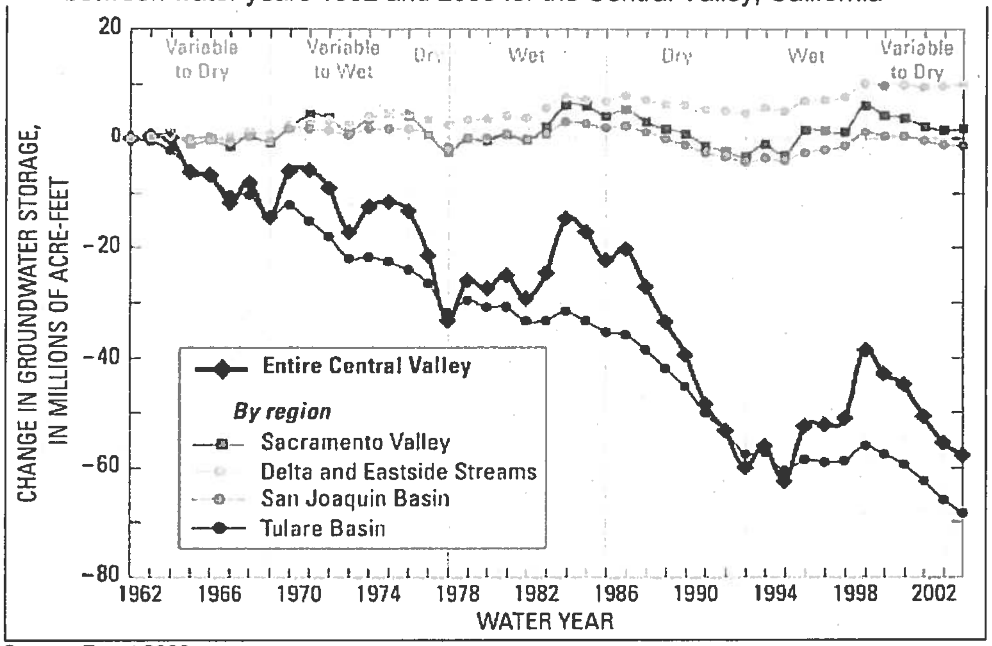
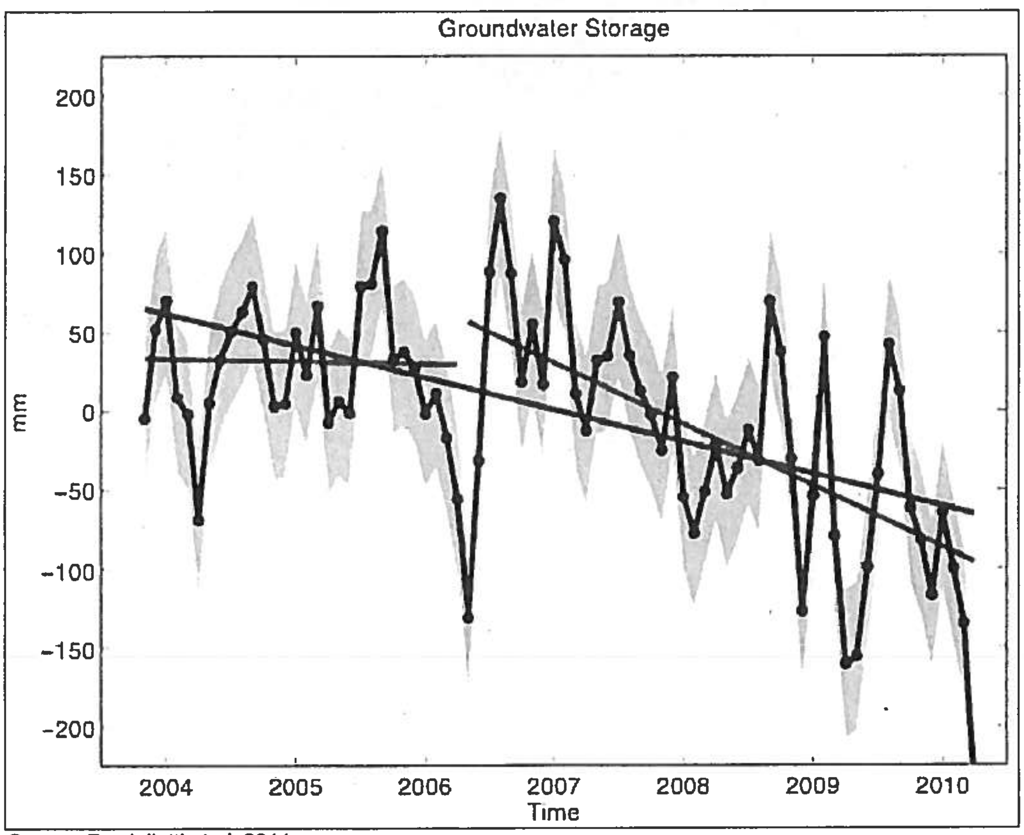
Figure 1. Simulated cumulative annual changes in aquifer-system storage between water years 1962 and 2003 for the Central Valley, California

