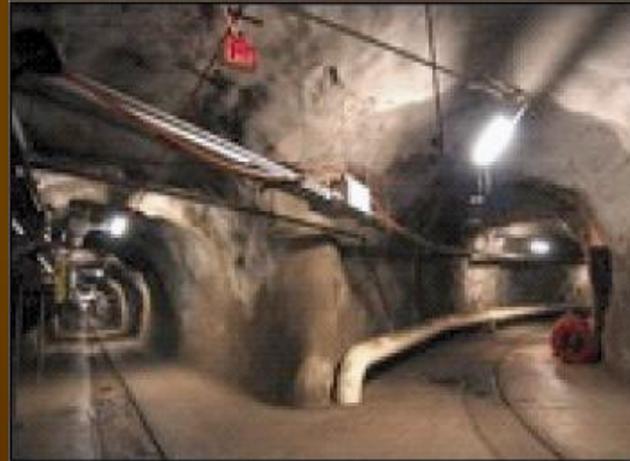
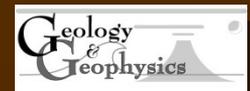


NUMERICAL GROUNDWATER FLOW SIMULATION OF RED HILL RIDGE, OAHU



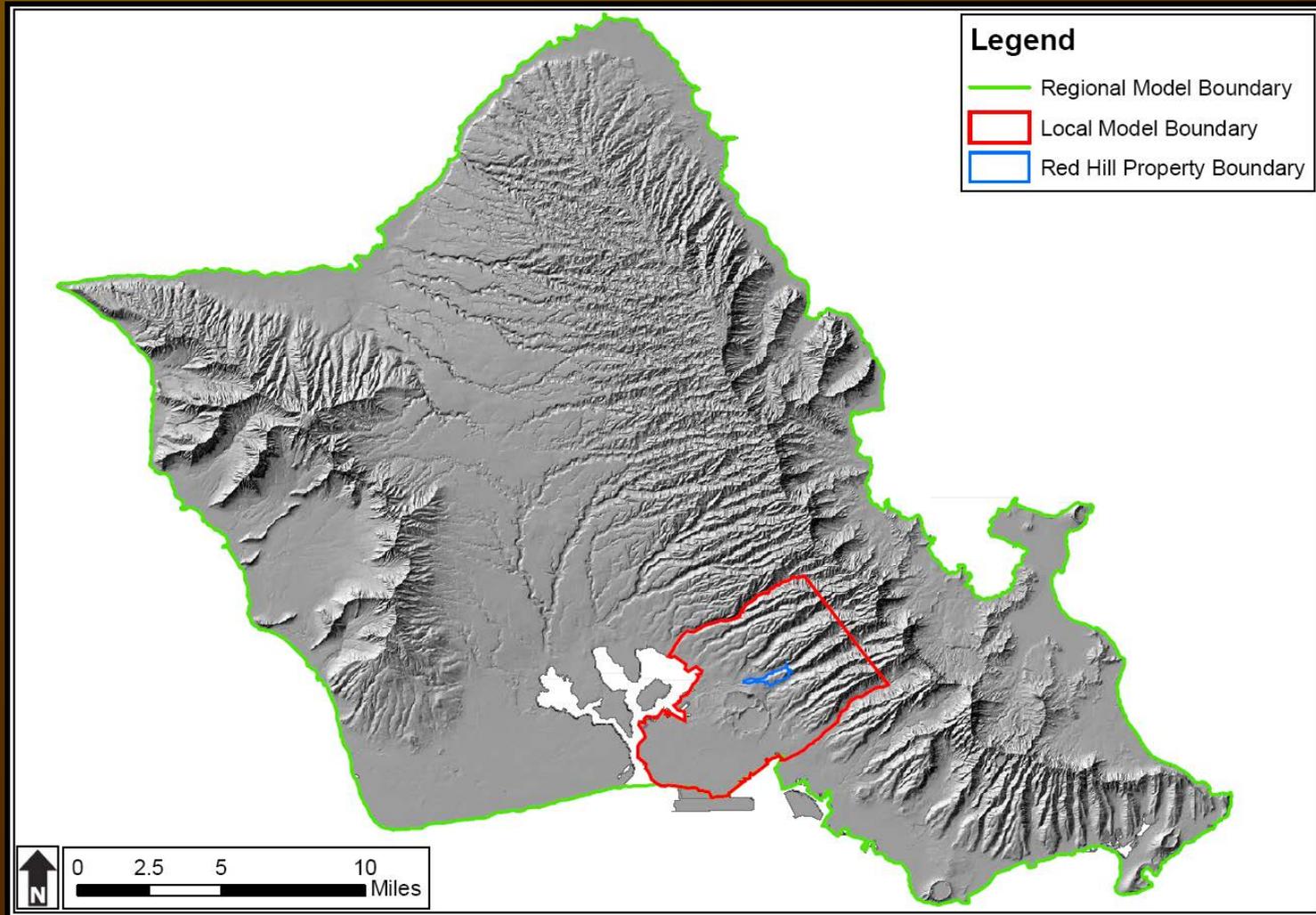
by
**KOLJA
ROTZOLL**



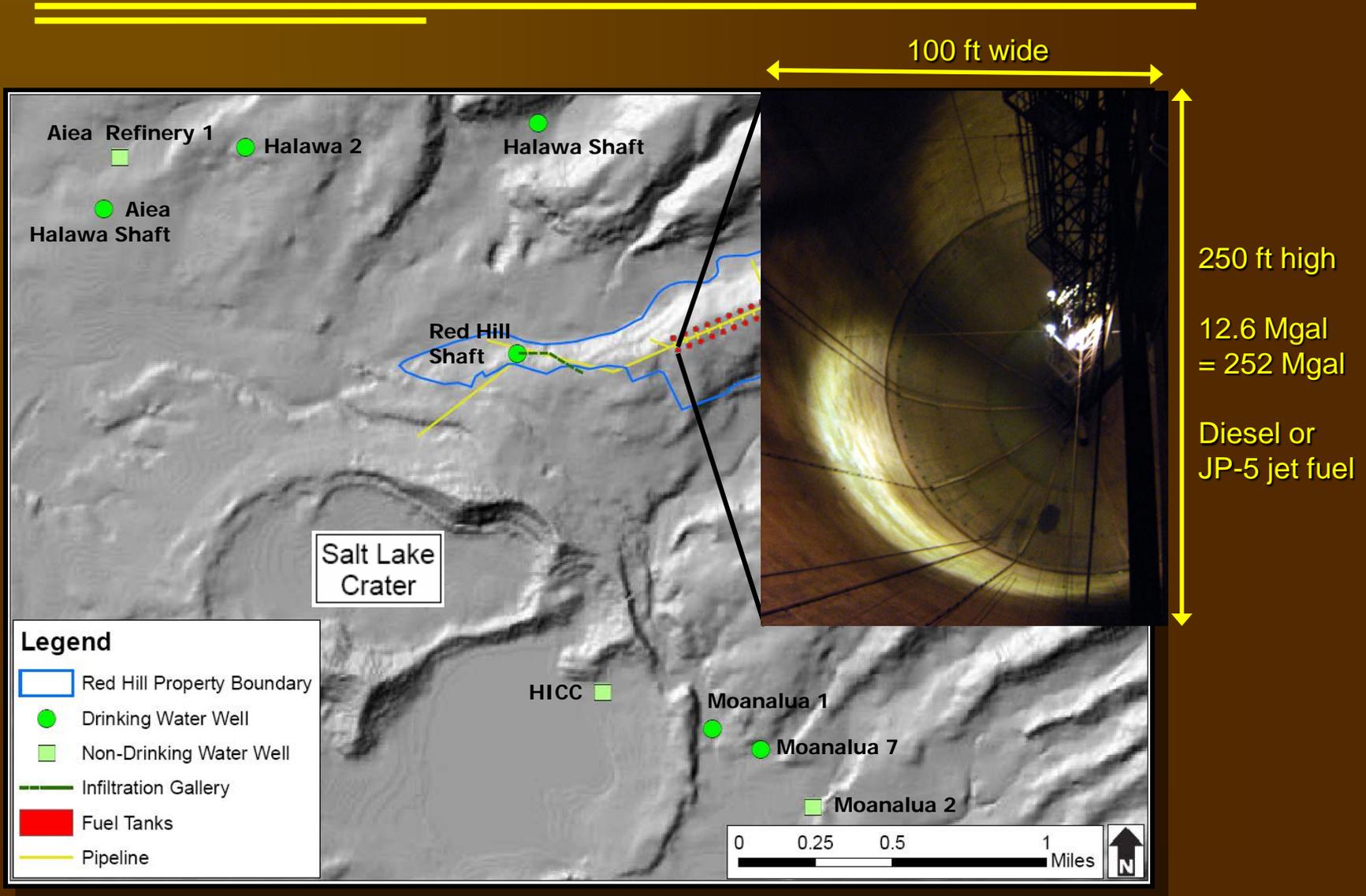
Summary

- Objective: Red Hill Fuel Storage Tanks
- Regional model, SWAP
 - Source area delineations
 - Source water susceptibility to contamination
- Updated SWAP model
- Conversion to Red Hill model
 - Conceptualization
 - Calibration
 - Capture Zones

PROJECT SITE LOCATION



RED HILL FUEL STORAGE FACILITY



OBJECTIVES

Determine groundwater flow around Red Hill Fuel Storage Facility:

- Develop 3-D groundwater flow model (MODFLOW)
- Determine capture zones of drinking-water wells
- Provide a flow model that can be used to simulate solute transport of dissolved hydrocarbons (RT3D)



SWAP

Source Area Delineations

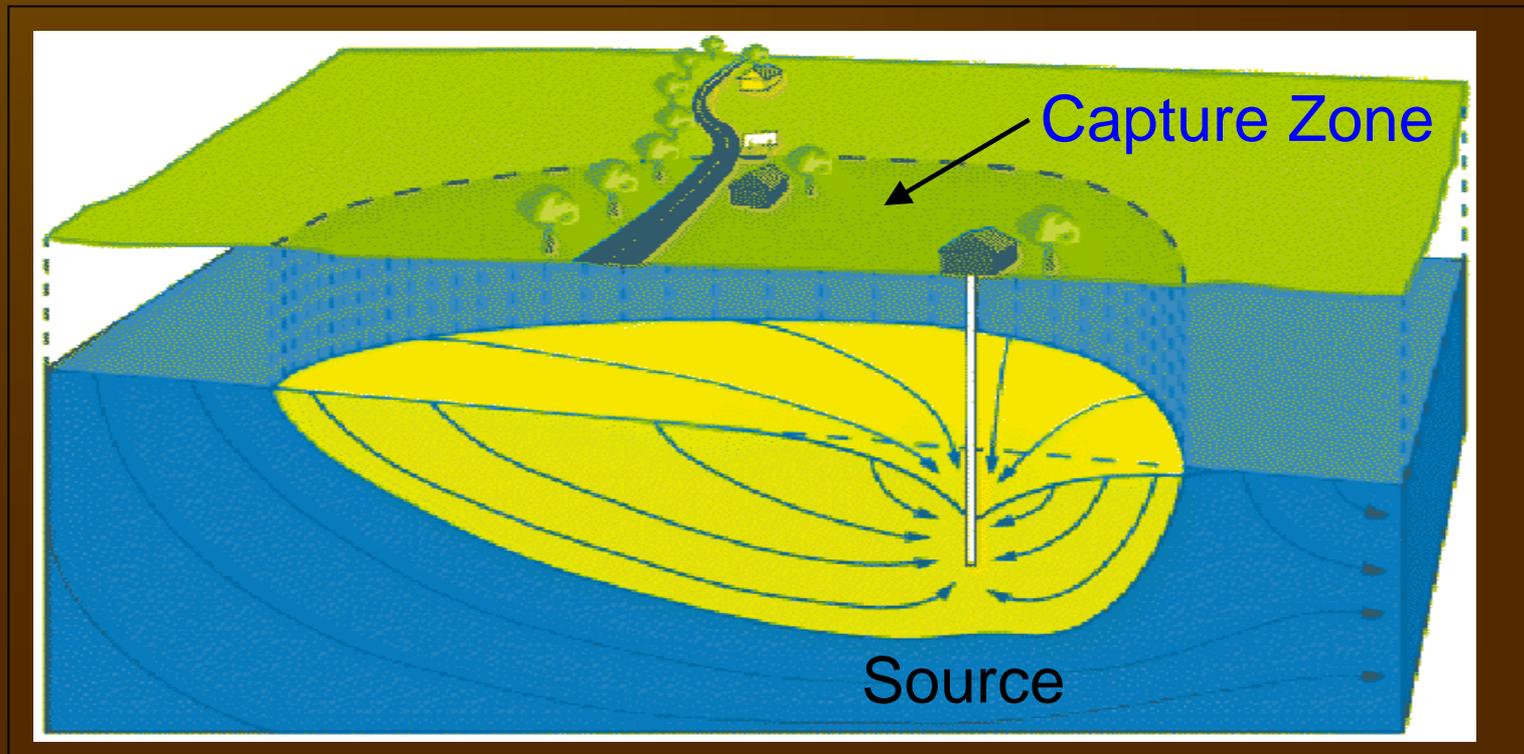
- Identify all public drinking water sources
- Island-wide groundwater flow models
- Source water capture zone delineation
 - Delineate Zone A (50-ft around well)
 - Delineate Zone B (2-year capture zone)
 - Delineate Zone C (10-year capture zone)

Source water susceptibility to contamination

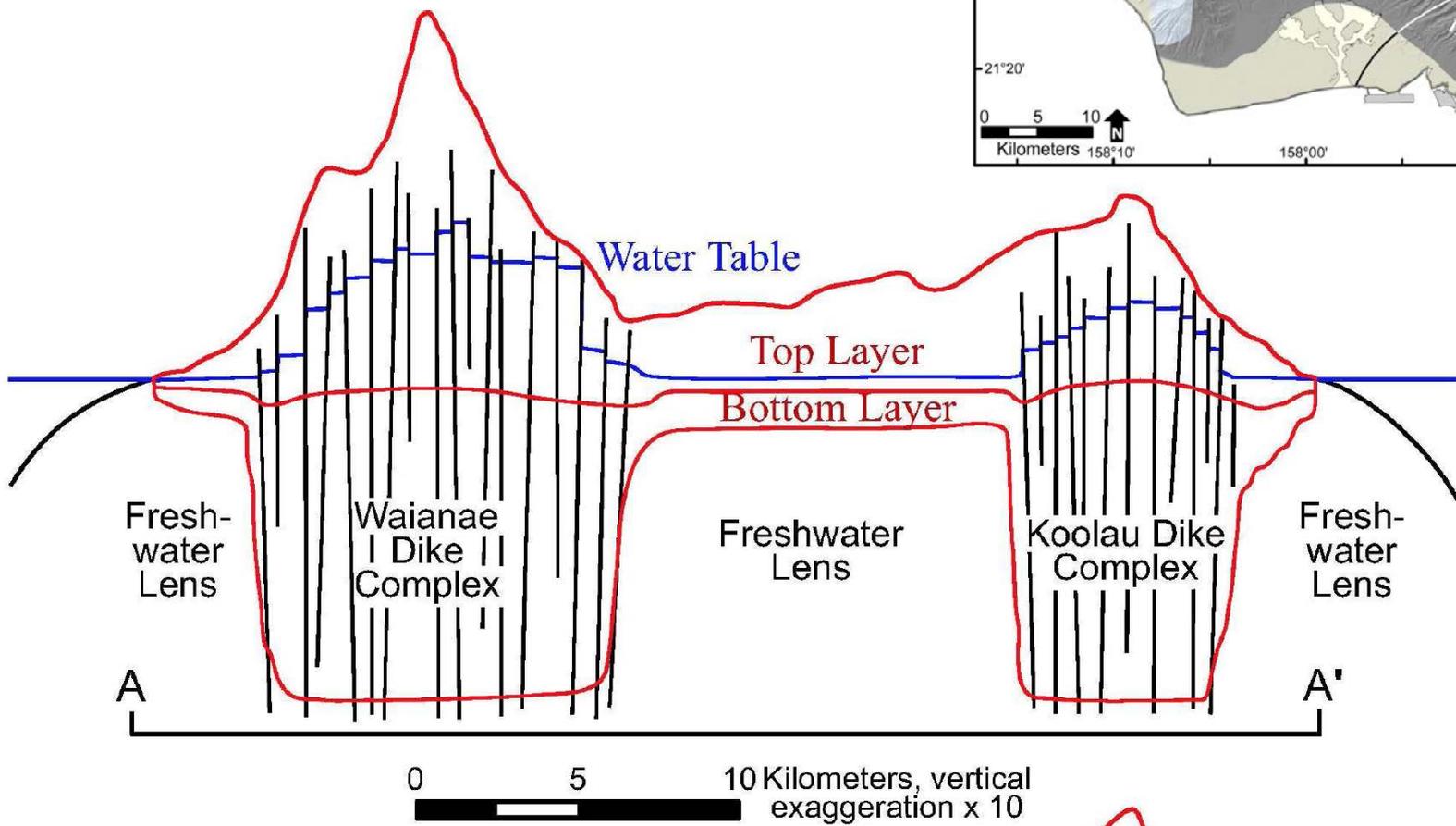
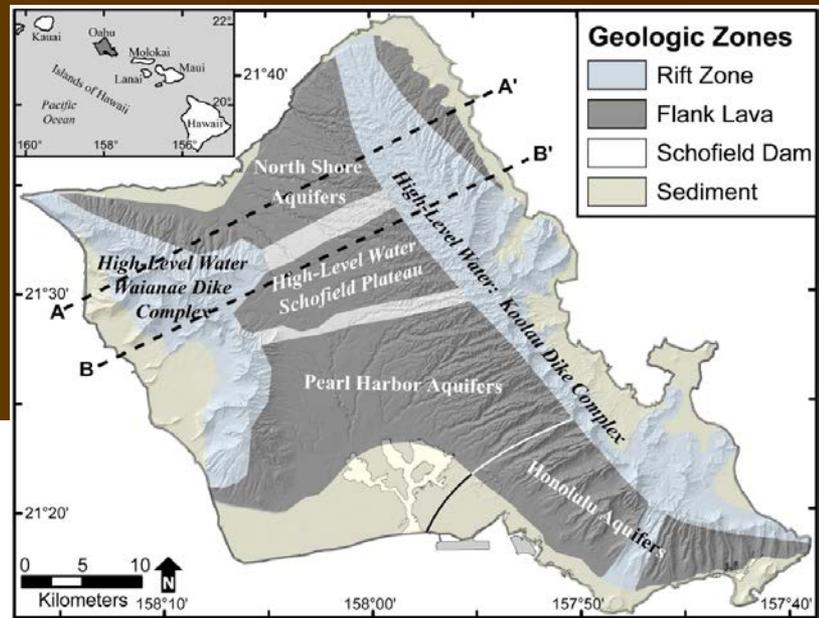
- Potential contaminating activities assessment
- Assessing the susceptibility of water sources to contamination

