

Groundwater Availability, Moloka'i, Hawai'i

**Kulana 'Ōiwi Hālau, Moloka'i
June 1, 2019**

**Delwyn S. Oki, U.S. Geological Survey
In cooperation with Department of Hawaiian Home Lands, Office of
Hawaiian Affairs, Maui Department of Water Supply**

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?

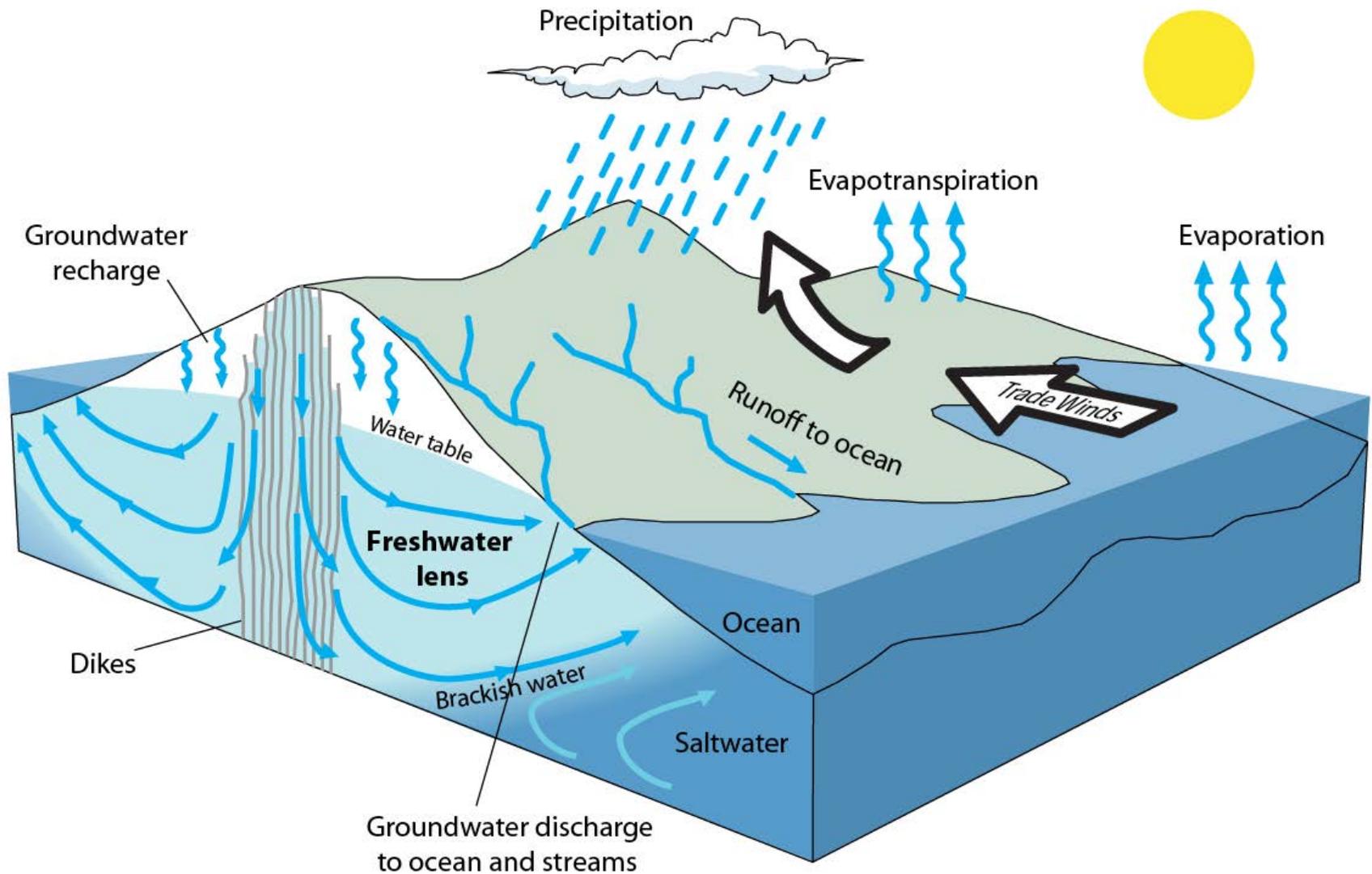
Recent History of Groundwater-Related Events

- 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 Moloka'i
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

Rainfall Atlas of Hawai'i

Geography Department - University of Hawai'i at Mānoa



- HOME
- INTERACTIVE MAP
- DOWNLOADS
- HOW TO CITE
- HISTORY
- METHODS
- RAINFALL
- ACKNOWLEDGMENTS
- PEOPLE

Mean Monthly Rainfall (in)  

Rainfall Atlas of Hawai'i 2011, University of Hawai'i

Map Station Uncert.

20
16
12
8
4
0

Mean Annual Rainfall:

► Rainfall Data (in)

► Station Information

▼ Legend

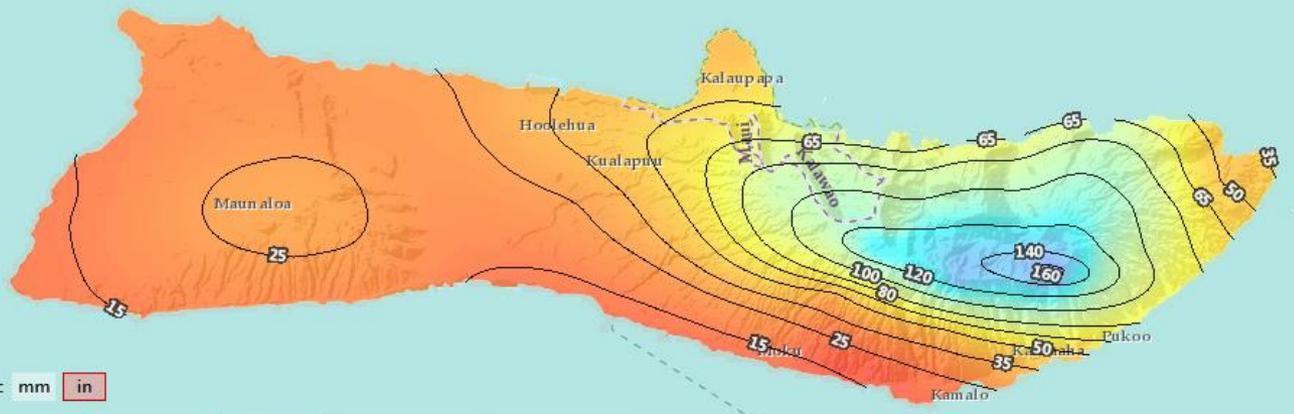
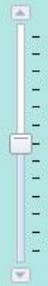
Rainfall Grid
staterf_ann

High : 404.39 in

Low : 8.04 in

Help Location: Degrees: Latitude, Longitude Go

► Base Maps



Units: mm in

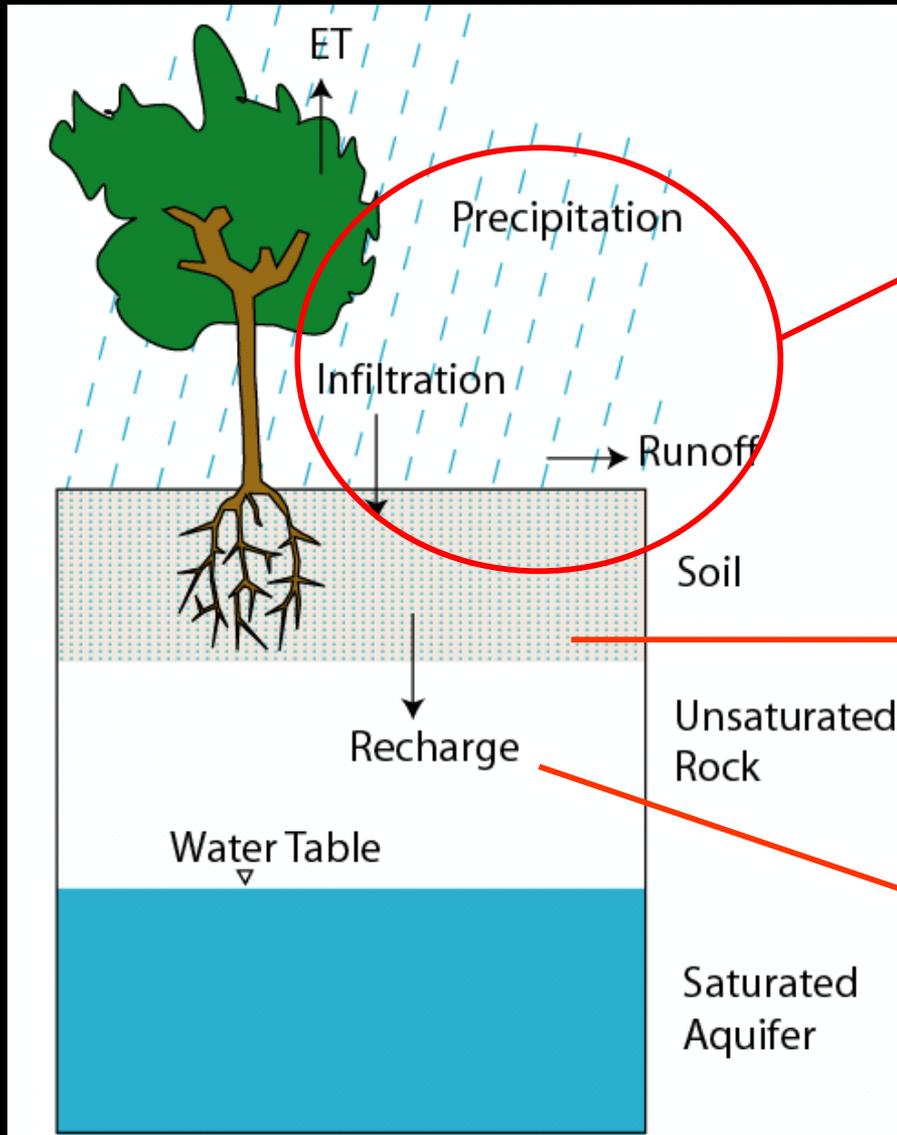
Show: Rainfall Uncertainty RF Isohyets RF Atlas Stations Other Stations

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



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Water Budget

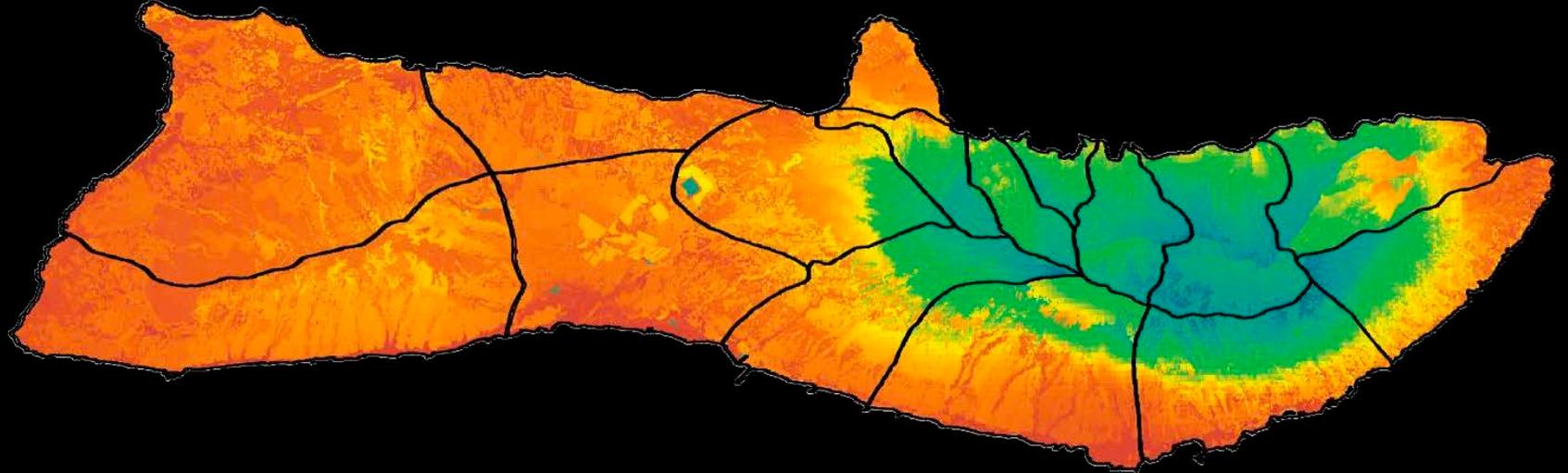


Water from precipitation either runs off, evaporates from surfaces, or infiltrates the soil

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

Some water passes through soil and recharges aquifer

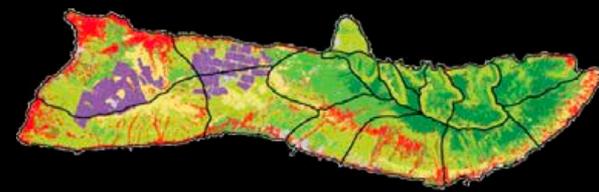
Recharge



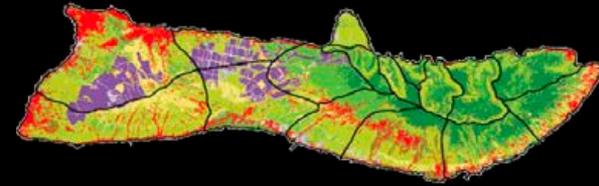
- Climate and land cover are important factors controlling recharge
- Recharge can be estimated with a water-budget model (accounts for land-use changes and daily rainfall and evapotranspiration changes)

Land Use by Decade

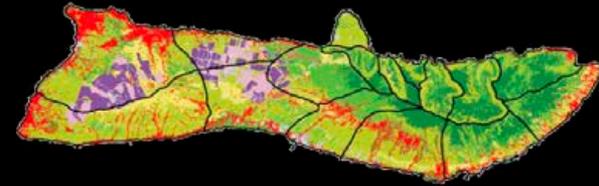
1940s



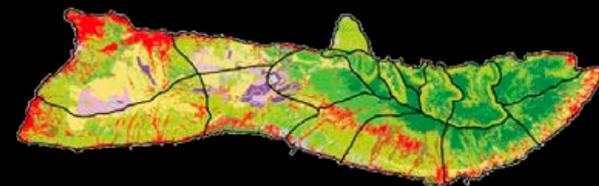
1950s



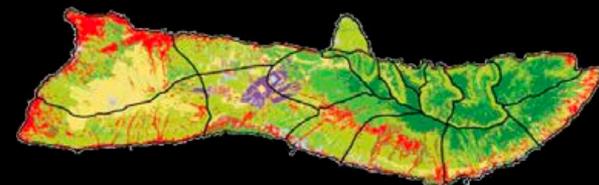
1960s



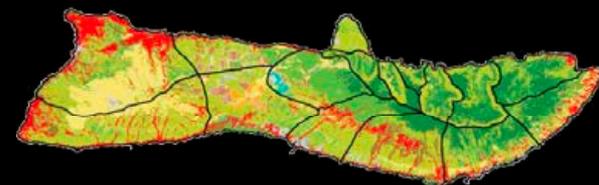
1970s



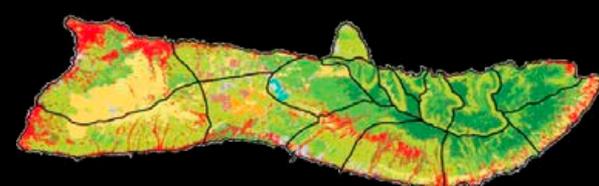
1980s



1990s



2000s



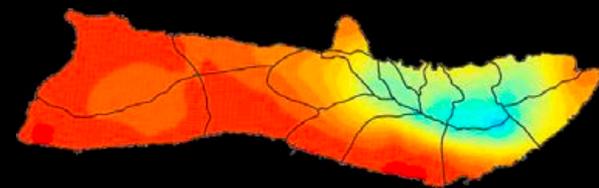
EXPLANATION

	Native forest		Diversified agriculture
	Alien forest		Kiawe/phreatophytes
	Shrubland		Low-intensity developed
	Grassland		Medium-intensity developed
	Pineapple-abandoned		High-intensity developed
	Pineapple		Sparsely vegetated
	Coffee		Wetland
	Corn		Water body

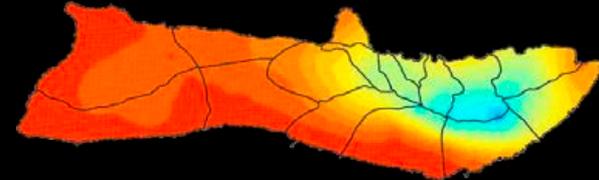
Rainfall By Decade

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

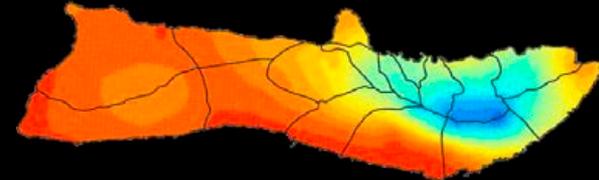
1940s



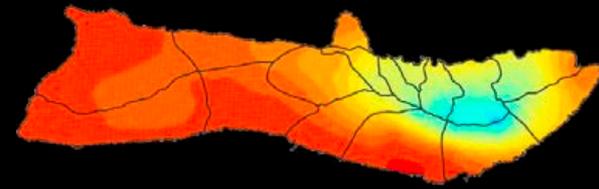
1950s



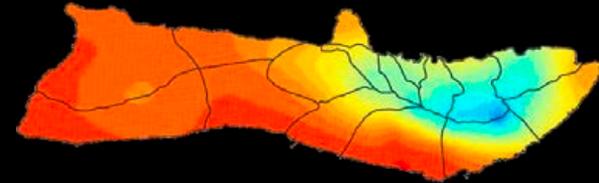
1960s



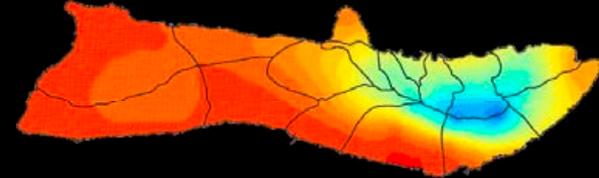
1970s



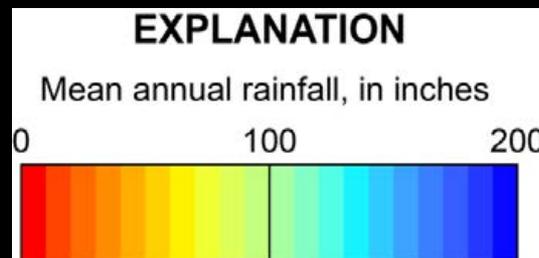
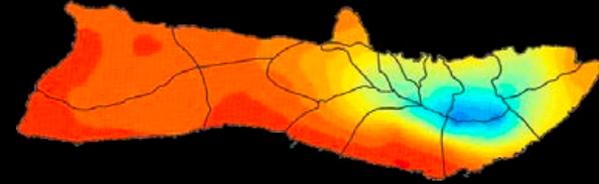
1980s



1990s

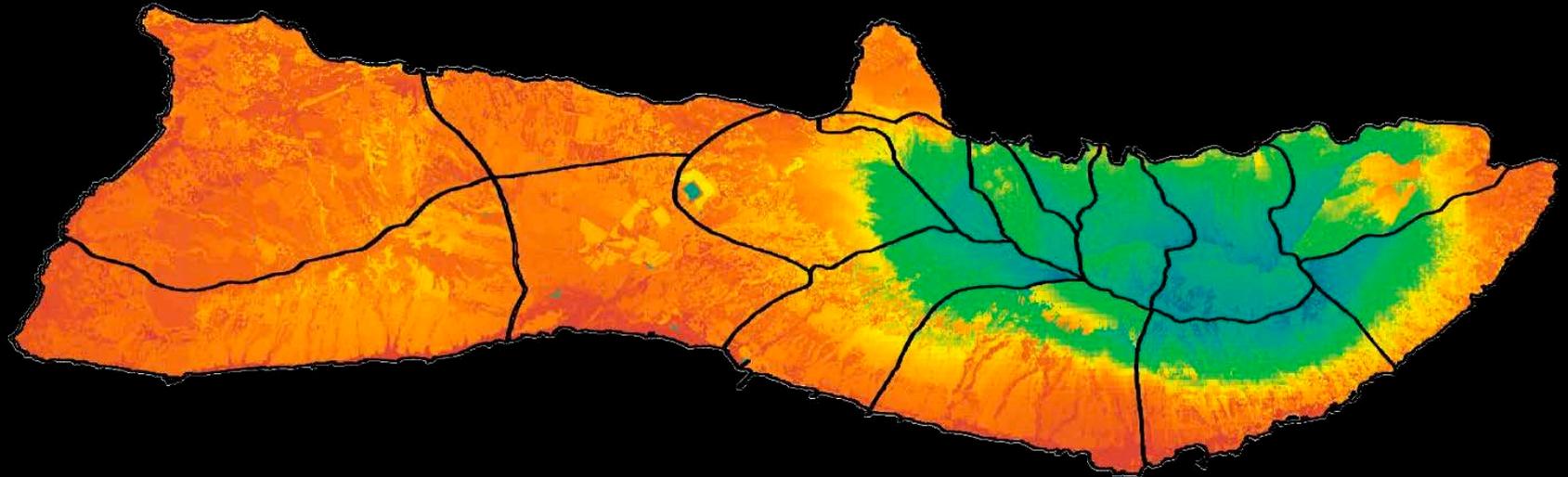


2000s



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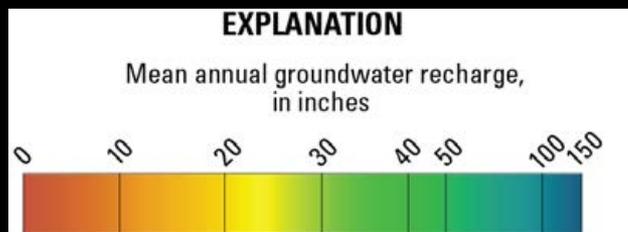
Recharge for Moloka'i



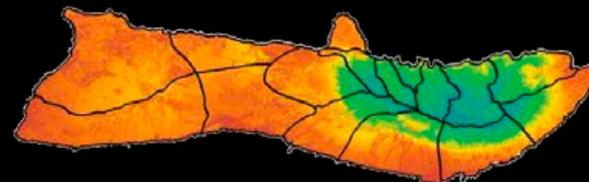
- Current study provides updated recharge estimates
 - Uses daily model and detailed spatial information
 - Accounts for land-use change over time
 - Utilizes best available rainfall and evapotranspiration information
- Previous recharge estimates based on simplified models, less detailed spatial information,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

Recharge By Decade

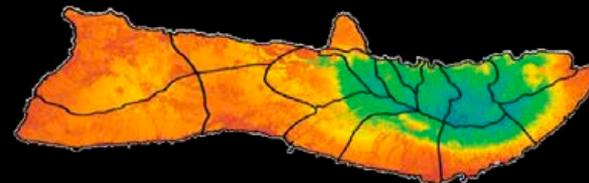
Period	Island-wide recharge, in million gallons per day
1940s	208
1950s	222
1960s	278
1970s	189
1980s	240
1990s	223
2000s	205
1978–2007	227



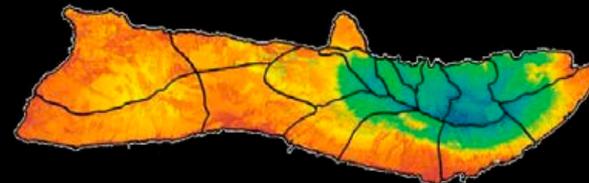
1940s



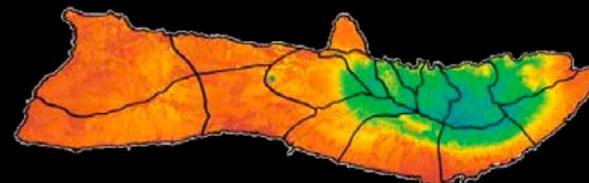
1950s



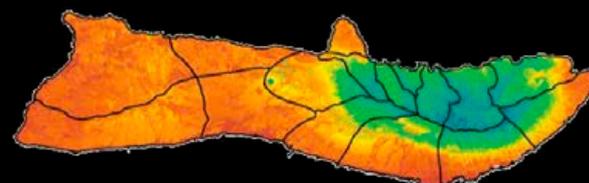
1960s



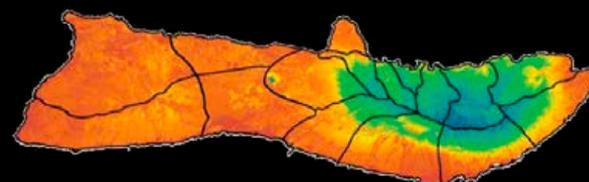
1970s



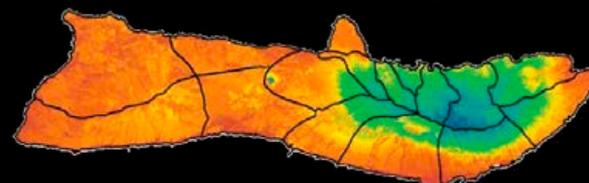
1980s



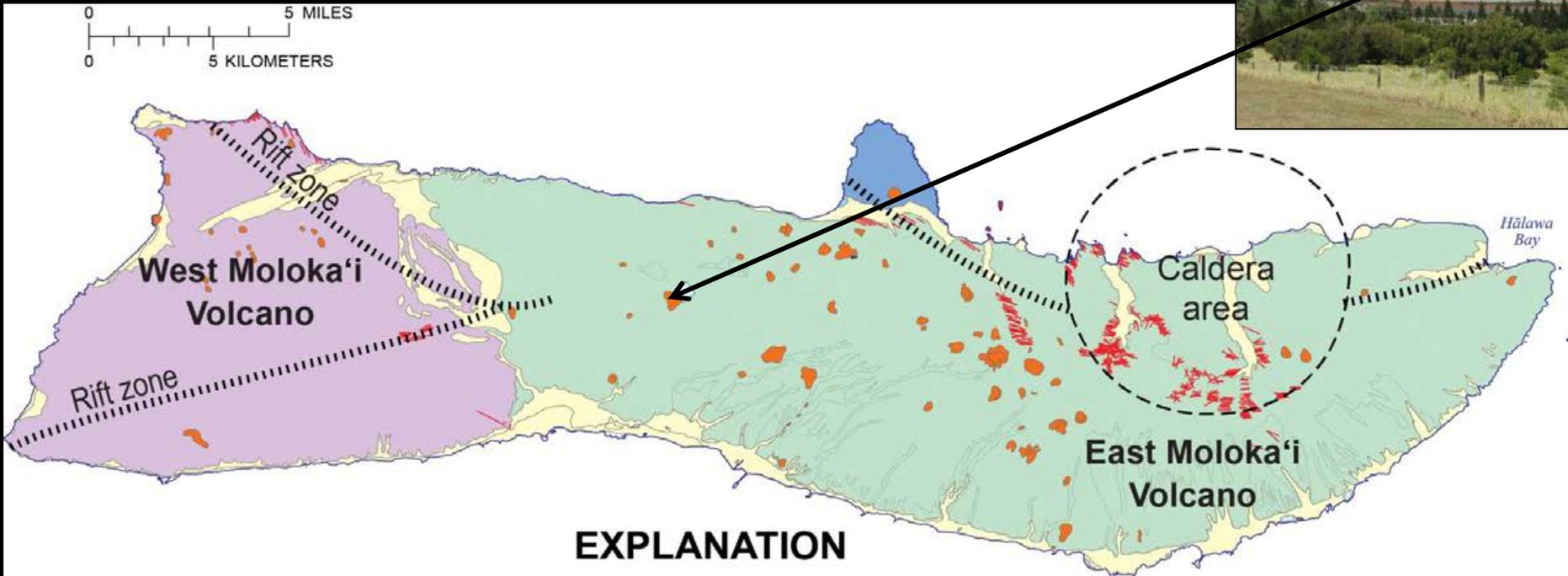
1990s



2000s



Geology



EXPLANATION

 Sedimentary deposits

 Kalaupapa Volcanics

 East Moloka'i Volcanics
(Upper and Lower members)

