KAWAI NUI STREAM FLOW RESTORATION PROJECT

SIPHON FLOW RESTORATION EXPERIMENT REPORT

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Prepared For

State of Hawaii, Department of Land and Natural Resources, Engineering Division

Prepared By

Oceanit Laboratories Inc.

ACKNOWLEDGEMENTS

This study could not have been conducted were it not for the input and support received from the community. The Kailua Neighborhood Board both publically supported the project and provided written commentary through the long and difficult permit process. Private citizens, including Hugo DeVries (owner of the Kaelepulu Wetlands) and Larry Bartley (Neighborhood Board member) provided both technical expertise and physical labor to assist the installation of the syphon. Mr. Derek Esibill of the Pacific American Foundation supported the project by providing the use of a YSI data-sonde, accompanying the field crew on the majority of water quality data collection events, and by spreading his knowledge and enthusiasm to the surprisingly large number of public school students he convinced to follow us out onto the water during many of our pre-dawn surveys.

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1 INTRODUCTION

1.1 PROJECT BACKGROUND

The project, located in Kailua on the windward side of Oahu, Hawaii, proposes to design a system to transfer water, preferably by gravity, from the Kawai Nui Marsh across the existing flood control levee into the Kawai Nui Stream without adverse impacts either to the levee or to the flood protection it provides. The physical extent of the project is small, but the potential impacts could spread upstream to the 800 acre Kawai Nui Marsh, and downstream to the 142 acre KWS System (KWS) including Hamakua Wetlands, Kaelepulu Pond, associated wetlands, and ocean outfall at Kailua Beach.

The focus of this study is the 142-acre coastal estuary commonly referred to as the KWS system. This highly modified urban estuary consists of the Kaelepulu Stream leading from the Kaelepulu Pond and Kaelepulu Wetland, plus the remnant of Kawai Nui Stream that runs adjacent to the town of Kailua where it feeds the Hamakua Marsh before joining Kaelepulu Stream.

1.1.1 Purpose

The goal of the project is to partially restore water flow from Kawa Nui Marsh to Kawai Nui Stream across the flood control levee that has blocked this flow since 1966. It is believed that restoration of the flow will improve water quality in the stream and estuary system and improve the stability and efficacy of tidal exchange through the Kaelepulu Stream mouth.

An experimental trial was initiated to test the impact of partial water flow restoration to Kawai Nui Stream and the surrounding environment and upon the opening efficiency of the stream mouth during the limited experimental trial period. Several Water quality parameters were monitored before and after the temporary water transfer to assess impacts to the KWS. The results of the experiment are documented in this report.

1.1.2 History

Historically, water from the Kawai Nui Marsh flowed through Kawai Nui and Kaelepulu Streams before discharging into the ocean at the south end of Kailua Bay. In response to repeated flooding in the developing urban community of Kailua, the United States Army Corps of Engineers (USACE) designed and completed construction of the Oneawa Canal in 1952. Oneawa Canal diverted the Kawai Nui Marsh flow from Kawai Nui and Kaelepulu Streams and redirected it to the ocean at the north end of Kailua Bay. However, floods continued to occur until the USACE completed the construction of the Kawai Nui Levee in 1966. The levee further reduced the flood threat to the town, but completely eliminated the historically provided flow from Kawai Nui Marsh to the 142 acres of Kawai Nui Stream, Hamakua Wetlands, Kaelepulu Stream, Kaelepulu Pond and Kaelepulu Wetlands. The Kawai Nui Marsh overtopped the levee on New Year's Eve of 1987, which resulted in a reassessment of the levee design by the USACE. By 1993 the size of the levee structure had been increased and the levee topped with a 4-foot high concrete floodwall.

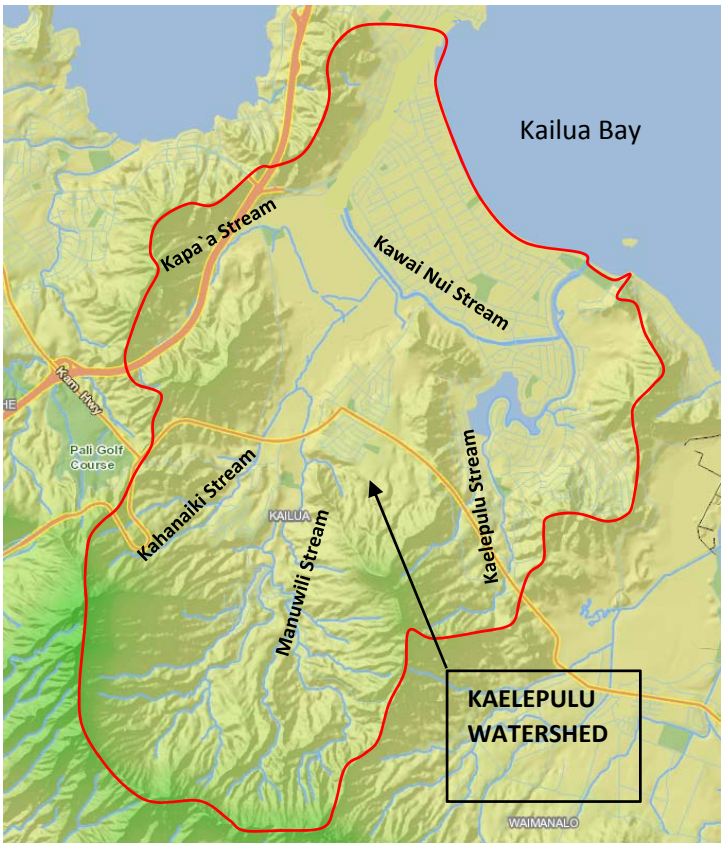


Figure 1.1. Prior to 1950, the Kaelepulu Watershed encompassed about 11,000 acres of land with a single outlet at the southern end of Kailua Bay.

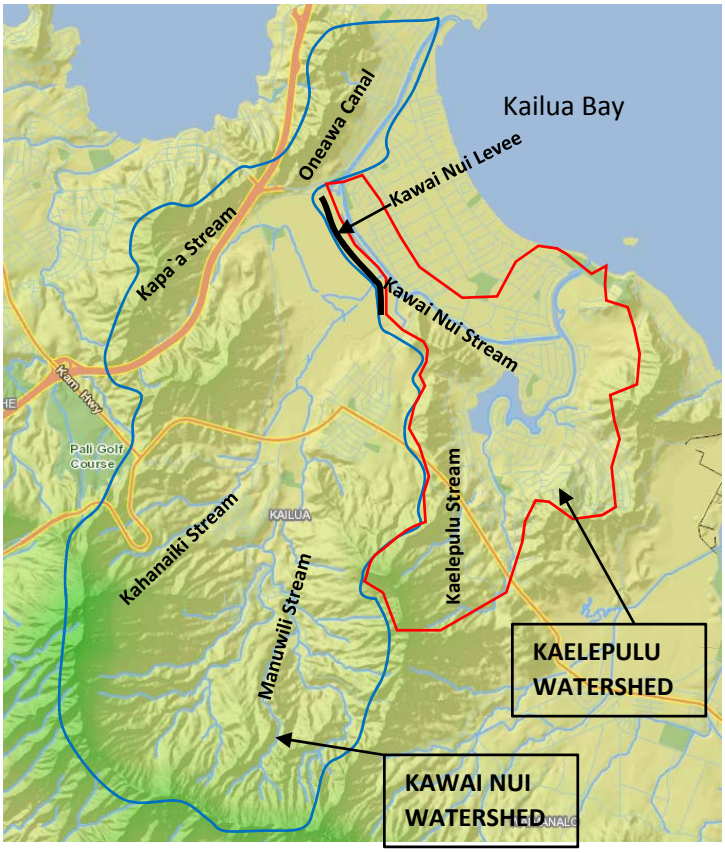


Figure 1.2. By 1966 the construction of the Kawai Nui Levee and the Oneawa Canal draining to the north end of Kailua Bay had created the new Kawai Nui Watershed. This divorced the Kaelepulu Watershed from the main source of its water flow.

Kapa'a, Kahanaiki, and Maunawili Streams contribute flow to Kawai Nui Marsh. Prior to the completion of the flood control measures, these waters then flowed from the Kawai Nui Marsh into Kawai Nui Stream which joined with Kaelepulu Stream before discharging into Kailua Bay at the south end of Kailua Bay. (Figure 1.1). The flood protection scheme consisting of the Kawai Nui Levee, flood wall, and Oneawa Canal isolated Kawai Nui Stream from the larger watershed and eliminated flow from the Marsh to Kawai Nui Stream. This resulted in a drastic reduction of flow through the Kaelapulu Stream into the south end of Kailua Bay, and undoubtedly affected the natural stability of the stream mouth. Examination of maps and aerial photos from prior to 1966, and discussions with long-time residents agree that prior to construction of the levee the stream almost continuously flowed across the beach into the bay. Currently, the stream mouth is closed with a sand bar and has to be opened with heavy equipment to prevent flooding of low-lying home lots near the mouth of Kaelapulu Stream.

Coincident with construction of the flood control levee, the Kaelepulu Pond was also undergoing drastic physical changes. Urban development and the creation of the Enchanted Lake Community in the 1960's converted the 180-acre Kaelepulu Pond and wetland into a deeper 100 acre lake surrounded by fast land supporting urban home lots. Topographic modifications included grading (removal) of an 80-foot tall hill from the center of Kailua and dredging the pond. The excavated and dredged materials were used as fill for the home lots around the pond perimeter. The storm drain system constructed as part of the urban development used the pond as a component of the storm water receiving and transmission system and this use was deeded over to the City.

Subsequent water quality surveys conducted by AECOS (1992), Fujioka (1994), USGS (2008), and the Total Maximum Daily Load (TMDL) studies conducted by the University of Hawaii (Tamaru & Babcock, 2011) indicate that the waters of the system did not meet the State of Hawaii Department of Health (DOH) water quality standards for streams. The TMDL study also indicated that KWS did not fit clearly into the State definition as either a stream or an estuary. The system is listed by DOH as "water quality limited", exceeding state estuary standards for nutrients and turbidity.

The main environmental problems faced by the KWS System (Bourke, 2016) include:

- Lack of headwater flow into Kawai Nui Stream
- Limited and irregular water exchange with the ocean
- Overgrowth of mangrove in the KWS System
- Presence of a submerged berm in Kaelepulu stream that restricts internal circulation, and
- Uncontrolled pollutant loads from storm drains into the pond, particularly from graded construction sites.

Figure 1.3 shows the current conditions, major land and water system features, and the location of the experimental water transfer.

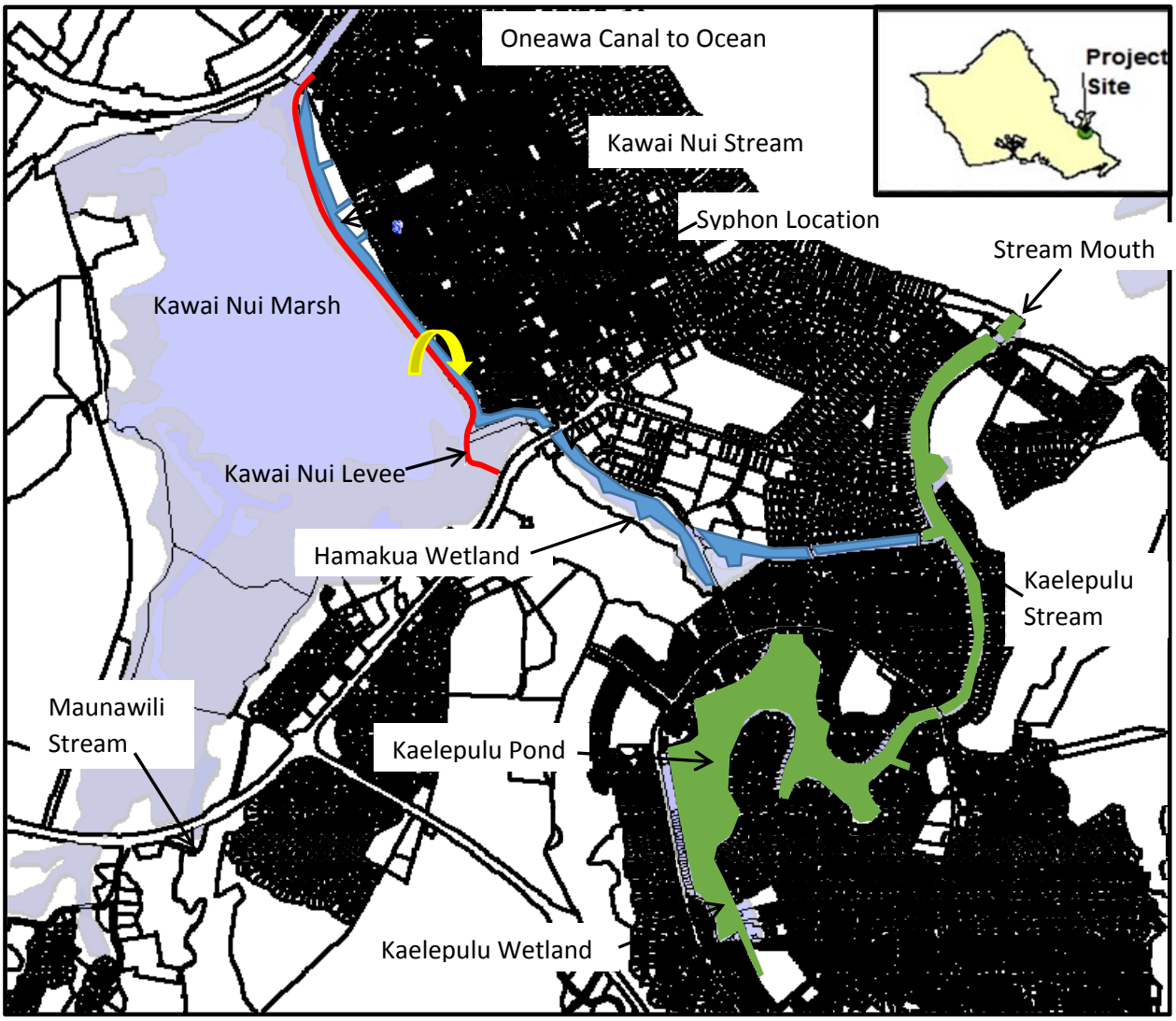


Figure 1.3 Site map

1.1.3 Baseline hydrology and rainfall

The new Kawai Nui watershed created by construction the flood control levee is roughly twice the size (7,175 ac) of the remnant Kaelepulu watershed (3,450 ac) and reaches to the crest of the Koolau Mountains that experience heavy rainfall. The water surface area of Kawai Nui Marsh (894 ac) is approximately six times greater than the surface area of the Kauai Waterways system (142 ac).

Annual rainfall near the center of Maunawili Valley (the headwaters of Kawai Nui Marsh) averages about 75 inches per year. Rainfall statistics for the Kaelepulu watershed (Giambelluca et al, 2012; NOAA Atlas, 2016) indicate an annual rainfall of about 41 inches per year. 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 3.9-inches.

The pan evaporation rate for the windward side of Oahu is about 0.25-inch per day. This is consistent with a range of 0.2-inch/day to 0.33-inch/day (~7.5 inches per month) lake water elevation drop measured during periods without precipitation on the pond.

The flow of water into Kawai Nui Marsh, as measured by USGS gauges on the Maunawili and Kahanaiki Streams (USGS#'s 1626055 & 16264100) averages about 15 cubic feet per second (CFS) and 1 CFS respectively. The flow from Maunawili Stream changes with the seasons, varying monthly from a low of about 7 CFS in July to 26 CFS in March (Figure 1.4). Some flow from Maunawili Valley (~1-2 CFS, per USGS site # 16249900) is diverted into the adjacent Waimanalo watershed for irrigation purposes. No flow data are available for Kapa`a Stream although it is likely less than 1 CFS. The most recent flow measurements in Maunawili Stream indicate a daily average flow of 11.5 CFS. There is no estimate of groundwater flow to Kawai Nui Marsh, although the geology of the site suggests that this flow may also be minimal.

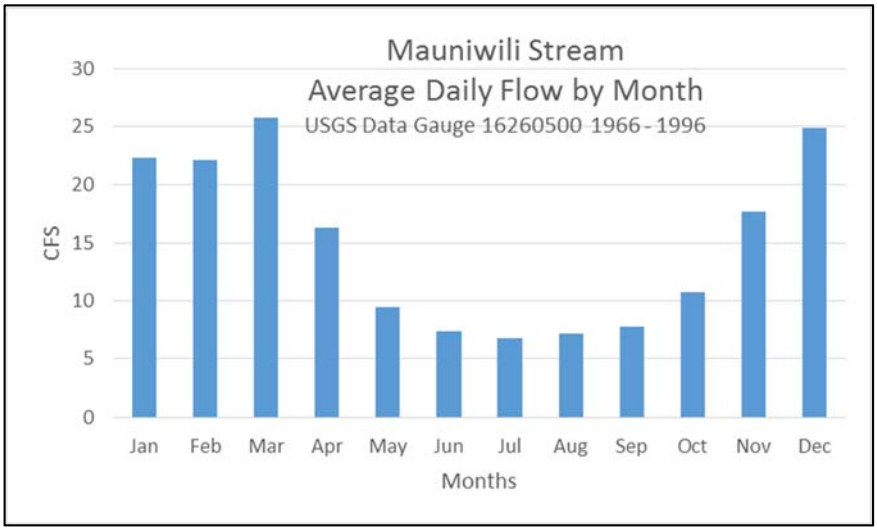


Figure 1.4 Average Daily Flow into Kawai Nui Marsh from Maunawili Stream

Recent simultaneous rainfall measurements in Kaelepulu watershed and water level measurements in the pond show that an inch of rainfall in the watershed produces about a three inch rise in pond water level (Bourke 2016). This means that an equivalent of one twelfth inches of rainfall is required to compensate for a drop of quarter inch of water elevation drop in the pond due to daily evaporation. The monthly evaporation loss from the area, 7.5 inches (30 days at 0.25 in. per day) therefore requires a rainfall of 2.5 inches per month to offset evaporation losses. Monthly average rainfall and the rainfall in the watershed required to compensate for water level drop in the pond from evaporative loss are shown in Figure 1.5.

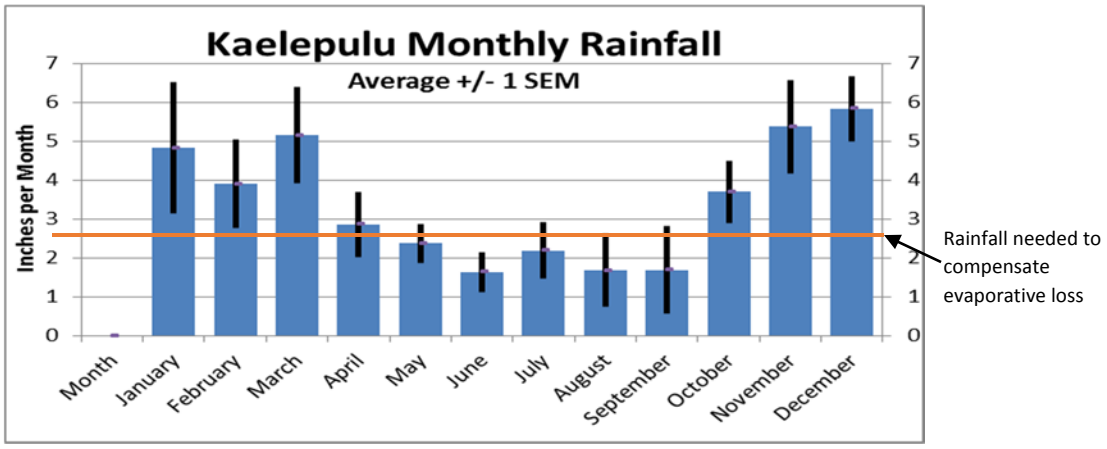


Figure 1.5 Monthly average rainfall compensation required to match evaporative loss

Hydraulic studies of the flow capacity of the system were conducted by the City in 1971 to design flood control basins and dredge Kawai Nui and Kaelepulu Channels, and again by the USACE in 1992 (ParEn, 1993) after the flooding event in 1987, when flood waters overtopped the Kawai Nui Levee and flooded parts of the Coconut Grove area in Kailua. These studies concluded peak outflow to the ocean during an 100-year 24-hour storm (11-13-inches) was estimated to be about 2,840 CFS with a stream elevation (at the confluence of Kaelepulu and Kawai Nui) of 4.1 ft. MLLW and 6.4 ft. MLLW in the Kaelepulu Pond. The Kawai Nui Stream contribution to this flow was estimated to be about 300 CFS (ParEng, 1993). However, the flow currently is impeded by excessive mangrove growth and the monthly buildup of the sand berm at the stream mouth.

1.1.4 Kaelepulu Stream Mouth Openings

Long-time residents of Kailua remember that the Kaelepulu Stream mouth was open and discharged into Kailua Bay naturally most of the year. With the decrease in flow into Kawai Nui Stream, the Kaelepulu Stream outflow is not sufficient to offset the accumulation of beach sand mobilized by shoreline waves. Stream mouth openings have been conducted by the City and County of Honolulu (City) on a regular basis since at least the 1970s (Turner-DeVries, personnel communication).

Assuming an initial water surface elevation of 1.5 ft MLLW, a 100-year 24-hour storm (8.7" rain) will allow City maintenance crews a 6 – 8 hour "lead time" for clearing the mouth of the stream before flooding occurs, but this time could be shorter in more intense shorter rainfall events (ParEn, 1993).

Figure 1.6 A long-reach excavator and bulldozer are typically used to conduct stream mouth openings.

In addition to flood protection, a stream mouth open to the ocean increases water exchange and promotes circulation within the KWS system. Indeed, during typical rainfall events that result in a stream mouth opening, the quantity of seawater entering the system over several tidal cycles almost always exceeds the quantity of fresh water that flowed in during the storm. In the absence of rainfall however, during dry months (May, June July and August) the water surface elevation of Kaelepulu can fall as low as about 1.0 ft. MLLW as a result of evaporation. At this elevation, most of the Hamakua and Kaelepulu wetlands are dry and mud flats and mangrove roots become exposed. This sometimes result in malodorous conditions in adjacent residential areas. The lack of flow, stagnant water, buildup of nutrients from birds, fish, feral animals, and vegetation, and decrease in water volume has in the past resulted in fish die-offs during summer months. Fish die-off events are a threat not only to public health but also to the health of the endangered water bird species that inhabit the Hamakua and Kaelepulu wetlands.

An often overlooked, but important, contribution from regular stream mouth openings is the positive impact of the estuary to nearshore fisheries. The estuary acts to transform nutrients into phytoplankton and zooplankton of importance to the broader aquatic ecosystem. These zooplankton provide an important dietary contribution to larval fish and invertebrates (including corals). 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. The exchange of plankton and fish through the stream mouth during a flow event should have a positive impact upon nearshore fisheries and coastal ecosystems.

2 METHODS

2.1 EXPERIMENTAL SITE

A temporary syphon was constructed across the Kawai Nui Levee approximately 1,550 feet west of its junction with Kailua Road. The site is approximately 100 feet north of the existing USGS water level gauge (#16264100). Aerial views of the levee and the siphon site are shown in Figure 2.1 to 2.3.

Figure 2.1 View from above siphon site to Kailua Road

Figure 2.2 View from above siphon site towards Aikahi and Mokapu.

Figure 2.3. Aerial view of syphon installed across Kawai Nui levee from the marsh (bottom) to the stream

Four 6-inch diameter PVC pipes were laid over a distance of 160-feet from Kawai Nui Marsh across the crest of the levee to Kawai Nui Stream. The pipes were attached to a metal rack constructed over the levee to avoid any physical attachment to the levee (Figure 2.3, Figure 2.4). All PVC pipe joints were double sealed on the outside of each joint using silicone calk. The pipes were linked together at intervals by cross members to provide stability. The open ends of the pipes were terminated at approximately 2-feet below the water surface at either end. A ramp was constructed over the pipes across the levee crest to allow the passage of vehicles and pedestrians. A 4' by 8' plywood board was affixed to the metal bracing on the pathway side of the wall both to protect the pipes and to act as a sign-board for public information concerning the experiment.

Syphon flow was established by pumping the air out of each pipe through a valve located at the top of each pipe (Figure 2.4). Flow was initially established on May 22, 2015 with the Kawai Nui Marsh at an elevation 4.63 ft. MLLW and the Kawai Nui Stream at an elevation 1.0 ft. MLLW. At the 3.6 ft. head difference, the syphon was measured to be delivering 2.2 CFS from the marsh to the stream.

The syphons were checked on a daily basis and re-primed as necessary when flow stopped due to air accumulation at the top of the pipe. Syphon flow was discontinued on September 3, 2015 when the elevation of Kawai Nui Stream rose above 2.0 ft. MLLW.

Figure 2.4. Syphon and pedestrian ramp across the levee.

2.2 WATER SURFACE ELEVATIONS

Water surface elevation of the ocean, the Kawai Nui Marsh, and the Kawai Nui and Kaelepulu Streams were recorded. In addition to the tide, local water surface elevation is influenced by winds, waves, stream discharges and evaporation.

National Oceanic and Atmospheric Administration (NOAA) maintains a real-time tide gage (#1612480) at Moku O Loe (Coconut Island) in Kaneohe Bay (~5 miles from the project site) that records both predicted tide elevation and the actual water surface elevation. This establishes the difference between the actual water elevation and predicted tide elevation at the site. NOAA also calculates tide predictions in Waimanalo (Station #1612376) about 2 miles from the project site. It is assumed that the water deviation from predicted and measured values are the same for the two gages separated by 7 miles.

In 2008 a staff gage was established on a support piling of the Lanikai Pedestrian Bridge at the Kaelepulu Stream Mouth. The gage was adjusted to the apparent local mean lower low water ocean surface elevation. The City subsequently set a staff gage on the adjacent vehicular Lanikai Bridge set to the City's MSL datum. This gage reads 0.28 feet higher than our local MLLW staff gage datum. The USGS gages on the Kawai Nui Levee are also set to the City's MSL base tied to a City street monument. Figure 2.5 shows a plot of the measured Kaneohe Moku O Loe tide (set to MLLW) and the Waimanalo predicted tide (also set to MLLW) compared to the tide measured at the head of the Oneawa Canal tied to the USGS staff gage (set to the City's MSL). The tide at the project site appears to agree well with the predicted Waimanalo tide offset by a 0.32 foot difference between the MLLW tide datum and the City's MSL datum. Field data for this project was collected referenced to the MLLW staff gage. For consistency in this report elevations set to the City's MSL datum are adjusted to MLLW by adding 0.30 feet.

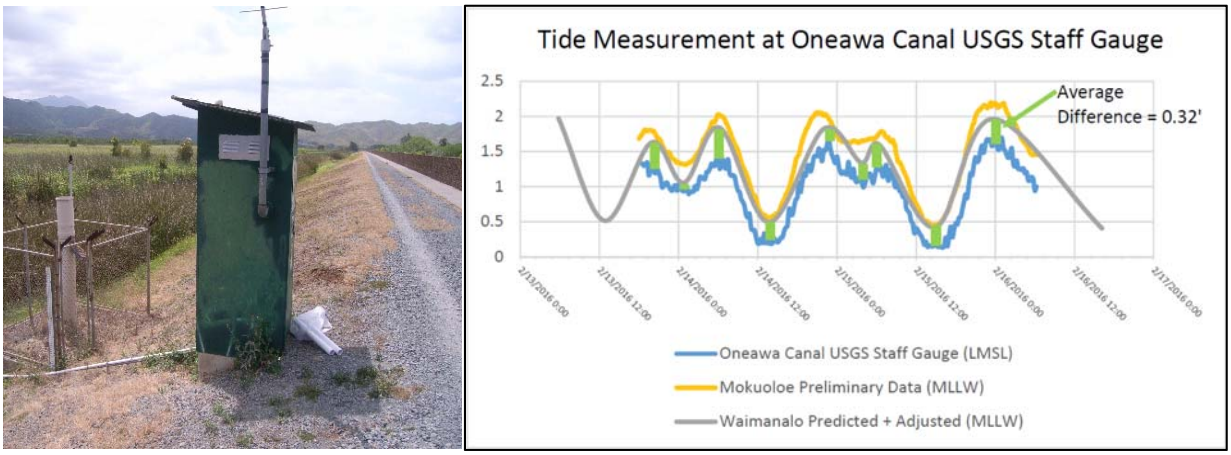


Figure 2.5 USGS Kawai Nui Levee water level gauge near syphon site (left) records the marsh water surface elevation linked to the City's MSL survey datum. Tides measured in Kaneohe at Moku O Loe (yellow), predicted with corrections for Waimanalo (grey) both measured to MLLW datum. Tides measured at head of Oneawa Canal are based upon the USGS staff gage at that site and differ from the MLLW datum by about 0.32 feet.

To monitor the water surface elevation of the Kawai Nui and Kaelepulu Streams, a secondary staff gauge was established in Kaelepulu Pond adjacent to 437 Keolu Drive set to the same MLLW datum as the staff gauge affixed to the Lanikai pedestrian bridge over Kaelepulu Stream. During the course of the experiment water surface elevations were measured at this secondary staff gauge either manually or by the use of pressure gauges affixed to the staff gauge. When water surface elevation changes were anticipated to be slow, as from evaporation or occasional rain storms, daily (or weekly) hand measurements were sufficient. When more rapid elevation changes were anticipated, such as during a stream mouth opening event, Schlumberger Diver sondes were used in pairs, one in the water and one in the air, to log pressures at 15-minute intervals. By subtracting the daily atmospheric tides (which can be equivalent to a 4 cm water surface change) from the water pressure readings, depth accuracy better than 0.5 cm is typically achieved.

2.3 WATER QUALITY TRANSECTS

Water quality dynamics of estuaries are often mediated through vertical stratification and mixing that results from waters with different salinities flowing in the same channel. Previous work in the estuary had established the spacing and location of sample sites thought to be able to capture dynamic changes in the system brought about by the tidal changes and freshwater inflow from rainfall and syphon inflow. Twenty stations were established forming two transects through the twin branches of the estuary with the lower three sites common to both transects (Figure 2.6). At each site physical water quality parameters (Temperature, Salinity, pH, Dissolved Oxygen, and Turbidity) were recorded using a YSI multimeter datasonde calibrated prior to each survey. Measurements were taken at the surface (~0.5 ft), 1 ft, 2 ft, 4 ft, 6 ft, and 8 ft depths at each site and recorded in a data book.

An additional parameter, Percent Exchange, was calculated by comparing the salinity data from each point with the salinity reading at that same point taken during the previous survey. Assuming that salt is a conservative factor, percent exchange was calculated as:

$$\% \text{ Exchange} = (S_F - S_I) / (34 - S_I)$$

Where S_F is the salinity of the sample and S_I is the salinity of that sample site during the previous exchange event. An exchange that results in fresher water is negative (-) and for saltier water is positive (+). Fresh water exchange typically occurs between opening events when the inflow is either from the syphon or from runoff associated with rainfall events. Saltwater exchange is associated with stream mouth opening events and the flow of denser salt water into the base of the estuary.

Data were plotted on cross sections of each transect and areas of equivalent value were interpolated using an AutoCAD topography plotting program. Areas of equivalent value are colored to simplify visual interpretation of the data. Each dataset results in two sets (one for each estuary branch) of 6 plots each (Appendices D & E).

Figure 2.6 Sample station locations for physical water quality measurements

2.4 MONITORING OF STREAM MOUTH OPENING EVENTS

Stream mouth openings were either scheduled months in advance by the City or occurred on short notice as the result of rainfall events. The basic factors effecting opening events began to be recorded for this project in September 2012. For each opening event, the day, date, and time of opening were recorded. Information on the stream elevation and tides were typically provided in advance to the City with recommendations for the optimum day and time to open the stream mouth. The type of equipment, number of crew, and number of work days required to achieve an opening were recorded. Water surface elevations were recorded using the pressure data sondes (see Section 2.2). Ocean tide elevations were physically recorded on one occasion in the ocean fronting the stream, and were found to closely agree with the Waimanalo predicted tide elevation when corrected for the deviations from predicted as recorded at the Kaneohe Moku O Loe tide gauge. For subsequent opening events, the corrected Waimanalo tide data was used to represent the ocean water elevation.

By the end of the project it was clear that the amount of effort put into opening the stream mouth and dredging the channel between the beach and the Lanikai Bridge varied greatly between events. City personnel offered that on occasion, perhaps twice a year, the equipment operators felt they needed to dredge the channel to "catch up" with the sand slowly accumulating in the stream channel with each subsequent stream opening event. To measure how fast the sand migrated back into the channel a bathymetry survey on a 20-foot grid was conducted from the Lanikai Bridge extending 400 feet down the channel towards the beach. The survey was conducted on 2/6/15 after dredging was complete, but before the channel was open to the ocean, and again one week later after the stream mouth had closed following 4 days of tidal exchange. Only the depths below the water surface were measured, and a correction was made for the different water elevations before and after the opening event.

To better understand the dynamics of the stream erosion and accretion dynamics a drone was used to capture aerial videos of the outflowing and inflowing stream process on October 13, 2015 (Figure 3.9).

Figure 2.7 Opening the Kaelepulu Stream mouth at Kailua Beach using a small bull dozer and a long reach excavator. Beginning pile of excavated sand can be seen between trees behind the excavator.

3 RESULTS

Observations on rainfall, flow, stream opening events and water surface elevations were made for a total of three years between September 2012, and September 2015. The 142 acre stream and estuary system is estimated to contain 30 million cubic feet (MCF) of water at an elevation of 1.5 ft MLLW (Table 1). Flow through the syphon restored water to the system at an average rate of 1.5 cfs for 104 days between May 22 and September 3, 2015 contributing an average of 13% (4 MCF) of the estuary volume per month to the system. During the 3 year period there were 29 stream mouth opening events, each contributing an average of 2.5 feet of ocean water inflow (~1.8 ft/mo.) representing 35% (11 MCF) of the estuary volume per month to the system. Rainfall during the period totaled 108 inches (3"/mo.), with runoff contributing an average of 9-inches per month to the water surface elevation or about 15% of the estuary's volume (4.6 MCF) per month. There was a great deal of monthly variation in both rainfall and stream mouth inflow from the ocean. Four of the stream mouth openings contributed more than 50% of the total ocean flow to the system. 21 of the 36 months had less than the average (3-inch/month) rainfall, with 18 months receiving less than 2.5-inches of rain necessary to offset evaporative losses. A syphon flow of 2 cfs would contribute a flow of about 18% of the estuary's volume per month (5.4 MCF), equivalent to, but more consistent than, the inflow resulting from the average rainfall.

3.1 WATER FLOW AND SURFACE ELEVATION RESPONSES

The volume of each segment of the estuary was estimated at a surface elevation of 1.3 ft MLLW based upon the mapped surface area and the depths as determined during the water quality transects (Table 1). The volume of the entire 142 acre estuary is about 30 million cubic feet (MCF), with the 20-acre Kawai Nui Stream containing 2 MCF, the 15-acre lower Kaelepulu Stream containing 4 MCF, and the 6-acre upper Kaelepulu Stream containing 1.5 MCF (Table 1). The main body of the pond with a volume of about 22.5 MCF is divided between the 89 acre lake owned by the ELRA and the 12 acres of shallow privately owned wetlands.

Table 1 Area and volume of KWS pond and stream systems

	Length (ft)	Width (ft)	Area (ac)	Ave Depth Ft	Volume, MCF
Upper Kawai Nui	6,600	55	10.3	2.2	0.8 MCF
Lower Kawai Nui	6,000	70	9.7	3	1.2 MCF
Lower Kaelepulu	3,500	190	15	6	4.0 MCF
Upper Kaelepulu	3,300	80	6	5.7	1.5 MCF
Kaelepulu Pond			89	5.	22.0 MCF
Kaelepulu Wetland			12	1	0.5 MCF
Total			142		30 MCF

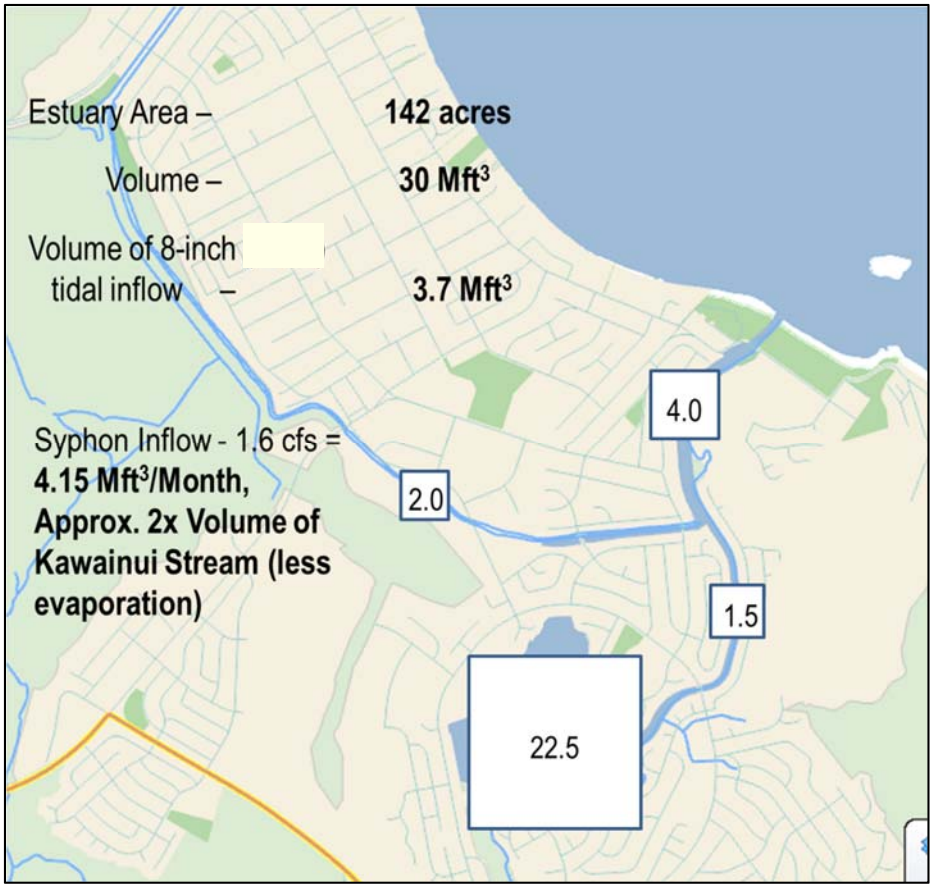


Figure 3.1 Distribution of water volume (MCF) in the estuary

The syphon transferred water from the marsh to the stream for a total of 104 days. During this time three complete and one partial exchange cycles were monitored between May 22 and September 3, 2015 (Figure 3.4, Figure 3.5). Maintaining consistent flow in all four syphons proved to be a challenge (due to minute air leaks in the PVC joints) and resulted a range of flow rates less than the 2.2 cfs anticipated from the initial measurements. During this period of time the system was open to flow at the stream mouth on five occasions for a total of 28 days. The final partial filling cycle only lasted 5 days, and was interrupted by heavy rainfall from a series of near-miss hurricanes which coincided with the termination of the experiment. For the purpose of the analyses, this experiment will only examine the initial first three fill and drain cycles between A) May 25 – June 16, B) June 21 – July 15, and C) July 19 – August 11. The syphons were turned off on September 3, 2015, when the water surface elevation reached 2.0 ft MLLW and heavy rainfall from nearby hurricanes began to impact Oahu.

The impact of water withdrawal upon the water surface elevation of Kawai Nui Marsh was slight but detectable. Looking at the elevation changes over a longer period of time (Figure 3.2) we see that the rate and magnitude of water surface elevation change in the marsh varies greatly from one year to the next and that the withdrawal of 1.5 cfs has a negligible impact on the water budget of the marsh as a whole.

A closer examination (Figure 3.3) of water surface elevations within Kawai Nui Marsh prior to the initiation of syphon shows that the water surface elevation fell at an average rate of 0.14 inch per day.

During the experiment when the syphon was flowing the rate of elevation drop within Kawai Nui marsh averaged 0.21-inch/day, with a range of 0.14 to 0.27 inch per day. This is comparable to the average evaporative loss within the Kaelepulu system of 0.2 inch per day. The difference in the rate of water surface drop was 0.21"/da – 0.14"/da = 0.07"/da. Over the 894 acre area of Kawai Nui Marsh, a 0.07"/da water surface drop would correspond to a water withdrawal rate of about 2.6 cfs, or just slightly higher than the average syphon flow rate of 1.5 cfs measured during the course of the experiment. The observed increase in water surface fall rate of Kawai Nui Marsh during the experiment is consistent with the quantity of water removed by the syphons.

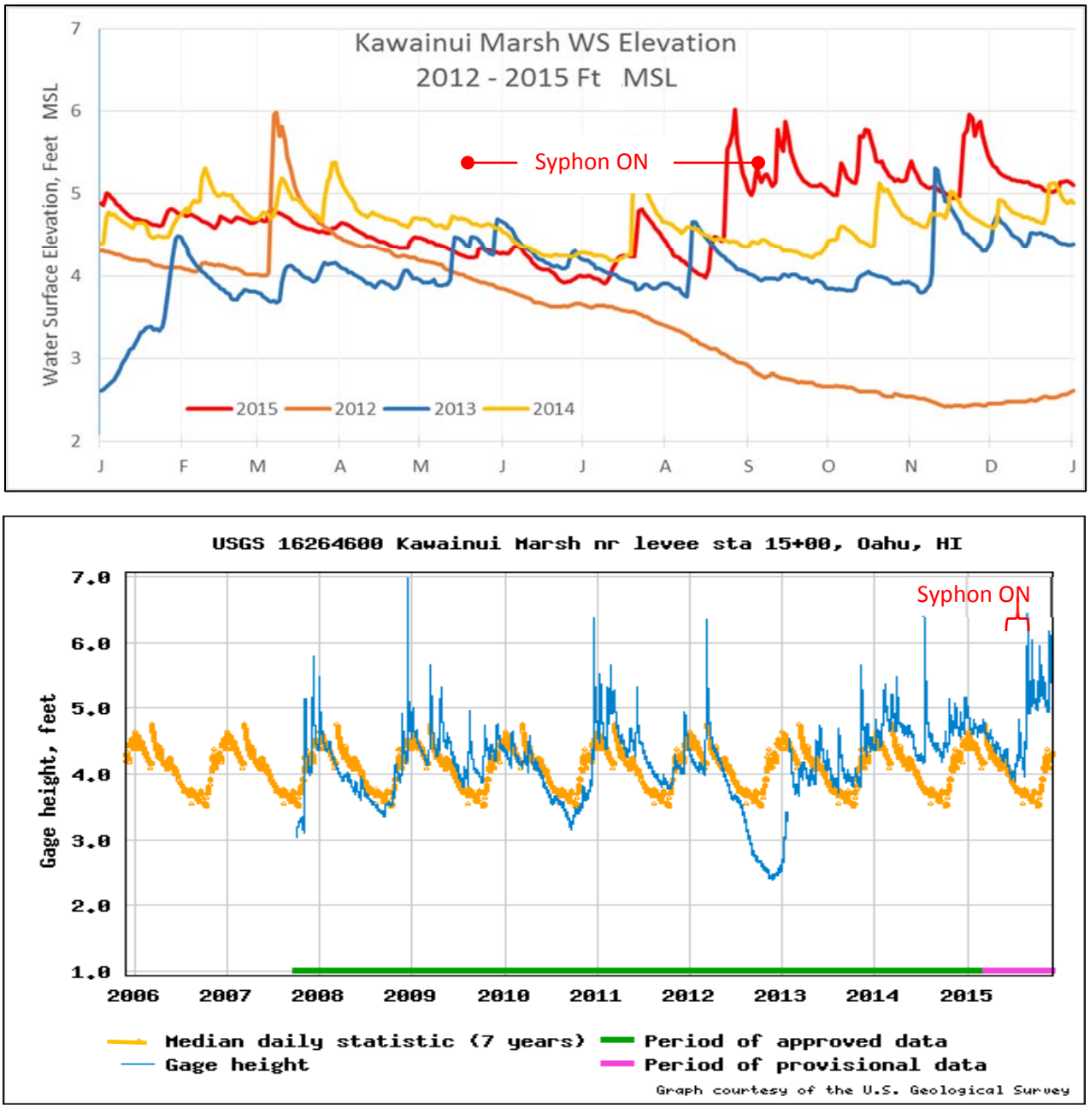


Figure 3.2 Annual series of Kawai Nui Marsh water surface elevation Top: overlaid data from 2012-2015 Bottom: Elevation data from 2007 – 2015 plotted over long term annual average (USGS data)

The impact of flow restoration to the water surface elevation of the Kawai Nui Stream and Kaelepulu system was quite significant. Figure 3.4 shows the elevation of the Kawai Nui Stream and Kaelepulu system prior to, during, and following the experiment. Prior to the experiment the draw-down of the water surface elevation due to evaporation in the absence of rainfall was a very consistent 0.2-inch/day as indicated by the slope of the red arrows. After the initiating flow restoration from the syphons, the water surface elevation rises as indicated by the orange arrows in Figure 3.5, particularly as compared to the expected decline as indicated by the blue arrows.

Table 2 Water flow calculations during each trial

Trial	**Initial Elevation** Ft. MLLW	**Flow Period Days**	**Evaporation** @ 0.2"/da Inches	**Rain** Inches	**Rise due to rainfall** Inches	**Predicted Elev. w/o Syphon, Ft**	**Actual Elevation** Ft.MLLW	**Syphon Flow** MCF	**Syphon Flow** CFS
A	**1.28**	**22.5**	**-4.5**	**0.89**	**2.6**	**1.13**	**1.60**	**2.9**	**1.50**
B	**1.49**	**23.5**	**-4.9**	**1.39**	**4.14**	**1.44**	**1.75**	**1.9**	**0.92**
C	**1.05**	**24**	**-4.9**	**0.66**	**2.0**	**0.82**	**1.5**	**4.2**	**2.04**

Trial A began on May 25 when the stream mouth closed at the beach, and ended 22 ½ days later on the morning of June 16 when the City reopened the stream mouth. During this period there was 0.89 inches of rain in the watershed, which at a 3:1 rise:rain ratio could be expected to raise the elevation of the water by 2.6 inches (Bourke, 2016). Evaporation at 0.2-inch per day would contribute -4.5-inches to the water surface elevation, for a net expected fall in the system of -1.9 inches (0.16 ft). During this period the water system rose from 1.28 feet to 1.60 feet MSL. The total gain in water surface elevation due to syphon flow was about 0.48 feet, for an average flow rate of 1.50 cfs.

Trial B began on June 21 when the stream mouth closed, and extended until July 15, a total of 24 ½ days. During this period there was 1.38-inches of rain, which at a 3:1 rise:rain ratio could be expected to raise the elevation of the water by 4.1-inches. Evaporation at 0.2-inch per day would be expected to drop the elevation by about 4.9 inches over 24.5 days, for a net expected decrease in the system water surface elevation by about 0.8 inches. During this period the lake water surface elevation rose from 1.49 feet to 1.75 feet or about 3.01 inches. The total gain in water surface elevation due to syphon flow was about 3 inches (0.33 feet), which is about 2 MG for an average flow rate of 0.92 cfs.

Trial C began on July 19 at a water surface elevation of 1.05 ft and ended 23 days later on August 11 at a water surface elevation of 1.5 feet. During this period of time there was a total of 0.66 inches of rain which may have contributed about 2.0 inches to the systems elevation. This was offset by an evaporation loss of 4.9 inches for a net expected loss of 2.9 inches of water surface elevation. The total water contributed by the syphon is about 8.9 inches (0.74 ft) for an average flow rate of 2.04 cfs.

Rainfall was within normal bounds during the three trial periods but exceeded normal bounds beginning in September with the first of several near-misses by hurricanes. The average syphon flow rate for all three trial periods was 1.51 cfs.

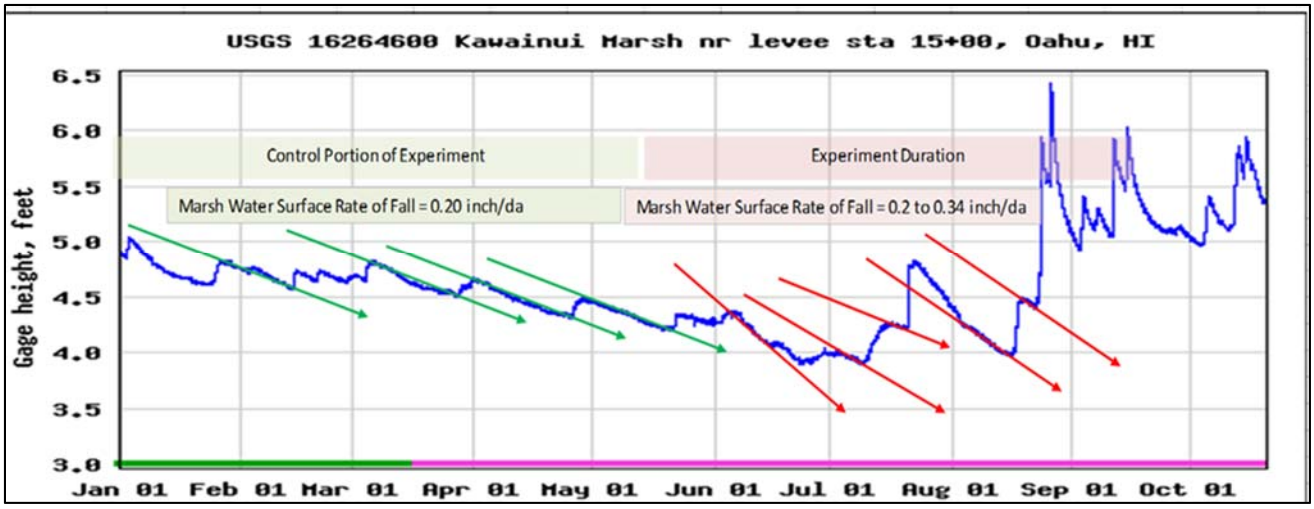


Figure 3.3 Elevation of Kawai Nui Marsh in 2015 before, during, and after experiment (USGS Gage data)

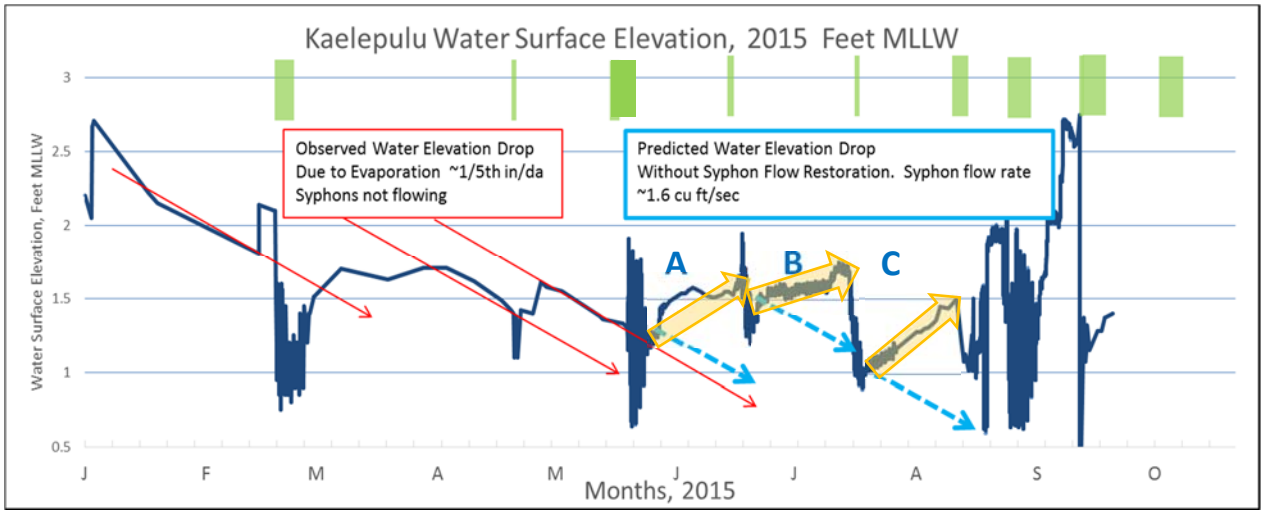


Figure 3.4 Kaelepulu water surface elevations showing evaporation trends before experiment (red arrows) extrapolated to during experiment (blue arrows), and observed increase (orange) due to syphon flow.

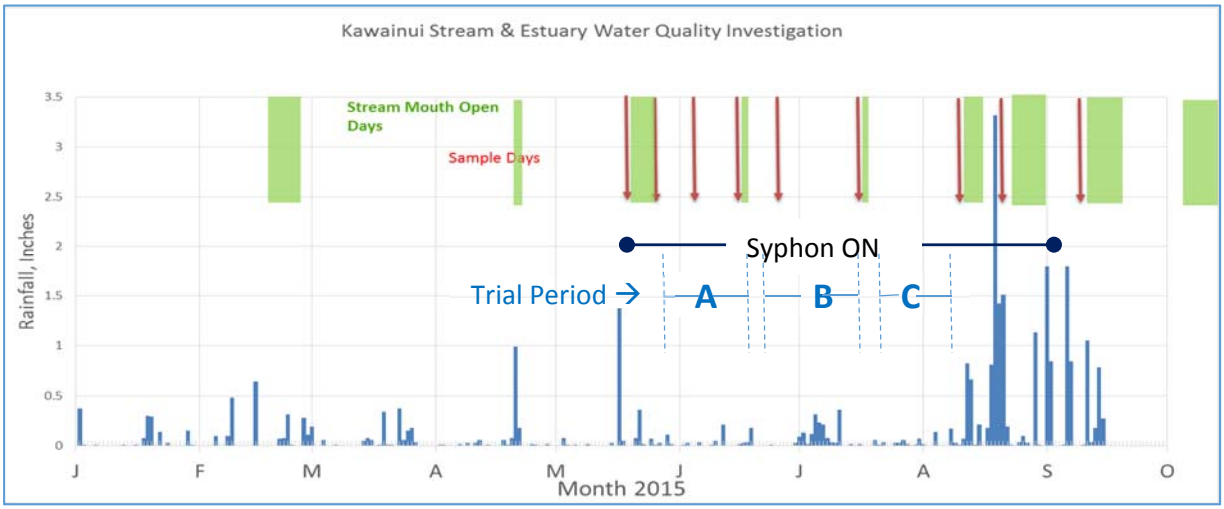


Figure 3.5 2015 Kaelepulu Rainfall with overlay showing berm openings and timing of sampling events

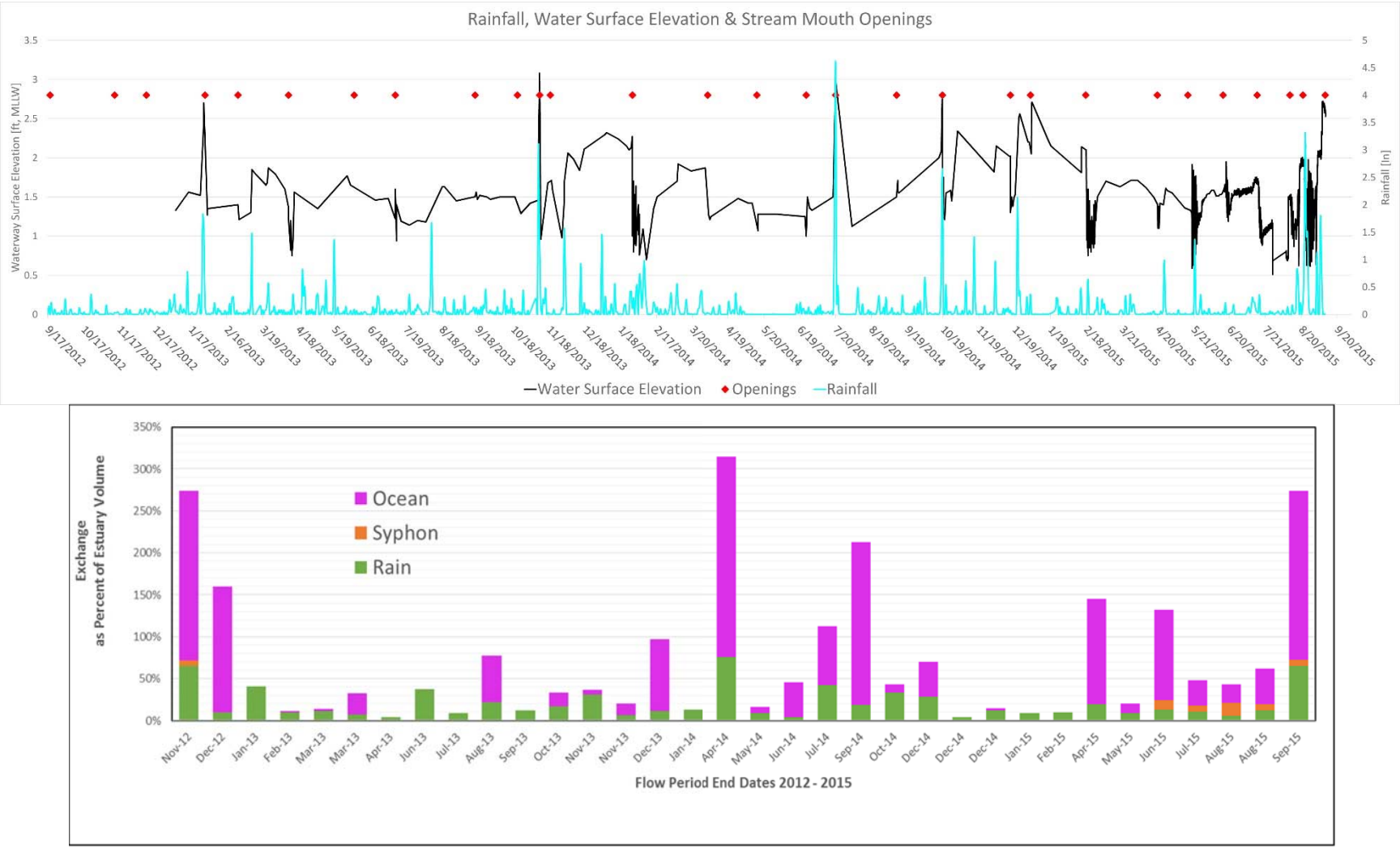


Figure 3.6 Kawai Nui and Kaelepulu Streams water surface elevations, rainfall, and stream mouth opening dates 2012-2015.

3.2 STREAM OPENING EVENTS

3.2.1 Timing of Stream Opening Event

Between September 2012 and October 2015 a total of 29 berm opening events were recorded at the Kaelepulu Stream mouth at Kailua Beach. 20 of the events were scheduled in advance by the City and 9 were in response to rises in water surface caused by storm rainfall runoff. Of the 9 storm related events the berm was opened 5 times by the City and 4 times when the stream overflowed the sand berm and eroded its own channel. None of the storm related events resulted in water surface elevations in excess of the 3.3-foot MLLW flood elevation. Basic statistics of each opening event are displayed in Table 3.

Wednesdays were the most common day for a scheduled opening event using the City's heavy equipment, with an average of 2 to 3 days of preparation prior to the actual breaching of the sand berm barrier. However, preparation varied greatly between opening events requiring 4 or more days on three occasions. On at least two of these occasions the equipment arrived a week prior to the scheduled opening to conduct dredging of the stream with the intent to remove built up sand from the 120-foot wide, 500-foot long channel between the Lanikai Bridge and the beach. Sand dredged from the channel (estimated at 400 to 1800 cu yd) was placed behind the active beach on the back side of the sand dunes where it would remain for many months until moved by the City Parks Department.

During un-scheduled opening events associated with rainfall and higher stream water levels, typically a single bulldozer was used to facilitate the opening within an hour or two after arrival at the site. During the more common scheduled events either a bulldozer or a bulldozer and long-reach excavator would be delivered to the site on Friday or Monday morning. This equipment would be used to lower the level of the beach sand dune, usually pushing the sand to the east or west along the upper extremity of the active (un-vegetated) beach, and then to excavate below the water line to create a flow path from the stream to the ocean. Most often the bulldozer would be used in the stream bed, with the excavator used to transfer sand up-slope from one location to another. The excavator was also used to advantage to deepen an existing channel once flow had been initiated. Opening a wide (~100 ft x 0.5 ft) shallow bed for flow did not appear to be as effective as creating a narrow (~20 ft x 3 ft) but deep flow channel.

The results of three separate opening events with similar tidal amplitude but markedly different results are displayed in Figure 3.7. The opening events of September 2012 and September 2013 (top two graphics) allowed little or no time for the outflowing stream to erode a significant channel and were closed within one or two days. The opening event of February 2015 (bottom graphic) began with a high stream elevation and provided a long (13 hr.) initial outflow period. This resulted in a large initial channel that remained open to flow for 9 days. While this appears to be the general case, exceptions do occur, such as on January 29, 2013 (See Appendix A) when a high stream elevation (2.6 ft MLLW) and a long initial outflow period (29 hours) resulted in the stream closing upon reaching the first high tide. In this instance, the presence of strong trade winds and heavy shore break likely provided an abundance of sand during the initial inflow effectively closing the stream mouth.

KAELEPULU STREAM MOUTH BERM OPENING EVENTS

Date of Opening	Day	Event	Time of Opening	# Days City Effort to Open	Opened by City or Overflow	Opening Scheduled or Storm Mediated	Inflow, feet	Outflow, feet	# Days Open	Hours to Incomming Tide	WS Elev at Opening Ft LMLLW	Inflow MCF	Comments
19-Sep-12	Wd	1	15:00	1	City	Scheduled	0.4	0.0	1	0	0.95	2.47	Tried to open with incoming tide
13-Nov-12	Tu	2	16:15	2	City	Scheduled	6.4	6.1	5	7	1.00	39.77	
10-Dec-12	Mo	3	na	1	City	Scheduled	na	na	na	na	na		
29-Jan-13	Tu	4	16:00	0	Overflow	Storm	0.1	1.3	2	29	2.60	0.56	Google Earth Photo: City arrived after opening
27-Feb-13	Wd	5	10:00	3	City	Scheduled	0.1	0.3	1.0	5	1.50	0.62	Self closed at high tide
10-Apr-13	Wd	6	9:00	3	City	Scheduled	1.1	1.8	4	4	1.59	6.80	City used excavator only
5-Jun-13	Wd	7	11:00	3	City	Scheduled	0.0	0.0	0.1	0	1.35	0.00	Opened at mid-day high tide
10-Jul-13	Wd	8	8:15	3	City	Scheduled	2.4	2.8	5	7	1.49	14.85	
21-Aug-13	Mo	X	na	0	City	Scheduled	0.0	0.0	0	na	0.00	0.00	Opening canceled by City
16-Sep-13	Mo	9	12:25	1	City	Scheduled	0.7	0.7	2	0	1.50	4.33	Used only bulldozer
22-Oct-13	Tu	10	17:00	2	City	Scheduled	0.3	0.4	1	3	1.45	1.55	
10-Nov-13	Su	11	13:30	0	Overflow	Storm	0.6	1.7	2	0	3.08	3.71	4.29" rain over 4 days raises WS by 18.5"
19-Nov-13	Tu	12	9:00	5	City	Scheduled	3.7	4.5	9	15	1.75	22.70	Dredge & stockpile 1800 cu yd sand
28-Jan-14	Tu	13	9:00	0	City	Storm	10.3	11.1	22	14	2.14	63.40	Single bulldozer opened
1-Ap-14	Wd	14	10:00	2	City	Scheduled	0.3	1.0	2.0	5	1.84	1.86	Lack of floating boom delays opening by bulldozer
14-May-14	Wd	15	9:00	3	City	Scheduled	1.4	1.7	5	6.0	1.50	10.93	Bulldozer only
24-Jun-14	Wd	16	9:00	2	City	Scheduled	3.0	3.2	10	3.0	1.25	18.56	Bulldozer and excavator used
20-Jul-14	Mo	17	4:45	0	Overflow	Storm	8.3	8.7	14	6.5	3.70	51.34	
10-Sep-14	Wd	18	11:30	3	City	Scheduled	0.4	0.5	2	2.5	1.50	2.47	
19-Oct-14	Su	19	14:00	1	City	Storm	1.8	3.2	3	7	2.81	11.13	City tried to open at 10am but prevented by high tide
16-Dec-14	Tu	20	9:45	1	City	Storm	0.1	0.5	1	11	2.02	0.62	Large surf closes opening quickly
18-Feb-15	Wd	21	11:00	4	City	Scheduled	5.4	6.2	9	13	2.10	33.40	Dredge & pile up sand above OHWM
20-Apr-15	M	22	8:00	4	City	Scheduled	0.5	0.5	1	6	1.42	3.09	
19-May-15	Tu	23	10:00	3	City	Scheduled	4.6	4.7	7	3	1.10	28.45	Dredge & pile up ~400 cu yd sand above OHWM
15-Jun-15	Wd	24	9:00	2	City	Scheduled	1.3	1.5	4.5	4	1.60	7.98	Wide shallow opening - poor flow/channel formation
15-Jul-15	Wd	25	8:30	2	City	Scheduled	0.9	1.8	3	4	1.75	5.75	
11-Aug-15	Tu	26	8:30	0	City	Scheduled	1.8	2.2	5	3	1.50	11.13	Dig narrow deep channel
22-Aug-15	Sa	27	21:00	0	Overflow	Storm	8.7	9.0	9	7	2.00	53.50	Overtopped - possibly helped by citizens w shovels
11-Sep-15	Fr	28	15:00	1	City	Storm	na	na	9	12	2.56		
13-Oct-15	Tu	29	10:00	1	City	Storm	na	na	10	18	3.10		Dig single narrow deep channel

Table 3 Stream mouth opening events

Elevation data is reported in MLLW. To convert to MSL, subtract 0.3 ft.

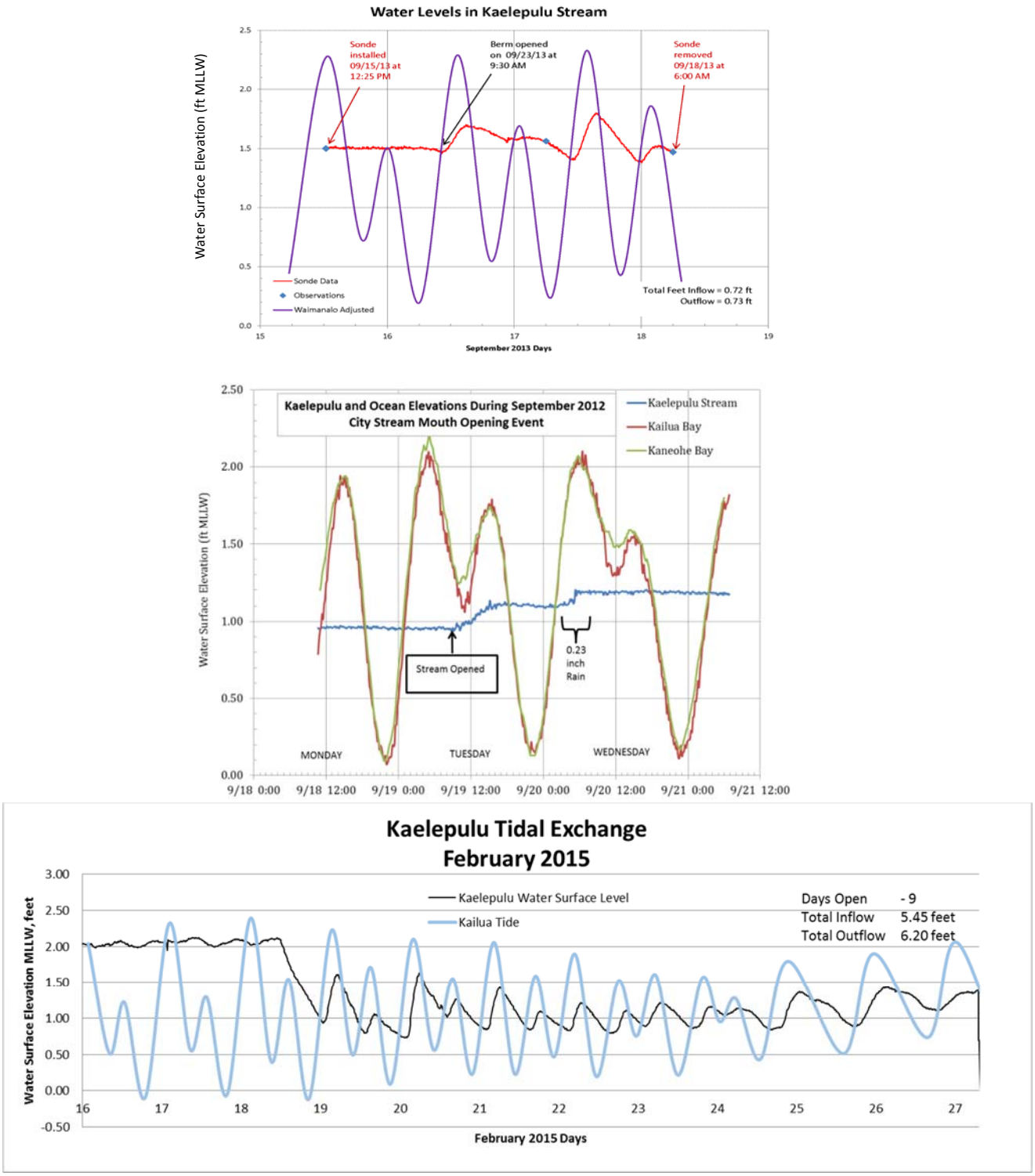


Figure 3.7 Stream mouth openings initiated by City heavy equipment operators vary greatly in the quantity of resulting exchange.

3.2.2 Stream Channel Opening Dynamics

The outflowing stream is capable of eroding a significant channel over a short time span if there is sufficient hydraulic head. As can be seen in the lower portion of Figure 3.8, during a self-initiated overflow event, the laminar stream flow begins eroding sand from the surface of the bed as the stream narrows and flow velocity increases. Separate measurements suggest that this critical flow to induce shear erosion is about 3 feet per second. As the stream continues to narrow, flow speed increases and becomes turbulent which greatly increases the rate of erosion and sand transfer to the ocean. Once the flow reaches the ocean, the average flow speed quickly decreases and the sand is deposited in the nearshore. Longshore currents in Kailua Bay can run in either direction along the beach. On January 29, 2013 the currents were moving from east to west (top to bottom in the photo) and sand transfer from the stream mouth was to the west, towards the Lanikai boat ramp.

Figure 3.8 Stream mouth opening by storm overflow (1/29/13. Google). Upper photo: Area between Lanikai Bridge and Kailua Beach with ocean current flowing from west to east (top to bottom) and sand being deposited just offshore and to the west (boat ramp) end of Kailua Beach. Lower photo shows how outflowing current erodes sand from the channel as the current speed increases in the narrow channel.

The ability of the stream channel to open itself when properly timed with the ocean tides was demonstrated on Sunday, October 19, 2014 (Figure 3.10), when the City responded to the flood threat of a high water surface elevation (2.81 ft MLLW) and an approaching rainstorm. The City crew arrived in the morning and successfully graded down the sand dune by 10:00, at which time they attempted to open the stream mouth to flow. Unfortunately the combination of a high tide (2.3 ft MLLW, about a half foot higher than predicted), stiff trade winds, and high (for Kailua) surf rapidly closed the opening they attempted to make. At 13:00 as the tide was rapidly falling, they again attempted to develop an opening, this time with much better results. A single bulldozer pass through the shallow sand bar quickly established an outflow that, over the course of about 2 hours, eroded the stream to a 40 foot wide and 2 to 3 ft deep channel. Between 13:00 when flow was established and 22:00 when the falling pond reached the level of the incoming tide (1.20 ft MLLW) a total of about 10 million cubic feet of water flowed out of the system for an average flow rate of about 300 CFS.

Figure 3.9. Stream mouth initial outflow, August 11, 2015

Figure 3.10 October 2014 the City responded to a high water surface in the pond and an impending rainstorm by conducting an "emergency" opening of the stream mouth. Flow established in a 1/2-foot deep 20 foot wide channel completed at 16:15. Flow and erosion fist concentrate at the center of the channel and then widen into a 40-foot wide 3 foot deep channel in about an hour and fifteen minutes.

3.2.3 Stream Channel Filling From Beach Sand Inflow

The opportunity to measure the rate of sand flow back into the stream channel presented itself in January 2016. For the week prior to the February 8, 2015 stream opening event, the City crew deepened the 500 foot stream reach between the Lanikai Bridge and the shoreline. The channel is about 175 feet wide at the bridge and narrows to about 100 feet near the back side of the active sand beach and dune 400 feet from the bridge. Measuring the depth of the dredged stream bed on a 20-foot grid before the stream was open to flow, and again after the stream mouth had closed resulted in the tabulation below of sand accumulated during the 3 day flow event.

During the flow event a layer of sand up to 16-inches thick was deposited within the stream channel. The deposits were thickest nearer the ocean and tapered off to near zero about 30 feet from the pedestrian bridge. The total volume of sand transported from the active beach into the stream channel was 1,469 cubic yards. The tabulation does not include the accumulation of sand on the active beach and dune that develops in the stream channel from 400 ft to the wetted shoreline at about 500 feet from the bridge.

Accumulation of Sand in Dredged Kaelepulu Stream Channel During 3-Day Flow Event (Inches depth)

Distance from Bridge, Ft.-->	10	30	50	70	90	110	130	150	170	190	210	230	250	270	290	310	330	350	370	390
0																				
D A 20	-5	2	6	3	12	12	10	7	3	3	3	6	0	3	3	12	15	6	8	6
I C 40	4	0	-3	3	10	11	9	12	10	9	11	10	9	16	14	17	15	13	15	20
S R 60	1	2	3	1	10	10	10	12	8	15	17	15	13	16	15	16	14	13	14	15
T 0 80	-13	12	3	11	13	14	10	6	7	14	17	16	15	18	14	16	10	13	14	14
A S 100	1	3	6	8	9	14	12	13	12	14	17	16	17	14	10	18	13	13	12	24
N S 120	7	-6	14	7	4	4	13	10	12	10	16	16	19	16	10	16				
C 140	-5	-5	12	-3	0	-2	-1	1	3	-9	3	3	1							
E 160	-4	-4	-6	8	9	2	8	1												
Average Inches	-2	1	4	5	8	8	9	8	8	8	12	12	11	14	11	16	13	12	13	16
Cubic Yards	-17	5	43	47	83	80	88	77	68	69	104	101	91	102	81	117	83	72	78	98
																		Total Cubic Yards		1469

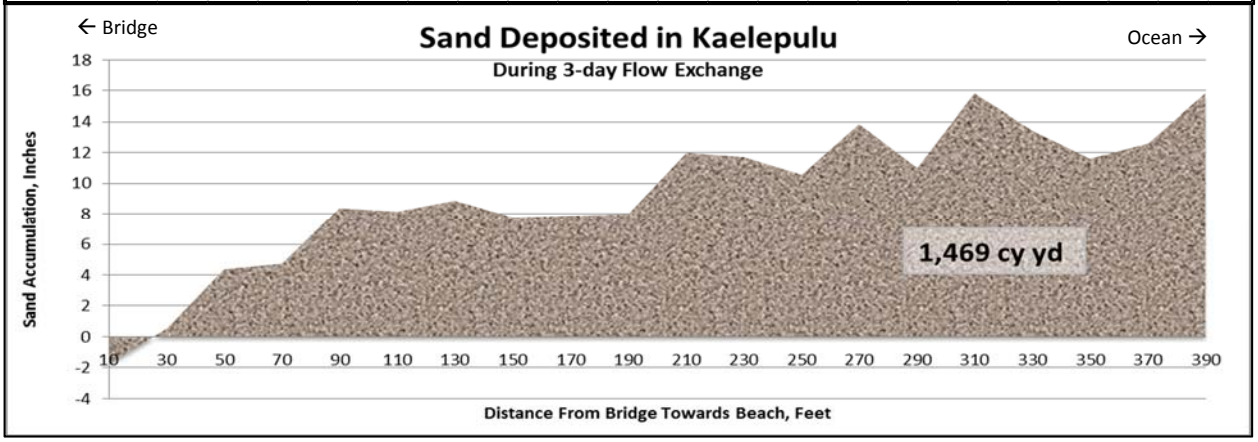


Figure 3.11 Bathymetry survey of stream bed between Lanikai Bridge and beach, measured in inches of fill depth, showing sand accumulated during 3-day stream mouth opening flow event. Dotted lines indicate areas of equal fill depth.

