Hydrogeology Investigations in the Moanalua and Pearl Harbor Hydrological Units of the Honolulu Aquifer

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Opening Remarks

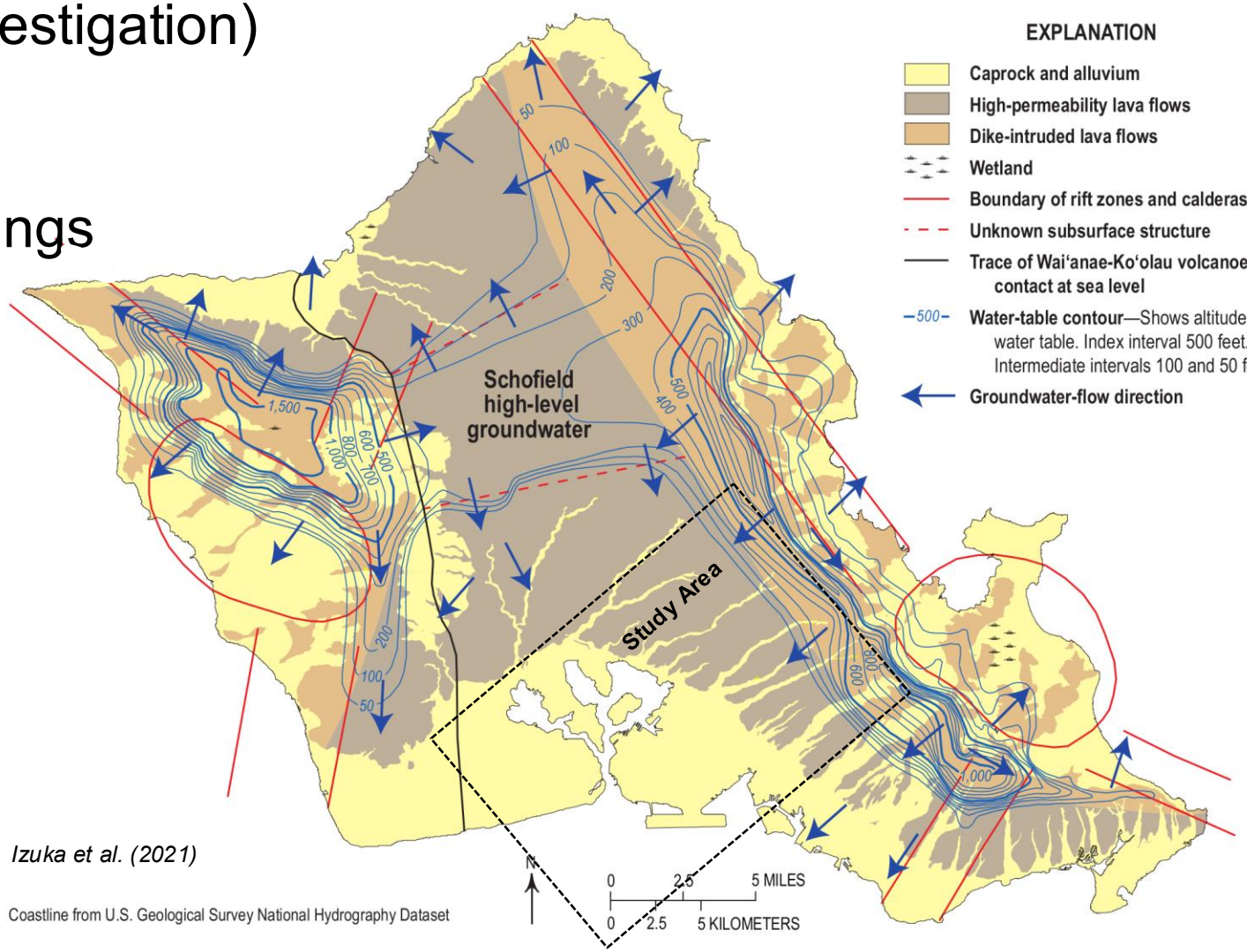
1) Introduction (Purpose of the Investigation)

2) Methods Applied

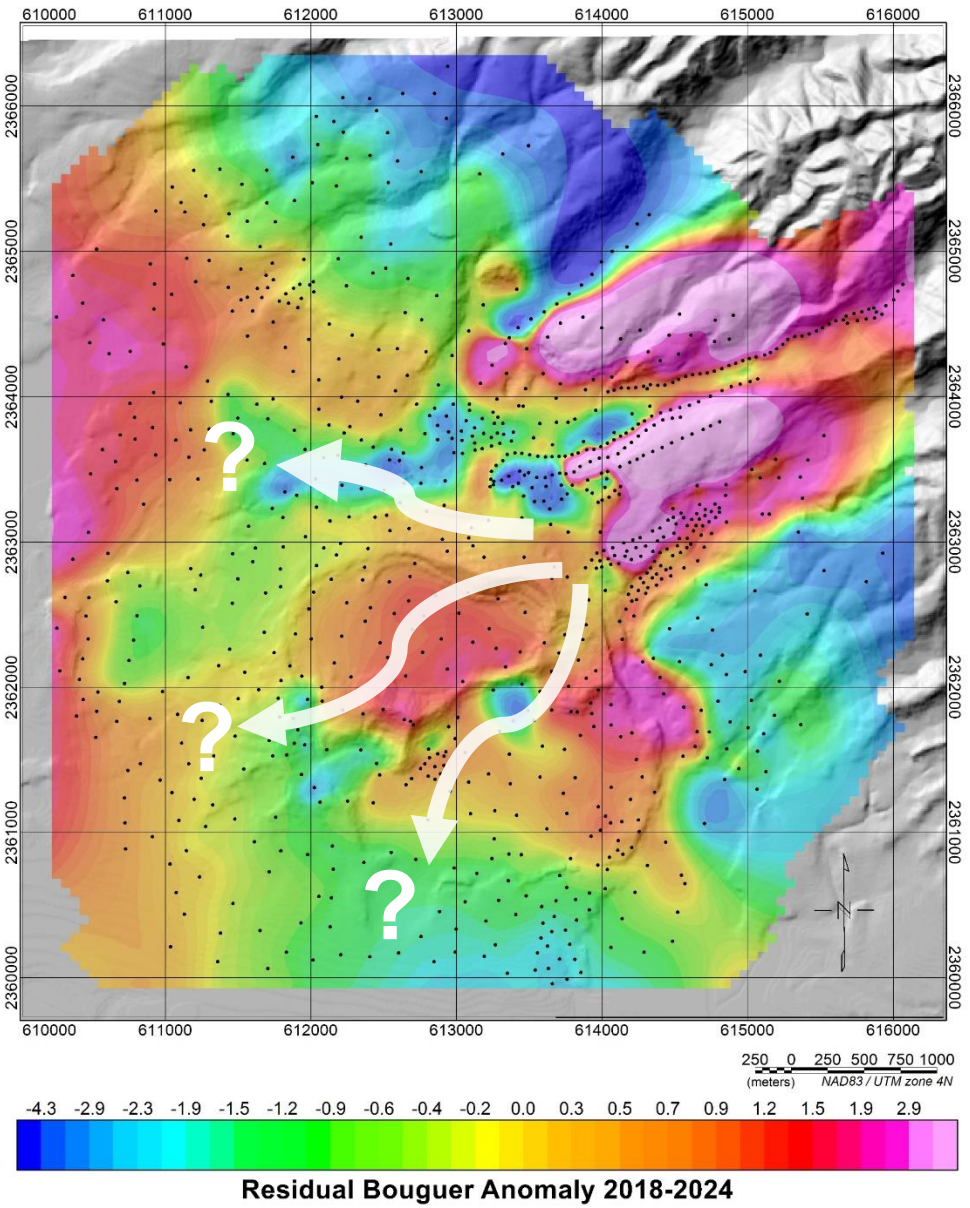
2) Status and most significant findings

3) Numerical model development

Q & A



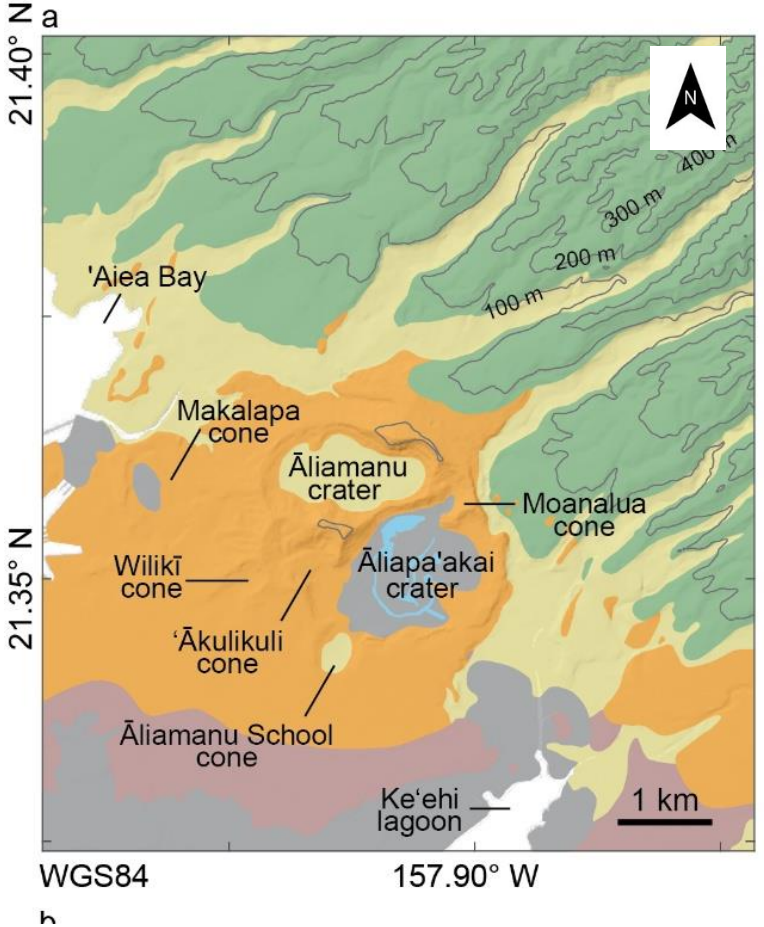
Gravity Survey and Density Models



Updated:

- Residual Bouguer Anomaly Maps
- Regional Density Model

The newly developed Groundwater model will be used to test if groundwater flow deviates around the high-density intrusion of the Honolulu volcanics or flows through the fractures.



