

# Groundwater Educational Outreach Webinar Series

Webinar #2: Basics of Groundwater Flow

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June 13, 2025

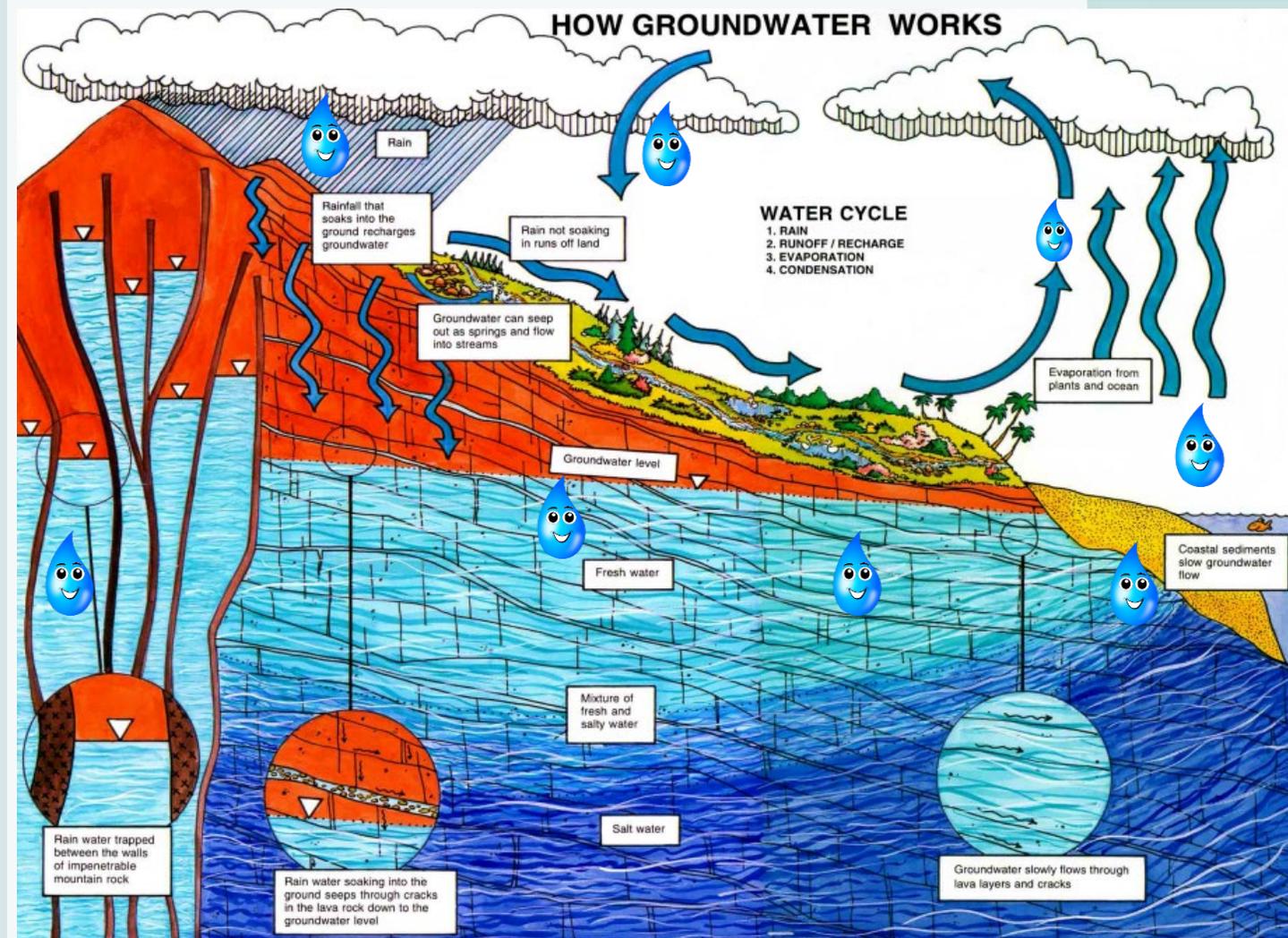


KA 'OIHANA OLAKINO

# How Does Groundwater Occur and Move?



- Subsurface sediments and rocks with larger pores and fractures are called **permeable**
- Rainfall can move into the ground through permeable sediments and rocks via gravity
- Some of the water that is not evaporated may recharge our **aquifers** that store groundwater





# What Is Hydraulic Conductivity?

- A measure of the rock and sediment's ability to transmit water (related to permeability)
- A function of interconnected porosity



- Unfractured rock and clay can have high porosity but **low hydraulic conductivity** (less connected pores)

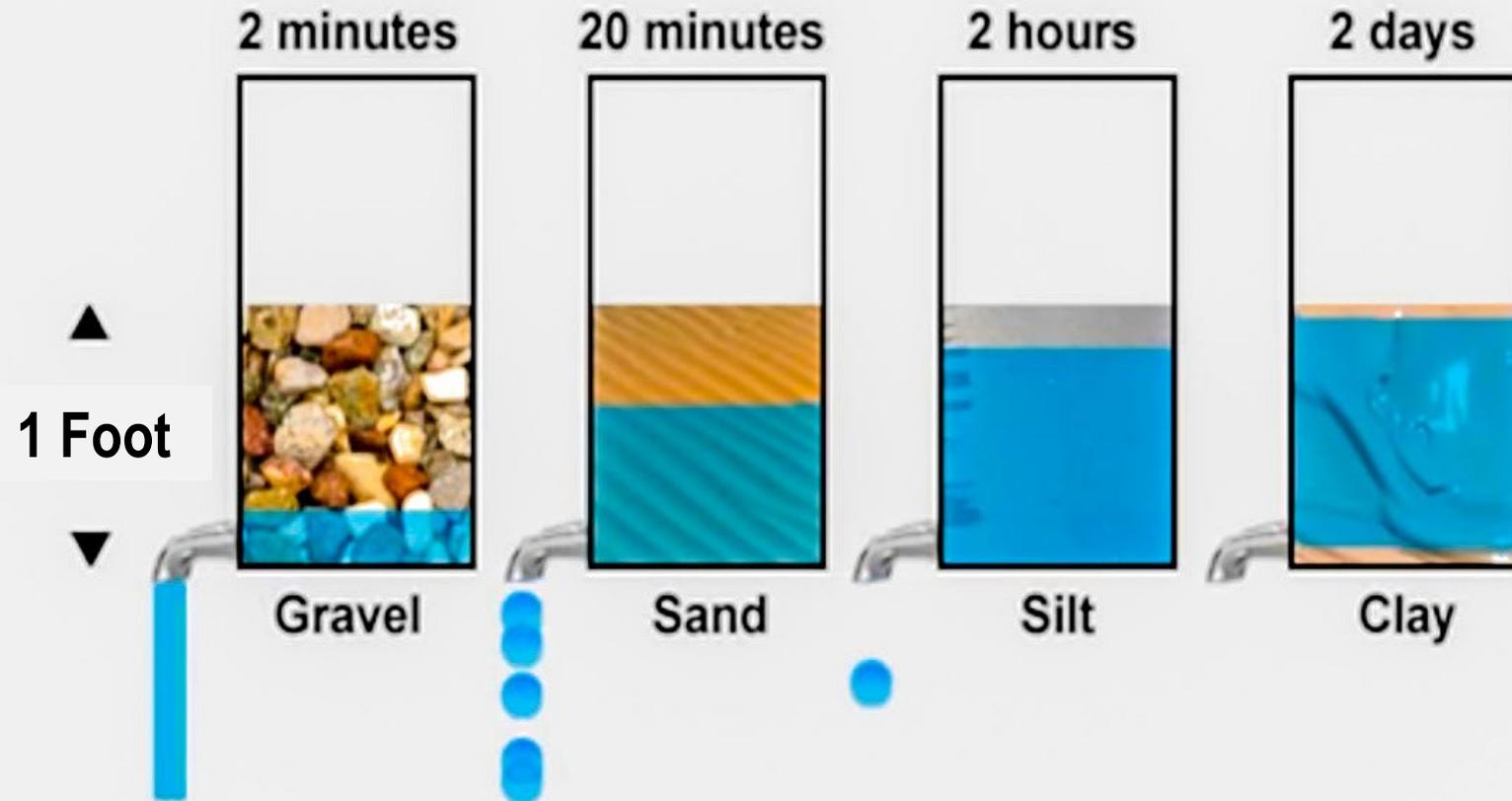


Sand and gravel can have **high hydraulic conductivity**



# Permeability

(Similar to hydraulic conductivity)



