Integrating Precipitation and Groundwater Chemistry to Interpret Groundwater Flow in the Hawaiian Islands

Diamond K. Tachera[1], Nicole C. Lautze[1,2]

[1]Hawaiʻi Institute of Geophysics & Planetology, Univ. of Hawaiʻi at Mānoa, Honolulu, HI 96822; [2]Water Resources Research Center, Univ. of Hawaiʻi at Mānoa , Honolulu, HI 96822

Introduction

Hawaiʻi is dependent on groundwater resources, yet how water moves through the subsurface is not well understood in many locations across the state. ***ʻIke Wai*, a 5 year NSF-funded EPSCoR project, incorporates analyses of precipitation and groundwater chemistry in its effort to better understand Hawaiʻi's hydrologic systems.** The focus areas of the project are the Pearl Harbor aquifer (Oʻahu) and the Hualālai aquifer (Hawaiʻi Island) (Figure 1). Previous work on the Hualālai aquifer has prompted us to look further inland for the source of groundwater recharge (Tillman et al., 2014; Fackrell dissertation, 2016). Groundwater models currently use water level elevations to model groundwater flow, but in many cases, there is a lack of data in the upslope regions where groundwater sources and recharge occurs.

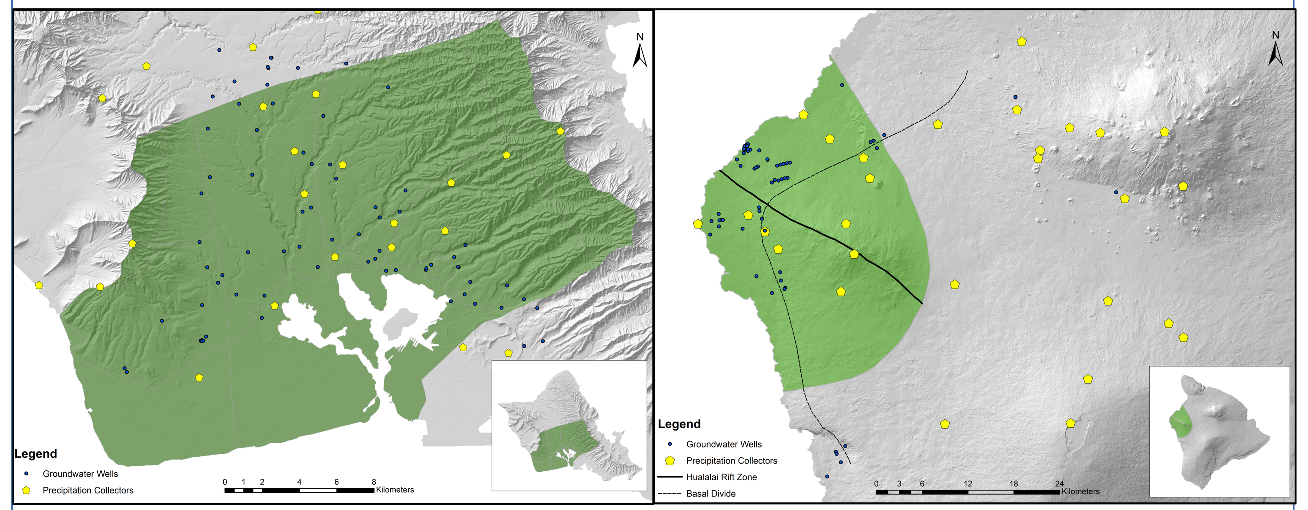


Figure 1: The ʻIke Wai study areas include the Pearl Harbor aquifer, located in south central Oʻahu (top) and the Hualālai aquifer, located in leeward Hawaiʻi (bottom).

The integration of groundwater chemistry along flow paths will provide constraints in these groundwater flow models. We use the known correlation between precipitation $\delta^{18}O$ and $\delta^{2}H$ isotopic values and elevation of rainfall to evaluate the source location of each groundwater sample taken from wells along previously modeled flow paths. We also use major ions and trace metals as natural tracers by relating respective concentrations to the subsurface geology.

