.3000	0.0050	79.0000	0.0250	1	3.1	19200
PNC6A	12	8/12/2009	12.4000	0.0734	0.1000	0.0700	68.0000	0.0150	1380	8.8	13800
PNC6A	13	7/21/2009	17.0833	0.0100	0.0500	0.0100	63.7500	0.0150	1	4.9	22000
PNC6A	14	6/3/2009	10.4000	0.0010	0.0500	0.0050	7.6875	0.0050	2	2.7	17400
PNC6B	1	12/20/2010	26.5000	3.2800	3.2000	0.2000	1.0000	0.1450	122	58.3	2462
PNC6B	2	6/23/2010	19.6000	0.0100	0.1000	0.0250	49.0000	0.0250		3.7	23590
PNC6B	3	5/26/2010	11.6000	0.0100	0.6000	0.0250	8.0000	0.0250	54	2.6	24810
PNC6B	4	4/28/2010	9.2000	0.0100	0.1000	0.0250	50.0000	0.0250	1		
PNC6B	5	3/11/2010	13.2000	0.0100	0.0500	0.0050	21.3000	0.0250	1	6.2	19410
PNC6B	6	2/2/2010	16.6000	0.0100	1.9000	0.0050	23.0000	0.0800	1	1.9	23390
PNC6B	7	12/15/2009	10.3846	0.0100	0.0500	0.0250	36.0000	0.0699	3	3.1	
PNC6B	8	11/17/2009	15.0000	0.0100	2.2000	0.0250	130.0000	0.0250	3	5.6	19000
PNC6B	9	10/26/2009	13.2075	0.0100	0.0500	0.0500	48.0000	0.0250	3	2.7	20900
PNC6B	10	10/6/2009	10.8000	0.0100	0.0500	0.0500	23.0000	0.0250	3	2.4	24900
PNC6B	11	9/9/2009	14.2500	0.0100	0.0500	0.0050	78.0000	0.0250	1	3.2	19700
PNC6B	12	8/12/2009	11.6000	0.0631	0.0500	0.0800	89.0000	0.0150	1160	8.7	14100
PNC6B	13	7/21/2009	14.3137	0.0100	0.0500	0.0050	56.2500	0.0150	1	4.4	22400
PNC6B	14	6/3/2009	10.8000	0.0010	0.0500	0.0050	8.2500	0.0050	2	2.3	16000
PNC7	1	12/20/2010	31.5000	2.9100	3.6000	0.0500	6.0000	0.1220	254	51.8	3409
PNC7	2	6/23/2010	22.4000	0.0100	1.4000	0.0250	41.0000	0.0250		6.1	23980
PNC7	3	5/26/2010	10.2000	0.0100	2.4000	0.0250	18.6700	0.0250	88	3.4	24810
PNC7	4	4/28/2010	12.0000	0.0100	0.1000	0.0250	14.0000	0.0250	107		
PNC7	5	3/11/2010	16.8000	0.0100	0.0500	0.0050	28.0000	0.0250	120	7.8	19480
PNC7	6	2/2/2010	24.4000	0.0100	1.8000	0.0050	27.0000	0.0900	2	2.5	23720
PNC7	7	12/15/2009	15.2941	0.0100	0.0500	0.1500	54.0000	0.0598	3	5.6	
PNC7	8	11/17/2009	21.0000	0.0100	1.2000	0.0250	132.0000	0.0250	3	7.8	19200
PNC7	9	10/26/2009	13.1373	0.0100	0.0500	0.0250	48.0000	0.0250	3	3.0	23500
PNC7	10	10/6/2009	10.9615	0.0100	0.1000	0.1000	30.0000	0.0250	3	2.1	24900
PNC7	11	9/9/2009	17.8000	0.0100	0.0500	0.0050	50.0000	0.0250	1	3.2	19900
PNC7	12	8/12/2009	12.1154	0.0100	0.0500	0.0400	72.0000	0.0150	2200	7.8	15600
PNC7	13	7/21/2009	20.6667	0.0100	0.0500	0.0050	48.8000	0.0150	1	4.8	23200
PNC7	14	6/3/2009	48.3333	0.0010	0.0500	0.0050	9.9375	0.0050	2	2.6	16400
PNC8	1	12/20/2010	13.5000	2.4300	5.2000	0.1000	32.0000	0.2840	78	42.7	3865
PNC8	2	6/23/2010	24.4000	0.0100	0.1000	0.0250	48.0000	0.0250		6.9	23600
PNC8	3	5/26/2010	12.4000	0.0100	0.1000	0.0250	22.6700	0.0250	42	3.6	24490
PNC8	4	4/28/2010	10.0000	0.0100	0.1000	0.0250	60.0000	0.0250	33		
PNC8	5	3/11/2010	16.2907	0.0100	0.0500	0.0050	16.0000	0.0250	56	10.8	19520
PNC8	6	2/2/2010	11.2000	0.0100	2.7000	0.0050	49.0000	0.0900	6	2.1	25510
PNC8	7	12/15/2009	11.9608	0.0100	1.2000	0.0250	44.0000	0.0513	5	3.8	
PNC8	8	11/17/2009	20.1961	0.0100	0.4000	0.0250	93.0000	0.1455	3	9.1	18500
PNC8	9	10/26/2009	15.0000	0.0100	0.0500	0.1000	57.3333	0.0250	3	2.7	25700
PNC8	10	10/6/2009	10.2000	0.0100	0.5000	0.1000	20.0000	0.0250	3	1.9	24900
PNC8	11	9/9/2009	13.8776	0.0100	0.0500	0.0050	59.0000	0.0900	1	3.8	20100
PNC8	12	8/12/2009	11.2000	0.0419	0.0500	0.0500	67.0000	0.0150	760	8.2	14500
PNC8	13	7/21/2009	19.2157	0.0100	0.0500	0.0050	53.7500	0.0150	1	6.0	22700
PNC8	14	6/3/2009	11.6000	0.0010	1.5000	0.0050	11.3333	0.0050	2	3.5	16500
PNC9A	1	12/20/2010	14.7500	2.6800	4.4000	0.0250	32.0000	0.2740	116	54.6	3638
PNC9A	2	6/23/2010	19.2000	0.0100	0.1000	0.0250	41.0000	0.0250		4.8	23360
PNC9A	3	5/26/2010	11.0000	0.0100	0.2000	0.0250	20.0000	0.0250	42	3.4	24410
PNC9A	4	4/28/2010	8.4000	0.0100	0.1000	0.0250	64.0000	0.0250	56		
PNC9A	5	3/11/2010	17.4000	0.0100	0.0500	0.0050	29.0000	0.0250	50	7.4	19650
PNC9A	6	2/2/2010	15.6000	0.0100	1.9000	0.0050	17.0000	0.0800	1	1.5	23180
PNC9A	7	12/15/2009	12.5490	0.0100	0.0500	0.0500	48.0000	0.0670	3	4.7	
PNC9A	8	11/17/2009	18.5404	0.0100	0.5000	0.0250	160.0000	0.0250	10	6.7	18000
PNC9A	9	10/26/2009	11.5686	0.0100	0.0500	0.0250	45.3333	0.0250	3	2.4	23400
PNC9A	10	10/6/2009	16.0606	0.0100	0.3000	0.0500	38.0000	0.0250	3	1.7	24800

