



LeonardRice
ENGINEERS, INC.

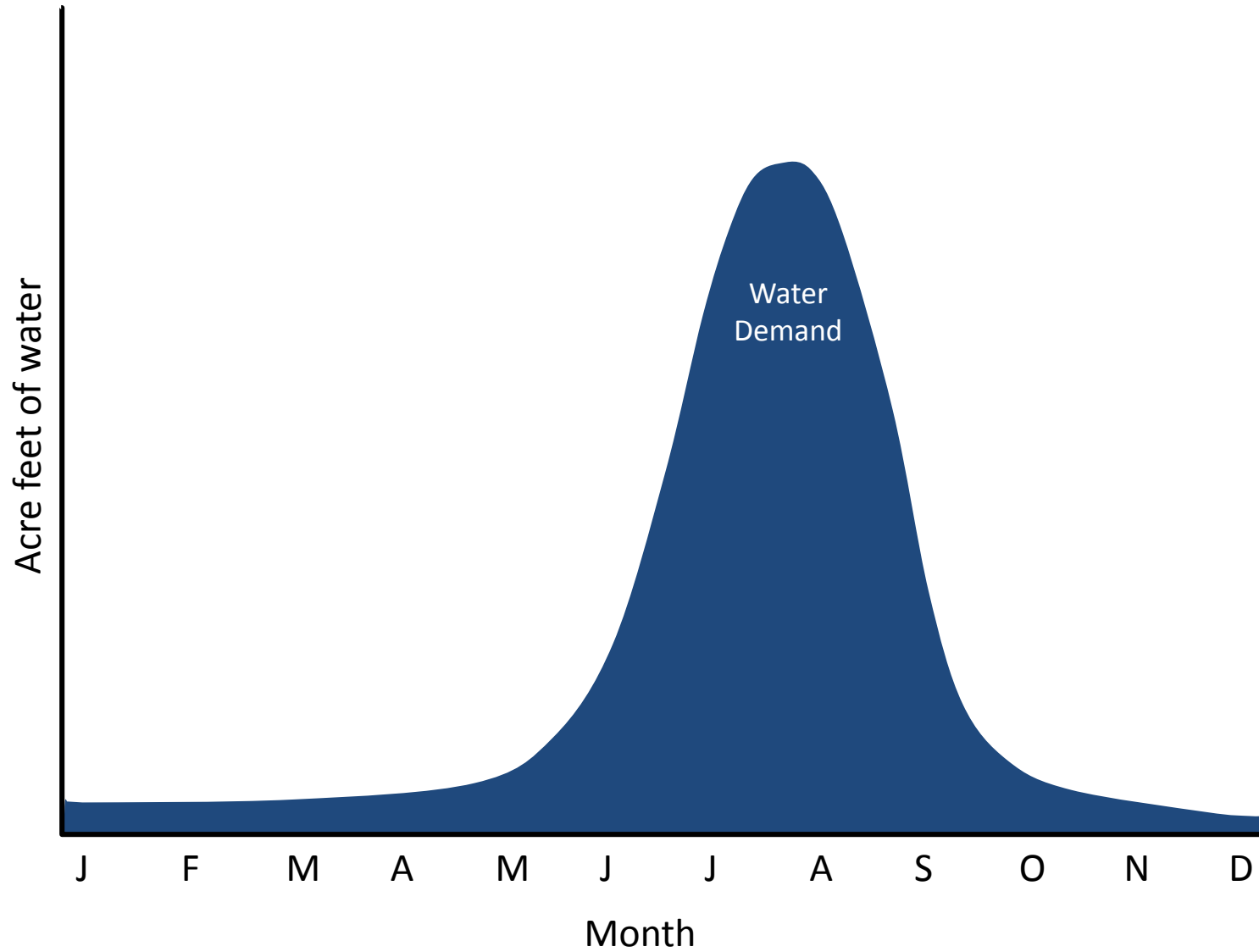
Advantages of Alluvial Aquifer Storage

