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Groundwater Availability, Molokaʻi, Hawaiʻi

Kulana ʻŌiwi Hālau, Molokaʻi
June 1, 2019

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In cooperation with Department of Hawaiian Home Lands, Office of Hawaiian Affairs, Maui Department of Water Supply

U.S. Department of the Interior
U.S. Geological Survey

Motivation for Understanding Groundwater Availability

1. Groundwater resources are limited
   - Limited rainfall in developed areas
   - Salinity increases in some wells

2. Demand for groundwater likely will increase
   - Department of Hawaiian Home Lands
   - Maui County Dept. Water Supply
   - Private entities

3. Effects of additional groundwater withdrawal uncertain
   - Will proposed withdrawals affect salinity of other wells?
   - Will reduction in freshwater discharge to nearshore ecosystems be acceptable?

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Recent History of Groundwater-Related Events

- 1992 Groundwater Management Area designation

- 1997/1998 contested-case hearings
  - 1997—Wai‘ola 1.25 Mgal/d request (Kamiloloa)
  - 1998—Kukui 1.259 Mgal/d request (well 17)

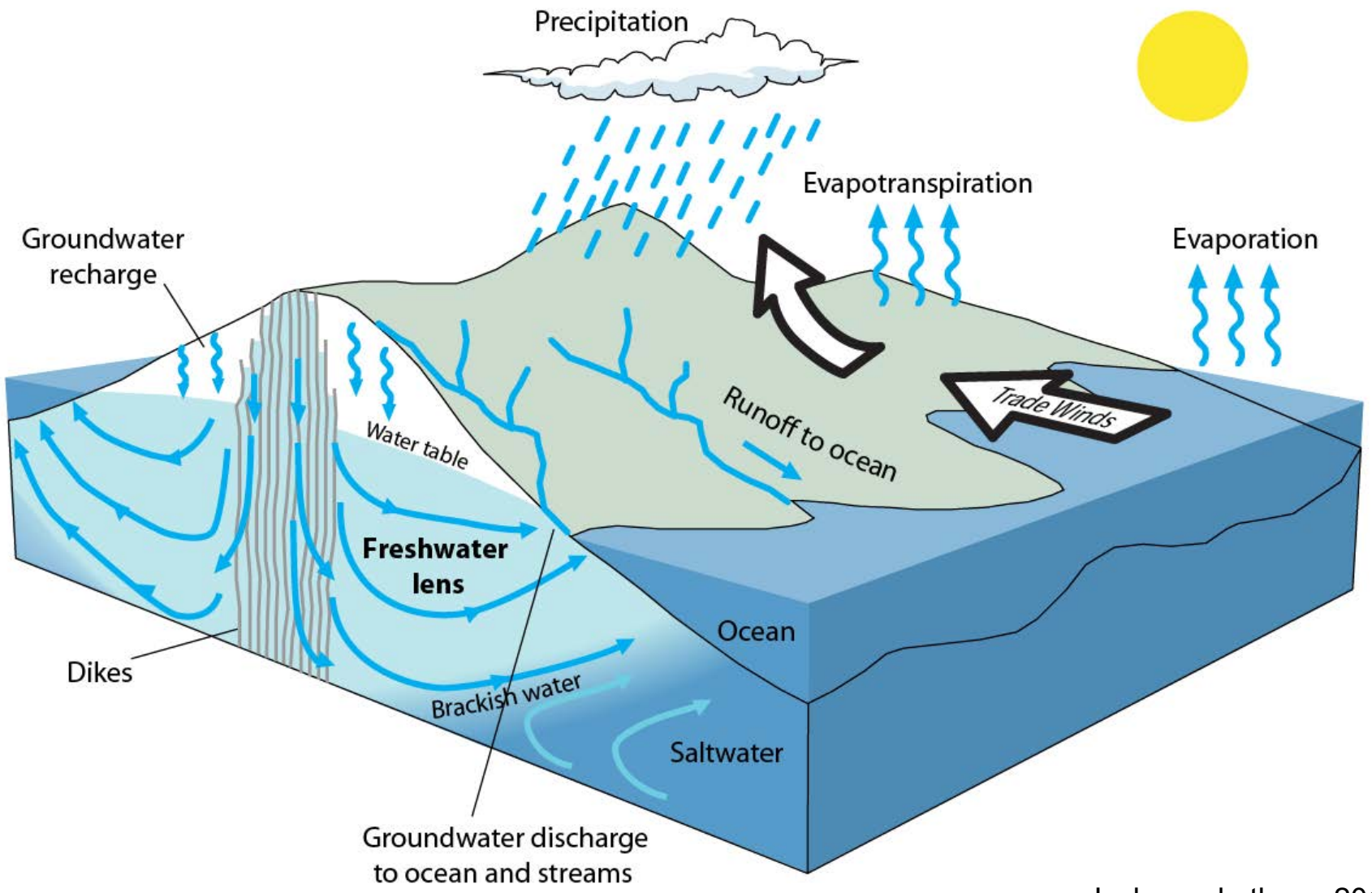
- Contested cases not fully resolved as of 2019

- Today State and County agencies evaluating how to best meet future water needs

Outline

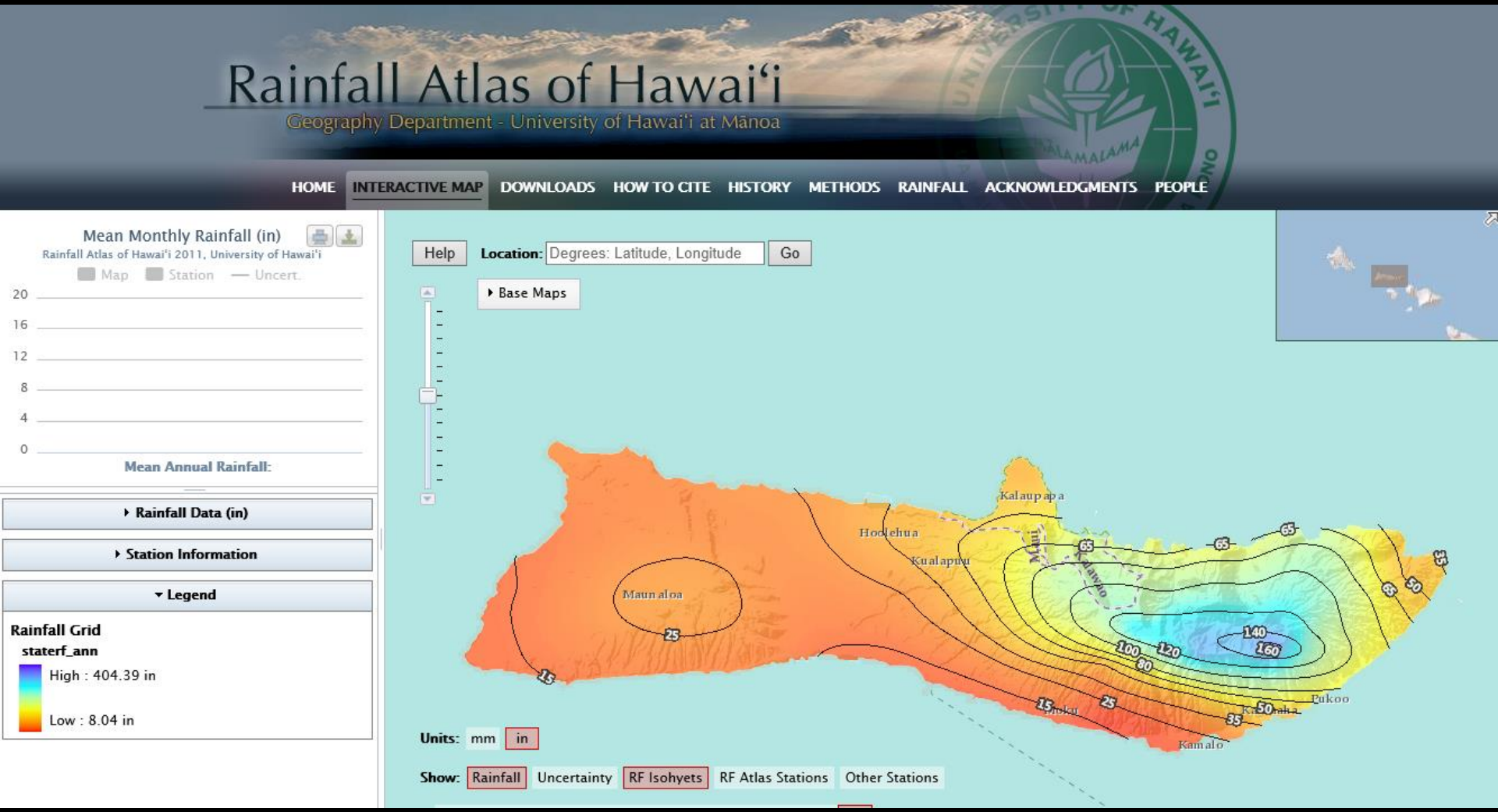
1. Background hydrology and geology of Molokaʻi
2. Background on how geology affects groundwater
3. Recent groundwater conditions
4. Conceptual effects of groundwater withdrawals
5. USGS study

Hydrologic Cycle



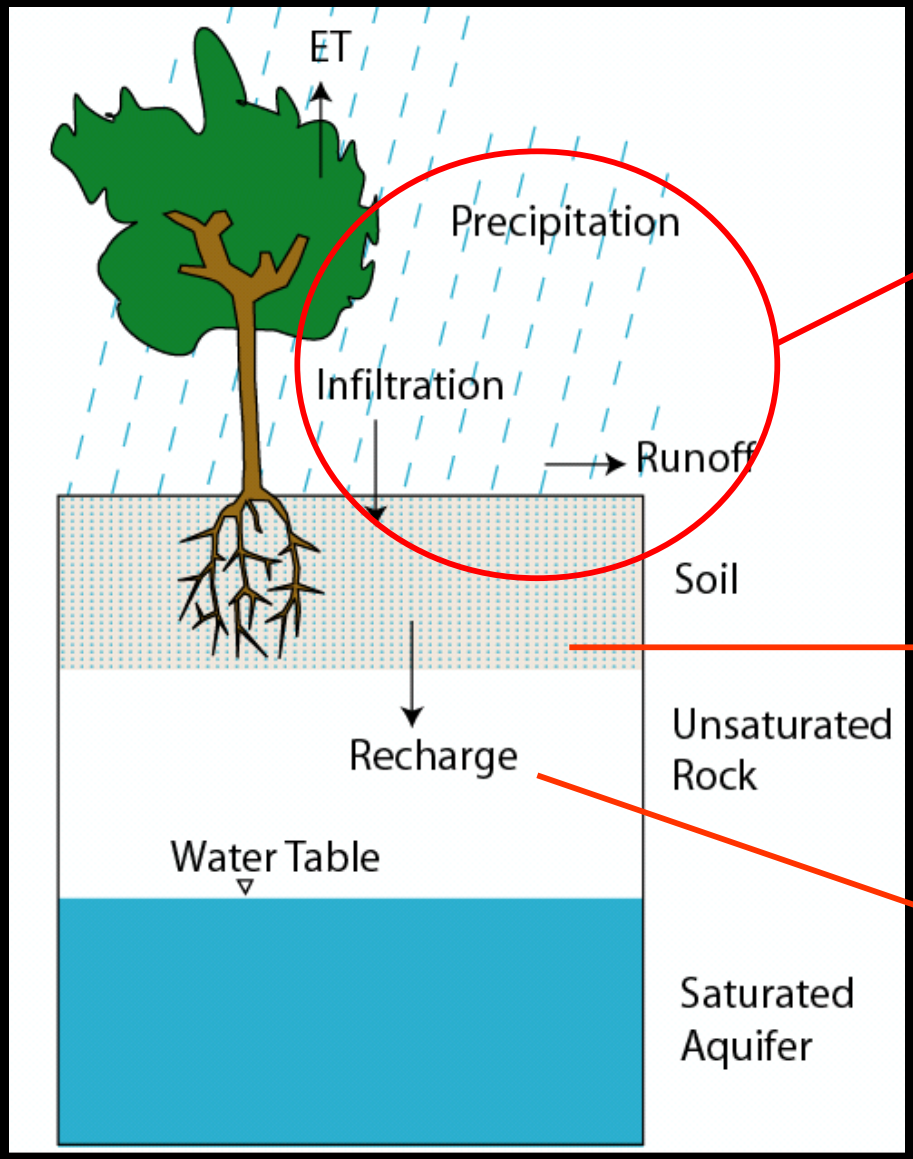
Izuka and others, 2018

Mean Annual Rainfall



http://rainfall.geography.hawaii.edu/

Water Budget

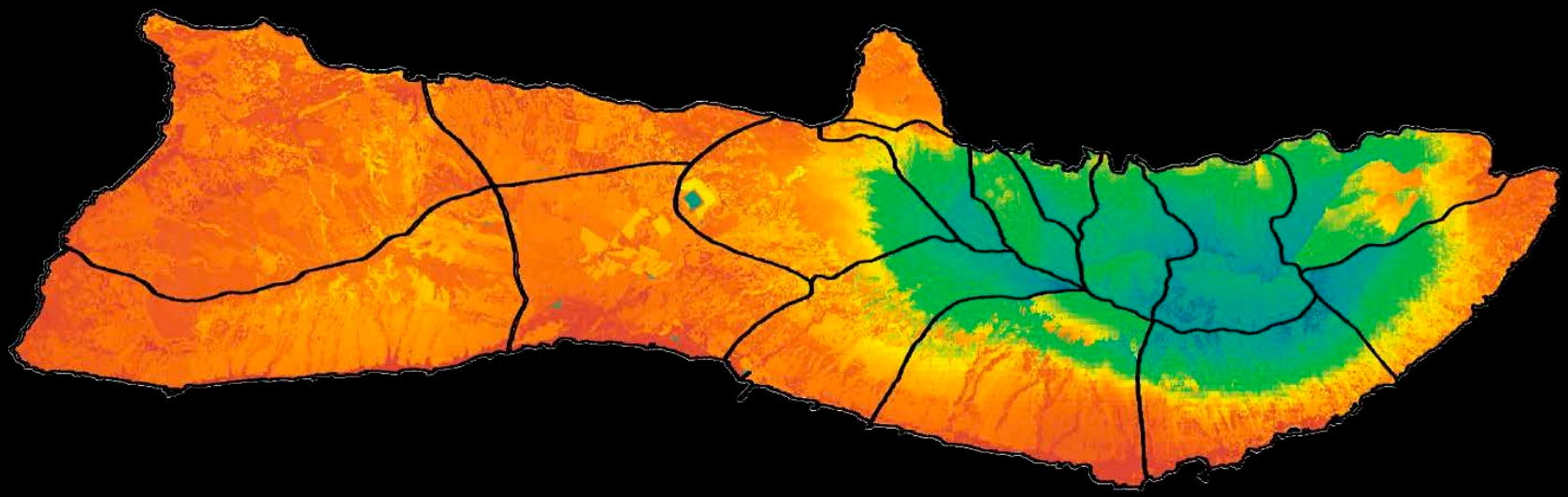


Water from precipitation either runs off, evaporates from surfaces, or infiltrates the soil

Water in soil is subject to transpiration by plants and evaporation (ET)

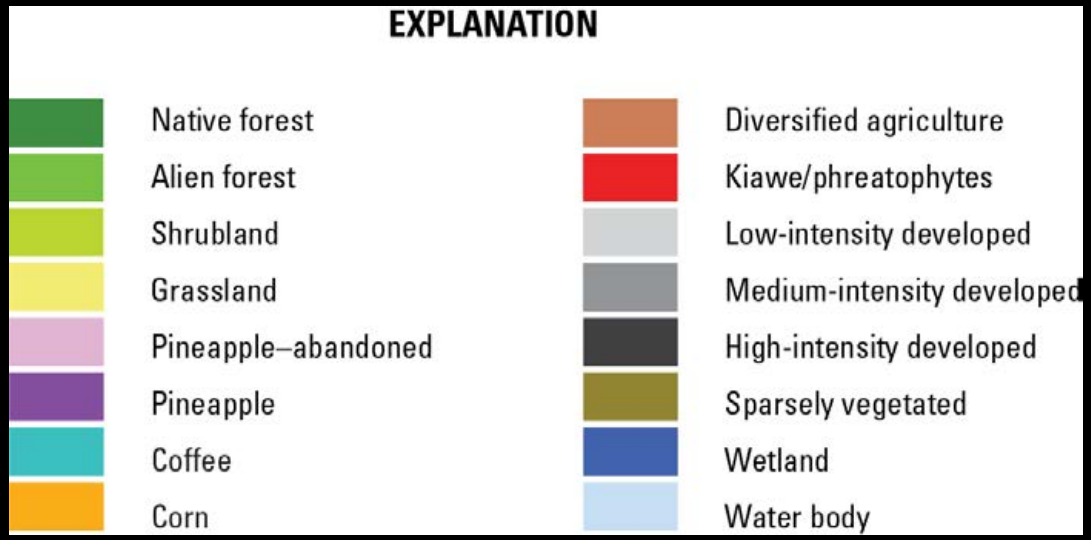
Some water passes through soil and recharges aquifer

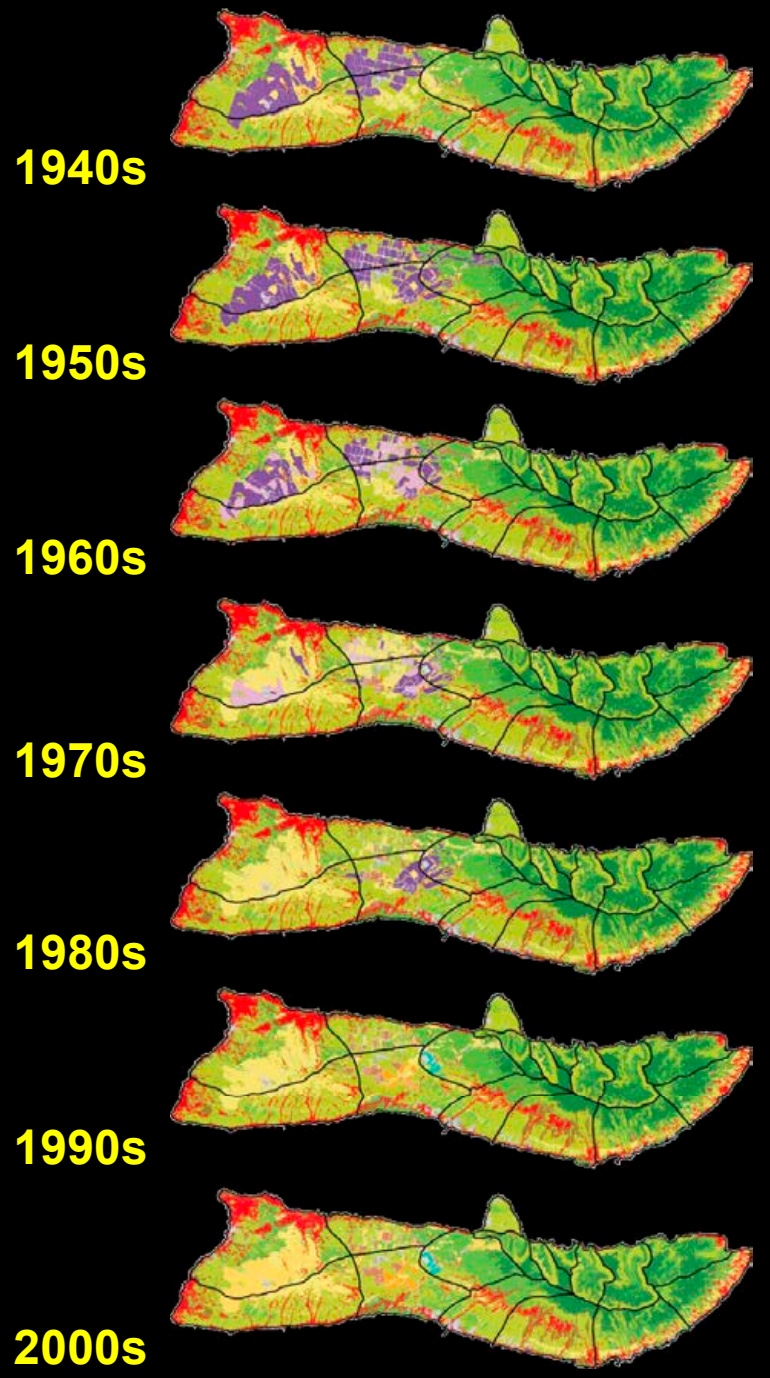
Recharge



- Climate and land cover are important factors controlling recharge
- Recharge can be estimated with a water-budget model (accounts for land-use changes and daily rainfall and evapotranspiration changes)

Land Use by Decade





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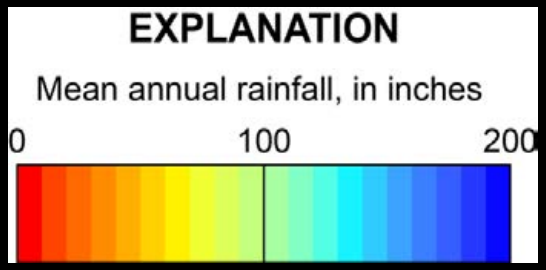
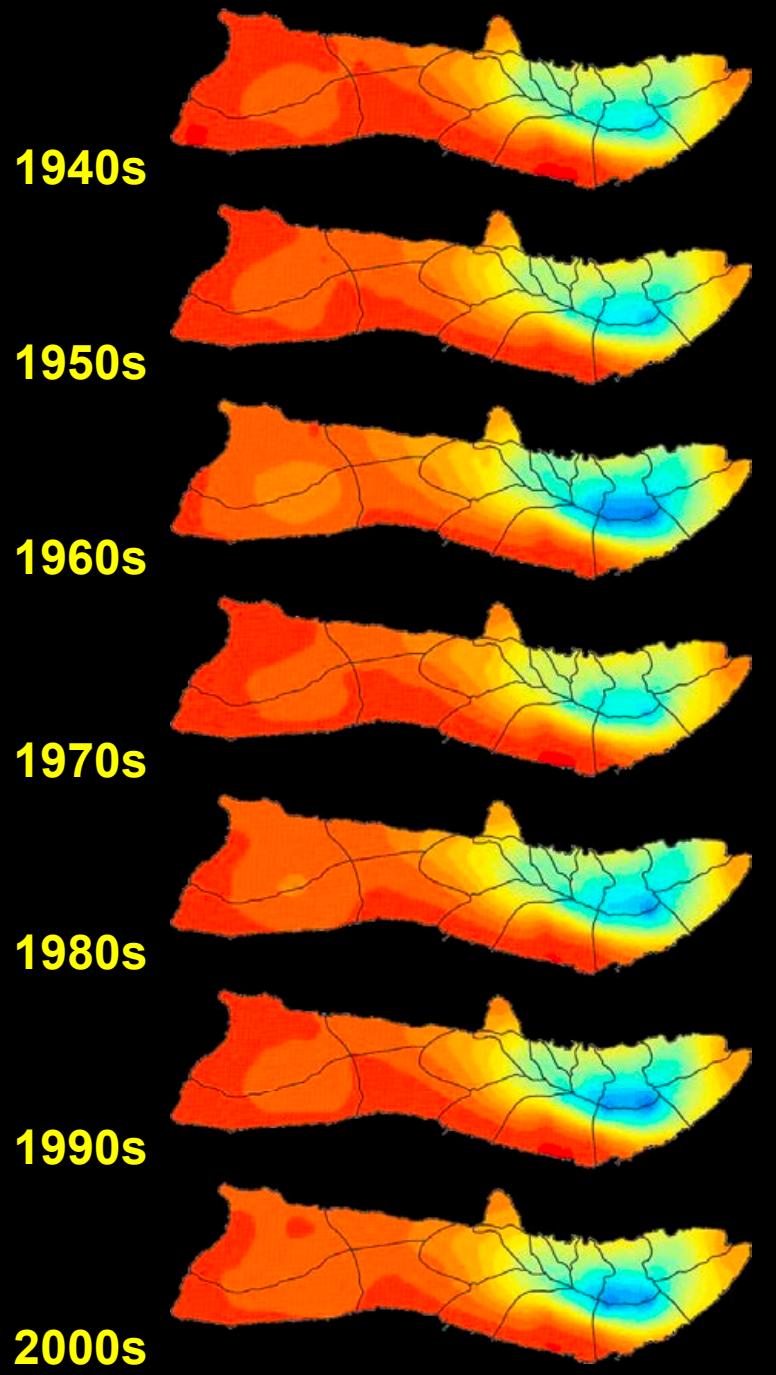
Rainfall By Decade

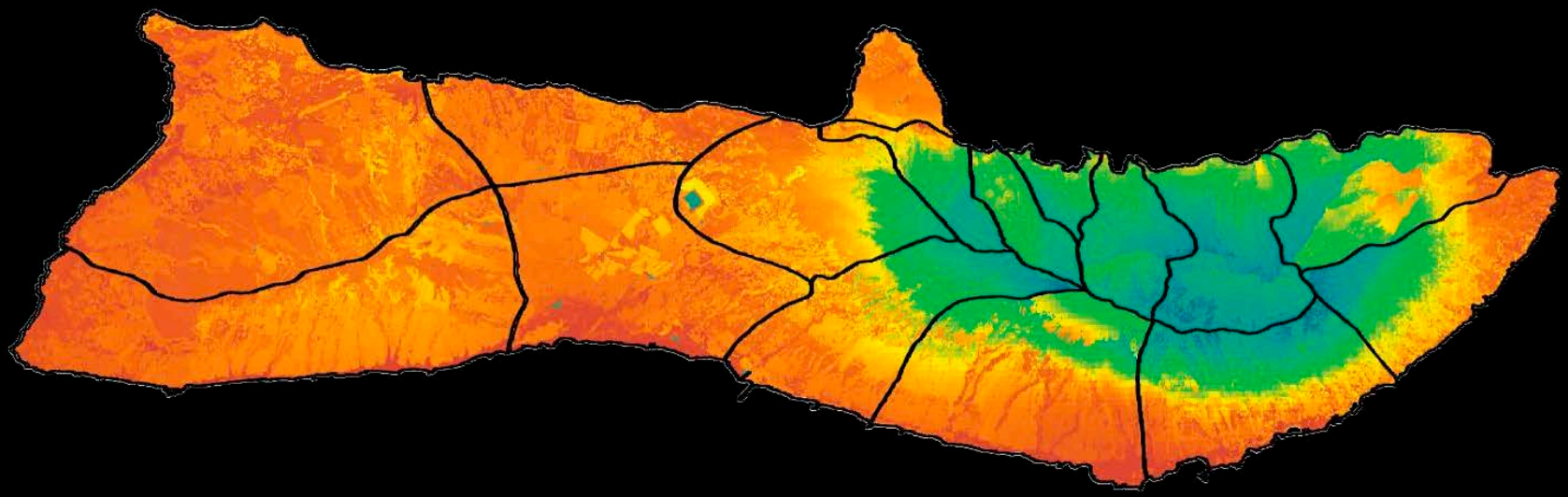
Period	Island-wide rainfall, in million gallons per day
1940s	536
1950s	566
1960s	691
1970s	522
1980s	625
1990s	611
2000s	592

Giambelluca and others, 2013





Recharge for Moloka‘i

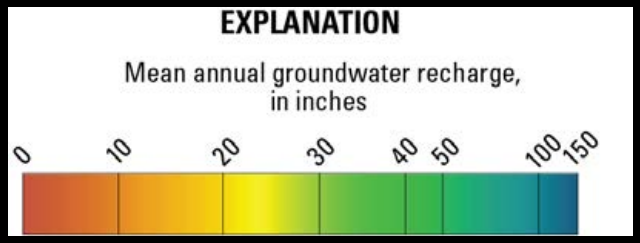


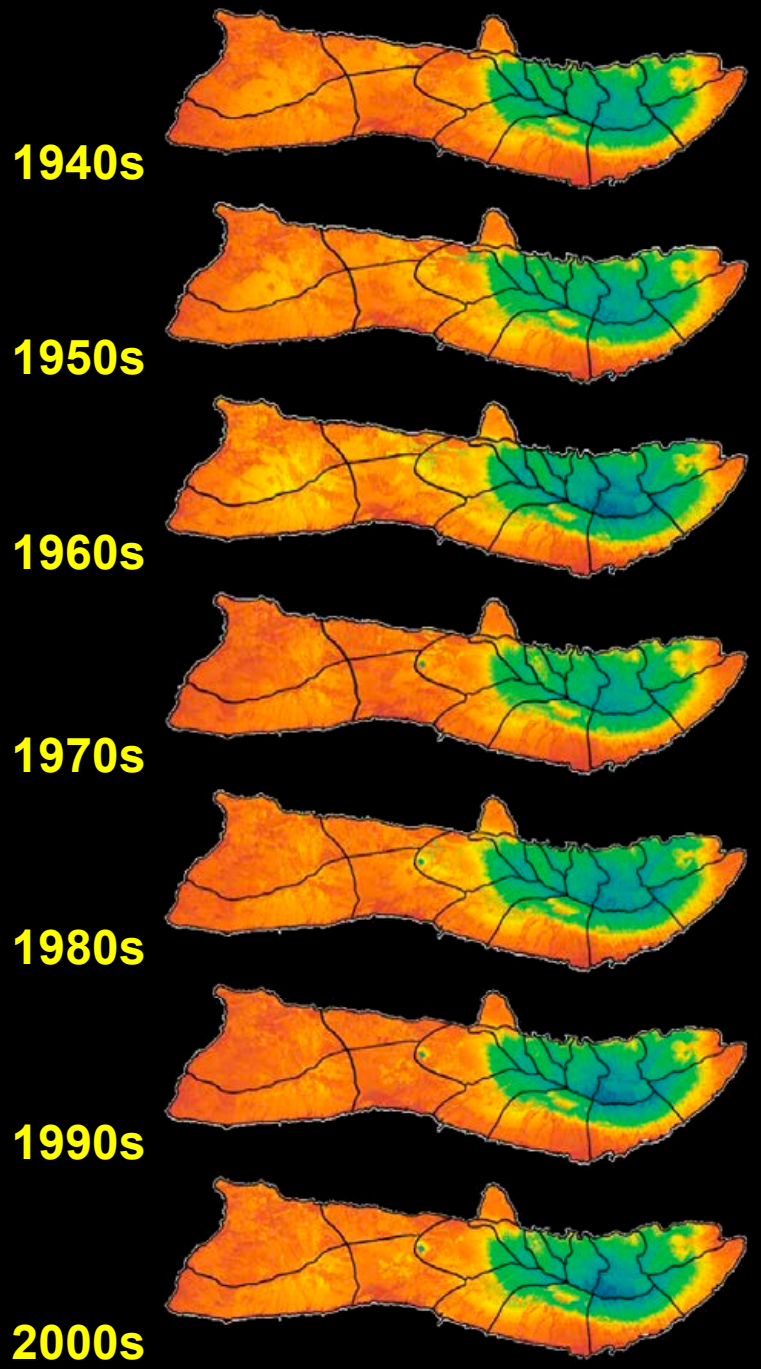
- Current study provides updated recharge estimates
  - Uses daily model and detailed spatial information
  - Accounts for land-use change over time
  - Utilizes best available rainfall and evapotranspiration information
- Previous recharge estimates based on simplified models, less detailed spatial information, and older data

USGS

Recharge By Decade

Period	Island-wide recharge, in million gallons per day
1940s	208
1950s	222
1960s	278
1970s	189
1980s	240
1990s	223
2000s	205
1978–2007	227





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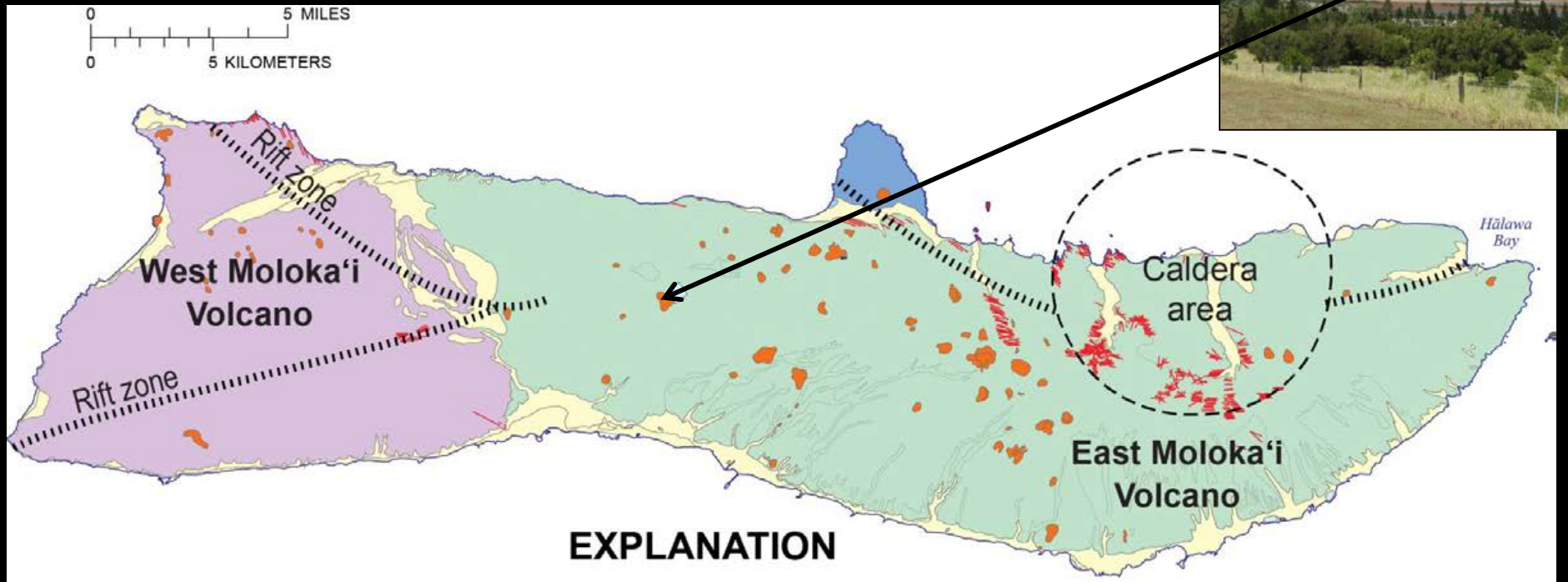
Geology