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
PNC9A	11	9/9/2009	14.8000	0.0100	0.0500	0.0050	67.0000	0.0250	1	3.4	19900
PNC9A	12	8/12/2009	16.0000	0.0472	0.0500	0.0050	78.7097	0.0150	290	7.4	16200
PNC9A	13	7/21/2009	16.1538	0.0100	0.0500	0.0200	46.2500	0.0150	1	5.5	22600
PNC9A	14	6/3/2009	11.4000	0.0010	8.4000	0.0050	8.5526	0.0050	2	2.5	16400
PNC9B	1	12/20/2010	25.5000	2.7800	4.2000	0.0500	1.0000	0.0645	148	53.6	3672
PNC9B	2	6/23/2010	18.4000	0.0100	0.6000	0.0250	32.0000	0.0250		4.9	22770
PNC9B	3	5/26/2010	39.2000	0.0100	2.2000	0.0250	18.6700	0.0250	42	3.6	24510
PNC9B	4	4/28/2010	8.0000	0.0100	0.1000	0.0250	10.0000	0.0250	41		
PNC9B	5	3/11/2010	18.4000	0.0100	0.0500	0.0050	27.0000	0.0250	62	6.7	20440
PNC9B	6	2/2/2010	11.6000	0.0100	1.3000	0.0300	2.0000	0.0700	1	2.7	23300
PNC9B	7	12/15/2009	10.4000	0.0100	0.0500	0.0500	32.0000	0.0250	3	4.5	
PNC9B	8	11/17/2009	15.3846	0.0100	0.0500	0.0250	78.0000	0.0250	3	7.3	18100
PNC9B	9	10/26/2009	11.1765	0.0100	0.0500	0.0500	66.6667	0.3100	3	2.4	23700
PNC9B	10	10/6/2009	9.8039	0.0100	0.4000	0.0500	46.0000	0.0250	3	2.0	24900
PNC9B	11	9/9/2009	14.2308	0.0100	0.0500	0.0050	54.0000	0.0250	1	3.4	19700
PNC9B	12	8/12/2009	12.1569	0.0437	0.0500	0.0050	61.3333	0.0030	200	7.0	16200
PNC9B	13	7/21/2009	13.3333	0.0100	0.0500	0.0050	62.5000	0.0150	1	4.8	22600
PNC9B	14	6/3/2009	10.0000	0.0010	4.0000	0.0050	8.1250	0.0050	2	2.5	17700
PNC10	1	12/20/2010	15.7500	3.1100	4.0000	0.0500	4.0000	0.1080	50	54.9	2742
PNC10	2	6/23/2010	17.2000	0.0100	0.1000	0.0250	36.0000	0.0250		3.8	22590
PNC10	3	5/26/2010	13.2000	0.0100	0.1000	0.0250	37.3300	0.0250	54	2.5	24780
PNC10	4	4/28/2010	8.6000	0.0100	0.1000	0.0250	26.0000	0.0250	77		
PNC10	5	3/11/2010	16.0000	0.0100	0.0500	0.0050	38.0000	0.0250	68	5.1	20800
PNC10	6	2/2/2010	12.2000	0.0100	2.3000	0.0050	1.0000	0.0600	1	1.6	20660
PNC10	7	12/15/2009	12.6000	0.0100	0.0500	0.1000	54.0000	0.0250	80	3.4	
PNC10	8	11/17/2009	15.6000	0.0100	0.0500	0.0250	131.0000	0.0250	3	6.4	18000
PNC10	9	10/26/2009	11.8000	0.0100	0.0500	0.0500	29.3333	0.0250	3	4.1	20500
PNC10	10	10/6/2009	11.0204	0.0100	0.0500	0.0500	25.0000	0.0250	3	1.4	24800
PNC10	11	9/9/2009	11.4815	0.0100	0.0500	0.0050	51.0000	0.0250	1	2.5	19700
PNC10	12	8/12/2009	10.2000	0.0713	0.0500	0.0100	74.0000	0.0150	55	6.4	16200
PNC10	13	7/21/2009	13.0612	0.0100	0.0500	0.0100	57.5000	0.0150	2	3.6	22500
PNC10	14	6/3/2009	9.6000	0.0010	3.2000	0.0050	8.7500	0.0050	2	2.0	16000
PNC11	1	12/20/2010	13.5000	2.8500	3.8000	0.3000	1.0000	0.1130	118	48.7	2983
PNC11	2	6/23/2010	15.6000	0.0100	0.1000	0.0250	46.0000	0.0250		2.9	22860
PNC11	3	5/26/2010	12.8000	0.0100	0.1000	0.0250	9.3300	0.0250	88	2.5	25350
PNC11	4	4/28/2010	12.8000	0.0100	0.1000	0.0250	52.0000	0.0250	13		
PNC11	5	3/11/2010	15.4000	0.0100	0.0500	0.0050	25.0000	0.0250	20	5.3	20720
PNC11	6	2/2/2010	11.0000	0.0100	2.0000	0.0050	0.0001	0.0500	2	2.0	19790
PNC11	7	12/15/2009	15.4902	0.0100	0.0500	0.1000	118.0000	0.0895	3	4.6	
PNC11	8	11/17/2009	18.0000	0.0100	0.0500	0.0250	144.0000	0.0750	3	7.3	18200
PNC11	9	10/26/2009	13.9726	0.0100	0.0500	0.0500	45.3333	0.0250	3	3.3	22300
PNC11	10	10/6/2009	12.1569	0.0100	0.0500	0.0500	36.0000	0.0250	3	2.3	24900
PNC11	11	9/9/2009	15.0000	0.0100	0.0500	0.0050	64.0000	0.0250	1	2.6	19900
PNC11	12	8/12/2009	18.7368	0.0652	0.0500	0.0100	58.5714	0.0150	170	5.9	18700
PNC11	13	7/21/2009	12.7103	0.0100	0.0500	0.0050	56.2500	0.0150	1	3.3	23000
PNC11	14	6/3/2009	10.4000	0.0010	1.3000	0.0050	6.3971	0.0050	2	2.2	16700
SNC1	1	12/20/2010	0.5000	1.1100	1.0000	0.1000	1.0000	0.3780	1	1.6	2724
SNC1	2	6/23/2010	0.8000	0.0100	0.1000	0.0250	249.0000	0.6000		2.5	4141
SNC1	3	5/26/2010	5.8000	0.0100	1.8000	0.0250	225.3300	0.4545	42	4.1	7076
SNC1	4	4/28/2010	7.6000	0.0100	0.6000	0.2500	208.0000	0.6800	198		
SNC1	5	3/11/2010	7.6000	0.0100	1.4000	0.0050	149.0000	0.5900	210	2.7	8407
SNC1	6	2/2/2010	4.4000	0.0100	1.0000	0.1900	16.0000	1.0800	90	1.9	5813
SNC1	7	12/15/2009	10.8163	0.0100	0.0500	0.2500	182.0000	0.6400	60	2.5	
SNC1	8	11/17/2009	5.4902	0.0100	0.6000	0.0250	136.0000	0.0250	3	2.7	9610
SNC1	9	10/26/2009	8.7755	0.0100	0.5000	0.2000	717.6471	0.2310	3	4.8	12500
SNC1	10	10/6/2009	8.9320	0.0100	0.5000	0.0250	127.0000	0.2500	920	4.9	11200
SNC1	11	9/9/2009	7.4000	0.0100	0.0500	0.1000	423.0000	0.2060	140	4.5	11700
SNC1	12	8/12/2009	6.6176	0.0100	2.0000	0.0900	271.0000	0.3470	2140	3.3	11700
SNC1	13	7/21/2009	9.3878	0.0100	0.0500	0.1100	413.7500	0.3610	158	6.8	10300

