

Datasets: Field surveys and maps of He'eia watershed hydrology and biogeochemistry

This document provides detailed information about three datasets that were generated through a Collaborative Research project titled *Wetland Water and 'Ike (WAI): Improving Understanding of Hydrology to Inform Management Decisions*. This [webpage](#) provides information about the project. The project was supported by the National Estuarine Research Reserve System (NERRS) Science Collaborative, which is funded by the National Oceanic and Atmospheric Administration. All Science Collaborative supported projects that collect new data adhere to federal data sharing and archiving requirements.

About the Associated Project

Project page: <https://nerrssciencecollaborative.org/project/Rii2022>

Grant Type: Collaborative Research

Focus Area(s): Climate Change, Habitat Restoration, Water Quality

Keyword(s): water quality, traditional ecological knowledge

Reserve(s): He'eia, HI

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Project Contacts:

Project and Collaborative Lead:

- Shimi Rii, He'eia NERR, University of Hawai'i at Mānoa, shimi@hawaii.edu

Technical Lead:

- Henrietta Dulai, University of Hawai'i at Mānoa, hdulaiov@hawaii.edu

Project Description

Native Hawaiian communities hold wai (fresh water) and its life-giving power as sacred. *Wai* has been historically managed by Native Hawaiian communities to sustain food security on the most remote islands on Earth. However, in the past century, land use and socio-economic change has transformed many of Hawai'i's coastal landscapes, leading to altered groundwater recharge, storage, and transport, and reduced surface water flows. These changes have contributed to the decline of traditional agroecology and aquaculture systems at He'eia National Estuarine Research Reserve (NERR) on O'ahu, Hawai'i. To bring back abundance into the He'eia *ahupua'a* (Native Hawaiian social-ecological land and sea division roughly following watershed boundaries), the community expressed the need to understand how much and what kind of *wai* flows through the wetland and estuary, and its potential influence on the restoration of Indigenous biocultural systems.

This project performed an in-depth characterization of surface and groundwater flow throughout He'eia to inform biocultural restoration and future groundwater management. Building on previous conceptual understandings, the project team measured surface and groundwater flow within He'eia. This project elucidated main questions characterizing the quantity, quality, and ages of surface and groundwater flowing through the He'eia watershed, with downstream implications for food and wildlife, fishpond productivity, and nearshore reef health. Looking forward, this work established collaborations with Indigenous resource managers, interfaced with complimentary work conducted by utility and government agencies, and provided *'ike* to inform comprehensive and collaborative management of *wai* in the He'eia *ahupua'a*.

The project's collaborative process was essential to this work and included the convenings of a project advisory group and intended users (named Hui WAI). Iterative Hui WAI meetings shaped the project from its beginning to end, through the codevelopment of the proposal, research methods, workshops, and outputs. This process enhanced communication and relationships among investigators, resource managers, educators and helped build collective knowledge of the ways *wai* links biocultural restoration projects at partner sites.

Major outputs from this work include: 1) a dataset describing above and belowground hydrology and water quality in He'eia, including seasonal and extreme event variability; 2) a consolidated web-based access point to multiple data streams related to water quality and hydrology in He'eia; 3) workshops that promoted intergenerational transfer of *'ike* (knowledge) of water management, with shared objectives of Indigenous and conventional knowledge on cultural, scientific, policy, and management aspects of water; 4) piloted water science and management education programs at partner sites; and 5) data analysis reports and conference presentations shared with local, national, and international audiences advancing the knowledge of hydrology and nutrients as they relate to biocultural restoration.