The Hawaiʻi EPSCoR project, *ʻIke Wai,* is incorporating water chemistry, groundwater modeling, geophysics, engineering, microbiology and economics with community knowledge and Hawaiian *moʻolelo* (stories) to better understand groundwater resources. **We will work with community stakeholders and researchers to better understand their diverse needs in order to provide useful data and visualization tools.**

Objectives

In Kona, we have identified *mauka* (mountain) and *makai* (sea) wells that have different water table elevations, separated by what we are calling a "basal divide". **We will look at the water chemistry in both *mauka* and *makai* wells to assess the source region and degree of connectivity between them.** Tillman et al. (2014) hypothesized that the *makai* wells are sourced from normal recharge events, and this water represents a normal water table; whereas the *mauka* wells are sourced from high-slope precipitation and fog on the slopes of Mauna Kea and Mauna Loa. Also that a subsurface structure is causing the water level in *mauka* wells to be higher (Figure 2).

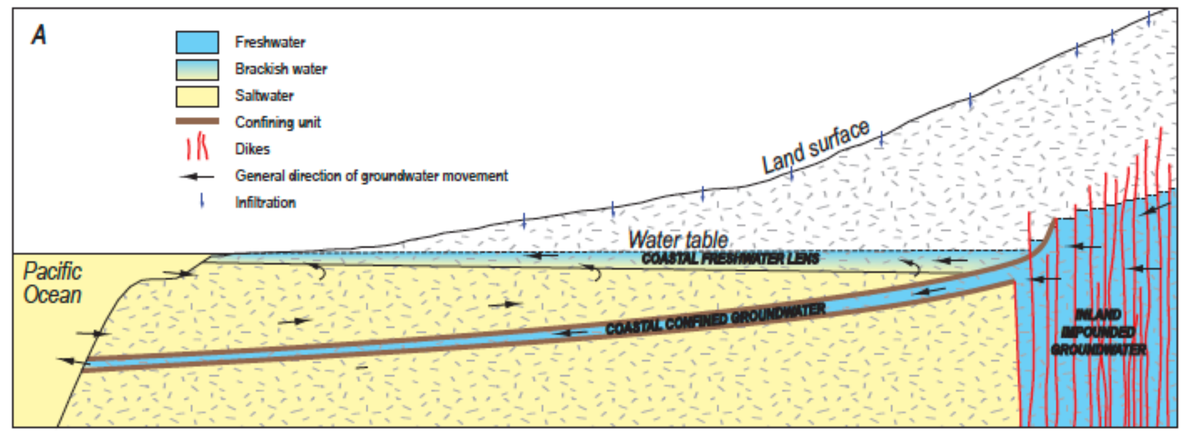


Figure 2: USGS schematic of hypothesized separation of freshwater lens and impounded high-level water (Tillman et al., 2014).

Precipitation collectors well be deployed to better understand the source of groundwater in both aquifers - rain. We need to better understand the chemistry of water before it enters the groundwater system, in order to understand how the geology can affect and change its chemistry. Since the isotopic composition of groundwater can be directly related to the elevation of rainfall, we are placing precipitation collectors around Hualālai, as well as the western slopes of Mauna Kea and Mauna Loa (Craig, 1961). **The elevation-derived relationship between $\delta^{18}O$ and $\delta^{2}H$ in precipitation does not account for island environments such as on Hawaiʻi Island, where multiple volcanoes provide a variety of elevations spatially** (Figure 3).

