Ka’elepulu Stream and Ka’elepulu Pond Water Quality Assessment Report

The Hawaii State Department of Health
Clean Water Branch
July 30, 2021

Acknowledgments

Hawaii State Department of Health Clean Water Branch would like to thank all those who contributed to this water quality assessment of Ka'elepulu Stream and Ka'elepulu Pond. A special thank you to the Mid Pacific Country Club, the Enchanted Lake Residents Association, and the residents of Kailua for granting CWB access to the pond and stream, enabling us to conduct our sampling. We could not have done it without you.

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Abbreviations and Definitions

% E STNDRD	Percent of data that exceeds the relevant standard
(µg N/L)	Micrograms of Nitrogen Per Liter
(µg NH_4-N/L)	Micrograms of Ammonia Nitrogen Per Liter
(µg [NO_3+NO_2]-N/L)	Micrograms of Nitrate plus Nitrite Nitrogen Per Liter
(µg P/L)	Micrograms of Phosphorus Per Liter
(cfu/100ml)	Colony forming units per 100 milliliters
(mg/L)	Milligrams Per Liter
(NTU)	Nephelometric Turbidity Units
10% NTE	90% of data must fall below the listed value in order to meet water quality standards (WQS).
AVG	Average or Arithmetic Mean
Chl a	Chlorophyll *a*
Cp	*Clostridium perfringens*
CWB	Clean Water Branch of Department of Health
DO	Dissolved Oxygen
DOH	Department of Health
DO sat.	Dissolved Oxygen Saturation
Dry Event	When the Ka'elepulu region experienced < 0.3 inches of rainfall in a day within 3 days of sampling
Dry Season	May through October
Ent.	Enterococci
GM	Geometric Mean
Makai	In the direction of the sea
Mauka	In the direction of the mountains
NH_4	Ammonia
NHD	National Hydrography Dataset
NO_3+NO_2	Nitrate plus Nitrite
ppt	Parts Per Thousand
QAPP	Quality Assurance Project Plan
Sal.	Salinity
Sample Size	Number of samples collected for each parameter
SOP	Standard Operating Procedures
STNDRD	Standard
Temp.	Temperature
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USACE	US Army Corps of Engineers
Wet Event	When the Ka'elepulu region experienced ≥ 0.3 inches of rainfall in a day within 3 days of sampling
Wet Season	November through April
WQS	Water Quality Standards

Introduction

The Ka'elepulu Waterbody is located on the windward (east) side of the island of Oahu in the Hawaiian Archipelago within the town of Kailua. This waterbody consists of a stream portion (Ka'elepulu Stream) and pond portion (Ka'elepulu Pond), otherwise known as Enchanted Lake (Figure 1). This system resides in the lower basin of the approximately 3,486-acre Ka'elepulu Watershed, draining the lower rises of Olomana, Keolu, Ehu, Kaiwa, and Kalaei Ridges. Materials like sediment and pollutants are carried through the watershed by runoff and stream flow and either settle in the waterbody or flush out to Kailua Bay, depending on the flow velocity and presence of a naturally forming sand berm. Historically, the stream and pond functioned as part of a wetland system also referred to as Ka'elepulu Pond. There are also historical accounts of the pond being maintained by the locals as a fishpond, but this practice has long since ended.

In 1952, in response to repeated flooding events in the urban areas of Kailua, Oneawa canal (Figure 1) was constructed by the US Army Corps of Engineers (USACE). This canal ran along the north side of town and diverted the flow from Kawai Nui marsh away from Kawai Nui Stream and into the northern side of Kailua Bay. Prior to this divergence, Kawai Nui marsh was connected to Ka'elepulu Stream through the Kawai Nui Stream. The remaining flow connection was further severed when the USACE completed construction of a levee in 1966. The levee was built in response to continued flooding events. In 1993, the levee was increased, and an additional four-foot-high concrete wall was added. This was in response to a flood event in 1987 that topped the levee at the time.

In the 1960s, the pond and wetlands were altered and filled as part of a housing development later named Enchanted Lake. As part of this development, the pond was dredged to 15 feet and the area was reduced from 180 acres of wetland and pond to a 100 acre "lake." This alteration of the pond combined with the lack of flow from Kawai Nui resulted in an overall decrease in stream flow for the Ka'elepulu Waterbody and, ultimately, an increase in sedimentation. Additionally, this lake was incorporated into the newly constructed stormwater system that was built to serve the recent housing development. The use of this stormwater system was later deeded to the City and County of Honolulu.

The Ka'elepulu Waterbody was originally listed by the Hawaii State Department of Health (DOH) Clean Water Branch (CWB) as two separate waterbodies: "Kaelepulu", classified as a stream, and "Kaelepulu Stream-Kailua Beach", (mis)classified as an estuary. Both have been listed as impaired on the Hawaii DOH Integrated Report since 1998. "Kaelepulu Steam-Kailua Beach" was assessed based on analytical data. However, "Kaelepulu" (stream) was only visually assessed by the US Environmental Protection Agency in 1998 and deemed to be impaired for total nitrogen (TN), nitrate plus nitrite (NO_3+NO_2), total phosphorus (TP), and turbidity. "Kaelepulu Stream-Kailua Beach" was considered impaired for enterococci, total nitrogen, total phosphorus, turbidity, and chlorophyll *a* based on analyses of water samples and comparison to water quality standards. Until recently, further assessment had been challenging due to access constraints. DOH CWB's work to address the Ka'elepulu impairments began in 2005. Unfortunately, the data that was collected for that project did not meet data quality standards. This prevented further action by DOH CWB. DOH CWB resumed work in Ka'elepulu in 2019 to collect new data using more reliable quality assurance and control procedures.

This assessment study was designed to collect recent data in order to evaluate the current status of the water quality within the stream and pond as well as to numerically, rather than visually, assess the water quality within the pond. DOH CWB needed to evaluate the waterbody for both wet and dry weather conditions. Instead of lumping data for certain months and considering them wet or dry season data, DOH CWB was more interested in capturing data representative of "wet events" and "dry events." Wet events were defined as sample collection days where the area experienced a daily rainfall of at least 0.3 inches within three days of the sample day. Dry events occurred when the area experienced a daily rainfall of less than 0.3 inches within three days of the sample day. Thus, wet events and dry events were sampled during both wet and dry seasons (the wet season is defined as November through April and the dry season is defined as May through October in Hawaii's water quality standards).

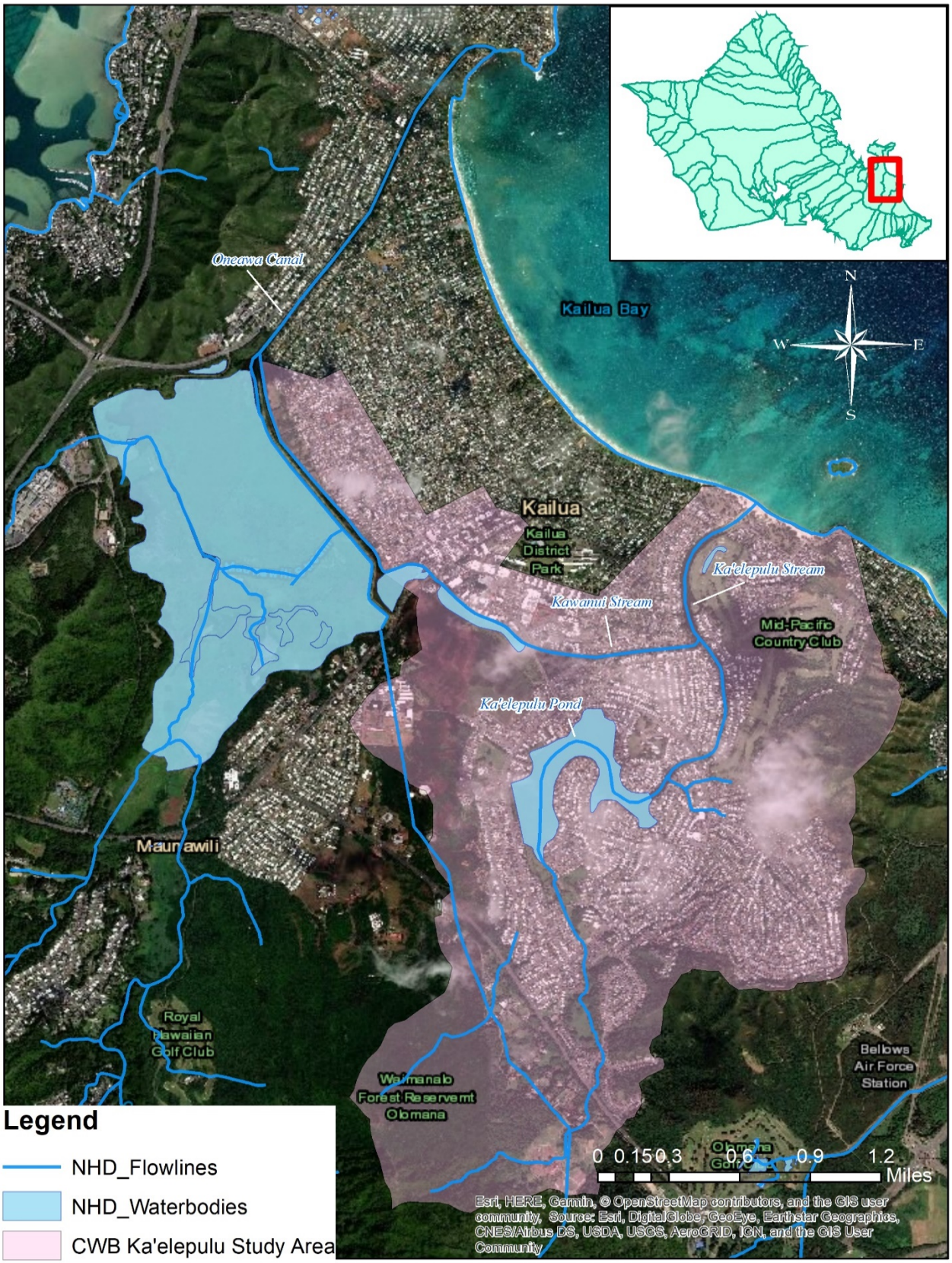


FIGURE 1: IDENTIFICATION OF RELEVANT WATERBODIES AND CWB'S STUDY AREA. FLOWLINES AND WATERBODIES ARE AS IDENTIFIED BY THE U.S. GEOLOGICAL SURVEY'S NATIONAL HYDROGRAPHY DATASET (NHD).

