

Geology of Ground Water and Aquifer Management

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California Water Action Plan (CWAP)

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*“...water recycling, expanded storage and **serious groundwater management** must all be part of the mix. It is a tall order. But it is what we must do to get through this drought and prepare for the next.”* _ Gov. Edmund Brown



CWAP, 2014

6. EXPAND WATER STORAGE CAPACITY AND IMPROVE GROUNDWATER MANAGEMENT

“...we need to expand our state’s storage capacity, whether surface or groundwater, whether big or small.” CWAP

“The administration will take steps, **including sponsoring legislation**, if necessary, to define local and regional responsibilities and to give local and regional agencies **the authority to manage groundwater sustainably...**” CWAP



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The Sustainable Groundwater Act

AB1739, SB1168, SB1319 – passed August 2014

- “Sustainable groundwater management” means the management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results.
- Decision makers in local government and water districts will need to understand groundwater management issues.



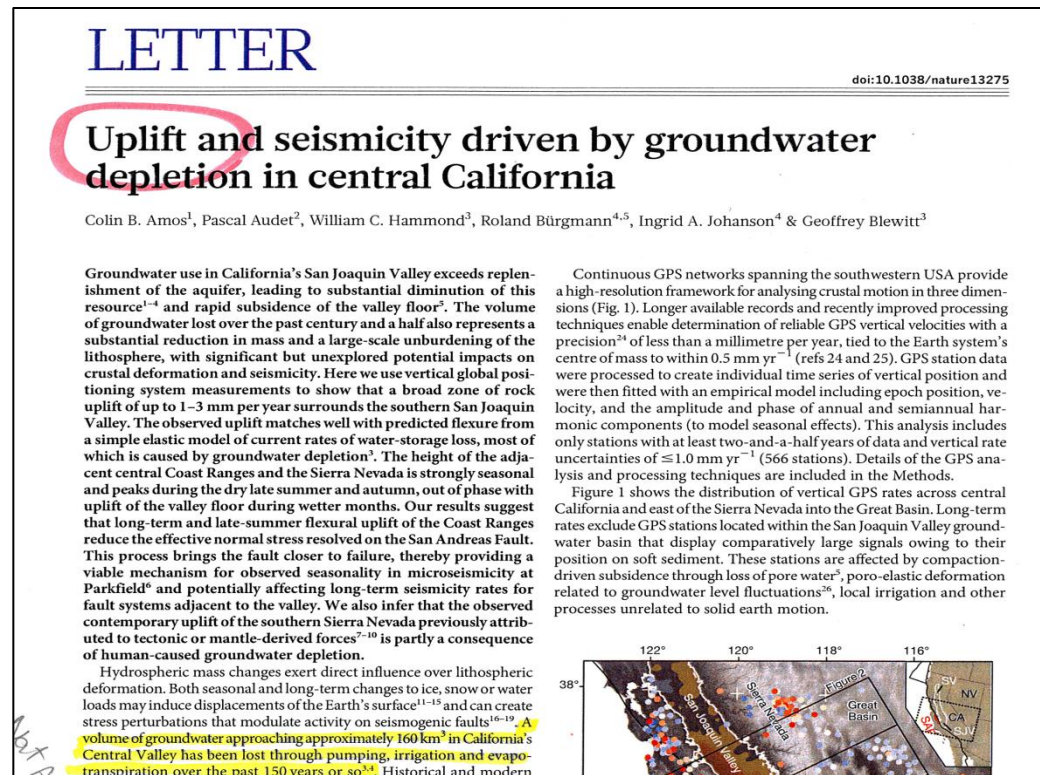
Groundwater can be confusing. Take for example land subsidence.

Subsidence 1925-1977.

But! Then we read:



From Borchers and Carpenter, 2014.
Land Subsidence from Groundwater
Use in California



Subsidence or Uplift? Which is it?