SOURCE WATER AREA DELINEATION

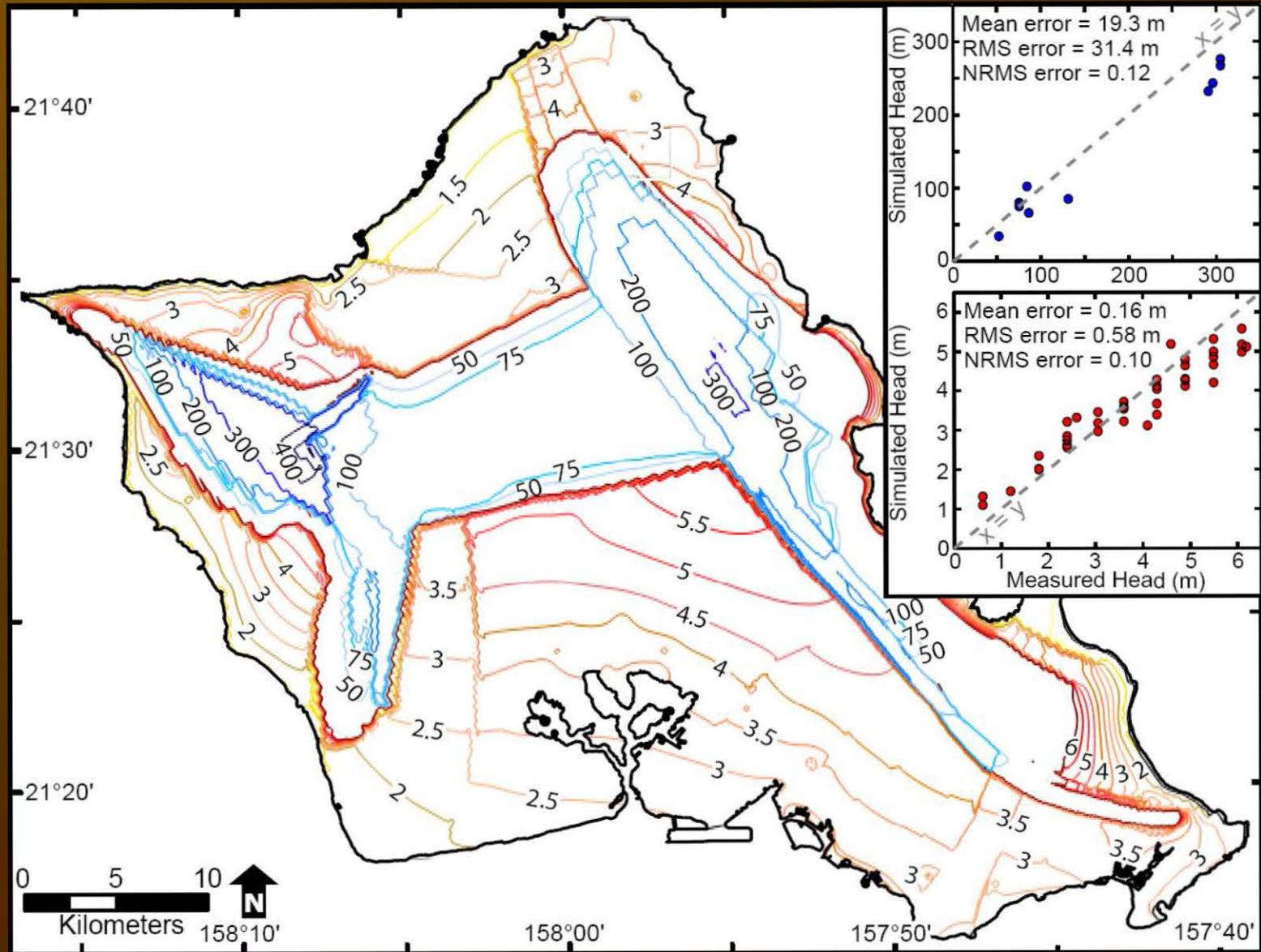
Zone through which contaminants, if present, are likely to migrate and reach a drinking water source (well or surface water intake)



MODFLOW Grid in Cross-section View

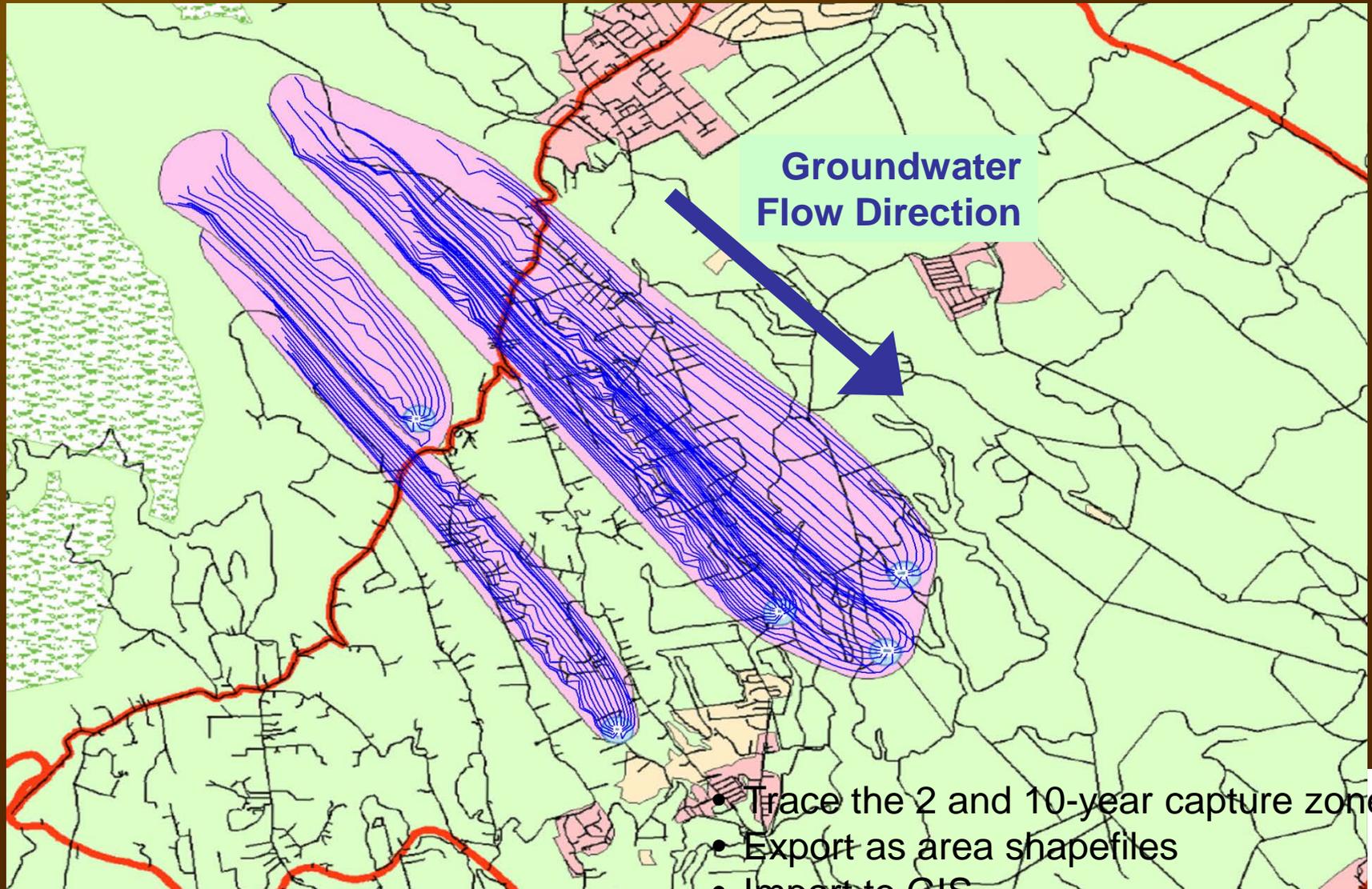


Simulated Groundwater Levels, Oahu (in m)



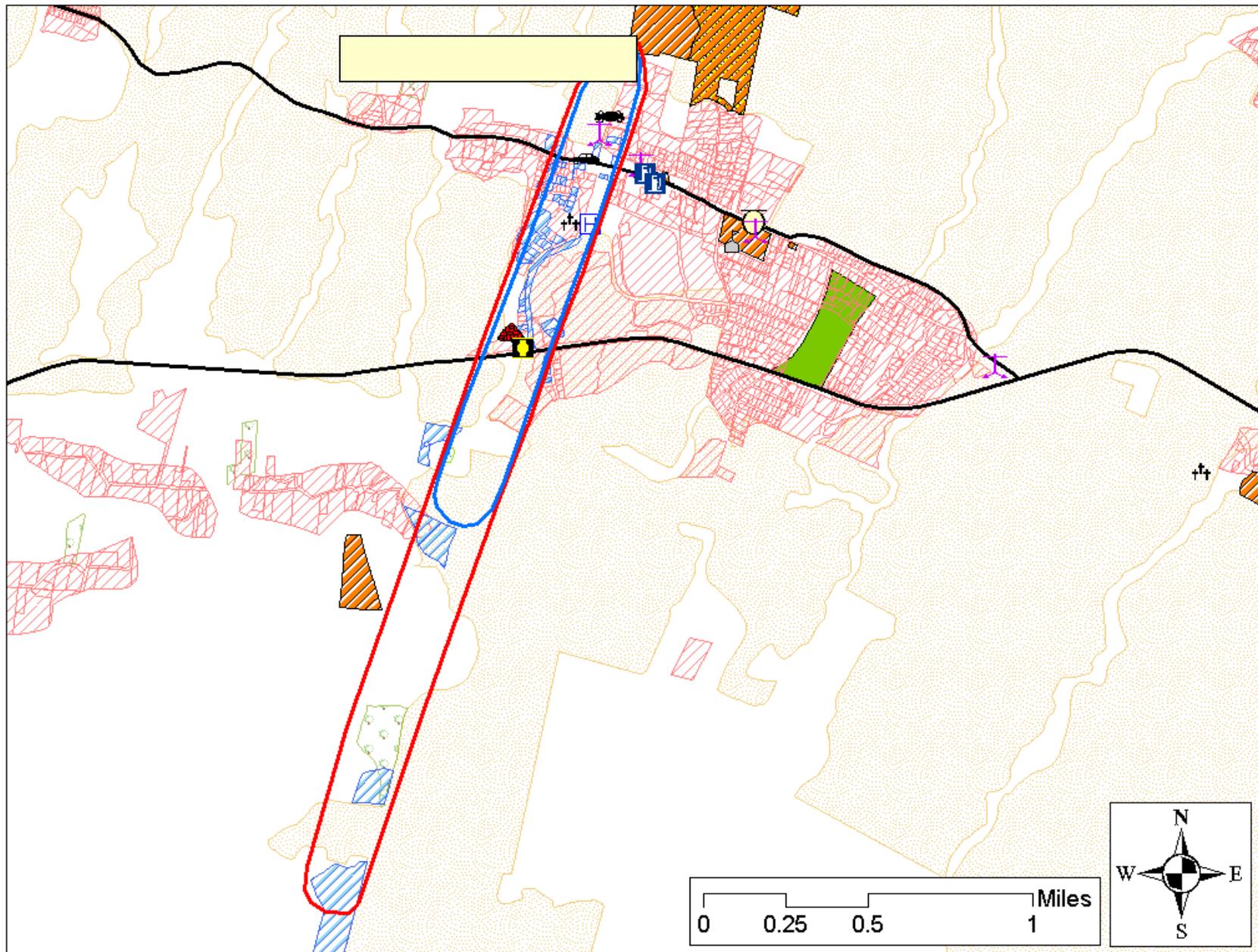
Delineate Well Capture Zones

using computer generated particles traveling backwards

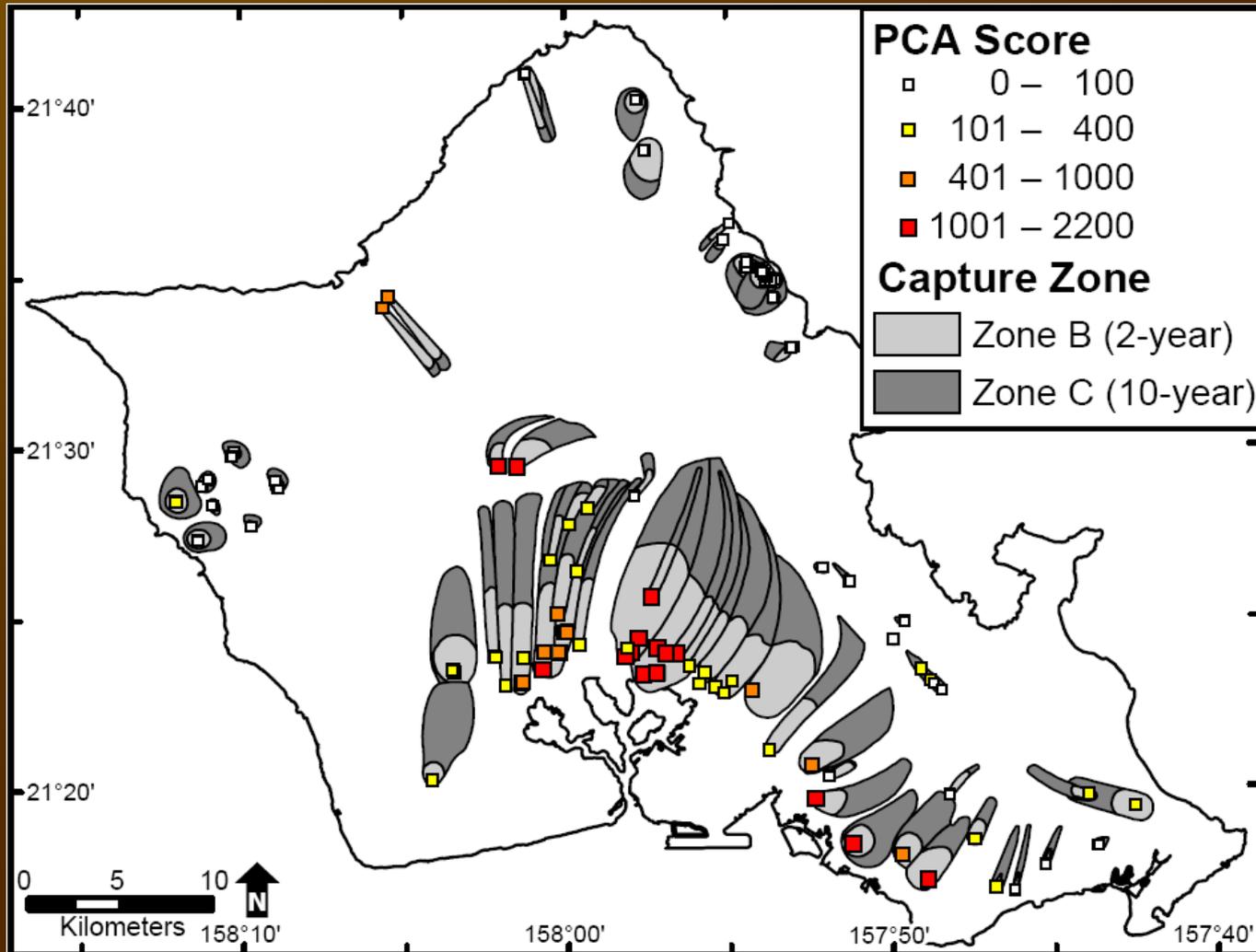


- Trace the 2 and 10-year capture zones
- Export as area shapefiles
- Import to GIS