Permeability of sediments and rock measure the aquifer's ability to transmit water



Permeability determines how fast Pete can move

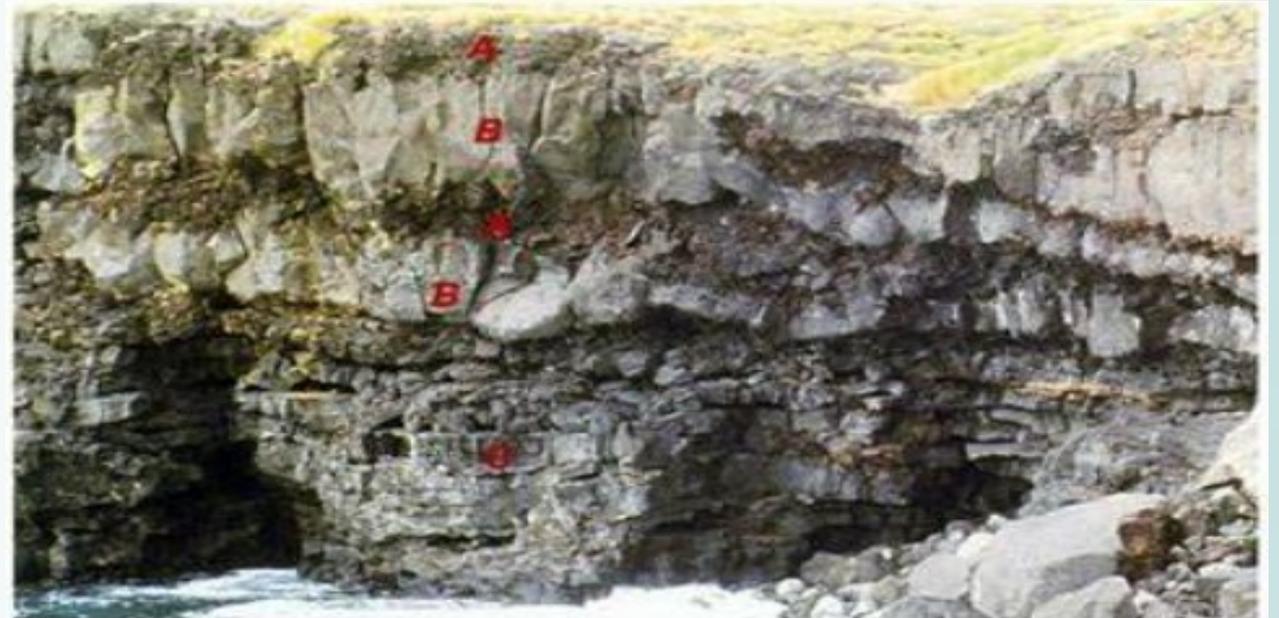
# Hydraulic Conductivity and Permeability

Both measure medium's ability to transmit water



Pahoehoe Lava Flow

'A'a Lava Flow



- A** High permeability clinker zones in a'ā lava flows
- B** Lower permeability cores of a'ā lava flows
- C** High permeability pahoehoe lava flows



# Homogeneity and Heterogeneity of Subsurface Geology in Hawai'i



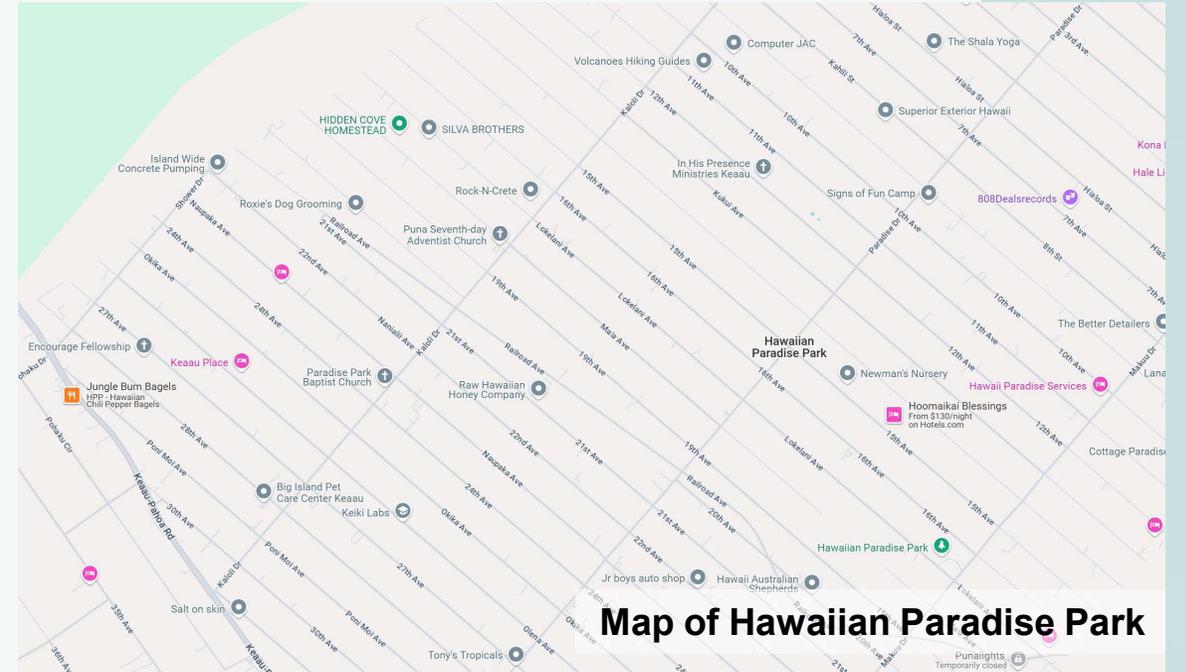
**Homogeneous** sediments and rocks have similar permeability (limited heterogeneity)