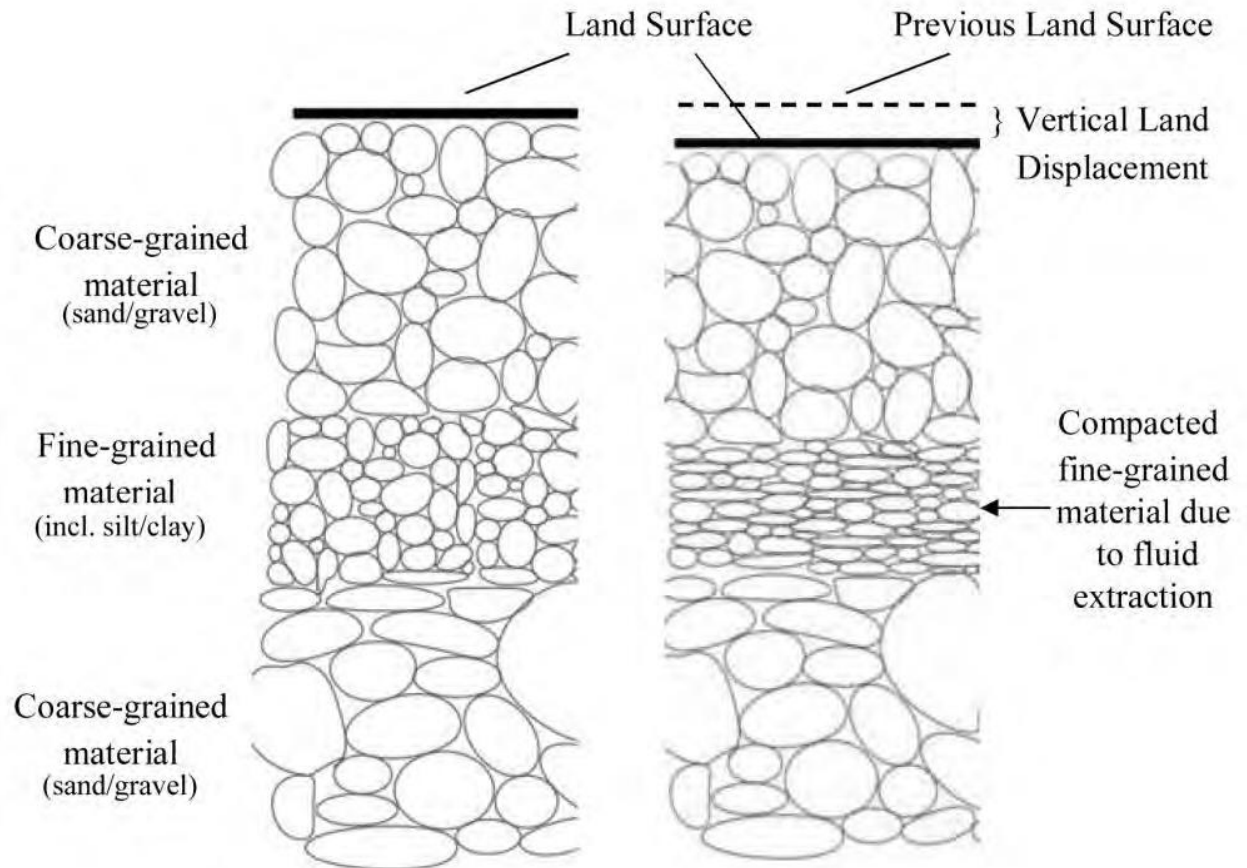


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Subsidence



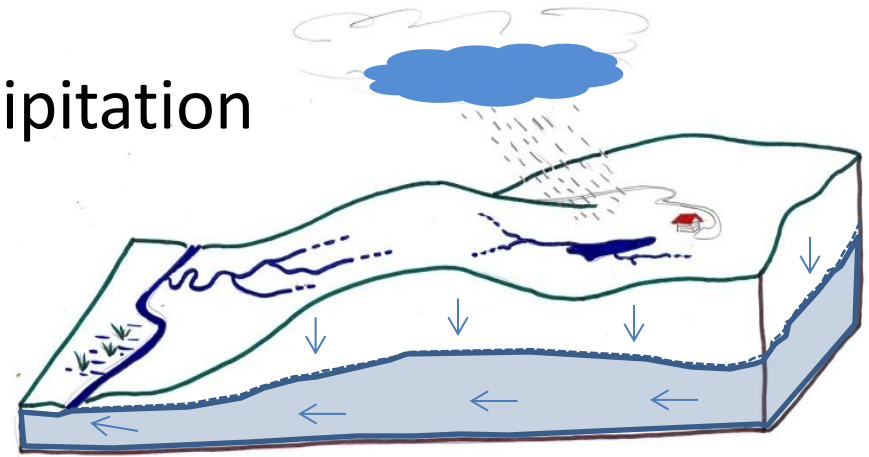
Casing of an abandoned gas well protrudes more than 46 cm (1.5 ft) higher than when it was painted 2 years earlier. (CWF, 2014)



Groundwater Basics

- Groundwater is from precipitation in the watershed.

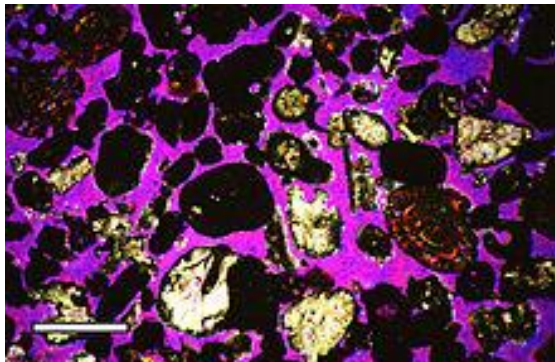
There are no underground rivers from unlimited distant sources. There is only water stored in soil over thousands of years.



- Groundwater fills rock voids

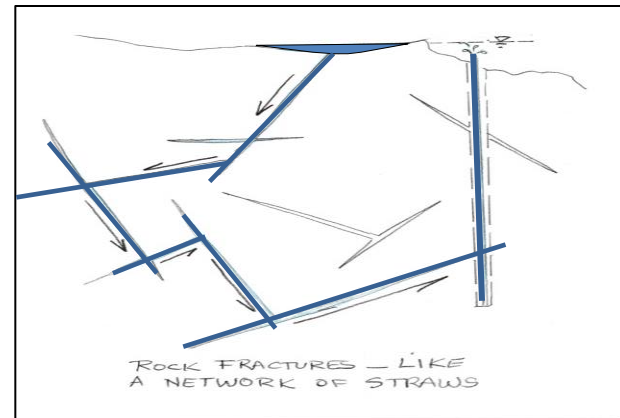
Sedimentary Deposits

(pores between grains)



Bedrock

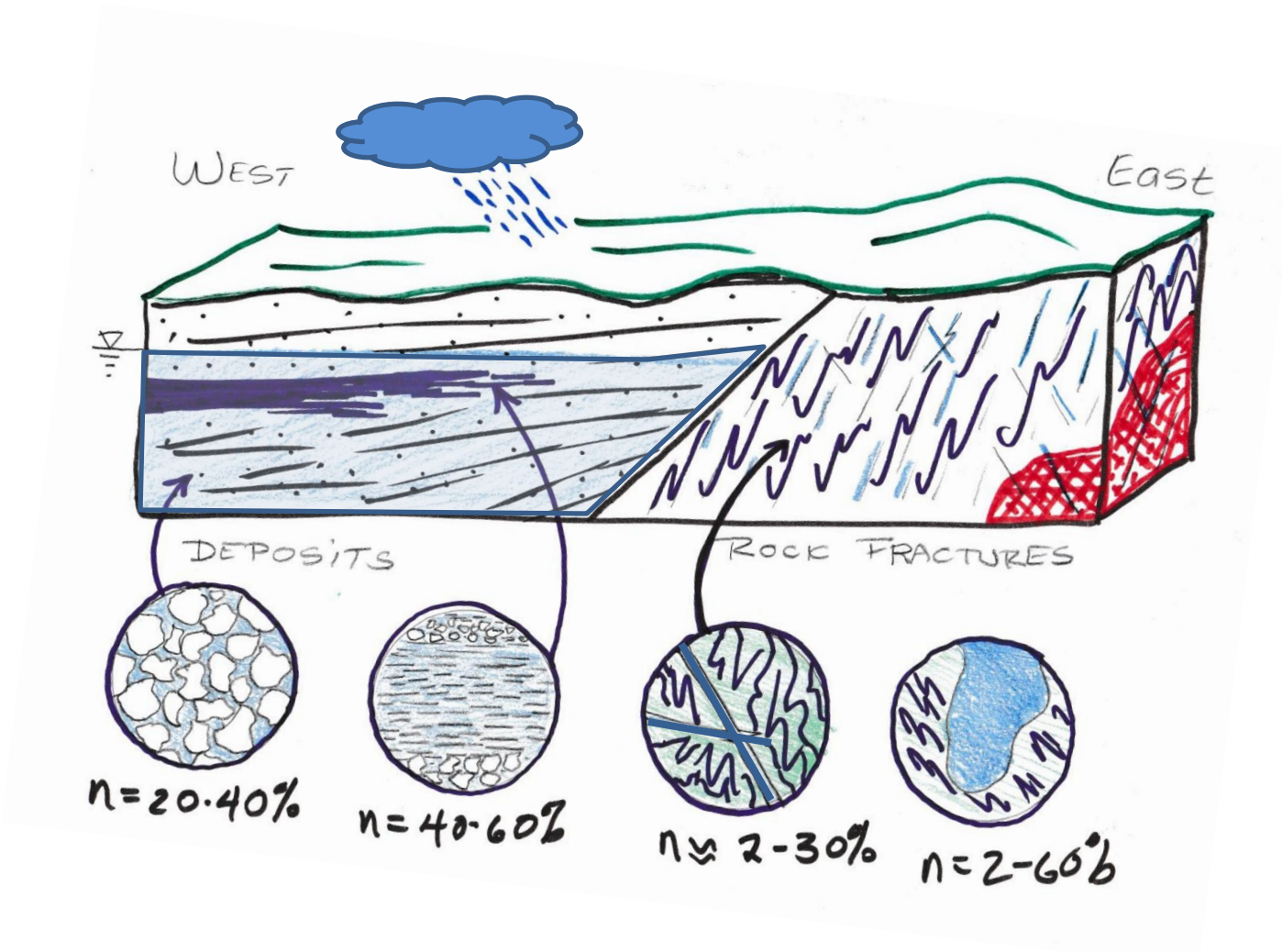
(cracks, caverns, mines)