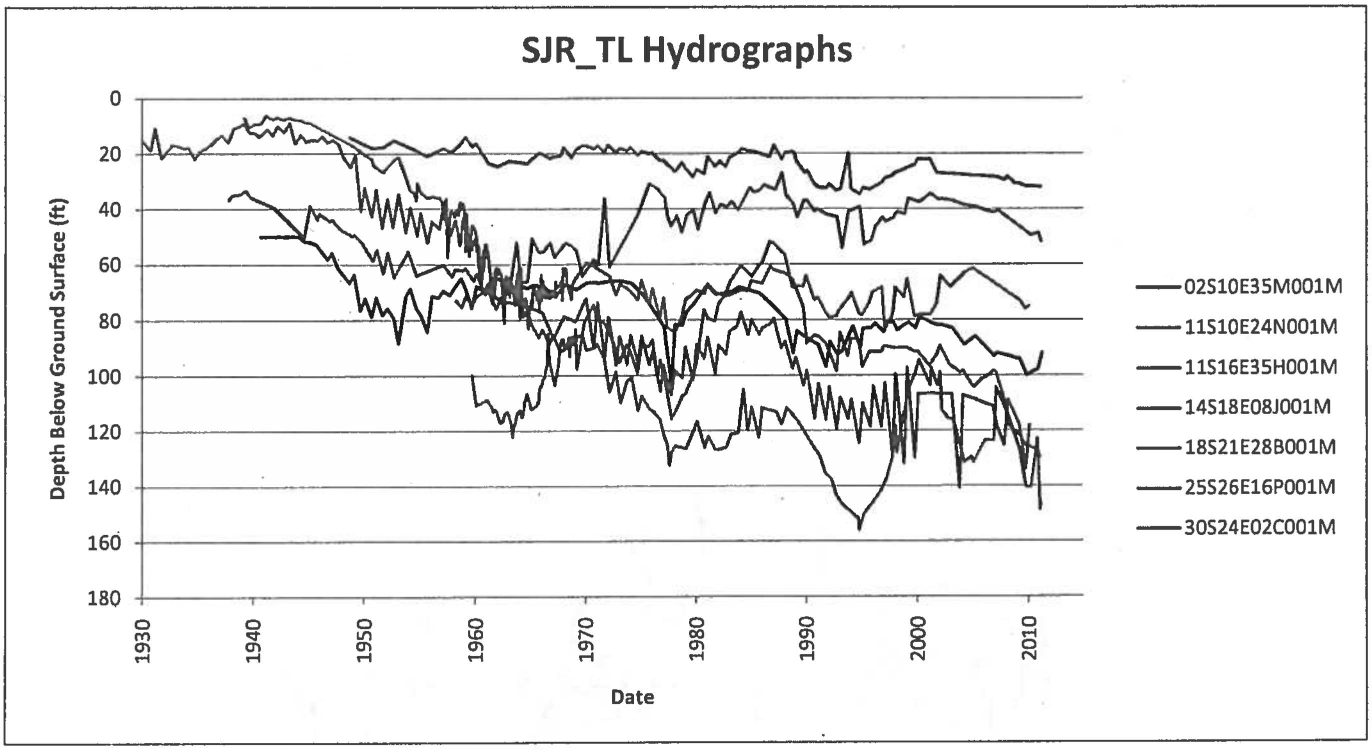


Source: Faunt 2009.

Figure 2. Monthly groundwater storage anomalies for the Sacramento and San Joaquin River basins in millimeters, from October 2003 to March 2010



Source: Famiglietti et al. 2011.



SJR_TL Hydrographs
Depth Below Ground Surface (ft)