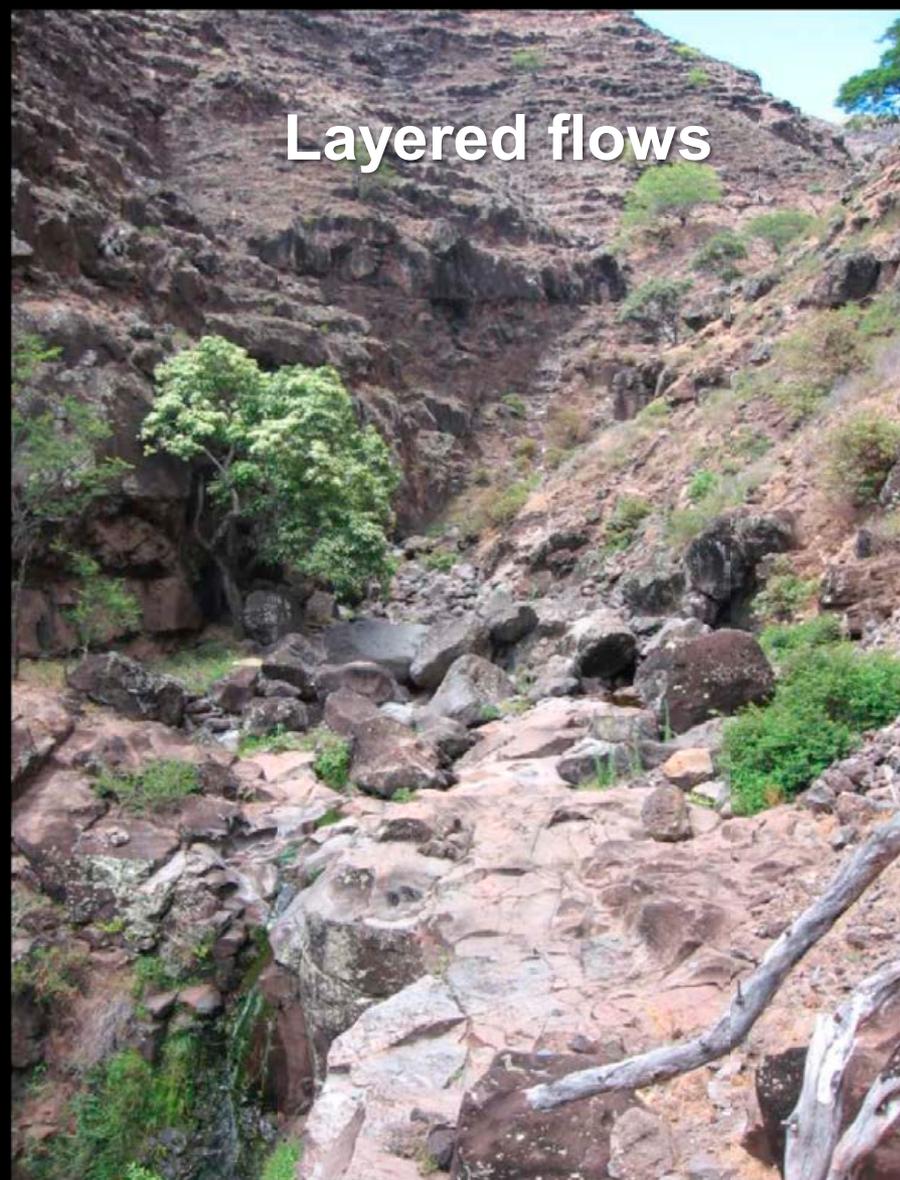
 West Moloka'i Volcanics

 Volcanic vent

 Dike

Modified from Sherrod and others, 2007

Lava Flows



Dikes



Moloka'i Volcanic Vents Fed by Dikes

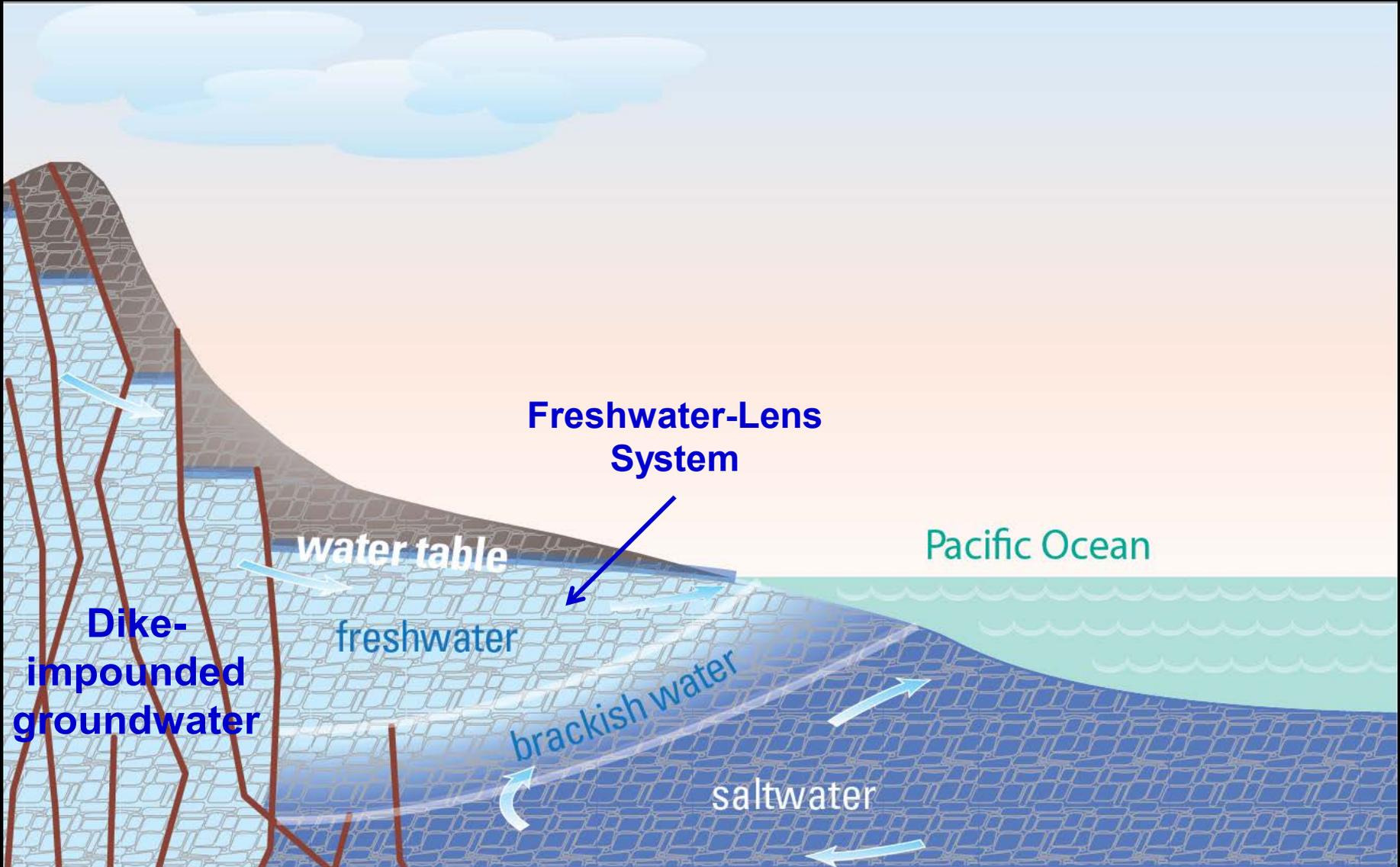
Kākahale



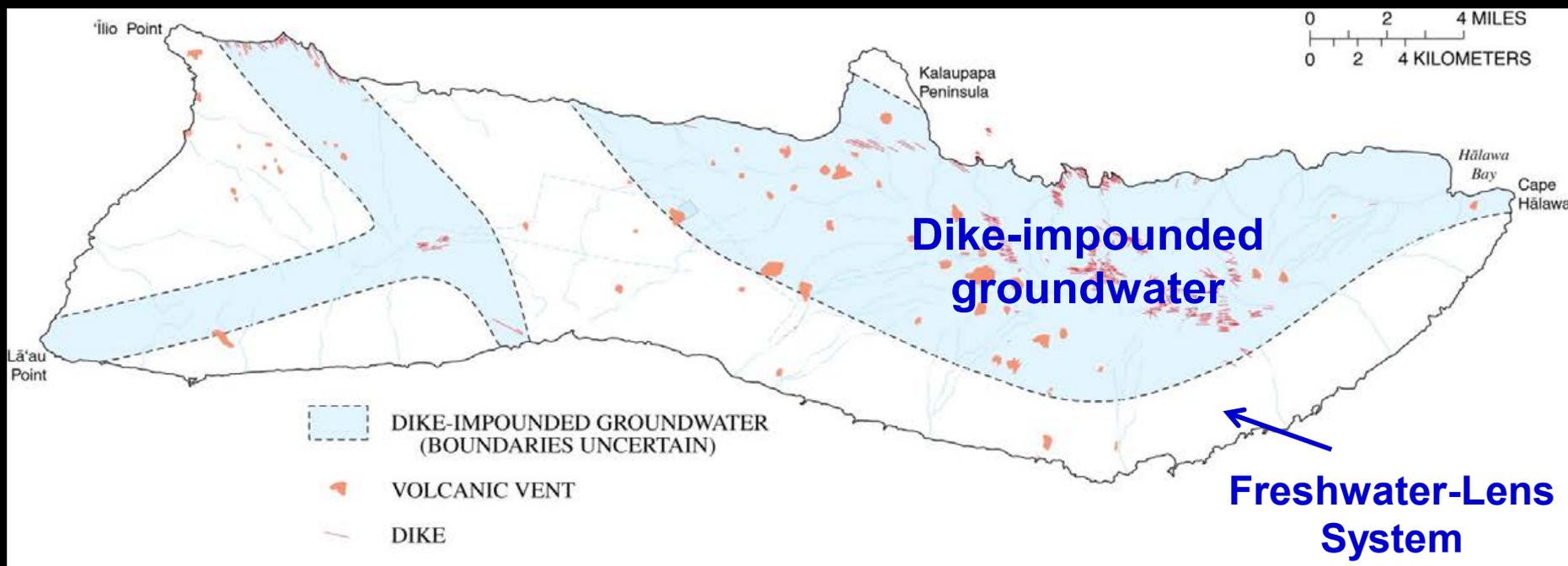
Pu'u Luahine



Conceptual Modes of Groundwater Occurrence

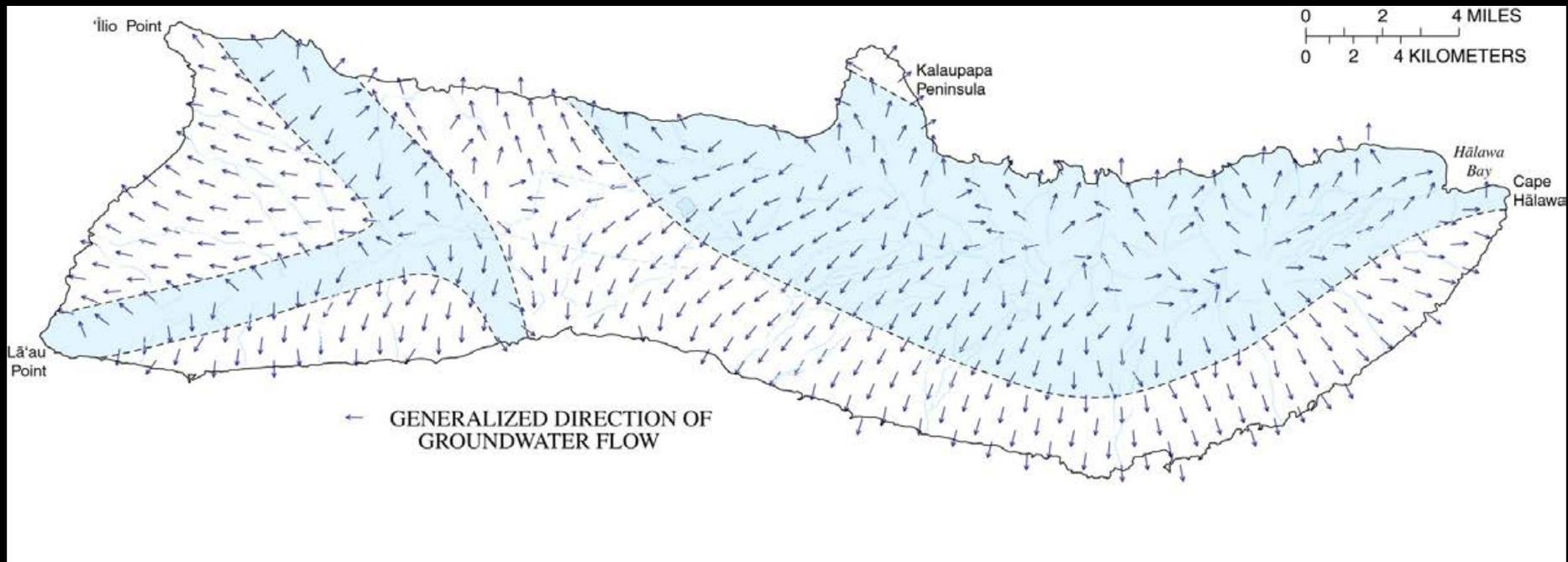


Generalized Groundwater Occurrence



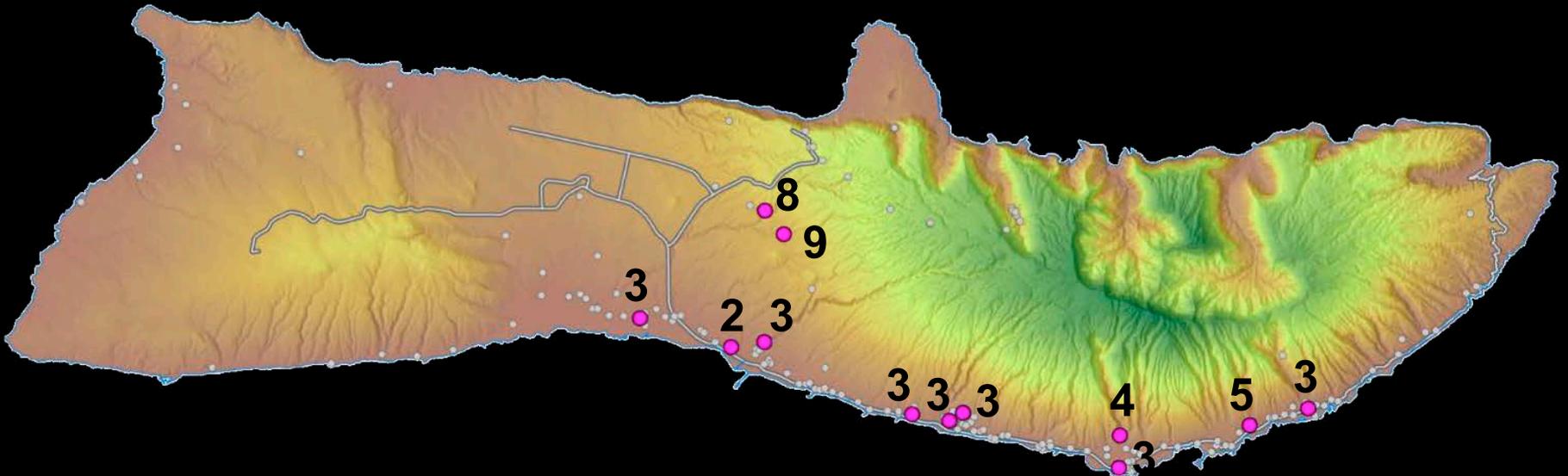
Volcanic vents and dikes from Sherrod and others (2007)

Generalized Groundwater-Flow Directions

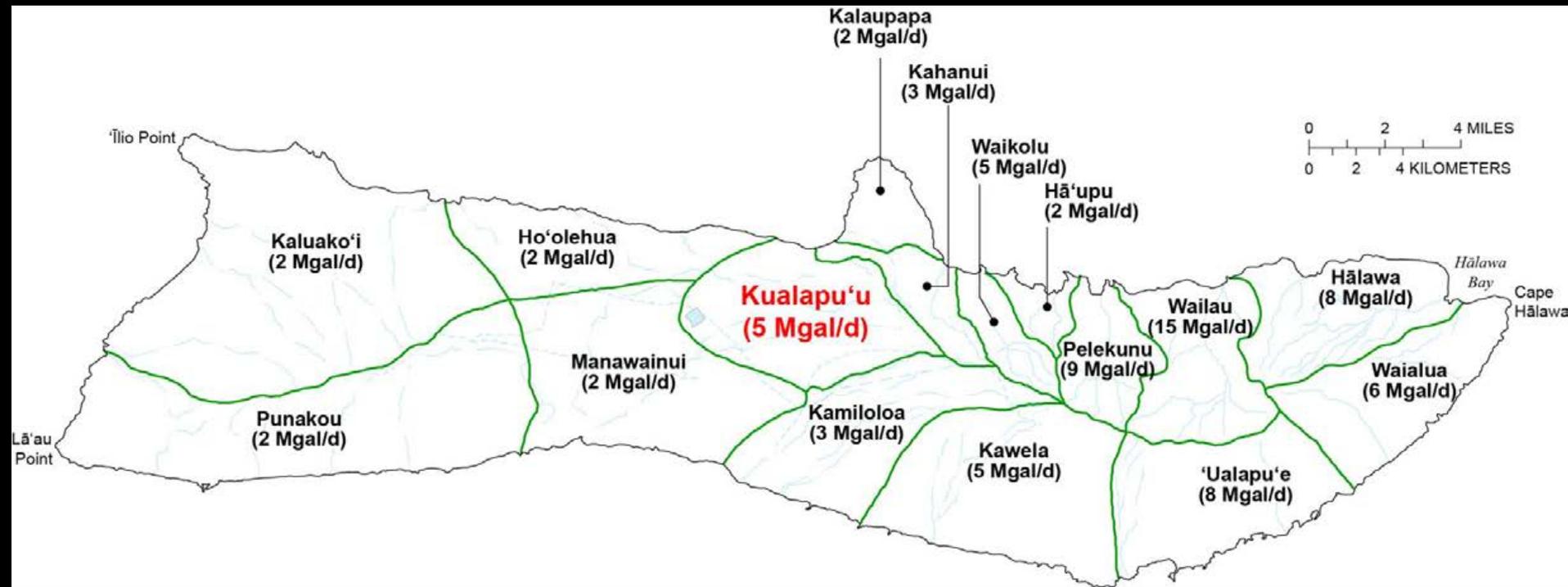


Recent Groundwater Levels

- 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

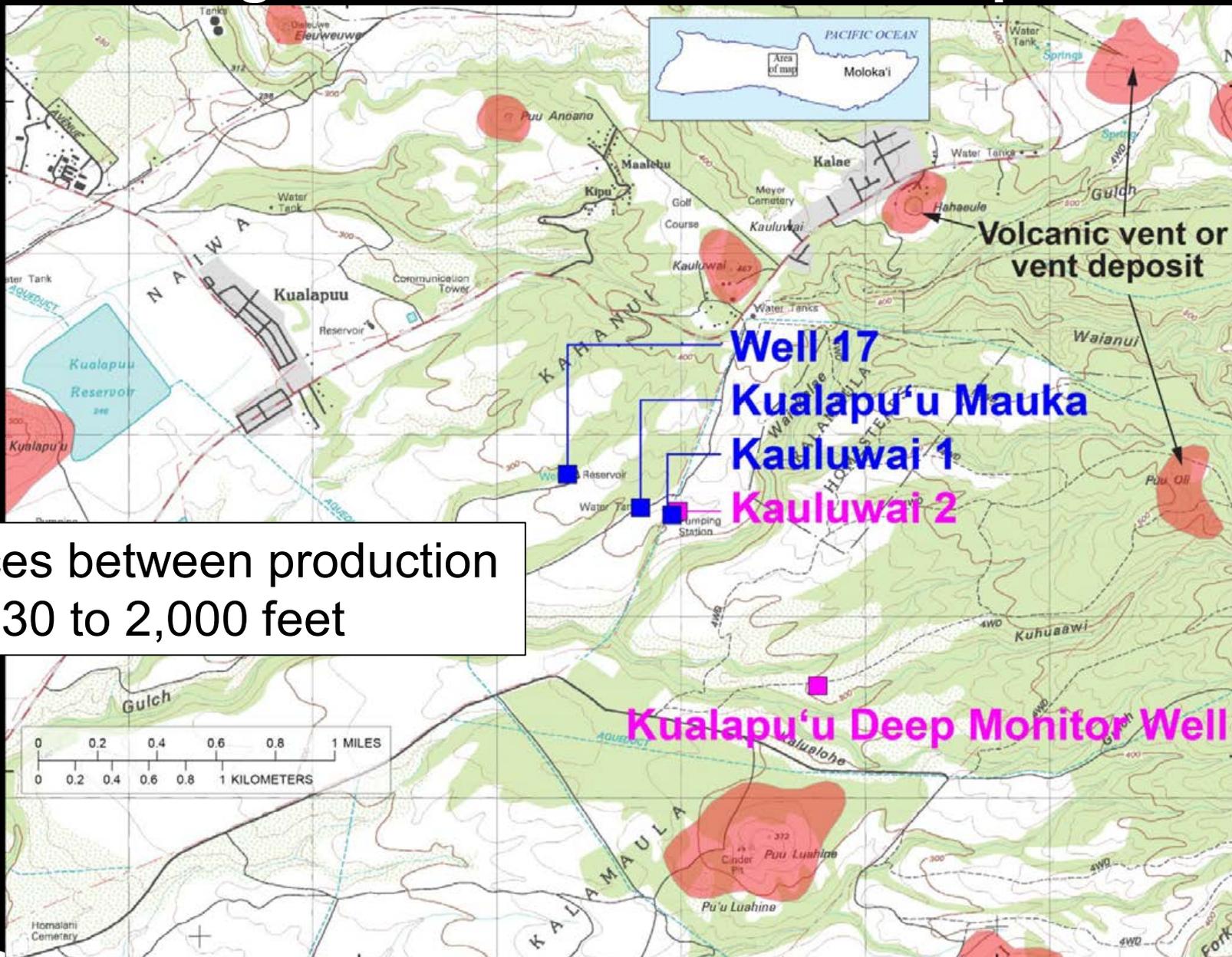


Kualapu'u Aquifer System



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

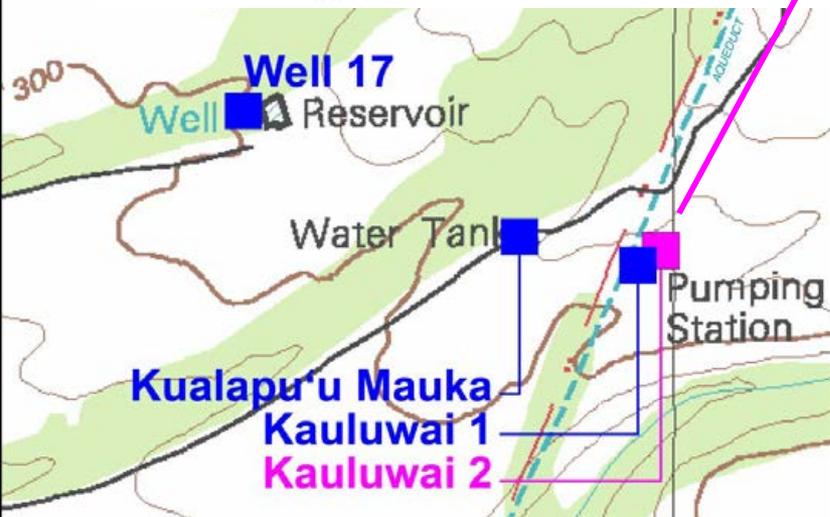
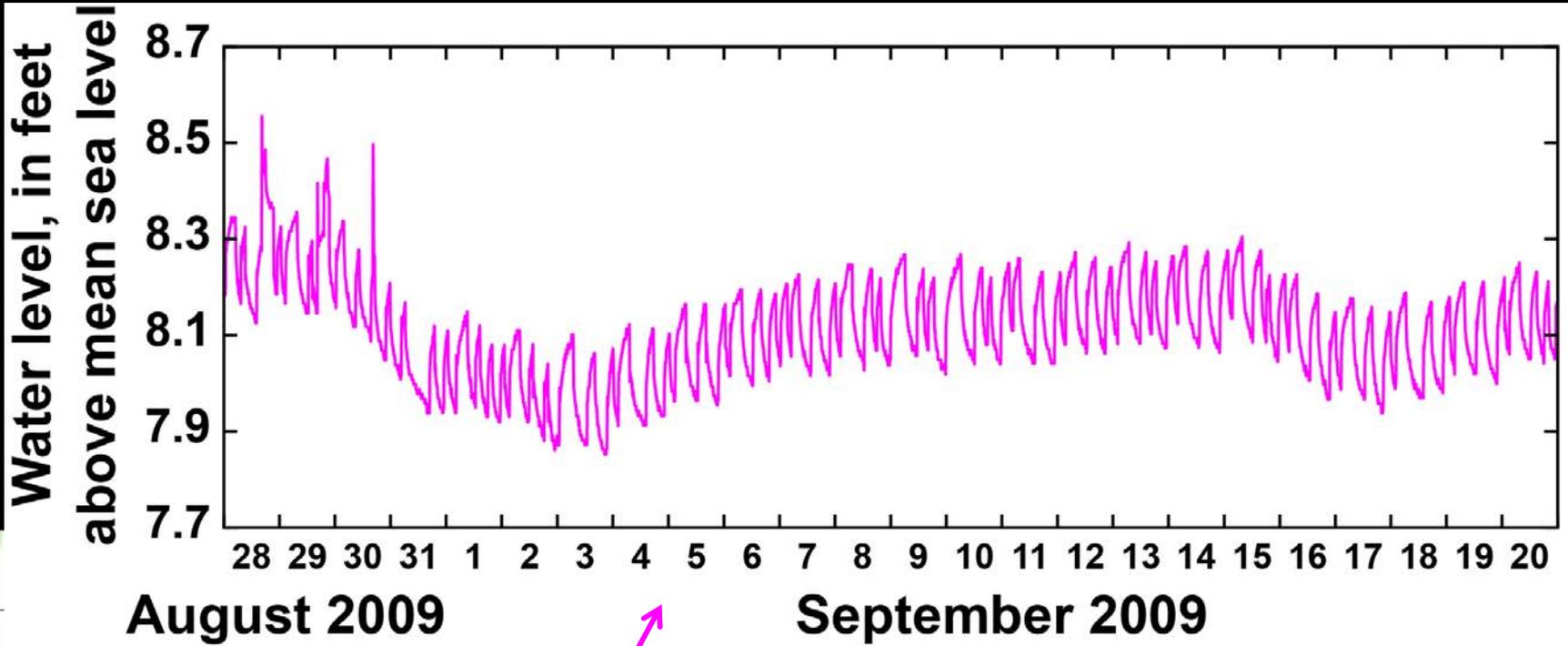