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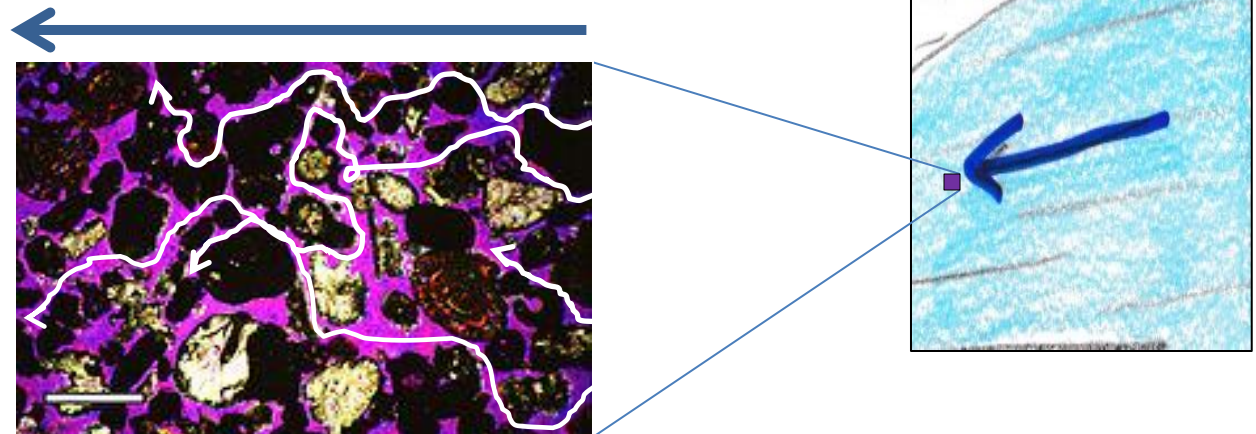
Groundwater Basics

- Groundwater fills openings in deposits and rocks.



Groundwater Basics

- **Recharge is slow** : *“2,200 to 13,400 years before present in Eastern San Joaquin Groundwater Sub-basin”* USGS, OFR 2012-1049.
- **Flow is tortuous**: linear velocity of water particles in a silty-sand aquifer **<1 to <200 ft/year**.

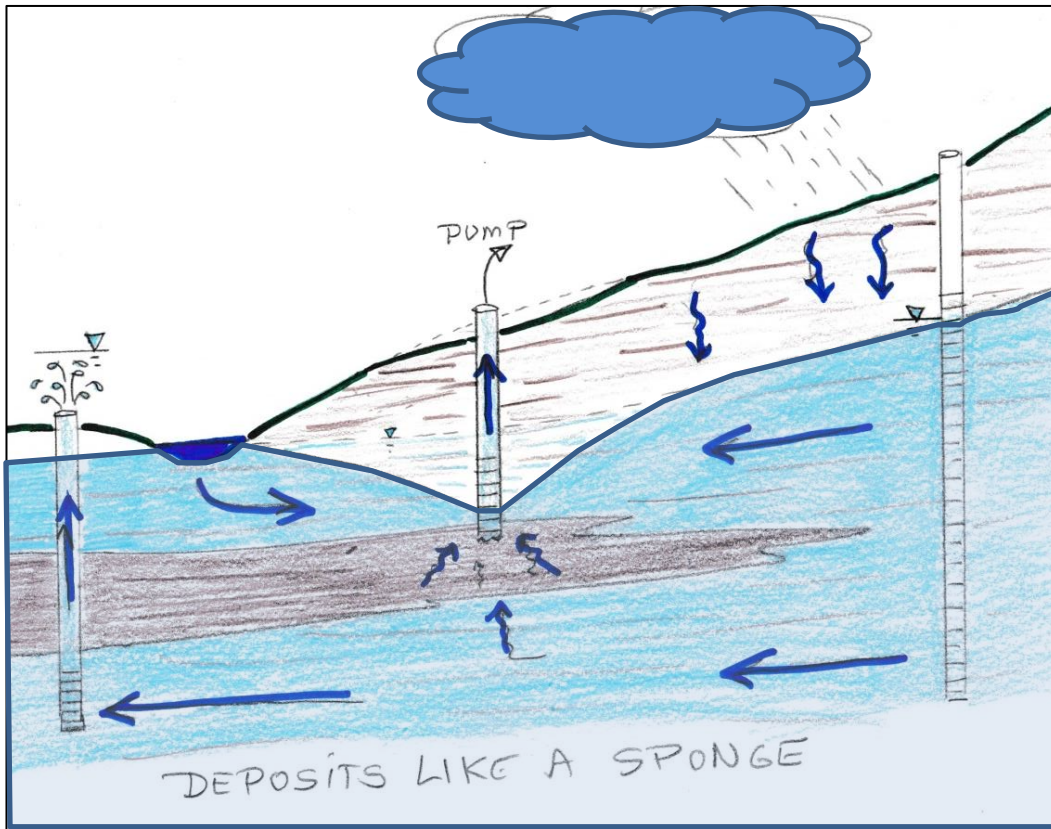


Groundwater Basics

- Groundwater is pushed (or sucked) through openings by hydraulic pressure gradients.

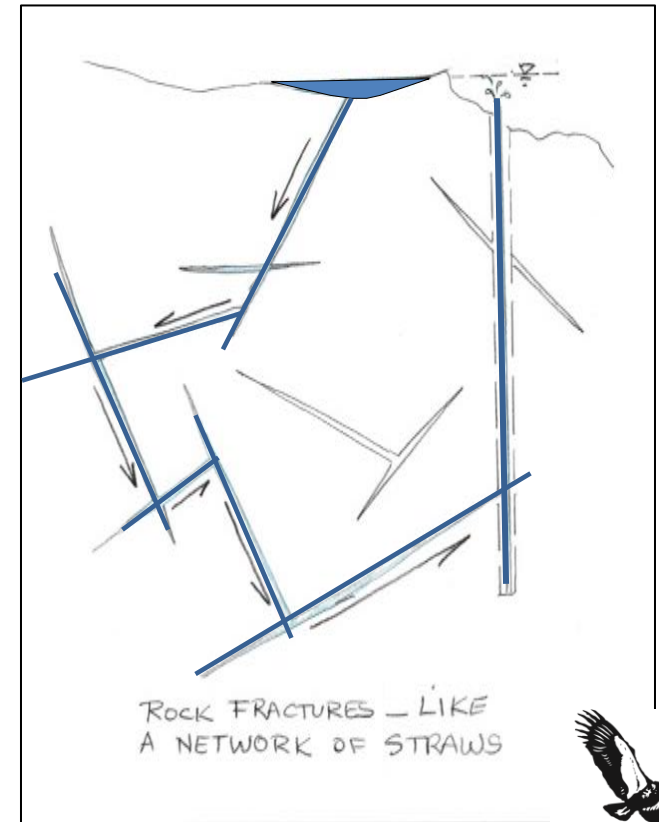
Sedimentary Deposits

(pores between grains)



