Tracing Interconnectivity Between High-level and Basal Groundwaters in West Hawaii

Basic Information

Title:	Tracing Interconnectivity Between High-level and Basal Groundwaters in West Hawaii
Project Number:	2014HI434B
Start Date:	3/1/2014
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	1
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Hydrogeochemistry, Hydrology
Descriptors:	None
Principal Investigators:	Craig R Glenn

Publication

1. There are no publications.

Problem and Research Objectives

Recent rapid development in the North Kona District of West Hawaii has raised concerns regarding the sustainability of the region's groundwater resources in the face of increasing demand. A large portion of the region's municipal water supply is withdrawn from wells tapping a high-level groundwater system (Oki 1999). However, the effects of withdrawals from this high-level aquifer on the underlying and adjacent basal groundwater system, which itself sustains the region's unique coastal ecosystems while also being utilized for municipal, industrial, and irrigation purposes, are not well understood. Several previous scientific studies of groundwater in the North Kona district (Oki 1999, Bauer 2003, Kelly 2012) have proposed that the high-level groundwater system in this area recharges the basal lens and that withdrawals from the high-level system could potentially impact the basal system. However, recent reports done in support of environmental impact statements for development in the region (e.g., Nance, 2013) have challenged these findings by citing evidence for an impermeable barrier separating the basal and high level systems. Additional research into the relationship between basal and high-level groundwater is needed to better assess the merit of these competing claims.

Concerns over the potential for future development and associated increases in groundwater withdrawals to impact the groundwater-dependent coastal ecosystem of Kaloko-Honokohau National Historical Park resulted in the National Park Service submitting a petition in September 2013 for the Hawaii Commission on Water Resource Management (CWRM) designate the Keauhou Aquifer as a "Ground Water Management Area." This designation would place more stringent controls on groundwater development and withdrawals in the region and has provoked controversy between proponents of development and conservationists. This proposed project should yield solid insight into the relationship between basal and high-level groundwater in this region and assist the CWRM in determining the future regulatory status of the Keauhou Aquifer as well as strategies for its sustainable use.

The fundamental nature of this project is to continue the investigation into the use of water isotopes as conservative tracers of groundwater flow and mixing that began under NSF award #0903833 (IMUA III: Pacific High Island Evolutionary Biogeography: Impacts of Invasive Species, Anthropogenic Activity and Climate Change on Hawaiian Focal Species). Work under that grant included determination of δ^2H and $\delta^{18}O$ values for 129 groundwater and coastal ocean samples (to be used in mixing analysis) as well as the establishment and sampling at 6-month intervals of 8 cumulative precipitation collectors across the region Continued sampling of these collectors in the present work resulted in improved insight into temporal variation in δ^2H and $\delta^{18}O$ values in precipitation in this region, and has provided a robust data set (> 2 years for all collectors) for use in mixing analyses.

Methodology

The cumulative precipitation collectors used in this study were designed to prevent evaporation of accumulated rainfall over a long-term deployment. The design is based on collectors used for the same purpose by Scholl et al. (1996) and consists of a 5 gallon HDPE tank with a 76 or 110 mm diameter funnel affixed to the lid mounted on a wooden base with metal legs. Prior to deployment, a 1 cm layer of mineral oil was added to each collector to

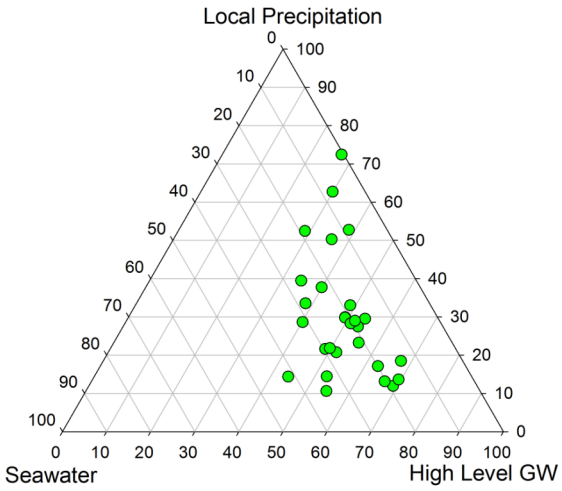

Figure 1. End-member mixing analysis using water isotope values indicates that basal groundwater sample in the Keauhou aquifer consist of a large portion of high-level groundwater.

prevent evaporation of collected precipitation and the apparatus is wrapped in a trash bag to prevent sun exposure. The mount was secured to the ground by weighting the legs with rocks, and, if ground conditions permitted, digging shallow holes into which the legs are placed. Locations near currently active precipitation monitoring stations were utilized whenever possible in order to evaluate the efficiency of the cumulative precipitation collectors with respect to the existing rain gauge.