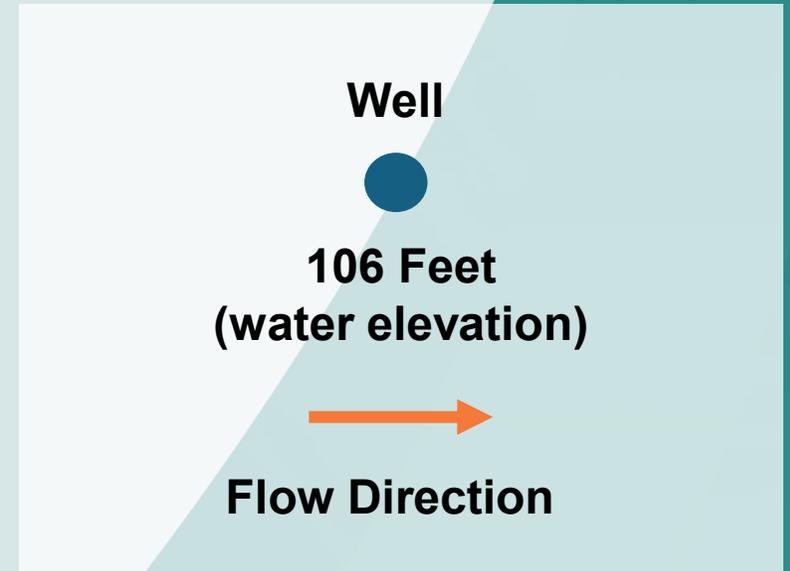
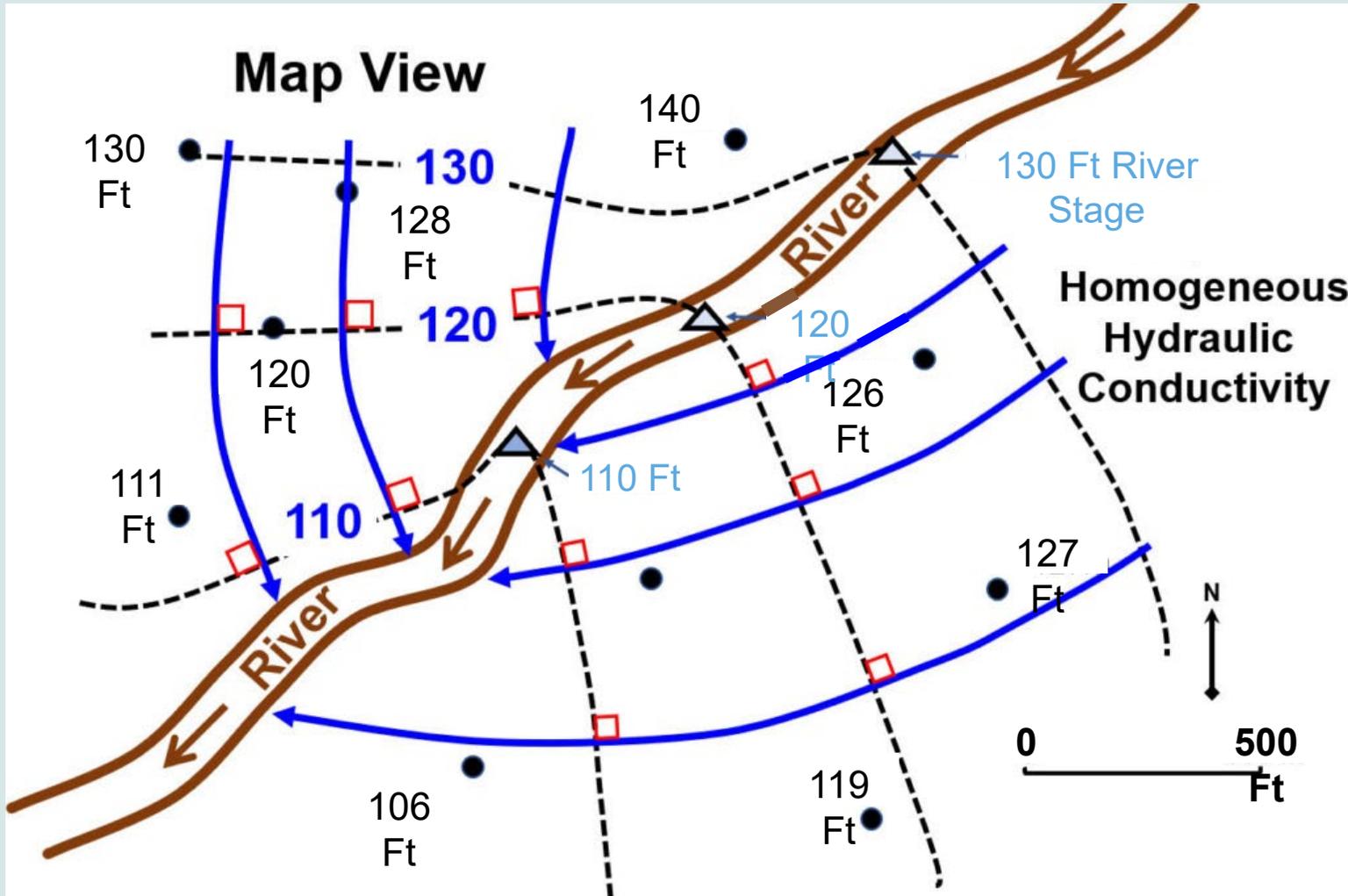
**Heterogeneous** describes mixtures of different sediments

# Fracture Network Complexity

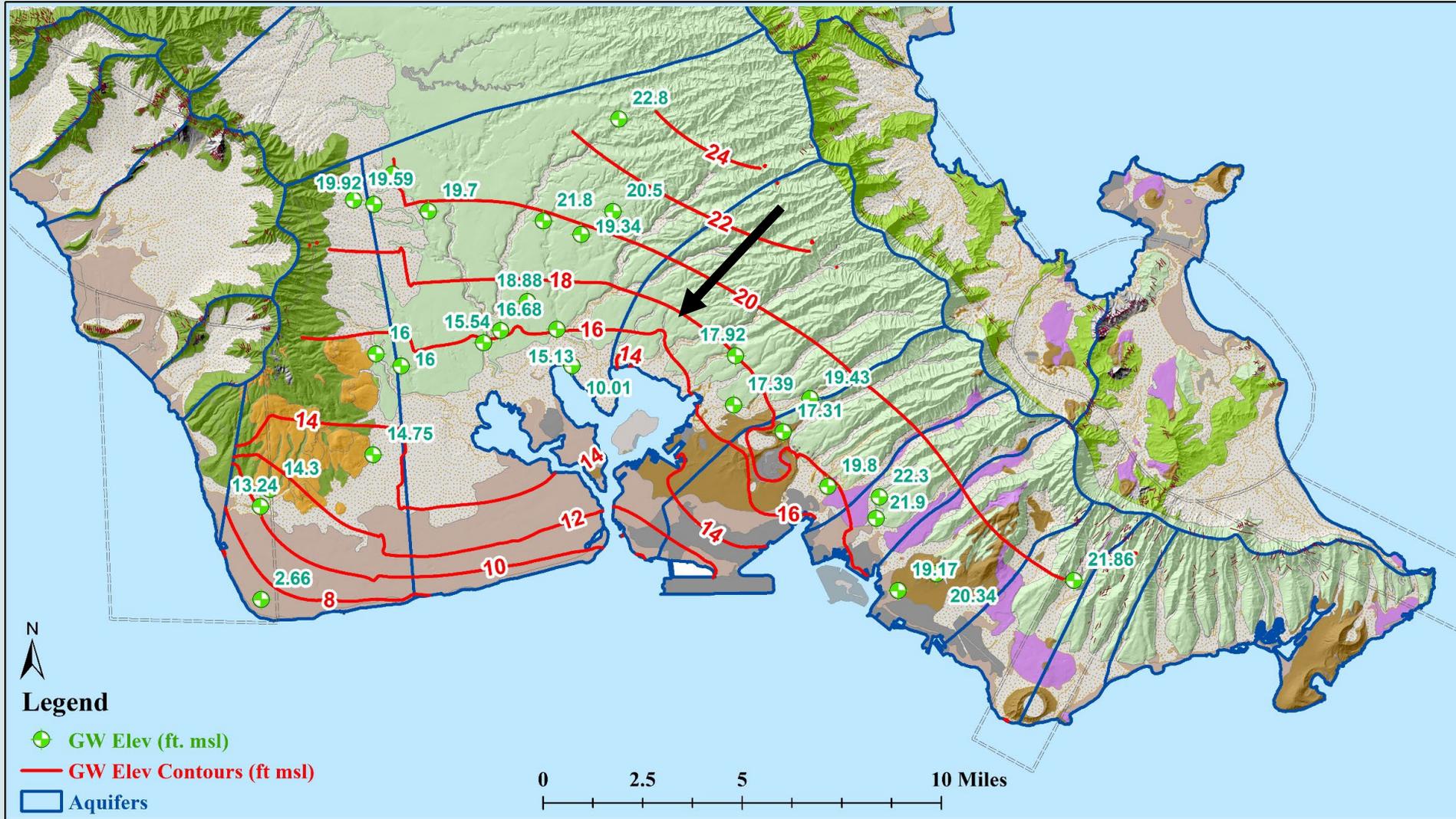
- Fractures in rocks are similar to patterns of roads
  - More water flows through larger connected fractures
  - Smaller fractures have limited flow but can store a lot of water
  - Connection of fractures determines direction of flows