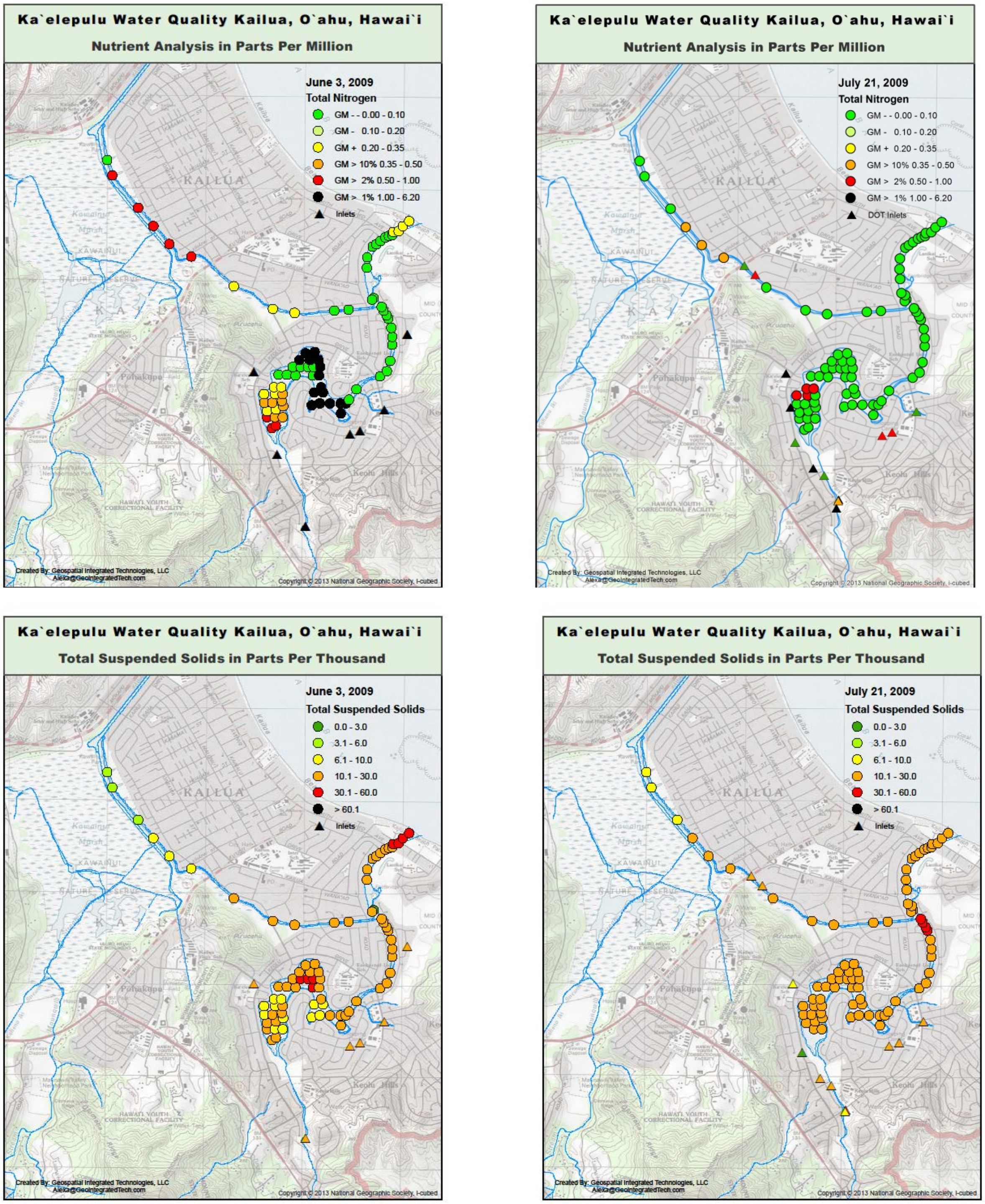
Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
SNC1	15	6/2/2009	4.8000	0.0010	0.9000	0.0050	21.7500	1.0300	2	4.3	10700
SNC2	1	12/20/2010	1.5000	0.4600	1.8000	0.0500	30.0000	0.5600	74	1.8	2814
SNC2	2	6/23/2010	8.4000	0.0045	2.6000	0.1500	241.0000	0.9600		2.6	5208
SNC2	3	5/26/2010	3.6000	0.0100	1.2000	0.0250	346.6700	0.4765	42	3.2	69520
SNC2	4	4/28/2010	5.0000	0.0100	1.4000	0.0500	224.0000	0.6200	85		
SNC2	5	3/11/2010	9.4000	0.0100	1.0000	0.1500	281.0000	0.4215	92	5.2	8442
SNC2	6	2/2/2010	5.2000	0.0100	1.5000	0.2600	10.7000	1.2100	336	2.1	6391
SNC2	7	12/15/2009	6.8000	0.0100	0.9000	0.4500	150.0000	0.5950	15	2.1	
SNC2	8	11/17/2009	4.9020	0.0100	0.7000	0.1000	70.0000	0.5500	5	3.3	9770
SNC2	9	10/26/2009	6.6667	0.0100	0.4000	0.1500	391.2500	0.2620	40	2.2	13500
SNC2	10	10/6/2009	7.9612	0.0100	0.8000	0.0250	217.0000	0.2700	115	3.0	11900
SNC2	11	9/9/2009	11.0000	0.0100	0.0500	0.2000	463.0000	0.1950	3	3.9	13000
SNC2	12	8/12/2009	7.7778	0.0251	1.5000	0.1900	340.0000	0.3240	1920	4.9	12400
SNC2	13	7/21/2009	13.2075	0.0100	0.5000	0.1400	503.7500	0.2310	120	7.6	10300
SNC2	15	6/2/2009	7.4000	0.0010	0.7000	0.0050	30.2500	0.6500	83	4.2	10300
SNC3A	1	12/20/2010	2.5000	0.1900	2.6000	0.1500	56.0000	0.6100	1	4.1	5056
SNC3A	2	6/23/2010	11.6000	0.0100	0.6000	0.0250	133.0000	0.2100		2.4	17920
SNC3A	3	5/26/2010	10.6000	0.0100	0.6000	0.0250	188.0000	0.3600	184	3.7	19710
SNC3A	4	4/28/2010	6.4000	0.0100	3.0000	0.2000	128.0000	0.9900	120		
SNC3A	5	3/11/2010	9.6000	0.0100	0.4000	0.0050	85.0000	0.1470	112	2.3	15810
SNC3A	6	2/2/2010	10.2000	0.0100	0.2000	0.1900	8.0000	0.8700	384	2.7	13720
SNC3A	7	12/15/2009	6.0000	0.0100	0.0500	0.3000	80.0000	0.4620	110	1.3	
SNC3A	8	11/17/2009	8.2692	0.0100	2.3000	0.0250	48.0000	0.5400	3	1.0	15000
SNC3A	9	10/26/2009	9.2000	0.0100	0.0500	0.0500	211.0000	0.2350	55	2.7	20300
SNC3A	10	10/6/2009	10.6000	0.0100	1.5000	0.0250	117.0000	0.1800	95	3.1	17200
SNC3A	11	9/9/2009	15.4000	0.0100	0.0500	0.1000	217.0000	0.0250	70	4.6	19700
SNC3A	12	8/12/2009	8.8636	0.0100	0.9000	0.0700	153.0000	0.2050	1840	4.7	16200
SNC3A	13	7/21/2009	13.8000	0.0100	0.0500	0.0050	182.5000	0.1960	20	4.6	19000
SNC3A	15	6/2/2009	9.1489	0.0010	0.4000	0.0050	16.6667	0.5880	2	2.9	17700
SNC3B	1	12/20/2010	2.7500	0.1200	2.6000	0.1500	52.0000	0.6850	172	5.5	5132
SNC3B	2	6/23/2010	60.8000	0.0100	0.4000	0.0250	145.0000	0.1855		2.4	18830
SNC3B	3	5/26/2010	10.0000	0.0100	2.2000	0.0250	192.0000	0.3350	86	3.5	20210
SNC3B	4	4/28/2010	6.2000	0.0100	1.2000	0.2000	134.0000	0.6600	87		
SNC3B	5	3/11/2010	10.8000	0.0100	2.3000	0.0050	82.0000	0.1220	98	3.5	16310
SNC3B	6	2/2/2010	12.4000	0.0100	0.0500	0.2700	4.0000	0.8100	160	2.5	15440
SNC3B	7	12/15/2009	7.8000	0.0100	0.0500	0.1500	68.0000	0.4150	200	1.1	
SNC3B	8	11/17/2009	4.4898	0.0100	0.5000	0.0250	38.0000	0.5650	3	1.3	15800
SNC3B	9	10/26/2009	10.5882	0.0100	0.0500	0.1000	126.0000	0.2305	45	3.0	20600
SNC3B	10	10/6/2009	12.2449	0.0100	0.3000	0.0250	160.0000	0.1800	125	3.3	17900
SNC3B	11	9/9/2009	19.4000	0.0100	0.0500	0.1000	278.0000	4.2220	45	5.0	19800
SNC3B	12	8/12/2009	9.6154	0.0100	1.2000	0.0050	125.0000	0.1710	1060	3.4	16000
SNC3B	13	7/21/2009	15.7895	0.0100	0.0500	0.0700	200.0000	0.1200	1	4.6	19500
SNC3B	15	6/2/2009	11.2500	0.0010	0.0500	0.0050	15.3333	0.0400	23	2.6	19500
SNC4	1	12/20/2010	2.2500	1.2700	3.2000	0.0500	22.0000	0.4450	1	10.1	6321
SNC4	2	6/23/2010	15.6000	0.0100	0.1000	0.0250	61.0000	0.0250		3.9	25150
SNC4	3	5/26/2010	14.2000	0.0100	0.1000	0.0250	76.0000	0.1075	100	3.6	27200
SNC4	4	4/28/2010	10.0000	0.0100	0.1000	0.1500	96.0000	1.6400	10		
SNC4	5	3/11/2010	12.6000	0.0100	1.4000	0.0050	18.0000	0.0250	14	1.4	21160
SNC4	6	2/2/2010	15.2000	0.0100	16.7000	0.0050	2.0000	0.5200	6	2.6	17090
SNC4	7	12/15/2009	12.1739	0.0100	0.0500	0.2000	86.0000	0.1370	50	1.8	
SNC4	8	11/17/2009	12.8571	0.0100	5.6000	0.0250	89.0000	0.2110	3	3.3	19000
SNC4	9	10/26/2009	11.2871	0.0100	0.0500	0.1000	80.0000	0.0250	3	4.4	18800
SNC4	10	10/6/2009	18.1250	0.0100	0.1000	0.1000	96.0000	0.0250	3	5.7	23000
SNC4	11	9/9/2009	17.5510	0.0100	0.0500	0.0050	158.0000	0.0250	3	3.6	19400
SNC4	12	8/12/2009	11.1905	0.0100	1.2000	0.0050	148.0000	0.0830	960	4.3	20000
SNC4	13	7/21/2009	19.2000	0.0100	0.0500	0.0050	112.5000	0.0922	1	5.5	24500
SNC4	15	6/2/2009	11.4000	0.0010	0.0500	0.0050	11.2500	0.0470	2	2.5	26400
SNC5	1	12/20/2010	23.0000	2.4900	3.4000	0.2000	32.0000	0.0400	98	49.8	3985
SNC5	2	6/23/2010	17.6000	0.0100	0.1000	0.0250	48.0000	0.0250		3.7	25800

Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
SNC5	3	5/26/2010	15.6000	0.0100	0.6000	0.0250	57.3300	0.0250	88	4.4	26900
SNC5	4	4/28/2010	9.8000	0.0100	0.1000	0.0250	80.0000	0.0250	1		
SNC5	5	3/11/2010	13.9394	0.0100	0.3000	0.0050	18.5000	0.0250	1	3.4	21470
SNC5	6	2/2/2010	13.6000	0.0100	0.0500	0.0050	9.0000	0.1400	4	2.5	18410
SNC5	7	12/15/2009	10.2000	0.0100	0.0500	0.0500	106.0000	0.0690	3	2.8	
SNC5	8	11/17/2009	16.8627	0.0100	12.1000	0.0250	87.0000	0.1640	3	6.6	19700
SNC5	9	10/26/2009	8.7037	0.1644	0.0500	0.1000	39.0000	0.0250	3	5.3	17600
SNC5	10	10/6/2009	7.5472	0.0100	1.0000	0.0250	35.0000	0.0250	3	3.1	25000
SNC5	11	9/9/2009	12.1154	0.0100	0.0500	0.0050	54.0000	0.0250	3	2.4	20300
SNC5	12	8/12/2009	9.5455	0.0100	0.9000	0.0050	56.0000	0.0150	1140	4.4	22000
SNC5	13	7/21/2009	15.8824	0.0100	0.0500	0.0100	57.5000	0.1120	4	2.4	23800
SNC5	15	6/2/2009	11.2000	0.0010	0.0500	0.0050	7.7143	0.0220	2	2.3	25300
SNC6A	1	12/20/2010	6.2500	2.7000	4.8000	0.2500	10.0000	3.8350	68	45.7	6373
SNC6A	2	6/23/2010	18.4000	0.0100	1.0000	0.0250	55.0000	0.0250		3.5	26630
SNC6A	3	5/26/2010	21.2000	0.0100	0.1000	0.0250	106.6700	0.0250	10	5.8	29700
SNC6A	4	4/28/2010	8.6000	0.0100	0.1000	0.0500	30.0000	0.0250	5		
SNC6A	5	3/11/2010	11.4000	0.0100	0.0500	0.0050	0.0001	0.0250	2	2.2	23850
SNC6A	6	2/2/2010	13.0000	0.0100	0.0500	0.0050	10.0000	0.2400	2	2.2	18780
SNC6A	7	12/15/2009	8.4000	0.0100	0.0500	0.0500	126.0000	0.0660	3	2.0	
SNC6A	8	11/17/2009	13.7255	0.0100	6.0000	0.0250	68.0000	0.1390	3	3.3	20400
SNC6A	9	10/26/2009	9.8361	0.1821	0.0500	0.2000	18.0000	0.0250	3	6.5	16400
SNC6A	10	10/6/2009	12.2000	0.0100	1.5000	0.1000	59.0000	0.0250	3	2.5	23900
SNC6A	11	9/9/2009	13.2000	0.0100	0.0500	0.0050	107.0000	0.0250	3	2.2	20400
SNC6A	12	8/12/2009	7.3333	0.0100	0.3000	0.0400	95.0000	0.0150	160	4.1	22800
SNC6A	13	7/21/2009	15.2000	0.0100	0.0500	0.0200	48.7500	0.0150	1	5.1	26000
SNC6A	15	6/2/2009	13.8000	0.0010	0.0500	0.0050	8.0000	0.0164	2	2.0	28000
SNC6B	1	12/20/2010	7.7500	2.6600	4.8000	0.0250	8.0000	0.1375	174	47.4	6638
SNC6B	2	6/23/2010	14.8000	0.0100	1.4000	0.0250	47.0000	0.0250		3.9	26280
SNC6B	3	5/26/2010	16.8000	0.0100	0.4000	0.0250	96.0000	0.0250	4	5.8	29540
SNC6B	4	4/28/2010	8.8000	0.0100	0.1000	0.0500	40.0000	0.0250	4		
SNC6B	5	3/11/2010	13.4000	0.0100	0.0500	0.0050	5.0000	0.0250	6	3.4	24250
SNC6B	6	2/2/2010	12.6000	0.0100	0.0500	0.0050	1.0000	0.2300	2	2.5	19040
SNC6B	7	12/15/2009	10.4000	0.0100	0.0500	0.0500	84.0000	0.0636	3	1.9	
SNC6B	8	11/17/2009	14.2308	0.0100	13.5000	0.0250	58.0000	0.1255	3	3.0	20300
SNC6B	9	10/26/2009	12.0000	0.1210	0.0500	0.0500	31.0000	0.0250	3	7.0	18800
SNC6B	10	10/6/2009	10.5882	0.0100	0.0500	0.1500	100.0000	0.0250	3	2.5	23900
SNC6B	11	9/9/2009	13.8000	0.0100	0.0500	0.0050	119.0000	0.0250	3	2.2	20300
SNC6B	12	8/12/2009	12.0455	0.0100	0.3000	0.0050	95.0000	0.0150	140	4.9	23100
SNC6B	13	7/21/2009	16.4706	0.0100	0.0500	0.0100	48.7500	0.0150	1	4.2	26200
SNC6B	15	6/2/2009	13.8000	0.0010	0.0500	0.0050	7.3333	0.0242	2	2.1	28700
SNC7	1	12/20/2010	4.7500	5.5600	8.0000	0.2000	12.0000	1.9350	1	23.1	4610
SNC7	2	6/23/2010	20.8000	0.0100	0.1000	0.0250	56.0000	0.0250		4.2	26660
SNC7	3	5/26/2010	9.4000	0.0100	0.1000	0.0250	106.6700	0.0250	2	4.7	29460
SNC7	4	4/28/2010	8.8000	0.0100	0.1000	0.0500	62.0000	0.0250	4		
SNC7	5	3/11/2010	12.2000	0.0100	0.0500	0.0050	9.0000	0.0250	2	2.1	24060
SNC7	6	2/2/2010	11.6000	0.0100	0.0500	0.0050	0.0001	0.2500	2	3.2	19260
SNC7	7	12/15/2009	11.4286	0.0100	0.0500	0.1000	110.0000	0.0861	3	2.6	
SNC7	8	11/17/2009	12.7451	0.0100	10.7000	0.0250	56.0000	0.1260	3	2.2	20200
SNC7	9	10/26/2009	34.3396	0.1341	0.0500	0.1000	37.3333	0.0250	3	5.9	17800
SNC7	10	10/6/2009	11.9608	0.0100	0.6000	0.0500	72.0000	0.0250	3	3.6	23500
SNC7	11	9/9/2009	13.0000	0.0100	0.0500	0.0050	139.0000	0.0250	3	2.6	20600
SNC7	12	8/12/2009	18.0887	0.0100	0.0500	0.0050	69.0000	0.0150	210	4.0	23700
SNC7	13	7/21/2009	30.6122	0.0100	0.0500	0.0100	68.7500	0.0150	1	3.6	26600
SNC7	15	6/2/2009	13.0000	0.0010	0.0500	0.0050	8.0833	0.7300	2	2.3	27900
SNC8	1	12/20/2010	10.2500	1.8700	3.6000	0.4000	18.0000	0.2440	166	37.6	6592
SNC8	2	6/23/2010	15.2000	0.0100	0.1000	0.0250	60.0000	0.0250		3.7	26370
SNC8	3	5/26/2010	26.2000	0.0100	1.4000	0.0250	90.6700	0.0250	1	4.0	29170
SNC8	4	4/28/2010	9.0000	0.0100	0.4000	0.0500	60.0000	0.3500	1		
SNC8	5	3/11/2010	12.0000	0.0100	0.0500	0.0050	0.0001	0.0250	1	2.3	23700
SNC8	6	2/2/2010	22.8000	0.0100	0.0500	0.0050	0.0001	0.1200	1	3.7	27110
SNC8	7	12/15/2009	9.0000	0.0100	0.0500	0.1000	66.0000	0.0660	3	2.4	
SNC8	8	11/17/2009	13.0769	0.0100	10.0000	0.0250	75.0000	0.0690	3	3.3	20000
SNC8	9	10/26/2009	12.6000	0.0100	0.0500	0.1000	77.3333	0.0250	3	5.6	19200
SNC8	10	10/6/2009	15.0000	0.0100	1.5000	0.0500	59.0000	0.0250	3	3.5	24500
SNC8	11	9/9/2009	13.7736	0.0100	0.0500	0.0050	84.0000	0.0250	3	2.6	21000
SNC8	12	8/12/2009	12.1569	0.0100	1.1000	0.0050	94.0000	0.0150	270	4.5	24700
SNC8	13	7/21/2009	16.7677	0.0100	0.0500	0.0300	75.0000	0.0150	2	3.4	25700
SNC9A	1	12/20/2010	2.5000	1.4600	4.8000	0.1500	40.0000	0.2990	1	20.9	9414
SNC9A	2	6/23/2010	11.6000	0.0100	1.6000	0.0250	45.0000	0.0250		4.0	27400
SNC9A	3	5/26/2010	23.2000	0.0100	2.0000	0.0250	97.3300	0.0250	1	4.0	29430
SNC9A	4	4/28/2010	8.8000	0.0100	0.2000	0.1000	56.0000	0.0250	1		
SNC9A	5	3/11/2010	15.6000	0.0100	0.0500	0.0050	0.0001	0.0250	1	4.5	25340
SNC9A	6	2/2/2010	11.8000	0.0100	0.0500	0.0050	1.0000	0.0500	1	4.2	37270
SNC9A	7	12/15/2009	10.4000	0.0100	0.0500	0.0500	48.0000	0.0684	3	2.3	
SNC9A	8	11/17/2009	15.2000	0.0100	9.7000	0.0250	86.0000	0.0250	3	4.2	20800