0
20
40
60
80
100
120
140
160
180
1930
1940
1950
1960
1970
1980
1990
2000
2010
Date
02S10E35M001M
11S10E24N001M
11S16E35H001M
14S18E08J001M
18S21E28B001M
25S26E16P001M
30S24E02C001M

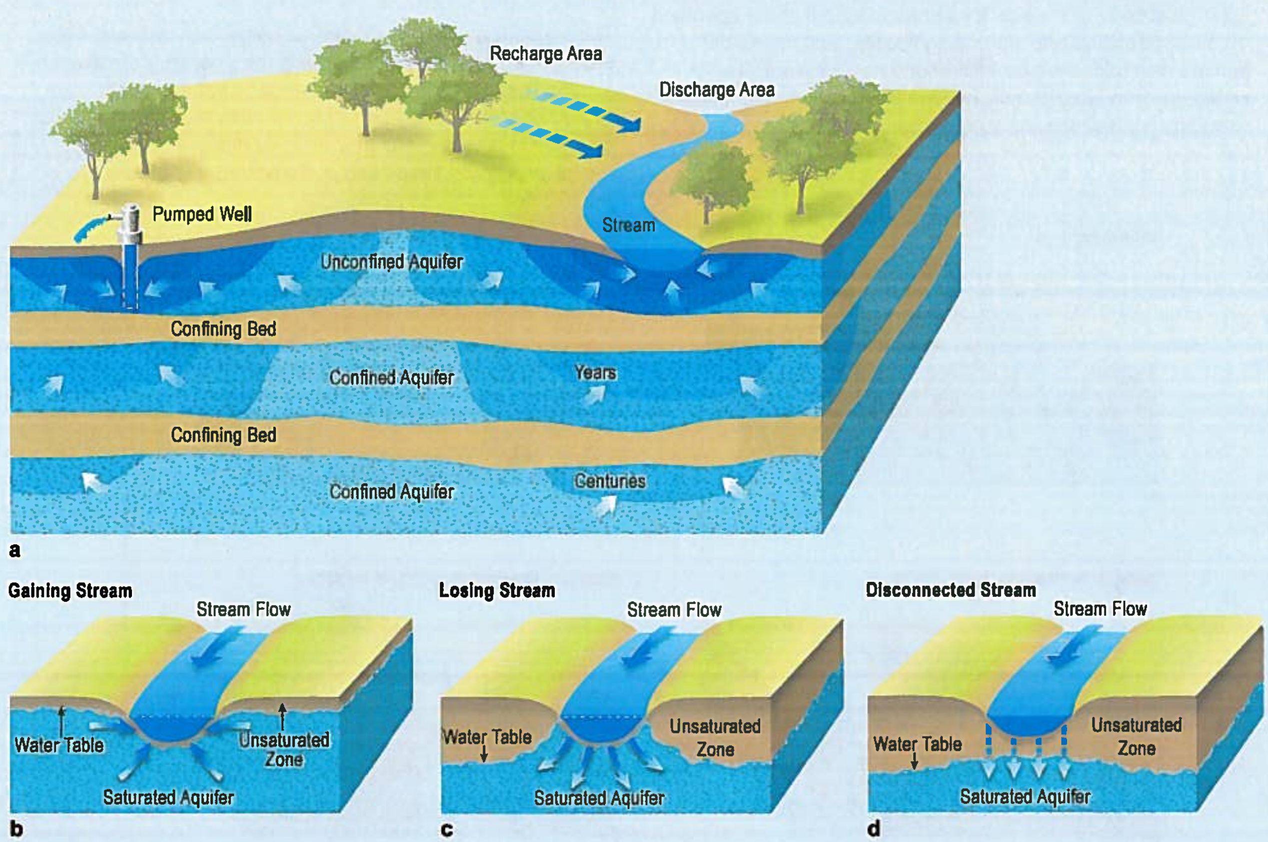
Box 8-2 Groundwater and Surface Water, a Single Resource