Once deployed, the collectors were sampled at 6-month intervals. During sampling, collected precipitation was withdrawn from a spigot located near the bottom of the bucket and measured in a graduated cylinder. The protective trash bag and mineral oil layer was replaced upon completion of sampling. We analyzed the samples for δ^2H and $\delta^{18}O$ at the University of Hawaii Stable Isotope Biogeochemistry Lab using our Picarro cavity ring-down mass spectrometer. Our analytical precision for this method is evaluated by comparison of duplicate samples and was typically <0.1‰ for $\delta^{18}O$ and <0.6‰ for δ^2H.

The determination of δ^2H and $\delta^{18}O$ values for the area's precipitation, groundwater, and seawater provides the means to assess the contribution of high-level groundwater to the basal system via end-member mixing analysis. For the purpose of this analysis, seawater, local precipitation (approximated by the volume weighted average of precipitation collected across the basal aquifer's elevation gradient), and high-level groundwater were employed as the end-members. The percent contributions of these three end-members to each basal groundwater sample were determined analytically using our δ^2H and $\delta^{18}O$ values as tracers (e.g., Christophersen and Hooper 1992, Hooper 2003, Liu et al. 2004).

Principal Findings and Significance

Mixing analysis of basal groundwater in the Keauhou aquifer using water isotopes was completed and presented as a poster at the Ocean Sciences Meeting in February 2014, just prior to the commencement of the reporting period. The principal finding of this analysis was that basal groundwater in the Keauhou aquifer contains a significant portion of recharge from the high-level aquifer (Figure 1). This finding attracted a great deal of interest from

stakeholders in the debate regarding the designation of the Keauhou aquifer and was later validated by the published results of Tillman et al. (2014), which used our methodologies to come to the same conclusions.

Final precipitation collector sampling took place in December 2014. These samples have been analyzed and integrated into previously acquired data yielding the most robust and comprehensive meteoric water line (Figure 2) and water isotope/altitude relationship (Figure 3) to date. Our newly acquired data was used in updated basal groundwater mixing scenarios that were provided to Paul Eyre of CWRM to assess the validity of various conceptual models of groundwater flow in the Keauhou aquifer. Additionally, the data acquired by this study has been utilized in presentations by Delwyn Oki (USGS) and Donald Thomas (UH) during CWRM contested case hearings regarding the designation of the Keauhou aquifer as a special management area in late 2014. Our data is also currently being shared with and utilized by Robert Whittier of the Hawaii Department of Health to develop a new model of groundwater flow in West Hawaii for the purpose of evaluating source water protection.

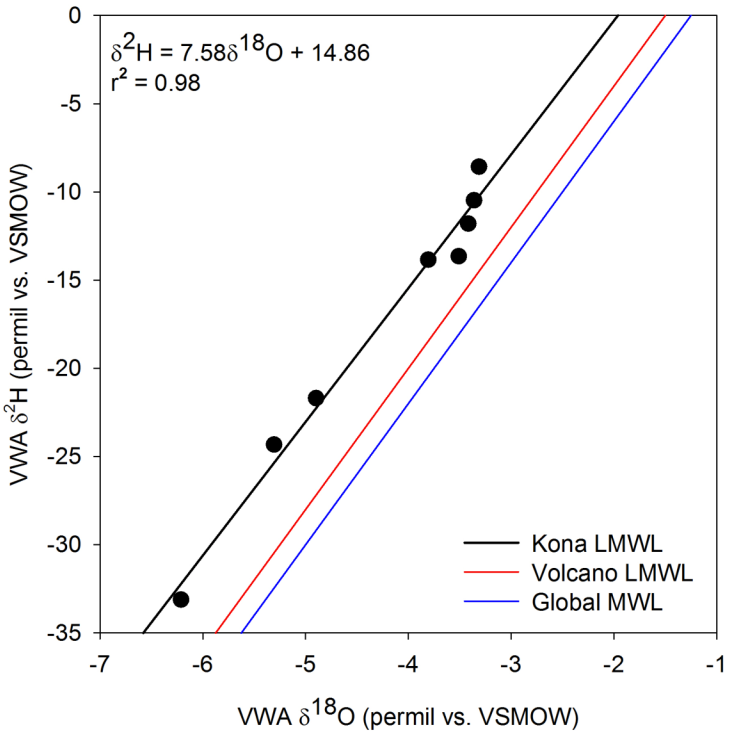

Figure 2. Local Meteoric Water Line (LMWL) determined for West Hawaii based on >2 years of data.