3.2.4 Water Inflow and Exchange from Stream Opening Events

During each stream mouth opening event the water from the stream and estuary flows out to Kailua Bay and then ocean water flows back into the stream on the subsequent high tide. Over a series of tidal flow exchanges the quantity of water flowing in and out can be very significant. For each opening event the total of all inflows and outflows were added and plotted together in Figure 3.12. During most opening events the total outflow exceeded the inflow from the ocean resulting in a lower stream level after the opening event than before the event. The magnitude of ocean exchange varied greatly between opening events. The total quantity of inflow increases with the number of days the stream is open to tidal flow as shown in Figure 3.13(a). On the average, every day the stream mouth is open to flow adds about 0.5 foot of seawater to the estuary equal to about 10% of the volume of the entire estuary. The length of time of the initial outflow on the day the stream mouth is opened is correlated with the number of days the stream mouth remains open and therefore with the total inflow from the ocean to the stream and estuary Figure 3.13(b). The height of the stream at the time of opening was also positively correlated with the total quantity of inflow, although the strength of this correlation was low. There are likely a number of factors involved in developing a successful (i.e. long duration) stream mouth opening that were not tracked in this study. The number of days spent by the City crew to open the stream mouth had no correlation with the length of time the stream remained open to flow.

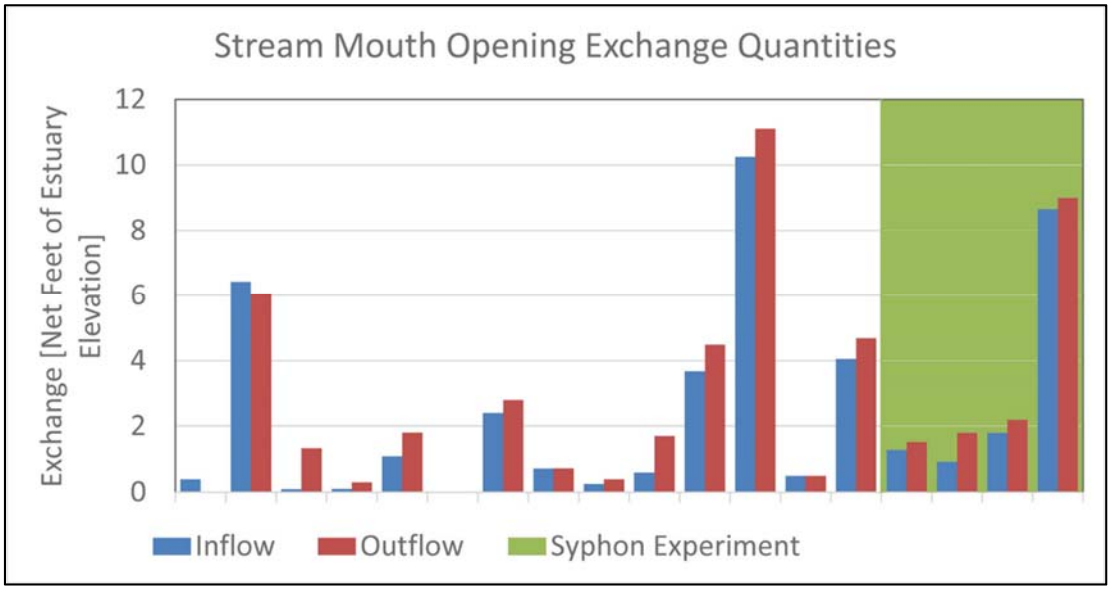


Figure 3.12 Total ocean exchange through the stream mouth was not significantly different during the operation of the syphon.

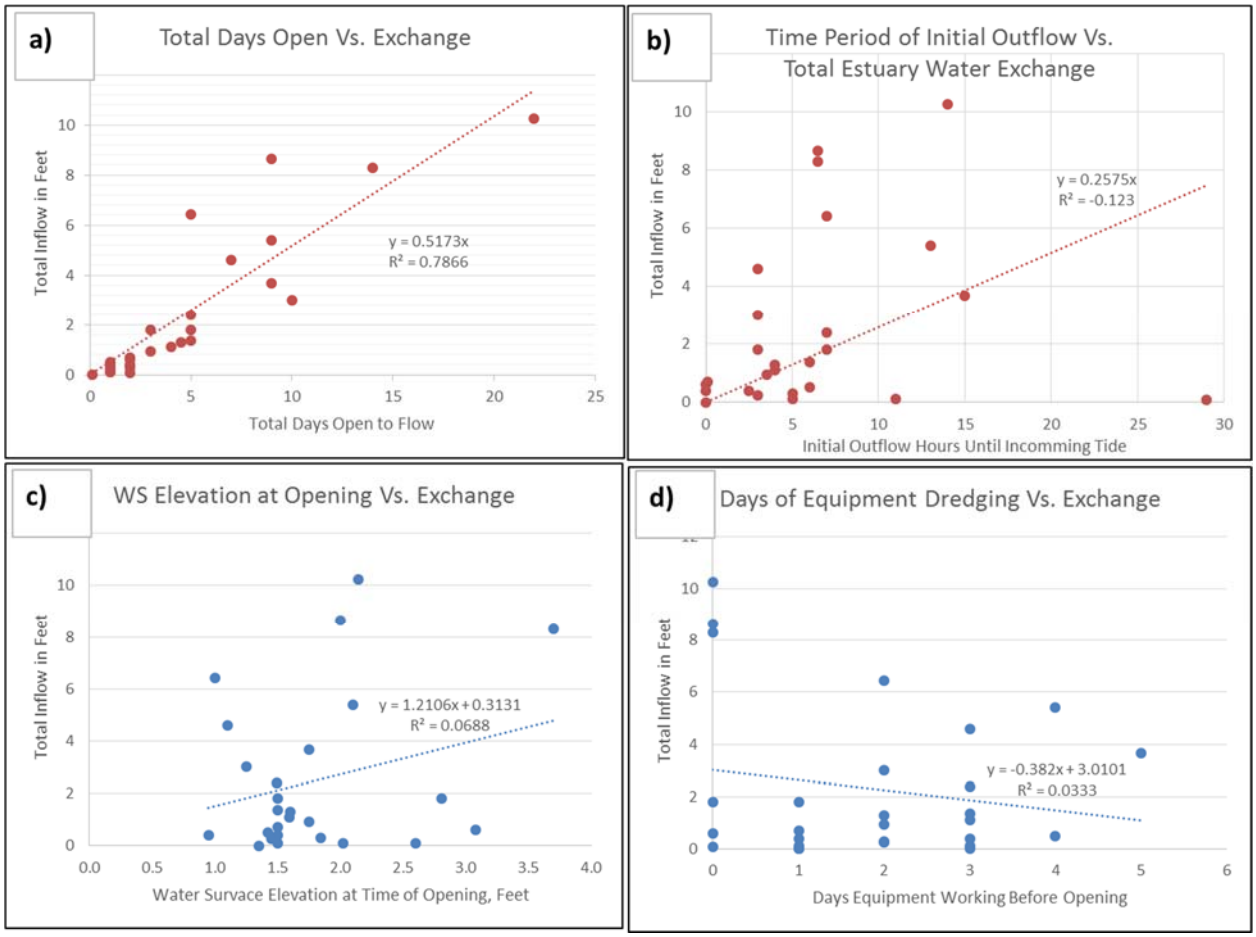


Figure 3.13 Most important factors influencing the total ocean inflow to the estuary during an opening event were a) the total days the stream mouth was open to flow, b) the length of time of the initial outflow, and c) the height of the stream water at the time of opening. The number of days used by City equipment operators to open the channel to flow had no correlation with the number of days the stream remained open to flow.

3.2.5 Stream Opening Events During Syphon Experiment

There were three stream mouth opening events conducted by the City during the period when the syphon was actively flowing. These events (June 15, July 15, and Aug 11, 2015) are highlighted in Table 3 and Figure 3.12. The goal of the syphon inflow was to achieve a water surface elevation of 2.0 ft MLLW prior to the opening but this level was not attained during any of the three opening events.

The stream mouth opening on June 15 began at 0900 with a 60 foot wide, but only 6-inch deep, channel cut by the bulldozer with the excavator being used to move sand up off the beach above the high water line. By 1200, the channel had narrowed to about 12-feet and deepened to about 2-feet with a velocity of 4 ft/sec and was visibly eroding a larger channel. However, the incoming tide began at 1230, and a significant channel did not develop on the first outflow. The channel closed during high tide 4 ½ days after the opening at an elevation of 1.49 ft after allowing a total net inflow of about 1.3 feet of ocean water to the estuary during 4 high tide periods. The stream water elevation at the time of opening was only 1.6 ft, up from 1.28 ft at the previous stream mouth closing on May 25. The measured rain fall of 0.89-inches during the 22 ½ days the berm was closed (May 25-June15) would be expected to contribute about (3X) 2.6-inches to the stream water surface elevation, but the evaporation (-0.2 inch/da) would be expected to lower the water surface elevation by 4.5-inches. This would yield a predicted elevation at opening on June 15, of only 1.12 feet. The syphon therefore contributed about 0.48 feet to the water surface elevation during the 22 ½ days for an average flow rate of 1.53 cfs. During the month, problems were encountered keeping the syphons flowing consistently, but typically 3 of the 4 syphons were running most of the time.

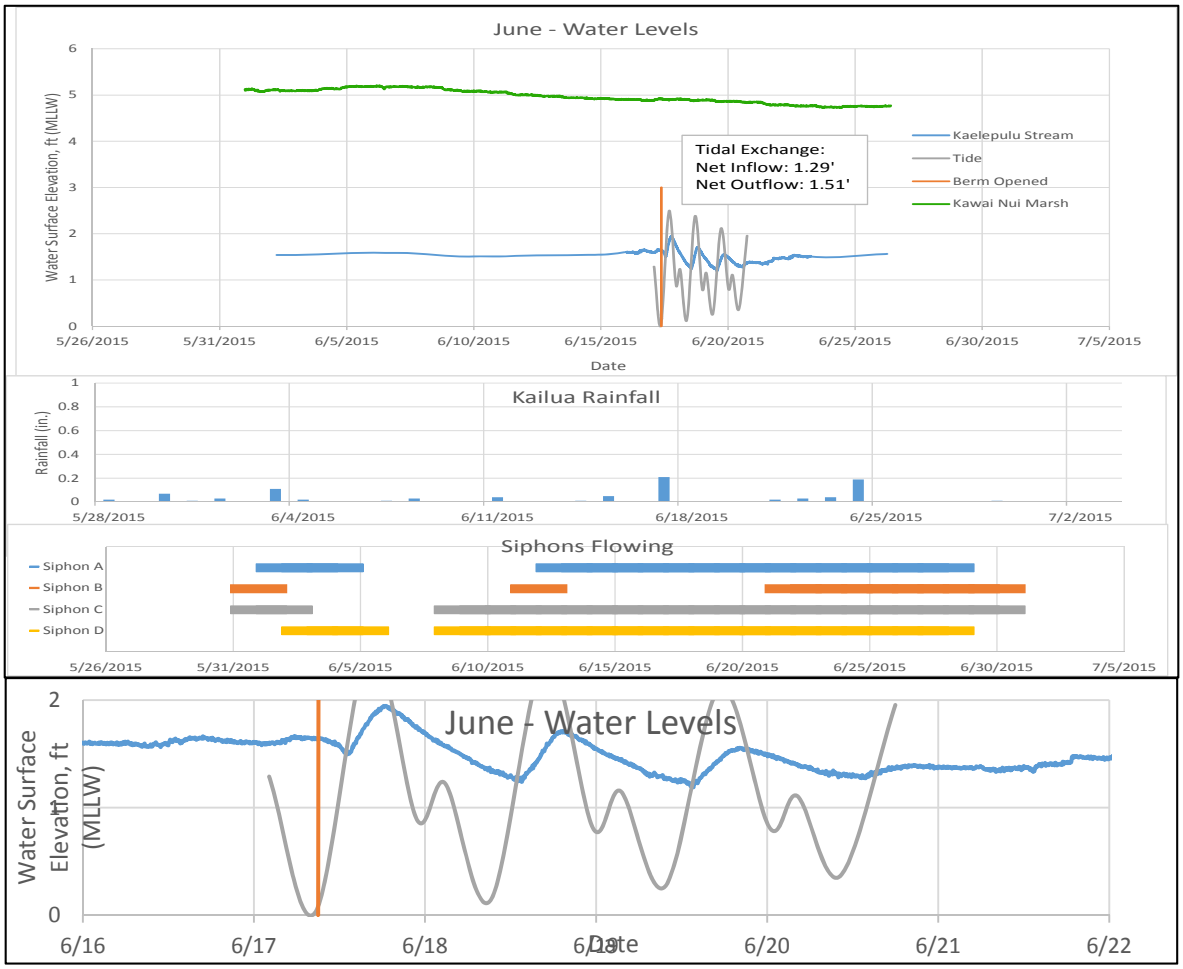


Figure 3.14 June 2015 Water surface elevations and syphon operation

The stream mouth opening on July 15 was initiated at 0830 from a stream water surface elevation of 1.75 feet, up from an elevation of 1.49 at the closing of the stream mouth 24 ½ days earlier (June 19). The stream mouth across the beach was again opened with a wide but shallow channel and required three hours to develop into a narrow (20 ft) deep (2-3 ft) flow channel. Even though the opening was cut 7 hours prior to the rising tide, effective flow was only attained four hours prior to inflow. The drop in the stream water surface elevation was much more pronounced during the subsequent low tide cycle on July 16. The opening only achieved an inflow of 0.9 feet with an outflow of 1.8 feet over 4 tide cycles and closed at an elevation of 1.05 feet. Rainfall during the closed period was 1.39-inch which could contribute (3X) 4.14-inch to the water surface elevation of the stream. Evaporative loss (0.2 inch/da) would be expected to decrease the water surface elevation by 4.9 inches, yielding an expected elevation of 1.43 feet. The difference in water surface elevations is attributed to inflow from the syphon of 0.93 cfs. During the flow period only two of the four syphons were consistently flowing, with the other two requiring re-priming on a daily basis.

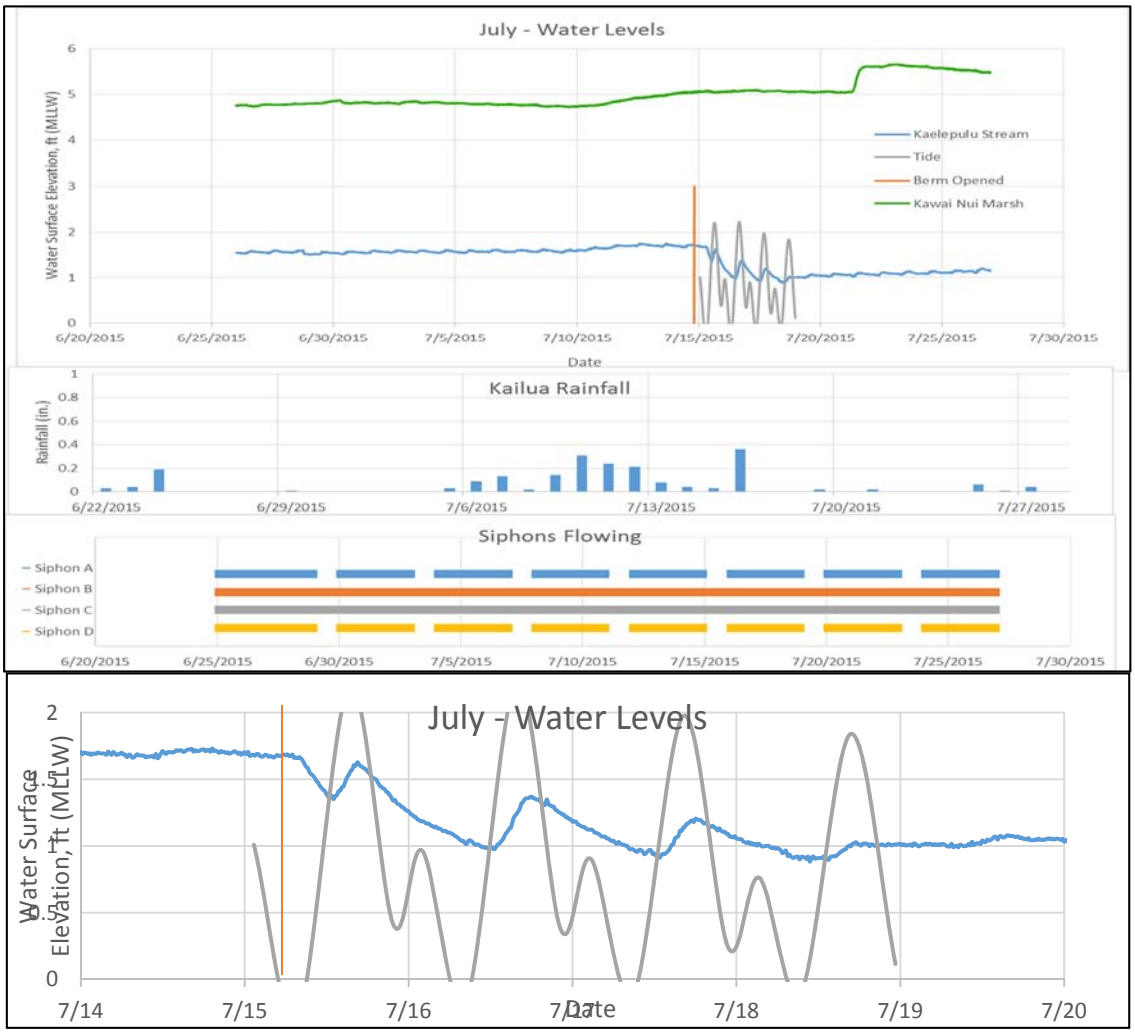


Figure 3.15 July 2015 Water surface elevations and syphon operation.

The stream mouth opening on August 11 was initiated at 0830 from a stream water surface elevation of 1.5 ft, up from an elevation of 1.05 ft at the closing of the stream mouth 25 days earlier (July 19). The stream mouth across the beach was opened with a relatively narrow (20 ft) channel cut through the center of the sand berm which had been graded down to less than a foot above the stream water elevation. An hour after the opening (0930) the excavator was used to dredge a narrow (~4 ft) but deep (~3 ft) channel through the center of the flow. The effect of the narrow deeper channel was visually dramatic, with obvious channel bank and bed erosion occurring at an increased rate in proportion to the flow rate. In the enlarged (lower) portion of Figure 3.16 below, the effect of the narrow channel can be seen as a steep decrease in the surface elevation. Even though the opening was initiated only about 5 hours prior to the inflowing tide, the channel developed was sufficient to maintain flow over a period of almost 7 days. The opening achieved an inflow of 1.8 feet with an outflow of 2.2 feet and closed at an elevation of 1.6 feet. Rainfall during the closed period was 0.66-inch which could contribute (3X) 2.0-inch to the water surface elevation of the stream. Evaporative loss (0.2 inch/da) would be expected to decrease the water surface elevation by 4.9 inches, yielding an expected elevation of 0.81 feet. This low water surface elevation in the estuary would generally be associated with fish die-offs, the threat of bird botulism, and complaints of foul odors from adjacent residential neighborhoods. The difference in water surface elevations is attributed to inflow from the syphon of 2.06 cfs. During the flow period all four syphons were flowing most of the time with only occasional needs for re-priming.

Figure 3.16 August 2015 Water surface elevations and syphon operation.

3.3 IMPACTS TO PHYSICAL WATER QUALITY

Transects measuring physical water quality parameters were conducted through both branches of the estuary on 23 occasions during the 3-year study period with 9 transects conducted between 5/15/15 and 9/4/15, bracketing the period when flow was restored from Kawai Nui Marsh to Kawai Nui Stream. During each transect measurements of oxygen percent saturation, pH, turbidity, temperature, and salinity were made from the surface to the bottom at 20 stations. A "percent exchange" parameter was calculated in relation to the previous survey based upon salinity. Results of salinity (only) transects are displayed in Appendix C aligned with bar charts showing inputs of salt water from the ocean and fresh water from rainfall runoff and from the syphon. Graphical results for all parameters from surveys conducted in 2012-2014 (control, no syphon) are printed as cross sections in Appendix D. Appendix E contains the graphical cross sections of surveys conducted in 2015 when the syphon restored 1.5 cfs to the Kawai Nui Stream between May 22 and September 3. Results for each parameter are displayed as representative cross-section graphics for Trial A and as depth averaged time series for 2015. Data summarized by each water body segment are summarized for all depths and all sample points within that segment in Tables 5 and 6 for the control conditions (2012-2014) and the flow restored condition (2015).

Table 4 Water quality transect surveys

Water Quality Transect Surveys				
Transect Date	*Relation to Opening*	*Transect #*	*Associated Berm Opening Date*	*WSE, ft MLLW*
17-Sep-12	PRE	1	19-Sep-12	0.93
24-Sep-12	POST	2	19-Sep-12	1.19
12-Nov-12	PRE	3	13-Nov-12	1.05
1-Dec-12	POST	4	13-Nov-12	1.40
7-Feb-13	MID	5	13-Nov-12	1.35
8-Jul-13	PRE	6	10-Jul-13	1.43
21-Jul-13	POST	7	10-Jul-13	1.15
19-Aug-13	MID	8	10-Jul-13	1.63
16-Sep-13	PRE	9	23-Sep-13	1.50
26-Sep-13	POST	10	23-Sep-13	1.50
16-Nov-13	PRE	11	19-Nov-13	1.69
29-Nov-13	POST	12	19-Nov-13	0.98
23-Jan-14	PRE	13	28-Jan-14	2.25
15-Feb-14	POST	14	28-Jan-14	1.35
18-May-15	PRE	15	19-May-15	1.33
26-May-15	POST	16	19-May-15	1.25
4-Jun-15	PRE	17	17-Jun-15	1.68
14-Jun-15	PRE	18	17-Jun-15	1.56
24-Jun-15	POST	19	17-Jun-15	1.49
14-Jul-15	PRE	20	14-Jul-15	1.30
9-Aug-15	PRE	21	11-Aug-15	1.46
18-Aug-15	POST	22	11-Aug-15	1.60
10-Sep-15	POST	23	7-Sep-15	2.56

Table 5 Summary physical water quality results: control

Summary Physical Water Quality Results: Control - No Supplemental Flow														
Survey Date →	10/2	9/17	9/24	11/12	12/1	2/7	7/8	8/19	9/16	11/29	1/23	2/15	AVERAGE	Stand
SALINITY, ppt	2011	2012				2013	*				2014			Dev
WETLAND	na	21.3	20.7	18.1	25.5	na	13.6	14.9	13.5	18.1	13.3	11.5	17.0	4.5
LAKE	13.7	22.2	21.7	21.1	26.3	na	14.8	16.9	16.3	21.5	13.4	11.5	18.1	4.7
UPPER KAELEPULU	25.5	21.5	21.9	20.1	27.4	na	13.6	18.4	16.5	26.1	12.6	25.9	20.9	5.2
LOWER KAELEPULU	26.4	21.3	23.5	19.7	27.1	na	13.6	18.8	16.7	26.8	12.6	27.9	21.3	5.5
UPPER KAWAINUI	21.6	5.9	7.4	10.4	21.2	0.9	4.7	6.6	6.1	na	7.9	8.5	9.2	6.5
LOWER KAWAINUI	25.1	18.3	19.2	59.7	28.3	1.7	12.5	29.4	15.4	na	11.0	23.1	22.1	14.9
Average -->	22.5	18.4	19.1	24.8	26.0	1.3	12.1	17.5	14.1	23.1	11.8	18.1	18.1	
OXYGEN % Saturation							*							
WETLAND	na	15.5	8.9	32.1	5.9	na	139.0	8.6	14.4	6.1	42.1	23.8	29.6	40.3
LAKE	63.3	86.7	57.6	86.3	85.9	na	108.0	69.8	70.3	49.5	85.1	73.0	76.0	16.4
UPPER KAELEPULU	95.4	79.7	43.9	68.4	75.9	na	153.9	64.5	87.1	76.2	76.1	60.9	80.2	28.0
LOWER KAELEPULU	97.8	90.6	75.7	83.4	104.0	na	118.0	79.0	77.0	91.7	80.1	80.2	88.9	13.3
UPPER KAWAINUI	64.5	5.4	6.0	5.0	3.8	4.8	7.2	6.2	8.9	na	4.8	4.3	11.0	17.8
LOWER KAWAINUI	46.8	40.7	23.1	40.5	63.7	5.7	52.7	40.8	26.8	na	47.0	27.3	37.8	16.0
Average -->	73.6	53.1	35.9	52.6	56.5	5.3	96.5	44.8	47.4	55.9	55.9	44.9	53.9	
pH														
WETLAND	na	6.6	7.2	8.4	8.1	na	8.2	6.4	7.0	7.0	7.6	7.9	7.4	0.7
LAKE	6.8	8.0	7.8	8.3	8.4	na	8.2	7.5	8.0	7.4	8.2	8.0	7.9	0.5
UPPER KAELEPULU	8.0	7.8	7.6	8.1	8.2	na	8.4	7.6	8.1	7.7	8.2	8.0	8.0	0.3
LOWER KAELEPULU	8.0	7.9	7.8	8.2	8.3	na	8.3	7.8	7.9	7.9	8.3	8.0	8.0	0.2
UPPER KAWAINUI	7.8	7.3	7.2	7.5	7.4	7.2	7.3	7.5	7.6	na	7.7	7.6	7.5	0.2
LOWER KAWAINUI	7.5	7.5	7.5	7.8	9.8	7.5	7.7	7.5	7.7	na	8.1	7.7	7.8	0.7
Average -->	7.6	7.5	7.5	8.0	8.4	7.4	8.0	7.4	7.7	7.5	8.0	7.9	7.8	
Turbidity, NTU														
WETLAND	na	24.1	8.9	3.4	1.3	na	1.0	1.7	8.7	56.6	4.7	11.4	12.2	17.1
LAKE	2.3	5.2	7.5	4.4	3.9	na	1.8	1.6	2.1	5.8	2.7	1.6	3.5	2.0
UPPER KAELEPULU	1.8	1.4	2.2	2.0	1.5	na	0.5	1.4	0.9	0.5	0.6	2.0	1.3	0.6
LOWER KAELEPULU	2.2	3.0	1.5	2.4	1.3	na	1.8	1.4	0.8	0.0	2.4	1.6	1.7	0.8
UPPER KAWAINUI	3.4	3.3	7.9	14.5	9.8	19.6	5.4	4.0	6.9	na	6.9	26.8	9.9	7.5
LOWER KAWAINUI	2.3	4.1	4.2	3.5	2.0	2.7	2.1	2.7	2.4	na	1.9	1.4	2.7	0.9
Average -->	2.4	6.8	5.4	5.0	3.3	11.2	2.1	2.1	3.6	15.7	3.2	7.5	5.2	
TEMPERATURE, C														
WETLAND	na	29.2	26.1	22.5	23.8	na	32.3	26.3	26.2	23.5	21.8	22.3	25.4	3.4
LAKE	26.9	29.1	26.9	24.7	24.0	na	30.6	38.8	29.1	25.2	23.0	24.7	27.6	4.4
UPPER KAELEPULU	28.4	0.0	27.3	25.1	24.1	na	31.2	28.8	29.6	26.0	23.5	25.0	24.5	8.5
LOWER KAELEPULU	27.9	24.1	26.8	24.7	23.8	na	30.4	28.2	28.8	25.2	23.7	24.1	26.2	2.4
UPPER KAWAINUI	29.2	26.9	25.5	23.7	24.4	22.5	27.1	27.2	27.7	na	21.6	24.6	25.5	2.3
LOWER KAWAINUI	29.1	27.6	27.7	24.9	25.8	24.1	29.1	29.5	29.8	na	23.4	25.4	26.9	2.3
Average -->	28.3	22.8	26.7	24.3	24.3	23.3	30.1	29.8	28.5	25.0	22.8	24.4	26.0	
	* 7/8/13 survey conducted in the afternoon - not morning													

** Values in the table represent the average of all depths and all sample points within each identified segment of the estuary. "Average" calculations in the table do not account either for the total number of measurements within each segment nor the volume of water in the estuary represented by each sample point.

Table 6 Summary physical water quality results during flow restoration

Summary Physical Water Quality Results During Flow Restoration											
Survey Date →	5/15	5/26	6/4	6/14	6/24	7/14	8/9	8/18	9/10	AVERAGE	1 Std Dev
SALINITY, ppt											
WETLAND	18.9	21.8	20.8	24.6	7.0	17.2	20.1	5.7	13.1	16.6	6.6
LAKE	20.9	23.7	24.7	25.1	19.0	18.3	19.8	15.6	16.4	20.4	3.5
UPPER KAELEPULU	19.2	27.7	24.9	23.6	15.1	17.4	17.4	16.1	18.0	19.9	4.4
LOWER KAELEPULU	19.1	28.1	25.9	23.4	20.6	17.2	18.8	20.4	18.3	21.3	3.7
UPPER KAWAINUI	4.8	10.5	6.5	4.3	1.5	2.5	0.8	1.2	6.1	4.2	3.1
LOWER KAWAINUI	16.7	26.7	22.8	21.4	5.6	15.1	4.5	6.1	16.4	15.0	8.1
Average -->	16.6	23.1	20.9	20.4	11.5	14.6	13.6	10.8	14.7	16.2	
OXYGEN % Saturation											
WETLAND	5.6	4.6	4.3	6.4	28.3	33.2	33.8	19.1	30.7	18.4	13.2
LAKE	86.5	80.5	32.2	54.3	79.8	79.6	70.0	62.9	41.7	65.3	19.0
UPPER KAELEPULU	77.3	87.4	13.0	32.7	67.6	54.7	51.5	40.8	41.2	51.8	23.1
LOWER KAELEPULU	77.6	90.0	61.4	58.9	80.3	55.1	68.2	72.5	66.8	70.1	11.2
UPPER KAWAINUI	5.6	6.7	4.8	5.9	4.9	3.7	9.7	4.1	6.3	5.7	1.8
LOWER KAWAINUI	45.1	59.9	36.5	31.5	43.1	20.3	27.4	34.3	28.2	36.3	11.8
Average -->	49.6	54.8	25.4	31.6	50.7	41.1	43.4	39.0	35.8	41.3	
pH											
WETLAND	7.2	6.8	6.9	7.2	7.3	7.4	7.7	7.5	7.2	7.2	0.28
LAKE	8.2	7.8	7.4	7.5	7.7	8.0	8.0	7.7	7.6	7.8	0.26
UPPER KAELEPULU	7.9	7.8	7.3	7.5	7.6	7.8	7.8	7.4	7.6	7.6	0.21
LOWER KAELEPULU	7.8	7.7	7.6	7.7	7.8	7.7	7.8	7.5	7.8	7.7	0.10
UPPER KAWAINUI	7.2	7.2	7.1	7.1	6.9	7.2	7.2	7.0	7.2	7.1	0.12
LOWER KAWAINUI	7.6	7.5	7.4	7.4	7.3	7.5	7.3	7.3	7.4	7.4	0.08
Average -->	7.6	7.5	7.3	7.4	7.4	7.6	7.6	7.4	7.5	7.5	
Turbidity, NTU											
WETLAND	1.9	0.7	3.8	4.1	2.1	2.8	0.0	0.0	6.1	2.4	2.0
LAKE	0.0	0.5	3.4	2.2	0.8	1.8	0.6	0.7	4.3	1.6	1.5
UPPER KAELEPULU	1.0	0.9	5.0	1.6	0.4	1.8	0.3	1.1	3.4	1.7	1.5
LOWER KAELEPULU	1.5	1.3	0.6	0.7	0.6	1.7	0.2	1.5	2.7	1.2	0.8
UPPER KAWAINUI	6.9	7.1	2.7	4.0	4.7	4.3	4.7	7.8	4.6	5.2	1.7
LOWER KAWAINUI	5.1	1.3	1.3	1.3	0.6	2.4	1.5	2.2	3.3	2.1	1.4
Average -->	2.7	1.9	2.8	2.3	1.5	2.5	1.2	2.2	4.1	2.4	
TEMPERATURE, C											
WETLAND	22.9	24.9	25.3	27.4	26.7	28.0	27.4	29.3	30.9	27.0	2.4
LAKE	23.9	24.7	25.5	28.1	27.3	28.5	27.9	28.8	30.8	27.3	2.2
UPPER KAELEPULU	24.8	24.5	25.7	28.7	27.9	29.0	28.4	28.8	30.5	27.6	2.1
LOWER KAELEPULU	25.0	24.8	26.1	28.9	28.0	29.0	28.4	29.1	30.5	27.8	2.0
UPPER KAWAINUI	25.1	25.1	26.4	29.0	28.1	29.0	28.5	29.3	30.6	27.9	1.9
LOWER KAWAINUI	25.1	25.6	26.4	29.1	28.0	29.0	28.5	29.4	30.8	28.0	1.9
Average -->	24.5	24.9	25.9	28.5	27.6	28.8	28.2	29.1	30.7	27.6	

* Values in the table represent the average of all depths and all sample points within each identified segment of the estuary. "Average" calculations in the table do not account either for the total number of measurements within each segment nor the volume of water in the estuary represented by each sample point.

3.3.1 Temperature

During the period of the experiment, from May through September, there was a general rise in the average water temperature from about 25C to 30C. In the mornings when measurements were taken it was common for reverse stratification to occur with the surface waters several degrees cooler than waters several feet deep. No change in temperature profiles was anticipated as a result of restoring water flow from the syphon and none was observed. Although the data suggests that the water temperature in the Kaelepulu Wetland and Lake are lower, this is likely an artifact of the sampling protocol as these sites were typically sampled prior to sunup.

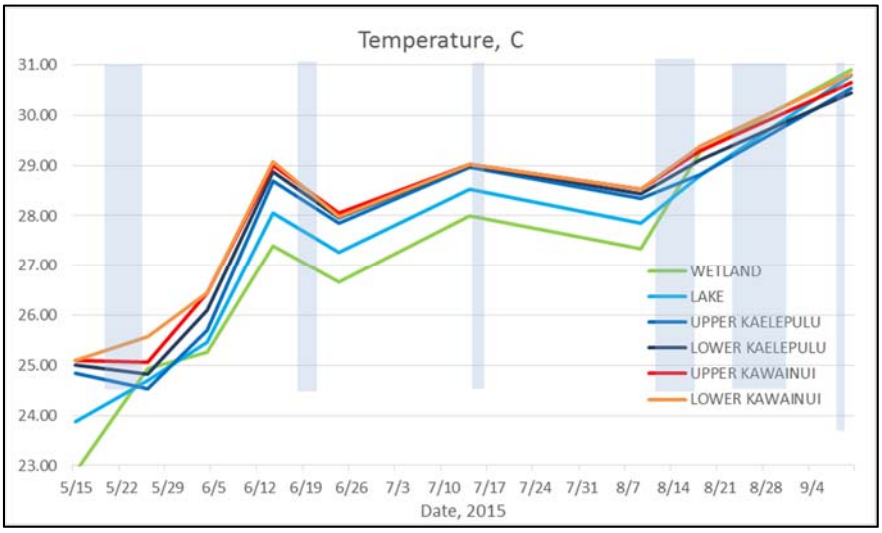


Figure 3.17 Temperature by estuary reach during 2015. Gray shaded vertical bars indicate periods when stream mouth was open to the ocean.

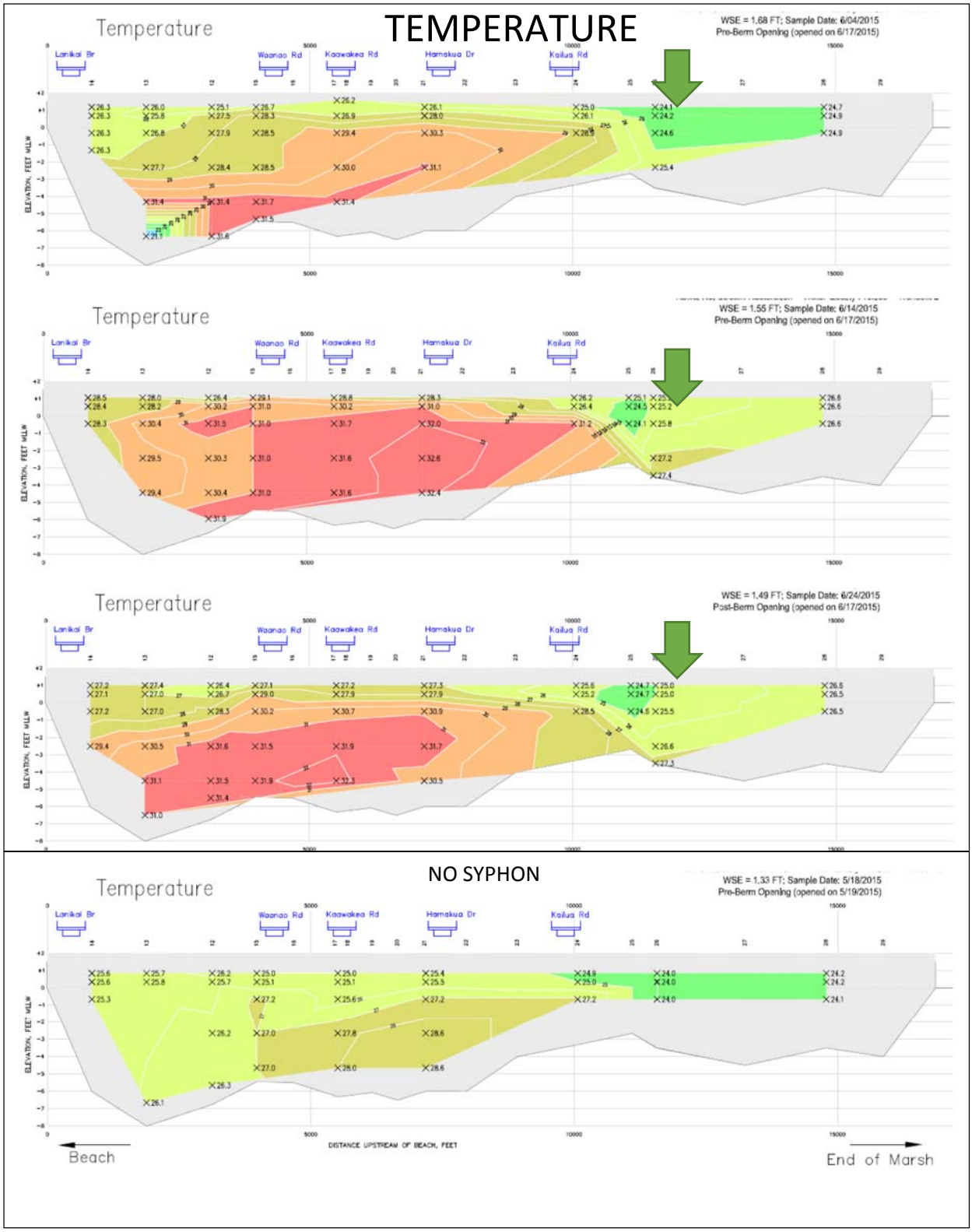


Figure 3.18 Inflow of water from syphon (green arrow) had no impact on temperature levels in Kawai Nui Stream. Transects taken on 6/4 (top), 6/14 (mid), and 6/24 (bottom) with the stream mouth open to flow from 6-17 through 6/20/2015. Bottom transect is from 5/18 prior to any flow from the syphon.

3.3.2 Oxygen

Because of the wide variance in temperature and salinity in the estuary, oxygen levels were measured as percent saturation. Water quality measurements were collected early in the morning because oxygen levels in natural systems tend to fall to a minimum overnight until photosynthesis begins again with the sun rise. In general oxygen saturation levels below about 40% do not sustain a wide variety of fish and invertebrate life, and only a very few specially adapted species (i.e. tilapia) can survive if saturation levels fall below 15%.

The general pattern of oxygen saturation within the system consisted of extremely hypoxic conditions in the entire upper reach and most of the lower reach of the Kawai Nui Stream while the Kaelepulu Stream and Lake system typically maintained high oxygen levels. This pattern remained consistent before and after initiation of the flow restoration from Kawai Nui Marsh to Kawai Nui Stream. Except for cleared shores along the bank of the Hamakua Wetland (between the Kailua and Hamakua bridges) the areas where low oxygen levels persist have high densities of mangrove.

Oxygen levels within the Kaelepulu Pond (Lake) and Stream were generally quite high. An exception occurred during the survey conducted on June 4, 2015. Relatively low oxygen percent saturation was apparent in the entire system, but particularly in the upper Kaelepulu Stream and lake (See Figure in Appendix E). The survey was conducted only about two weeks following closure of the stream mouth and a 1.4-inch rainfall event that brought significant runoff into the system. A large (47" FL) dead barracuda was seen in the wetland at the beginning the survey and the water was noted to vary from a "gray-brown" in the wetland to a "lime green" in the lake and upper Kaelepulu Stream channel.

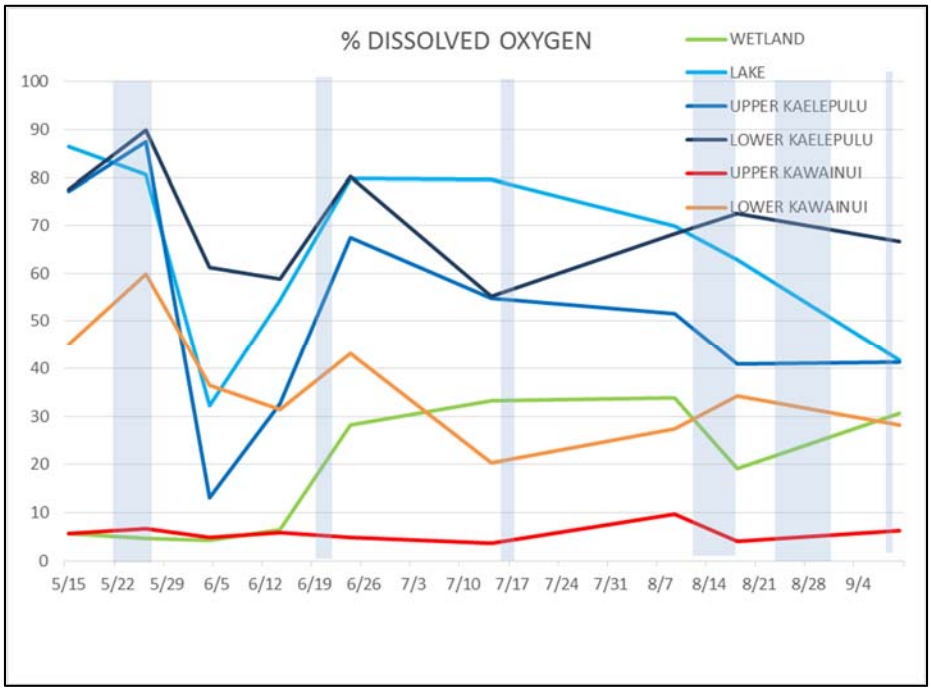


Figure 3.19 Oxygen saturation percent by estuary reach during 2015. Blue bars indicate periods when stream mouth was open to the ocean.

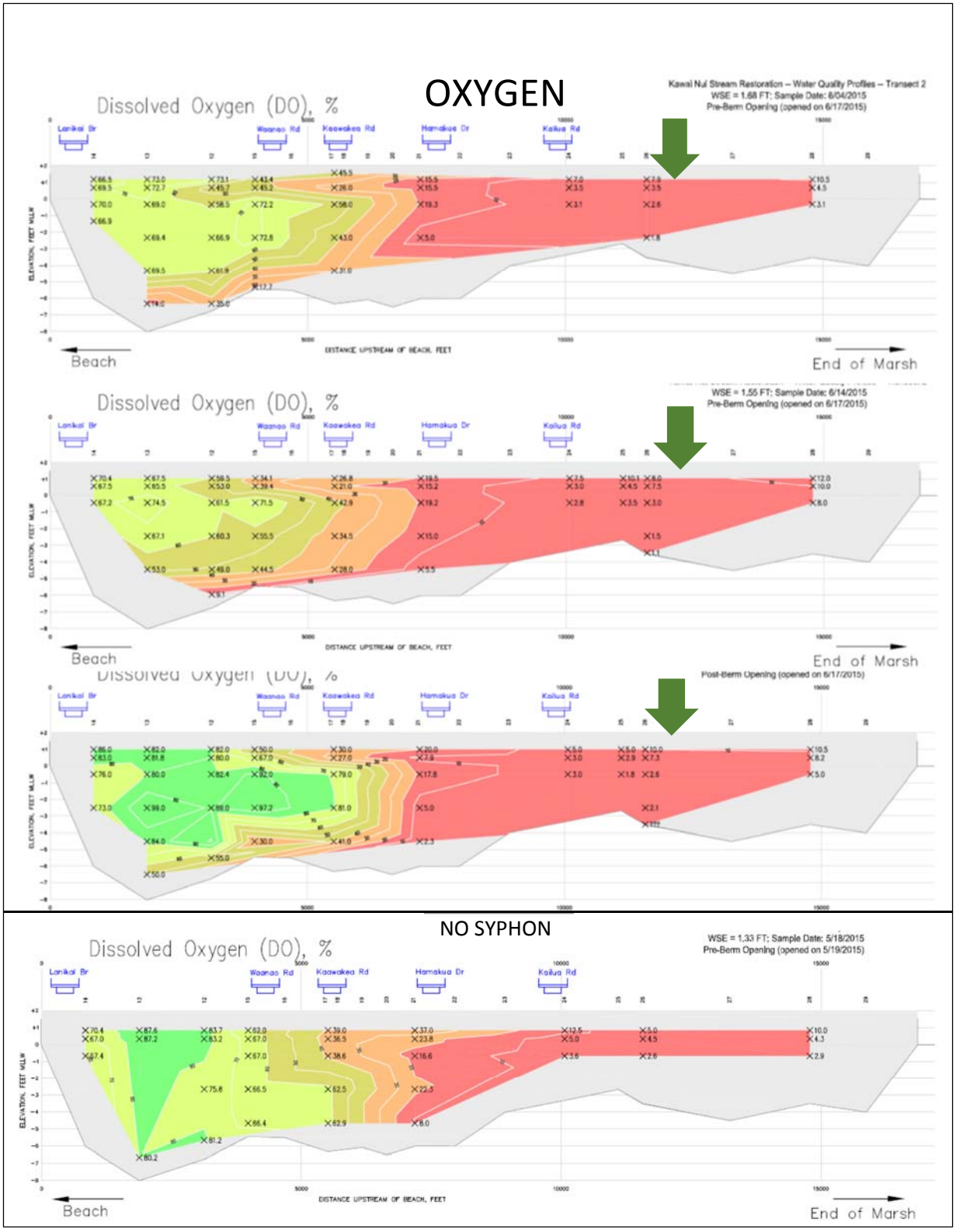


Figure 3.20 Inflow of water from syphon (green arrow) had no positive impact upon the very low dissolved oxygen levels in Kawai Nui Stream. Transects taken on 6/4 (top), 6/14 (2nd), and 6/24 (3rd) with the stream mouth open to flow from 6-17 through 6/20/2015. Bottom transect is from 5/18 just prior to starting the syphon.

3.3.3 pH

During the three trials, with the exception of the survey conducted on 6/4/15, the pH of the Kaelepulu Lake and Stream varied between 7.5 and 8.1. The lower pH (7.3-7.4) measured on 6/4/15 was associated with the phytoplankton bloom and lower oxygen levels during this survey. The pH of water flowing through the syphon from the marsh to the Kawai Nui Stream varied between 6.7 and 7.1. In the upper Kawai Nui Stream the lower pH levels (6.9 – 7.4) were consistent with the low oxygen levels and high organic load associated with the overgrowth of mangrove along this reach. Organic acids produced by anaerobic bacterial decomposition of plant and animal detritus can contribute significantly to low pH. During all three trial periods a plume of low pH water appears to be associated with the inflow from the syphon. This area of low pH was not apparent during any of the control surveys.

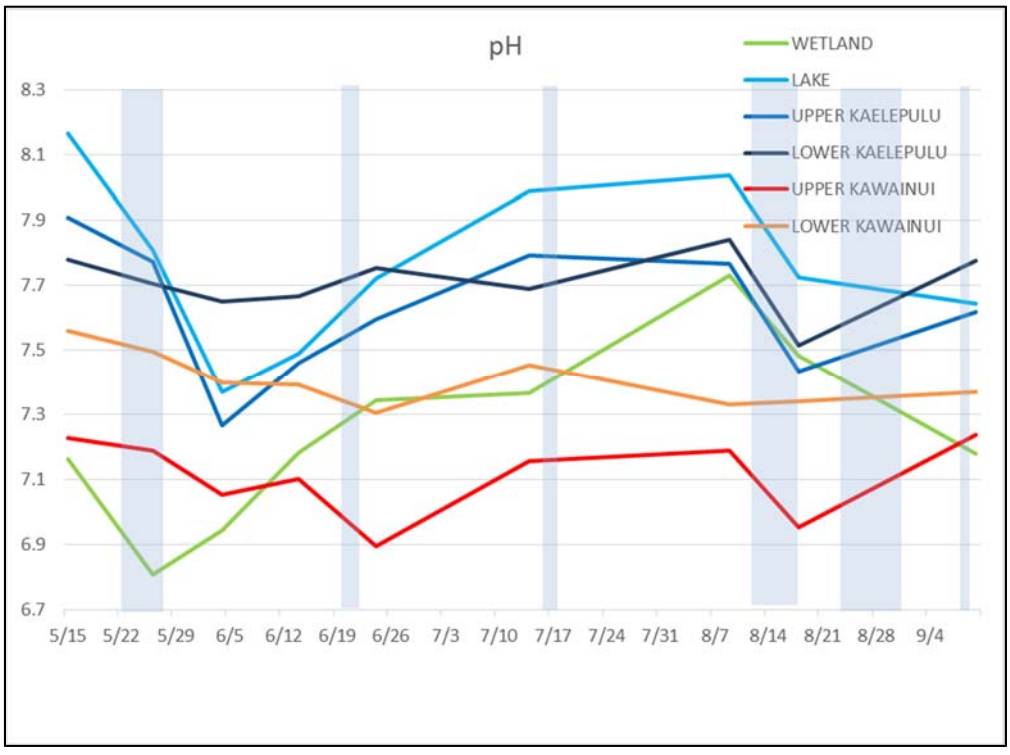


Figure 3.21 pH by estuary reach during 2015. Blue bars indicate periods when stream mouth was open to the ocean.

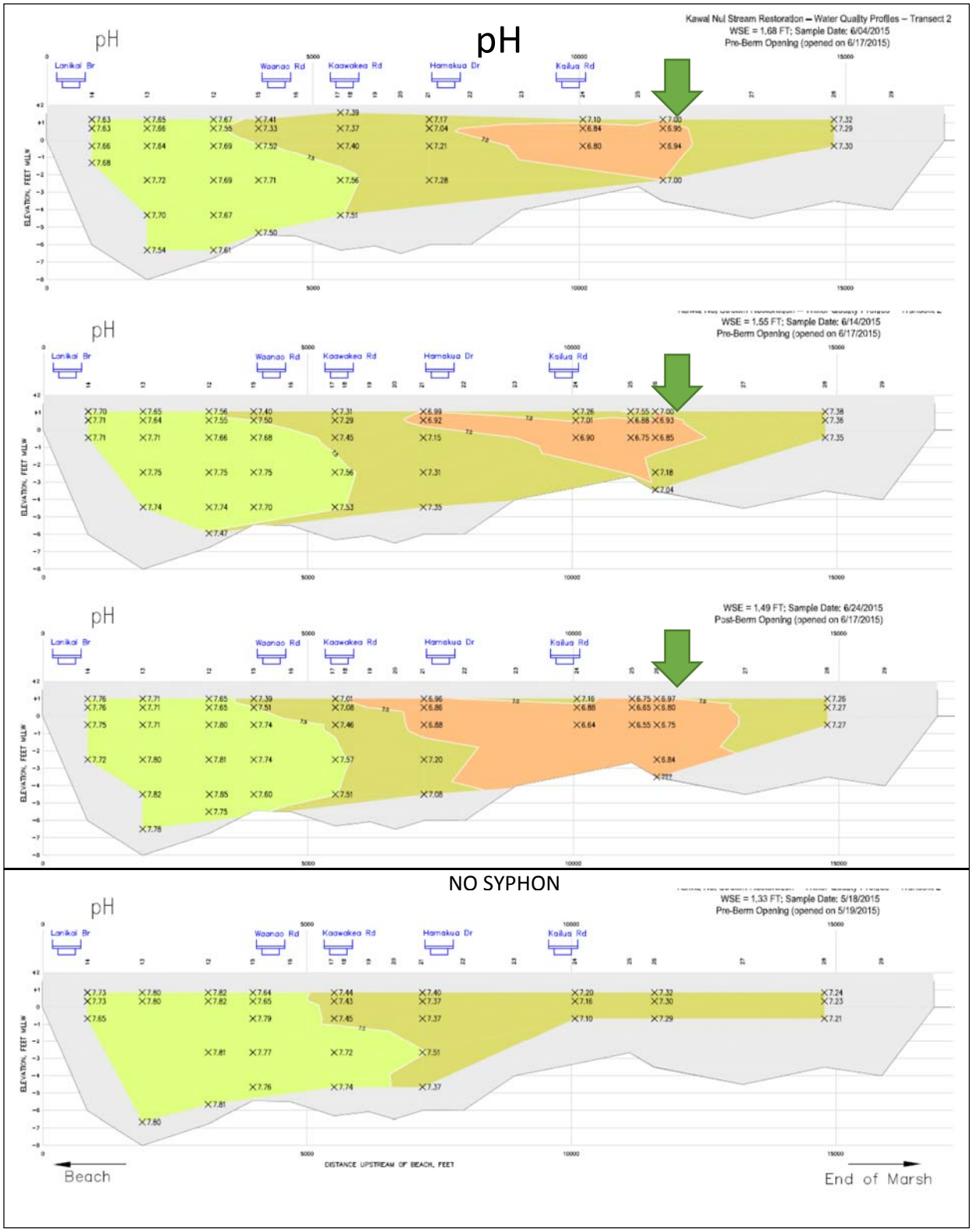


Figure 3.22 Inflow of water from syphon (green arrow) appears to have lowered the pH in Kawai Nui Stream. Transects taken on 6/4 (top), 6/14 (2nd), and 6/24 (3rd) with the stream mouth open to flow from 6-17 through 6/20/2015. Bottom transect is from 5/18 just prior to starting the syphon.

3.3.4 Turbidity

Turbidity varied greatly throughout the system associated both with the inflow of turbid water from the watershed and with the bloom of plankton within the system on 6/4/15. The turbidity of water flowing in from the marsh was relatively high, varying between about 5 to 7 NTU and was roughly consistent with the turbidity of the water in the upper Kaelepulu Stream. The most turbid portion of the system is the upper Kawai Nui Stream. This turbidity appears to be a function of the heavy organic load associated with the mangroves and with bioturbation caused by tilapia suspending the very fine sediments along this reach. The inflow of water from the syphon did not appear to have any effect upon the turbidity of the Kawai Nui Stream.

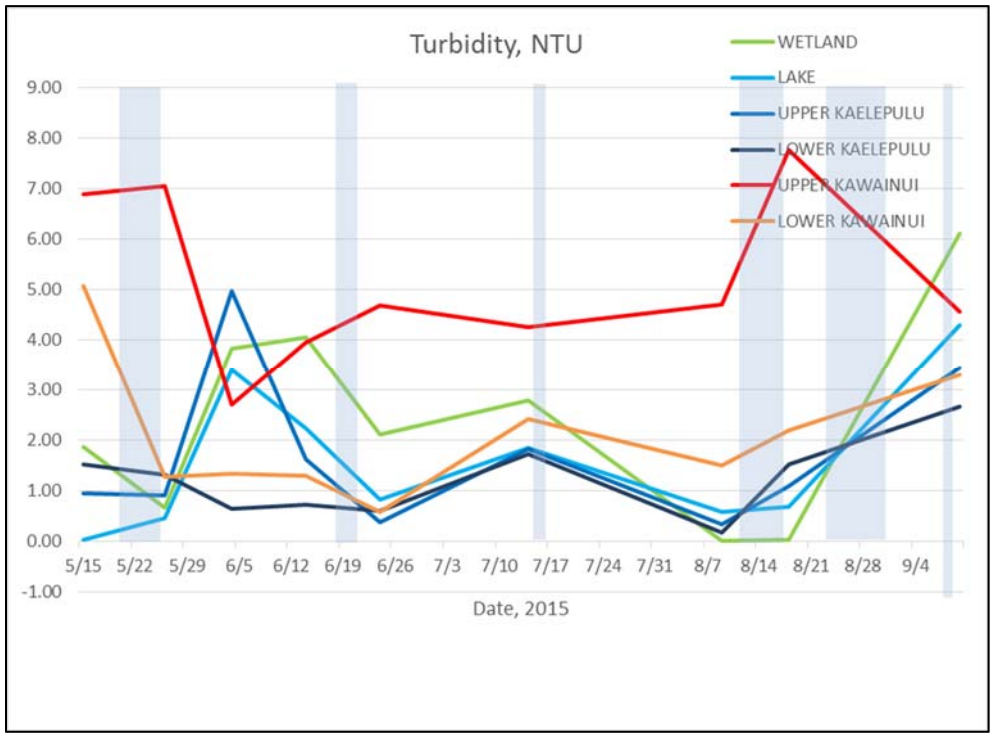


Figure 3.23 Turbidity by estuary reach during 2015. Blue bars indicate periods when stream mouth was open to the ocean.

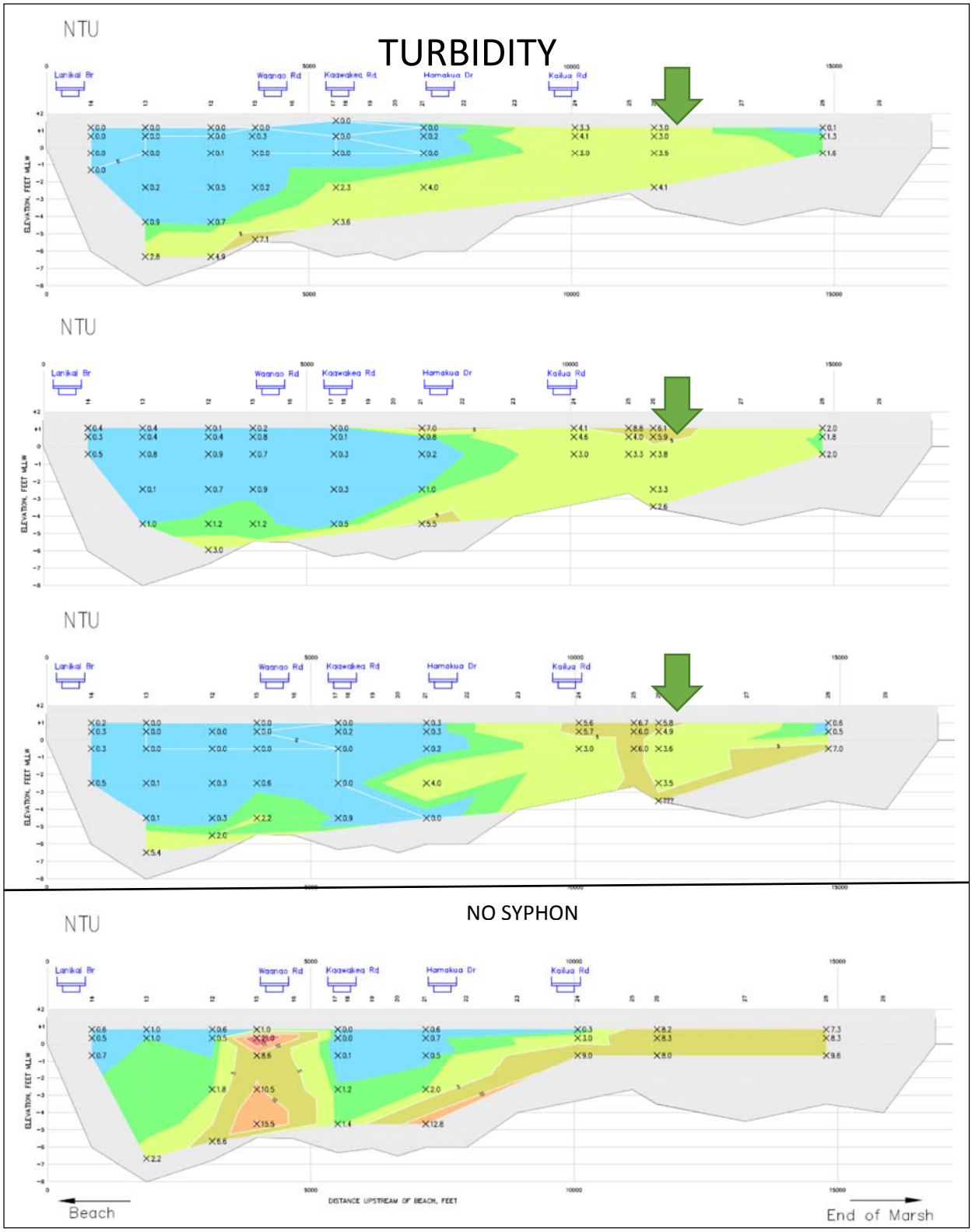


Figure 3.24 Inflow of water from syphon (green arrow) had no impact on turbidity levels in Kawai Nui Stream. Transects taken on 6/4 (top), 6/14 (mid), and 6/24 (bottom) with the stream mouth open to flow from 6-17 through 6/20/2015. Bottom transect is from 5/18 prior to any flow from the syphon.

3.3.5 Salinity

Salinity within the system varied from near freshwater, to near seawater depending upon season and location within the estuary. Average salinity within the lake (75% of the system volume) varied from 16-25 ppt during 2015, and ranged as low as 13 ppt in 2014 (see 1/23/14 transect Appendix C). The upper reach of Kawai Nui Stream consistently displays the lowest salinity. In the surveys conducted prior to flow restoration (2012-2014) the average salinity of this reach was 9.2 ranging from 0.9 to 21.6 ppt. The restoration of fresh water flow to the Kawai Nui branch of the estuary did lower the salinity of the distal end of the channel from a pre-syphon average of 8ppt to about 2 ppt during Trials B and C (Overall Average = 4ppt), but the salt wedge persisted in the bottom of the channel up through the Hamakua Wetlands to the Kailua Bridge. Given that the volume of fresh water restored during each of the trial periods (2-4 MCF, Table 2) was one to two times the volume of the entire Kawai Nui Stream channel (2 MCF), the persistence of the salt wedge was somewhat surprising. Examination of the graphics (Figure 3.26) shows the fresh water lens spreading across the surface of the Kawai Nui Stream and into the lower Kaelepulu Stream. Over the course of the month in Trial A, this thin lens persists and can be seen to depress the salt wedge in the lower Kaelepulu, likely through wind driven vertical mixing.

The continual replenishment of this thin freshwater lens from the syphon resulted in the persistence of stratification within the lower Kaelepulu Stream, although this effect did not appear to extend up into the upper Kaelepulu Stream or into the pond. As demonstrated in Figure 3.27 during the pre-syphon control conditions mixing tended to result in a uniform salinity throughout the water column, whereas with the syphon salinity differences persisted from the top to the bottom.

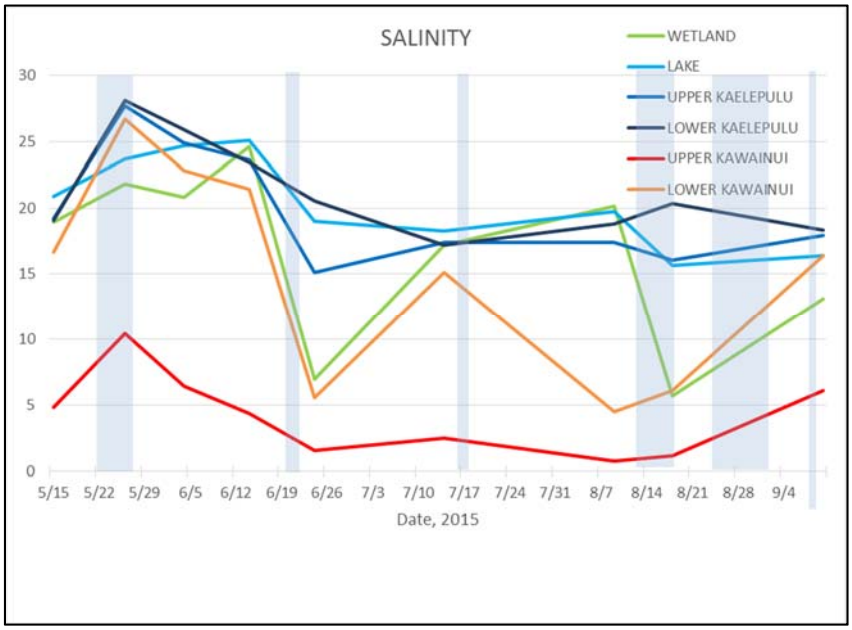


Figure 3.25 Salinity by estuary reach during 2015. Blue bars indicate periods when stream mouth was open to the ocean.

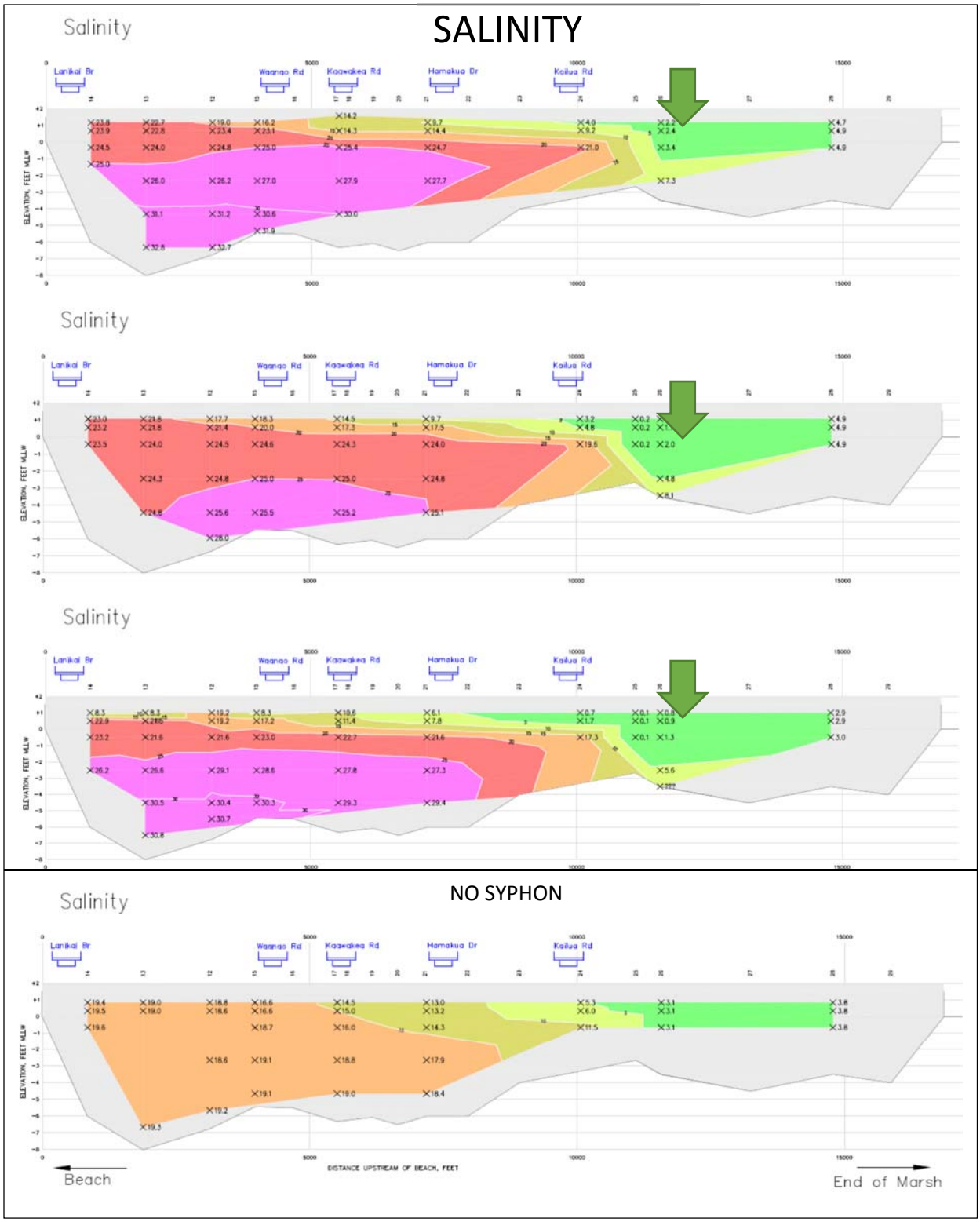
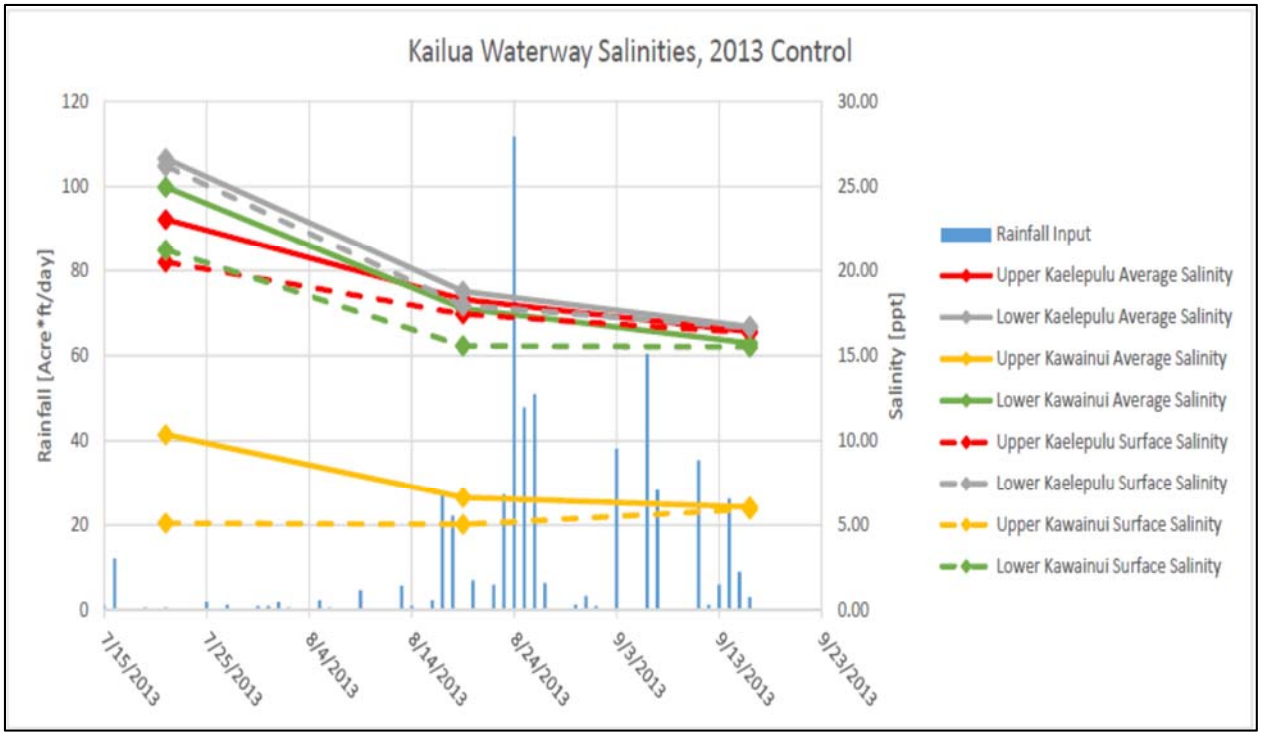


Figure 3.26 Inflow of water from syphon (green arrow) lowered salinity levels and depressed the salt wedge in Kawai Nui Stream. Transects on 6/4 (top), 6/14 (2nd), and 6/24 (3rd) with the stream mouth open to flow from 6-17 through 6/20/2015. The bottom transect is from 5/18, prior to flow from the syphon.



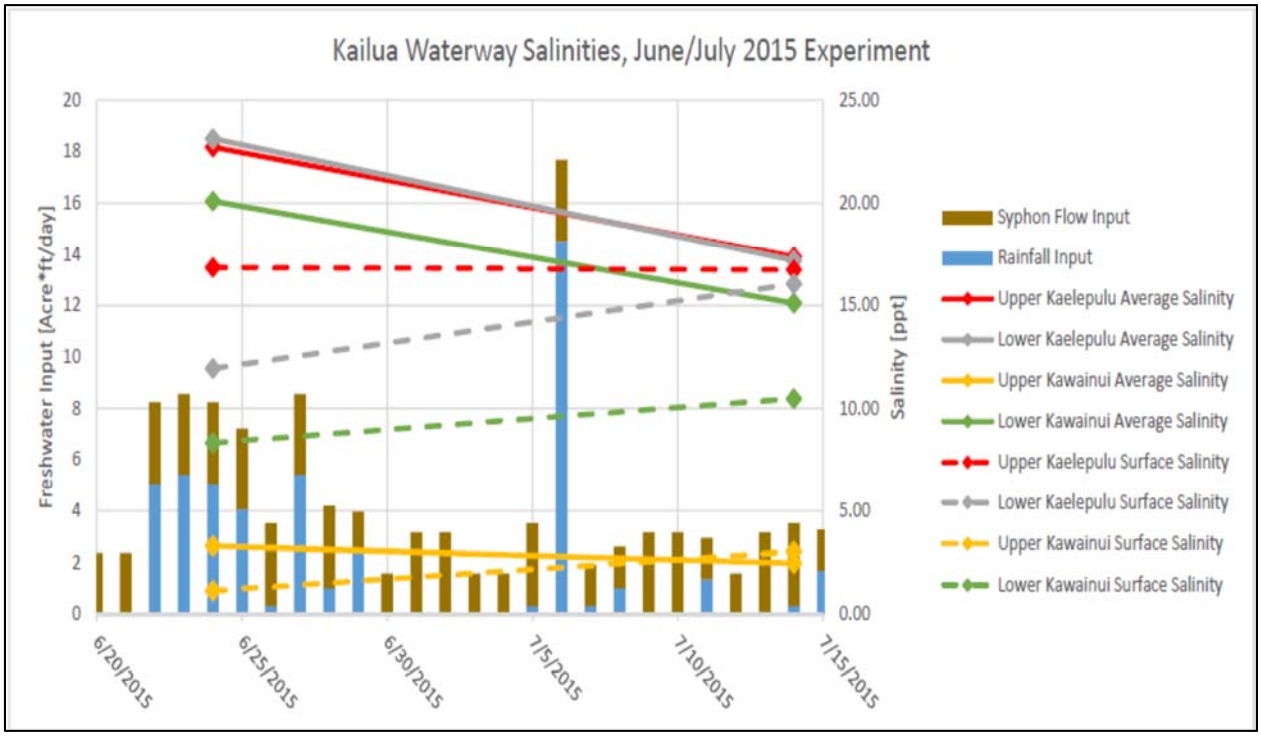


Figure 3.27 Salinity changes between stream mouth openings with (bottom) and without (top) supplemental flow from syphons.

