Hydrogeological features of freshwater lenses on volcanic islands - physical and numerical modeling

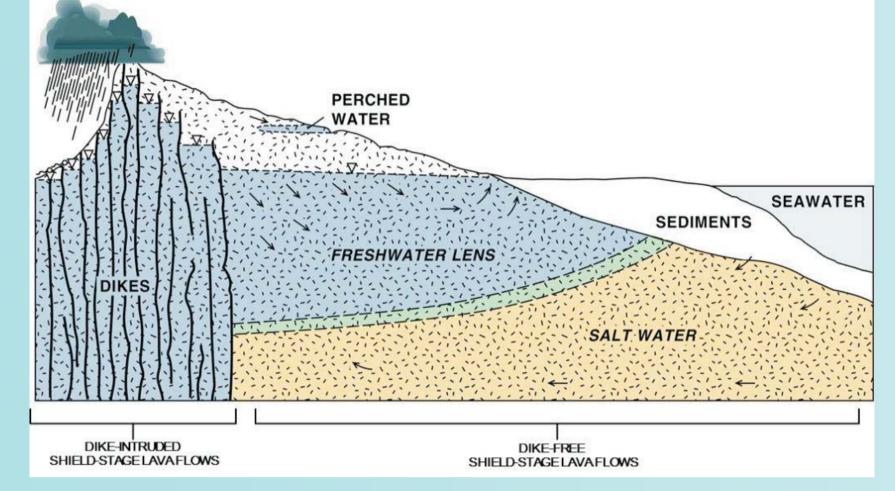Katrina Mariner[1,2], **Georg J. Houben**[3], Leonard Stoeckl[2,3] and Martin Thullner[4]

[1] Samoa Water Authority (SWA), Apia, Samoa
[2] Leibniz University, Hannover, Germany,
[3] Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany   georg.houben@bgr.de
[4] Helmholtz Centre for Environmental Research - UFZ, Leipzig, Germany

Volcanic Islands

Volcanic islands of the Hawaiian type often show secondary sheeted intrusions (dikes) of low permeability which cause separation into hydraulic compartments
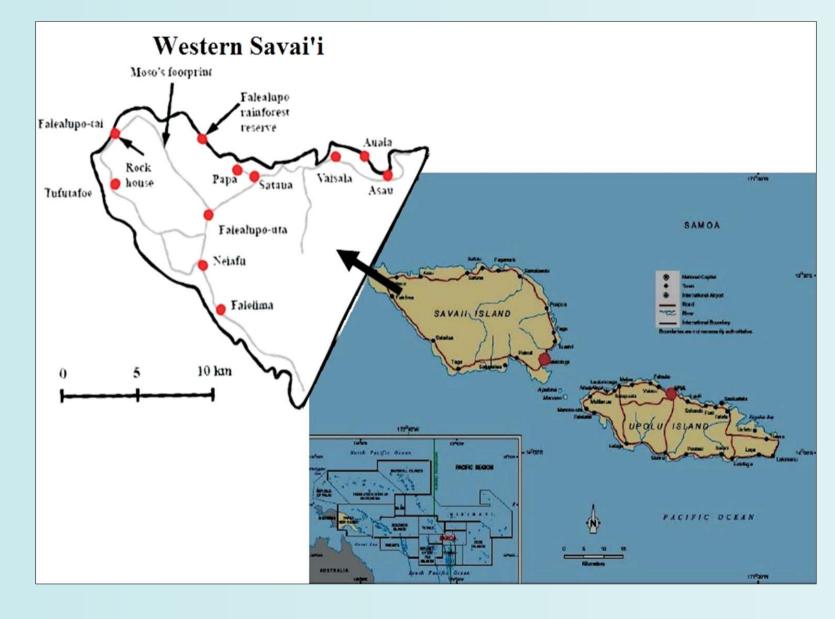

Source: USGS, Pacific Islands Water Science Center

The coastline is often rimmed by a coral reef (fringing reef) made of porous limestone which acts as a cap rock for the even more permeable volcanic rocks.