Overview of Datasets

Three datasets are described in this document:

- **Dataset 1:** He'eia watershed geochemical tracer, nutrient concentrations, and water flux measurements
- **Dataset 2:** Submarine groundwater discharge and nutrient concentrations to the coastal Indigenous aquaculture system
- **Dataset 3:** Relative groundwater level in the He'eia wetland

Questions about these datasets can be directed to:

Shimi Rii, He'eia NERR, University of Hawai'i at Mānoa, shimi@hawaii.edu

Please note: Additional permissions are associated with these datasets. This study utilized and generated local, generational, and Indigenous data belonging to the stewards of the He'eia ahupua'a. Express permission and approval from the stewards of He'eia ahupua'a (Paepae o He'eia, Kāko'o 'Ōiwi, and Papahana Kuaola) should be obtained before using these data for any future work. Please contact the He'eia National Estuarine Research Reserve (info@heeianerr.org) for facilitation.

About the Project Datasets

Detailed dataset descriptions are provided below.

Dataset 1: He'eia watershed geochemical tracer, nutrient concentrations, and water flux measurements

Data overview:

Monitoring of surface and groundwater flow, geochemical tracers, and nutrients was conducted at 47 sites to understand the hydrology and water quality in the He'eia ahupua'a (Native Hawaiian social-ecological land division, roughly following watershed boundaries). Sampling was performed during wet and dry conditions, as well as during extreme tidal and rain conditions. This dataset was collected as part of a project to meet the needs of the He'eia resource management stewardship community that sought to better understand how much water and what quality of water was flowing through the ahupua'a, and how that understanding informs biocultural restoration strategies.

Please note: additional permissions are associated with this dataset. This study utilized and generated local, generational, and Indigenous data belonging to the stewards of the He'eia ahupua'a. Where indicated, express permission and approval from the stewards of He'eia ahupua'a (Paepae o He'eia, Kāko'o 'Ōiwi, and Papahana Kuaola) should be obtained before using these data for any future work. Please contact the He'eia National Estuarine Research Reserve (info@heeianerr.org) for facilitation."

Keywords:

Surface water groundwater interactions, apparent age, recharge source tracking, stable isotopes of water, age tracers, nutrients, water flow, stream discharge

More about the data:

Whenever possible, grab sample pairs consisted of a surface water sample and a pore-water sample from the substrate at the sample site. Common water quality parameters (salinity, temperature, pH, dissolved oxygen, turbidity) were measured in-situ in each sample. Nutrients (nitrate+nitrite, ammonium, silicate, phosphate for dissolved inorganic nutrients, and total dissolved nitrogen and phosphorus) were analyzed in all samples. Surface water-groundwater interactions were quantified using radon mass balance models and direct stream discharge measurements. The source of water within the ahupua'a was inferred from stable isotopes of hydrogen and oxygen of water based on their characteristic elevation lapse rates. Groundwater apparent ages at selected sites were determined using chlorofluorocarbons and sulfur hexafluoride.

The variability across space was captured along upstream, developed, wetland, and coastal regions. Variability in time/seasons was captured by sampling repeatedly at specific times as explained below. Water samples from the surface were collected using a battery operated peristaltic pump, and groundwater samples were collected using a pushpoint sampler (M.H.E. Products, Michigan, USA), which was inserted into the soil/sediment 0.4-0.8 m below surface and then attached to the peristaltic pump.

Data sondes were calibrated prior to each sampling session. QA/QC checks are in place at each analytical facility. Duplicate samples were collected for all water quality sample datasets. All hand entered data was checked by another staff member to ensure accuracy of the data entry.

Variables measured include:

- Site_Name: Short descriptive name of the sites sampled each session
- Session: The name of the sampling session (e.g., W1, W2, W3, ...W8)
- Display_name: Names of sites displayed on maps, corresponding to U=Uplands, D=Developed, W=Wetlands, C=Coastal
- Latitude [°N] and Longitude [°E] were retrieved from a handheld Garmin GPS unit.
- Date [mm/dd/yyyy] : Local time in Hawaii Standard Time, which is UTC-10 hrs.
- Wai_type: Type of water sampled, either 'surface' or 'groundwater'
- Location: Region sampled, either 'upland', 'developed', 'wetland', or 'coastal'
- Depth_samp: description of depth sampled in the field
- Tidal_Height: height of tide at time of sampling for extreme tidal sampling, either 'high', 'mid', or 'low'
- Temperature [°C], SpCond, or specific conductivity [mS/cm], salinity [psu], dissolved oxygen [% saturation, and mg/L], pH, turbidity [FNU] were measured using a YSI multi-parameter sonde (ProDSS) that was inserted into a flow-through cylinder through which water was pumped at the beginning of each sample collection.
 - YSI_Time [hh:mm:ss, 24 hr]: local time in Hawaii Standard Time, which is UTC-10 hrs, time measurement was taken with YSI sonde
 - YSI_Temp [°C]: Temperature taken with YSI sonde
 - YSI_SpCond [mS/cm]: Specific conductance taken with YSI sonde, units in milliSiemens/cm
 - YSI_OdoPer [% Saturation]: Dissolved oxygen taken with YSI sonde, units in % saturation
 - YSI_OdoMg [mg/L]: Dissolved oxygen taken with YSI sonde, units in mg/L
 - YSI_Turbidity [FNU]: Turbidity taken with YSI sonde, units in FNU
 - YSI_pH: pH taken with YSI sonde, no units
- Radon in water [Rn, Bq/m³], uncertainty is given as 1 sigma, was measured using a RAD-H₂O radon-in-water monitor (RAD7 with a RAD-H₂O attachment both manufactured by DurrIDGE Company, Inc). For surface water, a 2-L big bottle system was used, and for groundwater we used a 250 mL glass bottle system. Radon_Time [hh:mm, 24 hr] is the time at which the radon measurement was taken.
- Stable isotopes of oxygen [δ 18O-H₂O, ‰] and hydrogen [δ 2H-H₂O, ‰] in water were sampled unfiltered and with no headspace into 20 mL glass vials and analyzed at the University of Hawai'i Stable Isotope Biogeochemistry Laboratory using an L2130-I Picarro scanned cavity ring down spectroscopy and are reported relative to V-SMOW. Standard deviations for the measurements follow these columns.
- Chlorofluorocarbons [cfc11, cfc12, cfc13, pmol/kg] and sulfur hexafluoride [Sf6, fmol/kg] water samples were collected unfiltered using copper tubing into 500 mL glass bottles with no headspace and were analyzed at the University of Miami Rosenstiel School of Marine and Atmospheric Science Tritium Laboratory using a purge-and-trap gas chromatograph with electron capture detection. All concentrations are reported on the

SIO2005 absolute calibration scale. The data user is cautioned about CFC results from the wetland as significant biodegradation was observed when compared to SF6 ages.

- Flow_rate [m³ /s] indicates surface water flow that was measured using a handheld portable Hach FH 950 flow meter, which is programmed to calculate stream flow using the sum of partial discharges method. In this method, a cross-sectional transect is divided into individual sections, of which the velocity and area of each are measured and summed to obtain total stream discharge. Flow_error refers to the error of the instrumentation (1.5 cm for measuring depth and 0.02% for velocity) associated with each flow measurement.
- Nutrient fluxes (NN_flux, Amm_flux, BioN_flux, OrganicN_flux, P_flux, Silicate_flux, Total_N_avg, μmol/s) were calculated with surface water flow and associated nutrient concentrations.
- Water samples for nutrient analysis were collected in duplicates (rep1, rep2, and avg as designated in headings), filtered through a 0.45 μm AquaPrep 600 hydrophilic polyethersulfone membrane filter into triple rinsed 50 mL falcon tubes. Nutrients were analyzed using a Seal Analytical AA3 HR AutoAnalyzer for total nitrogen (TotalN), total phosphorus (TotalP), Phosphate (PO₄³⁻), Silicate (SiO₄⁴⁻), combined NN (nitrate and nitrite, or NO₃⁻+NO₂⁻), NH₄ (ammonium or NH₄⁺), and Nitrite (NO₂⁻) all reported in [μM]. BioN refers to sum of bioavailable inorganic nitrogen (NN + NH₄), and Organic N refers to TotalN minus BioN.
- Permissions indicate the following: "This study utilized and generated local, generational, and Indigenous data belonging to the stewards of the He'eia ahupua'a. Express permission and approval from the stewards of He'eia ahupua'a (Paepae o He'eia, Kāko'o 'Ōiwi, and Papahana Kuaola) should be obtained before using these data for any future work. Please contact the He'eia National Estuarine Research Reserve (info@heeianerr.org) for facilitation."