Distances between production wells: 130 to 2,000 feet

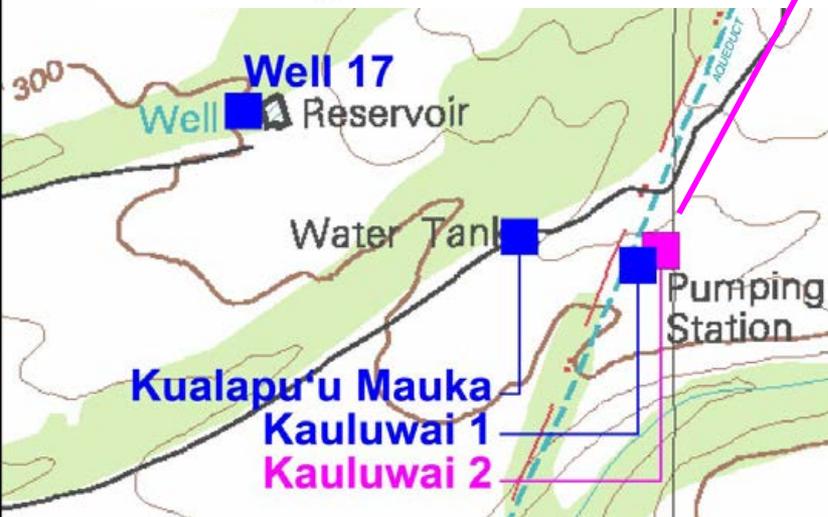
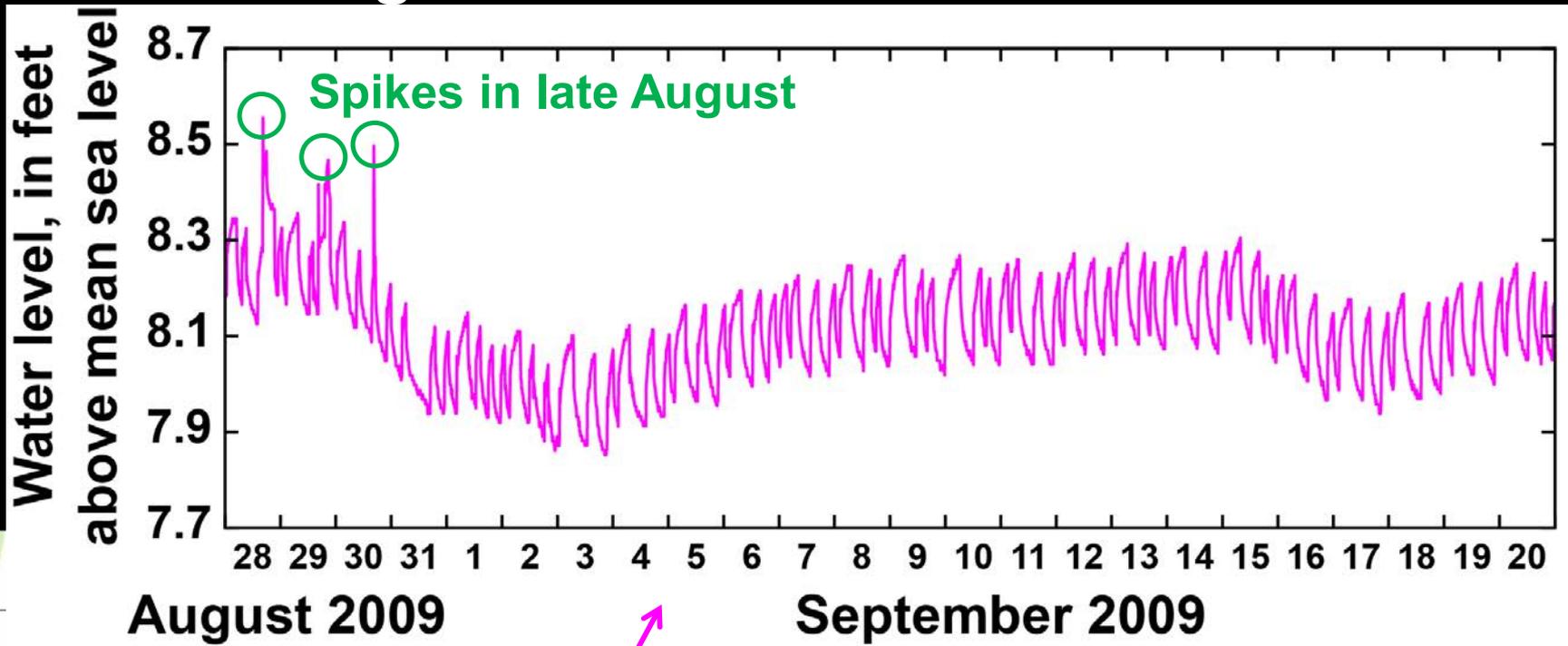


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Water Level in Kauluwai 2

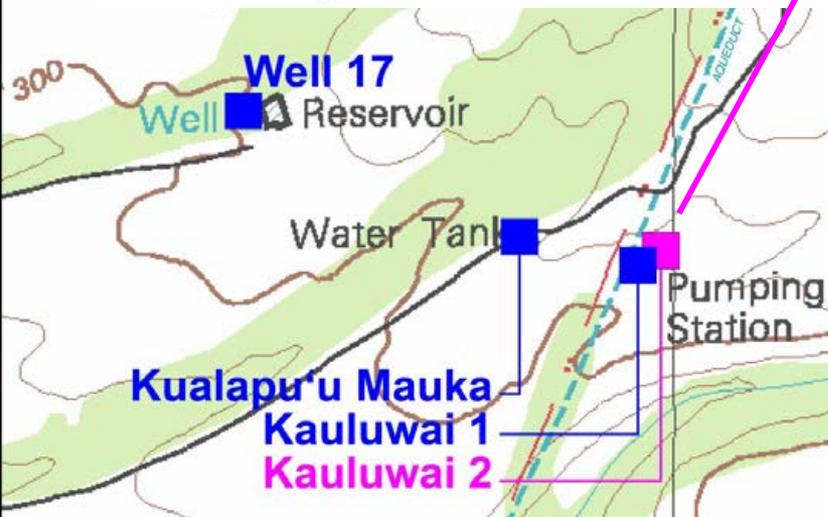
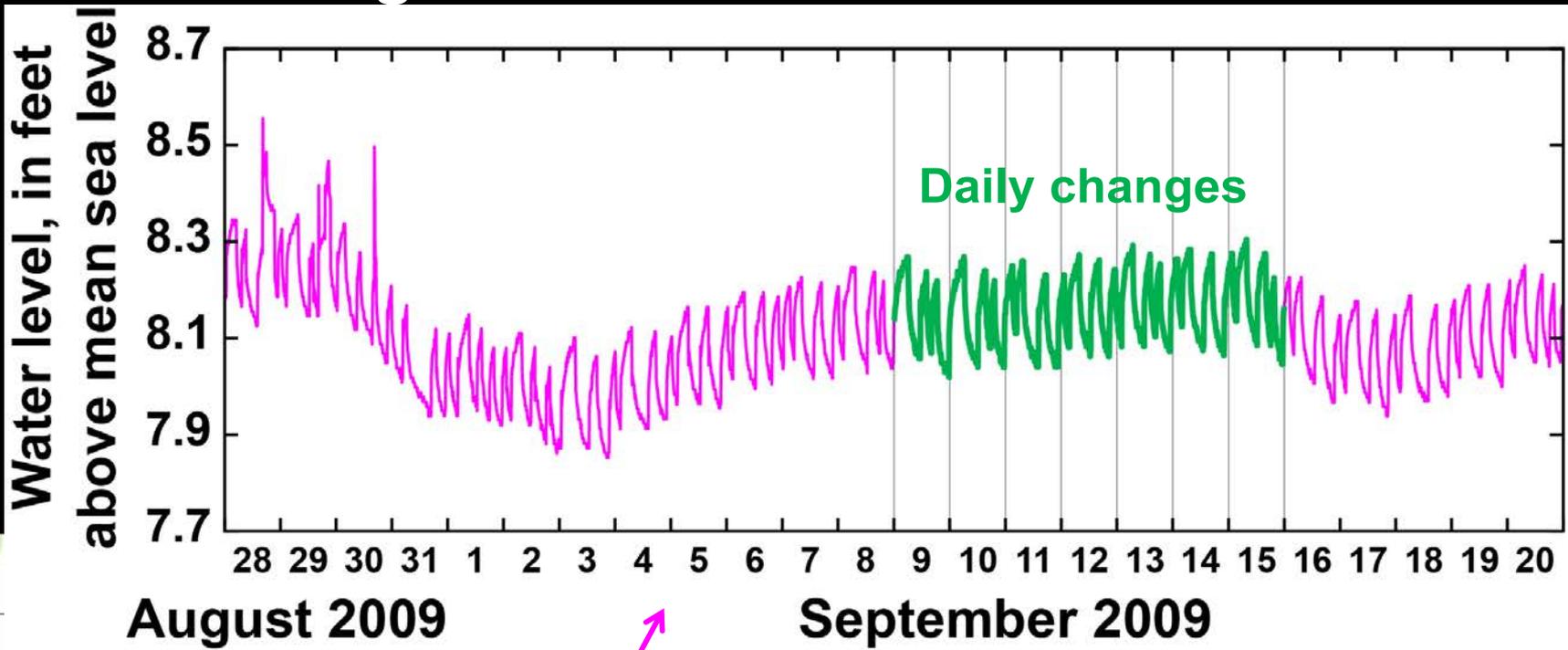


Diagnostic Water-Level Features



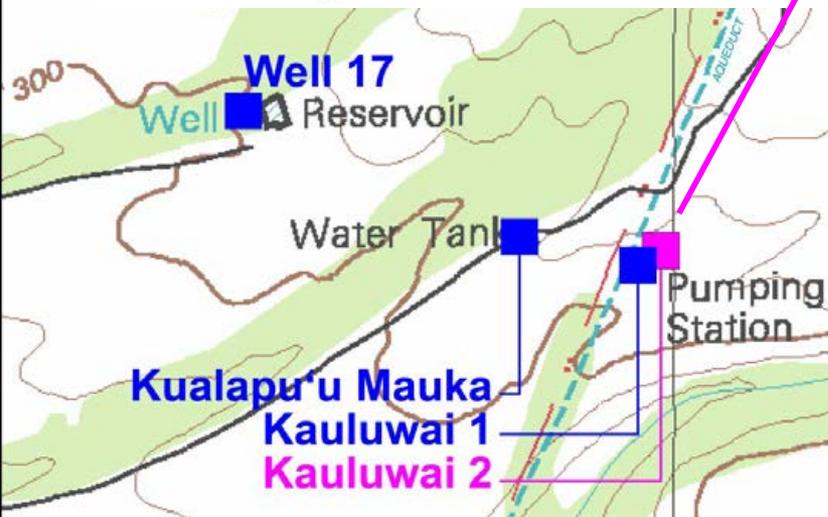
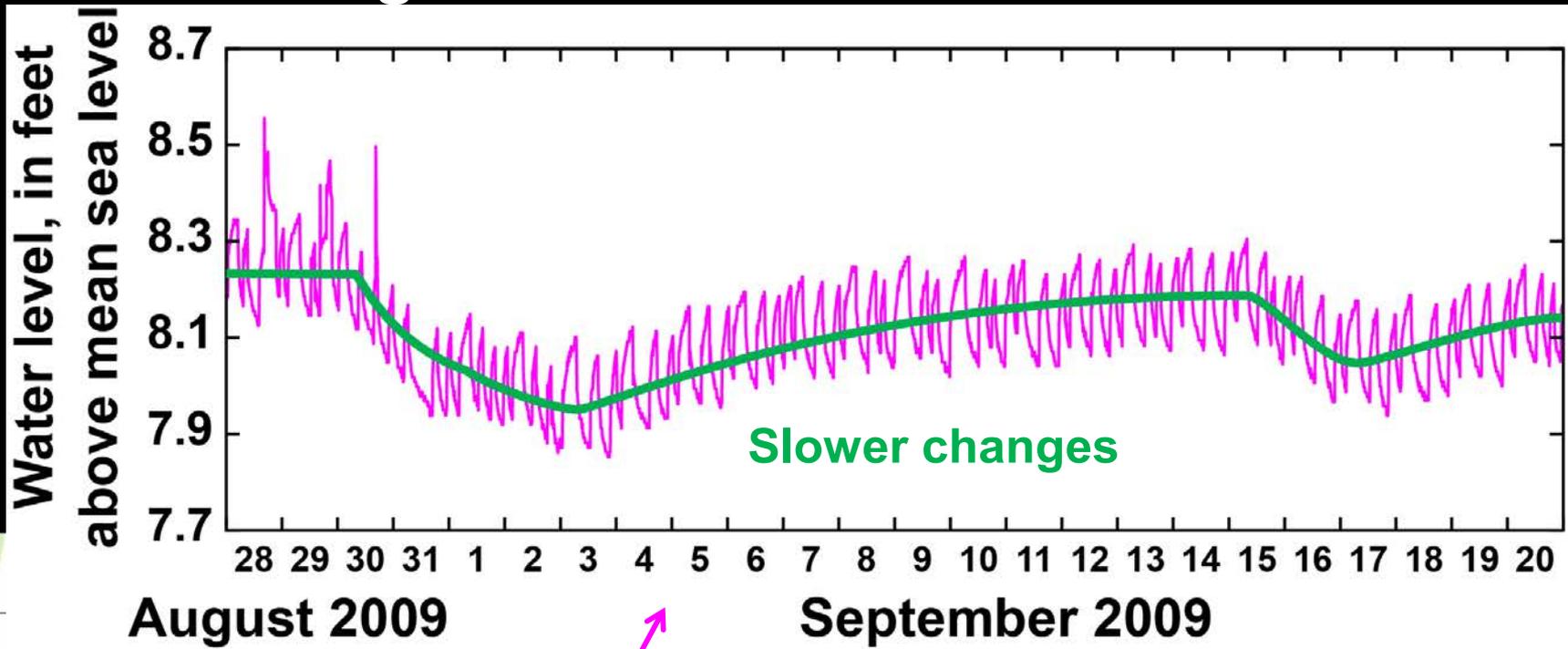
- Spikes in late August
- Daily changes (sawtooth appearance)
- Slower changes (several days)

Diagnostic Water-Level Features



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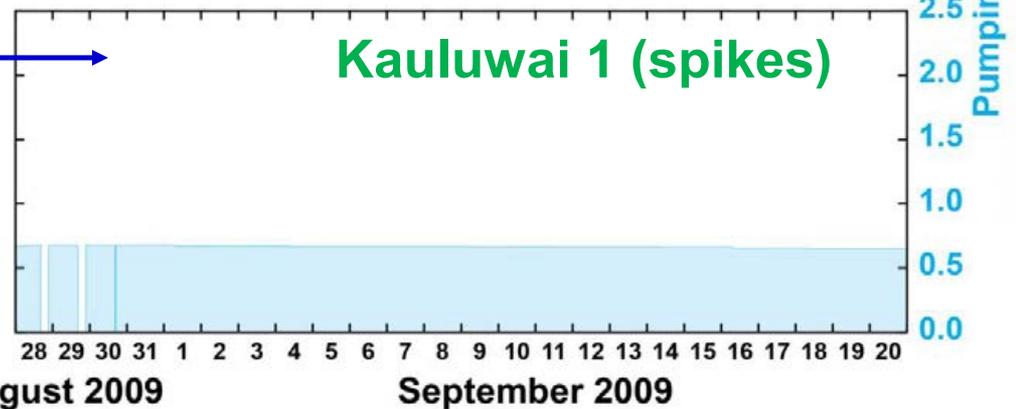
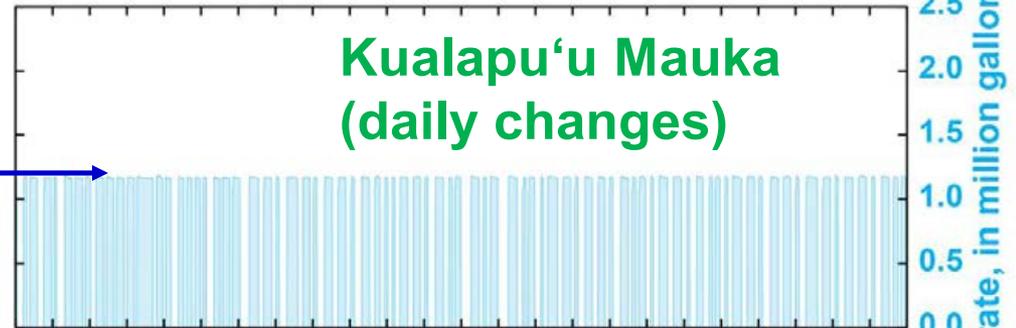
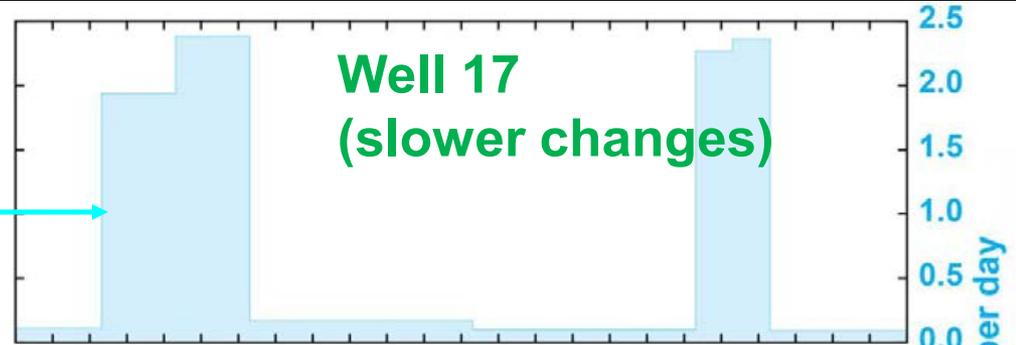
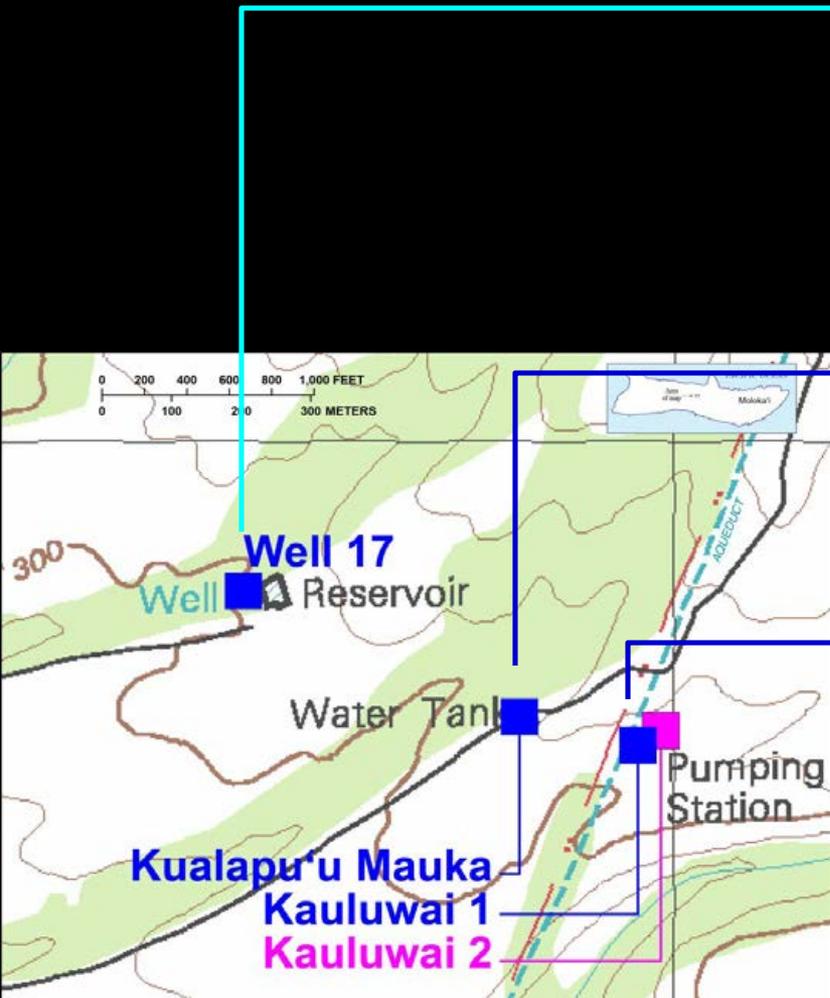
Diagnostic Water-Level Features



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- Slower changes (several days)

Kualapu'u Pumpage

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



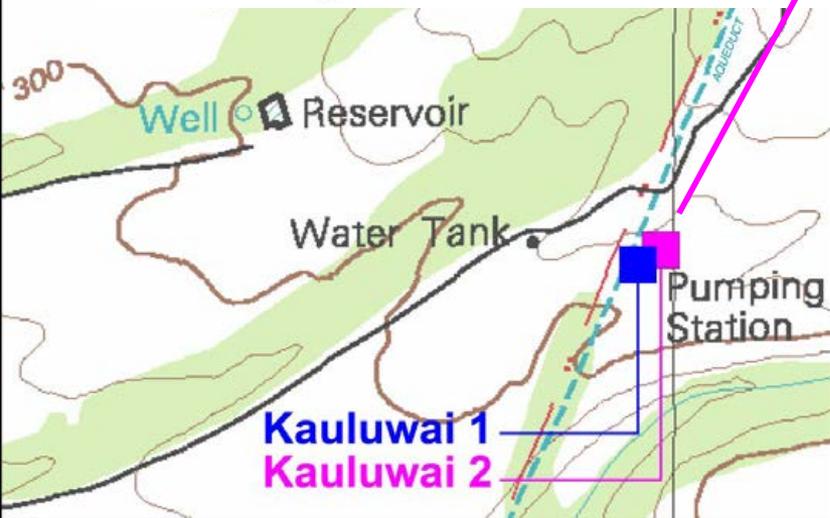
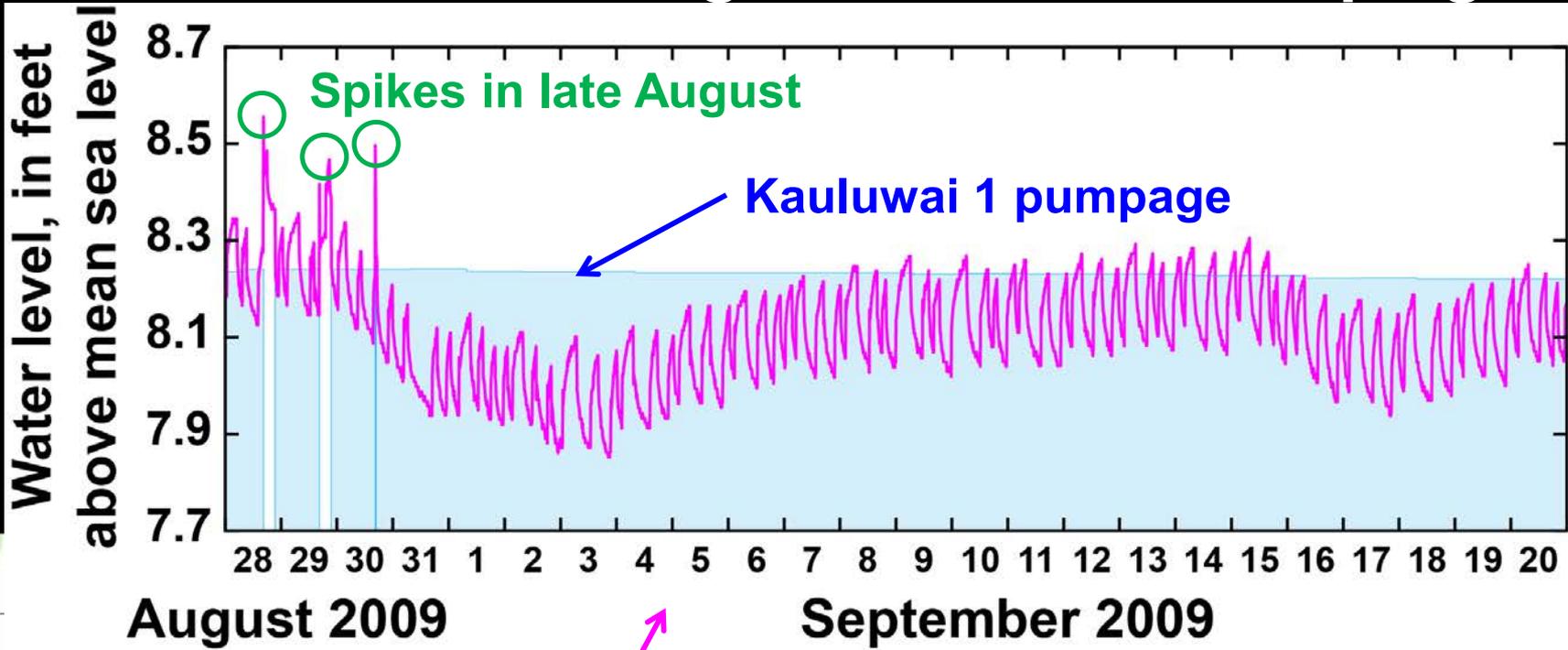
August 2009