3.3.6 Percent Exchange

The percent of water exchanged within an aquatic system over time is critical to the stability of the system. Averaged over the 36-month study period, rainfall contributed an average of 20% of the volume of the estuary per month. Freshwater contribution from rainfall varied from 4% to 75% of the estuary volume per month (Figure 3.28). Flow from the ocean to the estuary averaged 72% of the estuary's volume and varied from 0% to 315%. Although the average percent exchange was 72%, the mean exchange was only about 40%, and four months exceeded 200% exchange (Figure 3.28). In contrast, 4 months received almost no inflow and 13 months received less than 20% of the estuary volume per month (Figure 3.28). Inflow from the syphon during the three trial months ranged from 7% to 16% of the estuary volume. A 2 CFS flow for a month would be expected to contribute about 5 MCF or 17% of the estuary volume per month. If a 17% flow contribution was input per month then no month during the 36-month study period would have fallen below a 20% exchange threshold.

Figure 3.29 displays the percent water exchange graphics from Trial-A. Section (a) shows that the rate of salinity decrease due to the inflow from the syphon extended throughout the entire Kawai Nui branch of the estuary. Section (b), taken about two weeks later, shows that this trend continued. Following the stream mouth opening (6/17 -> 6/20) Section (c) shows a large exchange of salt water in the deeper (ocean) end of the channel, but continued freshening on the surface and at the end of the channel due to syphon inflow from Kawai Nui Marsh.

The correlation between stream height and total exchange volume (Figure 3.13 c) indicates that the additional elevation due to syphon flow input should correlate to an additional 2% increase (0.6 MCF) of ocean inflow, however due to the wide variability in the data this relationship is not statistically significant.

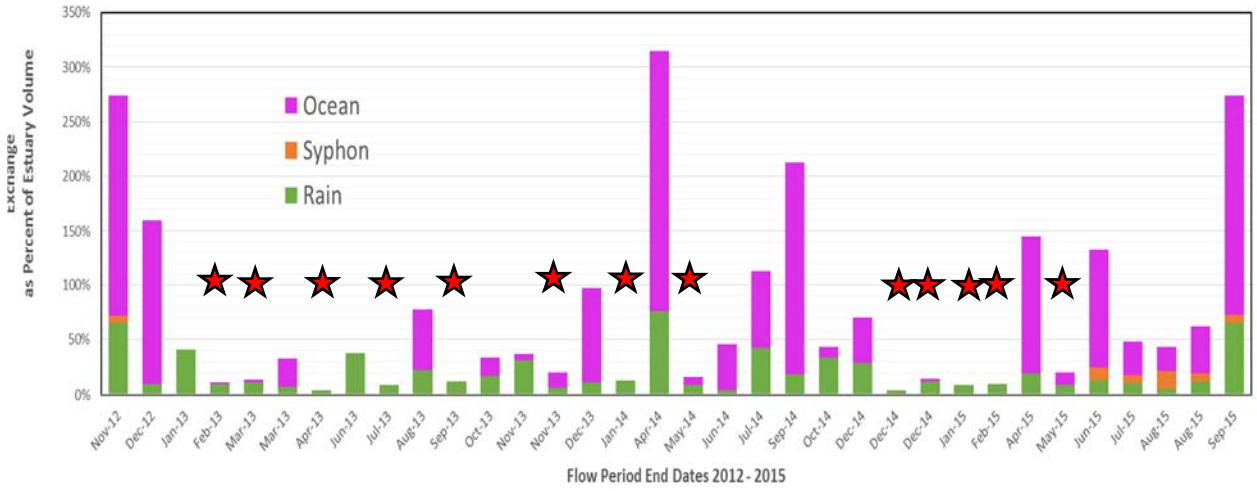


Figure 3.28 Contributions to estuary inflow from rainfall runoff, inflow from the ocean and syphon. Stars indicate 13 months that fall below the minimum 20% exchange threshold deemed acceptable for this estuary.

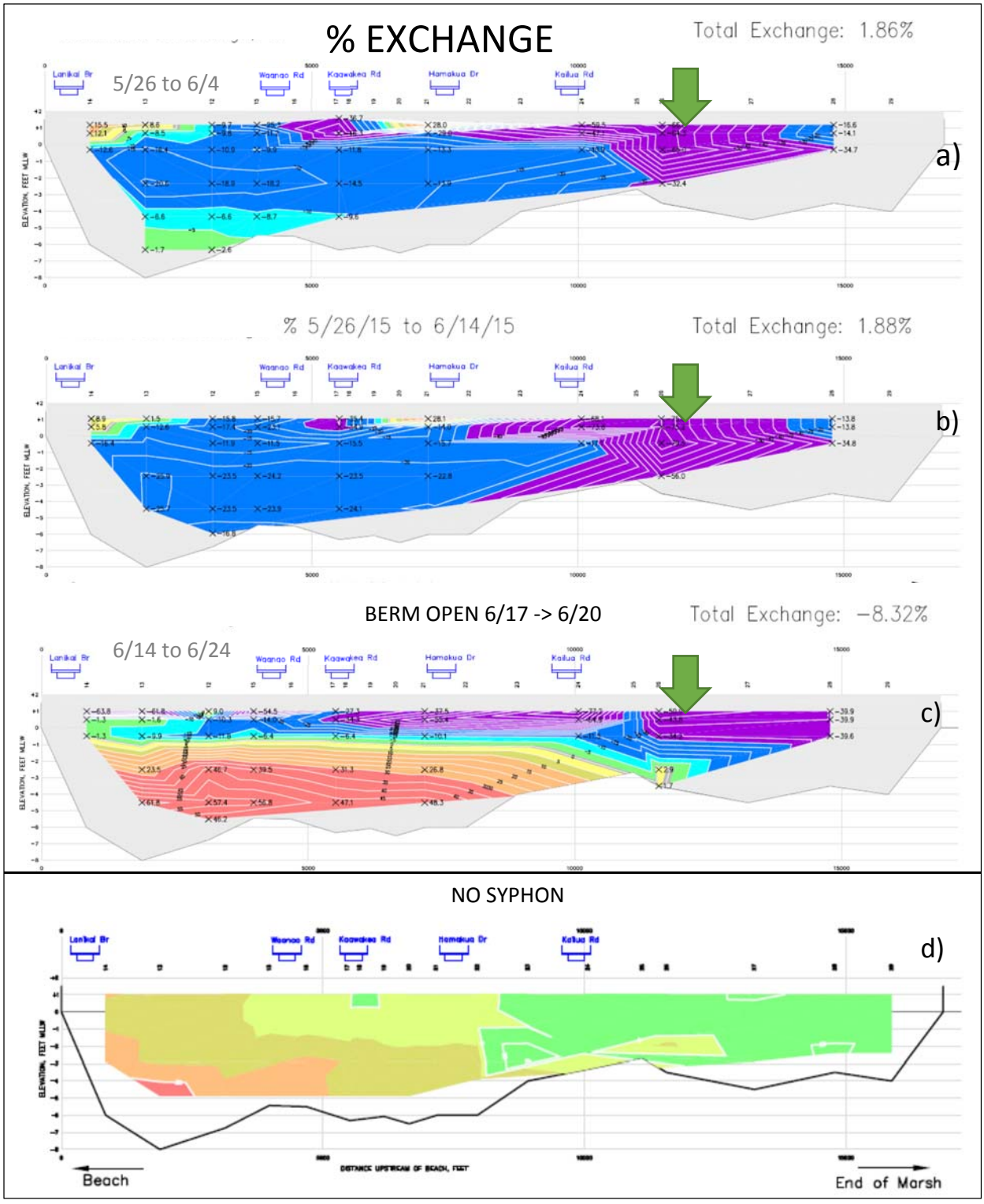


Figure 3.29 Inflow of water from syphon (green arrow) had a positive impact on water exchange in Kawai Nui Stream. Transects taken on 6/4 (top), 6/14 (2nd), and 6/24 (3rd) with the stream mouth open to flow from 6-17 through 6/20/2015. Bottom graph is a "pre-opening transect" from 11/12/12 prior to any flow from the syphon and demonstrates typical case of stagnant water (0% exchange) at the distal end of Kawai Nui Stream. Note bottom graph uses a separate color gradation scale.

3.4 RESIDUAL FLOOD THREAT UNDER EXISTING CONDITION

One of the concerns expressed about raising the water surface elevation to 2.0 feet MLLW was the possible increase in flood threat due to the reduction in response time to open the stream mouth to flow across the sand beach dune. Initiation of flooding in low-lying residential areas, primarily near the beach, begins at about 3.3-feet MLLW. The flooding occurs when the beach sand berm is higher than 3.3 feet, and a significant storm event results in the Kaelepulu water surface rising before the sand berm at the beach can be manually opened to flow. Typically the water surface elevation of the estuary rises about 3-inches for every inch of rain, although during brief or intense events, this can be closer to a 4:1 ratio (Bourke, 2016). Assuming a 4:1 rise to rain ratio and a water surface elevation of 1.5 feet, it would require about (12x[3.3-1.5]/4) 5.4 inches of rainfall to raise the estuary to the flood elevation. A 5.4-inch 6-hour rainfall event may be expected in the watershed about once every 10 years. At a water surface elevation of 2.0 feet, a rainfall event of only 3.9-inches would be necessary to reach the flood elevation. A 3.9-inch 6-hour rainfall event can be expected in the watershed about every other year, but this same quantity of rainfall can be expected annually as a 24-hour storm in the Kaelepulu watershed. (NOAA Atlas, 2016). If the sand berm at the stream mouth is not maintained at an elevation lower than 3.3 feet, MLLW, and assuming a 10-year return, 6-hour storm event of 5.4` inches of rain, then maintaining the water surface at the higher elevation of 2.0 feet as compared to a 1.5 ft elevation would decrease the response time for the City to open the berm from approximately 5.6 hours to 4.2 hours.

The above risk scenario assumes that the elevation of the water system is 1.5 ft, which is only correct on an average basis because the City does not control the water elevation and under present conditions it varies between about 0.9 ft and 2.2 ft. Maintaining the water surface elevation higher than 2.0 feet with a sand berm higher than 3.3-feet invites the possibility of flooding from a one-year 24-hour storm event. During the 255 days of 2015 the water surface elevation was higher than 2.0 feet during three time periods for a total of about 45 days or 18% of the time (Figure 3.30). Therefore, under existing conditions it would appear that the community is under increased risk of flood threat due to the inability of the system to reliably maintain the water below the 2.0 ft MLLW elevation.

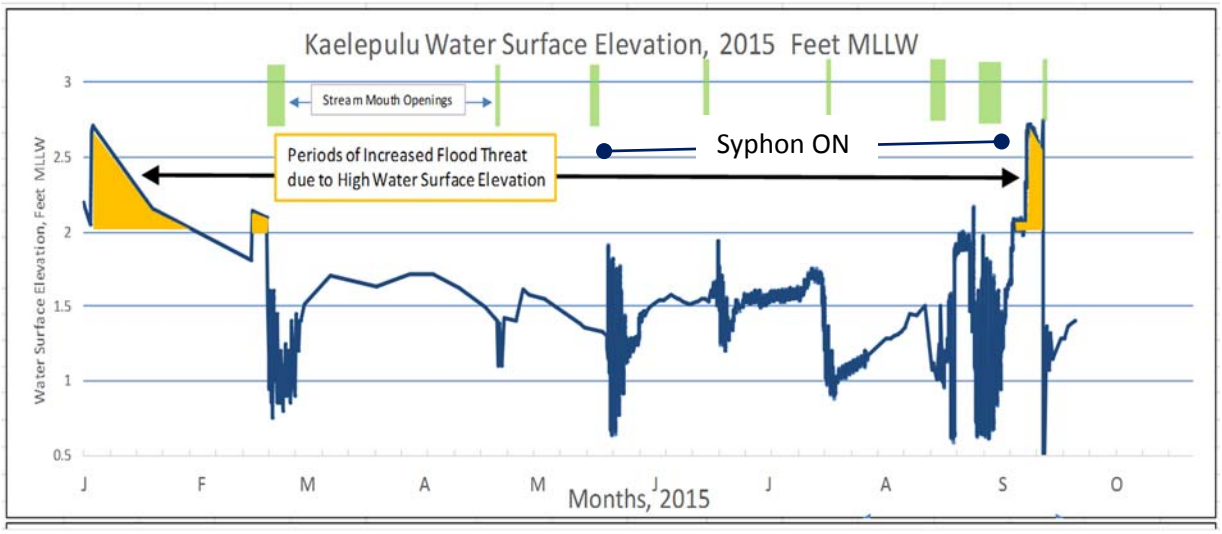


Figure 3.30 During 2015, the water surface elevation exceeded 2.0 feet MLLW during three time periods. Water surface elevations in excess of 2.0 feet MLLW may pose an increased flood threat.

4 DISCUSSION

4.1 SUMMARY OF RESULTS

Water Quantity

- The Kailua Waterway System (KWS) (Kawai Nui Stream, Hamakua Wetlands Kaelepulu Stream, Kaelepulu Pond, Kaelepulu Wetlands) have a combined area of about 142 acres and a volume of about 30 million cubic feet at a water surface elevation of 1.5 ft MLLW.
- Restoration of approximately 1.5 CFS flow from Kawai Nui Marsh to Kawai Nui Stream resulted in positive ecosystem benefits to KWS with no discernable adverse impacts to the marsh source-water ecosystem.
- Inflow to Kawai Nui Marsh from the Maunawili and Kahanaiki Streams varies seasonally from 7 to 26 cfs with an annual average of 16 cfs.
- Water withdrawal at 1.5 cfs from Kawai Nui Marsh resulted in a detectable increased rate of water surface elevation fall by about 0.07-inch per day (from 0.20”/da w/o syphon to 0.27”/da with the syphon). This rate was well within the natural daily fluctuations typically experienced in the Kawai Nui Marsh.
- Evaporation during periods without rainfall results in an average drop in the KWS water surface elevation of about ¼-inch per day, or $7^1/_2$ –inch per month. During the experiment, humidity was high and measured evaporation was about $^1/_5$-inch per day.
- At an average rain:rise ratio of 1:3, the KWS water surface elevation falls during months that do not have 2.5-inch rainfall (May through October).
- The restoration of 1.5 cfs flow was sufficient to offset evaporation and resulted in the water surface rising by about $^1/_8$-inch per day. When flow was 2.0 cfs, the water surface elevation of KWS rose by about ¼-inch per day.
- In 13 of the 36 months of the study period, the estuary experienced less than 20% exchange.
- A syphon flow rate of 2 cfs would contribute about 17% exchange to the system per month.

Physical Water Quality

- Physical water quality within the Kawai Nui Stream is very poor, exhibiting low pH, very high turbidity and very low dissolved oxygen levels. Physical water quality within the balance of the Kaelepulu Stream and Pond system was on par with State water quality standards for “wet embayments” or “estuaries” and was much better than that seen in Kawai Nui Stream.
- The restored flow did not result in any impact upon temperature, turbidity or oxygen concentrations within the Kawai Nui Stream. This is likely due to the high biological oxygen demand brought about by the mangroves and highly organic sediments in this stagnant stream channel.
- The restored flow did appear to slightly decrease pH in Kawai Nui Stream to below 7.0 in the vicinity of the syphon inflow.
- The 4 MCF of fresh water flowing into the 2 MCF Kawai Nui Stream over the period of a month, did not displace the brackish water from the channel. Instead, the fresh water appears to have spread across the surface of the system down into the lower Kaelepulu Stream.

- The spread of the restored water flow across the surface of the Kawai Nui Stream and lower Kaelepulu Stream resulted in a persistent salinity stratification, as compared to control periods when the waters would have been well mixed and without stratification.
- During the period when flow was restored, there were no reports or complaints from the public regarding bad odors emanating from the system. These reports have been common in previous years.
- During the period when flow was restored there were no fish die-offs or conditions that would warrant concern from wetland managers about avian botulism. This is in contrast to the previous two summer seasons.
- Initial restoration of water flow may be correlated with the cessation of a pre-existing algae bloom and the lack of fish die-off conditions typical of this season.

Stream Mouth Opening

- Higher water surface elevations were positively correlated with increased exchange at the stream mouth but the magnitude of this impact during the three opening events was not sufficient to be statistically significant.
- Openings conducted when the ocean was higher than the stream level were not effective
- Openings timed to provide a long period of drawdown prior to an incoming tide were effective
- Narrow, deeper openings (20 x 3 ft), were more effective than wide shallow (60 x 1) openings.
- Sand removed during annual dredging of the entire stream channel between the bridge and the beach was replaced within three days by inflow of sand from the beach into the stream channel.

Ecosystem Impacts

- The increased water surface elevation kept both the Hamakua and Kaelepulu wetlands wet throughout the summer and, according to the wetland managers, had a positive effect upon the foraging and breeding habitat of endangered Hawaiian waterbirds that frequent these wetlands.
- There were neither any fish die-offs nor reports of avian botulism within the system, as had occurred during previous summer seasons.
- There were no telephone complaints from residents adjacent to the estuary concerning odors emanating from the estuary, as had occurred during previous summer seasons

Flood Threat

- Raising the average elevation of the system up to 2.0 feet from its present average of 1.5 ft MLLW would decrease the City's necessary response time to open the stream mouth and avoid flooding from 5.6 hours to 4.2 hours (in response to a 5.4-inch rainfall over a period of 6 hours).
- Under existing conditions there is a previously unrecognized increased threat from flooding due to the height of the beach sand berm across the stream mouth. This sand berm accumulates because since the construction of the levee there has been insufficient flow to keep the stream mouth open. Assuming a flood elevation of 3.3 ft MLLW, system surface elevations higher than 2 ft MLLW may result in increased flood risk from intense storm events exceeding about 3.9 inches of rainfall (a 1-year 24 hour storm for this area).

4.2 DISCUSSION

Inflow from the syphon during the three trial periods varied from about 1 to 2 cfs, depending upon the number of syphon pipes that could be kept operational in the face of persistent vacuum air leaks. Despite these problems, the inflow raised the water surface elevation by 0.3 to 0.7 feet during each of the three 24-day periods between stream mouth openings. Unfortunately, given the low water elevations post-opening, the inflow was not sufficient to reach the intended goal of a 2.0 ft water surface elevation by the time of the next opening. Difficulties with air leaks resulting in loss of syphon flow was not a minor problem and would need to be addressed if a syphon is considered as the permanent design solution.

Water withdrawal from Kawai Nui Marsh did result in a detectable decrease in the marsh water surface (from 0.2”/day to 0.27”/day) and this rate is consistent with the quantity of water withdrawn. However, this rate of withdrawal is well within the natural variation experienced by the marsh and is not likely to have any detrimental impact upon the overall marsh ecosystem.

Although the flow restoration did not have a significant impact upon turbidity or oxygen content of the stagnant water within Kawai Nui Stream, this may have been an unreasonable expectation given the large buildup of organic material from past decades and the thick overstory of mangroves engulfing much of this stream reach. The biological oxygen demand in this channel resulting from accumulated decaying plant and animal matter likely consumes much more oxygen than could be supplied by any reasonable water flow from the marsh. The low pH of the marsh water did have an effect upon the water within the Kawai Nui Stream, but this only serves to demonstrate the minimal ability of this stream reach to adequately buffer the water as a likely result of the heavy mangrove overstory, and high biological oxygen demand.

The volume of fresh water flowing into Kawai Nui Stream through the syphon over the levee during each of the 24-day flow periods was about twice the volume of the Kawai Nui Stream, and yet the stream did not fill with this fresh water as was expected. It appears that the density gradient was sufficient to force the water to flow only within the shallow surface lens where it spread downstream into the lower Kaelepulu Stream. This fresh water lens then contributed both to surface evaporation and also to mixing with lower water strata as demonstrated by the depressed salinity and maintenance of stratification (Figure 4.1). The impact of the syphon flow upon stratification was significant, as shown in Figure 4.2.

There was a great deal of variability between opening events with respect to the total number of days the stream stayed open to tidal flow and the quantity of water exchanged. Taking all of the openings into consideration there does appear to be a positive correlation between water surface elevation and the length of time the opening persists (Figure 3.13). The relationship suggests that raising the water surface elevation of the stream by 0.5 ft would result in an increased length of time the stream mouth is open and a subsequent increased inflow of seawater of about 0.6 MCF. However this correlation is not highly statistically significant and it is clear that other factors (likely including wind and wave impact and opening geometry) also influence the efficiency of opening events. Given the great deal of variability between openings, the analyses of only three opening events conducted during the experiment does not allow a definitive conclusion about the effect of a 6-inch rise in water surface elevation upon the persistence of the opening over time.

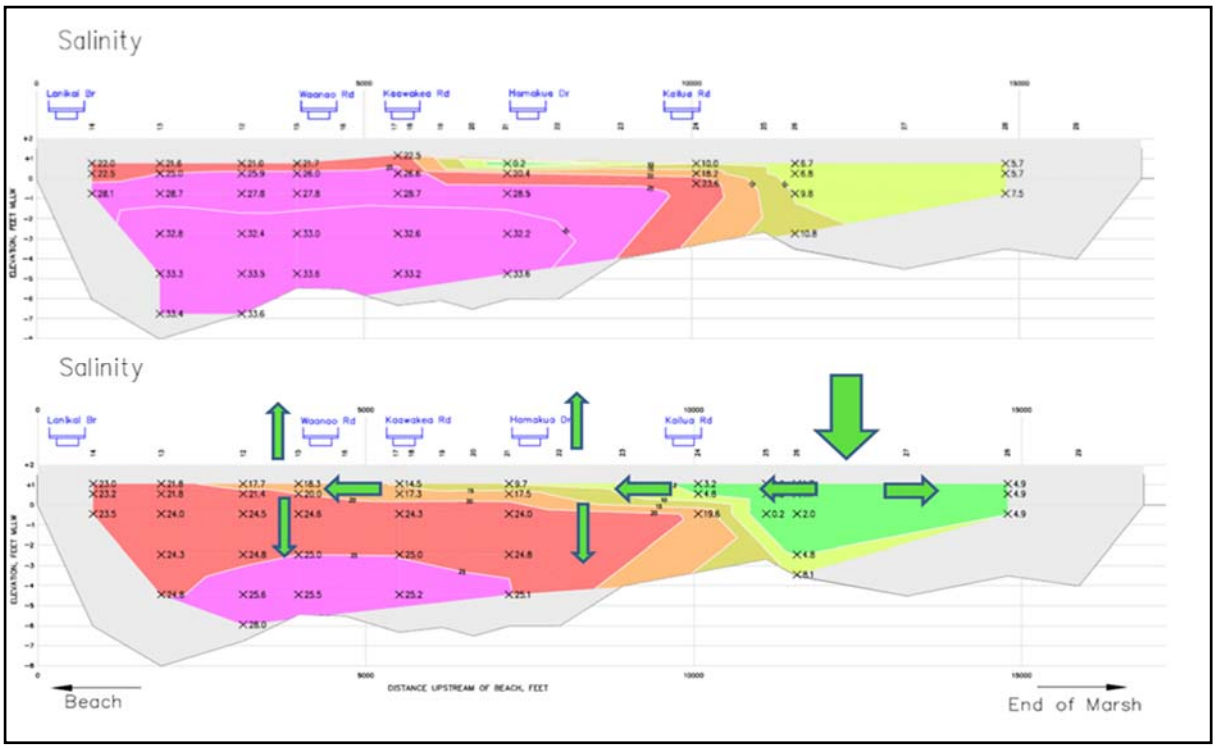


Figure 4.1 General impact of syphon inflow upon salinity. Top: Cross section of Kawai Nui Stream showing intrusion of salt wedge from ocean. Bottom: Same cross section after 1-month of inflow from syphon (large arrow) showing flow of fresh water along stream surface, evaporation, and depression of the salt wedge throughout stream.

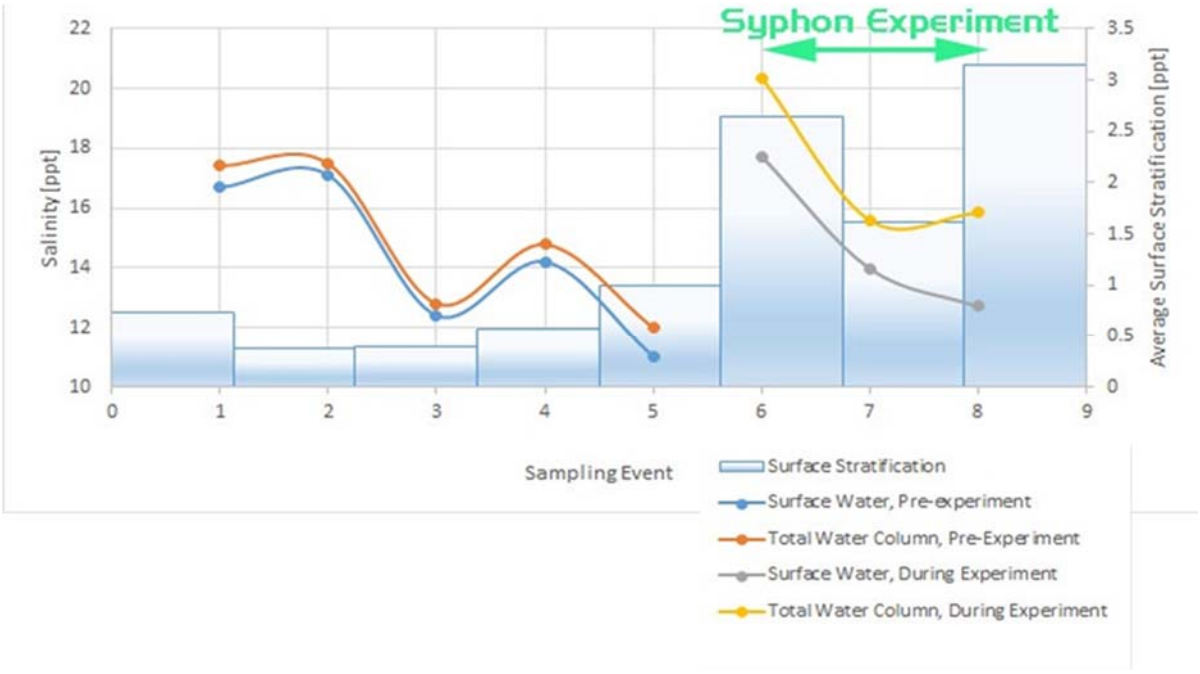


Figure 4.2 Inflow of water resulted in increased water stratification within the Kawai Nui Stream Branch

Two wetlands important for breeding habitat to three species of endangered waterfowl are impacted by water elevation within the system. The 13-acre Hamakua Wetland is adjacent to Kawai Nui Stream and the 11-acre Kaelepulu Wetland is at the upper end of Kaelepulu Pond. At water surface elevations below about 1.2 ft MLLW the area of quality wetland in both of these systems dramatically decreases. During recent summers both of these wetlands experienced challenges related to low water elevations. One of the unique challenges has to do with the nesting habits of Hawaiian Stilts. When water elevations are low, these birds will nest relatively far down in the wetland, presumably to remain close to the water. But when rainfall or stream mouth opening events cause the water level to rise, these nests become inundated. Keeping the stream elevation at a more consistent higher elevation should limit this type of mortality among Hawaiian Stilts. Another complication with low water surface elevations is the problem of avian botulism that results when fish stranded in the drying wetland become infested with maggots that carry the botulism bacteria. This problem is avoided if water elevations are maintained to prevent fish mortalities in shallow ponds within the wetlands.

During previous summers, government agencies (State Department of Health, State Division of Forestry and Wildlife, City Department of Facilities Management) commonly receive multiple calls complaining of foul odors emanating from Kawai Nui Stream. This typically occurs during episodes of low water elevation following an opening event and a plankton bloom which results in low oxygen levels in the system. The low oxygen levels, warm water, and exposed mangrove root systems can, by themselves, generate sufficient odors (methane & sulphur dioxide) to result in complaint calls. However, what can also occur during these phytoplankton bloom events are massive fish kills. When kills occur, the odor of rotting fish combined with the methane and sulphur dioxide is sure to generate numerous calls. No calls were received by any of these agencies during the summer of 2015 during the trial period. In addition, review of the June 4, 2015 sampling event (at the initiation of restored water flow) reveals that there was a phytoplankton bloom event in Kaelepulu (but not in Kawai Nui) that resulted in the death of a single large barracuda and low (but not critically low) oxygen levels in Kaelepulu. However, this bloom quickly ran its course and did not result in any additional fish deaths or episodes of foul odors. It is impossible to say for certain, but it seems plausible that the inflow of water from the syphon during June of 2015 may have prevented the pre-existing bloom from occurring in the Kawai Nui branch of the system, and limited the adverse effects of the bloom within the Kaelepulu system.

The percentage of water exchanged within an aquatic system over time is a critical factor determining the overall stability and character of the waterbody. Most water bodies exist as flow through systems, with the rate of flow higher in a stream, than in a lake, than in a marsh. Prior to the construction of the Kawai Nui flood control levee and the Oneawa Canal, the Kawai Nui Marsh contributed about 28 MCF monthly to the downstream Kaelepulu System (Figure 4.3) and the total flow through the stream mouth was about 30 MCF per month. This average flow rate is equivalent to a 100% exchange of the 30 MCF KWS. Since being divorced from its major water source, flow through the Kaelepulu stream mouth has been reduced from 30 MCF to only 1.5 MCF per month. Restoring flow at a rate of 2 cfs would increase the flow through the Kaelepulu stream mouth from 1.5 MCF to 6.25 MCF/mo. This flow would occur on a pulsed basis during monthly stream mouth openings at a -0.5 foot higher head pressure (2.0 ft Vs. 1.5 ft) and would result in a higher flow rate, higher flow volume, and correspondingly higher sand flow rate out of the stream mouth. This should minimize both the amount of time required by City crews to establish an opening flow, and the necessary frequency of dredging the stream channel back to the Lanikai Bridge.

Major flow events, either inflow from rain runoff, or inflow from the ocean, occur on a periodic basis. This pulsed flow makes the system inherently unstable. Changes in the volume of water in (or passing through) the system are important as this affects the concentration of dissolved metabolites within the system. The estuary receives inputs of nutrients and minerals from the surrounding watershed and transforms them through photosynthesis into organic compounds at the base of the food chain. Balancing the rate of water exchange allows the system to remain in equilibrium with its surroundings. A lack of sufficient exchange will likely lead to a loss of equilibrium, a loss of system stability, and the build-up of waste products that the system is unable to incorporate and will ultimately discharge to the ocean. Restoring a minimal flow from the marsh to the stream will result in increased system stability.

In Figure 3.28 the total water inflows to the system from the ocean, from rainfall runoff, and from the syphon flow restoration are portrayed on a monthly basis over the 3-year period of the project. Flows are expressed as a percent of the entire estuary volume (30 MCF). Even though the average monthly exchange in the estuary is about 72%, the median monthly flow is only about half this, and on eight occasions the flow exceeds 100% exchange. In contrast, 13 of the months demonstrate total exchange of less than 20%. If syphon flow was established at 17% of the estuary volume per month (~2 cfs), then no month would fall below a 20% exchange threshold. Continued flow input from Kawai Nui Marsh to Kawai Nui stream at a rate of 2 cfs is sufficient to replace 17% of the estuary volume per month and is likely to greatly increase the ecological stability of the system.

An unanticipated finding of the study was documentation of the period of time that the water surface elevation of the system exceeded 2.0 ft MLLW and therefore posed an increased flood threat to the Kailua community. At an elevation of 2.0 ft the system is 1.3 feet below the elevation observed to initiate flooding to low-lying residential lots near the beach. Given a rain:rise ration of 1:4, the one-year-24-hour storm of 3.9 inches would be sufficient to reach this flood elevation. Providing a mechanism that could automatically lower the estuary level down to 2.0 ft MLLW would reasonably be expected to greatly limit this flood risk.

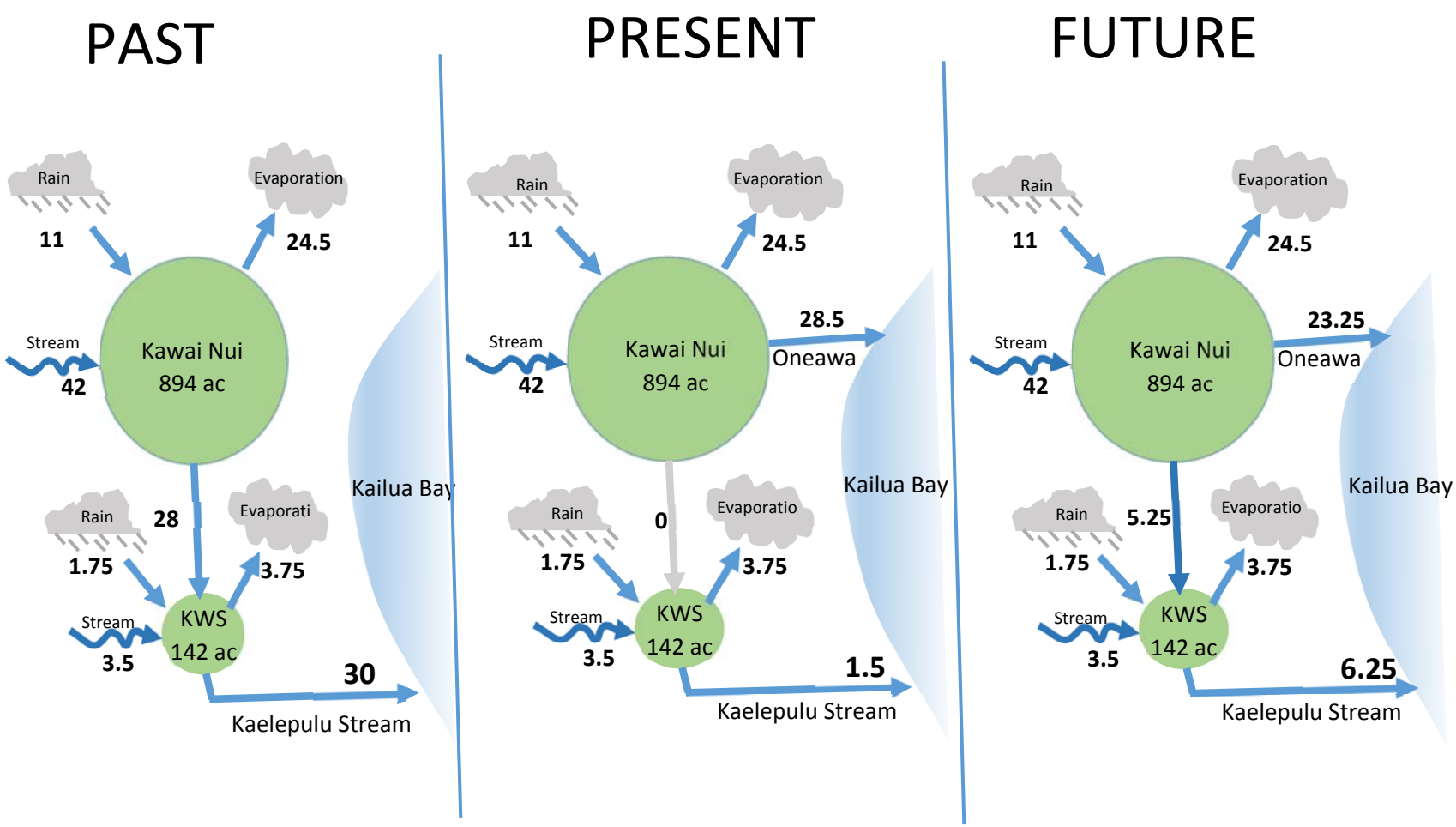


Figure 4.3 Monthly flow of fresh water through the Kawai Nui and Kailua Waterway Systems in millions of cubic feet (MCF) based on average annual flows before (left) and after construction of the Oneawa Canal and flood control levee (center), and after flow is restored in the future (right).

5 CONCLUSIONS AND RECOMMENDATIONS

Partial restoration of historical flow from Kawainui Marsh to Kawainui Stream has shown to provide benefits to wetland bird habitat for endangered species, improve stream mouth opening conditions for the City, improve stratification in the estuary, and increase total water exchange in the estuary. Conclusions of this study, as summarized from the discussion section of the previous chapter include:

Water Flow and Water Volume

The 142-acre KWS estuary has a volume of about 30 MCF, 88% of which is in within Kaelepulu Pond. Prior to construction of the Oneawa Canal and Kawainui Levee an average of 30 MCF/mo flowed from the mouth of Kaelepulu Stream to the ocean, but today this flow has been reduced to about 5% of this volume or 1.5 MCF/mo. A 2 cfs inflow restored to the Kawai Nui Stream branch of the estuary would contribute about 5.25 MCF (17%) to the system over a month. This inflow offsets losses from evaporation (3.75 MCF/mo) preventing the water level from falling during dry months (May – September) and allow the water surface elevation to rise to a controlled 2.0 ft. MLLW.

Water Quality

Physical water quality within the Kawai Nui Stream is very poor, exhibiting low pH, very high turbidity and very low dissolved oxygen levels and the inflow of 1.5 cfs did not result in any appreciable improvement to these parameters. The likely cause of this poor water quality is a combination of stagnation compounded by a highly organic fine sediment load and a heavy overgrowth of mangroves. Although the water quality in this branch of the estuary remained poor, during the period of the inflow experiment it did not result in the production of obnoxious odors nor did it result in fish die-offs as has occurred during previous summers. Physical water quality within the Kaelepulu Stream and Pond was relatively good with adequate dissolved oxygen and values for turbidity in the same range as the State standard for “wet embayments” or “estuaries”. A brief episode of poor water quality associated with a plankton bloom in the pond at the start of the experiment was short-lived and did not result in significant fish mortalities or adverse odors.

Water Exchange through the Stream Mouth

Water exchange between KWS and the ocean through the stream mouth typically exceeds water inflow from rainfall runoff events and is an important tool with which to manage estuary water quality and ecosystem diversity. Proper timing of stream mouth openings with the tide cycles both minimizes effort on the part of the City equipment operators and increases the effectiveness of the opening events. More regular scheduled openings (29-43 day cycles) would be benefit both water quality and public safety through flood threat minimization. Major dredging events when equipment operators attempt to dredge the stream back to its pre-1966 flow capacity are not effective and likely enhance local beach erosion. Increased outflow through the stream mouth (from 1.5 MCF to 6.25 MCF) should help remove sand from the channel, but should not be expected to result in the same channel depth maintained by the pre-1966 30 MCF/mo flow.

Ecosystem Impacts

Restored water flow had positive impacts upon wetland habitats by keeping them inundated during the breeding season and preventing fish deaths and foul odors associated with avian botulism.

Flood Threat

Raising the average water surface elevation by about 6-inches, to no more than 2.0 ft MLLW results in a minimal increase in flood threat, due to the decreased amount of time available for City crews to respond before the rising waters exceed the 3.3 ft lower limit of flooding. However, this threat is likely counter-balanced by more regular stream mouth openings that would keep the beach sand berm from building significantly above the 3.3 ft flood elevation. The previously unrecognized flood threat presented by the buildup of this berm should be dealt with as a public safety issue.

The following recommendations are derived from this study:

- Move forward with planning and permitting for a permanent flow restoration structure designed to transfer approximately 2 cfs from Kawai Nui Marsh to Kawai Nui Stream.
- Given the effectiveness of the temporary syphon and the length of time likely required for final planning, permitting, and construction of a permanent structure, consideration should be given to keeping the temporary syphon in place and operational until the permanent structure is built.
- The flow of ocean water through the stream mouth contributes about twice as much exchange as inflow from rainfall and runoff. Opening events should be conducted every 29 to 42 days coordinated with lunar cycles and peak ocean tides.
- Flood threat minimization should focus on lowering the sand berm height across the full width (approximately 100 ft) of the stream mouth on a more regular basis.
- Stream mouth openings through the lowered sand berm should be excavated in a narrow (20 ft) but relatively deep (3 ft) channel for optimal flow. Excavated sand should remain on the beach.
- Stream mouth openings should be timed to occur just prior to the highest tides of the lunar cycle and timed to provide the longest possible period of initial outflow to be the most effective and result in a longer period of tidal exchange with the ocean.
- Flood threat may be reduced to the community by providing an overflow at an elevation of 2-ft MLLW from the distal end of Kawai Nui Stream through the flood control levee to the Oneawa Canal (Figure 5.1).

Figure 5.1 Levee separating Oneawa Canal (left) from terminus of Kawai Nui Stream (right). Proposed location for 2-foot water surface elevation control drain.

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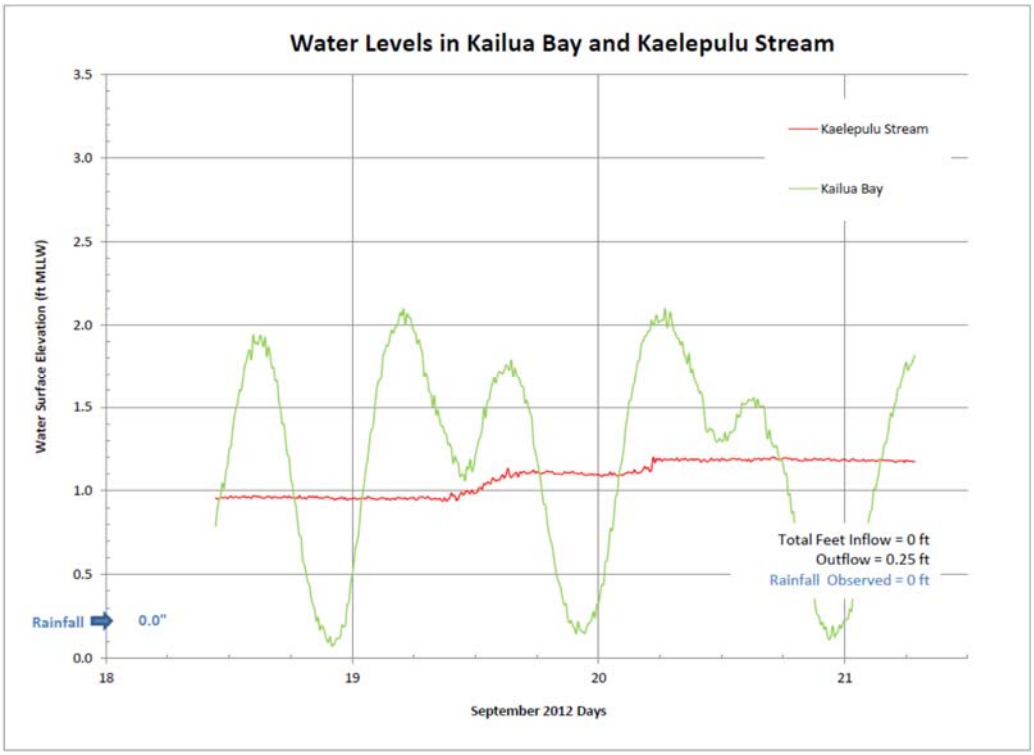
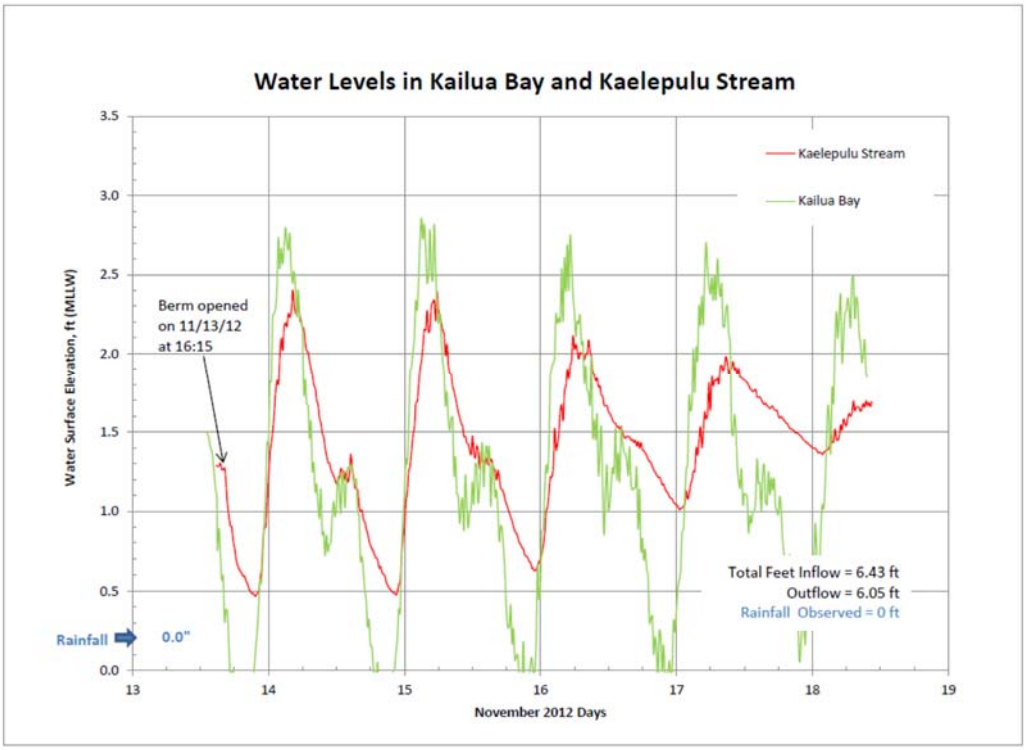
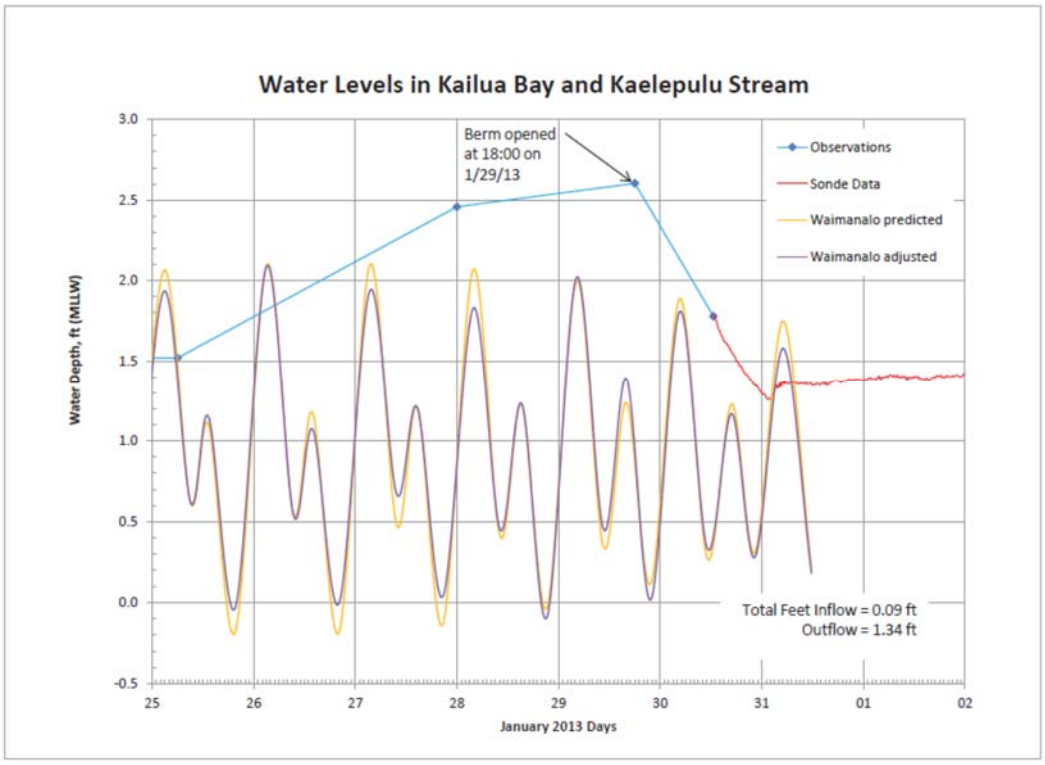
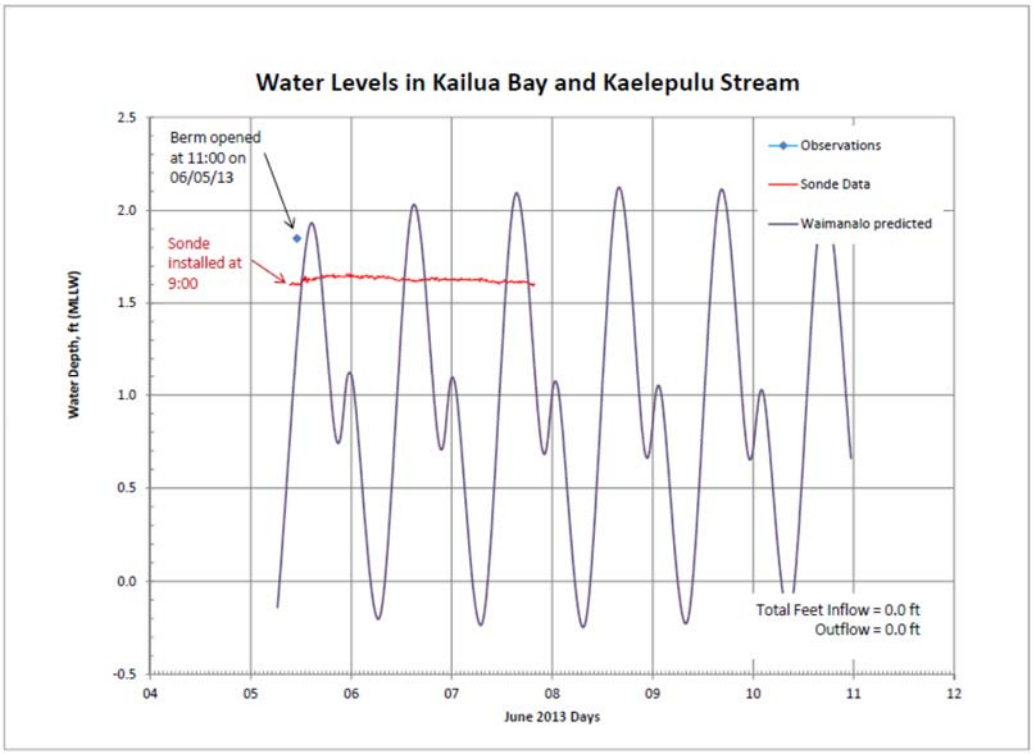
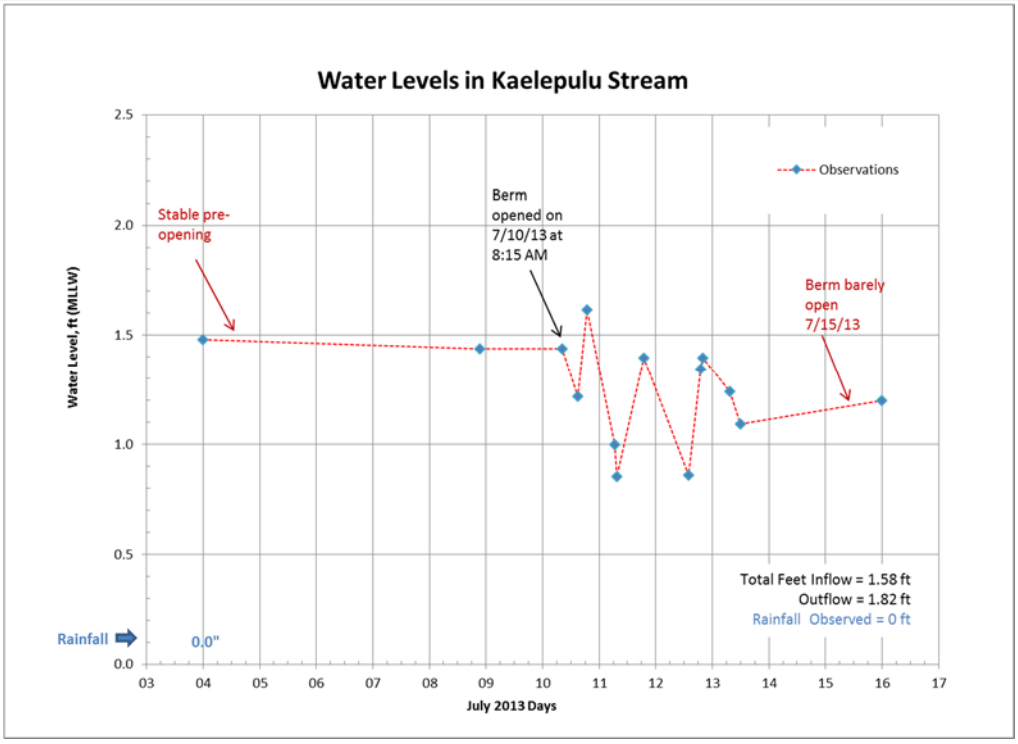
A. APPENDIX: STREAM MOUTH OPENING EVENTS

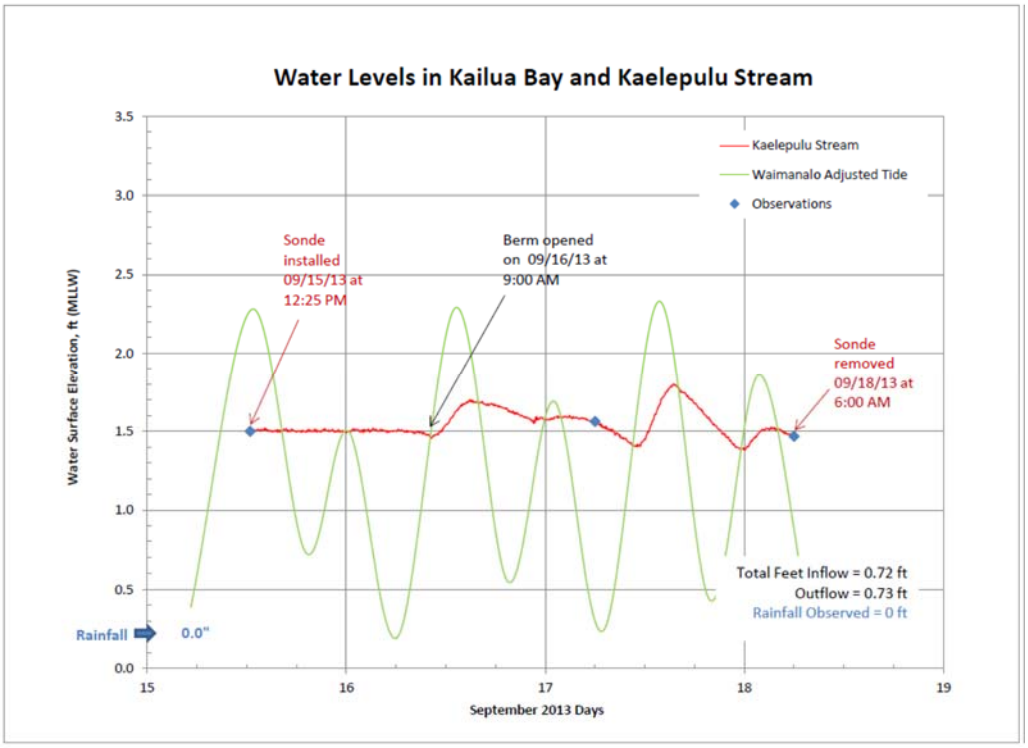


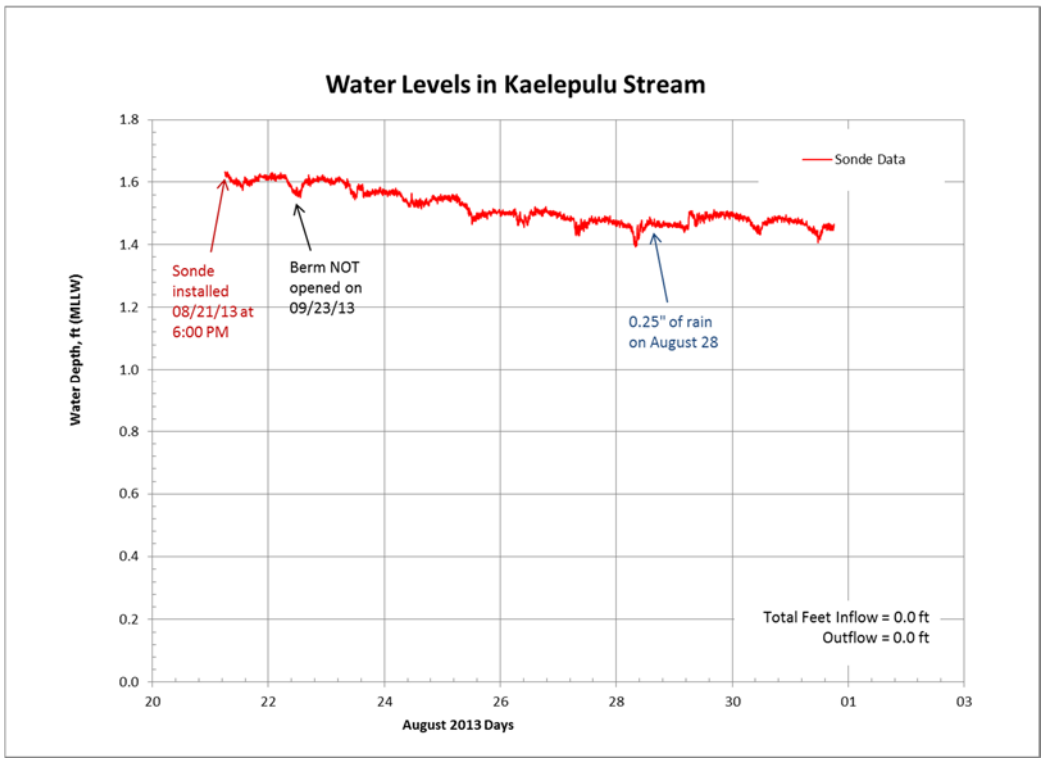


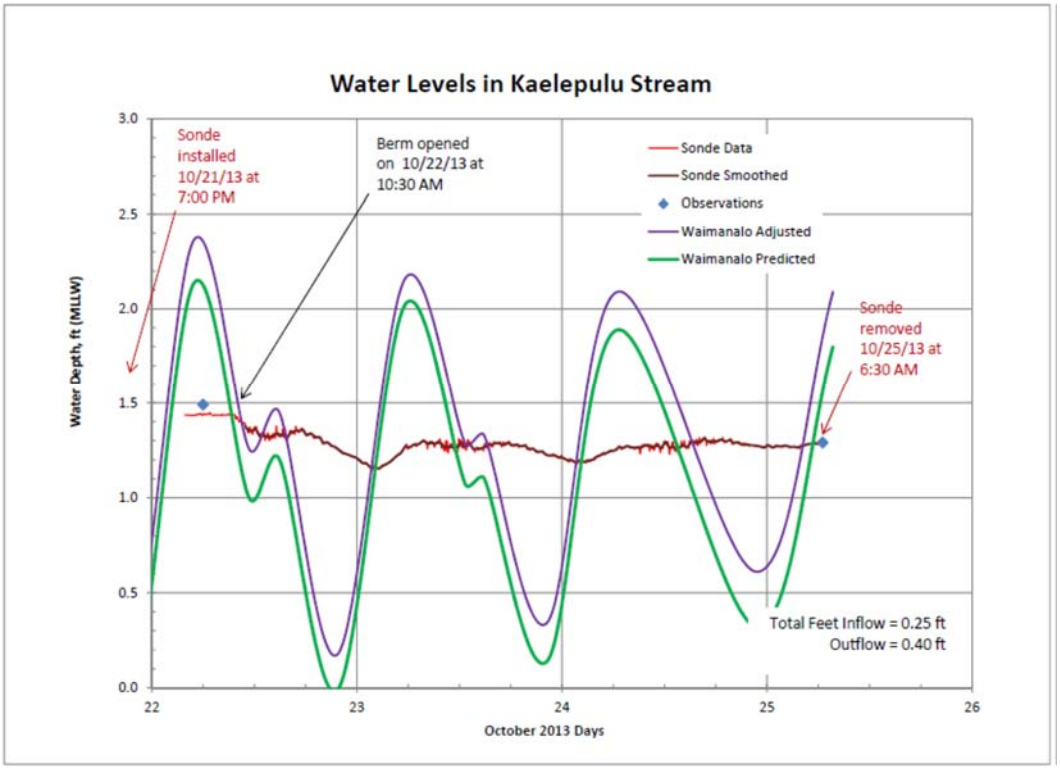

Water Levels in Kailua Bay and Kaelepulu Stream
Berm opened at 18:00 on 1/29/13
Observations
Sonde Data
Waimanalo predicted
Waimanalo adjusted
Total Feet Inflow = 0.09 ft
Outflow = 1.34 ft
Water Depth, ft (MLLW)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
25
26
27
28
29
30
31
01
02
January 2013 Days

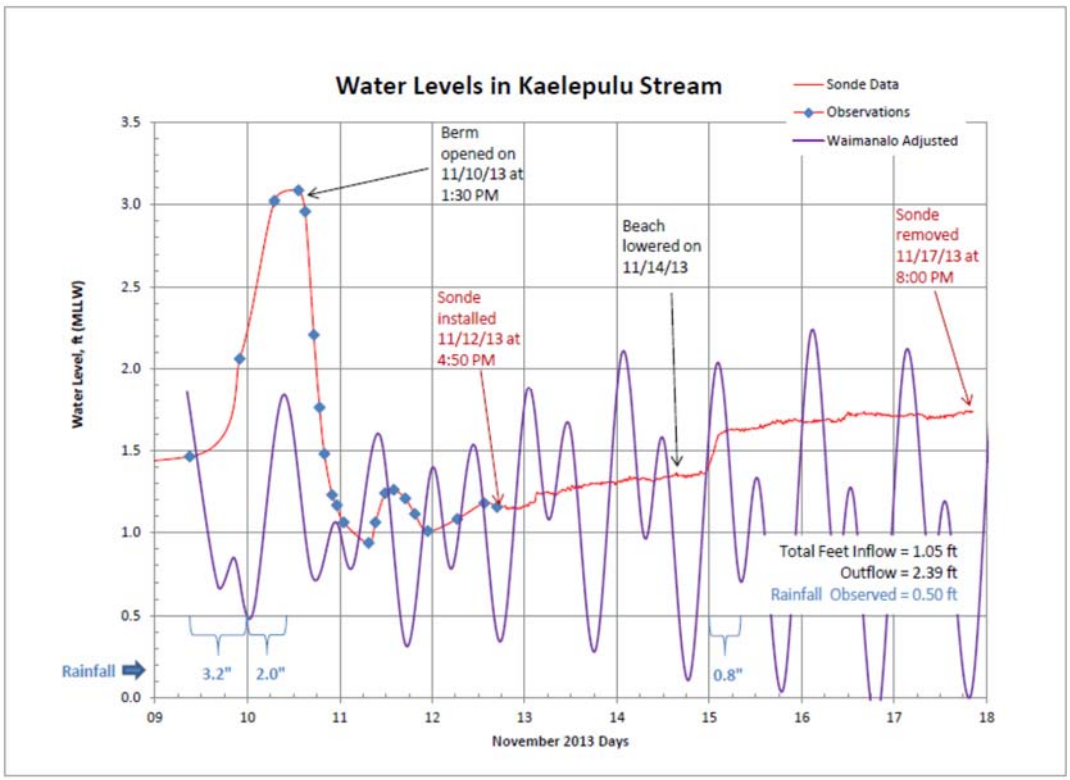

Water Levels in Kailua Bay and Kaelepulu Stream
Berm opened at 11:00 on 06/05/13
Sonde installed at 9:00
Observations
Sonde Data
Waimanalo predicted
Total Feet Inflow = 0.0 ft
Outflow = 0.0 ft
Water Depth, ft (MLLW)
June 2013 Days

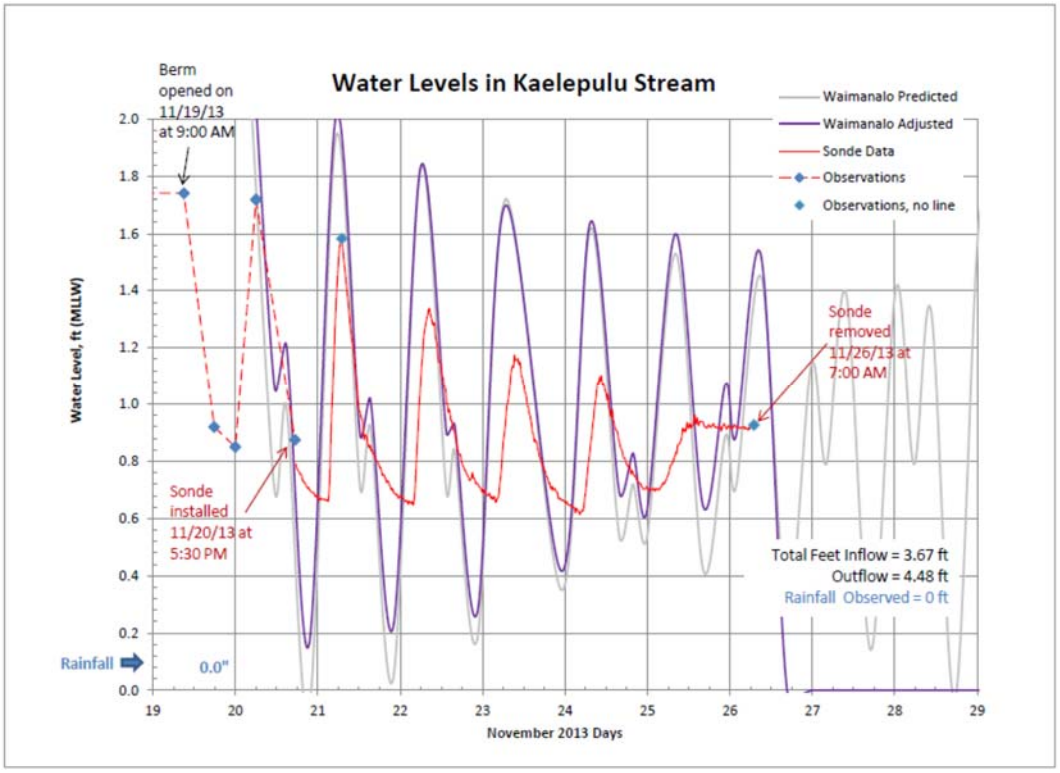

Water Levels in Kaelepulu Stream
Observations
Stable pre-opening
Berm opened on 7/10/13 at 8:15 AM
Berm barely open 7/15/13
Total Feet Inflow = 1.58 ft
Outflow = 1.82 ft
Rainfall Observed = 0 ft
Rainfall
0.0"
Water Level, ft (MLLW)
July 2013 Days

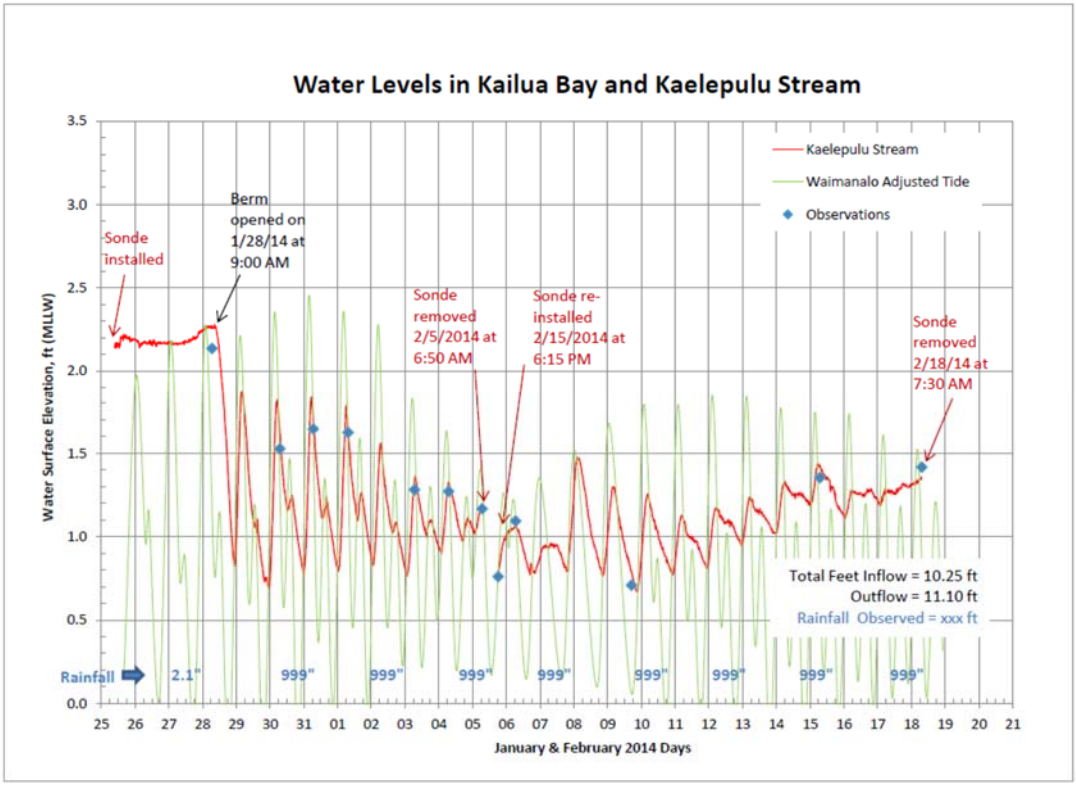

Water Levels in Kailua Bay and Kaelepulu Stream
Kaelepulu Stream
Waimanalo Adjusted Tide
Observations
Sonde installed 09/15/13 at 12:25 PM
Berm opened on 09/16/13 at 9:00 AM
Sonde removed 09/18/13 at 6:00 AM
Total Feet Inflow = 0.72 ft
Outflow = 0.73 ft
Rainfall Observed = 0 ft
Rainfall
0.0"
Water Surface Elevation, ft (MLLW)
September 2013 Days
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
15
16
17
18
19

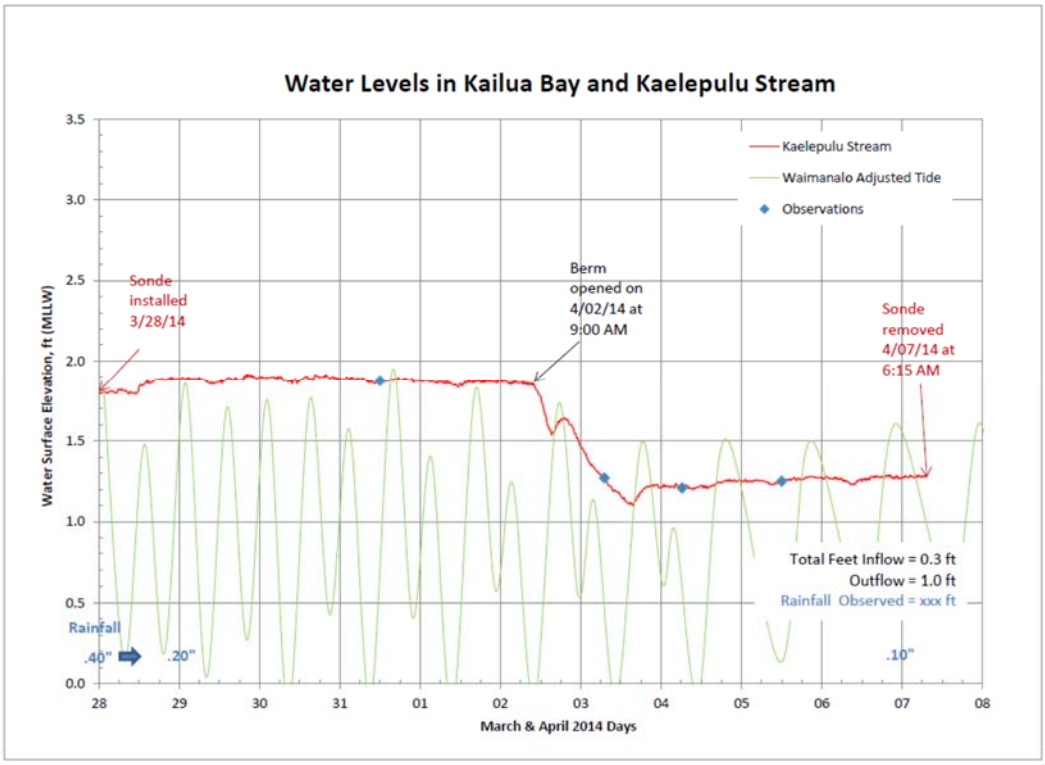

Water Levels in Kaelepulu Stream
Sonde Data
Sonde installed 08/21/13 at 6:00 PM
Berm NOT opened on 09/23/13
0.25" of rain on August 28
Total Feet Inflow = 0.0 ft
Outflow = 0.0 ft
Water Depth, ft (MLLW)
August 2013 Days
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
20
22
24
26
28
30
01
03

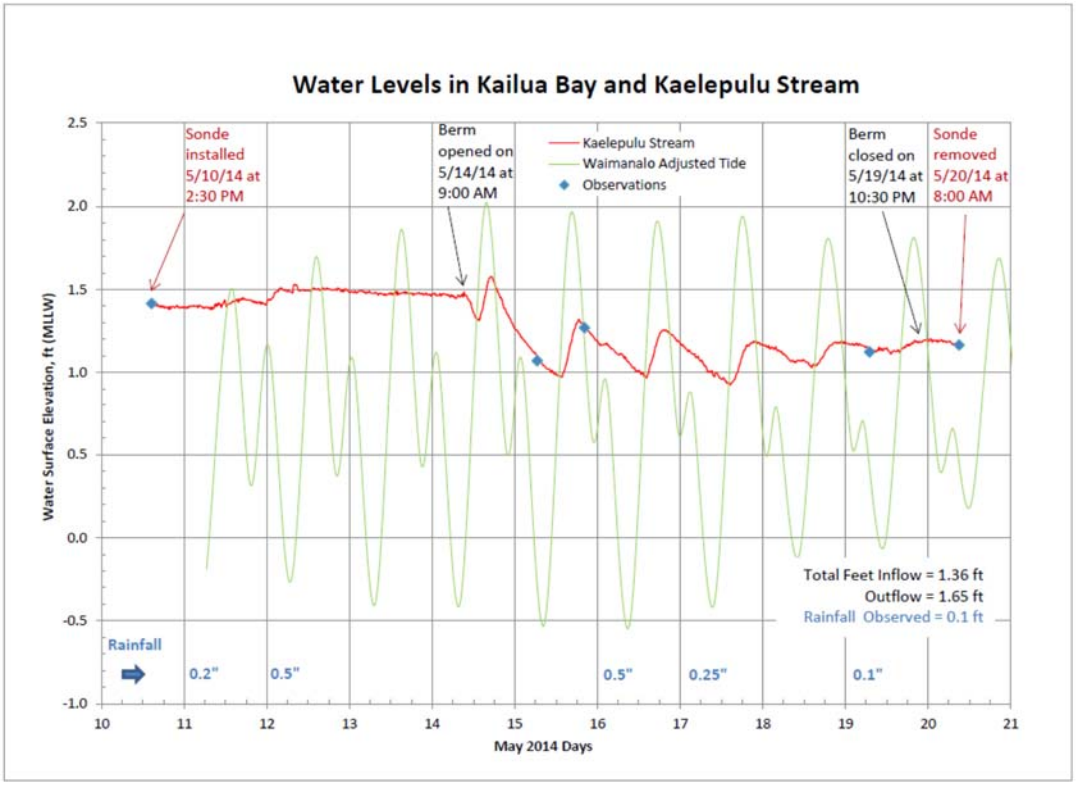

Water Levels in Kaelepulu Stream
Sonde installed 10/21/13 at 7:00 PM
Berm opened on 10/22/13 at 10:30 AM
Sonde Data
Sonde Smoothed
Observations
Waimanalo Adjusted
Waimanalo Predicted
Sonde removed 10/25/13 at 6:30 AM
Total Feet Inflow = 0.25 ft
Outflow = 0.40 ft
Water Depth, ft (MLLW)
October 2013 Days

