Up and Down--How Can We Assess Hydraulic Properties from Tidal Fluctuations in Coastal Aquifers?

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1. Abstract

Detailed estimates of hydraulic properties are important for models that are used to assess groundwater availability and quality. The attenuation of tidal variations in groundwater levels with distance from the coast reflects an aquifer's hydraulic properties. We present a regional compilation of tidal-attenuation information for Hawaii, and estimate hydraulic properties using groundwater-level records from more than 250 wells in volcanic rock and more than 200 wells in coastal sediments. Results are combined in a regional context with respect to the hydrogeologic framework of each island in Hawaii. The tidal response in groundwater levels can help to distinguish and identify hydrogeologic units. For example, no tidal signal was observed in dike-intruded volcanic rock, and the lower-permeability coastal sediments caused a damping effect of the tidal signal. Aquifer-diffusivity and hydraulic-conductivity estimates in dike-free volcanic rock decrease with island age, consistent with a reduction in permeability through weathering. The results will be useful for developing island-wide numerical ground-water models of Hawaii.

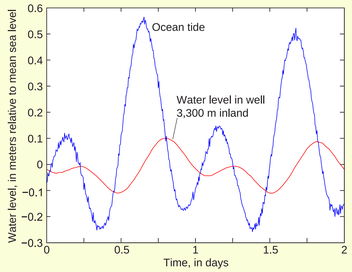
2. Tidal Attenuation

With increasing distance from the coast (*x*):
- Tidal amplitude decreases exponentially
- Time lag increases linearly

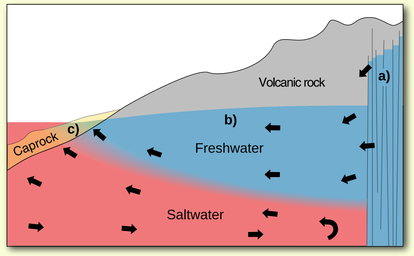
$$\text{Tidal efficiency} = \frac{\text{Amplitude in well}}{\text{Amplitude in ocean}}$$

$$\text{Diffusivity} = \frac{x^2 * \text{Constant}}{\ln(\text{Tidal efficiency})^2}$$

$$\text{Hydraulic conductivity} = \frac{\text{Diffusivity} * \text{Specific yield}}{\text{Aquifer thickness}}$$



3. Hydrogeologic Framework

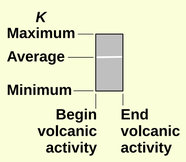


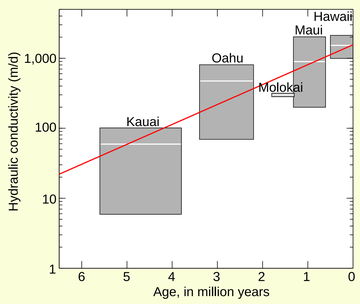
Hawaii aquifers can be categorized into
a) dike-intruded volcanic rock
b) dike-free volcanic rock
c) caprock.

Coastal sedimentary deposits form a caprock in some places that confines, attenuates tidal propagation into, and creates a thick freshwater lens within the volcanic-rock aquifer.