Bedrock

(cracks, caverns, mines)



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Hydrogeology Basics

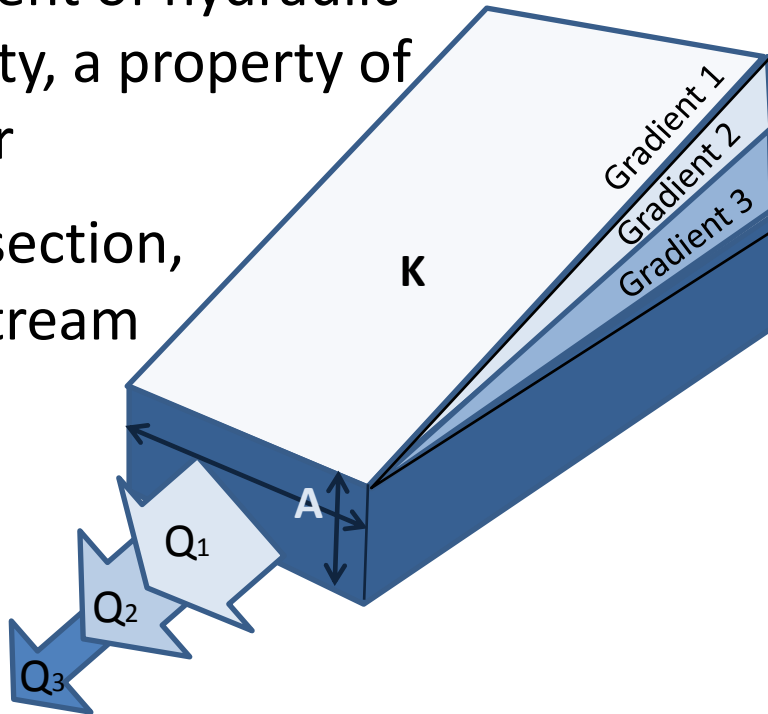
$$Q = -KA i$$

Flowrate = Conductivity x cross section x gradient

How much water flows through the land?

K= coefficient of hydraulic conductivity, a property of the aquifer

A = Cross section, the flow stream of interest



i = Gradient, the drop in head pressure along a flow path that drives flow

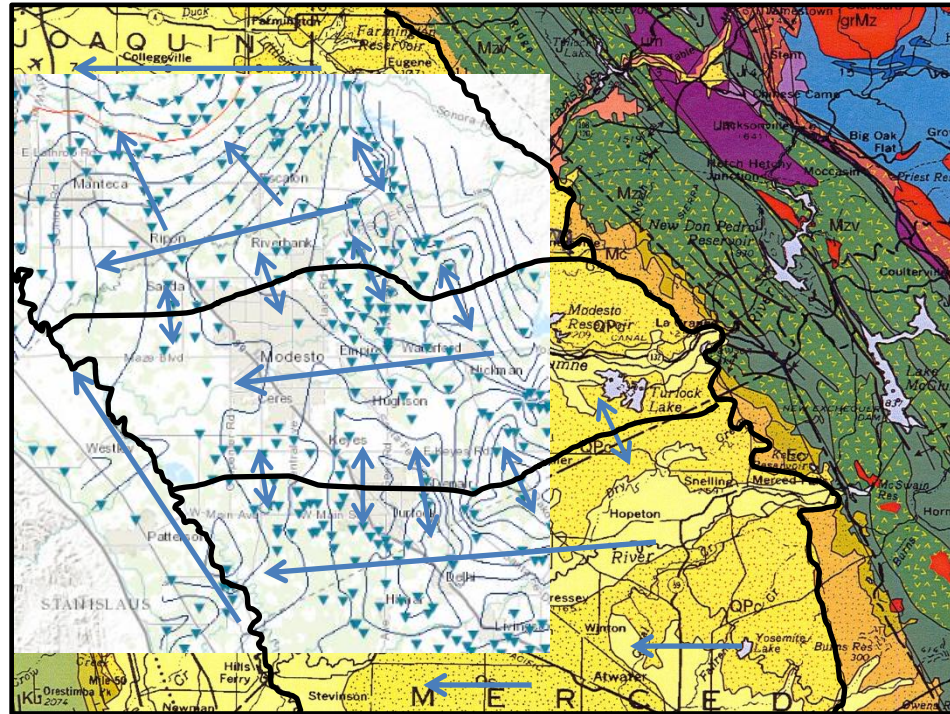
Aquifers are managed by controlling gradients with artificial recharge and wells

Declining gradients reduce flow

Geology Controls Aquifer Geometry, Storage and Transmissivity

Groundwater Basins are underground reservoirs.

They initially mirror surface watersheds with dimples and pimples under wells and recharge centers.



Foothill bedrock forms aquifer boundaries and hosts fracture pathways.

Low storage and Transmissivity, small glacial basins.

Deposits from rivers, beaches, dunes, lakes and seas form wedge-shaped layers in this area with different storage and Transmissivity.

Aquifer Storage and Recovery

- Buckets of recoverable storage anywhere? Not.