Applicable Standards

Hawaii does not currently have definitive numeric water quality standards that are applicable to the Ka'elepulu Waterbody. It is unclear or certainly debatable if the Ka'elepulu Waterbody should be treated like an estuary since there is a natural buildup of a sand berm near the mouth of the Ka'elepulu Stream. This is due to the low stream flow velocity and the stronger currents and wave action within Kailua Bay pushing against the stream flow which has greatly reduced surface water connection between the Ka'elepulu Waterbody and Kailua Bay. There may have been more surface water connection prior to the construction of the levee and the Enchanted Lake residential development, but these projects worked to reduce the stream flow. Due to the historic hydrologic modifications made to the Ka'elepulu stream and pond, the waterbody no longer has a natural surface water connection to the open ocean and therefore does not function as an estuary.

DOH has determined that applying the numeric standard for streams (Hawaii Administrative Rule §11-54-5.2) seems reasonable as a start. However, the Ka'elepulu Stream does not technically meet the definition of a freshwater stream per the Hawaii Administrative Rule §11-54-5.1 (given that the salinity is greater than 0.5 ppt). Nevertheless, DOH has determined the stream standards to be the most applicable of current available standards. The heavily modified nature of the waterbody makes it unclassifiable at this time, based on existing water quality standards. Hawaii's stream standards are still incredibly stringent and a very worthy goal for any waterbody.

Hawaii does not have stream standards for parameters such as ammonia, dissolved silica, Cp or Chl *a*. Data was collected for these parameters to be informative but was not used to determine impairment since there are no applicable standards for these parameters. Tables with the analyses of these parameters can be found in Appendix – B.

Hawaii's recreational water criteria are applicable to all state waters. These criteria are designed to protect the public from exposure to harmful levels of pathogens while participating in water-contact activities. Enterococci are used as fecal indicator bacteria to determine the presence of harmful pathogens. As specified in HAR 11-54-8, enterococci counts shall not exceed a geometric mean (GM) of 35 colony forming units per one hundred milliliters (cfu/100ml).

Monitoring Design and Methods

All monitoring methods for sample collection and analysis are consistent with all relevant DOH CWB Quality Assurance Project Plans (QAPP) and Standard Operating Procedures (SOP) for Stream Monitoring, Beach Monitoring, and Nearshore Coastal Chemistry Monitoring. Refer to those documents for more detail.

Study Area

While the State has defined watershed boundaries for each of the major islands, the study area of Ka'elepulu has been modified to account for stormwater facilities that affect natural flows. The State-defined watershed boundaries are based upon elevation contours and may not take into consideration channelized or hard pipe flows that may be conveyed into the watershed. When evaluating both elevation contours and these other flows, it was found that the watershed extends north, encompassing the residential area along Kihapai Street (Figure 2).

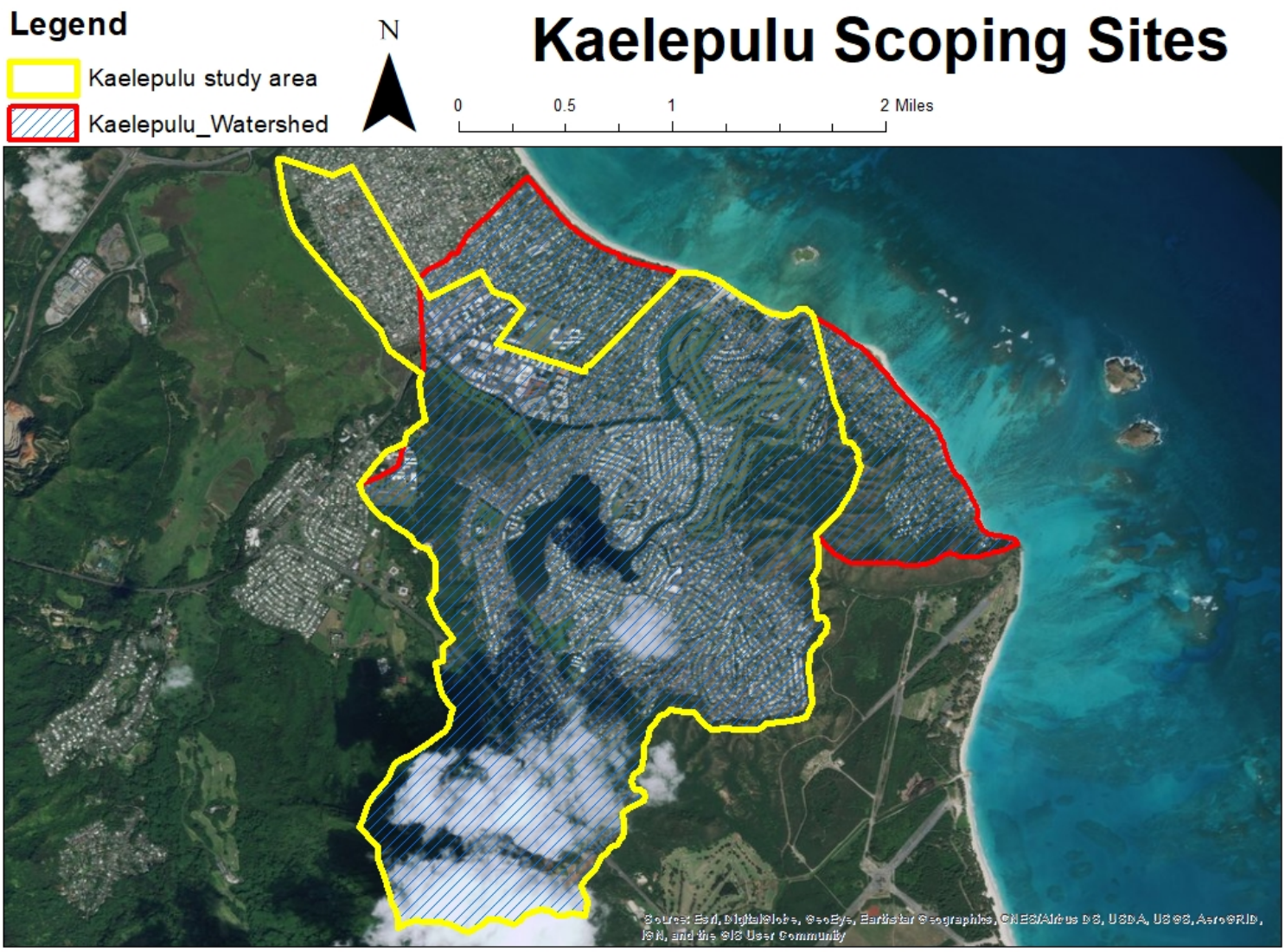


FIGURE 2: KA'ELEPULU WATERSHED DELINEATION OVERLAID WITH THE KA'ELEPULU ASSESSMENT PROJECT STUDY AREA. THE STUDY AREA EXTENDS NORTH TO ACCOMMODATE CHANNELIZATION AND HARD PIPE FLOWS.

Sample Sites

Sampling sites were chosen based upon access and spread throughout the waterbody. Nineteen sites were chosen in total. A summary of the locations is given in Table 1. Their approximate locations are visualized in Figure 3.

Sampling Location	Number of Sampling Sites	Number of Samples Per Sampling Site	Total Number of Samples
Ka'elepulu Pond	8	10	80
Between pond and confluence*	3	10	30
Between confluence* and ocean	3	10	30
Kawai Nui Canal	2	10	20
Confluence*	1	10	10
Mouth of Ka'elepulu Stream	1	10	10
Kailua Beach Park	1	10	10
Total Number of Sites	**19**		
Total Number of Samples			**190**

TABLE 1: KA'ELEPULU WATER QUALITY ASSESSMENT SAMPLING SITE SUMMARY.