Groundwater moves along flow paths of varying lengths from areas of recharge to areas of discharge. The generalized flow paths start at the water table, continue through the groundwater system, and terminate at the stream or at the pumped well. The source of water to the aquifer is infiltration through the unsaturated soil zone resulting from precipitation, irrigation applied water, managed recharge, etc. The flow paths through the various aquifers onto the stream can be tens to hundreds of feet in length and have corresponding travel times of days to several years or more (see Figure a below).

The interaction of streams with groundwater may take place in three different ways: streams may gain water from discharge of groundwater through the streambed (gaining stream), streams may lose water to groundwater by seepage through the streambed (losing stream), or streams may gain in some reaches (gaining reaches) and lose in rest of the reaches (losing reaches). As shown in Figure b, for streams to gain water from groundwater, the stream water surface elevation must be lower than the surrounding groundwater table elevation. In contrast, as shown in Figure c and Figure d, for streams to lose water to groundwater, the stream water surface elevation must be higher than the surrounding groundwater table elevation. Losing streams can be connected to the groundwater system by a continuous saturated zone (Figure c) or can be disconnected from the groundwater system by an unsaturated zone (Figure d). A distinguishing characteristic of a stream that is disconnected from groundwater is that shallow groundwater pumping in the vicinity of the stream does not necessarily induce additional seepage of water from the stream to groundwater (Winter et al., 1998).

The direction of flow between the stream and the groundwater system may change because of storms (or floodflows moving down the stream), causing water to flow from the stream to groundwater. The direction of flow between the stream and groundwater can alter as a result of groundwater pumping near the stream. In the case of a gaining stream, pumping is likely to decrease discharge from the aquifer to the stream and in some cases, high pumping rates can even modify a gaining stream to a losing stream. In the case of a losing stream, pumping is likely to further increase seepage from the stream to the aquifer (Winter et al., 1998).

The characteristics and extent of the interactions of groundwater and surface water in an area will likely define the success of conjunctive management projects. Therefore, a better understanding of the interconnection between groundwater and surface water is instrumental for effective conjunctive management.



Box 8-3 Groundwater Recharge: Natural and Managed

Groundwater recharge is the mechanism by which surface water moves from the land surface, through the topsoil and subsurface, and into de-watered aquifer space, or through injection of water directly into the aquifer by wells. Groundwater recharge can be either natural or managed. Natural recharge occurs from precipitation falling on the land surface, from water stored in lakes, and from streams carrying storm runoff (Figure a). Managed recharge occurs when water is placed into constructed recharge or spreading ponds or basins, or when water is injected into the subsurface by wells. Managed recharge is also known as artificial, intentional, or induced recharge. Two widely used methods for managed groundwater recharge are recharge basins and injections wells:

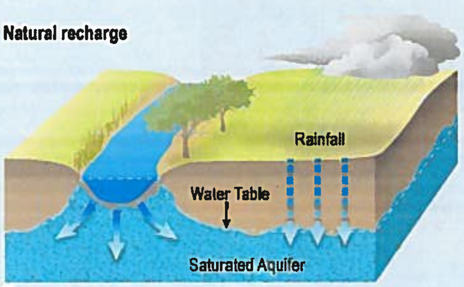
Recharge Basins. Recharge basins are frequently used to recharge unconfined aquifers. Water is spread over the surface of a basin or pond in order to increase the quantity of water infiltrating into the ground and then percolating to the water table. Recharge basins concentrate a large volume of infiltrating water on the surface. As a result, a groundwater mound forms beneath the basin. As the recharge starts, the mound begins to grow; when the recharge ceases, the mound recedes as the water spreads through the aquifer (Figure b). The infiltration capacity of recharge basins is initially high, and then as recharge progresses the infiltration rate decreases as a result of surface clogging by fine sediments and biological growth in the uppermost layer of the soil. It has been found that the operation of recharge basins with alternating flooding and drying-out periods maintains the best infiltration rates. Fine surface sediments may occasionally need to be removed mechanically to maintain the effectiveness of recharge basins.

Injection Wells. Injection wells are used primarily to recharge confined aquifers. The design of an injection well for artificial recharge is similar to that of a water supply well. The principal difference is that water flows from the injection well into the surrounding aquifer under either a gravity head or a head maintained by an injection pump (Figure c). As a large amount of water is pushed through a small volume of aquifer near the well face, injection wells are prone to clogging, which is one of the most serious maintenance problems encountered. Clogging can occur in the well perforations, in the well-aquifer interface, and in the aquifer materials. It is suspected that a combination of a build-up of materials brought in by the recharging water and chemical changes brought about by the recharging water are the primary causes of clogging. The most economical way to operate artificial recharge by injection consists of using dual purpose wells (injection and pumping) so that cleaning of the well and the aquifer may be achieved during the pumping period. However, pretreatment of the water to be injected is always necessary to eliminate the suspended matter.

Another widely used method for managed recharge is through release of water into streams beyond what occurs from the natural hydrology (Figure d). Significant amounts of recharge can also occur either intentionally or incidentally from applied irrigation water and from water placed into unlined conveyance canals.

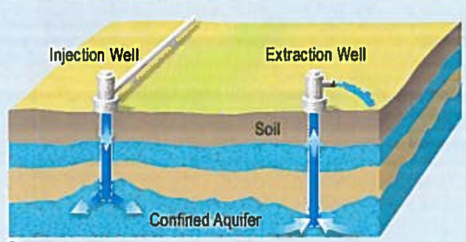
The major purpose of managed recharge is to increase water supply in an area by supplementing the existing groundwater supply. The use of managed recharge to enhance the availability and quality of groundwater has received increased attention in recent years. In California, numerous managed recharge projects have been implemented and others are planned.