Las Posas Basin Aquifer Failure Illustrates Risks Of Underground Reservoirs

AP By Michael R. Blood
and Elliot Spagat



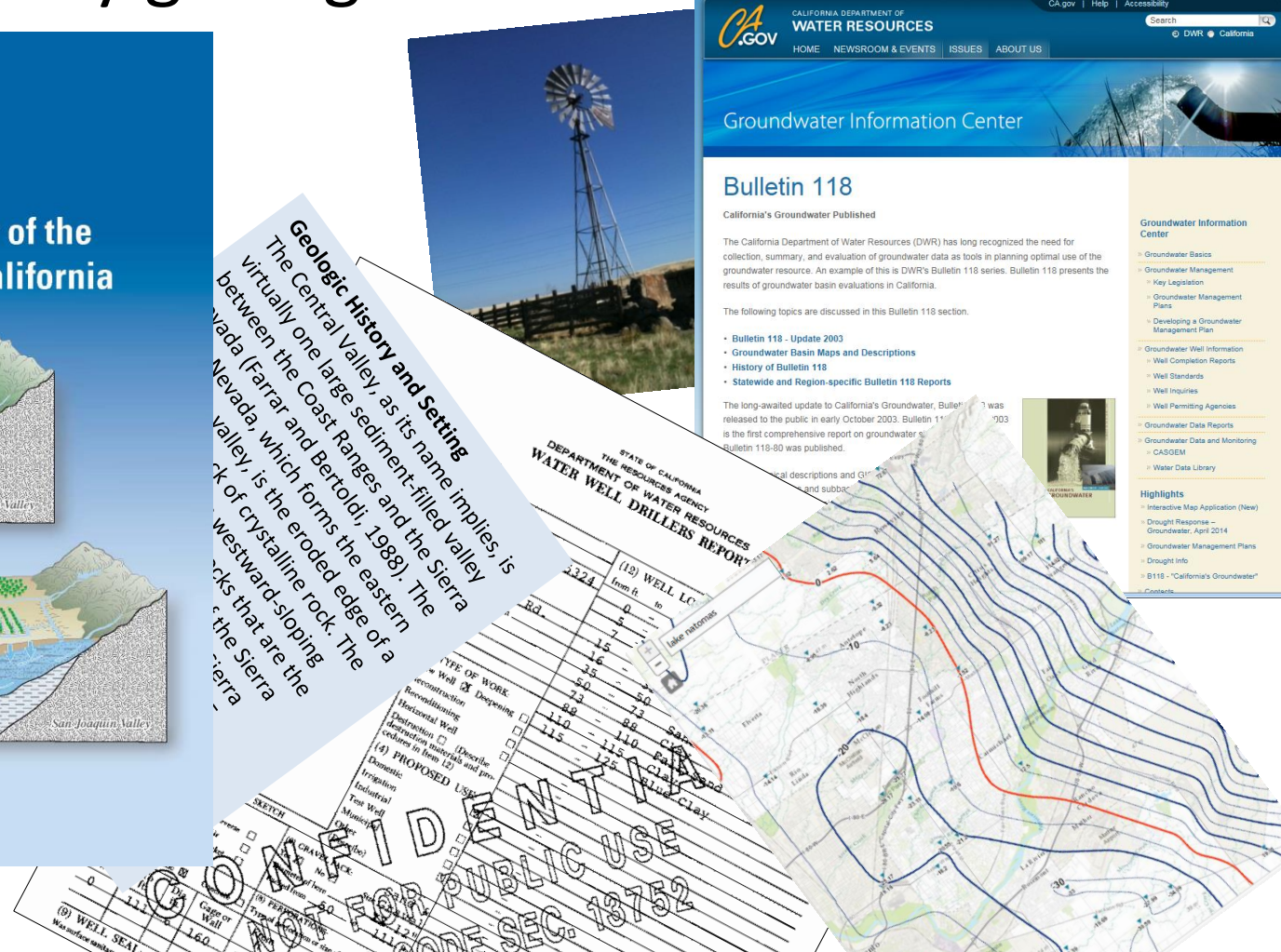
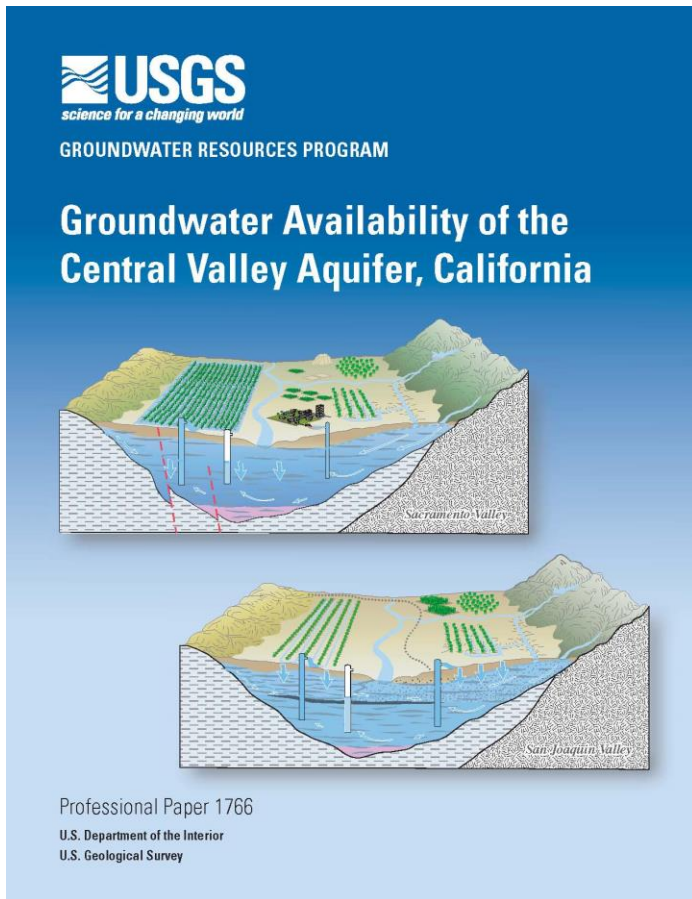
“...the venture was marred by insufficient research, poor judgment and hollow assurances – all with a hefty price tag for ratepayers. The cost, estimated in 1995 at \$47 million, has gradually tripled to about \$150 million. More than \$56 million in long-term debt remains... ‘What was known about the basin wasn't the whole picture,’ said Calleguas general manager Susan Mulligan. ‘It doesn't work for a drought. The basin doesn't store it.’”