Geophysical Modeling Results and Groundwater Flow Models

Combined with other data, resistivity, density, and other geophysical models:

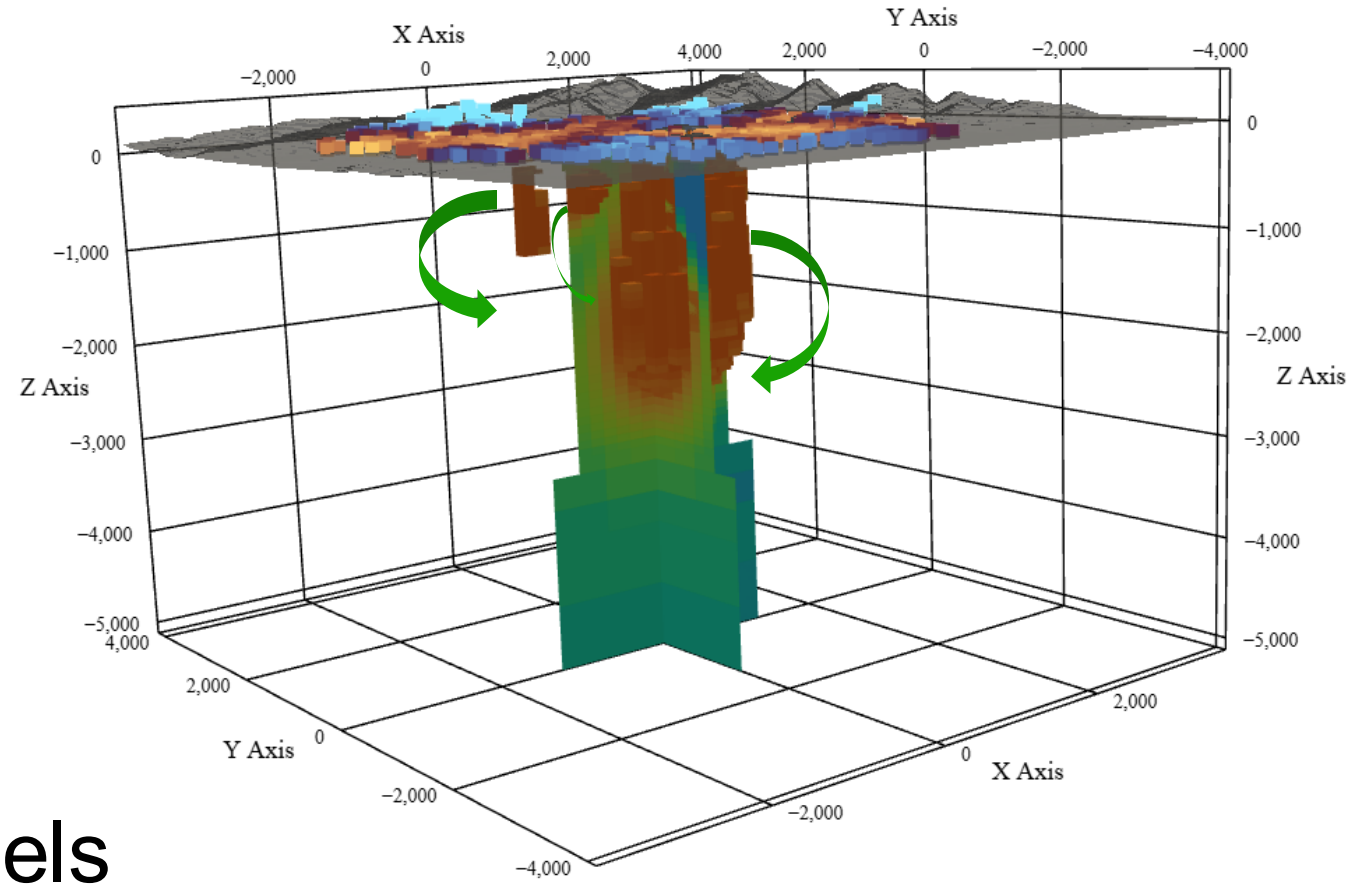
Study
- Caprock
- Subsurface Structures

Identify
- Aquicludes/Aquitards
- Alluvium and Bedrock interfaces

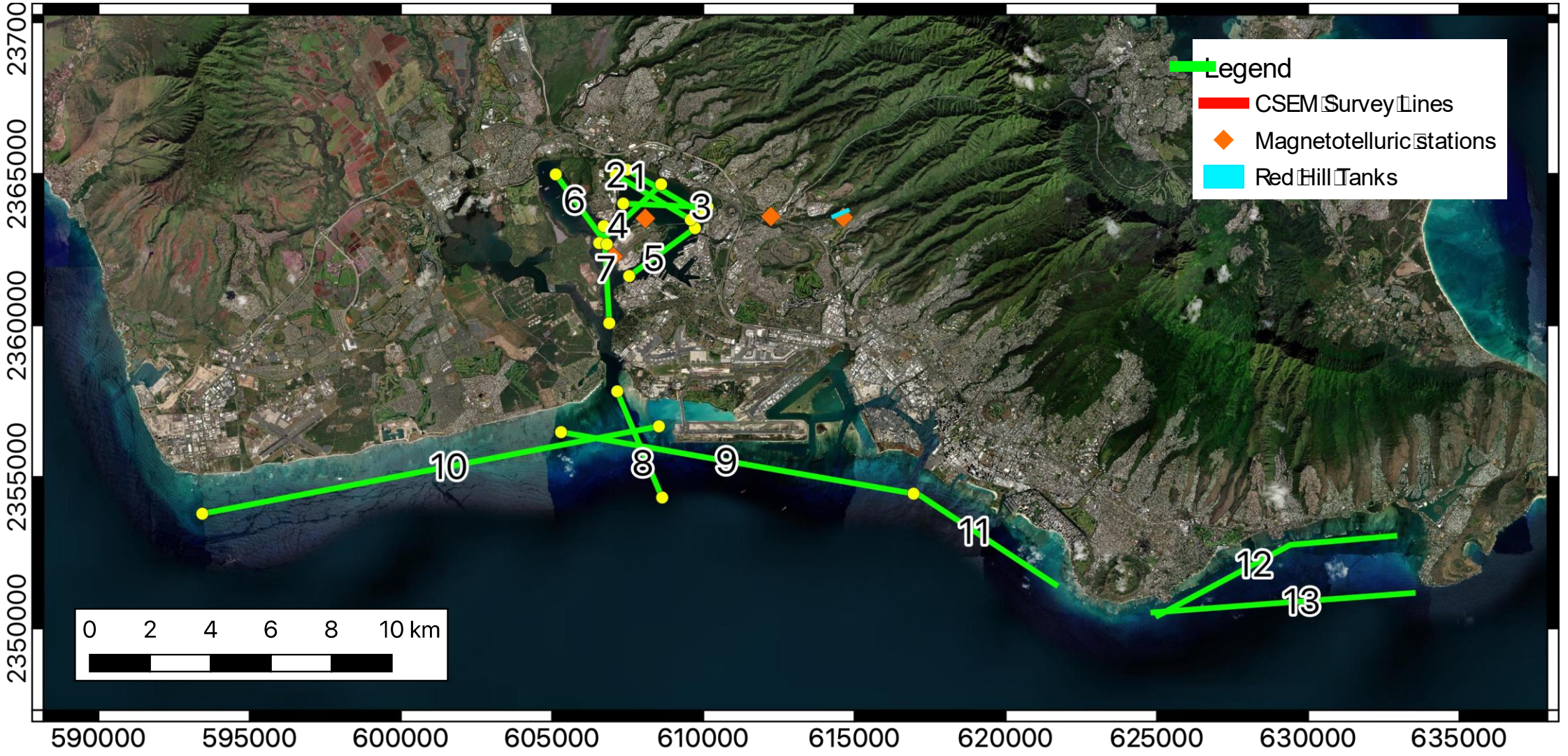
Map
- Saprolite depths
- Fresh and brackish water