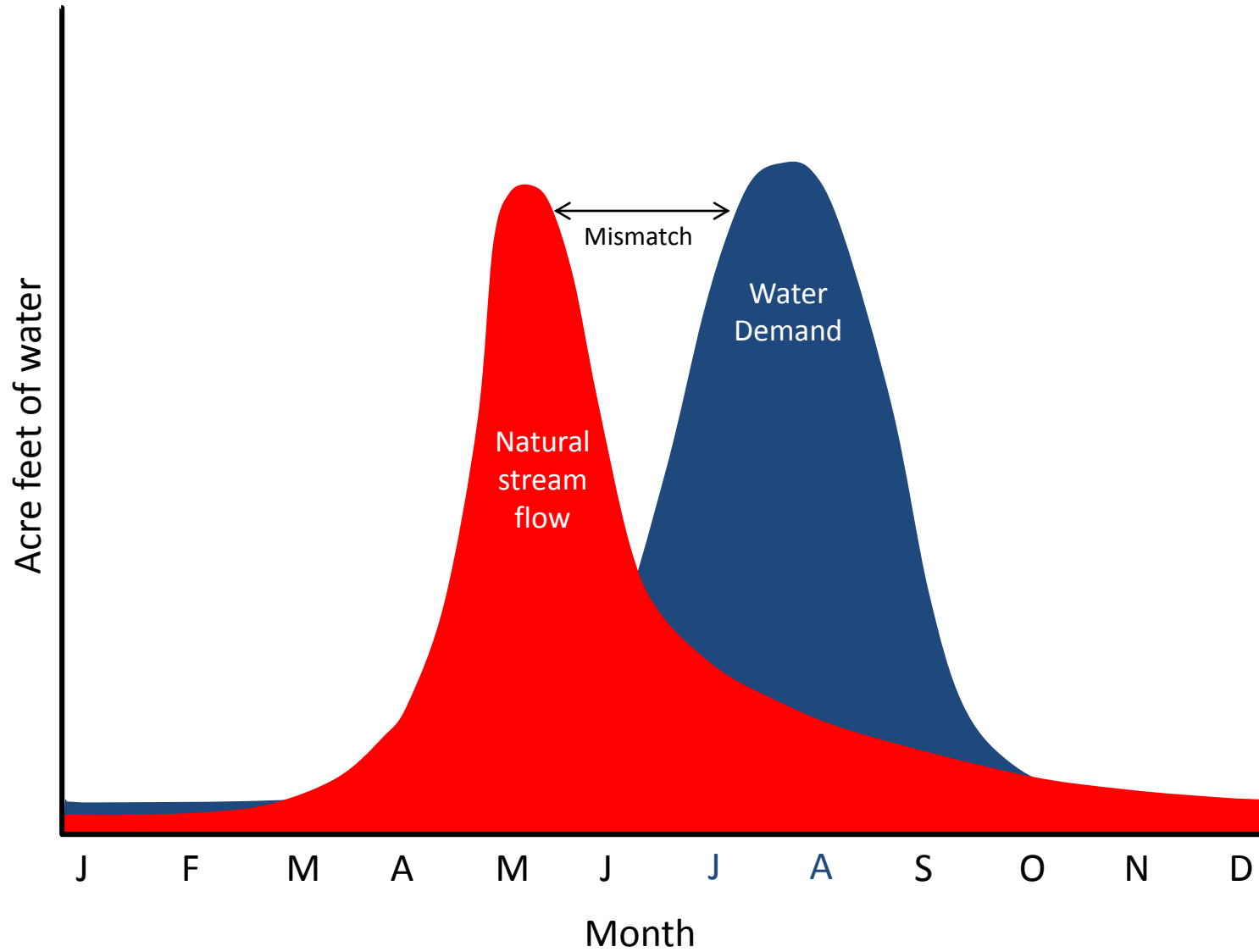
*Alternatives for Managing Hydrologic Extremes