***CONFLUENCE REFERS TO PLACE WHERE KAWAI NUI CANAL AND KA'ELEPULU STREAM MEET**

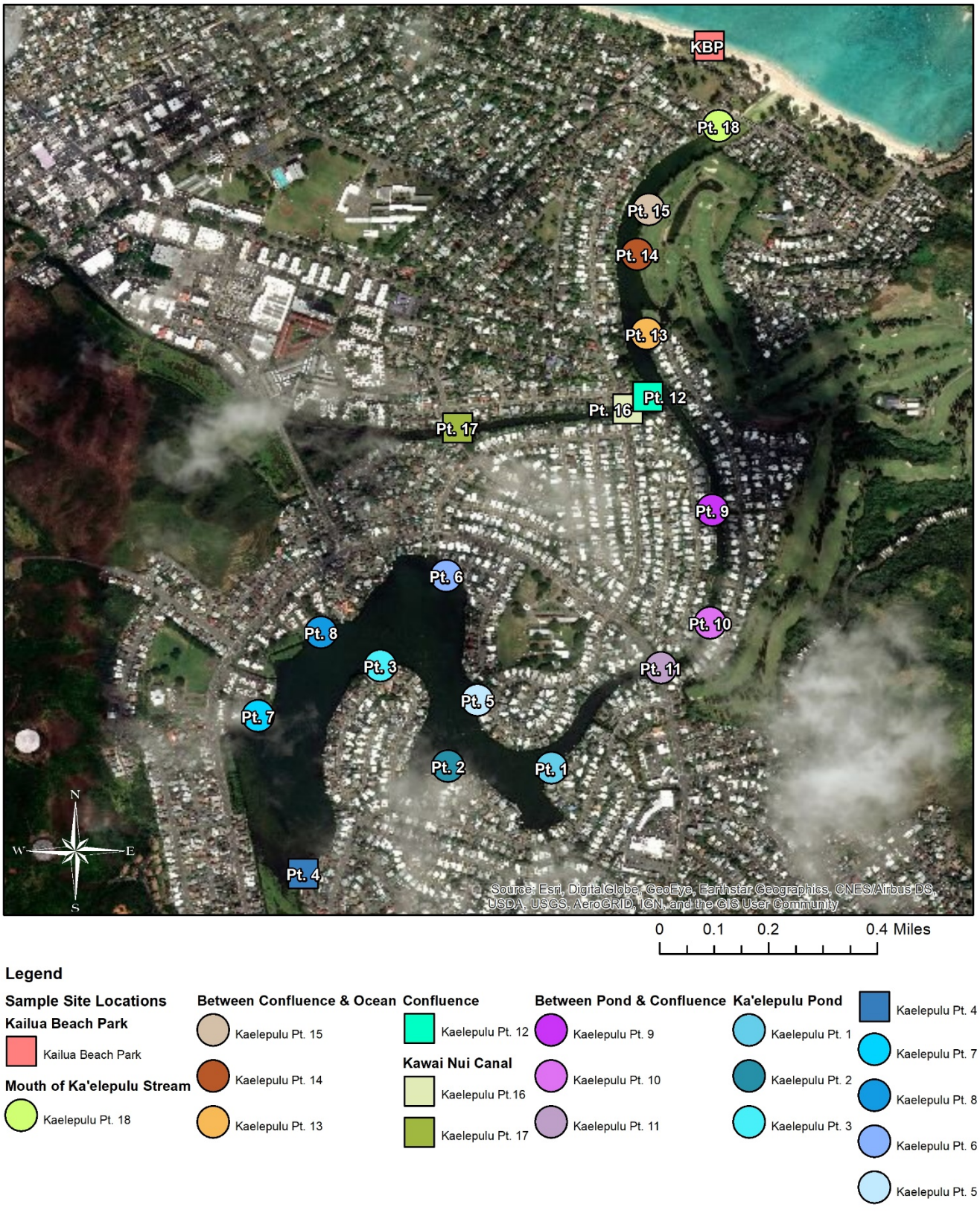


FIGURE 3: KA'ELEPULU SAMPLING SITES. GROUPINGS REFLECT TABLE 1. DATA FROM SITES WITH CIRCLE SYMBOLS WERE INCLUDED IN THE ANALYSIS OF THE KA'ELEPULU WATERBODY WHILE DATA FROM SITES WITH SQUARE SYMBOLS WERE OMITTED. JUSTIFICATION FOR THE OMISSIONS CAN BE FOUND IN SECTION ENTITLED" DECISION UNITS".

Monitoring Methods

Each site was evaluated for temperature (temp.), salinity (sal.), dissolved oxygen (DO), dissolved oxygen saturation (DO sat.), pH, turbidity, *Clostridium perfringens* (Cp), enterococci (ent.), ammonia (NH_4), nitrate plus nitrite, total nitrogen (TN), total phosphorus (TP), dissolved silica, total suspended solids (TSS), and chlorophyll *a* (Chl *a*). Temperature, salinity, DO, DO saturation, pH, and turbidity are grouped together as "field parameters" while ammonia, nitrate plus nitrite, TN, and TP are known as nutrients. Both Cp and enterococci are known as fecal indicator bacteria and are used to assess risk of sewage associated pathogens.

Samples were taken either directly from the stream or from stream water collected in a stainless-steel bucket. If the bucket was used, it was rinsed twice at each site before collecting sampling water. Samples were taken from the middle of the water column except for sites that required the lowering of a bucket down on a rope; typically from a bridge or balcony. Due to the nature of this sample collection process, the water most likely came from the top of the column.

Field parameters were measured using a YSI Pro Plus meter and turbidity was measured using a HACH 2100Q Turbidimeter. Equipment was calibrated according to the manufacturer's instructions and checked twice a day, both before and after sample collection, to ensure all readings were accurate.

Water samples for ammonia, nitrate plus nitrite, TN, TP, dissolved silica, TSS, and Chl *a* analysis were collected in a single, two-liter, brown, High-Density Polyethylene bottle after the bottle was rinsed twice with sample water from each site. Water samples for enterococci and Cp analysis were collected in 500 mL Nalgene bottles. All water samples were taken to the Hawaii State Laboratories Division for analysis.

Data was collected from all 19 sites between October 2019 and July 2020. Initially, the sampling was scheduled to end in May 2020, but sampling efforts experienced a delay due to the ongoing COVID-19 pandemic.

Results

Results were analyzed both by site and as a waterbody. For site analysis, data were grouped by sample site and, depending on the parameter, event type. All parameters were summarized using the geometric mean (GM or geomean), except for pH which was summarized by arithmetic mean (AVG). These means were then plotted onto a map using ArcMap 10.6.1. Tables that correspond to the maps can be found in Appendix – A.

Salinity, pH, temperature, DO saturation, and enterococci summarizations use all relevant, available data, regardless of season or event. This is because these parameters do not have season-specific criteria. The maps in Figure 4 do not apply any standard as their intended purpose is to depict the spread of physical parameters such as salinity and pH throughout the study area. The map in Figure 10 includes data from all sample sites, but applies the recreational water quality standard, because the recreational water quality standard is the same for all waters regardless of classification.

TN, TP, nitrate plus nitrite, TSS, and turbidity summarizations use data grouped by site in addition to event type as these parameters' standards are season-dependent (Figure 5 through Figure 10). Stream standards were used to determine if a sample site met water quality standards. Justification for this choice can be found in the "Applicable Standards" section. Stream standards do not apply to Kailua Beach Park; thus, it was omitted from this analysis.

For the Ka'elepulu Waterbody analysis, only data from Ka'elepulu Pts. 1-3, 5-11, 13-15, and 18 were used. Justification for this can be found in "Decision Units" section. Like with the sample site analysis, salinity, pH, temperature, DO saturation, and enterococci summarizations used all relevant data regardless of event and TN, TP, nitrate plus nitrite, TSS, and turbidity summarizations were grouped by event type. Stream standards were used to determine if the Ka'elepulu Waterbody met nutrient water quality standards.

Sample Site Data Summary

Sample Site Field Measurements and Enterococci

The GM for salinity ranges between 7.87 and 12.32 ppt within Ka'elepulu Stream and Ka'elepulu Pond (Figure 4). Most of the stream and pond sites range between 11.13 and 12.32 ppt, with the less saline sites being closer to areas of freshwater input, such as Kawai Nui Stream.

The AVG for pH ranges between 7.89 and 8.47 across all sample sites (Figure 4). Most of the sites within the Ka'elepulu Stream and pond range between 8.09 and 8.47. The pH in Kawai Nui Stream tends to be lower, ranging between 7.89 and 8.01. The southernmost site of Ka'elepulu Pond (Ka'elepulu pt. 4) has a pH of 8.02, lower than the rest of the pond.

The GM for temperature ranges from 25.0 ˚C to 25.91˚C for all sites (Figure 4). The sites within the mauka section of the stream, Kawai Nui, and Ka'elepulu Pond tend to run warmer than the makai stream sites. However, samples were taken throughout the day starting from early morning and ending around noon. Because sites are usually sampled in a set order, the time of day itself could be a contributing factor to the difference in water temperature between sites.

The GM for DO saturation ranges between 42.97% and 98.30% across all sites (Figure 4). The highest overall DO saturation was at Kailua Beach Park (98.30%). Inland sampling sites range between 42.97% and 94.57% with the lowest DO saturation GM observed in Kawai Nui (Ka'elepulu Pt 17, 42.97%) and the highest DO saturation GM observed within the pond section of Ka'elepulu (Ka'elepulu pt. 2, 94.57%).