Data collection period:

March, 2023 to April, 2024 Temporal coverage: Water samples were collected during eight sampling campaigns as follows:

- March 16-23, 2023 represented a typical wet season
- May 8-17, 2023 was intended to represent the beginning of a dry season but we captured a rain event similar to a wet season
- August 28-31, 2023 captured the effects of a king tide across the wetland, during the dry season
- September 11-18, 2023 represented a dry season with low precipitation
- October 29-30th, 2023 captured the effects of a king tide during a dry season, only at the estuarine flows out of the wetland and into the coastal aquaculture system
- November 20, 2023 captured the initial pulse of the first large rain event following an extended dry period
- December 8-13, 2023 was a wet season sampling
- April 8-11, 2024 captured a rain event after a prolonged wet season

Geographic extent:

The sites sampled for this project spanned from the upper watershed in both Ha'ikū and Ioleka'a valleys, through the developed region, He'eia wetland, and the coastal region near He'eia

Project Datasets: Field surveys and maps of He'eia watershed hydrology and biogeochemistry

Fishpond. The study area spans from 21.43758296°N to 21.40690897°N from north to south, and -157.831236°E to -157.806269°E from west to east, and the nearest town is Kāne'ohe, HI.

File format:

.CSV

File name(s):

DS1_watershed_hydrology_heeia.csv

Data access and archival:

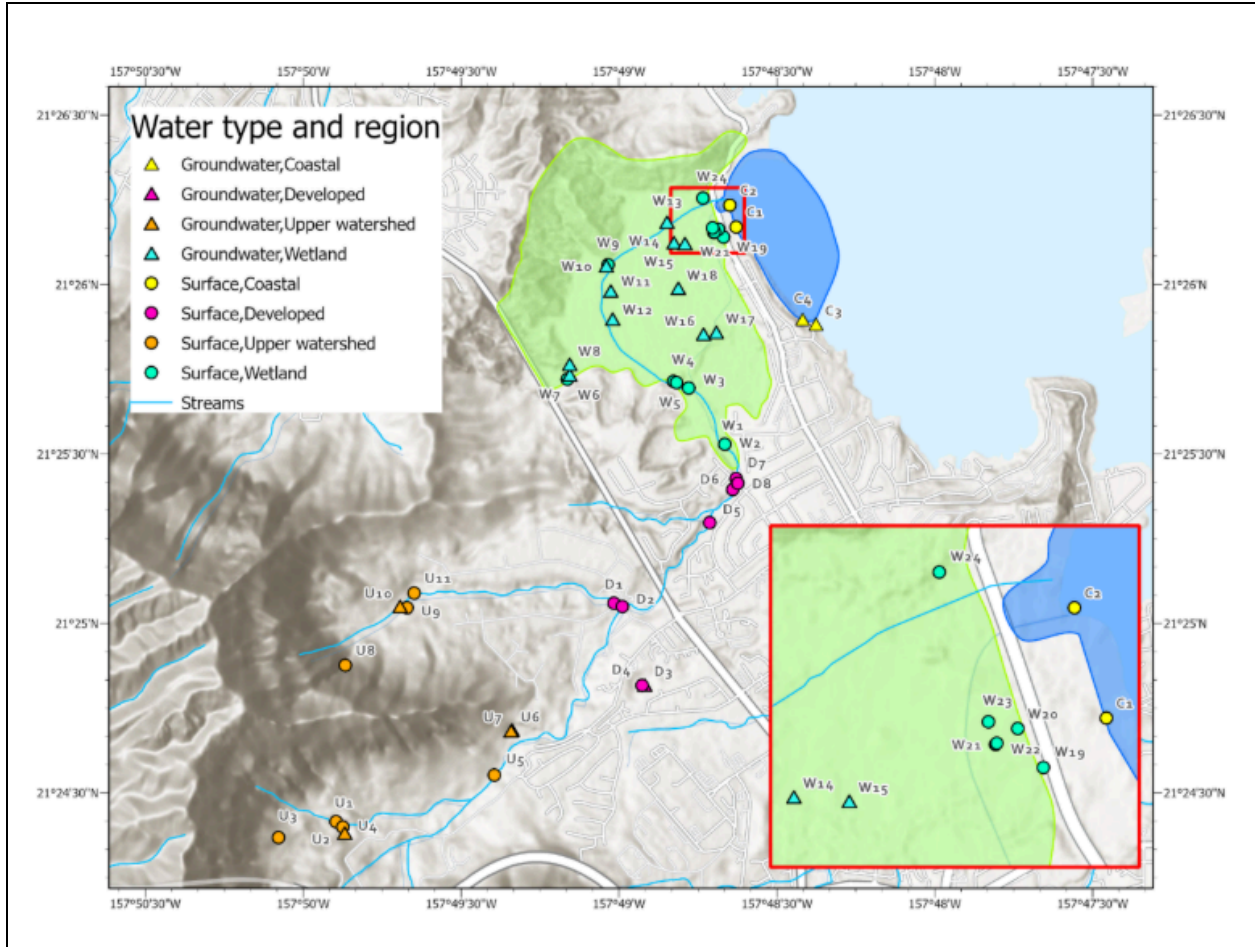
This dataset is archived with the NERRS Centralized Data Management Office.