and Future Water Supply Risks*

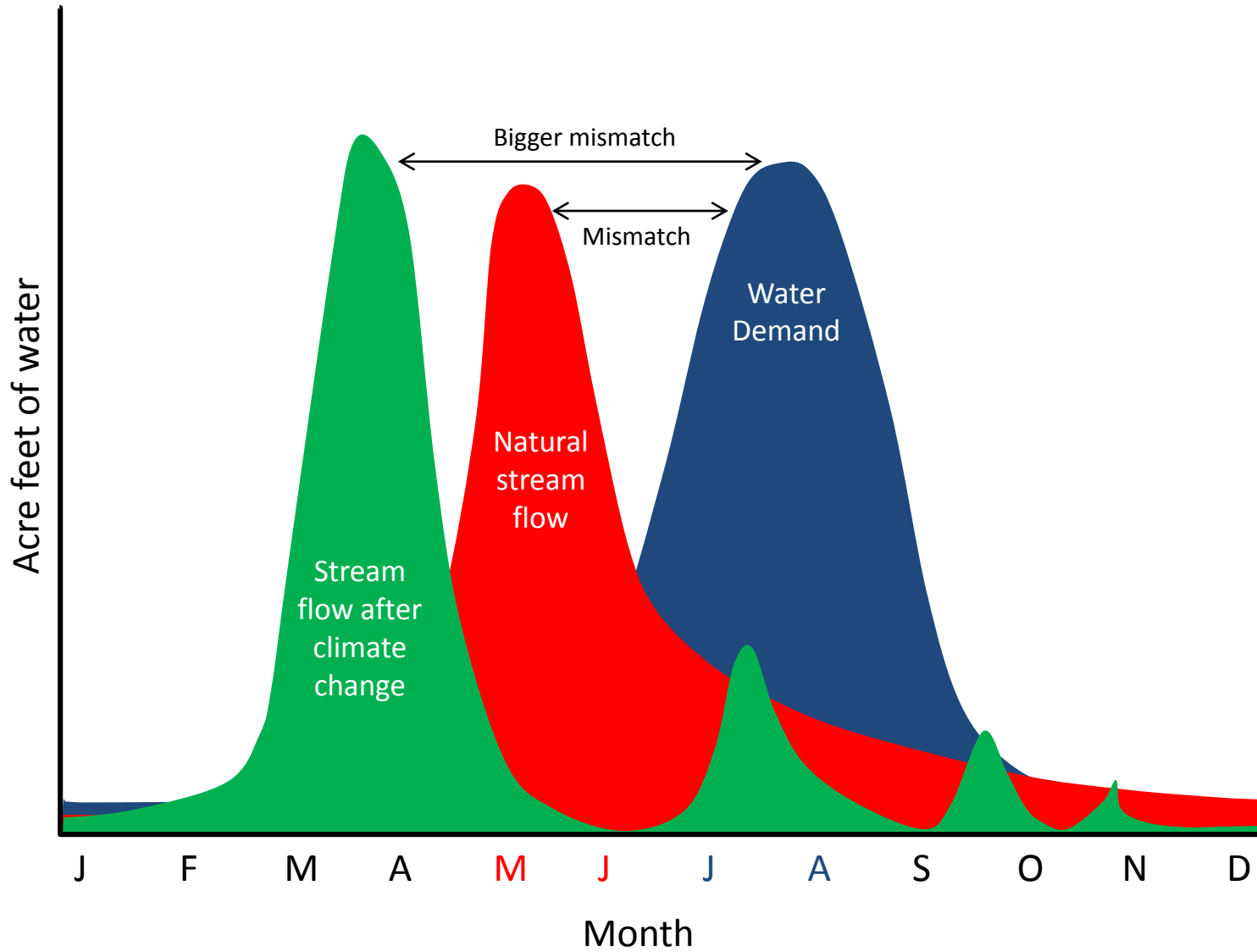
2014 Upper Colorado River