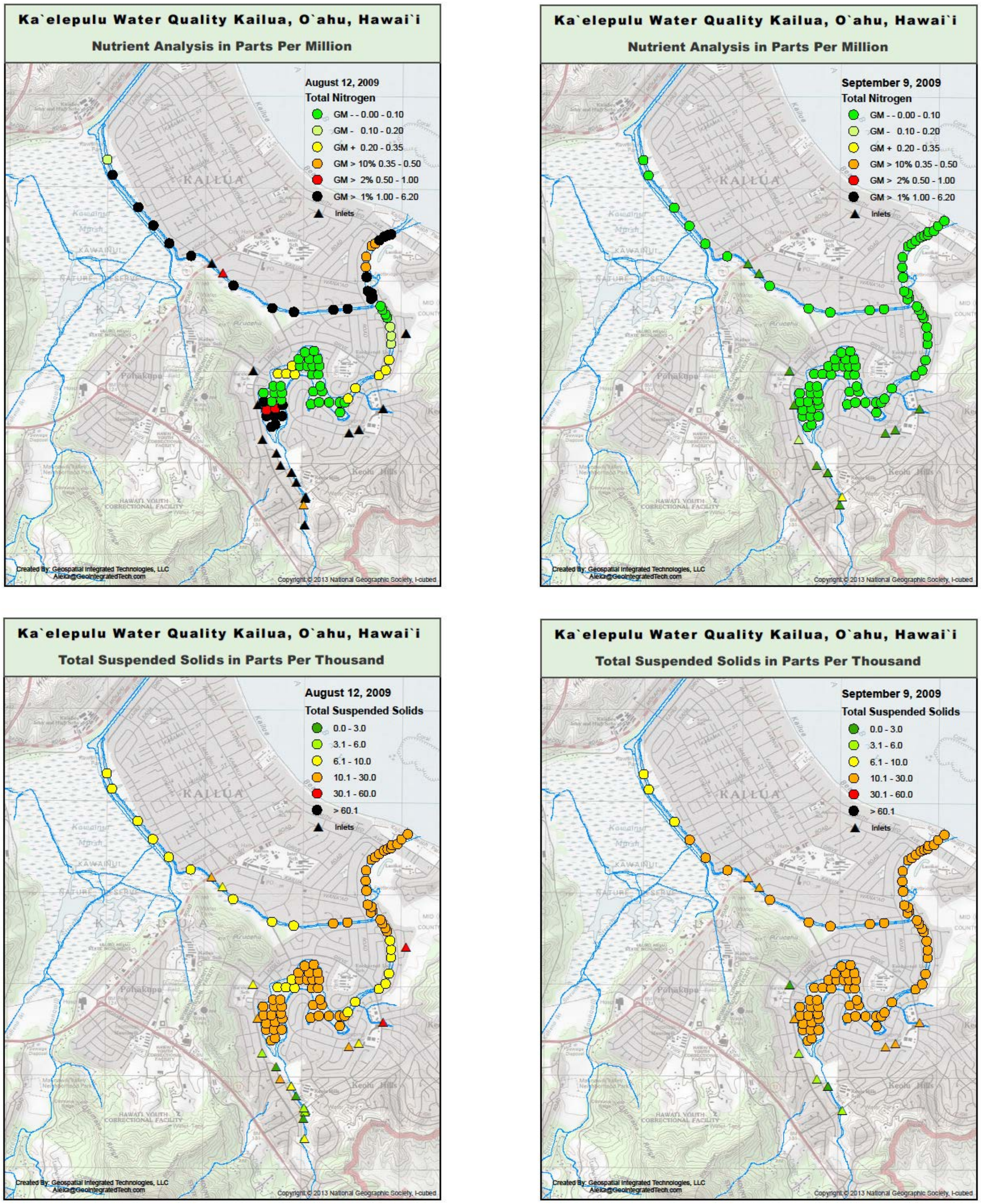
Composite Site Name	# of Date	Date	TSS (mg/l)	Nitrate-N (ppm)	TN (ppm)	TP (ppm)	Chlorophyll-a (mg/m3)	Ammonia (ppm)	Enterococci (colonies/100ml)	Tubidity (NTU)	Conductivity (µs/cm)
SNC8	13	7/21/2009	16.7677	0.0100	0.0500	0.0300	75.0000	0.0150	2	3.4	25700
SNC9A	1	12/20/2010	2.5000	1.4600	4.8000	0.1500	40.0000	0.2990	1	20.9	9414
SNC9A	2	6/23/2010	11.6000	0.0100	1.6000	0.0250	45.0000	0.0250		4.0	27400
SNC9A	3	5/26/2010	23.2000	0.0100	2.0000	0.0250	97.3300	0.0250	1	4.0	29430
SNC9A	4	4/28/2010	8.8000	0.0100	0.2000	0.1000	56.0000	0.0250	1		
SNC9A	5	3/11/2010	15.6000	0.0100	0.0500	0.0050	0.0001	0.0250	1	4.5	25340
SNC9A	6	2/2/2010	11.8000	0.0100	0.0500	0.0050	1.0000	0.0500	1	4.2	37270
SNC9A	7	12/15/2009	10.4000	0.0100	0.0500	0.0500	48.0000	0.0684	3	2.3	
SNC9A	8	11/17/2009	15.2000	0.0100	9.7000	0.0250	86.0000	0.0250	3	4.2	20800
SNC9A	9	10/26/2009	13.3981	0.0100	0.0500	0.0500	73.3333	0.0250	3	6.5	19400
SNC9A	10	10/6/2009	13.0612	0.0100	2.0000	0.0250	71.0000	0.0250	3	3.0	24800
SNC9A	11	9/9/2009	15.3061	0.0100	0.0500	0.0050	60.0000	0.0250	3	2.3	22000
SNC9A	12	8/12/2009	11.0000	0.0100	0.6000	0.0500	107.0000	0.0150	200	4.3	22800
SNC9A	13	7/21/2009	18.4314	0.0100	0.0500	0.0200	62.5000	0.0300	1	3.0	27300
SNC9A	15	6/2/2009	12.4000	0.0010	0.0500	0.0050	5.3896	0.0140	2	2.2	28300
SNC9B	1	12/20/2010	3.5000	1.3900	3.0000	0.1500	38.0000	0.2855	1	21.4	9355
SNC9B	2	6/23/2010	17.2000	0.0100	0.1000	0.0250	56.0000	0.0250		4.1	27250
SNC9B	3	5/26/2010		0.0100	0.1000	0.0250	108.0000	0.0250	1	3.8	30060
SNC9B	4	4/28/2010	8.6000	0.0100	0.4000	0.0250	52.0000	0.0250	6		
SNC9B	5	3/11/2010	15.0000	0.0100	0.0500	0.0050	1.0000	0.0250	8	3.4	24740
SNC9B	6	2/2/2010	21.6000	0.0100	0.0500	0.0050	0.0001	0.0250	1	5.2	38450
SNC9B	7	12/15/2009	9.6000	0.0100	0.0500	0.0500	50.0000	0.0626	5	2.4	
SNC9B	8	11/17/2009	14.9057	0.0100	10.7000	0.0250	71.0000	0.0250	3	4.2	21400
SNC9B	9	10/26/2009	12.3810	0.0100	0.0500	0.1000	133.3333	0.0250	3	6.3	18300
SNC9B	10	10/6/2009	14.4231	0.0100	0.6000	0.0500	72.0000	0.0250	3	3.1	24800
SNC9B	11	9/9/2009	15.3061	0.0100	0.0500	0.0050	47.0000	0.0250	3	2.5	21700
SNC9B	12	8/12/2009	11.9608	0.0100	0.4000	0.0200	109.0000	0.0150	330	4.2	23100
SNC9B	13	7/21/2009	16.8627	0.0100	0.0500	0.0200	53.7500	0.0310	1	3.2	27200
SNC9B	15	6/2/2009	13.0000	0.0010	0.0500	0.0050	358.3333	0.0116	2	1.9	28200
SNC10	1	12/20/2010	4.5000	1.5700	2.6000	0.1000	68.0000	0.2625	128	31.1	10360
SNC10	2	6/23/2010	14.8000	0.0100	0.6000	0.0250	46.0000	0.0250		5.1	28010
SNC10	3	5/26/2010	23.0000	0.0100	2.8000	0.0250	82.6700	0.0250	1	5.0	30780
SNC10	4	4/28/2010	8.4000	0.0100	1.4000	0.0500	30.0000	0.0250	2		
SNC10	5	3/11/2010	15.0000	0.0100	0.0500	0.0050	0.0001	0.0250	4	4.5	26570
SNC10	6	2/2/2010	28.2000	0.0100	0.8000	0.0050	0.0001	0.0250	1	4.8	38360
SNC10	7	12/15/2009	7.8000	0.0100	0.0500	0.0250	72.0000	0.0566	190	2.3	
SNC10	8	11/17/2009	17.6471	0.0100	12.2000	0.0250	96.0000	0.0250	5	6.1	22500
SNC10	9	10/26/2009	15.0649	0.0100	0.0500	0.1000	69.3333	0.0250	3	7.4	18600
SNC10	10	10/6/2009	15.8000	0.0100	1.1000	0.0250	82.0000	0.0250	3	3.4	24200
SNC10	11	9/9/2009	17.7500	0.0100	0.0500	0.0050	66.0000	0.0250	3	2.3	22200
SNC10	12	8/12/2009	13.9959	0.0100	3.7000	0.0050	115.0000	0.0150	300	4.7	22900
SNC10	13	7/21/2009	17.9412	0.0100	0.0500	0.0200	55.0000	0.0150	4	3.6	28200
SNC10	15	6/2/2009	15.4000	0.0010	0.0500	0.0050	4.5455	0.0570	2	2.9	29000
SNC11	1	12/20/2010	13.0000	1.4300	3.0000	0.1500	No Result	0.2050	94	25.6	12360
SNC11	2	6/23/2010	17.2000	0.0100	0.8000	0.0250	43.0000	0.0250		5.8	28000
SNC11	3	5/26/2010	17.8000	0.0100	0.1000	0.0250	100.0000	0.0250	12	4.6	31450
SNC11	4	4/28/2010	9.2000	0.0100	0.4000	0.0250	56.0000	0.0250	17		
SNC11	5	3/11/2010	13.6000	0.0100	0.0500	0.0050	6.0000	0.0250	16	3.4	27140
SNC11	6	2/2/2010	22.8000	0.0100	0.0500	0.0050	0.0001	0.0250	1	5.7	42470
SNC11	7	12/15/2009	9.4118	0.0100	0.0500	0.0250	36.0000	0.0500	10	2.5	
SNC11	8	11/17/2009	18.6000	0.0100	12.0000	0.0250	84.0000	0.0250	25	4.6	22500
SNC11	9	10/26/2009	13.7331	0.0100	0.0500	0.0500	50.6667	0.0250	3	7.5	18800
SNC11	10	10/6/2009	12.6000	0.0100	0.1000	0.0500	60.0000	0.1100	3	4.2	24000
SNC11	11	9/9/2009	14.8000	0.0100	0.0500	0.0050	68.0000	0.0250	3	2.3	22100
SNC11	12	8/12/2009	13.0612	0.0100	6.8000	0.0050	104.0000	0.0150	180	5.5	23000
SNC11	13	7/21/2009	20.5882	0.0100	0.0500	0.0050	61.2500	0.0522	24	3.6	29700
SNC11	15	6/2/2009	30.7407	0.0010	0.3000	0.0050	5.0000	0.0810	2	2.8	35200