=> Groundwater Flow Models

Red Hill Ridge

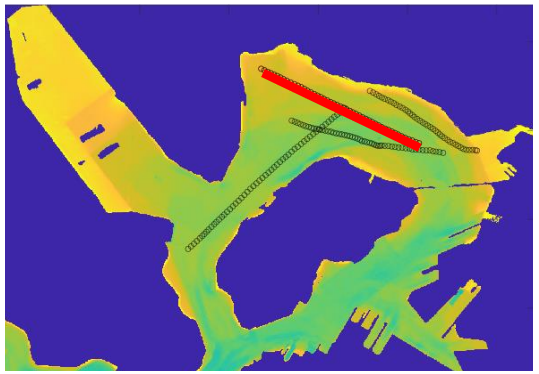


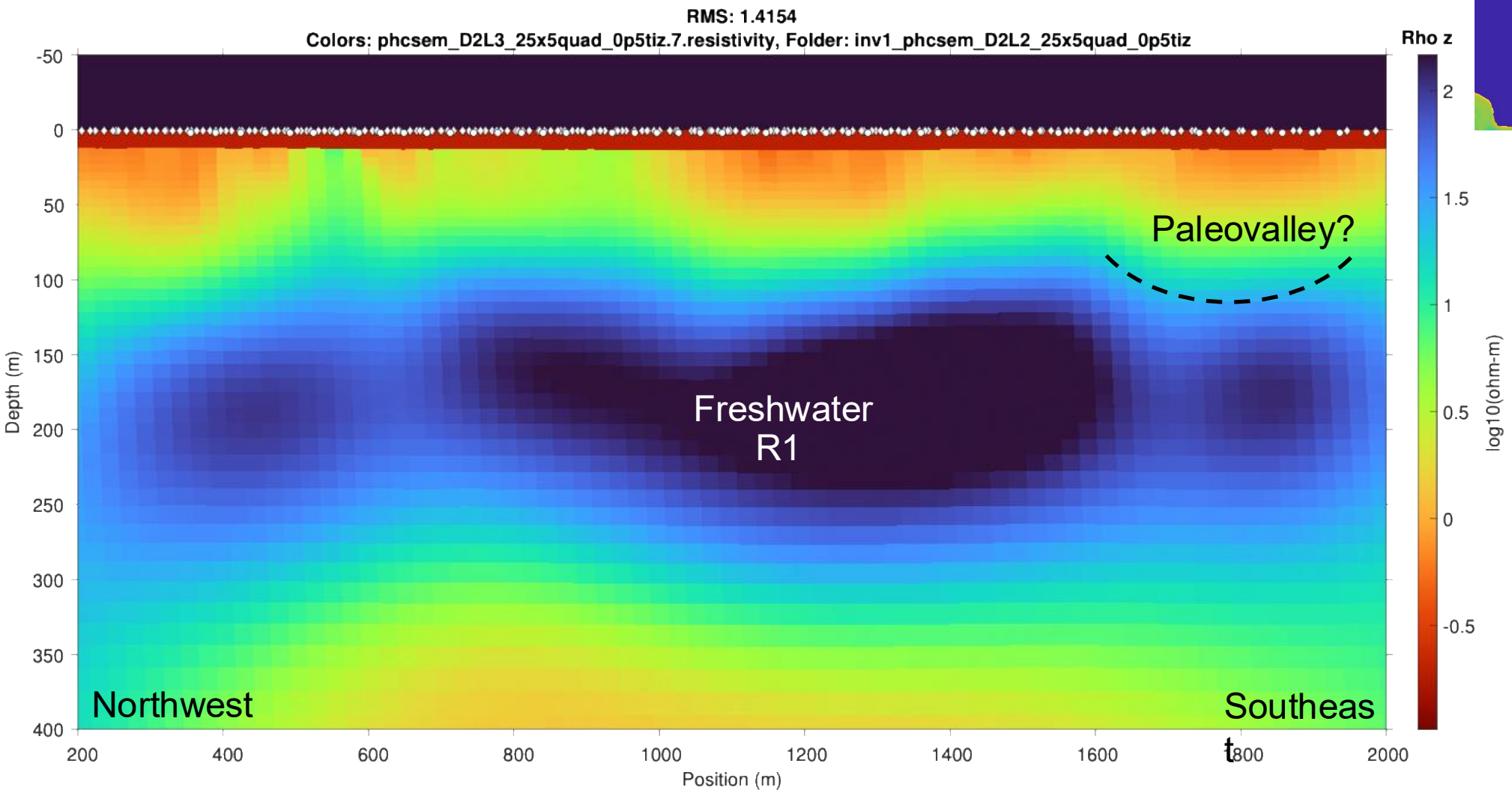
Pearl Harbor CSEM survey



Pearl Harbor Profiles - Line 3 Bonus Slide

- Freshened water beneath Pearl Harbor

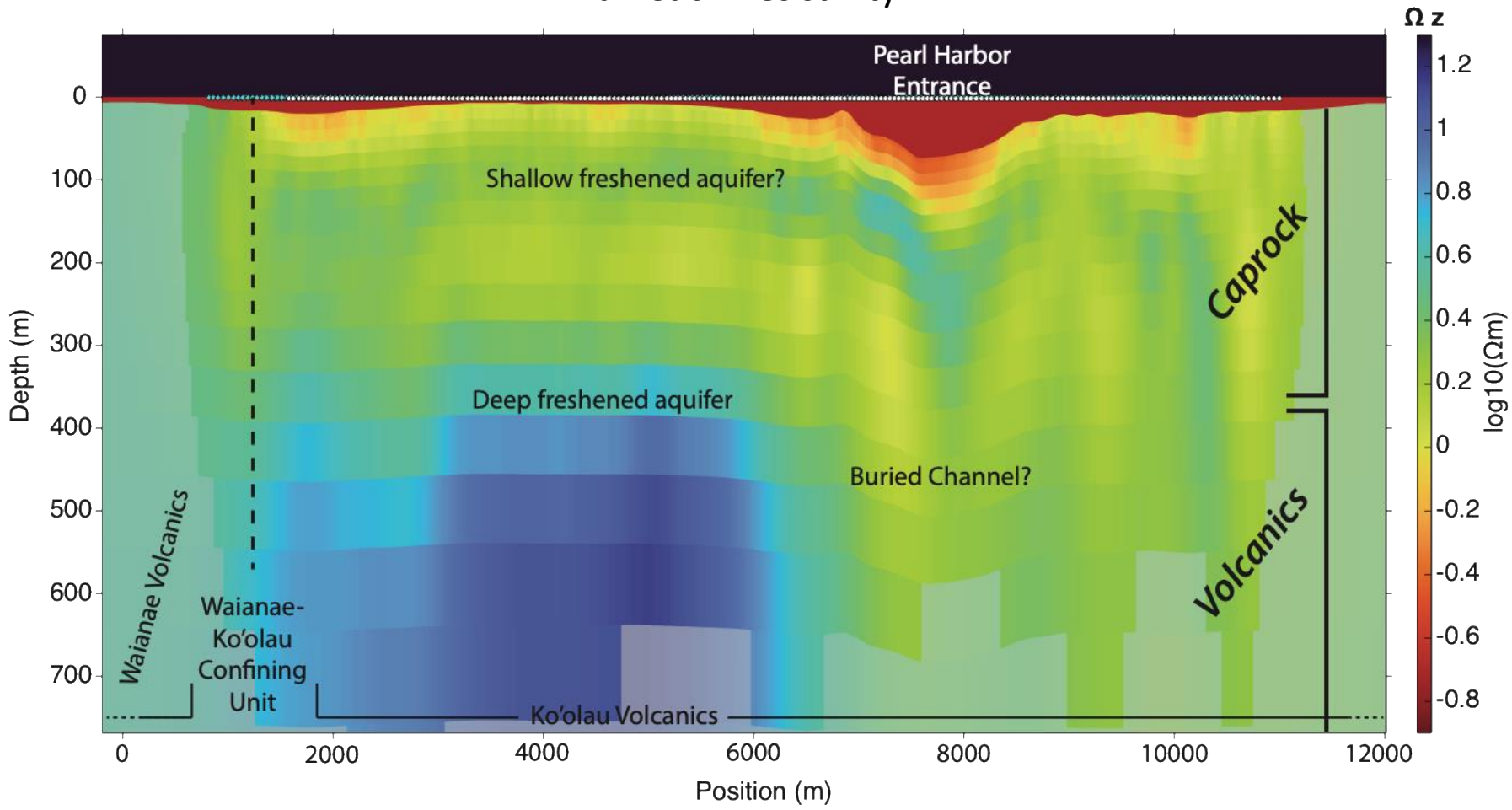




Ewa Beach Profile

- Offshore Ewa beach we see deep freshened groundwater at depths of ~300 meters below sea floor.
- Less robust shallow resistor that may be another freshened aquifer.
- Western extent of the offshore freshened groundwater is roughly coincident with the surface expression of the transition from the Ko‘olau volcanics to the Waianae volcanics

Ewa Beach Resistivity



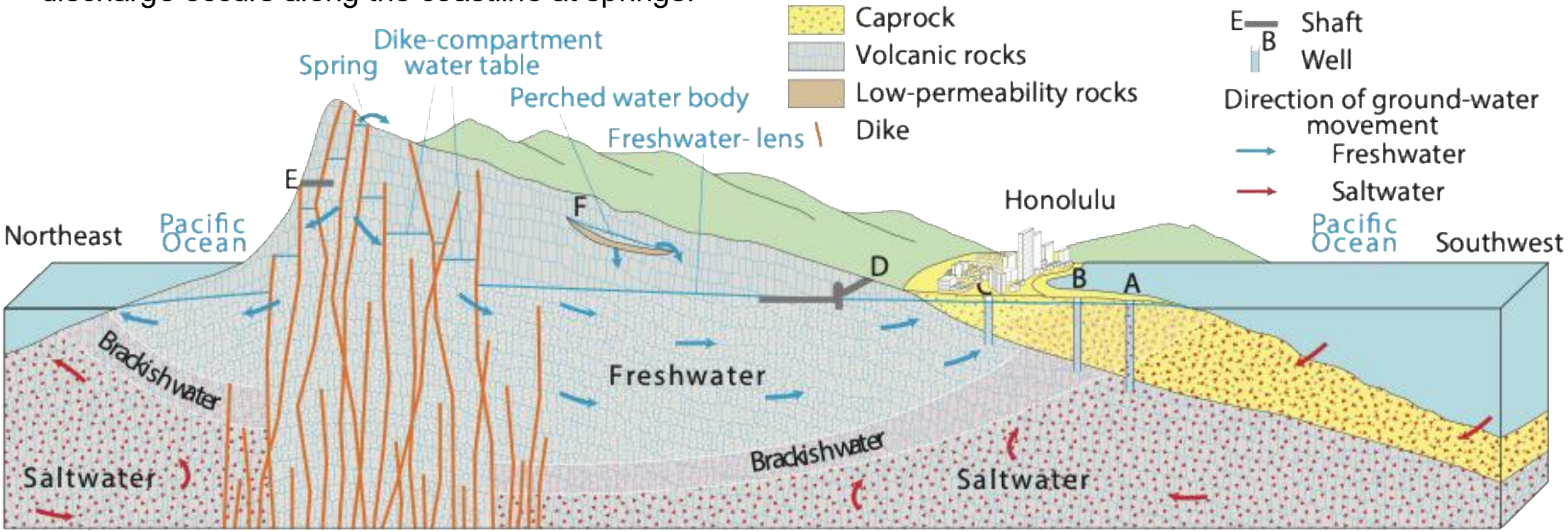
Motivation – Updating the standard conceptual model

The standard model:

- lens of buoyant freshwater rests on denser saltwater
- freshwater lens is charged by a central dike complex
- discharge occurs along the coastline at springs.

Motivation:

- Determine the hydrologic role of the caprock.
- Show whether discharge occurs exclusively along coastal springs.

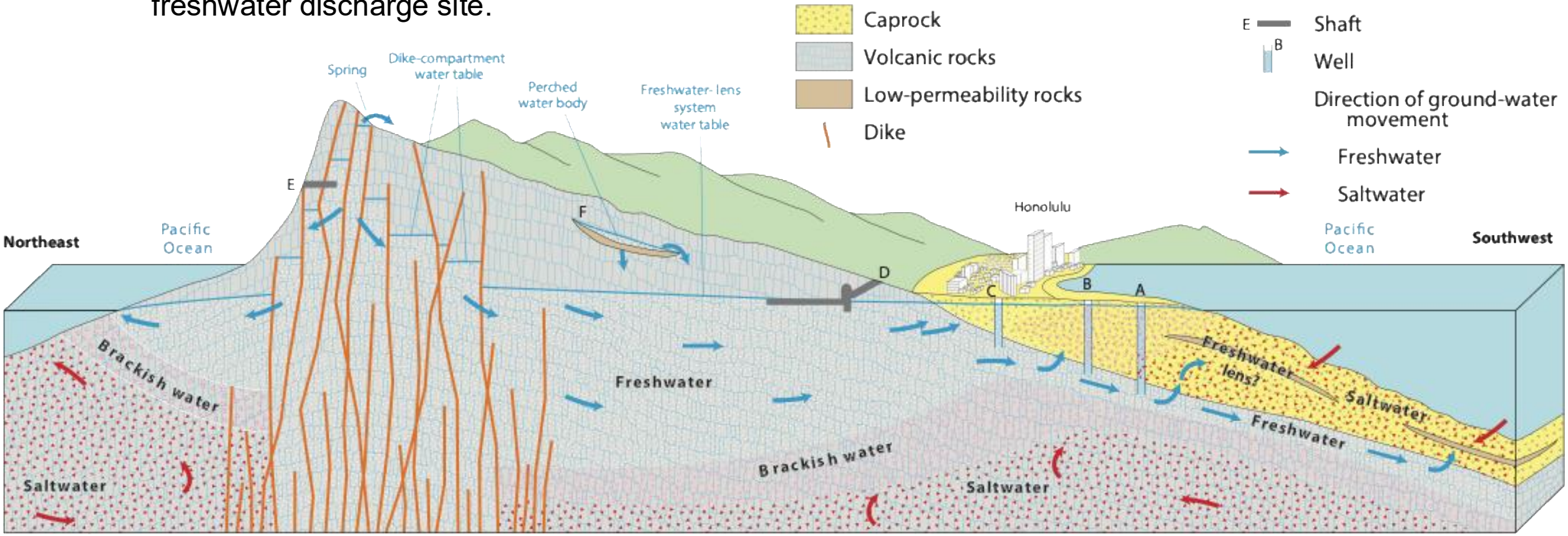


Gingerich and Oki, 2000

Updating the Conceptual Model

We are seeing freshwater offshore, the standard model needs to be updated to reflect this.

- caprock that acts as an imperfect confining bed, inhibiting freshened water in the Ko‘olau basalts discharging into the caprock and overlying ocean
- Freshwater can freely flow beneath Pearl Harbor and further offshore. Springs are not the sole freshwater discharge site.