Basin Water Forum

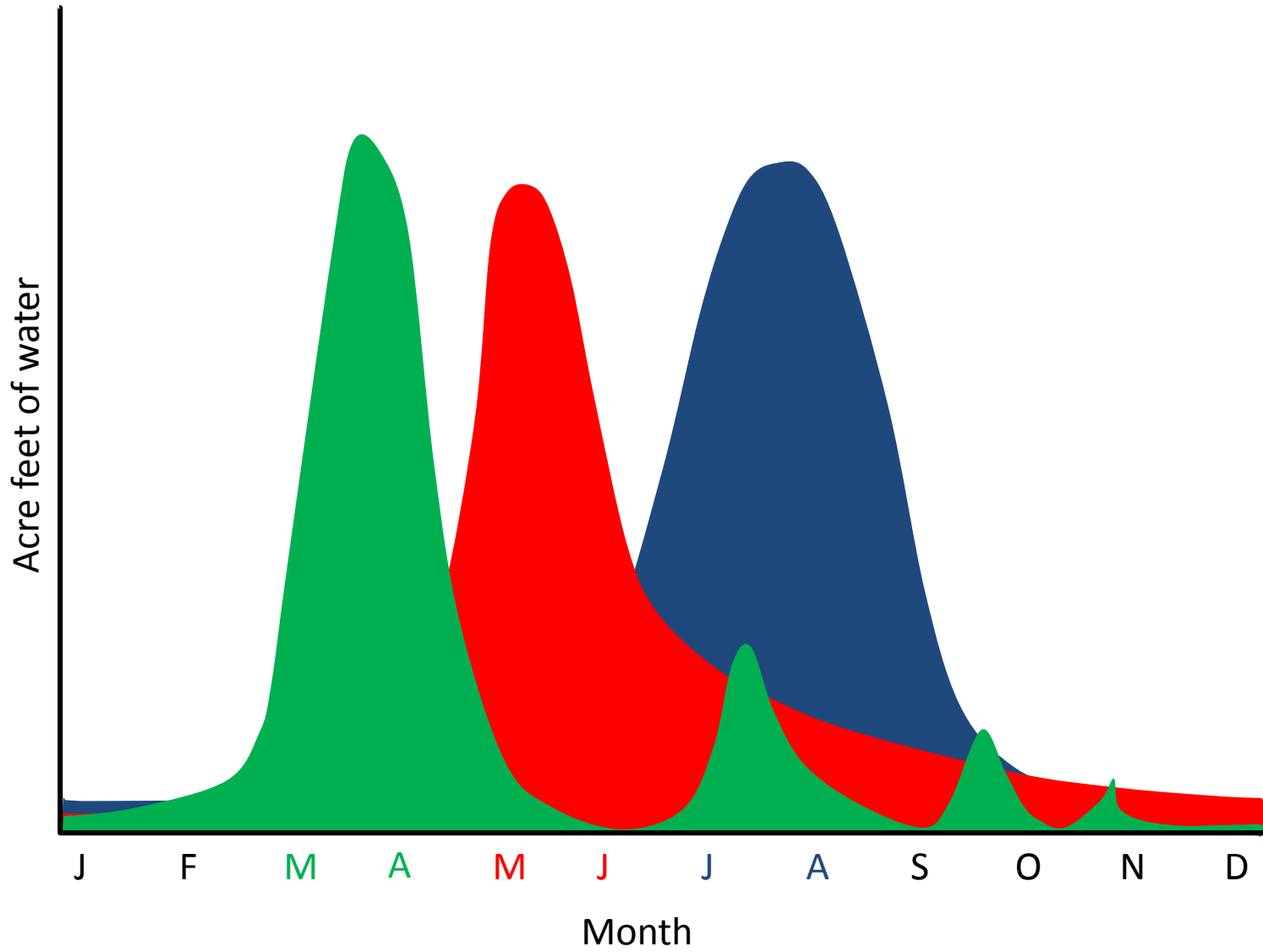
Colorado Mesa University, Grand Junction, CO