September 2009



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Water-Level Changes Related to Pumping

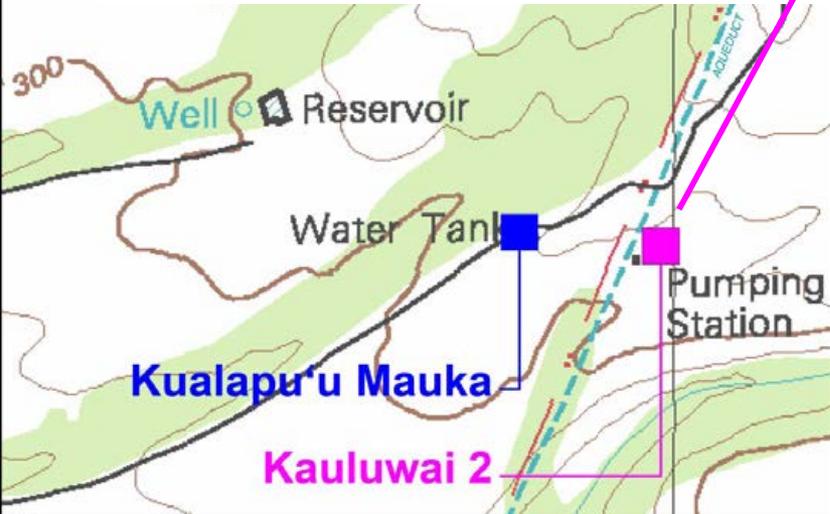
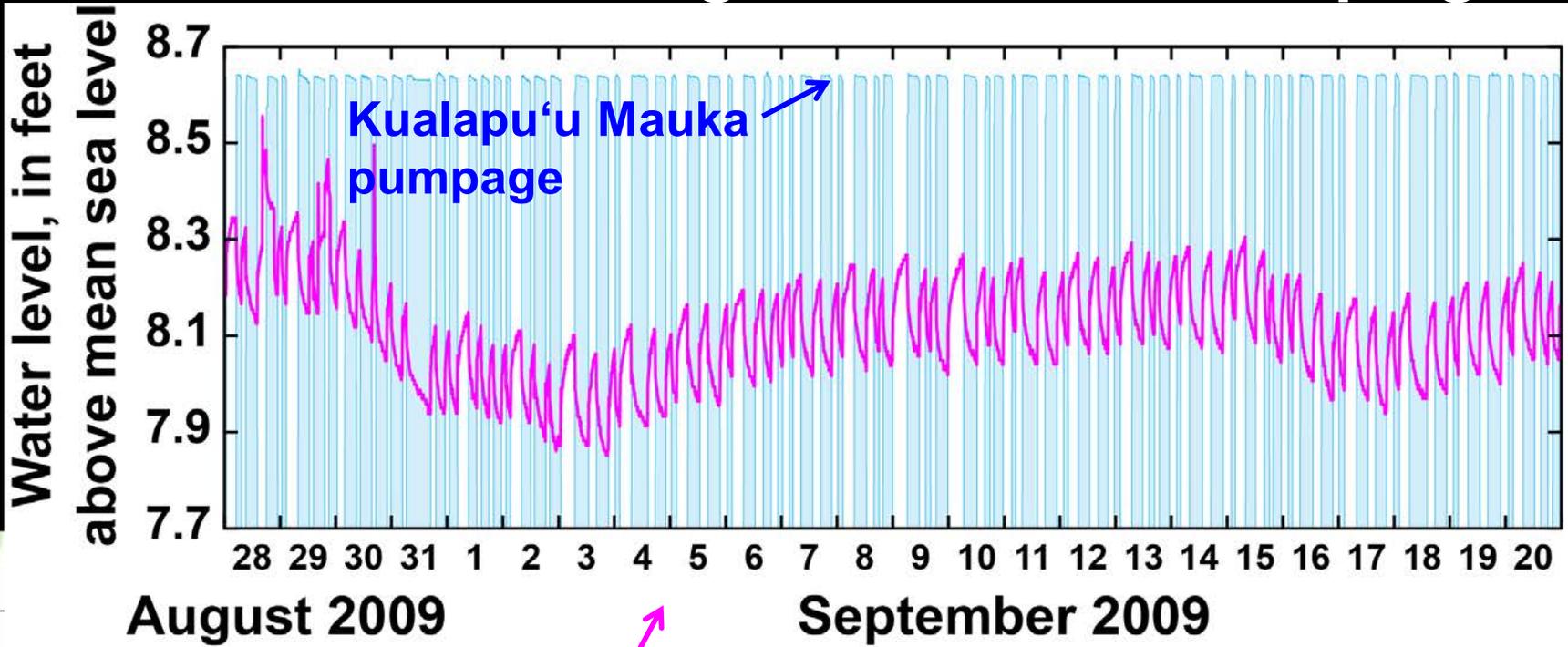


- Spikes in late August
- Daily changes (sawtooth appearance)
- Slower changes (several days)



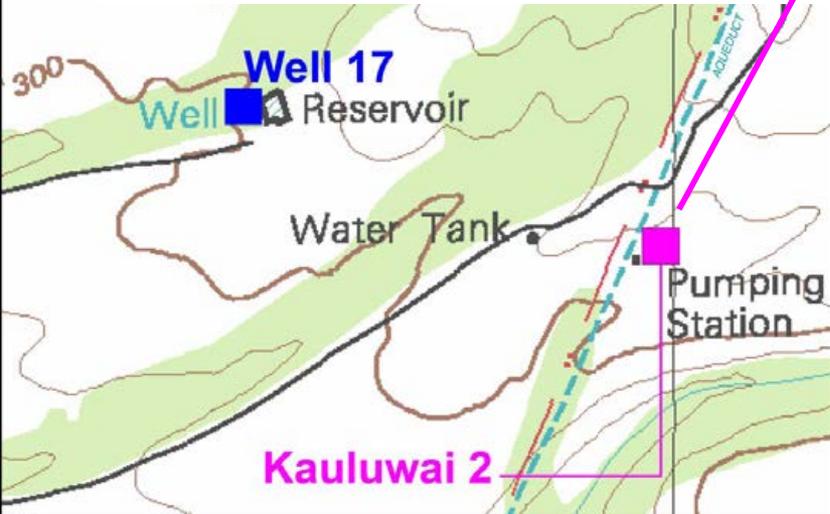
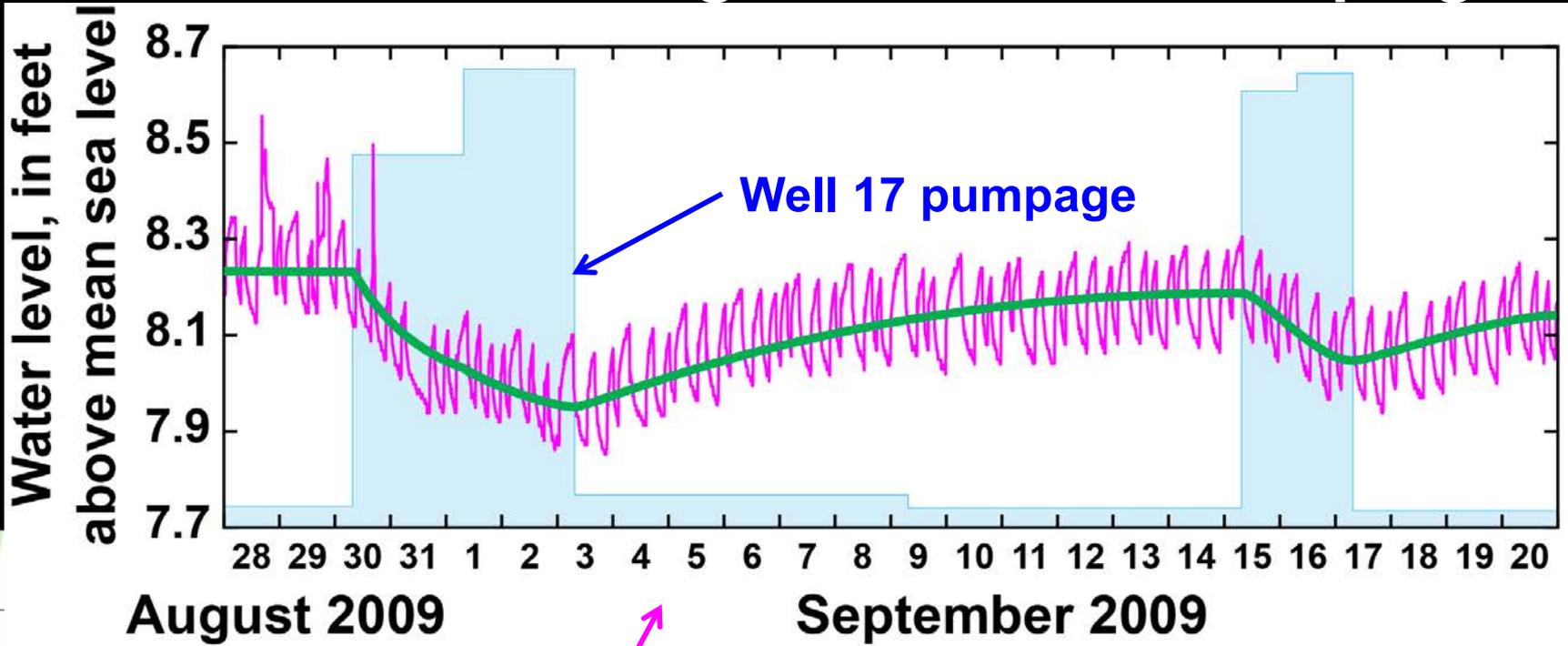
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Water-Level Changes Related to Pumping



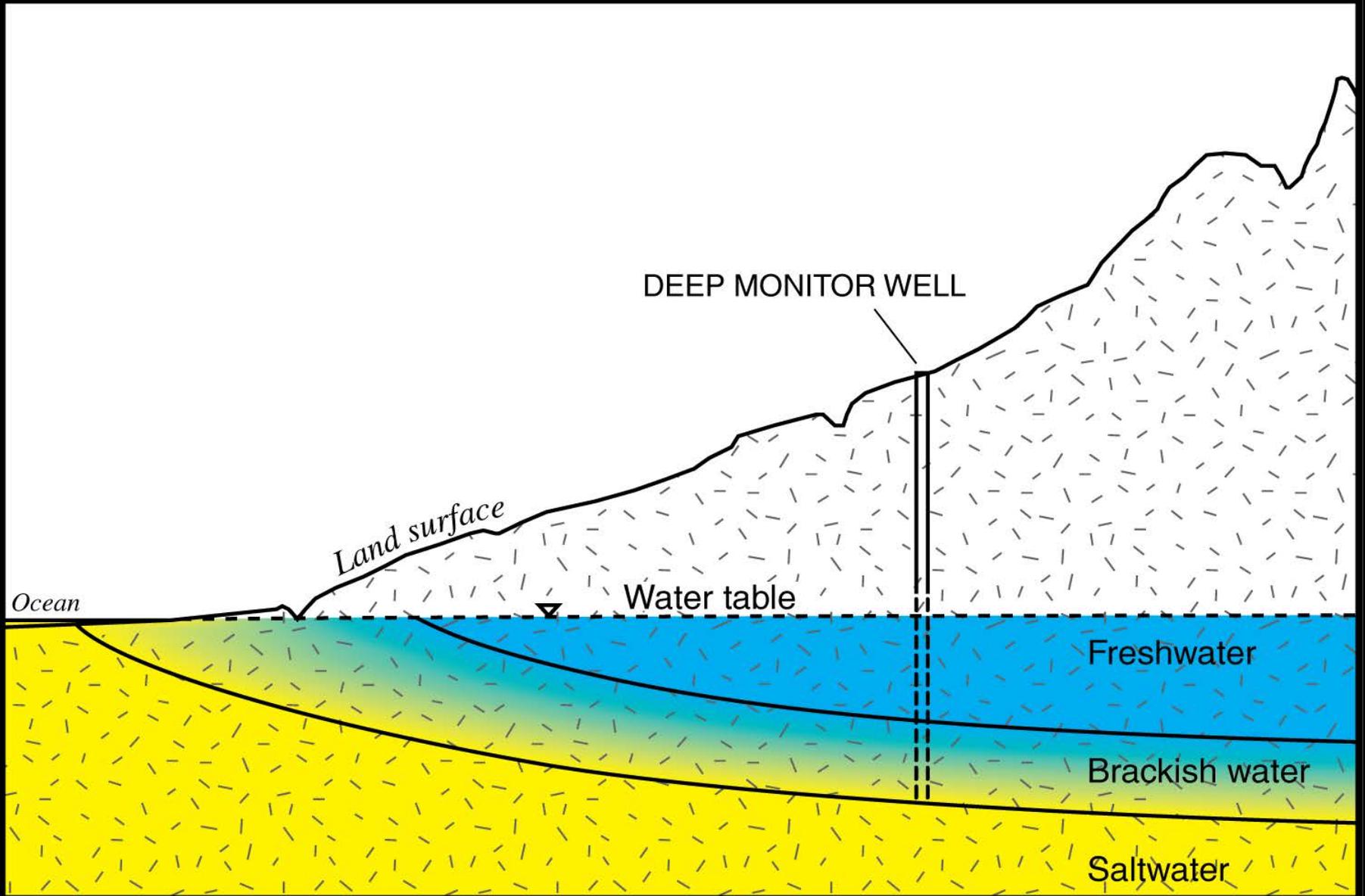
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Water-Level Changes Related to Pumping

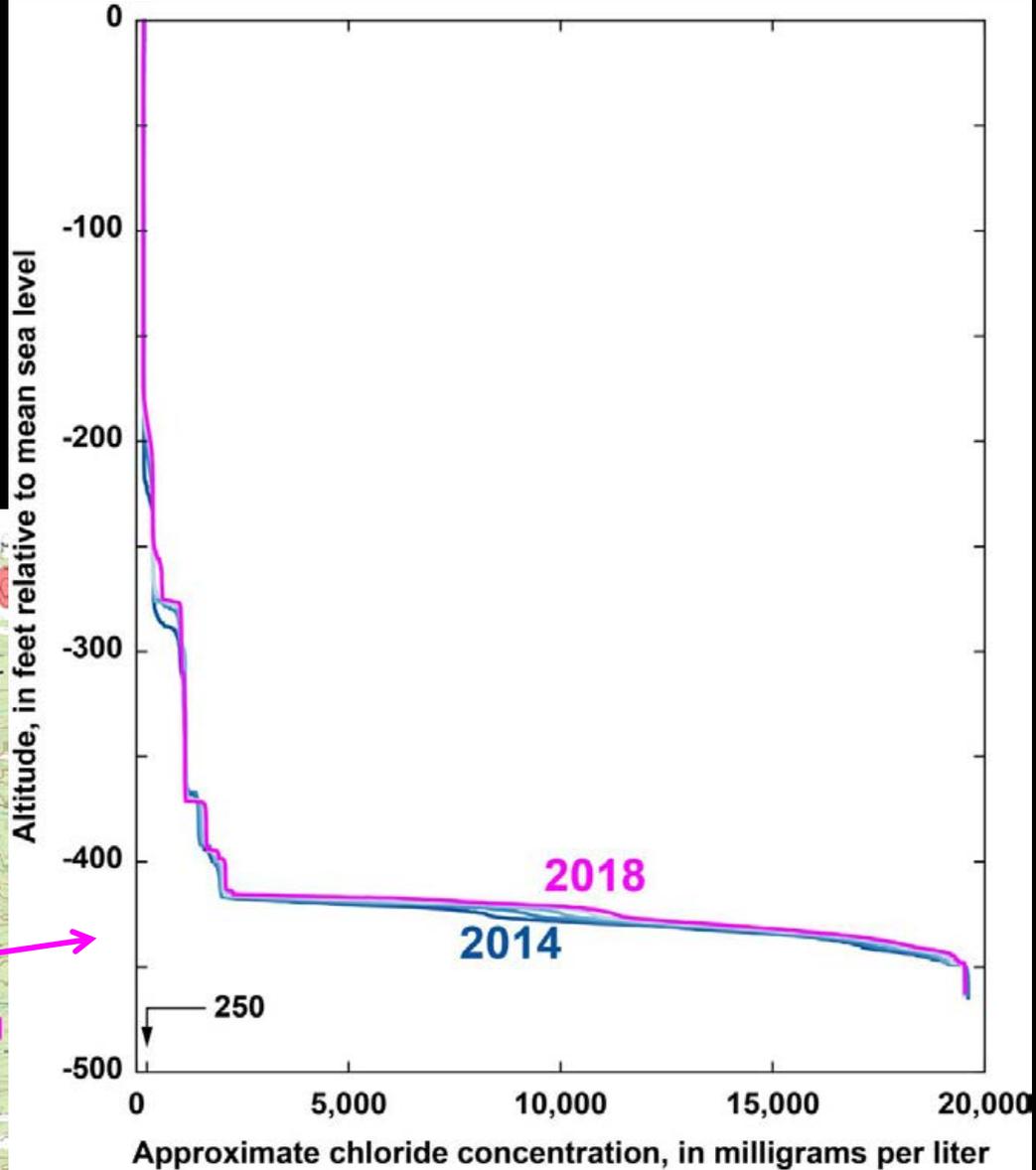
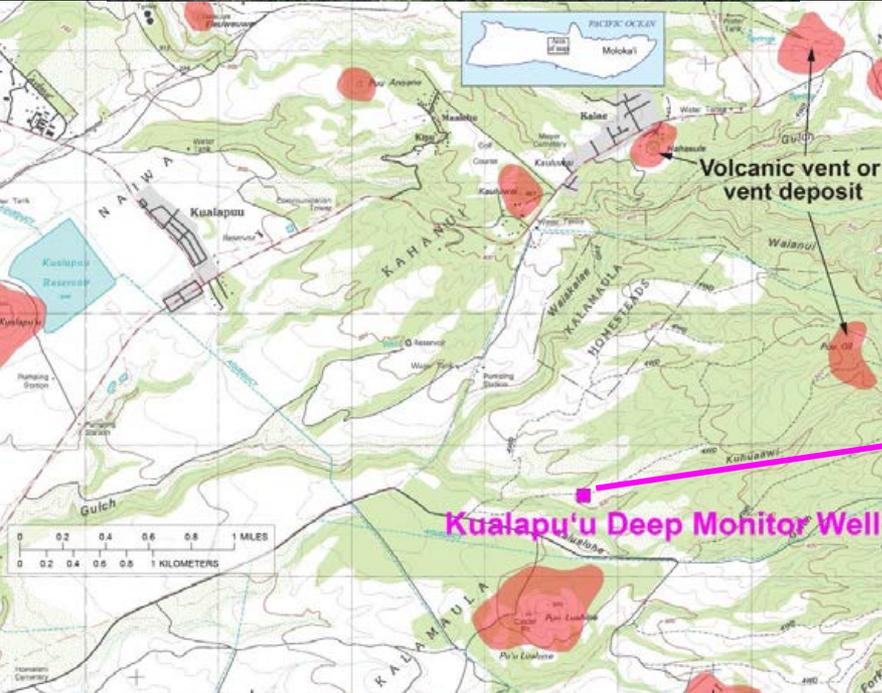


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Salinity Profiles

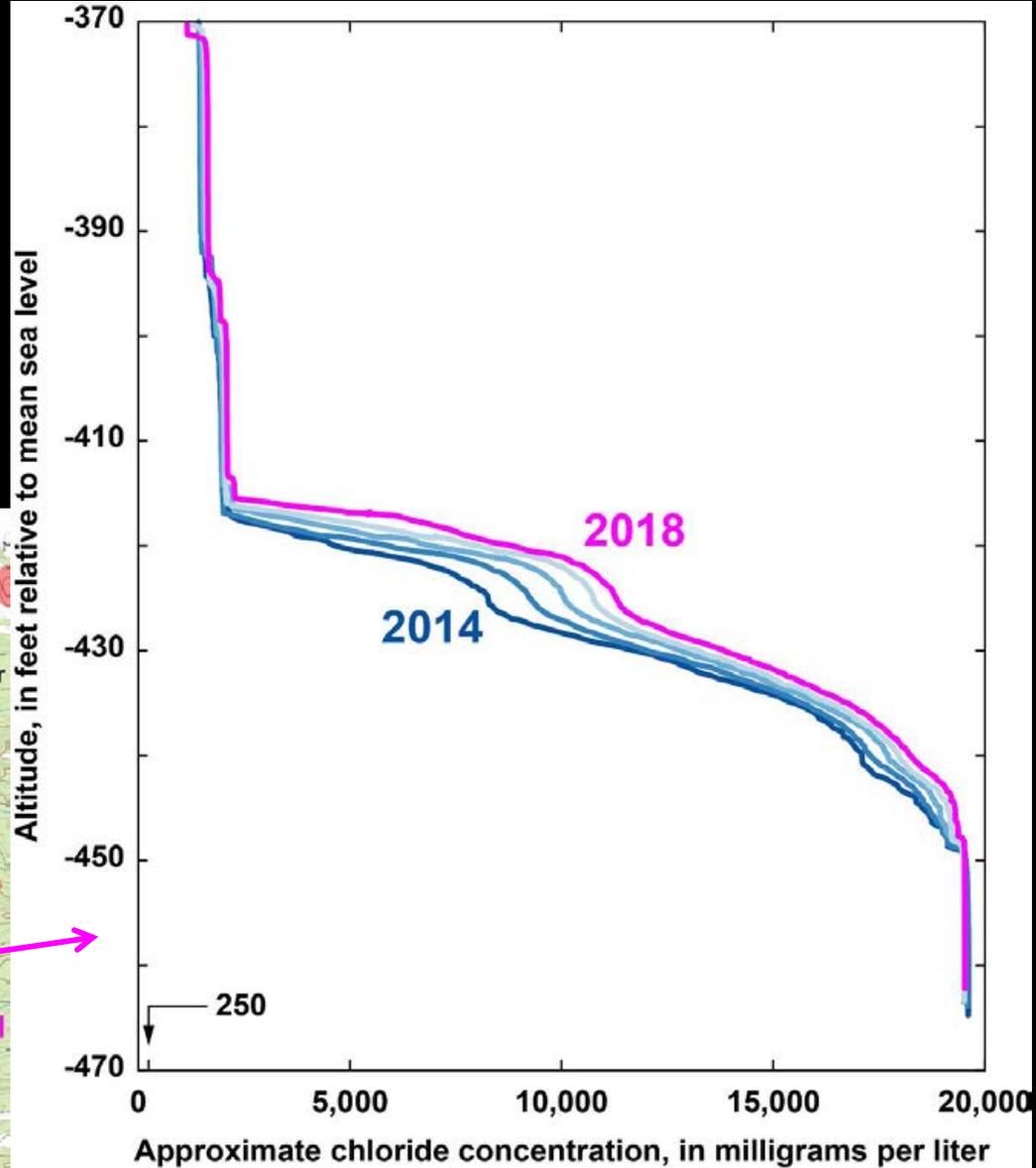
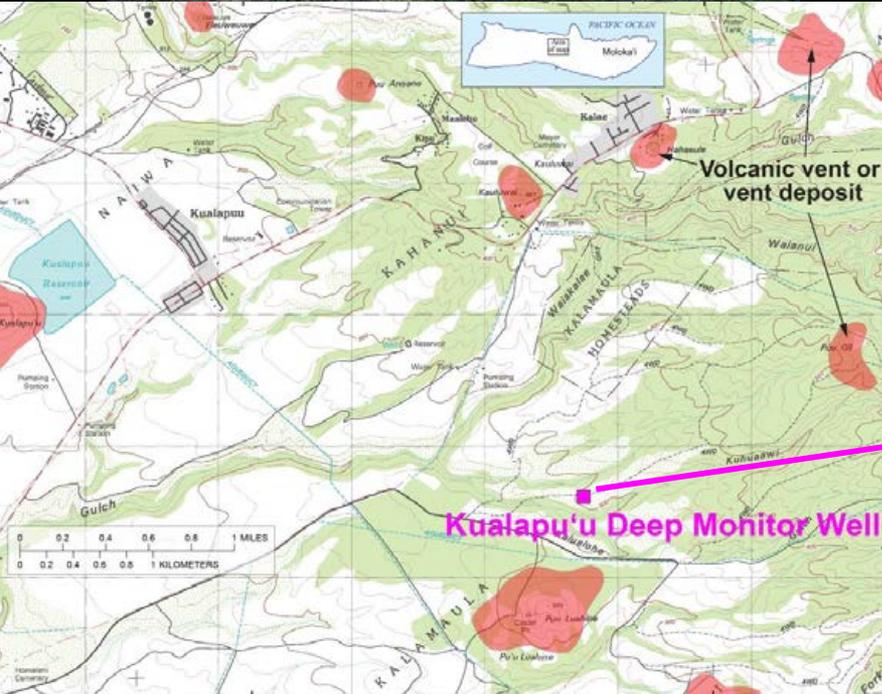