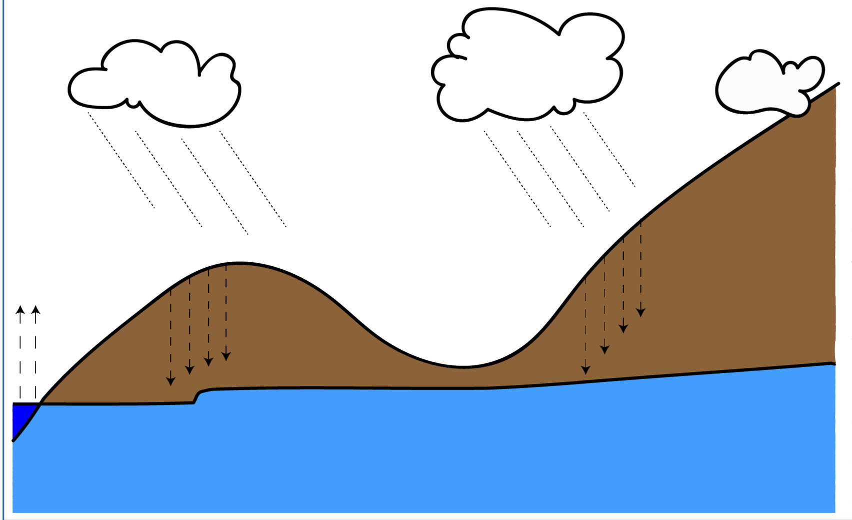


Figure 3: The $\delta^{18}O$ and $\delta^{2}H$ composition in rainfall can be correlated to the elevation at which it fell, as the heavier isotopes fall out first. The variability in elevations on Hawaiʻi Island make this challenging because then the elevation-derived equation is not always valid.

Methods and Materials

The groundwater wells targeted for sampling are chosen based on hypothesized flow paths, when possible, and to improve the spatial resolution of data. Groundwater samples will be collected and analyzed for many species, including:

- major ions (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SiO_2, HCO_3^-, SO_4^{2-}, NO_3^-, F^-, Cl^-)
- trace metals (As, Ba, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Re, Sr, U, V, Zn)
- isotopes ($\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$)

as well as water quality parameters measured in the field. The goal of such analyses is to use the chemical parameters as natural tracers to improve our understanding of groundwater source, flow path, and degree of connectivity between aquifers. Our goal is to collect data on a quarterly to bi-annual schedule, sampling in the "wet" winter and "dry" summer seasons of Hawaiʻi.

Figure 4: A Nova Lynx rain and snow gauge (left), and a schematic of a precipitation collector (right), based on previous precipitation collectors used in Hawaiʻi-based research projects (Scholl et al., 1996; Fackrell, 2016).

Precipitation collectors (Figure 4) will be deployed along transects in our study areas, and where possible co-located with other precipitation measurement stations (NOAA, USGS, etc.). Collectors are designed based on Scholl et al. (1996) USGS survey, or previously assembled rain gauges that are available online. Precipitation samples will be collected and analyzed for the same major ions and isotopes as the groundwater samples. The collectors will be maintained for at least two to three years, and samples will also be collected seasonally with groundwater.