# How Do We Estimate the Groundwater Flow Direction?

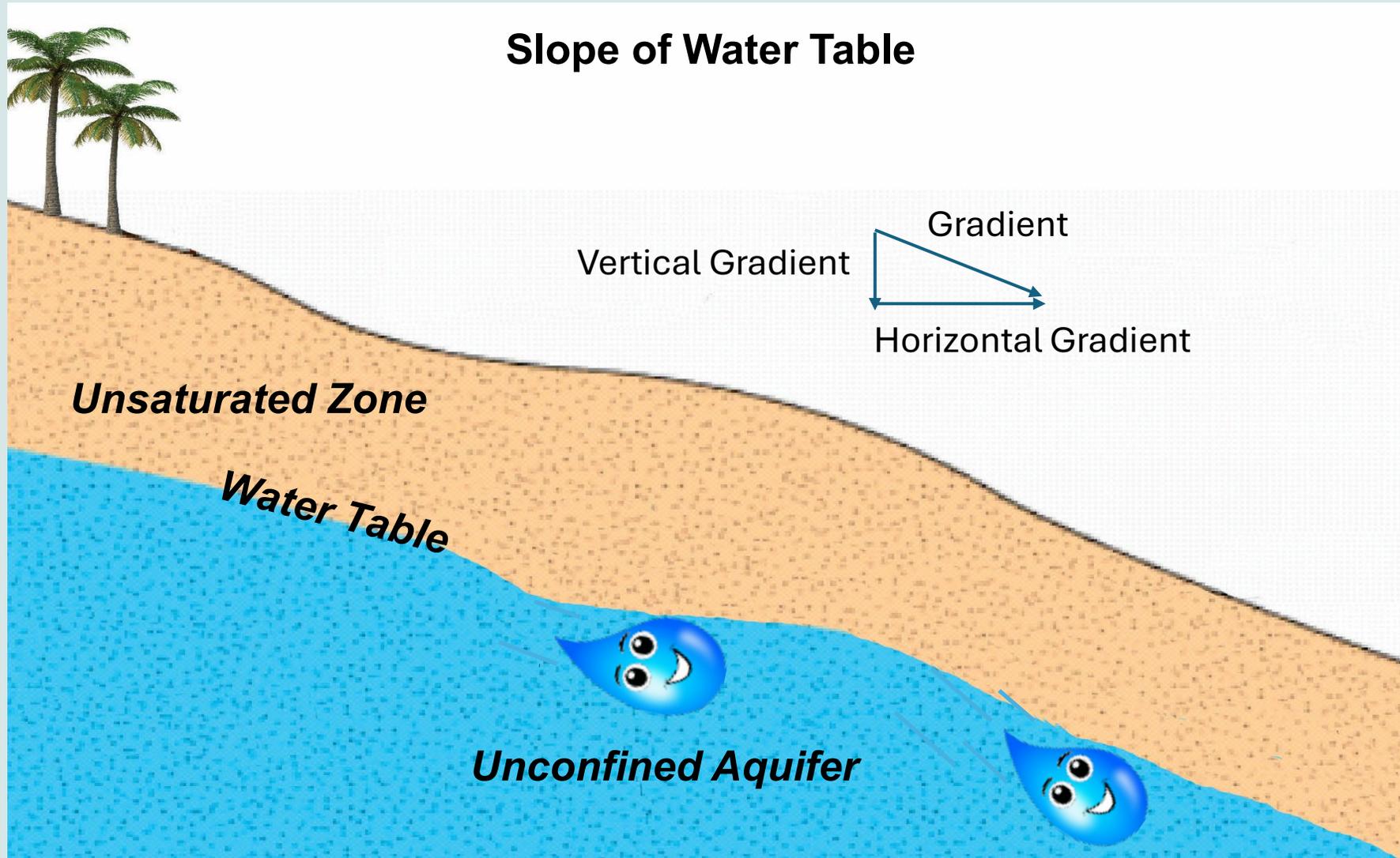


# O'ahu Groundwater Flow Map



Groundwater  
Flow Direction

# What Is Hydraulic Gradient?



# How Fast Does Pete Go?



**Speed** = Hydraulic conductivity times hydraulic gradient and divided by effective porosity

Velocity in Clay: 0.01 to 1 ft/yr

Velocity in Sand: 1 ft/yr to 100 ft/yr

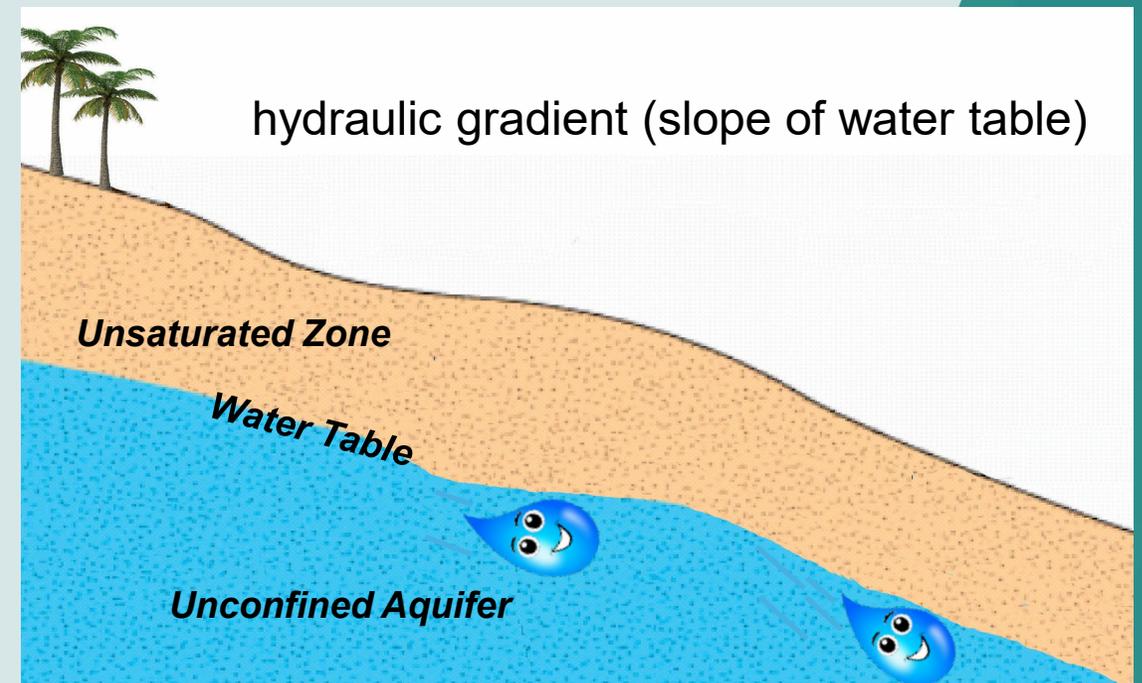
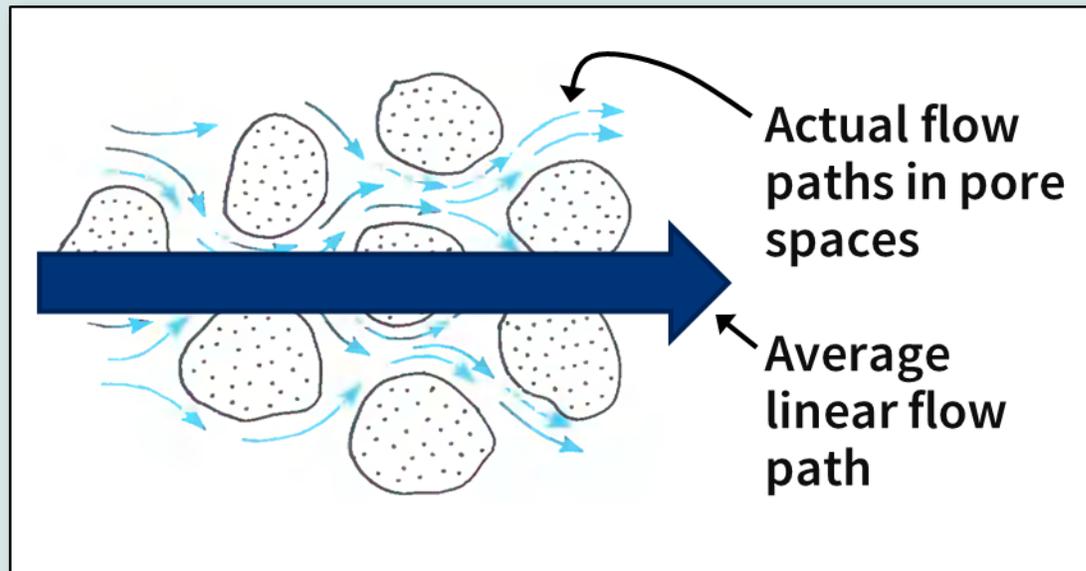
Velocity in Gravel: 100 to 1,500 ft/yr