Modified after Gingerich and Oki, 2000

Geochemical Testing and Analyses

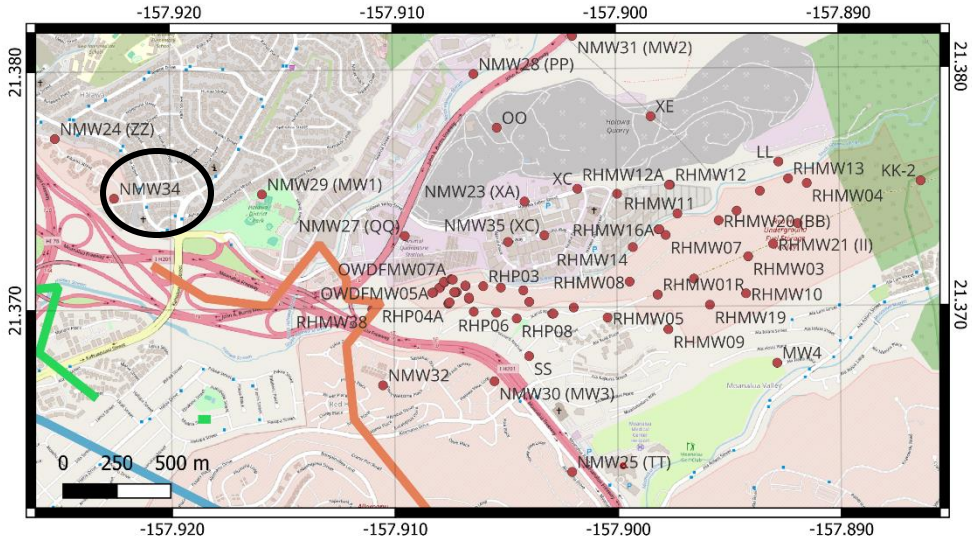
a) Dissolved ion compositions and concentrations

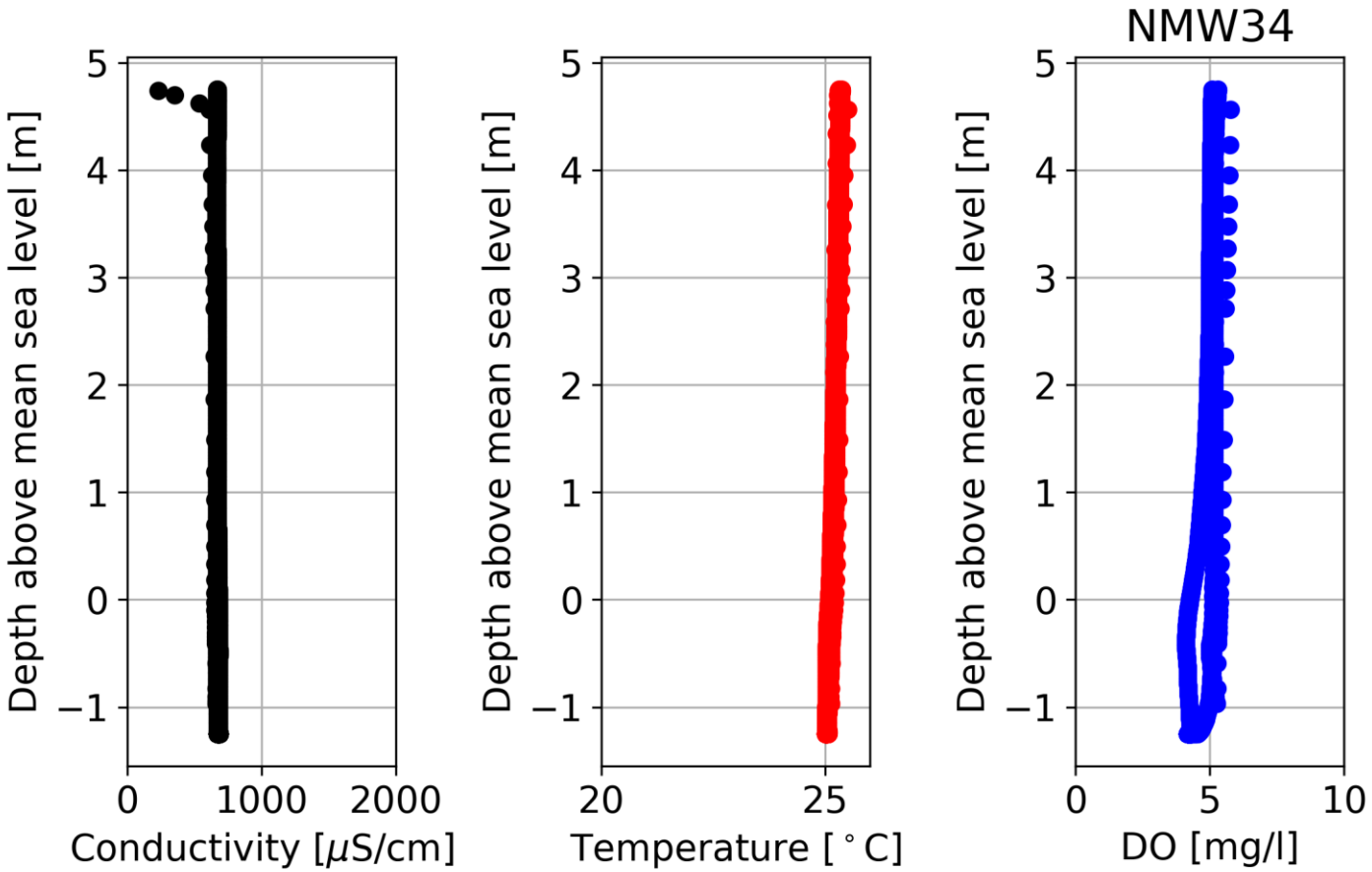
b) Isotopic Compositions of water and some ions

c) Apparent age determination for the water

CTD: NMW34

Slightly elevated conductivity; Significantly elevated temperature DO content; slightly elevated acid (lower pH).

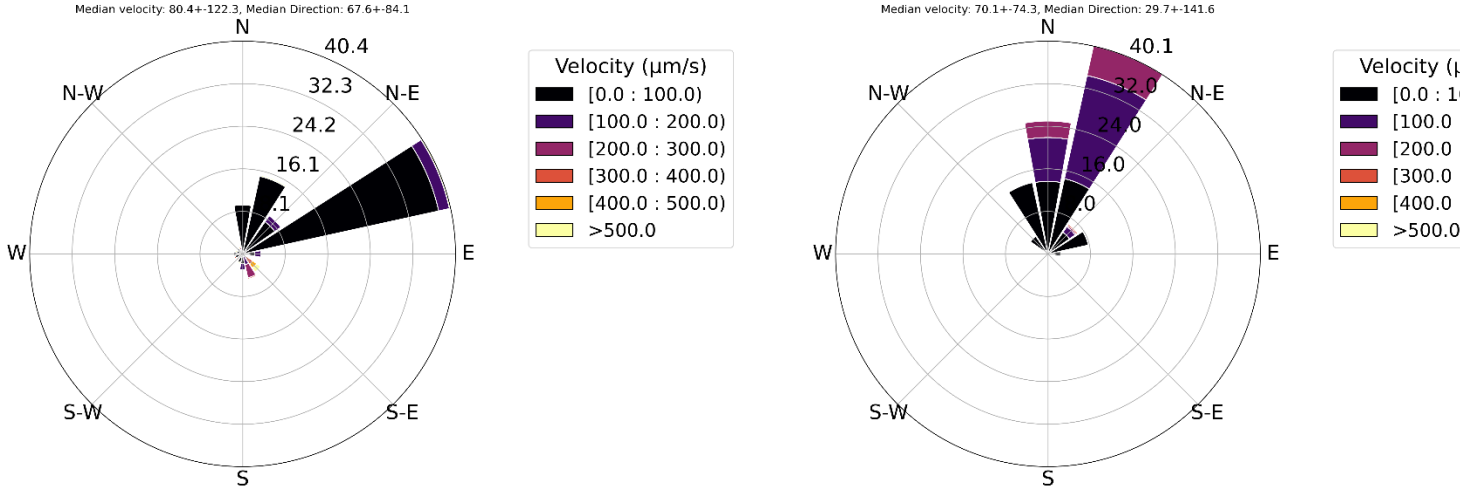


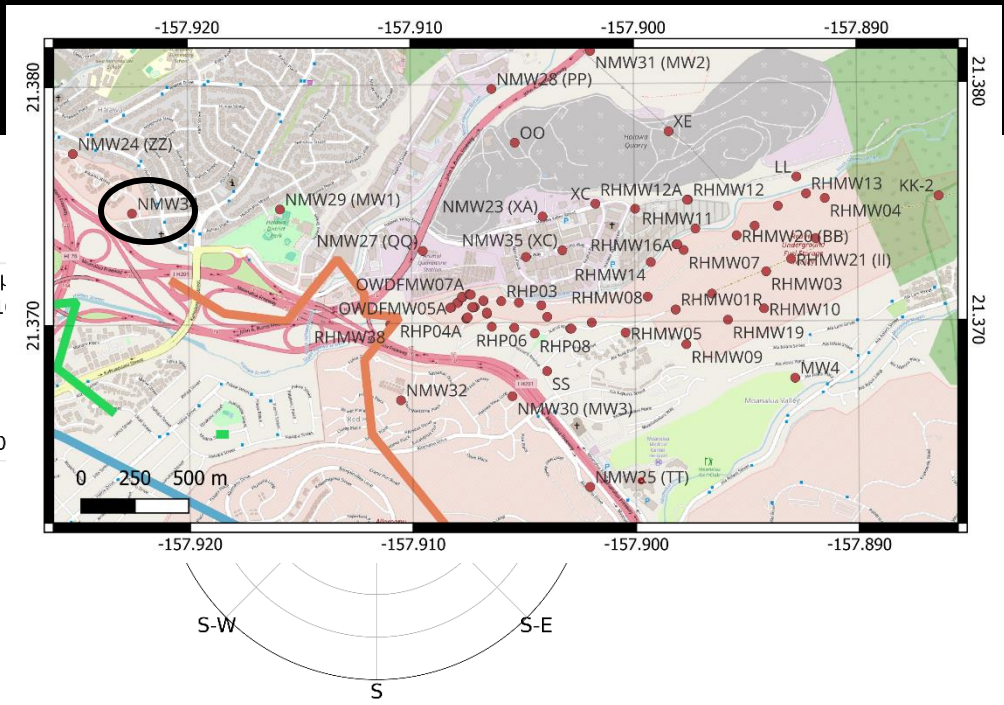


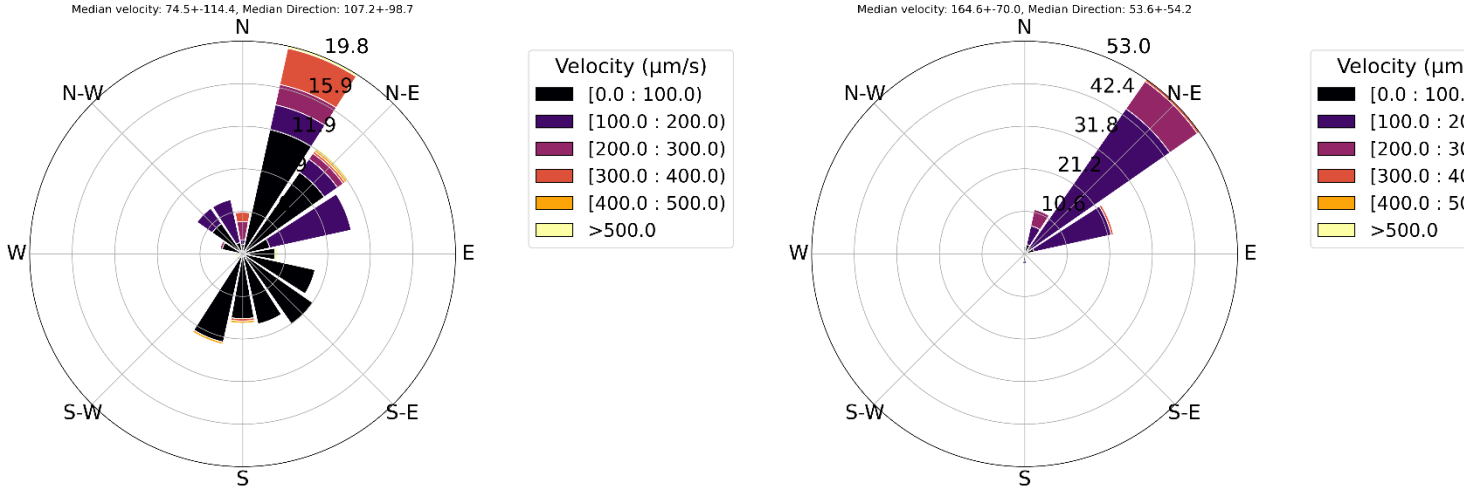
Colloidal Borescope Surveys

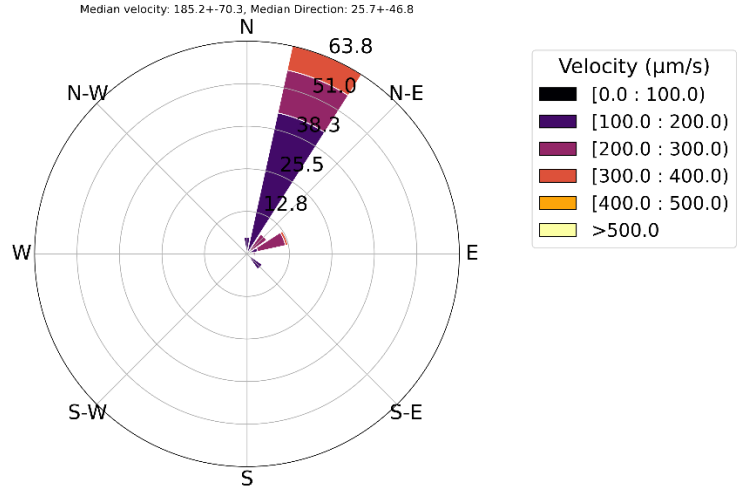
a) Determine rate and direction of lateral water flow through wellbores
b) Surveyed selected wells distributed over the area around Red Hill