Natural recharge



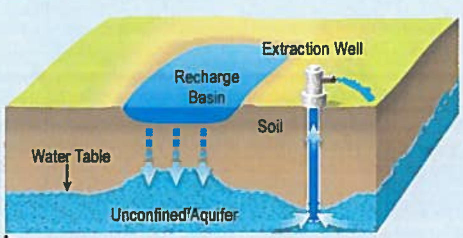
a

Managed recharge: Injection wells



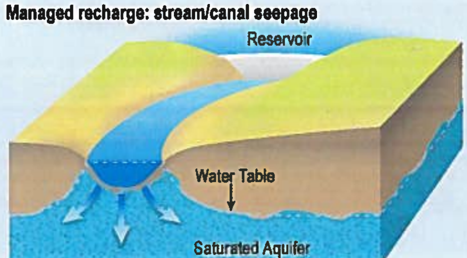
c

Managed recharge: recharge basins



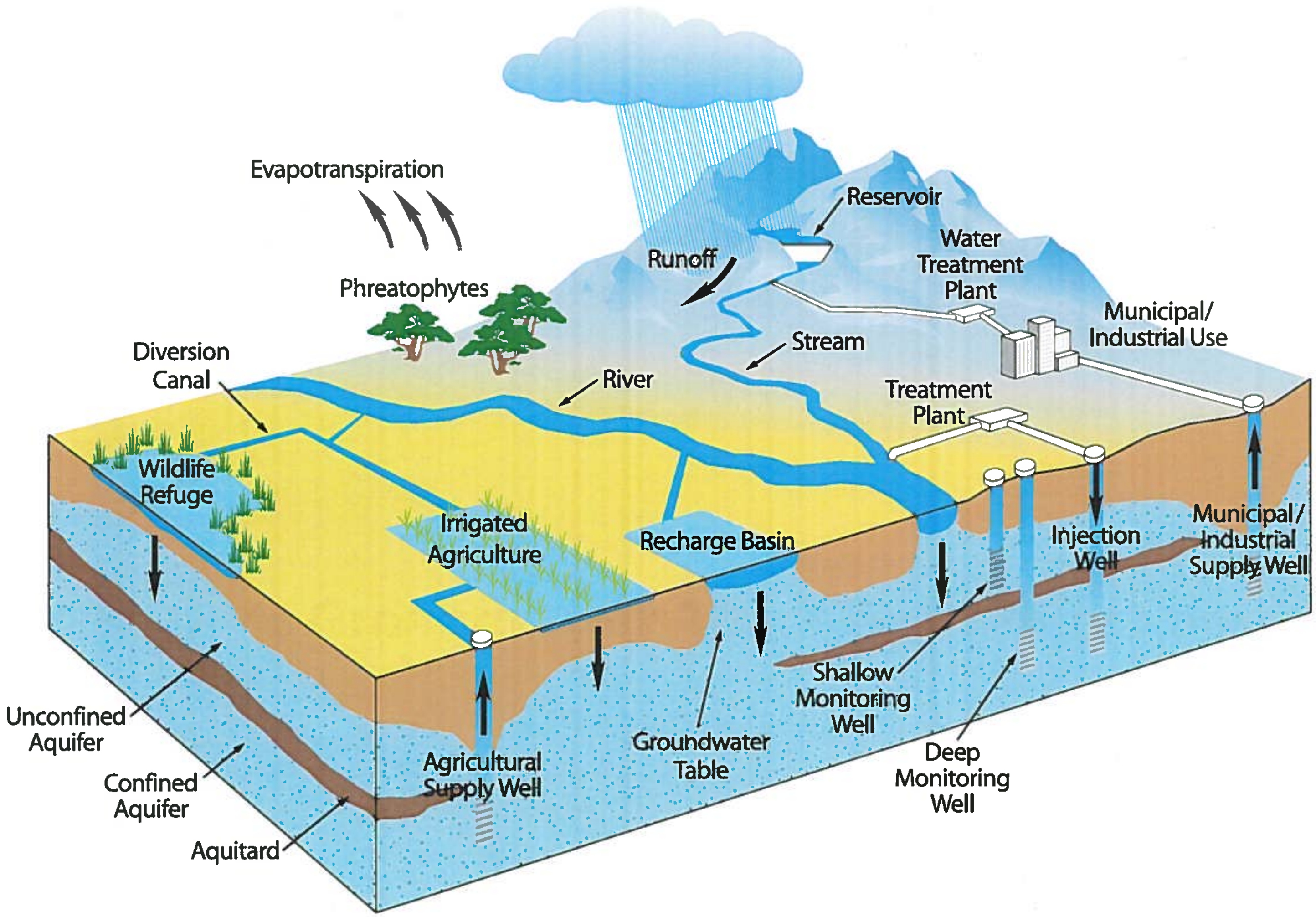
b

Managed recharge: stream/canal seepage



d

How Does Groundwater Affect Your Water Supply?