## Hydraulic Conductivity

Low: Clay

Medium: Sand

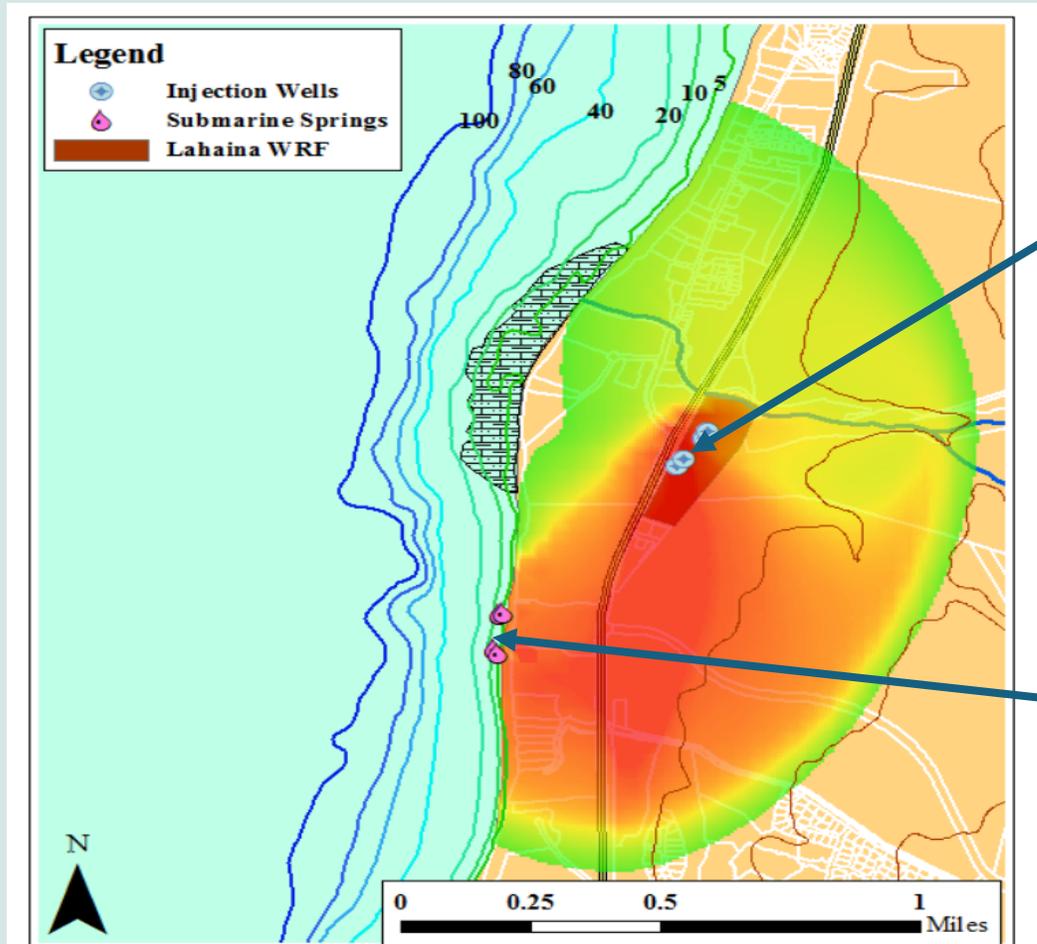
High: Gravel



# How do we directly estimate how fast groundwater moves?



## Dye Tracers



Put dye into wells



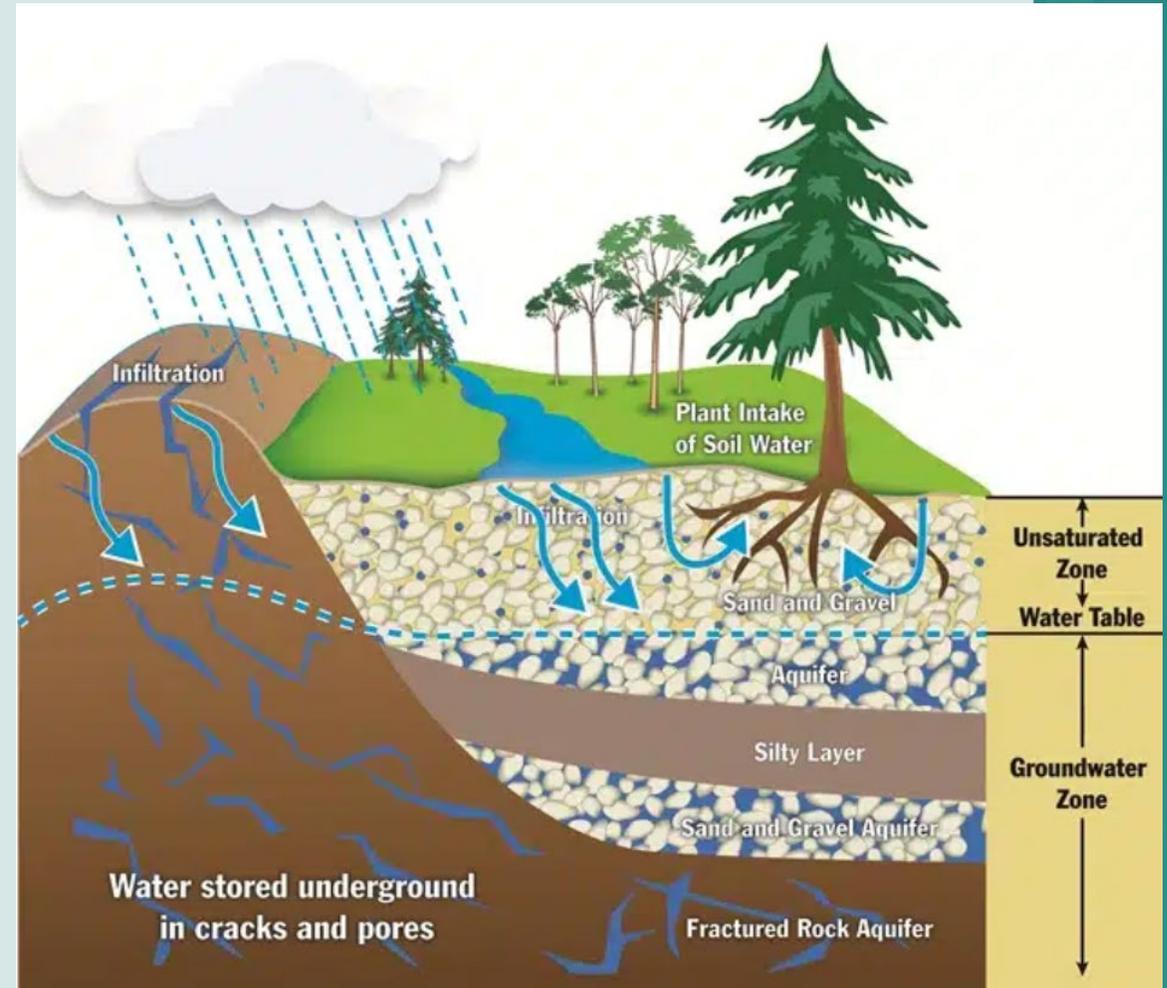
Estimate how fast the dye moves to other locations (wells and springs)

Figure 1. A map of the Kaanapali area showing the modeled tracer dye plume and the location of the major seep groups and injection wells.

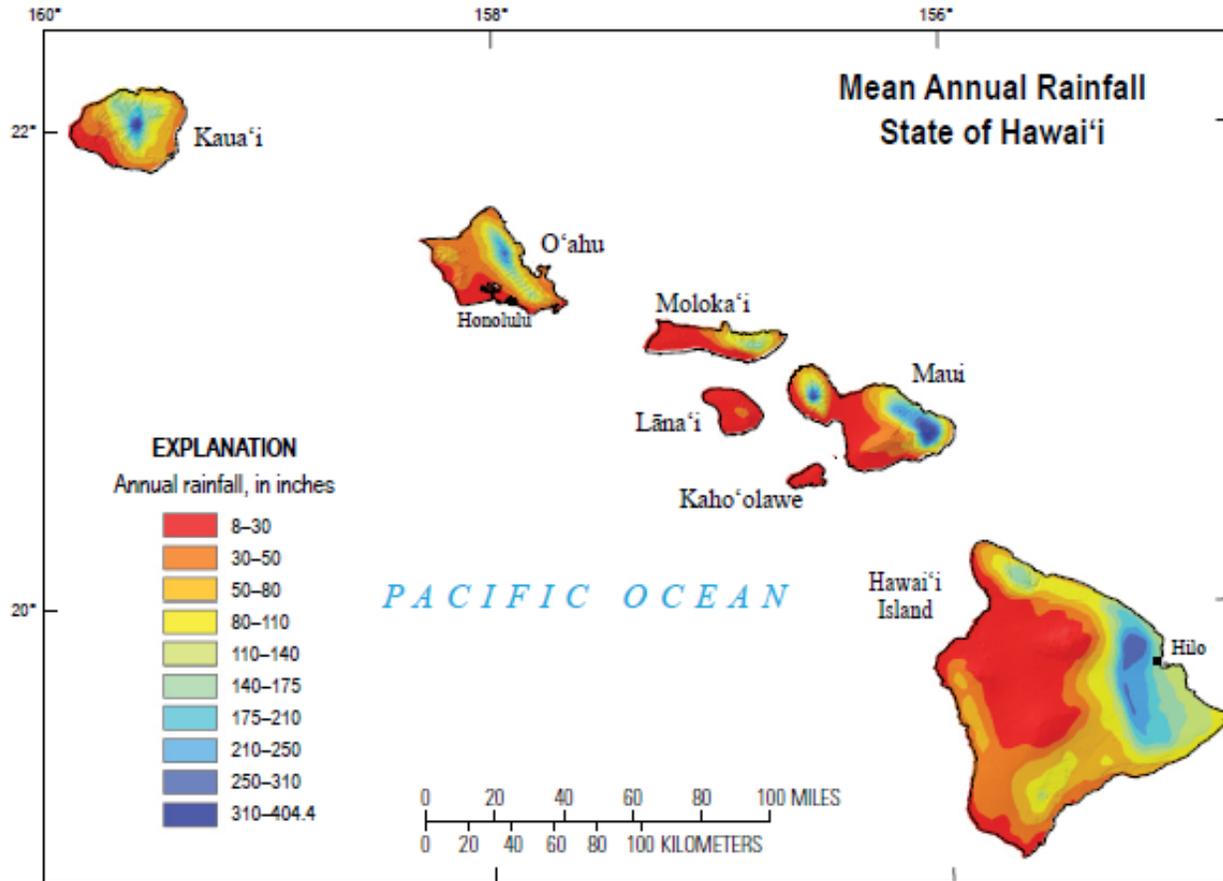
# Storage of Groundwater in Subsurface Aquifers