Colloidal Borescope: NMW34







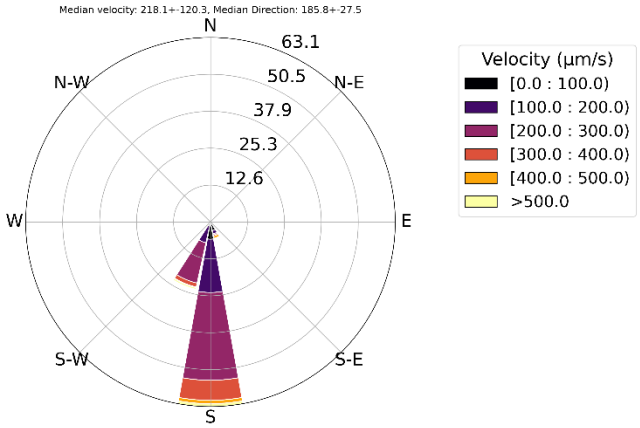


Velocity is generally low (<200 µm/s) with a direction of North-Northeast

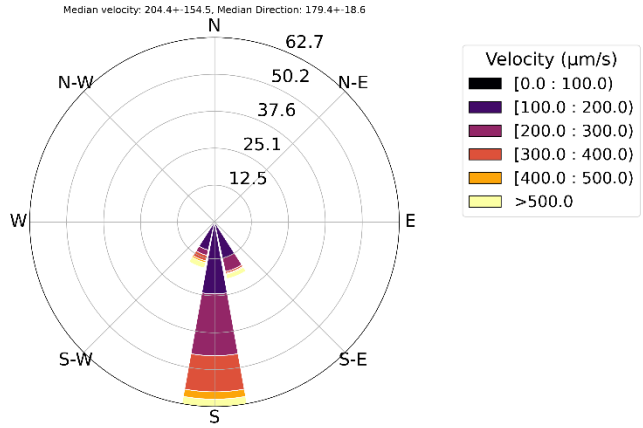
Colloidal Borescope: RHMW06

Time Series of Colloidal Borescope Measurements at different depths in RHMW06

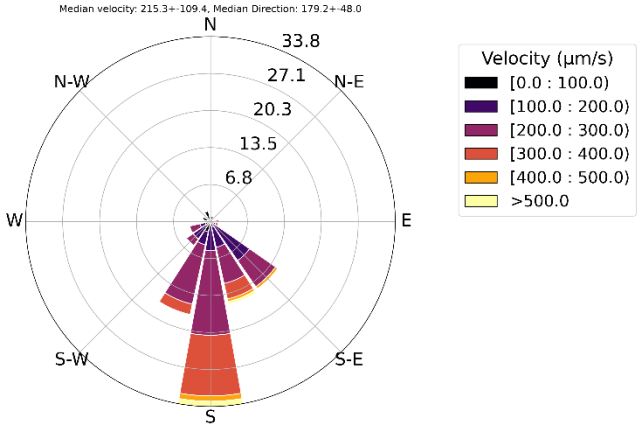
6.8 m amsl



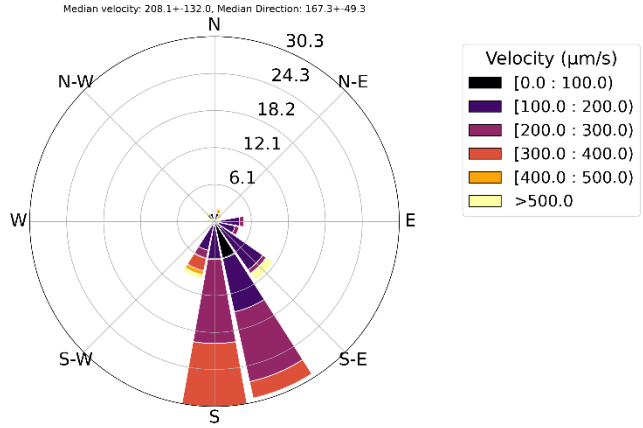
7.8 m amsl

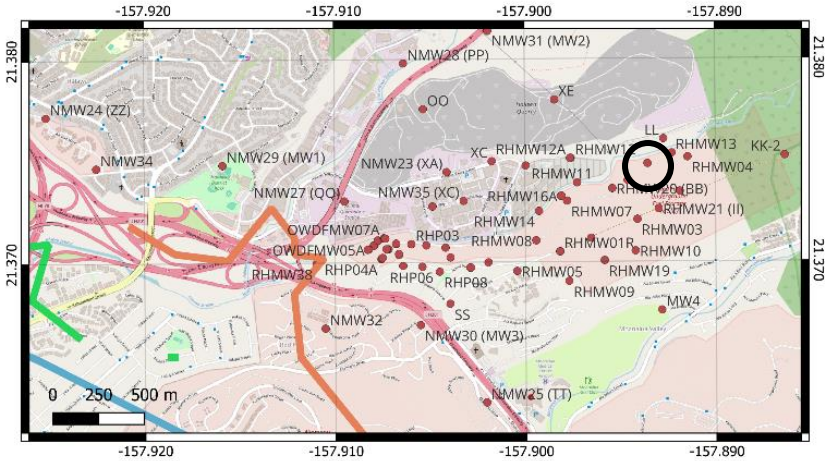


8.8 m amsl



9.8 m amsl





Velocity is generally below 500 µm/s flowing South

Dye Tracer Study

Dye was injected at RHMW08 (1/4 mile away from Red Hill Shaft) on February 11 - 15

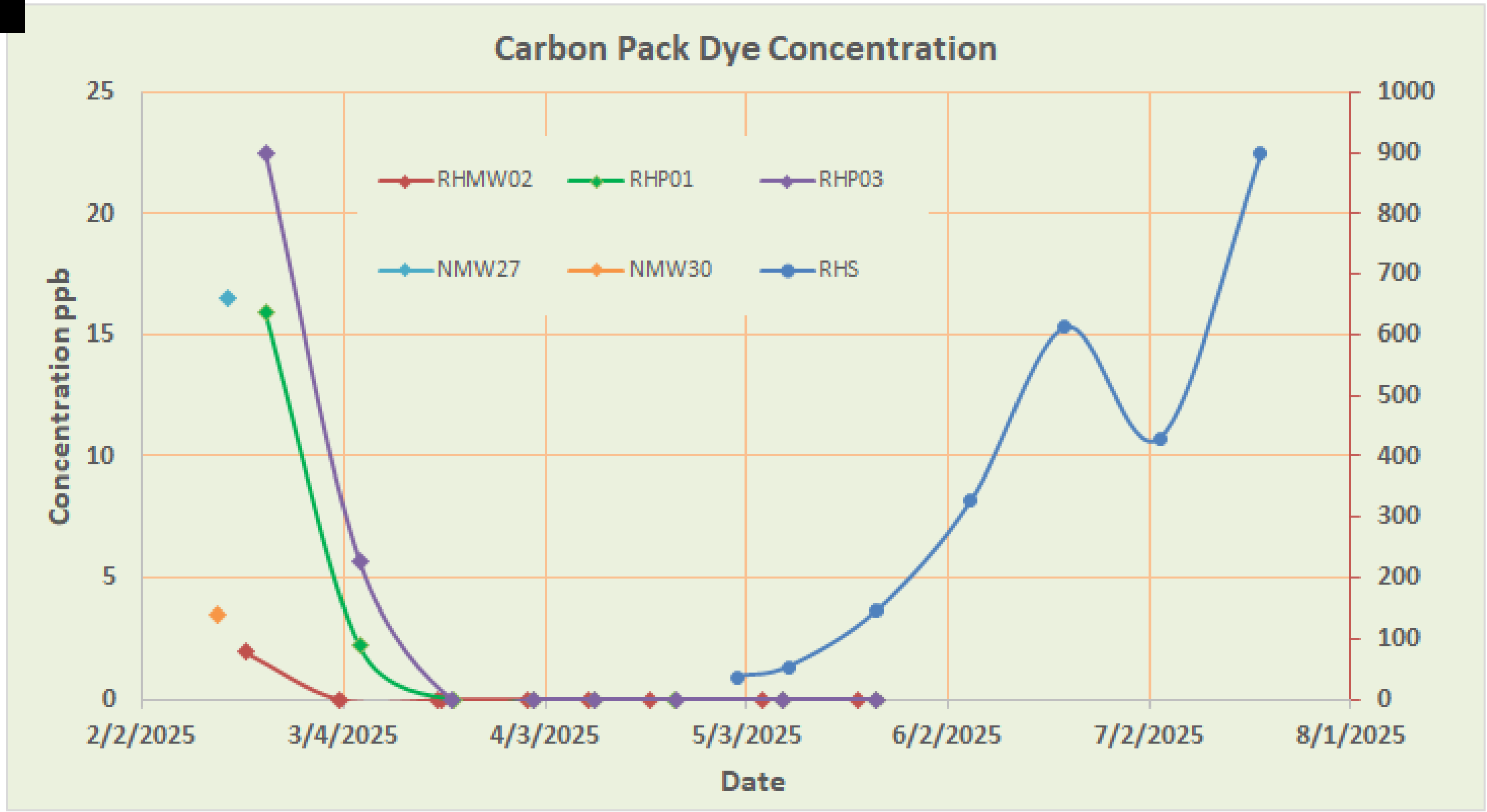
Multiple methods of dye detection were used in an array of wells (~24) surrounding the injection well and in Red Hill Shaft.