Combining Science and Culture

A GREAT STORM
FORCEFUL RAIN

Signs of a great storm coming

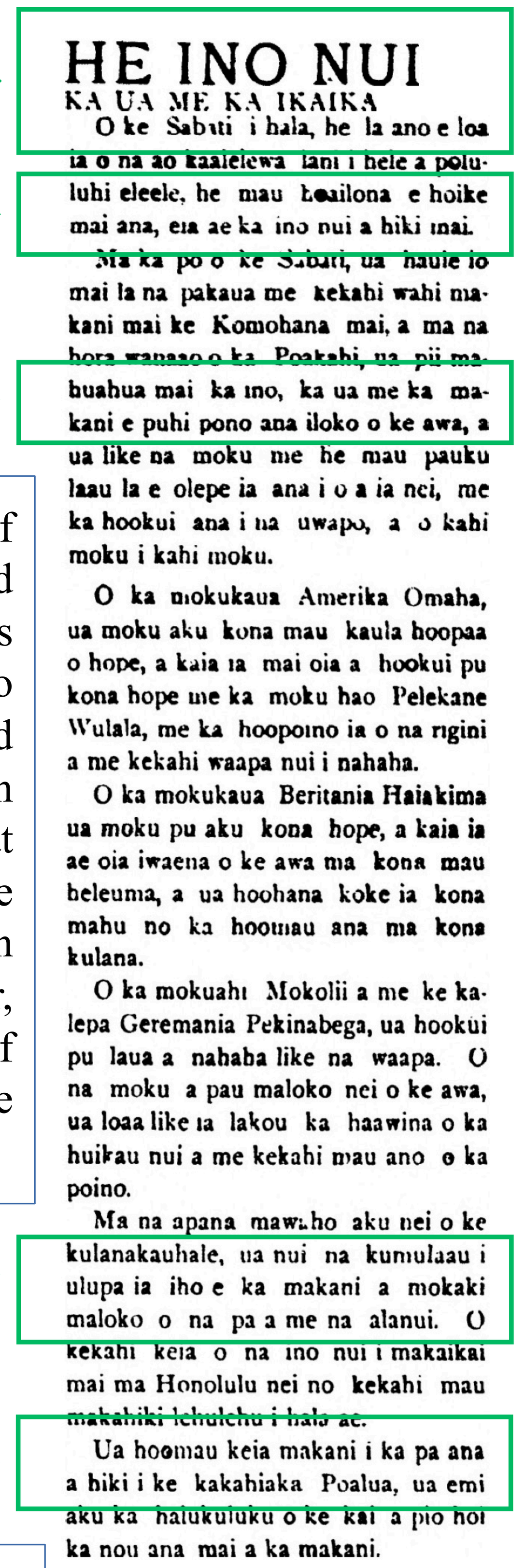
Rain & wind blowing in the harbor

Trees were destroyed by the wind, scattered in the streets

The wind continued until Tuesday

ʻIke Wai is working with the Institute of Hawaiian Language Research and Translation (IHLRT) to translate articles from Hawaiian newspapers that relate to the science objectives. There were around 100 different newspaper journals between 1834 and 1948, containing articles that ranged from daily weather, marriage announcements, and more, printed on 125,000 newspaper pages (Nogelmeier, 2010; Figure 5). The abundance of newspaper journals is attributed to the 97% literacy rate in Hawaiʻi by 1860.

For more information on the Institute of Hawaiian Language Research and Translation, visit **ihlrt.seagrant.soest.hawaii.edu**



HE INO NUI

KA UA ME KA IKAIKA

O ke Sabati i hala, he la ano e loa ia o na ao kaalelewa lani i hele a poluluhi eleele, he mau hoailona e hoike mai ana, eia ae ka ino nui a hiki mai.

Ma ka po o ke Sabati, ua hauie io mai la na pakaua me kekahi wahi makani mai ke Komohana mai, a ma na hora wanaao o ka Poakahi, ua pii mahuahua mai ka ino, ka ua me ka makani e puhi pono ana iloko o ke awa, a ua like na moku me he mau pauku laau la e olepe ia ana i o a ia nei, me ka hookui ana i na uwapo, a o kahi moku i kahi moku.

O ka mokukaua Amerika Omaha, ua moku aku kona mau kaula hoopaa o hope, a kaia ia mai oia a hookui pu kona hope me ka moku hao Pelekane Wulala, me ka hoopoino ia o na rigini a me kekahi waapa nui i nahaha.

O ka mokukaua Beritania Haiakima ua moku pu aku kona hope, a kaia ia ae oia iwaena o ke awa ma kona mau beleuma, a ua hoohana koke ia kona mahu no ka hoomau ana ma kona kulana.

O ka mokuahi Mokolii a me ke kalepa Geremania Pekinabega, ua hookui pu laua a nahaha like na waapa. O na moku a pau maloko nei o ke awa, ua loaa like ia lakou ka haawina o ka huikau nui a me kekahi mau ano o ka poino.

Ma na apana mawaho aku nei o ke kulanakauhale, ua nui na kumulaau i ulupa ia iho e ka makani a mokaki maloko o na pa a me na alanui. O kekahi keia o na ino nui i makaikai mai ma Honolulu nei no kekahi mau makahiki lehulehu i hala ae.

Ua hoomau keia makani i ka pa ana a hiki i ke kakahiaka Poalua, ua emi aku ka halukuluku o ke kai a pio hoi ka nou ana mai a ka makani.

Figure 5: *Ka Nupepa Kuokoa* article, published August 18th, 1888, talking of a storm that hit Honolulu.

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Further information about the Hawaiʻi EPSCoR Program can be found at:

www.hawaii.edu/epscor

Contact

Diamond K. Tachera
Hawaiʻi Institute of Geophysics & Planetology, University of Hawaiʻi at Mānoa
1680 East West Road, POST 619, Honolulu, HI 96822
Email: diamondt@hawaii.edu
Website: diamondsresearch.wordpress.com
Phone: (808) 956-5392

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