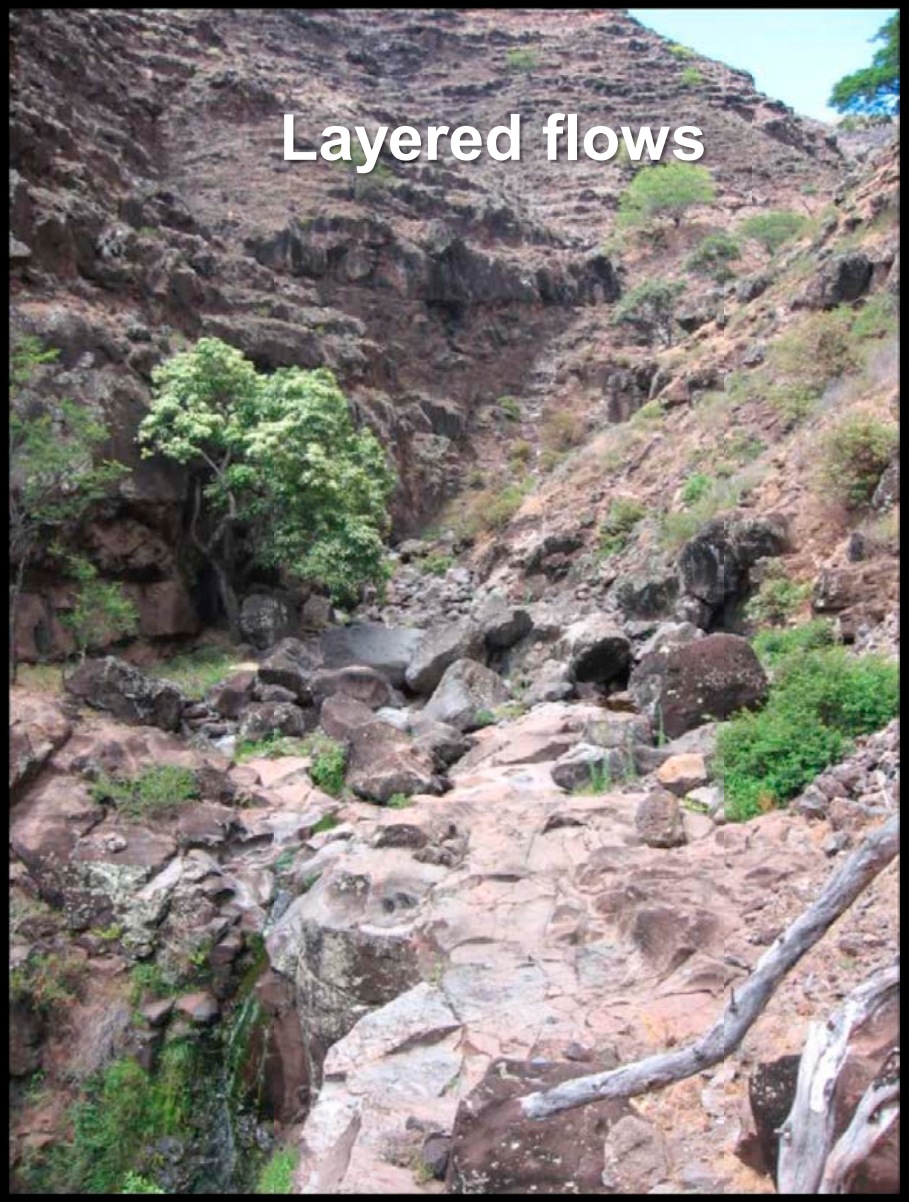


EXPLANATION

- Sedimentary deposits
- Kalaupapa Volcanics
- East Moloka‘i Volcanics (Upper and Lower members)
- West Moloka‘i Volcanics
- Volcanic vent
- Dike

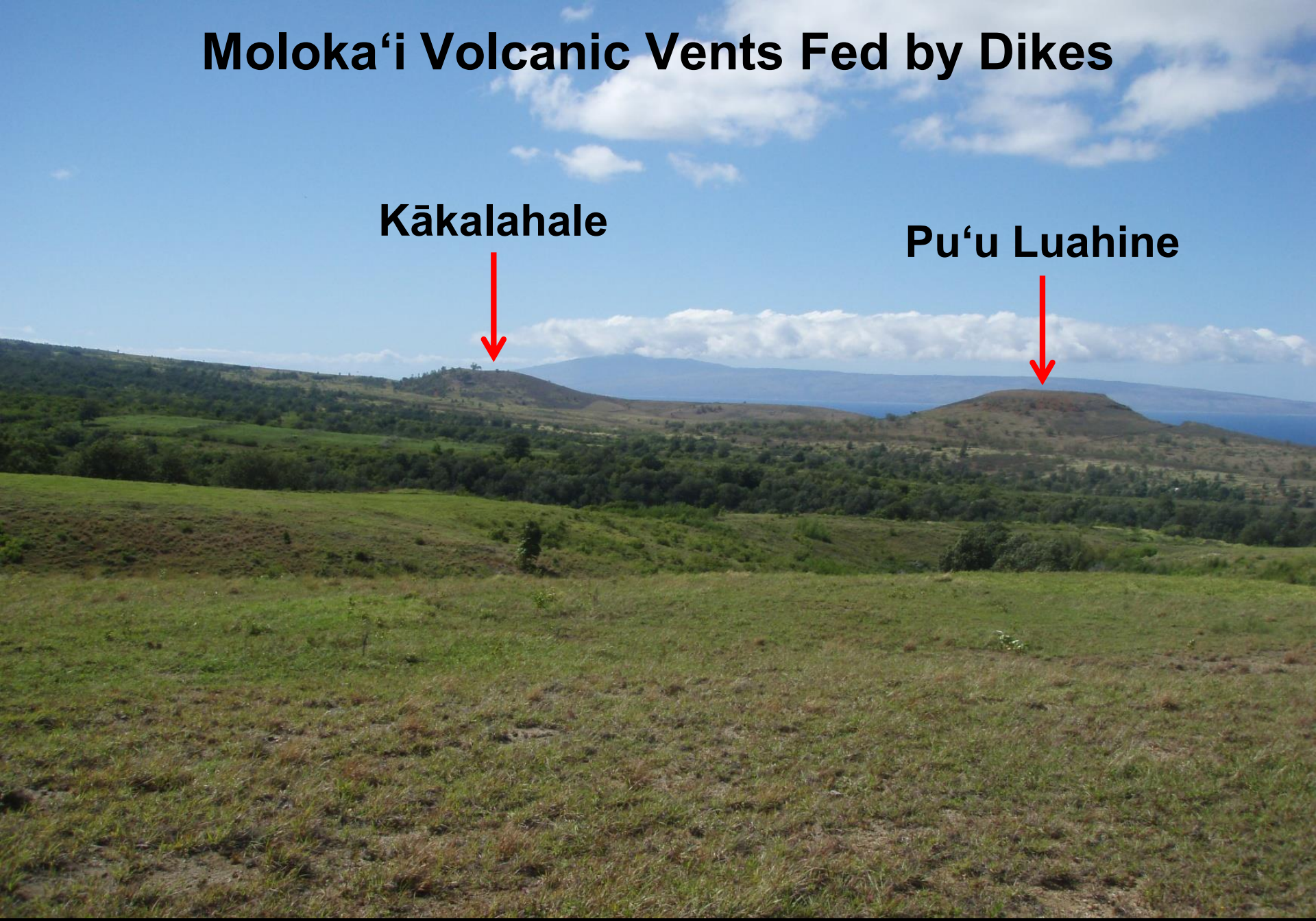
Modified from Sherrod and others, 2007

Lava Flows

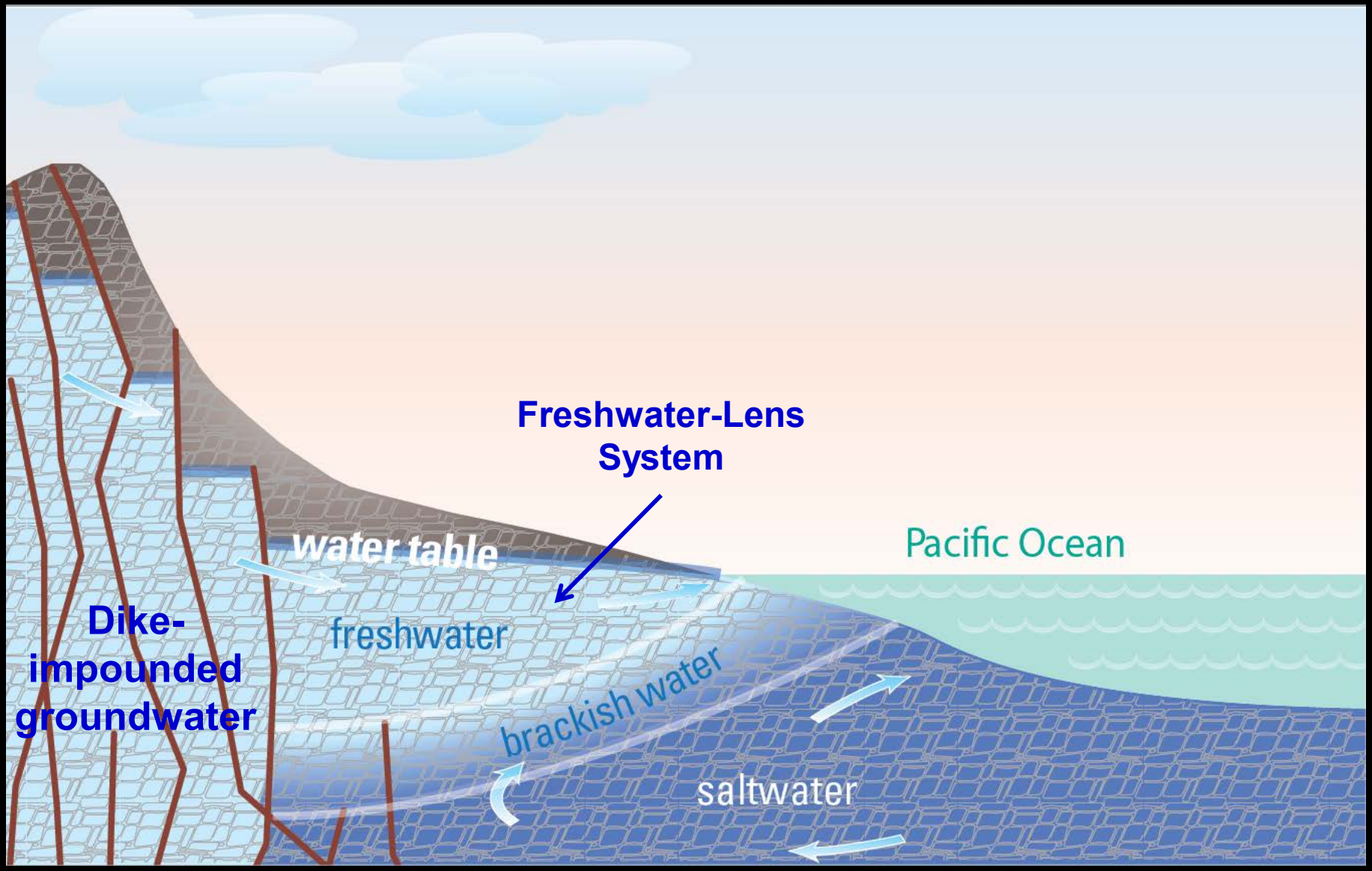


Dikes

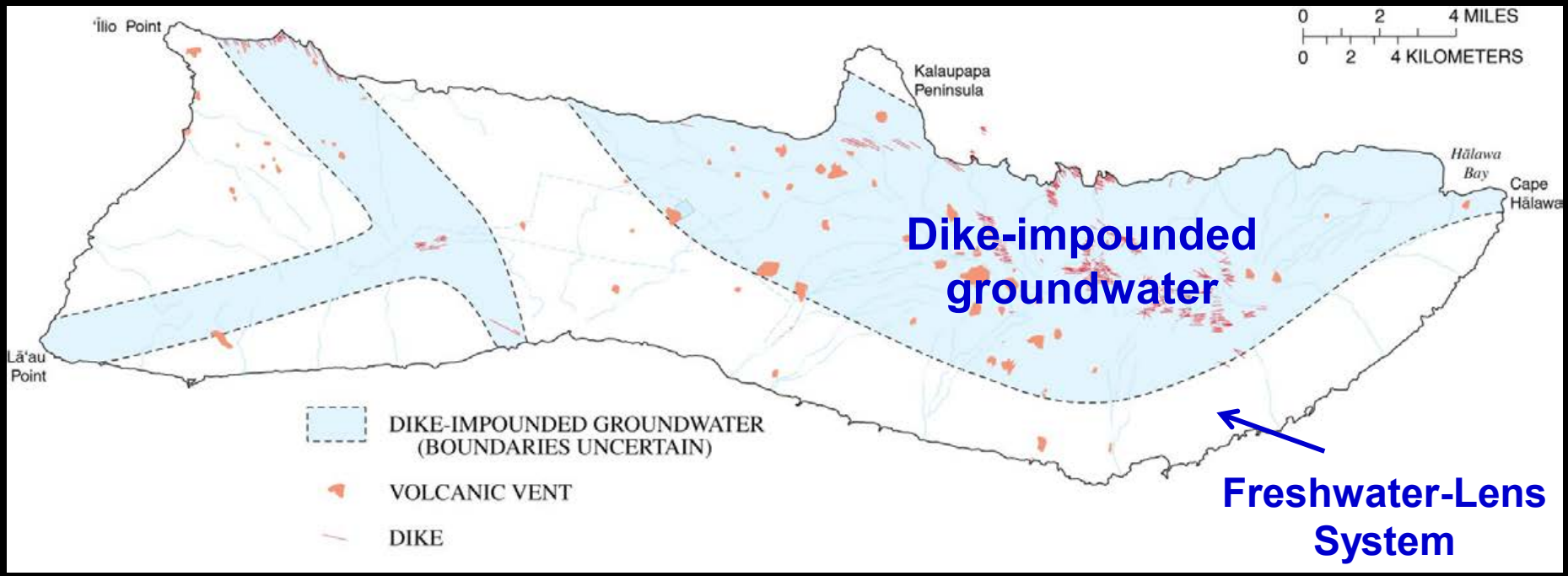
Moloka‘i Volcanic Vents Fed by Dikes



Conceptual Modes of Groundwater Occurrence

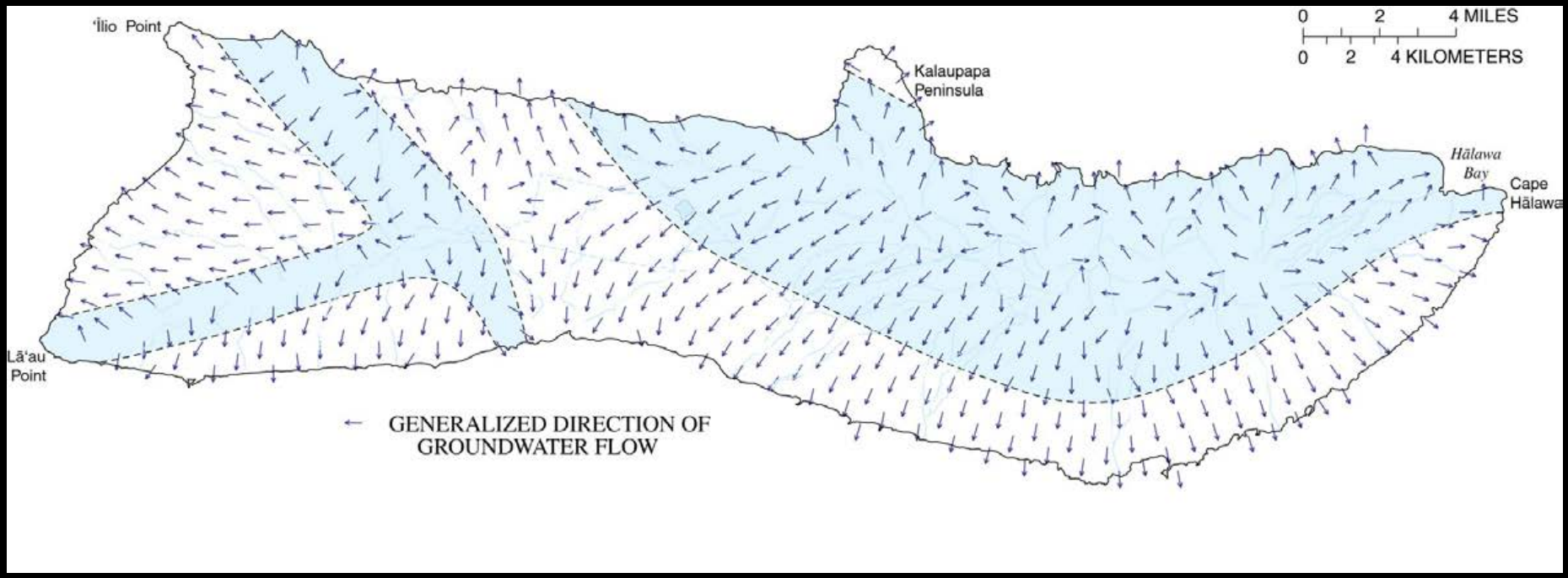


Generalized Groundwater Occurrence



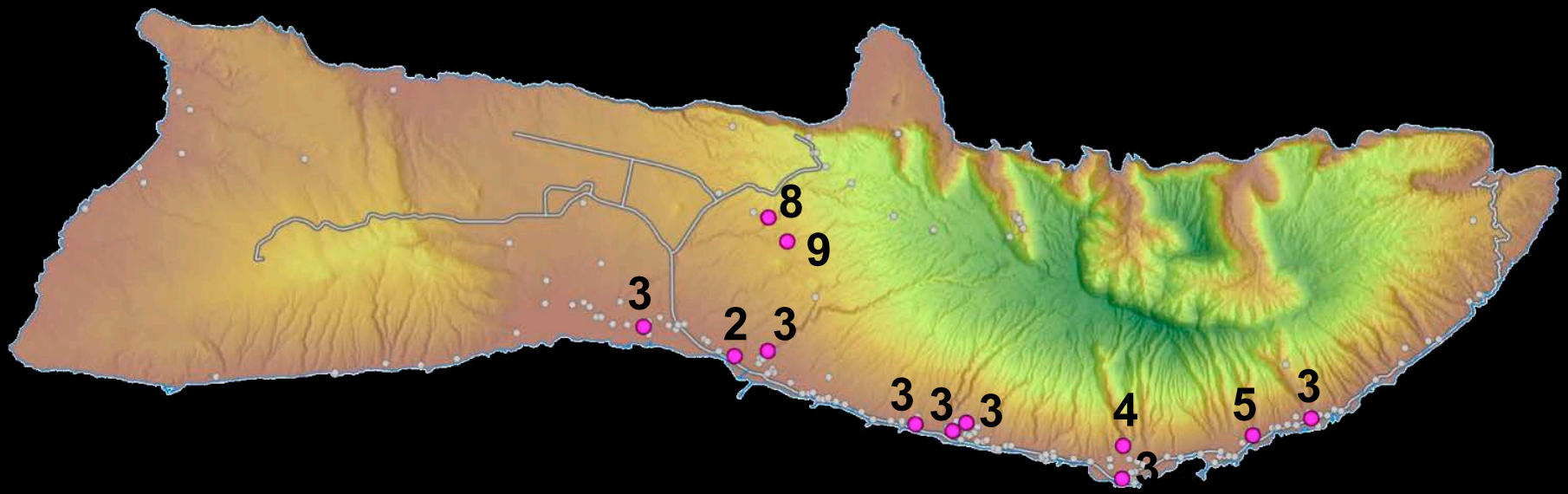
Volcanic vents and dikes from Sherrod and others (2007)

Generalized Groundwater-Flow Directions

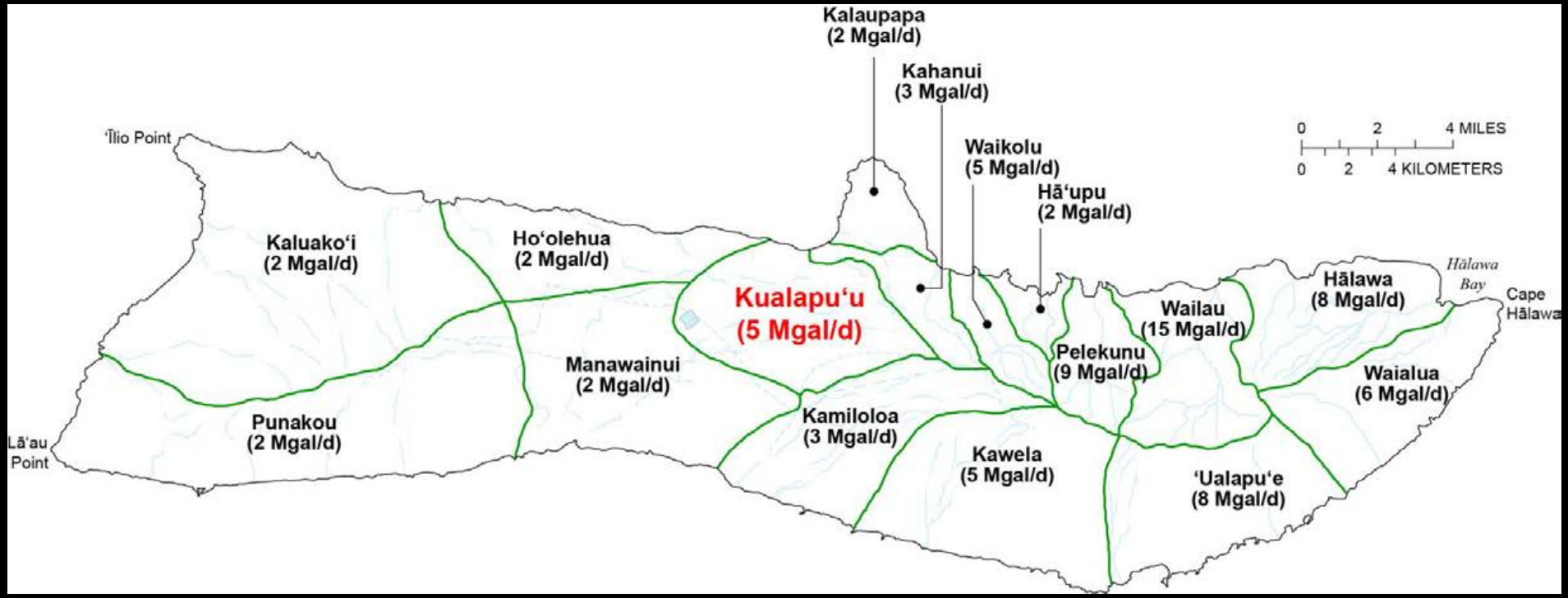


Recent Groundwater Levels

- Groundwater levels generally between about 2 and 10 feet above mean sea level where dikes are few
- Coastal wells have water levels less than about 4 feet
- Wells in Kualapu‘u area are greater than 8 feet
- Water levels vary in response to natural and human-related factors

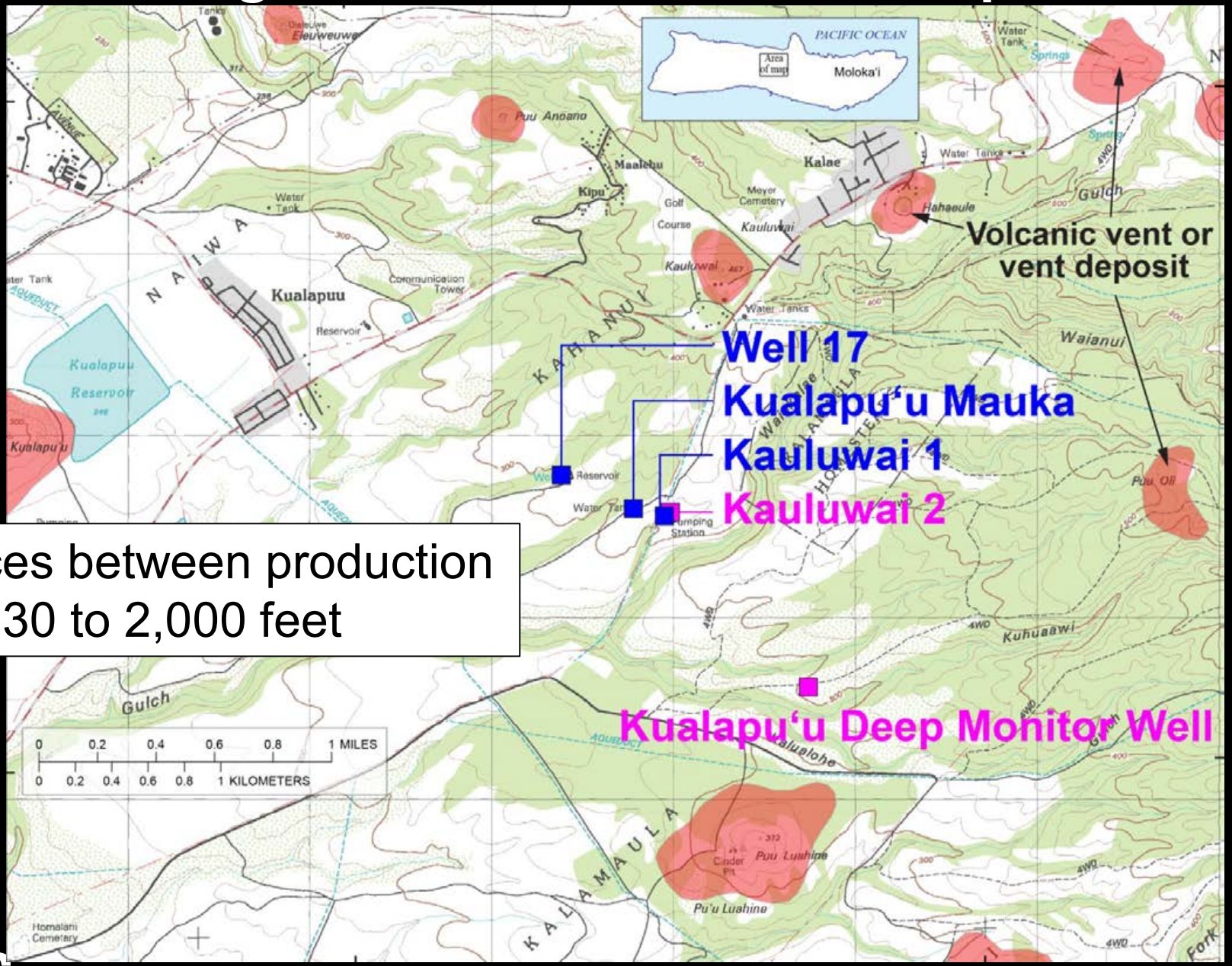


Kualapu‘u Aquifer System



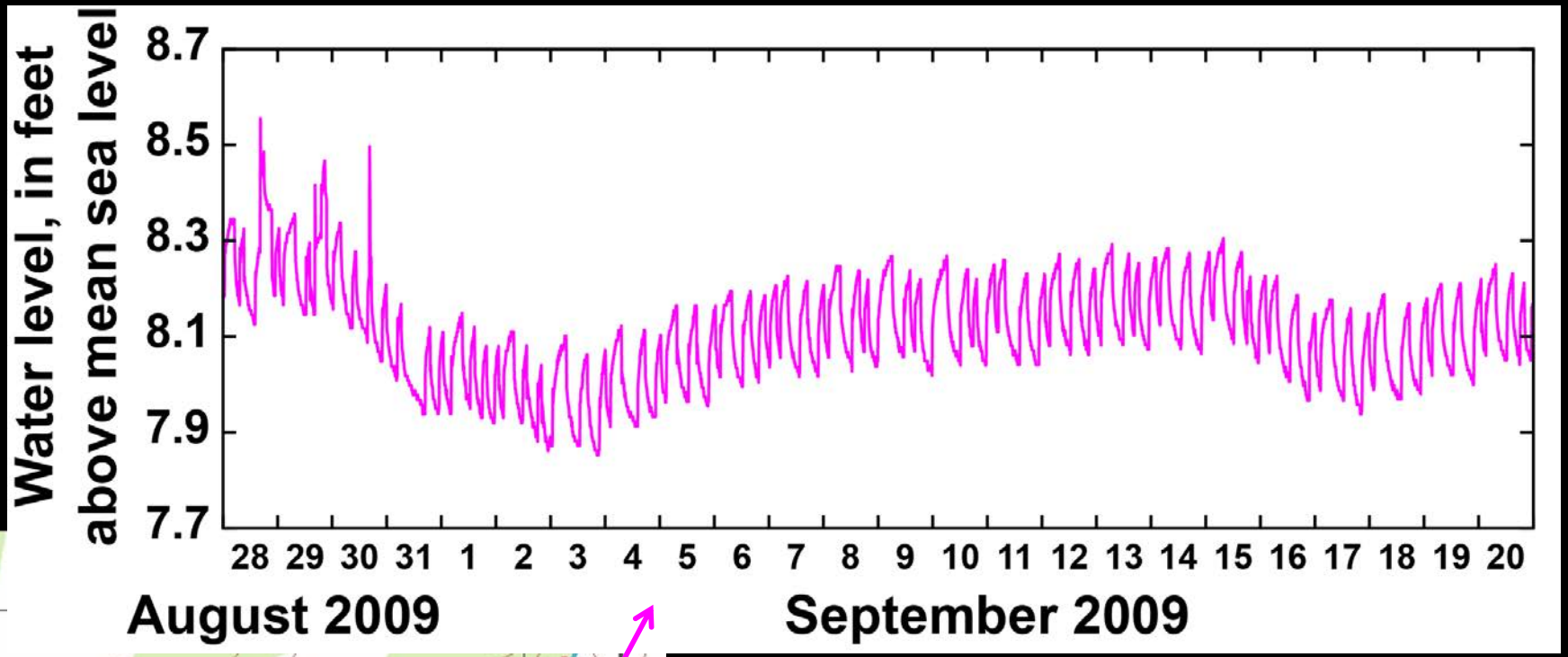
Commission on Water Resource Management aquifer systems and sustainable-yield values, in million gallons per day (Mgal/d)

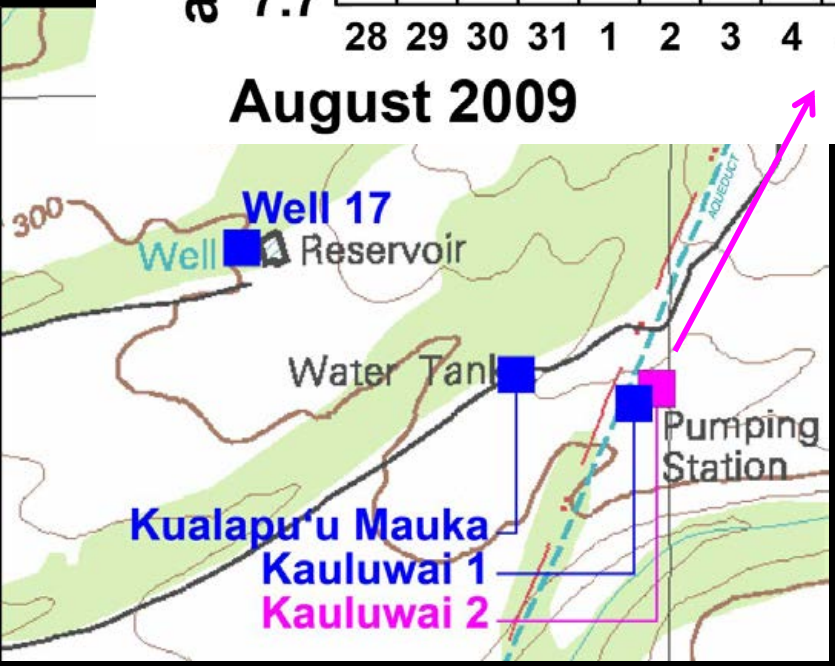
Understanding Groundwater in the Kualapu‘u Area