The first real detection of dye occurred on May 2 – we had some false positive hits as well

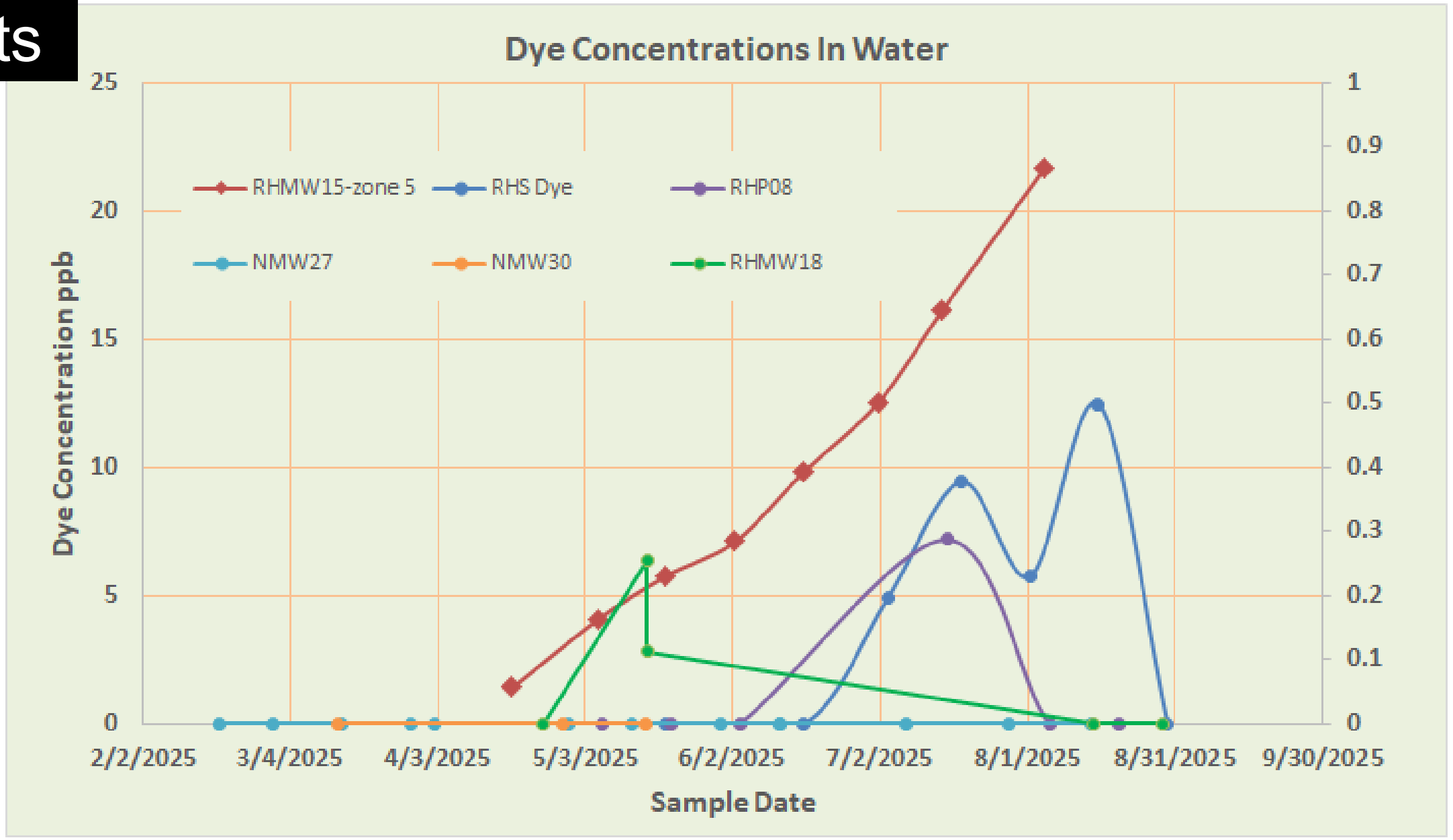
Initially monitoring was done with Red Hill Shaft Pumping 4.3 mgd, however with the slow arrival of the dye, pumping rates were reduced in May to 1.4 mgd.

Current Results

Current Results



Current Results



Modeling South Oahu Groundwater

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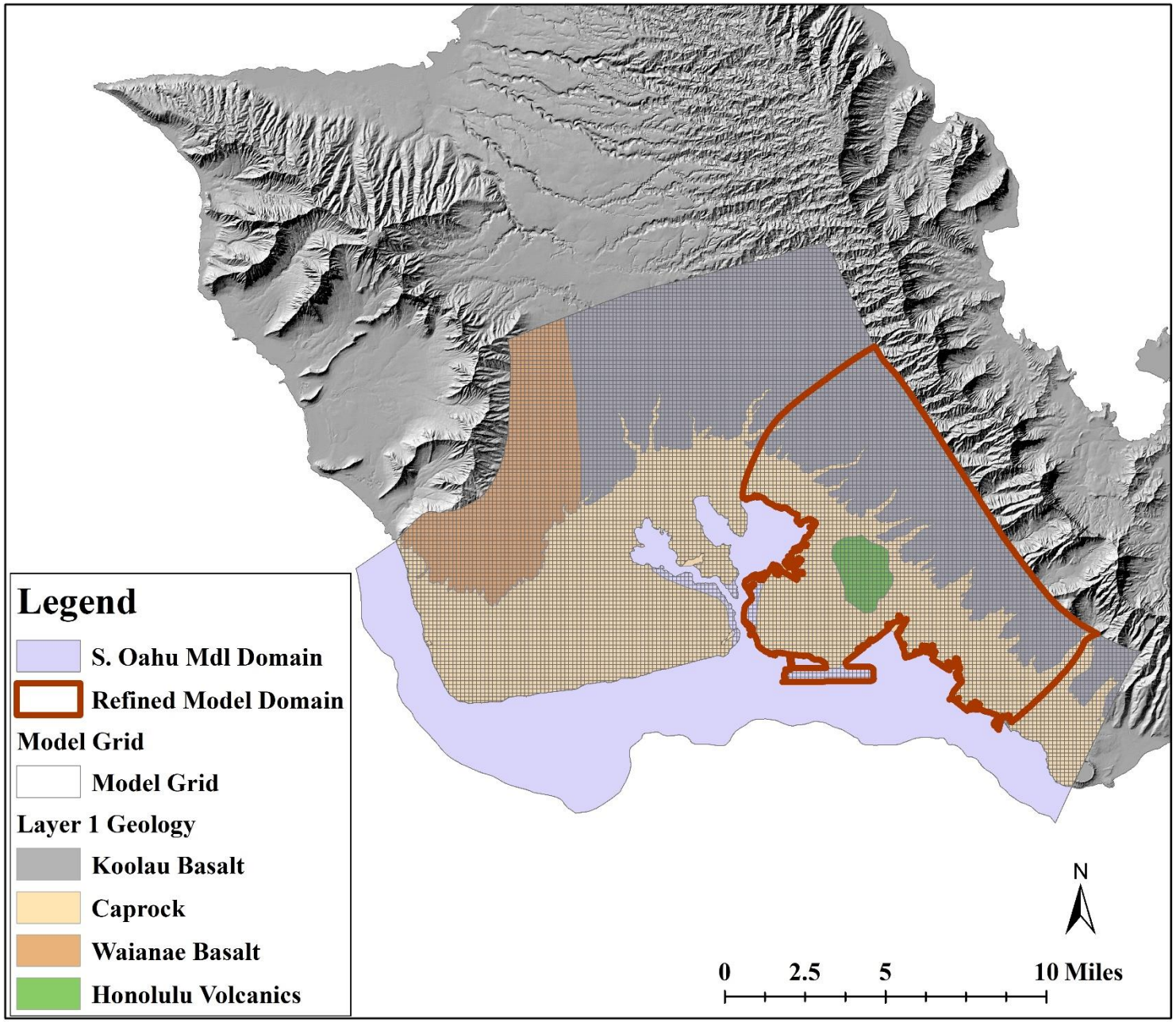
Groundwater Modeling – Objectives

- Incorporate the investigation's geophysics and geochemical findings into a regional and local model
- Establish a flow and transport model to delineate groundwater flow in the Pearl Harbor and Honolulu aquifers.
- Provide boundary conditions for a future nested high-resolution model around Red Hill
- Better constrain the groundwater flow trajectories within and seaward of the Moanalua/Red Hill/Halawa Region.

Modeling Logic

- Develop a focused model from the regional model
  - Use the regional model to establish boundary conditions for the local model
- Reducing domain size will:
  - Allow increased grid resolution
  - Add detail to model
  - Potentially allow us to used tilted layers
  - Optimize computer run time

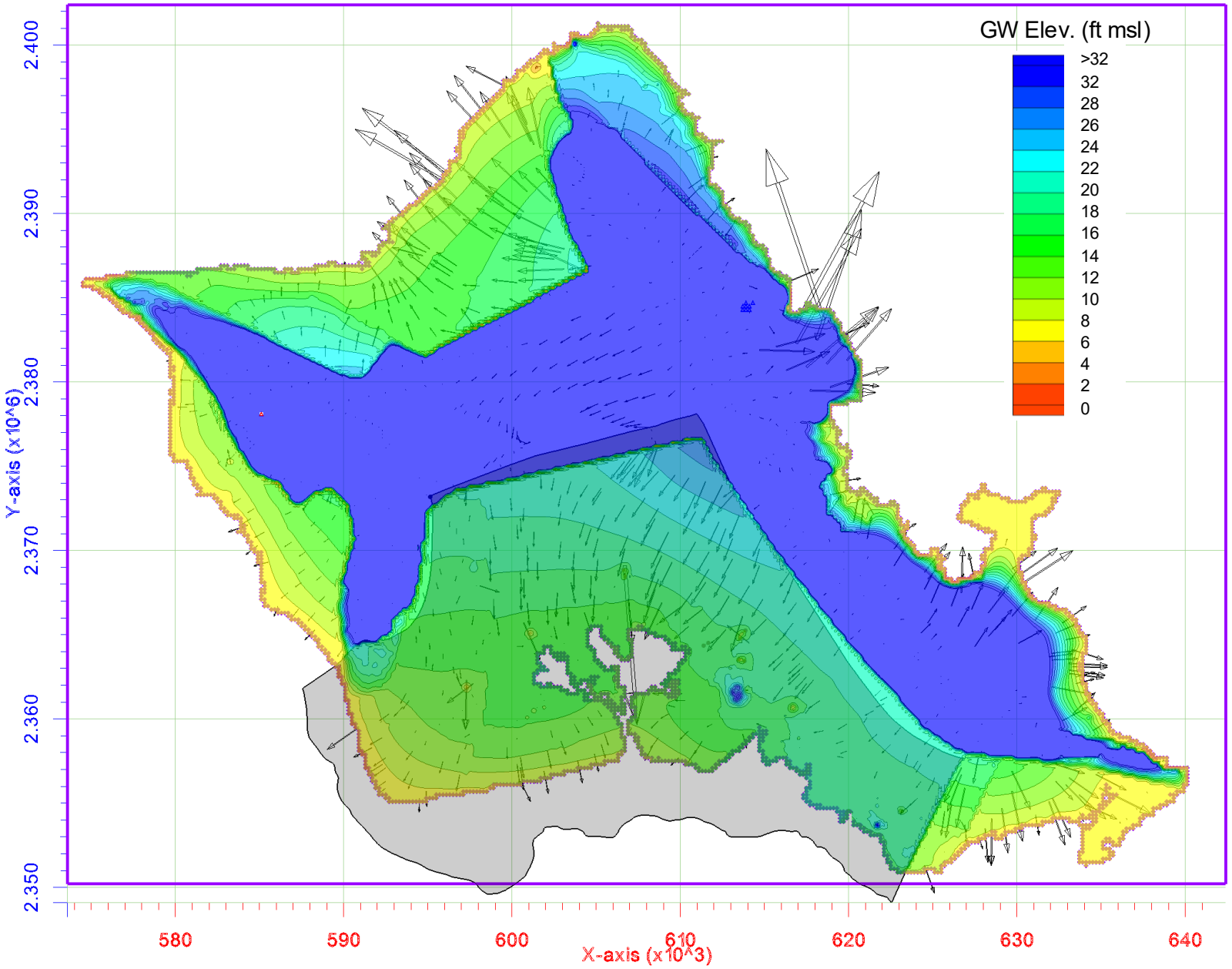


Thank you!