Example: Western Savai´i Island, Samoa

▶ highly permeable volcanic rocks (no surface water), secondary sheeted dike intrusions, coastal reefs
▶ precipitation: highlands 6000, coast 3000 mm/a
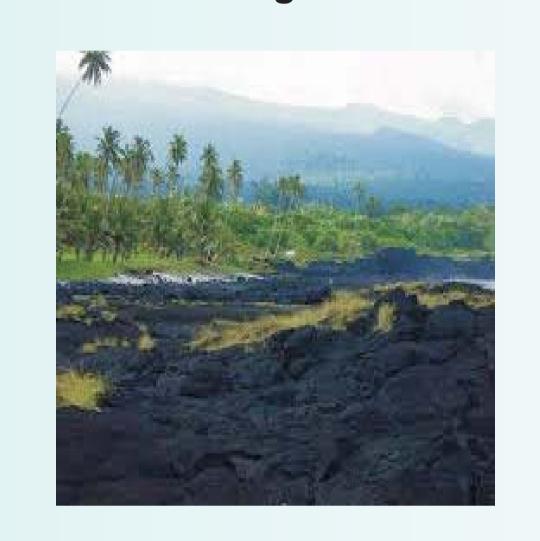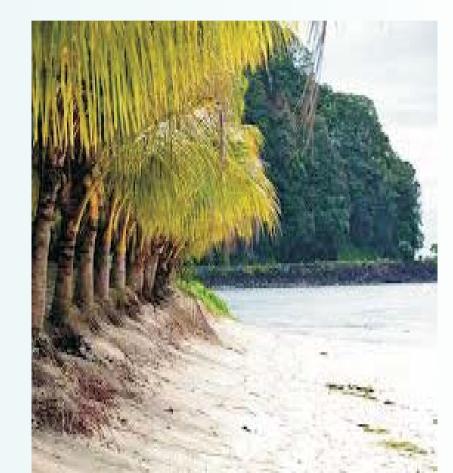▶ water supply: groundwater from freshwater lens(es)

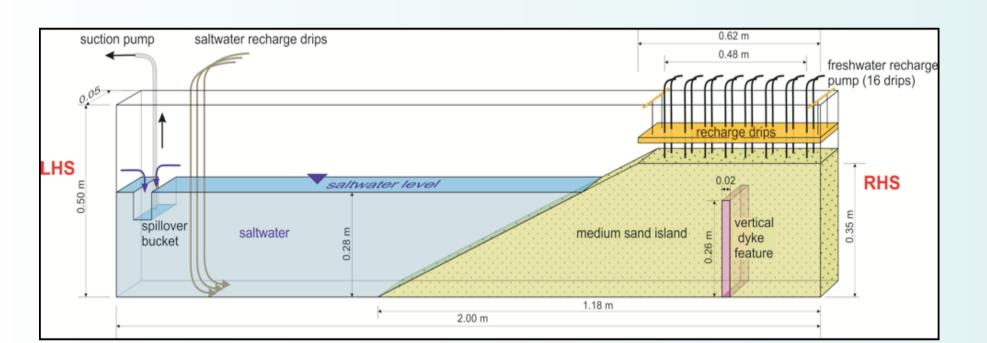Source: worldatlas.com

OBJECTIVES OF STUDY

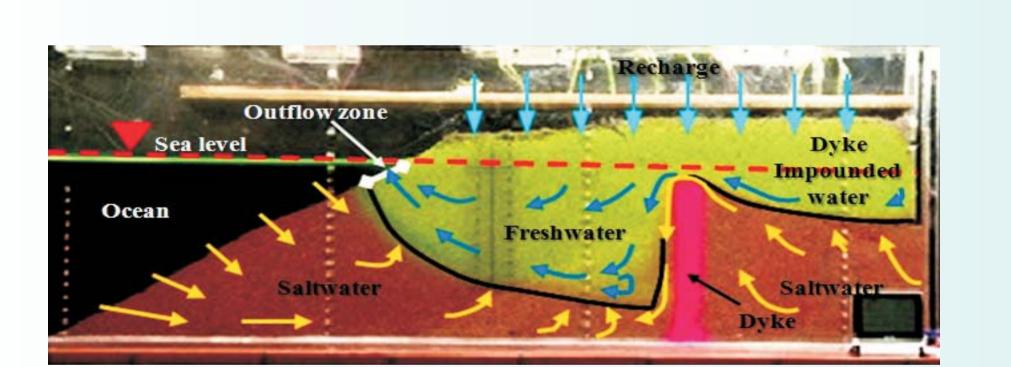*Physical and numerical models to assess*