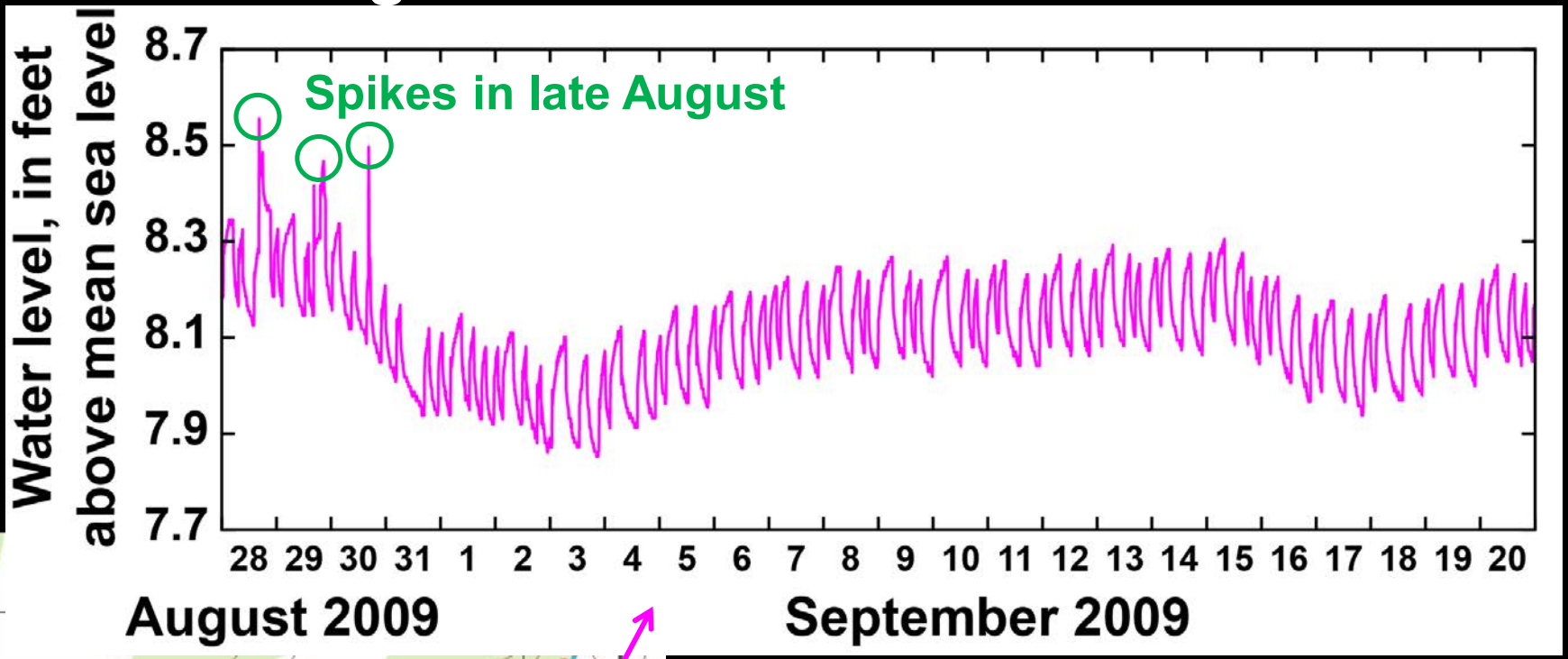
Distances between production wells: 130 to 2,000 feet

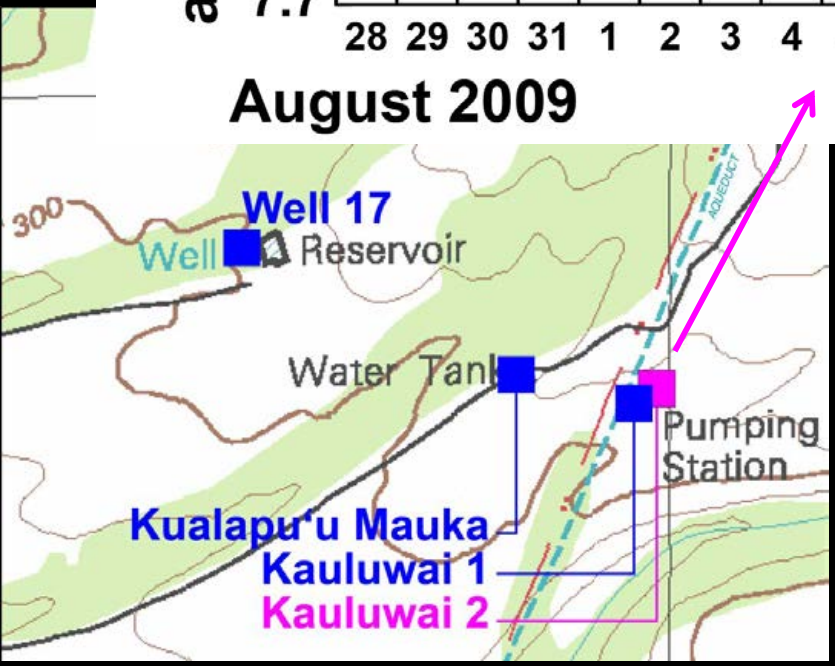
Water Level in Kauluwai 2





Diagnostic Water-Level Features





- Spikes in late August
- Daily changes (sawtooth appearance)
- Slower changes (several days)

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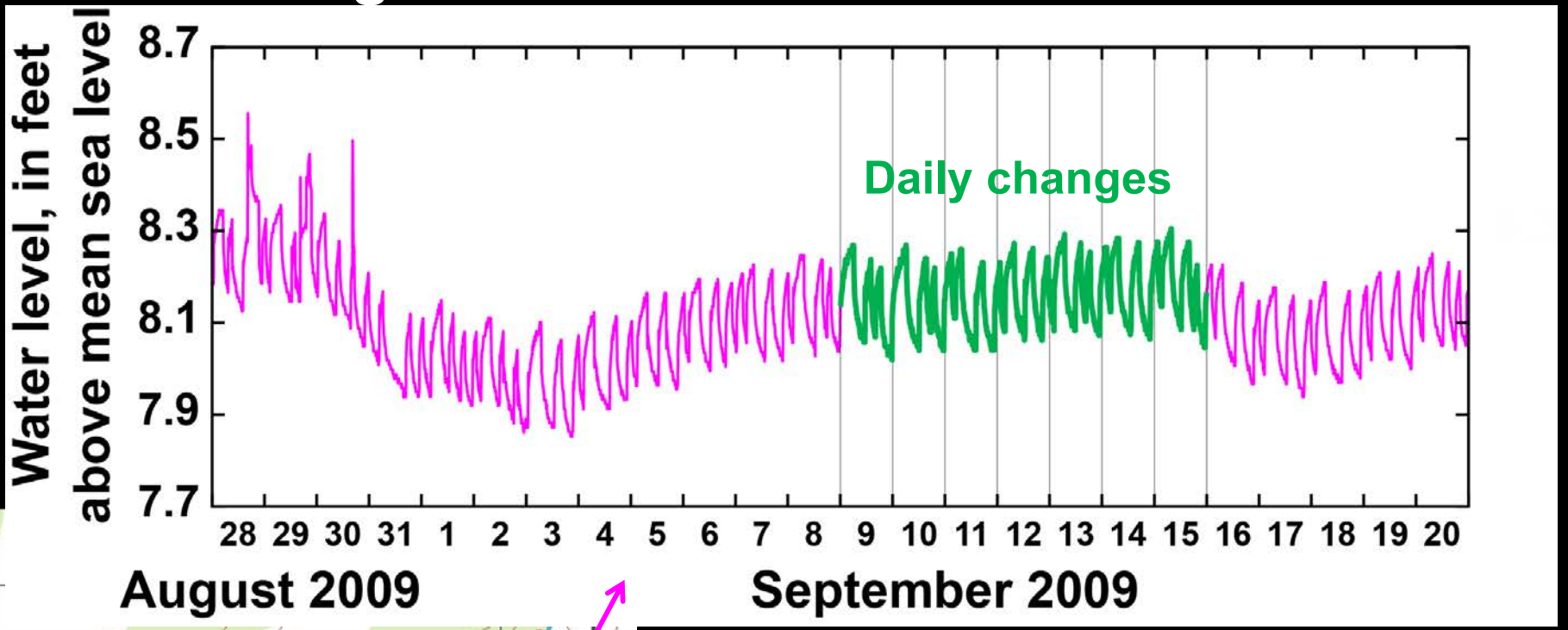

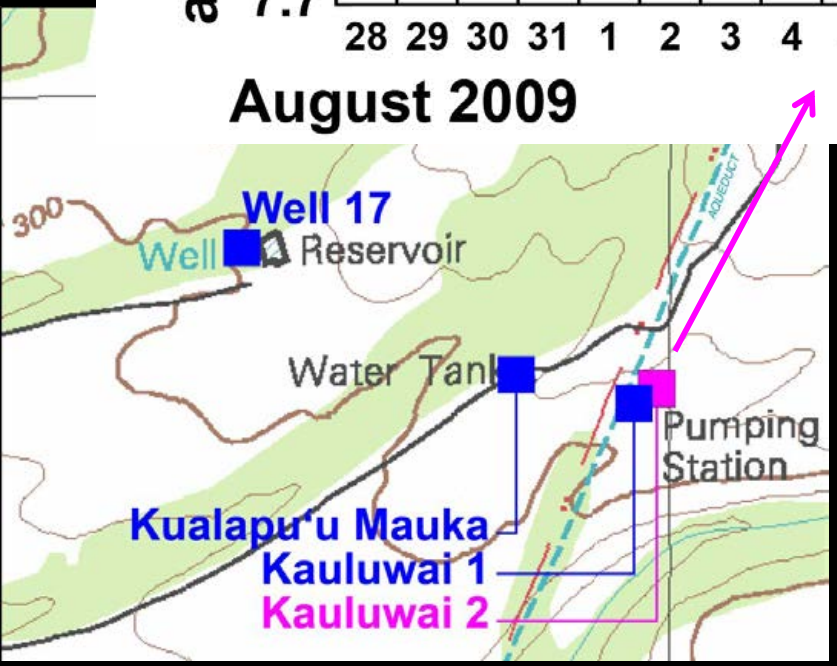

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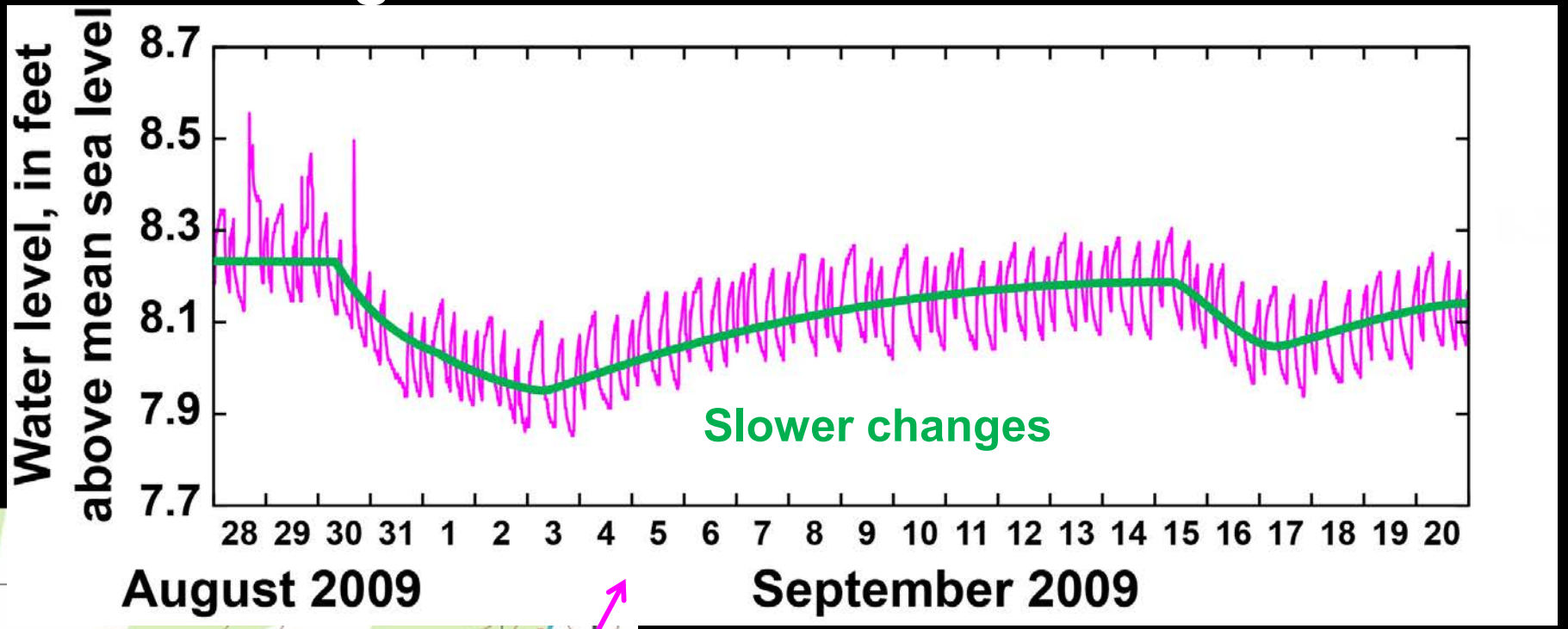

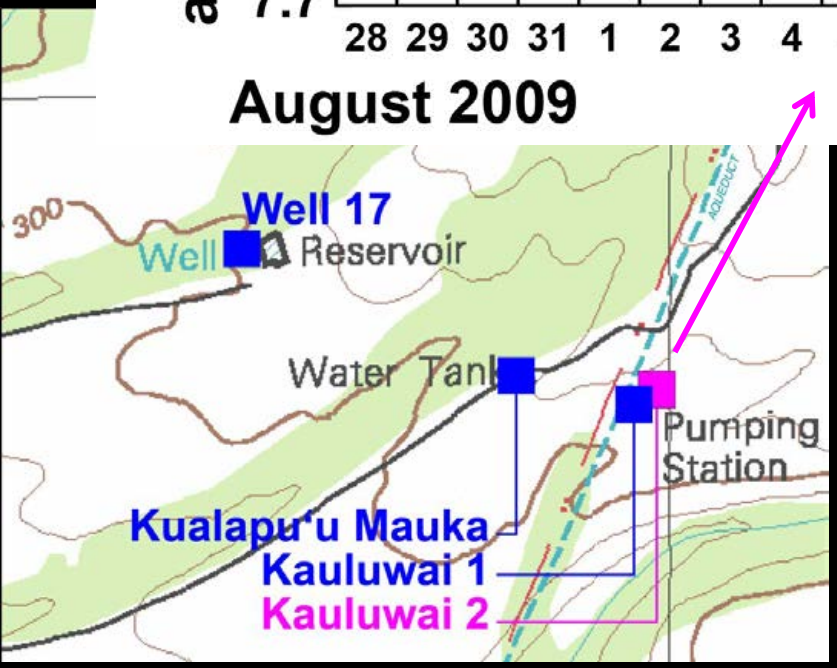

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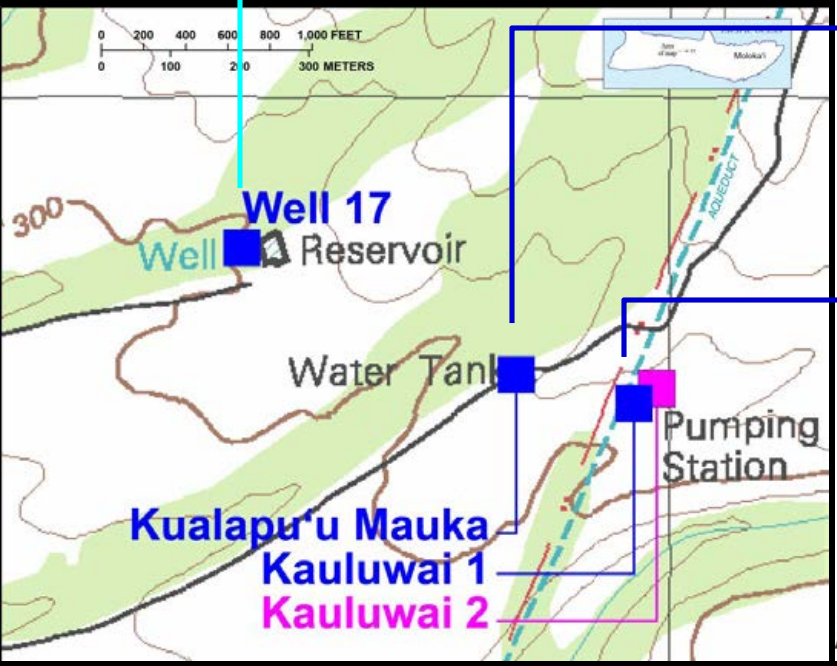
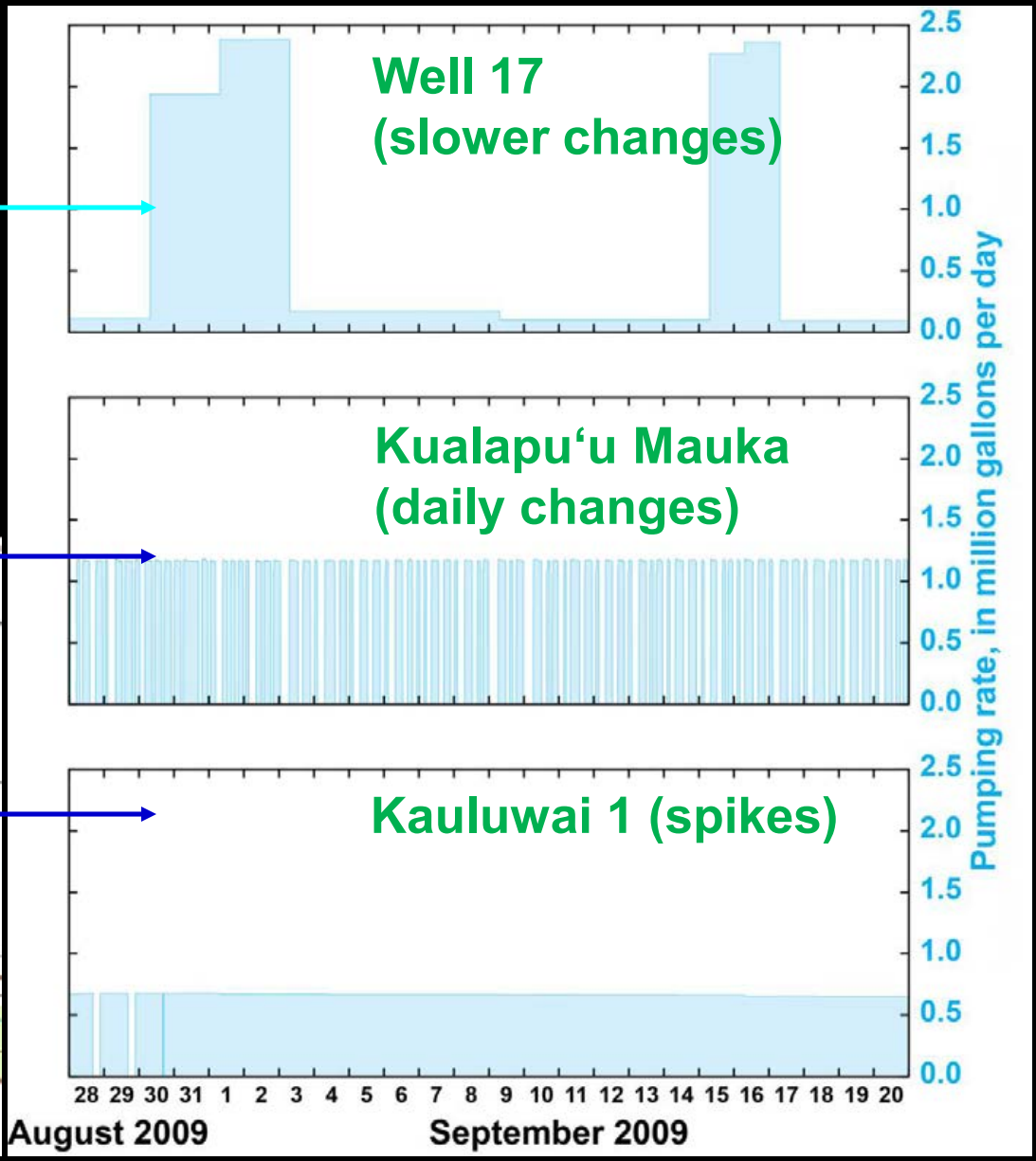
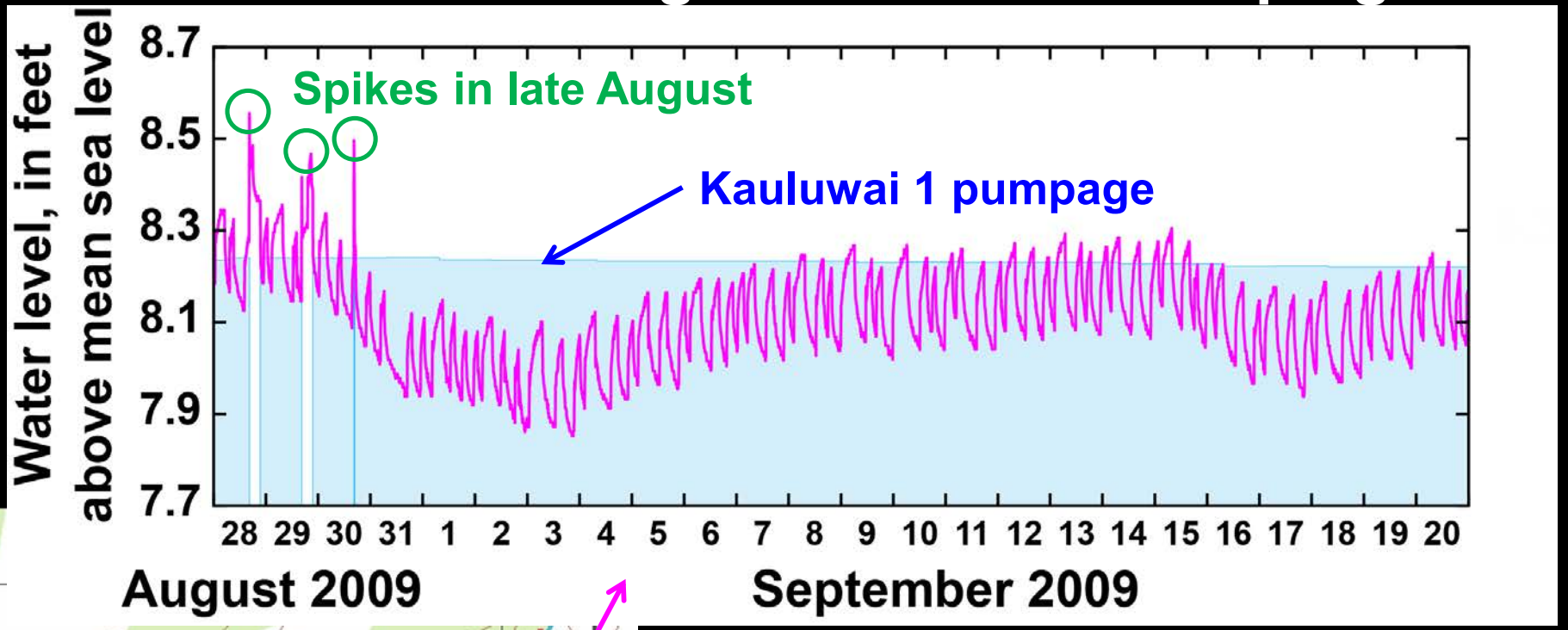
Kualapu‘u Pumpage

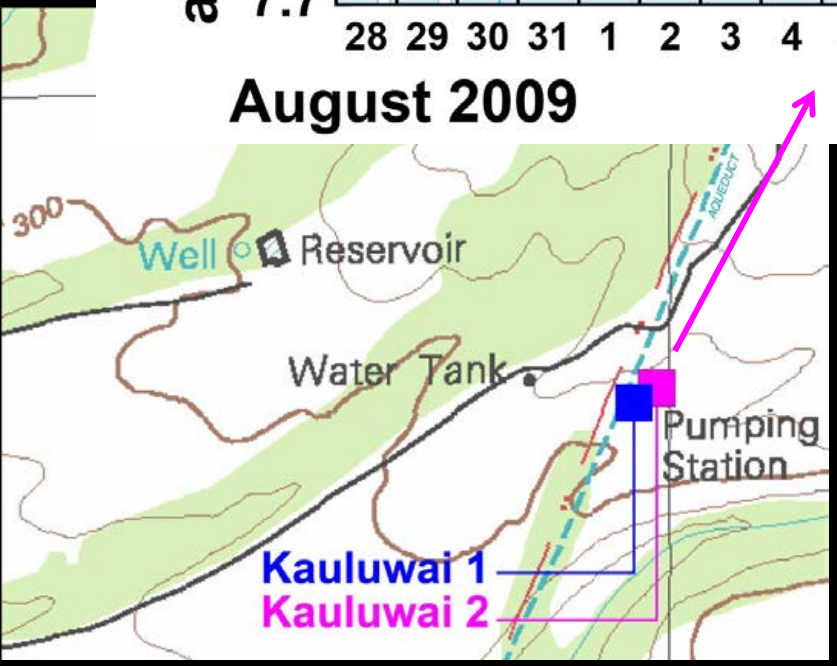
Pumpage data from Moloka‘i Ranch; Maui Department of Water Supply; and Department of Hawaiian Home Lands





Water-Level Changes Related to Pumping





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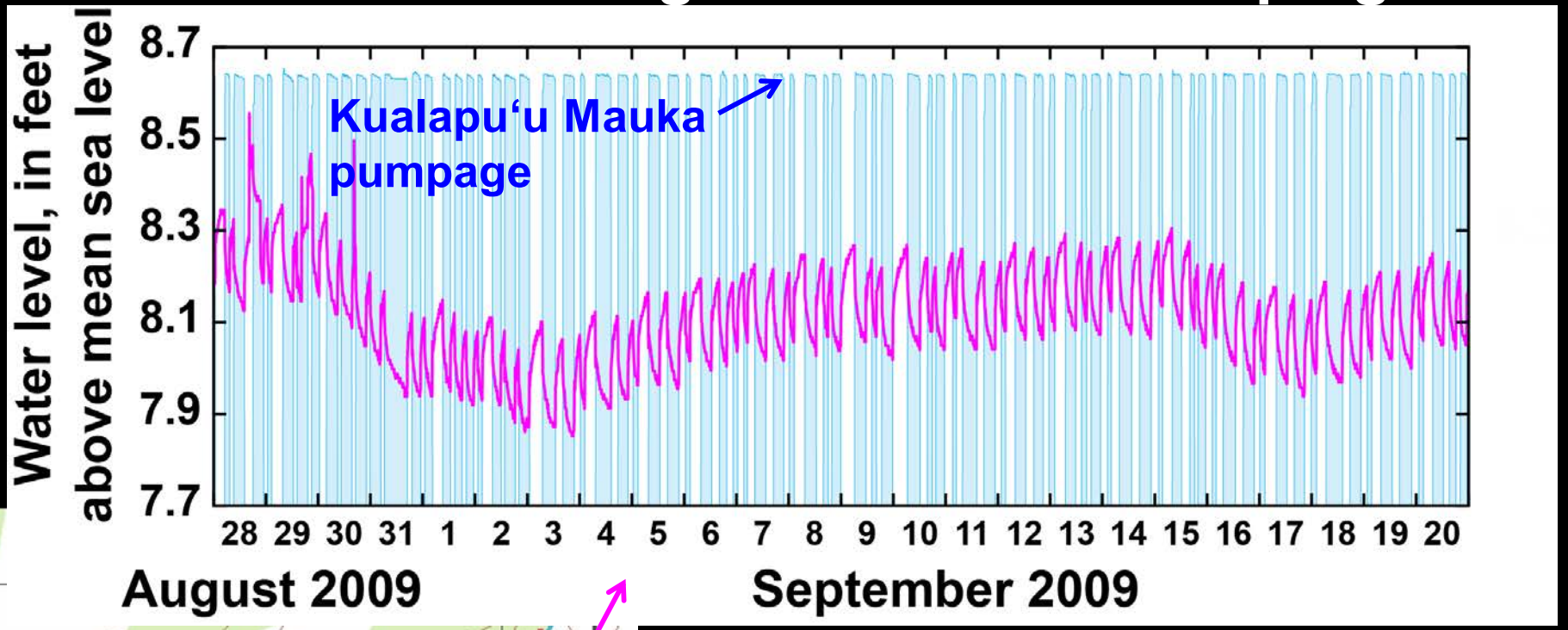

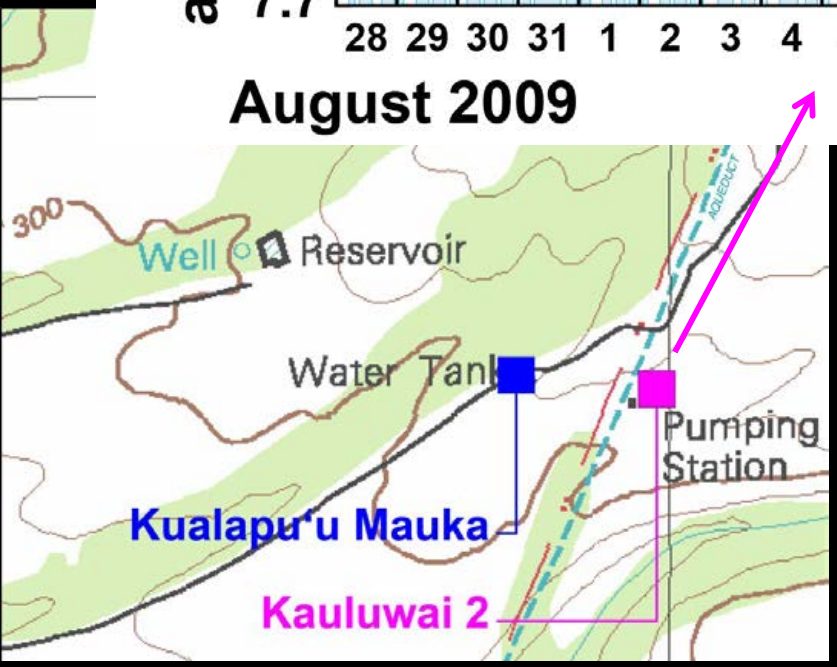

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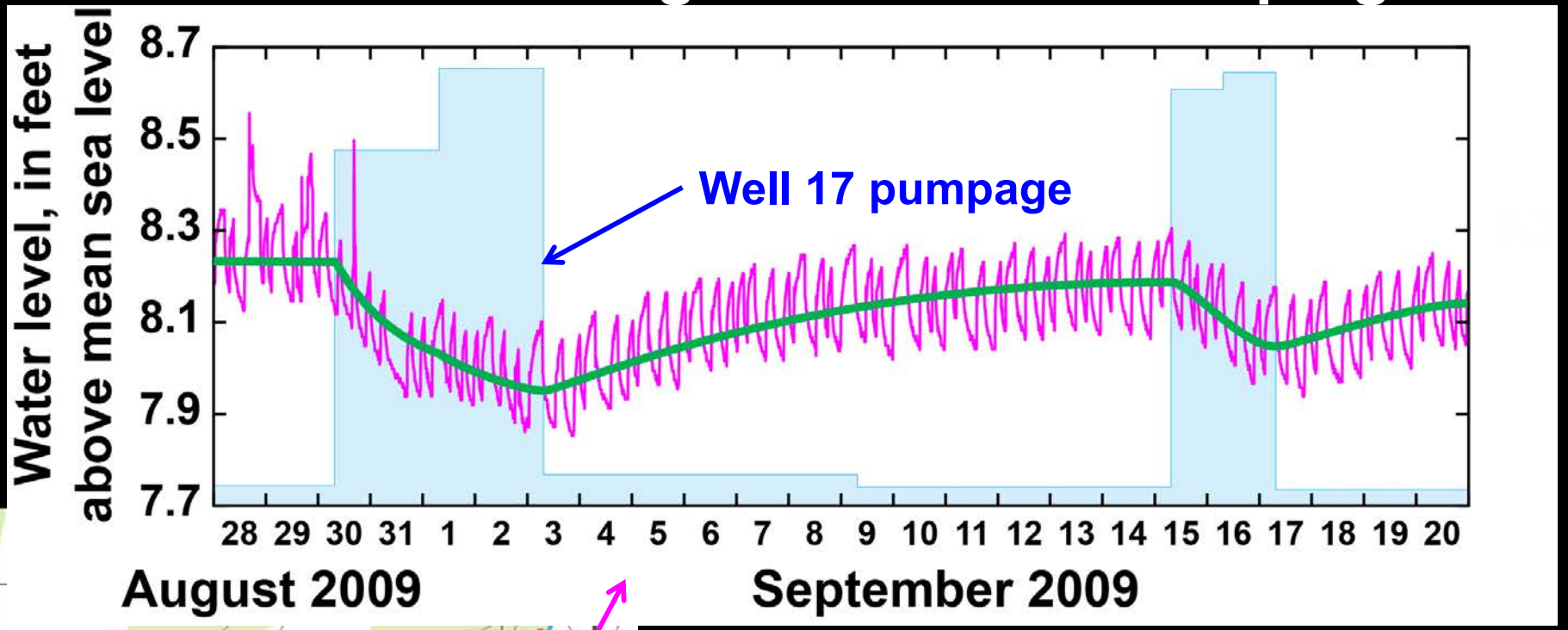