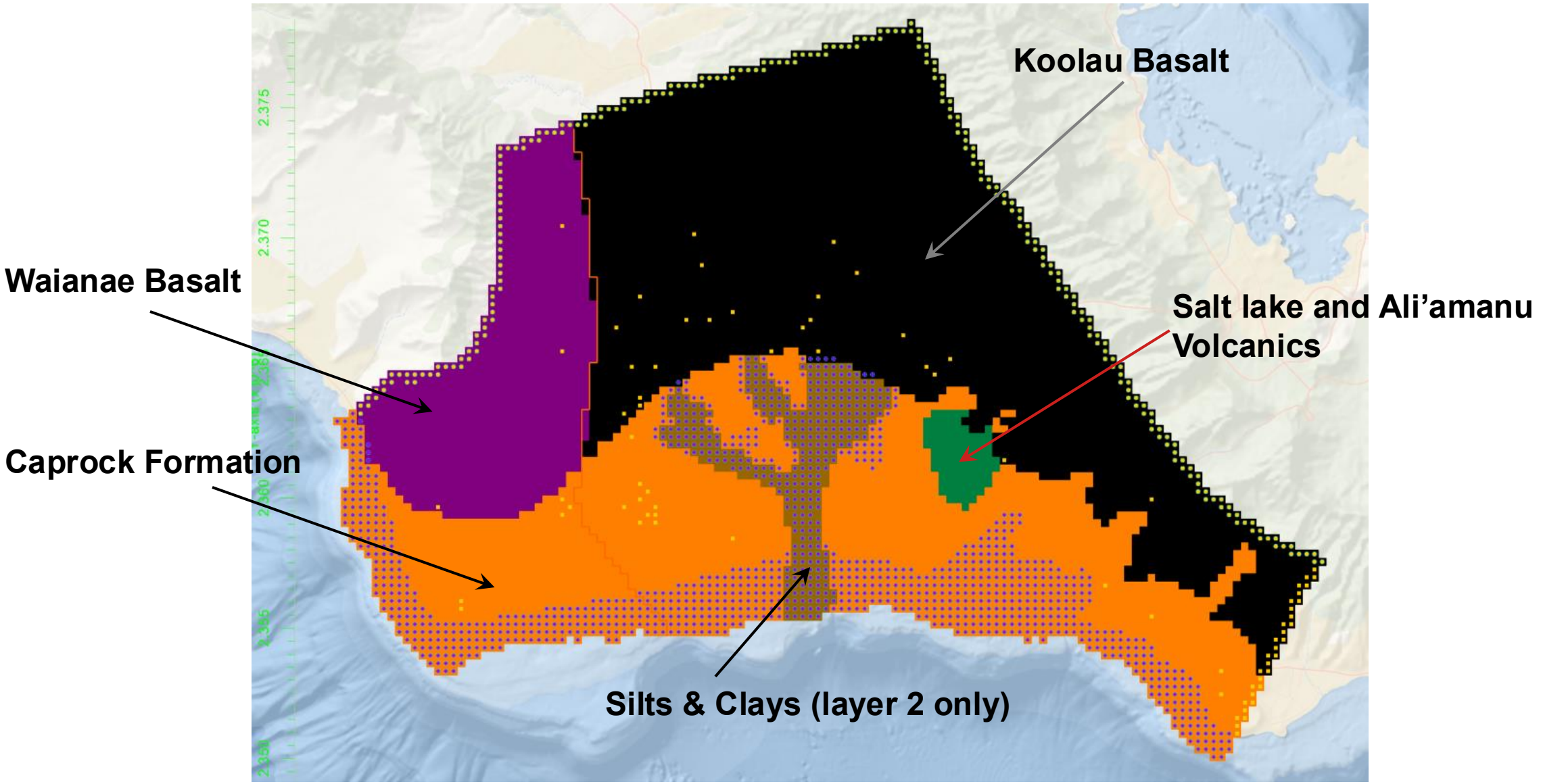
Questions???

Modeling approach

- Localize an Oahu groundwater model to the basal groundwater in the Honolulu and Pearl Harbor Aquifers.
  - Establish local model boundary conditions from island model
  - flow consistent with the prevailing conceptualization of groundwater flow
- Convert to density dependent model and extend the south boundary offshore
- Calibrate model using:
  - newly acquired data (e.g. geophysics and geochemistry)
  - Existing data (e.g. Deep Monitoring Well CTD profiles, measured groundwater elevation)

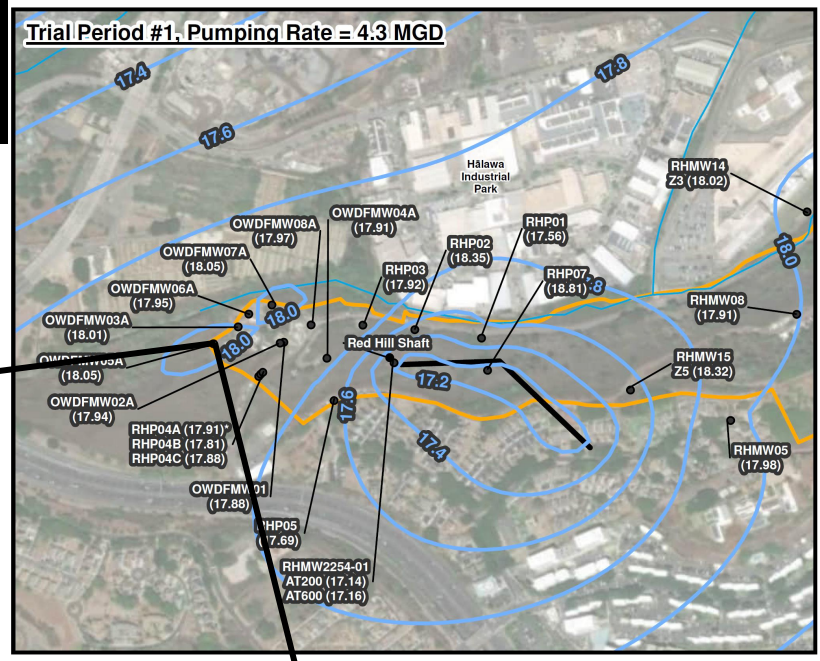


Groundwater Modeling – Geological Formation

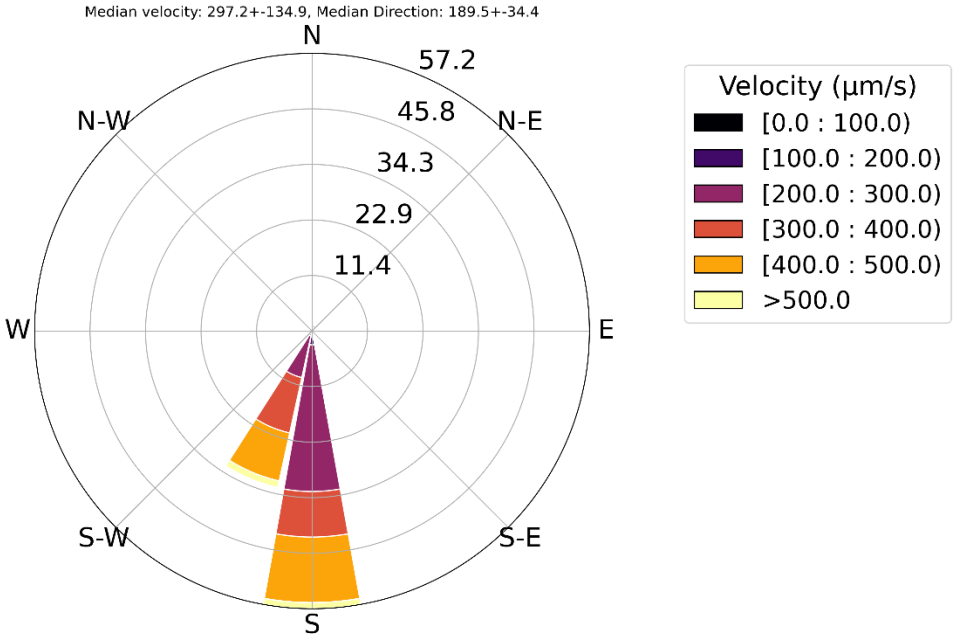


Colloidal Borescope: OWDFMW05A

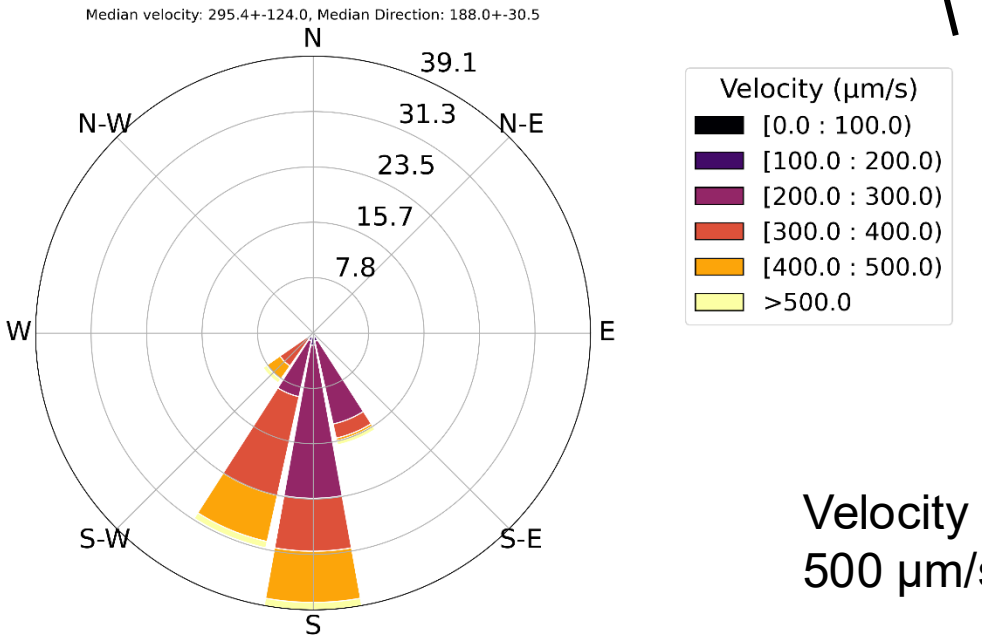
Bonus Slide showing additional examples of borescope results at other wells not shown in the presentation.