...To find out, check our websites listed below:

DWR Home Page
http://www.water.ca.gov/

Division of Planning and Local Assistance
http://www.dpla2.water.ca.gov/

Conjunctive Water Management Branch
http://www.groundwater.water.ca.gov/cwm/

DWR District Office Groundwater Pages

- Northern District
  http://wwwdpla.water.ca.gov/nd/GroundWater/index.html
- Central District
  http://wwwdpla.water.ca.gov/cd/groundwater/index.html
- San Joaquin District
  http://wwwdpla.water.ca.gov/sjd/groundwater/index.html
- Southern District
  http://wwwdpla.water.ca.gov/sd/groundwater/groundwater.html

DWR Groundwater Information Center
http://www.groundwater.water.ca.gov/

California's Groundwater: Bulletin 118
http://www.groundwater.water.ca.gov/bulletin118/index.cfm

DWR Drought Preparedness
http://watersupplyconditions.water.ca.gov/

CRWA California Drought Preparedness
http://www.cadroughtprep.net/

Information for Private Well Owners

- DWR Drought Preparedness
  http://watersupplyconditions.water.ca.gov/wells.cfm
- Groundwater Information Center
  http://www.groundwater.water.ca.gov/technical_assistance/gw_wells/gww_domown/index.cfm

Water Data Library (Groundwater Levels)
http://wdl.water.ca.gov/

California Water Conditions, California Data Exchange Center
(Access to DWR Operational Hydrologic Data)
http://cdec.water.ca.gov/

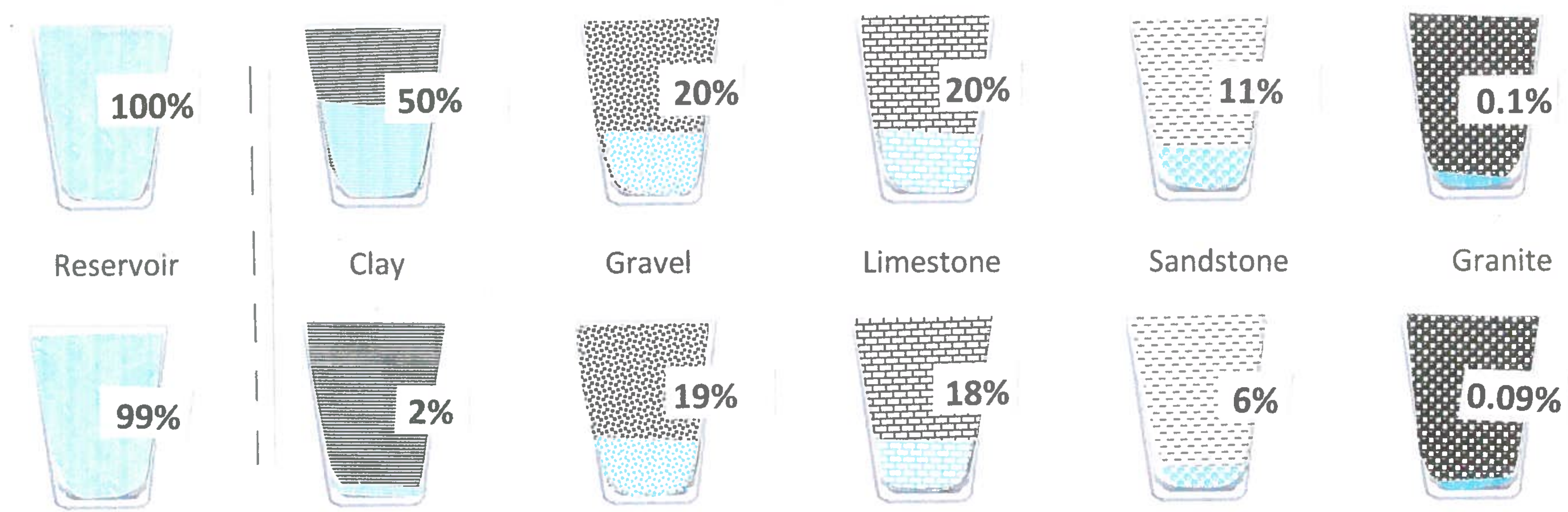
Water Projects Map
http://www.water.ca.gov/maps/allprojects.cfm