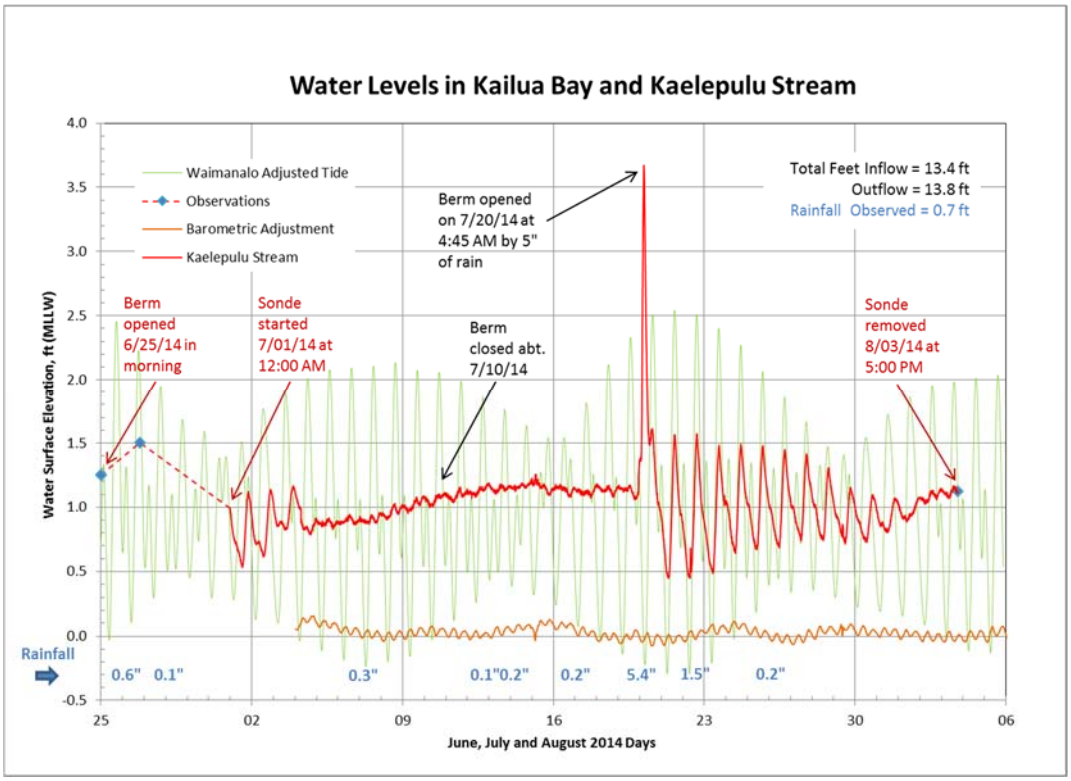

Water Levels in Kaelepulu Stream
Sonde Data
Observations
Waimanalo Adjusted
Berm opened on 11/10/13 at 1:30 PM
Beach lowered on 11/14/13
Sonde removed 11/17/13 at 8:00 PM
Sonde installed 11/12/13 at 4:50 PM
Total Feet Inflow = 1.05 ft
Outflow = 2.39 ft
Rainfall Observed = 0.50 ft
Rainfall
3.2"
2.0"
0.8"
Water Level, ft (MLLW)
November 2013 Days

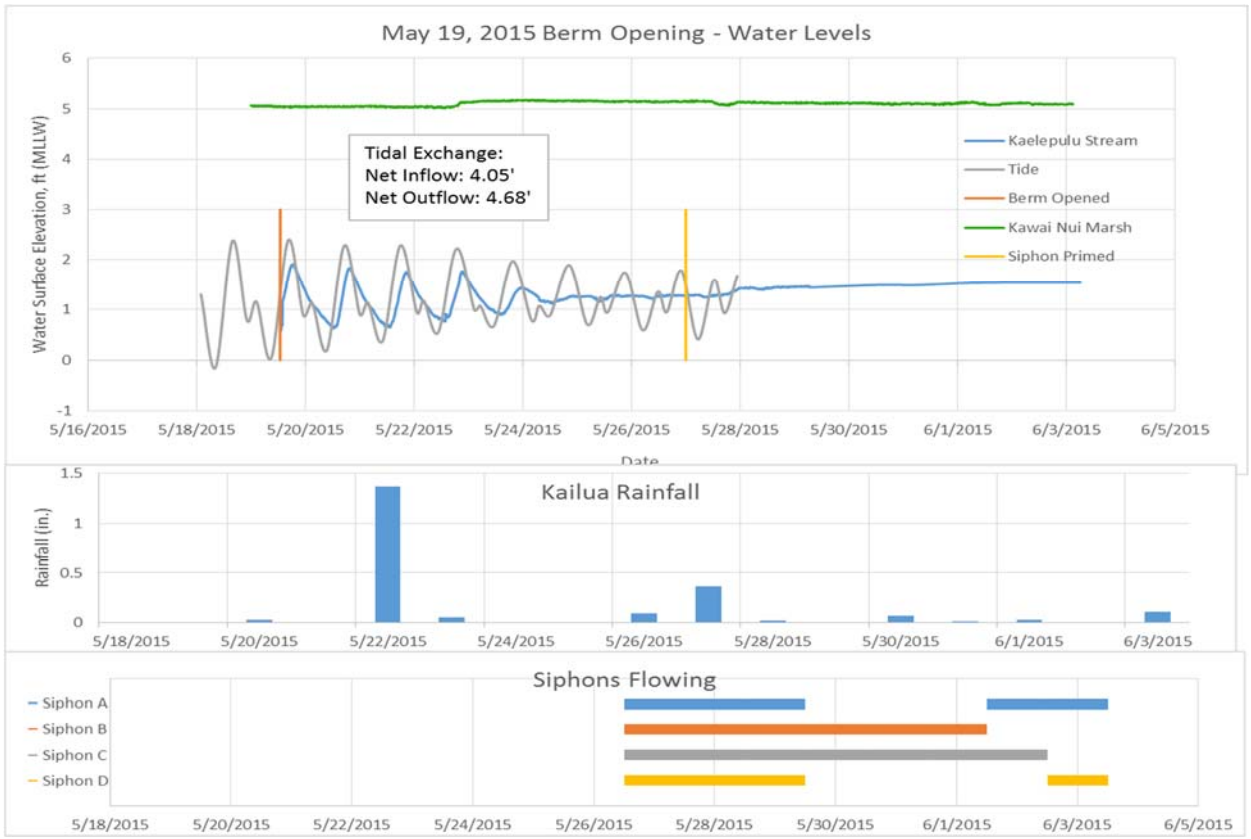

Water Levels in Kaelepulu Stream
Berm opened on 11/19/13 at 9:00 AM
Waimanalo Predicted
Waimanalo Adjusted
Sonde Data
Observations
Observations, no line
Sonde removed 11/26/13 at 7:00 AM
Sonde installed 11/20/13 at 5:30 PM
Total Feet Inflow = 3.67 ft
Outflow = 4.48 ft
Rainfall Observed = 0 ft
Rainfall
0.0"
Water Level, ft (MLLW)
November 2013 Days

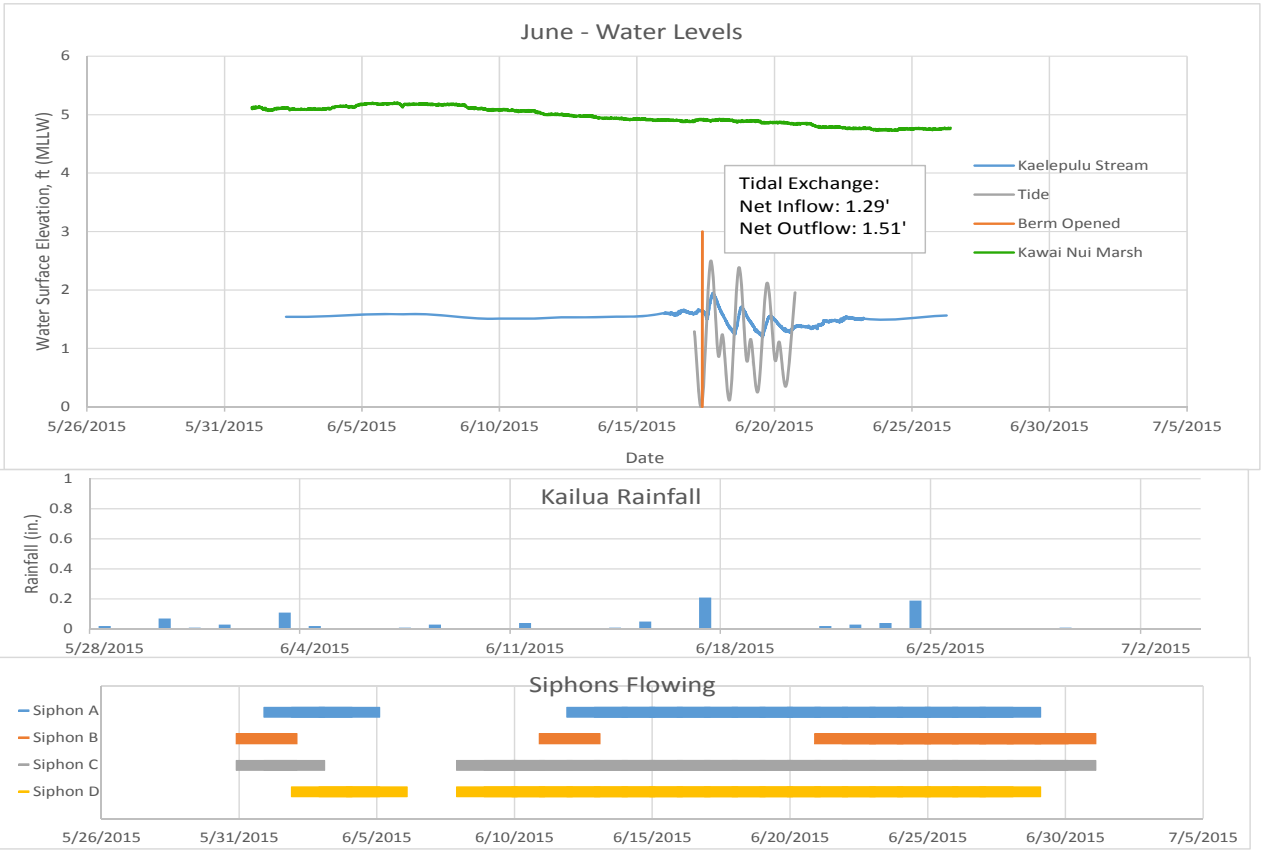

Water Levels in Kailua Bay and Kaelepulu Stream
Kaelepulu Stream
Waimanalo Adjusted Tide
Observations
Sonde installed
Berm opened on 1/28/14 at 9:00 AM
Sonde removed 2/5/2014 at 6:50 AM
Sonde re-installed 2/15/2014 at 6:15 PM
Sonde removed 2/18/14 at 7:30 AM
Total Feet Inflow = 10.25 ft
Outflow = 11.10 ft
Rainfall Observed = xxx ft
Rainfall
2.1"
999"
Water Surface Elevation, ft (MLLW)
January & February 2014 Days

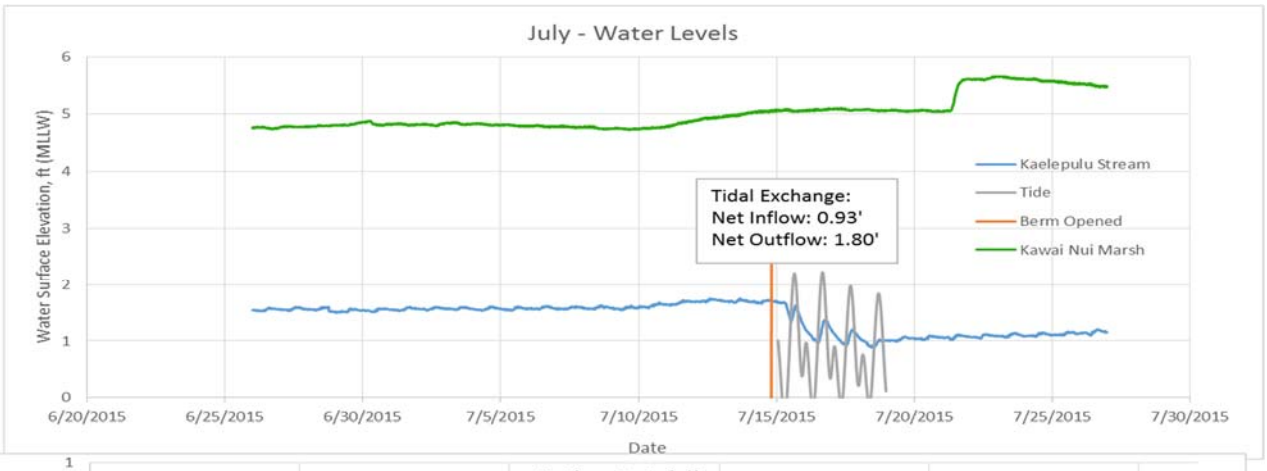

Water Levels in Kailua Bay and Kaelepulu Stream
Kaelepulu Stream
Waimanalo Adjusted Tide
Observations
Sonde installed 3/28/14
Berm opened on 4/02/14 at 9:00 AM
Sonde removed 4/07/14 at 6:15 AM
Total Feet Inflow = 0.3 ft
Outflow = 1.0 ft
Rainfall Observed = xxx ft
Rainfall
.40"
.20"
.10"
Water Surface Elevation, ft (MLLW)
March & April 2014 Days

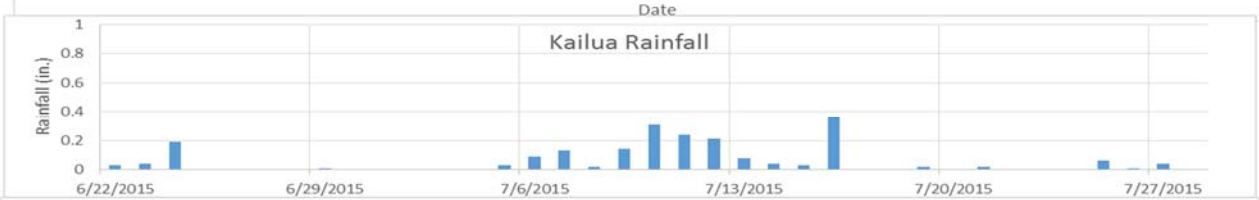

Water Levels in Kailua Bay and Kaelepulu Stream
Sonde installed 5/10/14 at 2:30 PM
Berm opened on 5/14/14 at 9:00 AM
Berm closed on 5/19/14 at 10:30 PM
Sonde removed 5/20/14 at 8:00 AM
Kaelepulu Stream
Waimanalo Adjusted Tide
Observations
Total Feet Inflow = 1.36 ft
Outflow = 1.65 ft
Rainfall Observed = 0.1 ft
Rainfall
0.2"
0.5"
0.5"
0.25"
0.1"
Water Surface Elevation, ft (MLLW)
May 2014 Days

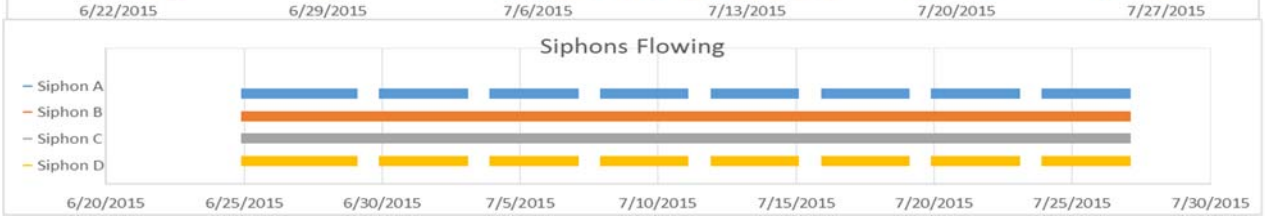

Water Levels in Kailua Bay and Kaelepulu Stream
Waimanalo Adjusted Tide
Observations
Barometric Adjustment
Kaelepulu Stream
Berm opened on 7/20/14 at 4:45 AM by 5" of rain
Total Feet Inflow = 13.4 ft
Outflow = 13.8 ft
Rainfall Observed = 0.7 ft
Berm opened 6/25/14 in morning
Sonde started 7/01/14 at 12:00 AM
Berm closed abt. 7/10/14
Sonde removed 8/03/14 at 5:00 PM
Water Surface Elevation, ft (MLLW)
Rainfall
0.6" 0.1" 0.3" 0.1"0.2" 0.2" 5.4" 1.5" 0.2"
June, July and August 2014 Days

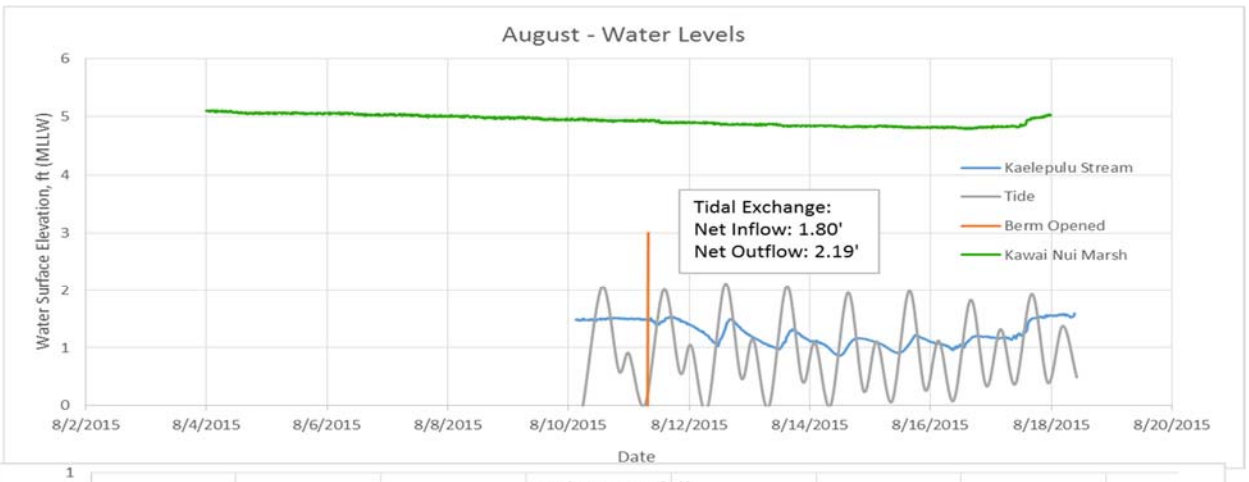

May 19, 2015 Berm Opening - Water Levels
Water Surface Elevation, ft (MLLW)
Tidal Exchange:
Net Inflow: 4.05'
Net Outflow: 4.68'
Kaelepulu Stream
Tide
Berm Opened
Kawai Nui Marsh
Siphon Primed
5/16/2015
5/18/2015
5/20/2015
5/22/2015
5/24/2015
5/26/2015
5/28/2015
5/30/2015
6/1/2015
6/3/2015
6/5/2015
Date
Kailua Rainfall
Rainfall (in.)
Siphons Flowing
Siphon A
Siphon B
Siphon C
Siphon D

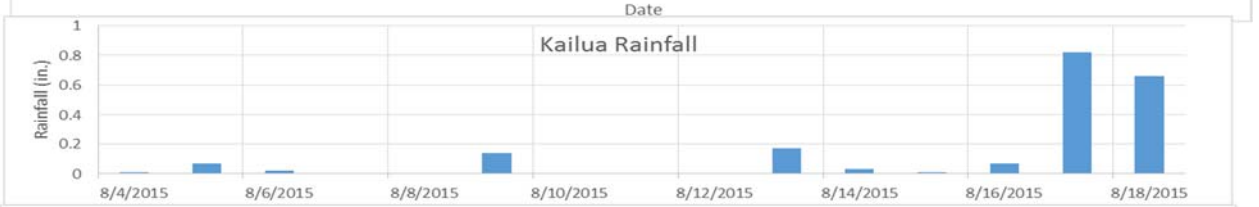

June - Water Levels
Water Surface Elevation, ft (MLLW)
Tidal Exchange:
Net Inflow: 1.29'
Net Outflow: 1.51'
Kaelepulu Stream
Tide
Berm Opened
Kawai Nui Marsh
5/26/2015
5/31/2015
6/5/2015
6/10/2015
6/15/2015
6/20/2015
6/25/2015
6/30/2015
7/5/2015
Date
Kailua Rainfall
Rainfall (in.)
5/28/2015
6/4/2015
6/11/2015
6/18/2015
6/25/2015
7/2/2015
Siphons Flowing
Siphon A
Siphon B
Siphon C
Siphon D

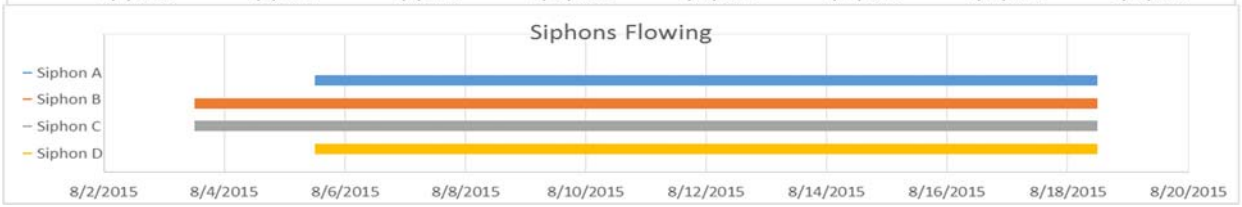

July - Water Levels
Water Surface Elevation, ft (MLLW)
Date
Kaelepulu Stream
Tide
Berm Opened
Kawai Nui Marsh
Tidal Exchange:
Net Inflow: 0.93'
Net Outflow: 1.80'

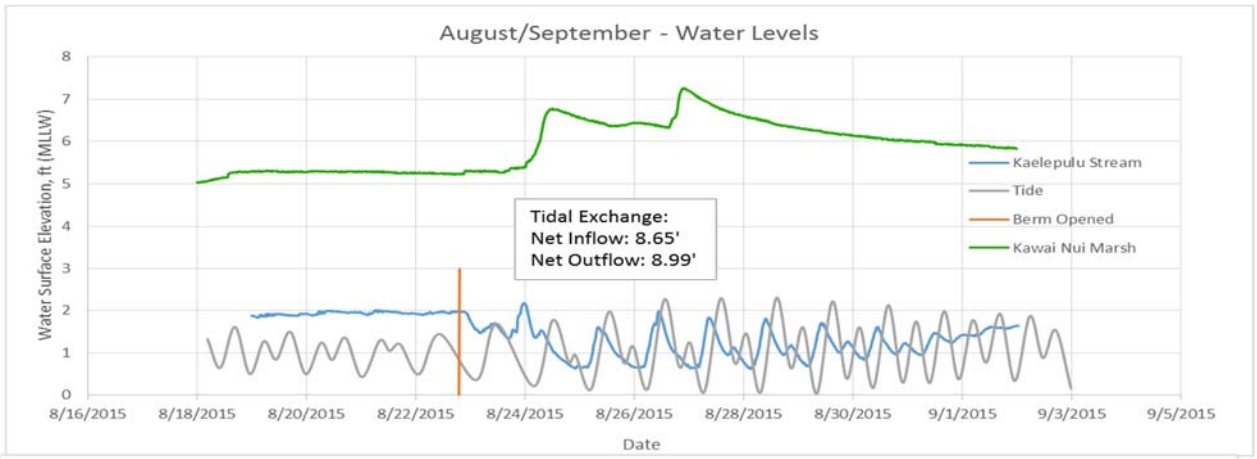

Kailua Rainfall
Rainfall (in.)

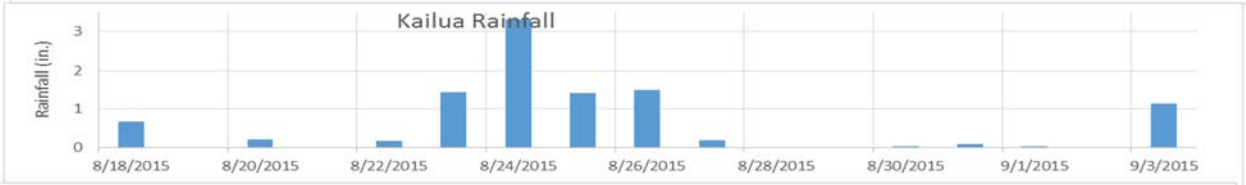

Siphons Flowing
Siphon A
Siphon B
Siphon C
Siphon D

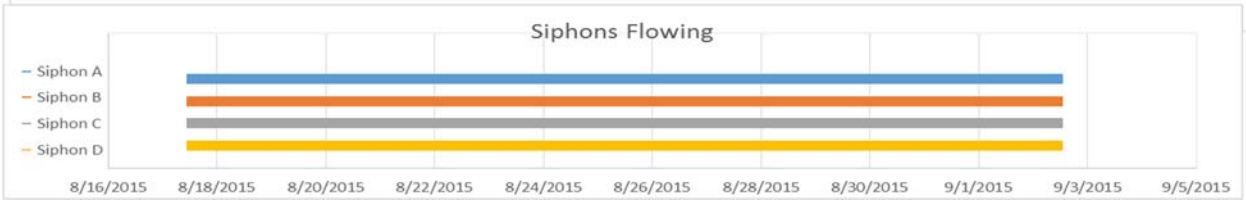

August - Water Levels
Water Surface Elevation, ft (MLLW)
Date
Kaelepulu Stream
Tide
Berm Opened
Kawai Nui Marsh
Tidal Exchange:
Net Inflow: 1.80'
Net Outflow: 2.19'

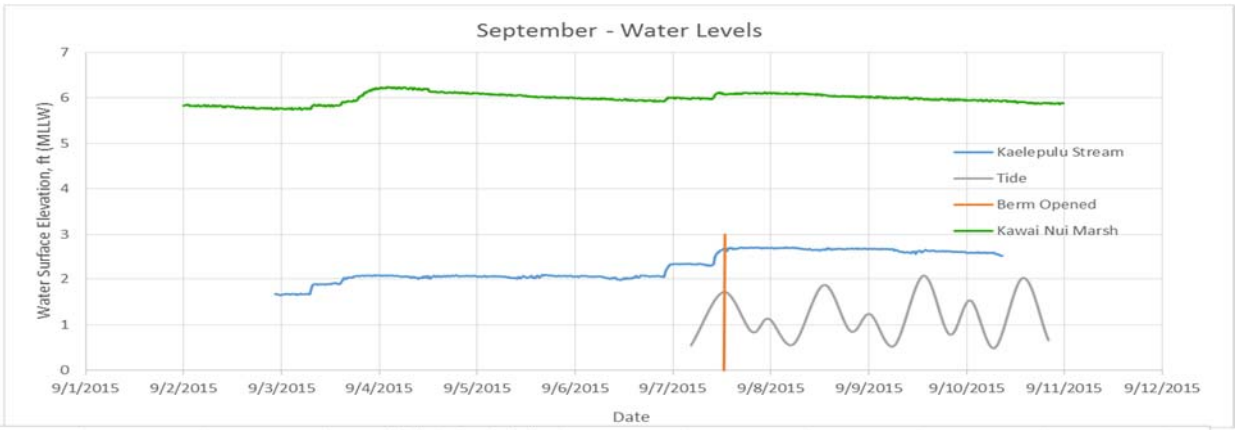

Kailua Rainfall
Rainfall (in.)

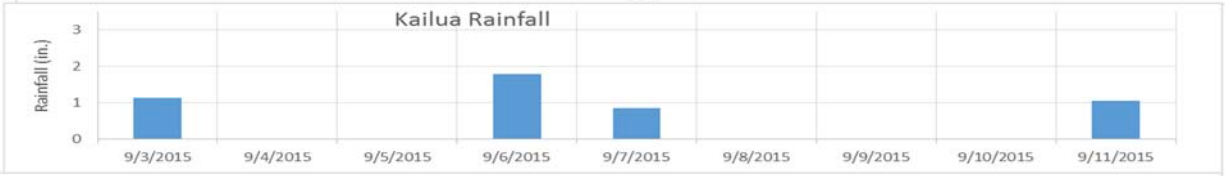

Siphons Flowing
Siphon A
Siphon B
Siphon C
Siphon D


August/September - Water Levels
Water Surface Elevation, ft (MLLW)
Tidal Exchange:
Net Inflow: 8.65'
Net Outflow: 8.99'
Kaelepulu Stream
Tide
Berm Opened
Kawai Nui Marsh
Date

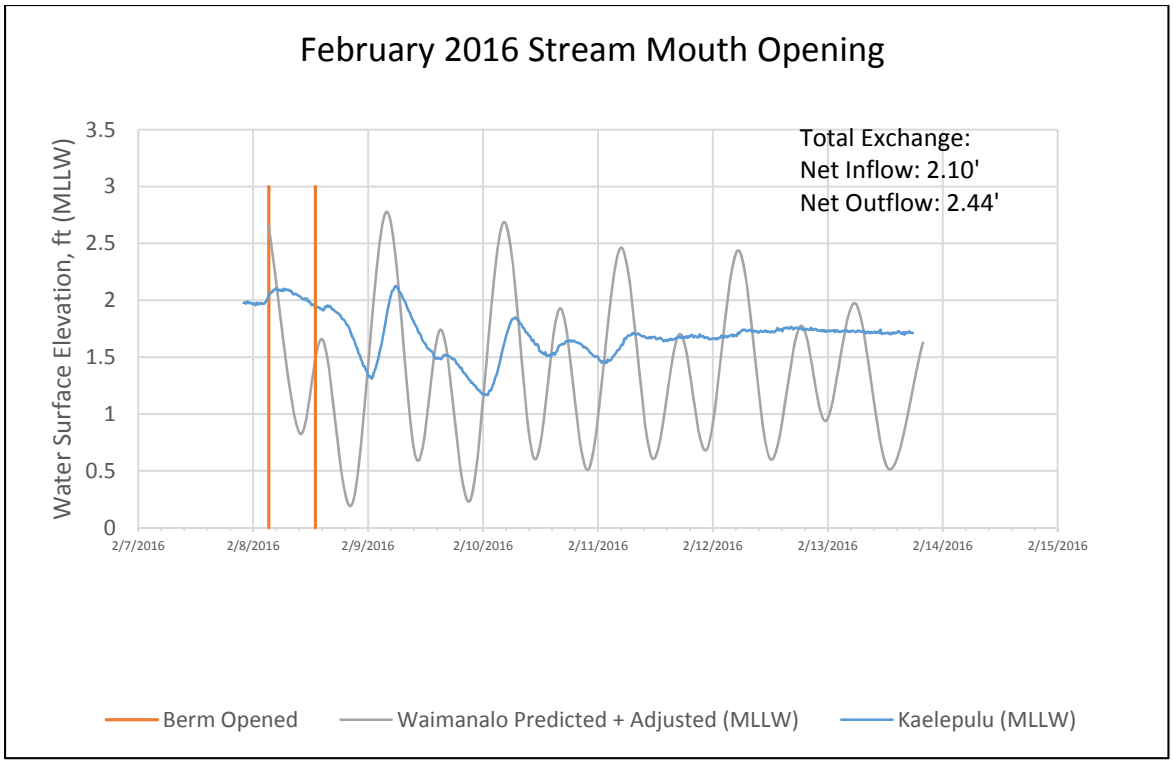

Kailua Rainfall
Rainfall (in.)


Siphons Flowing
Siphon A
Siphon B
Siphon C
Siphon D


September - Water Levels
Water Surface Elevation, ft (MLLW)
Kaelepulu Stream
Tide
Berm Opened
Kawai Nui Marsh
Date


Kailua Rainfall
Rainfall (in.)


Siphons Flowing
Siphon A
Siphon B
Siphon C
Siphon D


February 2016 Stream Mouth Opening
Total Exchange:
Net Inflow: 2.10'
Net Outflow: 2.44'
Water Surface Elevation, ft (MLLW)
3.5
3
2.5
2
1.5
1
0.5
0
2/7/2016
2/8/2016
2/9/2016
2/10/2016
2/11/2016
2/12/2016
2/13/2016
2/14/2016
2/15/2016
Berm Opened
Waimanalo Predicted + Adjusted (MLLW)
Kaelepulu (MLLW)

B. APPENDIX: NUTRIENT WATER QUALITY IN KAWAI NUI MARSH AND STREAM

AECOS, Inc.
45-939 Kamehameha Hwy., Room 104 • Kaneohe, HI 96744
Telephone: (808) 234-7770 • Fax: (808) 234-7775

CLIENT: Oceanit
828 Fort Street Mall, Suite 600
Honolulu, Hawaii 96813
ATTENTION: Bob Bourke

FILE No.: 631
REPORT DATE: 08/26/13
PAGE: 1 of 2

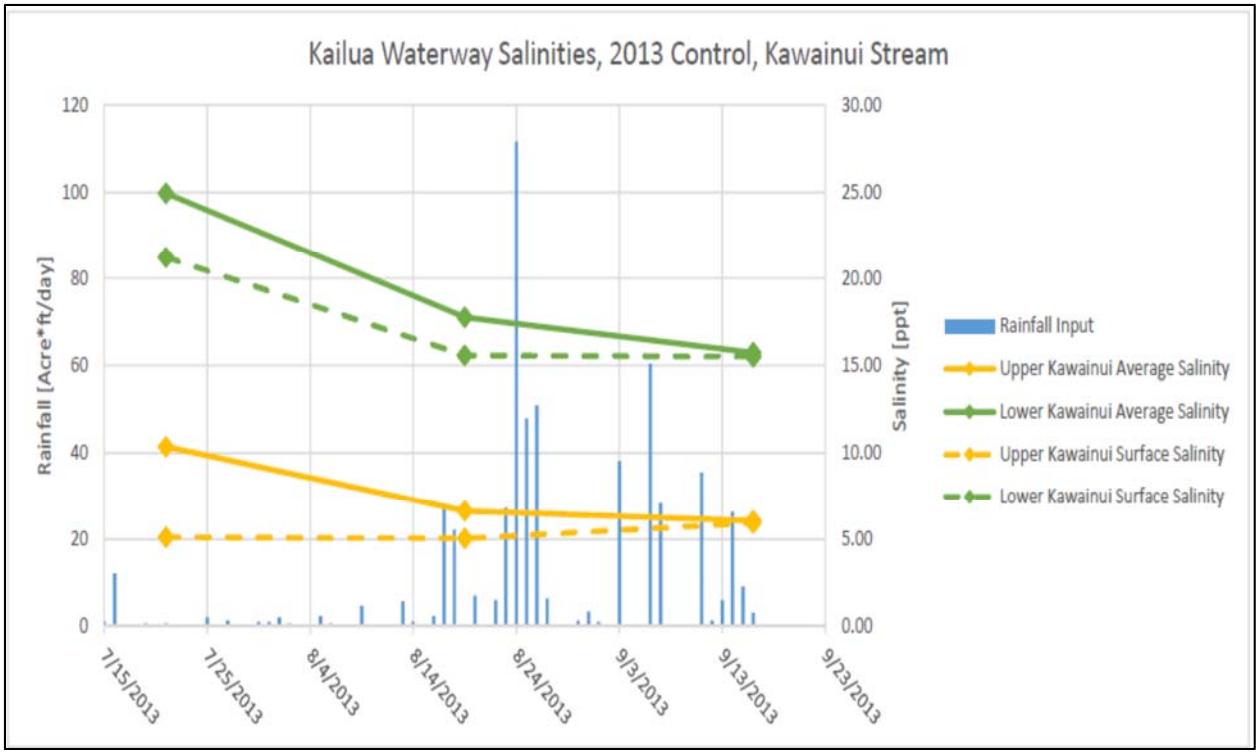
AECOS REPORT OF ANALYTICAL RESULTS

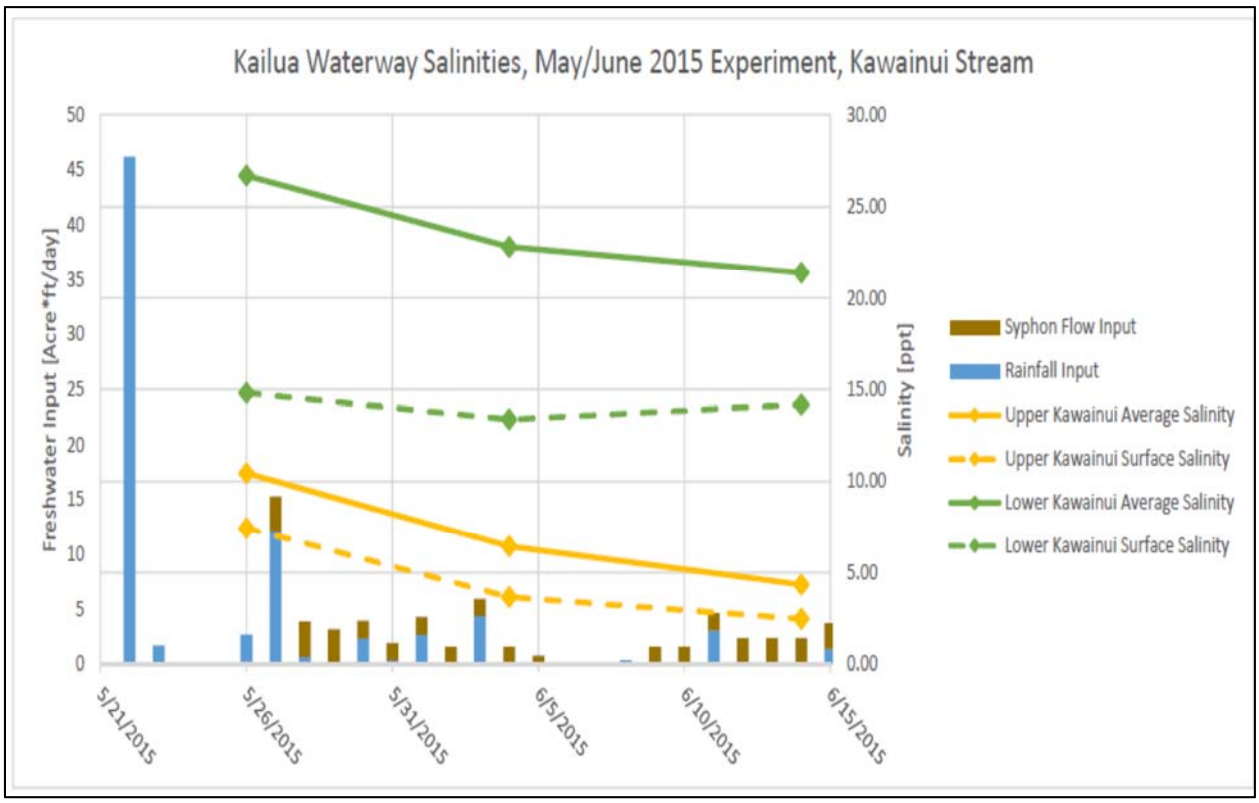
SAMPLE TYPE: Brackish water
DATE SAMPLED: 07/29/13
AECOS LOG No.: 29285
DATE RECEIVED: 07/29/13

SAMPLE ID ⇨ / ANALYTE ⇩	Marsh	Stream		Reporting / Detection Limit	Method Number	Analysis Date / Analyst ID
Turbidity (NTU)	43.0	2.18		0.01	EPA 180.1 (1993)	07/30/12 ml
Total Suspended Solids (mg/L)	14	4.0		0.1	SM 2540D (1998)	08/01/13 ml
Nitrate+Nitrite (µg/L)	<1	<1		1	Grasshoff et al	08/16/13 SLab
Total Nitrogen (µg/L)	370	979		7	Grasshoff et al	08/15/13 SLab
Total Phosphorus (µg/L)	37	59		3	Grasshoff et al	08/16/13 SLab
Salinity (ppt)	<1	5		1	Refractive Index	07/31/13 jw

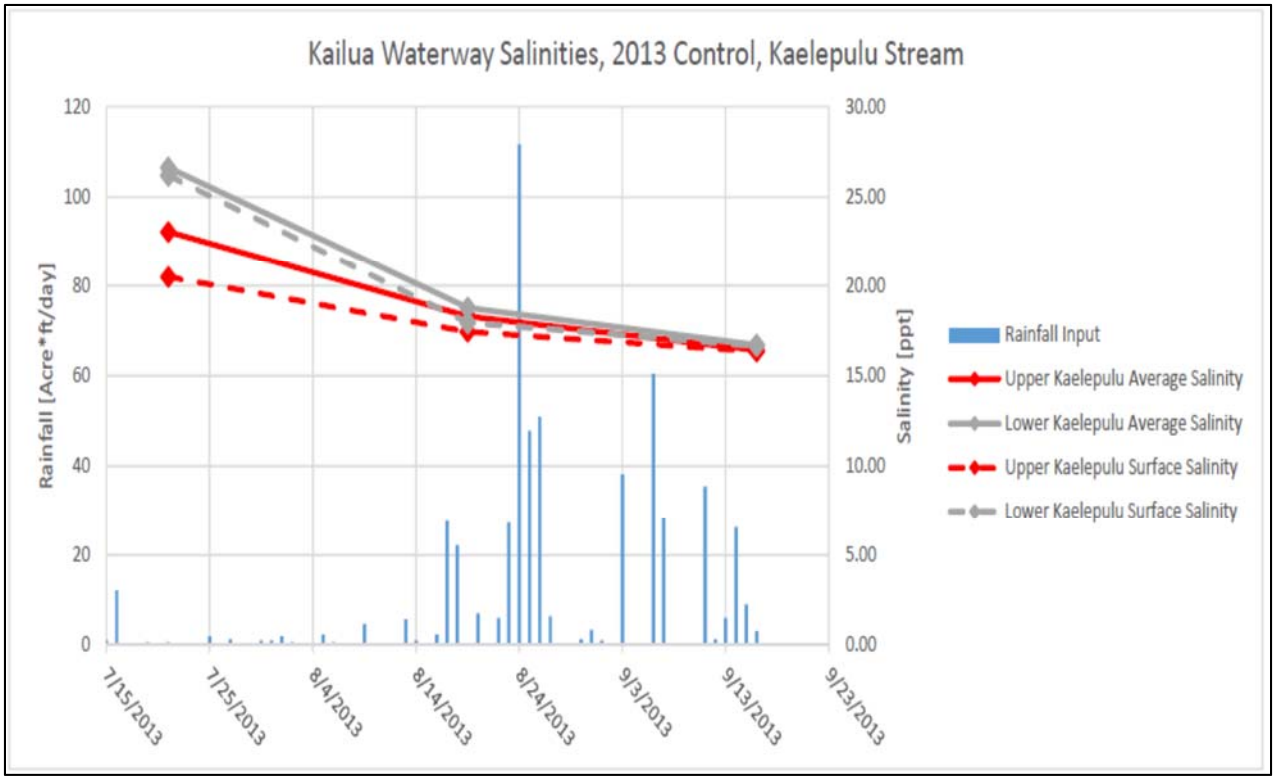
J. Mello, Laboratory Director

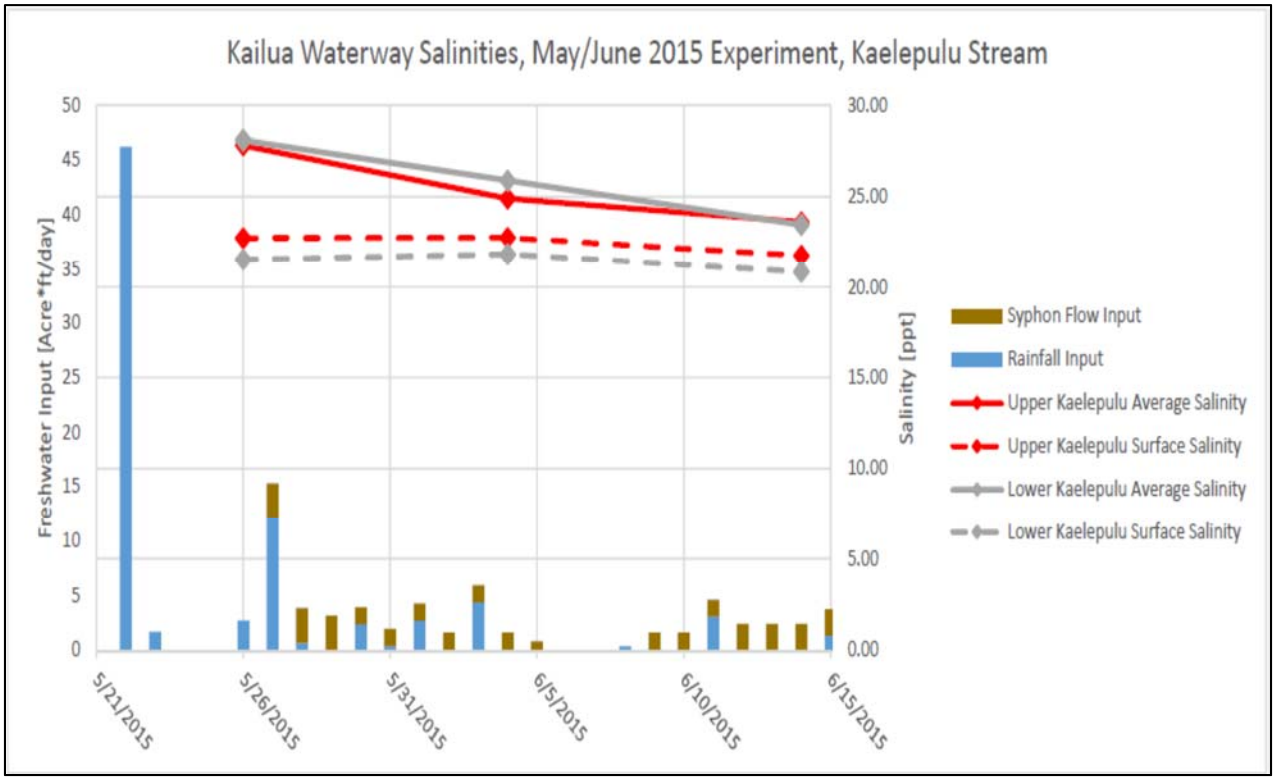
C. APPENDIX: COMPARATIVE WATER SALINITY GRAPHICS



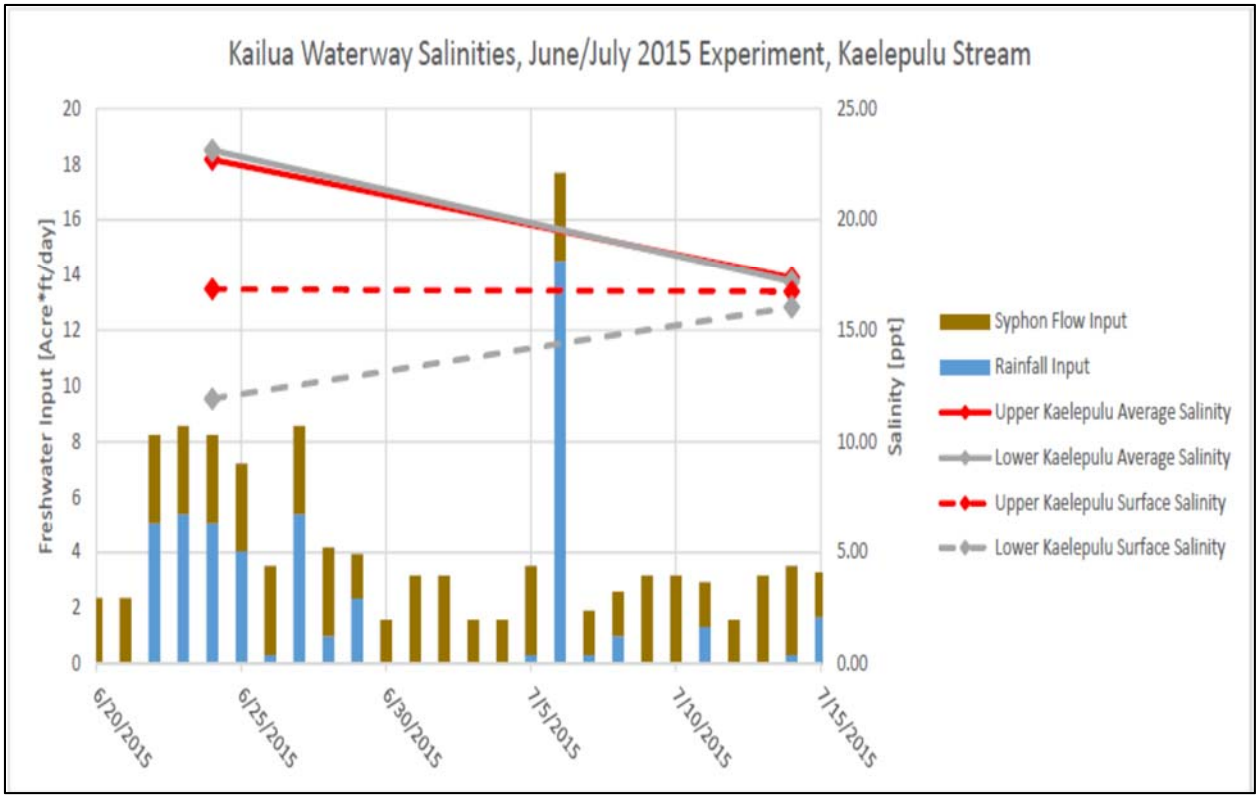


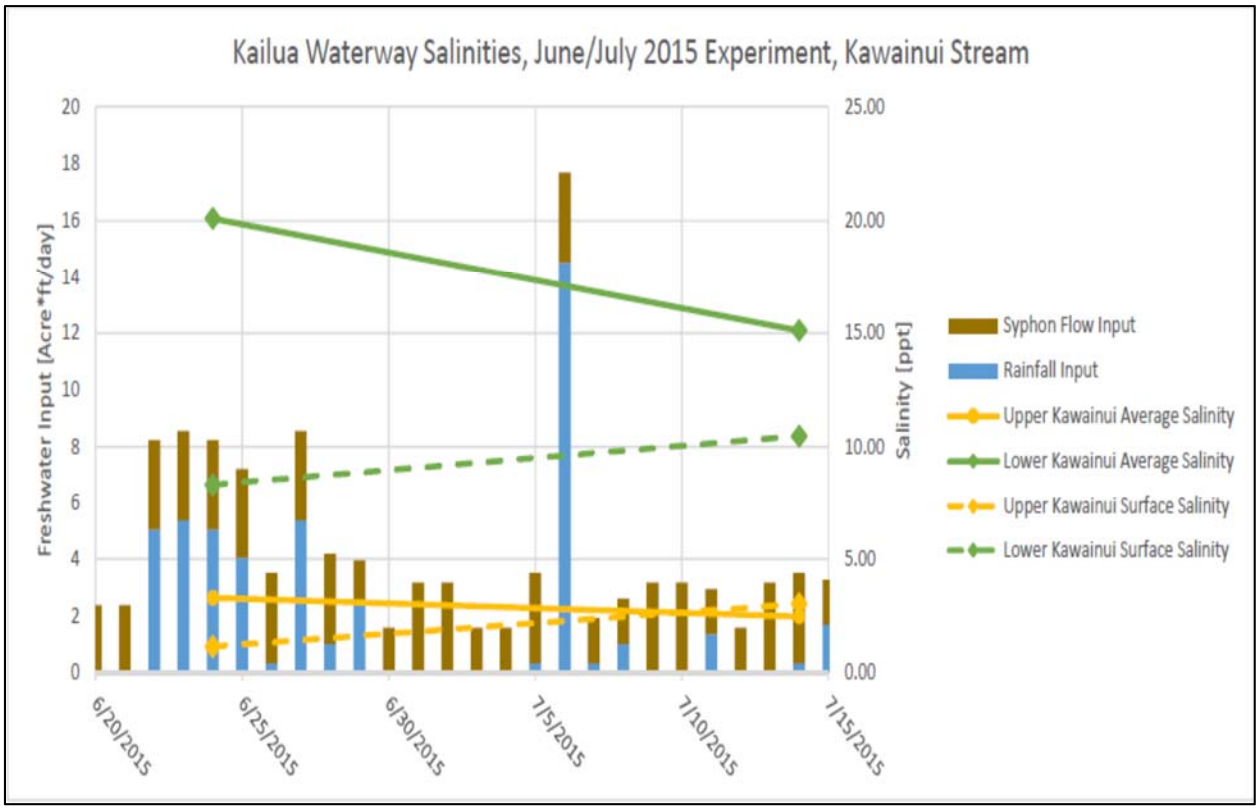
Changes in Kawai Nui Stream salinity between stream mouth opening events with (bottom) and without (top) syphon water flow





Changes in Kaelepulu salinity between stream mouth opening events with (bottom) and without (top) syphon water flow





During the first month of the experiment inflowing water from the syphon succeeded in lowering the average salinity despite an increase in average salinity, likely due to evaporation.

D. APPENDIX: WATER QUALITY TRANSECTS THROUGH ESTUARY
Pre-Syphon Controls

This project was initiated in 2012 and measurements of "pre-syphon control" water quality transects began almost immediately – not anticipating the 2^{+}-year delay for permitting of the experiment. As a result quite a few more transects were conducted than was likely necessary for the project. For each transect, physical water quality parameters (Temperature, Salinity, pH, Turbidity, O2) were measured from the surface down to the bottom of the estuary at 20 key locations in both branches of the estuary (Figure 2.6, main report). The dates of each transect are noted in the table below in relation to the stream mouth opening events. Each double page layout represents the twin transects conducted through the Kaelepulu branch (left page) and the Kawai Nui branch (right page) of the estuary. Color keys for the data are located on an oversized page at the end of the appendix, and is designed to be folded out for reference when viewing the following graphics.

Appendix D

2012-2014 Pre-Experiment Control Water Quality Transects

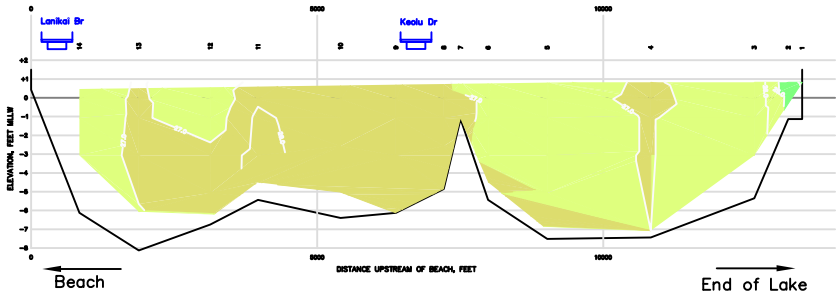
The graphics in this appendix depict the results of physical water quality surveys through both branches of the estuary. Each survey was conducted beginning at dawn at the Kaelepulu wetland and was generally completed within 3 hours ending at the terminus of Kawainui Stream. The left hand page represents results from the Kaelepulu branch and the right hand page from the Kawainui branch. A color key may be found as a fold-out page at the end of the appendices.

oceanit®

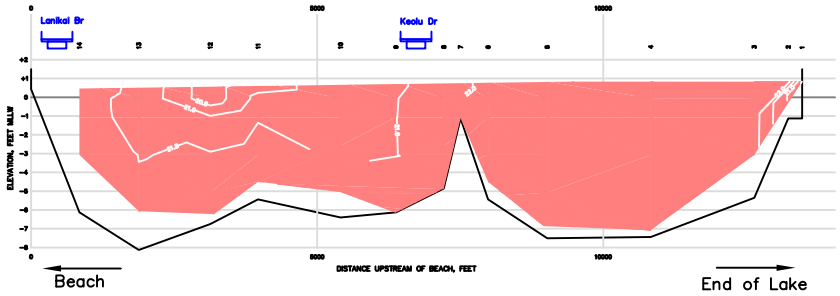
Kaelepulu

Transect 9/17/12

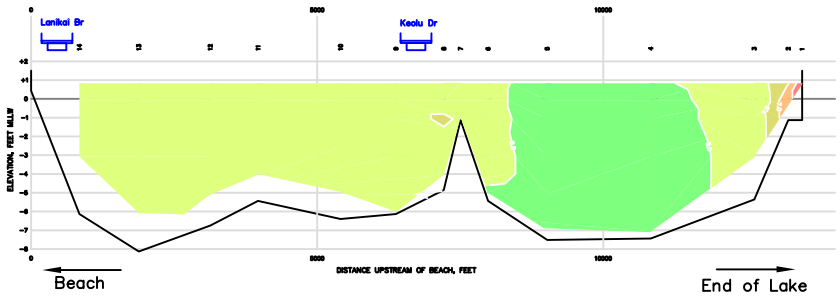
Temperature



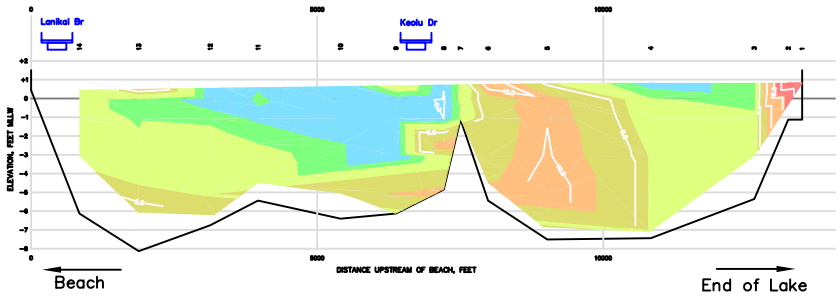
Salinity



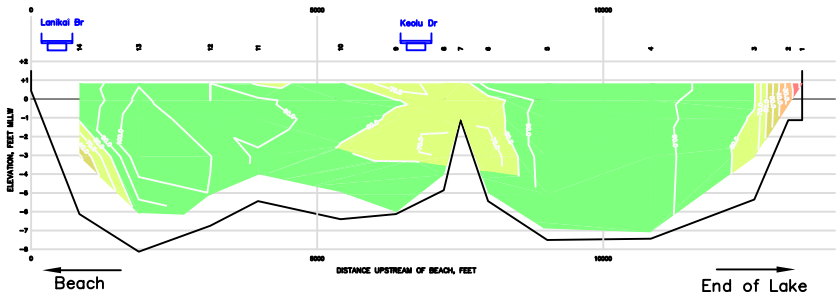
pH



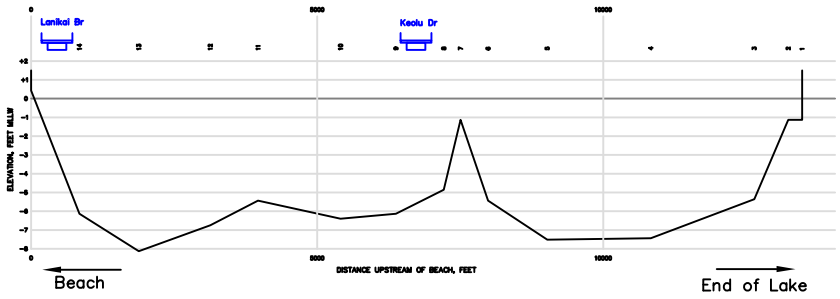
NTU



DO



Exchange



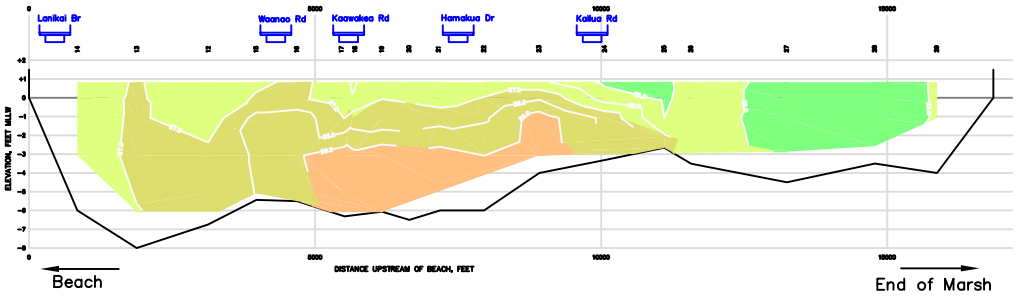
Kawainui

Transect 9/17/12

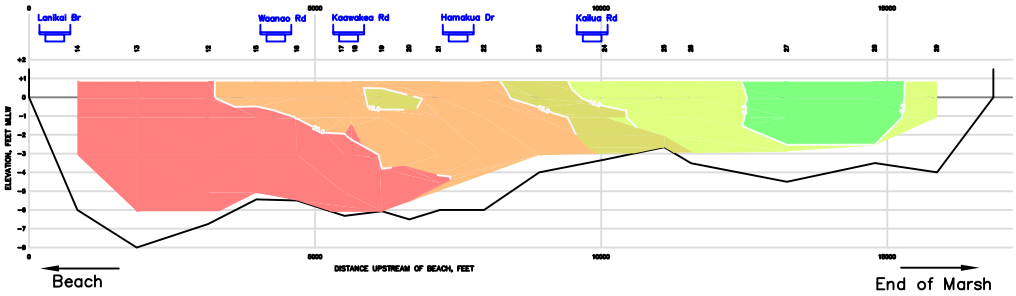
Next Stream Opening>
9/19/12

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 0.93 FT; Sample Date: 09/17/2012
Pre-Berm Opening (opened on 09/19/2012)

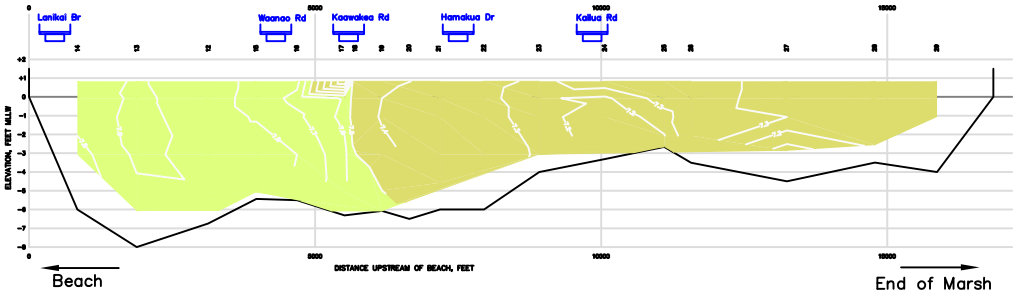
Temperature



Salinity



pH



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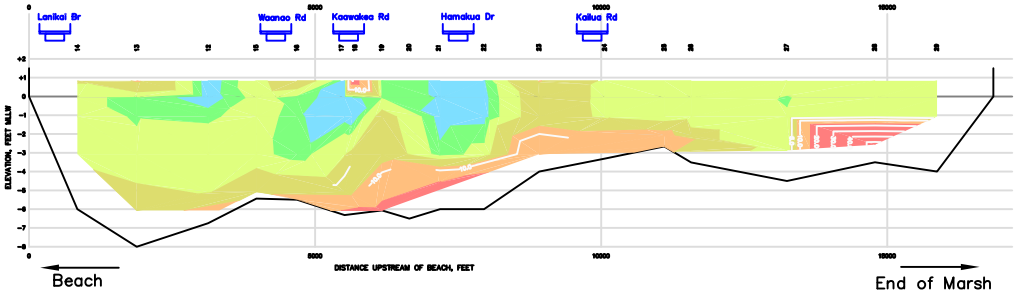

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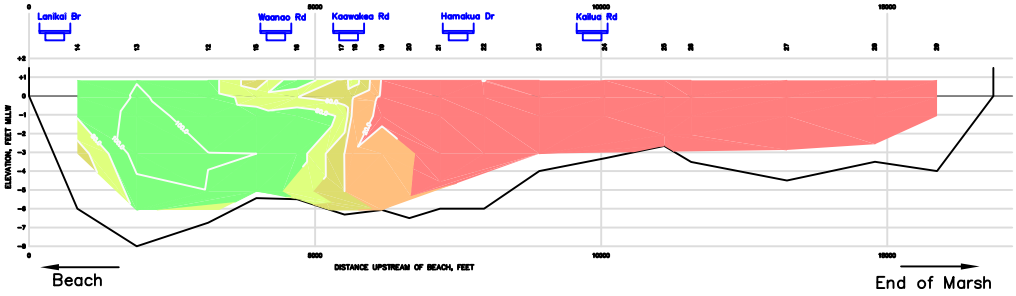
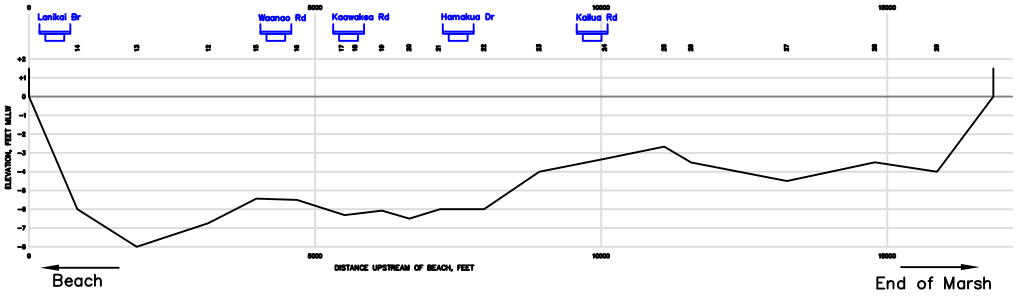


Exchange

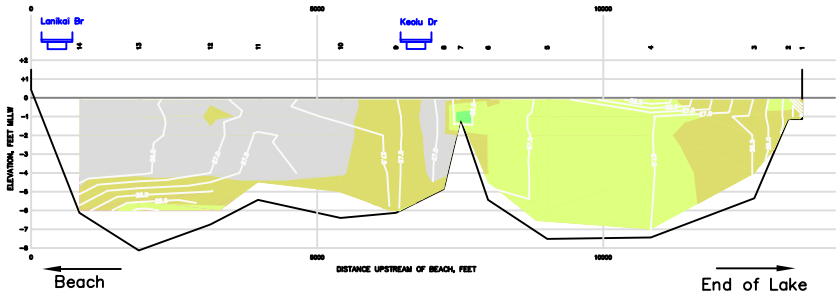


Kaelepulu

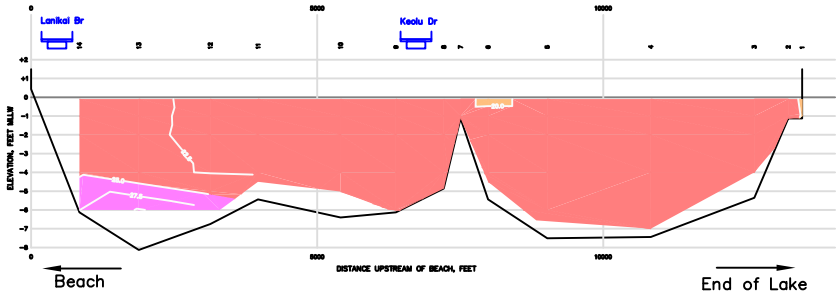
Transect 9/24/12

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.19 FT; Sample Date: 09/24/2012
Post-Berm Opening (opened on 09/19/2012)

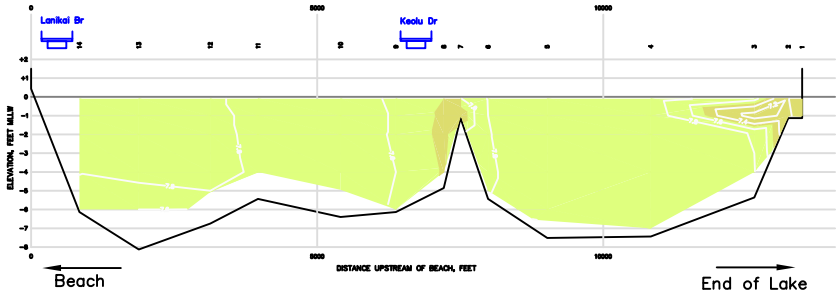
Temperature



Salinity



pH



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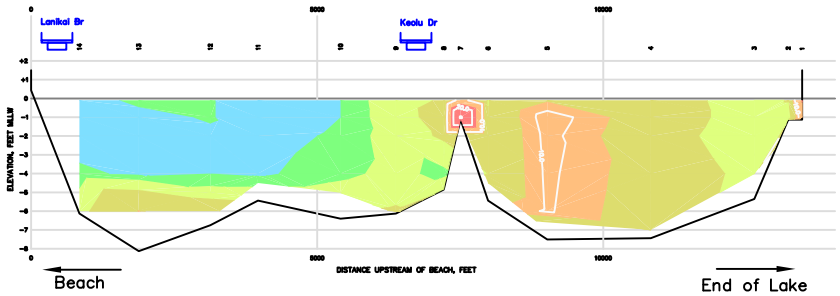

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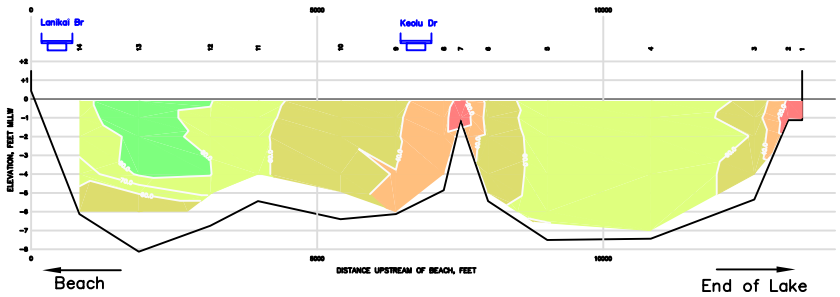

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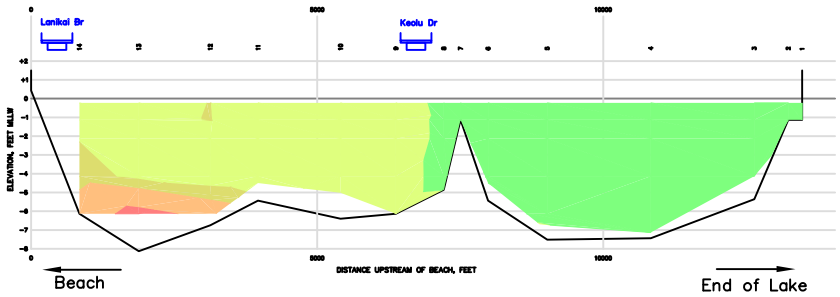


Kawainui

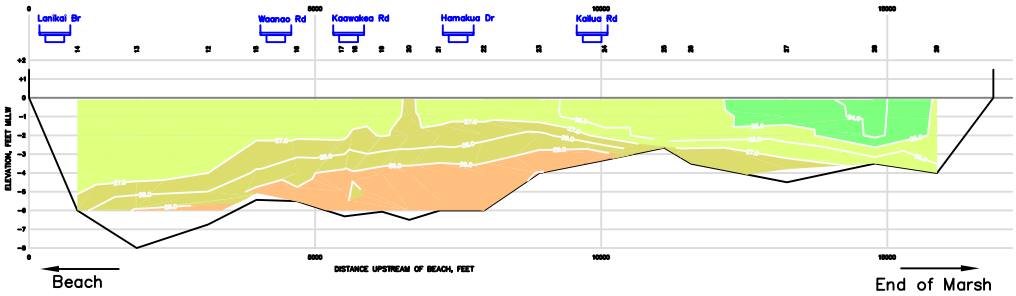
<Previous Stream Opening
9/19/12

Next Stream Opening>
11/13/12

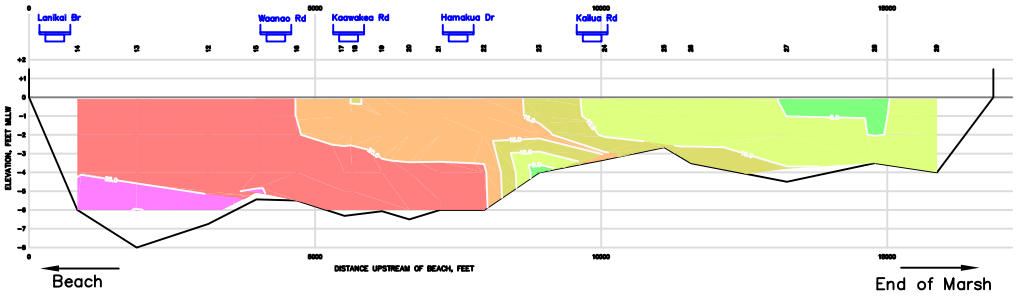
Transect 9/24/12

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.19 FT; Sample Date: 09/24/2012
Post-Berm Opening (opened on 09/19/2012)

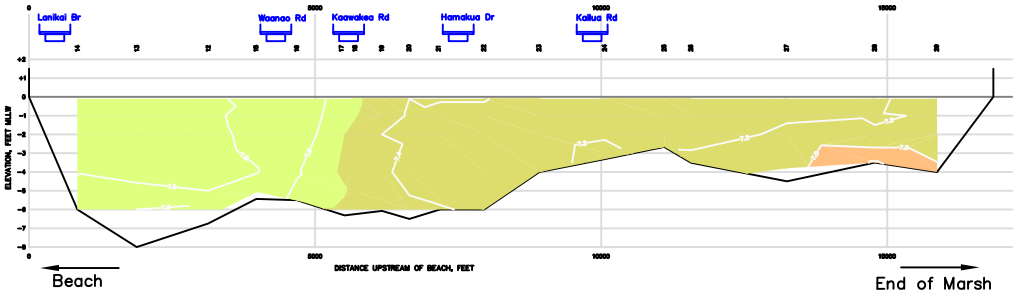
Temperature



Salinity



pH



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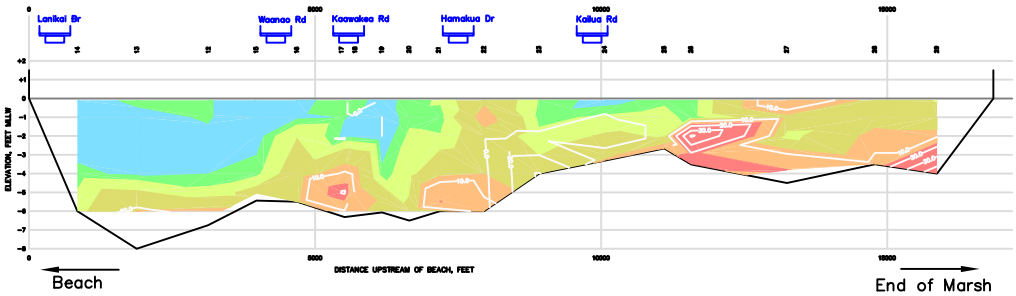

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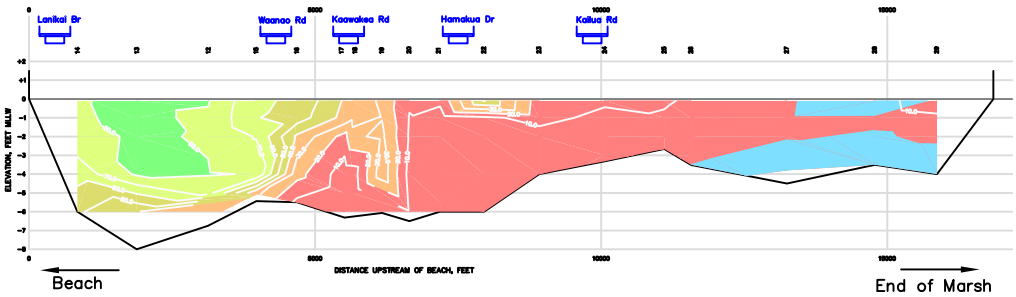

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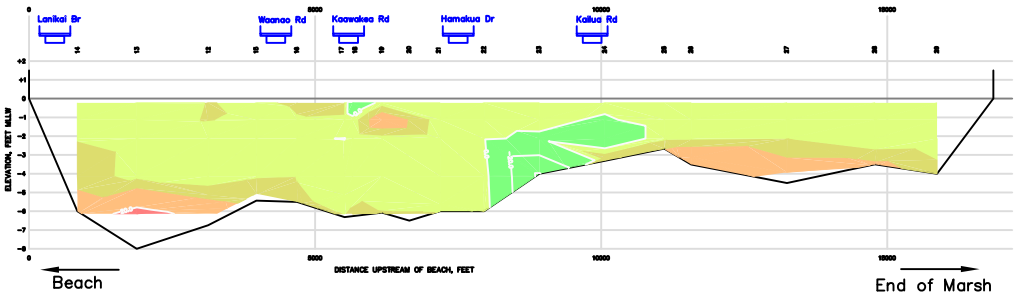
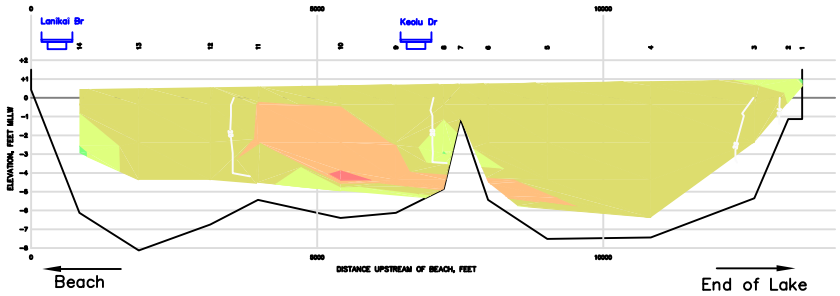