-20.5 m amsl



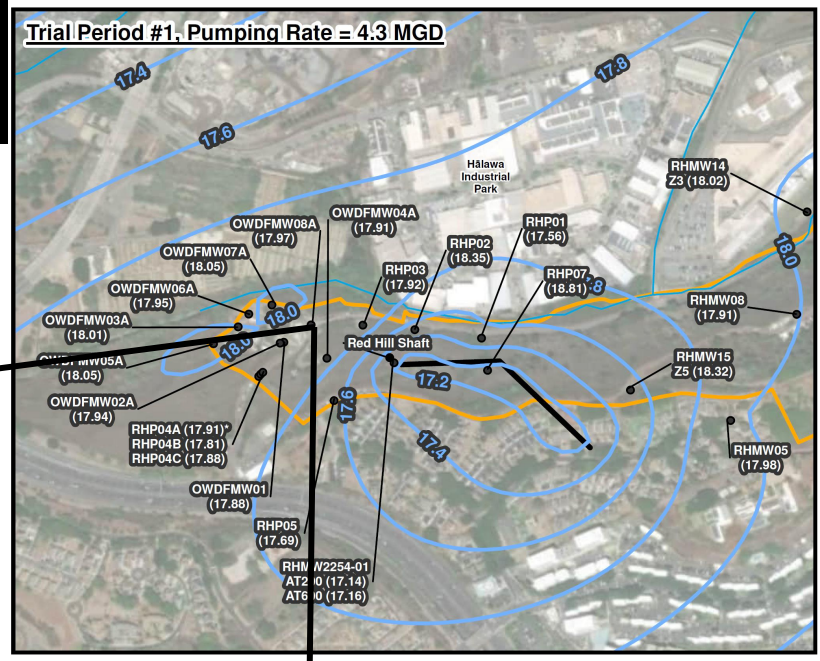
-19 m amsl



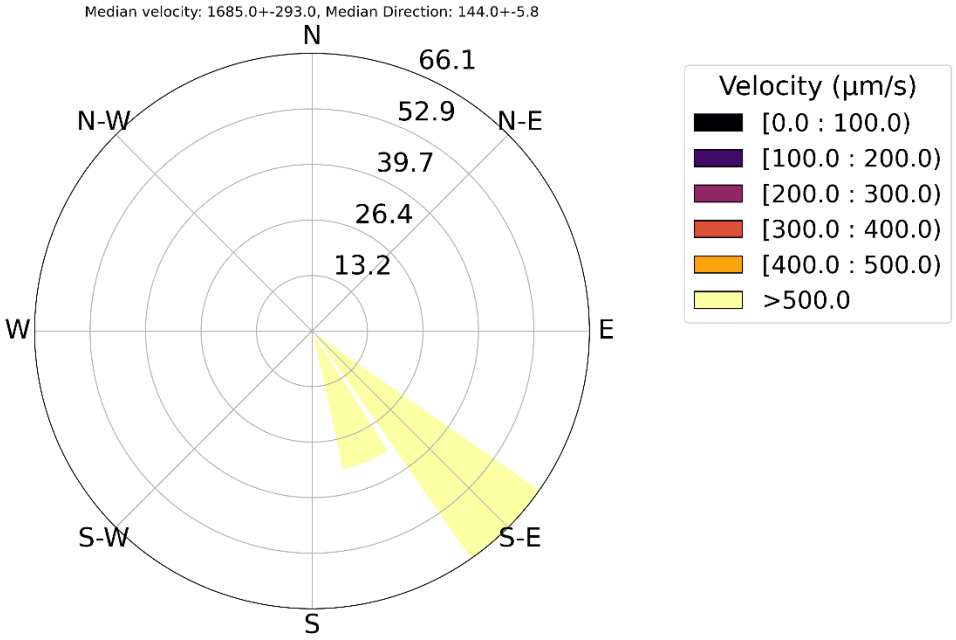
Velocity is generally below 500 µm/s flowing South

Colloidal Borescope: OWDFMW08A

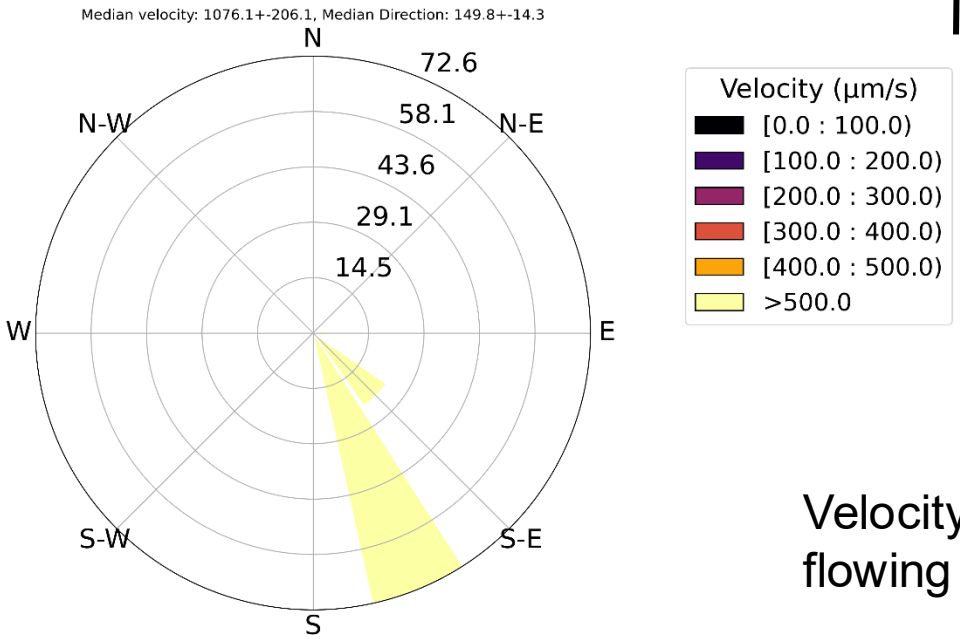
Bonus Slide showing additional examples of borescope results at other wells not shown in the presentation.



-6.4 m amsl



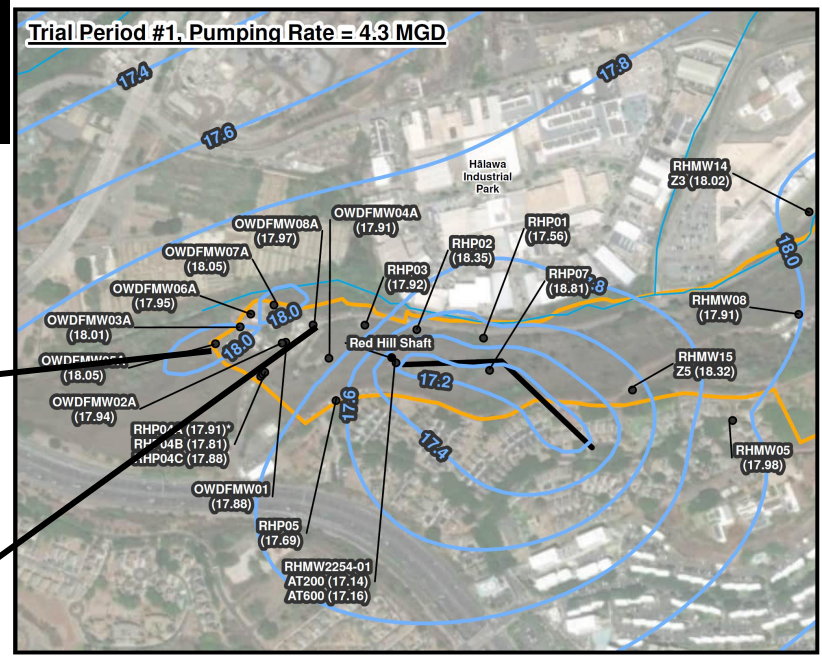
-12 m amsl



Velocity is above 500 µm/s flowing South

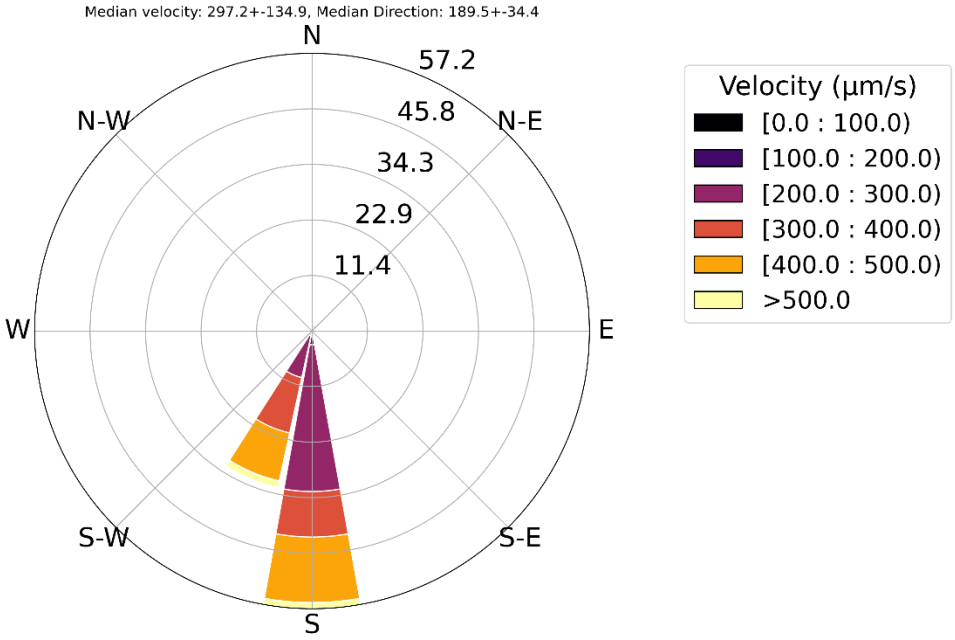
Colloidal Borescope: OWDFMW05A vs. 08A

Bonus Slide showing additional examples of borescope results at other wells not shown in the presentation. This is an example of two closely-spaced wells that show very divergent water flow directions that may be the result of geologic features impacting water flow directions.



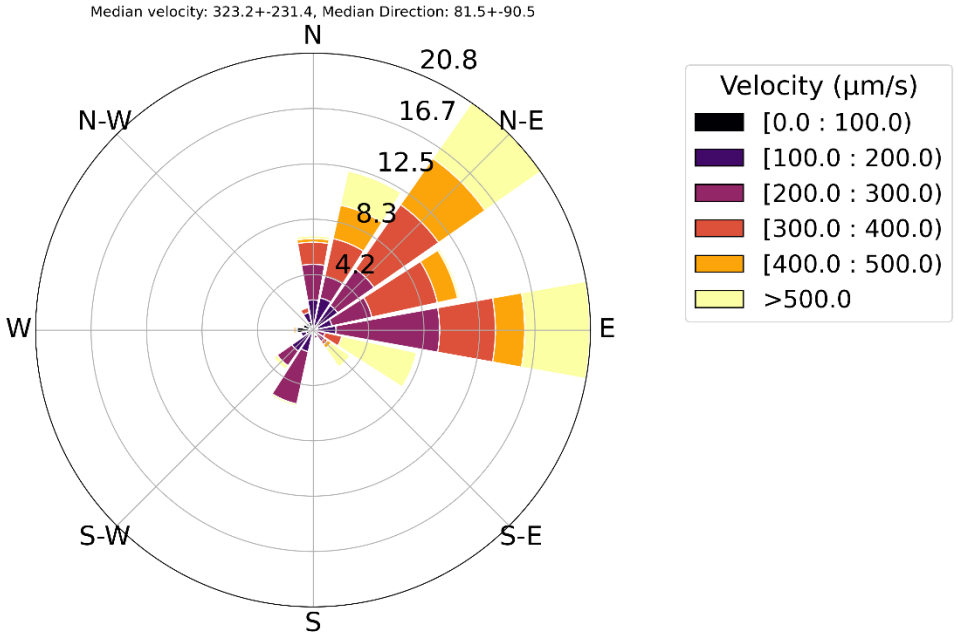
OWDFMW05A

-20.5 m amsl



OWDFMW08A

-20.5 m amsl



Water Level Contours with Red Hill Shaft Pumping

Does Red Hill Shaft Capture extend to the OWDF and Tank Farm? **Ambiguous!!**

OWDFM02A, 3A & 05A demonstrate flow away from the shaft

OWDFM04A & 08A show flow towards the general shaft direction depending on the depth interval

How do the borescope results compare to flow trajectories of the groundwater model?