▶ *impact of dikes and reefs on flow dynamics*
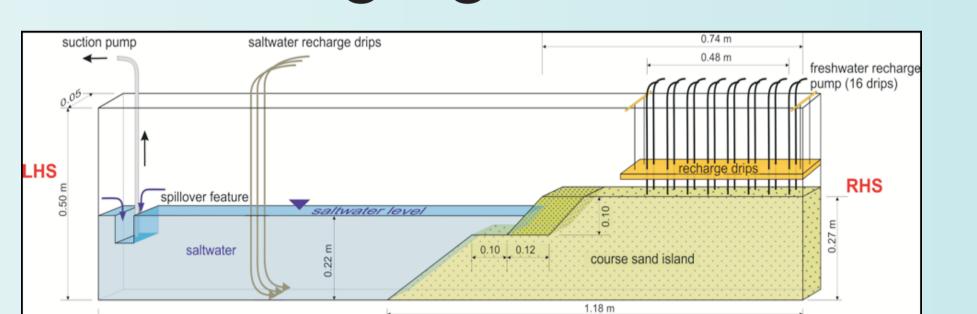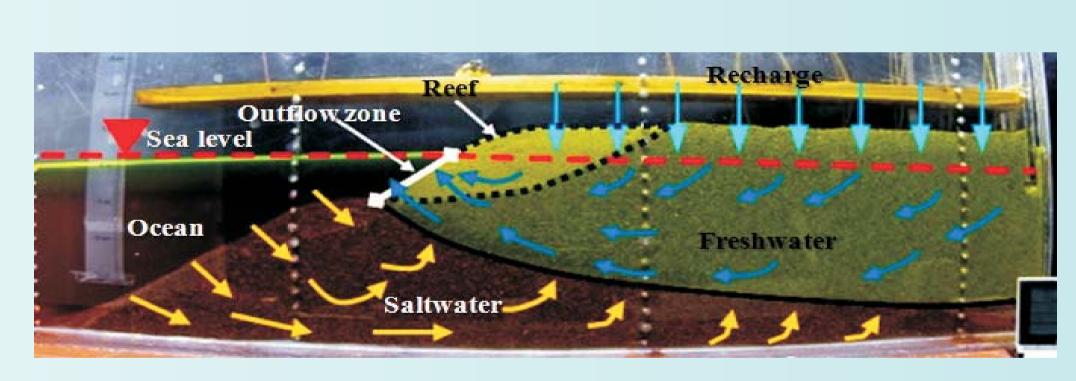▶ *contamination by saline water overwash through tsunamis and cyclones*

Sandtank experiments

Volcanic dike

Dike = plasticine wall in homogeneous sand aquifer
▶ increased vertical flow components
▶ conserved saline water "behind" the dike