Kaelepulu

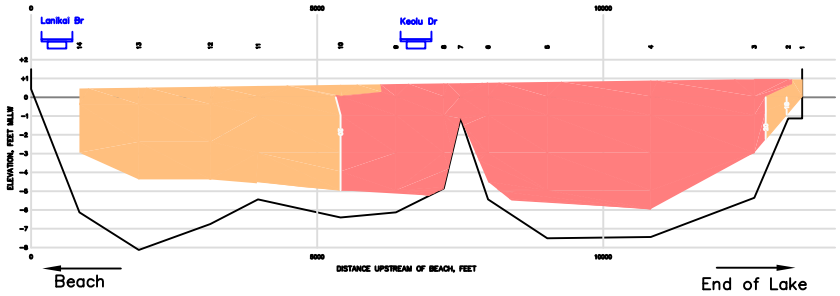
Transect 11/12/12

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.05 FT; Sample Date: 11/12/2012
Pre-Berm Opening (opened on 11/13/2012)

Temperature



Salinity



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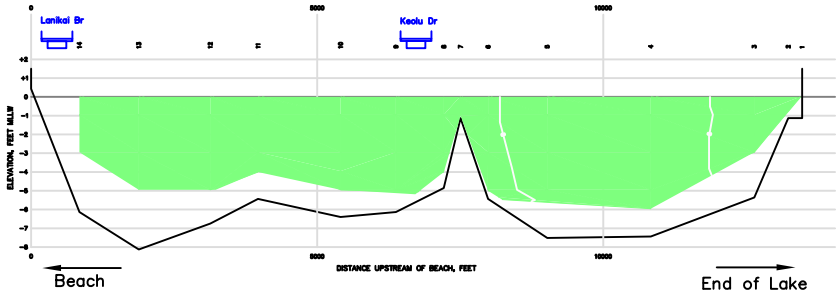

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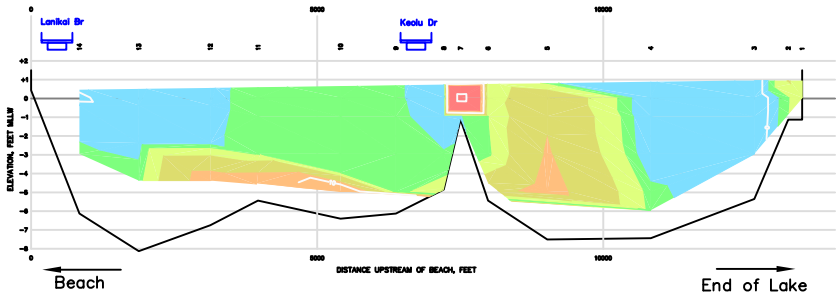

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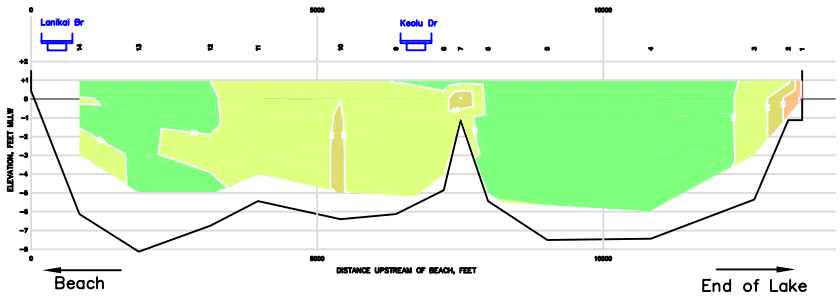

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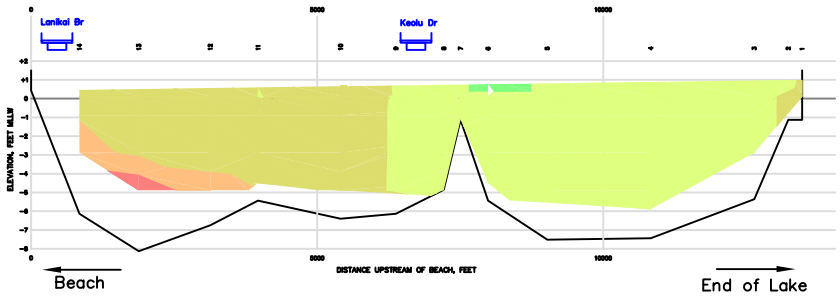


Kawainui

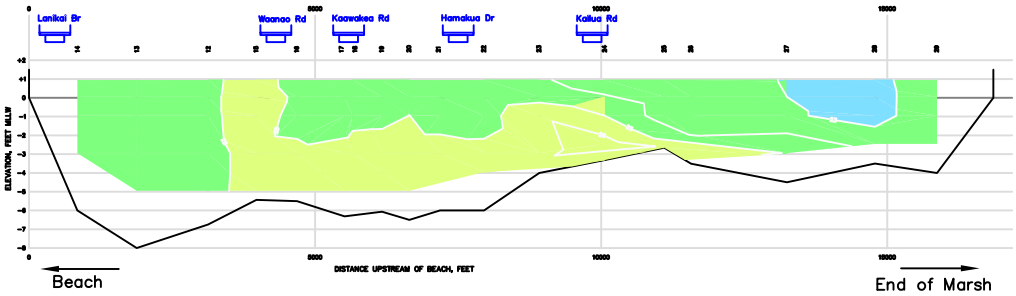
<Previous Stream Opening
9/19/12

Next Stream Opening>
11/13/12

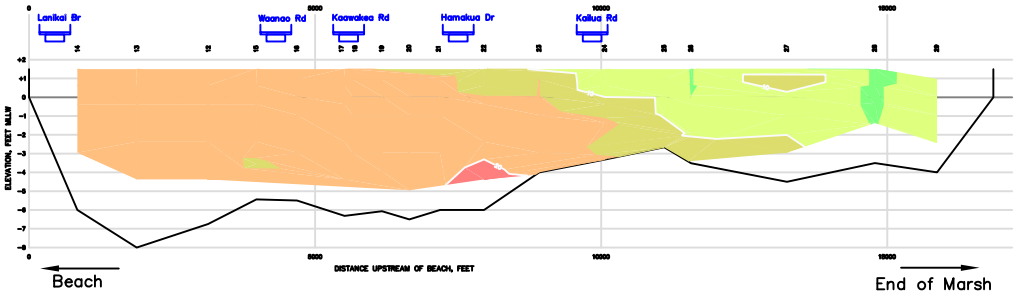
Transect 11/12/12

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.05 FT; Sample Date: 11/12/2012
Pre-Berm Opening (opened on 11/13/2012)

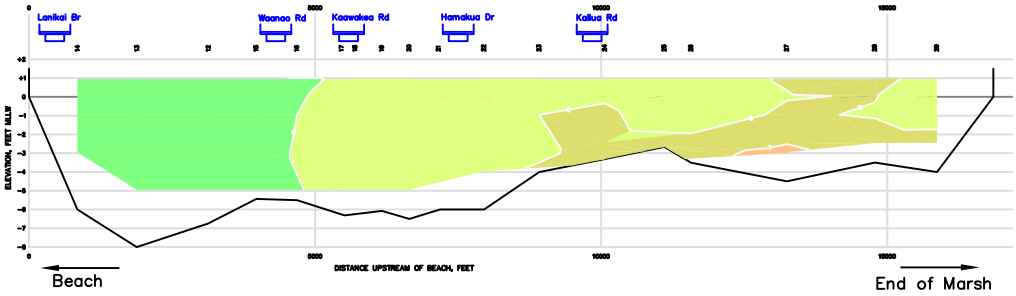
Temperature



Salinity



pH



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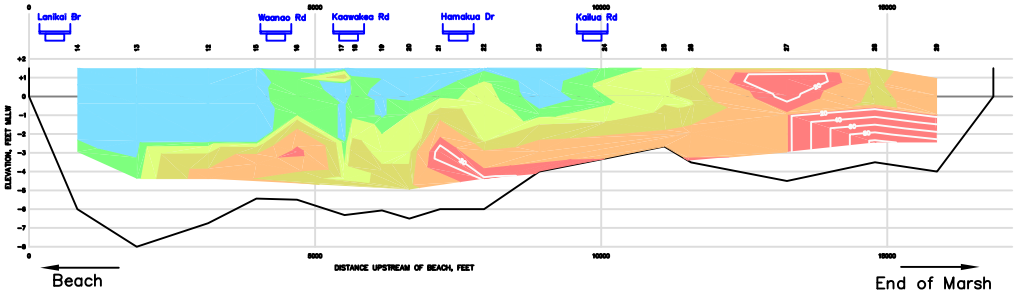

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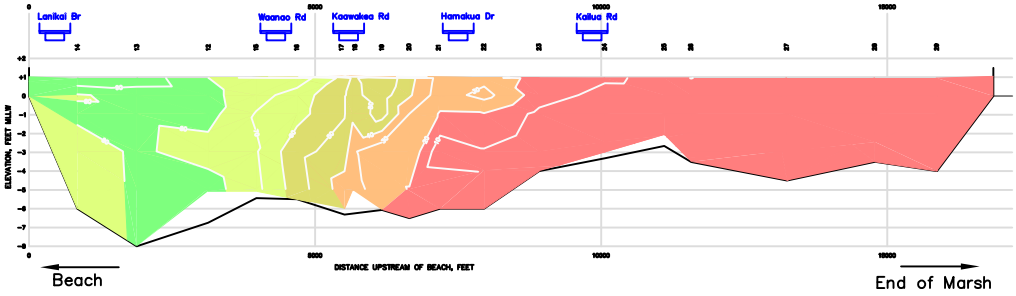
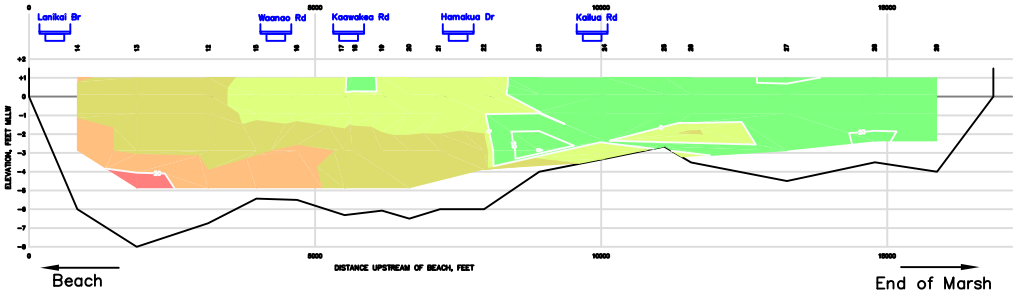


Exchange

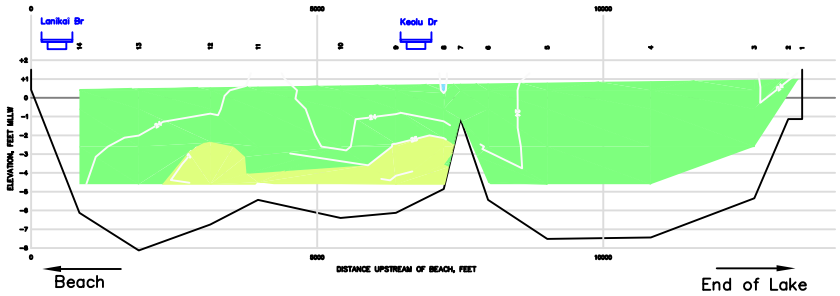


Kaelepulu

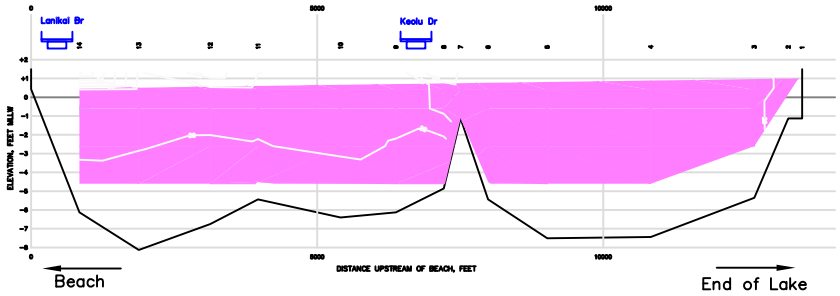
Transect 12/1/12

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.40 FT; Sample Date: 12/01/2012
Post-Berm Opening (opened on 11/13/2012)

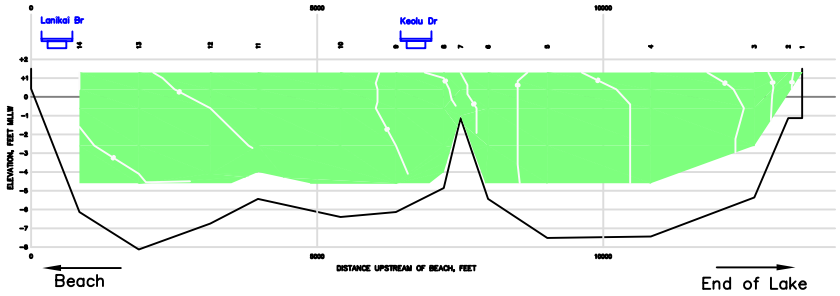
Temperature



Salinity



pH



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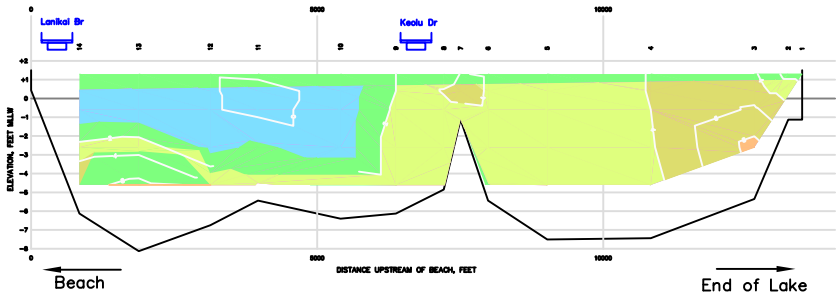
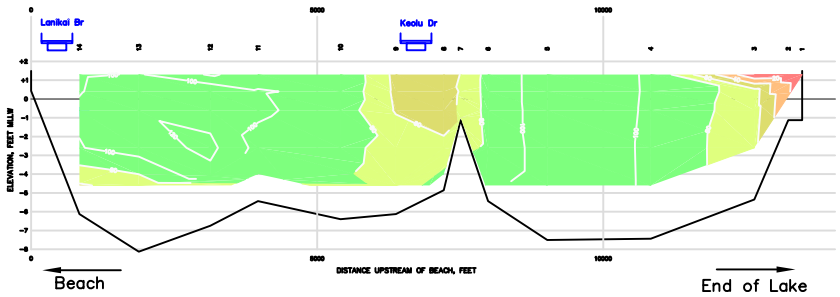
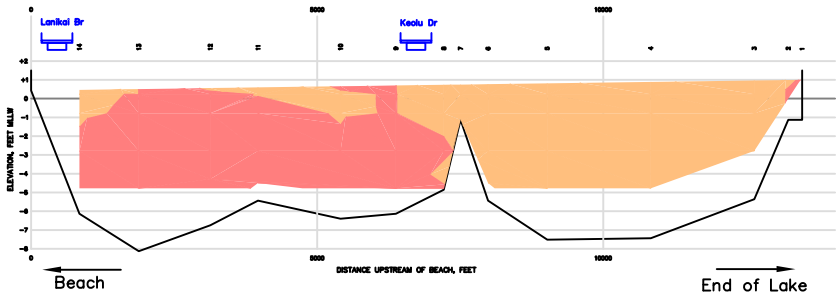


DO



Exchange



Kawainui

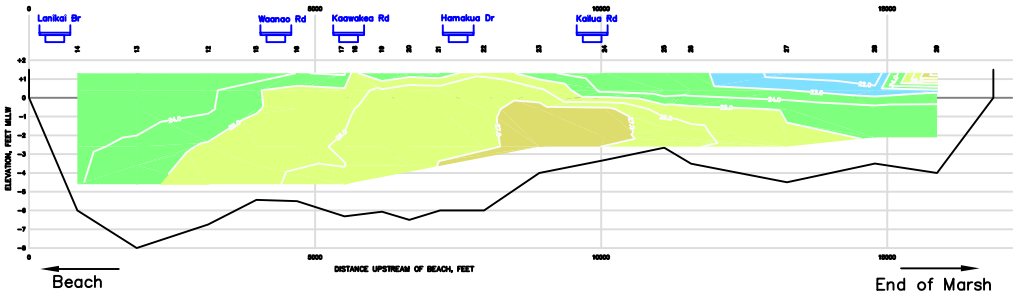
<Previous Stream Opening
11/13/12

Next Stream Opening>
12/10/12

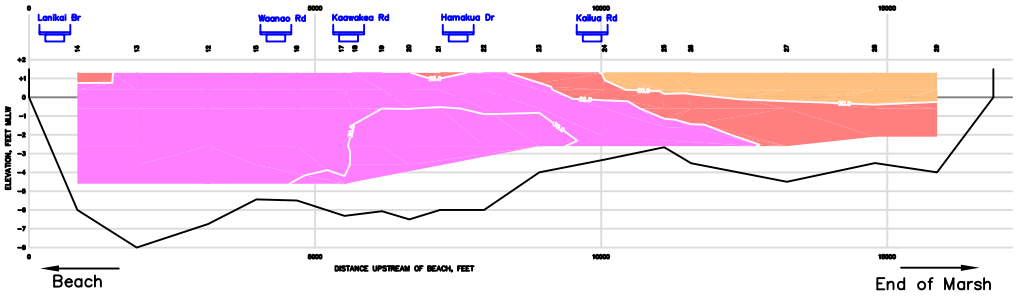
Transect 12/1/12

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.40 FT; Sample Date: 12/01/2012
Post-Berm Opening (opened on 11/13/2012)

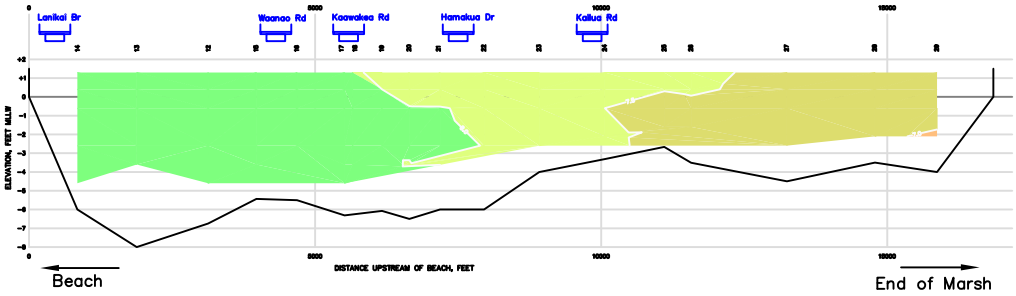
Temperature



Salinity



pH



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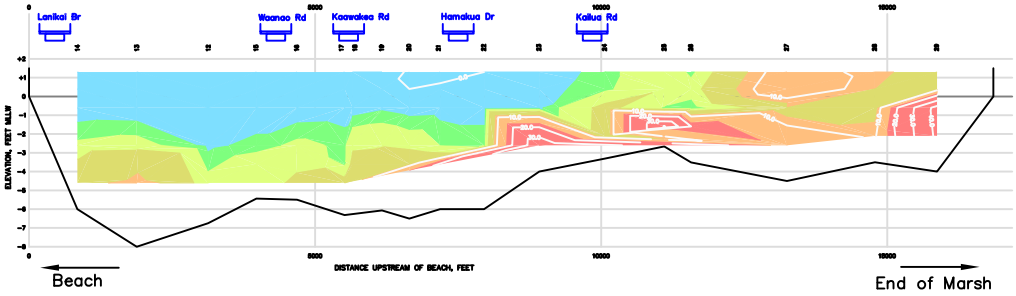
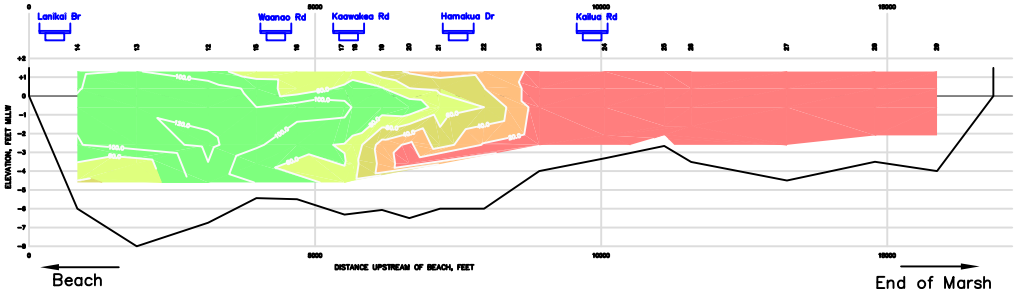
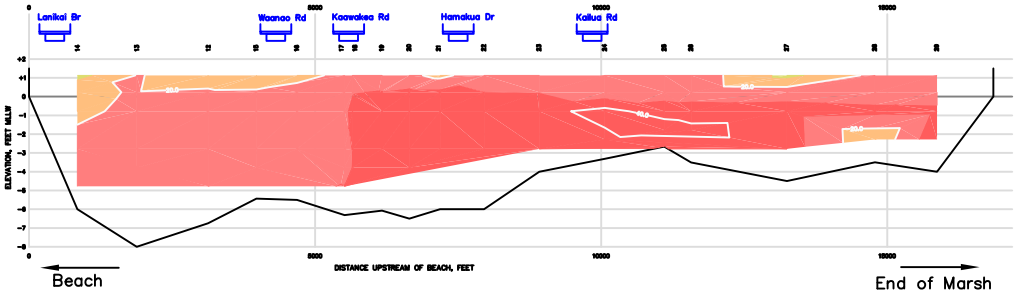


DO



Exchange

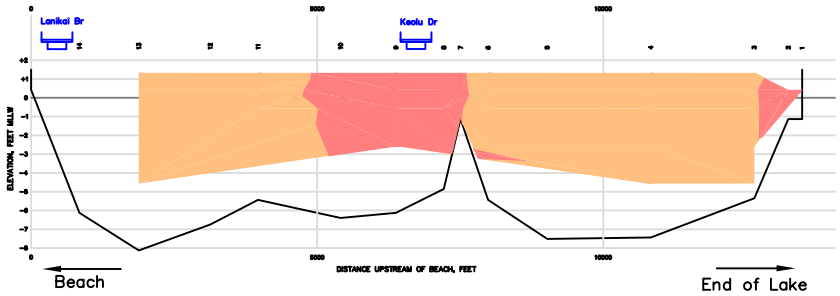


Kaelepulu

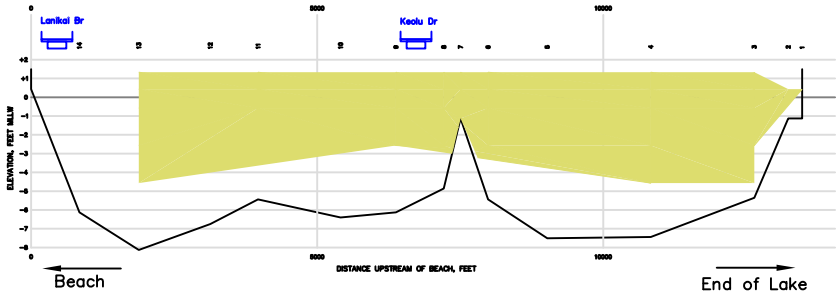
Transect 7/8/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.43 FT; Sample Date: 07/08/2013
Pre-Berm Opening (opened on 07/10/2013)

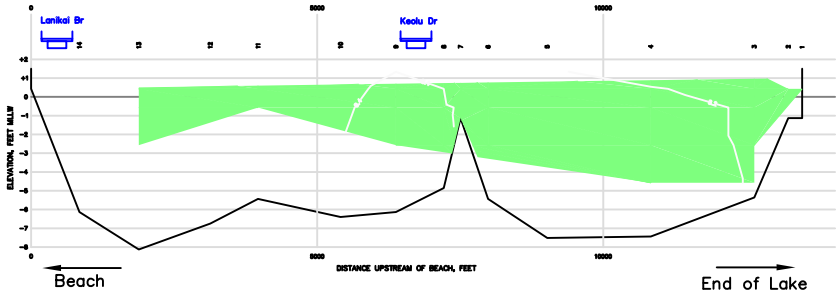
Temperature



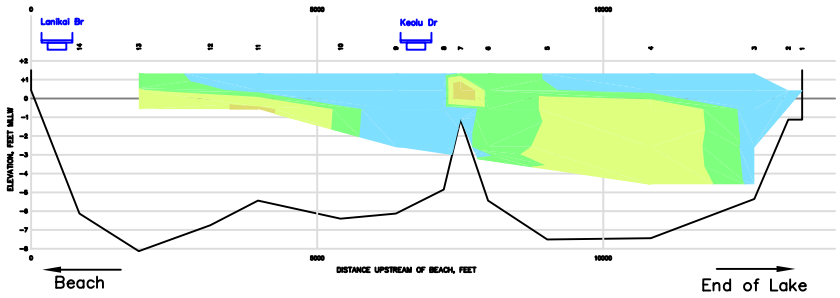
Salinity



pH



NTU



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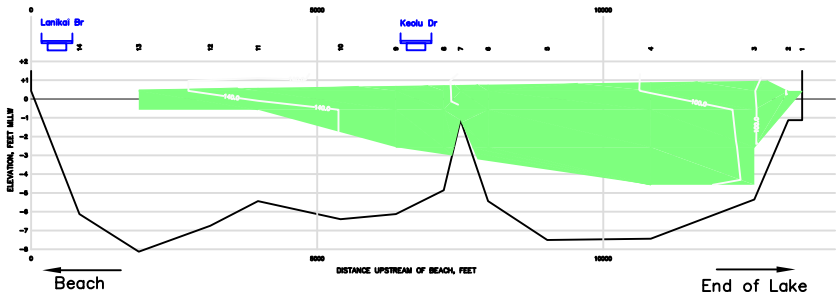
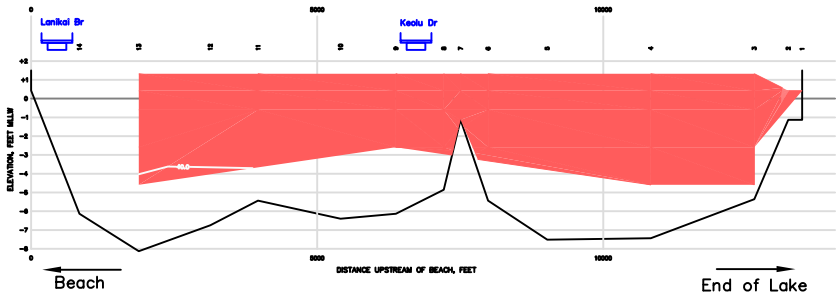


Exchange



Kawainui

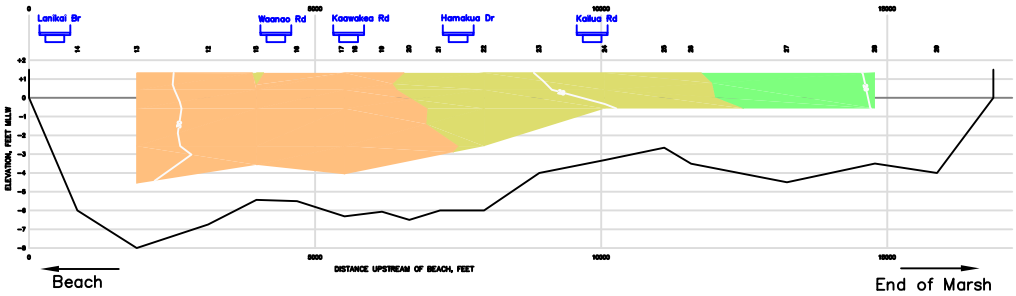
<Previous Stream Opening
6/5/13

Transect 7/8/13

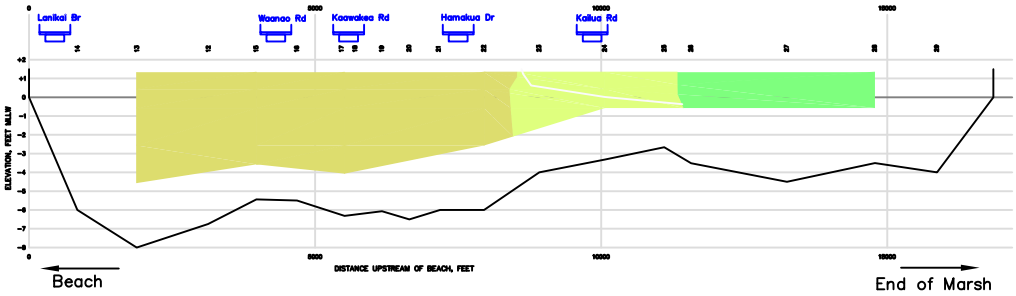
Next Stream Opening>
7/10/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.43 FT; Sample Date: 07/08/2013
Pre-Berm Opening (opened on 07/10/2013)

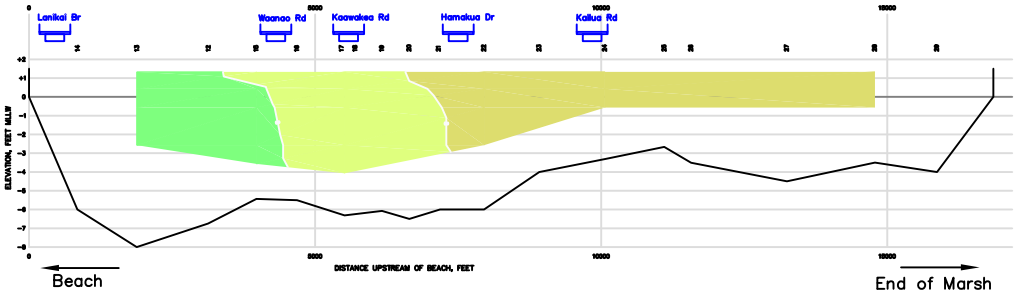
Temperature



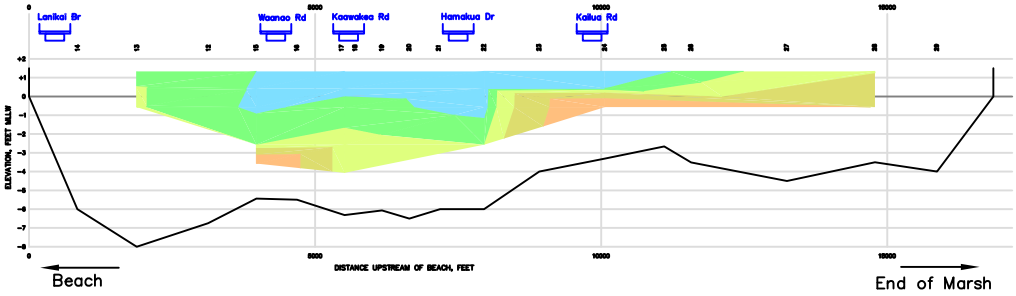
Salinity



pH



NTU



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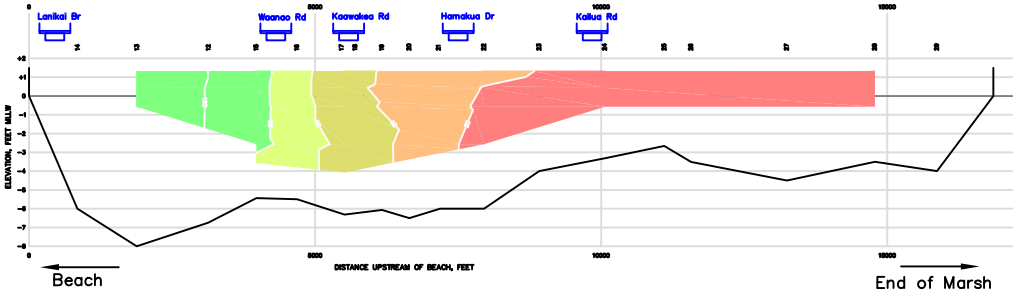
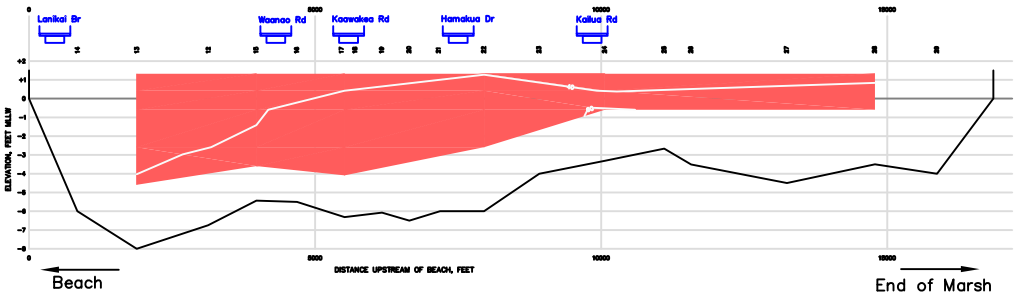


Exchange

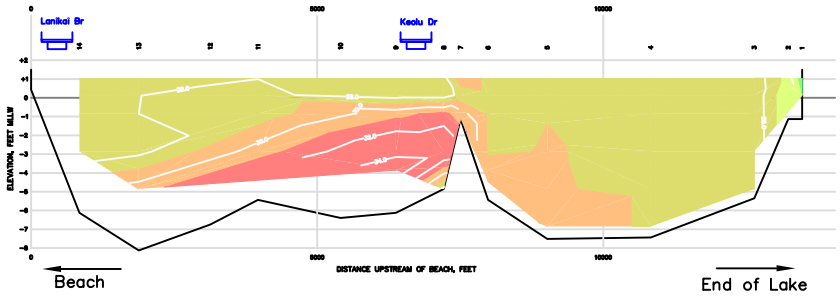


Kaelepulu

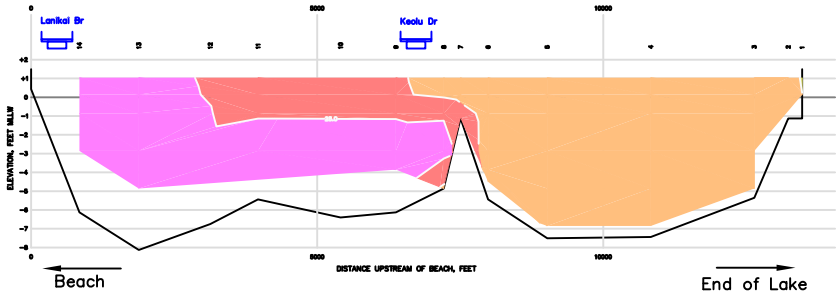
Transect 7/21/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.15 FT; Sample Date: 07/21/2013
Post-Berm Opening (opened on 07/10/2013)

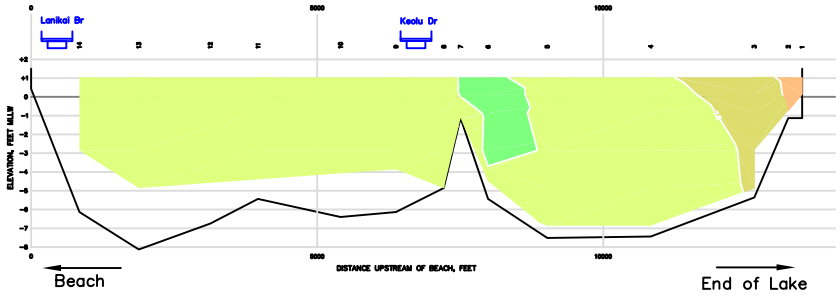
Temperature



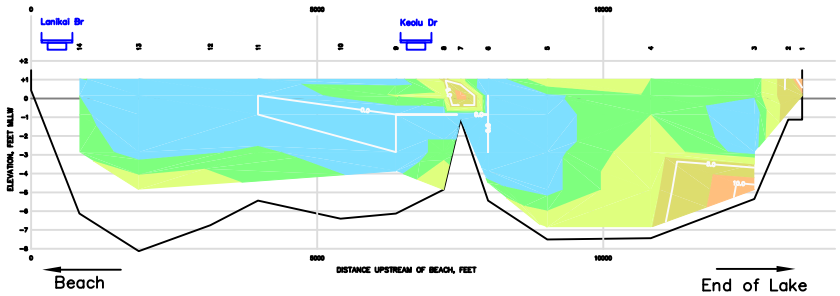
Salinity



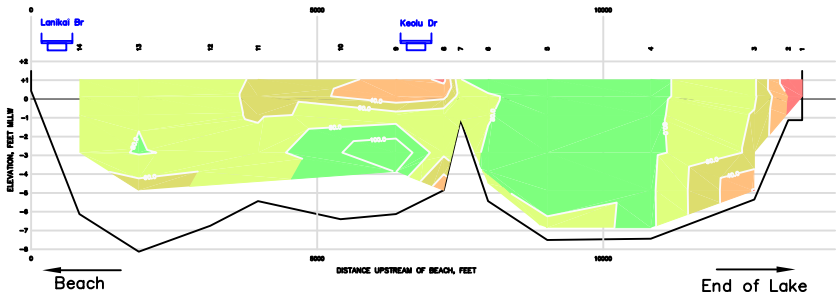
pH



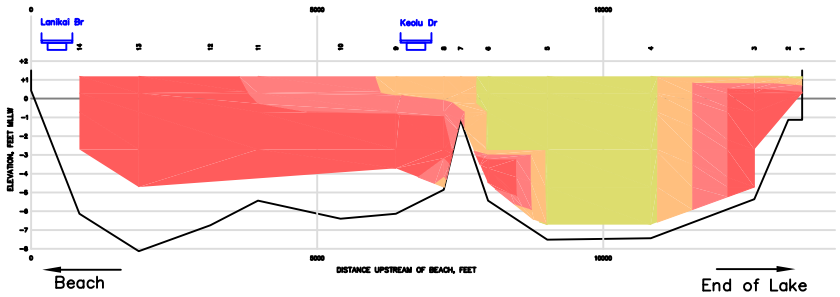
NTU



DO



Exchange



Kawainui

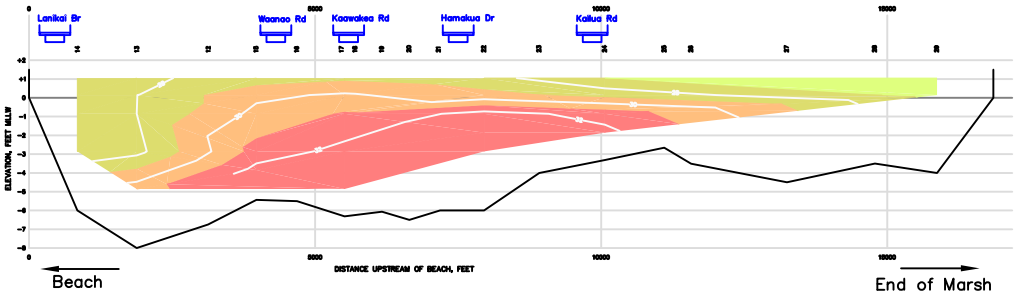
<Previous Stream Opening
7/10/13

Next Stream Opening>
8/10/13

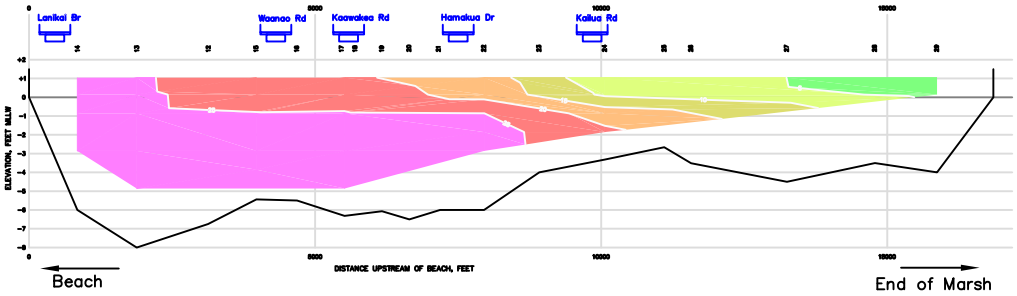
Transect 7/21/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.15 FT; Sample Date: 07/21/2013
Post-Berm Opening (opened on 07/10/2013)

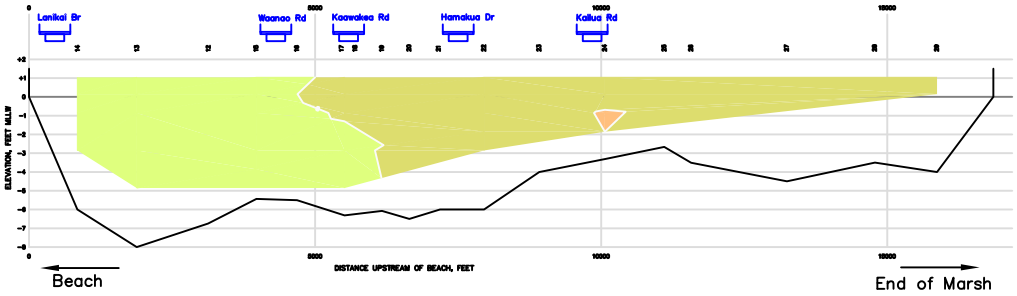
Temperature



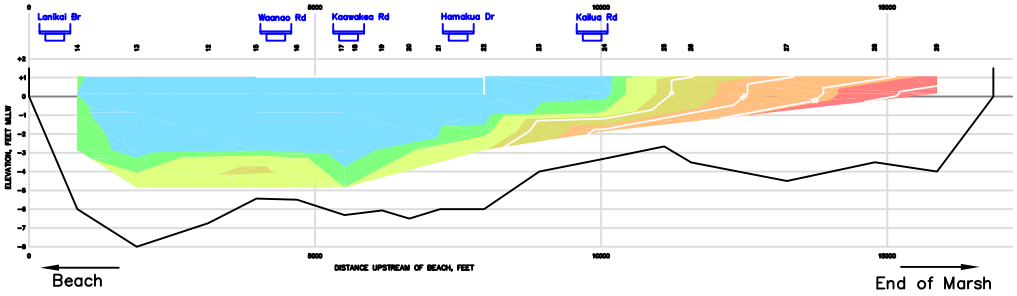
Salinity



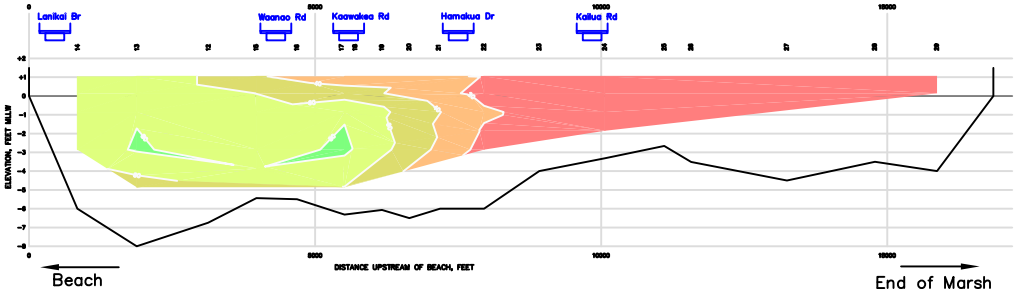
pH



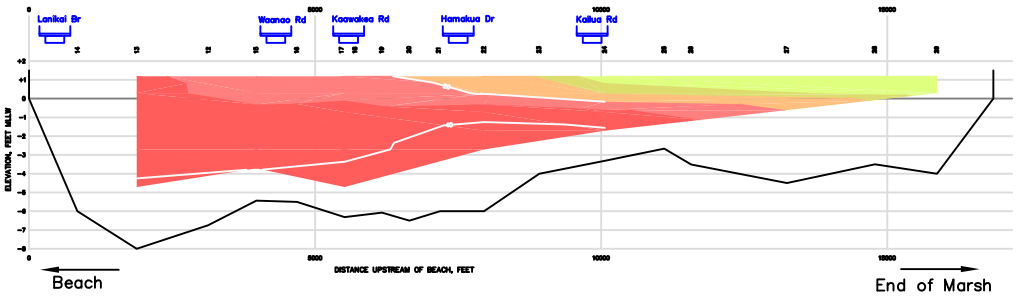
NTU



DO



Exchange

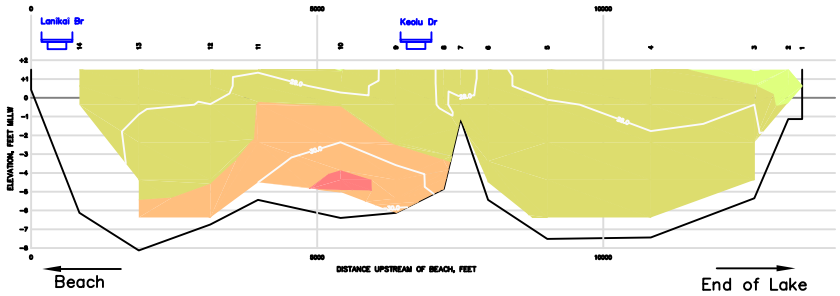


Kaelepulu

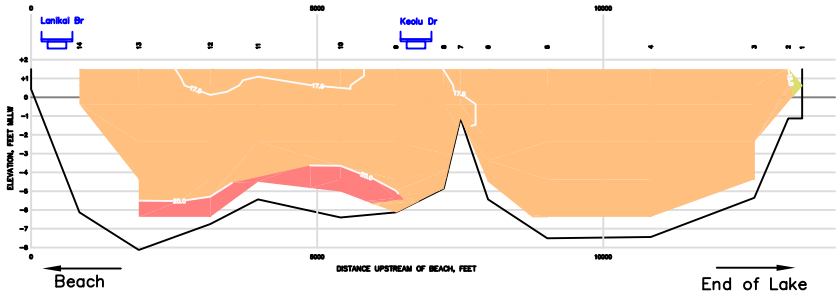
Transect 8/19/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.63 FT; Sample Date: 08/19/2013
Post-Berm Opening II (opened on 07/10/2012)

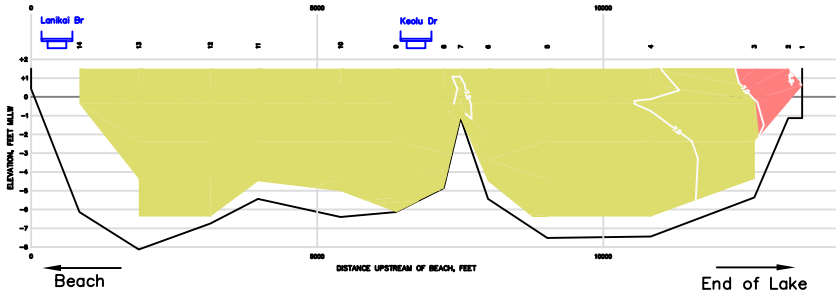
Temperature



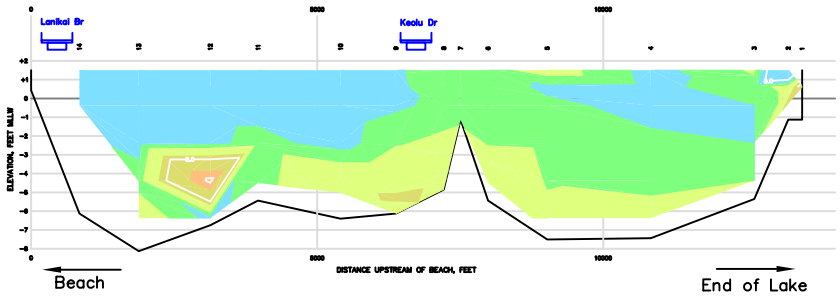
Salinity



pH



NTU



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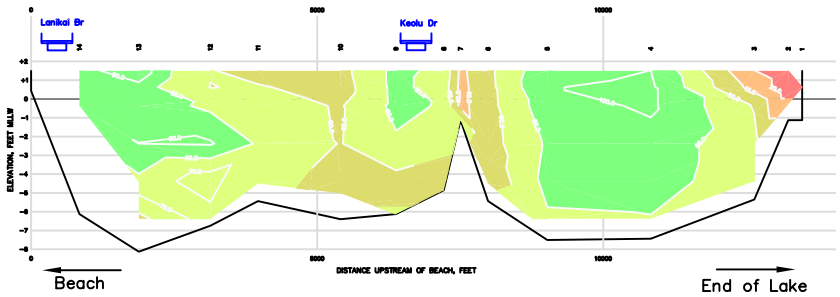
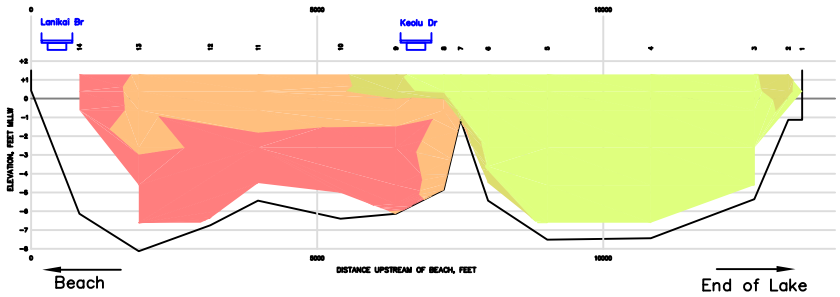


Exchange



Kawainui

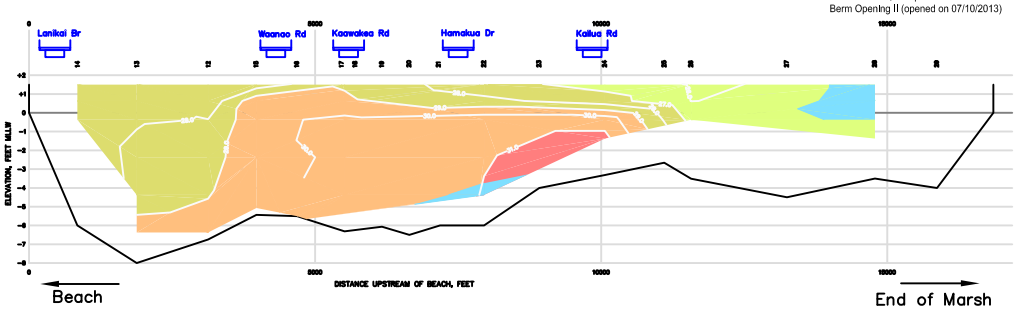
<Previous Stream Opening
8/10/13

Next Stream Opening>
9/16/13

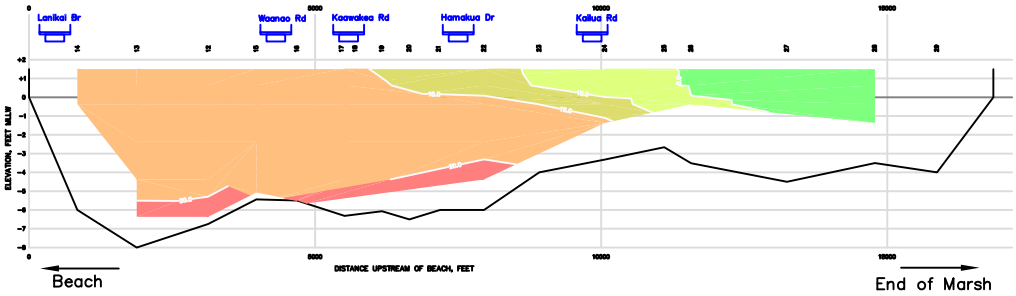
Transect 8/19/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.63 FT; Sample Date: 08/19/2013
Berm Opening II (opened on 07/10/2013)

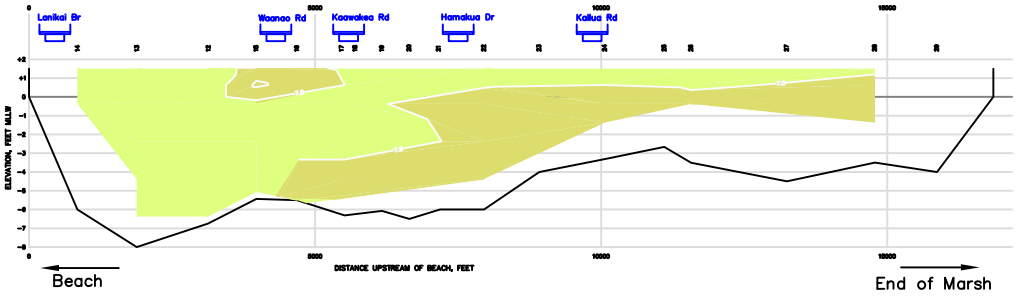
Temperature



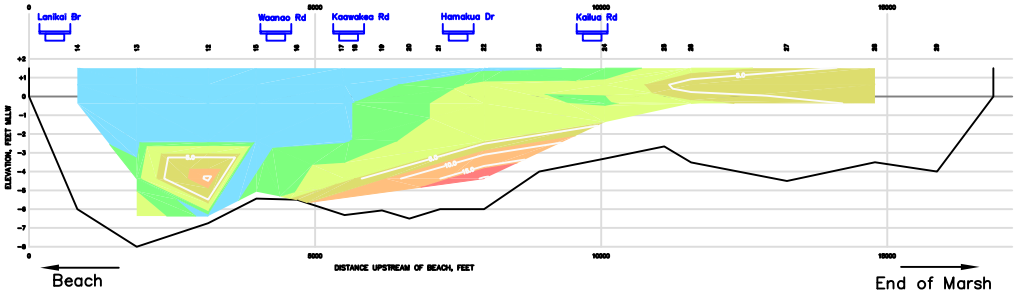
Salinity



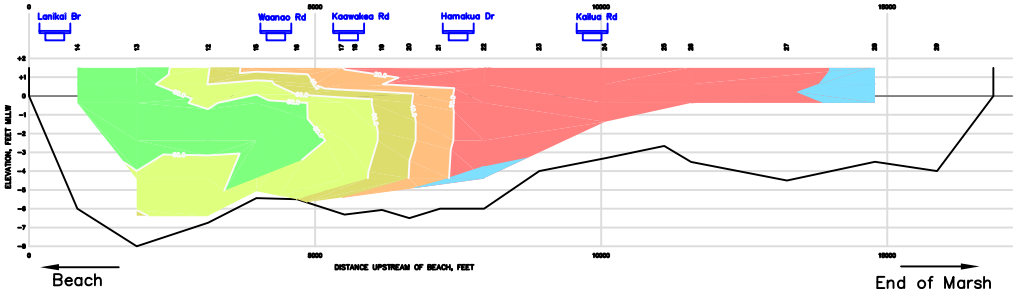
pH



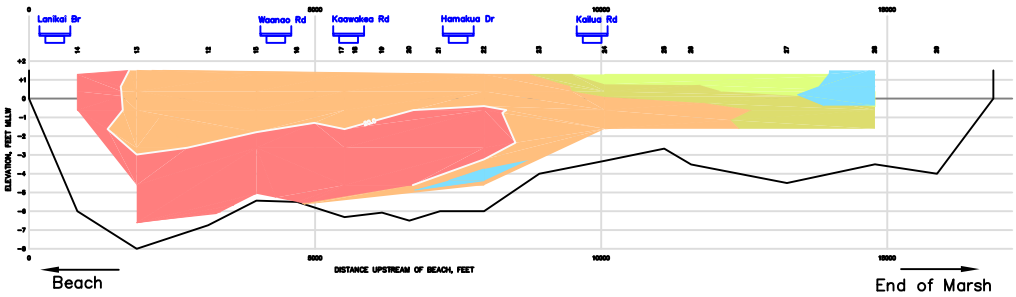
NTU



DO



Exchange

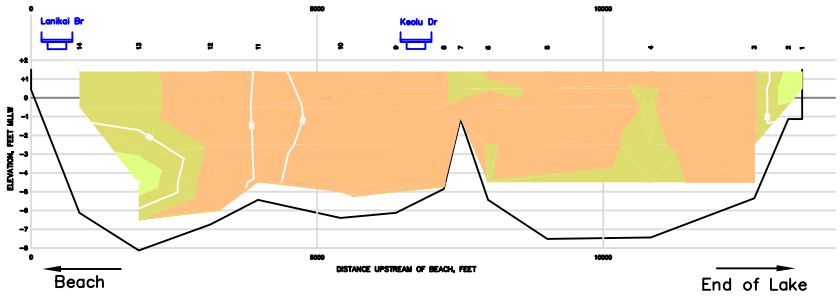


Kaelepulu

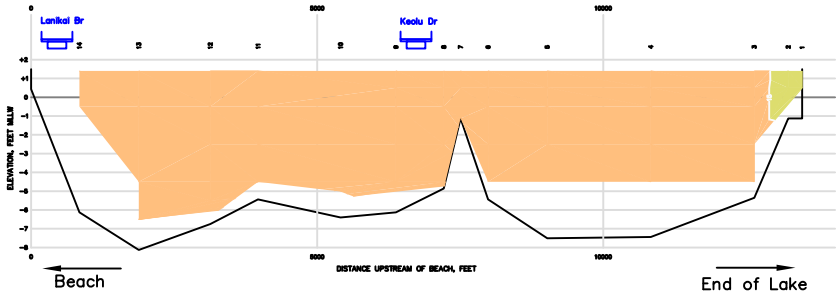
Transect 9/16/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.50 FT; Sample Date: 09/16/2013
Pre-Berm Opening (opened on 09/23/2013)

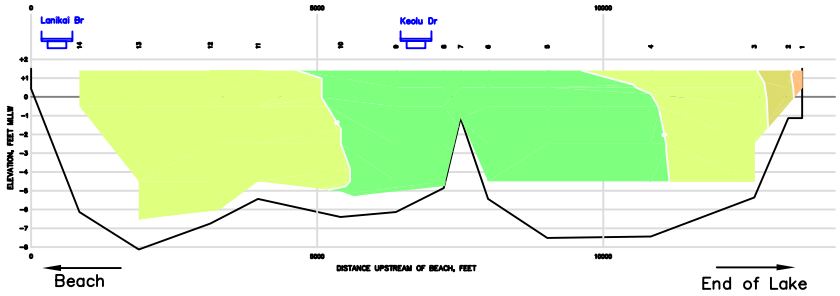
Temperature



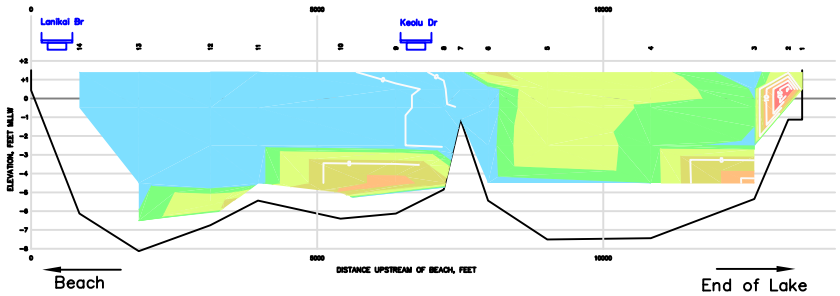
Salinity



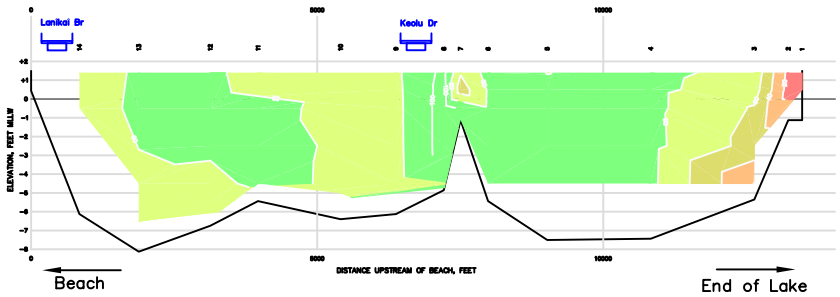
pH



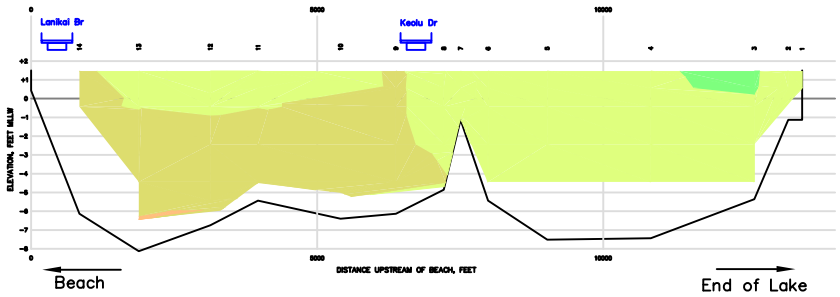
NTU



DO



Exchange



Kawainui

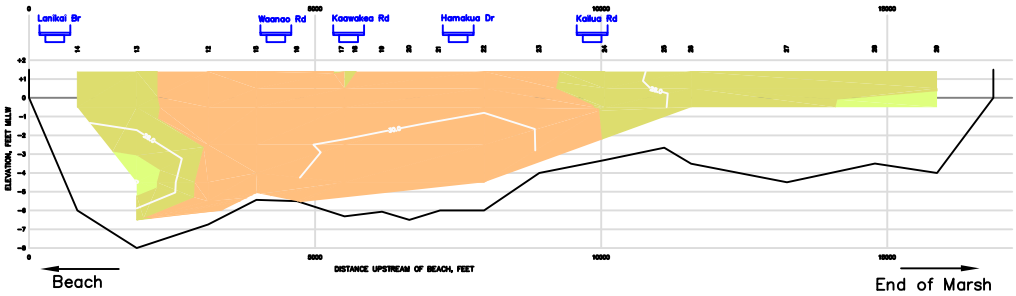
<Previous Stream Opening
8/10/13

Next Stream Opening>
9/16/13

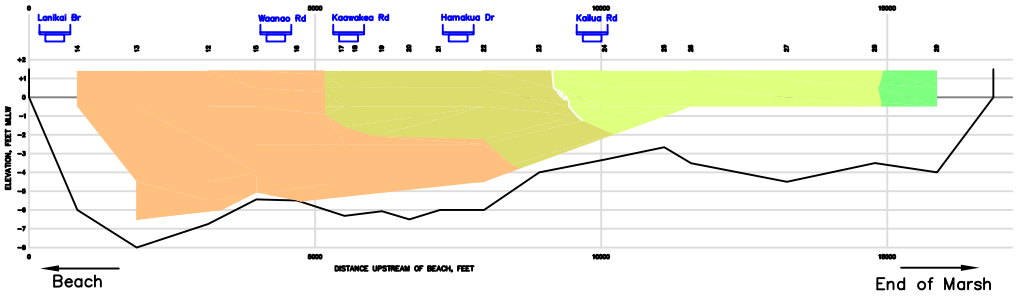
Transect 9/16/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.50 FT; Sample Date: 09/16/2013
Pre-Berm Opening (opened on 09/23/2013)

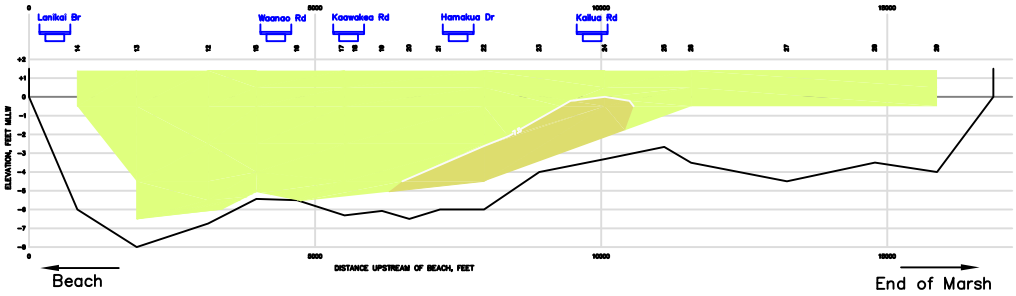
Temperature



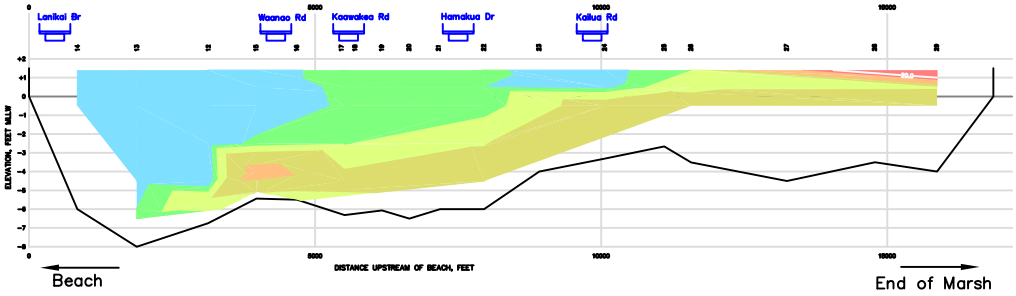
Salinity



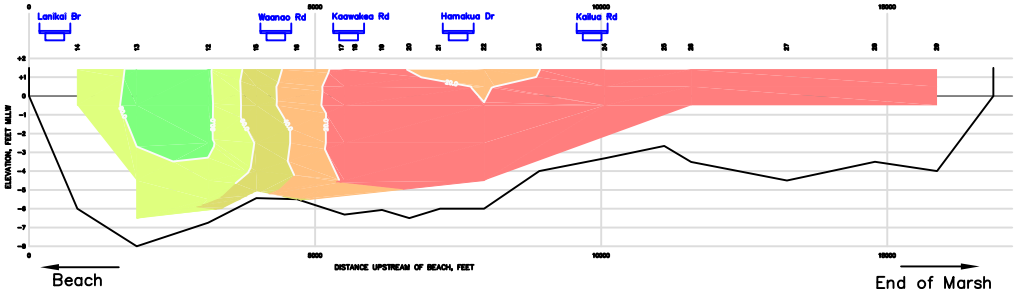
pH



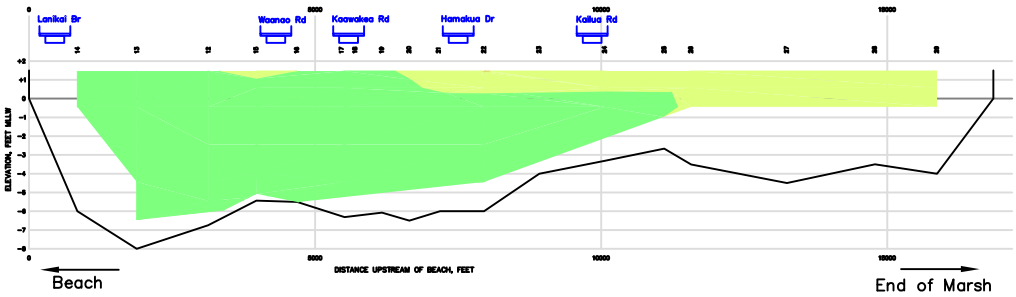
NTU



DO



Exchange

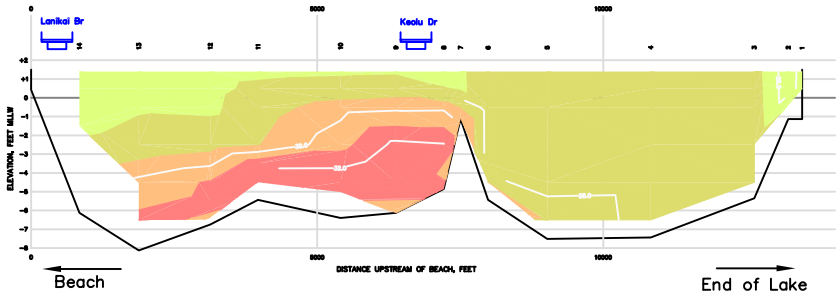


Kaelepulu

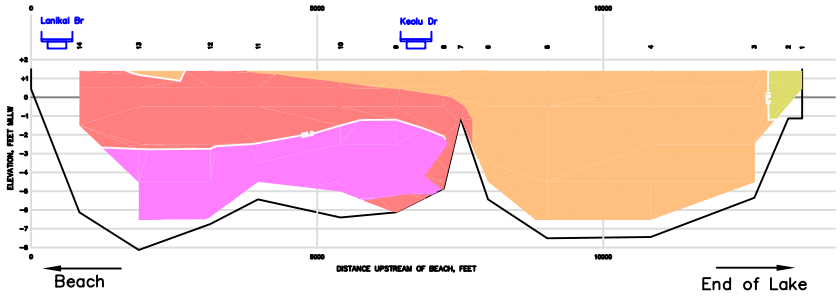
Transect 9/26/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.50 FT; Sample Date: 09/26/2013
Post-Berm Opening (opened on 09/23/2013)

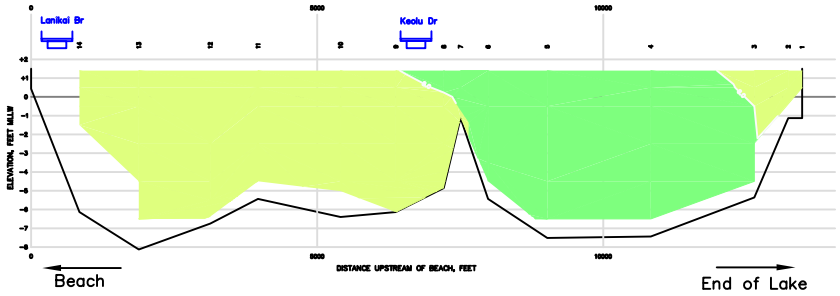
Temperature



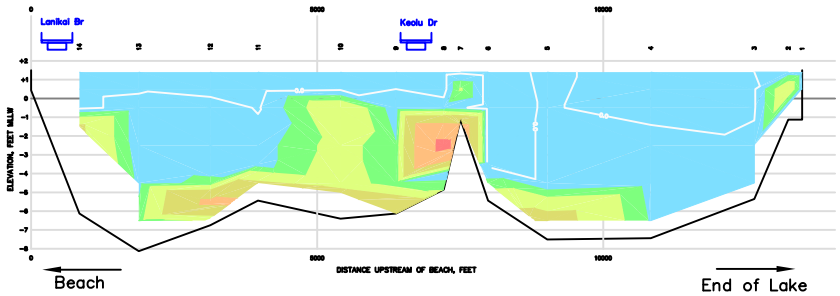
Salinity



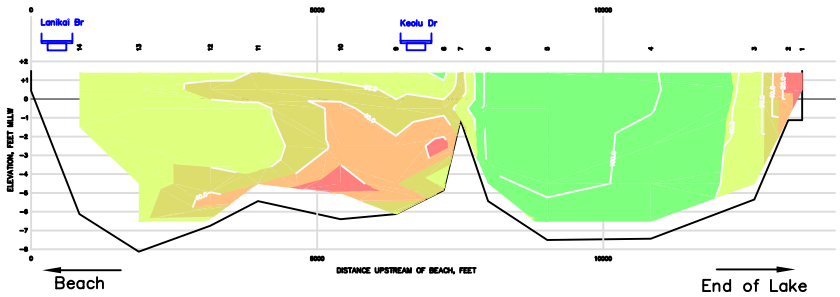
pH



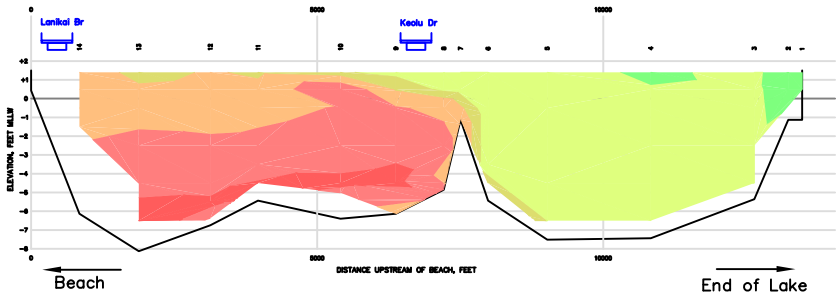
NTU



DO



Exchange



Kawainui

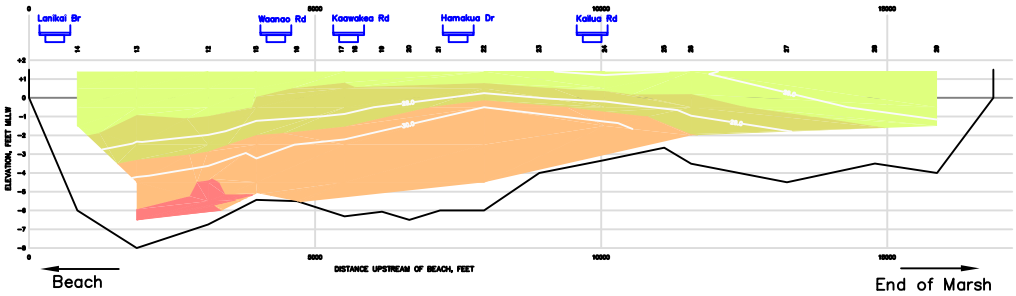
<Previous Stream Opening
9/16/13

Next Stream Opening>
10/22/13

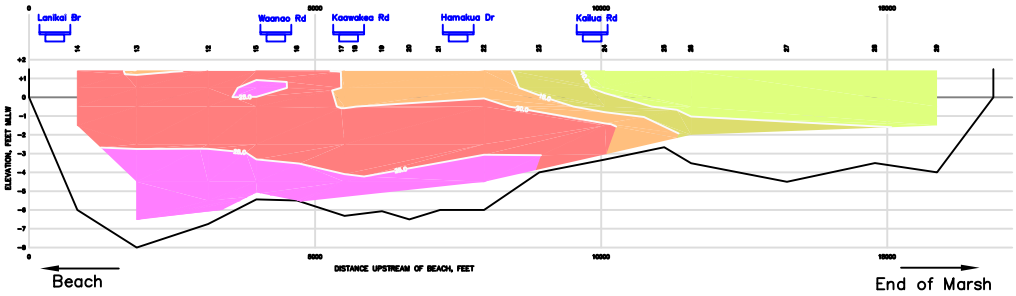
Transect 9/26/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.50 FT; Sample Date: 09/26/2013
Post-Berm Opening (opened on 09/23/2013)

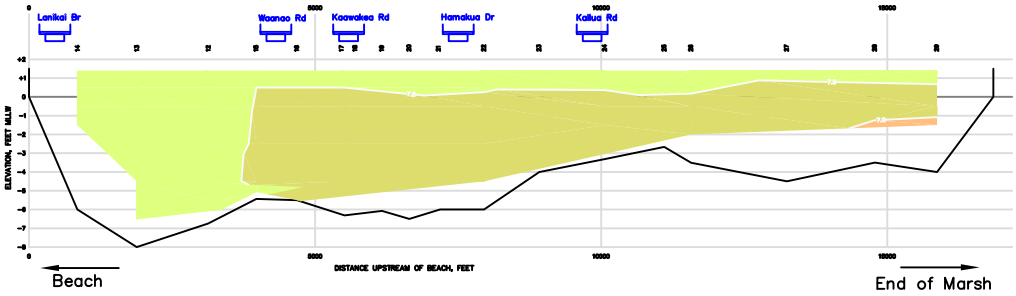
Temperature



Salinity



pH



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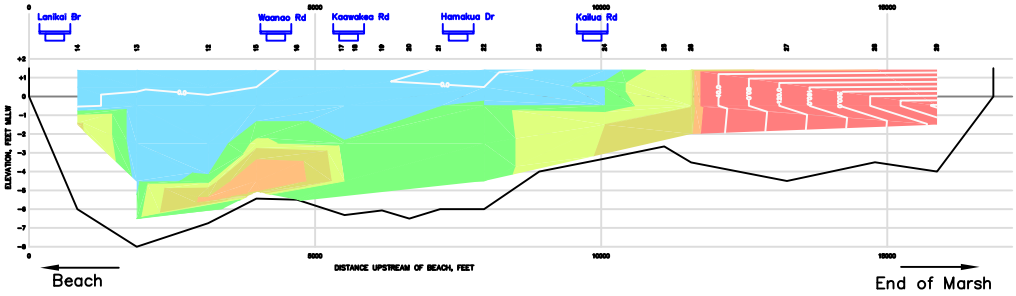