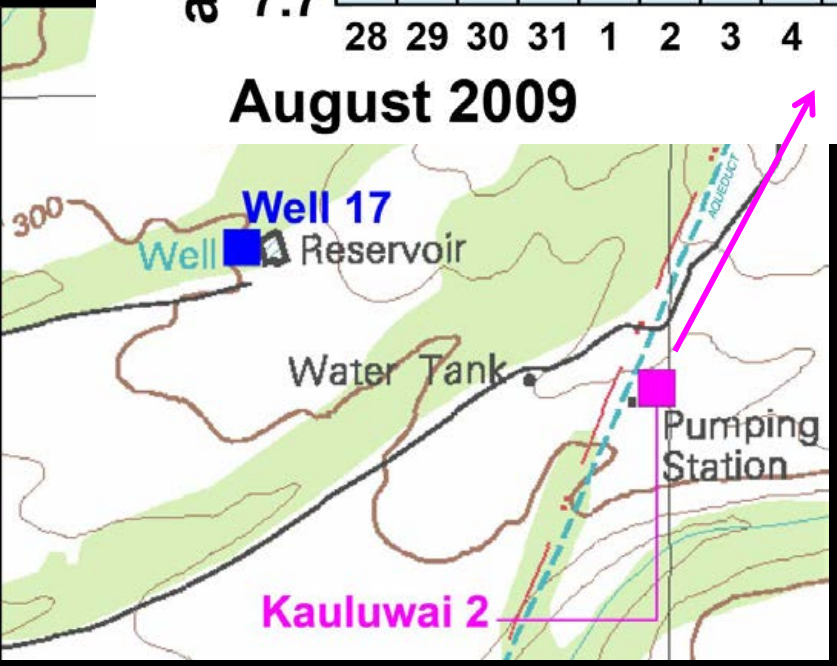

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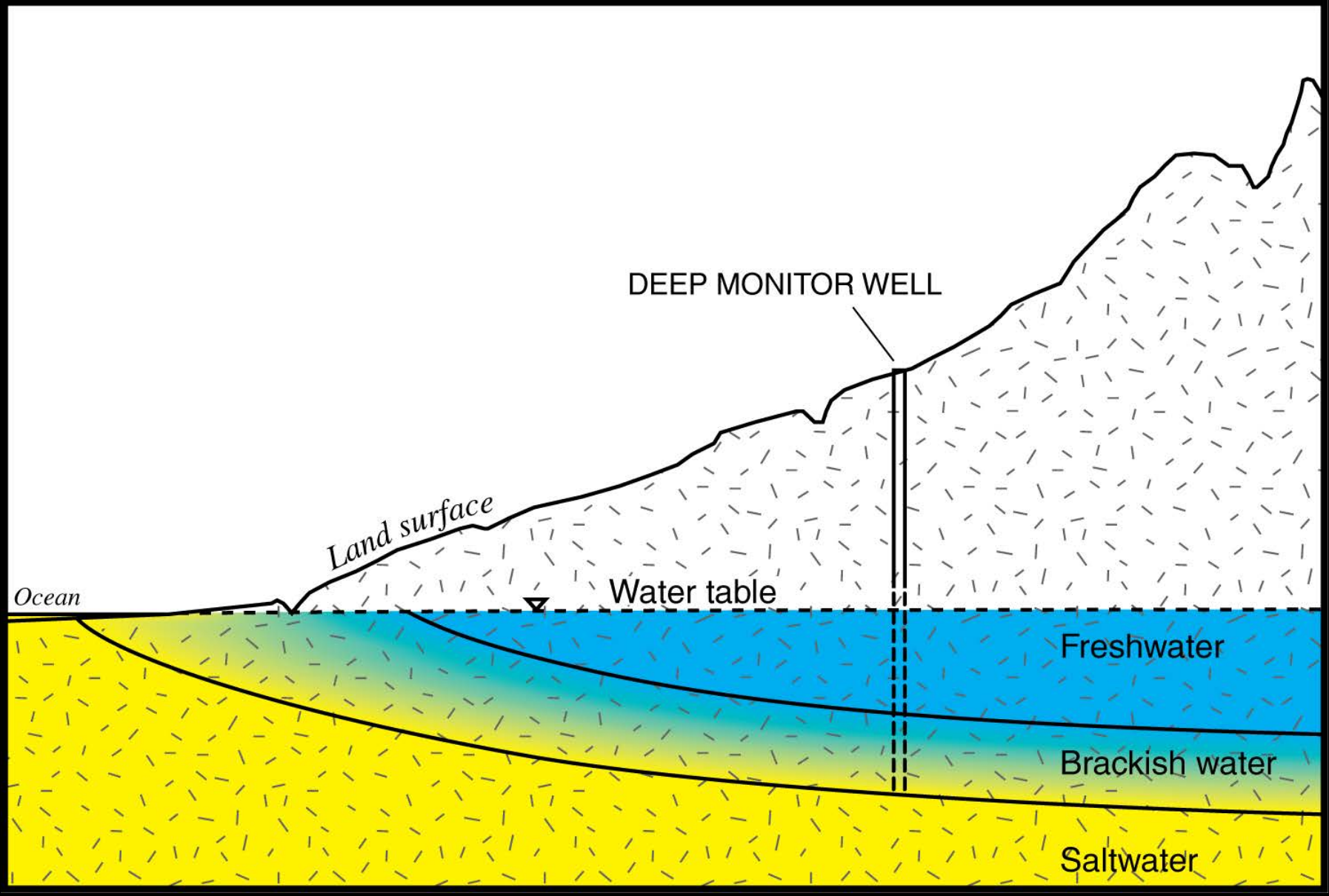
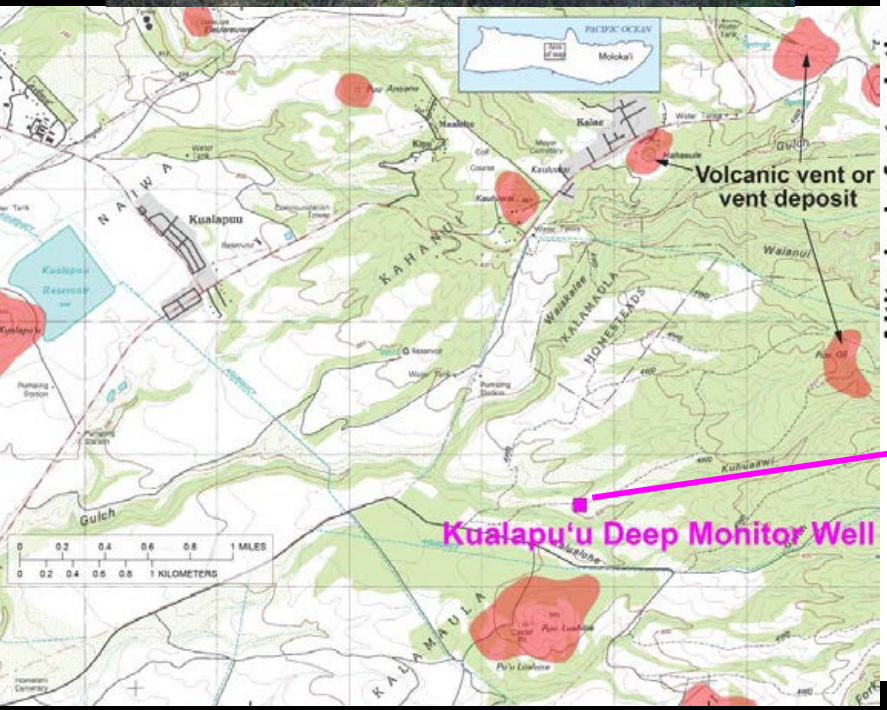
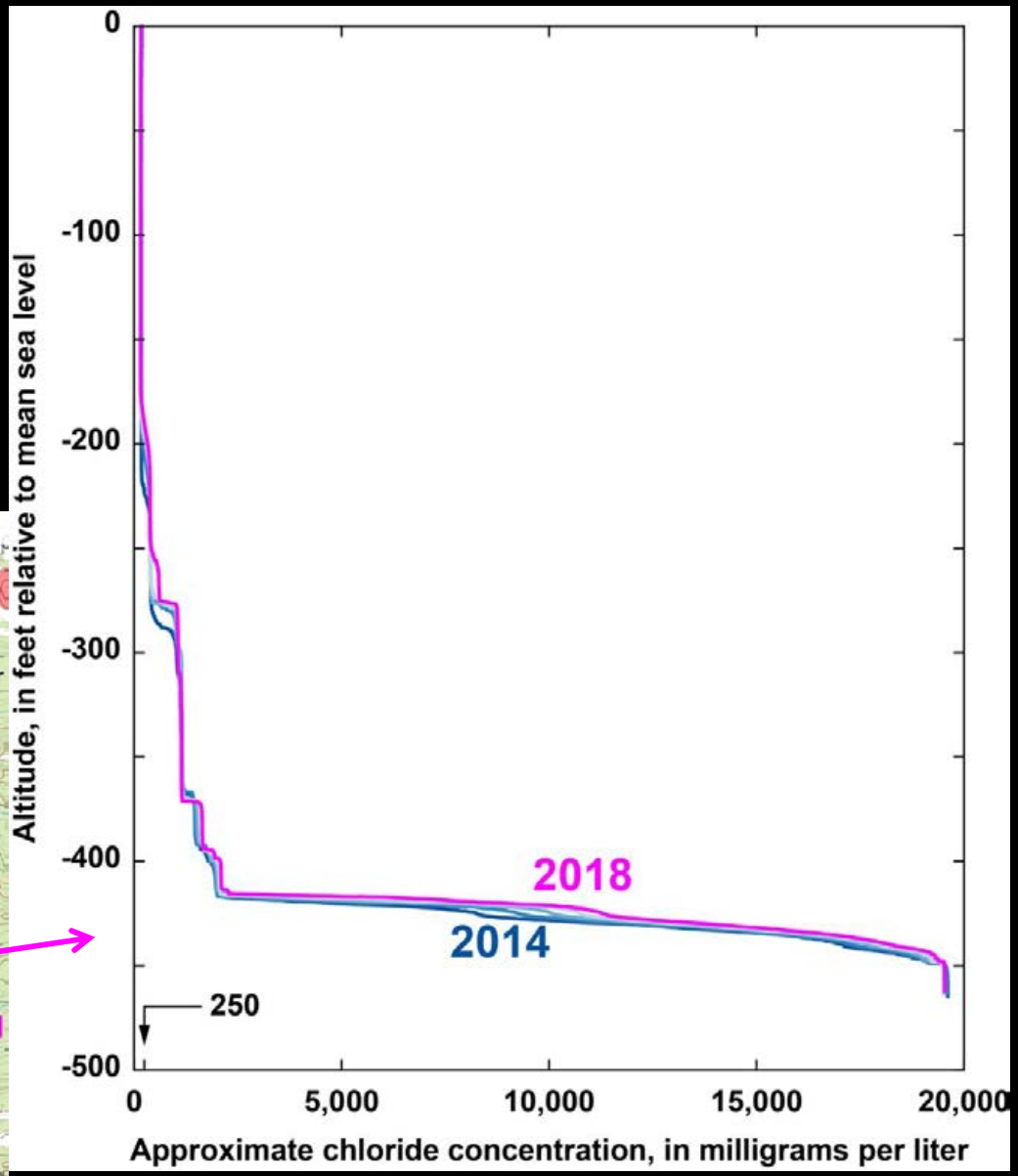
Salinity Profiles

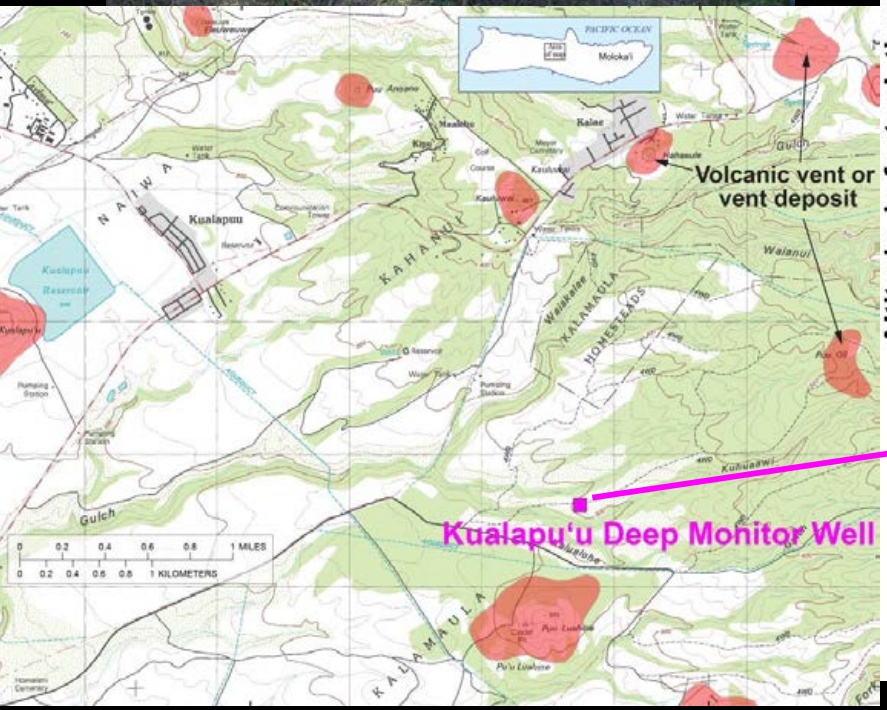


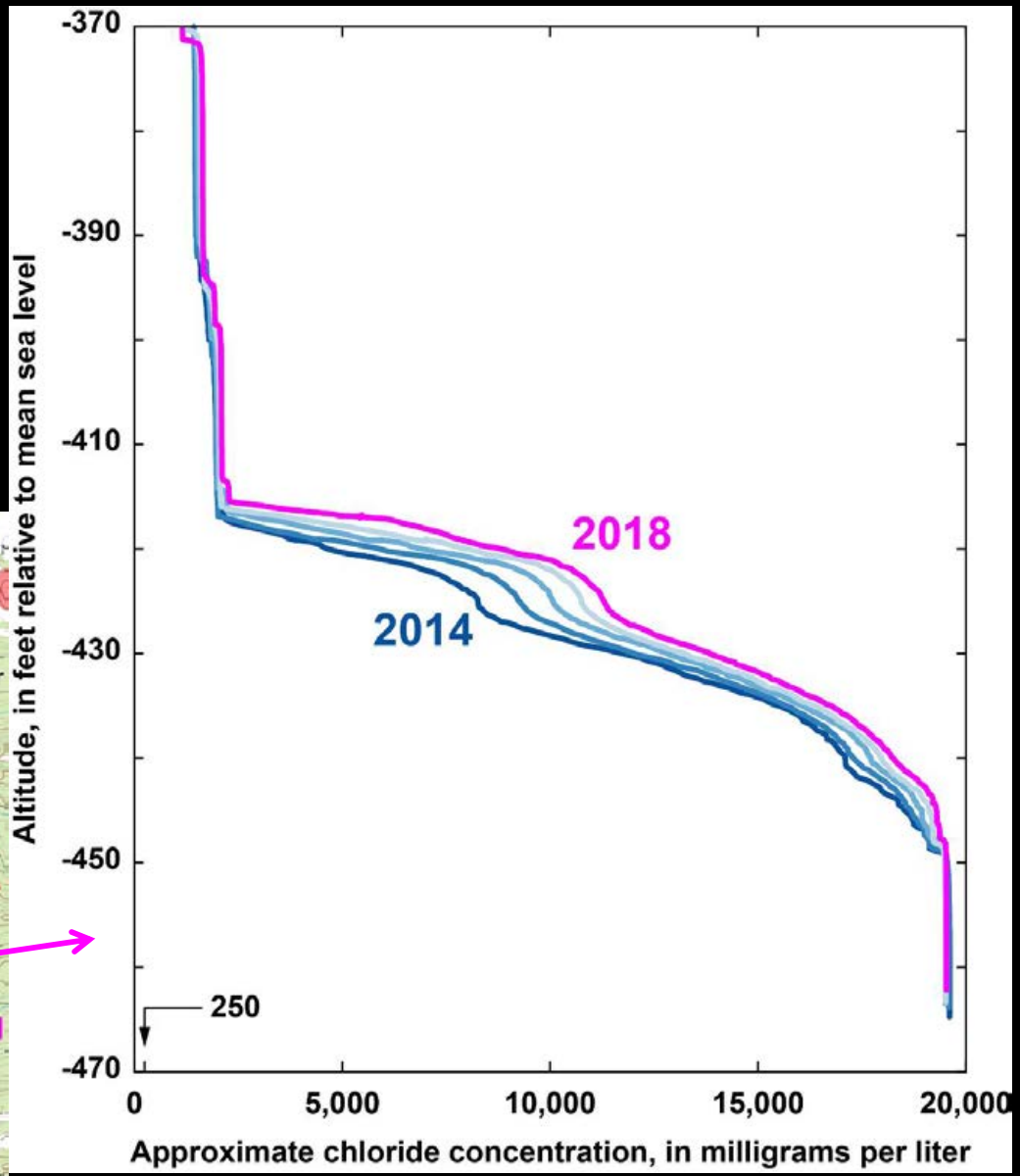
Groundwater Salinity



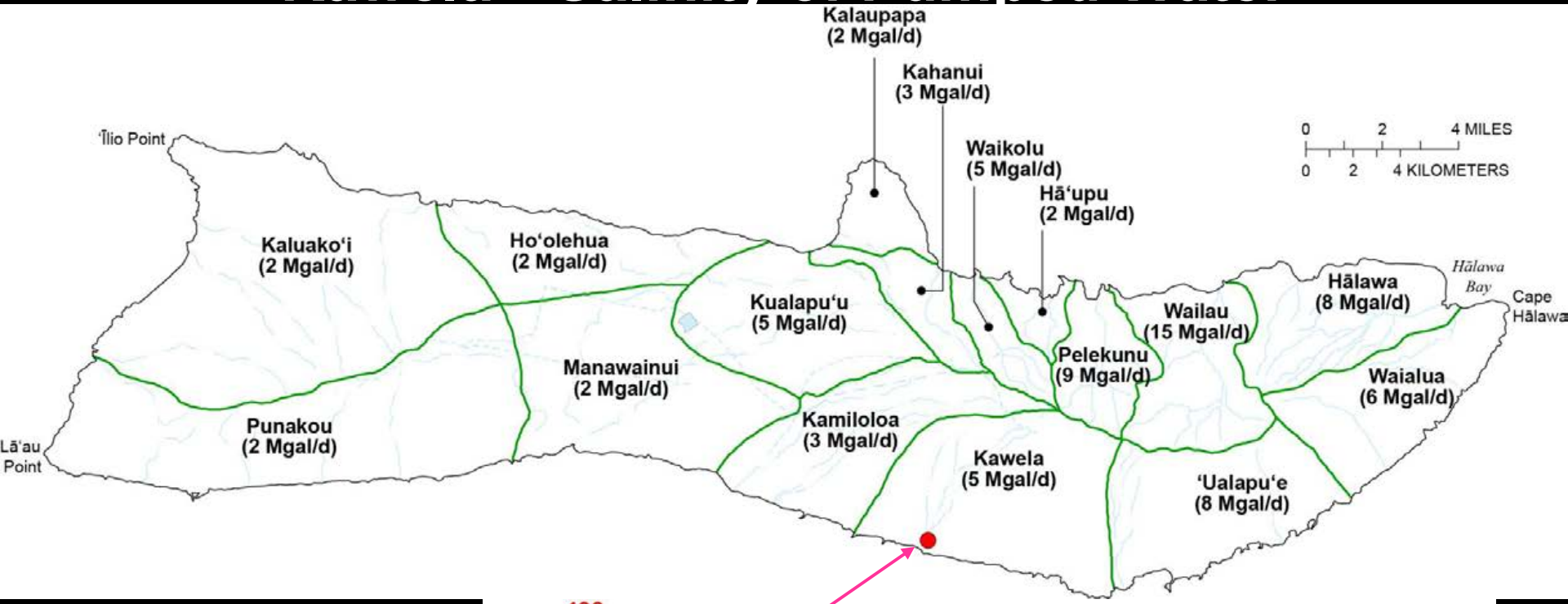


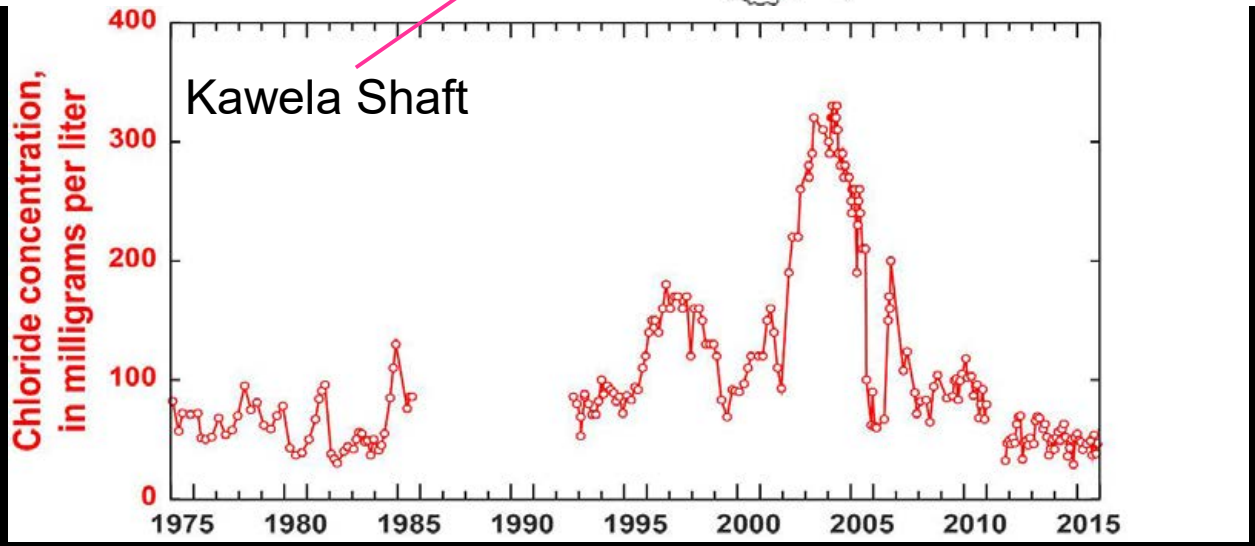
Groundwater Salinity





Kawela—Salinity of Pumped Water

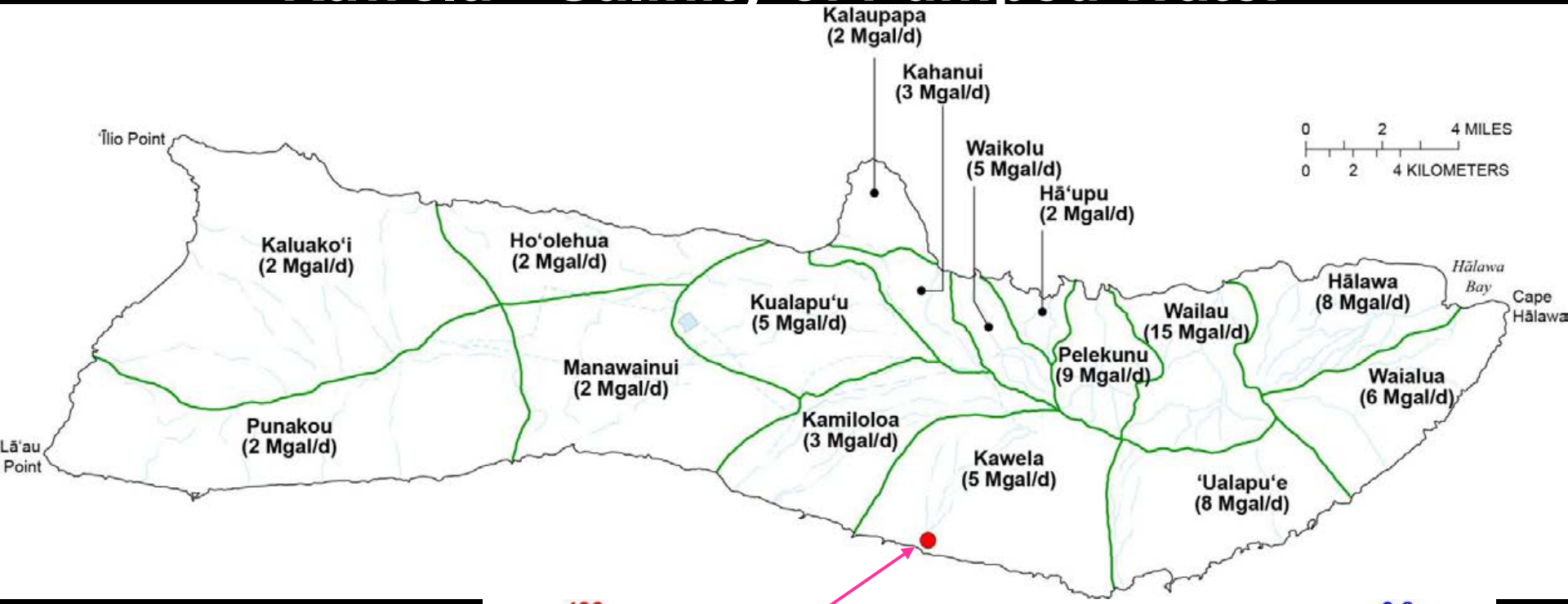


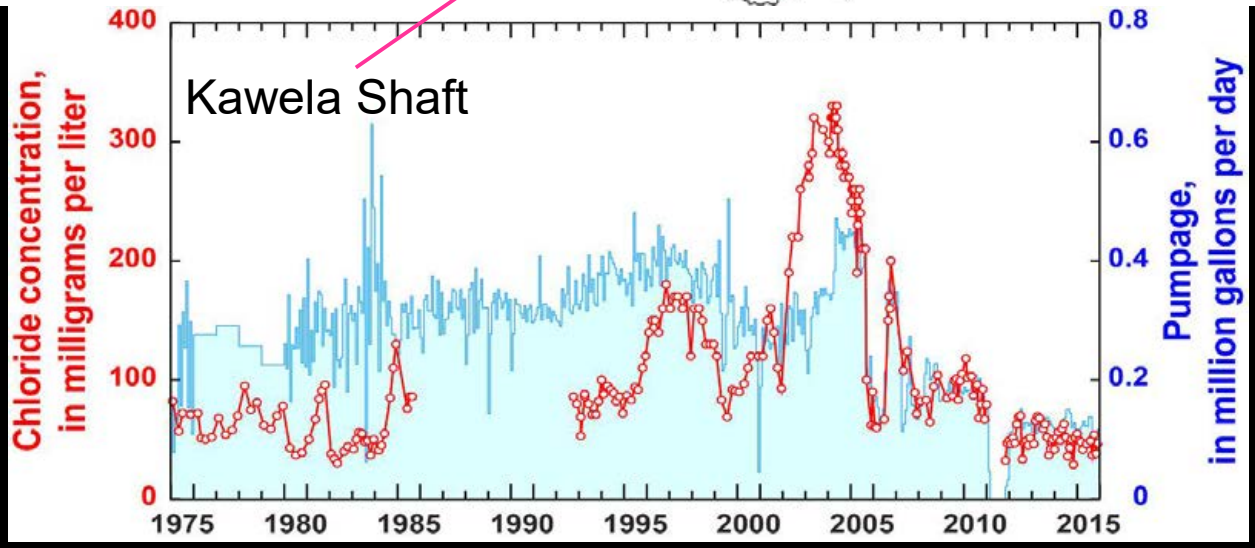


Data from Maui Department of Water Supply

USGS

Kawela—Salinity of Pumped Water





Data from Maui Department of Water Supply

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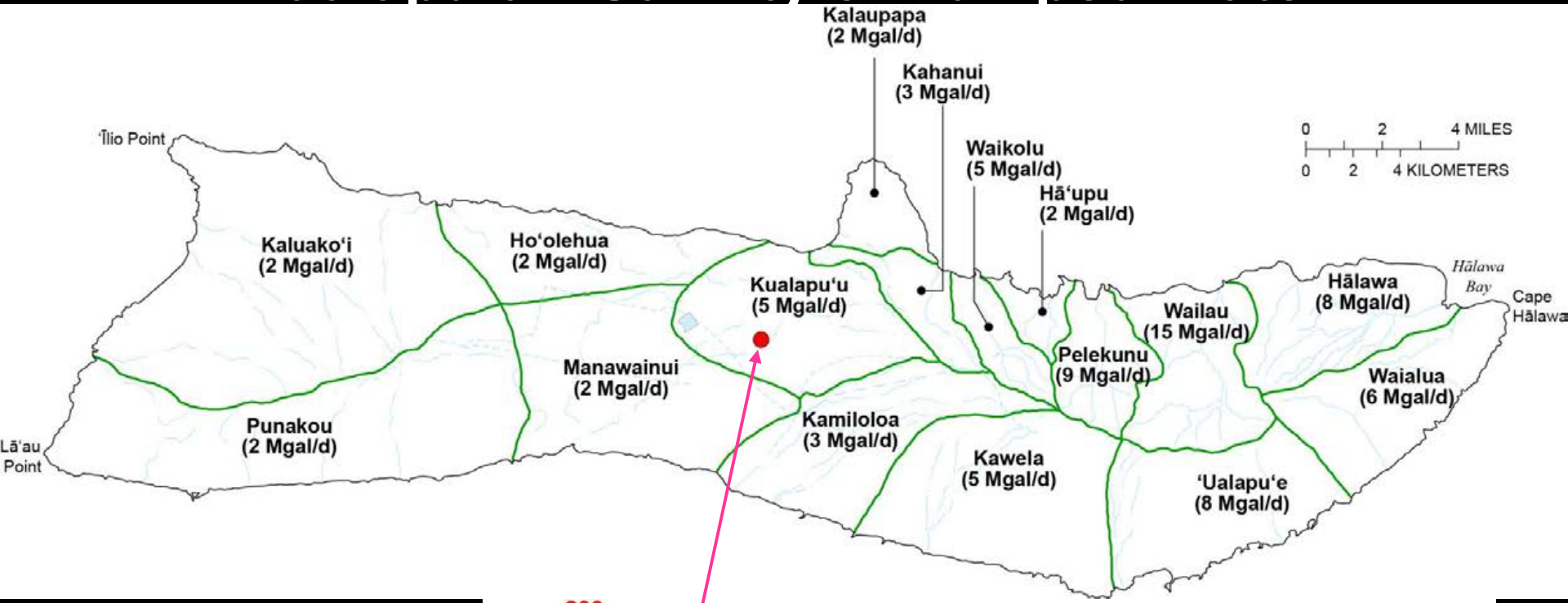
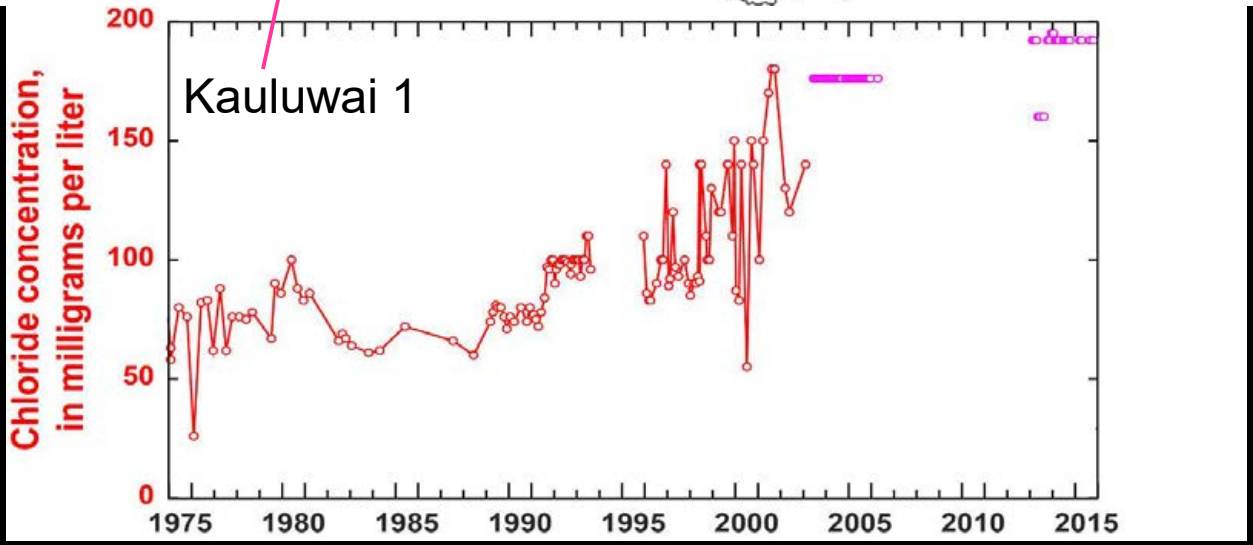
Kualapu‘u—Salinity of Pumped Water