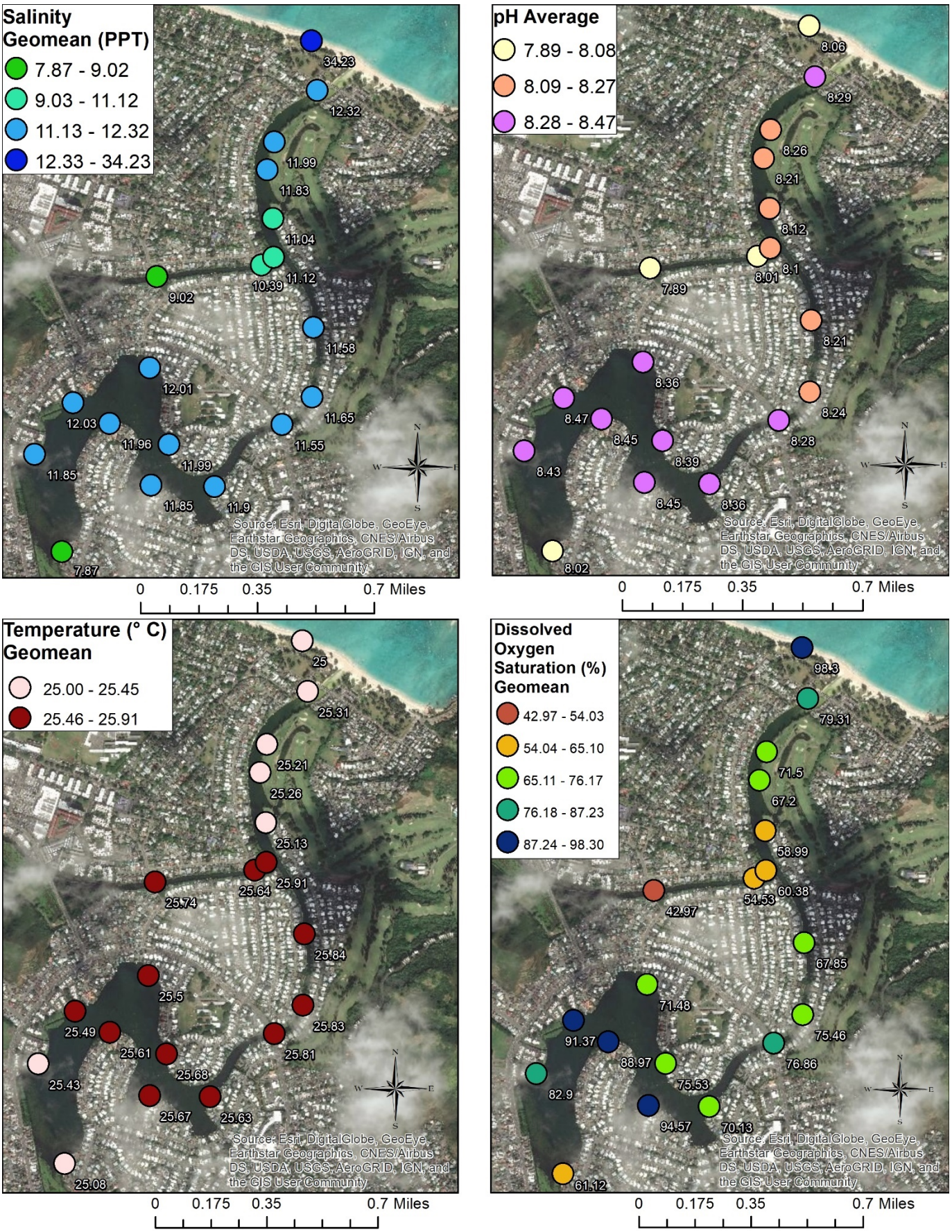


FIGURE 4: SERIES OF MAPS DEPICTING THE SPREAD OF FIELD MEASUREMENT RESULTS, INCLUDING SALINITY, PH, TEMPERATURE, AND DISSOLVED OXYGEN SATURATION. ALL VALUES ARE THE GEOMETRIC MEAN OF ALL THE MEASUREMENTS TAKEN FROM THE SAMPLE SITE, EXCEPT FOR PH WHICH IS THE ARITHMETIC MEAN OF THE MEASUREMENT.

Sample Site Impairments

All inland sites are deemed impaired for TN and TP for wet and dry events according to Hawaii's Stream Standards (§11-54-5.2, HAR) (Figure 5). Overall, the TN and TP GM tends to be lower in the pond portion of the Ka'elepulu Waterbody compared to the stream portion of the waterbody. This could be due to influence from the Kawai Nui Stream which tends to have higher concentrations of pollutants.

Most inland sample sites showed increased concentrations of TN during dry events with a few exceptions (Figure 5). Most notably, Ka'elepulu Pt. 10 experienced a large decrease in concentration from wet to dry, dropping from 774 (µg TN/L) to 472 (µg TN/L).

Kawai Nui Stream and the wetland portion of Ka'elepulu appear to have the highest concentrations of TP (Figure 6). There appears to be less difference between the stream portion and the pond portion of Ka'elepulu regarding TP concentrations.

All sites meet both wet and dry stream standards for nitrate plus nitrite (Figure 7). The wetland area has the highest concentration of nitrate plus nitrite during the wet events, but this pattern is not reflected in the dry events. Instead, the highest concentrations are seen in and around Kawai Nui.

All sites meet the wet stream standard for TSS and all but one site meets the dry stream standard for TSS (Figure 8). The only site to not meet the dry stream standard for TSS is Ka'elepulu Pt. 3.

All sites, except for Ka'elepulu pt. 4, meet wet turbidity stream standards (Figure 9). However, all sites exceed dry turbidity standards. Most of the inland sites range between 2 and 3 NTU, regardless of event type, with the highest turbidity observed at Ka'elepulu pt. 4.

The GM for enterococci ranges between 6.47 and 299.55 cfu/100ml across all sample sites (Figure 10). Kawai Nui and the mauka section of Ka'elepulu Stream trend higher in enterococci than Ka'elepulu Pond and the makai section of Ka'elepulu Stream. Kailua Beach Park had the lowest mean at 6.47 cfu/100ml while the Ka'elepulu wetland area (Ka'elepulu Pt. 4) experienced the highest enterococci GM at 299.55 cfu/100ml. The inland site with the lowest enterococci GM was Ka'elepulu Pond (Ka'elepulu Pt. 8, 9.18 cfu/100ml).

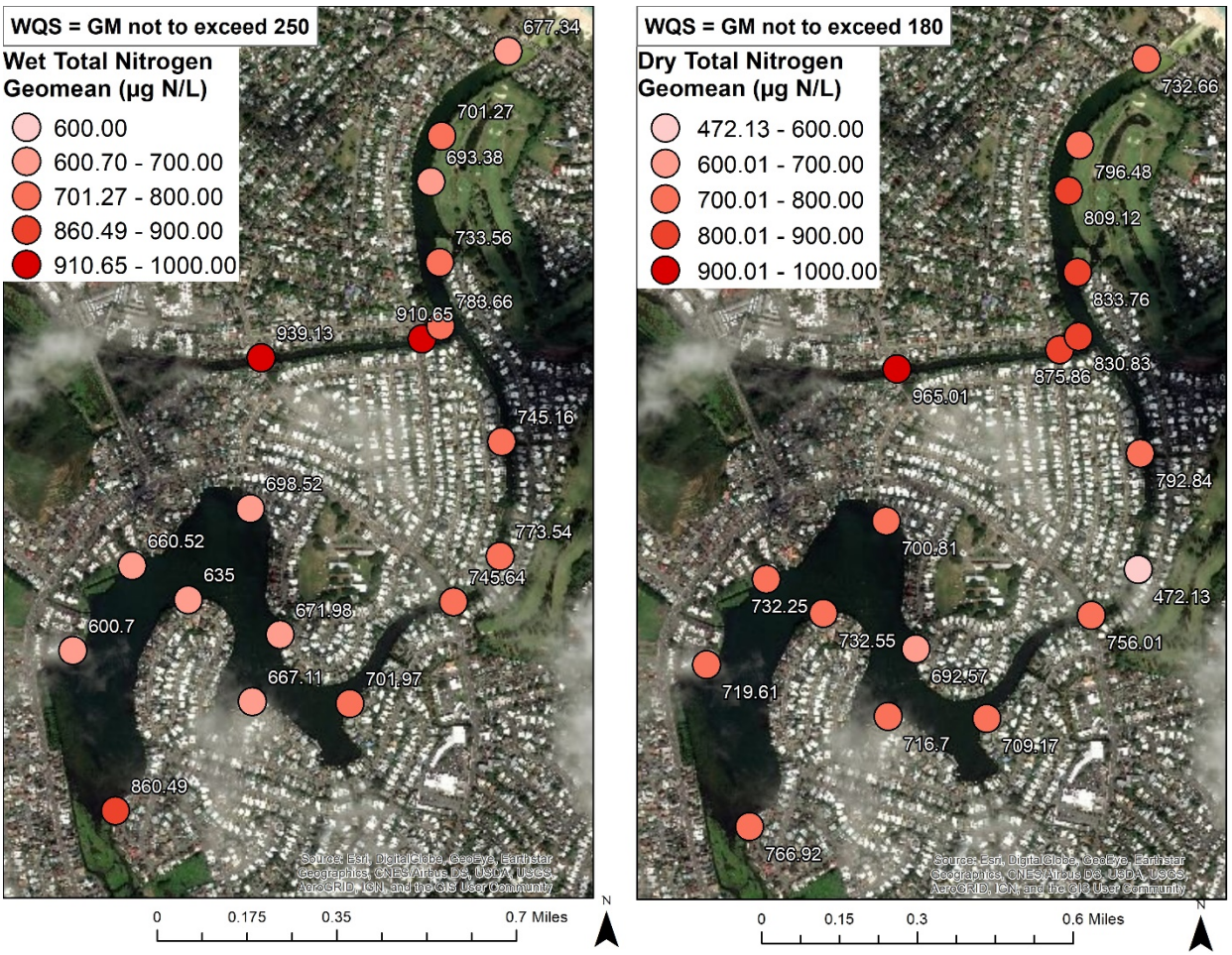


Figure 5: Geometric mean of total nitrogen data grouped by event type (wet or dry event). Data ranges reflect GM distribution and the relevant water quality standard. All sites are colored red because all values exceed the GM stream standard. The shade of red relates to the magnitude of impairment. The darker the shade, the greater the geometric mean

Figure 7: Geometric mean of total Phosphorus data grouped by event type (wet or dry event). Data ranges reflect GM distribution and the relevant water quality standard. All sites are colored red because all values exceed the GM stream standard. The shade of red relates to the magnitude of impairment. The darker the shade, the greater the geometric mean