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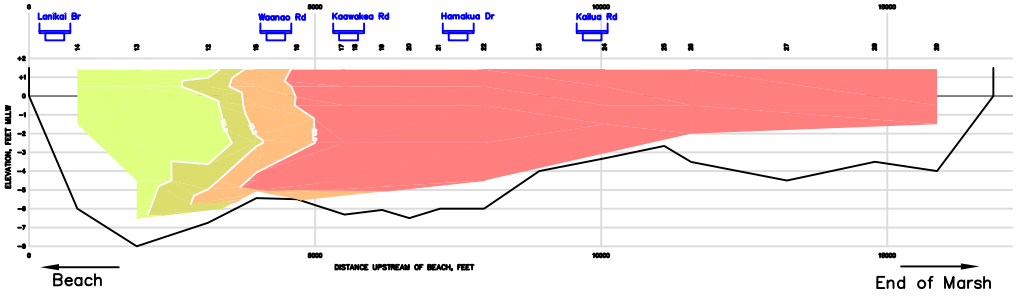

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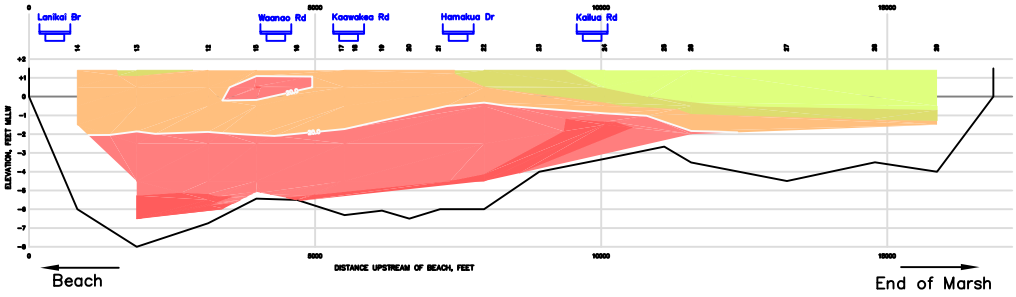
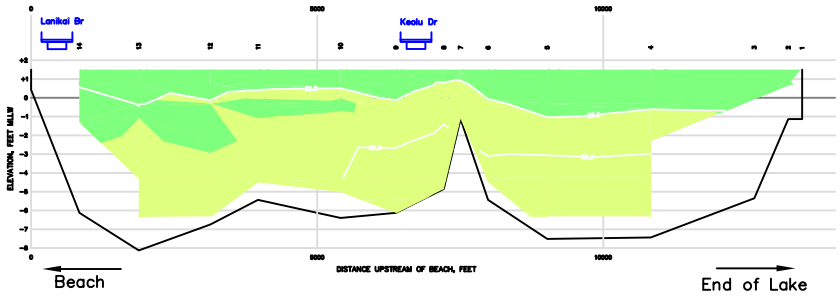


Kaelepulu

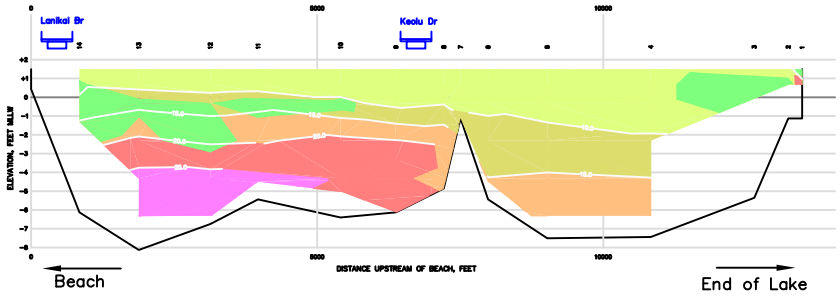
Transect 11/16/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.69 FT; Sample Date: 11/16/2013
Pre-Berm Opening (opened on 11/19/2013)

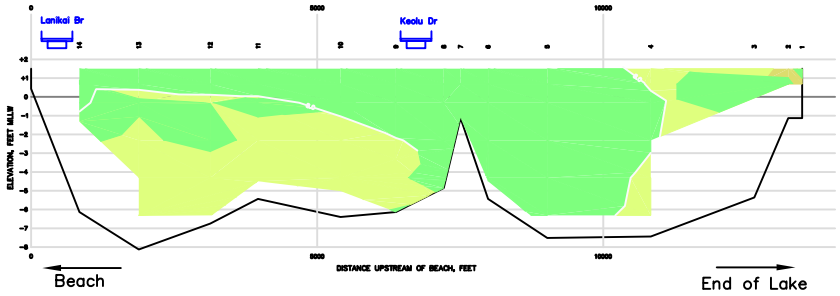
Temperature



Salinity



pH



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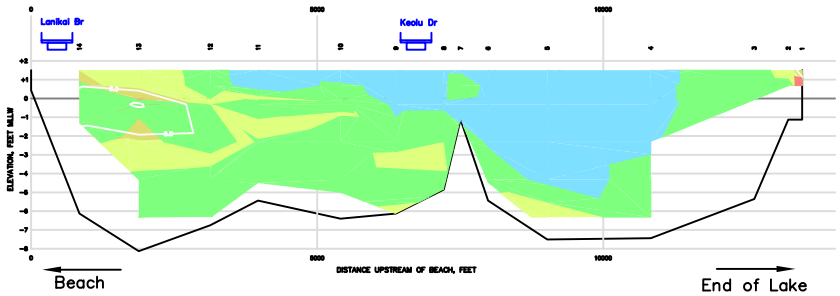

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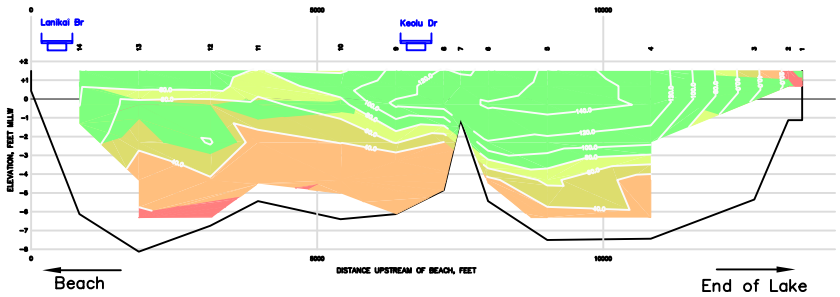
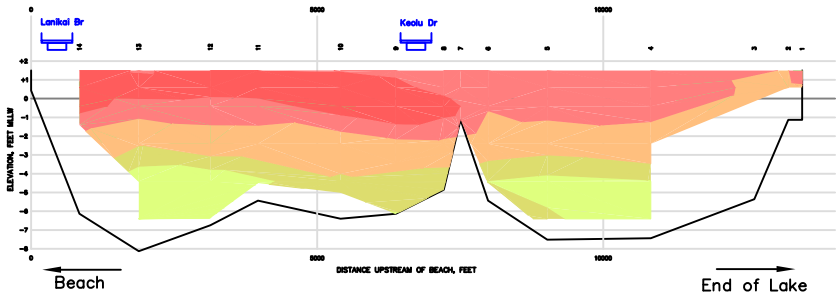


Exchange



Kawainui

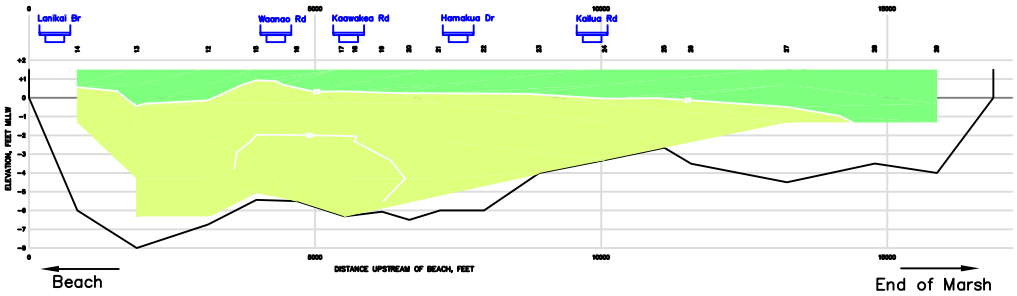
Transect 11/16/13

<Previous Stream Opening
11/10/13

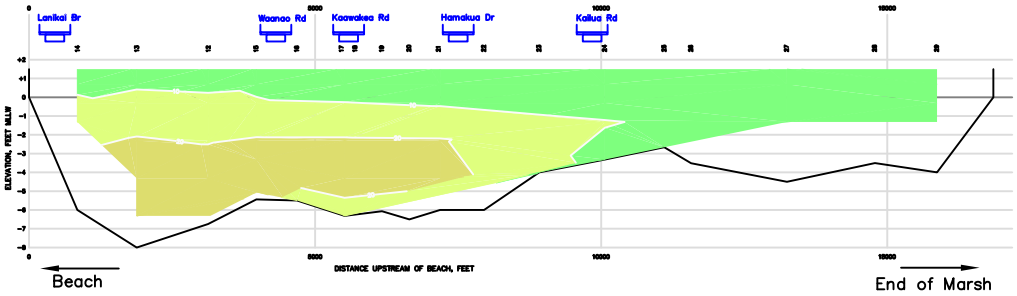
Next Stream Opening>
11/19/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.69 FT; Sample Date: 11/16/2013
Pre-Berm Opening (opened on 11/19/2013)

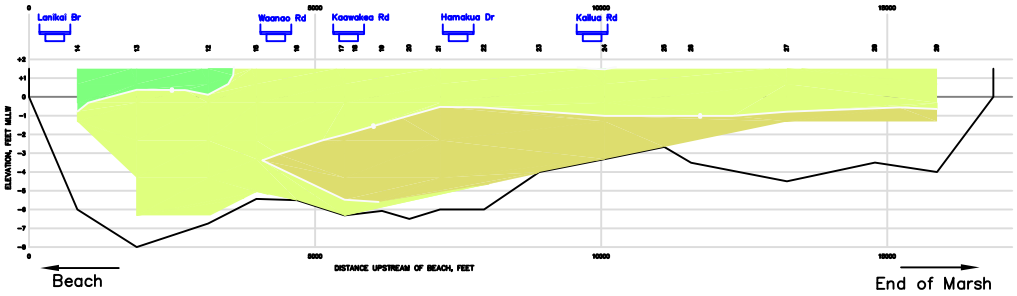
Temperature



Salinity



pH



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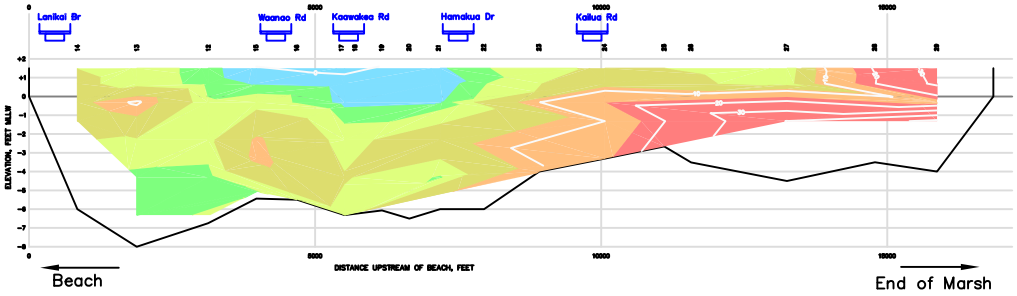
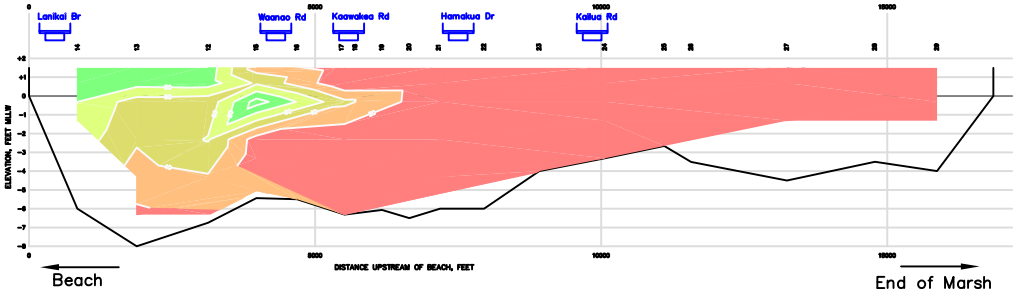
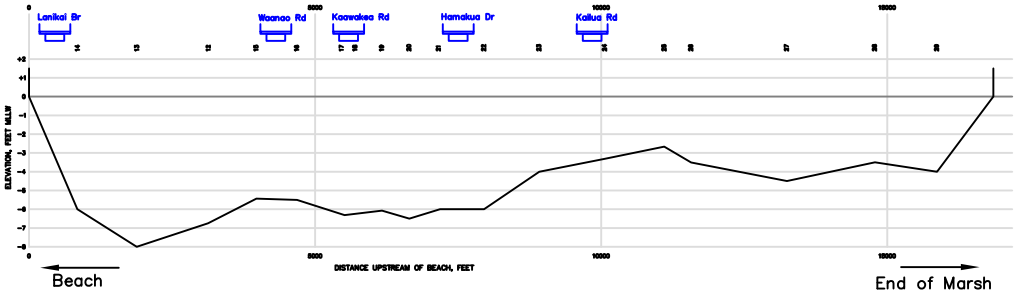


DO



Exchange

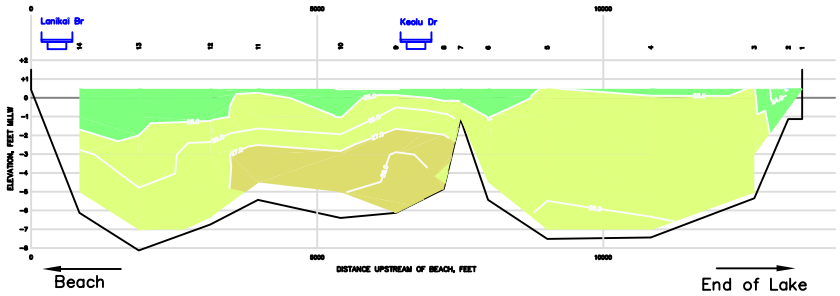


Kaelepulu

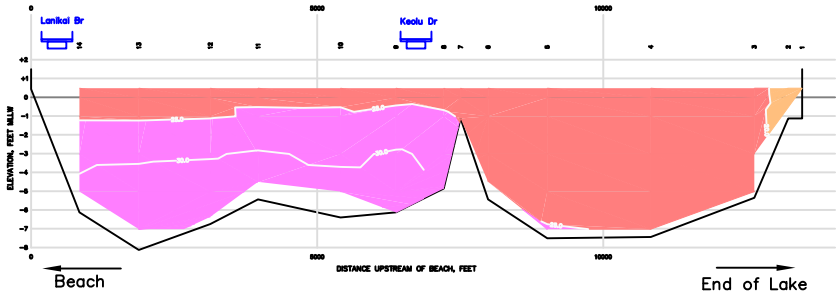
Transect 11/29/13

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 0.98 FT; Sample Date: 11/29/2013
Post-Berm Opening (opened on 11/19/2013)

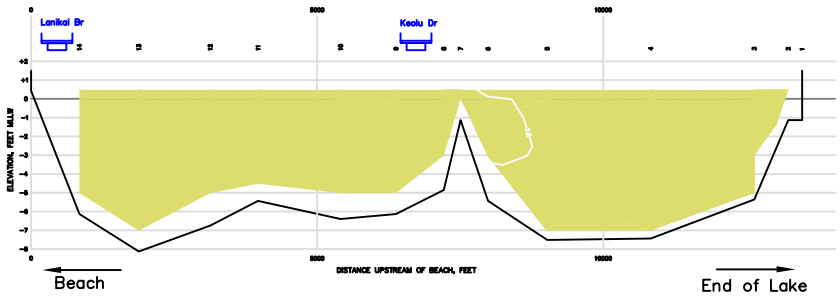
Temperature



Salinity



pH



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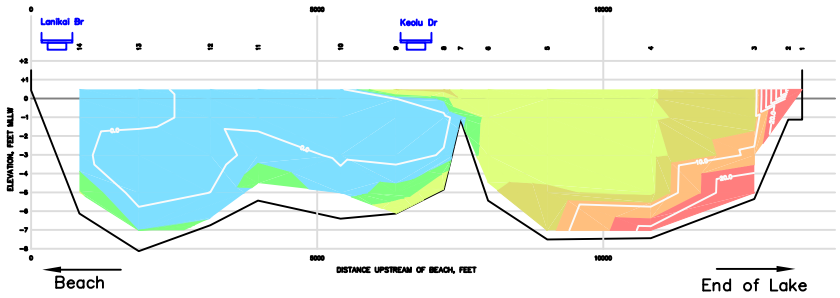

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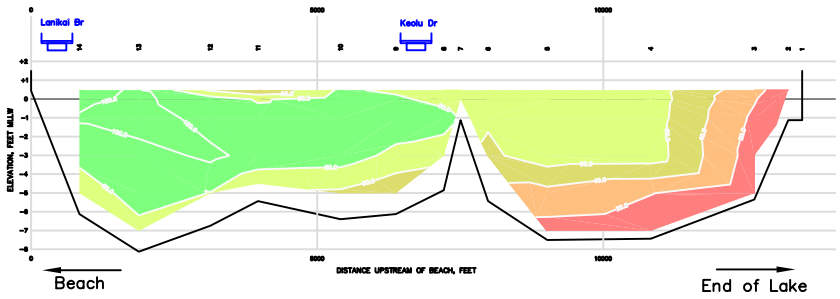
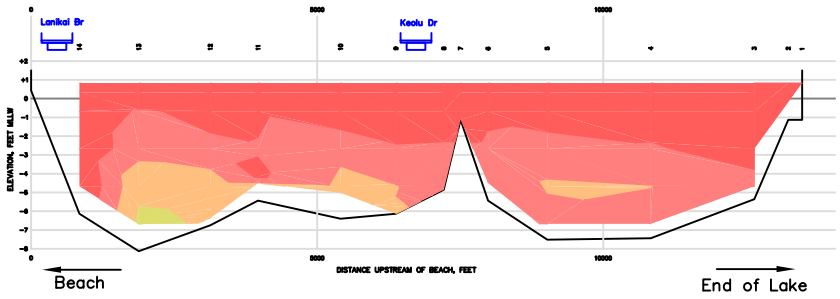


Exchange



Kawainui

Transect 11/29/13

<Previous Stream Opening
11/19/13

Next Stream Opening>
12/1/13

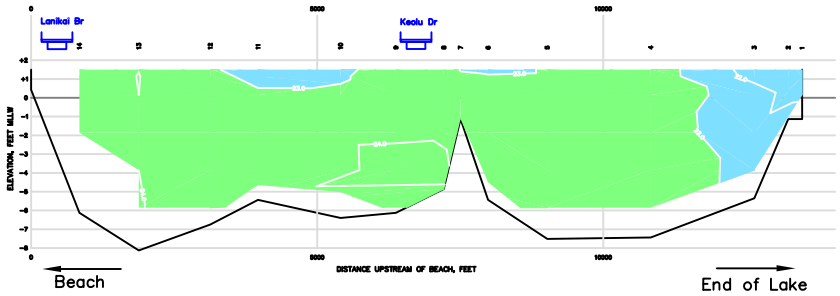
No Data Collected

Kaelepulu

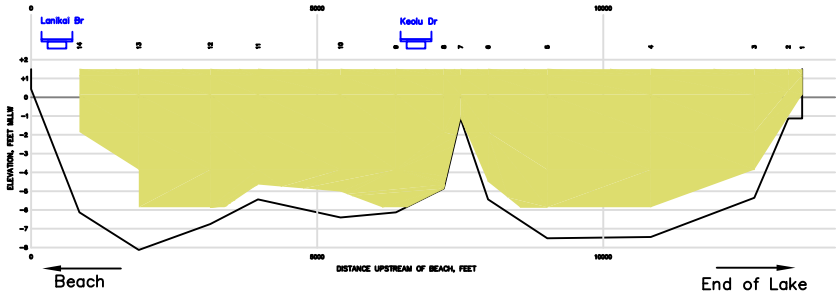
Transect 1/23/14

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 2.15 FT; Sample Date: 1/23/2014
Pre-Berm Opening (opened on 1/28/2014)

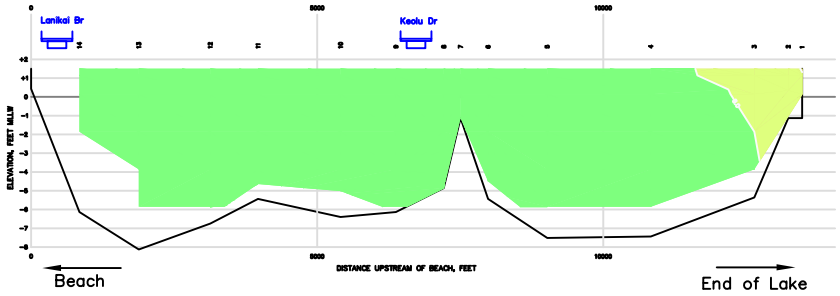
Temperature



Salinity



pH



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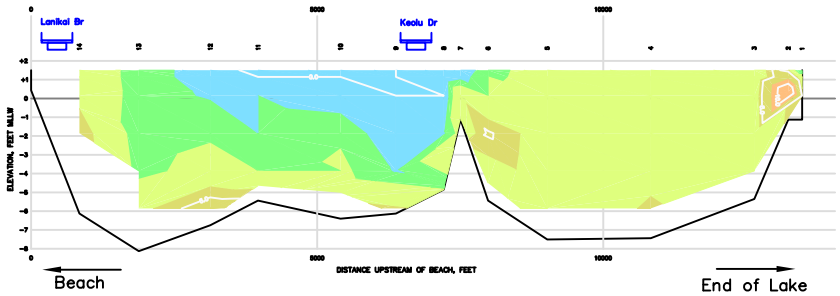

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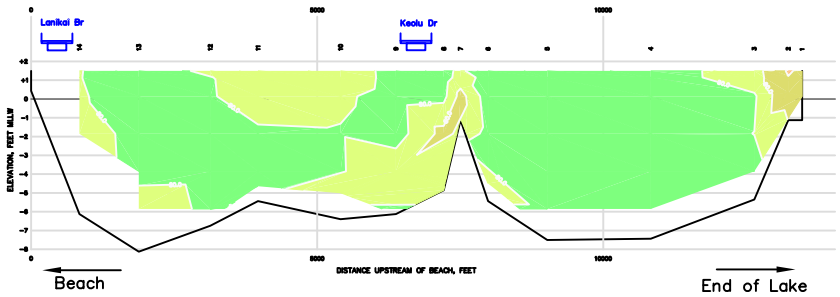
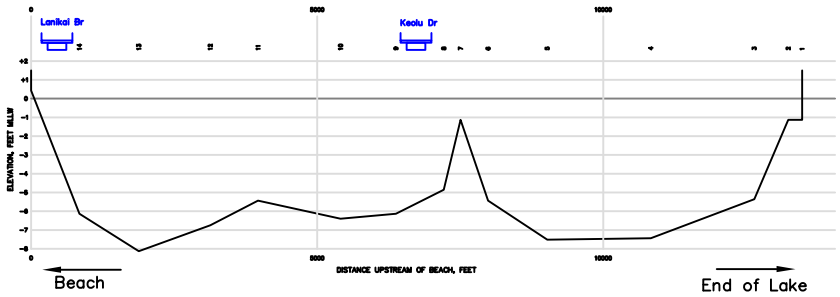


Exchange



Kawainui

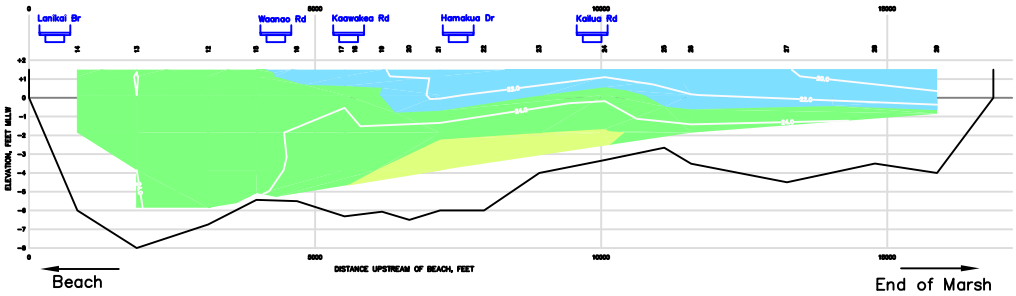
<Previous Stream Opening
12/1/13

Next Stream Opening>
1/28/14

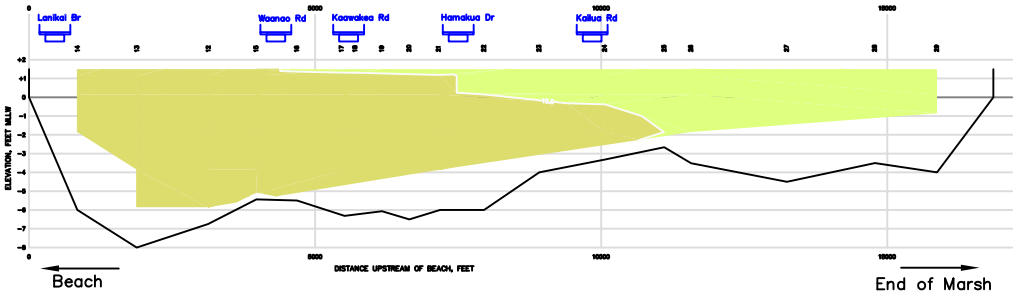
Transect 1/23/14

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 2.15 FT; Sample Date: 1/23/2014
Pre-Berm Opening (opened on 1/29/2014)

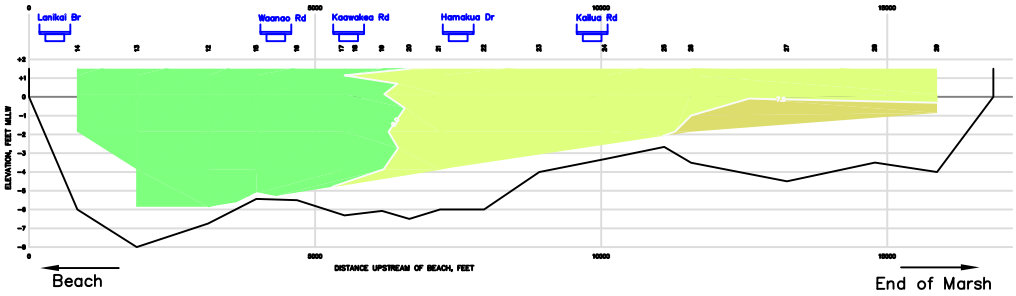
Temperature



Salinity



pH



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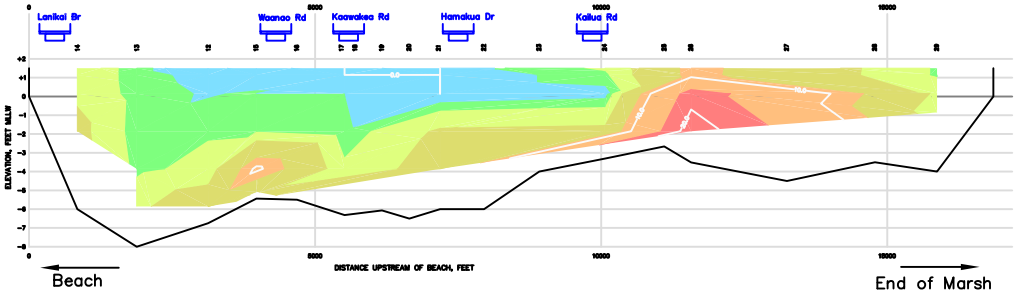

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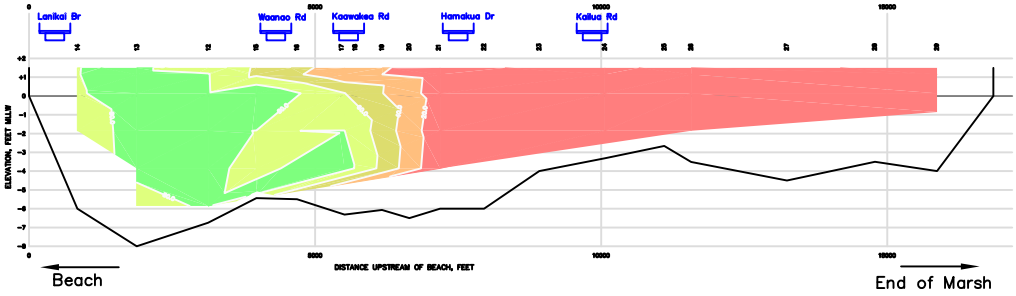
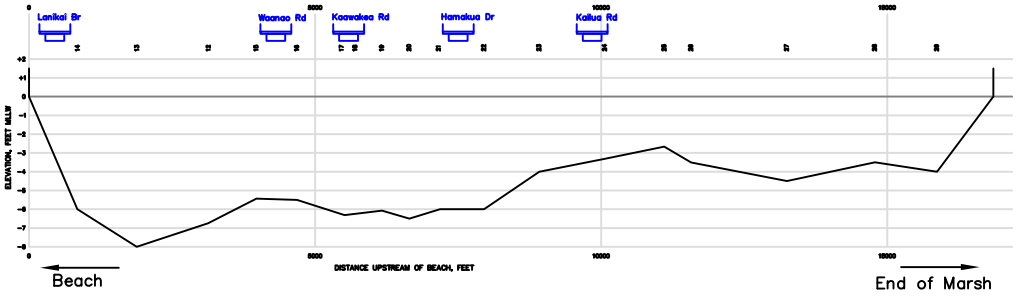


Exchange

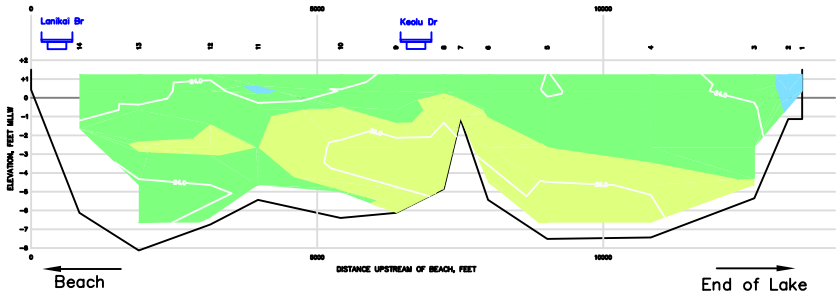


Kaelepulu

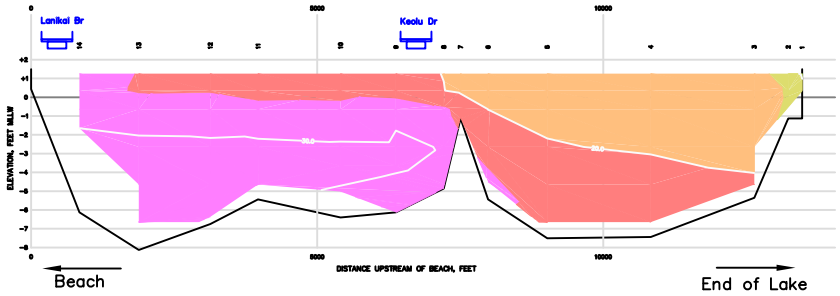
Transect 2/15/14

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.35 FT; Sample Date: 2/15/2014
Post-Berm Opening (opened on 1/28/2014)

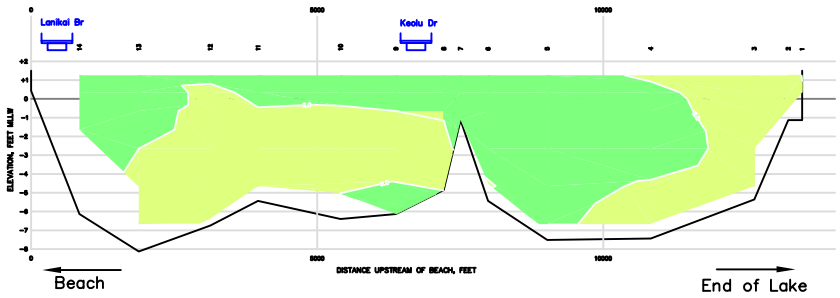
Temperature



Salinity



pH



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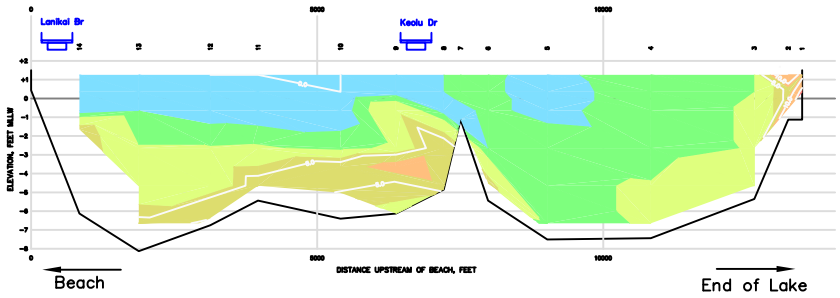

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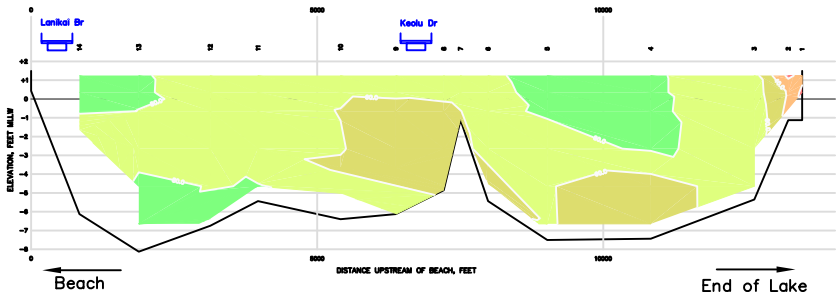
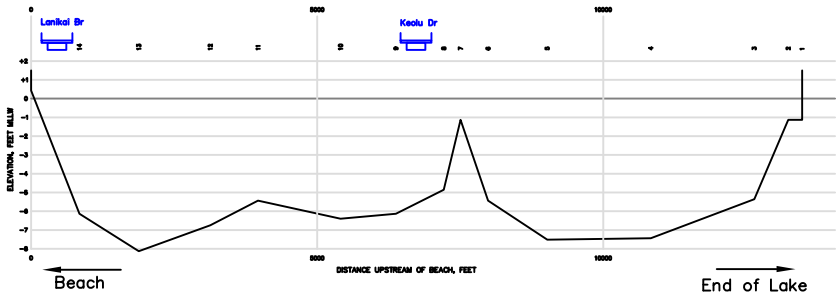


Exchange



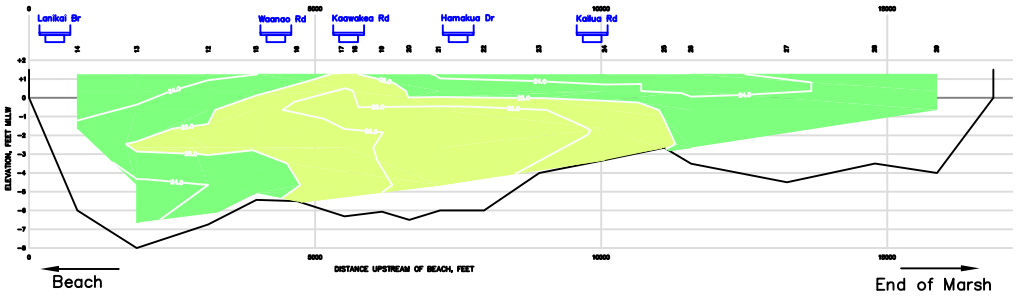
Kawainui

<Previous Stream Opening
1/28/14

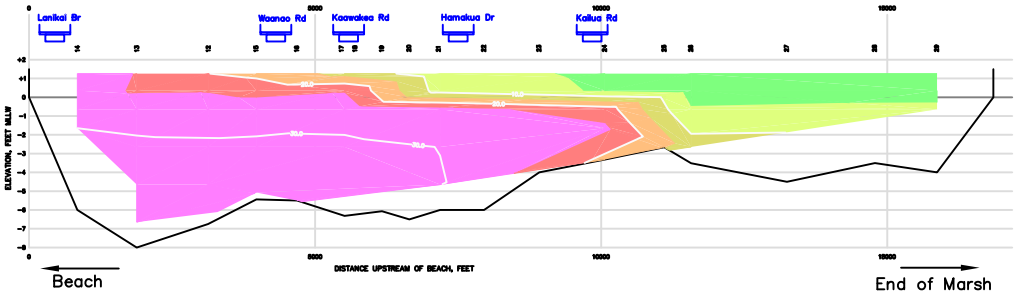
Transect 2/15/14

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 2
WSE = 1.35 FT; Sample Date: 2/15/2014
Post-Berm Opening (opened on 1/28/2014)

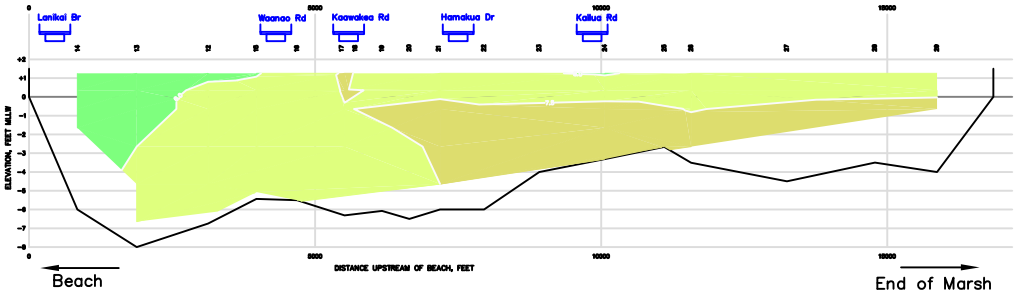
Temperature



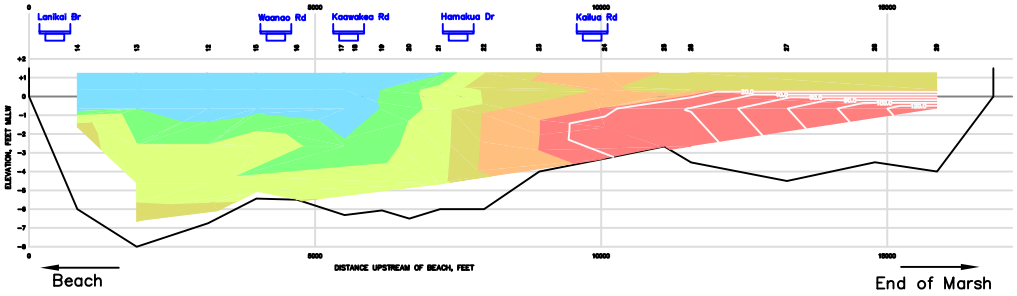
Salinity



pH



NTU



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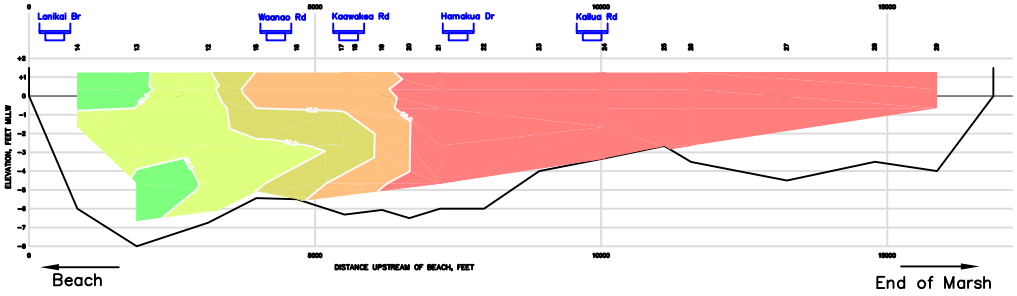
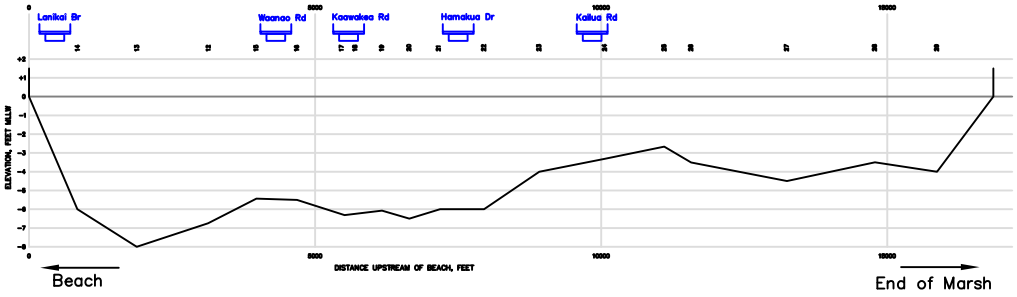


Exchange



Appendix E

2015 Experiment
Water Quality Transects

The graphics in this appendix depict the results of physical water quality surveys through both branches of the estuary. Each survey was conducted beginning at dawn at the Kaelepulu wetland and was generally completed within 3 hours ending at the terminus of Kawainui Stream. The left hand page represents results from the Kaelepulu branch and the right hand page from the Kawainui branch. A color key may be found as a fold-out page at the end of the appendices.

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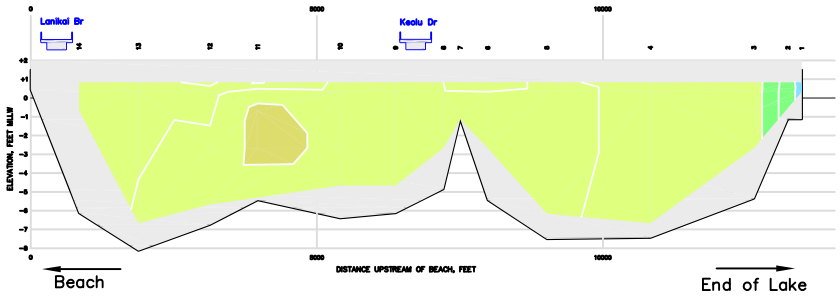
Kaelepulu

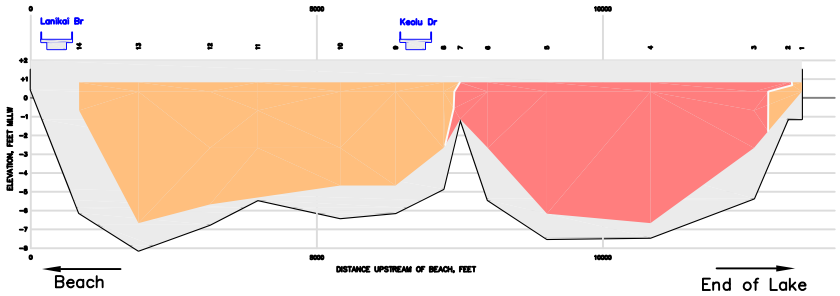
Transect 5/18/15

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.33 FT; Sample Date: 5/18/2015
Pre-Berm Opening (opened on 5/19/2015)

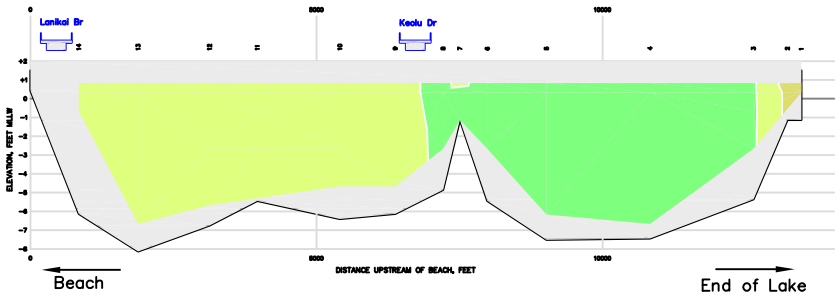
Temperature



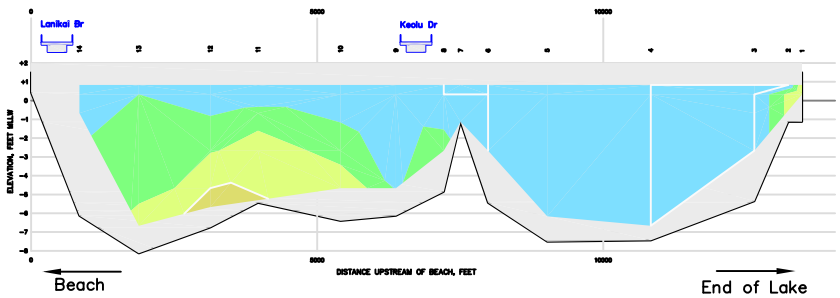
Salinity



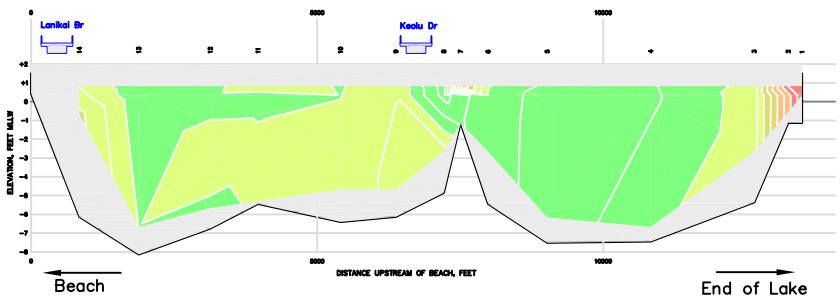
pH



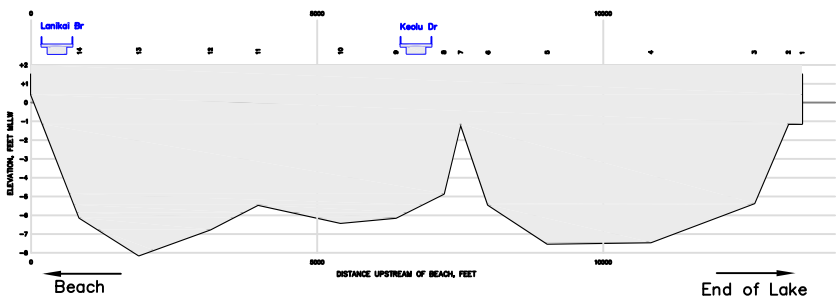
NTU



DO



Exchange



Kawainui

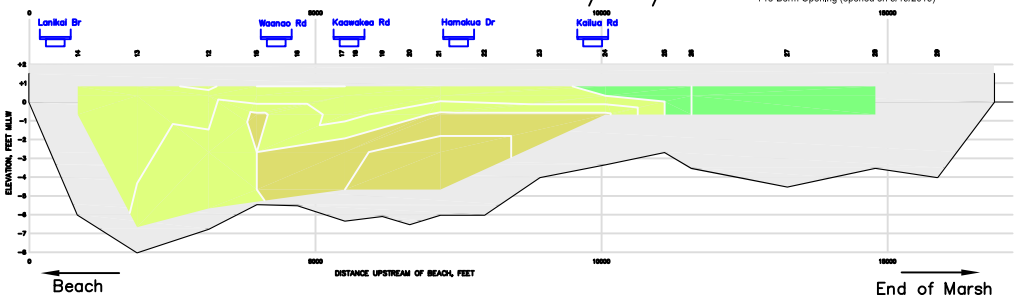
Transect 5/18/15

<Previous Stream Opening
5/16/15

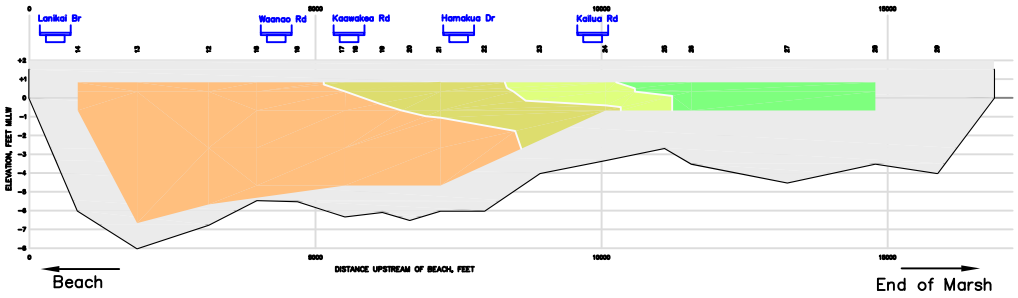
Next Stream Opening>
6/15/15

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 1.33 FT; Sample Date: 5/18/2015
Pre-Berm Opening (opened on 5/19/2015)

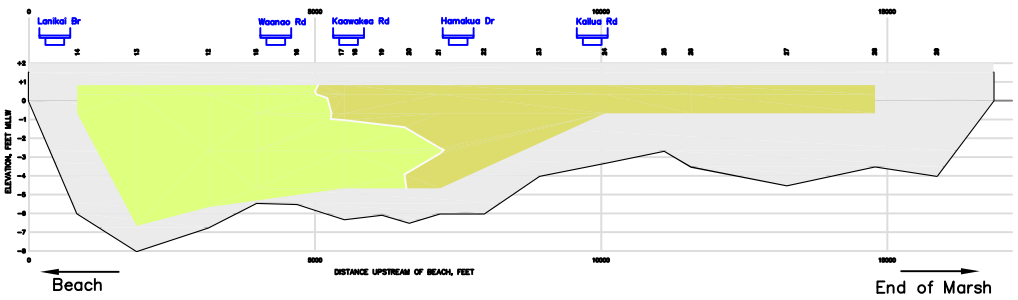
Temperature



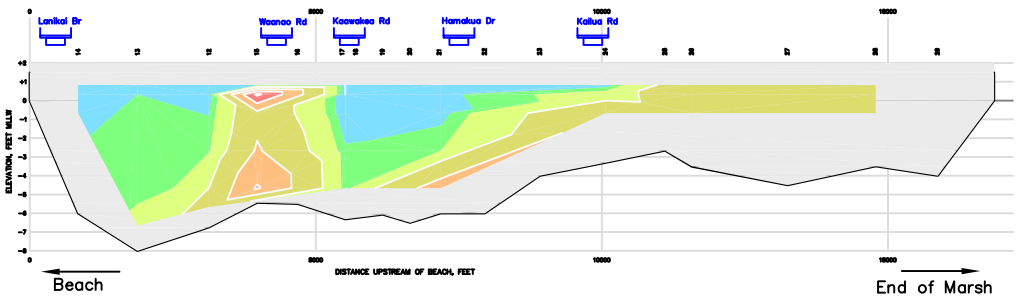
Salinity



pH



NTU



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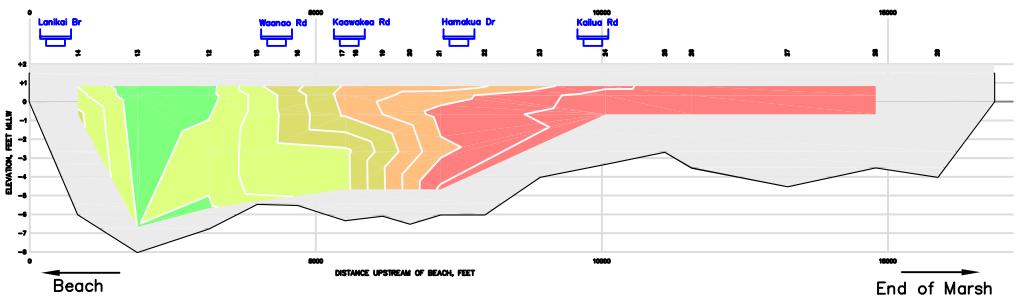
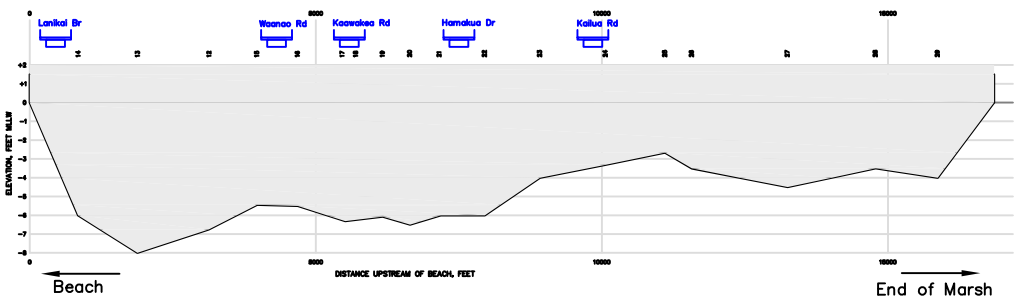


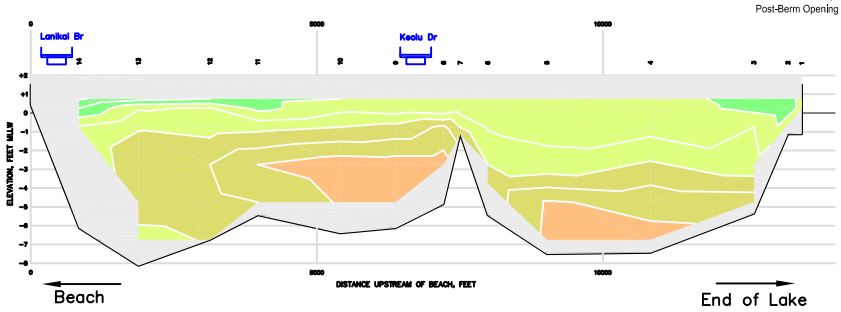
Exchange



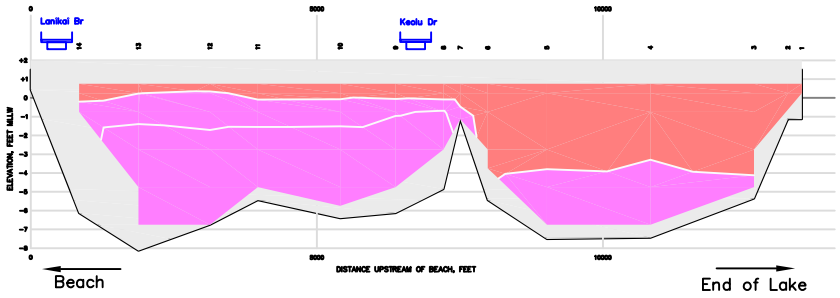
Kaelepulu

Transect 5/26/15

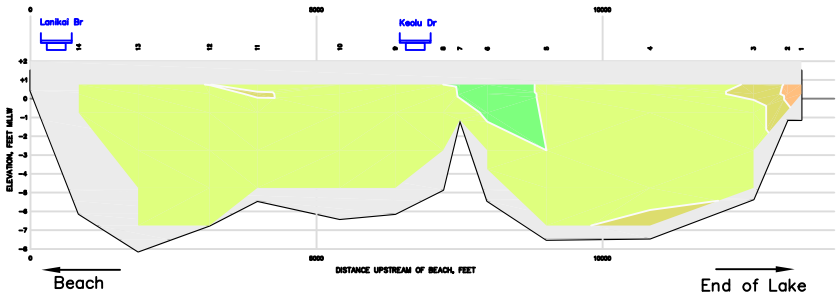
Temperature



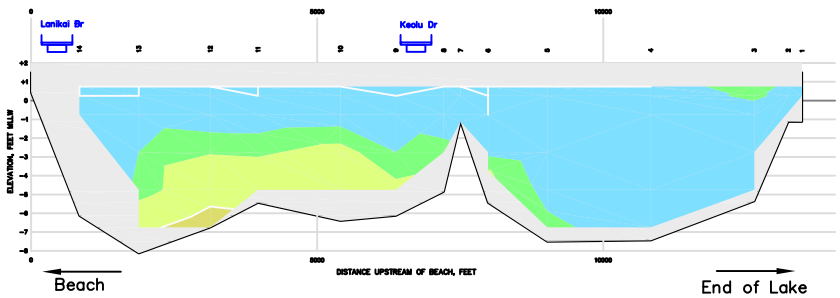
Salinity



pH



NTU



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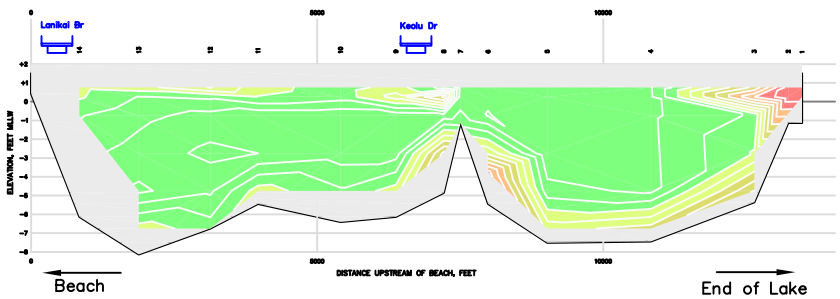

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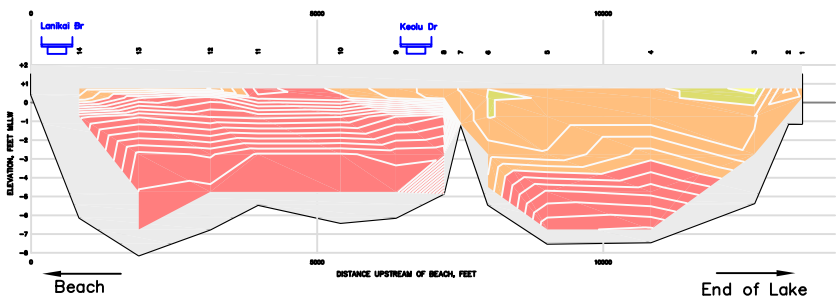


Kawainui

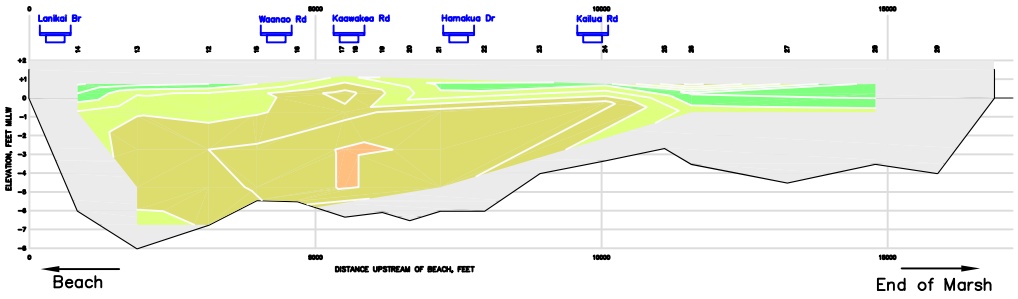
Transect 5/26/15

<Previous Stream Opening
5/16/15

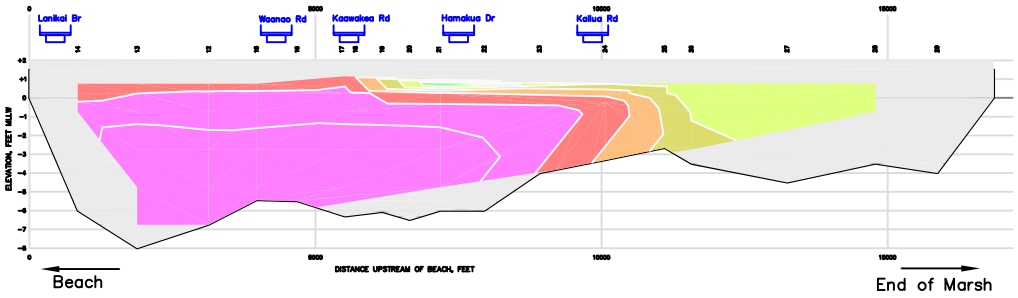
Next Stream Opening>
6/15/15

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 1.25 FT; Sample Date: 5/26/2015
Post-Berm Opening (opened on 5/19/2015)

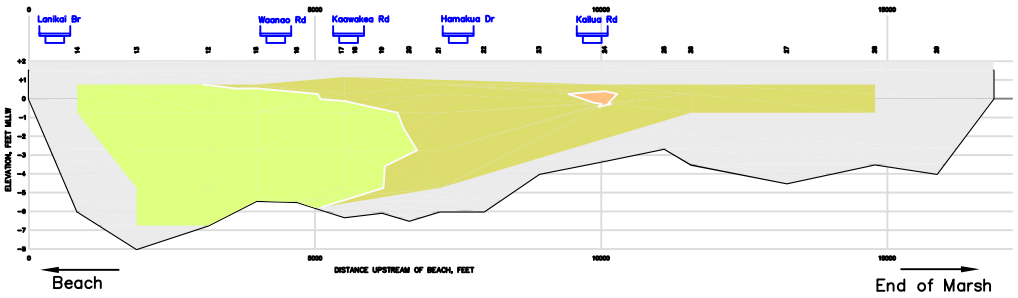
Temperature



Salinity



pH



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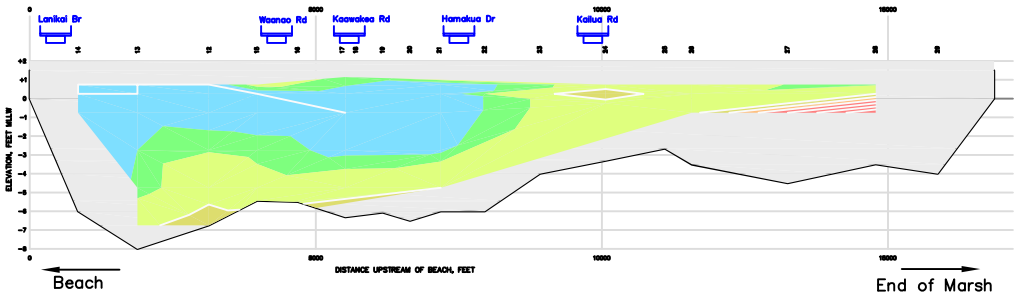

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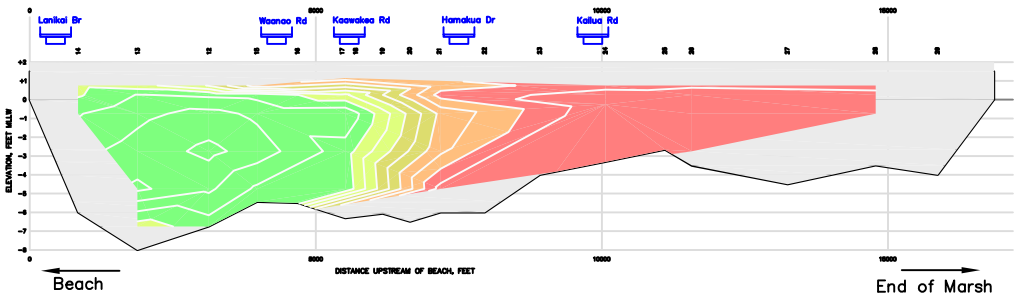
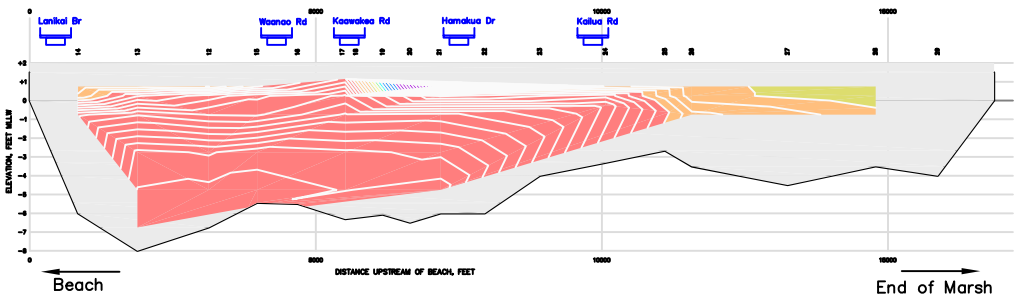


Exchange

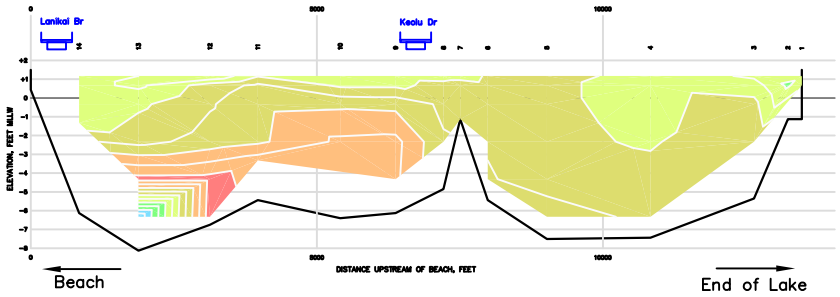


Kaelepulu

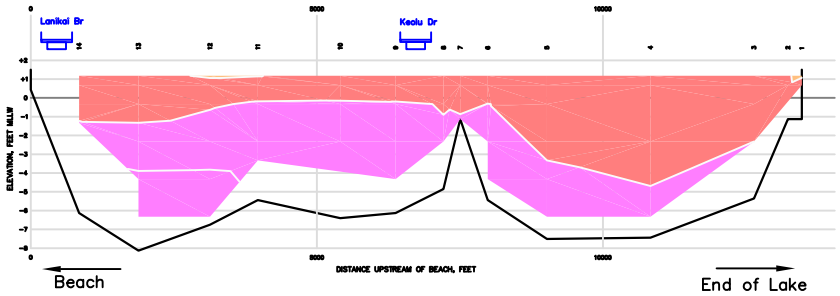
Transect 6/4/15

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.68 FT; Sample Date: 6/04/2015
Pre-Berm Opening (opened on 6/17/2015)

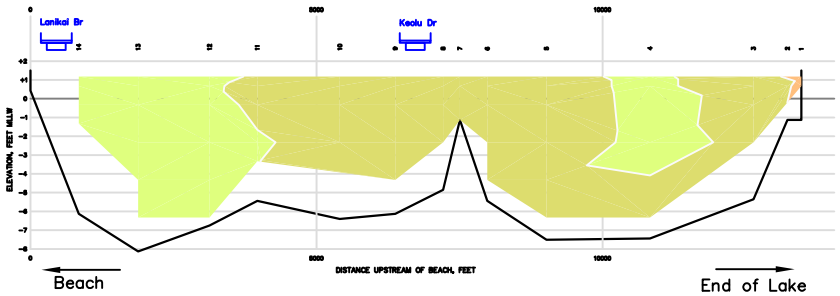
Temperature



Salinity



pH



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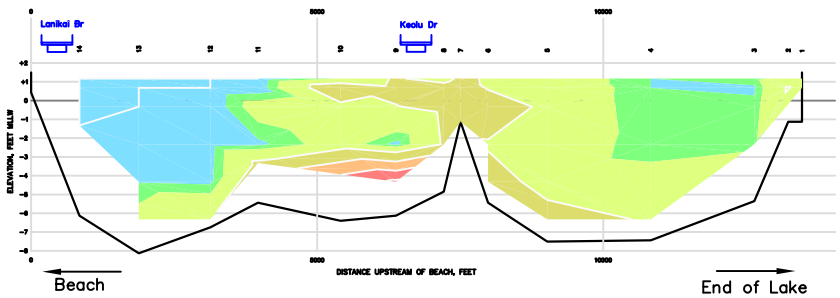

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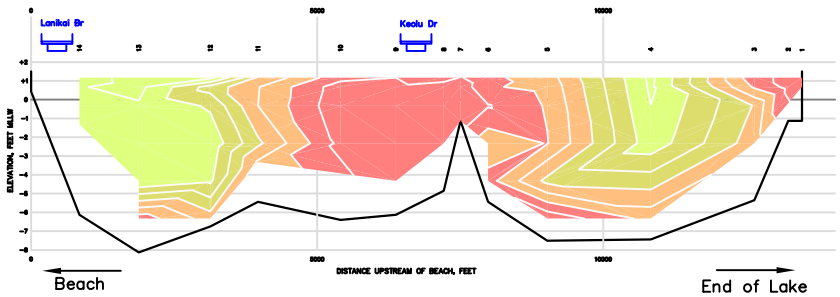

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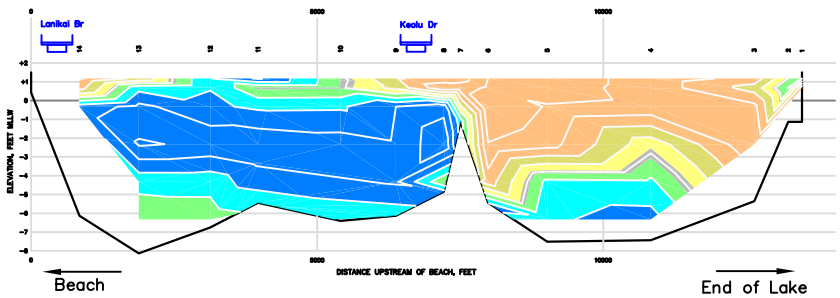


Kawainui

Transect 6/4/15

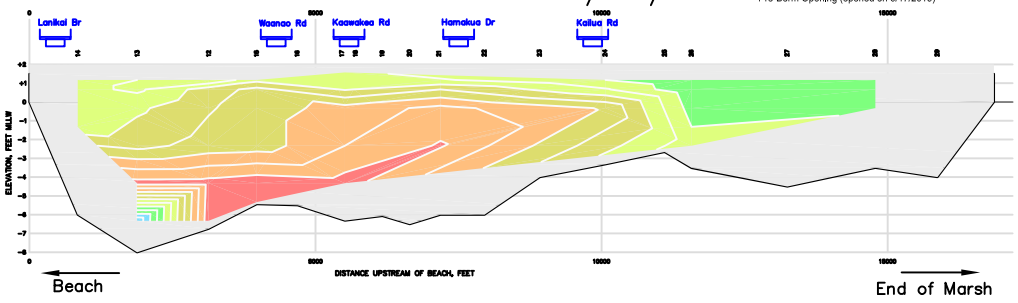
<Previous Stream Opening 5/16/15

Next Stream Opening> 6/15/15

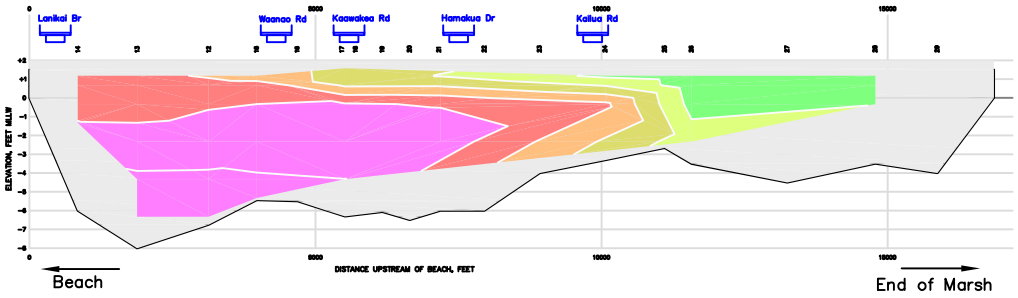
Syphon Flowing (Primed 5/27/15)

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 1.68 FT; Sample Date: 6/04/2015
Pre-Berm Opening (opened on 6/17/2015)

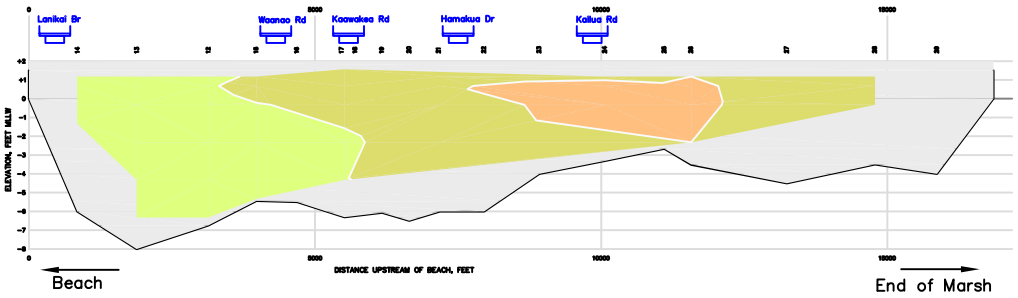
Temperature



Salinity



pH



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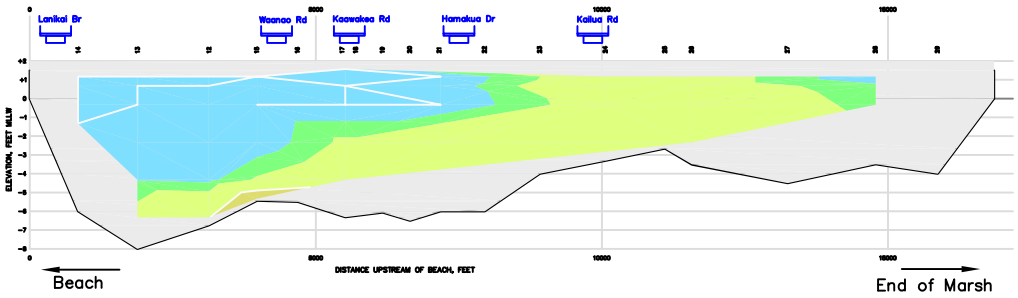

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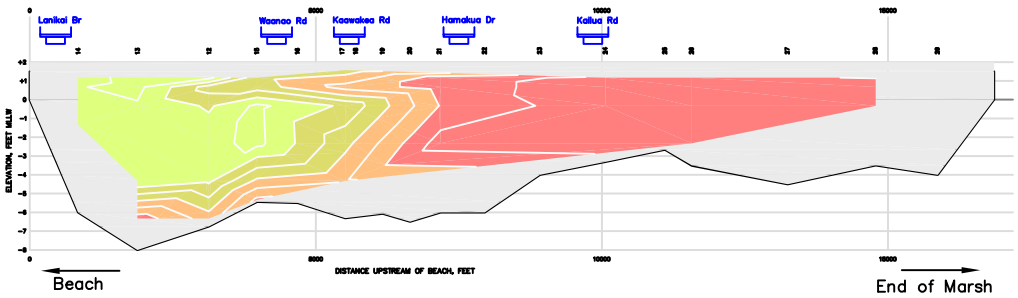
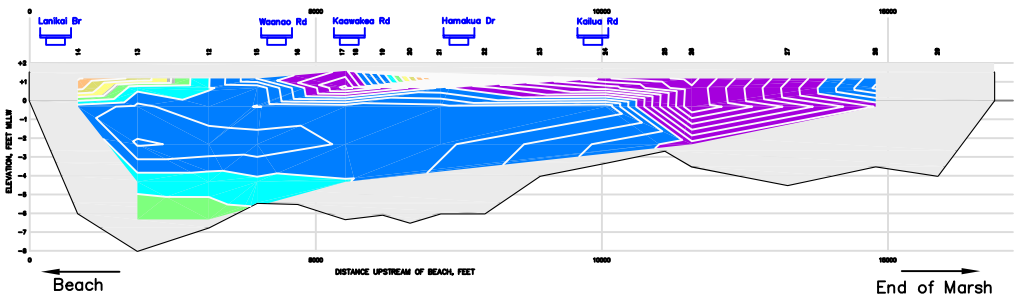