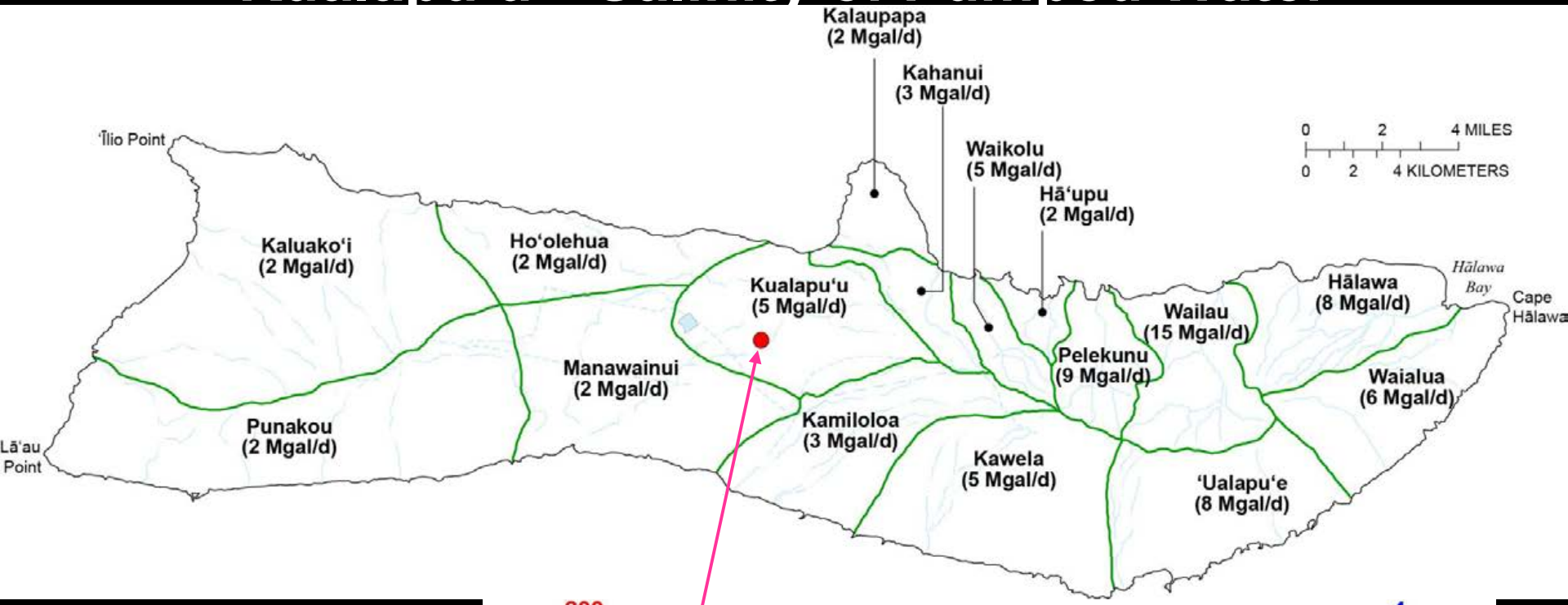


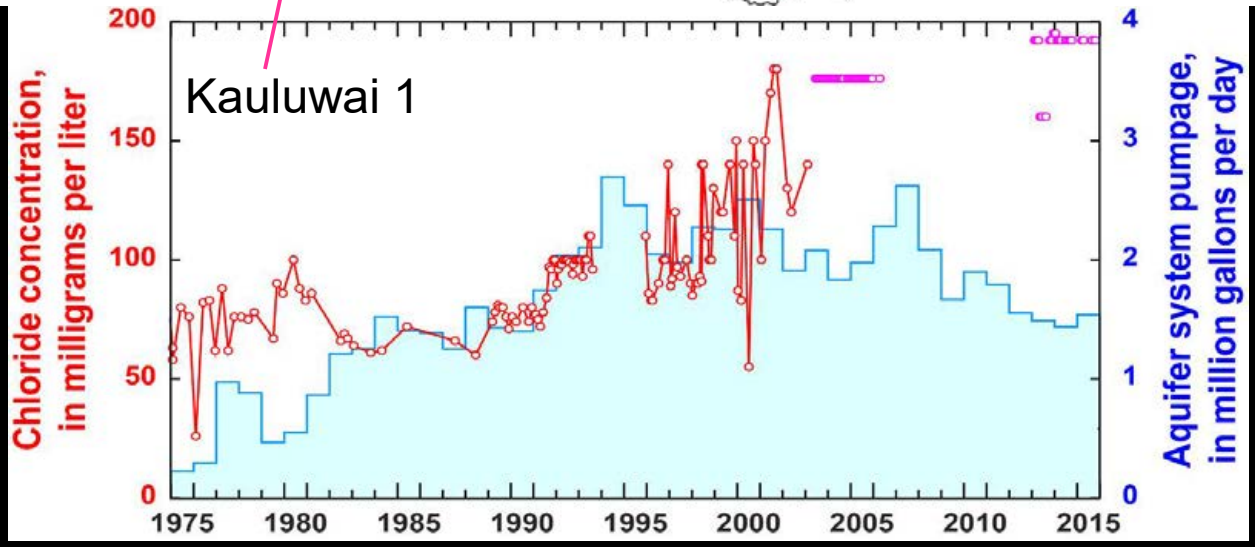


2003–15 chloride data from Hawai‘i Commission on Water Resource Management

USGS

Kualapu‘u—Salinity of Pumped Water





2003–15 chloride data and pumpage data from Hawai‘i Commission on Water Resource Management

USGS

Effects of Groundwater Withdrawals

Groundwater withdrawals can affect:

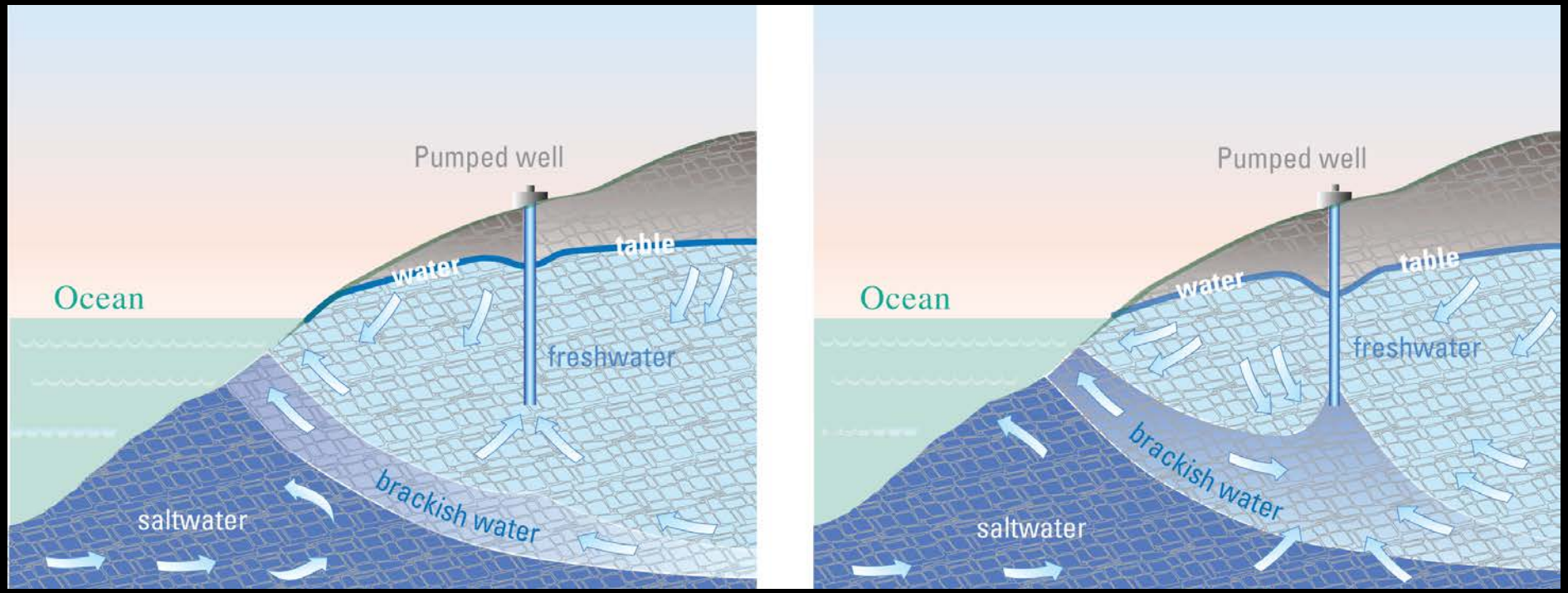
- Groundwater levels
- Thickness of freshwater lens
- Quality of water withdrawn from wells
- Natural discharge to streams and the nearshore environment

The magnitude of the effect is dependent on:

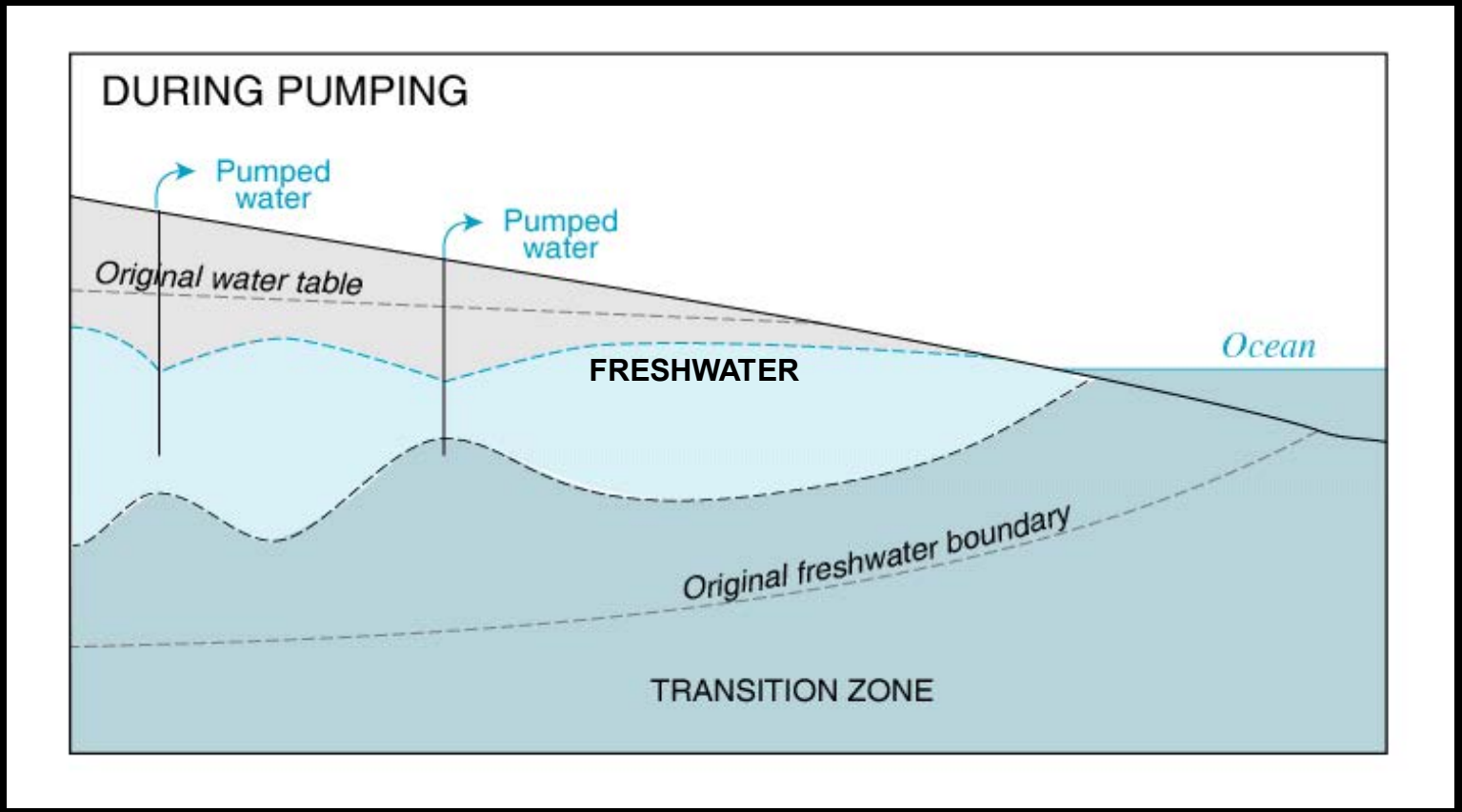
- Rate of groundwater withdrawal
- Where the groundwater is withdrawn

USGS

Groundwater Availability (Limited by Salinity)

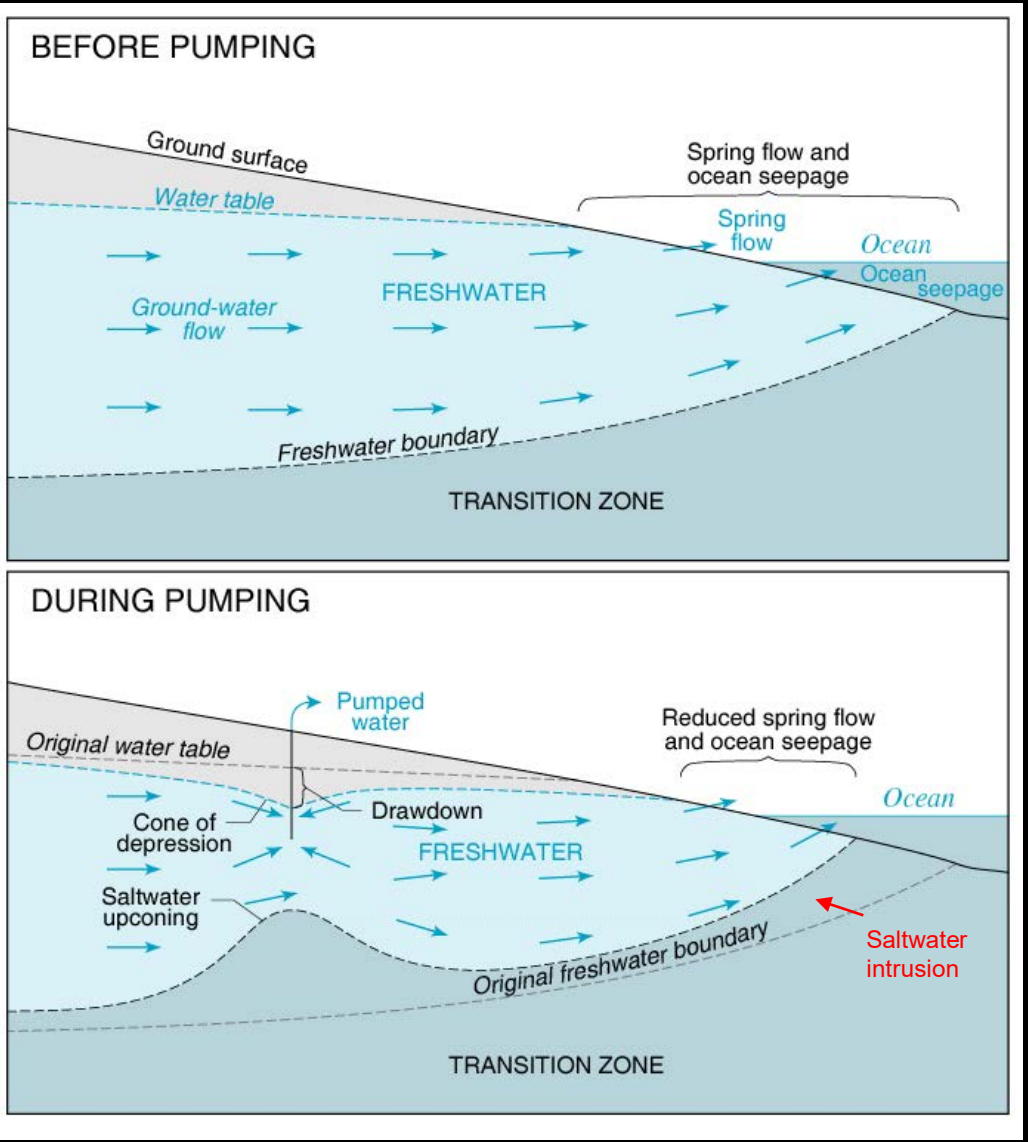


Pumping Can Affect Neighboring Wells



1. Increase salinity in another well
2. Lower water levels in another well

Pumping Reduces Natural Discharge



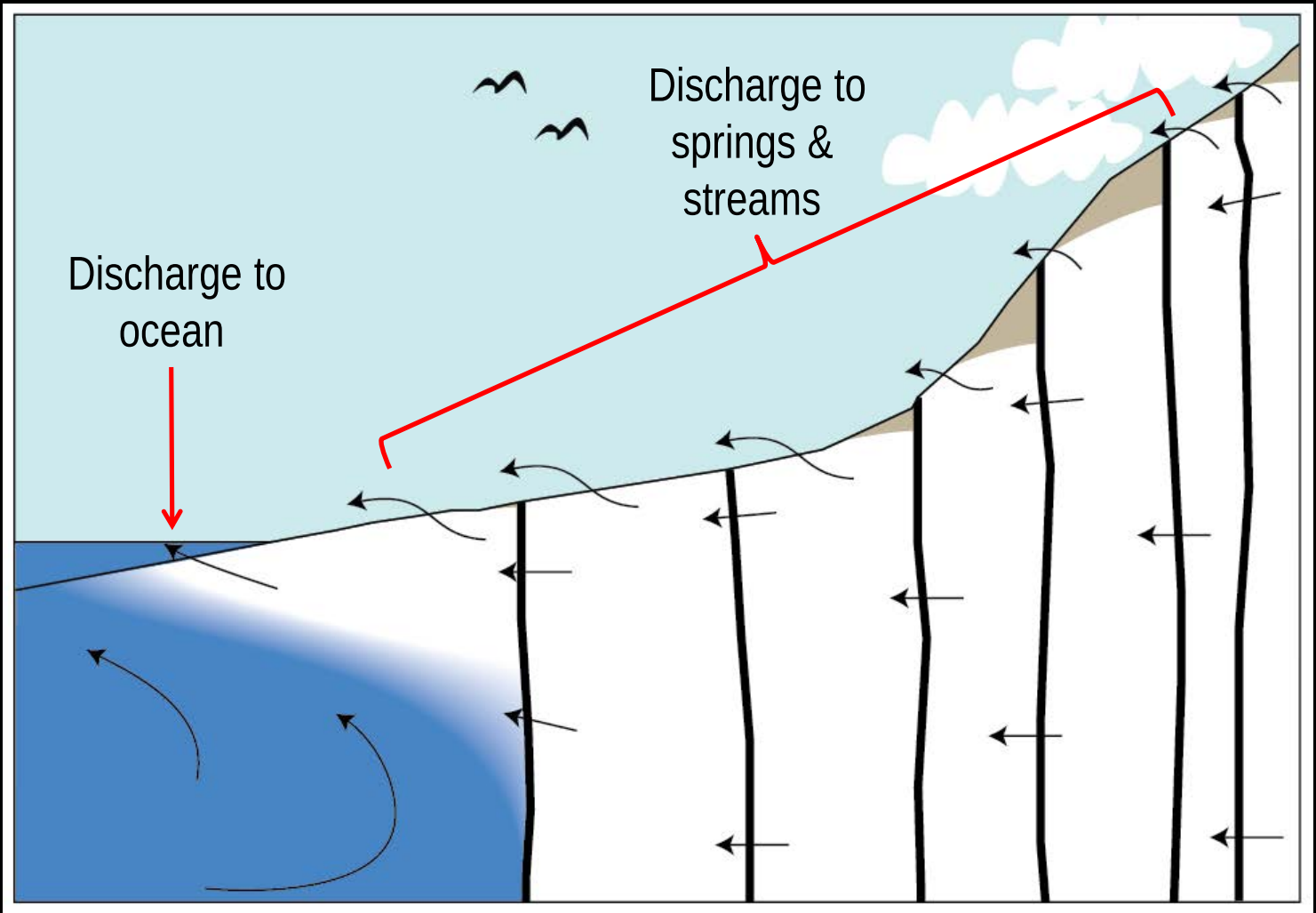
NATURAL EQUILIBRIUM

recharge = natural discharge

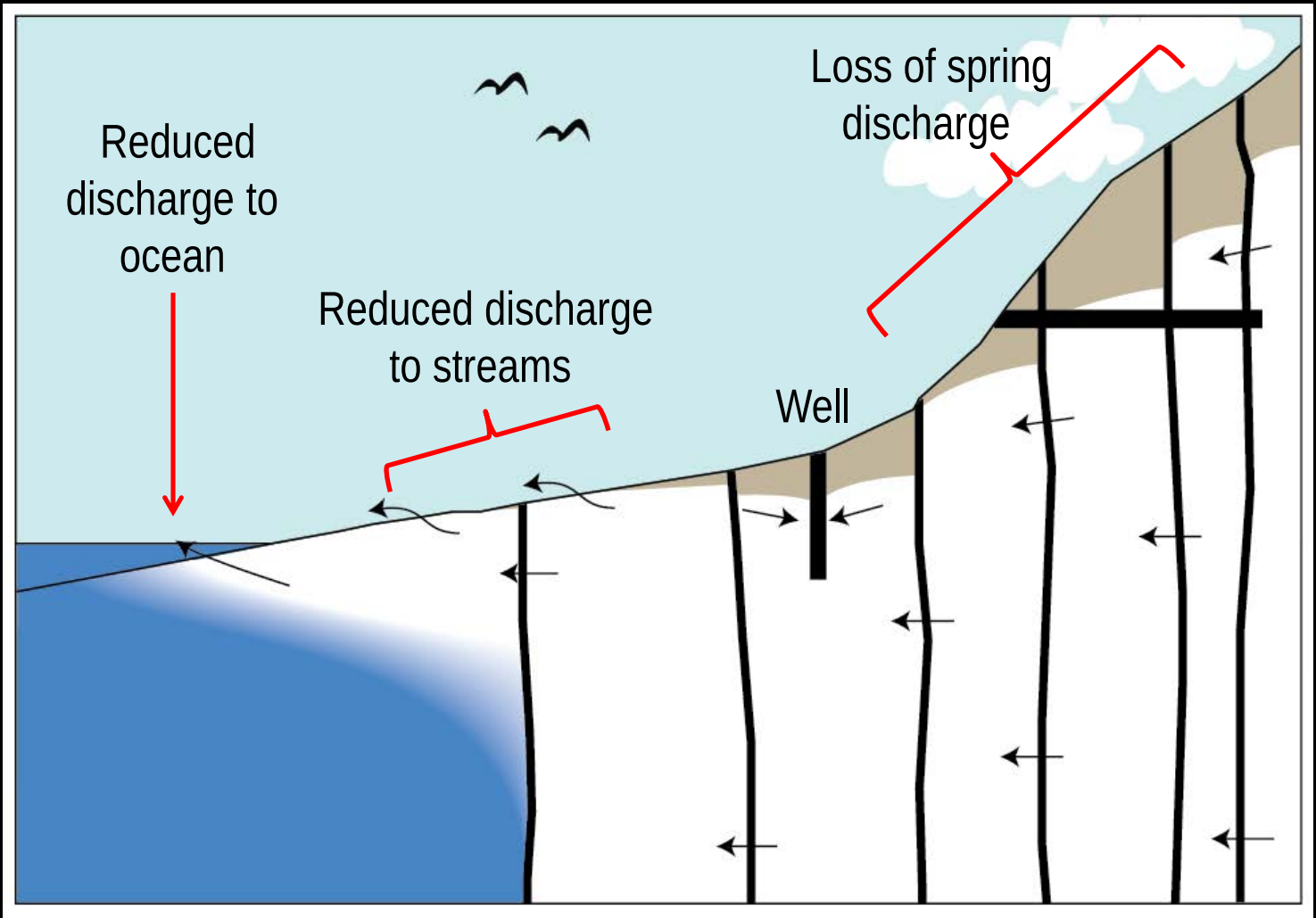
NEW EQUILIBRIUM

recharge = natural discharge + pumpage

Pumping Can Affect Streamflow



Pumping Can Affect Streamflow

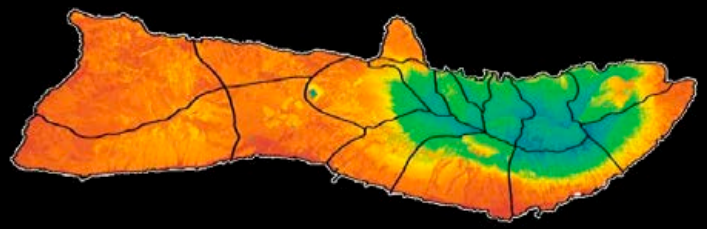


USGS Study Objective

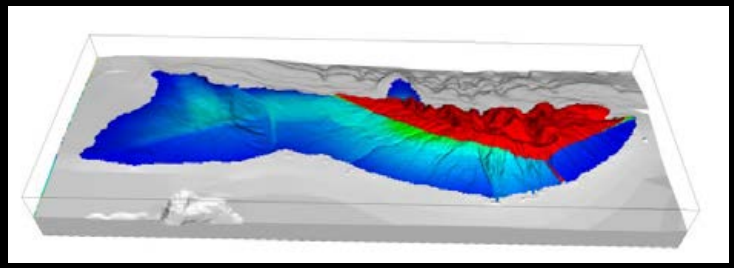
- Overall objective is to evaluate groundwater availability in central Molokaʻi
- Meet objective by developing a numerical groundwater model capable of quantifying changes in salinity and flow to nearshore areas
- Numerical model used to simulate selected withdrawal scenarios developed with input from State and County agencies

USGS Study

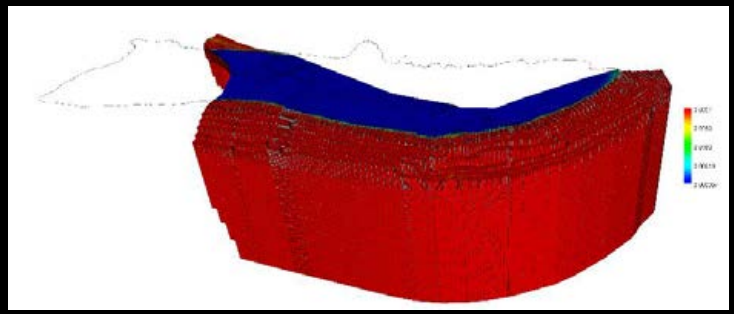
1. Collect data from wells



2. Update recharge estimates using latest data and tools



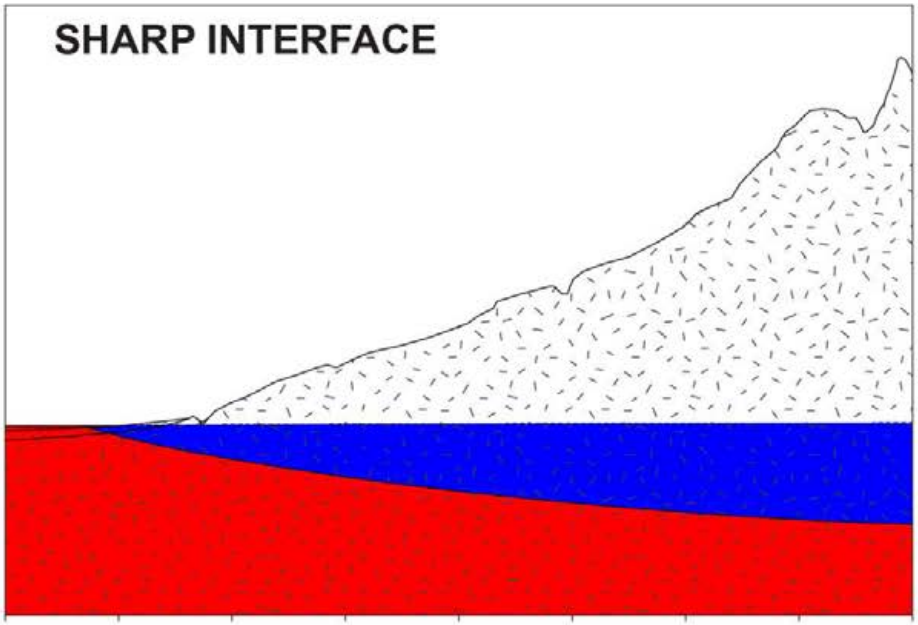
3. Construct 2D island-wide numerical model to estimate inflows to main area of interest



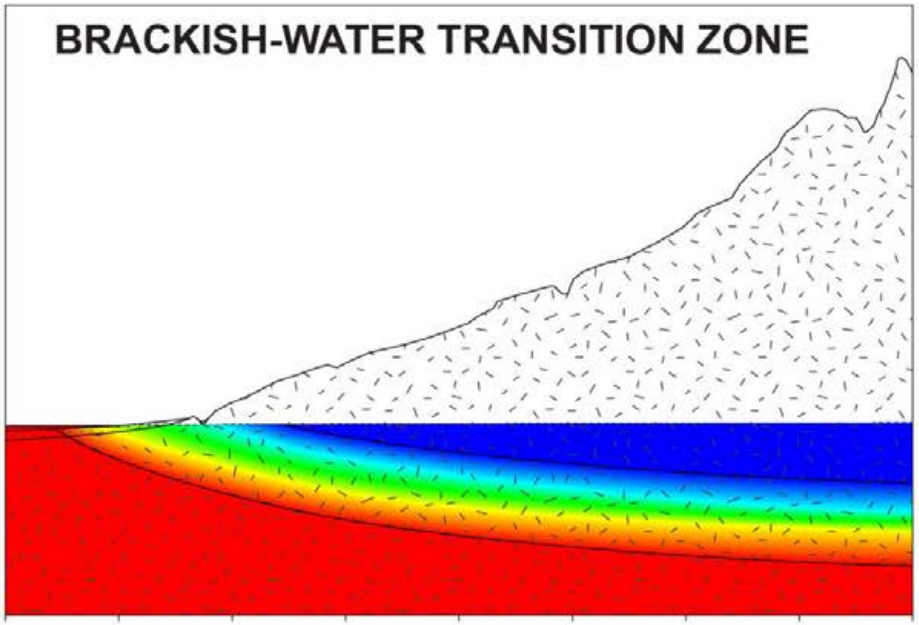
4. Develop 3-D numerical model capable of simulating salinity of groundwater