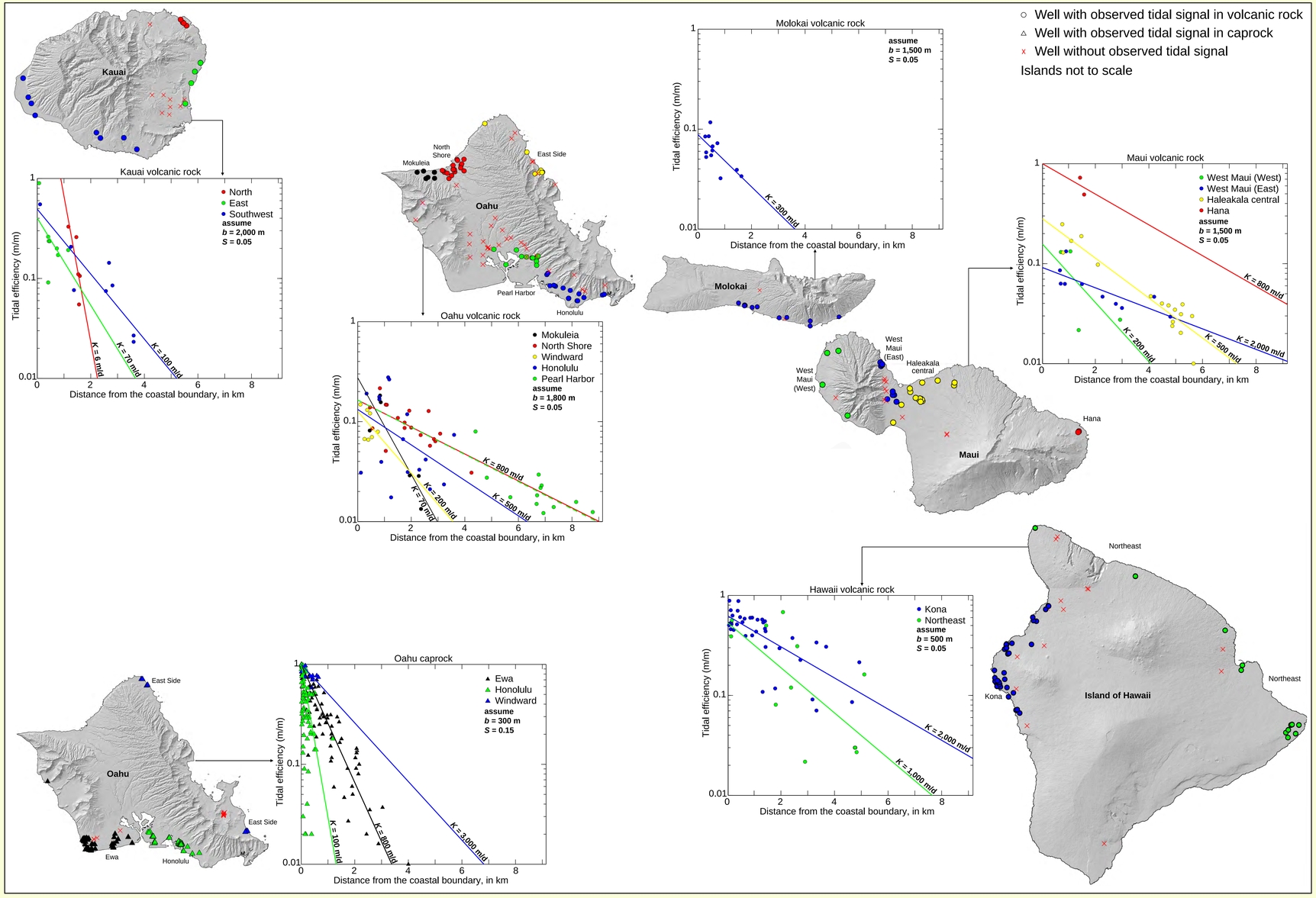
5. Volcanic-Rock Regional Synthesis

Combining volcanic-rock hydraulic conductivity of different regions on each Island and relating it to the general age of the island suggests that hydraulic-conductivity estimates decrease with island age, mainly because weathering reduces open pore space and flow paths.





4. Measured Tidal Efficiency and Estimated Hydraulic Conductivity



Wells in which groundwater levels are unaffected by ocean tides are located inland or in low-permeability rocks. The slope of logarithmic tidal efficiency with distance from the coastal boundary is directly related to aquifer diffusivity. Assuming typical values of specific yield (*S*) and aquifer thickness (*b*) allows estimating hydraulic conductivity (*K*).

Regional estimates of hydraulic conductivity for caprock and dike-free volcanic rock fall in the ranges of previously estimated values.

The analysis is part of an ongoing USGS regional volcanic-rock aquifer study: *http://hi.water.usgs.gov/studies/GWRP/*

6. Conclusions

- **Tidal efficiency can be used to estimate regional hydraulic properties.**
- **Hydraulic-conductivity estimates depend on assumed specific yield and aquifer thickness, yet results are consistent with published values for volcanic-rock and caprock aquifers.**
- **Hydraulic-conductivity estimates decrease with island age from the Island of Hawaii to Kauai.**