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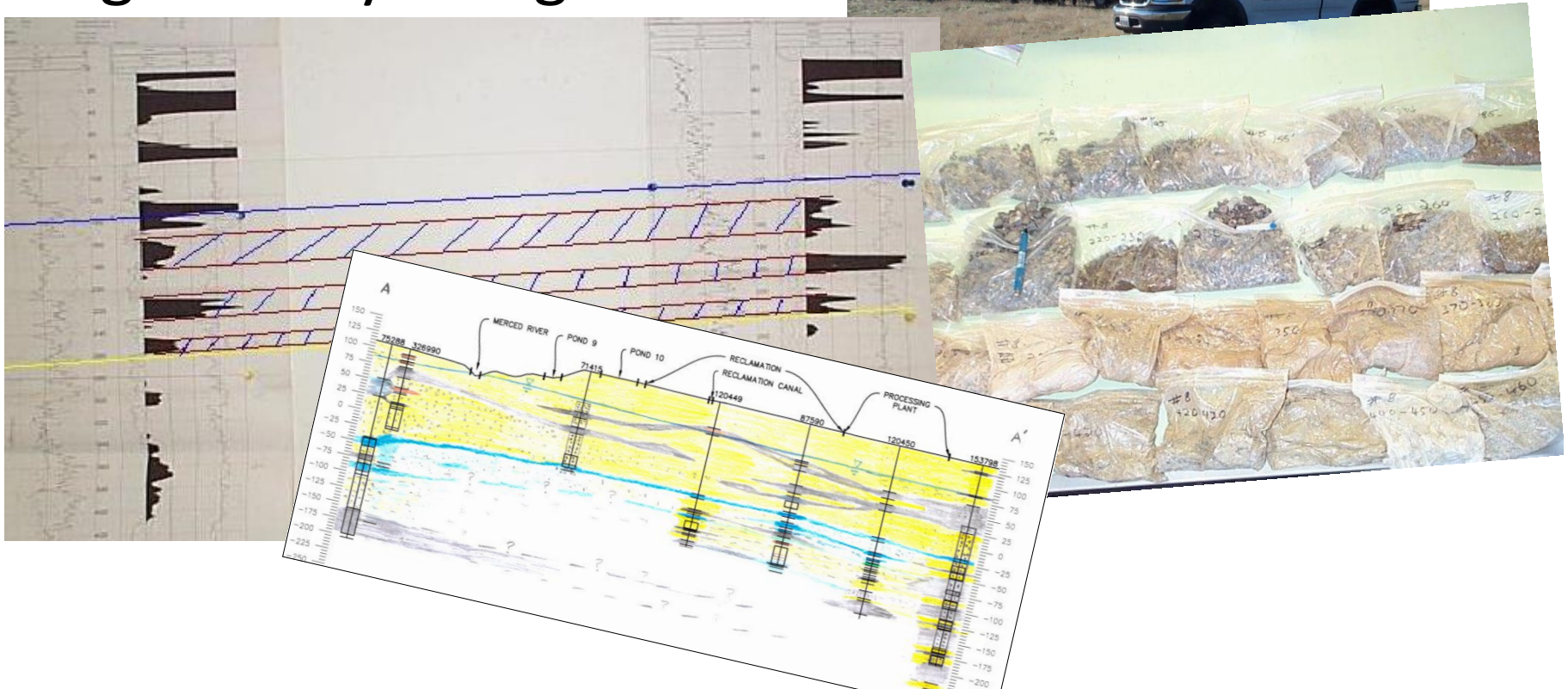
Aquifer Management Tools

- Preliminary geological research



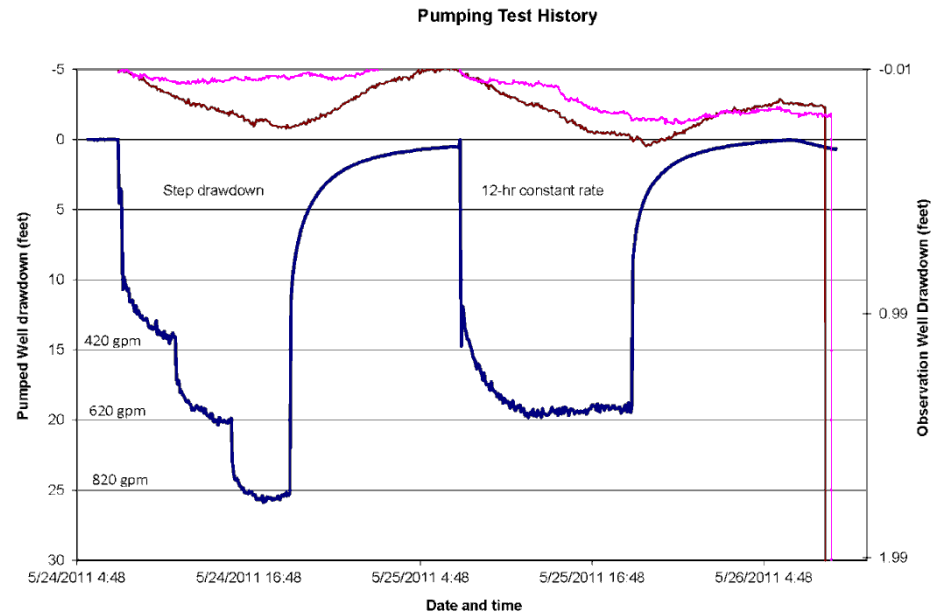
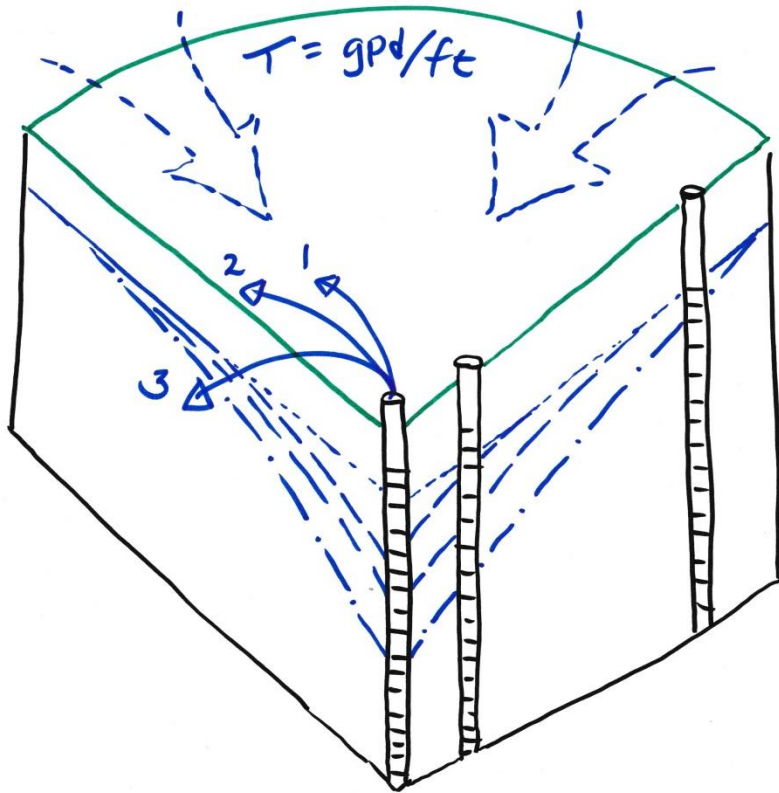
Aquifer Management Tools