Groundwater Salinity

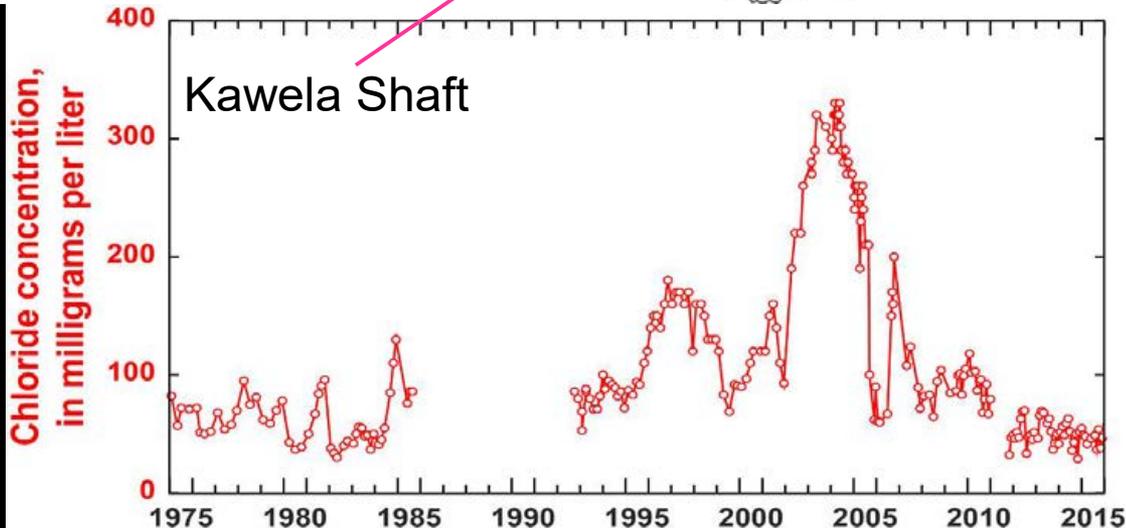
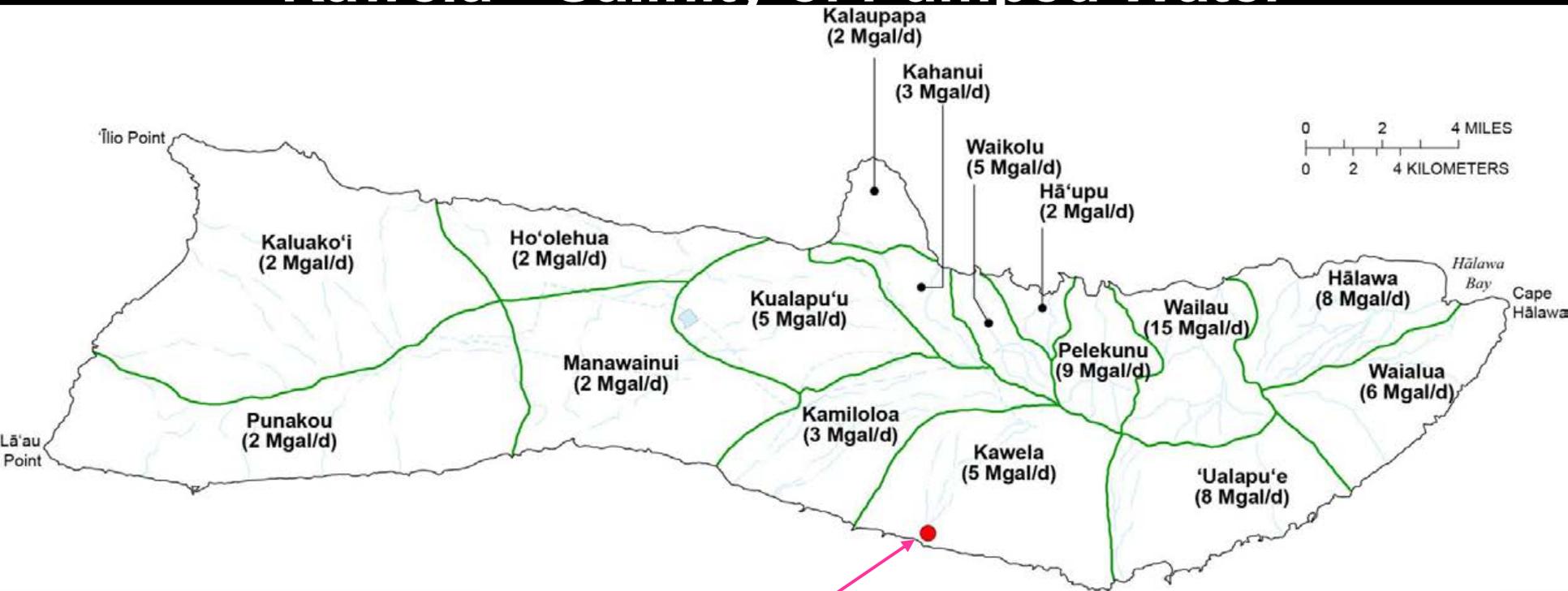


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Groundwater Salinity



Kawela—Salinity of Pumped Water

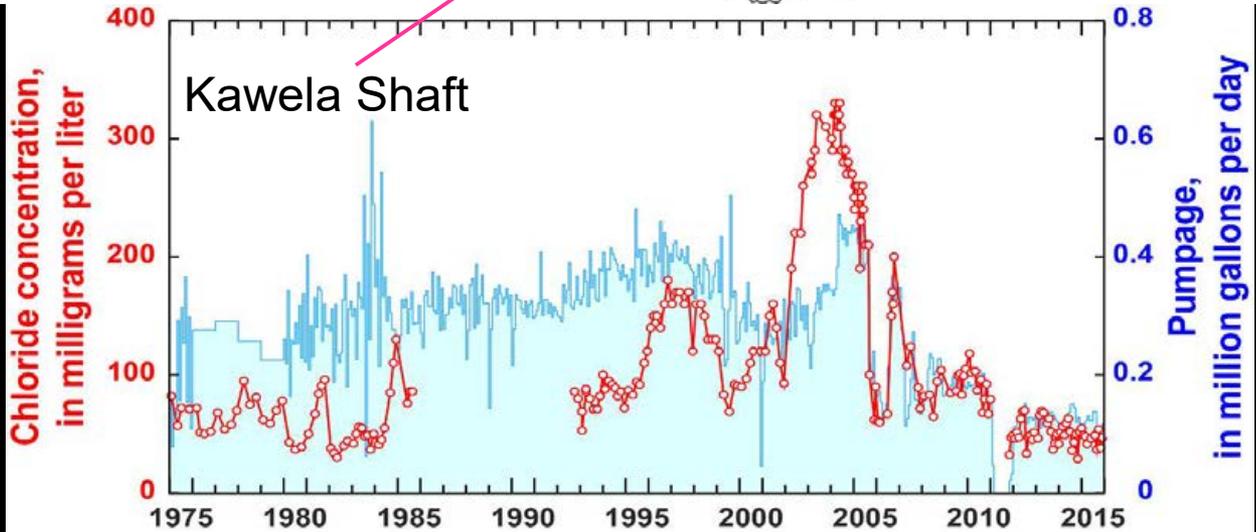
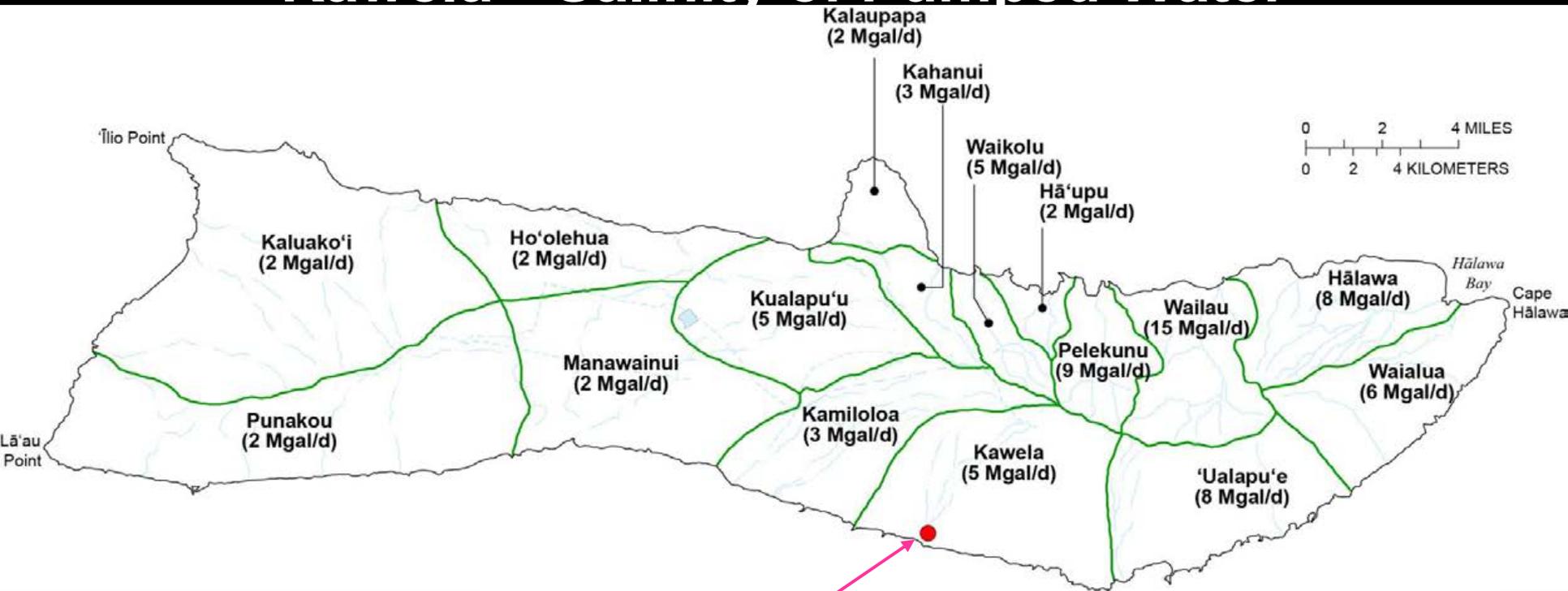


Data from Maui Department of Water Supply



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Kawela—Salinity of Pumped Water

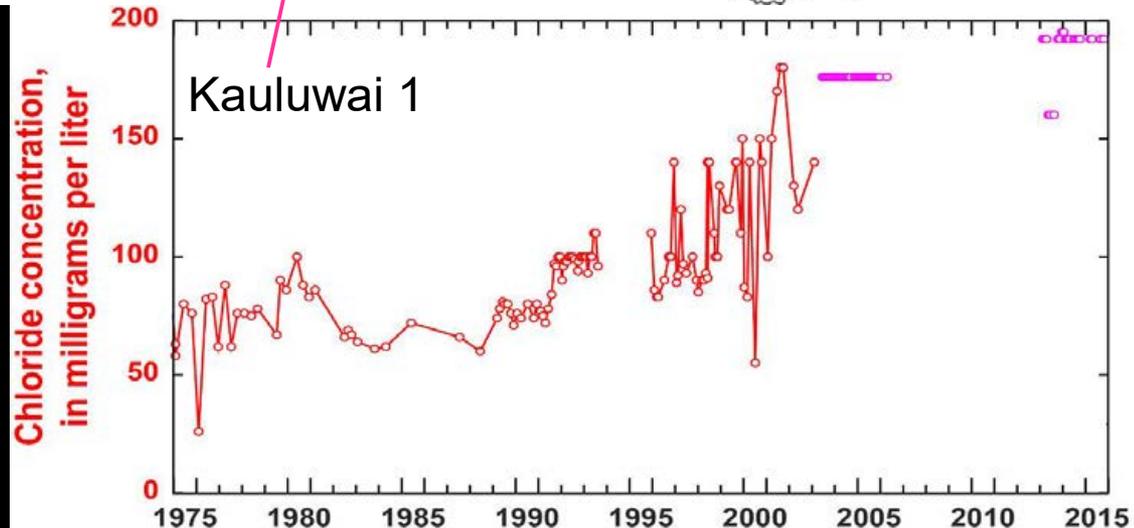
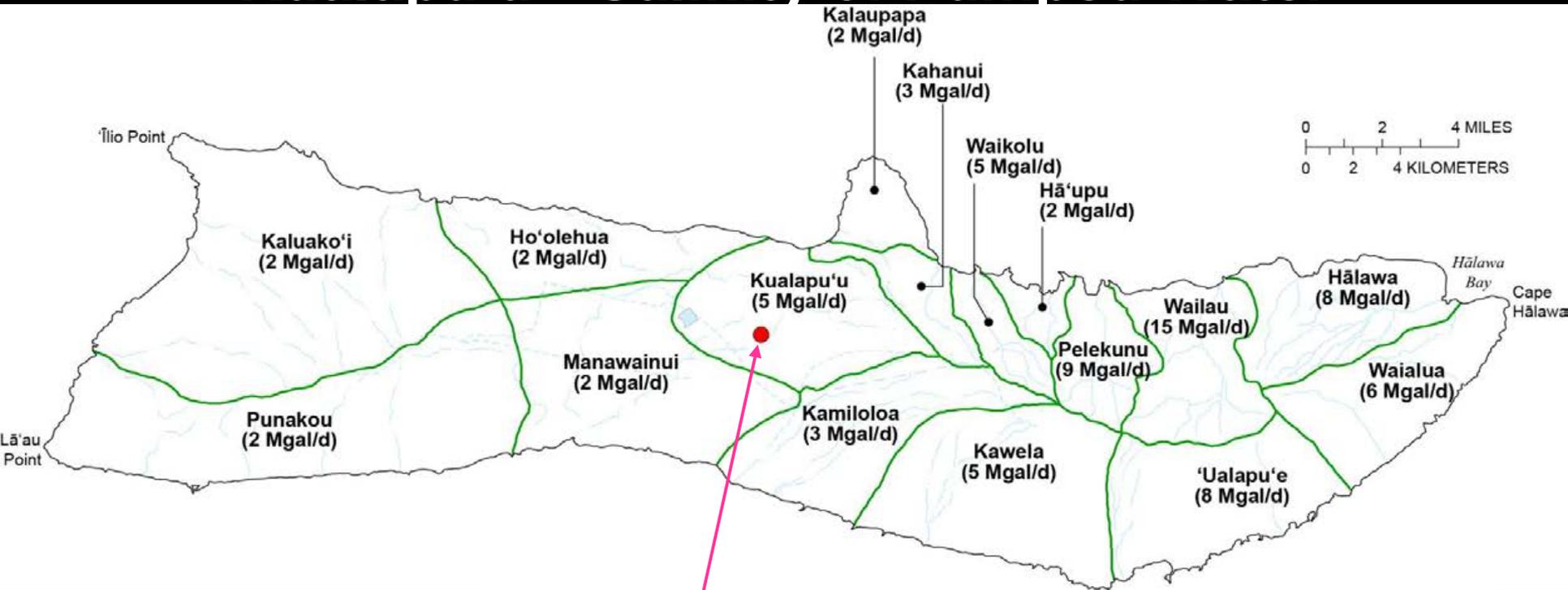


Data from Maui Department of Water Supply



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Kualapu'u—Salinity of Pumped Water

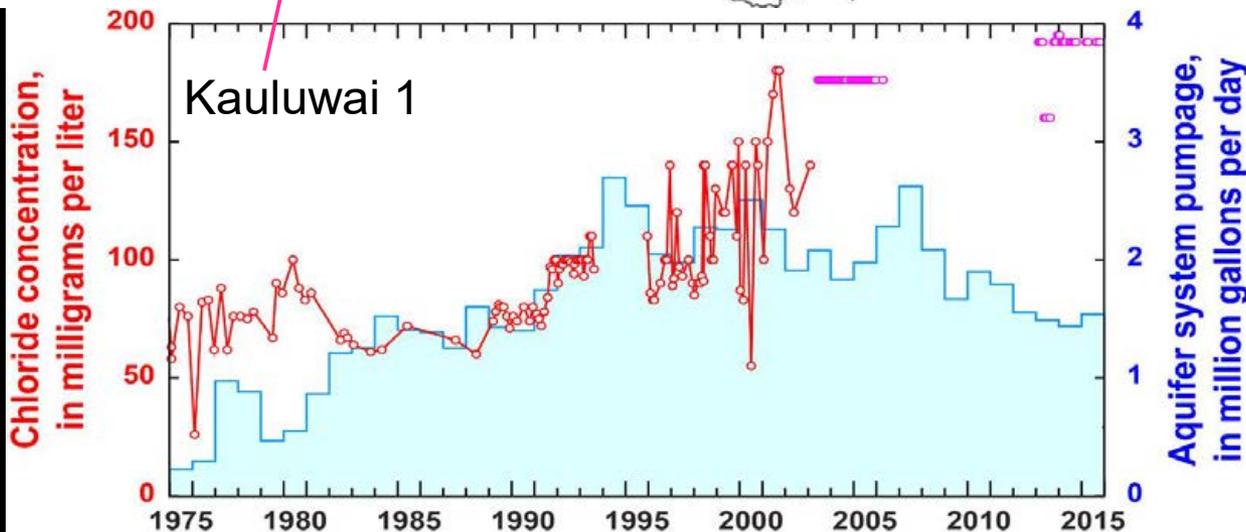
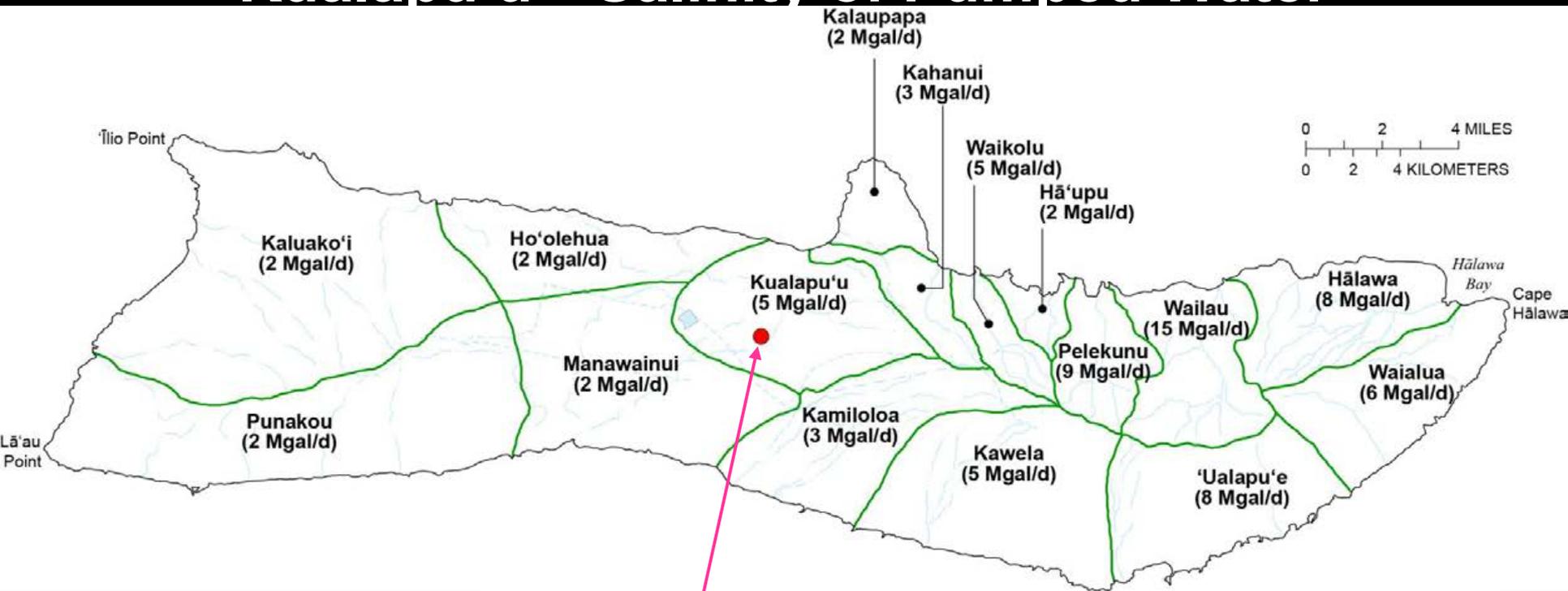


2003–15 chloride data from Hawai'i Commission on Water Resource Management



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Kualapu'u—Salinity of Pumped Water



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



This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

Effects of Groundwater Withdrawals

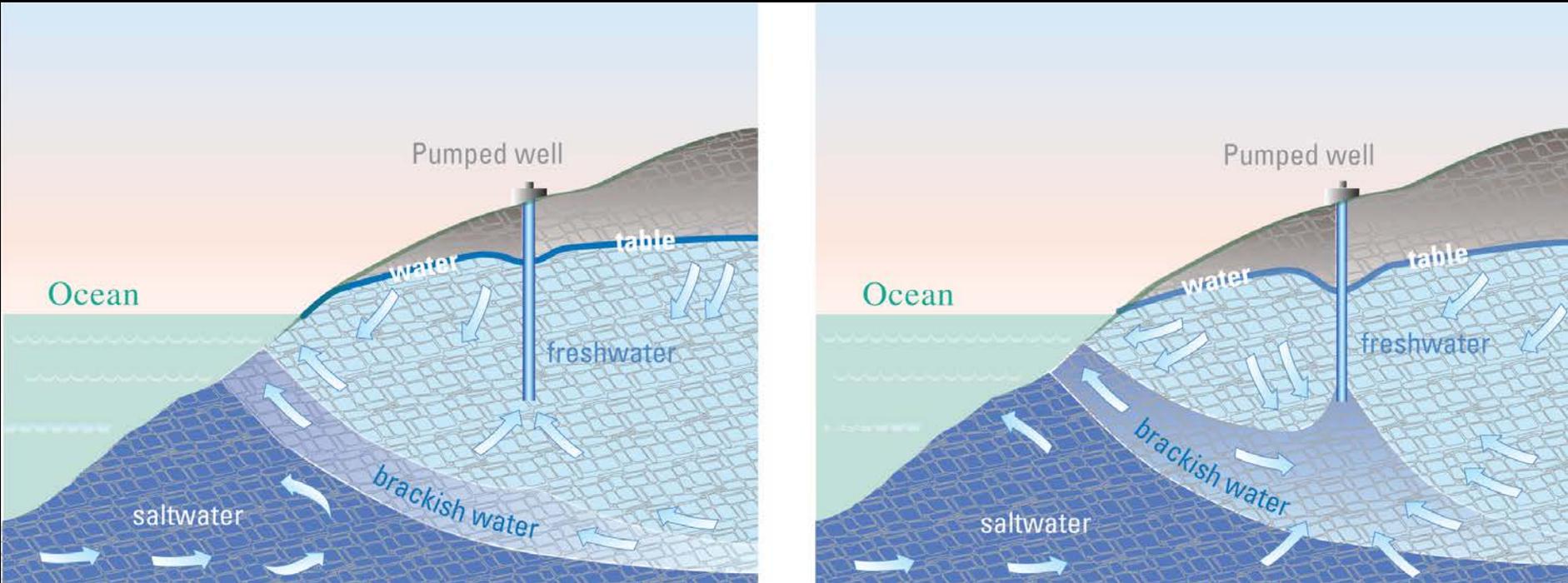
Groundwater withdrawals can affect:

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

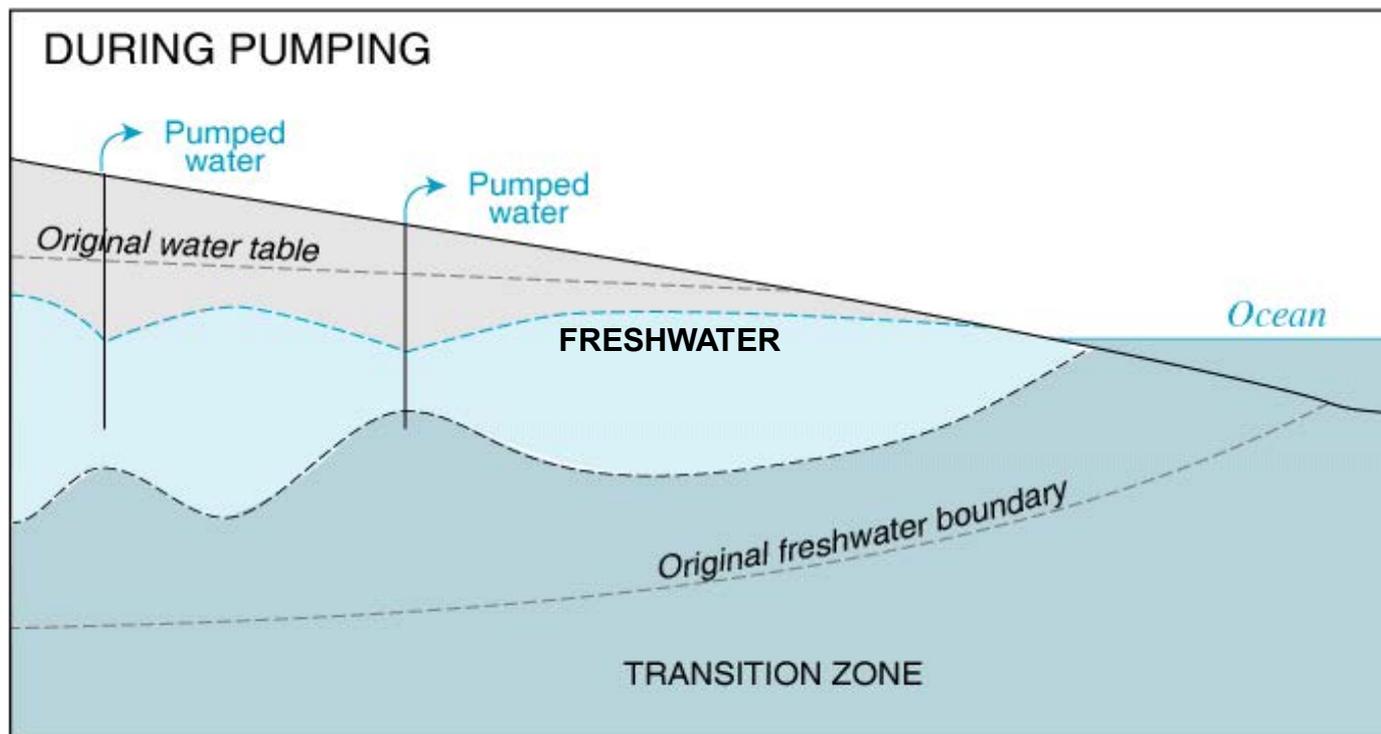
The magnitude of the effect is dependent on:

- Rate of groundwater withdrawal
- Where the groundwater is withdrawn

Groundwater Availability (Limited by Salinity)