Potential Contaminating Activities



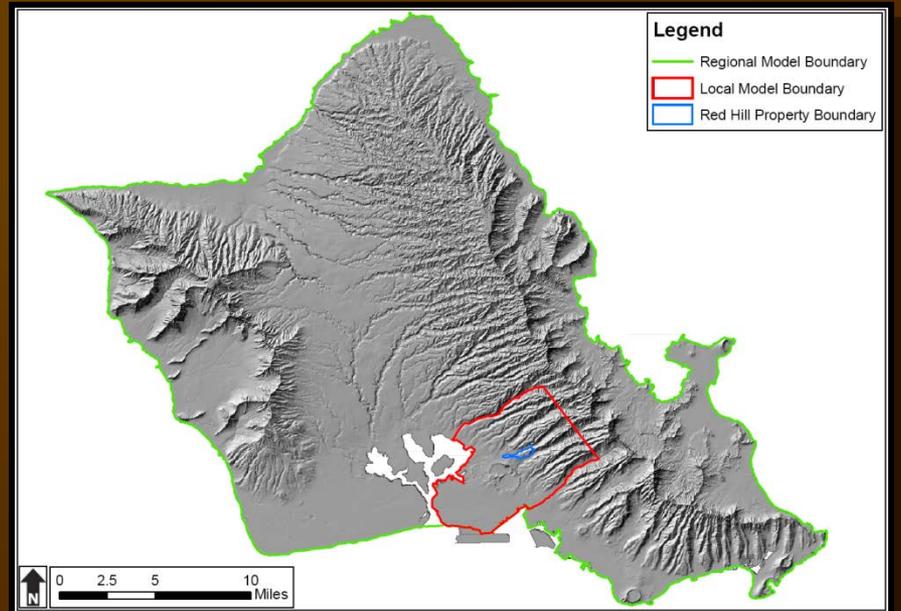
SWAP MODEL



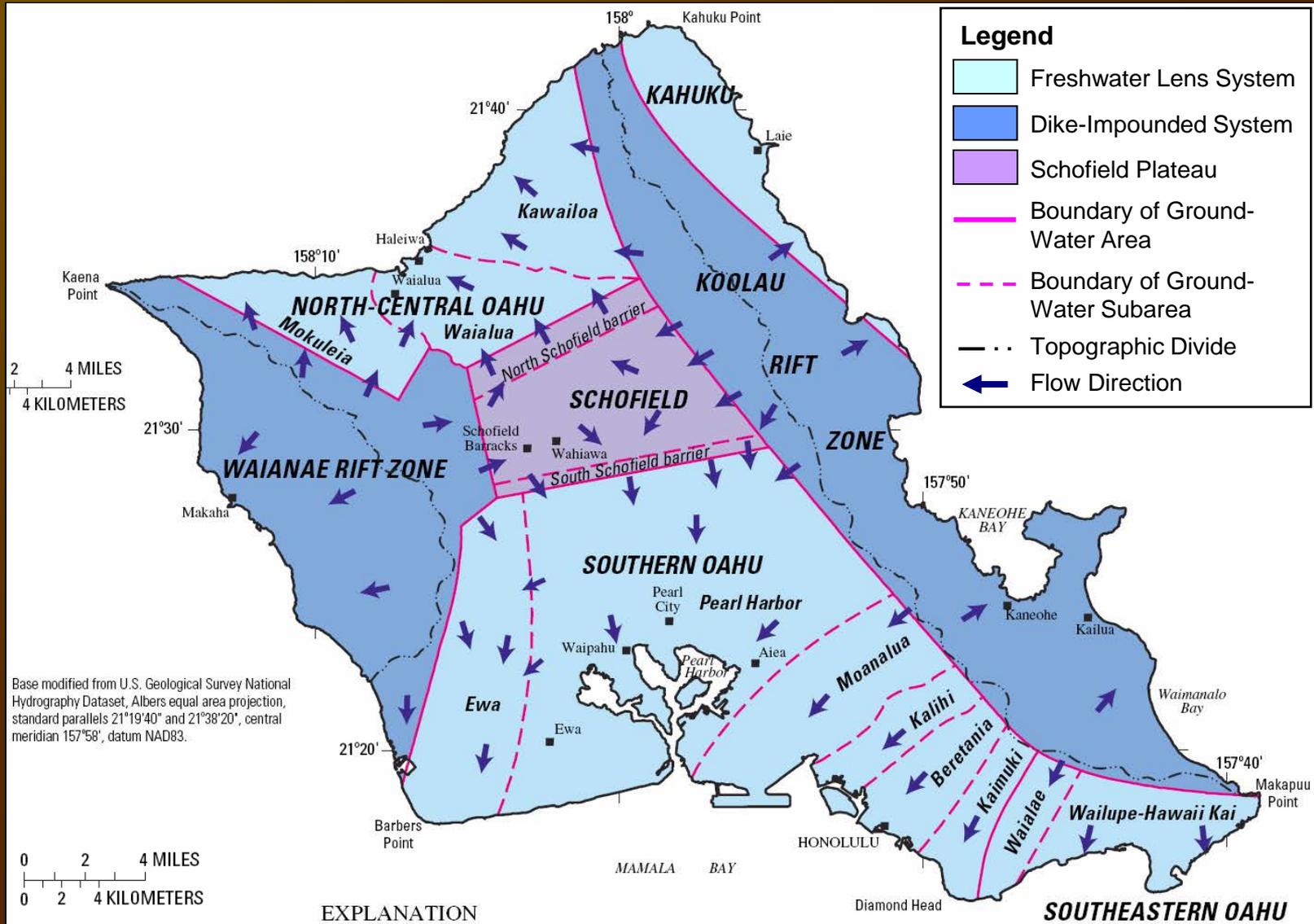
METHODOLOGY

Develop 3-D groundwater flow model:

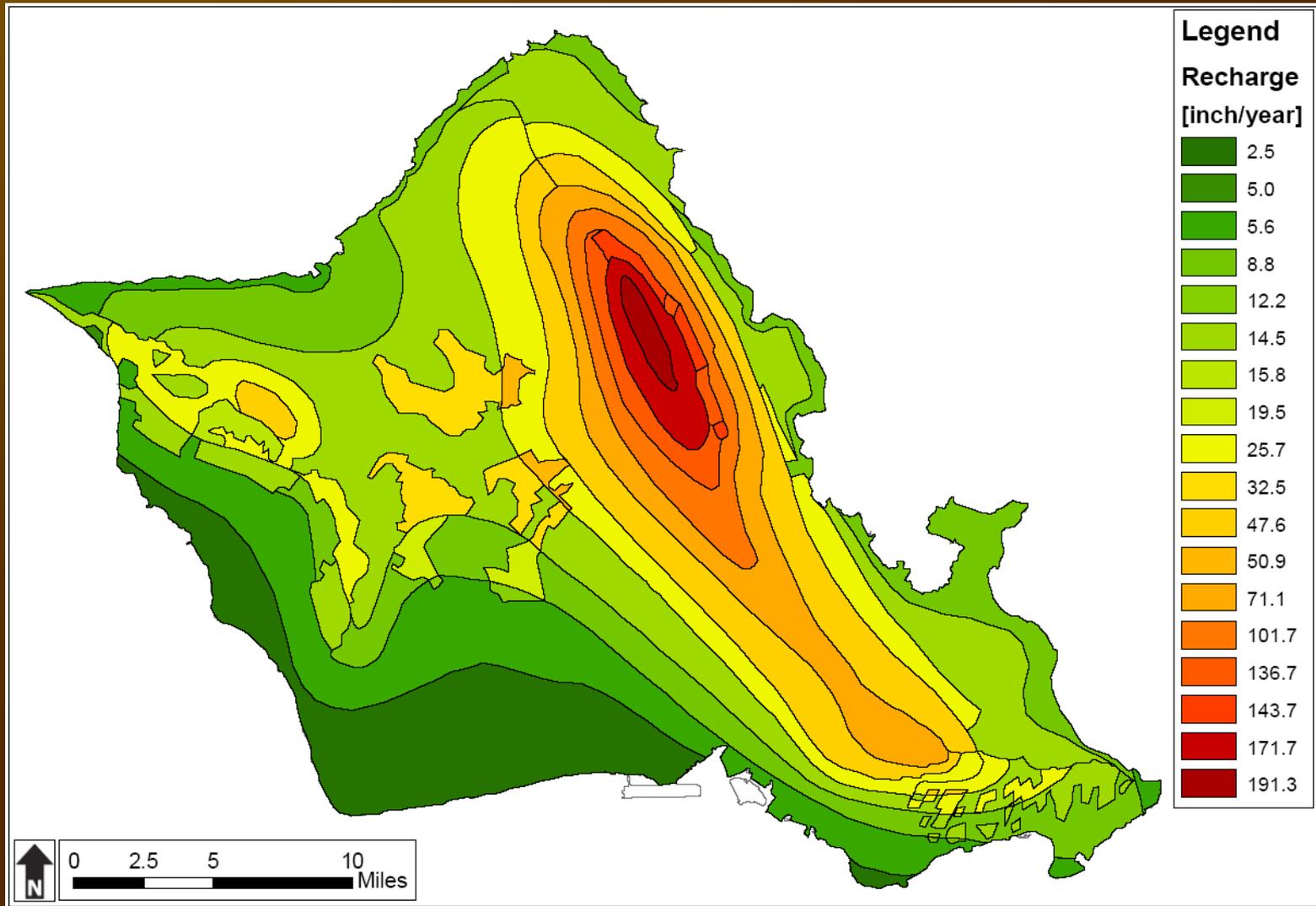
- Calibrate steady-state flow model with island-wide SWAP model
 - Recharge 1996-2005
 - Boundary conditions (specified head on sides, Ghyben-Herzberg interface as bottom boundary)
 - 10-year average withdrawal
- Calibrate transient flow model with a 18-day aquifer test