- Drilling and geophysics for measuring aquifer geometry and grain size



Aquifer Management Tools

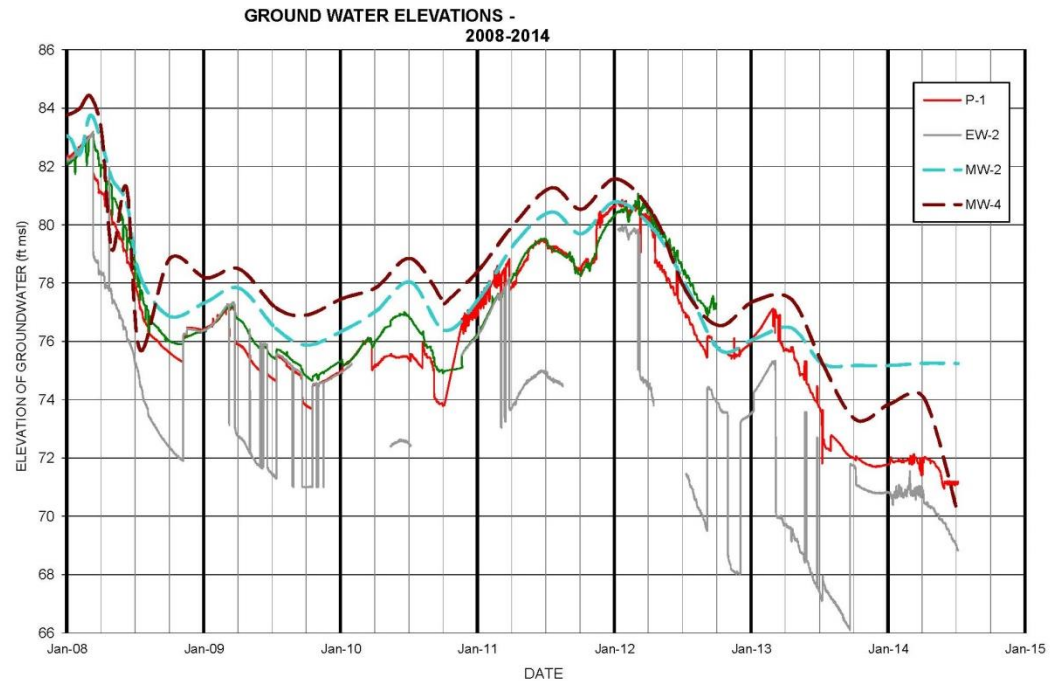
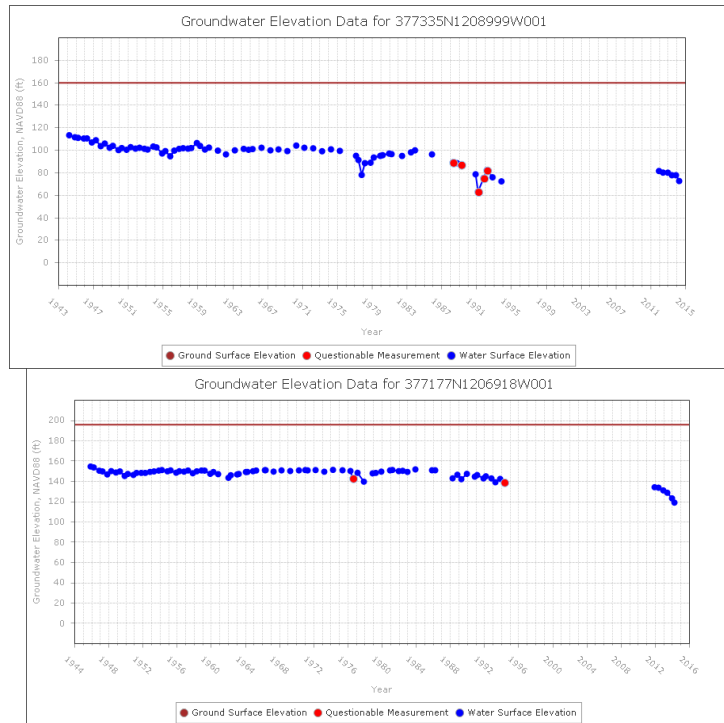
- Pumping Tests – to estimate Transmissivity and storage of aquifer, efficiency of well



Aquifer Transmissivity in gpd/ft (linear), specific yield of well in gpm/ft (drawdown)

Aquifer Management Tools

- Monitoring Well Hydrographs (pressure heads)



Aquifer Management Tools

- Groundwater Modeling

Calibration Run Mounding after 14 days at MW-2
 $S_y=0.3$ $K=20$ ft/d $I=1.6$ ft/d

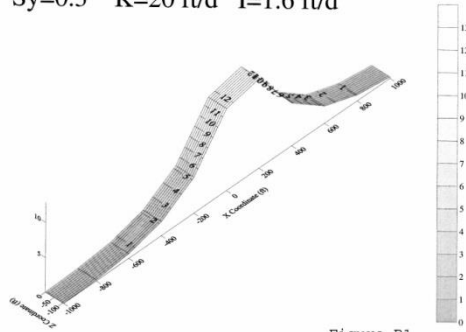
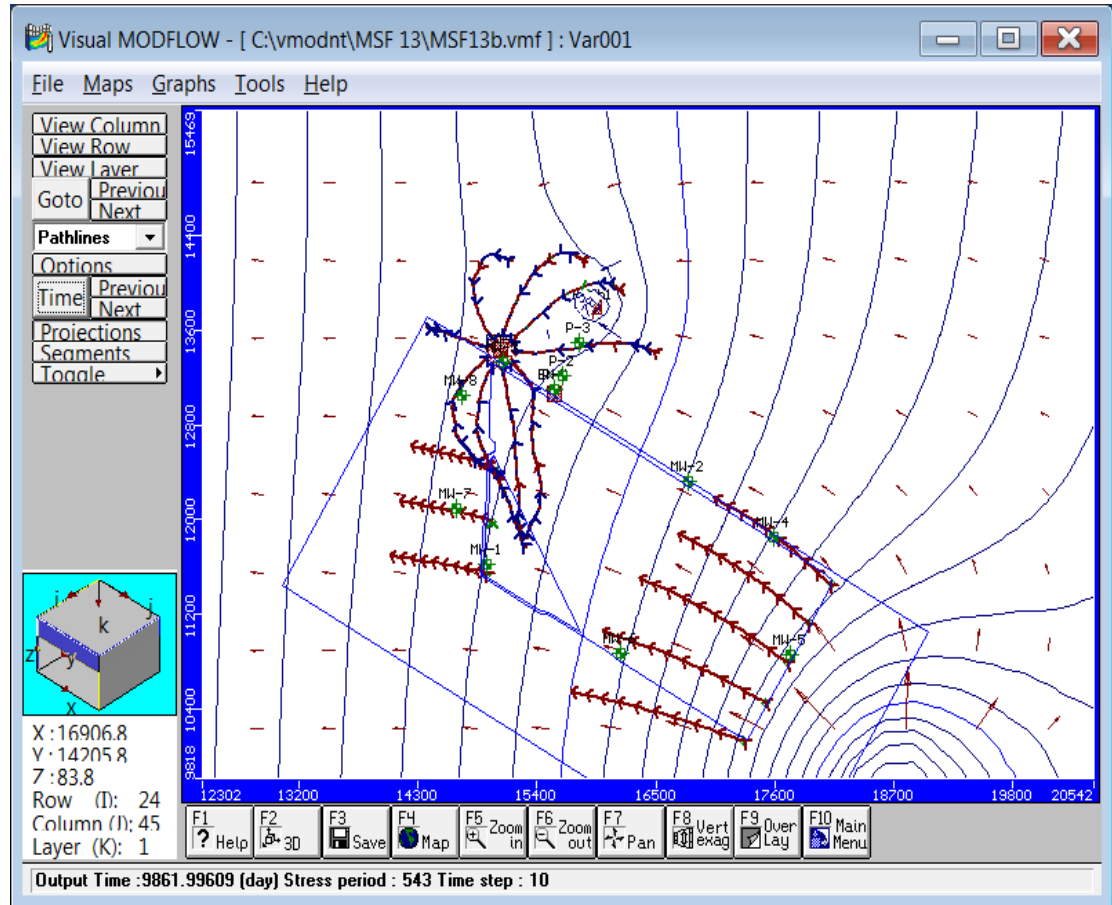
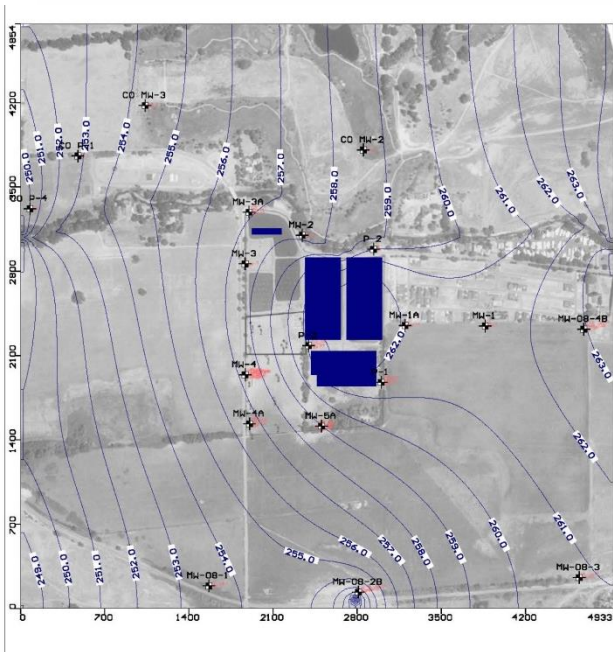