Groundwater Models for USGS Study

2D island-wide model



3D regional model

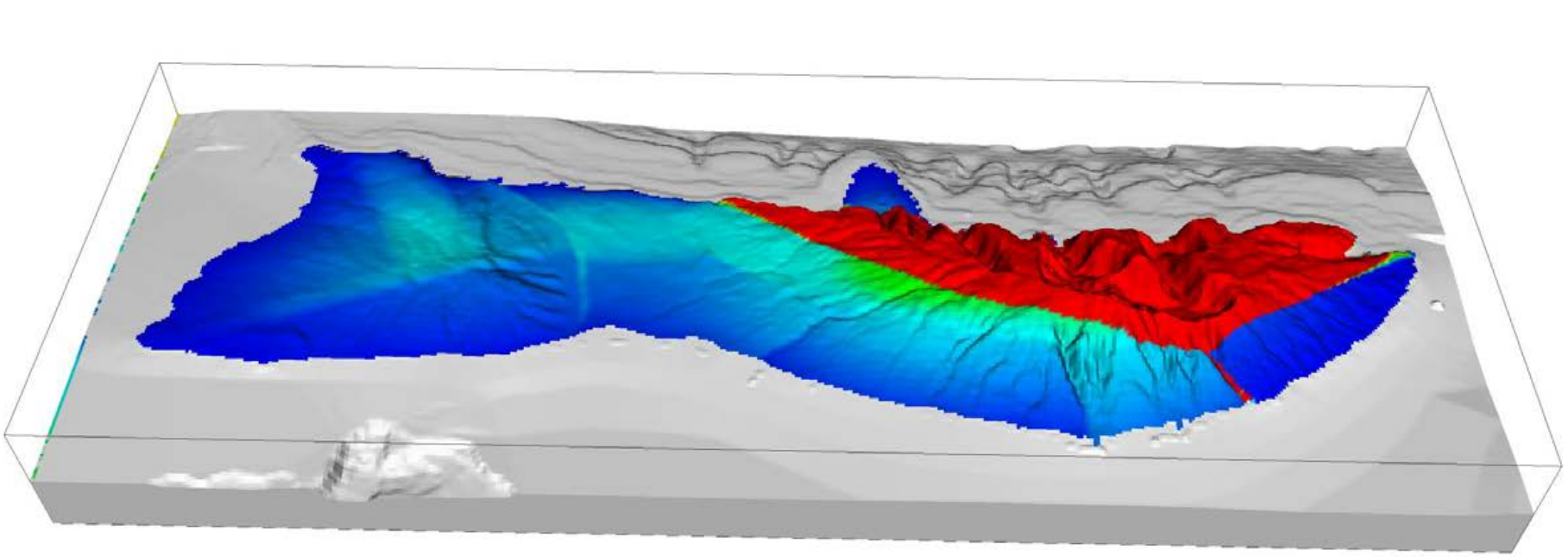


FRESHWATER

BRACKISH WATER

SALTWATER

Numerical (Computer) Groundwater Model

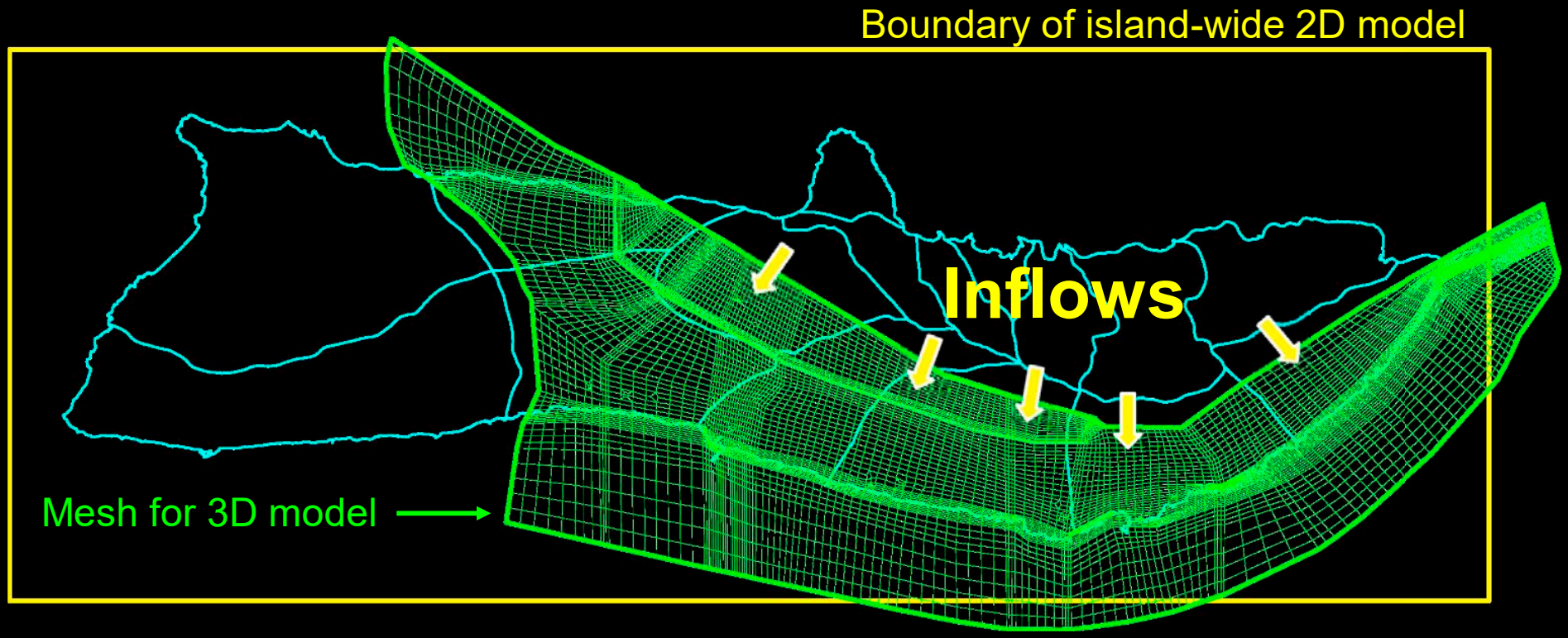


Requires:

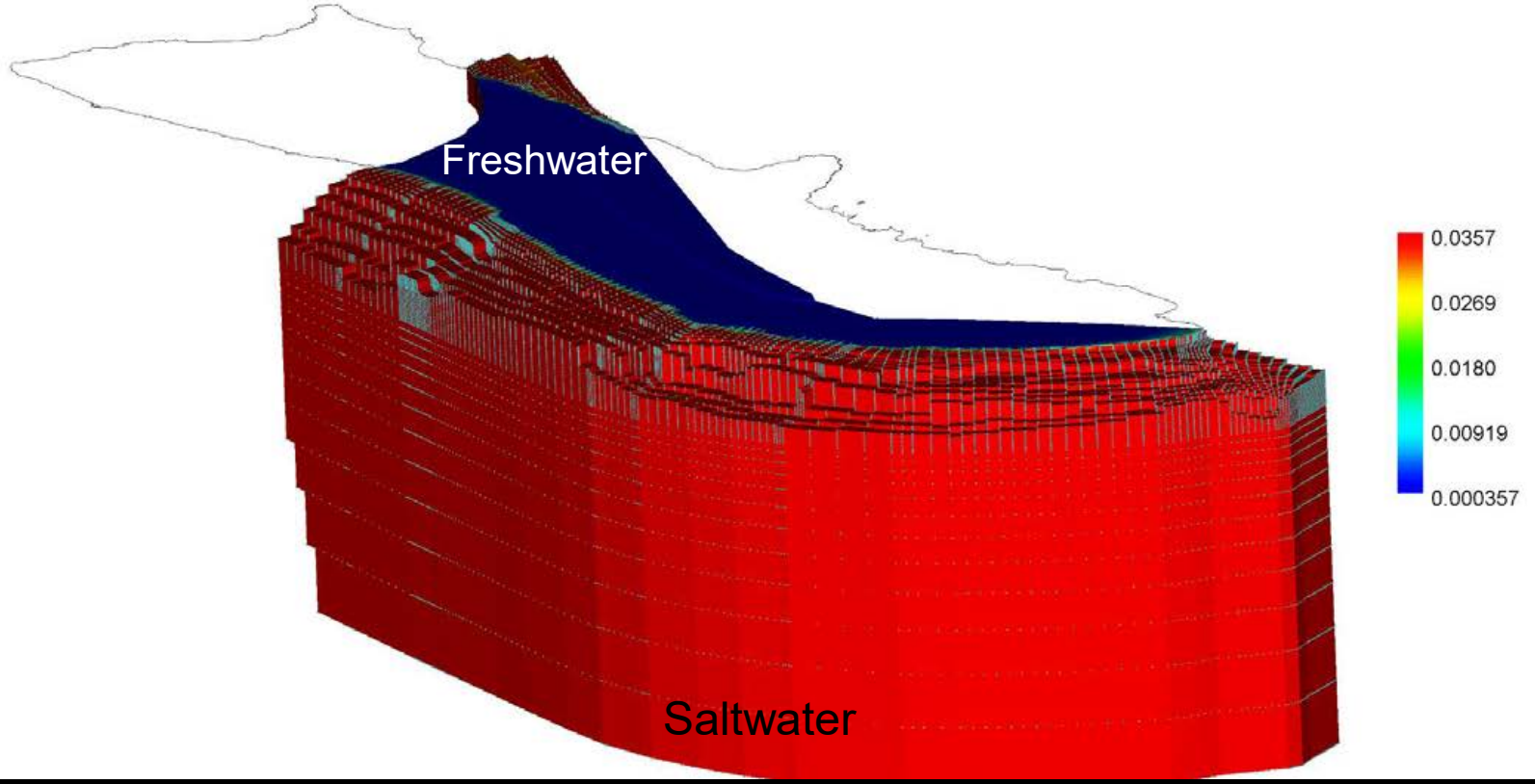
- Data on groundwater levels (and possibly salinity)
- Estimates of recharge
- Estimates of rock properties
- Understanding of hydrogeological setting

USGS

Numerical Models

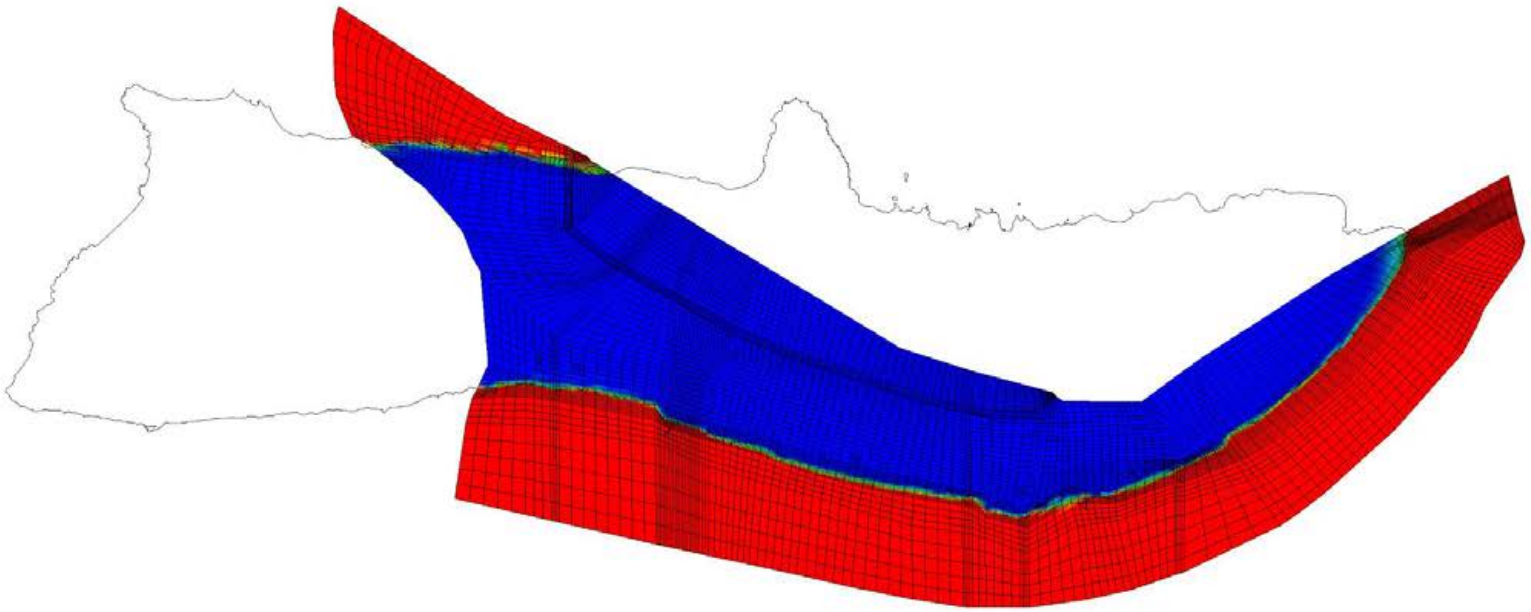


Study Area 3-D Model—Oblique View



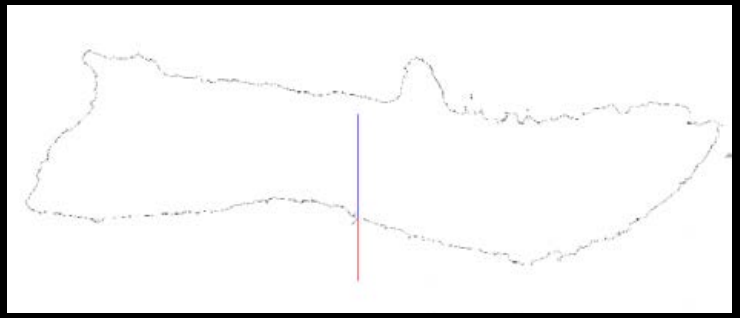
- Island-wide 2-D model does not simulate transition zone
- Study-area 3-D model simulates salinity variations

1940-2012 Animation of Freshwater Volume

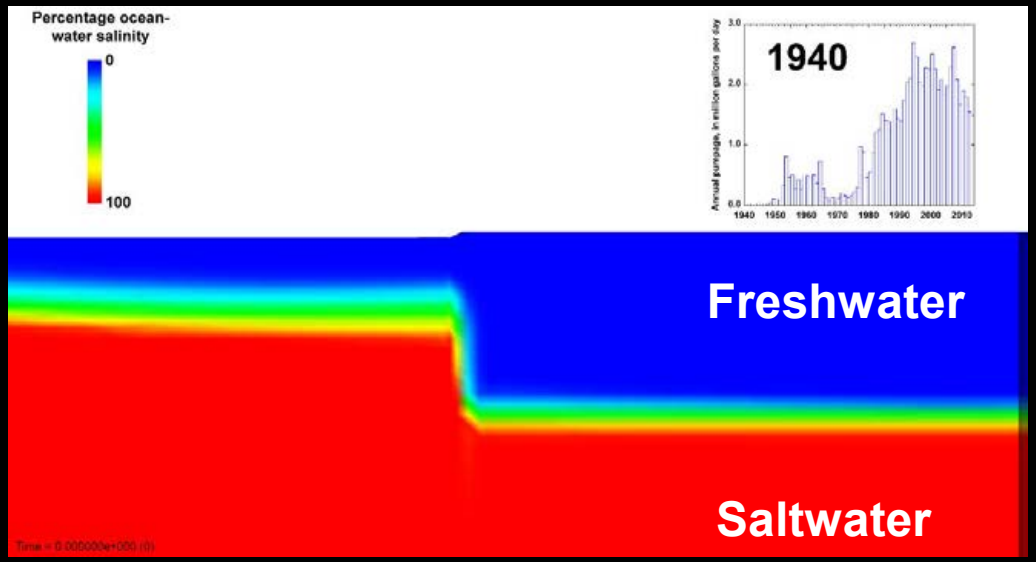


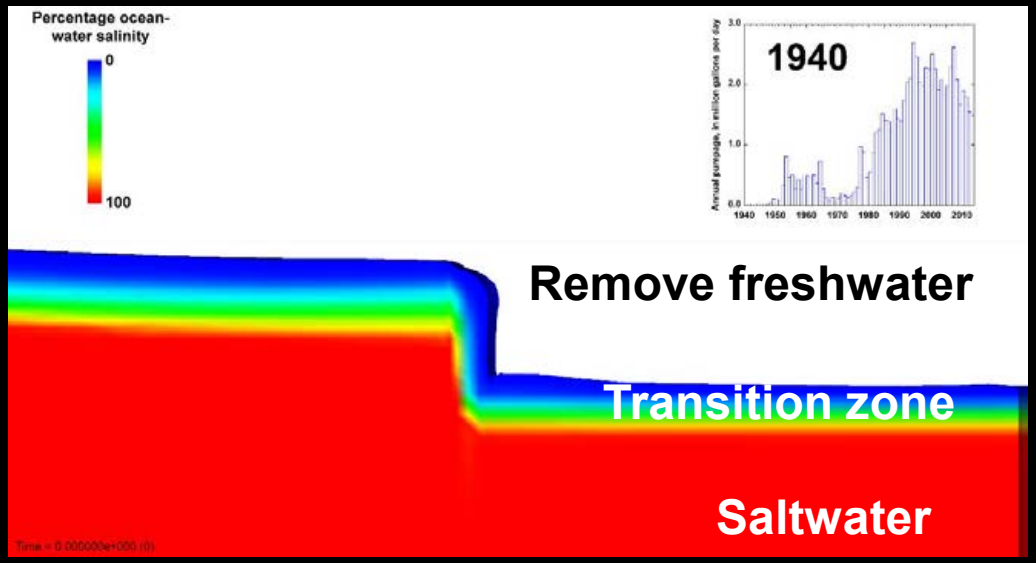
Time = 0.000000e+000 (0)

1940-2012 Animation Explanation



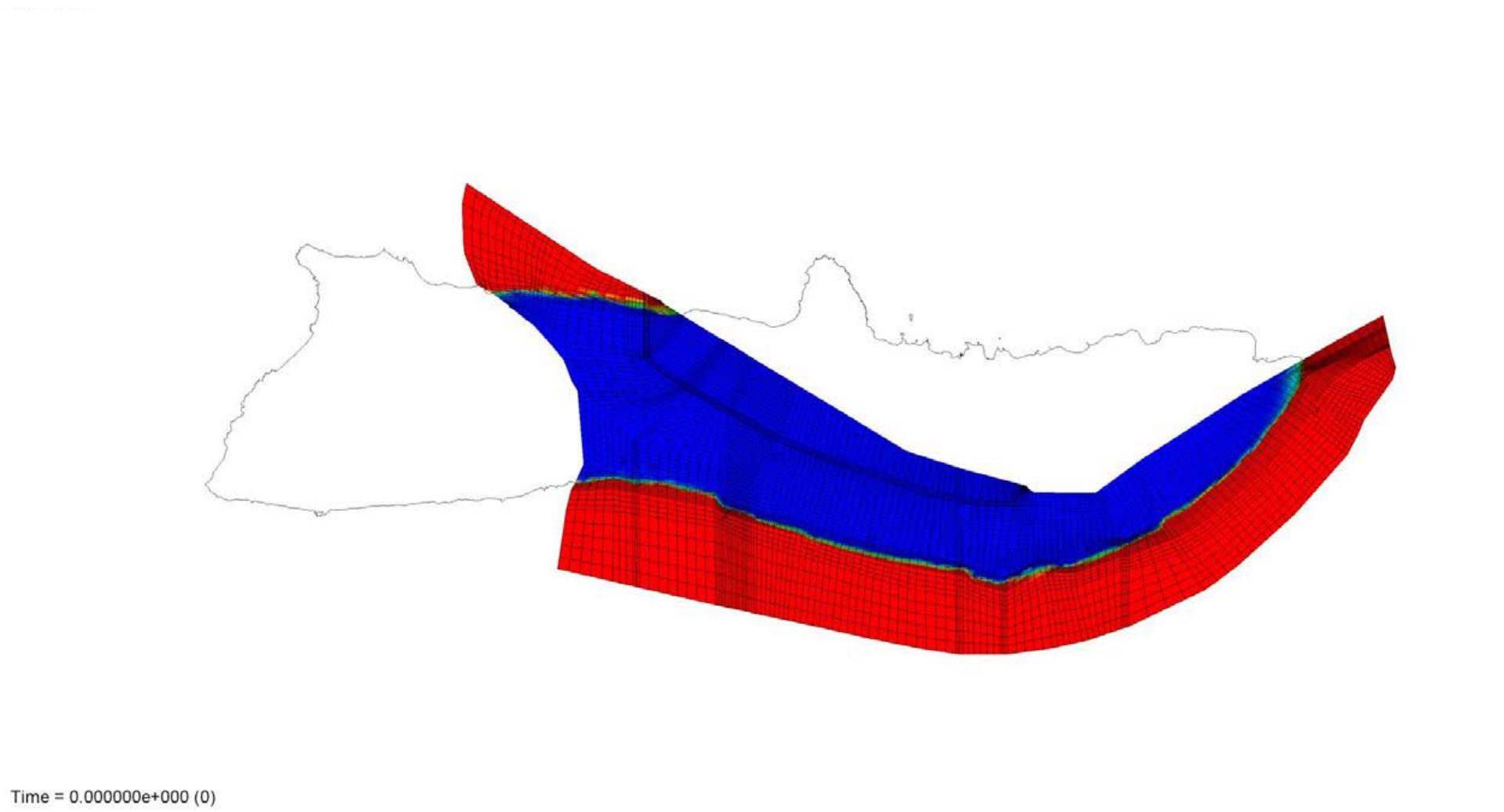
Cross section (slice of aquifer) view from top



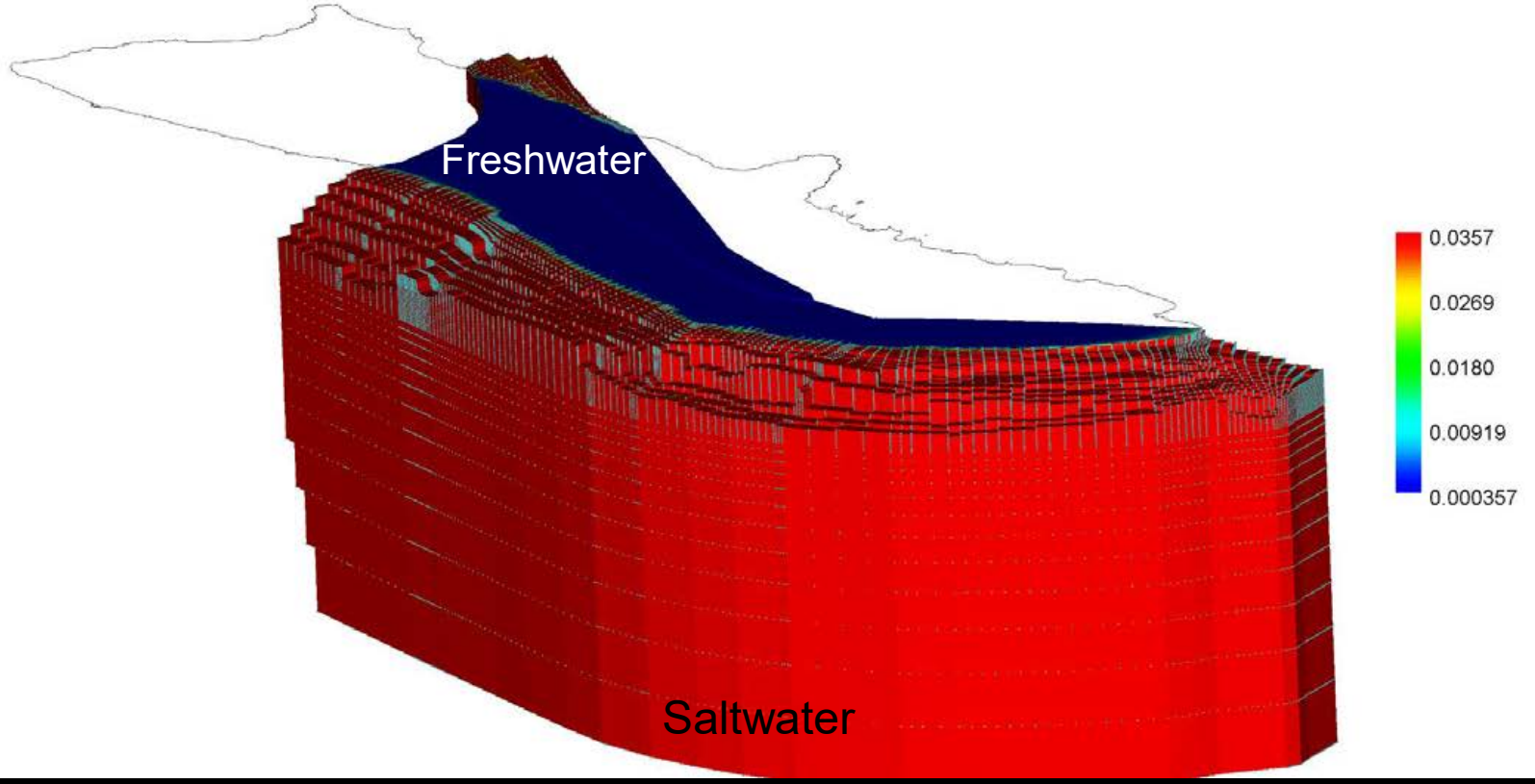


Cross section—view from side (east to west)

1940-2012 Animation of Freshwater Volume



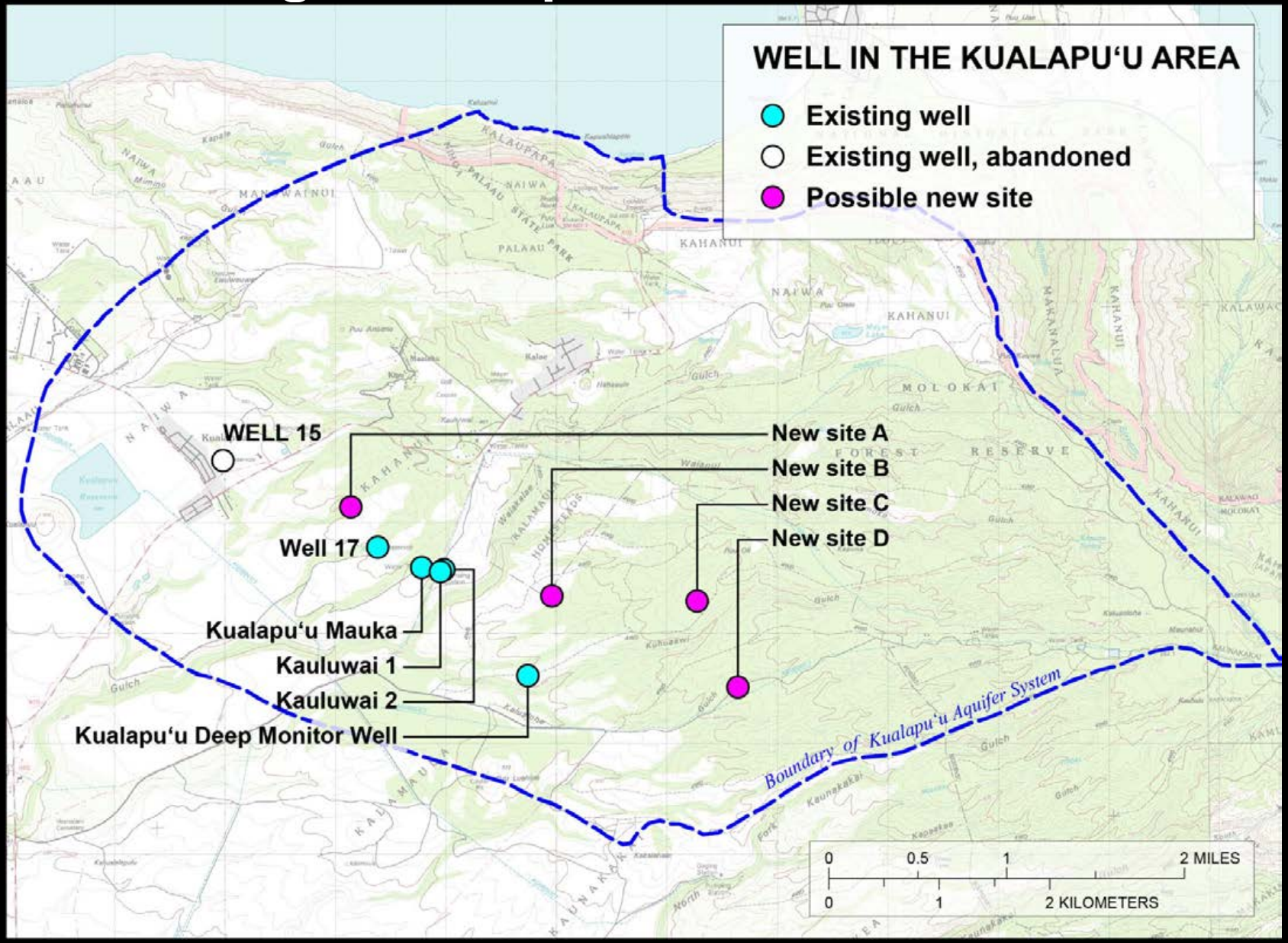
Application of Model



- Quantify changes in salinity
- Quantify changes in discharge to nearshore areas

USGS

Existing and Proposed Wells Considered



Summary of Scenarios Tested

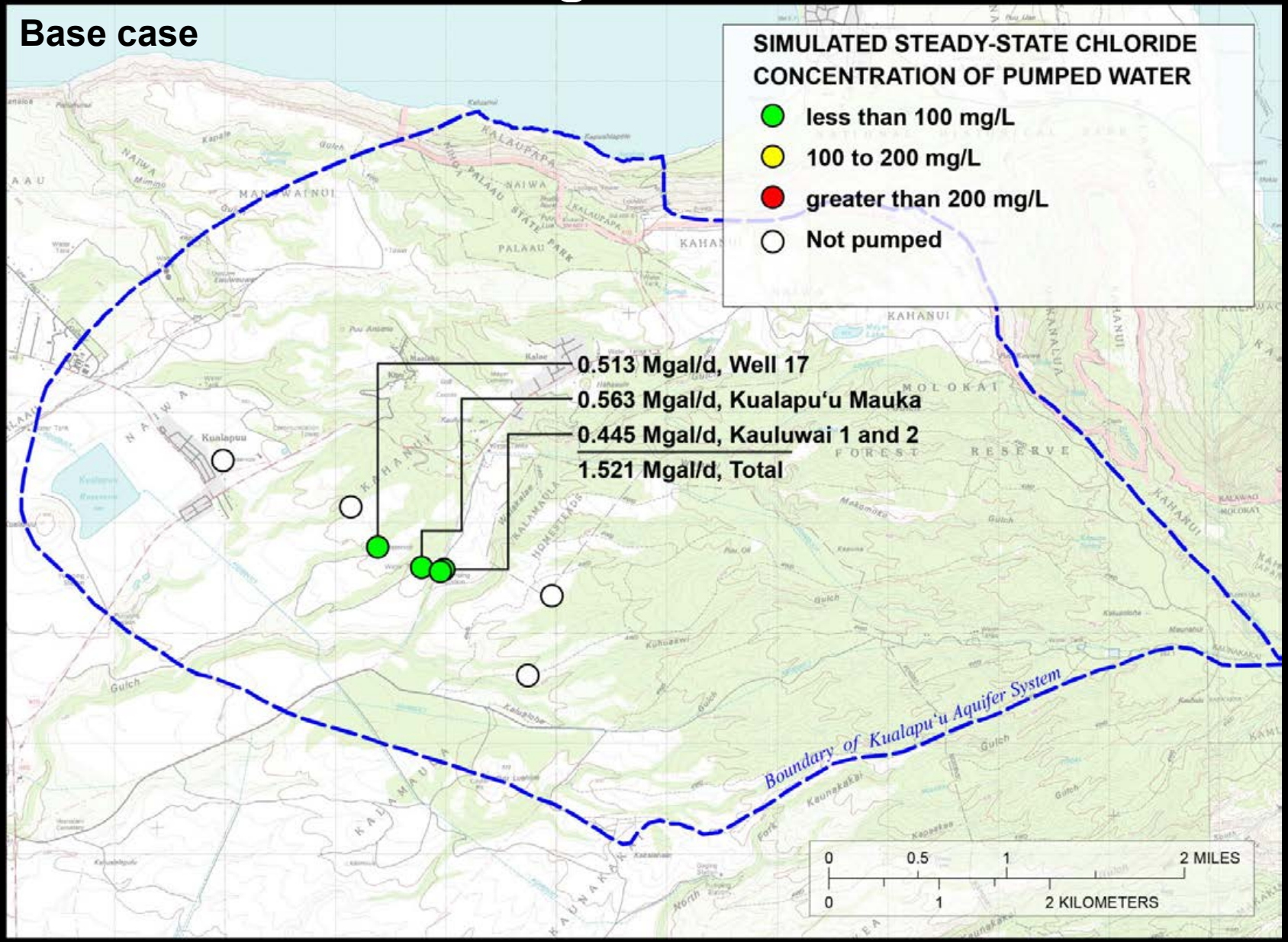
Table 1. Withdrawal rates used in the modeled scenarios, Kualapu‘u, Moloka‘i

Scenario	Withdrawal rate, in million gallons per day							
	Kauluwai 1, 0801-01	Kauluwai 2, 0801-02	Kualapu‘u Mauka, 801-03	Well 17, 0901-01	New site A	New site B	New sites C and D	Total
1. Average 2016–17 withdrawals	0.0897	0.3556	0.5634	0.5128	--	--	--	1.5215
2. Pending water-use permit (WUP) rates	--	0.6370	0.9000	1.1440	--	--	--	2.6810
3. Well 17 public-trust rate; New site B	--	0.5950	0.9500	0.1380	--	0.7926	--	2.4756
4. Well 17 pending WUP rate; New site B	--	0.5950	0.9500*	1.1440	--	0.7926	--	3.4816
5. Well 17 public-trust rate; New sites A and B	--	0.5950	--	0.1380	0.9500	0.7926	--	2.4756
6. Well 17 pending WUP rate; New sites A and B	--	0.5950	--	1.1440*	0.9500	0.7926	--	3.4816
7. Well 17 pending WUP rate; Switch sites A and B	--	0.5950	--	1.1440	0.7926	0.9500	--	3.4816
8. Spread out withdrawals	--	0.5950	--	1.1440	--	0.9500	1.7926	4.4816
9. Same as 6, but reduce recharge by 15 percent	--	0.5950*	--	1.1440*	0.9500*	0.7926	--	3.4816