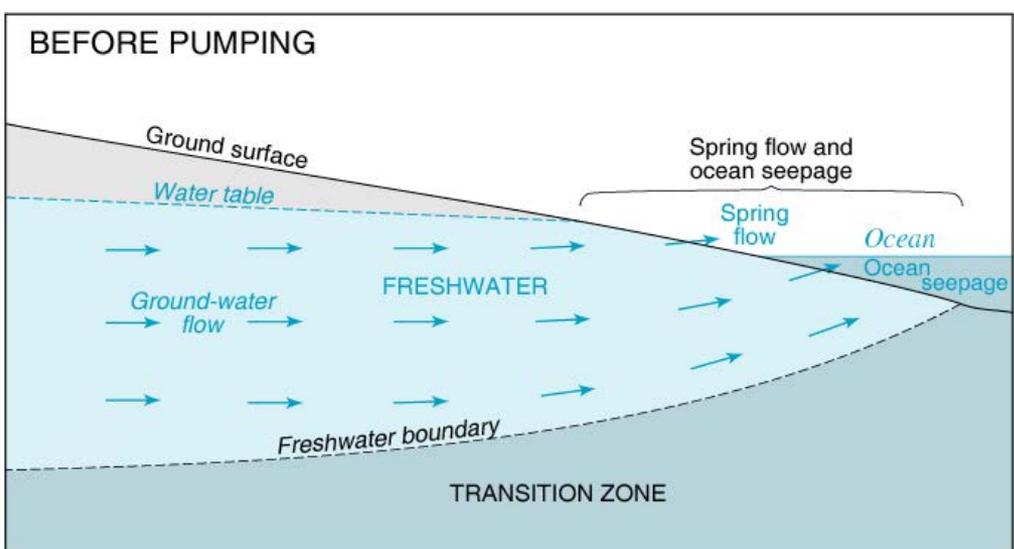


Pumping Can Affect Neighboring Wells



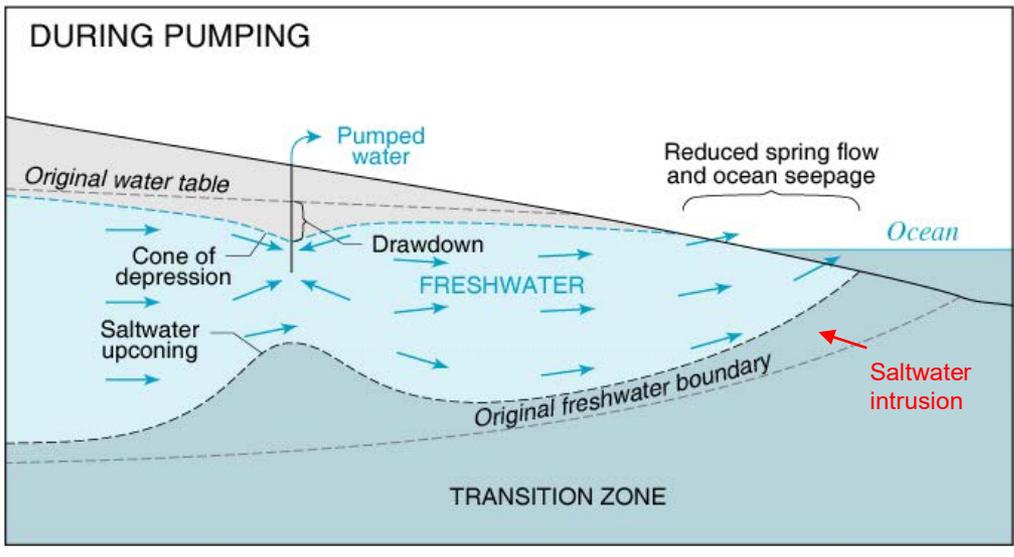
1. Increase salinity in another well
2. Lower water levels in another well

Pumping Reduces Natural Discharge



NATURAL EQUILIBRIUM

recharge = natural discharge

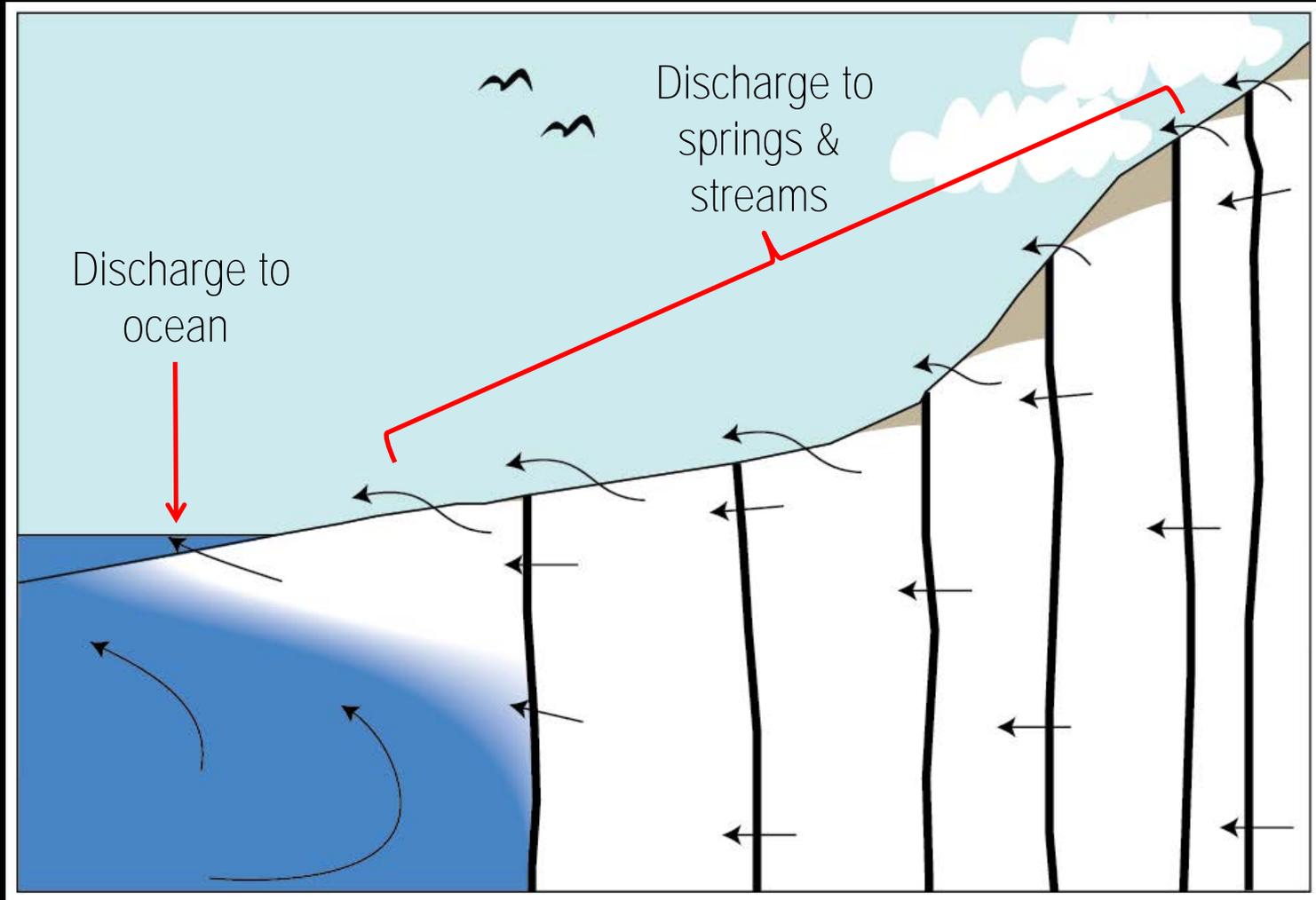


NEW EQUILIBRIUM

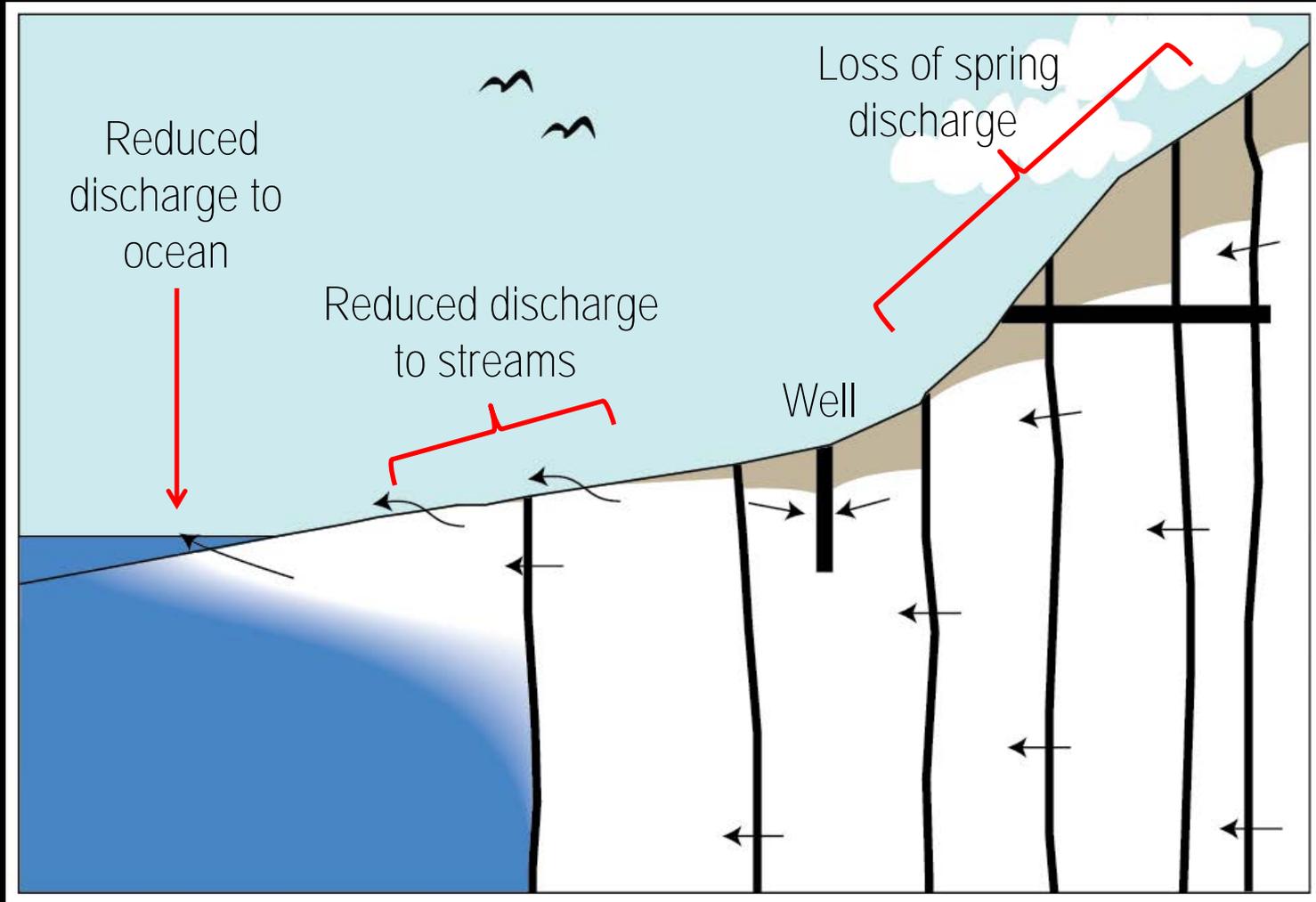
recharge = natural discharge + pumpage



Pumping Can Affect Streamflow



Pumping Can Affect Streamflow



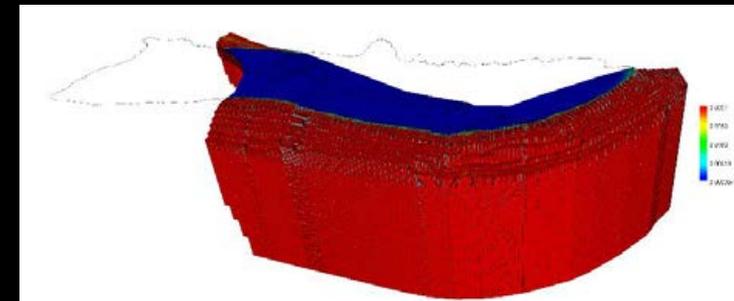
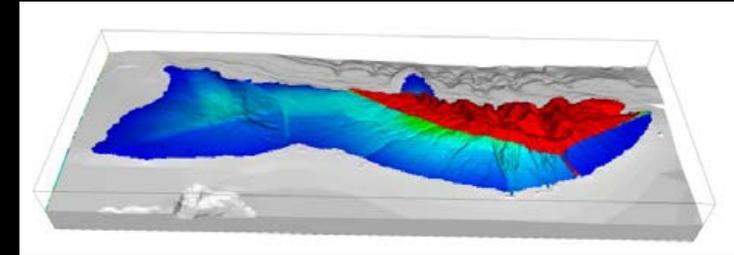
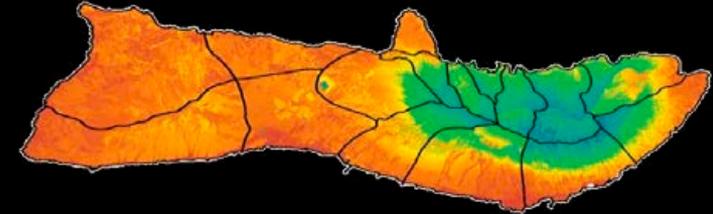
USGS Study Objective

- 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



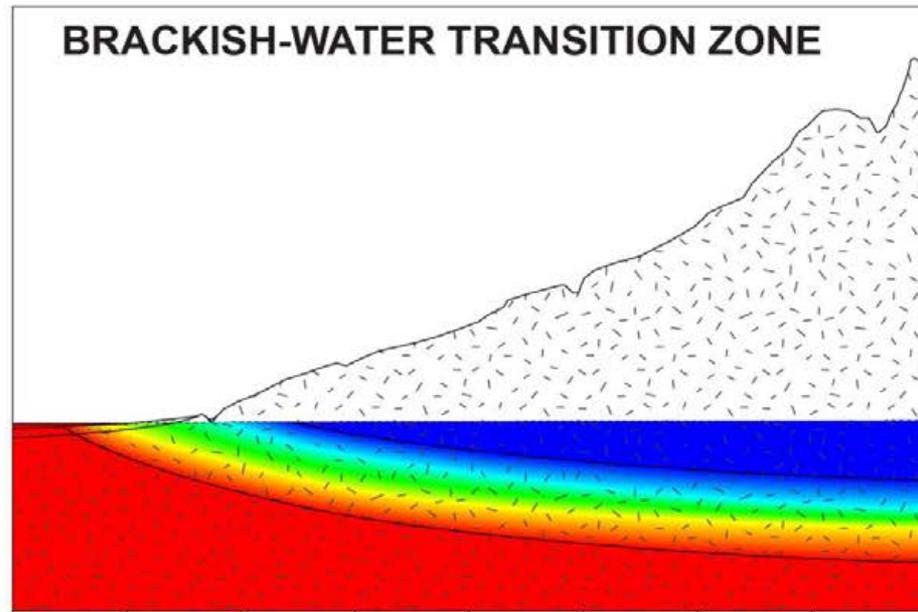
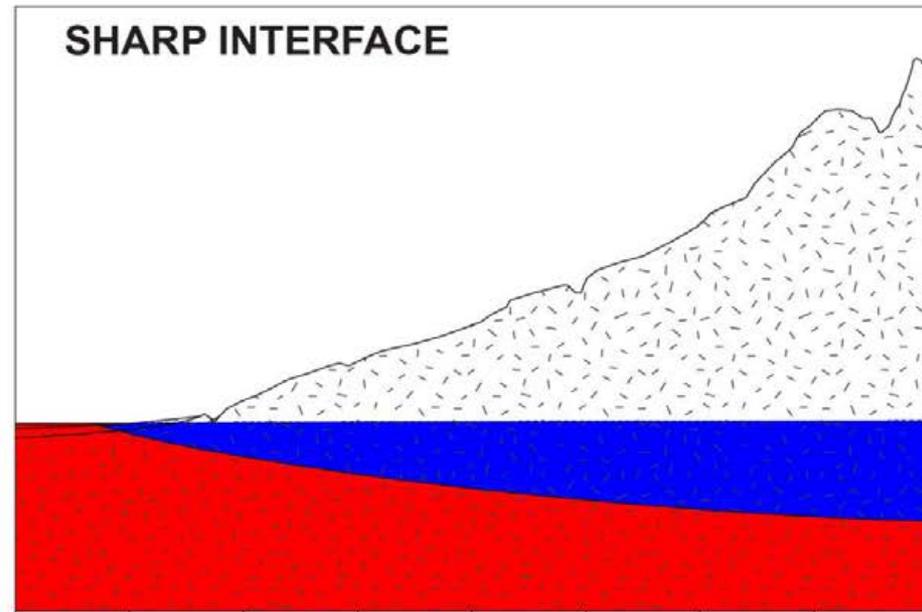
Groundwater Models for USGS Study

2D island-wide model

3D regional model

SHARP INTERFACE

BRACKISH-WATER TRANSITION ZONE

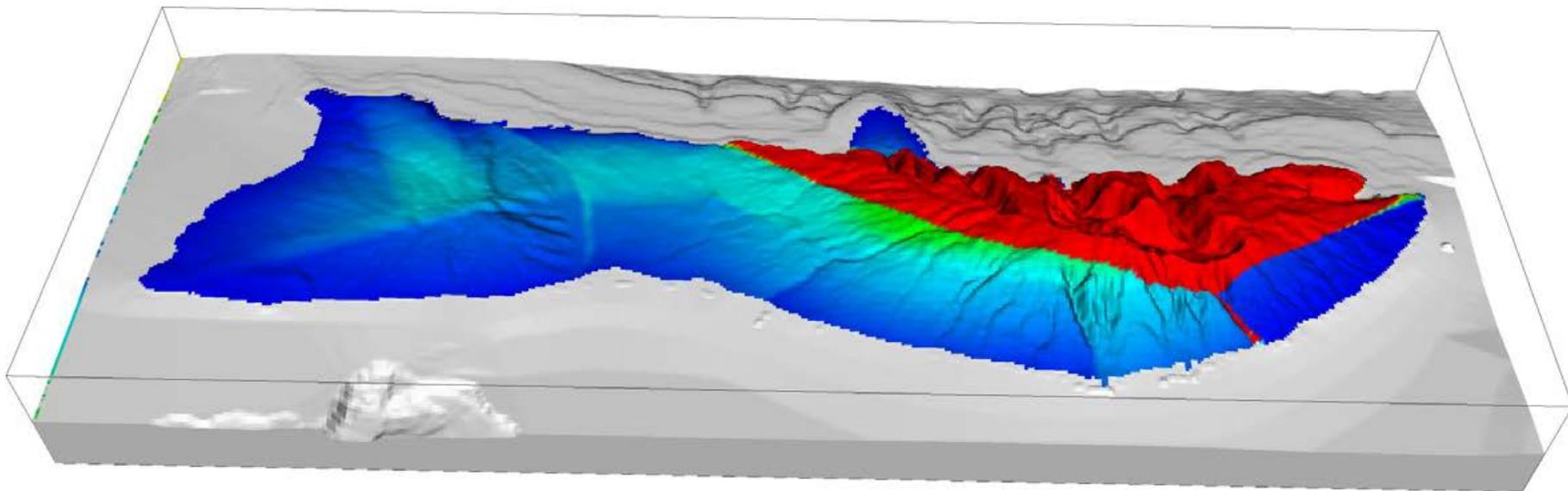


 FRESHWATER

 BRACKISH WATER

 SALTWATER

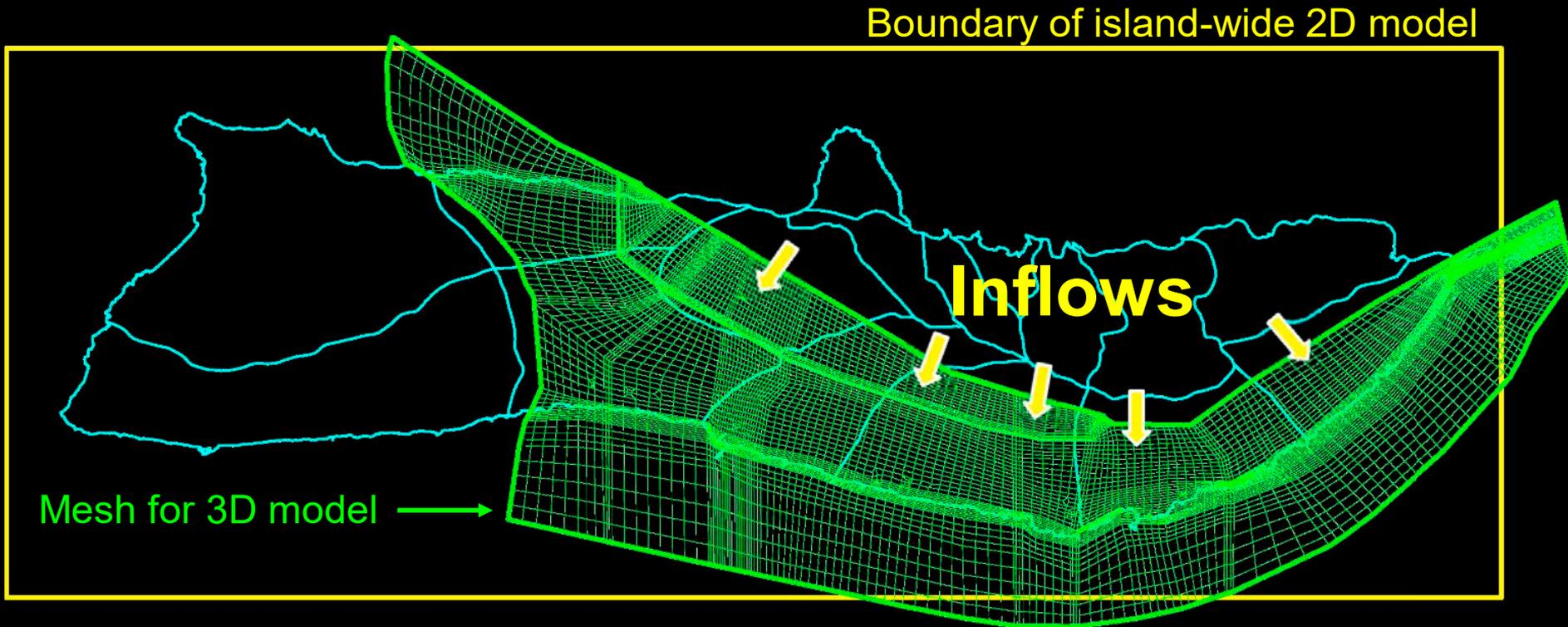
Numerical (Computer) Groundwater Model



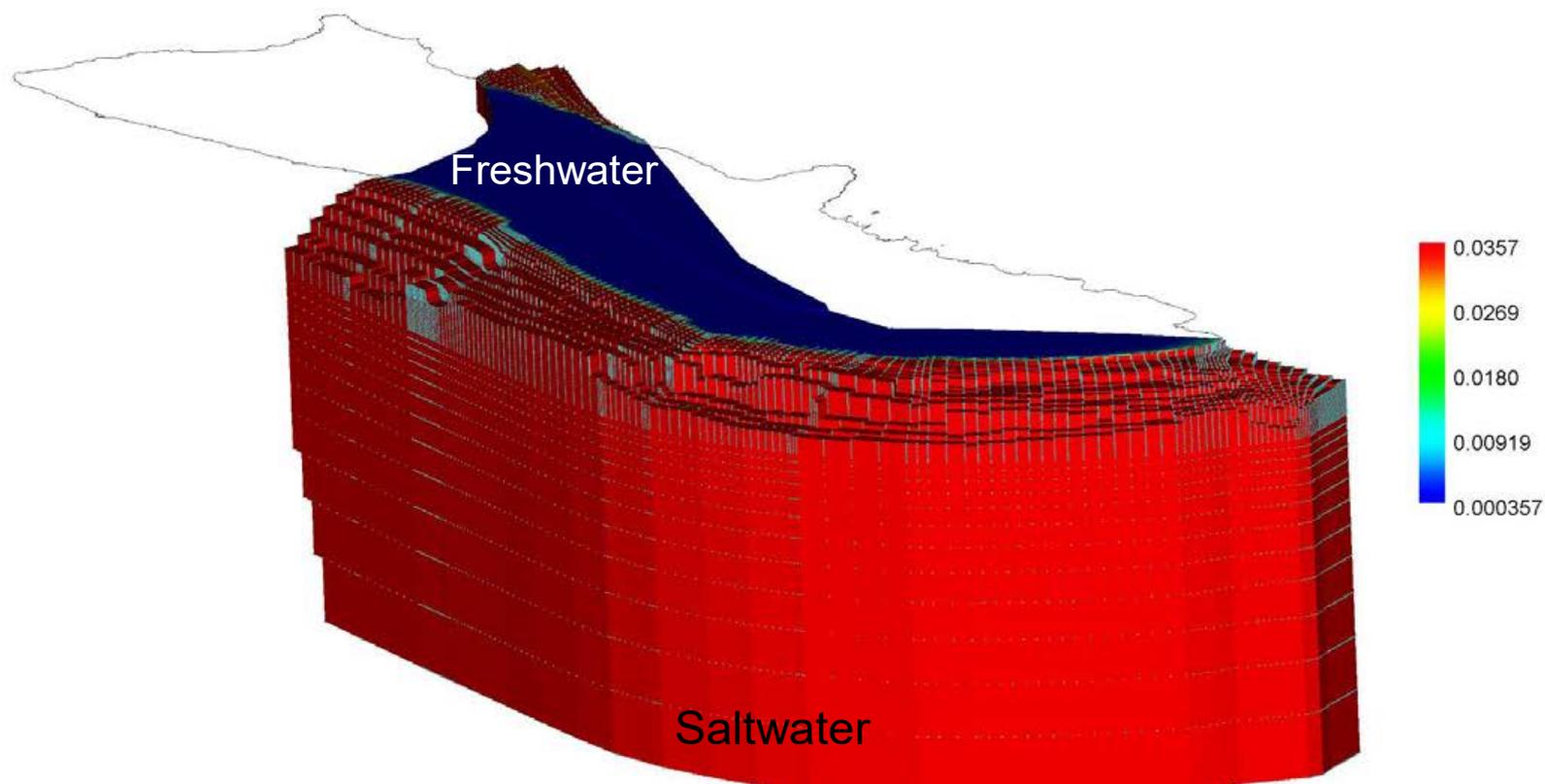
Requires:

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

Numerical Models

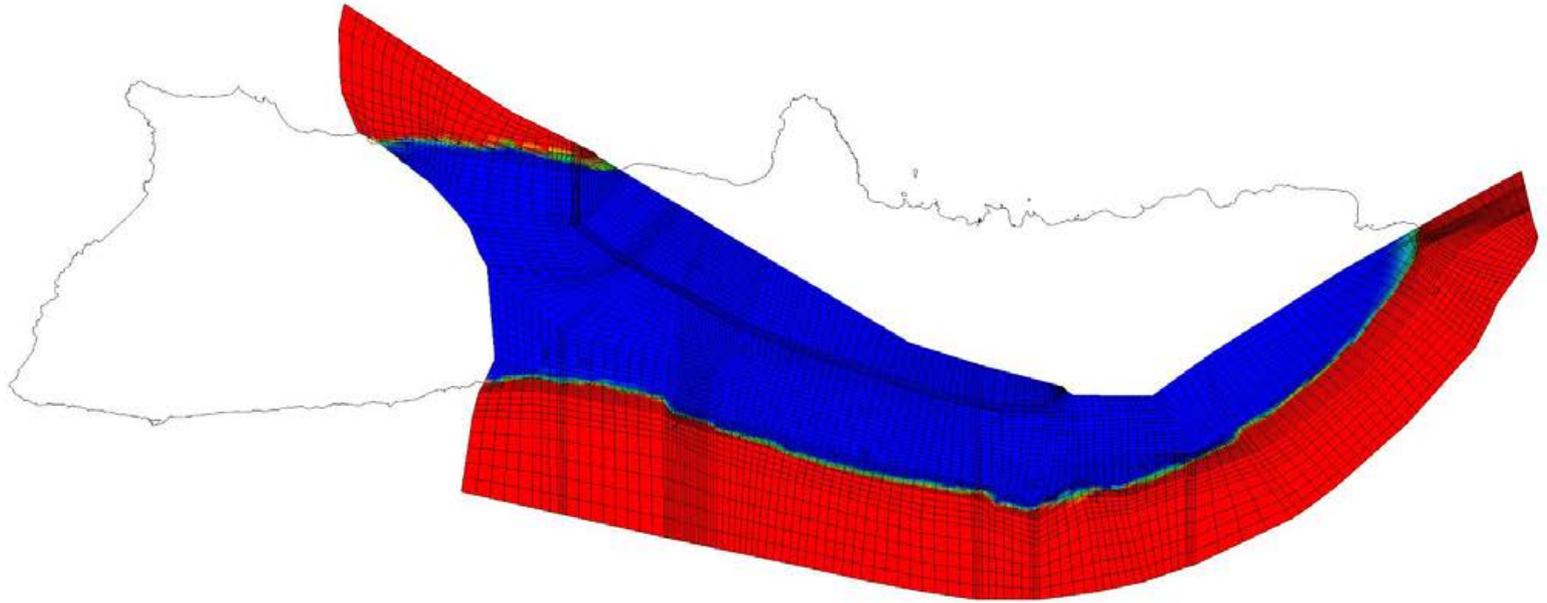


Study Area 3-D Model—Oblique View



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

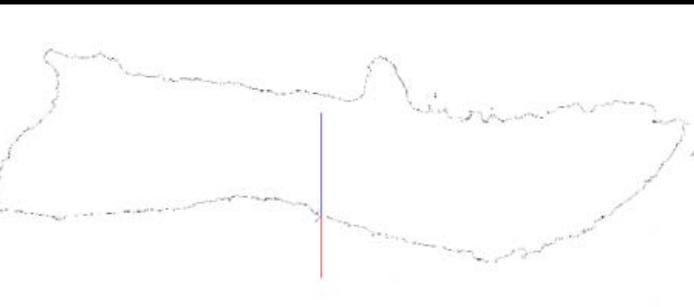
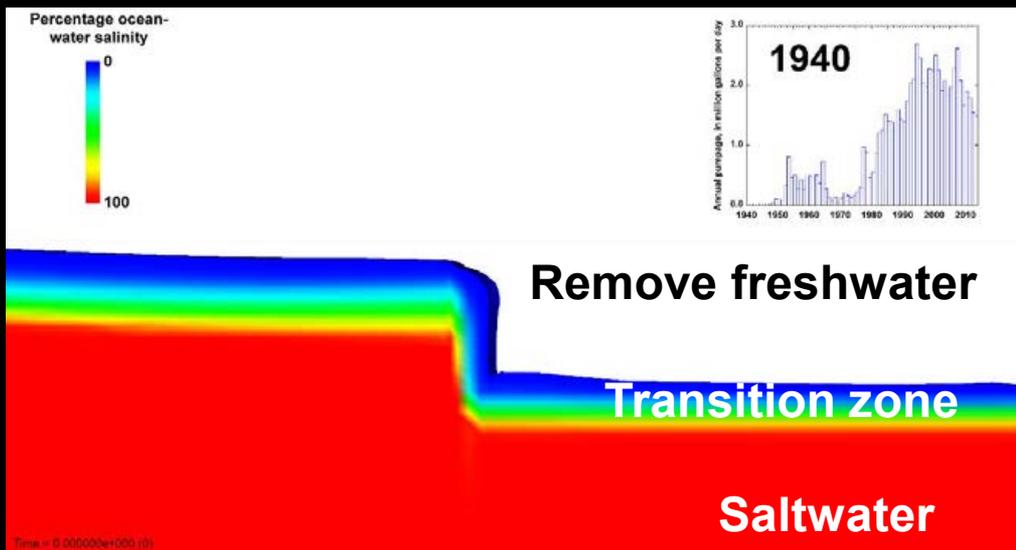
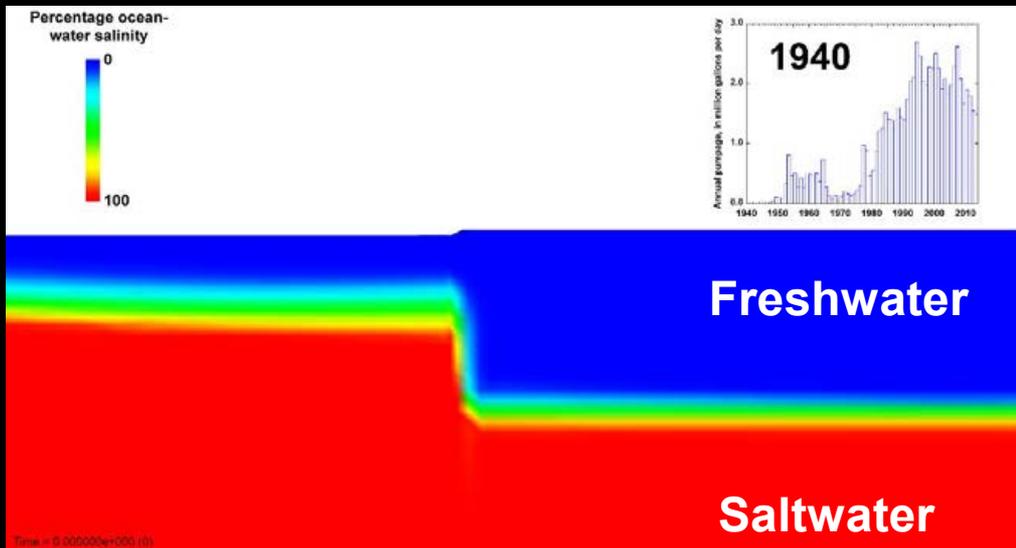
1940-2012 Animation of Freshwater Volume



Time = 0.000000e+000 (0)

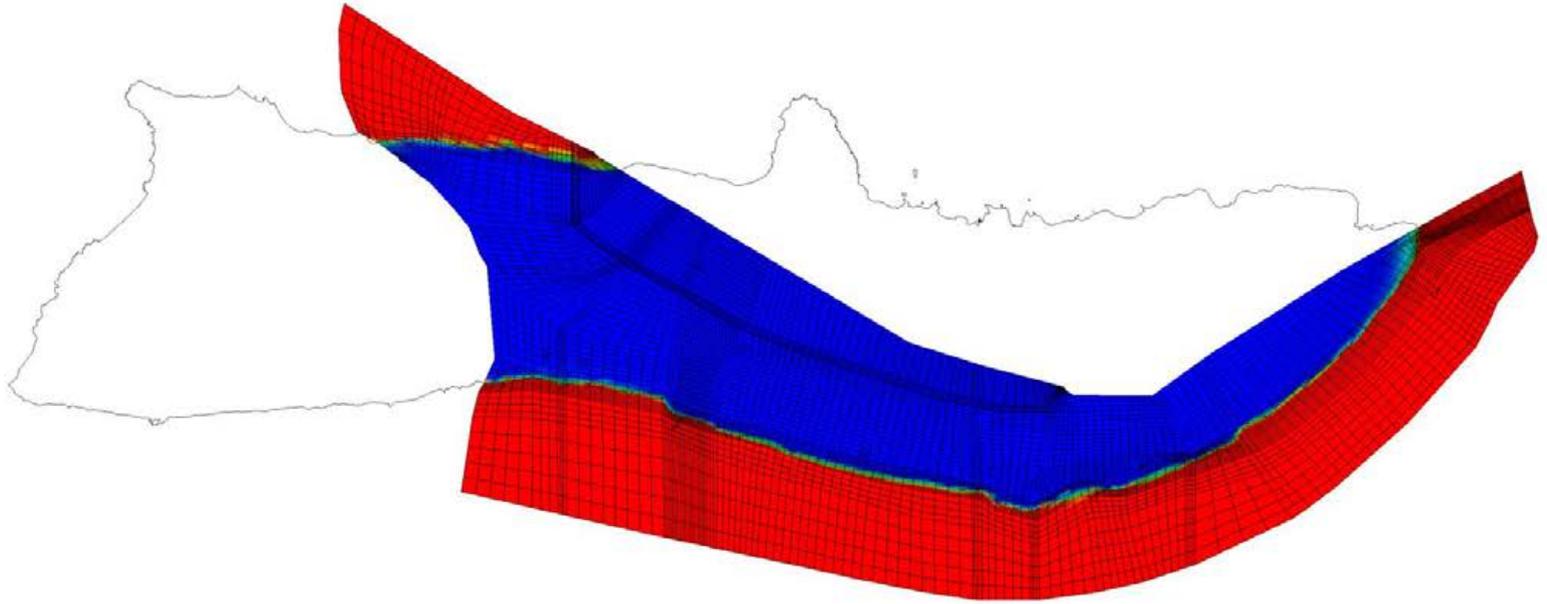
1940-2012 Animation Explanation

Cross section—view from side (east to west)



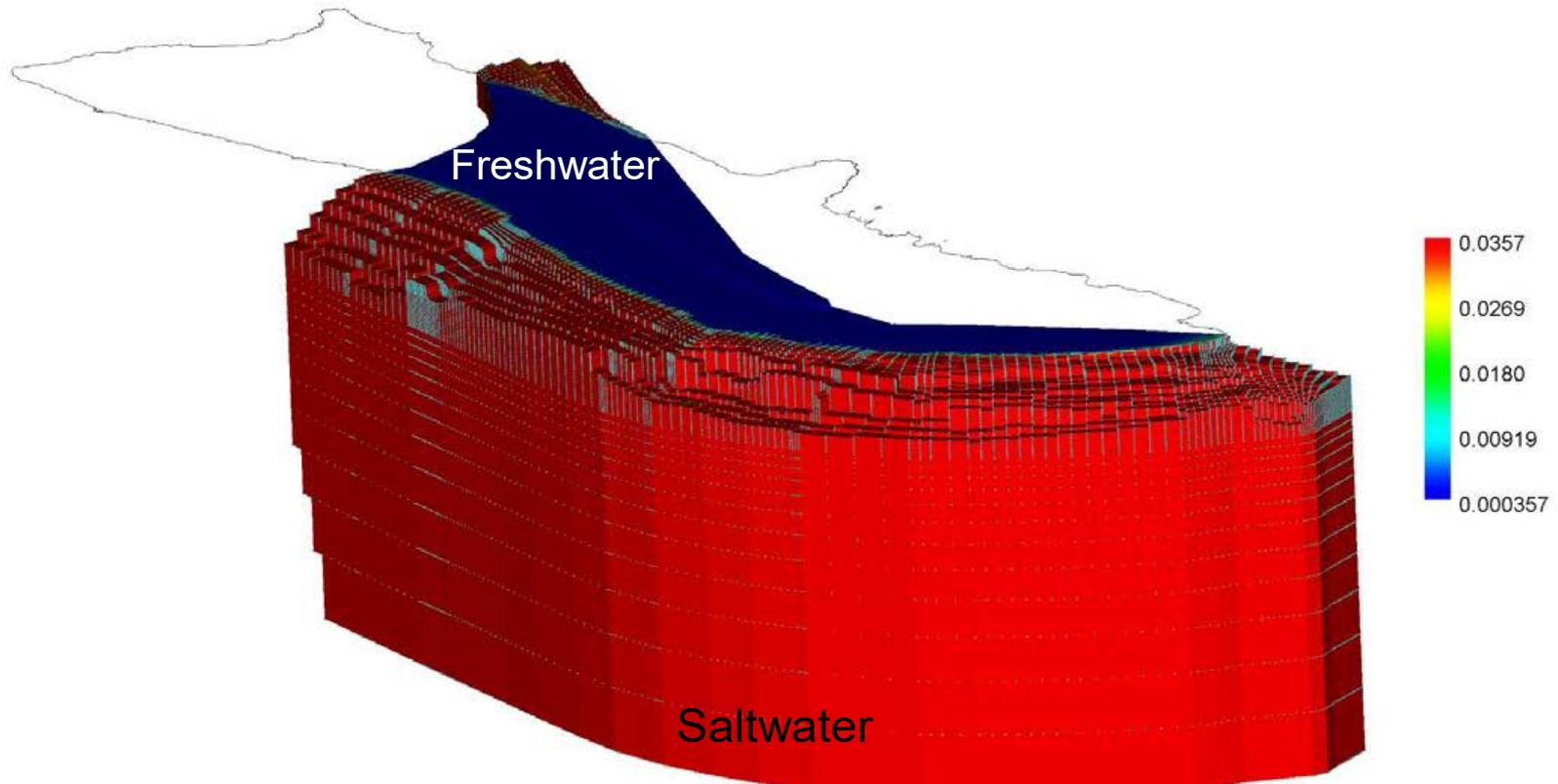
Cross section (slice of aquifer)
view from top

1940-2012 Animation of Freshwater Volume



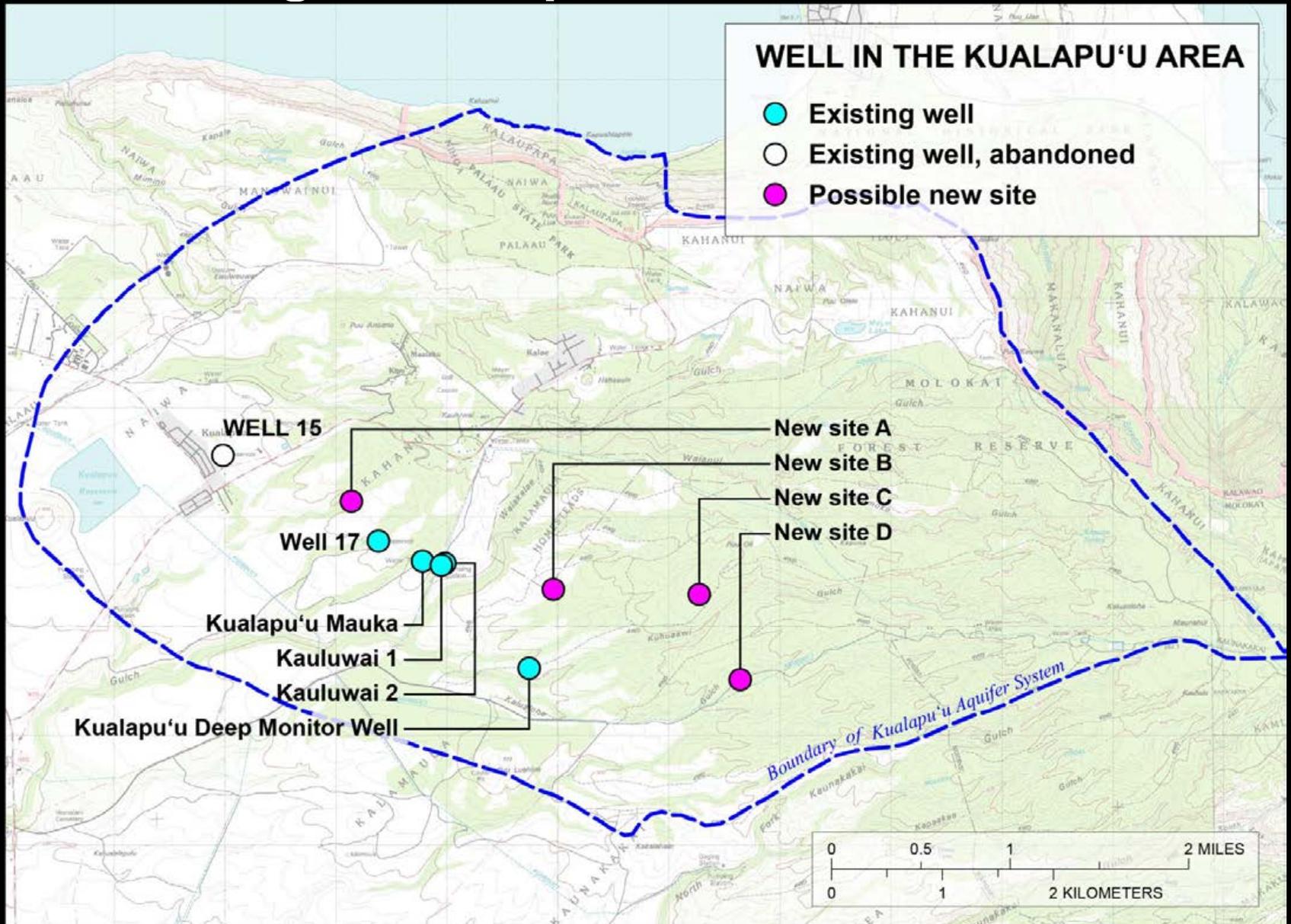
Time = 0.000000e+000 (0)

Application of Model



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

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							Total
	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	
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

Base case

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

- less than 100 mg/L
- 100 to 200 mg/L
- greater than 200 mg/L
- Not pumped

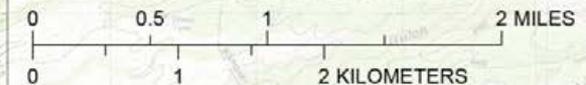
0.513 Mgal/d, Well 17

0.563 Mgal/d, Kualapu'u Mauka

0.445 Mgal/d, Kauluwai 1 and 2

1.521 Mgal/d, Total

Boundary of Kualapu'u Aquifer System



Scenario 2. Pending Water-Use Permit Rates

Existing wells only

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

- less than 100 mg/L
- 100 to 200 mg/L
- greater than 200 mg/L
- Not pumped

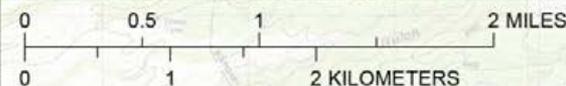
1.144 Mgal/d, Well 17

0.900 Mgal/d, Kualapu'u Mauka

0.637 Mgal/d, Kauluwai 2

2.681 Mgal/d, Total

Boundary of Kualapu'u Aquifer System



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

**Pump Well 17 at public-trust rate;
Continue Kualapu'u Mauka;
Continue Kauluwai 2;
Develop New site B**

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

-  less than 100 mg/L
-  100 to 200 mg/L
-  greater than 200 mg/L
-  Not pumped

0.138 Mgal/d, Well 17

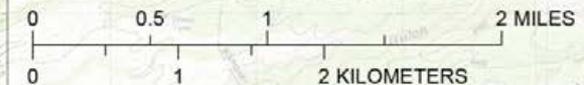
0.950 Mgal/d, Kualapu'u Mauka

0.595 Mgal/d, Kauluwai 2

0.793 Mgal/d, New site B

2.476 Mgal/d, Total

Boundary of Kualapu'u Aquifer System



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

Pump Well 17 at pending rate;
Continue Kualapu'u Mauka;
Continue Kauluwai 2;
Develop New site B

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

- less than 100 mg/L
- 100 to 200 mg/L
- greater than 200 mg/L
- Not pumped
- * indicates greater than 250 mg/L

1.144 Mgal/d, Well 17

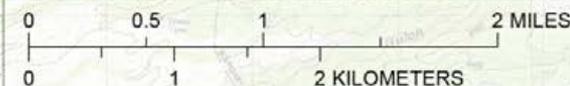
0.950 Mgal/d, Kualapu'u Mauka

0.595 Mgal/d, Kauluwai 2

0.793 Mgal/d, New site B

3.482 Mgal/d, Total

Boundary of Kualapu'u Aquifer System



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

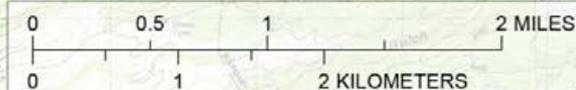
**Pump Well 17 at public-trust rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2;
Develop New sites A and B**

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

-  less than 100 mg/L
-  100 to 200 mg/L
-  greater than 200 mg/L
-  Not pumped

0.950 Mgal/d, New site A
0.138 Mgal/d, Well 17
0.595 Mgal/d, Kauluwai 2
0.793 Mgal/d, New site B
2.476 Mgal/d, Total

Boundary of Kualapu'u Aquifer System



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

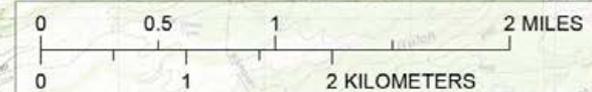
Pump Well 17 at pending rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2;
Develop New sites A and B

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

- less than 100 mg/L
- 100 to 200 mg/L
- greater than 200 mg/L
- Not pumped
- * indicates greater than 250 mg/L

0.950 Mgal/d, New site A
1.144 Mgal/d, Well 17*
0.595 Mgal/d, Kauluwai 2
0.793 Mgal/d, New site B
3.482 Mgal/d, Total

Boundary of Kualapu'u Aquifer System



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

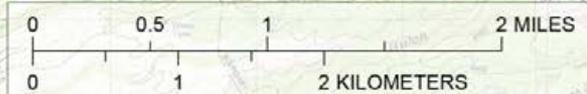
**Pump Well 17 at pending rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2;
Develop New sites A and B**

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

-  less than 100 mg/L
-  100 to 200 mg/L
-  greater than 200 mg/L
-  Not pumped

0.793 Mgal/d, New site A
1.144 Mgal/d, Well 17
0.595 Mgal/d, Kauluwai 2
0.950 Mgal/d, New site B
3.482 Mgal/d, Total

Boundary of Kualapu'u Aquifer System



Scenario 8. Spread Out Withdrawals

**Pump Well 17 at pending rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2;
Develop New sites B, C, and D**

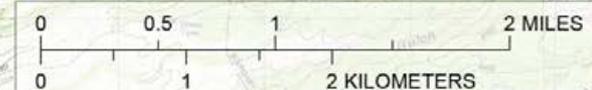
SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

-  less than 100 mg/L
-  100 to 200 mg/L
-  greater than 200 mg/L
-  Not pumped

1.144 Mgal/d, Well 17
0.595 Mgal/d, Kauluwai 2
0.950 Mgal/d, New site B
0.793 Mgal/d, New site C
1.000 Mgal/d, New site D

4.482 Mgal/d, Total

Boundary of Kualapu'u Aquifer System



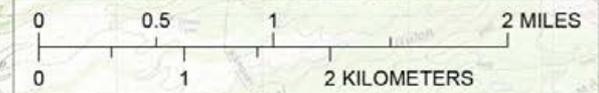
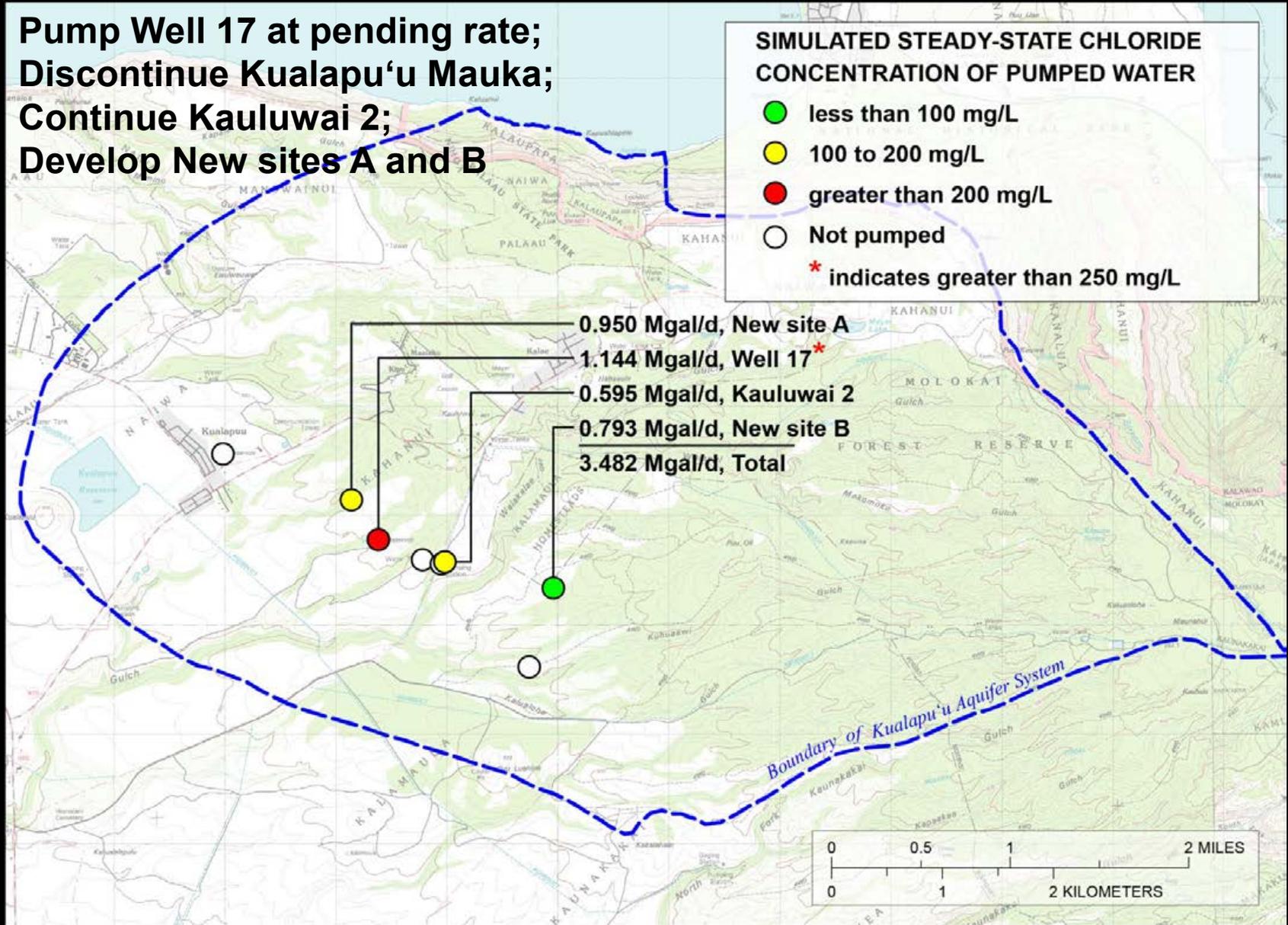
Scenario 6. Well 17 Pending; New Sites A and B

Pump Well 17 at pending rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2;
Develop New sites A and B

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

-  less than 100 mg/L
-  100 to 200 mg/L
-  greater than 200 mg/L
-  Not pumped
-  * indicates greater than 250 mg/L

0.950 Mgal/d, New site A
1.144 Mgal/d, Well 17*
0.595 Mgal/d, Kauluwai 2
0.793 Mgal/d, New site B
3.482 Mgal/d, Total



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Scenario 9. Recharge Reduced 15 Percent

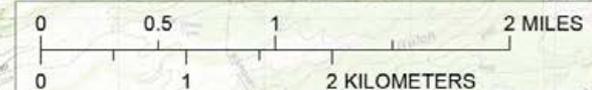
Pump Well 17 at pending rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2;
Develop New sites A and B

SIMULATED STEADY-STATE CHLORIDE CONCENTRATION OF PUMPED WATER

- less than 100 mg/L
- 100 to 200 mg/L
- greater than 200 mg/L
- Not pumped
- * indicates greater than 250 mg/L