- Recall that 85% of our drinking water comes from groundwater **stored** in subsurface aquifers
- Droughts can cause the water table to get deeper
- Pumping well can reduce the amount of groundwater stored in aquifers
- **Need sustainable amounts of groundwater stored in aquifers**



# Average Rates of Rainfall in Hawai'i



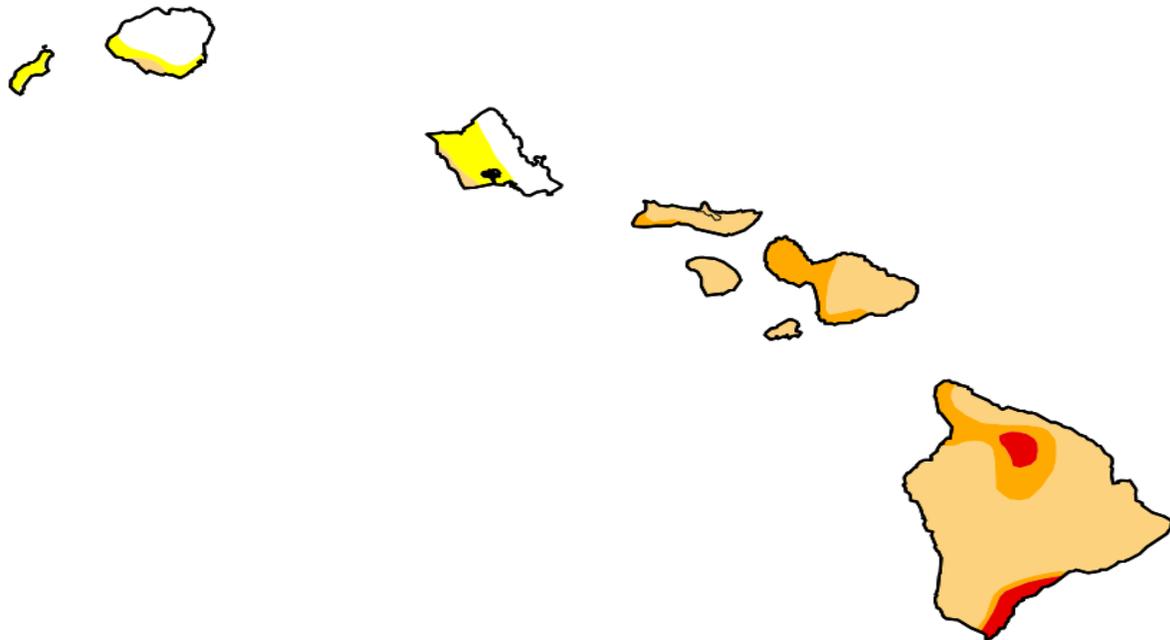
2013 Rainfall Atlas of Hawai'i, Department of Geography, University of Hawai'i at Mānoa

Figure 7. Map of mean annual rainfall in Hawai'i. Modified from Giambelluca and others (2013).

**Higher rates of rainfall increase recharge to aquifers**

Leads to increased amount of groundwater stored in aquifers

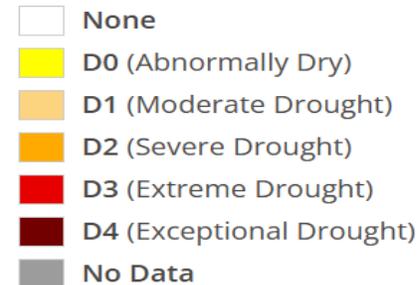
# Drought Conditions in Hawai'i



**Map released: Thurs. May 15, 2025**

Data valid: May 13, 2025 at 8 a.m. EDT

## Intensity



## Authors

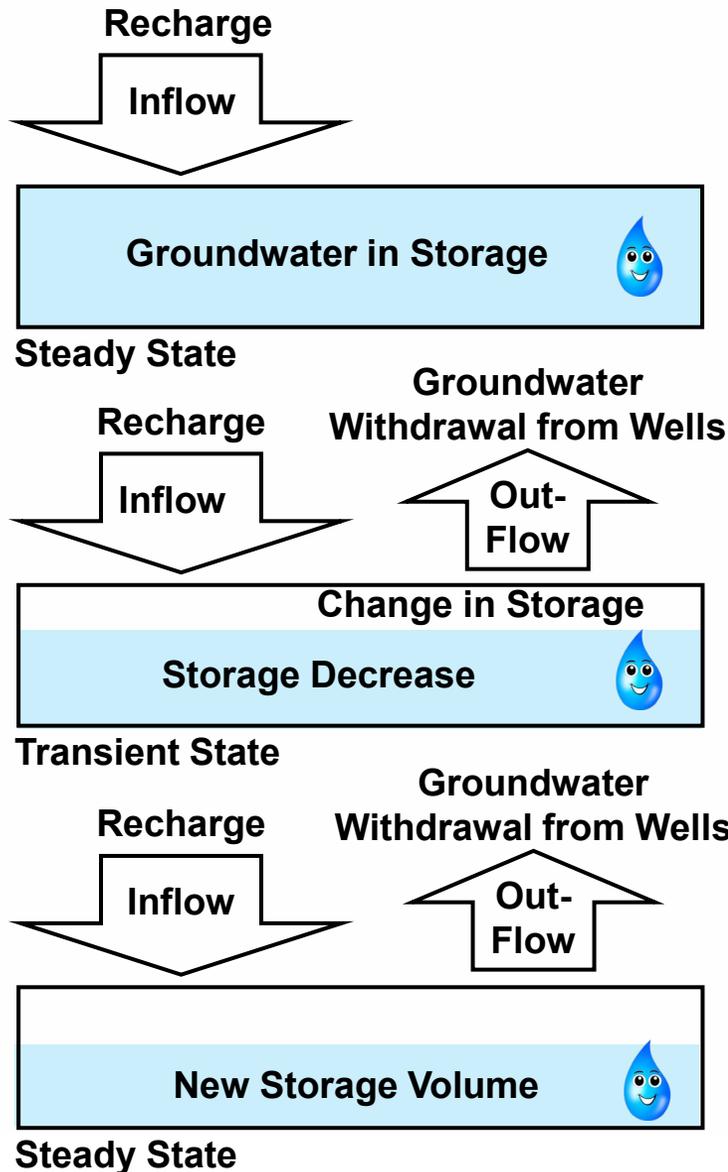
United States and Puerto Rico Author(s):

[Rocky Bilotta](#), NOAA/NCEI

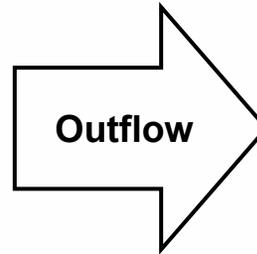
Pacific Islands and Virgin Islands Author(s):

[Richard Tinker](#), NOAA/NWS/NCEP/CPC

# Recharge Into and Outflow from Aquifers

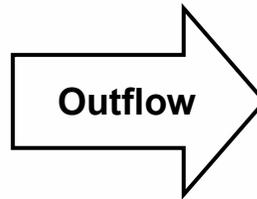


Recharge Rate Equals Natural Discharge Rate



Natural Discharge to Springs, Streams, Wetlands, and Submarine Seeps

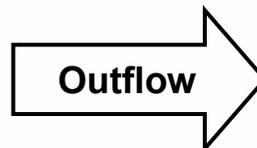
Recharge increases amount of groundwater storage in aquifers