While data is publicly accessible, we have incorporated a metadata code ('ILK') in our datasheets to protect the rights of our partners and Primary Intended Users regarding Indigenous data produced and utilized in this project (see 'More about the data' above). This metadata information is inserted not for the purpose of limiting access to the data, but to encourage future users to engage in a reciprocal relationship with appropriate entities for using and interpreting data obtained as part of this project. Express permission and approval from the stewards of He'eia ahupua'a (Paepae o He'eia, Kāko'o 'Ōiwi, and Papahana Kuaola) should be obtained before using these data for any future work. Please contact the He'eia National Estuarine Research Reserve (info@heeianerr.org) for facilitation.

This dataset is available for download at the following link:

<https://nerrsciencecollaborative.org/resource/hydrology-geochemical-tracer-and-biogeochemical-data-heeia-watershed>

Maps and schematics for data collection:



The table below shows all of the dates of sampling per sampling session, and the type (e.g., Wet, Dry, Rain, King Tide) of session it corresponded to:

Session	Dates	Session Type
W1	March 16-24, 2023	Wet I
W2	May 8-16, 2023	Rain - prolonged
W3	August 28-31, 2023	King tide I
W4	September 11-18, 2023	Dry I
W5	November 20, 2023	Rain - initial pulse
W6	October 29-30, 2023	King tide II
W7	December 7-13, 2023	Wet II
W8	April 8-11, 2024	Wet III

Dataset 2: Submarine groundwater discharge and nutrient concentrations to the coastal Indigenous aquaculture system

Data overview:

Submarine groundwater discharge (SGD) into the coastal Indigenous aquaculture system (fishpond, or loko i'a) is an essential driver of nutrient fluxes and hence sustains the food web. SGD can be estimated indirectly through the measurement of radon in the loko i'a, which is highly elevated in groundwater but very low in surface waters. We performed temporal and spatial surveys of radon to determine the spatial extent and hotspots of SGD in He'eia Fishpond. Along with continuous integrated radon measurements using a water intake pump, we also deployed a YSI multiparameter sonde (ProDSS) for basic water parameter monitoring and GPS logger to obtain high spatial resolution measurements of the fishpond. For temporal time series monitoring, we deployed the pump and CTD-diver on the pond bottom at 5 select sites, and also collected YSI measurements, and water samples for nutrients and stable isotopes of hydrogen and oxygen.