Department of Water Resources
Division of Planning & Local Assistance
901 P Street
Sacramento CA 94236-0001
(916) 651-9236

HOW AN AQUIFER IS NOT LIKE A RESERVOIR.

Some of the physical properties that affect groundwater when considering an aquifer's overall ability to yield water.

POROSITY: **The ratio of voids in a rock or sediment to the total volume; a measure of the amount of water that may be stored in that material .**

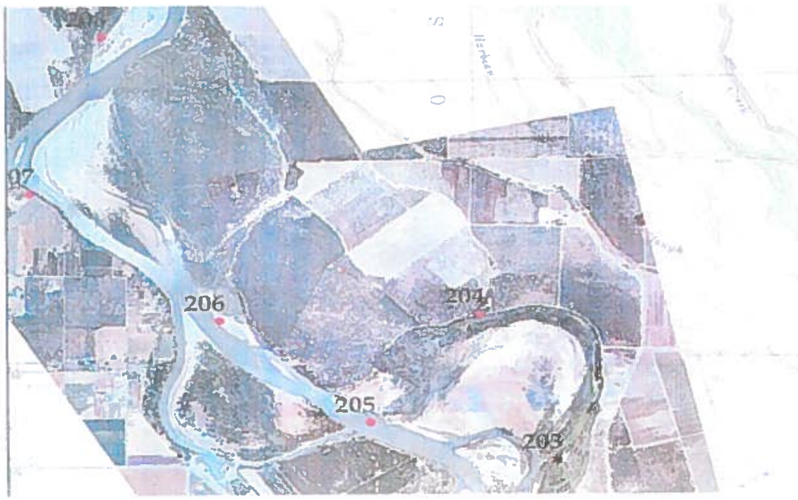


SPECIFIC YIELD: The fractional amount of water that would drain freely from rocks or sediments due to gravity; describes the portion of groundwater that could actually be available for extraction.

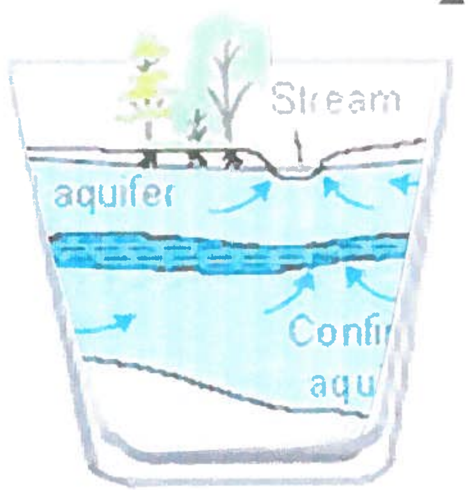
Barbara Hennigan --BSBAGU barbhnign@aol.com

Source: DWR Bulletin 118 Update 2003 pg. 85

Graphics describing ***functions*** of an aquifer don't depict very well the ***reality*** of an aquifer.



An aerial view of the Sacramento River just north of Hamilton City shows oxbow lakes cut off from the river by recent meanders. Over centuries as material is washed off the mountains and layer after layer is laid down, streams cut through gravel deposits, moving them about. Volcanic eruptions fill stream beds with volcanic mudflows that set up like concrete and the resulting aquifer looks less like this and actually more like this.



4-20-2012 Barbara Hennigan --BSBAGU- barbhnign@aol.com