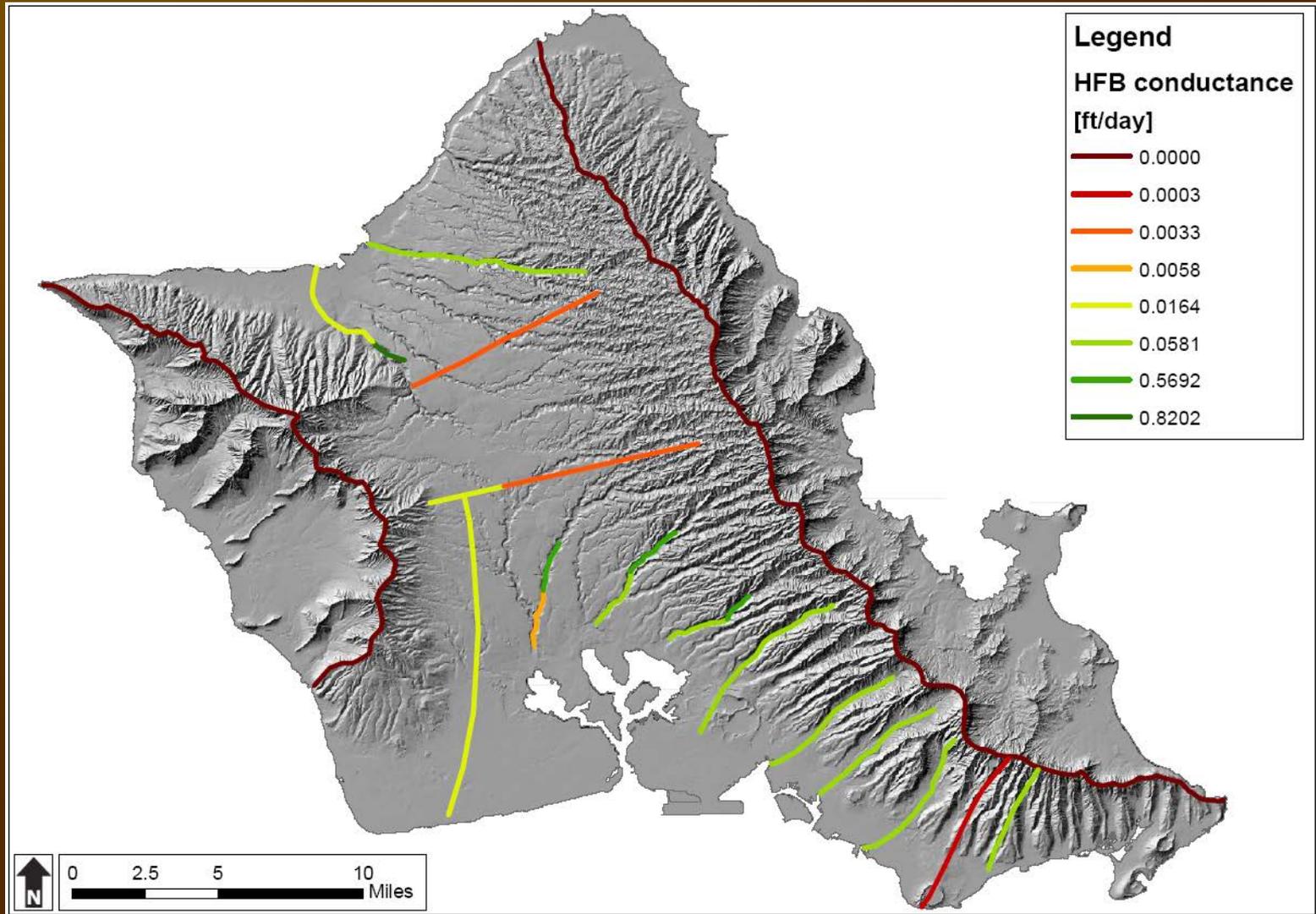
GROUNDWATER FLOW SYSTEM



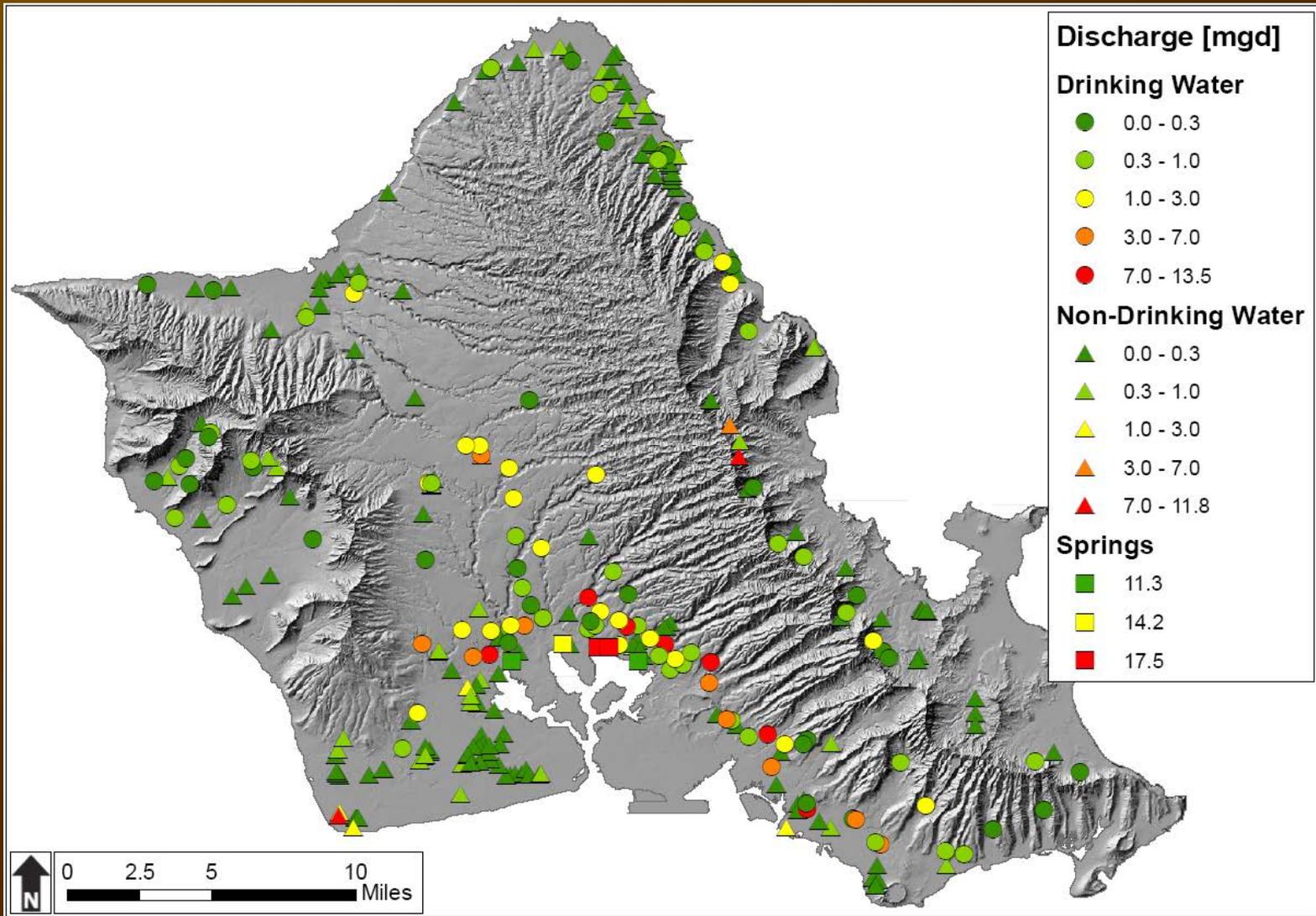
RECHARGE



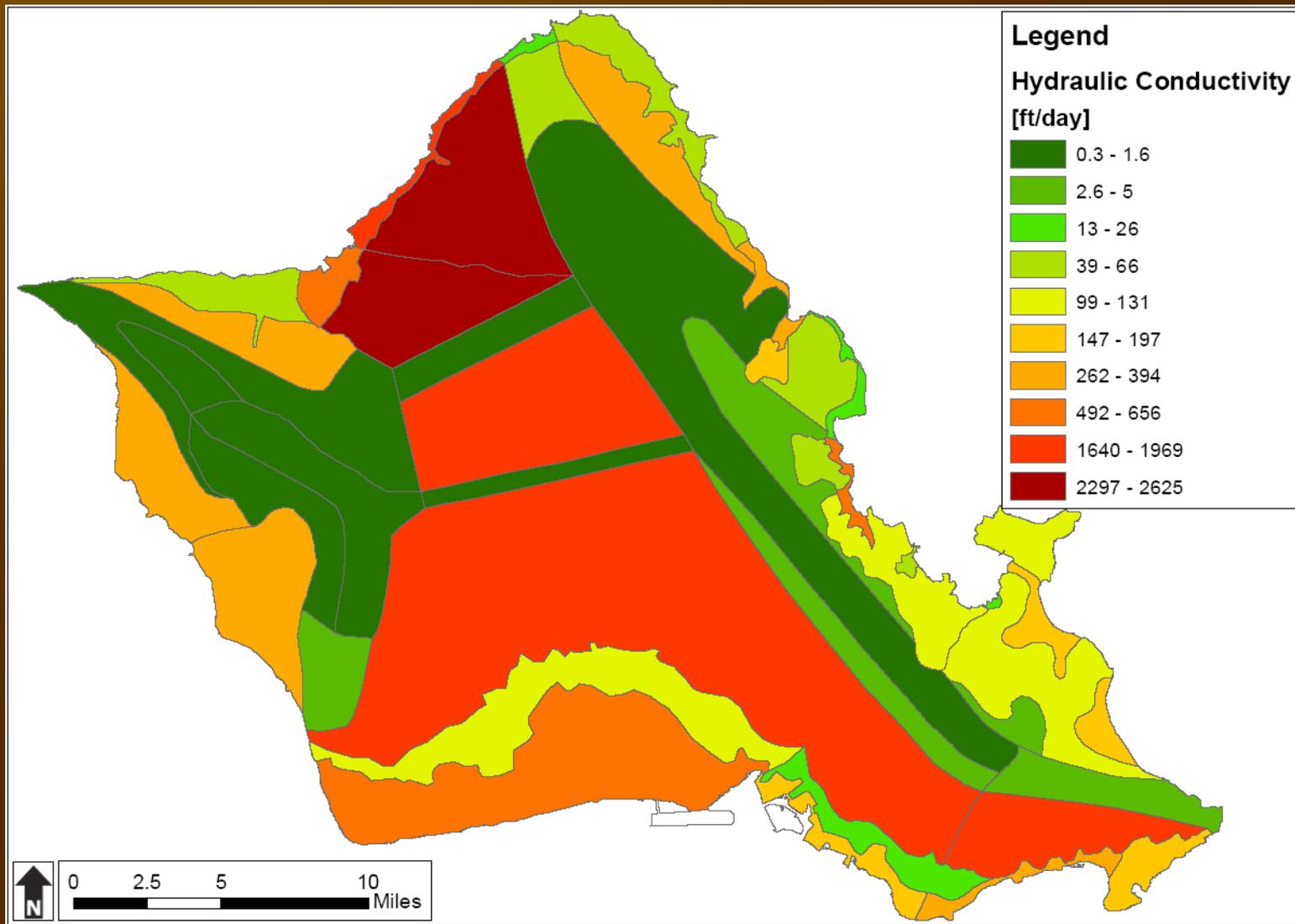
HYDRAULIC FLOW BARRIERS



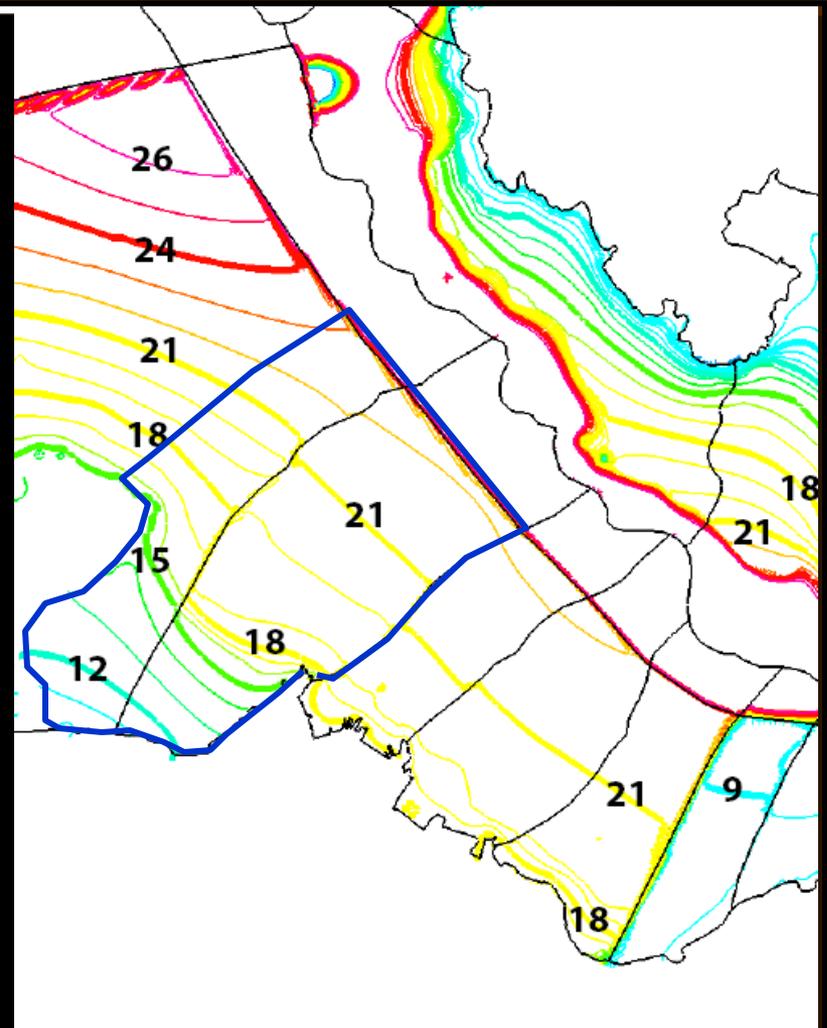
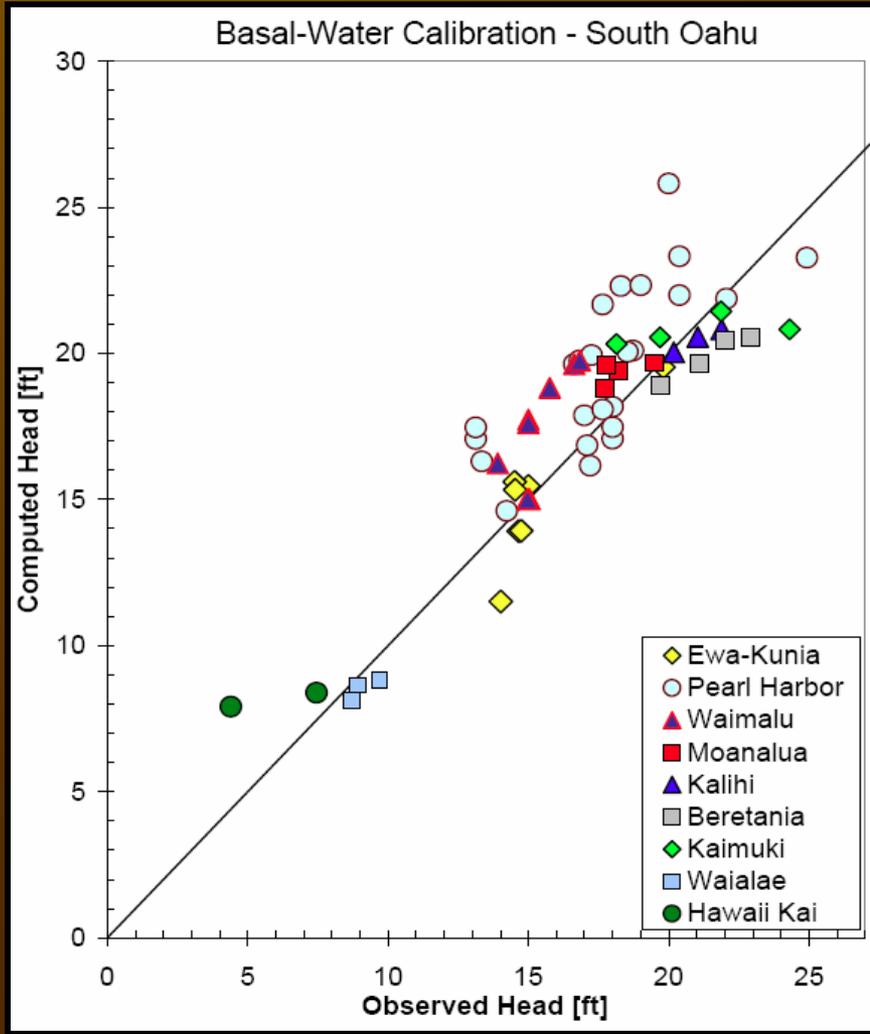
10-YEAR AVERAGE PUMPAGE