November 5-6, 2014

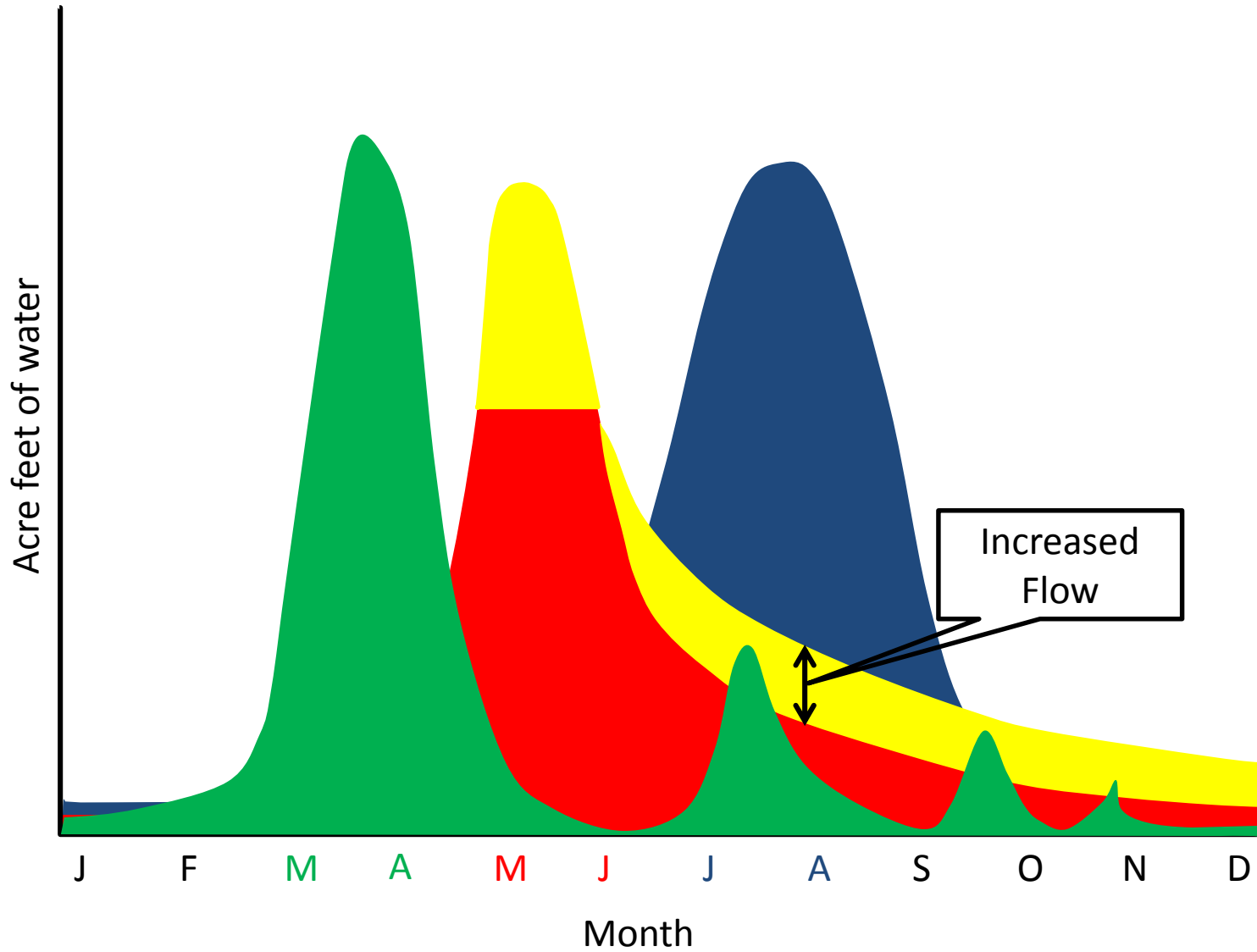
Dave Colvin and William Loopesko