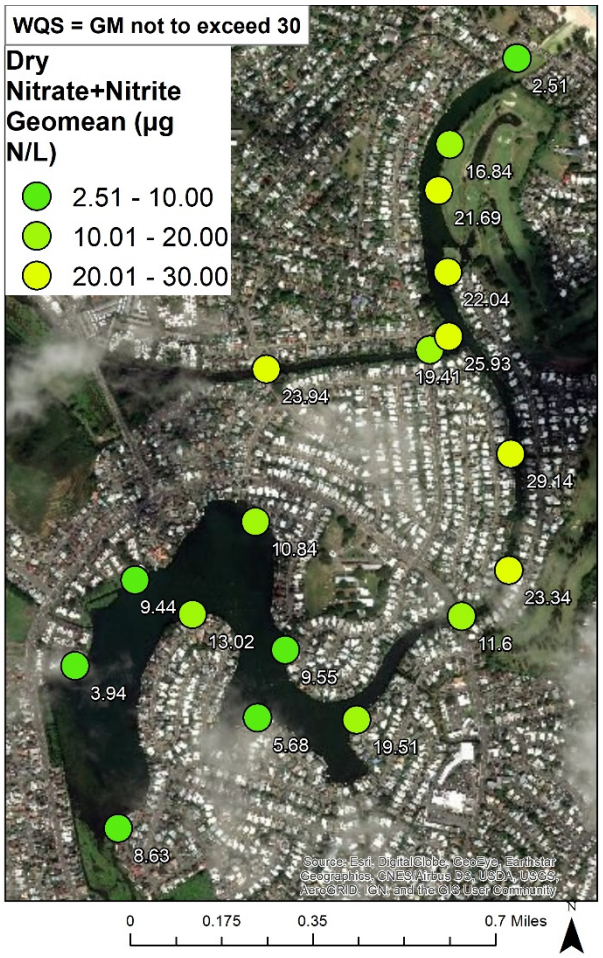
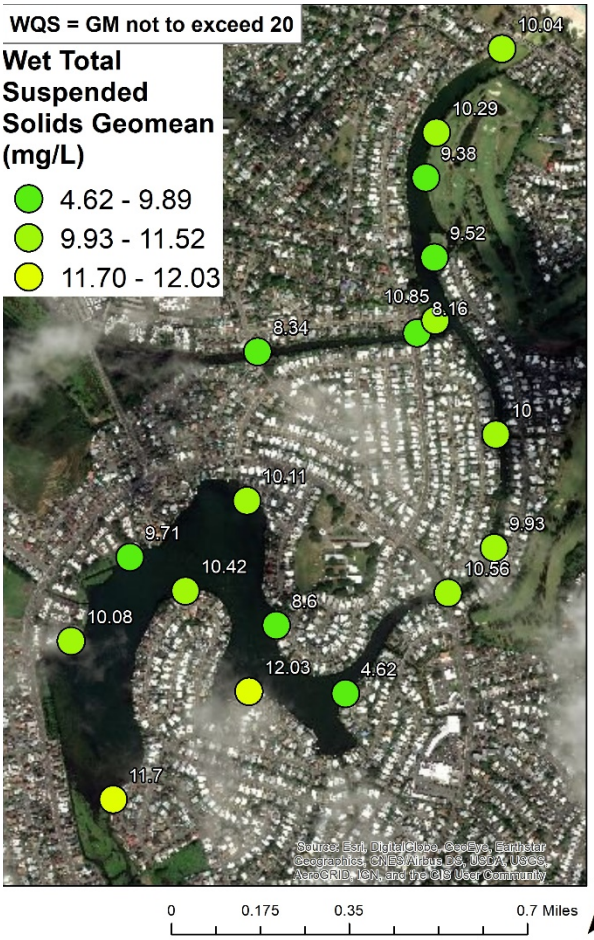


Figure 6: Geometric mean of nitrate plus nitrite data grouped by event type (wet or dry event). Data ranges reflect GM distribution and the relevant water quality standard. All sites are colored green because all values meet the GM stream standard. The more yellow the shade, the greater the geometric mean



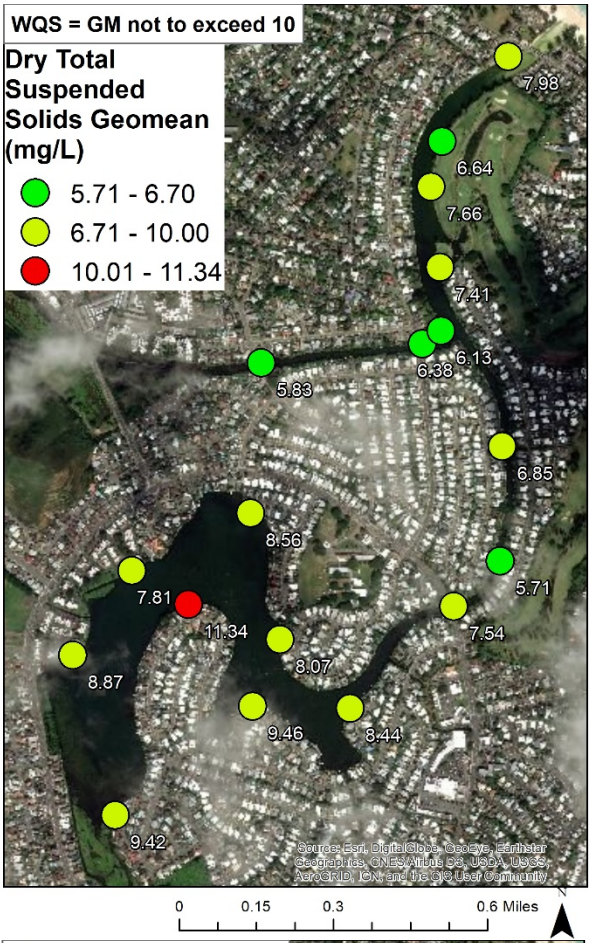
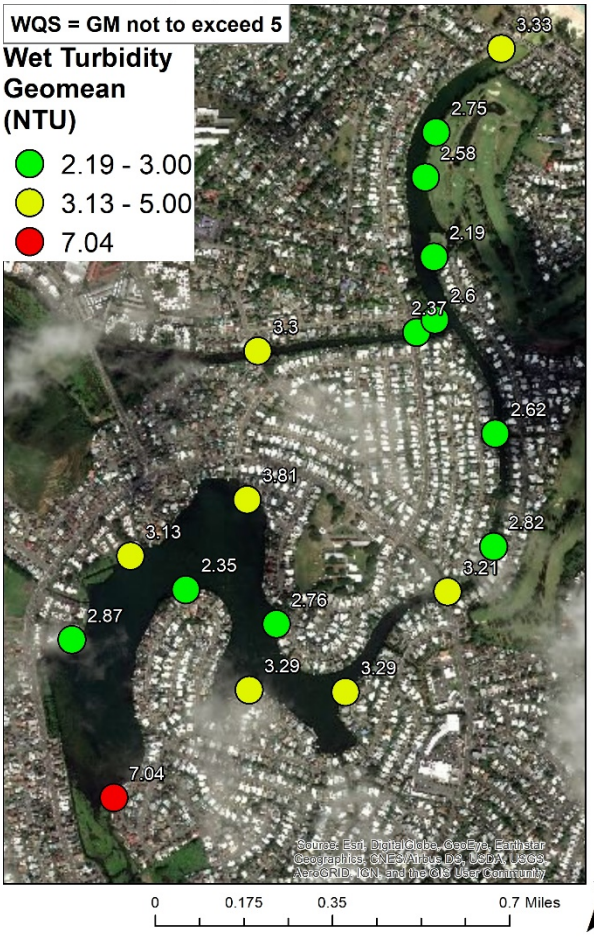


Figure 9: Geometric mean of Total Suspended Solids data grouped by event type (wet or dry event). Data ranges reflect GM distribution and the relevant water quality standard. Sites that meet the geometric mean stream standard are shaded green. The yellower the shade, the greater the geometric mean while still meeting the standard. Red shades symbolize impairment.



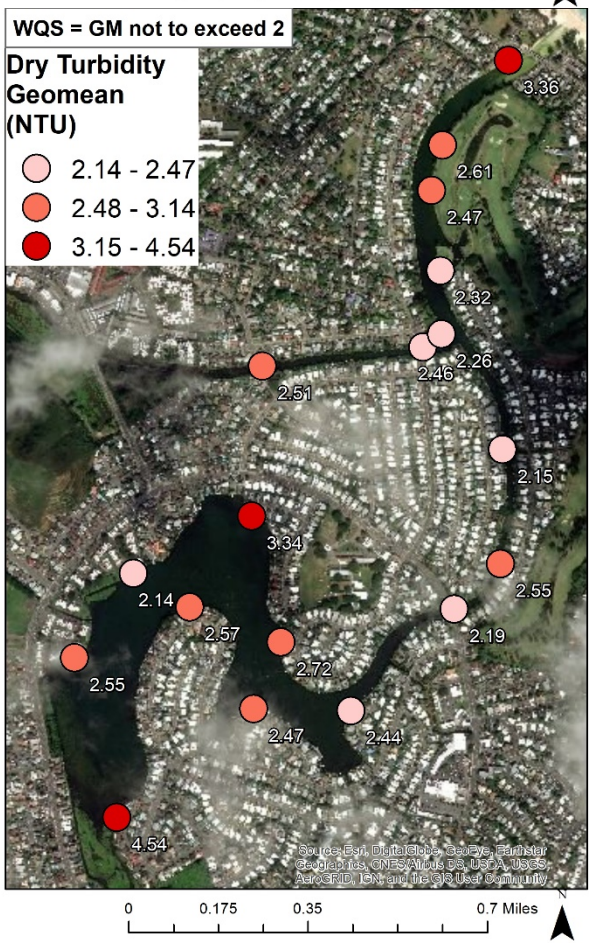


Figure 8: Geometric mean of Turbidity data grouped by event type (wet or dry event). Data ranges reflect GM distribution and the relevant water quality standard. Sites that meet the geometric mean stream standard are shaded green. The yellower the shade, the greater the geometric mean while still meeting the standard. Red shades symbolize impairment. The darker the red shade, the greater the geometric mean.