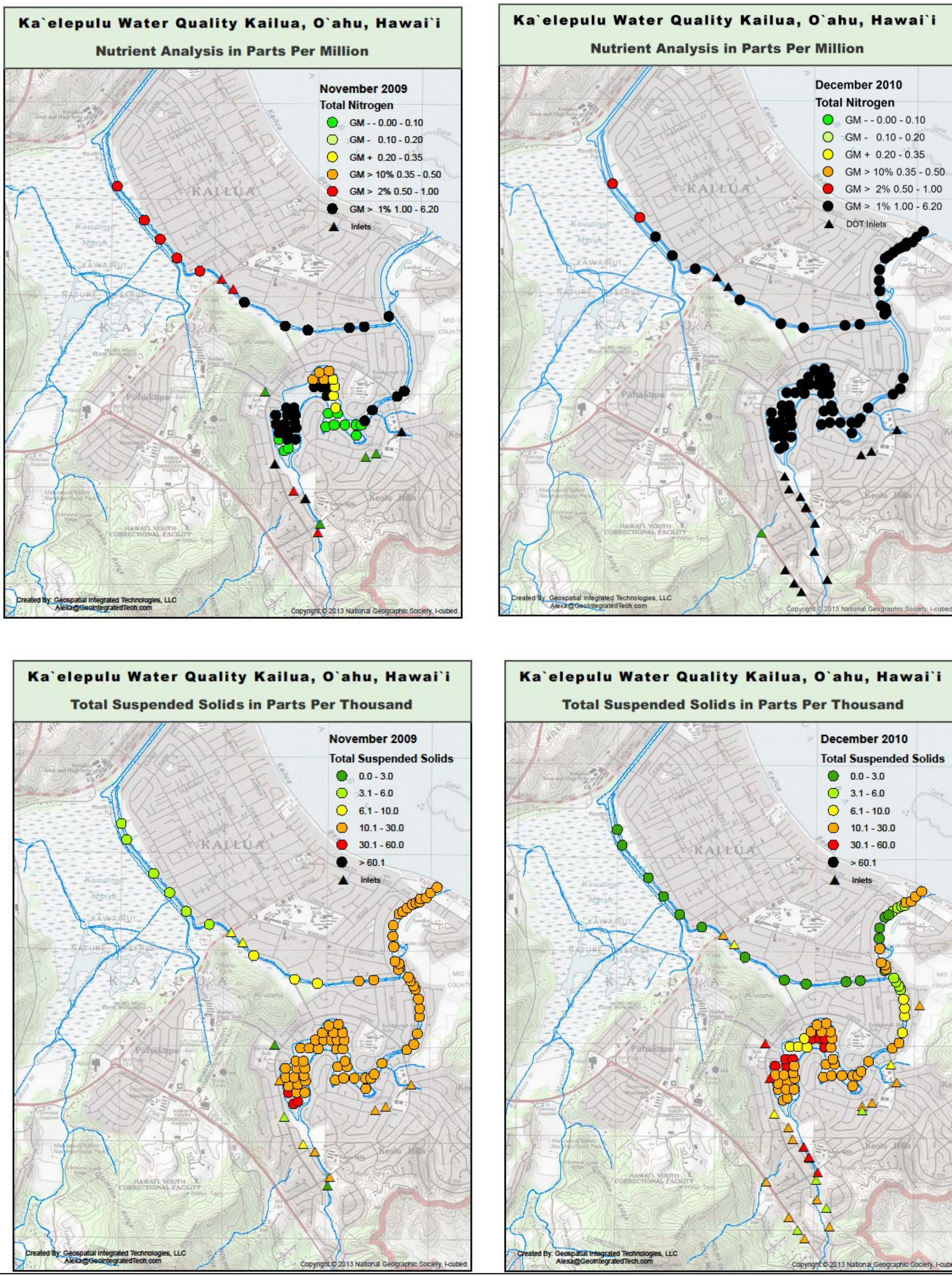
Enterococcus
Average
Colony Count/l
Total Phosphorus
Average
TP mg/l
Total Suspended Solids
Average
TSS mg/l
Turbidity
Average
Turbidity, NTU
Chlorophyl-a
Average
Chl-a mg/l
Nitrate + Nitrite
Averge
NO3 + NO2 mg/l
Conductivity
Average
Conductivity
Ammonia
Average
NH3 mg/l
Total Nitrogen
Average
TN mg/l
Inlets
Kawainui Stream
Kaelepulu Lower Str
Kaelepulu Upper Str
Pond Body
Kaelepulu Wetland