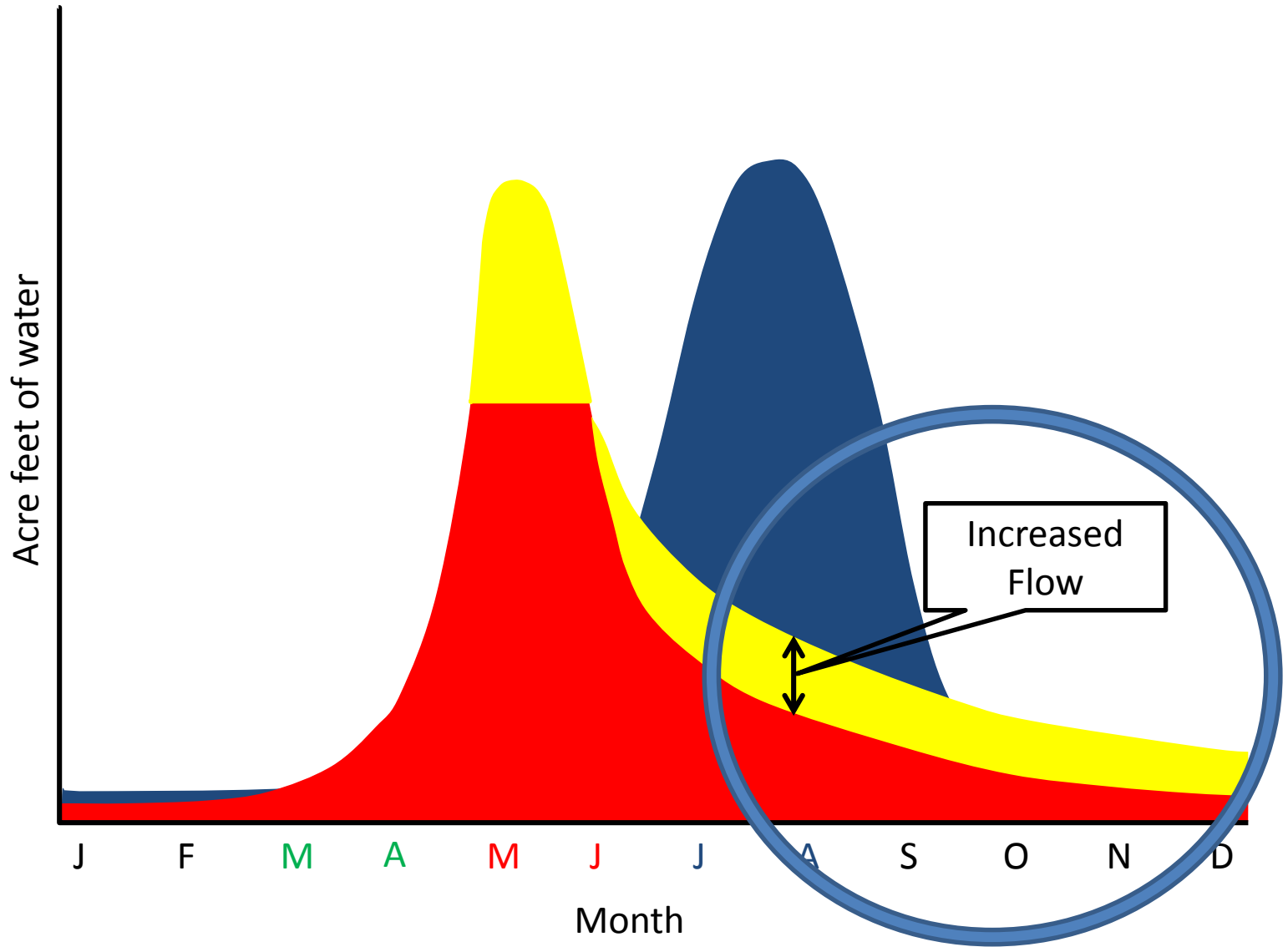






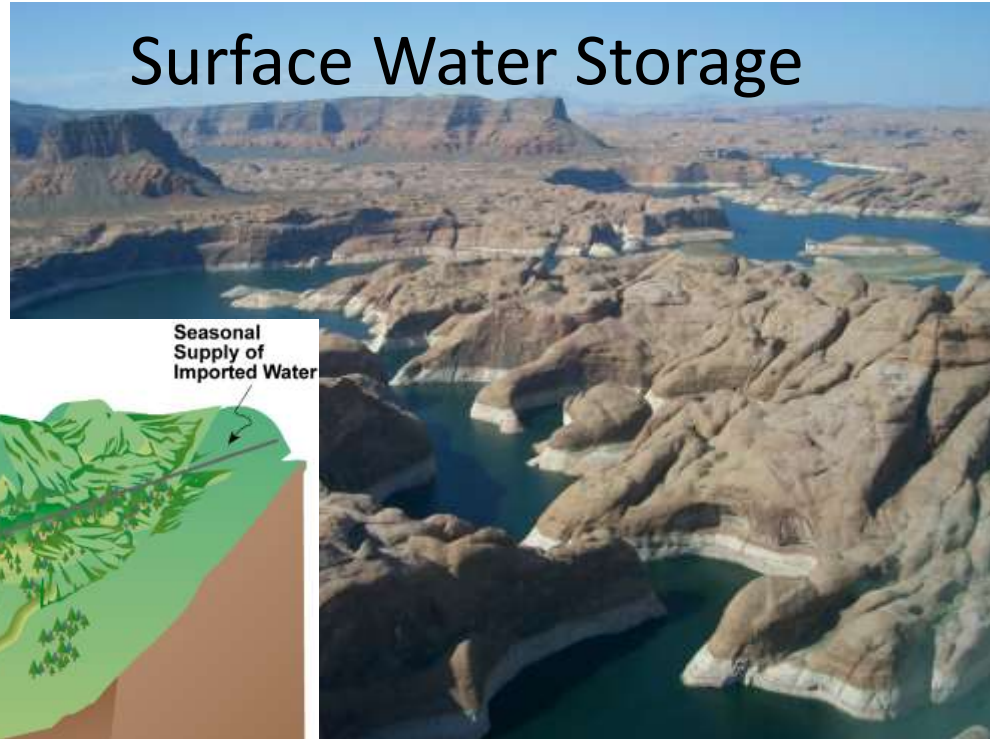