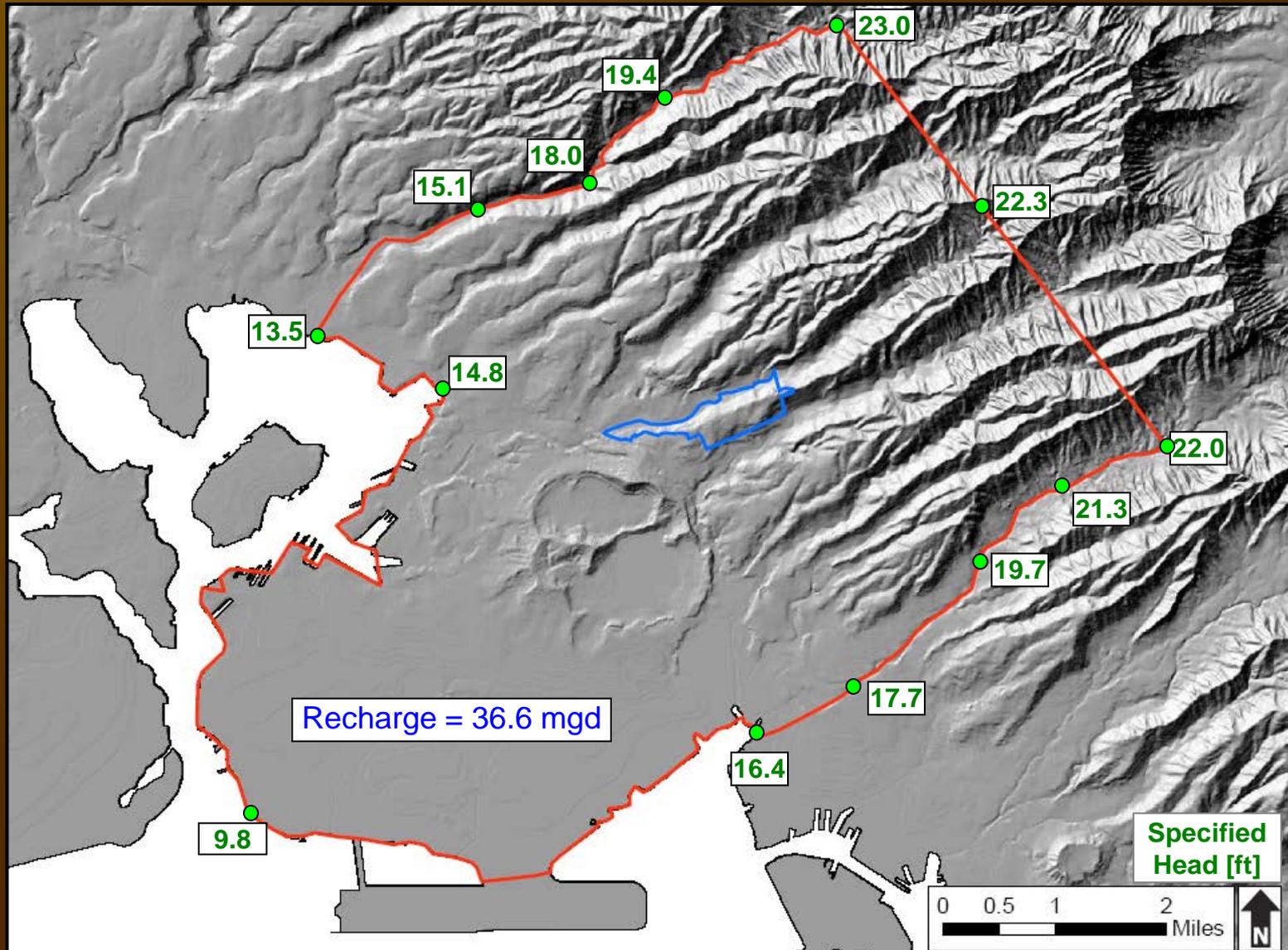
HYDRAULIC CONDUCTIVITY



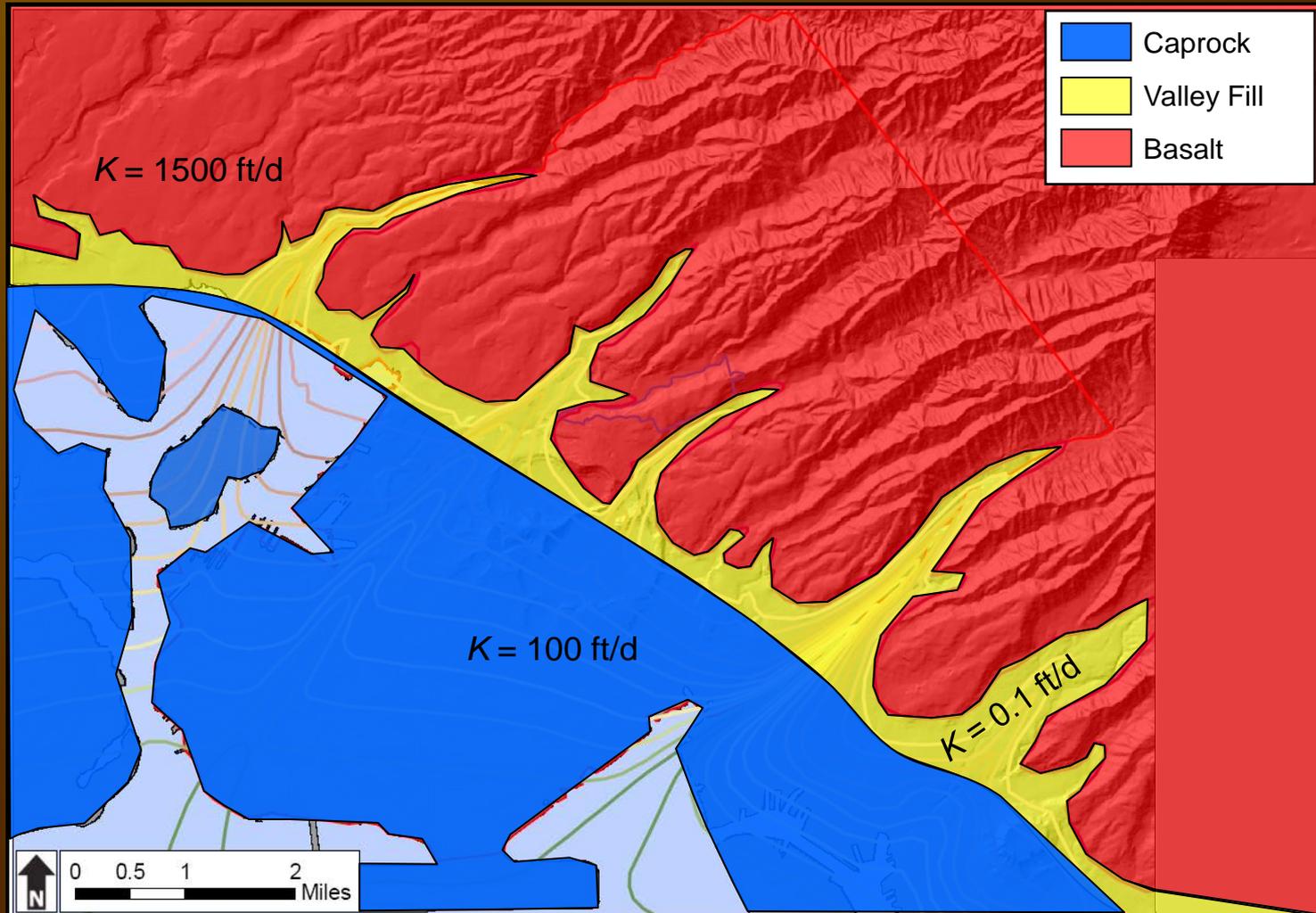
REGIONAL SWAP MODEL – BOUNDARY CONDITIONS



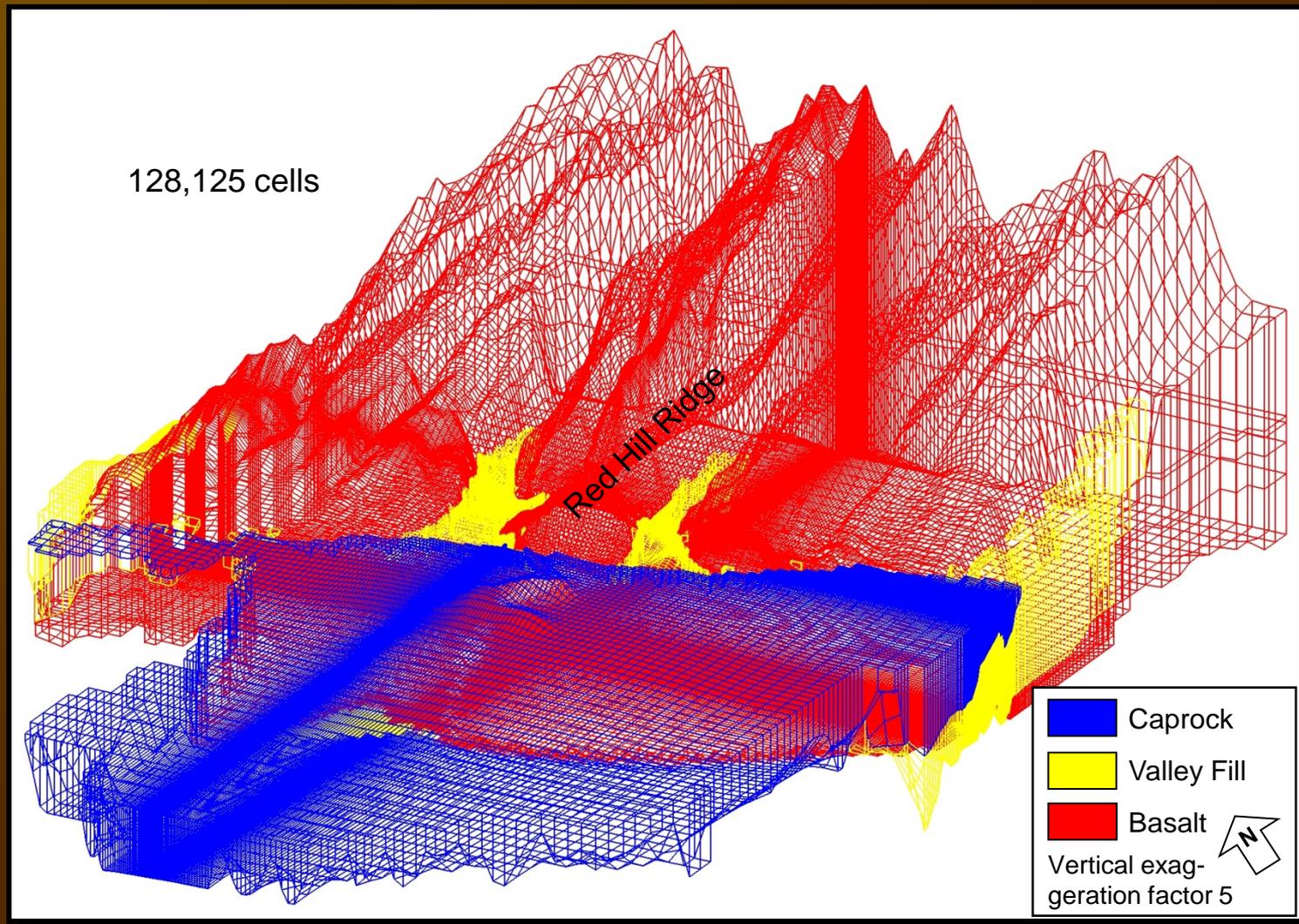
LOCAL MODEL - BOUNDARY CONDITIONS



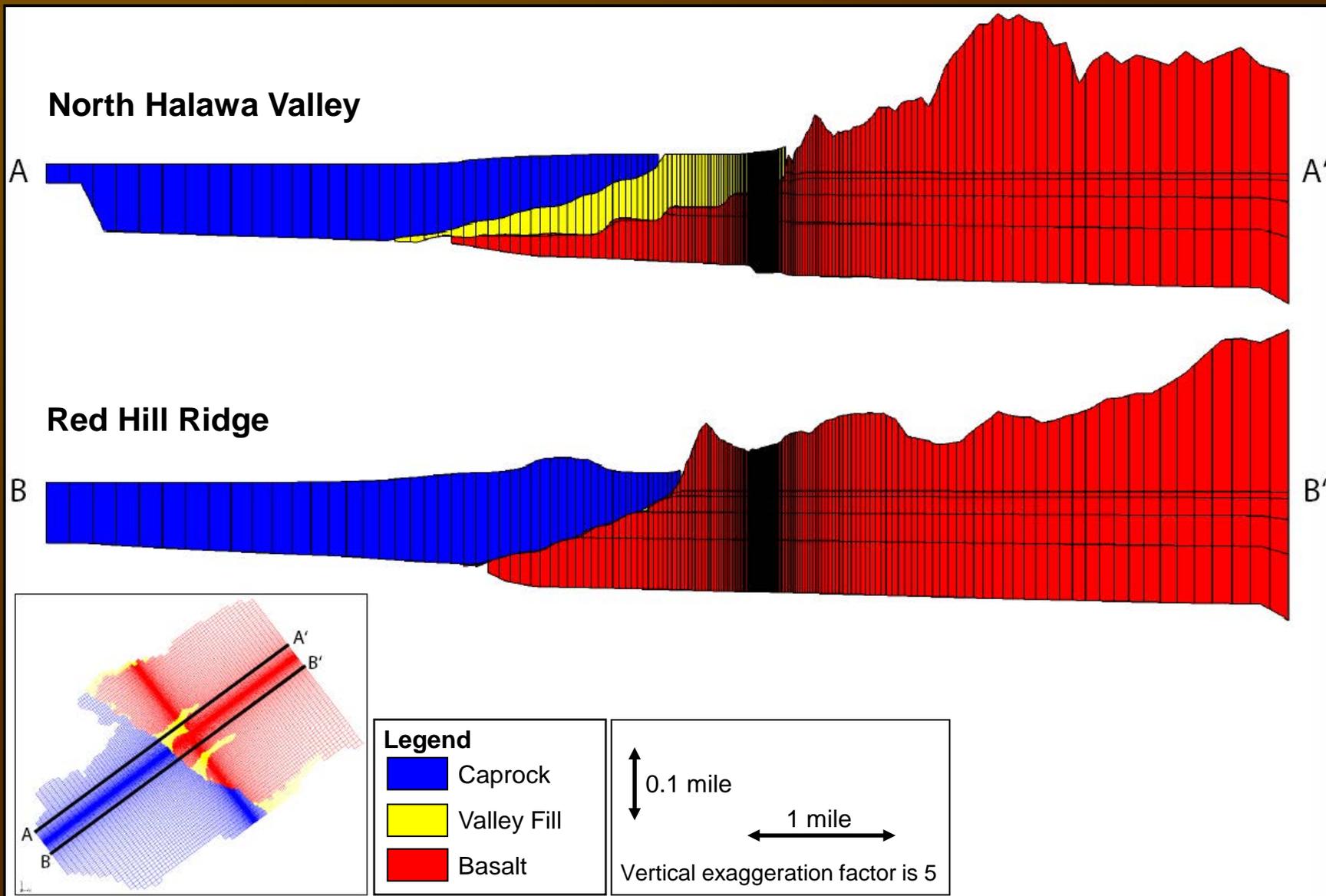
SIMPLIFIED SURFACE GEOLOGY



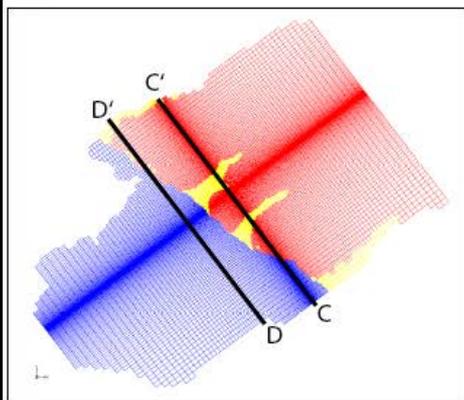
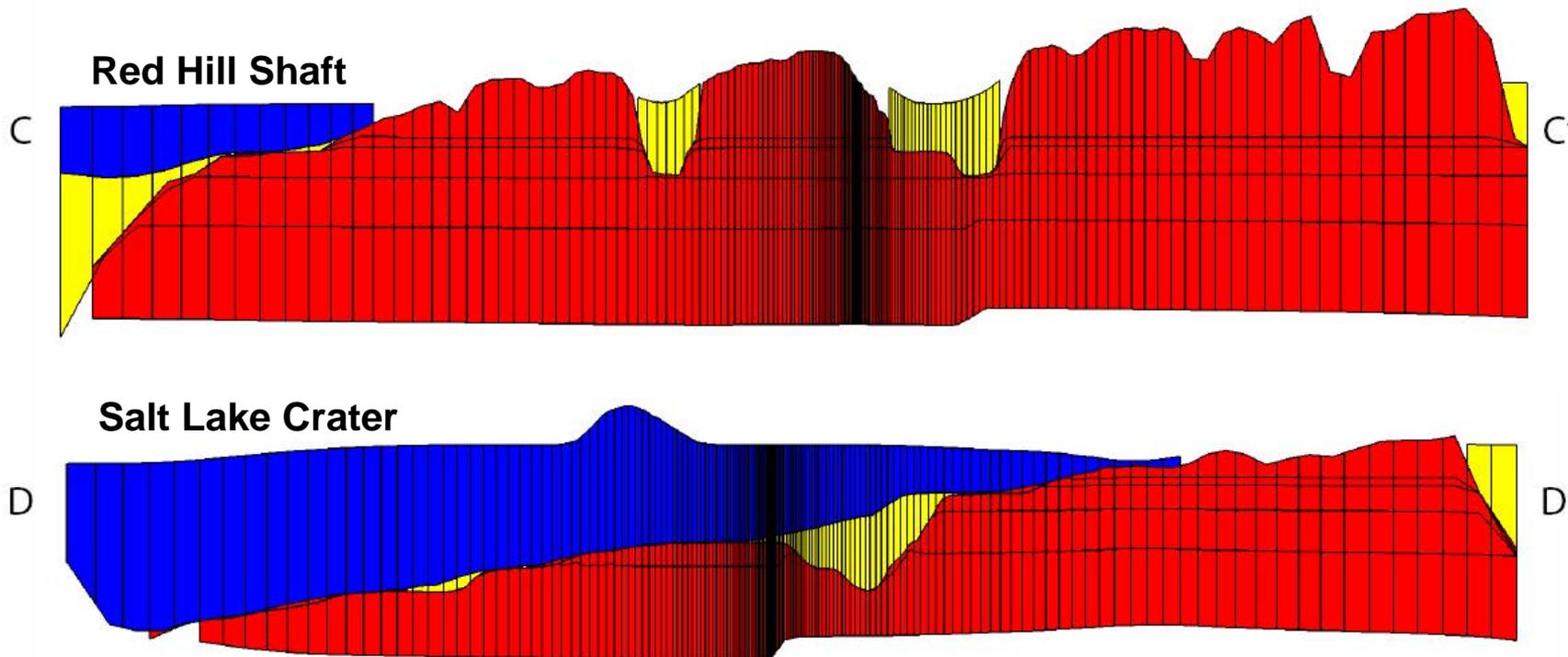
7-LAYER MODFLOW MODEL GRID