TMDL data (Tamaru, 2012) displayed for June (left) and July (right) for total nitrogen (top) and TSS (bottom) with colors representing ranges above State water quality standards.

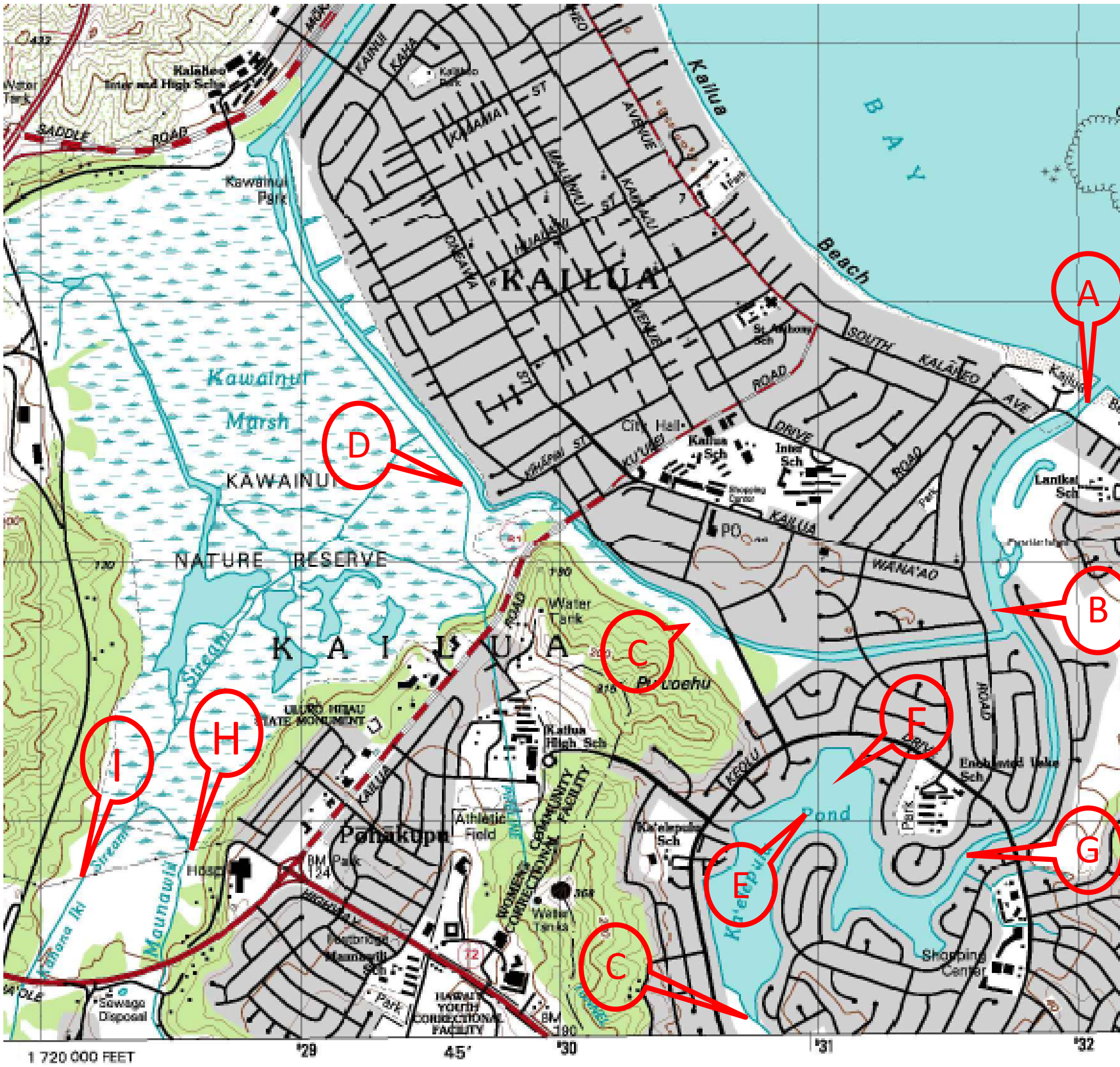


TMDL data (Tamaru, 2012) displayed for August (left) and Sept (right) for total nitrogen (top) and TSS (bottom) with colors representing ranges above State water quality standards.



TMDL data (Tamaru, 2012) displayed for November (left) and Dec, 2010 (right) for total nitrogen (top) and TSS (bottom) with colors representing ranges above State water quality standards.

RELATIONSHIP TO OTHER WATERSHED PROJECTS



A. Regular muliwai opening of Kaelepulu Stream at Kailua Beach
B. Mangrove removal from estuary by ELRA and Kailua Canoe Club
C. Wetland restoration for improved bird habitat, Kawainui, Hamakua, Kaelepulu .
D. Kawainui Stream Flow Restoration from Kawainui Marsh
E. State Total Maximum Daily Load study of Kaelepulu
F. City Drainage Improvement Study and Implementation Report
G. Dredging of blocked segment of Kaelepulu channel for improved circulation.
H. Kawainui Bird Pond Construction
I. State Stream Bank and Wetland Restoration

B. Mangrove removal from estuary by ELRA and Kailua Canoe Club

B-1 Kaelepulu Pond Mangrove Control.
2002-2004 - Complete
Cost: $44,000 ($20,000 State DOH 319 funds, $24,000 match from ELRA and Kamehameha Schools)

Mangrove in Hawaii is an alien invasive species that ruins native ecosystems and leads to poor water quality. In 2002 the DOH awarded a 319-grant to the ELRA to assist with the removal of large stands of mangroves within Kaelepulu Pond. Today there are no mangroves in the pond and regular maintenance continues to eliminate young sprouts that come into the system as seedlings.

B-2 Control of Mangrove in the Lower Kawainui and Kaelepulu Streams.
2011-2012 – Complete
Cost $89,666 (HCF: $14,000, Match from ELRA & KCC: $48,666, Castle Foundation: $25,000)

In 2011 the Hawaii Community Foundation and Harold Castle Foundation awarded ELRA and the Kailua Canoe Club a grant to eliminate mangroves from the lower reaches of the Kawainui Stream and the Kaelepulu Stream between the beach and the pond. This effort was initiated on the coat-tails of a City funded (~$150K) effort two years prior to cut the large mangroves from this same body of water. Experience has shown that a single cutting of large mangrove is not effective at long-term control because of the thousands of seedlings that sprout within the tangled mat of cut mangrove roots. Today this project is about 90% complete

C. Upper watershed restoration for improved bird habitat

C-1 Kawainui Marsh Bird Pond Creation
2003-2011 Planning and Permitting, complete.
2012 (summer) Contracted Construction
Cost:$5,000,000. (Cost share between State DLNR /USACE)

Thirteen ponds are to be constructed in two groupings on either side of the Manawili Stream just below Castle Hospital with a total water surface of 8 acres. The ponds are to be fed from rainfall and shallow wells. At an elevation of 10 to 22 feet, it is not anticipated that the Kawainui Stream flow restoration project, at an elevation of about 6 feet, will have any adverse impact on the operation of the bird ponds.