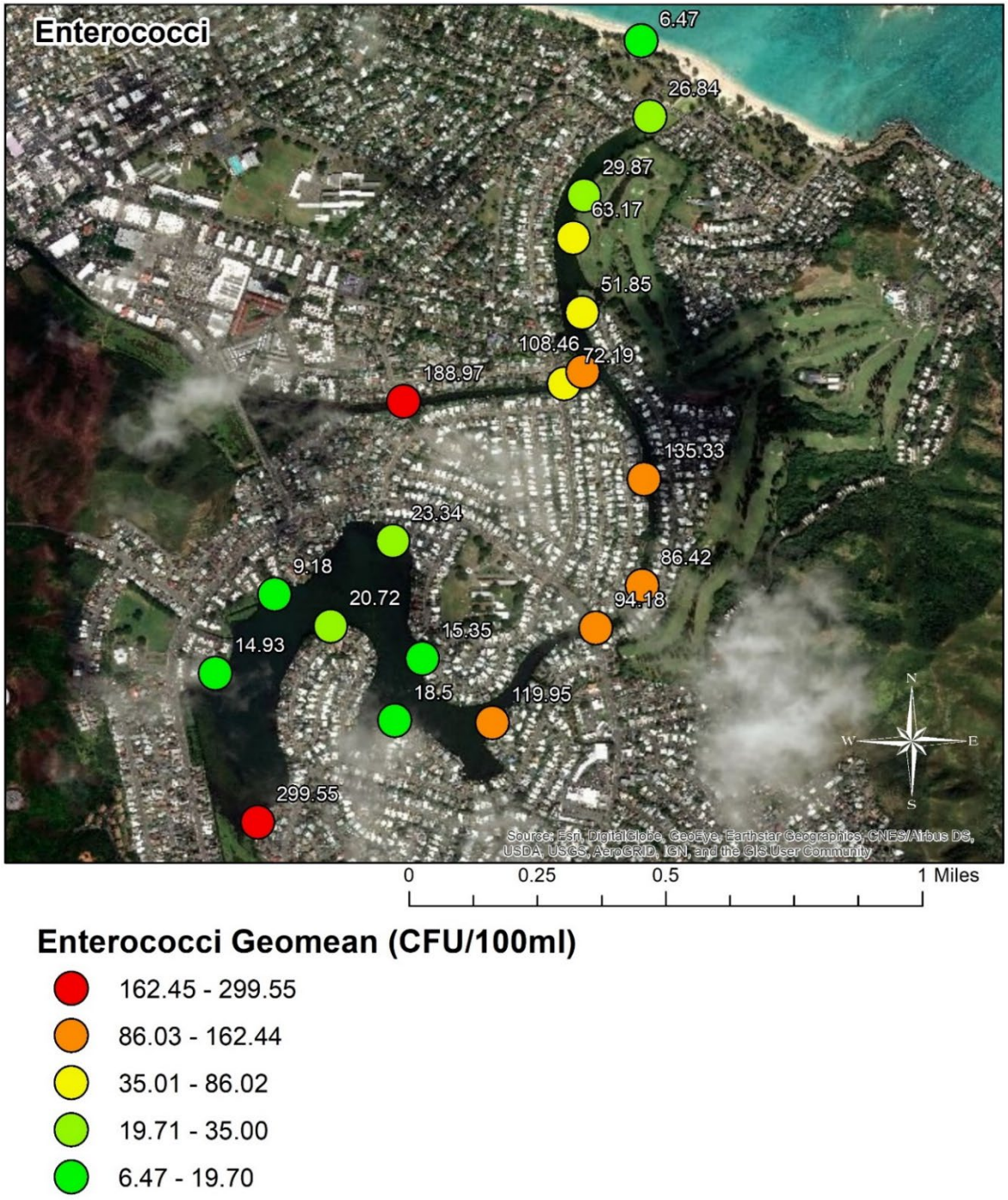


FIGURE 10: ENTEROCOCCI DATA RESULTS ACROSS THE SAMPLE SITES SUMMARIZED USING THE GEOMETRIC MEAN. ENTEROCOCCI RESULTS ARE NOT GROUPED BY EVENT TYPE OR WATER BODY TYPE. THIS IS BECAUSE THE RECREATIONAL WATER QUALITY STANDARD (35 CFU/100ML) IS THE SAME FOR EVERY WATERBODY REGARDLESS OF SEASON OR WATERBODY TYPE. GREEN CIRCLES INDICATE THAT THE SITE MEETS WATER QUALITY STANDARDS WHILE YELLOW, ORANGE, AND RED CIRCLES REPRESENT AN EXCEEDANCE OF THE WATER QUALITY STANDARD. THE REDDER THE SHADE, THE LARGER THE GM.

Ka'elepulu Waterbody Data Summary

Decision Units

When the project was originally designed, sites were broken up between Ka'elepulu Stream (Pts. 9-11 and Pts. 13-15), Ka'elepulu Pond (Pts. 1-8), Kawai Nui (Pts. 16-17), the confluence (Pt. 12), the canoe launch (Pt. 18), and Kailua Beach Park. After analyzing the data, it appeared Ka'elepulu Pond and Ka'elepulu Stream were too similar to justify being managed separately. Thus, they were grouped together to form Ka'elepulu Waterbody (Pts. 1-3, 5-11, 13-15, and 18). Ka'elepulu Pt. 4 (near the wetland) was omitted from analysis of the Ka'elepulu Waterbody because its pH and salinity values fell outside the range of values of the other waterbody sample sites (Figure 4). This site is nearby the Ka'elepulu Wetland and it is reasonable to exclude it from analysis and management of the flowing waterbody. Additionally, Ka'elepulu Pt. 18 (stream site closest to ocean) was added to the Ka'elepulu Waterbody for analysis. The values from this sample site fall within a reasonable range of the other Ka'elepulu Waterbody sites.

Data from Kawai Nui, the confluence, and Kailua Beach Park was used to understand the potential influences of these sites to the Ka'elepulu Waterbody but were not included in the Waterbody analysis. It was outside the scope of this project to determine and address the impairments within Kawai Nui Stream.

Ka'elepulu Waterbody Field Measurements and Enterococci

Field measurement summaries used all available relevant data since stream standards for these parameters are not divided between the wet and dry seasons. DO saturation, temperature, salinity, and enterococci are all summarized using a GM, and the pH is summarized using an AVG (Table 2). DO saturation has a sample size of 136 opposed to the 140 samples of the other parameters. This is due to an issue with the DO meter used to collect 4 of the waterbody samples. The DO meter failed its post calibration check, rendering all DO values measured that day invalid.

The AVG pH of the Ka'elepulu waterbody is 8.32, slightly higher than the stream standard (Table 2.). The GM of DO saturation is 75.61 % which is lower than the stream standard. The GM of the temperature and salinity is 25.53 °C and 11.82 ppt, respectively.

The Ka'elepulu Waterbody's enterococci GM is 36.16 cfu/100ml, which barely exceeds the recreational water quality standard of 35 cfu/100ml (Table 2). This slight exceedance is likely linked to the effort to collect samples after rain events. It is known that, in Hawaii, enterococci counts are typically greater after rain. This is likely due to sediment, a natural environmental source of enterococci, washing into waterbodies. Because the Ka'elepulu Waterbody Assessment Project targeted rain events equally as dry events, the enterococci GM may be driven higher with increased samples capturing wet events. Sampling in select sites has continued in order to gain a better representation of the condition of the water quality regarding enterococci

Ka'elepulu Waterbody Impairments

Table 3 and Table 4 contain the water quality analysis of the Ka'elepulu Waterbody. Because stream standards are dependent on season (wet/dry), the water quality analysis is divided similarly. Table 3 groups the data based upon season, meaning that all wet analyses come from data collected between November and April. The dry analyses come from data collected between May and October. However, there is a difference in sample quantities taken; far more wet season samples were collected. This is because the assessment was designed to capture data representative of the actual dry or wet conditions, not during the season itself.

Table 4 groups data based upon event type. Wet analyses use data gathered during wet events and dry analyses use data gathered during dry events. The two event types are represented equally in this analysis. It should be noted that there is little difference between the season and event data groupings regarding impairment status. Most pollutants maintain the same status of impairment regardless of how the data is grouped. The exception is the wet 10% Not to Exceed standard for nitrate plus nitrite. This standard is met with season-based grouping, but not with the event-based grouping.

The Ka'elepulu Waterbody exceeds all standards for TN and TP; both wet and dry (Table 3 and Table 4). It also exceeds the 10% Not to Exceed standard for wet nitrate plus nitrite, as well as the dry GM standard for turbidity (Table 4).

The Ka'elepulu Waterbody meets all standards for TSS (Table 3 and Table 4). It meets the geometric mean standards for wet and dry nitrate plus nitrite and wet turbidity. Additionally, it meets the 10% Not to Exceed standard for dry nitrate plus nitrite as well as wet and dry turbidity.

Combined Data, Field Measurements and Enterococci Geomean			
	Ka'elepulu Waterbody		Stream Standards
pH	Sample #	140	
	AVG	8.32	<0.5 from ambient and 5.5-8.0
DO % Sat	Sample #	136	
	GM	75.61	≥ 80%
Temp	Sample #	140	
	GM	25.53	≤ 1°C from ambient
Salinity	Sample #	140	
	GM	11.82	
ENT	Sample #	140	
	GM	36.16	35

TABLE 2: KA'ELEPULU WATERBODY FIELD MEASUREMENTS AND ENTEROCOCCI GM COMPARED TO STREAM STANDARDS. ALL AVAILABLE, RELEVANT DATA WAS USED FOR THIS ANALYSIS REGARDLESS OF SEASON OR EVENT.

Season Calculation Summary Table						
	Ka'elepulu Waterbody			Stream Standards		
		Wet	Dry		Wet	Dry
	Sample #	98	42			
Total Nitrogen	GM (µg TN/L)	677.52	781.22	GM	250	180
	% E STNDRD	77%	100%	10% NTE	520	380
Nitrate + Nitrite	GM (µg N/L)	24.57	3.56	GM	70	30
	% E STNDRD	9%	0%	10% NTE	180	90
Total Phosphorus	GM (µg P/L)	57.05	63.91	GM	50	30
	% E STNDRD	15%	67%	10% NTE	100	60
Total Suspended Solids	GM (mg N/L)	8.64	8.73	GM	20	10
	% E STNDRD	0%	0%	10% NTE	50	30
Turbidity	GM (NTU)	2.54	3.16	GM	5	2
	% E STNDRD	7%	7%	10% NTE	15	5.5

TABLE 3: SEASON-BASED KA'ELEPULU WATER QUALITY ANALYSIS RESULTS COMPARED TO STREAM STANDARDS. DATA WAS GROUPED BY SEASON (WET/DRY) AND ANALYZED FOR COMPARISON WITH STREAM STANDARDS. RED CELLS SYMBOLIZE THE KA'ELEPULU WATERBODY EXCEEDING THE STANDARD, AND GREEN CELLS SYMBOLIZE MEETING THE STANDARD.