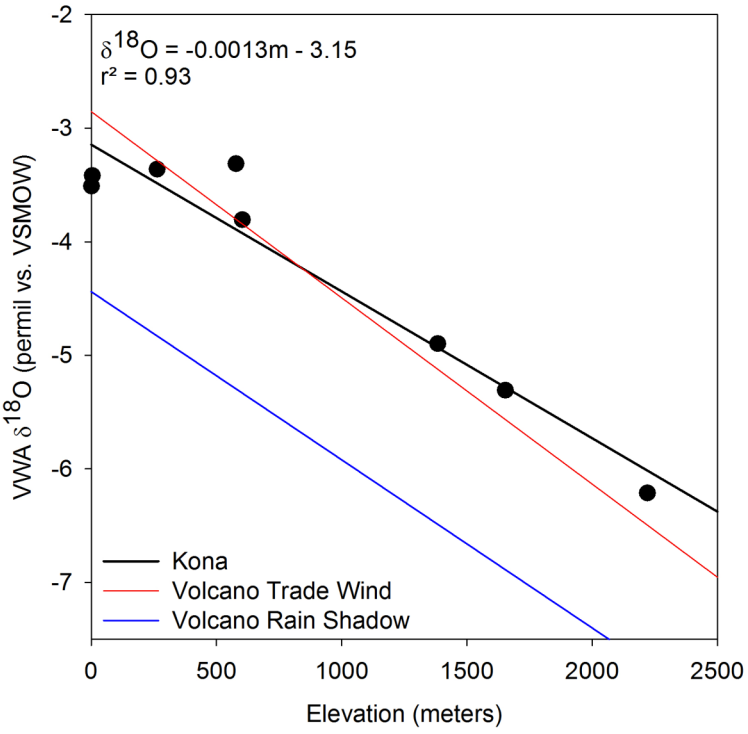

Figure 3. Relationship of $\delta^{18}O$ values in precipitation with elevation determined for West Hawaii based on >2 years of data.

Publications Cited in Synopsis

Bauer, G.R., 2003, "A study of the ground-water conditions in North and South Kona and South Kohala districts Island of Hawaii, 1991–2002," State of Hawaii Department of Land and Natural Resources, PR-2003-01, 75 p. plus appendixes.

Christophersen, N., and R.P. Hooper, 1992, "Multivariate analysis of stream water chemical data: the use of principal components analysis for the end-member mixing problem," Water Resources Research, 28(1) 99–107.

Glenn, C.R., R.B. Whittier, M.L. Dailer, H. Dulaiova, A.I. El-Kadi, J. Fackrell, J.L. Kelly, and C.A. Waters, 2012, "Lahaina groundwater tracer study – Lahaina, Maui, Hawaii," Final Interim Report prepared for the State of Hawaii Department of Health, the U.S. Environmental Protection Agency, and the U.S. Army Engineer Research and Development Center. http://www.epa.gov/region9/water/groundwater/uic-pdfs/lahaina02/lahaina-final-interim-report.pdf

Hooper, R.P., 2003, "Diagnostic tools for mixing models of stream water chemistry," Water Resources Research, 39(3), doi:10.1029/2002WR001528.

Kelly, J.L., 2012, "Identification and quantification of submarine groundwater discharge in the Hawaiian Islands," Ph.D Dissertation, Department of Geology and Geophysics, University of Hawaii at Manoa, Honolulu, HI, 811 p.

Liu, F., M.W. Williams, and N. Caine, 2004, "Source waters and flow paths in an alpine catchment," Colorado Front Range, United States, Water Resources Research, 40, W09401, doi:10.1029/2004WR003076.

Nance, T., 2013, "Assessment of the potential impact of the proposed Kaloko Makai project on Water Resources," report by Tom Nance Water Resource Engineering, appendix C in Kaloko Makai draft environmental impact statement, 23 p.

Oki, D., 1999, "Geohydrology and numerical simulation of the ground-water flow system of Kona, Island of Hawaii," USGS, Water-Resources Investigation Report 99-4073, 70 p.

Scholl, M.A., S.B. Gingerich, and G.W. Tribble, 2002, "The influence of microclimates and fog on stable isotope signatures used in interpretation of regional hydrology, East Maui, Hawaii," Journal of Hydrology, 264(1-4) 170–184.

Scholl, M.A., S.E. Ingebritsen, C.J. Janik, and J.P. Kauahikaua, 1996, "Use of precipitation and groundwater isotopes to interpret regional hydrology on a tropical volcanic island: Kilauea volcano area, Hawaii," Water Resources Research, 32(12) 3525–3537.

Tillman, F.D., D.S. Oki, A.G. Johnson, L.B. Barber, and K.R. Beisner, 2014, "Investigation of geochemical indicators to evaluate the connection between inland and coastal groundwater systems near Kaloko-Honokohau National Historical Park, Hawaii," Applied Geochemistry, 51, 278–292, doi:10.1016/j.apgeochem.2014.10.003.