Natural Discharge Decreases

Pumping decreases groundwater storage in aquifers

Natural Discharge Rate Decreased by Amount Equal to Withdrawal Rate from Wells



New Natural Discharge Rate

Sustainability requires a balance between recharge and outflow

Izuka et al. (2018)

# Two Types of Aquifers

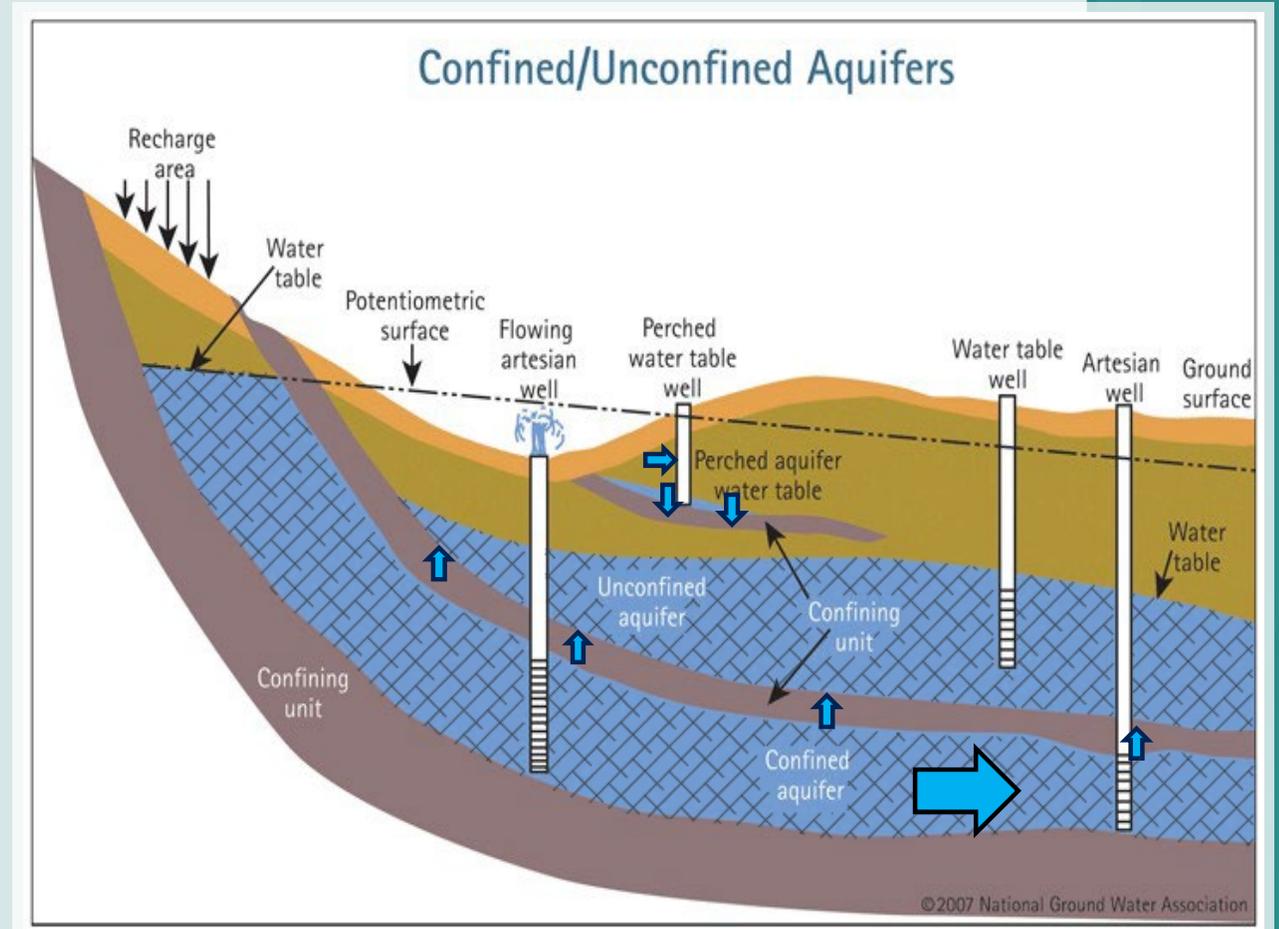
## Unconfined Aquifer

- Has a **water table** forming its top boundary
- Above water table, pores and fractures are partially filled in with groundwater (**unsaturated zone**)
- Below water table, pores and fractures are fully filled in the aquifer
- Dense (less fractured) zone (**aquitard**) forming its bottom

## Confined Aquifer

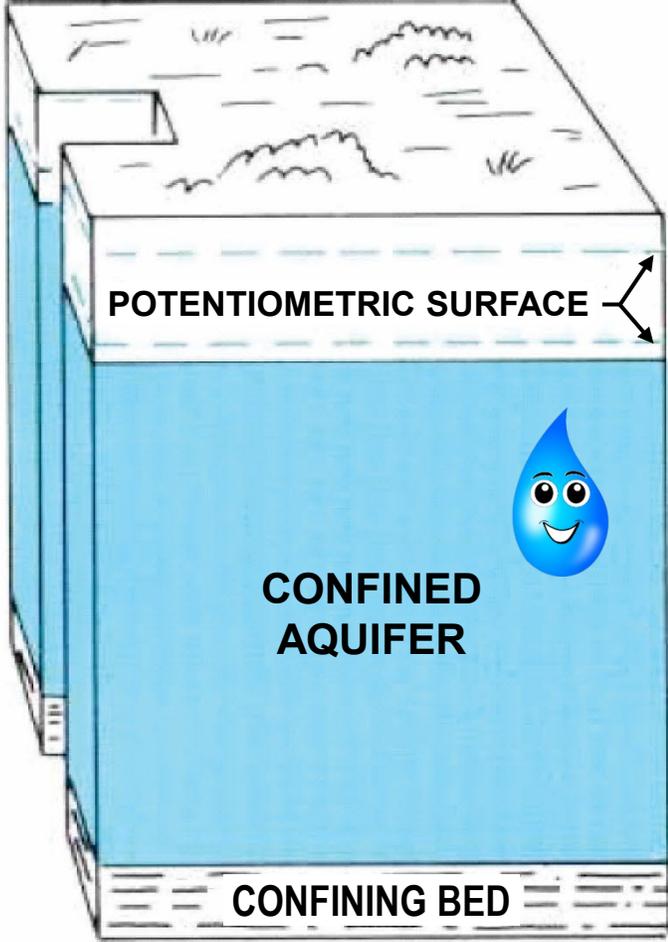
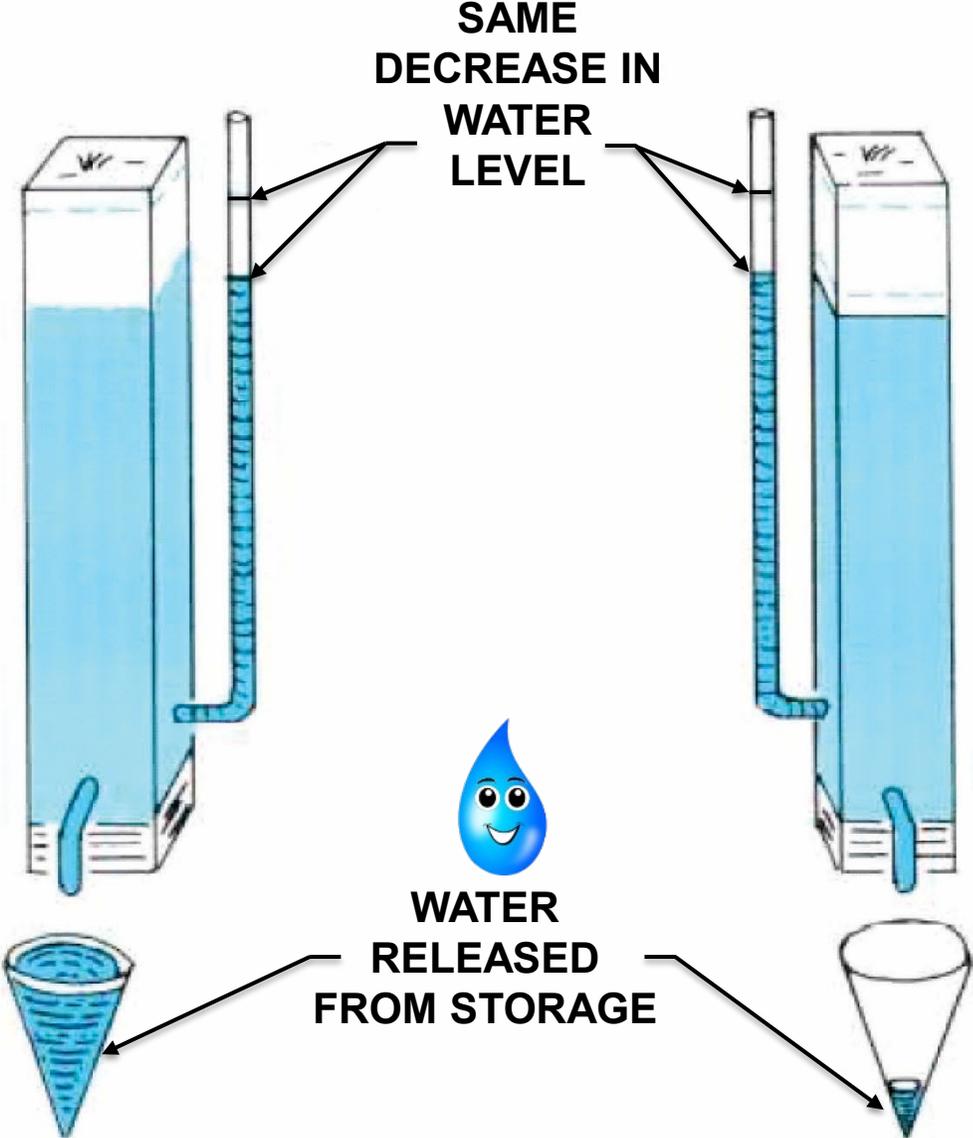
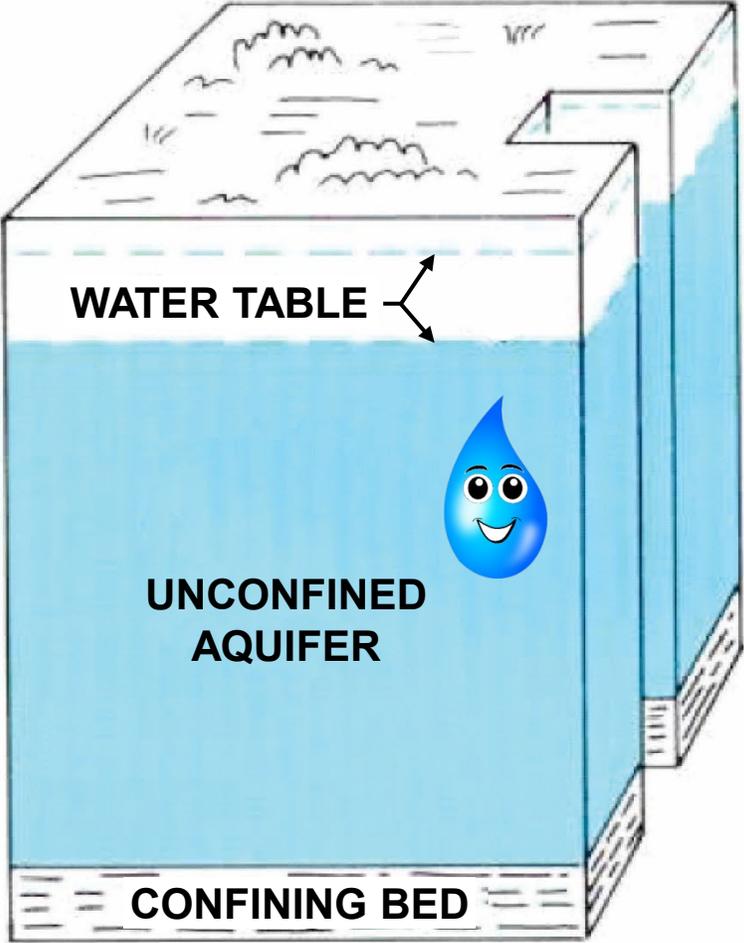
Restricted Above/Below