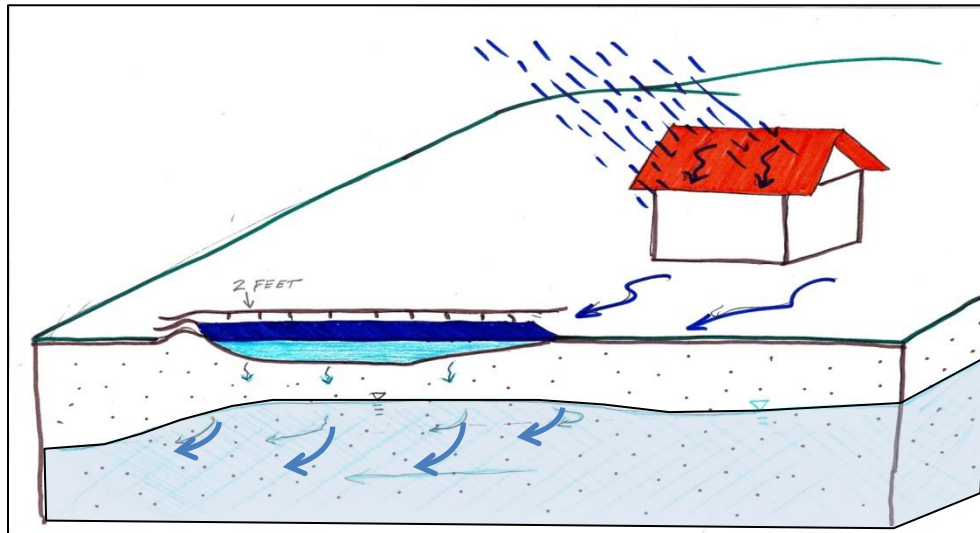
Figure B1



Aquifer Recharge

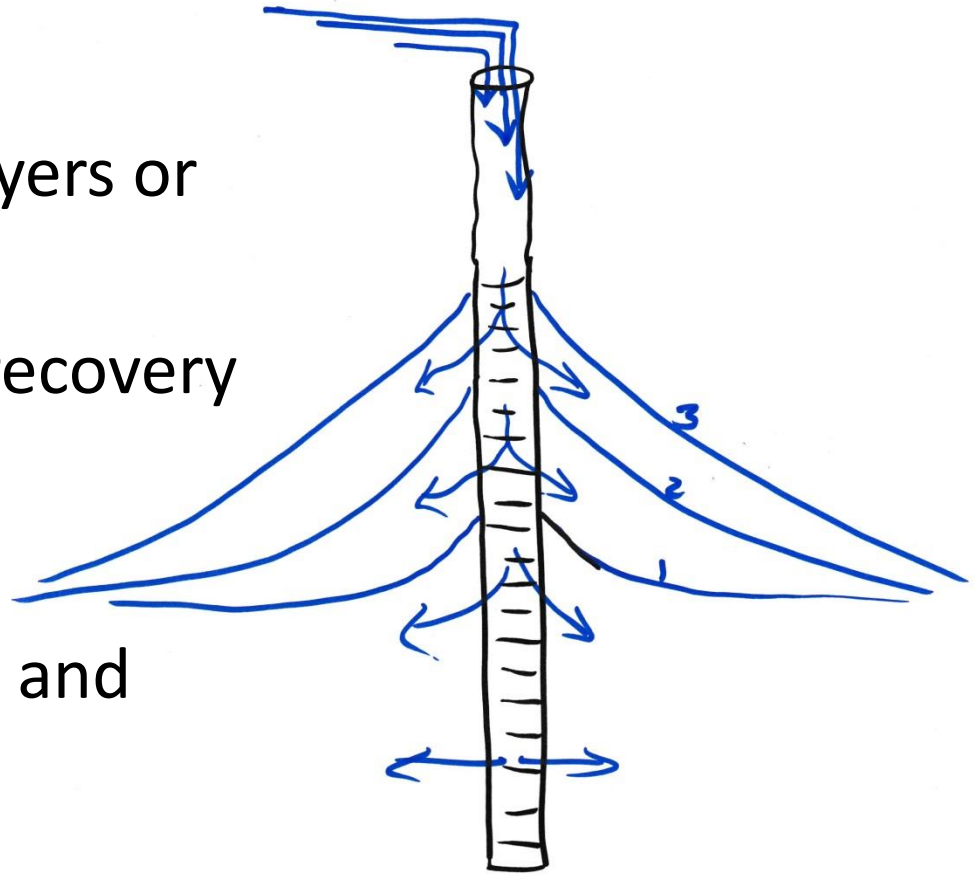
- Infiltration Basins – most used technique

Groundwater mounds up under recharge sources, increasing the gradient that drives groundwater flow away from center.



Aquifer Recharge

- Injection Wells
 - Can target specific layers or zones
 - Can be reversed for recovery
 - Special designs and maintenance
 - Requires disinfection and filtration



Conclusion

- The California Water Action Plan calls for Sustainable management of groundwater basins.
- Groundwater is out of sight but is not mysterious- it's occurrence and flow are intuitive and obvious if you understand the basic principles.
- Decision makers should rely on thorough hydrogeologic characterizations to manage aquifers in their basins.
- Hydrogeologists study aquifers to understand where water is stored, how much is there, and how it flows through the land.

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