EPSCoR

National Science Foundation
Experimental Program to Stimulate Competitive Research

A Proposal for a Collaborative Resource
(Re-)Analysis

Geophysics

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• The quality of Hawai‘i’s groundwater resources is among the best in the world

• We all recognize these resources as critical assets for our communities

• For most communities, the available resource is adequate to meet current needs…. BUT
The resource is under varying degrees and urgencies of threat from multiple stressors:

- Over production in some locations
- Contamination
  - Red Hill
  - Pesticide use
  - Wastewater spills
  - On Site Disposal Systems
- Climate Change
• These threats are managed by
  
  • **CWRM** – production and protection
  
  • **DOH** – water quality and contamination
  
  • **DWS** – quality delivered to the user

All over committed and under-resourced to fully manage the complete spectrum of threats that the resource is facing...
There is a further threat that compounds all the others:

We don’t yet fully understand how water flows, or how it is stored, inside Hawai’i’s volcanoes
Conceptual Model for Hawaii’s Groundwater

Hasn’t changed much in about 70 years
Hydrologic Units
The hydrology of Mauna Kea is much more complicated than our cartoon:

- Deep structures
- Dike complexes
- Aquitards

Affecting the groundwater storage, accumulation, distribution, and flow

HSDP – Hawaii Scientific Drilling Project
The hydrology of Hawaii’s volcanoes is complicated

- Hawaii’s volcanoes are not large homogeneous “sponges” with uniform flow
- Deep structures, including dike complexes and aquitards are controlling groundwater accumulation, distribution, storage, and flow
- More water is being stored inside Mauna Kea than was thought
- To optimally manage and protect the aquifers we need to understand how these internal structures affect water (and contaminant) flow
Geophysical Investigations
(What can we tell without drilling)

- Magnetotelluric and audiomagnetotelluric surveys and modeling

- Gravity surveys and modeling

- Develop better models for groundwater flow that can more reliably project the rates and direction of flow of the groundwater (and potential contaminants)
Natural fluctuations in the earth’s magnetic field are used as a source of low frequency electromagnetic waves.

Detection depth depends on the frequency (or period) of the wave and electrical conductivity.

Long periods (low frequencies) penetrate more deeply into the earth than short periods; get a picture from depths of a few 10 s of metres to depths of 10 s of kilometres.
Magnetotelluric (MT) equipment in the field
Electrical Resistivity Across the Saddle
Gravity Survey and Modeling

High Density

Volcanic necks

Dike complexes
Geophysical Method Depends on the Properties and Depth of the target

- **SURFACE**: Thermal Infrared (TIR)
- **0 - 20 METERS**: Ground Penetrating Radar (GPR)
- **0 - 60 METERS**: Electrical Resistivity Tomography (ERT) and seismic refraction
- **20 METERS TO 2 KM**: Controlled source audiomagnetotellurics (CSAMT), Time Domain Electromagnetics (TEM)
- **1 KM – 10’s KM**: Magnetotellurics (MT)
Aerial Thermal Infrared (TIR) Mapping and Monitoring
Is this how GPR works?
GPR for Archaeology
Via Cappa Santa, Salemi Sicily  
house floor remnants  
4th - 6th c. BC
PCE Spill Experiment

Experimental monitoring:

- **Crosswell GPR**
- Surface GPR
- Complex resistivity
- Directional borehole radar
- Acoustic logging
- Dielectric logging
- High frequency sounding
- Very early time EM
Parameters of Crosswell Radar

- Zero Offset Gathers
- Common Source Gathers
- 23.8 L PCE in 72 hours
- 1.4 GHz antenna (air)
- Recorded 100 ns data trace
- 20 ps sample interval
- 2.5 cm depth interval
Variation in PCE size and shape at depth of 77cm
(4 cm below boundary between 3% clay-sand and 5% clay-sand interface)
Velocity of Direct Arrivals $\Rightarrow \varepsilon$

\[ RDP = \left( \frac{v_0}{v_m} \right)^2 \]

\[ v_m = \frac{\text{distance between wells (m)}}{\text{direct arrival time (s)}} \]

\[ v_0 = 3 \times 10^8 \text{ m/s} \]
Velocity Tomograms

Bruggeman-Hanai Sen mixing formula ⇒ Porosity ⇒ $S_{PCE}$
(Sander 1994 and Sneddon 2000)
Contoured PCE Saturations (from BHS formula)

**1.5 Hours**

- Depth (m): -0.4, -0.6, -0.8

**10.5 Hours**

- Depth (m): -0.4, -0.6, -0.8

**Postspill**

- Depth (m): -1.4, -1.2, -1.0

SPCE Saturations

$S_{PCE}$

$Tx - Rx = 0.76 \text{ m}$
Electrical Resistivity Tomography
Electrical Resistivity Tomography

Leaking tanks

B-Complex Mesh

B-Tank Farm

BY-Tanks

BY-Cribs

Tile Field

Easting (m)

Northing (m)

B-Complex Inversion Results

Log10 Conductivity (S/m)

BY-Cribs

Tile Field

B-Tanks

Easting (m)

Northing (m)
One primary contaminant plume with two lobes that appear to settle at the water table and extend eastward.
TEM Soundings provide information about the electrical conductivity of the upper few hundred metres of the earth’s crust.
 Proposal

– Develop a collaborative effort among the UH, CWRM, DOH, and county DWS to:

– Better define the distribution and extent of groundwater aquifers statewide

– Develop better models for groundwater flow that can more reliably project the rates and direction of flow of the groundwater (and potential contaminants)

“...we still don’t have an understanding of the groundwater system. There’s nowhere near enough outflow in the surface waters to balance the recharge...” MacDonald, 1974
How Do We Propose To Do This

- Compile “legacy” data into geospatial database
- Develop suite of visualization tools
- Conduct geophysical surveys to characterize subsurface distribution of groundwater
- Geophysical experiments at monitoring wells
- Apply geophysical methods to contaminant problems
- Sampling and analysis of GW for non-compliance parameters as novel tracers
- Downhole monitoring instruments for real-time water level and chemistry data in select wells
- Improved estimates of coastal discharge
- Use new and legacy data to test and refine models
Simple database example

Average Annual Surface Temperature Versus Well Temperature
(>1,500 wells)

Temperature difference (°C)
- 20 - 45
- 10 - 20
- 5 - 10
- 2 - 5
- 0 - 2
- -2 - 0
- -5 - -2
- -10 - -5
- -20 - -10
- -45 - -20
How Do We Propose To Do This?

- NSF proposal that would allow us to accomplish these goals in the Keauhou/Kiholo and Pearl Harbor/Honolulu aquifers

- Provide funding for interns, field work, development of the visualization software, monitoring tools, models, etc.

- Now working on a proposal to DOD for site specific work in the Pearl Harbor area
Cooperation from our Collaborators

- Access to legacy data and clear guidance on (C.I.) access restrictions
- Guidance on the types of monitoring that would be most beneficial
- Access to a subset of wells that can be monitored
- Guidance on what mapping or sorting capabilities would be most useful to potential users
- Feedback on areas of interest for conducting active or passive geophysical surveys and tests
Outcomes

- Better understanding of GW flow and storage
- Suite of useful, user-friendly tools for agency staff
- Tools to allow agencies to convey information to the public and decision makers
- Robust modeling capabilities
- Knowledge on how to best access water resources – sustainably – while minimizing costs and adverse impacts
Mahalo

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