Exchange

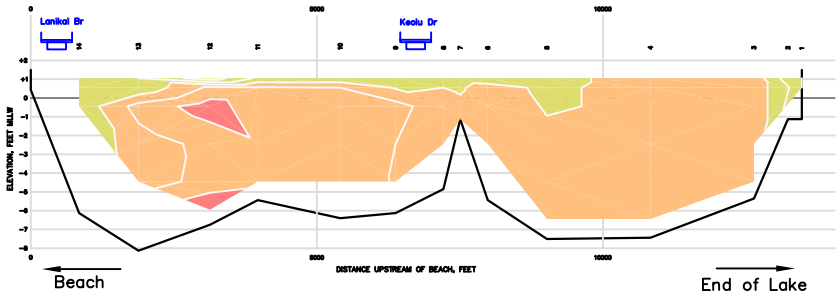


Kaelepulu

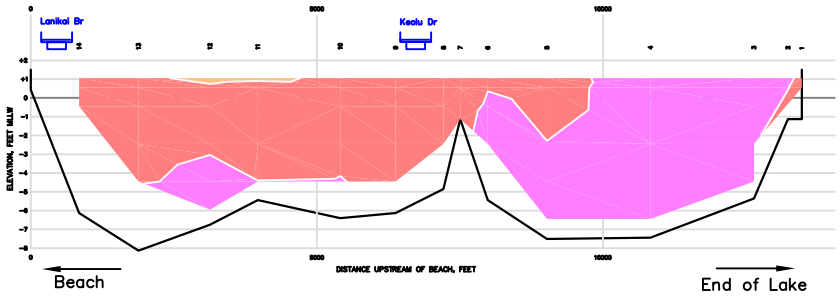
Transect 6/14/15

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.55 FT; Sample Date: 6/14/2015
Pre-Berm Opening (opened on 6/17/2015)

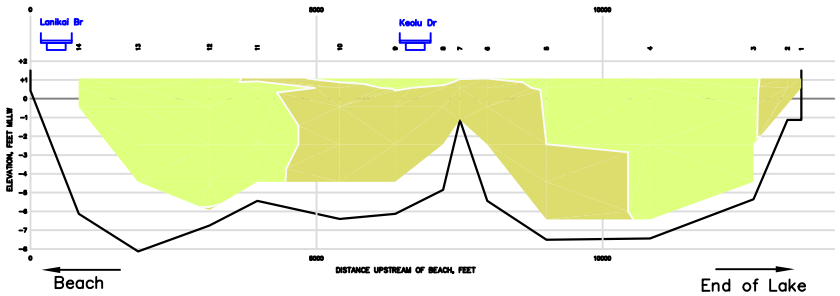
Temperature



Salinity



pH



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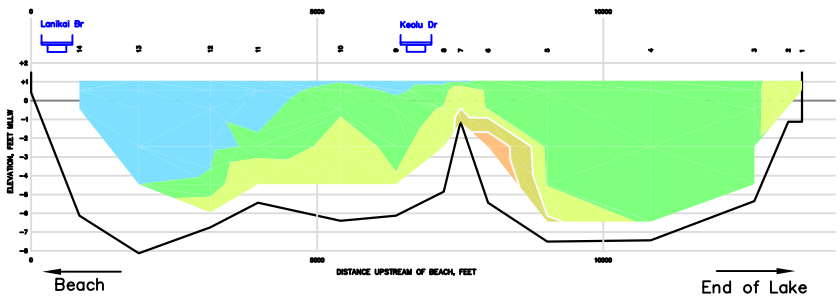
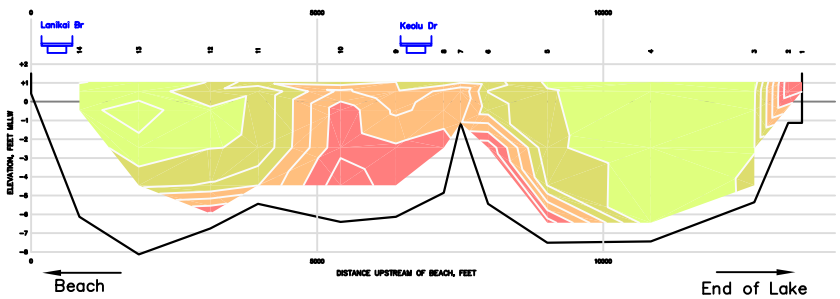
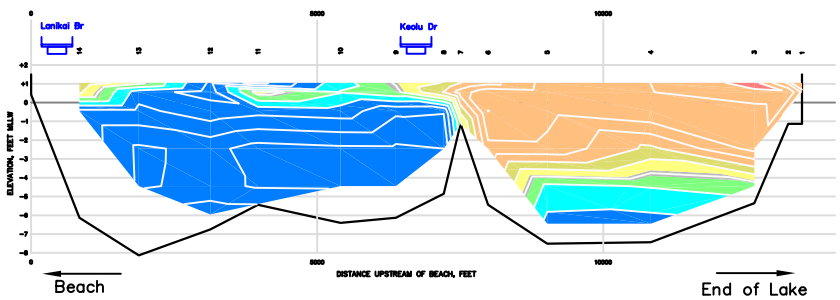


DO



Exchange



Kawainui

Transect 6/14/15

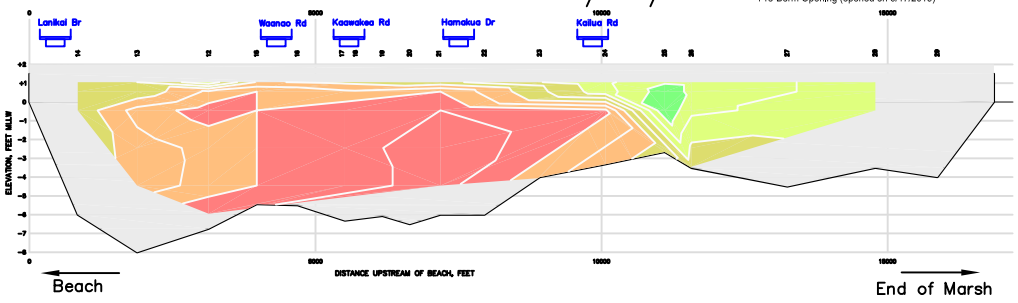
<Previous Stream Opening
5/16/15

Syphon Flowing (Primed 5/27/15)

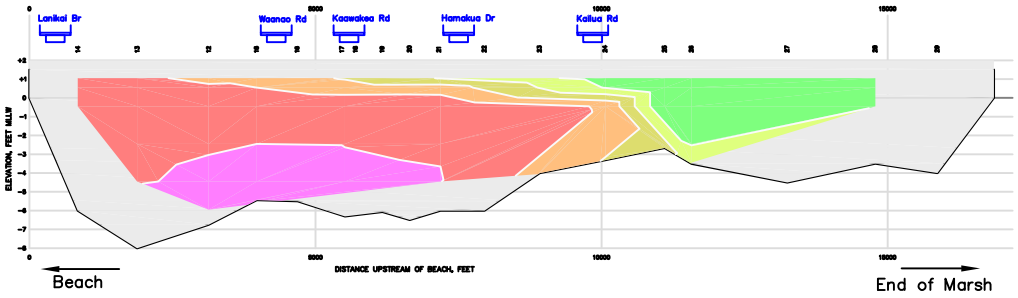
Next Stream Opening>
6/15/15

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 1.55 FT; Sample Date: 6/14/2015
Pre-Berm Opening (opened on 6/17/2015)

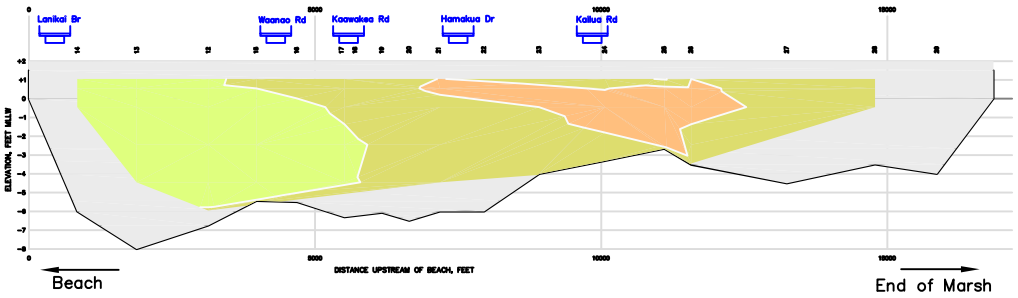
Temperature



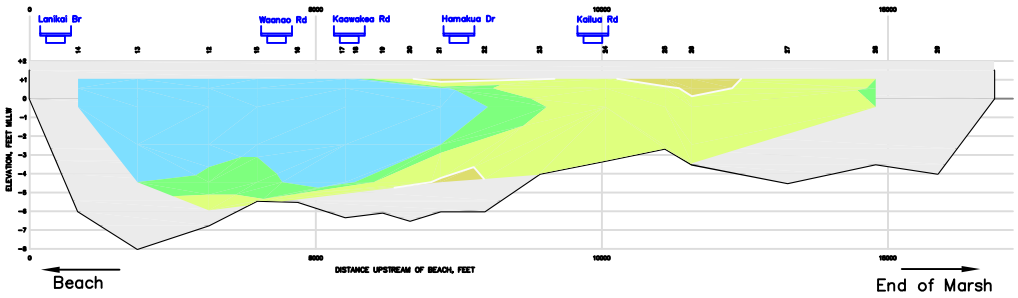
Salinity



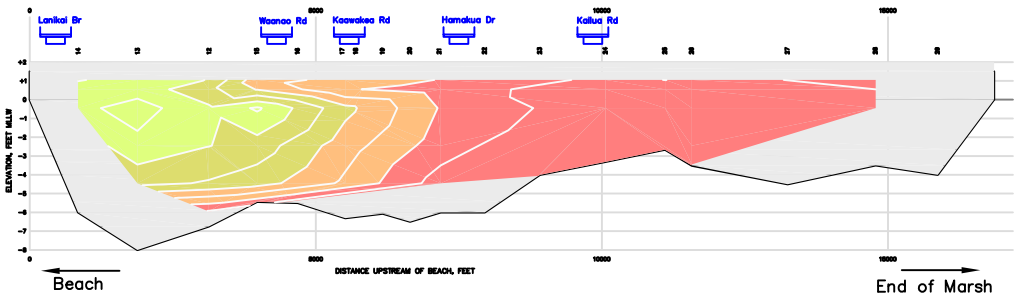
pH



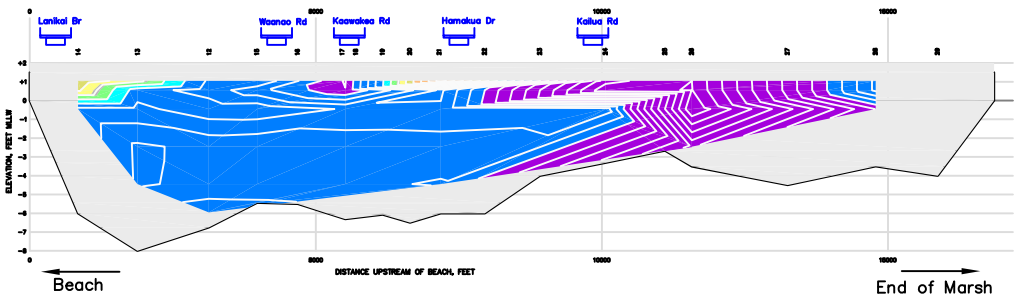
NTU



DO



Exchange

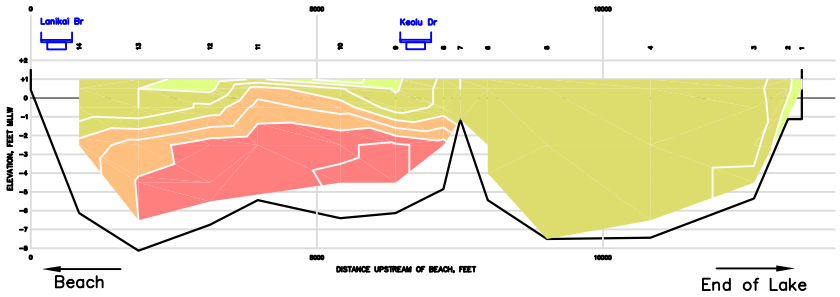


Kaelepulu

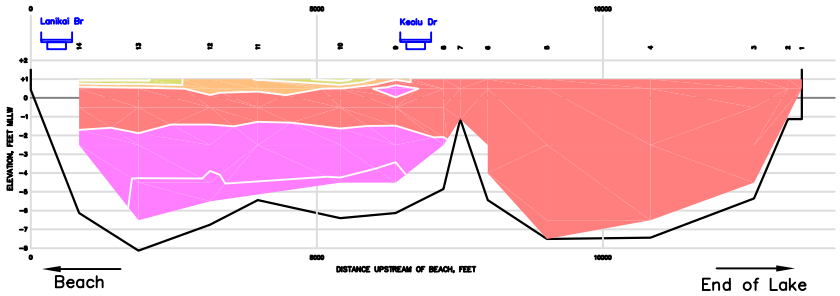
Transect 6/24/15

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 1.49 FT; Sample Date: 6/24/2015
Post-Berm Opening (opened on 6/17/2015)

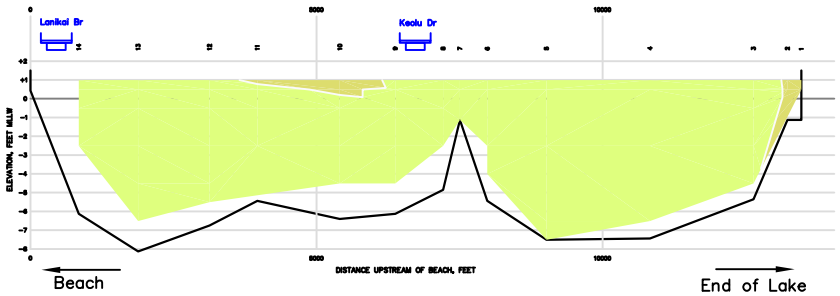
Temperature



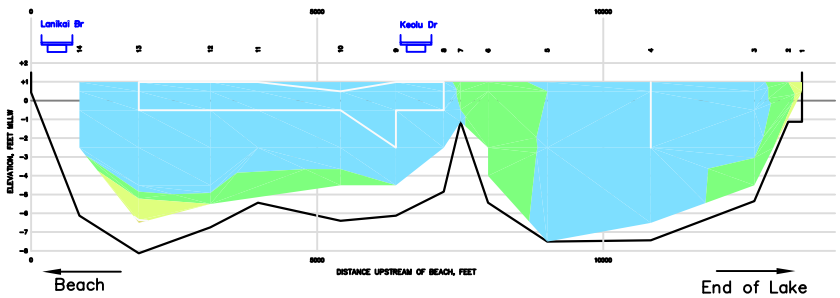
Salinity



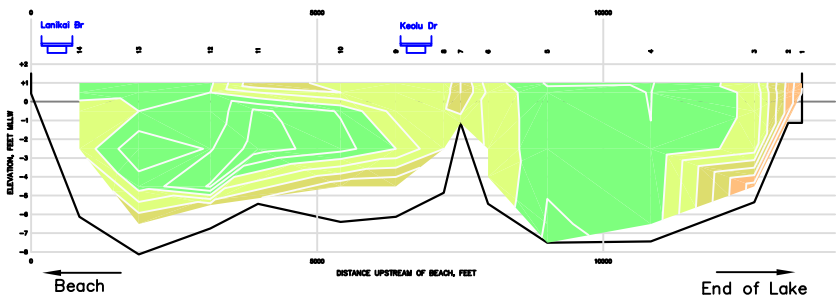
pH



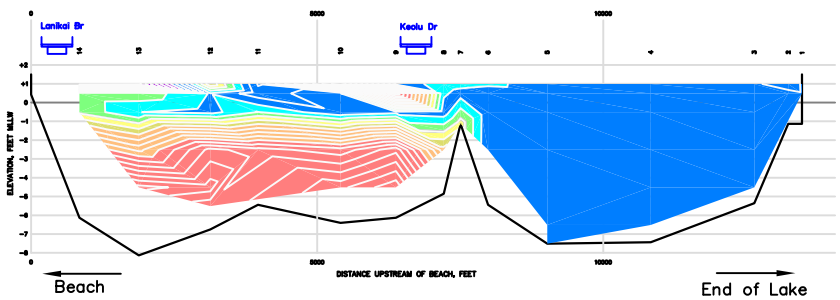
NTU



DO



Exchange



Kawainui

Transect 6/24/15

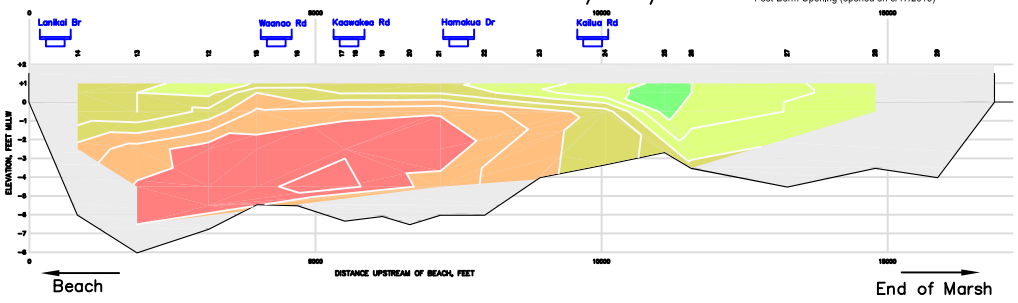
<Previous Stream Opening
6/15/15

Syphon Flowing (Primed 5/27/15)

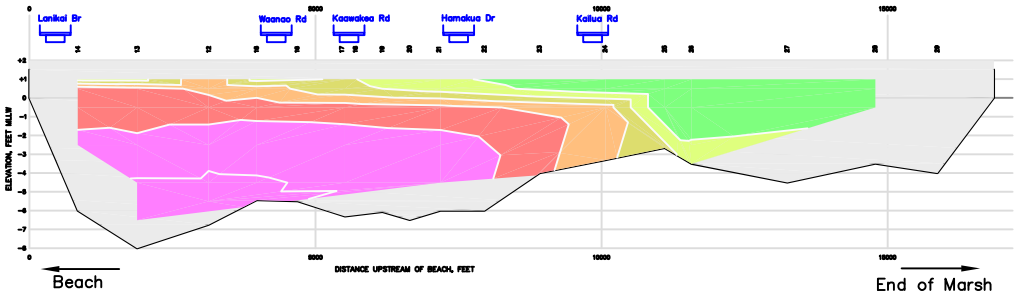
Next Stream Opening>
7/14/15

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 1.49 FT; Sample Date: 6/24/2015
Post-Berm Opening (opened on 6/17/2015)

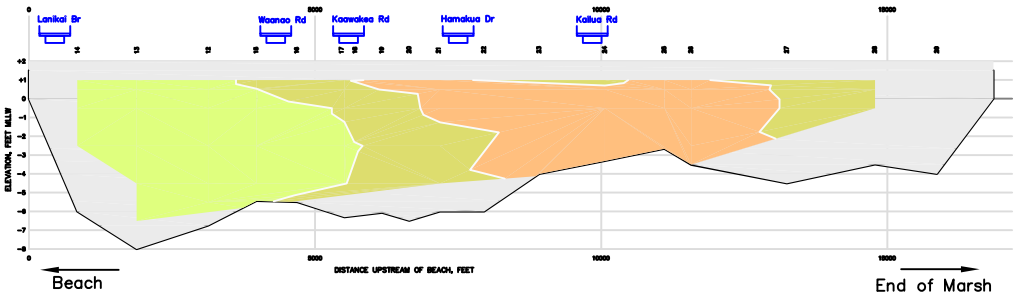
Temperature



Salinity



pH



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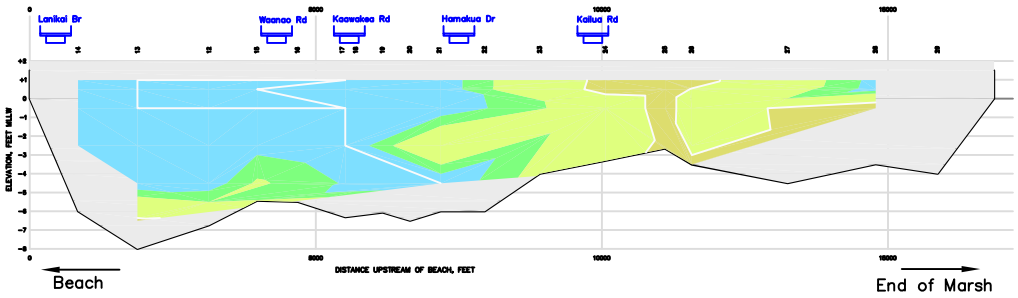
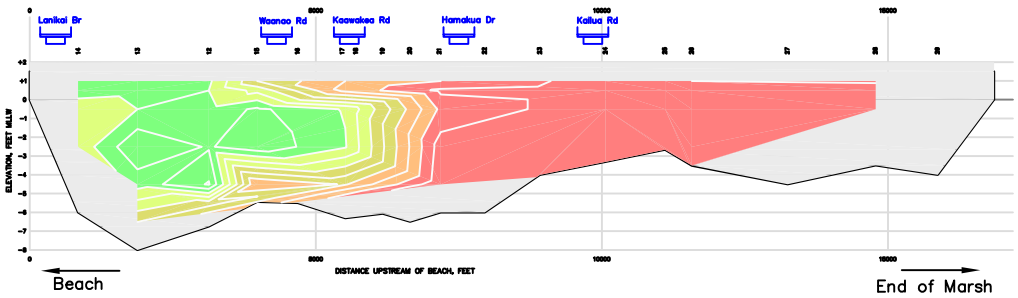
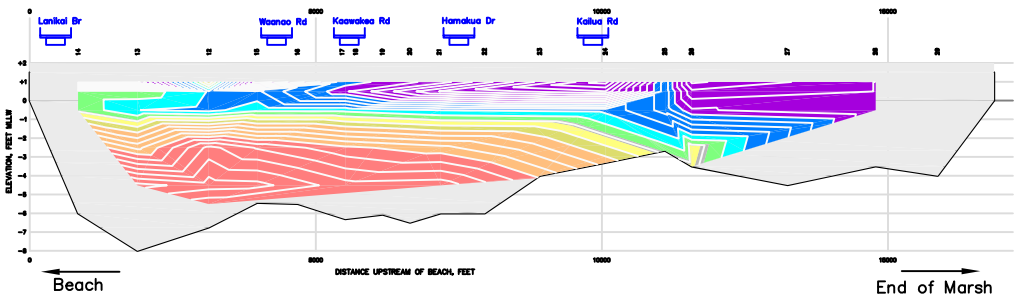


DO



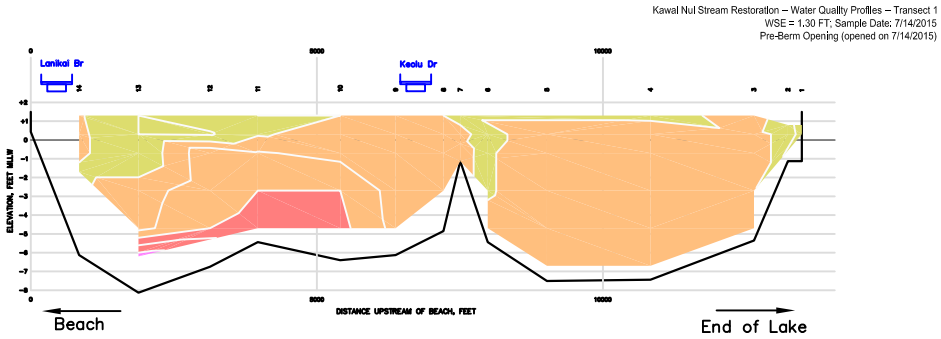
Exchange



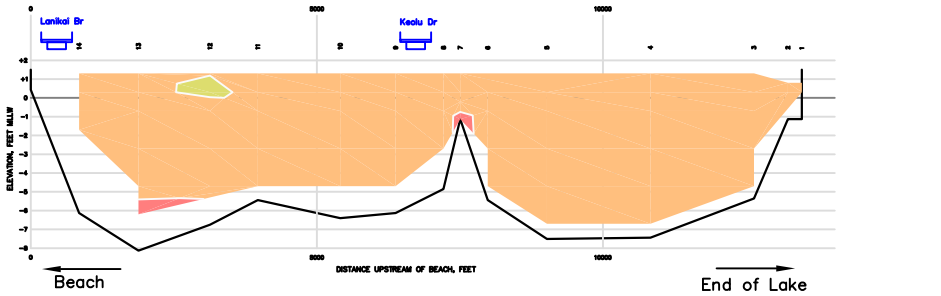
Kaelepulu

Transect 7/14/15

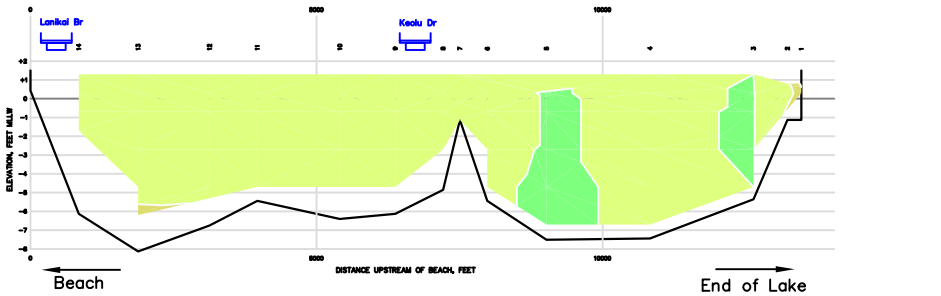
Temperature



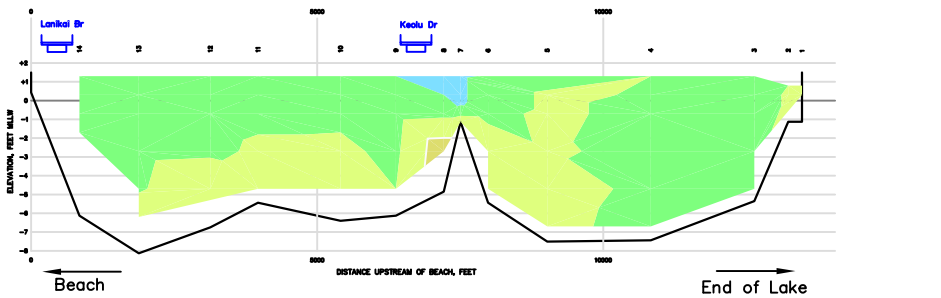
Salinity



pH



NTU



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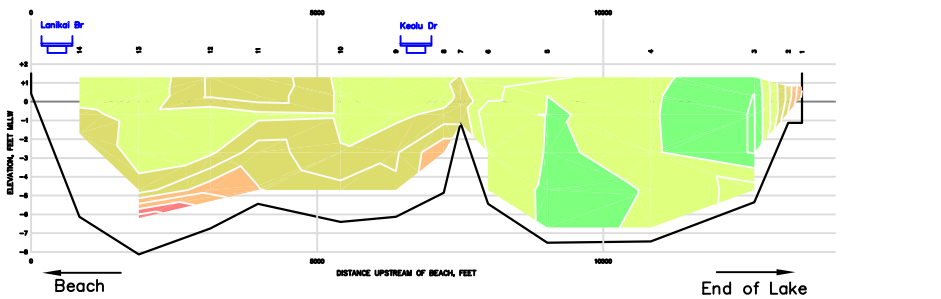
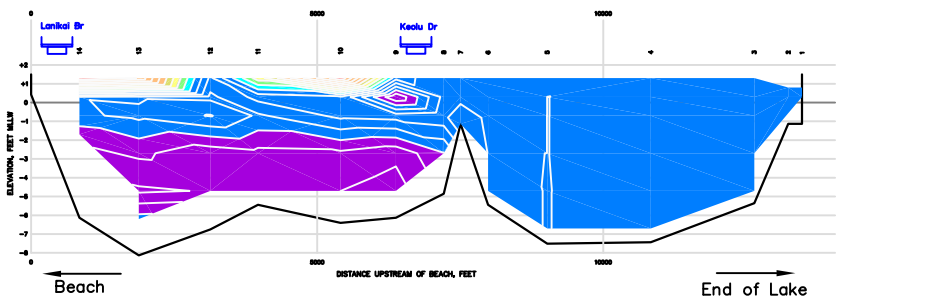


Exchange



Kawainui

Transect 7/14/15

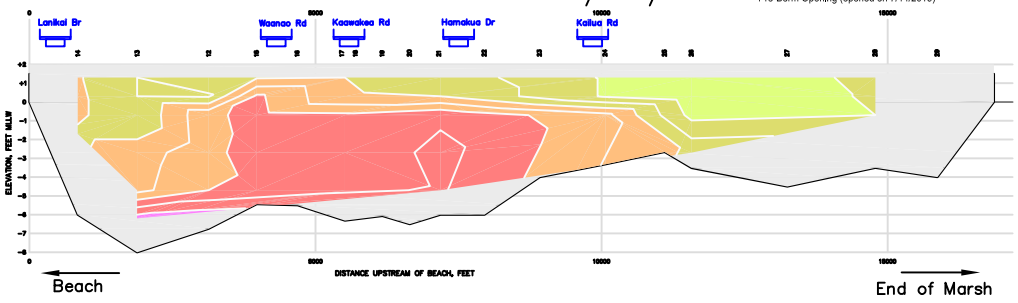
<Previous Stream Opening
6/15/15

Syphon Flowing (Primed 5/27/15)

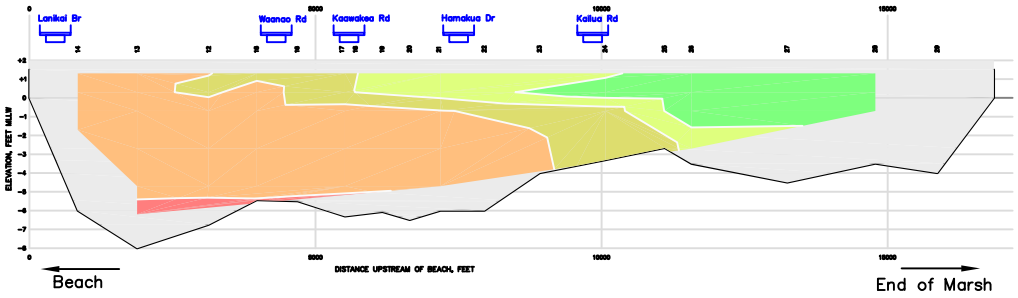
Next Stream Opening>
7/14/15

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 1.30 FT; Sample Date: 7/14/2015
Pre-Berm Opening (opened on 7/14/2015)

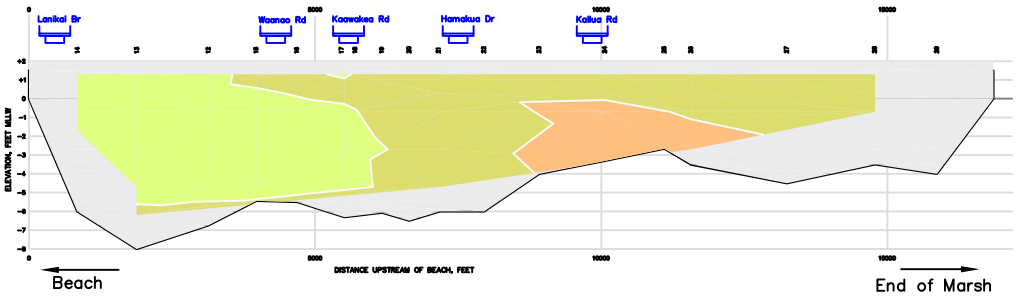
Temperature



Salinity



pH



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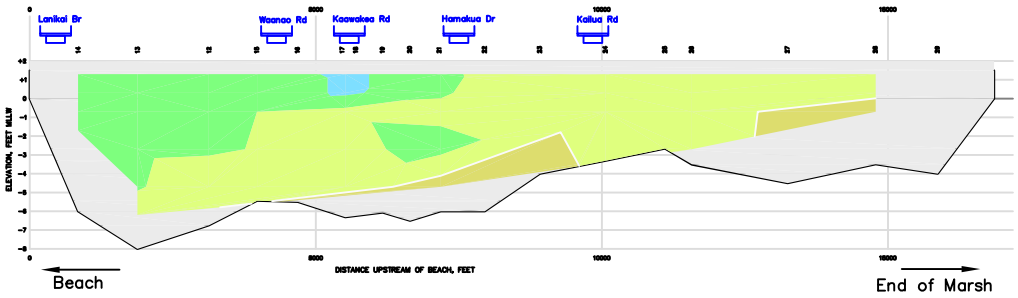

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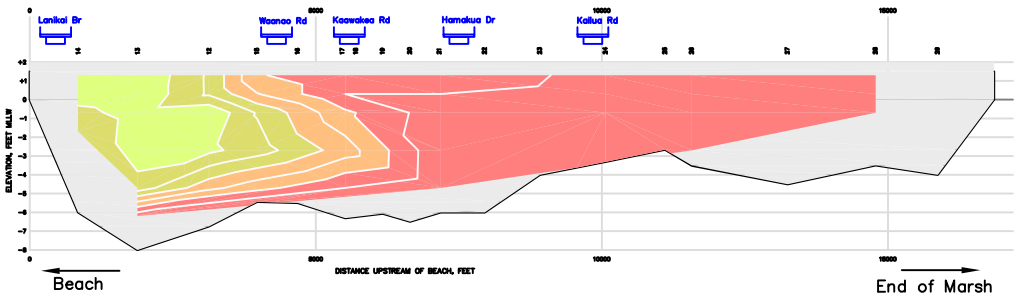
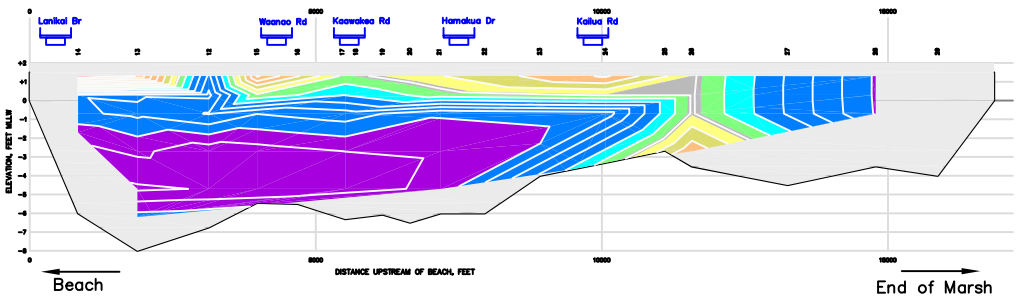


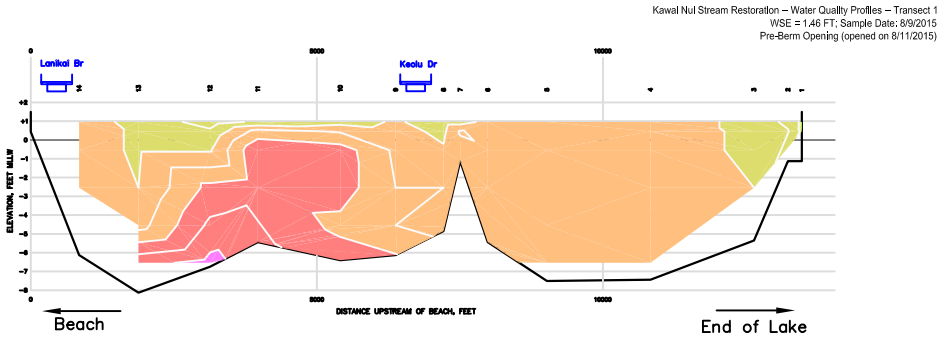
Exchange



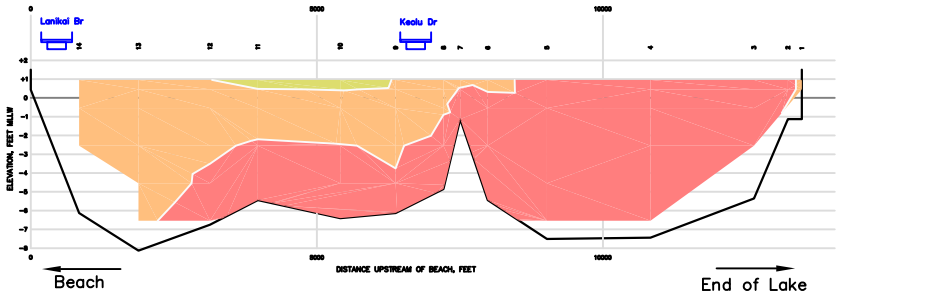
Kaelepulu

Transect 8/9/15

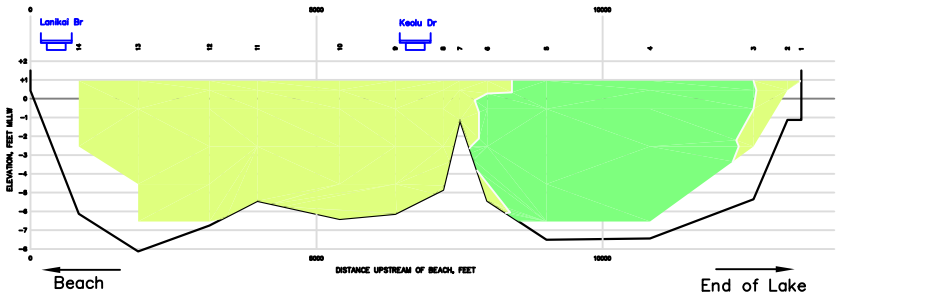
Temperature



Salinity



pH



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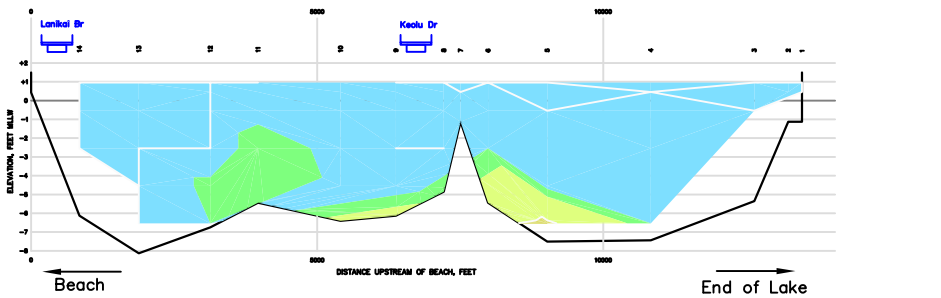

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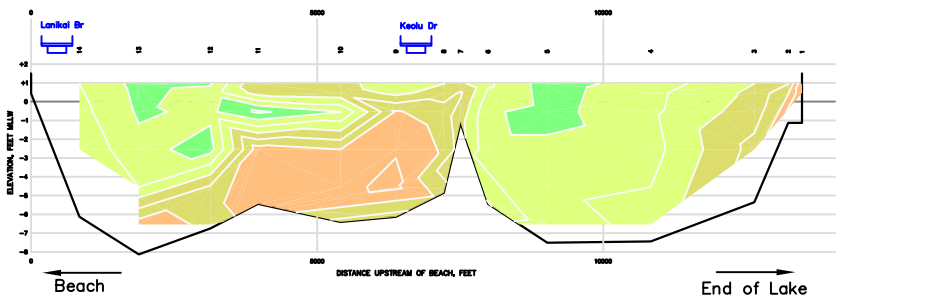
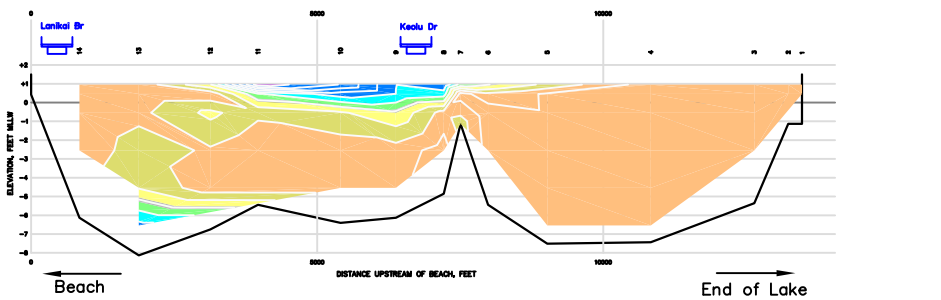


Exchange



Kawainui

Transect 8/9/15

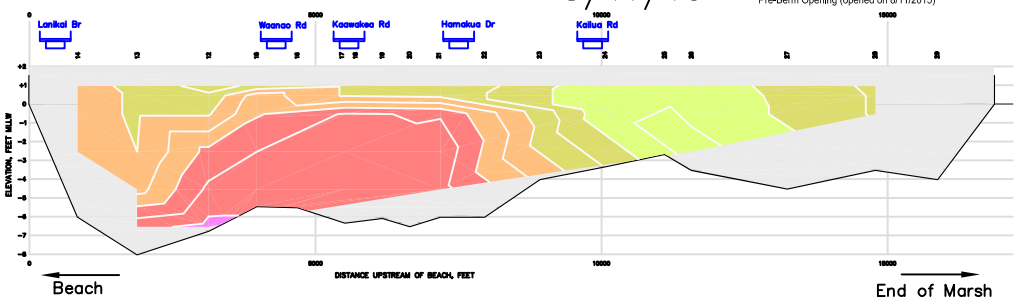
<Previous Stream Opening
7/14/15

Syphon Flowing (Primed 5/27/15)

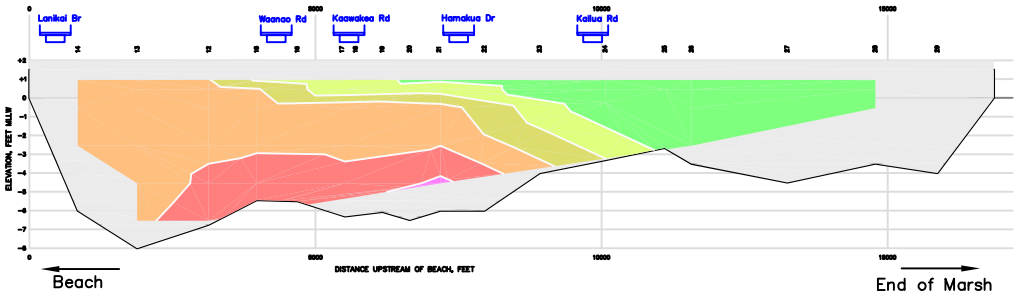
Next Stream Opening>
8/11/15

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 1.46 FT; Sample Date: 8/9/2015
Pre-Berm Opening (opened on 8/11/2015)

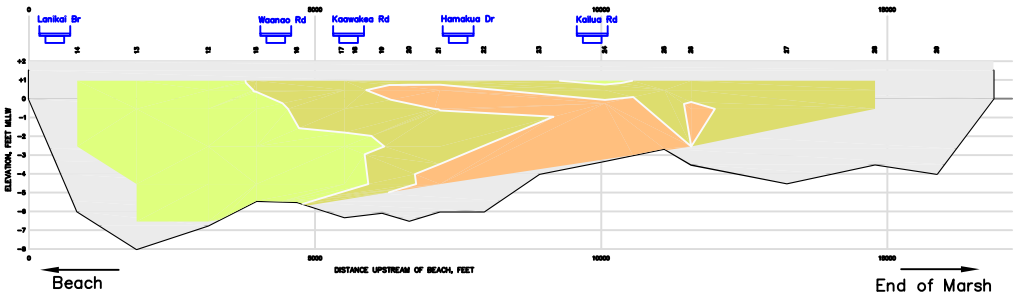
Temperature



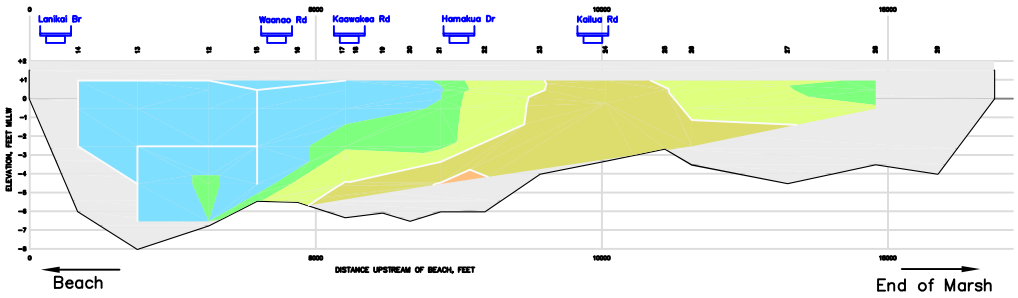
Salinity



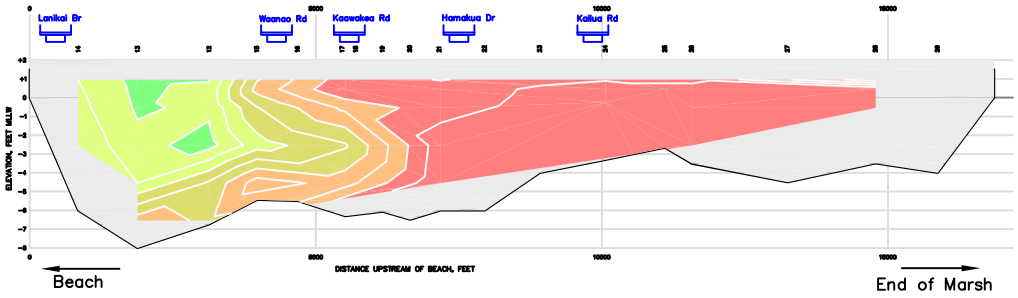
pH



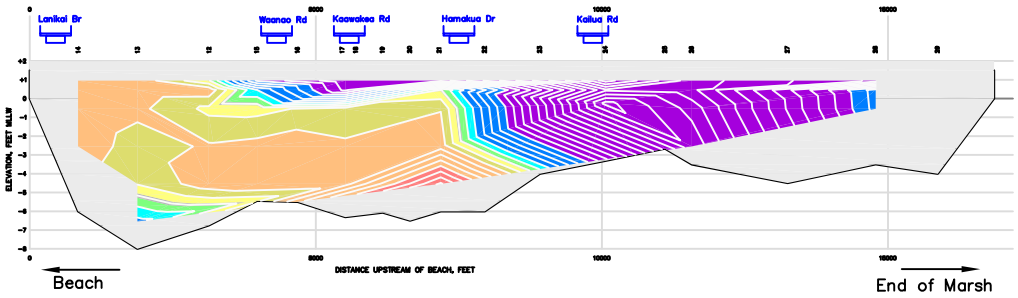
NTU



DO



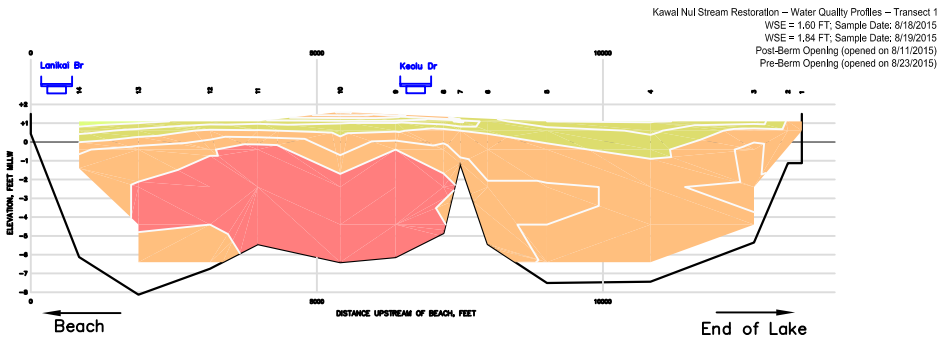
Exchange



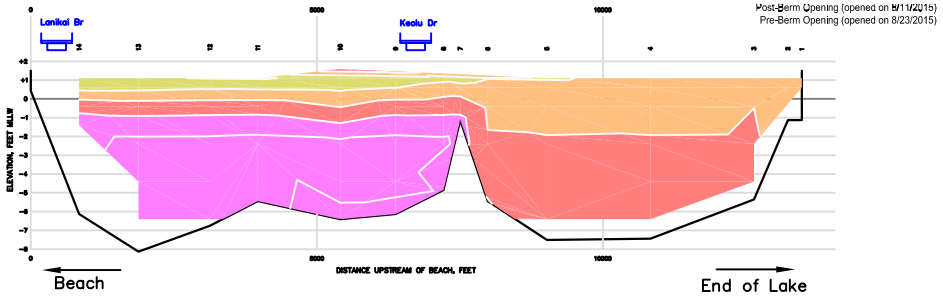
Kaelepulu

Transect 8/18/15

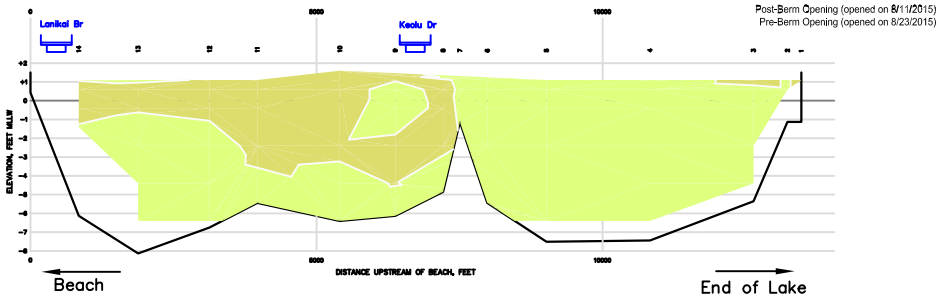
Temperature



Salinity



pH



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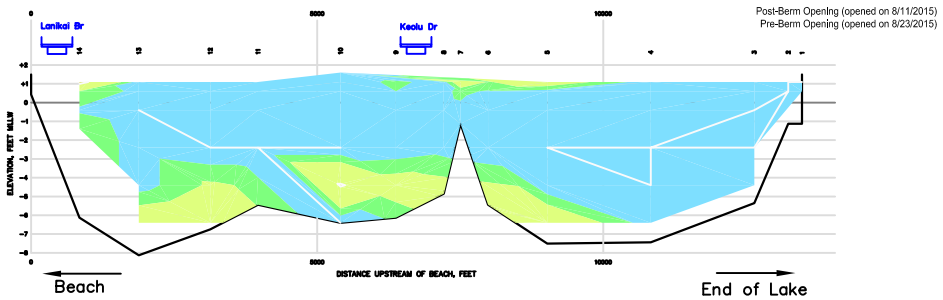

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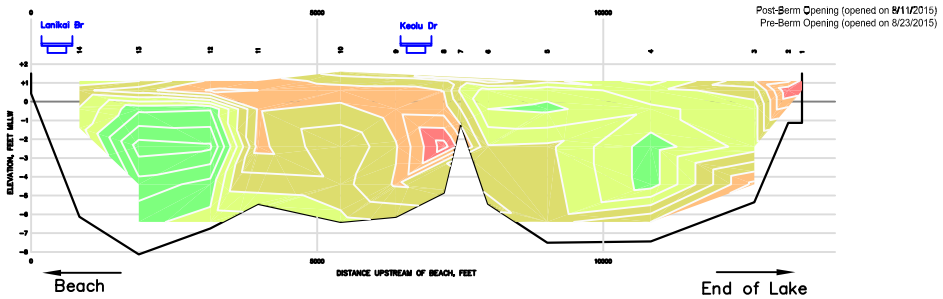

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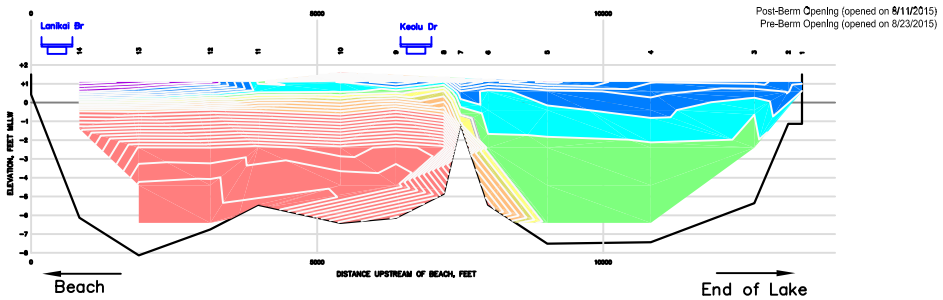


Kawainui

Transect 8/18/15

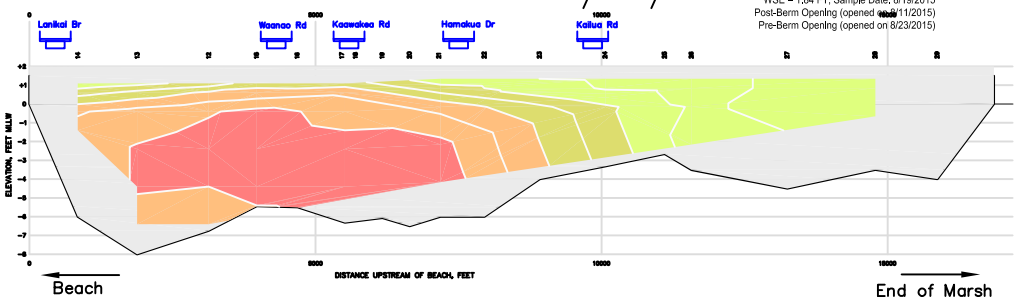
<Previous Stream Opening 8/11/15

Syphon Flowing (Primed 5/27/15)

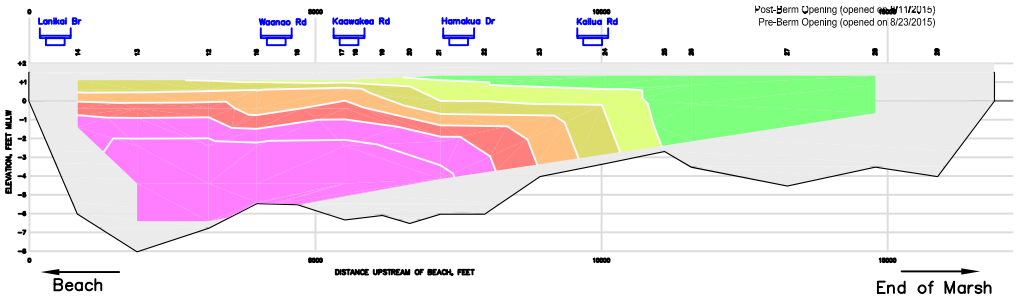
Next Stream Opening> 8/22/15

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 1.60 FT; Sample Date: 8/18/2015
WSE = 1.84 FT; Sample Date: 8/19/2015
Post-Berm Opening (opened on 8/11/2015)
Pre-Berm Opening (opened on 8/23/2015)

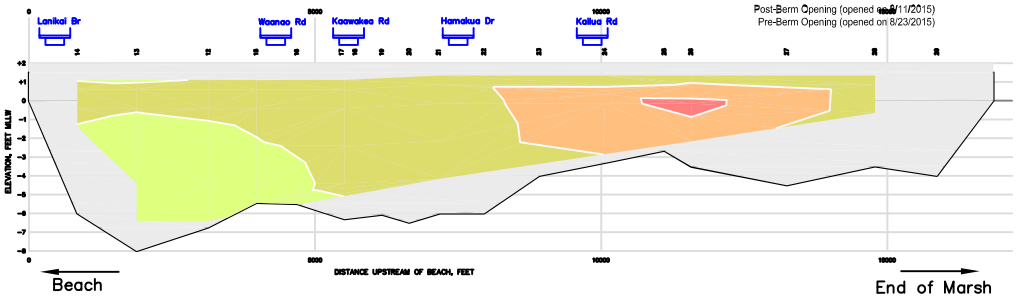
Temperature



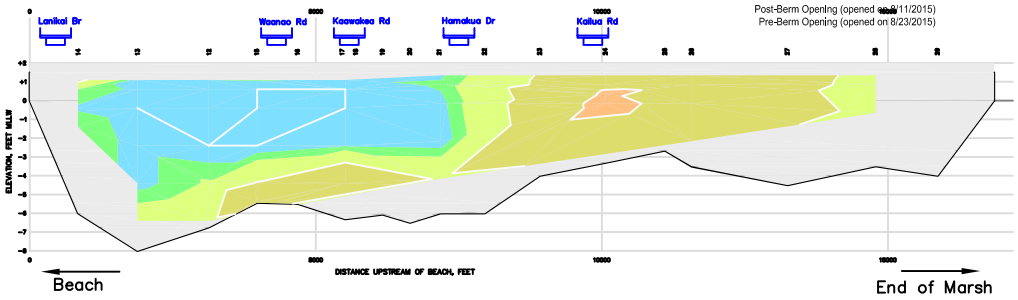
Salinity



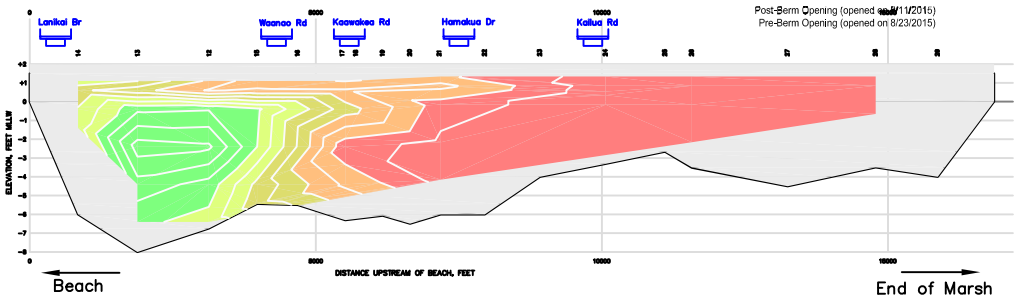
pH



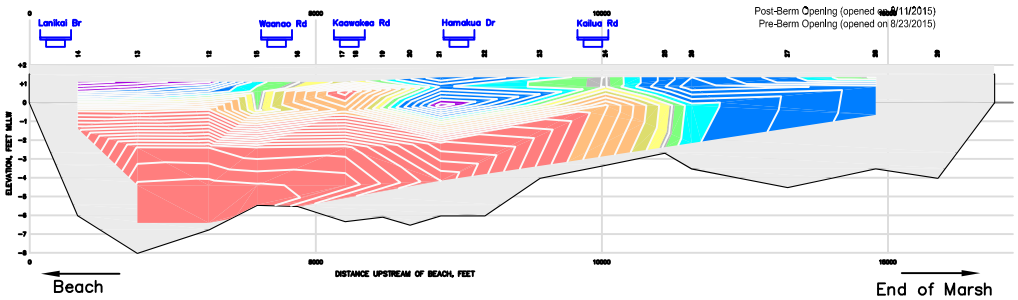
NTU



DO



Exchange

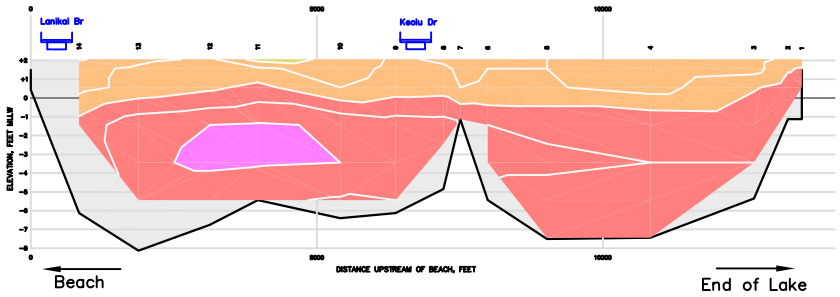


Kaelepulu

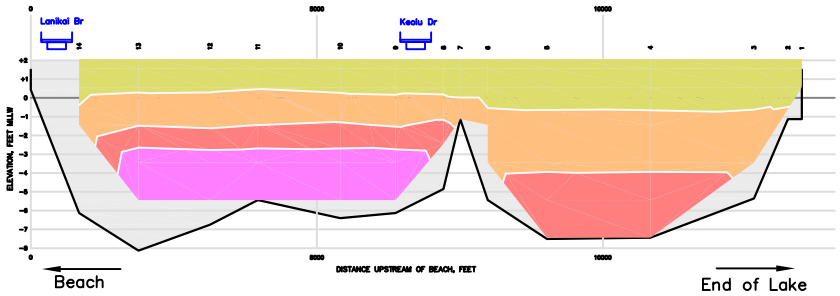
Transect 9/10/15

Kawai Nui Stream Restoration – Water Quality Profiles – Transect 1
WSE = 2.56 FT; Sample Date: 9/10/2015
Post-Berm Opening (opened on 9/7/2015)

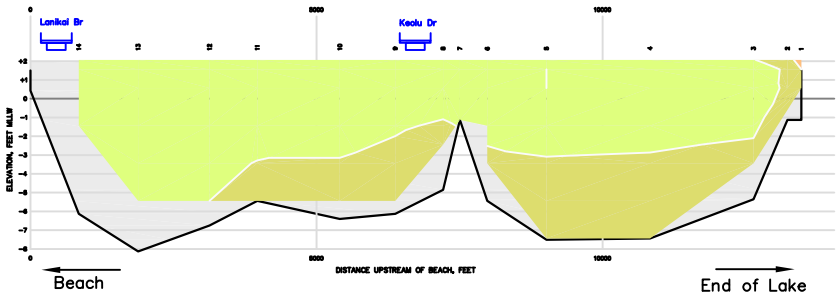
Temperature



Salinity



pH



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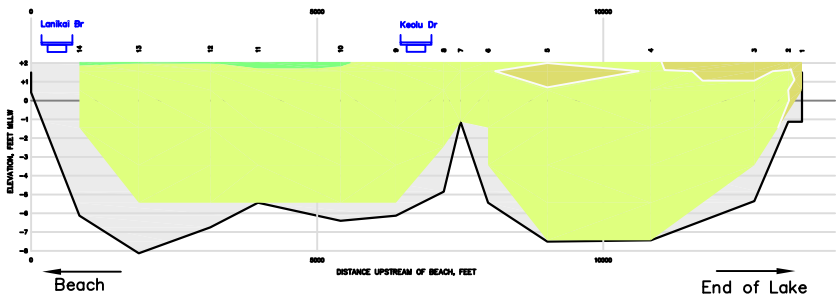
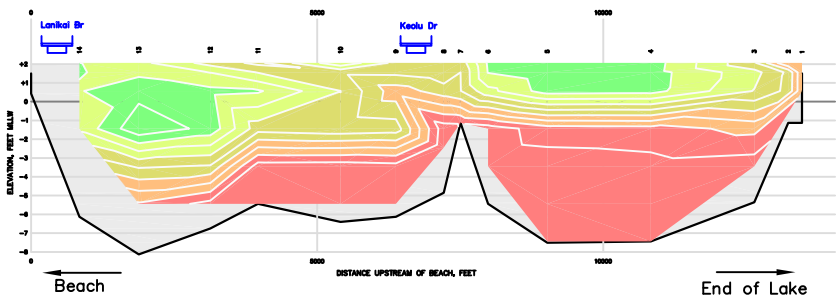
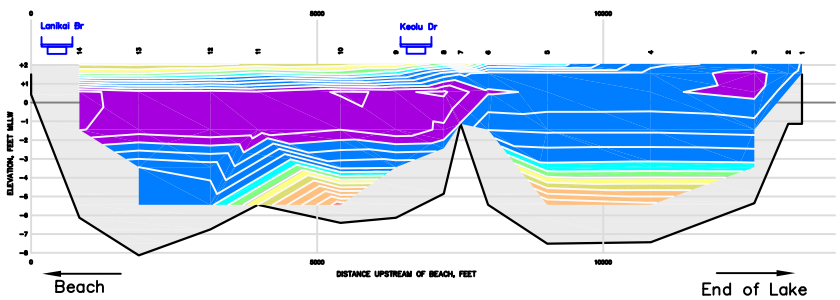


DO



Exchange



Kawainui

Transect 9/10/15

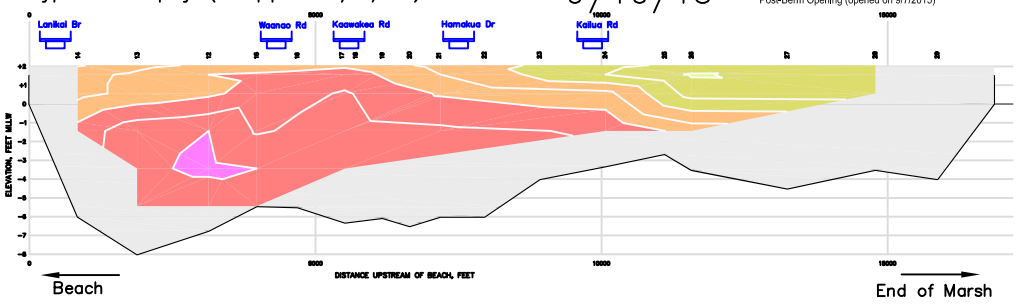
<Previous Stream Opening
8/22/15

Syphon Empty (Stopped 9/2/15)

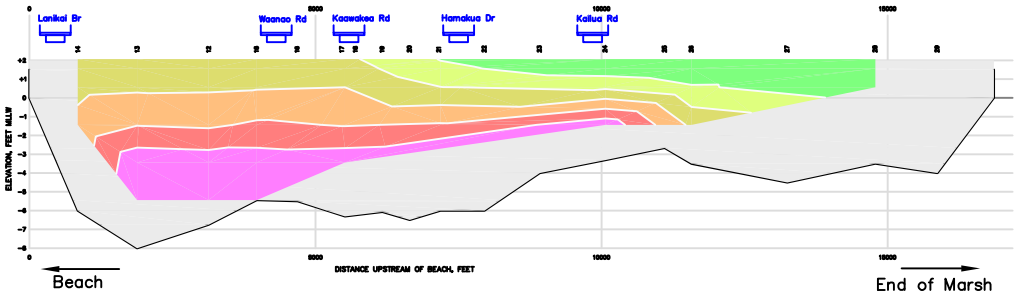
Next Stream Opening>
9/10/15

Kawai Nui Stream Restoration -- Water Quality Profiles – Transect 2
WSE = 2.56 FT; Sample Date: 9/10/2015
Post-Berm Opening (opened on 9/7/2015)

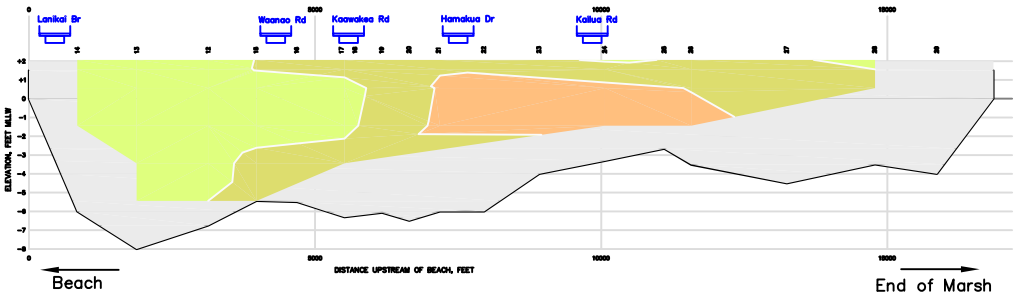
Temperature



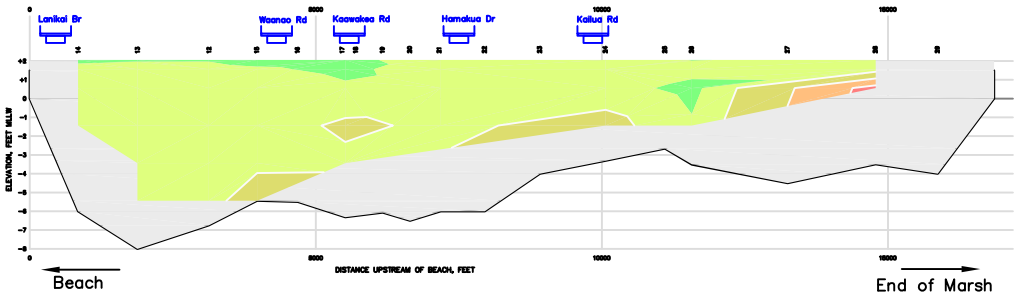
Salinity



pH



NTU



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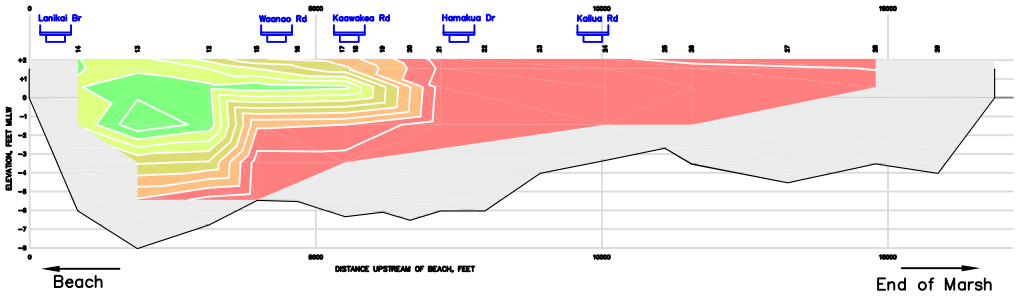
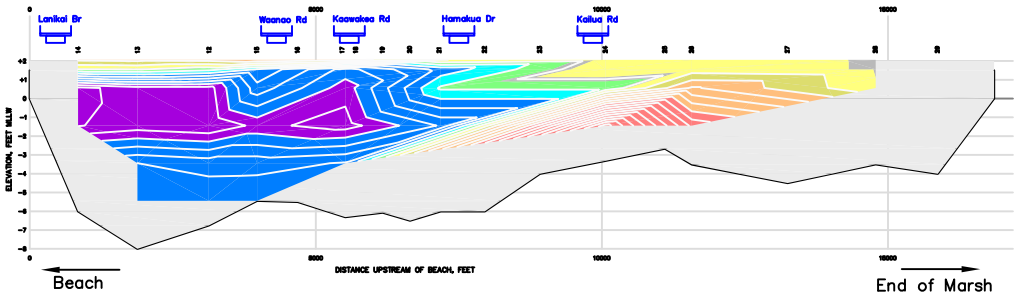


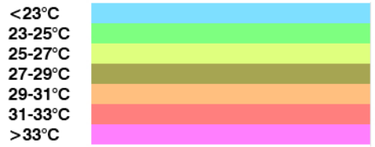
Exchange



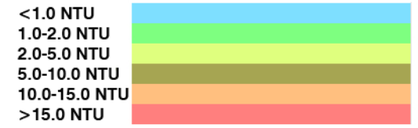
Contour Color Key

Kawainui Stream Flow Restoration Water Quality Transects

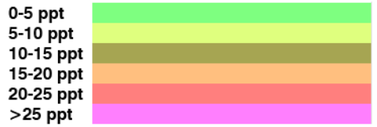
Temperature [°C]



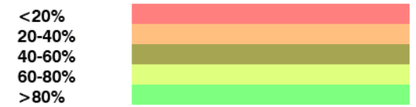
Turbidity [NTU]



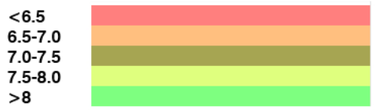
Salinity [ppt]



Dissolved Oxygen [% Sat]



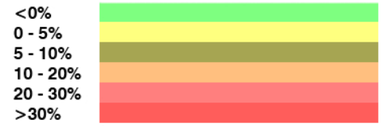
pH



Salt/Freshwater Exchange [%]

Control (2012-2014)

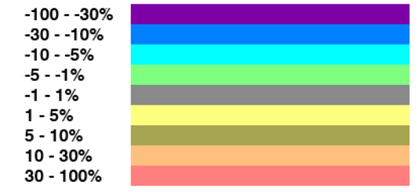
Freshwater Exchange



Saltwater Exchange

Experiment (2015)

Freshwater Exchange



Saltwater Exchange

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F. APPENDIX

2015 WATER QUALITY TRANSECT DATA

Kawainui Flow Restoration Project 201243

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary

			Date:	5/18/2015	104.9	20.9 Corrected		8.24	28.6	21
	Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU	
WETLAND	1	Bob's Dock	0.5	4.1	17.8	17.8	7.06	22.5	2.8	
WETLAND	1		1	2.9	18.12	18.12	7.12	22.6	3.2	
WETLAND										
WETLAND										
WETLAND										
WETLAND										
WETLAND	2	Wetland	0.5	9.7	20.87	20.87	7.31	23.5	-0.4	
WETLAND	2		1							
WETLAND										
WETLAND										
WETLAND										
WETLAND										
LAKE	3	Kofsky's	0.5	76.3	20.82	20.82	8.06	25.5	-0.1	
LAKE	3		1	74.8	20.8	20.8	8.06	25.5	-0.2	
LAKE	3		2	74.9	20.8	20.8	8.07	25.5	-0.2	
LAKE	3		4	74.1	20.79	20.79	8.06	25.5	-0.2	
LAKE	3		6							
LAKE										
LAKE	4	Tom's	0.5	91.1	20.9	20.9	8.14	25.8	-0.2	
LAKE	4		1	91.8	20.9	20.9	8.16	25.9	0	
LAKE	4									
LAKE	4									
LAKE	4									
LAKE	4		8	82.4	20.73	20.73	8.15	25.8	-0.6	
LAKE										
LAKE	5	Mike's	0.5	92.4	20.89	20.89	8.22	26.1	0.5	
LAKE	5		1	96.5	20.89	20.89	8.24	26.1	0.3	
LAKE	5		2	96.7	20.89	20.89	8.24	26.1	0.35	
LAKE	5		4	96.9	20.89	20.89	8.24	26.1	0.4	
LAKE	5		6	97.1	20.89	20.89	8.23	26.1	0.45	
LAKE	5		7.5	97.3	20.89	20.89	8.23	26.1	0.5	
LAKE										
LAKE	6	Stone's	0.5	79.4	20.83	20.83	8.18	25.8	-0.2	
LAKE	6		1	80.5	20.86	20.86	8.2	26	-0.2	
LAKE	6									
LAKE	6		4	82.3	20.86	20.86	8.2	26.1	-0.2	
LAKE	6									
LAKE	6									
Upper Kaelepulu	7	Shallows	0.5	39.8	20.01	20.01	7.91	25.1	1	
Upper Kaelepulu	7									
Upper Kaelepulu	7		2							
Upper Kaelepulu	7		4							
Upper Kaelepulu	7		6							
Upper Kaelepulu	7		7							
Upper Kaelepulu	8	End of Lake	0.5	104.9	19.73	19.73	8.09	26	0	
Upper Kaelepulu	8		1	103.7	19.72	19.72	8.09	26.1	0	
Upper Kaelepulu	8		2	84.85	19.85	19.85	8.07	26.05	0.8	
Upper Kaelepulu	8		4	66	19.98	19.98	8.05	26	1.6	
Upper Kaelepulu	8									
Upper Kaelepulu	8									
Upper Kaelepulu	9	Pig Head	0.5	70.1	19.49	19.49	7.9	26.6	0.3	
Upper Kaelepulu	9		1	70.3	19.48	19.48	7.9	26.5	0.2	
Upper Kaelepulu	9									
Upper Kaelepulu	9									
Upper Kaelepulu	9		6	67.1	19.47	19.47	7.89	26.5	0.9	
Upper Kaelepulu	9									
Upper Kaelepulu	10	Side Channel	0.5	81	18.87	18.87	7.84	26.2	0.7	
Upper Kaelepulu	10		1	80.3	18.86	18.86	7.84	26.3	0.6	
Upper Kaelepulu	10		2	78.15	18.945	18.945	7.85	26.55	1	

	Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU
Upper Kaelepulu	10		4	76	19.03	19.03	7.86	26.8	1.4
Upper Kaelepulu	10		6	76.2	19.28	19.28	7.88	26.6	3
Upper Kaelepulu	10								
Upper Kaelepulu	11	Above Junction	0.5	71.5	17.31	17.31	7.7	24.9	0
Upper Kaelepulu	11		1	84.7	18.23	18.23	7.82	26.5	0.6
Upper Kaelepulu	11		2	80.5	19.05	19.05	7.86	27.3	1.2
Upper Kaelepulu	11		4	78.2	19.28	19.28	7.89	27.3	2.9
Upper Kaelepulu	11								
Upper Kaelepulu	11								
Lower Kaelepulu	12	Golf Island	0.5	83.7	18.76	18.76	7.82	26.2	0.6
Lower Kaelepulu	12		1	83.2	18.6	18.6	7.82	25.7	0.5
Lower Kaelepulu	12		2	79.5	18.625	18.625	7.815	25.95	1.15
Lower Kaelepulu	12		4	75.8	18.65	18.65	7.81	26.2	1.8
Lower Kaelepulu	12		7	81.2	19.19	19.19	7.81	26.3	6.6
Lower Kaelepulu	12								
Lower Kaelepulu	13	Mid Golf Course	0.5	87.6	19.01	19.01	7.8	25.7	1
Lower Kaelepulu	13		1	87.2	19.02	19.02	7.8	25.8	1
Lower Kaelepulu	13								
Lower Kaelepulu	13								
Lower Kaelepulu	13								
Lower Kaelepulu	13		8	80.2	19.32	19.32	7.8	26.1	2.2
Lower Kaelepulu	14	End Golf Course	0.5	70.4	19.45	19.45	7.73	25.6	0.6
Lower Kaelepulu	14		1	67	19.46	19.46	7.73	25.6	0.5
Lower Kaelepulu	14		2	57.4	19.55	19.55	7.65	25.3	0.7
Lower Kaelepulu	14								
Lower Kaelepulu	14								
Lower Kaelepulu	14								
Lower Kawainui	15	Below Wanaao Br	0.5	62	16.6	16.6	7.64	25	1
Lower Kawainui	15		1	67	16.62	16.62	7.65	25.1	21
Lower Kawainui	15		2	67	18.7	18.7	7.79	27.2	8.6
Lower Kawainui	15		4	66.5	19.11	19.11	7.77	27	10.5
Lower Kawainui	15		6	66.4	19.07	19.07	7.76	27	15.5
Lower Kawainui	15		7						
Lower Kawainui	17	Below KaawakeaB	0.5	39	14.49	14.49	7.44	25	0
Lower Kawainui	17		1	36.5	15.01	15.01	7.43	25.1	0
Lower Kawainui	17		2	38.6	16.02	16.02	7.45	25.6	0.1
Lower Kawainui	17		4	62.5	18.83	18.83	7.72	27.8	1.2
Lower Kawainui	17		6	62.9	19.05	19.05	7.74	28	1.4
Lower Kawainui	17								
Lower Kawainui	21	Below Hamakua	0.5	37	13.03	13.03	7.4	25.4	0.6
Lower Kawainui	21	In mangroves	1	23.8	13.19	13.19	7.37	25.5	0.7
Lower Kawainui	21		2	16.6	14.3	14.3	7.37	27.2	0.5
Lower Kawainui	21		4	22.3	17.9	17.9	7.51	28.6	2
Lower Kawainui	21		6	8	18.36	18.36	7.37	28.6	12.8
Lower Kawainui	21								
Upper Kawainui	24	Above Kailua Br	0.5	12.5	5.27	5.27	7.2	24.9	0.3
Upper Kawainui	24		1	5	5.99	5.99	7.16	25	3
Upper Kawainui	24		2	3.6	11.5	11.5	7.1	27.2	9
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	26	PreSch	0.5	5	3.1	3.1	7.32	24	8.2
Upper Kawainui	26		1	4.5	3.1	3.1	7.3	24	8.3
Upper Kawainui	26		2	2.6	3.1	3.1	7.29	24	8
Upper Kawainui	26		4						
Upper Kawainui	26		6						
Upper Kawainui	26		7						
Upper Kawainui	28	End Kaha Field	0.5	10	3.8	3.8	7.24	24.2	7.3
Upper Kawainui	28		1	4.3	3.8	3.8	7.23	24.2	8.3
Upper Kawainui	28		2	2.9	3.82	3.82	7.21	24.1	9.6
Upper Kawainui	28		3						

Kawainui Flow Restoration Project 201243 Staff: REBourke Derek E

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary WSE = 1.25 FT MLLW

	Date:	5/26/2015	112.7	33.8 Corrected		8.06	29.6	35	0		
Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU	Chl-a	time	date	Max Depth
1	Bob's Dock	0.5	6.2	20.3	20.3	6.65	25.4	0.8		530	5/26/2015	1
1		1	3.9	21.1	21.1	6.74	25.4	0.8				
2	Wetland	0.5	5.1	24.4	24.4	6.94	24.5	0.5			5/26/2015	1
2		1	3.3	21.46	21.46	6.91	24.4	0.5				
3	Kofsky's	0.5	47.1	21.2	21.2	7.44	24.5	1.9			2/15/2014	6
3		1	20.3	21.7	21.7	7.34	24.7	1.3				
3		2	88.5	22.75	22.75	7.85	26	0.1				
3		4	79.1	22.83	22.83	7.85	26.3	0.1				
3		6	39.5	25.99	25.99	7.65	28.6	0				
4	Tom's	0.5	100.8	22.37	22.37	7.94	25.6	0			2/15/2014	8
4		1	101.3	22.37	22.37	7.94	25.6	0.1				
4		2	101.5	22.37	22.37	7.94	25.6	0.1				
4		4										
4		6	102.4	26.5	26.5	7.91	28.7	0.4				
4		8	55.7	28.8	28.8	7.21	29.3	0.2				
5	Mike's	0.5	100.8	22.22	22.22	7.99	25.4	0			2/15/2014	8
5		1	100.6	22.21	22.21	7.99	25.4	0.1				
5		2										
5		4	108.7	22.92	22.92	8	26.3	0.1				
5		6	96	26.9	26.9	7.88	29.1	0.6				
5		8	63.9	28.65	28.65	7.72	29.2	1.3				
6	Stone's	0.5	106.3	22.15	22.15	8.04	25.8	0			2/15/2014	4
6		1	108.7	22.15	22.15	8.05	25.9	0				
6		2	110.5	22.15	22.15	8.05	25.9	0				
6		4	62.2	23.23	23.23	7.84	27	0.7				
6		5	16.5	24.2	24.2	7.51	27.4	2.1				
6												
7	Shallows	0.5	103.9	22.04	22.04	8.06	25.5	0			2/15/2014	1
7		1	105.8	22.3	22.3	8.04	25.5	0.1				
7		2										
7		4										
7		6										
7		7										
8	End of Lake	0.5	93.6	22.24	22.24	8	25	0			2/15/2014	4
8		1	39	22.24	22.24	7.78	25.1	0.8				
8		2	105.5	30.5	30.5	7.75	28.2	0.3				
8		4	37.3	33.2	33.2	7.56	29.5	1.4				
8												
8												
9	Pig Head	0.5	75.5	22.66	22.66	7.81	25.3	0.1			2/15/2014	5
9		1	66	22.96	22.96	7.77	25.4	0				
9		2	106.9	29.65+G92F5	29.65+G92F5	7.75	27.3	0.6				
9		4	104.7	33.05	33.05	7.75	29.5	1				
9		6	75.1	33.8	33.8	7.7	29.5	2.4				
9												
10	Side Channel	0.5	85.2	23.16	23.16	7.8	25	0			2/15/2014	5
10		1	85.8	23.59	23.59	7.77	25.7	0.1				
10		2	108	27.93	27.93	7.76	27	0.3				
10		4	105	33.35	33.35	7.74	29.6	2.5				
10		6	88.6	33.77	33.77	7.72	29.1	4.1				
10		7		33.66	33.66							
11	Above Junction	0.5	76	23.5	23.5	7.73	24.7	0			2/15/2014	6
11		1	80.5	23.55	23.55	7.43	24.7	0				
11		2	108	27.77	27.77	7.79	26.7	0.2				
11		4	110	33.35	33.35	7.78	29	1.8				
11		6	75	33.6	33.6	7.74	28	3.4				
11												
12	Golf Island	0.5	59.4	21.03	21.03	7.49	24	0			2/15/2014	6

Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU	Chl-a	time	date	Max Depth
12		1	88.2	25.9	25.9	7.69	26.1	0.1				
12		2	103.5	27.8	27.8	7.74	26.6	0.2				
12		4	112.7	32.37	32.37	7.78	28	1.9				
12		6	101.9	33.47	33.47	7.78	27.7	3.8				
12		8	85	33.58	33.58	7.75	27.1	6.5				
13	Mid Golf Course	0.5	74.1	21.6	21.6	7.64	23.7	0		905	2/15/2014	8
13		1	90.5	24.95	24.95	7.68	25.9	0				
13		2	97.4	28.7	28.7	7.75	26.9	0.5				
13		4	104	32.75	32.75	7.75	27.8	1				
13		6	112	33.3	33.3	7.78	27.6	1.1				
13		8	75	33.36	33.36	7.76	26.6	4.3				
14	End Golf Course	0.5	77.6	21.95	21.95	7.62	22.9	0			2/15/2014	3
14		1	78.8	22.5	22.5	7.63	24	0				
14		2	89.3	28.07	28.07	7.72	26.1	0.2				
14		4										
14		6										
14		7										
15	Below Wanaao Br	0.5	35	21.7	21.7	7.36	25	2.6			2/15/2014	4
15		1	87	26	26	7.71	26.8	0				
15		2	97.8	27.75	27.75	7.74	26.9	0.1				
15		4	105.5	33	33	7.76	28.2	1.6				
15		6	88.1	33.55	33.55	7.76	28.1	2.7				
15		7										
17	Below KaawakeaB	0.1	25	22.5	22.5	7.2	26.2	1.8			2/16/2014	4
17		1	72.1	26.62	26.62	7.41	28.4	0.3				
17		2	98.9	28.73	28.73	7.65	27.7	0				
17		4	84.8	32.65	32.65	7.69	29.1	0.6				
17		6	87.1	33.22	33.22	7.68	29.1	3.4				
17												
21	Below Hamakua	0.5	25	0.25	0.25	7.26	24.8	0			2/16/2014	6
21	In mangroves	1	16	20.35	20.35	7.14	25.1	0.1				
21		2	37.5	28.48	28.48	7.38	28.6	0.1				
21		4	32	32.2	32.2	7.44	28.9	0.7				
21		6	6	33.63	33.63	7.24	28.4	5				
21												
24	Above Kailua Br	0.5	14	9.98	9.98	7.1	24.7	2.9			2/16/2014	3
24		1	5	18.16	18.16	6.96	26.5	7.2				
24		1.5	2.8	23.6	23.6	6.99	28.3	3.6				
24												
24												
24												
26	Above Island	0.5	11.3	6.72	6.72	7.3	28.3	2.3			2/16/2014	4
26	PreSch	1	5.8	6.81	6.81	7.24	23.9	2.2				
26		2	3.2	9.76	9.76	7.13	25.6	3.6				
26		4	2	10.8	10.8							
26		6										
26		7										
28	End Kaha Field	0.5	13.1	5.66	5.66	7.41	23.5	1.7			2/16/2014	2
28		1	7.1	5.66	5.66	7.37	23.5	5				
28		2	3.1	7.5	7.5	7.21	25.4	35				
28		3										
28		6										
28		7										

Kawainui Flow Restoration Project 201243

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary

			Date:	6/4/2015	73.1	32.8 Corrected		7.72	31.7	21
	Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU	
WETLAND	1	Bob's Dock	0.5	4.2	19.2	19.2	6.94	25.2	3.4	
WETLAND	1		1	1.5	22.87	22.87	6.82	25.8	2.8	
WETLAND										
WETLAND										
WETLAND										
WETLAND										
WETLAND	2	Wetland	0.5							
WETLAND	2		1	7.1	20.35	20.35	7.07	24.8	5.3	
WETLAND										
WETLAND										
WETLAND										
WETLAND										
LAKE	3	Kofsky's	0.5	13.8	22.87	22.87	7.08	25.8	1.5	
LAKE	3		1	18.7	22.67	22.67	7.15	26.5	0.8	
LAKE	3		2	39.3	24.6	24.6	7.37	27.3	1.3	
LAKE	3		4	34.6	25	25	7.43	27.8	1.7	
LAKE	3		6							
LAKE										
LAKE	4	Tom's	0.5	72.3	24.48	24.48	7.63	26.8	1	
LAKE	4		1	71.7	24.48	24.48	7.63	26.8	1	
LAKE	4		2	68.95	24.545	24.545	7.62	26.85	1.1	
LAKE	4		4	66.2	24.61	24.61	7.61	26.9	1.2	
LAKE	4		6	44.85	24.94	24.94	7.485	27.3	2.9	
LAKE	4		8	23.5	25.27	25.27	7.36	27.7	4.6	
LAKE										
LAKE	5	Mike's	0.5	25.1	24.89	24.89	7.34	27.2	3.5	
LAKE	5		1	23	24.83	24.83	7.28	27.1	3.9	
LAKE	5		2	21	24.81	24.81	7.26	27.1	3.8	
LAKE	5		4	19.5	24.82	24.82	7.28	27.2	3.5	
LAKE	5		6	42.9	25.18	25.18	7.43	27.5	3.3	
LAKE	5		8	2.5	26.02	26.02	7.37	28.6	6.8	
LAKE										
LAKE	6	Stone's	0.5	17.8	24.52	24.52	7.27	27.1	4.5	
LAKE	6		1	18.9	24.61	24.61	7.26	27.2	4.6	
LAKE	6		2	9.3	25.01	25.01	7.26	27.4	8.5	
LAKE	6		4	27.2	25.36	25.36	7.4	27.9	4.5	
LAKE	6		6	16.1	25.43	25.43	7.28	28.1	7.2	
LAKE	6									
Upper Kaelepulu	7	Shallows	0.5	9.2	23.55	23.55	7.23	26.6	6	
Upper Kaelepulu	7		1	3.8	24.4	24.4	7.19	27.5	8.2	
Upper Kaelepulu	7		2							
Upper Kaelepulu	7		4							
Upper Kaelepulu	7		6							
Upper Kaelepulu	7		7							
Upper Kaelepulu	8	End of Lake	0.5	16	23.64	23.64	7.27	26.6	3.4	
Upper Kaelepulu	8		1	3.4	24.46	24.46	7.18	27.3	6.8	
Upper Kaelepulu	8		2	2.4	24.94	24.94	7.14	27.8	5.7	
Upper Kaelepulu	8		4	1.7	25.15	25.15	7.11	28.1	5.3	
Upper Kaelepulu	8									
Upper Kaelepulu	8									
Upper Kaelepulu	9	Pig Head	0.5	10	23.74	23.74	7.26	26.7	5.4	
Upper Kaelepulu	9		1	8	23.7	23.7	7.23	26.8	5.7	
Upper Kaelepulu	9		2	2.5	25.2	25.2	7.07	28.7	4.9	
Upper Kaelepulu	9		4	3.5	27.9	27.9	7.21	30.3	0.6	
Upper Kaelepulu	9		6	1.8	28.5	28.5	7.09	30.2	21	
Upper Kaelepulu	9									
Upper Kaelepulu	10	Side Channel	0.5	13.5	22.91	22.91	7.3	26.8	2.1	
Upper Kaelepulu	10		1	4.6	23.44	23.44	7.27	26.8	7.9	
Upper Kaelepulu	10		2	2.7	25.34	25.34	7.21	28.8	4.1	

	Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU
Upper Kaelepulu	10		4	7.1	27.47	27.47	7.29	30.2	3
Upper Kaelepulu	10		6						
Upper Kaelepulu	10		7						
Upper Kaelepulu	11	Above Junction	0.5	39.1	19.8	19.8	7.43	26.9	0
Upper Kaelepulu	11		1	30.5	23.48	23.48	7.39	28.2	0.2
Upper Kaelepulu	11		2	30	25.24	25.24	7.38	28.7	2.9
Upper Kaelepulu	11		4	42.1	26.94	26.94	7.56	28.8	0.7
Upper Kaelepulu	11		5	28.5	28.33	28.33	7.51	30.5	5.6
Upper Kaelepulu	11								
Lower Kaelepulu	12	Golf Island	0.5	73.1	18.98	18.98	7.67	25.1	0
Lower Kaelepulu	12		1	45.7	23.35	23.35	7.55	27.5	0
Lower Kaelepulu	12		2	58.5	24.77	24.77	7.69	27.9	0.1
Lower Kaelepulu	12		4	66.9	26.25	26.25	7.69	28.4	0.5
Lower Kaelepulu	12		6	61.9	31.25	31.25	7.67	31.4	0.7
Lower Kaelepulu	12		8	35	32.71	32.71	7.61	31.6	4.9
Lower Kaelepulu	13	Mid Golf Course	0.5	73	22.67	22.67	7.65	26	0
Lower Kaelepulu	13	Halfway	1	72.7	22.84	22.84	7.66	25.8	0
Lower Kaelepulu	13		2	69	24	24	7.64	26.8	0
Lower Kaelepulu	13		4	69.4	26	26	7.72	27.67	0.2
Lower Kaelepulu	13		6	69.5	31.1	31.1	7.7	31.37	0.9
Lower Kaelepulu	13		8	14	32.8	32.8	7.54	21.1	2.8
Lower Kaelepulu	14	End Golf Course	0.5	66.5	23.82	23.82	7.63	26.3	0
Lower Kaelepulu	14	Lanikai Bridge	1	69.5	23.89	23.89	7.63	26.3	0
Lower Kaelepulu	14		2	70	24.54	24.54	7.66	26.3	0
Lower Kaelepulu	14		3	66.9	25.05	25.05	7.68	26.3	0
Lower Kaelepulu	14		6						
Lower Kaelepulu	14		7						
Lower Kawainui	15	Below Wanaao Br	0.5	43.4	16.22	16.22	7.41	26.7	0
Lower Kawainui	15		1	45.2	23.1	23.1	7.33	28.3	0.3
Lower Kawainui	15		2	72.2	25	25	7.52	28.5	0
Lower Kawainui	15		4	72.8	27	27	7.71	28.5	0.2
Lower Kawainui	15		6	37.7	30.63	30.63	7.56	31.7	2.2
Lower Kawainui	15		7	17.7	31.94	31.94	7.5	31.5	7.1
Lower Kawainui	17	Below KaawakeaB	0.1	45.5	14.25	14.25	7.39	26.2	0
Lower Kawainui	17		1	26	14.3	14.3	7.37	26.9	0
Lower Kawainui	17		2	58	25.35	25.35	7.4	29.4	0
Lower Kawainui	17		4	43	27.93	27.93	7.56	30	2.3
Lower Kawainui	17		6	31	30.03	30.03	7.51	31.4	3.6
Lower Kawainui	17								
Lower Kawainui	21	Below Hamakua	0.5	15.5	9.69	9.69	7.17	26.1	0
Lower Kawainui	21	In mangroves	1	15.5	14.44	14.44	7.04	28	0.2
Lower Kawainui	21		2	19.3	24.7	24.7	7.21	30.3	0
Lower Kawainui	21		4	5	27.74	27.74	7.28	31.1	4
Lower Kawainui	21		6						
Lower Kawainui	21								
Upper Kawainui	24	Above Kailua Br	0.5	7	4.04	4.04	7.1	25	3.3
Upper Kawainui	24		1	3.5	9.6	9.6	6.84	26.1	4.1
Upper Kawainui	24		2	3.1	21.03	21.03	6.8	28.9	3
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	26	Above Island	0.5	7.9	2.23	2.23	7	24.1	3
Upper Kawainui	26	PreSch	1	3.5	2.43	2.43	6.95	24.2	3
Upper Kawainui	26	Sunshine Sch	2	2.6	3.42	3.42	6.94	24.6	3.5
Upper Kawainui	26		4	1.8	7.3	7.3	7	25.4	4.1
Upper Kawainui	26		6						
Upper Kawainui	26		7						
Upper Kawainui	28	End Kaha Field	0.5	10.5	4.72	4.72	7.32	24.7	0.1
Upper Kawainui	28		1	4.5	4.86	4.86	7.29	24.9	1.3
Upper Kawainui	28		2	3.1	4.9	4.9	7.3	24.9	1.6
Upper Kawainui	28		3						

Kawainui Flow Restoration Project 201243

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary

	Site	Name	Date: 6/14/2015 Depth ft	DO % 74.5	Salinity 27.95	Corrected Salinity	pH 7.75	Temp C 32.6	NTU 15
WETLAND	1	Bob's Dock	0.5	9.5	23.49	23.49	7.26	27	3.1
WETLAND	1		1	9.5	23.52	23.52	7.21	27	3.5
WETLAND									
WETLAND									
WETLAND									
WETLAND									
WETLAND	2	Wetland	0.5	3.5	26.23	26.23	7.15	27.5	4.6
WETLAND	2		1	3	25.17	25.17	7.11	28.1	5
WETLAND									
WETLAND									
WETLAND									
WETLAND									
LAKE	3	Kofsky's	0.5	65.5	25.28	25.28	7.58	29.6	1.1
LAKE	3		1	61.5	25.27	25.27	7.57	29.6	1.2
LAKE	3		2	60.8	25.27	25.27	7.56	29.6	1.2
LAKE	3		4	60.3	25.27	25.27	7.55	29.6	1.3
LAKE	3		6	58.5	25.27	25.27	7.53	29.5	1.5
LAKE									
LAKE	4	Tom's	0.5	65.3	25.28	25.28	7.53	29.4	1.3
LAKE	4		1	66.2	25.26	25.26	7.54	29.4	1.3
LAKE	4		2	66.5	25.265	25.265	7.54	29.4	1.3
LAKE	4		4	66.8	25.27	25.27	7.54	29.4	1.3
LAKE	4		6	66.9	25.27	25.27	7.54	29.4	1.35
LAKE	4		8	67	25.27	25.27	7.54	29.4	1.4
LAKE									
LAKE	5	Mike's	0.5	61.5	24.79	24.79	7.52	28.7	1.3
LAKE	5		1	59.3	24.82	24.82	7.51	28.8	1.3
LAKE	5		2	58.8	24.915	24.915	7.505	29	1.3
LAKE	5		4	58.3	25.01	25.01	7.5	29.2	1.3
LAKE	5		6	50.2	25.19	25.19	7.35	29.1	1.8
LAKE	5		8	4.5	25.3	25.3	7.29	29.1	5.6
LAKE									
LAKE	6	Stone's	0.5	45.4	23.7	23.7	7.5	28.4	1.2
LAKE	6		1	50.3	24.97	24.97	7.47	29.4	1.8
LAKE	6		2	45.1	25.12	25.12	7.41	29.5	1.9
LAKE	6		4	2.1	25.23	25.23	7.21	29.4	15
LAKE	6		5.5						
LAKE	6								
Upper Kaelepulu	7	Shallows	0.5	42	23.23	23.23	7.51	28.6	0.8
Upper Kaelepulu	7		1	21.1	24.35	24.35	7.34	28.9	3
Upper Kaelepulu	7		2						
Upper Kaelepulu	7		4						
Upper Kaelepulu	7		6						
Upper Kaelepulu	7		7						
Upper Kaelepulu	8	End of Lake	0.5	47.5	22.87	22.87	7.55	28.5	0.6
Upper Kaelepulu	8		1	27.1	23.44	23.44	7.48	29	1.6
Upper Kaelepulu	8		2	26	24.53	24.53	7.39	29.3	2.1
Upper Kaelepulu	8		4	14	24.9	24.9	7.34	29.5	2.5
Upper Kaelepulu	8								
Upper Kaelepulu	8								
Upper Kaelepulu	9	Pig Head	0.5	40	22.72	22.72	7.54	28.9	0.6
Upper Kaelepulu	9		1	39.4	22.7	22.7	7.51	28.9	0.8
Upper Kaelepulu	9		2	32	24	24	7.44	30.4	1.5
Upper Kaelepulu	9		4	18.5	24.52	24.52	7.38	30	1.8
Upper Kaelepulu	9		6	14.5	24.61	24.61	7.32	29.9	2.1
Upper Kaelepulu	9								
Upper Kaelepulu	10	Side Channel	0.5	46.5	21.55	21.55	7.52	28.2	0.9
Upper Kaelepulu	10		1	27.4	22.5	22.5	7.47	30	1.5
Upper Kaelepulu	10		2	13.6	24.5	24.5	7.28	30.7	1.9
Upper Kaelepulu	10		4	12.5	24.7	24.7	7.28	30.7	2.4
Upper Kaelepulu	10		6	3.5	25.05	25.05	7.27	30.8	3.5
Upper Kaelepulu	10		7						
Upper Kaelepulu	11	Above Junction	0.5	43	18.35	18.35	7.47	28.2	0

	Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU
Upper Kaelepulu	11		1	59.5	23.77	23.77	7.57	30.1	0.4
Upper Kaelepulu	11		2	59.35	24.045	24.045	7.645	30.5	0.8
Upper Kaelepulu	11		4	59.2	24.32	24.32	7.72	30.9	1.2
Upper Kaelepulu	11		6	40.3	25.02	25.02	7.62	30.7	3.8
Upper Kaelepulu	11								
Lower Kaelepulu	12	Golf Island	0.5	59.5	17.7	17.7	7.56	26.4	0.1
Lower Kaelepulu	12		1	53	21.4	21.4	7.55	30.2	0.4
Lower Kaelepulu	12		2	61.5	24.5	24.5	7.66	31.5	0.9
Lower Kaelepulu	12		4	60.3	24.75	24.75	7.75	30.3	0.7
Lower Kaelepulu	12		6	49	25.6	25.6	7.74	30.4	1.2
Lower Kaelepulu	12		7.5	9.1	27.95	27.95	7.47	31.9	3
Lower Kaelepulu	13	Mid Golf Course	0.5	67.5	21.79	21.79	7.65	28	0.4
Lower Kaelepulu	13	Halfway	1	65.5	21.81	21.81	7.64	28.2	0.4
Lower Kaelepulu	13		2	74.5	24	24	7.71	30.4	0.8
Lower Kaelepulu	13		4	67.1	24.27	24.27	7.75	29.5	0.1
Lower Kaelepulu	13		6	53	24.75	24.75	7.74	29.4	1
Lower Kaelepulu	13		8						
Lower Kaelepulu	14	End Golf Course	0.5	70.4	23.02	23.02	7.7	28.5	0.4
Lower Kaelepulu	14	Lanikai Bridge	1	67.5	23.17	23.17	7.71	28.4	0.3
Lower Kaelepulu	14		2	67.2	23.48	23.48	7.71	28.3	0.5
Lower Kaelepulu	14		4						
Lower Kaelepulu	14		6						
Lower Kaelepulu	14		7						
Lower Kawainui	15	Below Wanaao Br	0.5	34.1	18.29	18.29	7.4	29.1	0.2
Lower Kawainui	15		1	39.4	20	20	7.5	31	0.8
Lower Kawainui	15		2	71.5	24.55	24.55	7.68	31	0.7
Lower Kawainui	15		4	55.5	25	25	7.75	31	0.9
Lower Kawainui	15		6	44.5	25.54	25.54	7.7	31	1.2
Lower Kawainui	15		7						
Lower Kawainui	17	Below KaawakeaB	0.5	26.8	14.54	14.54	7.31	28.8	0
Lower Kawainui	17		1	21	17.34	17.34	7.29	30.2	0.1
Lower Kawainui	17		2	42.9	24.28	24.28	7.45	31.7	0.3
Lower Kawainui	17		4	34.5	24.98	24.98	7.56	31.6	0.3
Lower Kawainui	17		6	28	25.2	25.2	7.53	31.6	0.5
Lower Kawainui	17								
Lower Kawainui	21	Below Hamakua	0.5	19.5	9.72	9.72	6.99	28.3	7
Lower Kawainui	21	In mangroves	1	15.2	17.5	17.5	6.92	31	0.8
Lower Kawainui	21	Hamakua Bridge	2	19.2	24	24	7.15	32	0.2
Lower Kawainui	21		4	15	24.85	24.85	7.31	32.6	1
Lower Kawainui	21		6	5.5	25.1	25.1	7.35	32.4	5.5
Lower Kawainui	21								
Upper Kawainui	24	Above Kailua Br	0.5	7.5	3.18	3.18	7.26	26.2	4.1
Upper Kawainui	24		1	3	4.75	4.75	7.01	26.4	4.6
Upper Kawainui	24		2	2.8	19.56	19.56	6.9	31.2	3
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	25	Marsh Big Bend	0.5	10.1	0.16	0.16	7.55	25.1	8.8
Upper Kawainui	25	Siphon	1	4.5	0.16	0.16	6.88	24.5	4
Upper Kawainui	25		2	3.5	0.16	0.16	6.75	24.1	3.3
Upper Kawainui	25		4						
Upper Kawainui	25		6						
Upper Kawainui	25		7						
Upper Kawainui	26	Above Island	0.5	8	1.68	1.68	7	25.2	6.1
Upper Kawainui	26	PreSch	1	7.5	1.69	1.69	6.93	25.2	5.9
Upper Kawainui	26	Sunshine Sch	2	3	2	2	6.85	25.8	3.8
Upper Kawainui	26		4	1.5	4.75	4.75	7.18	27.2	3.3
Upper Kawainui	26		5	1.1	8.06	8.06	7.04	27.4	2.6
Upper Kawainui	26		7						
Upper Kawainui	28	End Kaha Field	0.5	12	4.88	4.88	7.38	26.6	2
Upper Kawainui	28		1	10	4.88	4.88	7.36	26.6	1.8
Upper Kawainui	28		2	8	4.89	4.89	7.35	26.6	2
Upper Kawainui	28		3						

Kawainui Flow Restoration Project 201243

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary

	Site	Name	Date: 6/24/2015 Depth ft	DO % 90.8	Salinity 26.7	Corrected Salinity	pH 8.02	Temp C 33.5	NTU 7.5
WETLAND	1	Bob's Dock	0.5	21.3	19.63	16.34	6.9	27.1	3.5
WETLAND	1		1	18.5	19.86	16.53	7.19	27.3	3.4
WETLAND									
WETLAND									
WETLAND									
WETLAND									
WETLAND	2	Wetland	0.5	46.5	21.53	17.92	7.62	28.7	2
WETLAND	2		1	46.5	21.56	17.95	7.75	28.9	2.2
WETLAND									
WETLAND									
WETLAND									
WETLAND									
LAKE	3	Kofsky's	0	88.4	21.58	17.97	8	29.2	1.3
LAKE	3		1	90.2	21.6	17.98	8.01	29.1	1.2
LAKE	3		2	90.8	21.6	17.98	8.01	29.1	1.2
LAKE	3		4	90.8	21.6	17.98	8.01	29.1	1.2
LAKE	3		6	65	21.63	18.01	8	29.1	1.3
LAKE									
LAKE	4	Tom's	0	77.4	22.17	18.46	7.97	28.8	2
LAKE	4		1	78.7	22.17	18.46	7.97	29.5	1.9
LAKE	4		2	79	22.17	18.46	7.98	29.6	1.7
LAKE	4		4	78.7	22.17	18.46	7.98	29.6	1.8
LAKE	4		6	79.8	22.17	18.46	7.98	29.5	1.6
LAKE	4		8	79.4	22.17	18.46	7.98	29.5	1.5
LAKE									
LAKE	5	Mike's	0.5						
LAKE	5		1	80	22.22	18.50	8.01	29.6	2.2
LAKE	5		2	80.3	22.22	18.50	8.01	29.6	2.2
LAKE	5		4	80.6	22.22	18.50	8.01	29.6	2.1
LAKE	5		6	81.5	22.23	18.51	8.02	29.7	2.7
LAKE	5		8	81.4	22.23	18.51	8.02	29.7	2.4
LAKE									
LAKE	6	Stone's	0.5						
LAKE	6		1	66.8	21.64	18.02	7.95	28.7	1.3
LAKE	6		2	78.3	21.75	18.11	7.92	28.9	1.7
LAKE	6		4	71.3	22.06	18.37	7.96	28.9	2.8
LAKE	6		6	74.2	22.07	18.37	7.98	29.3	2.8
LAKE	6								
Upper Kaelepulu	7	Shallows	0	59.5	21.22	17.67	7.85	28.8	0.9
Upper Kaelepulu	7		1	56.5	21.45	17.86	7.85	29.2	0.9
Upper Kaelepulu	7		1.5	54	21.37	17.79	7.85	29.1	0.9
Upper Kaelepulu	7		4						
Upper Kaelepulu	7		6						
Upper Kaelepulu	7		7						
Upper Kaelepulu	8	End of Lake	0	61.8	20.98	17.47	7.86	29	0.9
Upper Kaelepulu	8		1	66	20.91	17.41	7.81	29.3	1
Upper Kaelepulu	8		2	56.6	21.46	17.87	7.83	29.3	1.4
Upper Kaelepulu	8		4	30.3	21.76	18.12	7.85	29.2	7
Upper Kaelepulu	8								
Upper Kaelepulu	8								
Upper Kaelepulu	9	Pig Head	0	67.2	20.3	16.90	7.81	29.4	1
Upper Kaelepulu	9		1	66.8	20.51	17.07	7.81	29.4	1.1
Upper Kaelepulu	9		2	62.6	20.9	17.40	7.8	29.6	1.1
Upper Kaelepulu	9		4	51.3	21.42	17.83	7.83	29.6	1.5
Upper Kaelepulu	9		6	48.7	21.51	17.91	7.83	29.7	2
Upper Kaelepulu	9								
Upper Kaelepulu	10	Side Channel	0	62.5	19.97	16.63	7.8	29	1.3
Upper Kaelepulu	10		1	61.5	20.4	16.98	7.76	29.4	1.3
Upper Kaelepulu	10		2	61.5	20.54	17.10	7.78	29.7	1.6
Upper Kaelepulu	10		4	59.5	21.6	17.98	7.87	31	2.4
Upper Kaelepulu	10		6	46.8	21.84	18.18	7.87	31.3	3.8
Upper Kaelepulu	10		7						
Upper Kaelepulu	11	Above Junction	0	41	18.1	15.07	7.62	29	1

	Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU
Upper Kaelepulu	11		1	43.2	19.15	15.94	7.6	28.9	1.3
Upper Kaelepulu	11		2	63	20.4	16.98	7.7	30.1	1.5
Upper Kaelepulu	11		4	44	21.65	18.02	7.75	31	2.4
Upper Kaelepulu	11		6	39.5	21.8	18.15	7.73	31.2	3.8
Upper Kaelepulu	11								
Lower Kaelepulu	12	Golf Island	0	48.5	18.15	15.11	7.58	28.5	1.8
Lower Kaelepulu	12		1	48.6	17	14.15	7.57	27.9	1.2
Lower Kaelepulu	12		2	68.5	20.85	17.36	7.72	30.8	1.1
Lower Kaelepulu	12		4	62.3	21.53	17.92	7.79	30.7	1.4
Lower Kaelepulu	12		6	33	22.05	18.36	7.82	31	4.9
Lower Kaelepulu	12		7						
Lower Kaelepulu	13	Mid Golf Course	0	69.7	19.2	15.98	7.7	28	1.4
Lower Kaelepulu	13	Halfway	1	68.7	19.15	15.94	7.72	28	1.14
Lower Kaelepulu	13		2	64.6	19.78	16.47	7.72	28.1	1.5
Lower Kaelepulu	13		4	65.5	21.06	17.53	7.6	29.5	1.1
Lower Kaelepulu	13		6	55.7	21.65	18.02	7.77	29.7	1.6
Lower Kaelepulu	13		7.5	3	26.7	22.23	7.33	33.5	4.4
Lower Kaelepulu	14	End Golf Course	0	66	20.48	17.05	7.74	29.1	1.1
Lower Kaelepulu	14	Lanikai Bridge	1	65.7	20.53	17.09	7.75	29.2	1.1
Lower Kaelepulu	14		2	56.5	20.65	17.19	7.76	29.2	1
Lower Kaelepulu	14		3	50.5	21.04	17.52	7.75	28.8	1
Lower Kaelepulu	14		6						
Lower Kaelepulu	14		7						
Lower Kawainui	15	Below Wanaao Br	0	21.3	16.36	13.62	7.42	28.9	1.5
Lower Kawainui	15		1	30.5	20.5	17.07	7.53	31.2	1.8
Lower Kawainui	15		2	49.1	20.73	17.26	7.62	31.3	2
Lower Kawainui	15		4	54.7	21.5	17.90	7.71	31.5	2.2
Lower Kawainui	15		6	23.5	22.15	18.44	7.69	31.2	5
Lower Kawainui	17	Below KaawakeaB	0	10	12.5	10.41	7.52	29	0.8
Lower Kawainui	17		1	10	12.35	10.28	7.43	29.1	0.8
Lower Kawainui	17		2	22	21.22	17.67	7.55	31.2	2.3
Lower Kawainui	17		4	35	21.72	18.08	7.64	31.2	2.6
Lower Kawainui	17		6	10	21.95	18.27	7.66	31.8	3.4
Lower Kawainui	21	Below Hamakua	0	20	8.89	7.40	7.23	28.6	1.6
Lower Kawainui	21	In mangroves	1	10	9.15	7.62	7.14	29	1.8
Lower Kawainui	21	Hamakua Bridge	2	4	18.3	15.24	7.2	31.8	2.5
Lower Kawainui	21		4	2.3	21.52	17.92	7.33	32.3	1.2
Lower Kawainui	21		6	1.9	23.5	19.56	7.12	32.1	6.6
Lower Kawainui	21								
Upper Kawainui	24	Above Kailua Br	0	5	7.16	5.96	7.24	26.9	4.5
Upper Kawainui	24		1	3	2.23	1.86	7.09	26.9	4.4
Upper Kawainui	24		2	2.3	15.03	12.51	6.85	30.3	4.4
Upper Kawainui	26	Above Island	0	7	1.3	1.08	7.4	26.3	4.4
Upper Kawainui	26	PreSch	1	5	1.33	1.11	7.15	26.3	3.9
Upper Kawainui	26	Sunshine Sch	2	3	1.78	1.48	7.05	26.7	3.6
Upper Kawainui	26		4	1.8	11.4	9.49	6.8	28.8	3.7
Upper Kawainui	26		5						
Upper Kawainui	26		7						
Upper Kawainui	28	End Kaha Field	0	5	2.44	2.03	7.35	27.2	2.2
Upper Kawainui	28		1	3	2.44	2.03	7.33	27.1	4
Upper Kawainui	28		2	1.9	2.47	2.06	7.31	27	7.5
Upper Kawainui	28		3						
Upper Kawainui	28		6						
Upper Kawainui	28		7						

*Salinity csv modified to reflect miscallibration, mult. By 34/40.84 0.83251714

Other dates that were changed to account for erroneously high values: 6/24/15, 8/9/15, 8/18/15

Kawainui Flow Restoration Project 201243

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary

	Site	Name	Date: 7/14/2015 Depth ft	DO % 90.8	Salinity 26.7	Corrected Salinity	pH 8.02	Temp C 33.5	NTU 7.5
WETLAND	1	Bob's Dock	0.5	21.3	19.63	16.34	6.9	27.1	3.5
WETLAND	1		1	18.5	19.86	16.53	7.19	27.3	3.4
WETLAND									
WETLAND									
WETLAND									
WETLAND									
WETLAND	2	Wetland	0.5	46.5	21.53	17.92	7.62	28.7	2
WETLAND	2		1	46.5	21.56	17.95	7.75	28.9	2.2
WETLAND									
WETLAND									
WETLAND									
WETLAND									
LAKE	3	Kofsky's	0	88.4	21.58	17.97	8	29.2	1.3
LAKE	3		1	90.2	21.6	17.98	8.01	29.1	1.2
LAKE	3		2	90.8	21.6	17.98	8.01	29.1	1.2
LAKE	3		4	90.8	21.6	17.98	8.01	29.1	1.2
LAKE	3		6	65	21.63	18.01	8	29.1	1.3
LAKE									
LAKE	4	Tom's	0	77.4	22.17	18.46	7.97	28.8	2
LAKE	4		1	78.7	22.17	18.46	7.97	29.5	1.9
LAKE	4		2	79	22.17	18.46	7.98	29.6	1.7
LAKE	4		4	78.7	22.17	18.46	7.98	29.6	1.8
LAKE	4		6	79.8	22.17	18.46	7.98	29.5	1.6
LAKE	4		8	79.4	22.17	18.46	7.98	29.5	1.5
LAKE									
LAKE	5	Mike's	0.5						
LAKE	5		1	80	22.22	18.50	8.01	29.6	2.2
LAKE	5		2	80.3	22.22	18.50	8.01	29.6	2.2
LAKE	5		4	80.6	22.22	18.50	8.01	29.6	2.1
LAKE	5		6	81.5	22.23	18.51	8.02	29.7	2.7
LAKE	5		8	81.4	22.23	18.51	8.02	29.7	2.4
LAKE									
LAKE	6	Stone's	0.5						
LAKE	6		1	66.8	21.64	18.02	7.95	28.7	1.3
LAKE	6		2	78.3	21.75	18.11	7.92	28.9	1.7
LAKE	6		4	71.3	22.06	18.37	7.96	28.9	2.8
LAKE	6		6	74.2	22.07	18.37	7.98	29.3	2.8
LAKE	6								
Upper Kaelepulu	7	Shallows	0	59.5	21.22	17.67	7.85	28.8	0.9
Upper Kaelepulu	7		1	56.5	21.45	17.86	7.85	29.2	0.9
Upper Kaelepulu	7		1.5	54	21.37	17.79	7.85	29.1	0.9
Upper Kaelepulu	7		4						
Upper Kaelepulu	7		6						
Upper Kaelepulu	7		7						
Upper Kaelepulu	8	End of Lake	0	61.8	20.98	17.47	7.86	29	0.9
Upper Kaelepulu	8		1	66	20.91	17.41	7.81	29.3	1
Upper Kaelepulu	8		2	56.6	21.46	17.87	7.83	29.3	1.4
Upper Kaelepulu	8		4	30.3	21.76	18.12	7.85	29.2	7
Upper Kaelepulu	8								
Upper Kaelepulu	8								
Upper Kaelepulu	9	Pig Head	0	67.2	20.3	16.90	7.81	29.4	1
Upper Kaelepulu	9		1	66.8	20.51	17.07	7.81	29.4	1.1
Upper Kaelepulu	9		2	62.6	20.9	17.40	7.8	29.6	1.1
Upper Kaelepulu	9		4	51.3	21.42	17.83	7.83	29.6	1.5
Upper Kaelepulu	9		6	48.7	21.51	17.91	7.83	29.7	2
Upper Kaelepulu	9								
Upper Kaelepulu	10	Side Channel	0	62.5	19.97	16.63	7.8	29	1.3
Upper Kaelepulu	10		1	61.5	20.4	16.98	7.76	29.4	1.3
Upper Kaelepulu	10		2	61.5	20.54	17.10	7.78	29.7	1.6
Upper Kaelepulu	10		4	59.5	21.6	17.98	7.87	31	2.4
Upper Kaelepulu	10		6	46.8	21.84	18.18	7.87	31.3	3.8
Upper Kaelepulu	10		7						
Upper Kaelepulu	11	Above Junction	0	41	18.1	15.07	7.62	29	1

	Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU
Upper Kaelepulu	11		1	43.2	19.15	15.94	7.6	28.9	1.3
Upper Kaelepulu	11		2	63	20.4	16.98	7.7	30.1	1.5
Upper Kaelepulu	11		4	44	21.65	18.02	7.75	31	2.4
Upper Kaelepulu	11		6	39.5	21.8	18.15	7.73	31.2	3.8
Upper Kaelepulu	11								
Lower Kaelepulu	12	Golf Island	0	48.5	18.15	15.11	7.58	28.5	1.8
Lower Kaelepulu	12		1	48.6	17	14.15	7.57	27.9	1.2
Lower Kaelepulu	12		2	68.5	20.85	17.36	7.72	30.8	1.1
Lower Kaelepulu	12		4	62.3	21.53	17.92	7.79	30.7	1.4
Lower Kaelepulu	12		6	33	22.05	18.36	7.82	31	4.9
Lower Kaelepulu	12		7						
Lower Kaelepulu	13	Mid Golf Course	0	69.7	19.2	15.98	7.7	28	1.4
Lower Kaelepulu	13	Halfway	1	68.7	19.15	15.94	7.72	28	1.14
Lower Kaelepulu	13		2	64.6	19.78	16.47	7.72	28.1	1.5
Lower Kaelepulu	13		4	65.5	21.06	17.53	7.6	29.5	1.1
Lower Kaelepulu	13		6	55.7	21.65	18.02	7.77	29.7	1.6
Lower Kaelepulu	13		7.5	3	26.7	22.23	7.33	33.5	4.4
Lower Kaelepulu	14	End Golf Course	0	66	20.48	17.05	7.74	29.1	1.1
Lower Kaelepulu	14	Lanikai Bridge	1	65.7	20.53	17.09	7.75	29.2	1.1
Lower Kaelepulu	14		2	56.5	20.65	17.19	7.76	29.2	1
Lower Kaelepulu	14		3	50.5	21.04	17.52	7.75	28.8	1
Lower Kaelepulu	14		6						
Lower Kaelepulu	14		7						
Lower Kawainui	15	Below Wanaao Br	0	21.3	16.36	13.62	7.42	28.9	1.5
Lower Kawainui	15		1	30.5	20.5	17.07	7.53	31.2	1.8
Lower Kawainui	15		2	49.1	20.73	17.26	7.62	31.3	2
Lower Kawainui	15		4	54.7	21.5	17.90	7.71	31.5	2.2
Lower Kawainui	15		6	23.5	22.15	18.44	7.69	31.2	5
Lower Kawainui	17	Below KaawakeaB	0	10	12.5	10.41	7.52	29	0.8
Lower Kawainui	17		1	10	12.35	10.28	7.43	29.1	0.8
Lower Kawainui	17		2	22	21.22	17.67	7.55	31.2	2.3
Lower Kawainui	17		4	35	21.72	18.08	7.64	31.2	2.6
Lower Kawainui	17		6	10	21.95	18.27	7.66	31.8	3.4
Lower Kawainui	21	Below Hamakua	0	20	8.89	7.40	7.23	28.6	1.6
Lower Kawainui	21	In mangroves	1	10	9.15	7.62	7.14	29	1.8
Lower Kawainui	21	Hamakua Bridge	2	4	18.3	15.24	7.2	31.8	2.5
Lower Kawainui	21		4	2.3	21.52	17.92	7.33	32.3	1.2
Lower Kawainui	21		6	1.9	23.5	19.56	7.12	32.1	6.6
Lower Kawainui	21								
Upper Kawainui	24	Above Kailua Br	0	5	7.16	5.96	7.24	26.9	4.5
Upper Kawainui	24		1	3	2.23	1.86	7.09	26.9	4.4
Upper Kawainui	24		2	2.3	15.03	12.51	6.85	30.3	4.4
Upper Kawainui	26	Above Island	0	7	1.3	1.08	7.4	26.3	4.4
Upper Kawainui	26	PreSch	1	5	1.33	1.11	7.15	26.3	3.9
Upper Kawainui	26	Sunshine Sch	2	3	1.78	1.48	7.05	26.7	3.6
Upper Kawainui	26		4	1.8	11.4	9.49	6.8	28.8	3.7
Upper Kawainui	26		5						
Upper Kawainui	26		7						
Upper Kawainui	28	End Kaha Field	0	5	2.44	2.03	7.35	27.2	2.2
Upper Kawainui	28		1	3	2.44	2.03	7.33	27.1	4
Upper Kawainui	28		2	1.9	2.47	2.06	7.31	27	7.5
Upper Kawainui	28		3						
Upper Kawainui	28		6						
Upper Kawainui	28		7						

*Salinity csv modified to reflect miscallibration, mult. By 34/40.84 0.83251714

Other dates that were changed to account for erroneously high values: 6/24/15, 8/9/15, 8/18/15

Kawainui Flow Restoration Project 201243

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary

			Date:	8/9/2015	92	31.45	0.83251714	8.07	33.3	10.3
	Site	Name	Depth ft	DO %	Salinity	Salinity	pH	Temp C	NTU	
WETLAND	1	Bob's Dock	0.5	22.2	23.05	19.19	7.46	26.8	0	
WETLAND	1		1	21.8	23.07	19.21		26.8	0	
WETLAND										
WETLAND										
WETLAND										
WETLAND										
WETLAND	2	Wetland	0.5	50.3	25.34	21.10	7.84	27.7	0	
WETLAND	2		1	40.9	25.35	21.10	7.89	28.1	0	
WETLAND										
WETLAND										
WETLAND										
WETLAND										
LAKE	3	Kofsky's	0.5	60	25.29	21.05	8	28.8	0	
LAKE	3		1	57.6	25.31	21.07	8.01	28.8	0	
LAKE	3		2	54.6	25.33	21.09	8	28.8	0	
LAKE	3		4	46.5	25.35	21.10	7.99	29	0	
LAKE	3		6							
LAKE										
LAKE	4	Tom's	0.5	75.4	25.43	21.17	8.04	29.4	0.2	
LAKE	4		1	72.5	25.47	21.20	8.05	29.5	0	
LAKE	4		2	71.9	25.47	21.20	8.05	29.5	0.1	
LAKE	4		4	73.9	25.48	21.21	8.06	29.5	0.2	
LAKE	4		6							
LAKE	4		8	66.1	25.52	21.25	8.04	29.4	1	
LAKE	5	Mike's	0.5	84.6	25.14	20.93	8.07	29.4	0	
LAKE	5		1							
LAKE	5		2	83.5	25.12	20.91	8.07	29.4	0	
LAKE	5		4							
LAKE	5		6	72.1	25.36	21.11	8.06	29.6	0.6	
LAKE	5		8	76.1	25.57	21.29	8.06	29.7	5.4	
LAKE										
LAKE	6	Stone's	0.5	68.4	23.09	19.22	7.95	29.3	0	
LAKE	6		1			0.00				
LAKE	6		2	78.6	25.29	21.05	8.06	29.9	0.9	
LAKE	6		4	77.8	25.3	21.06	8.06	29.8	1	
LAKE	6		5.5							
LAKE	6									
Upper Kaelepulu	7	Shallows	0.5	57.7	20.55	17.11	7.86	28.6	0	
Upper Kaelepulu	7		1	48.6	24.8	20.65	7.93	30.1	0	
Upper Kaelepulu	7		2							
Upper Kaelepulu	7		4							
Upper Kaelepulu	7		6							
Upper Kaelepulu	7		7							
Upper Kaelepulu	8	End of Lake	0.5	60.1	18.07	15.04	7.79	28.6	0	
Upper Kaelepulu	8		1	55.1	19.3	16.07	7.7	28.8	0.3	
Upper Kaelepulu	8		2	45	23.8	19.81	7.74	29.1	0.1	
Upper Kaelepulu	8		4	41.5	25.06	20.86	7.9	30	0	
Upper Kaelepulu	8									
Upper Kaelepulu	8									
Upper Kaelepulu	9	Pig Head	0.5	69.5	18.26	15.20	7.73	29.1	0	
Upper Kaelepulu	9		1	62.6	18.47	15.38	7.7	29.3	0.2	
Upper Kaelepulu	9		2	39	21.09	17.56	7.69	29.8	0.5	
Upper Kaelepulu	9		4	30.6	23.8	19.81	7.77	30	0	
Upper Kaelepulu	9		6	28	24.17	20.12	7.81	30	0.2	
Upper Kaelepulu	9									
Upper Kaelepulu	10	Side Channel	0.5	54.8	15.03	12.51	7.66	28.6	0.2	
Upper Kaelepulu	10		1	53.5	17.8	14.82	7.58	29.9	0.4	
Upper Kaelepulu	10		2	80.1	21.7	18.07	7.81	31.5	0.4	
Upper Kaelepulu	10		4	40	24.12	20.08	7.86	31.5	0.6	
Upper Kaelepulu	10		6	31.8	24.33	20.26	7.84	30.7	0.8	
Upper Kaelepulu	10		7							
Upper Kaelepulu	11	Above Junction	0.5	50	12.1	10.07	7.59	28.2	0	
Upper Kaelepulu	11		1	55.8	18.31	15.24	7.65	30.4	0.5	

Upper Kaelepulu	11		2	92	22.21	18.49	7.83	31.9	0.6
Upper Kaelepulu	11		4	35	24.39	20.31	7.87	31.6	1.7
Upper Kaelepulu	11		5						
Upper Kaelepulu	11								
Lower Kaelepulu	12	Golf Island	0.5	81.2	18.3	15.24	7.77	27.5	0
Lower Kaelepulu	12		1	76.3	20.2	16.82	7.79	28.2	0
Lower Kaelepulu	12		2	78	21.59	17.97	7.8	28.9	0
Lower Kaelepulu	12		4	83.6	23.59	19.64	7.89	31.3	0
Lower Kaelepulu	12		6	48.6	24.49	20.39	7.78	32.2	1.3
Lower Kaelepulu	12		8	42	25.32	21.08	7.88	33.3	1
Lower Kaelepulu	13	Mid Golf Course	0.5	83.2	22.07	18.37	7.9	28.8	0
Lower Kaelepulu	13	Halfway	1		22.09	18.39		28.9	
Lower Kaelepulu	13		2	81.3	22.16	18.45	7.9	28.9	0
Lower Kaelepulu	13		4	77.2	22.58	18.80		29	0
Lower Kaelepulu	13		6	70	22.67	18.87	7.88	29.6	0
Lower Kaelepulu	13		8	34.7	23.55	19.61	7.81	32.7	0
Lower Kaelepulu	14	End Golf Course	0.5	70	23.47	19.54	7.85	29.3	0
Lower Kaelepulu	14	Lanikai Bridge	1						
Lower Kaelepulu	14		2	66.8	23.51	19.57	7.85	29.3	0
Lower Kaelepulu	14		4	62.2	23.67	19.71	7.84	29.4	0
Lower Kaelepulu	14		6						
Lower Kaelepulu	14		7						
Lower Kawainui	15	Below Wanaao Br	0.5	40.7	11.29	9.40	7.42	28.3	0.2
Lower Kawainui	15		1	36.2	18.45	15.36	7.48	30.5	0
Lower Kawainui	15		2	50.5	21.4	17.82	7.69	30.9	0
Lower Kawainui	15		4	64.5	23.79	19.81	7.82	32	0
Lower Kawainui	15		6	24.7	24.94	20.76	7.81	32.3	0
Lower Kawainui	15		7						
Lower Kawainui	17	Below KaawakeaB	0.5	14.5	7.04	5.86	7.15	28.9	0
Lower Kawainui	17		1	11	7.22	6.01	7.05	28.9	0.2
Lower Kawainui	17		2	27.7	22.73	18.92	7.16	32.1	0.5
Lower Kawainui	17		4	51.4	23.75	19.77	7.7	32.3	1.7
Lower Kawainui	17		6	34.2	24.4	20.31	7.75	32.3	5.2
Lower Kawainui	17								
Lower Kawainui	21	Below Hamakua	0.5	20.5	5.15	4.29	7.13	29	1.1
Lower Kawainui	21	In mangroves	1	15.7	9.26	7.71	6.83	28.7	0.9
Lower Kawainui	21	Hamakua Bridge	2	14	20.5	17.07	6.99	31.9	1.1
Lower Kawainui	21		4	3.9	23.98	19.96	7.22	32.7	1.3
Lower Kawainui	21		6	1.6	31.45	26.18	6.75	32.3	10.3
Lower Kawainui	21								
Upper Kawainui	24	Above Kailua Br	0.5	11	0.56	0.47	7.64	26.2	7.3
Upper Kawainui	24		1	3.4	0.58	0.48	7.3	26.2	7.4
Upper Kawainui	24		1.7	2.6	1.23	1.02	6.9	26.2	8.6
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	25	Marsh Big Bend	0.5						
Upper Kawainui	25	Project Site	1	8.4	0.15	0.12	7.11	26.1	5.3
Upper Kawainui	25		2						
Upper Kawainui	25		4						
Upper Kawainui	25		6						
Upper Kawainui	25		7						
Upper Kawainui	26	Above Island	0.5	11	0.36	0.30	7.2	26.4	2.9
Upper Kawainui	26	PreSch	1	8.6	0.38	0.32	7.07	26.3	3
Upper Kawainui	26	Sunshine Sch	2	5.6	0.39	0.32	6.96	26.2	3.4
Upper Kawainui	26		4	1.7	1.83	1.52	7	25.6	8.7
Upper Kawainui	26		5						
Upper Kawainui	26		7						
Upper Kawainui	27	Last Side Channel	0.1						
Upper Kawainui	27		1						
Upper Kawainui	27		2						
Upper Kawainui	27		4						
Upper Kawainui	27		6						
Upper Kawainui	27		7						
Upper Kawainui	28	End Kaha Field	0.5	46	1	0.83	7.33	28.2	1.8
Upper Kawainui	28		1	1.07	1.89	1.57	7.3	28.1	1.2
Upper Kawainui	28		2	7.6	1.9	1.58	7.27	28.1	2.2

Kawainui Flow Restoration Project `` 201243

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary

			Date:	8/18/2015	115	40.48		7.87	31.9	11.5
	Site	Name	Depth ft	DO %	Salinity	Sal (correcte	pH		Temp C	NTU
WETLAND	1	Bob's Dock	0.5	16.9	19.28	16.05	7.37		29.3	0
WETLAND	1		1	15.4	20.82	17.33			29.4	0.1
WETLAND						0.00				
WETLAND						0.00				
WETLAND						0.00				
WETLAND						0.00				
WETLAND	2	Wetland	0.5	32	20.98	17.47	7.54		29.1	0
WETLAND	2		1	12	21.43	17.84	7.54		29.3	0
WETLAND						0.00				
WETLAND						0.00				
WETLAND						0.00				
WETLAND						0.00				
LAKE	3	Kofsky's	0.5	40.5	19.72	16.42	7.34		27.4	0.4
LAKE	3		1	55	22.15	18.44	7.63		29.5	0.4
LAKE	3		2	65	24	19.98	7.71		30.3	0
LAKE	3		4	65	24.53	20.42	7.74		30.2	0
LAKE	3		6	27	24.63	20.50	7.63		29.9	0.7
LAKE						0.00				
LAKE	4	Tom's	0.5	75	20.24	16.85	7.78		26.9	0.4
LAKE	4		1	64	21.23	17.67	7.77		27.8	0.8
LAKE	4		2	72	22.52	18.75	7.78		28.7	0.2
LAKE	4		4	85	24.48	20.38	7.83		29.9	0
LAKE	4		6	85	24.61	20.49	7.85		29.9	0
LAKE	4		8	40	24.64	20.51	7.66		29.6	0.4
LAKE										
LAKE	5	Mike's	0.5	57	17.19	14.31	7.87		27	3.1
LAKE	5		1	77	21.83	18.17	7.69		28.6	0.6
LAKE	5		2	82	22.87	19.04	7.8		29.2	0.3
LAKE	5		4	57.7	24.38	20.30	7.77		30.1	0
LAKE	5		6			0.00				0.1
LAKE	5		8	53.5	24.73	20.59	7.72		29.9	3.8
LAKE										
LAKE	6	Stone's	0.5	45	17.69	14.73	7.62		28.5	1.9
LAKE	6		1	74	21.92	18.25	7.7		28.9	0.9
LAKE	6		2	80	23.23	19.34	7.81		29.5	0.3
LAKE	6		4	59	24.49	20.39	7.78		30.1	0.1
LAKE	6					0.00				
LAKE	6					0.00				
Upper Kaelepulu	7	Shallows	0.5	56	14.05	11.70	7.62		26.8	3.3
Upper Kaelepulu	7		1	62	21.12	17.58	7.57		29	1.2
Upper Kaelepulu	7		2			0.00				
Upper Kaelepulu	7		4			0.00				
Upper Kaelepulu	7		6			0.00				
Upper Kaelepulu	7		7			0.00				
Upper Kaelepulu	8	End of Lake	0.5	48	16.35	13.61	7.38		27.3	0.6
Upper Kaelepulu	8		1	40.3	20.46	17.03	7.32		29.4	0.8
Upper Kaelepulu	8		2	35	27.63	23.00	7.38		30.3	0.7
Upper Kaelepulu	8		4	7	38.06	31.69	7.34		31.4	2.7
Upper Kaelepulu	8		4	5.1	38.22	31.82	7.34		31.9	0.6
Upper Kaelepulu	8					0.00				
Upper Kaelepulu	9	Pig Head	0.5	47	14.75	12.28	7.46		27.8	1.2
Upper Kaelepulu	9		1	34.6	17.89	14.89	7.76		28.9	1
Upper Kaelepulu	9		2	34	27.45	22.85	7.76		31	0.6
Upper Kaelepulu	9		4	41	38.64	32.17	7.39		31.5	0.2
Upper Kaelepulu	9		6	38.8	39.8	33.13	7.49		31.7	2.8
Upper Kaelepulu	9					0.00				
Upper Kaelepulu	10	Side Channel	0.5	44.1	13.48	11.22	7.46		27.8	0.5
Upper Kaelepulu	10		1	34.4	16.71	13.91	7.2		28.7	0.7
Upper Kaelepulu	10			55	28.4	23.64	7.25		31.2	0.2
Upper Kaelepulu	10		4	60	37.84	31.50	7.45		31.7	0
Upper Kaelepulu	10		6	53.5	39.97	33.28	7.57		31.5	5.2

	Site	Name	Depth ft	DO %	Salinity	Sal (correcte	pH	Temp C	NTU
Upper Kaelepulu	10		8	62.9	33	27.47	7.6	31.8	0
Upper Kaelepulu	11	Above Junction	0.5	34	11.56	9.62	7.33	27.6	0.9
Upper Kaelepulu	11		1	30	17	14.15	7.12	29.1	0.4
Upper Kaelepulu	11		2	39	27.53	22.92	7.36	31.7	0.3
Upper Kaelepulu	11		4	36.7	38.8	32.30	7.43	31.5	0
Upper Kaelepulu	11					0.00			
Upper Kaelepulu	11					0.00			
Lower Kaelepulu	12	Golf Island	0.5	38	11.75	9.78	7.46	27.4	1
Lower Kaelepulu	12		1	29	17.18	14.30	7.12	29.2	0.8
Lower Kaelepulu	12		2	89.3	27.48	22.88	7.44	30.9	0.4
Lower Kaelepulu	12		4	112	38.25	31.84	7.62	31.5	0
Lower Kaelepulu	12		6	86	40.35	33.59	7.72	31	2.2
Lower Kaelepulu	12		8	76	40.48	33.70	7.71	30.7	4
Lower Kaelepulu	13	Mid Golf Course	0.5	60.1	12.57	10.46	7.6	26.7	0.4
Lower Kaelepulu	13		1	43.8	16.44	13.69	7.25	28.3	0.7
Lower Kaelepulu	13		2	88	27.26	22.69	7.48	30.4	0
Lower Kaelepulu	13		4	115	38.2	31.80	7.66	31.1	0.5
Lower Kaelepulu	13		6	96	40.1	33.38	7.76	31.1	0.5
Lower Kaelepulu	13		8	82.4	40.36	33.60	7.71	30.6	3.3
Lower Kaelepulu	14	End Golf Course	0.5	67	12.18	10.14	7.52	26.2	5.8
Lower Kaelepulu	14		1	52	16.26	13.54	7.31	27.6	1.9
Lower Kaelepulu	14		2	61	28.4	23.64	7.33	29.9	0.8
Lower Kaelepulu	14		3	65	32.85	27.35	7.53	30.3	2
Lower Kaelepulu	14					0.00			
Lower Kaelepulu	14					0.00			
Lower Kawainui	15	Below Wanaao Br	0.5	23.3	10.56	8.79	7.3	28.6	1.1
Lower Kawainui	15		1	32	17.86	14.87	7.11	29.4	0
Lower Kawainui	15		2	82	21.15	17.61	7.4	31.3	0
Lower Kawainui	15		4	80	37.5	31.22	7.53	31.5	0
Lower Kawainui	15		6	57	40.14	33.42	7.6	31.3	5.2
Lower Kawainui	15		7	53	40.36	33.60	7.59	31	9.9
Lower Kawainui	17	Below KaawakeaB	0.5	19.6	9.41	7.83	7.41	28.5	0.8
Lower Kawainui	17		1	31.5	20.1	16.73	7.12	29.8	0
Lower Kawainui	17		2	45	26.8	22.31	7.2	30.7	0
Lower Kawainui	17		4	13	37.8	31.47	7.42	31.3	0.9
Lower Kawainui	17		6	28	39.8	33.13	7.45	31.3	10
Lower Kawainui	17					0.00			
Lower Kawainui	21	Below Hamakua	0.5	22	3.87	3.22	7.2	26.3	0.8
Lower Kawainui	21	In mangroves	1	33	8.25	6.87	7.18	27.4	1.2
Lower Kawainui	21		2	15	12.68	10.56	7.24	29.7	0.6
Lower Kawainui	21		4	7.9	32.55	27.10	7.33	31.3	0.2
Lower Kawainui	21		6	6.2	38.02	31.65	7.35	31.6	4.5
Lower Kawainui	21					0.00			
Upper Kawainui	24	Above Kailua Br	0.5	5.7	0.66	0.55	7.43	25.8	8.2
Upper Kawainui	24		1	4.2	0.71	0.59	7.21	25.9	8.3
Upper Kawainui	24		2	2.8	11.47	9.55	6.63	27.2	11.5
Upper Kawainui	24		1.5	2.8	10.3	8.57	6.62	26.3	10.5
Upper Kawainui	24		1.3	2.8	8	6.66	6.63	26.3	10.2
Upper Kawainui	24					0.00			
Upper Kawainui	26	PreSch	0.5	5.5	0.27	0.22	7.19	25.8	9.3
Upper Kawainui	26		1	3.9	0.27	0.22	6.95	25.8	9.3
Upper Kawainui	26		2	3.4	0.36	0.30	6.33	25.9	7.9
Upper Kawainui	26		4	2.6	1.66	1.38	6.81	25.6	6
Upper Kawainui	26		6			0.00			
Upper Kawainui	26		7			0.00			
Upper Kawainui	28	End Kaha Field	0.5	5.9	1.46	1.22	7.22	26.4	3.9
Upper Kawainui	28		1	3	1.46	1.22	7.21	26.4	3.7
Upper Kawainui	28		2.5	6.1	1.46	1.22	7.22	26.4	4.3
Upper Kawainui	28		3						
Upper Kawainui	28		6						
Upper Kawainui	28		7						
Upper Kawainui		Ocean calm surf	0.5	100	40.84		7.65	28.1	4.4
Upper Kawainui					*Salinity csv modified to reflect miscallibration, mult. By 34/40.84				

Kawainui Flow Restoration Project 201243

Physical Water Quality Transects of Kawainui (12-28) and Kaelepulu (1-14) Estuary

			Date:	9/10/2015	97.9	29.95 Salinity		8	33.2	17
	Site	Name	Depth ft	DO %	Salinity	Corrected	pH	Temp C	NTU	
WETLAND	1	Bob's Dock	0.5	25.4	12.18	12.18	6.73	30.3	6.9	
WETLAND	1		1	21.9	13.3	13.3	7	31.1	6.6	
WETLAND			2	21.7	13.67	13.67	7.23	31.4	5.6	
WETLAND										
WETLAND										
WETLAND										
WETLAND	2	Wetland	0.5	20	12.33	12.33	7.23	30.3	8.1	
WETLAND	2		1	47.9	13.15	13.15	7.45	30.9	4.5	
WETLAND			2	47	14	14	7.44	31.4	5	
WETLAND										
WETLAND										
WETLAND										
LAKE	3	Kofsky's	0.5	51.5	12.06	12.06	7.52	29.6	7.6	
LAKE	3		1	63.5	12.5	12.5	7.67	29.6	5.6	
LAKE	3		2	59.5	13.63	13.63	7.7	30.9	4.4	
LAKE	3		4	22.9	15.93	15.93	7.58	31.8	3.4	
LAKE	3		6	4.1	18.8	18.8	7.34	32	4.4	
LAKE										
LAKE	4	Tom's	0.5	84.7	12.87	12.87	7.87	29.2	4.7	
LAKE	4		1	84.2	12.95	12.95	7.93	29.3	4.6	
LAKE	4		2	83.8	13.28	13.28	7.97	29.6	4.4	
LAKE	4		4	16	16.09	16.09	7.7	31.9	3.5	
LAKE	4		6	6.5	18.84	18.84	7.42	32	2.9	
LAKE	4		8	3	23.42	23.42	7.25	31.8	4.3	
LAKE	4		10	2.4	24.6	24.6	7.08	31.4	2.2	
LAKE	5	Mike's	0.5	87.6	13.41	13.41	7.98	30	4.6	
LAKE	5		1	86.6	13.42	13.42	8	30	7.99	
LAKE	5		2	84.7	13.44	13.44	8	30.1	4.5	
LAKE	5		4	15.3	16.02	16.02	7.74	31.9	4.5	
LAKE	5		6	4.5	18.7	18.7	7.45	32.1	2.3	
LAKE	5		8	2	23.89	23.89	7.21	31.8	4.9	
LAKE	5		10	2.4	24.73	24.73	7.17	31.6	2.5	
LAKE	6	Stone's	0.5	81.5	13.36	13.36	7.94	29.9	4.7	
LAKE	6		1	80.5	13.37	13.37	7.98	30	4.6	
LAKE	6		2	67	13.42	13.42	7.96	30.1	4.6	
LAKE	6		4	4.3	16.28	16.28	7.63	32	3.6	
LAKE	6		6	2.9	18.34	18.34	7.39	32.1	2.4	
LAKE	6									
Upper Kaelepulu	7	Shallows	0.5	54.4	13.37	13.37	7.74	29.9	5	
Upper Kaelepulu	7		1	50	13.37	13.37	7.76	29.8	4.6	
Upper Kaelepulu	7		2	49.6	13.43	13.43	7.75	30	4.3	
Upper Kaelepulu	7		4							
Upper Kaelepulu	7		6							
Upper Kaelepulu	7		7							
Upper Kaelepulu	8	End of Lake	0.5	57.4	13.24	13.24	7.75	29.8	4.1	
Upper Kaelepulu	8		1	56.7	13.44	13.44	7.77	30.2	4.4	
Upper Kaelepulu	8		2	45.6	13.61	13.61	7.74	30.6	4.3	
Upper Kaelepulu	8		4	4.1	20.99	20.99	7.45	32.4	2.9	
Upper Kaelepulu	8		5	2.6	23.3	23.3	7.33	32.5	3.5	
Upper Kaelepulu	8									
Upper Kaelepulu	9	Pig Head	0.5	57	13.7	13.7	7.72	30.2	3.3	
Upper Kaelepulu	9		1	52.6	13.74	13.74	7.74	30.3	3.4	
Upper Kaelepulu	9		2	34.1	13.85	13.85	7.68	30.5	3.9	
Upper Kaelepulu	9		4	55.4	19.61	19.61	7.55	32.5	3.6	
Upper Kaelepulu	9		6	6.2	27.89	27.89	7.37	32.5	3.7	
Upper Kaelepulu	9		8	3.2	29.32	29.32	7.26	32	3.3	
Upper Kaelepulu	10	Side Channel	0.5	77.6	12.88	12.88	7.77	29.2	1.7	
Upper Kaelepulu	10		1	52.4	13.56	13.56	7.7	29.5	2.3	
Upper Kaelepulu	10		2	60.1	14.04	14.04	7.73	30	2.8	
Upper Kaelepulu	10		4	57	20.45	20.45	7.62	32.9	3.6	
Upper Kaelepulu	10		6	4.5	27.73	27.73	7.48	33	3.7	
Upper Kaelepulu	10		8	3	29.63	29.63	7.33	31.9	3.2	
Upper Kaelepulu	11	Above Junction	0.5	47.5	11.78	11.78	7.54	28.6	1.3	

	Site	Name	Depth ft	DO %	Salinity	Corrected pH	Temp C	NTU
Upper Kaelepulu	11		1	59.5	13.19	13.19	7.61	30.2	2.3
Upper Kaelepulu	11		2	81.3	14.74	14.74	7.84	31.3	2.9
Upper Kaelepulu	11		4	54.4	19.96	19.96	7.74	33.1	3.4
Upper Kaelepulu	11		6	5	28.03	28.03	7.48	33.1	4.2
Upper Kaelepulu	11								
Lower Kaelepulu	12	Golf Island	0.5	56.2	12.62	12.62	7.69	30.2	1.9
Lower Kaelepulu	12		1	69.7	13.9	13.9	7.76	31	2.4
Lower Kaelepulu	12		2	82.7	14.34	14.34	7.85	30.8	2.6
Lower Kaelepulu	12		4	86.7	19.24	19.24	7.8	33	3.3
Lower Kaelepulu	12		6	49	27.85	27.85	7.64	33.2	3.8
Lower Kaelepulu	12		8	6.5	29.93	29.93	7.5	32.3	3.4
Lower Kaelepulu	13	Mid Golf Course	0.5	73	13.2	13.2	7.81	29.7	1.9
Lower Kaelepulu	13	Halfway	1	78	13.77	13.77	7.84	30.2	2.4
Lower Kaelepulu	13		2	86	14.22	14.22	7.94	30.3	2.8
Lower Kaelepulu	13		4	97.9	19.81	19.81	7.85	32.7	3
Lower Kaelepulu	13		6	51.5	28.38	28.38	7.72	32.8	2.7
Lower Kaelepulu	13		8	18.8	29.69	29.69	7.63	32.3	2.1
Lower Kaelepulu	14	End Golf Course	0.5	80.1	12.73	12.73	7.83	28.9	1.8
Lower Kaelepulu	14	Lanikai Bridge	1	80.3	13.56	13.56	7.85	29.7	2.3
Lower Kaelepulu	14		2	79.5	13.82	13.82	7.9	29.7	2.4
Lower Kaelepulu	14		4	72.2	16.33	16.33	7.81	31.4	3.7
Lower Kaelepulu	14		6						
Lower Kaelepulu	14		7						
Lower Kawainui	15	Below Wanaao Br	0.5	40.8	12.27	12.27	7.49	30.6	1.5
Lower Kawainui	15		1	59.4	13.35	13.35	7.48	31.1	2.2
Lower Kawainui	15		2	86	14.63	14.63	7.76	31.4	2.9
Lower Kawainui	15		4	21.6	20.75	20.75	7.67	31.9	3.1
Lower Kawainui	15		6	5	27.75	27.75	7.38	33	4
Lower Kawainui	15		8	3.1	29.95	29.95	7.36	32.5	7.8
Lower Kawainui	17	Below KaawakeaB	0.5	34.4	10.98	10.98	7.41	30.8	1.4
Lower Kawainui	17		1	41.7	12.22	12.22	7.38	31.5	1.7
Lower Kawainui	17		2	82.9	15	15	7.66	32.1	2.2
Lower Kawainui	17		4	20	19.73	19.73	7.6	32.4	5.7
Lower Kawainui	17		6	5.4	28.3	28.3	7.31	32.7	4.1
Lower Kawainui	21	Below Hamakua	0.5	5.8	4.8	4.8	7.17	29.7	3.1
Lower Kawainui	21	In mangroves	1	8.2	5.96	5.96	7.02	30	2.7
Lower Kawainui	21	Hamakua Bridge	2	5.5	10.12	10.12	6.96	30.9	2.6
Lower Kawainui	21		4	3.1	20.48	20.48	6.91	32.2	4.3
Lower Kawainui	21		6						
Lower Kawainui	21								
Upper Kawainui	24	Above Kailua Br	0.5	7	1.27	1.27	7.56	28.3	4.4
Upper Kawainui	24		1	3.7	2.18	2.18	7.23	28	4.8
Upper Kawainui	24		2	3.4	9.15	9.15	6.9	30.3	3.2
Upper Kawainui	24		4	2.4	28.26	28.26	6.9	31.9	6.3
Upper Kawainui	24								
Upper Kawainui	24								
Upper Kawainui	26	Above Island	0.5	16.5	0.93	0.93	7.46	27.7	1.9
Upper Kawainui	26	PreSch	1	3.1	0.94	0.94	7.35	26.9	3
Upper Kawainui	26	Sunshine Sch	2	1.5	5.6	5.6	7.01	27.6	1.1
Upper Kawainui	26		4	1.6	14	14	6.92	30.6	2.4
Upper Kawainui	26		5						
Upper Kawainui	26		7						
Upper Kawainui	28	End Kaha Field	0.5	16.6	1.48	1.48	7.52	27.6	2.8
Upper Kawainui	28		1	10.8	1.48	1.48	7.5	27.7	3.2
Upper Kawainui	28		2	3.1	1.62	1.62	7.26	27.5	17
Upper Kawainui	28		3						
Upper Kawainui	28		6						
Upper Kawainui	28		7						
Upper Kawainui		Fresh Tap water		109	0.1	0.1	8.32	27.1	0