7-LAYER MODFLOW MODEL GRID

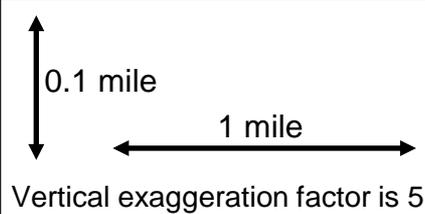


7-LAYER MODFLOW MODEL GRID

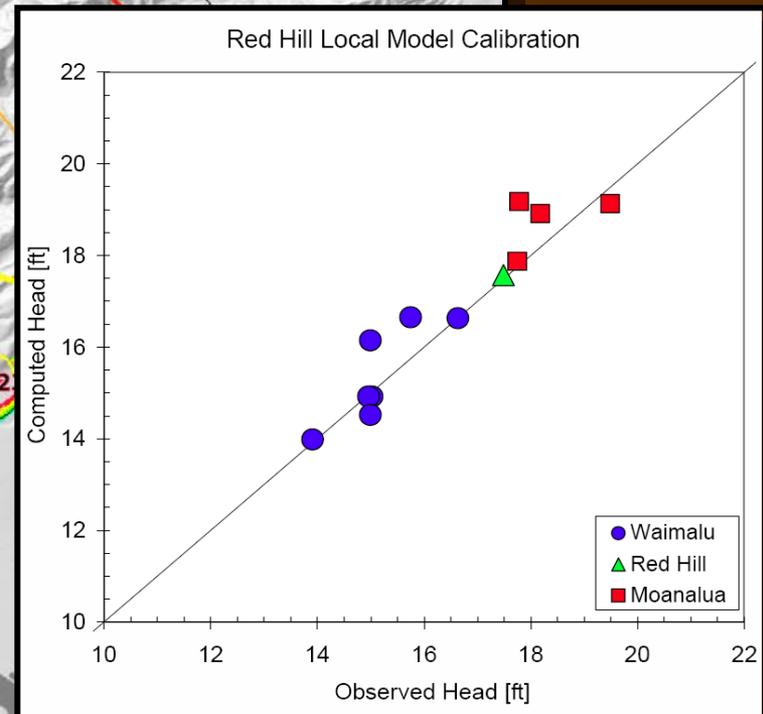
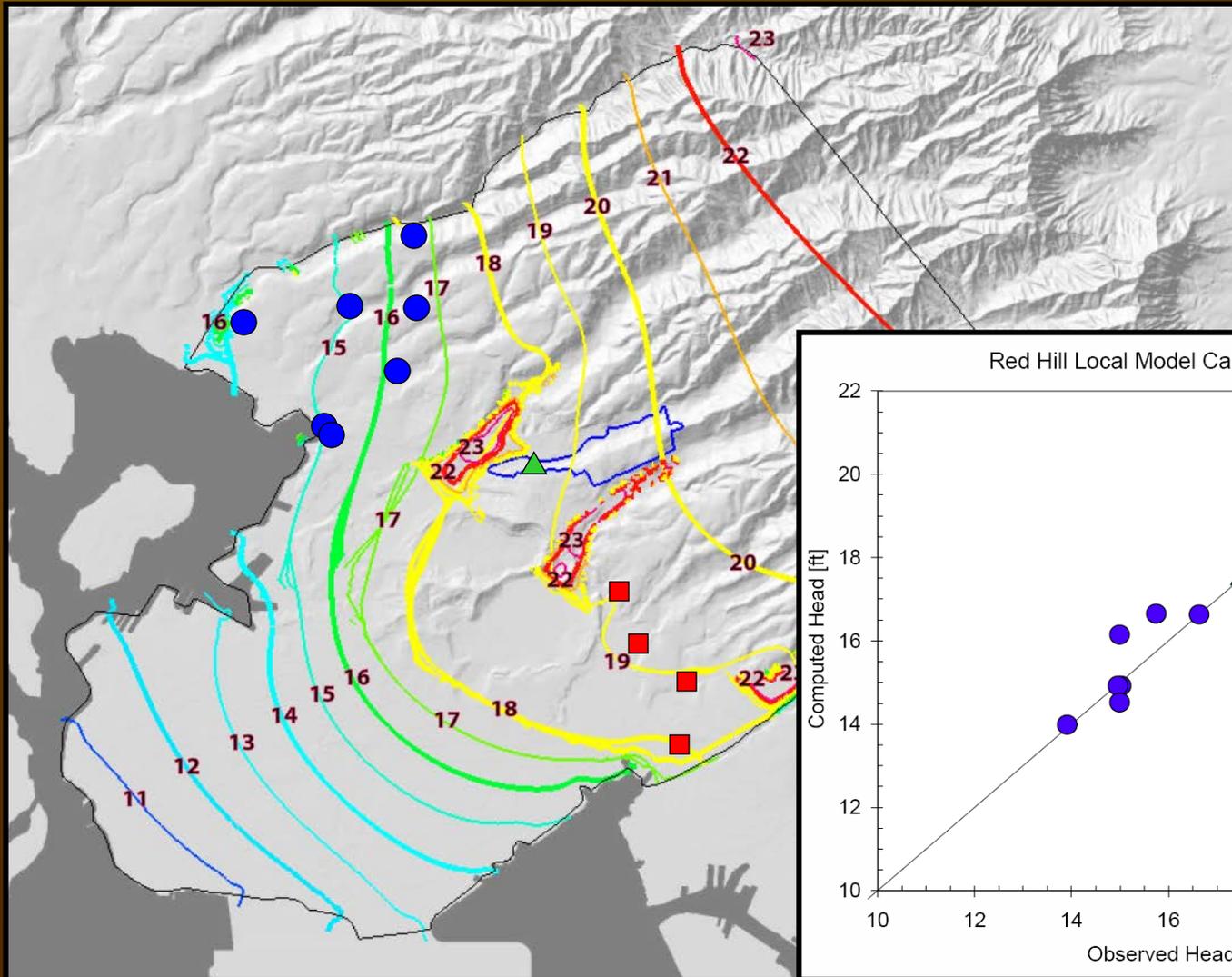