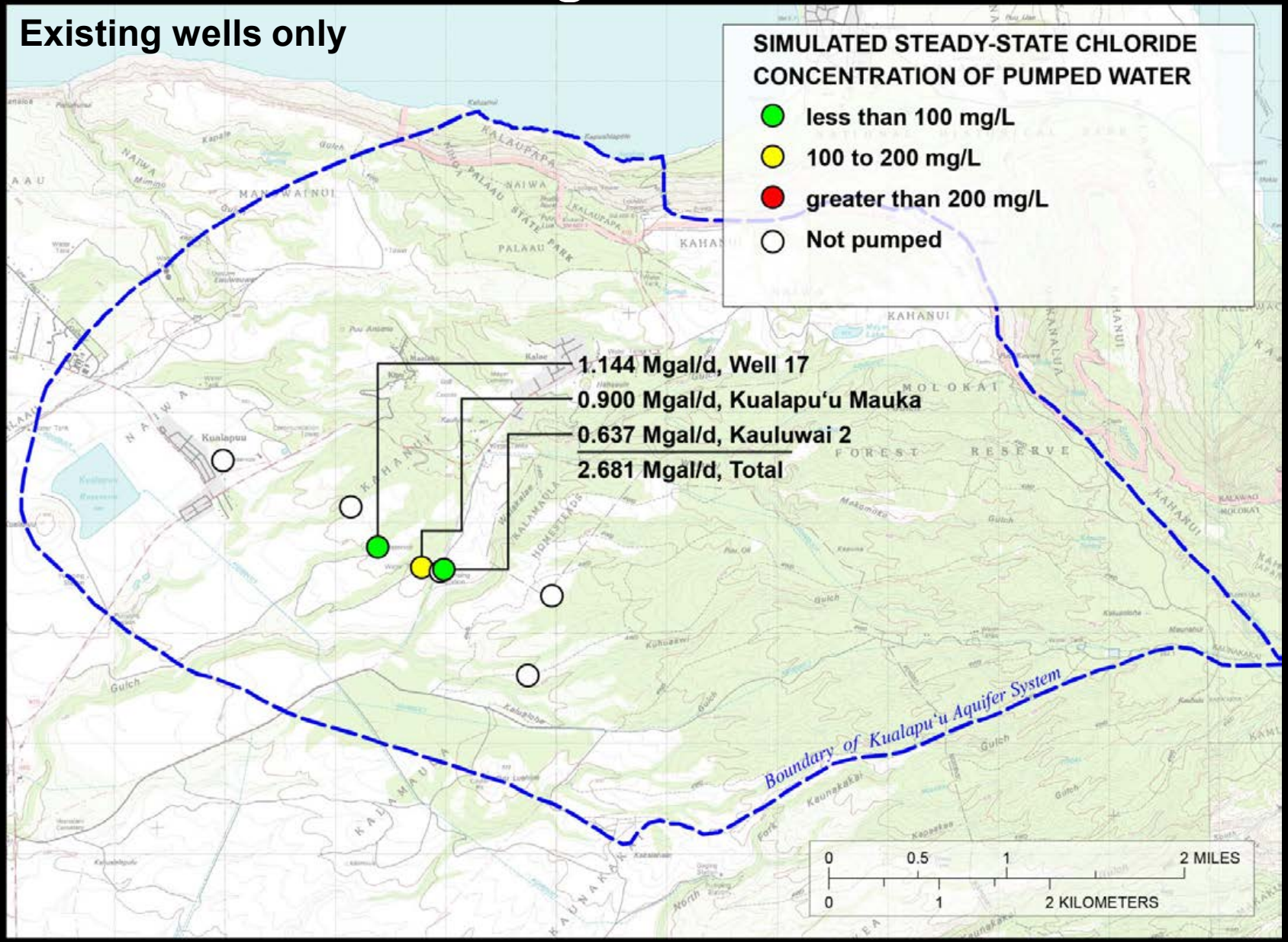
Colors indicate the following simulated chloride (Cl) concentrations, in mg/L: **Green, Cl< 100**; **Yellow, 100≤Cl≤200**; **Red, Cl>200**

*Chloride concentration exceeds 250 mg/L

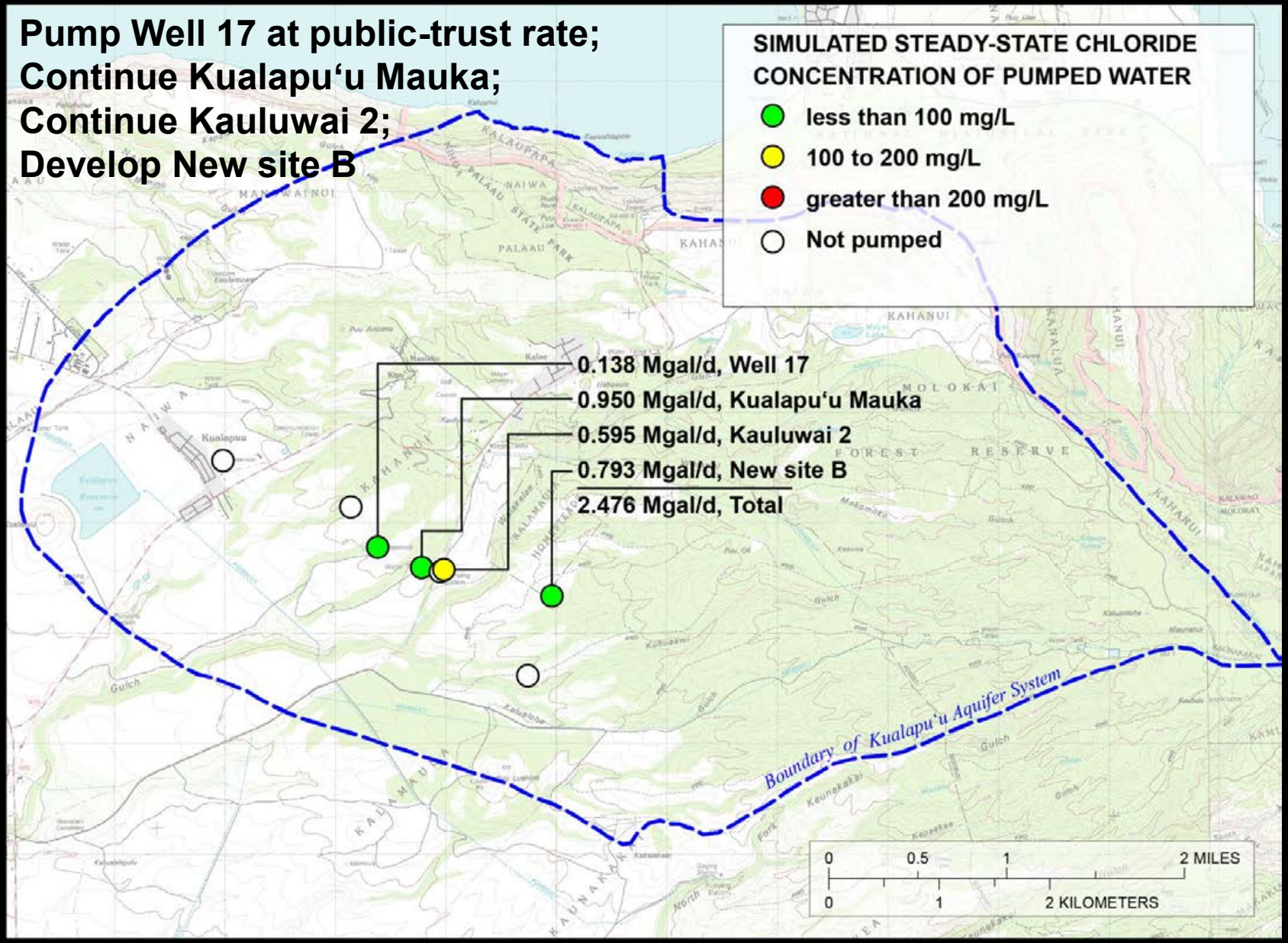
Scenario 1. Average 2016–17 Withdrawals



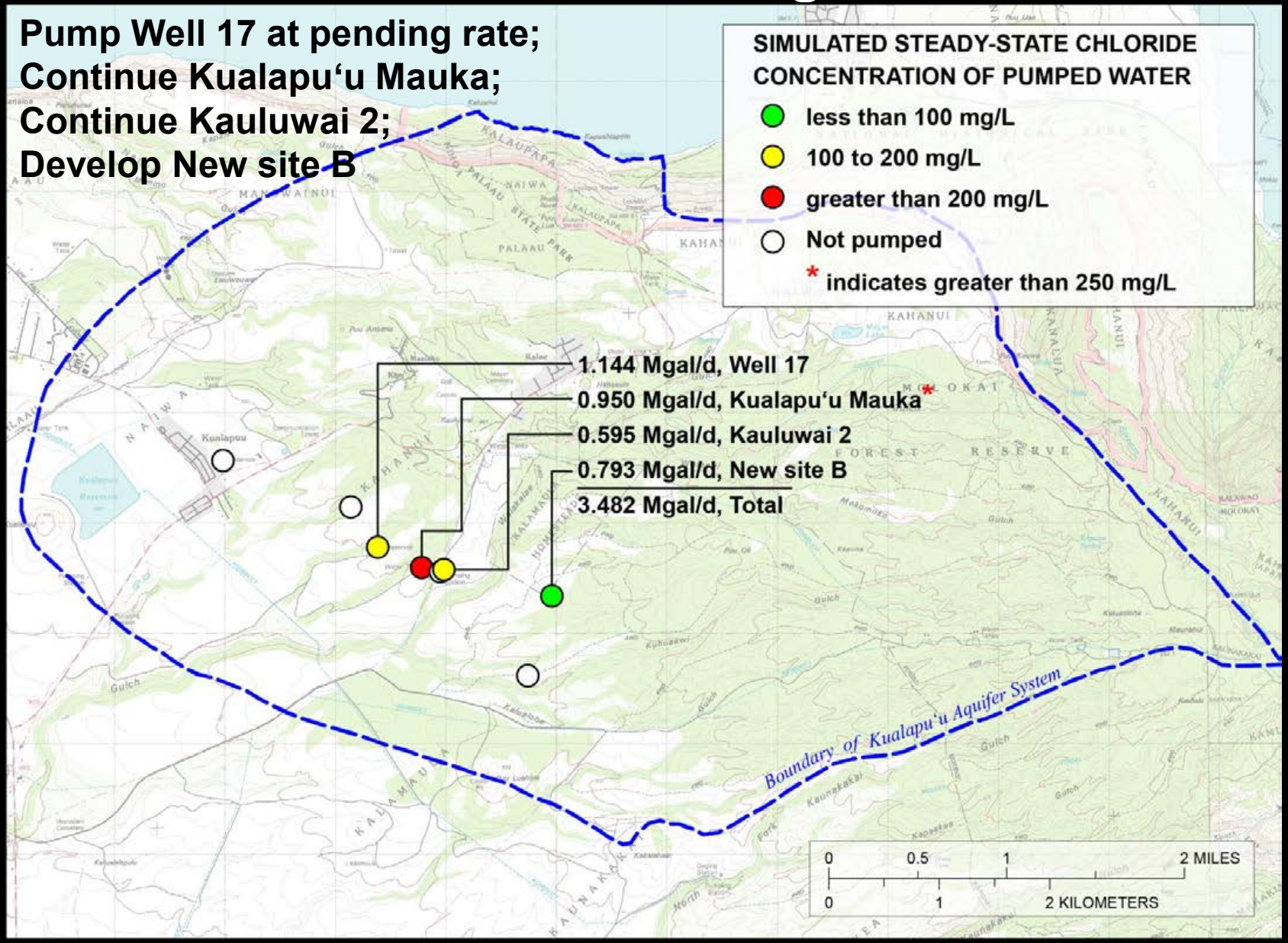
Scenario 2. Pending Water-Use Permit Rates



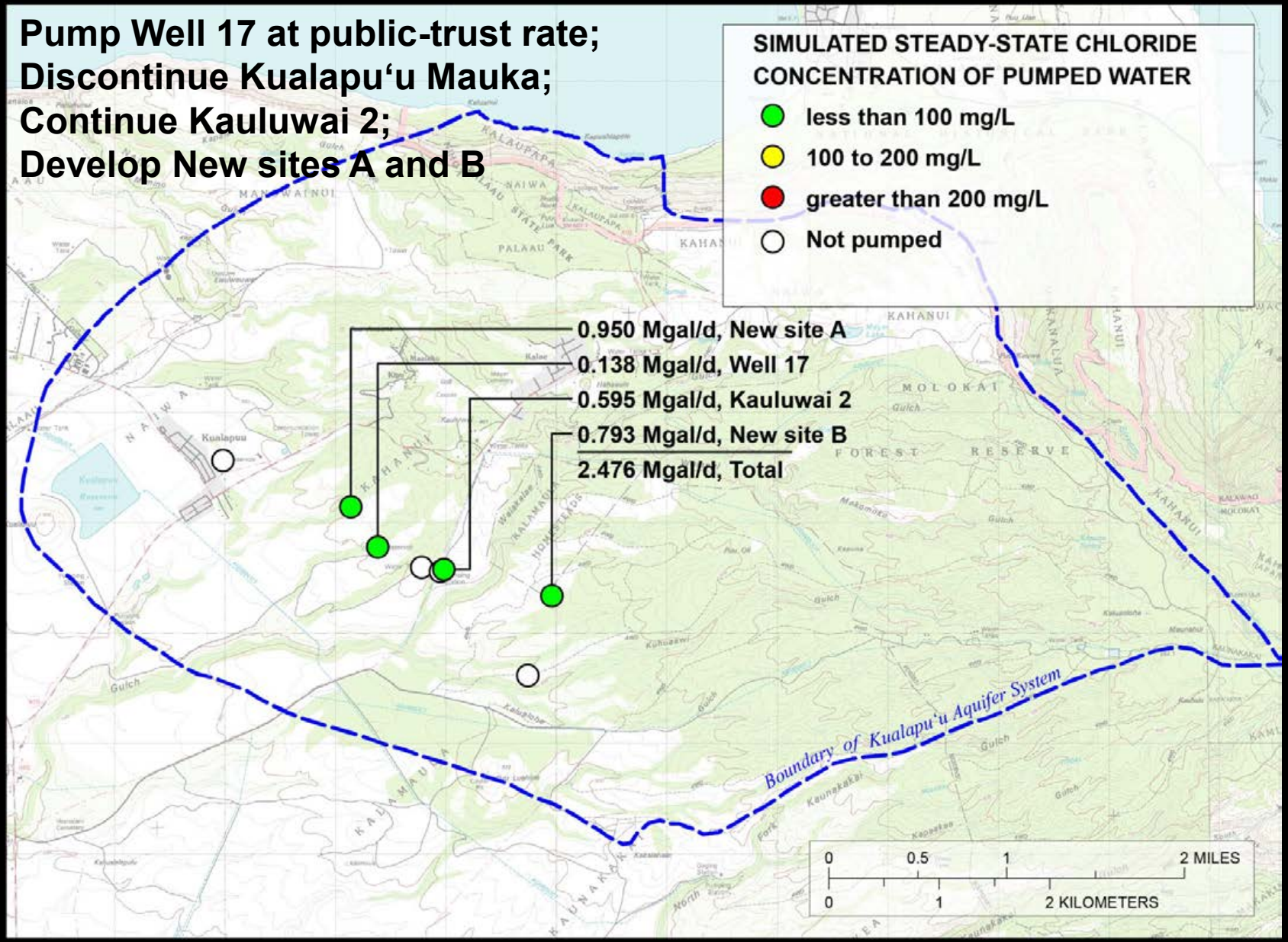
Scenario 3. Well 17 at Public-Trust Rate; New Site B



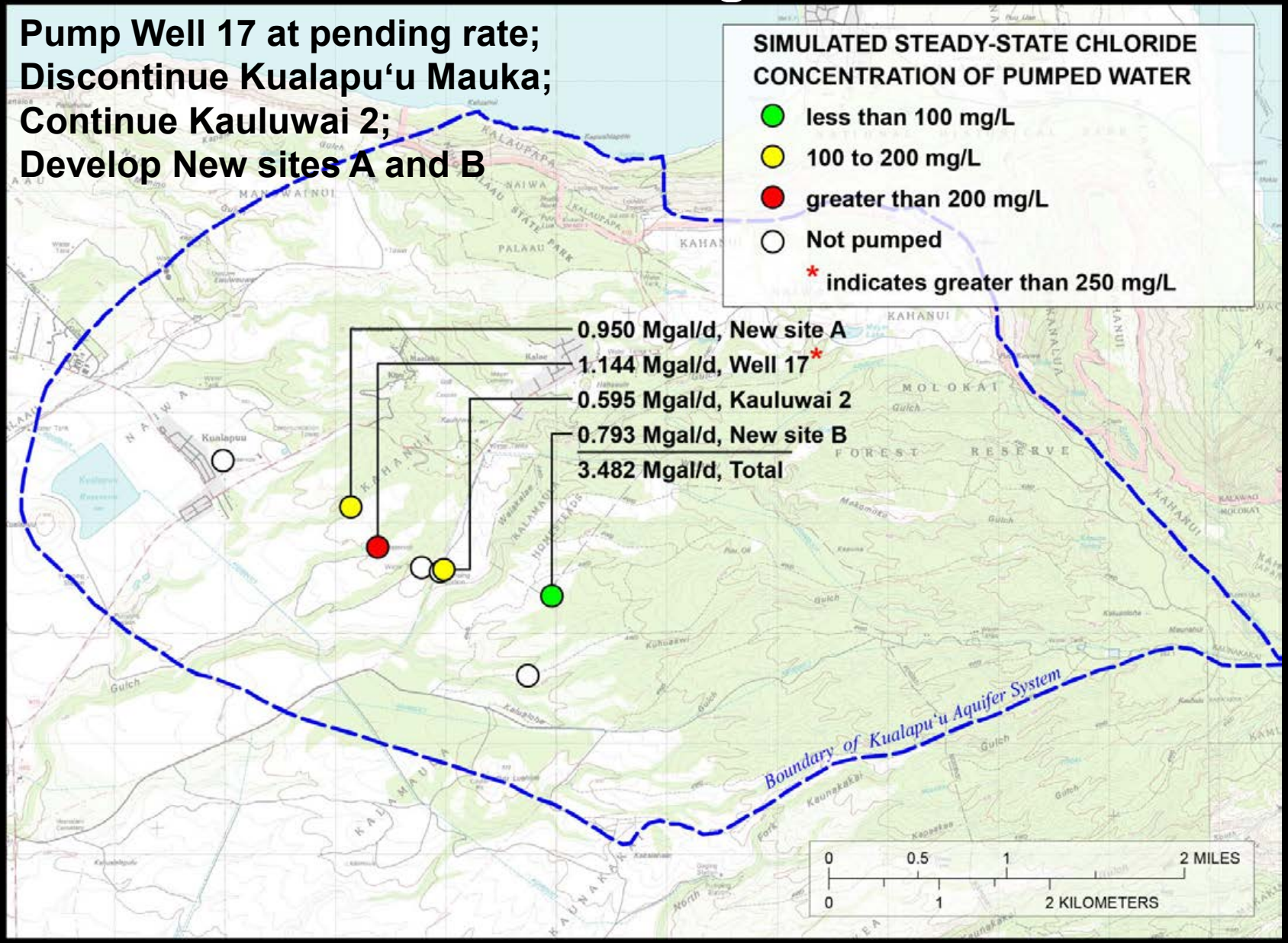
Scenario 4. Well 17 at Pending Rate; New Site B



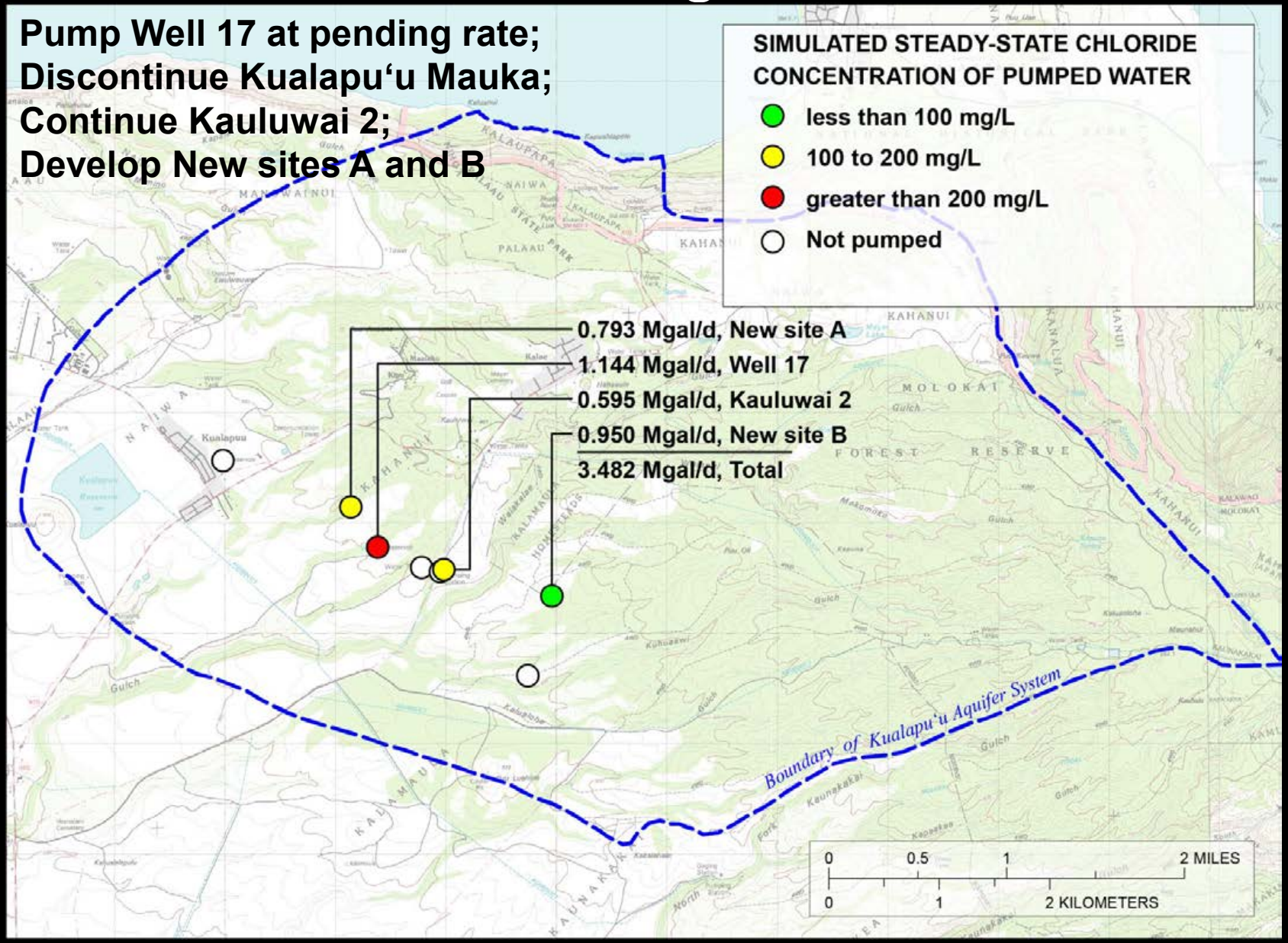
Scenario 5. Well 17 Public Trust; New Sites A and B



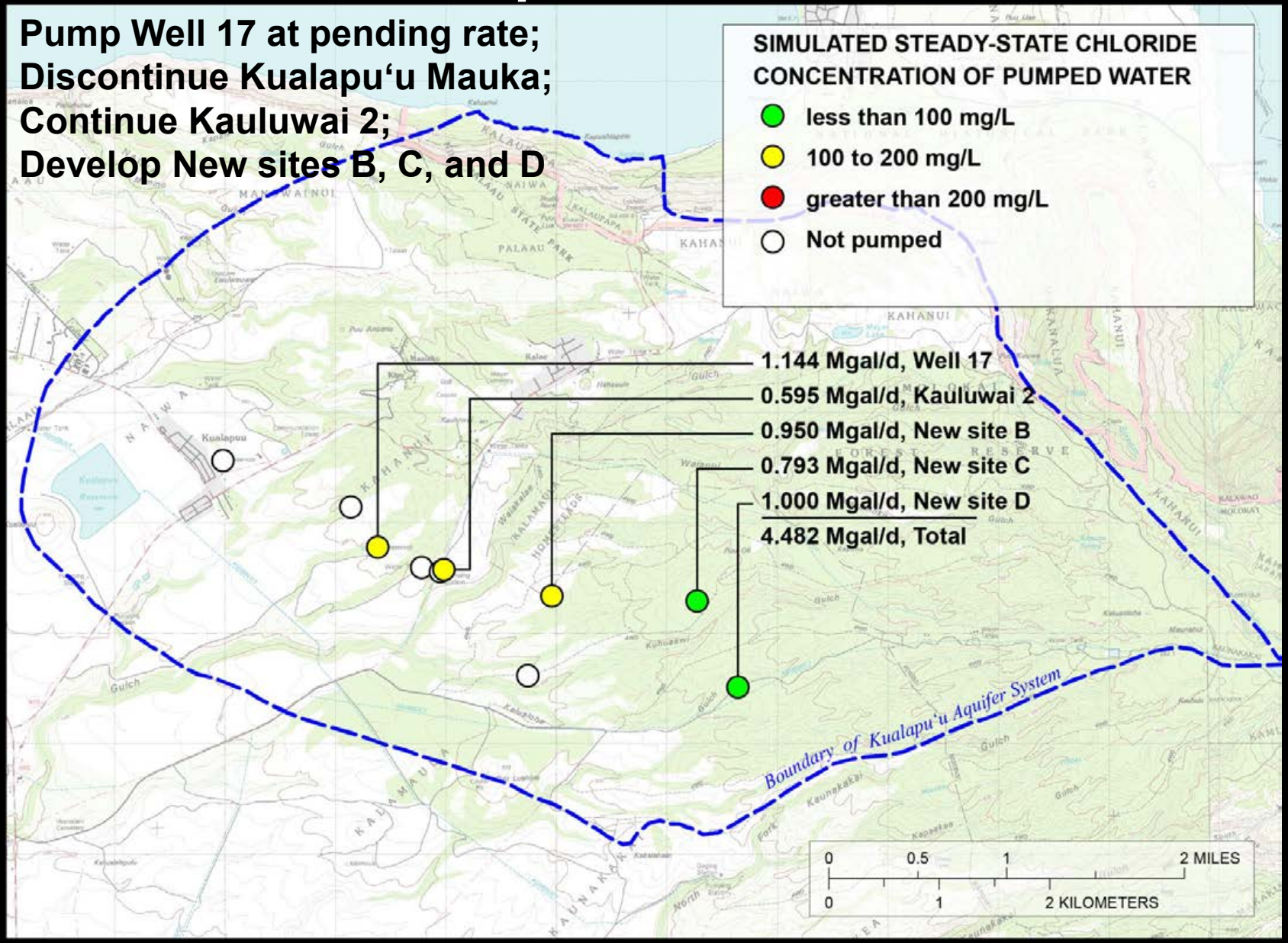
Scenario 6. Well 17 Pending; New Sites A and B



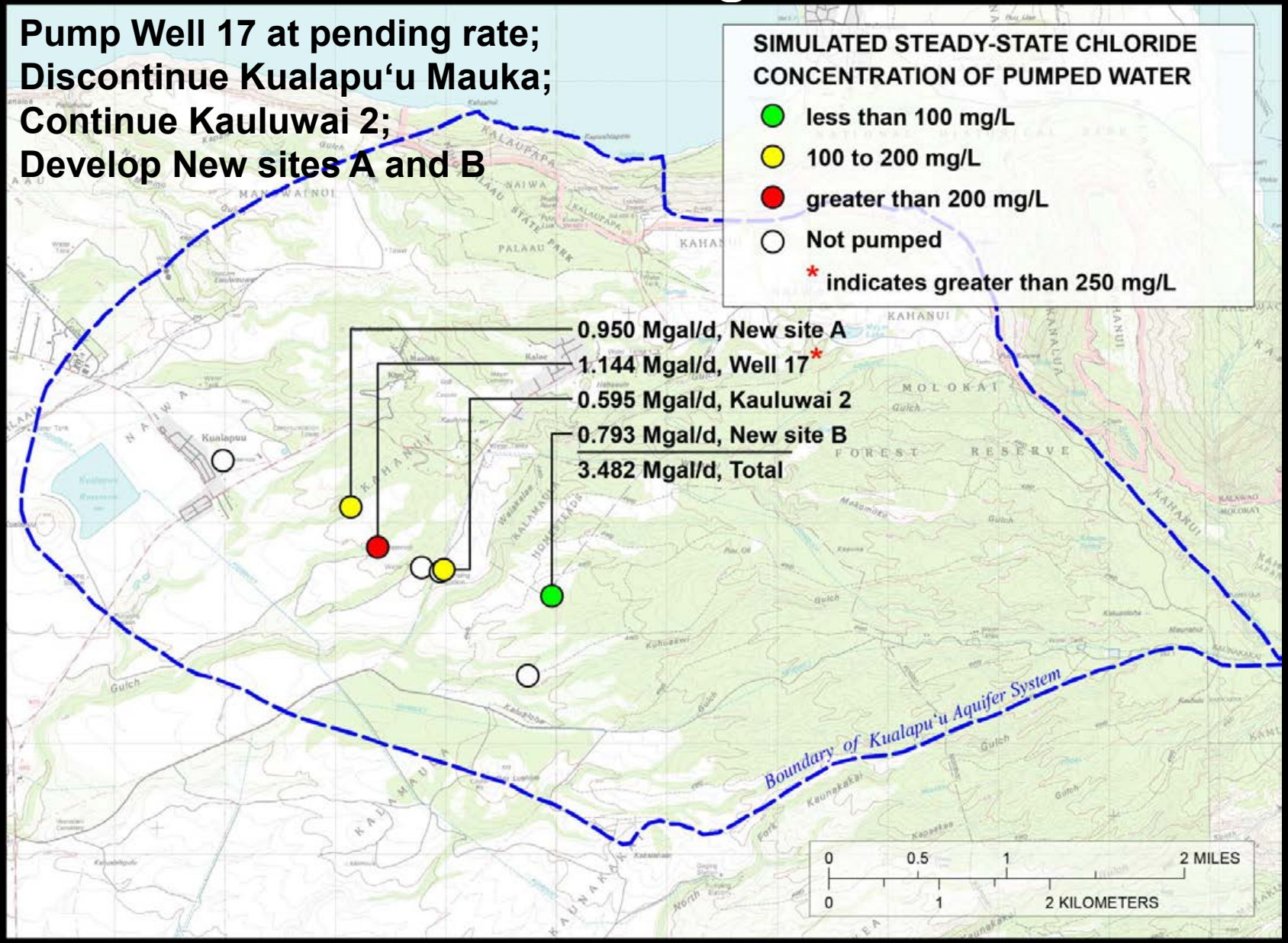
Scenario 7. Well 17 Pending; Switch Sites A and B