Keywords:

Submarine groundwater discharge, radon, salinity, water quality monitoring, spatial measurement, time series measurement, loko i'a, fishpond, Indigenous aquaculture system, nutrients

More about the data:

SGD was determined indirectly from radon mass balance models. See dataset 1 "He'eia watershed geochemical tracer, nutrient concentrations, and water flux measurements" for more detail about the variables measured.

Fishpond radon surveys: YSI, CTD, and Radon data

- Session: The name of the sampling session (e.g., Wai1, Wai2, Wai3, etc.)
- DATE [mm/dd/yyyy] : Local time in Hawaii Standard Time, which is UTC-10 hrs.
- TIME [hh:mm:ss AM/PM]: Time of sample
- Temp [°C], SpCond or specific conductivity [mS/cm], Salinity [psu], ODO, or dissolved oxygen [%Sat, and mg/L], pH, and Turbidity [FNU] were measured using a YSI multi-parameter sonde (ProDSS) below the water surface during the spatial surveys. The instrument logging was set to 30 seconds.
- Date_Time [mm/dd/yy hh:mm:ss HST]: local time in Hawaii Standard Time, which is UTC-10 hrs.
- Latitude [°N] and longitude [°E] were retrieved from a handheld Garmin GPS unit and the coordinates were matched to the radon, YSI, and CTD files using time stamps.
- Pressure [atm+cmH₂O], Specific conductance [mS/cm], Temperature [°C], and Salinity [psu] were measured with a CTD-diver (manufactured by Van Essen Instruments model DI281). We used a 15-second logging frequency for spatial surveys and 15-minute resolution for time series monitoring. For time series monitoring we also used the CTD diver for depth measurement where atmospheric pressure was subtracted from total pressure sensed by the sensor to get equivalents of cmH₂O.
- Latitude [°N] and Longitude [°E] were retrieved from a handheld Garmin GPS unit and the coordinates were matched to the radon, YSI, and CTD files using time stamps.
- Radon in water [Bq/m³], and Radon_unc (uncertainty is given as 1 sigma, Bq/m³) - was measured using a RAD-Aqua radon-in-water monitor (RAD7 with a RAD-Aqua attachment

both manufactured by Durrige Company, Inc). For spatial surveys we used a 2-minute integration time. For time series monitoring we applied a 15-minute integration time.

- Permissions indicate the following: “This study utilized and generated local, generational, and Indigenous data belonging to the stewards of the He'eia ahupua'a. Express permission and approval from the stewards of He'eia ahupua'a (Paepae o He'eia, Kāko'o 'Ōiwi, and Papahana Kuaola) should be obtained before using these data for any future work. Please contact the He'eia National Estuarine Research Reserve (info@heeianerr.org) for facilitation.”

Time-series data:

- Site Number: Site where time-series data was collected at each of the 5 selected sites.
- Session: The name of the sampling session (e.g., Wai1, Wai2, Wai3, etc.)
- DATE [mm/dd/yyyy] : Local time in Hawaii Standard Time, which is UTC-10 hrs.
- TIME [hh:mm:ss 24hr]: Time of sample
- Date_Time [mm/dd/yy hh:mm HST]: local date and time in Hawaii Standard Time, which is UTC-10 hrs.
- Latitude [°N] and longitude [°E] were retrieved from a handheld Garmin GPS unit and the coordinates were matched to the radon, YSI, and CTD files using time stamps.
- Pressure [atm+cmH₂O], Temperature [°C] and SpCond, or specific conductance [mS/cm], Salinity [psu], and Depth [m] at the site were measured using a CTD diver (manufactured by Van Essen Instruments model DI281) at a 15-minute logging interval. Atmospheric pressure readings from the Baro diver were subtracted from total pressure to get equivalents of cmH₂O, which were then converted to meters.
- Stable isotopes of oxygen [δ 18O-H₂O, ‰] and hydrogen [δ 2H-H₂O, ‰] in water were sampled unfiltered and with no headspace into 20 mL glass vials and analyzed at the University of Hawai'i Stable Isotope Biogeochemistry Laboratory using an L2130-I Picarro scanned cavity ring down spectroscopy and are reported relative to V-SMOW.
- Temp [°C], SpCond or specific conductivity [mS/cm], Salinity [psu], ODO, or dissolved oxygen [%Sat, and mg/L], pH, and Turbidity [FNU] were measured using a YSI multi-parameter sonde (ProDSS) below the water surface during the spatial surveys. The instrument logging was set to 30 seconds. YSI date and YSI_Time are the timestamp at which the measurement was taken.
- Radon in water [Bq/m³], and Radon_unc (uncertainty is given as 1 sigma, Bq/m³) - was measured using a RAD-Aqua radon-in-water monitor (RAD7 with a RAD-Aqua attachment both manufactured by Durrige Company, Inc). For spatial surveys we used a 2-minute integration time. For time series monitoring we applied a 15-minute integration time.
- Water samples for nutrient analysis were collected in duplicates for time series measurements, filtered through a 0.45 μ m AquaPrep 600 hydrophilic polyethersulfone membrane filter into triple rinsed 50 mL falcon tubes. Nutrients were analyzed using a Seal Analytical AA3 HR AutoAnalyzer for total nitrogen (TotalN), total phosphorus (TotalP), Phosphate (PO₄ 3-), Silicate (SiO₄ 4-), NN, or nitrate + nitrite (NO₃- + NO₂-), NH₄, or ammonium (NH₄+), and Nitrite (NO₂-). All nutrients are reported in [μ M].
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Data collection period:

Spatial surveys:

- April 11, 2023
- May 10, 2023
- September 13, 2023
- September 25, 2023
- December 11, 2023
- April 10, 2024

Time series measurements:

- April 20-21, 2023
- May 9-10, 2023
- September 12, 15, 2023
- September 25-26, 2023
- December 11-12, 2023

Geographic extent:

He'eia Fishpond spans from 21.4400 °N to 21.4300 °N from north to south, and -157.8050 °E to -157.8110 °E from west to east.

Site number	Description	Nearest town	Latitude (°N)	Longitude (°E)
TS1	Dock	Kāne'ohe	21.43194	-157.8071
TS2	Mid Float	Kāne'ohe	21.43723603	-157.810828
TS3	Kaho'okele	Kāne'ohe	21.435778	-157.805361
TS4	U Float	Kāne'ohe	21.43723603	-157.810828
TS5	Mangrove Float	Kāne'ohe	21.43523	-157.80942

File format:

.CSV

File name(s):

- DS2_radon_surveys_YSI.csv
- DS2_radon_surveys_CTD.csv
- DS2_radon_surveys_radon.csv
- DS2_timeseries_nuts.csv
- DS2_timeseries_CTD.csv
- DS2_timeseries_radon.csv

Data access and archival:

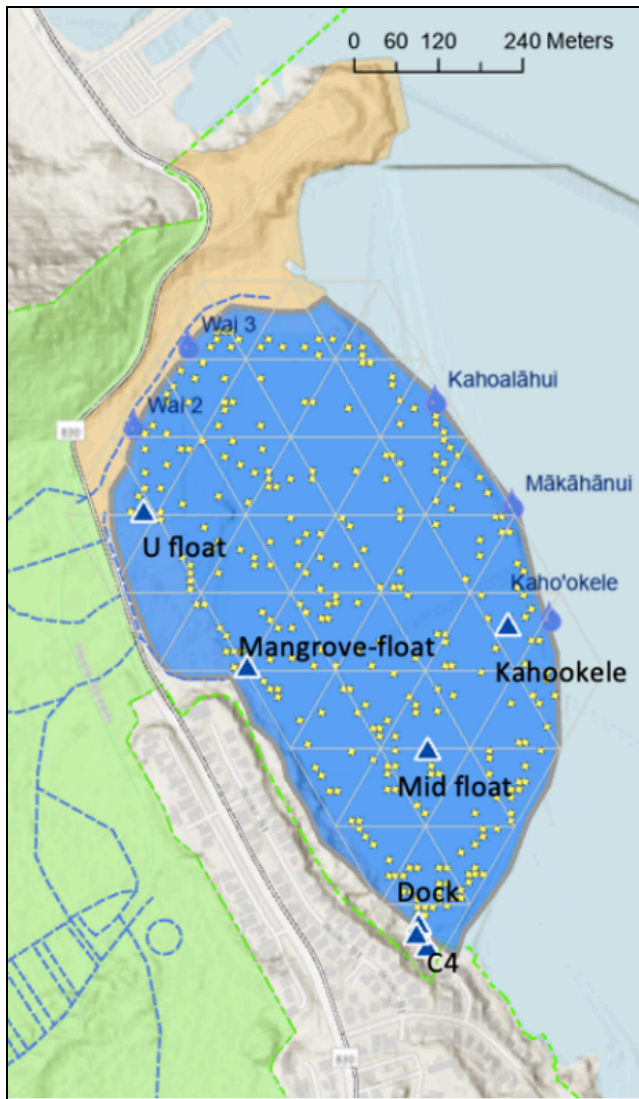
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Maps and schematics for data collection:



Map of fishpond with radon measurement interval end points indicated with yellow circles and five time series radon monitoring locations with triangles.

Dataset 3: Relative groundwater level in the He'eia wetland

Data overview:

Groundwater level at two locations in the wetland was monitored in order to detect any changes in response to tides, precipitation, and evaporation. We selected two monitoring locations, one towards the mountain side of the wetland and one towards the coastal side of the wetland. A Baro diver to monitor atmospheric pressure was deployed at the site at 2 m elevation above ground. The CTD divers at the two sites were deployed into a 0.3 m long 1 ¼” PVC well point coupled to a solid 1 ¼” PVC pipe.

Keywords:

Groundwater level monitoring, sea level, tidal cycle

More about the data:

- Date/Time [mm/dd/yy hh:mm HST]: local date and time in Hawaii Standard Time, which is UTC-10 hrs.
- Barometric pressure [cmH2O] was measured using a Baro diver (manufactured by Van Essen Instruments) at a 15-minute logging interval.
- Pressure [cmH2O], Temperature [°C] and SpecCond, or specific conductance [mS/cm], Salinity [psu], and Water level [m] at the site were measured using a CTD diver (manufactured by Van Essen Instruments model DI281) at a 15-minute logging interval. Atmospheric pressure readings from the Baro diver were subtracted from total pressure to get equivalents of cmH2O, which were then converted to meters.
- Latitude [°N] and longitude [°E] were retrieved from a handheld Garmin GPS unit.
- Permissions, 'ILK' indicates the following: “This study utilized and generated local, generational, and Indigenous data belonging to the stewards of the He'eia ahupua'a. Express permission and approval from the stewards of He'eia ahupua'a (Paepae o He'eia, Kāko'o 'Ōiwi, and Papahana Kuaola) should be obtained before using these data for any future work. Please contact the He'eia National Estuarine Research Reserve (info@heeianerr.org) for facilitation.”

Data collection period:

May, 2023 to December, 2024

Geographic extent:

Site number	Description	Nearest town	Latitude [°N]	Longitude [°E]
W-mauka	Site towards the mountain side of the wetland	Kāne'ohe	21.43269	-157.81932
W-makai	Site towards the coastal side of	Kāne'ohe	21.43684	-157.81308

	the wetland			
Baro	Site where the Baro diver was deployed for air pressure	Kāne'ohe	21.43757	-157.81261

File format:

.CSV, Each CSV below is a raw data output of the CTD divers at each of the sites (Baro, W-makai, and W-mauka).

File name(s):

- DS3_Bar.csv
- DS3_W-makai.csv
- DS3_W-mauka.csv

Data access and archival:

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