Event Calculation Summary Table						
	Ka'elepulu Waterbody			Stream Standards		
		Wet	Dry		Wet	Dry
	Sample #	70	70			
Total Nitrogen	GM (µg N/L)	691.80	722.73	GM	250	180
	% E STNDRD	80%	99%	10% NTE	520	380
Nitrate + Nitrite	GM (µg N/L)	16.20	11.68	GM	70	30
	% E STNDRD	13%	0%	10% NTE	180	90
Total Phosphorus	GM (µg P/L)	62.06	56.15	GM	50	30
	% E STNDRD	20%	53%	10% NTE	100	60
Total Suspended Solids	GM (mg /L)	9.49	7.92	GM	20	10
	% E STNDRD	0%	0%	10% NTE	50	30
Turbidity	GM (NTU)	2.90	2.54	GM	5	2
	% E STNDRD	10%	4%	10% NTE	15	5.5

TABLE 4: EVENT-BASED KA'ELEPULU WATER QUALITY ANALYSIS RESULTS COMPARED TO STREAM STANDARDS. DATA WAS GROUPED BY EVENT (WET/DRY) AND ANALYZED FOR COMPARISON WITH STREAM STANDARDS. RED CELLS SYMBOLIZE THE KA'ELEPULU WATERBODY EXCEEDING THE STANDARD, AND GREEN CELLS SYMBOLIZE MEETING THE STANDARD.

Conclusion

While the Ka'elepulu Waterbody is not technically a freshwater stream (according to the Hawaii regulations), Hawaii stream standards were applied due to a lack of more applicable numeric standards. The Ka'elepulu Waterbody is found to be impaired for TN (wet/dry criteria), TP (wet/dry criteria), and, to lesser degrees, nitrate plus nitrite (wet criteria), and turbidity (dry criteria). The waterbody meets the stream standards for nitrate plus nitrite (dry criteria), turbidity (wet criteria), and TSS (wet/dry criteria).

Further action is required to address the TN and TP impairments. Due to the interdependent relationship between nutrients, any actions taken to reduce the amount of nitrogen and phosphorus in the waterbody is expected to also address the nitrate plus nitrite and turbidity impairments. Given that the stream meets the TSS standard while exceeding the TN and TP standards suggests that these impairments may not be solely linked to sediment runoff as is typical for these types of impairments. Further research would be required to determine the exact sources and causes of the nutrient impairments (e.g., fertilizer runoff and decomposing green waste). It is recommended that efforts to reduce TN and TP inputs include, in addition to the traditional focus on reducing sediment runoff, considerations of addressing a variety of other potential sources, as listed above.

References

Commission on Water Resource. (2008). Watersheds - (CWRM). Hawaii: Hawaii State GIS. Retrieved 2020, from https://geoportal.hawaii.gov/datasets/watersheds?geometry=-167.931%2C18.755%2C-147.025%2C22.354

Department of Health. (2014). *Hawaii Administrative Rules Title 11 Chapter 54 Water Quality Standards.* State of Hawaii. Retrieved from https://health.hawaii.gov/cwb/files/2013/04/Clean_Water_Branch_HAR_11-54_20141115.pdf

Dr. Roger Babcock, J. (2005). *Scope Report Kaelepulu Stream Total Maximum Daily Loads (DRAFT).* State of Hawaii Department of Health Environmental Planning Office.

HDOH Clean Water Branch. (2018). *QUALITY ASSURANCE PROJECT PLAN FOR BEACH MONITORING.* State of Hawaii.

HDOH Clean Water Branch. (2018). *QUALITY ASSURANCE PROJECT PLAN FOR NEAR SHORE COASTAL CHEMISTRY MONITORING.* State of Hawaii.

HDOH Clean Water Branch. (2018). *STANDARD OPERATING PROCEDURE FOR BEACH MONITORING.* State of Hawaii.

HDOH Clean Water Branch. (2018). *STANDARD OPERATING PROCEDURE FOR NEAR SHORE COASTAL CHEMISTRY MONITORING.* State of Hawaii.

HDOH Clean Water Branch. (2019). *QUALITY ASSURANCE PROJECT PLAN FOR STREAM MONITORING.* State of Hawaii.

Kailua Bay Advisory Council. (2007). *Ko'olaupoko Watershed Restoration Action Strategy.* Hawaii State Department of Health. Retrieved from https://coast.noaa.gov/data/digitalcoast/pdf/opennspect-koolaupoko.pdf

Oceanit Laboratories Inc. (2016). *Kawai Nui Marsh Flow Restoration Project.*

U.S. Geological Survey. (2018, August). National Hydrography Dataset (selected features) for Hawaii. Hawaii State GIS. Retrieved January 2021, from https://geoportal.hawaii.gov/datasets/nhd-flowlines

Appendix – A

Tables used to inform the maps in Figures 3 through 9.

Sample Site	CMB Sample Count	CMB Temp GM	CMB Sal GM	CMB DO GM	CMB DO SAT GM	CMB pH AVG	CMB Turb. GM	CMB CP GM	CMB Ent GM	CMB NH_4 GM (ug N/L)	CMB NO_3 + NO_2 GM (ug N/L)	CMB TN GM (ug N/L)	CMB TP GM (ug P/L)	CMB Silicate GM (ug SiO_2/L)	CMB TSS GM (mg/L)	CMB Chl *a* GM (ug/L)
Kailua Beach Park	10	25.00	34.23	6.69	98.30	8.06	6.40	0.66	6.47	29.87	4.50	143.69	10.54	161.46	14.81	0.32
Kaelepulu Pt. 18	10	25.31	12.32	6.07	79.31	8.30	3.34	3.99	26.84	19.04	3.73	704.45	49.45	3704.93	8.95	5.55
Kaelepulu Pt. 15	10	25.22	11.99	5.48	71.50	8.26	2.68	16.89	29.87	41.97	13.44	747.36	58.71	4603.31	8.27	5.39
Kaelepulu Pt. 14	10	25.26	11.83	5.16	67.20	8.22	2.53	11.21	63.17	50.26	20.12	749.02	62.21	4839.07	8.48	5.39
Kaelepulu Pt. 13	10	25.13	11.04	4.55	58.99	8.12	2.26	1.97	51.85	67.70	22.93	782.06	75.22	5746.42	8.40	5.29
Kaelepulu Pt. 9	10	25.84	11.58	5.16	67.85	8.21	2.37	3.09	135.33	60.03	32.36	768.63	68.09	3147.96	8.28	4.73
Kaelepulu Pt. 10	10	25.83	11.65	5.74	75.46	8.24	2.68	3.71	86.42	41.00	16.17	604.33	63.12	3087.78	7.53	4.76
Kaelepulu Pt. 11	10	25.81	11.55	5.82	76.86	8.28	2.65	3.06	94.18	29.45	13.94	750.81	61.59	2684.04	8.92	4.99
Kaelepulu Pt. 1	10	25.63	11.90	5.34	70.13	8.36	2.84	3.93	119.95	36.62	19.47	705.56	58.20	2217.37	6.25	3.68
Kaelepulu Pt. 2	10	25.67	11.85	7.23	94.57	8.45	2.85	3.25	18.50	22.53	14.96	691.46	55.40	1671.28	10.66	3.37
Kaelepulu Pt. 3	10	25.61	11.96	6.81	88.97	8.45	2.46	1.78	20.72	23.49	23.29	682.03	54.12	1293.74	10.87	3.26
Kaelepulu Pt. 4	10	25.08	7.87	4.80	61.12	8.02	5.65	10.74	299.55	70.84	22.00	812.36	91.65	4882.49	10.5	3.57
Kaelepulu Pt. 7	10	25.43	11.85	6.37	82.90	8.43	2.70	0.90	14.93	22.62	7.03	657.47	57.97	1427.48	9.46	2.92
Kaelepulu Pt. 8	10	25.49	12.03	7.00	91.37	8.47	2.59	1.44	9.18	21.03	7.73	695.46	54.97	1357.21	8.71	3.24
Kaelepulu Pt. 6	10	25.51	12.01	5.45	71.48	8.36	3.57	2.49	23.34	23.90	14.80	699.66	55.81	1414.76	9.30	3.18
Kaelepulu Pt. 5	10	25.69	11.99	5.74	75.53	8.39	2.74	1.31	15.35	34.05	9.47	682.20	55.90	1531.89	8.33	3.41
Kaelepulu Pt. 17	10	25.74	9.02	3.32	42.97	7.89	2.88	4.63	188.98	125.86	25.88	951.98	108.97	9127.96	6.97	10.42
Kaelepulu Pt.16	10	25.64	10.39	4.19	54.53	8.01	2.41	2.57	72.19	83.83	19.69	893.09	91.39	5570.23	7.22	8.09
Kaelepulu Pt. 12	10	25.91	11.12	4.60	60.38	8.10	2.42	12.38	108.46	70.13	27.86	806.90	78.10	6151.35	8.16	5.83

TABLE 5: TOTAL SITE SUMMARY. EACH VALUE IS SUMMARIZED USING ALL DATA GATHERED FROM EACH SAMPLE SITE, REGARDLESS OF EVENT OR SEASON. ALL FIELDS ARE SUMMARIZED USING THE GEOMETRIC MEAN FUNCTION, EXCEPT FOR PH, WHICH USED THE ARITHMETIC MEAN FUNCTION.