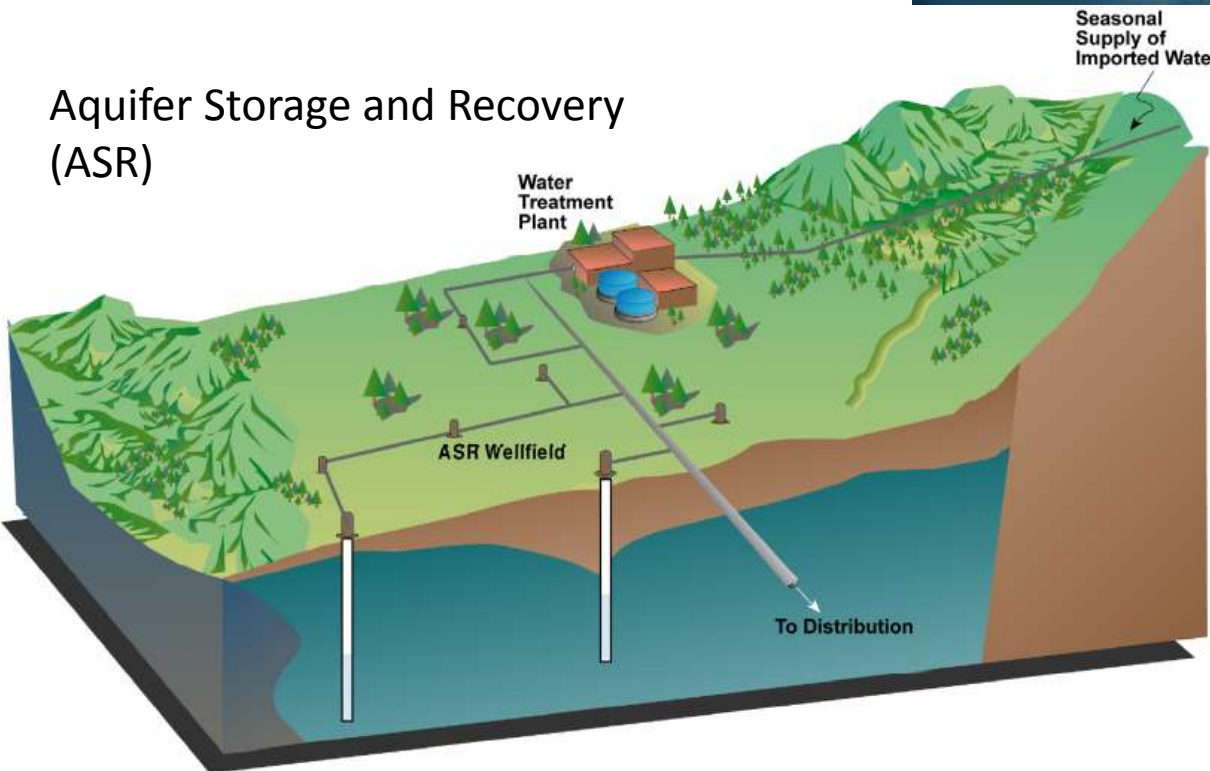


Alternatives

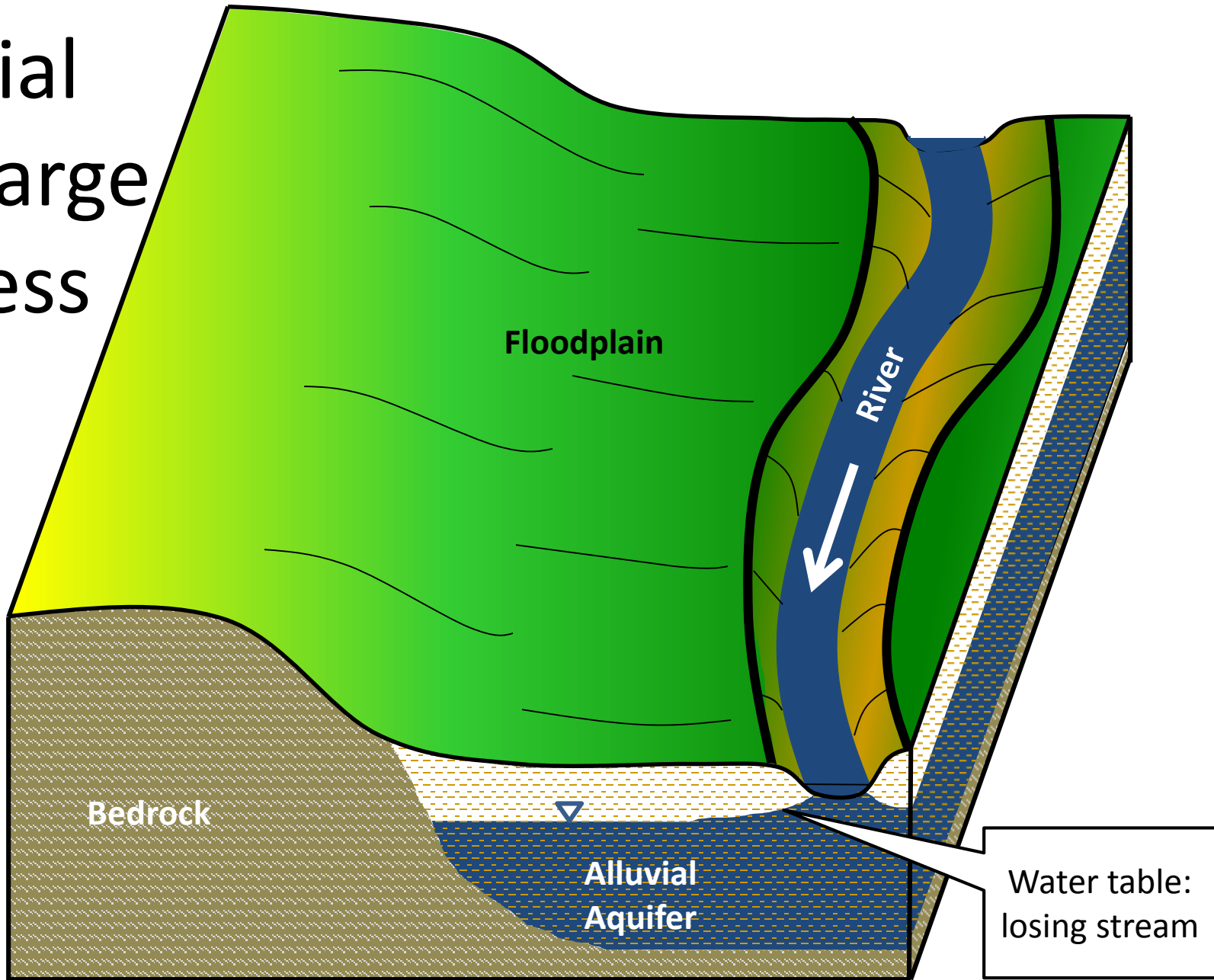