0.950 Mgal/d, New site A *
1.144 Mgal/d, Well 17 *
0.595 Mgal/d, Kauluwai 2 *
0.793 Mgal/d, New site B
3.482 Mgal/d, Total

Boundary of Kualapu'u Aquifer System

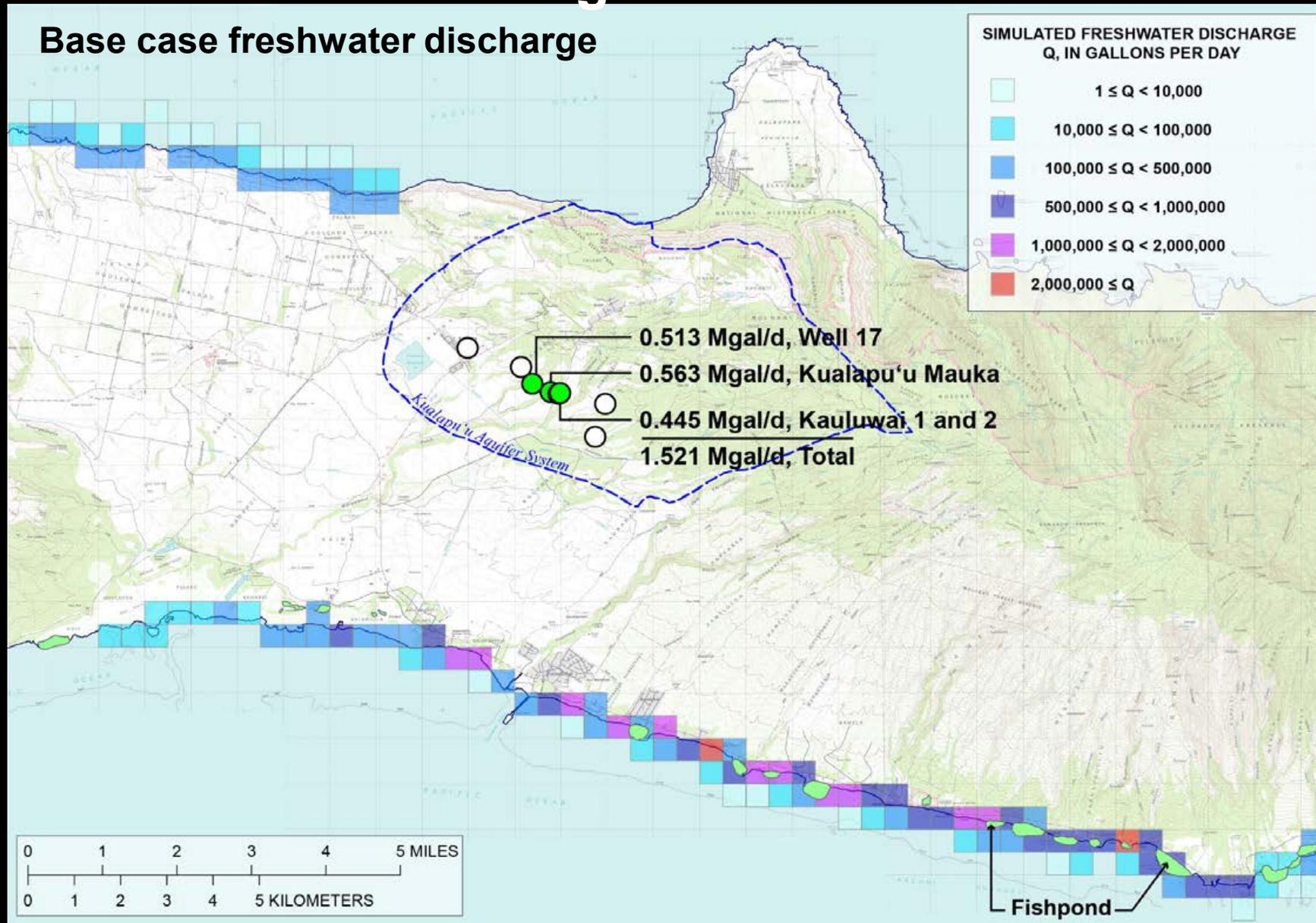


Groundwater Management

- 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

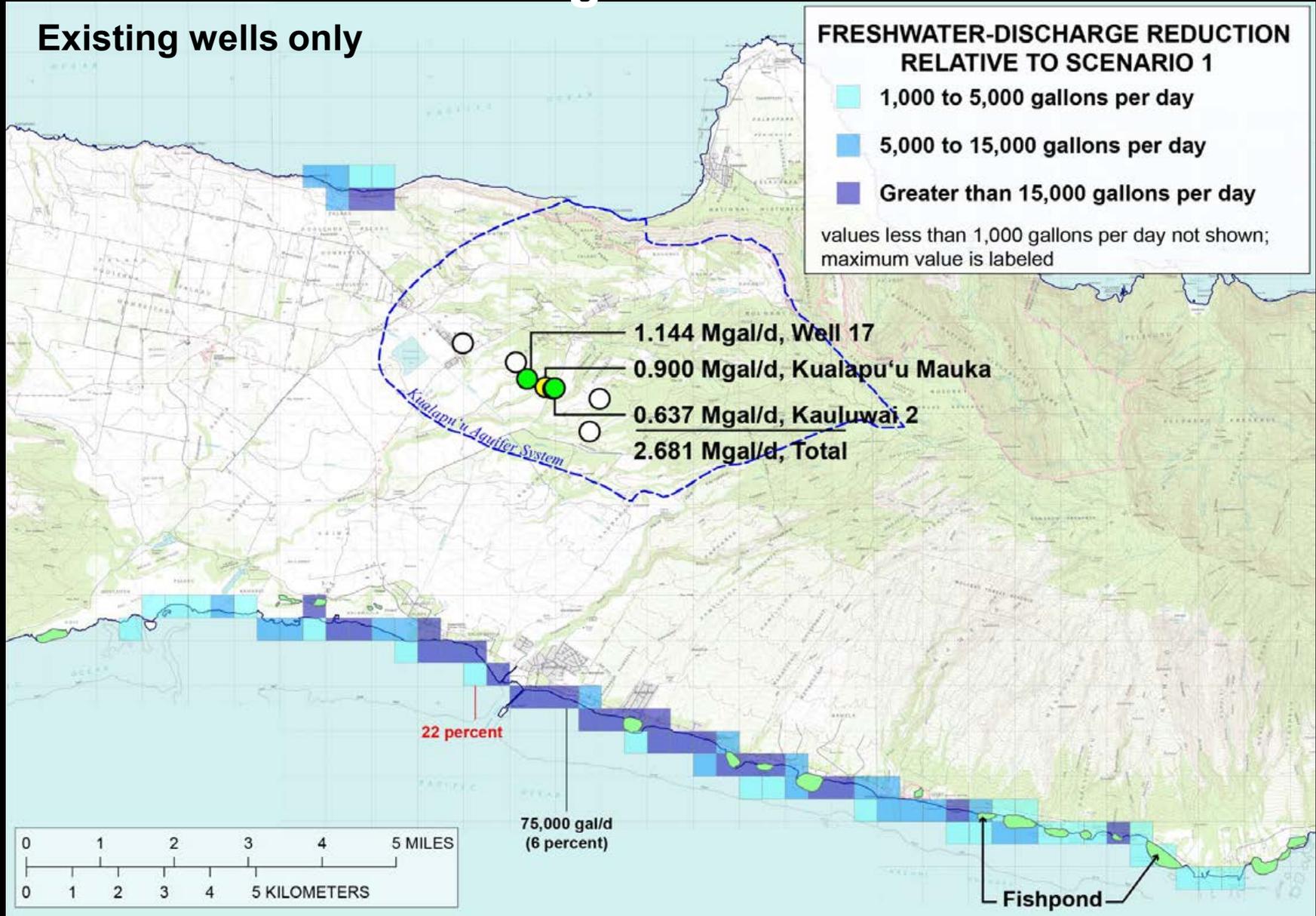
Scenario 1. Average 2016–17 Withdrawals

Base case freshwater discharge



Scenario 2. Pending Water-Use Permit Rates

Existing wells only



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

Pump Well 17 at public-trust rate;
Continue Kualapu'u Mauka and Kauluwai 2;
Develop New site B

FRESHWATER-DISCHARGE REDUCTION
RELATIVE TO SCENARIO 1

- 1,000 to 5,000 gallons per day
- 5,000 to 15,000 gallons per day
- Greater than 15,000 gallons per day

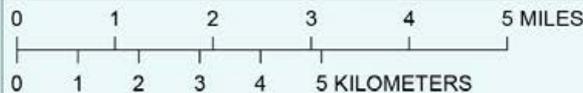
values less than 1,000 gallons per day not shown;
maximum value is labeled

0.138 Mgal/d, Well 17
0.950 Mgal/d, Kualapu'u Mauka
0.793 Mgal/d, New site B
0.595 Mgal/d, Kauluwai 2
2.476 Mgal/d, Total

14 percent

63,000 gal/d
(5 percent)

Fishpond



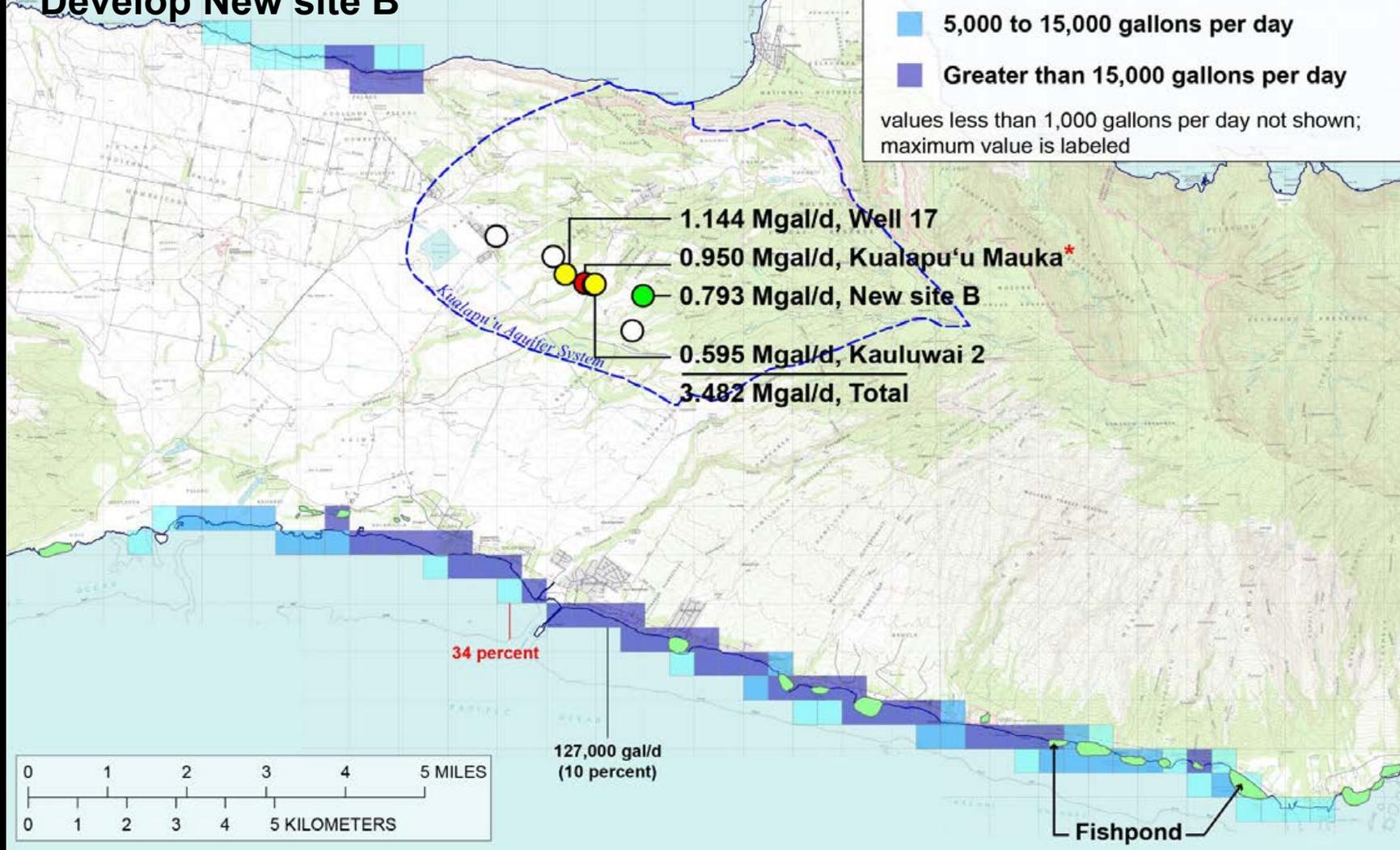
Scenario 4. Well 17 at Pending Rate; New Site B

Pump Well 17 at pending rate;
Continue Kualapu'u Mauka and Kauluwai 2;
Develop New site B

FRESHWATER-DISCHARGE REDUCTION
RELATIVE TO SCENARIO 1

- 1,000 to 5,000 gallons per day
- 5,000 to 15,000 gallons per day
- Greater than 15,000 gallons per day

values less than 1,000 gallons per day not shown;
maximum value is labeled



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

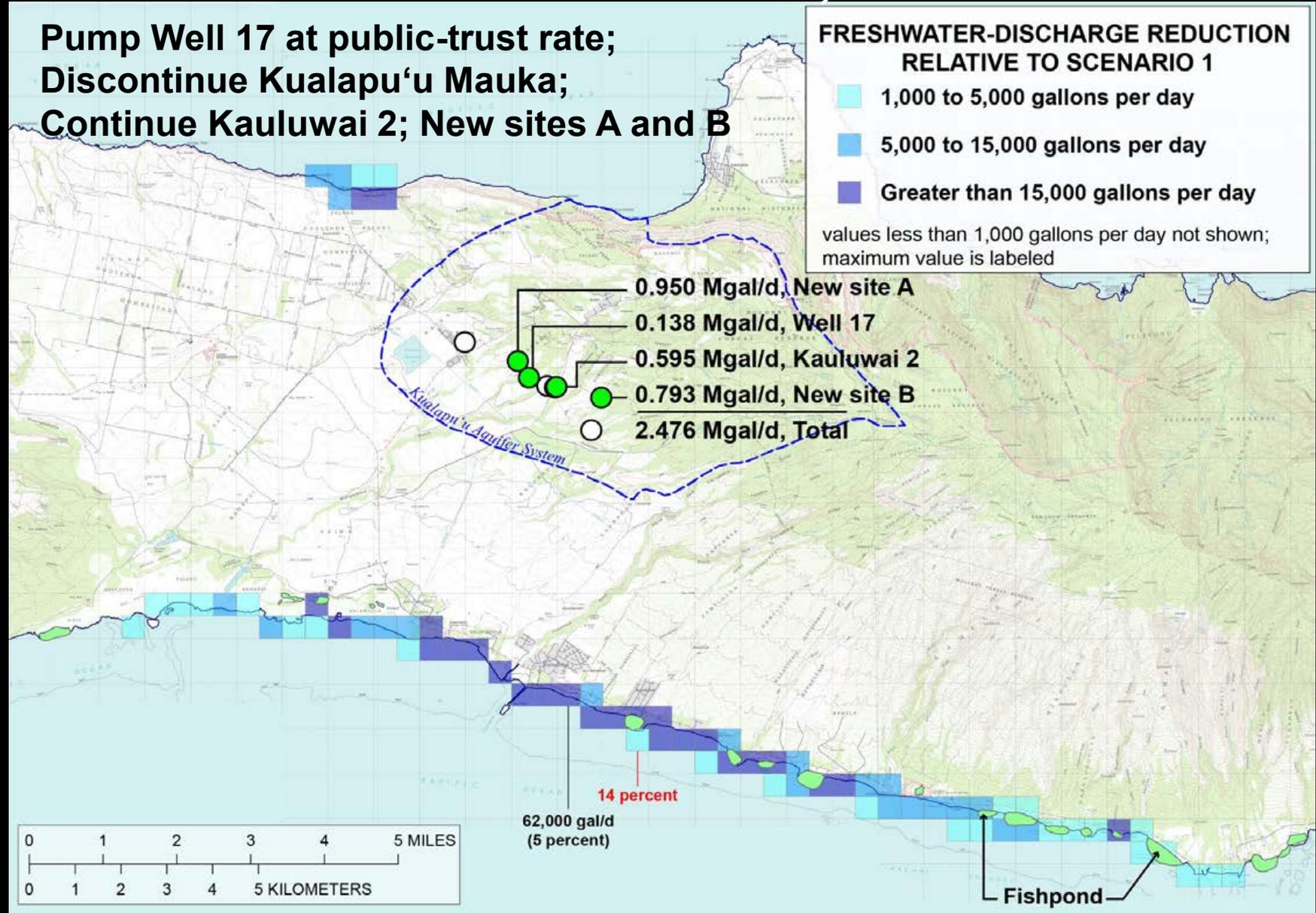
Pump Well 17 at public-trust rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2; New sites A and B

FRESHWATER-DISCHARGE REDUCTION RELATIVE TO SCENARIO 1

- 1,000 to 5,000 gallons per day
- 5,000 to 15,000 gallons per day
- Greater than 15,000 gallons per day

values less than 1,000 gallons per day not shown;
maximum value is labeled

- 0.950 Mgal/d, New site A
- 0.138 Mgal/d, Well 17
- 0.595 Mgal/d, Kauluwai 2
- 0.793 Mgal/d, New site B
- 2.476 Mgal/d, Total



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

Pump Well 17 at pending rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2; New sites A and B

FRESHWATER-DISCHARGE REDUCTION RELATIVE TO SCENARIO 1

- 1,000 to 5,000 gallons per day
- 5,000 to 15,000 gallons per day
- Greater than 15,000 gallons per day

values less than 1,000 gallons per day not shown;
maximum value is labeled

0.950 Mgal/d, New site A

1.144 Mgal/d, Well 17*

0.595 Mgal/d, Kauluwai 2

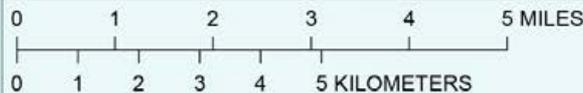
0.793 Mgal/d, New site B

3.482 Mgal/d, Total

34 percent

125,000 gal/d
(9 percent)

Fishpond



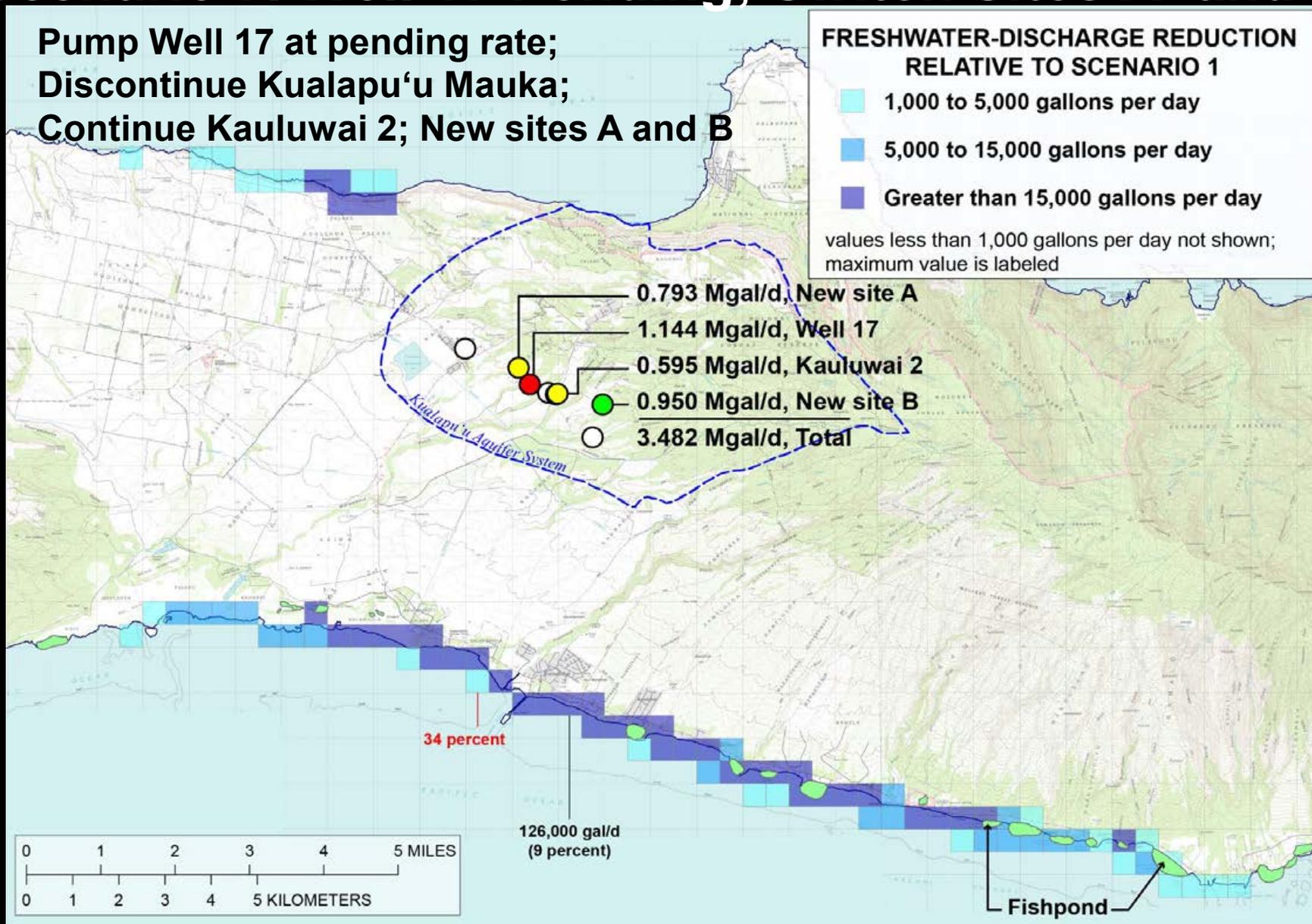
Scenario 7. Well 17 Pending; Switch Sites A and B

Pump Well 17 at pending rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2; New sites A and B

FRESHWATER-DISCHARGE REDUCTION
RELATIVE TO SCENARIO 1

- 1,000 to 5,000 gallons per day
- 5,000 to 15,000 gallons per day
- Greater than 15,000 gallons per day

values less than 1,000 gallons per day not shown;
maximum value is labeled



Scenario 8. Spread Out Withdrawals

**Pump Well 17 at pending rate;
Discontinue Kualapu'u Mauka;
Continue Kauluwai 2; New sites B, C, and D**

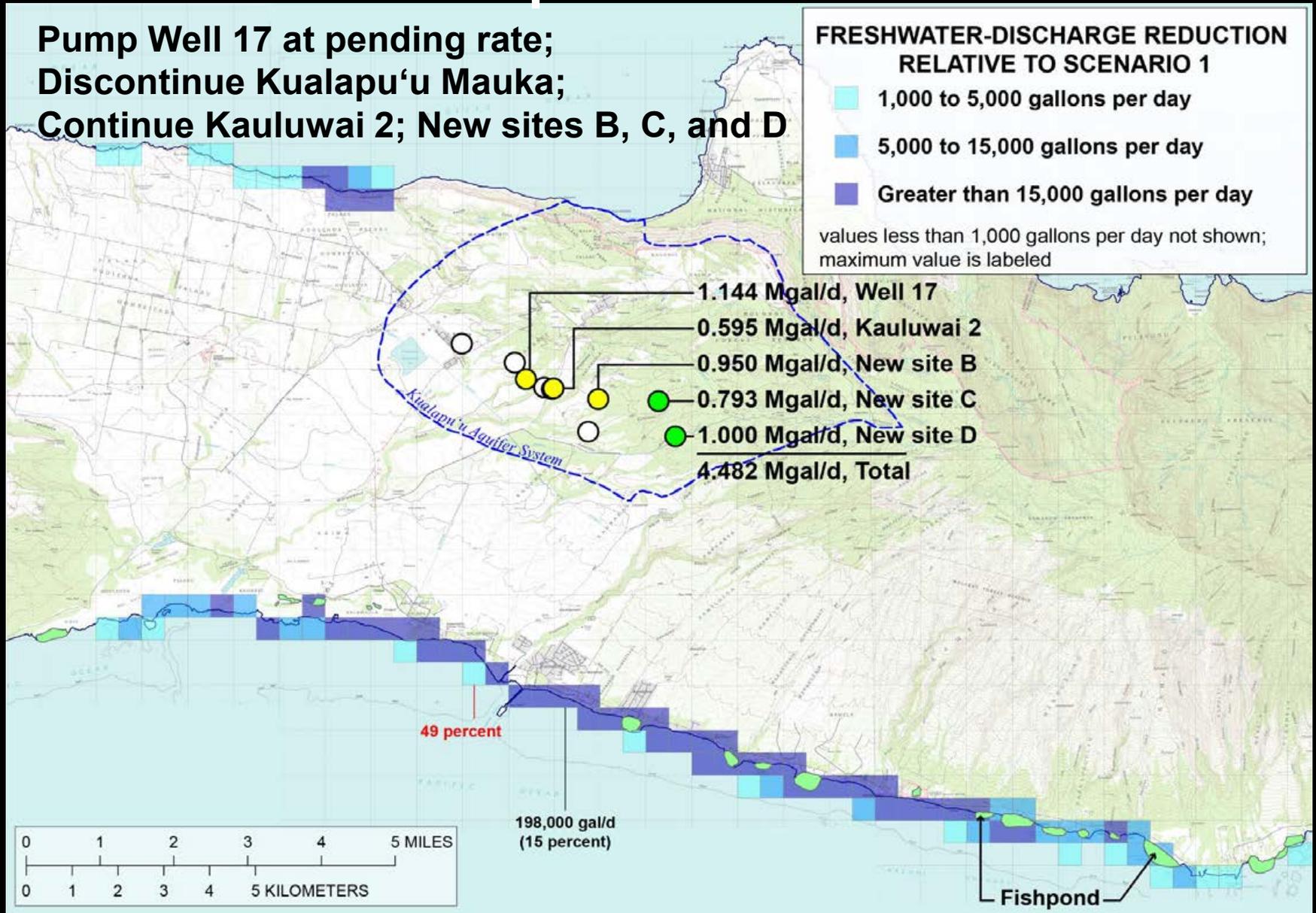
**FRESHWATER-DISCHARGE REDUCTION
RELATIVE TO SCENARIO 1**

1,000 to 5,000 gallons per day

5,000 to 15,000 gallons per day

Greater than 15,000 gallons per day

values less than 1,000 gallons per day not shown;
maximum value is labeled



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 Kualapu'u 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?