C-2 Kawainui Marsh Natural Area Wetland Enhancement
2010-present.
Cost $939,000 Cost share between DLNR/Federal NRCS & FFWS

About 30-acres of overgrown brush and invasive plants are being cleared from the lower reach of the Kahaniki Stream in Kawainui Marsh near the junction of the Quary Road with the Pali Highway. The project will expose the stream, wetland flats, and natural small ponds for use as native waterbird habitat. At an elevation of 10 to 30-feet, this project is above the elevation that may be impact by water withdrawal from the other side of Kawainui Marsh at an elevation of about 6 feet, or by manipulations of the stream mouth at an elevation of 0-2 feet.

C-3 Hamakua Marsh Restoration
2005-2008 Complete
Cost $ 500,000 DLNR with partial funding from NRCS. $1.2Million scheduled for purchase.

The DLNR cleared overgrown cattle pasture in a wetland area adjacent to the Kawainui Stream where is flows behind downtown Kailua. The land is at an elevation of 2 to 3 feet and is managed as habitat for Hawaiian Stilts, Coots, and Gallinules. An increase in water elevation, particularly during the summer months, would be seen as a benefit to this site, inundating more of the flat ex-pasture land to create more habitat for Hawaiian Stilts.

C-4 Kaelepulu Wetlands
1994-present
Cost – Privately Funded

In 1994 as a result of regulatory action by the USACE approximately 5.8 acres at the Diamond Head/Mauka end of Kaelepulu Pond are designated as preservation land to be managed as a wetland bird preserve. The wetland, now under different private ownership, is being very successfully managed as nesting and foraging habitat for Hawaiian Stilts, Coots, and Gallinules. The wetland managers believe that regular stream openings to the ocean are essential to the health and success of the wetland. The additional seawater flow helps control predators (bullfrog) and invasive vegetation and lowers the threat of high water flood events that drown the eggs and chicks of the endangered native waterbirds. Regular interchange of lake water with the ocean also minimizes the conditions that cause fish die-offs which in turn causes deadly avian botulism.

D. Kawainui Stream Flow Restoration from Kawainui Marsh

2012 – ongoing
Cost $248,000 (Funded Engineering Study & EA) $1,010,000 (Construction estimate) State of Hawaii

The State DLNR has completed an engineering study, and experimental flow restoration study, and environmental assessment to examine the feasibility and potential impact of restoring flow from the Kawainui Marsh to the Kawainui Stream over (through, around, under) the Kawainui flood control levee. An experimental phase (Summer 2014) siphoned water from the marsh to the stream to test for any adverse impacts of the water transfer. The concept is to allow the system to slowly raise over a period of a month to an elevation of about 2.0-feet. This is about 0.5 feet above the present average stream elevation. The additional flow was shown to improve water quality and allow for sufficient hydraulic head to augment the monthly mechanical opening of the stream mouth by City crews. Observations of multiple stream mouth openings have shown that this additional 0.5 foot of head can have a pronounced positive effect on the opening of the stream mouth during a falling tide.

The 2017 legislative session includes CIP funds of $1.01M to complete the EA, obtain permits, and establish controlled flow in a pipe around the southern end of the Kawainui levee. This flow would enter the present ITT wetland, turning it into more of an open water bird habitat at the entrance to Kailua, with overflow feeding into the Kawainui Stream and Kaelepulu estuary system.

E. State Total Maximum Daily Load study of Kaelepulu and Kailua Waterways

2004- Present. Cost $94,000 (to date) for studies of water quality.

The EPA has mandated that studies be conducted to determine the pollutant sources and pollutant loads to water bodies that do not meet water quality standards. Once the pollutant loads are understood, then methods are devised to control these sources and bring the water body back to within water quality standards. The DOH has funded studies by the UH and the USGS to investigate pollutant loads within the Kaelepulu Wetland, Pond, and Stream, and the Kawainui Stream. The study resulted in an excellent water quality data set collected monthly over a period of more than a year by Tamaru, however, this dataset was rejected by the DOH for unspecified “quality control” issues. The data set clearly shows that the source of excess nutrients and turbidity is from the NPDES permitted City storm drain system. The TMDL process has been stalled since 2011 due to lack of pressure by the EPA and lack of initiative by the DOH.

F. City Drainage Improvement Study and Implementation Report

F-1 Enchanted Lake Stormwater Drain Assessment

The City has conducted a survey of all drainage ways entering Kaelepulu Pond to assess their condition and their likely role in transmitting pollutants to the system. Areas requiring repairs were identified and the drainages that were likely contributing significant loads to the system were identified. Preliminary concepts to control pollutant loads from these drainages have been developed and were reported in a 2008 report by AECom: Stormwater Best Management

Practices for the Kaelepulu Watershed. However, the City decided not to implement the proposed solutions and has hired AECom to complete additional water quality and modeling studies of the watershed. A new draft report by AECom (2016 – public presentation) proposes to install curb inlet screens and/or catch basket filters on approximately 60 of the 1000+ curb inlets to the storm drain system feeding into the Kaelepulu estuary. Additional street sweeping and storm drain maintenance are also proposed although there is no street sweeping or vacuum truck equipment available in the Kailua/Waimanalo area, nor are there any facilities on Windward Oahu for off-loading of material collected from this equipment.

F-2 Enchanted Lake Stormwater Drainage System Modifications
Design Phase: 2012 - ?
The City has hired a consultant (AECom) to develop preliminary plans and cost estimates for the control of pollutants from selected drains within the watershed.

G. Dredging of blocked segment of Kaelepulu channel for improved circulation.

Future Project: Cost Estimate: $1,000,000

The 1993 Flood Capacity Study of the Kailua Waterways by Park Engineering concluded that the channels were not in need of dredging to accommodate flood flows, except in one location just outside the bounds of their official survey at the mouth of Enchanted Lake (Kaelepulu Pond). At this location they identified a 100-yard length of channel that was much shallower than the balance of the stream and could interfere with the flow of water from the lake into the channel under extreme storm events. However, this blockage was within the bounds of the Enchanted Lake Residents Association property.

The source of the sediment blocking the channel is from a side channel draining the commercial and residential areas of Enchanted Lake, as well as portions of the Mid-Pac Golf club. It is likely that the bulk of the sedimentation occurred prior to 1980 associated with the massive hillside residential community development in the absence of effective erosion control. Trash and green waste typical of residential drains continues to collect at this site following heavy rainfall events, but the actual sediment load from this drainage is low. The shoal inhibits boat traffic and (more importantly) greatly limits the exchange of water with the ocean. Saltwater entering from the ocean is denser than fresh water and cannot get up and over this hump in the stream bottom. The result is that effective salt water flushing is limited to the stream bed only. This lack of effective change has had, and will continue to have, adverse impacts on water quality in the pond. The ELRA is in the process of obtaining a permit through the USACE for dredge removal of the approximately 5,000 cubic yards of material that constitute this shoal. Dredging is scheduled for the summer of 2018. The ELRA would welcome any assistance from government agencies to remove this blockage that would help to restore water exchange and greatly improve water quality within the system.

Quotes from long-time Kailua Residents

Harry Morley, Wanaao Street, Kailua

11/7/2007 (via email)

In 1961 the Campos Dairy was still in operation where Daiei [Target] & Safeway are located, all the around the Kaneohe side of Enchanted Lake..during heavy rains the smell was enough to make us gag…and often did as high school students. At that time the high school was operating down in Kailua where the Intermediate school is. Anyway, the outflow during heavy rains was more polluted at that time due to the treatment plant near Keolu and the runoff from the dairy operations.

At the same time, there was no real dike across Kawainui Marsh…and the coconut grove area just flooded until the Mokapu canal could handle the load.

Cindy Turner DeVries.

2016 verbal

Growing up in Kailua in the 60s we lived at a number of different homes along both Kailua and Lanikai beaches. The stream at the Lanikai Bridge was almost always flowing, with at least a small channel that you could jump across flowing over the sand bar at the beach. I suppose it may have closed sometimes during the summer, but I always remember it flowing and being jealous of all the other kids who got to jump off the bridge into the deep stream, ‘cause my parents wouldn’t let me do that.

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Email: elra@kaelepulupond.org
Website: www.kaelepulupond.org