Overview

- What is groundwater?
  - How much groundwater is there?
  - How fast does groundwater move?
  - How do we measure groundwater?
- Where does groundwater come from and where does it go?
- How do Californians use it?
- Groundwater management and groundwater quality
What is Groundwater?

- An underground lake?
- A network of underground rivers?
- A rectangular network of pipelike water arteries?
- A giant sponge?
Groundwater = Water completely filling Pores/Fractures
Groundwater in Different Sediments and Rocks

- Well-sorted sediment
- Poorly sorted sediment
- Porous sediment
- Consolidated sediment
- Dissolution of rock
- Rock fractures
How fast does water flow?
How fast does water flow?

Loam

distance

water-level drop
How fast does water flow?

Darcy’s law:

groundwater flow = hydraulic conductivity x pressure gradient
How do we measure hydraulic conductivity?

- Estimate based on sediment type (gravel, sand, silt, clay, fractured rock):
  - => well logs (geologic logs, geophysical logs)

- Measure on sediment/rock cores in laboratory

- Estimate from specific capacity of wells:
  - ratio of pumping rate to well water level drawdown

- Measure using an aquifer test:
  - 1-day to 7-day well pumping tests

- Estimate from groundwater models:
  - => matching model results to measured water levels, groundwater flows
fractured bedrock of California’s mountain ranges

Sediments
=> result of erosion, water, wind, lake deposition, ocean bay deposition
Unconfined Aquifer

Losing stream

Diagram showing a section of land with a groundwater aquifer. The aquifer is unconfined, meaning it is not bounded by impermeable layers. The diagram includes a vadose zone, recharge area, and an unconfined aquifer. The losing stream indicates that water is being discharged to a stream or river.
What is Groundwater?
Unconfined Aquifer

- Spring
- Perched water table
- Gaining stream
Springs

Fall River, NE California

Alluvial Basin

Basalt-flow
Perched Water Table

adopted from: Fetter, 1988
Artesian Well (Confined Aquifer)
Vernal Pools

aka

Seasonal Wetlands
Direction of Groundwater Flow?
Direction of Regional GW Flow

Map from: http://www.dpla.water.ca.gov/sjd/groundwater/tile-emap99.html

Contours are dashed where inferred. Contour interval is 10 and 20 feet.
The Classic Hydrology View

From: Jeff Mount “California Rivers and Streams”
A Groundwater Well

- Access tube for water reading
- Gravel feed tube
- Pump motor housing
- Conductor casing
- Grout seal
- Pump shaft
- (blank) casing
- Pump bowl
- Gravel pack
- Well screen
- Sump
- Bottom plate

Layers:
- Sand
- Silty clay
- Water table
- Gravelly sand
- Clayey loam
- Sand
- Clay

Gravel pack
Well screen
Hydraulic Conductivity from Borehole Logs (Estimated)

clay
silt
sand
gravel
soils

Courtesy, Claudia Fawn, USGS, 2008
Cone of Depression near a Well

Gaining Stream
Disconnected Stream
Dry Stream
Reconnecting Groundwater to Surface Water: Role of Aquifer Heterogeneity

Fleckenstein et al., Ground Water 2006
Stream-Aquifer Connection at the Regional Scale

Gaining Stream

Spring 1999, Lines of Equal Elevation of Water in Wells, Unconfined Aquifer

Losing or Disconnected Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Well Near a Stream
Groundwater Dependent Ecosystems
And the GW - SW Interface
Conjunctive Use
Meandering Streams & Paleochannels

(a) Karstic spring, Spring-fed marsh at head of stream, Seep/spring from fissure

(b) Water surface, Downwelling, Upwelling, Parafluvial zone, Seepage, Outwelling, Paleochannel, Lens of coarse sediments, Upwelling groundwater, ALLUVIAL AQUIFER

Boulton and Hancock, Austral J Botany, 2006
The Hyporheic Zone
Losing – Gaining – Flow Through
Where does groundwater come from and where does it eventually go?

- The Hydrologic Cycle -
Space and Time Disconnect between Water Supply and Water Use
California’s Urban Water Users

Population (Year 2000): 34 million

Water Use: 8 - 9 MAF

MAF = million acre-feet
California’s Agricultural Water Users

Irrigated Acreage (Year 2000): 9.5 million acres

Water Use: 27 - 35 MAF

MAF = million acre-feet
California Water Infrastructure

Bridging the Spatial and Temporal Disconnect between SUPPLY and USE

Total reservoir storage: 40 MAF

California Water Plan, Bulletin 160-2005

State Project
Federal Project
Local Project
Groundwater Use in California: The Invisible Storage Reservoir

From: DWR California Water Plan 2009 (Bulletin 160-2009)
Tule River Basin: Monthly Water Budgets, Oct-Sep

Ruud, Harter et al., 2003, 2004
Irrigation Efficiency
Groundwater Management and Groundwater Quality
Integrated Regional Water Management Planning

⇒ toward Integrated Resource Management Planning

- Groundwater
- Surface Water
- Air
- Soil quality
- Energy / Carbon
- Landuse planning

(Courtesy: Sarge Green, CSU Fresno)
Questions?