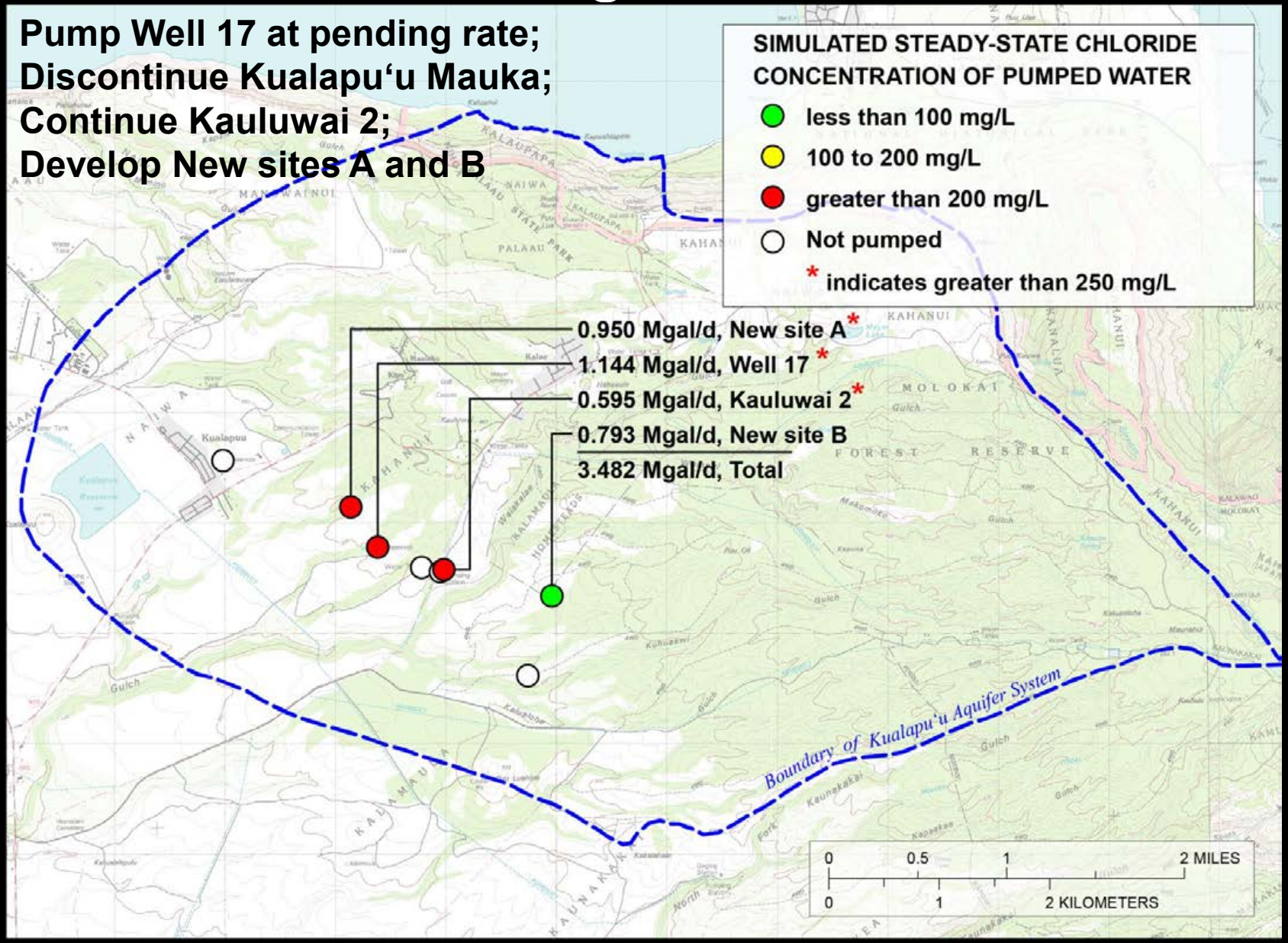
Scenario 8. Spread Out Withdrawals



Scenario 6. Well 17 Pending; New Sites A and B



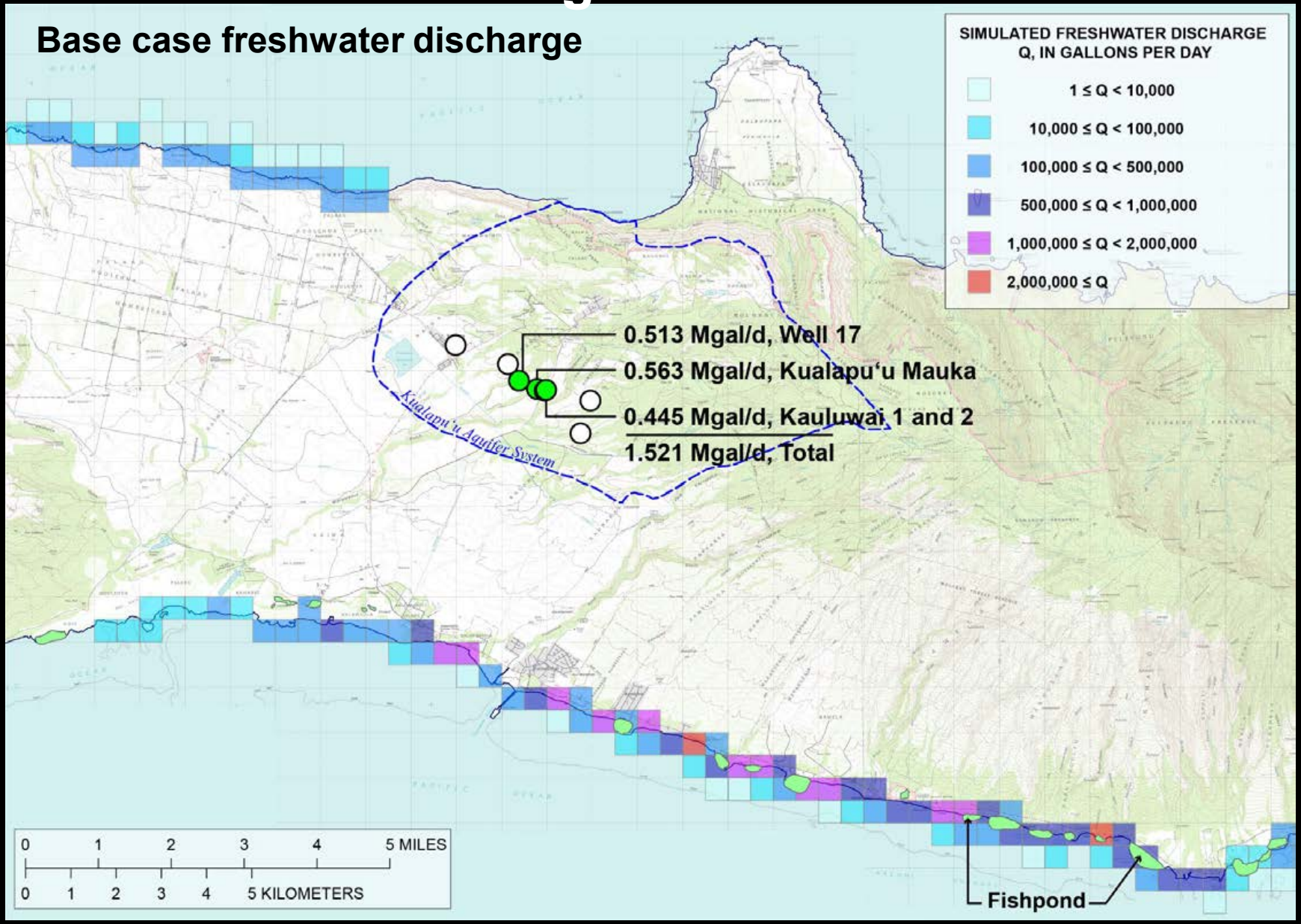
Scenario 9. Recharge Reduced 15 Percent



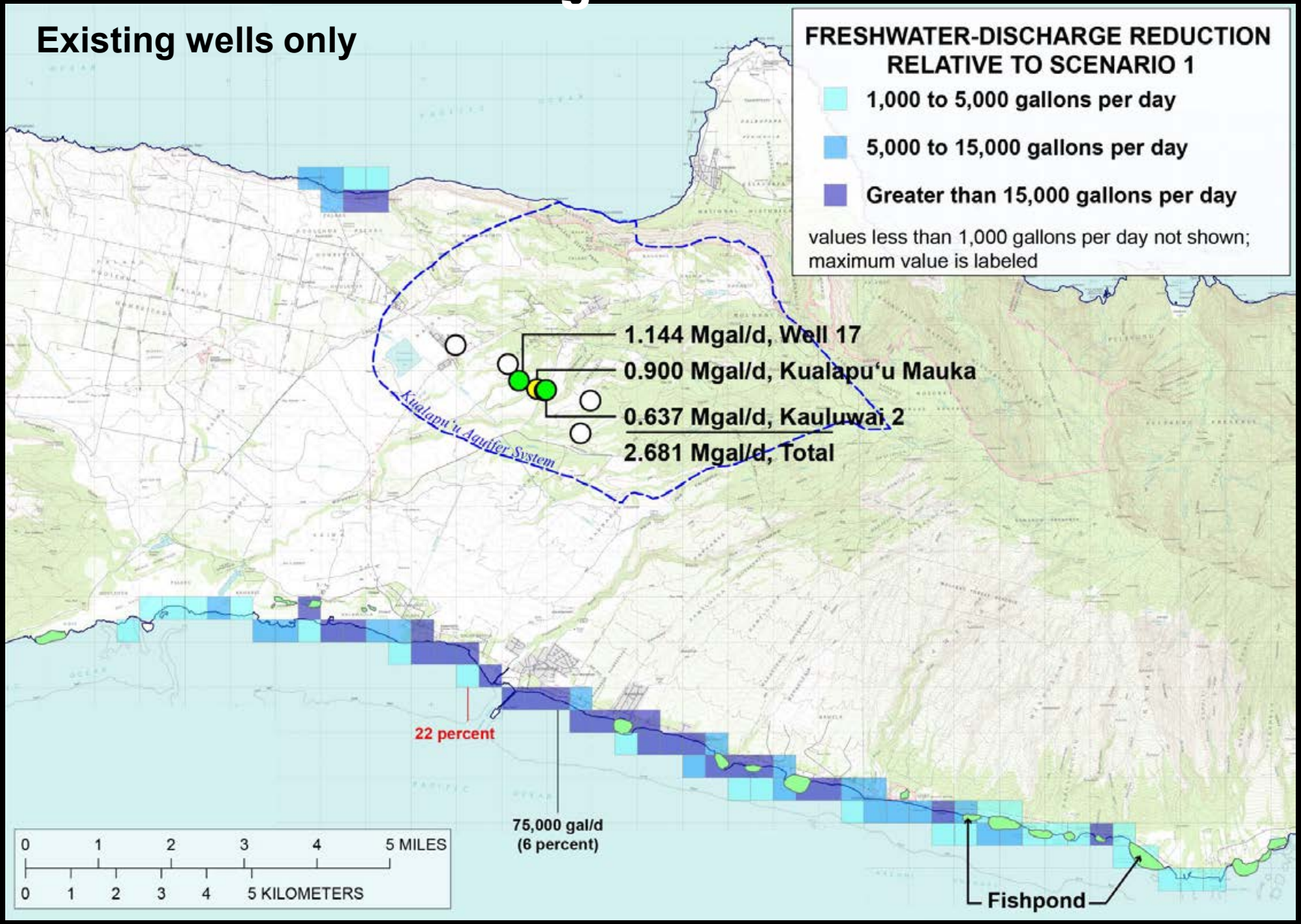
Groundwater Management

- Hawaii Commission on Water Resource Management (CWRM) responsible for managing State's water resources
- CWRM divides each island into aquifer systems and estimates sustainable-yield value for each aquifer system
- Method to estimate sustainable yield originally developed mainly to protect infrastructure from high salinity
- Protection of nearshore ecosystems, streams, and cultural practices dependent on groundwater is an emerging issue

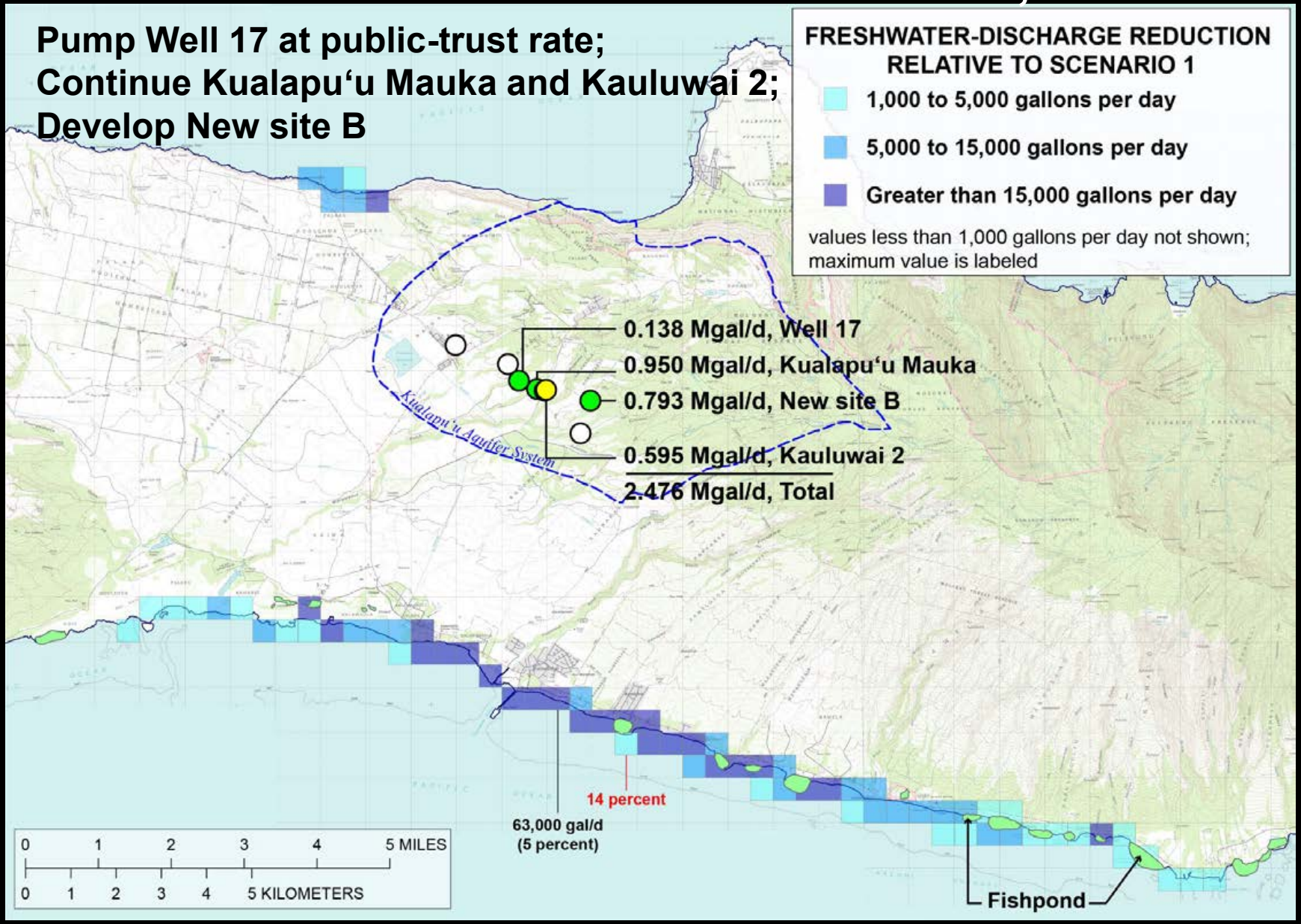
Scenario 1. Average 2016–17 Withdrawals



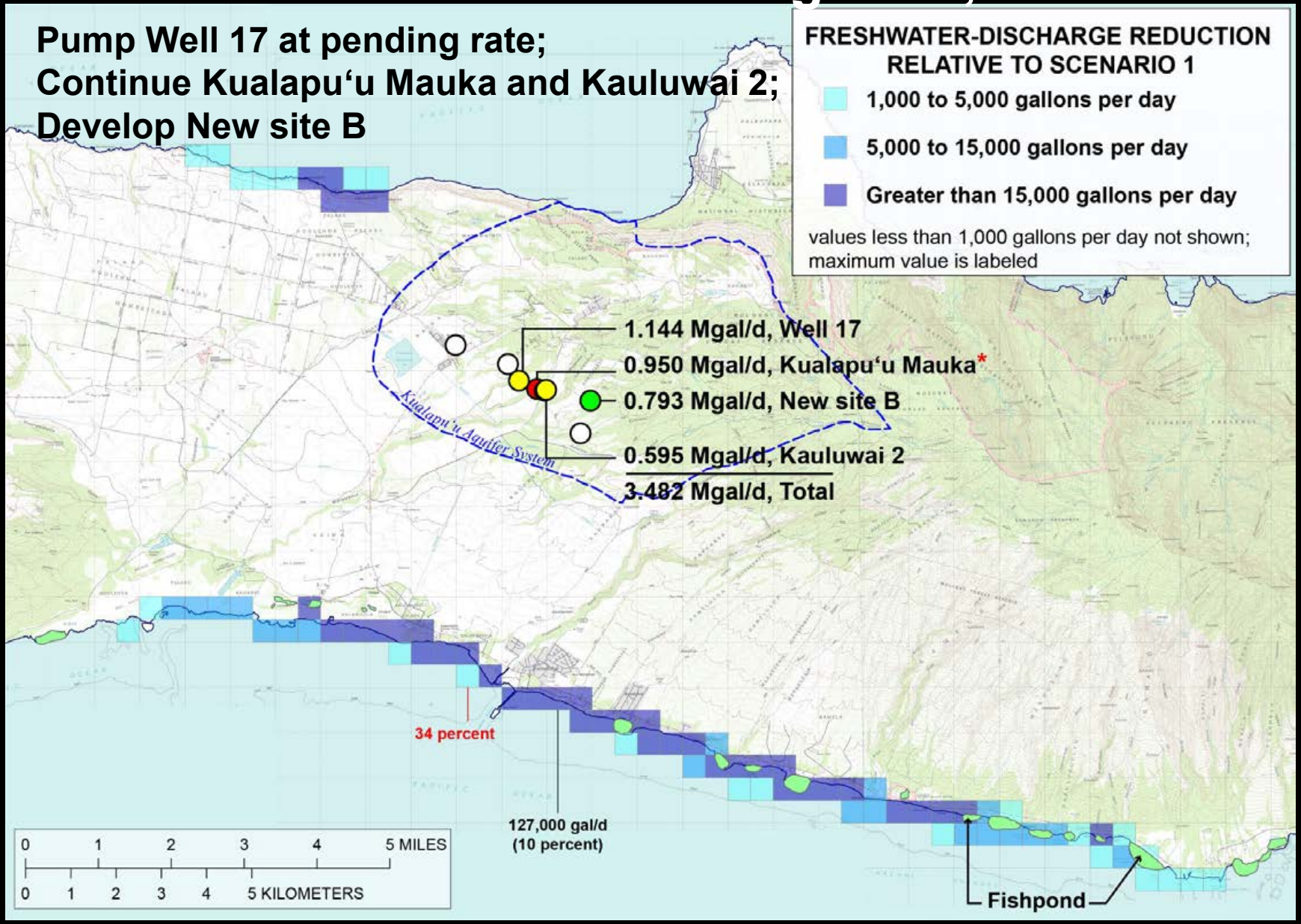
Scenario 2. Pending Water-Use Permit Rates



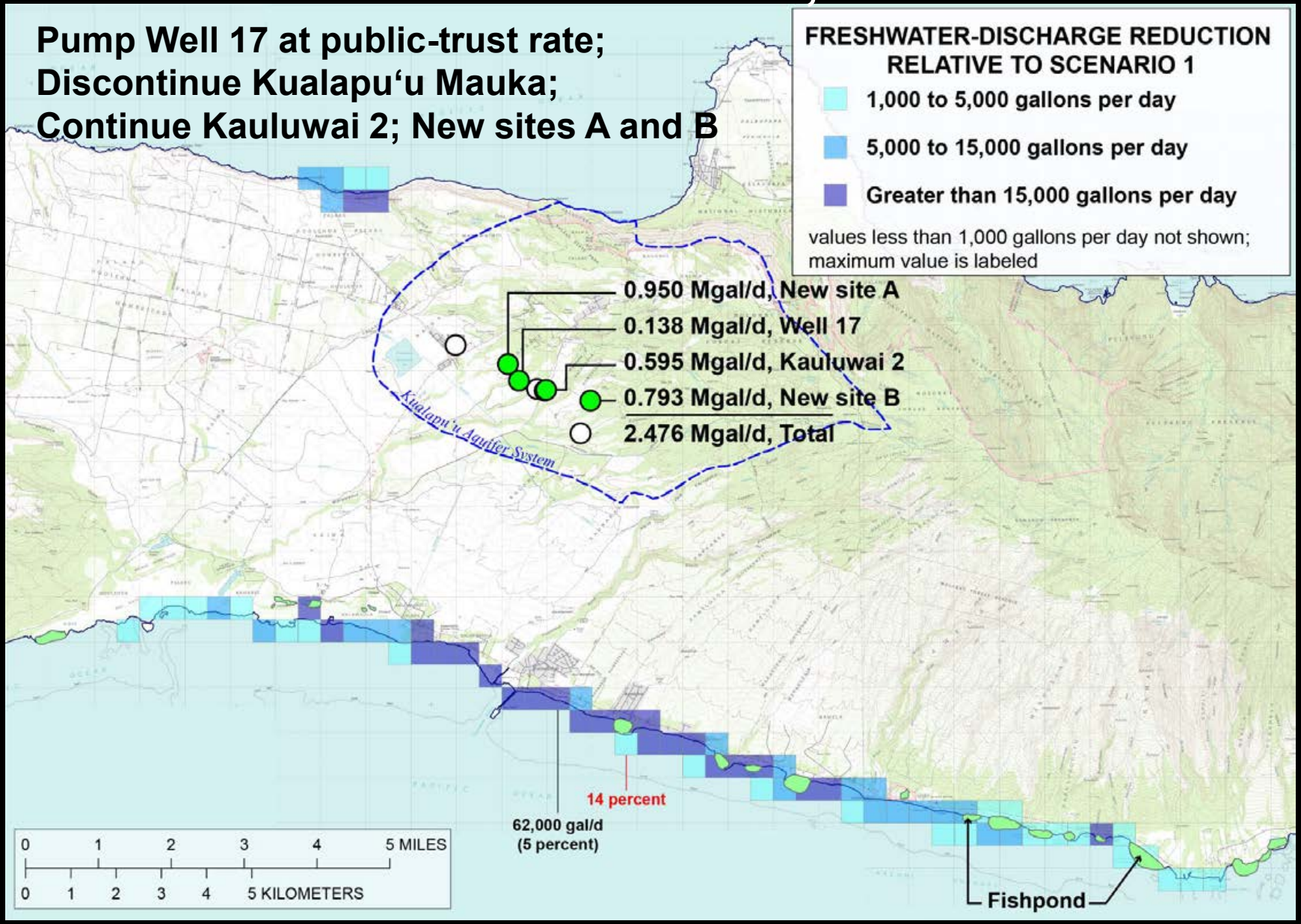
Scenario 3. Well 17 at Public-Trust Rate; New Site B



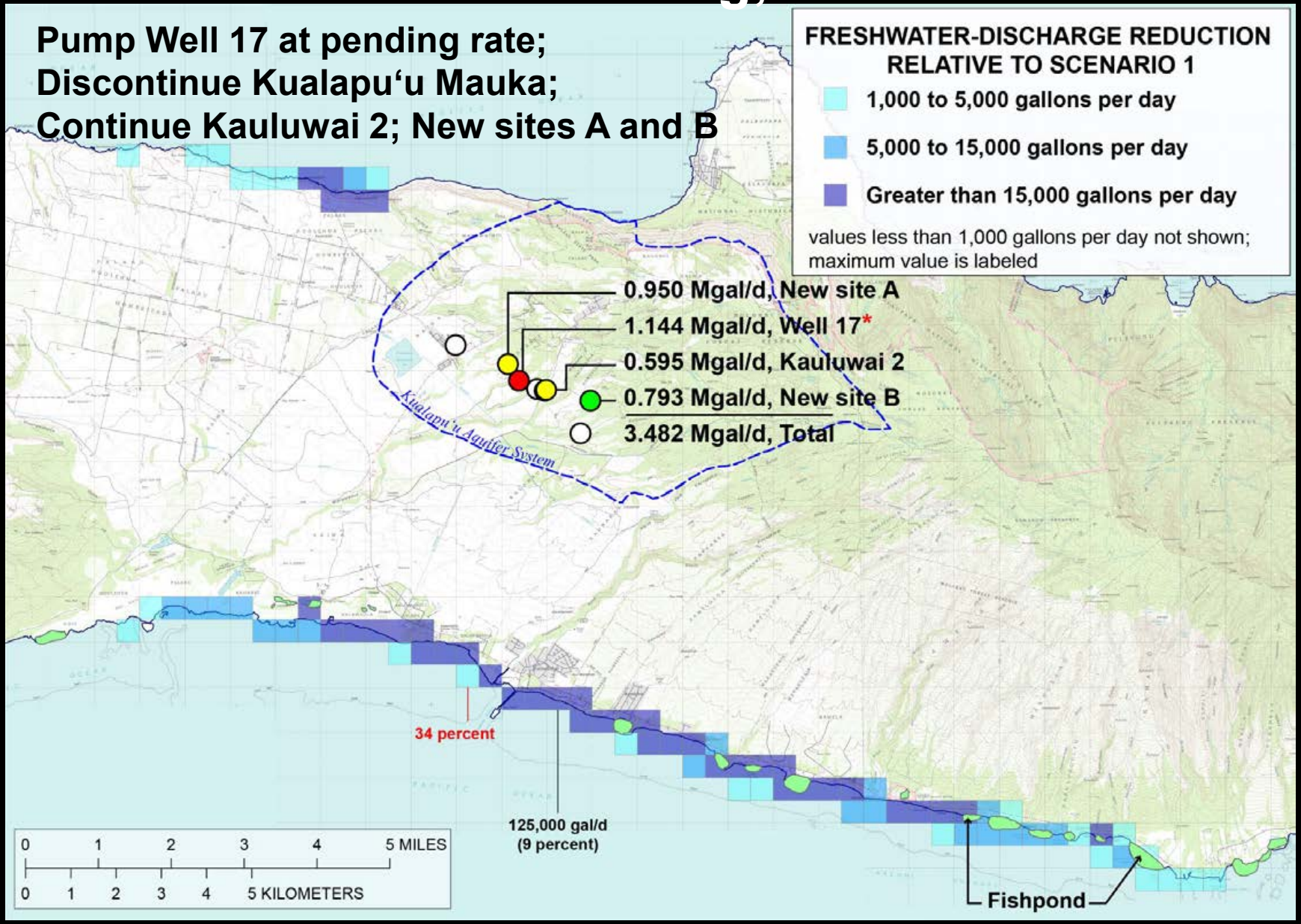
Scenario 4. Well 17 at Pending Rate; New Site B



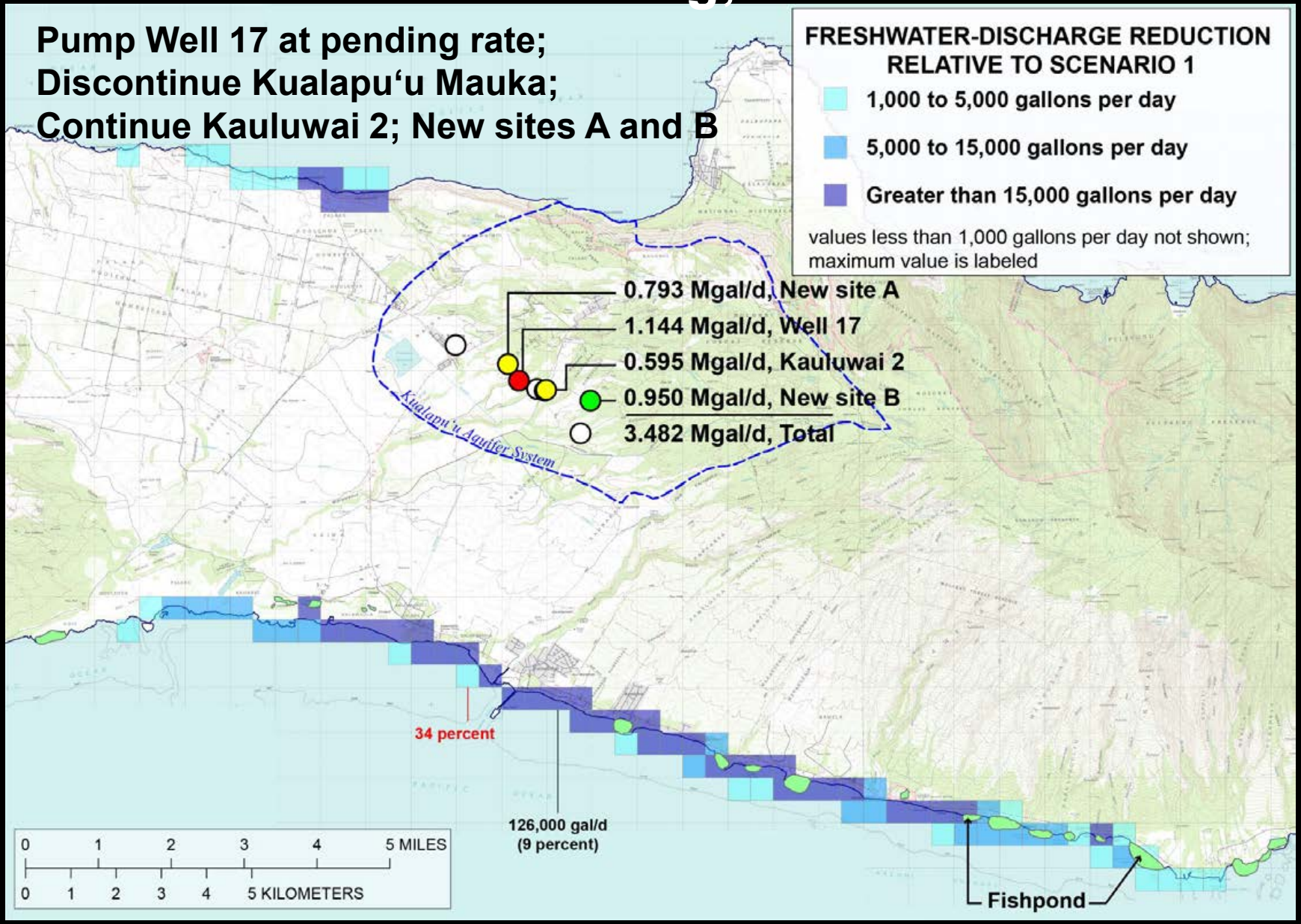
Scenario 5. Well 17 Public Trust; New Sites A and B



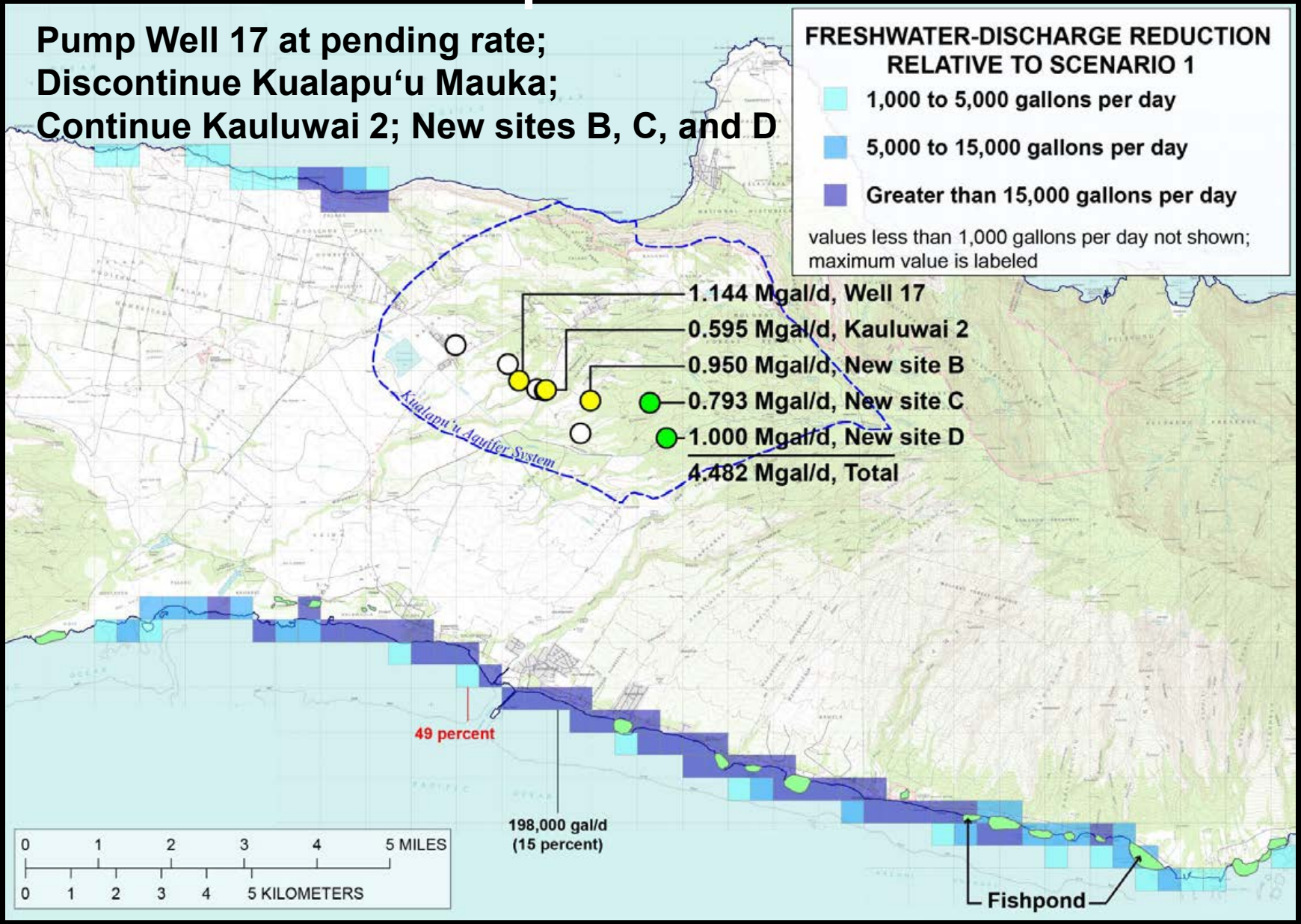
Scenario 6. Well 17 Pending; New Sites A and B



Scenario 7. Well 17 Pending; Switch Sites A and B



Scenario 8. Spread Out Withdrawals



Study Limitations

1. Groundwater model is regional in scale and may not accurately represent local conditions

2. Groundwater model can be improved

   A. subsurface geology poorly known
   B. model thus contains uncertainty
   C. additional data from wells would help to constrain model
   D. model can be updated as information becomes available

3. No wells available in the eastern part of the Kualapuʻu aquifer system

4. Model results are sensitive to recharge—additional data on important water-budget components would improve estimate

Next Steps

- Document results
- Submit for review
- Publish report and datasets (target end of year)

Questions?

USGS