Legend

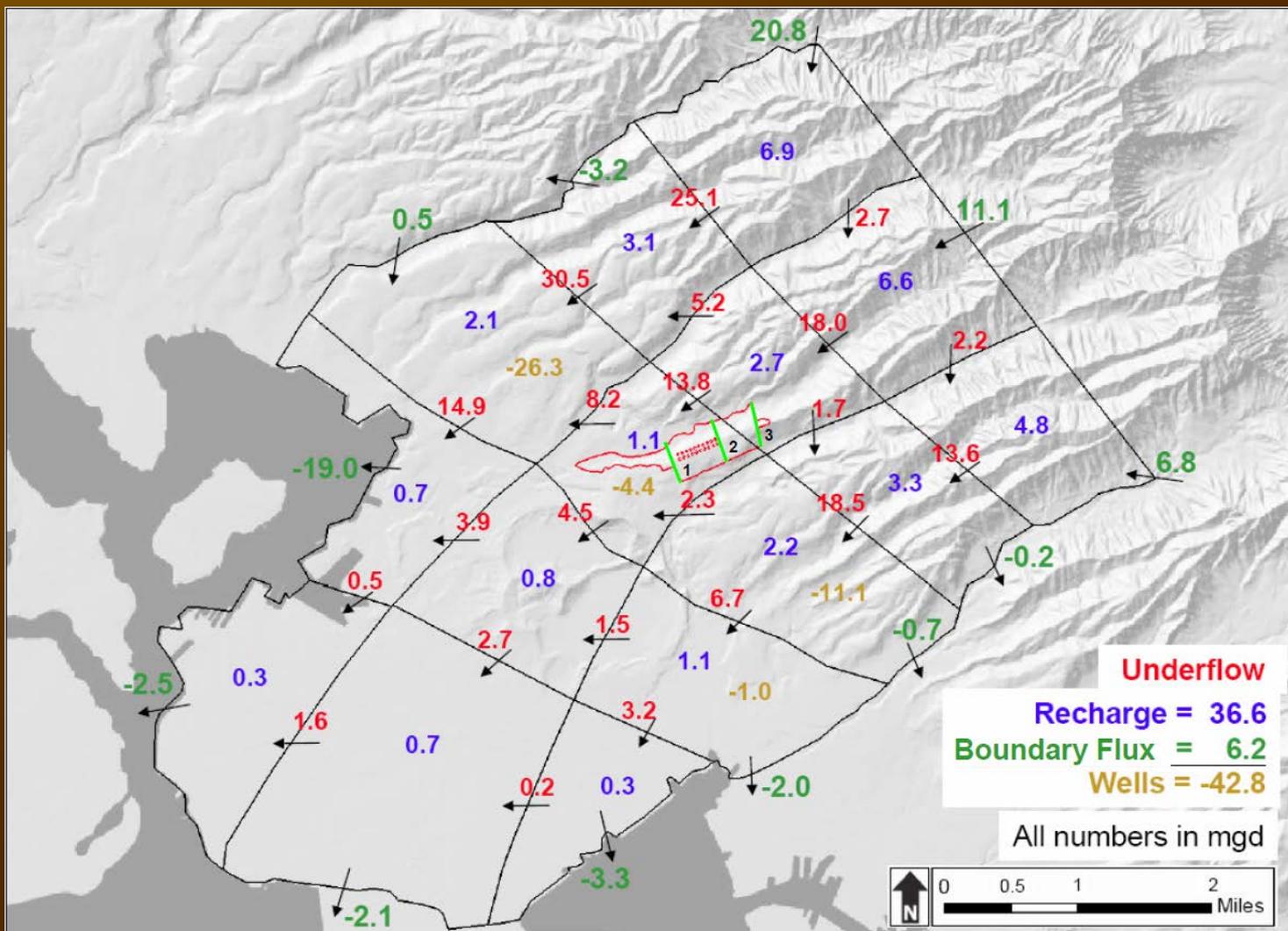
- Caprock
- Valley Fill
- Basalt



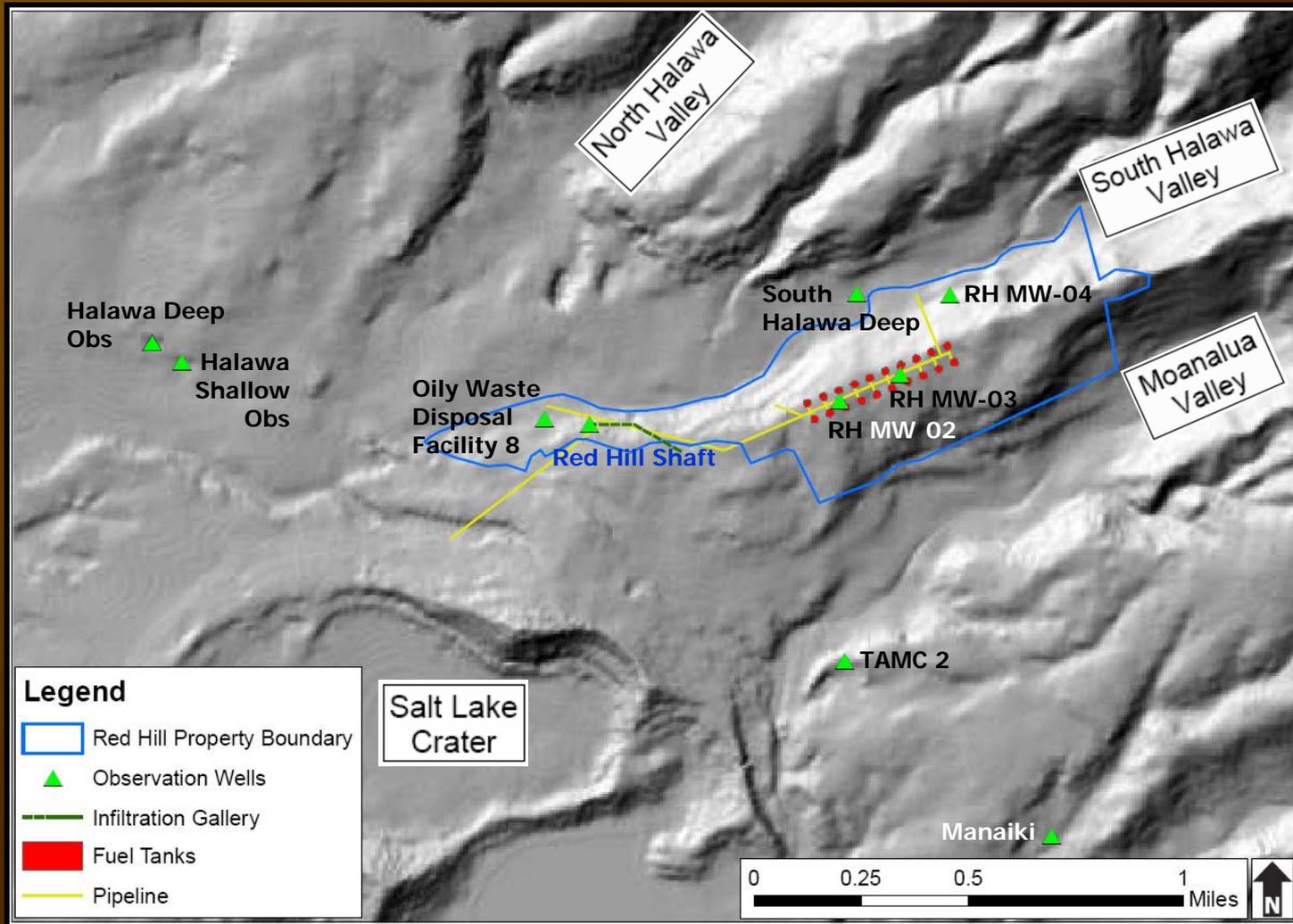
CALCULATED WATER LEVELS



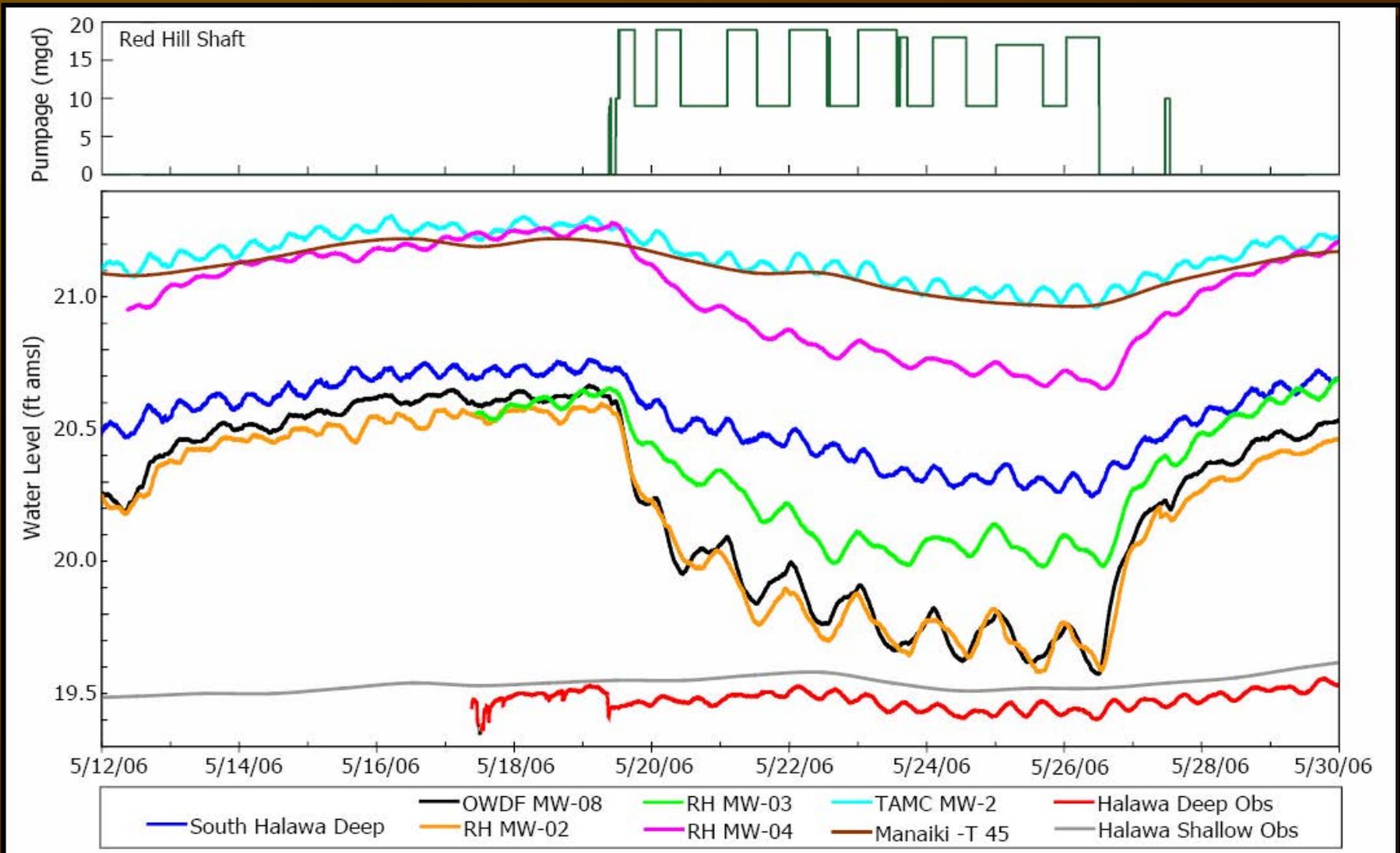
WATER BUDGET



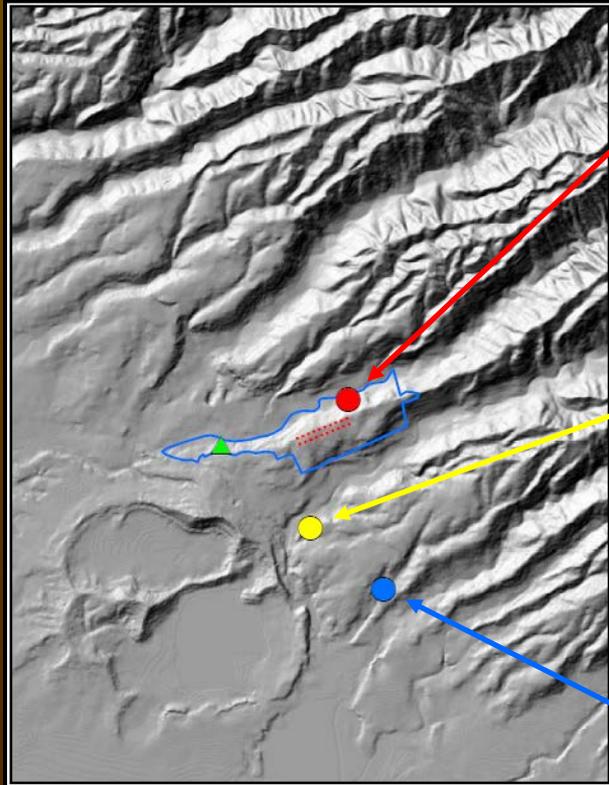
OBSERVATION WELLS



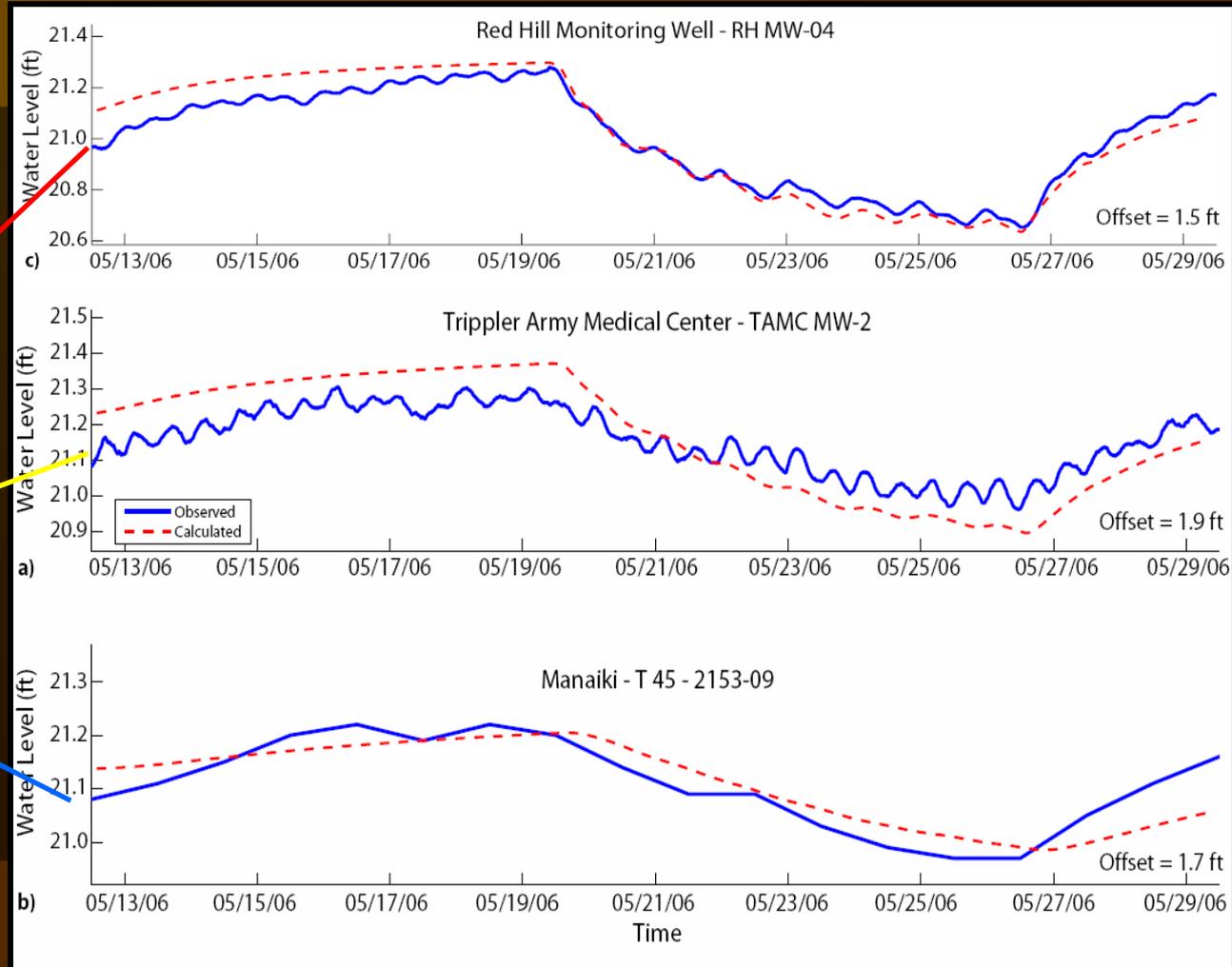
RED HILL SHAFT PUMPS ON/OFF



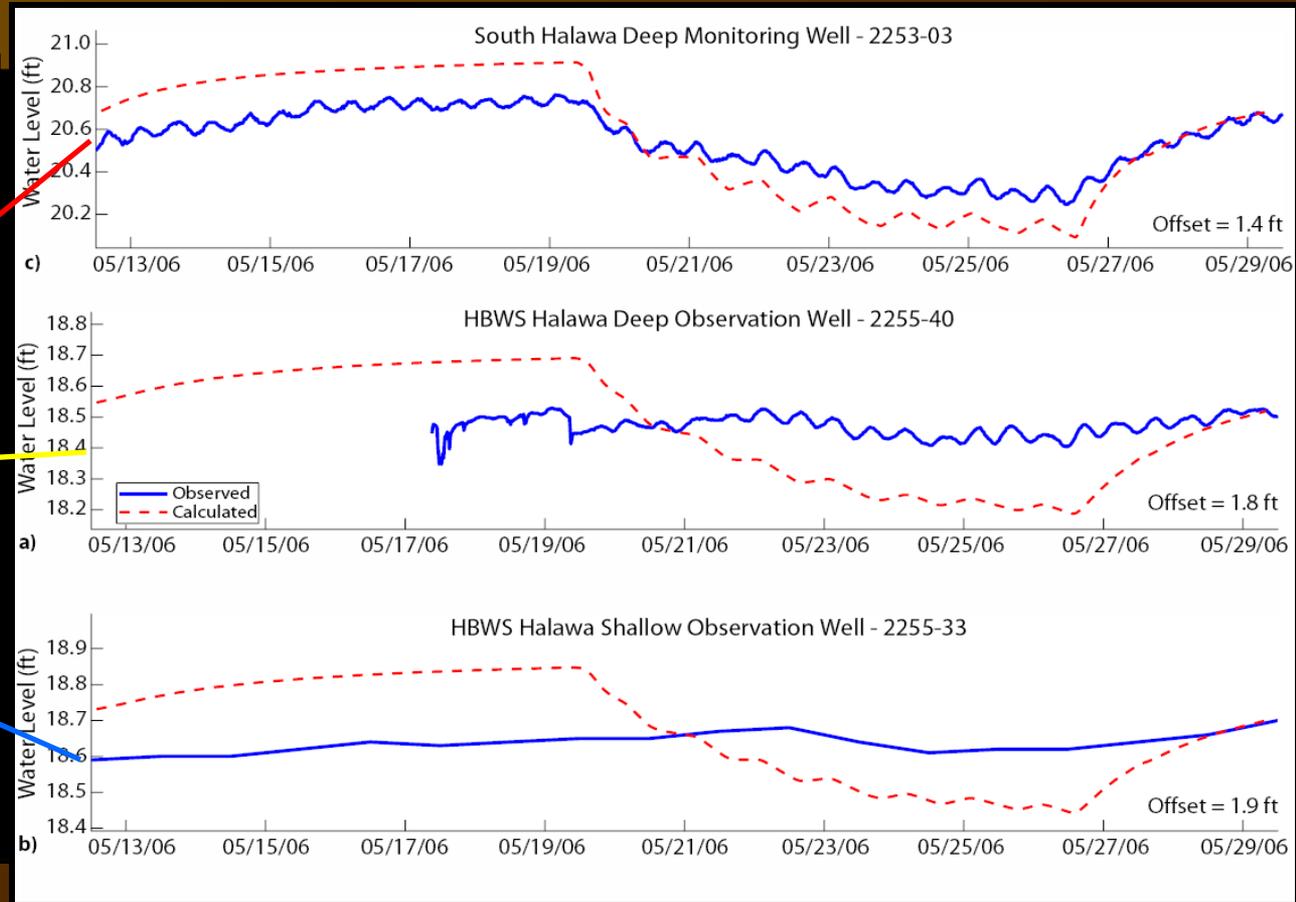
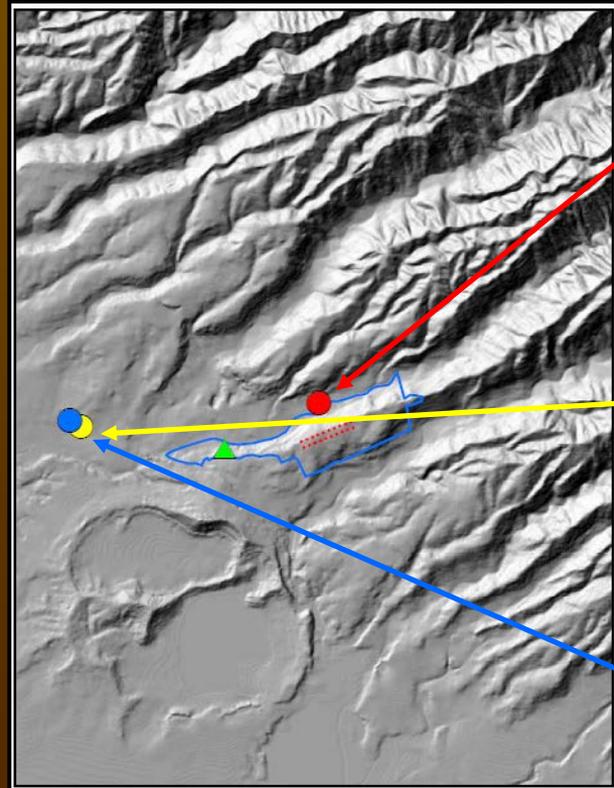
RED HILL SHAFT PUMPS ON/OFF