Sample Site	Wet Sample Count	Wet Temp GM	Wet Sal GM	Wet DO GM	Wet DO SAT GM	Wet pH AVG	Wet Turb. GM	Wet CP GM	Wet Ent GM	Wet NH_4 GM (ug N/L)	Wet $NO_3 + NO_2$ GM (ug N/L)	Wet TN GM (ug N/L)	Wet TP GM (ug P/L)	Wet Silicate GM (ug SiO_2/L)	Wet TSS GM (mg/L)	Wet Chl *a* GM (ug/L)
Kailua Beach Park	5	24.53	33.25	6.87	99.72	8.05	5.76	0.66	10.11	22.98	2.95	120.32	15.15	208.55	27.07	0.31
Kaelepulu Pt. 18	5	25.08	12.48	6.32	82.55	8.28	3.33	8.65	62.33	24.99	5.54	677.34	55.65	3910.38	10.04	4.86
Kaelepulu Pt. 15	5	24.77	11.96	5.86	75.92	8.30	2.75	24.70	68.08	32.04	10.73	701.27	61.74	4509.26	10.29	4.89
Kaelepulu Pt. 14	5	24.77	11.74	5.99	77.41	8.27	2.58	12.64	121.84	35.04	18.67	693.38	61.46	4597.01	9.38	5.16
Kaelepulu Pt. 13	5	24.50	10.57	5.12	65.46	8.15	2.19	4.10	98.23	50.47	23.85	733.56	77.44	5629.99	9.52	5.46
Kaelepulu Pt. 9	5	25.70	11.35	5.68	74.54	8.26	2.62	5.81	390.33	46.38	35.93	745.16	69.64	1908.65	10.00	3.84
Kaelepulu Pt. 10	5	25.51	11.07	6.09	79.50	8.25	2.82	5.54	197.18	35.75	11.20	773.54	72.55	2381.02	9.93	3.79
Kaelepulu Pt. 11	5	25.41	10.77	6.00	78.78	8.29	3.21	6.34	377.22	24.58	16.75	745.64	72.03	2188.37	10.56	4.09
Kaelepulu Pt. 1	5	25.21	10.93	5.79	75.26	8.37	3.29	9.00	261.47	32.98	19.43	701.97	62.06	2549.23	4.62	3.14
Kaelepulu Pt. 2	5	24.83	10.76	7.50	95.24	8.44	3.29	9.17	148.86	20.02	39.44	667.11	58.05	2425.26	12.03	3.10
Kaelepulu Pt. 3	5	24.78	11.02	7.10	90.12	8.44	2.35	1.92	43.94	15.49	41.66	635.00	53.81	1661.69	10.42	2.30
Kaelepulu Pt. 4	5	24.42	5.55	4.51	55.29	7.86	7.04	30.01	985.83	97.55	56.06	860.49	110.59	6711.44	11.70	2.67
Kaelepulu Pt. 7	5	24.60	10.85	6.01	76.02	8.39	2.87	2.43	37.12	15.25	12.55	600.70	54.25	1941.40	10.08	2.31
Kaelepulu Pt. 8	5	24.78	11.11	7.19	91.39	8.47	3.13	2.75	27.29	15.64	6.33	660.52	57.27	1842.34	9.71	2.44
Kaelepulu Pt. 6	5	24.87	11.05	5.25	67.77	8.28	3.81	5.71	68.10	28.40	20.20	698.52	58.78	1893.61	10.11	2.73
Kaelepulu Pt. 5	5	25.16	10.98	5.93	77.05	8.36	2.76	2.97	57.57	32.55	9.39	671.98	59.60	2157.03	8.60	3.04
Kaelepulu Pt. 17	5	25.29	8.48	3.25	41.63	7.91	3.30	6.45	556.98	101.77	27.98	939.13	121.93	7689.91	8.34	10.64
Kaelepulu Pt.16	5	25.05	9.87	4.35	55.90	8.01	2.37	5.61	176.98	70.11	19.97	910.65	104.67	4056.53	8.16	9.17
Kaelepulu Pt. 12	5	25.29	10.85	5.44	70.58	8.15	2.60	20.00	159.30	46.88	29.93	783.66	82.67	5580.30	10.85	6.55

TABLE 6: WET SITE SUMMARY. EACH VALUE IS SUMMARIZED USING ONLY "WET EVENT" DATA GATHERED FROM EACH SAMPLE SITE. ALL FIELDS ARE SUMMARIZED USING THE GEOMETRIC MEAN FUNCTION, EXCEPT FOR PH, WHICH USED THE ARITHMETIC MEAN FUNCTION. DUE TO AN ERROR WITH A DO METER, DO AND DO SATURATION VALUES FOR KA'ELEPULU PTS 2,3,7, AND 8 ONLY USE DATA FROM 4 WET EVENTS.

Sample Site	Dry Sample Count	Dry Temp GM	Dry Sal GM	Dry DO GM	Dry DO SAT GM	Dry pH AVG	Dry Turb. GM	Dry CP GM	Dry Ent GM	Dry NH_4 GM (ug N/L)	Dry NO3 + NO2 GM (ug N/L)	Dry TN GM (ug N/L)	Dry TP GM (ug N/L)	Dry Silicate GM (ug SiO2/L)	Dry TSS GM (mg/L)	Dry Chl *a* GM (ug/L)
Kailua Beach Park	5	25.47	35.24	6.50	96.91	8.07	7.11	0.66	4.14	38.81	6.85	171.59	7.33	125.00	8.11	0.32
Kaelepulu Pt. 18	5	25.47	12.16	5.82	76.21	8.31	3.36	1.84	11.56	14.51	2.51	732.66	43.94	3510.28	7.98	6.34
Kaelepulu Pt. 15	5	25.67	12.02	5.13	67.34	8.23	2.61	11.55	13.10	54.99	16.84	796.48	55.83	4699.32	6.64	5.95
Kaelepulu Pt. 14	5	25.76	11.92	4.44	58.34	8.16	2.47	9.95	32.75	72.08	21.69	809.12	62.97	5093.88	7.66	5.64
Kaelepulu Pt. 13	5	25.77	11.54	4.05	53.17	8.08	2.32	0.94	27.36	90.81	22.04	833.76	73.07	5865.26	7.41	5.12
Kaelepulu Pt. 9	5	25.97	11.81	4.68	61.76	8.16	2.15	1.64	46.92	77.70	29.15	792.84	66.58	5191.97	6.85	5.83
Kaelepulu Pt. 10	5	26.15	12.25	5.40	71.62	8.23	2.55	2.49	37.88	47.01	23.34	472.13	54.91	4004.33	5.71	5.98
Kaelepulu Pt. 11	5	26.22	12.38	5.64	74.99	8.28	2.19	1.48	23.51	35.28	11.60	756.01	52.67	3291.98	7.54	6.09
Kaelepulu Pt. 1	5	26.05	12.95	4.92	65.36	8.36	2.44	1.72	55.02	40.65	19.51	709.17	54.57	1928.71	8.44	4.30
Kaelepulu Pt. 2	5	26.55	13.05	7.02	94.03	8.47	2.47	1.15	2.30	25.35	5.68	716.70	52.88	1151.70	9.46	3.67
Kaelepulu Pt. 3	5	26.46	12.99	6.58	88.06	8.46	2.57	1.64	9.77	35.61	13.02	732.55	54.43	1007.27	11.34	4.61
Kaelepulu Pt. 4	5	25.77	11.17	5.05	66.22	8.17	4.54	3.85	91.02	51.44	8.64	766.92	75.96	3551.95	9.42	4.78
Kaelepulu Pt. 7	5	26.28	12.94	6.67	88.84	8.47	2.54	0.33	6.00	33.55	3.94	719.61	61.95	1049.60	8.87	3.69
Kaelepulu Pt. 8	5	26.23	13.03	6.85	91.35	8.47	2.14	0.76	3.09	28.28	9.44	732.25	52.76	999.82	7.81	4.29
Kaelepulu Pt. 6	5	26.16	13.06	5.66	75.38	8.43	3.34	1.08	8.00	20.11	10.84	700.81	53.00	1056.99	8.56	3.70
Kaelepulu Pt. 5	5	26.22	13.09	5.55	74.04	8.43	2.72	0.57	4.09	35.61	9.55	692.57	52.43	1087.93	8.07	3.83
Kaelepulu Pt. 17	5	26.21	9.60	3.39	44.34	7.87	2.51	3.31	64.12	155.65	23.94	965.01	97.38	10834.93	5.83	10.20
Kaelepulu Pt.16	5	26.23	10.94	4.04	53.20	8.00	2.46	1.18	29.45	100.23	19.41	875.86	79.80	7648.78	6.38	7.13
Kaelepulu Pt. 12	5	26.56	11.40	3.88	51.66	8.05	2.25	7.67	73.84	104.90	25.93	830.83	73.79	6780.83	6.13	5.20

TABLE 7: DRY SITE SUMMARY. EACH VALUE IS SUMMARIZED USING ONLY "DRY EVENT" DATA GATHERED FROM EACH SAMPLE SITE. ALL FIELDS ARE SUMMARIZED USING THE GEOMETRIC MEAN FUNCTION, EXCEPT FOR PH, WHICH USED THE ARITHMETIC MEAN FUNCTION.

Appendix – B

Table listing GM and AVG analysis for all evaluated parameters for the Ka'elepulu Waterbody.

Parameter	Wet Sample Size	Dry Sample Size	CMB Sample Size	Wet GM	Dry GM	CMB
TN (µg N/L)	70	70	140	691.8	722.7	707.1
NO_3+NO_2 (µg N/L)	70	70	140	16.2	11.7	13.8
NH_4 (µg N/L)	70	70	140	27.3	38.7	32.5
TP (µg P/L)	70	70	140	62.1	56.2	59.0
TSS (mg/L)	70	70	140	9.5	7.9	8.7
Chl *a* (µg/L)	70	70	140	3.5	4.8	4.1
Dissolved Silica	70	70	140	2610.1	2260.7	2429.1
Turbidity (NTU)	70	70	140	2.9	2.5	2.7
CP (cfu/100mL)	70	70	140	5.7	1.6	3.0
Ent (cfu/100ml)	70	70	140	100.0	13.1	36.2
pH	70	70	140	8.3	8.3	8.3
Sal (ppt)	70	70	140	11.2	12.5	11.8
DO (mg/L)	66	70	136	6.0	5.5	5.8
DO sat (%)	66	70	136	78.1	73.3	75.6
Temp (˚C)	70	70	140	25.0	26.1	25.5

TABLE 8: GM OR AVG OF ALL EVALUATED PARAMETERS GROUPED BY EVENT TYPE. COMBINED DATA USES ALL DATA REGARDLESS OF EVENT TYPE. ONLY DATA COLLECTED FROM KA'ELEPULU WATERBODY SAMPLE SITES WERE USED.