- Has aquitards forming its top and bottom
- Subsurface water in confined aquifers is under greater pressure
- Water can flow out in artesian wells and springs



# How much water is stored and release from the aquifer?

Pumping removes groundwater from storage



(Heath, 1982)

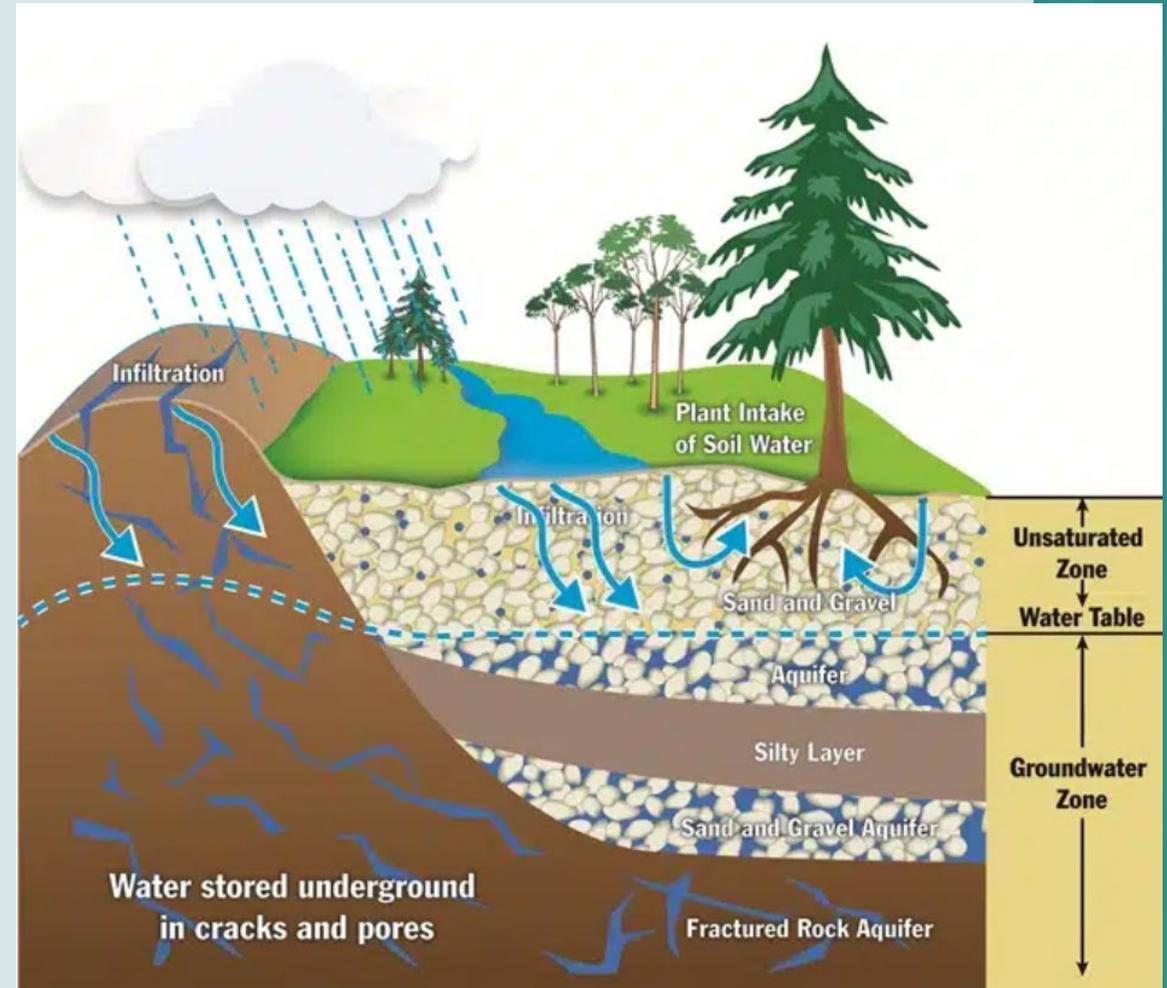
# Protection of Groundwater Resources



- Recall that 85% of our drinking water comes from groundwater **stored** in subsurface aquifers
- Droughts can cause the water table to get deeper
- Pumping well can reduce the amount of groundwater stored in aquifers
- **Human activities can cause chemical releases and spills that can impact this important natural resource**



**In our next webinar,** we will examine migration of contaminants into and within aquifers



# Next Webinar: Contaminant Transport in Groundwater

If you have further questions or would like more information on a specific topic, please send us an email at:

**[curtis.pruder@doh.hawaii.gov](mailto:curtis.pruder@doh.hawaii.gov)**



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