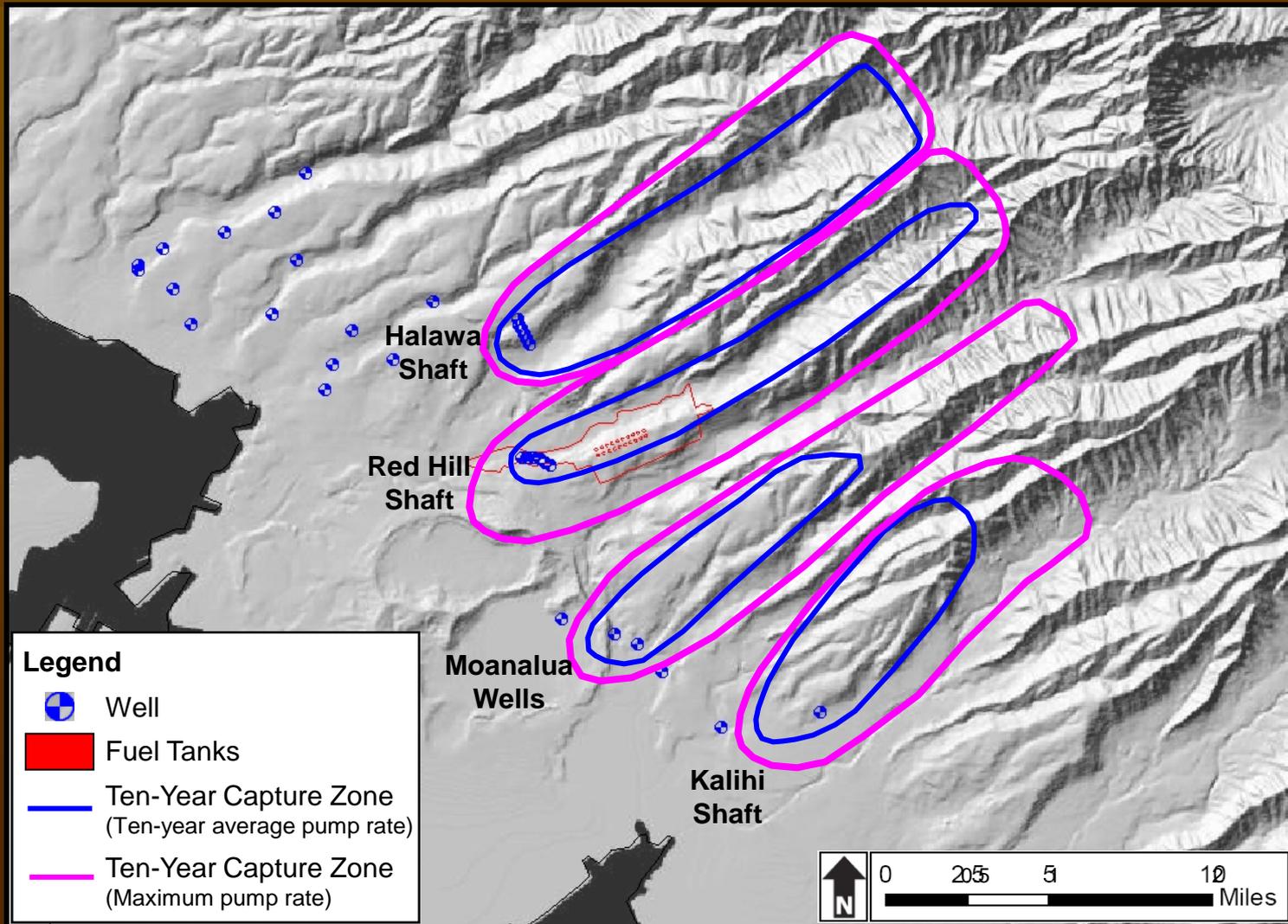
Specific Yield = 0.03



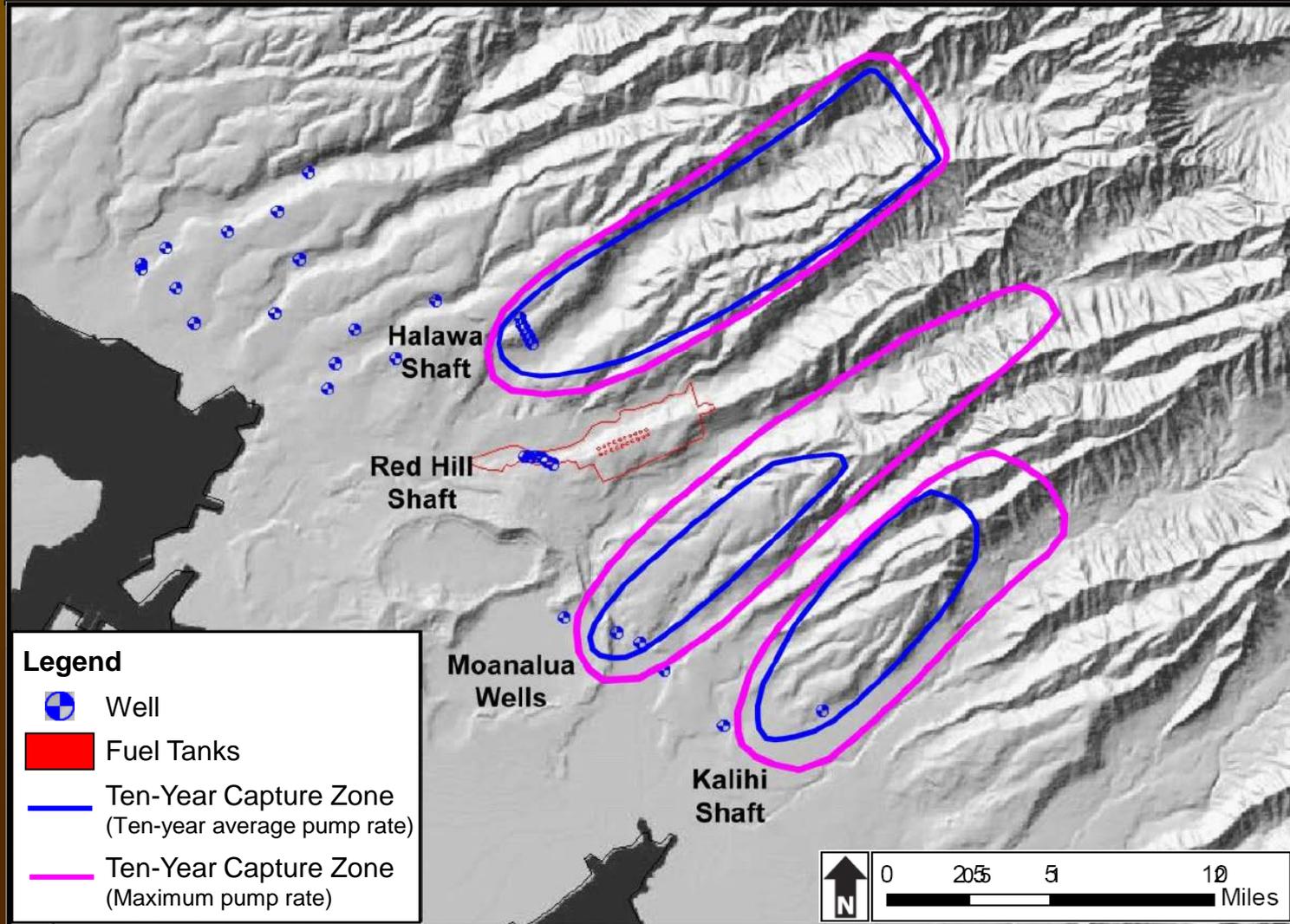
RED HILL SHAFT PUMPS ON/OFF



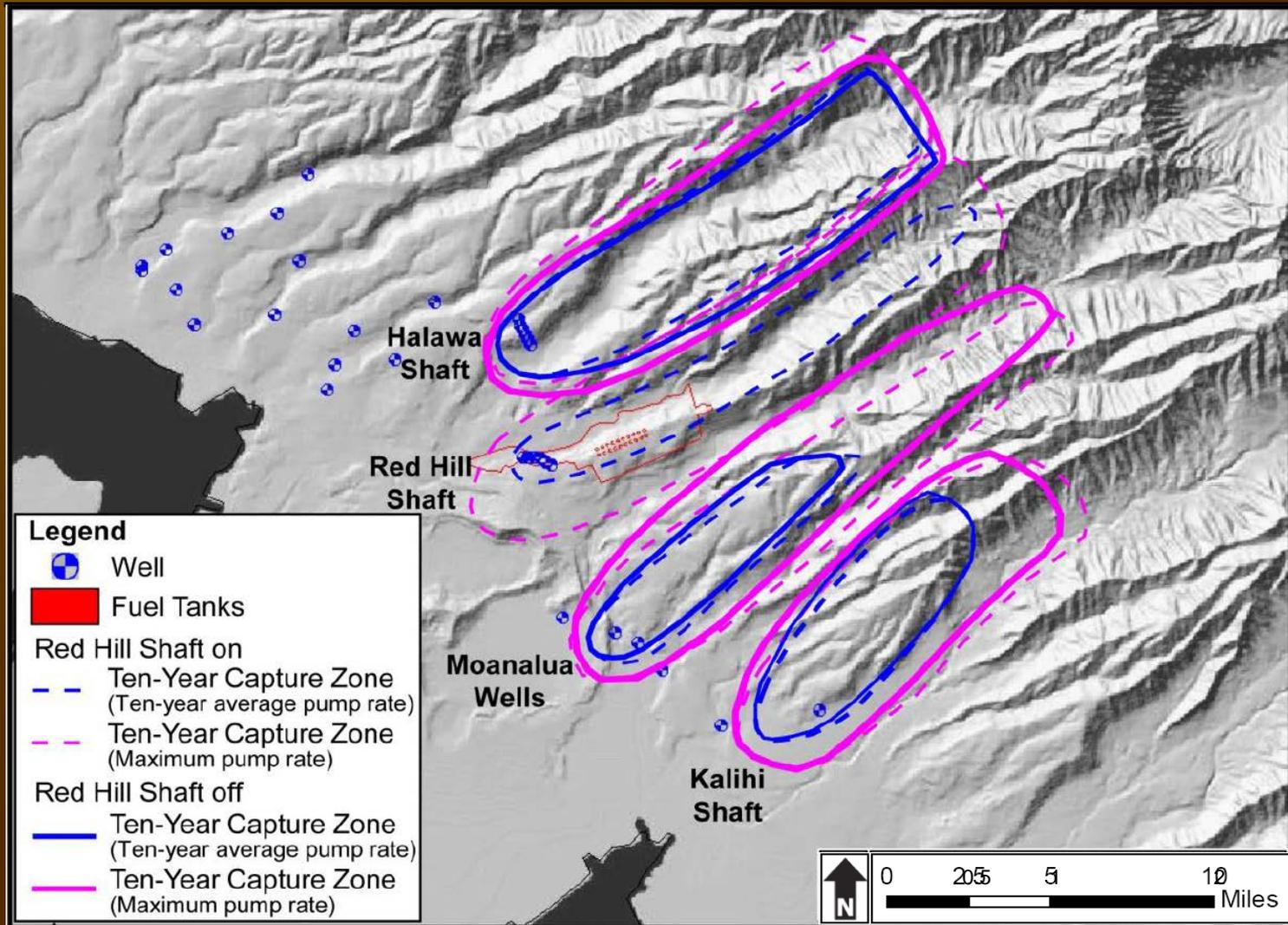
CAPTURE ZONE DELINEATION, all wells pumping



CAPTURE ZONE DELINEATION, Red Hill Shaft off



CAPTURE ZONE DELINEATION, both



CONCLUSIONS

- Incorporate geometries of low-permeability valley-fill barriers
- Successful regional to local model conversion
- Effectiveness of the North Halawa valley-fill barrier is underestimated
- Simulated aquifer test allows estimation of storage parameters ($S_Y = 0.03$)
- Capture zones of Red Hill Shaft only intersect Red Hill tanks
- Developed a groundwater flow around Red Hill Fuel Storage Facility that can be used to simulate solute transport (RT3D)



DATA GAPS & UNCERTAINTIES

Recharge

Engott, et al., 2015, USGS SIR 2015–5010

Water level elevation

GPS survey of well measuring points

Geology

Updated structural basalt contours

Include weathered basalt underneath valley fill

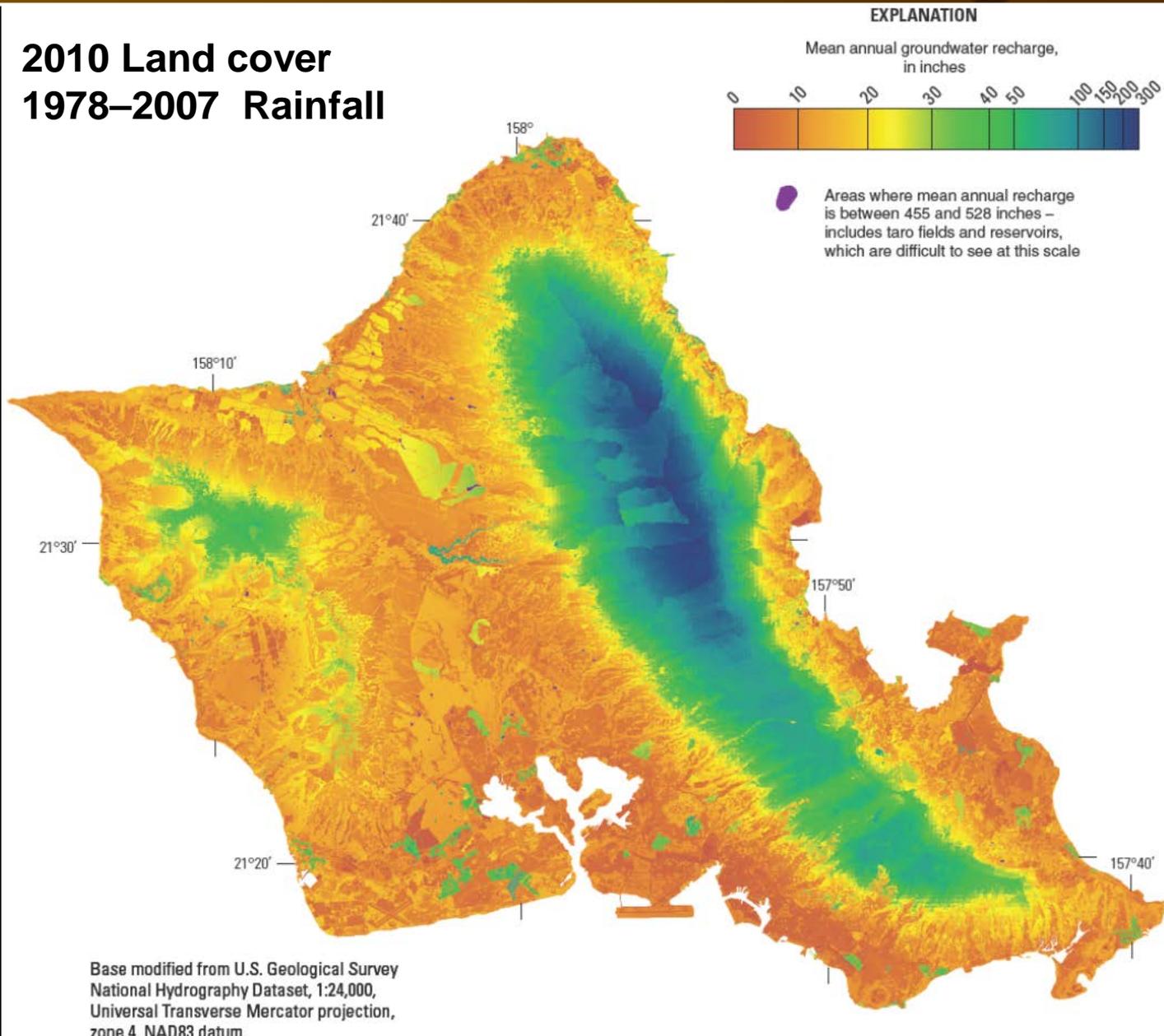
Consider rejuvenated volcanism around Salt Lake Crater

Aquifer Test

Pump on/off at Halawa Shaft

Recent 2010 Recharge

2010 Land cover
1978–2007 Rainfall

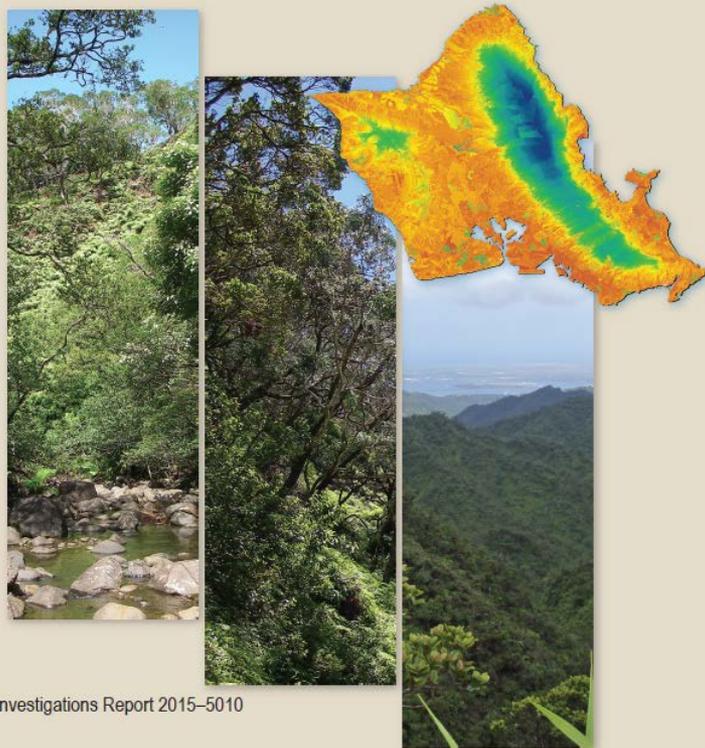


Oahu Recharge Report



Prepared in cooperation with the State of Hawai'i Commission on Water Resource Management and the City and County of Honolulu Board of Water Supply

Spatially Distributed Groundwater Recharge for 2010 Land Cover Estimated Using a Water-Budget Model for the Island of O'ahu, Hawai'i



Scientific Investigations Report 2015-5010

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

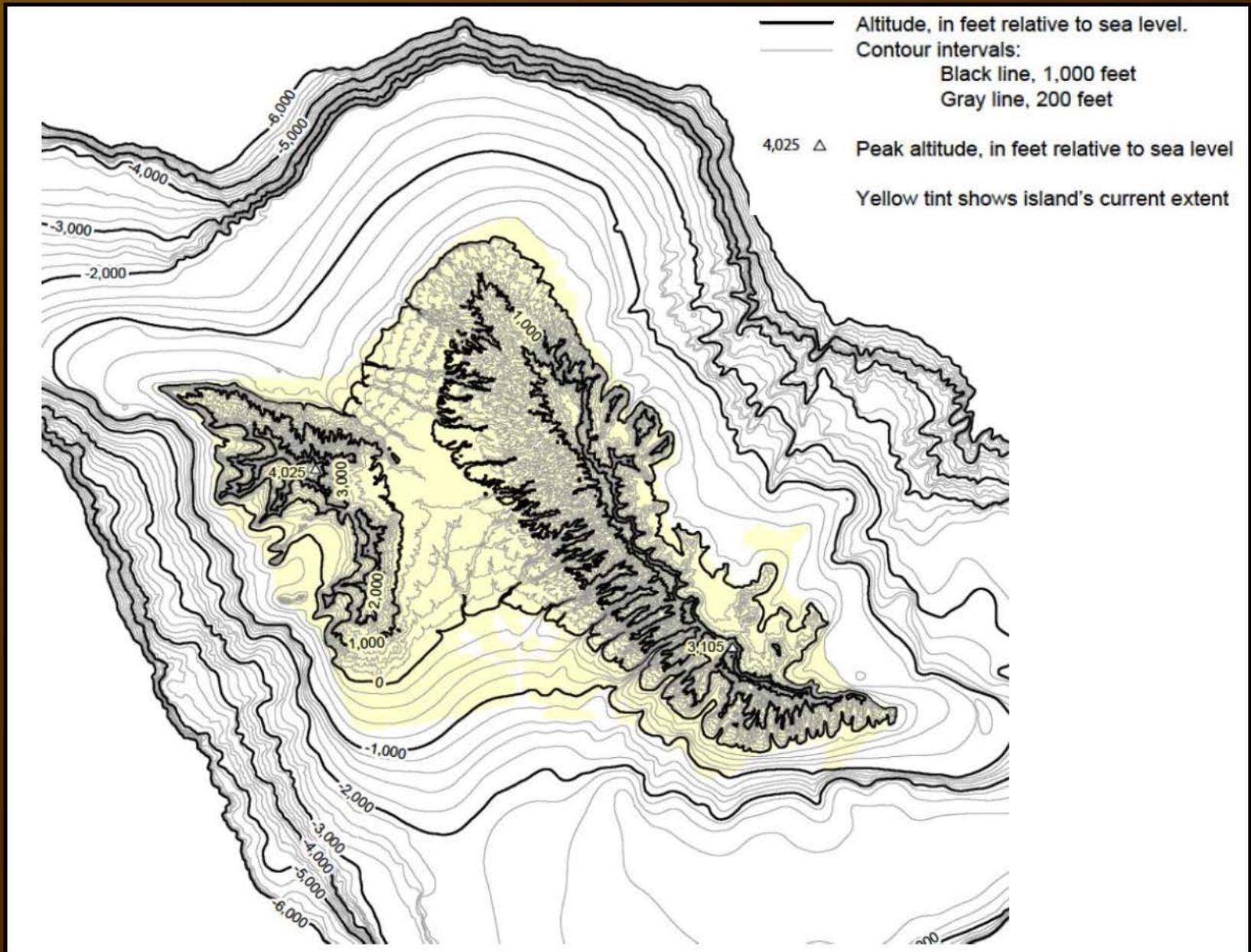
Engott, J.A., Johnson, A.G., Bassiouni, M., and Izuka, S.K.,
2015,

Spatially distributed groundwater recharge for 2010 land cover estimated using a water-budget model for the Island of O'ahu, Hawai'i:

U.S. Geological Survey Scientific Investigations Report 2015-5010,
49 p.

<http://dx.doi.org/10.3133/sir20155010>

Volcanic Structural Contours



Hawaii Volcanic Aquifers Report



Groundwater Resources Program

Hawai'i Volcanic Aquifers—Hydrogeology, Water Budgets, and Conceptual Models



Scientific Investigations Report 0000–0000

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

Izuka, S.K., Engott, J.A., Bassiouni, M., Johnson, A.G., Miller, L.D., Rotzoll, K., and Mair, A.,

in press,

Volcanic aquifers of Hawai'i — hydrogeology, water budgets, and conceptual models:

U.S. Geological Survey Scientific Investigations Report 2015-5164