Fringing reef

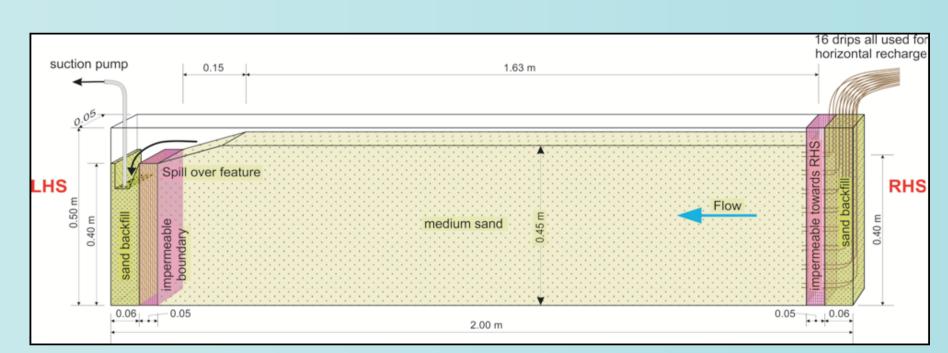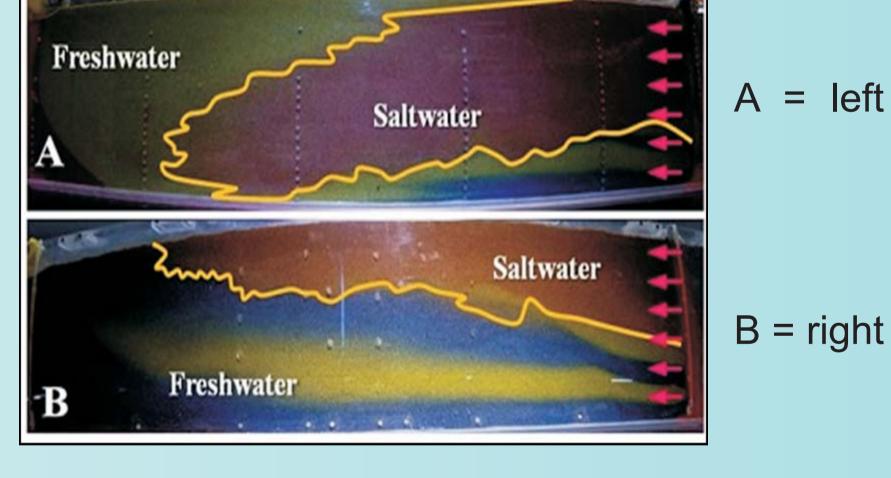Reef = fine sand cap on top of medium sand aquifer
▶ focused freshwater outflow below reef
▶ submarine springs
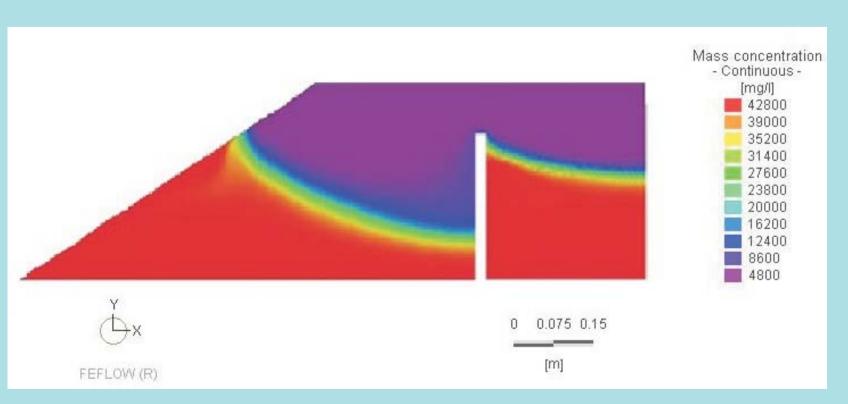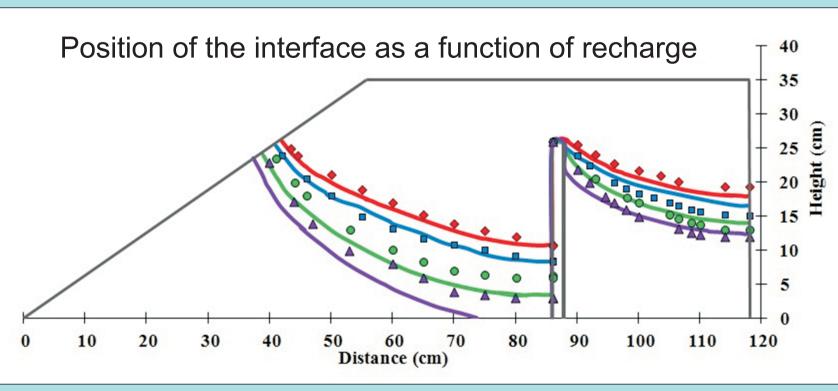
Overwash

A = left

B = right

Initial: horizontal flow of saline water on top of freshwater
▶ strong 3D effects in sandtank (5 cm width)
▶ numerical 2D model not applicable

Numerical modeling

Mass concentration - Continuous - [mg/l]
42000 39000 35200 31400 27600 23800 20000 16200 12400 8600 4800

FEFLOW (R)   0 0.075 0.15 [m]

Position of the interface as a function of recharge

◆ Physical model at q = 1.21 m/d   ● Physical model at q = 3.70 m/d
— Numerical model at q = 1.21 m/d   — Numerical model at q = 3.70 m/d
■ Physical model at q = 2.69 m/d   ▲ Physical model at q = 4.90 m/d
— Numerical model at q = 2.69 m/d   — Numerical model at q = 4.90 m/d

▶ physical models and numerical simulations of interface geometry show good fit for all recharge rates
▶ slight differences can be attributed to limited observational accuracy

Conclusions

▶ fringing reef: large freshwater volumes discharge as submarine springs at the bottom of the reef
▶ dikes: volcanic dike intrusions strongly influence head distribution, increase vertical flow component and may conserve saline water "behind" the dike
▶ overwash: strong 3D effects in physical model, 2D numerical model not applicable

GENERAL

▶ fringing reefs and dikes need to be included when studying freshwater lenses on volcanic islands of the Hawaiian type
▶ storm surge overwash (saline water on top of fresh water) needs numerical models in 3D, more experimental work needed as benchmark for numerical models