Surface Water Storage



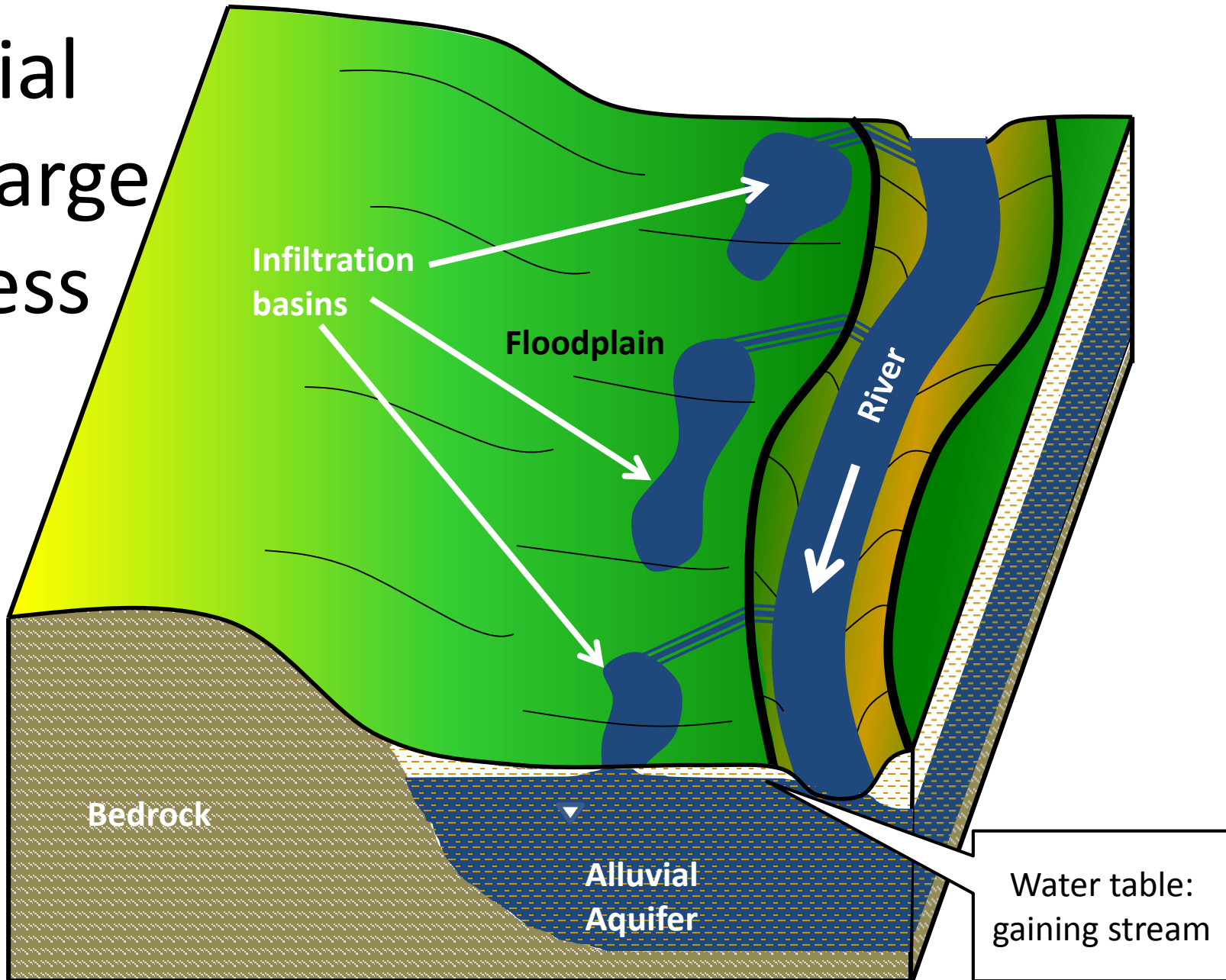
Aquifer Storage and Recovery (ASR)



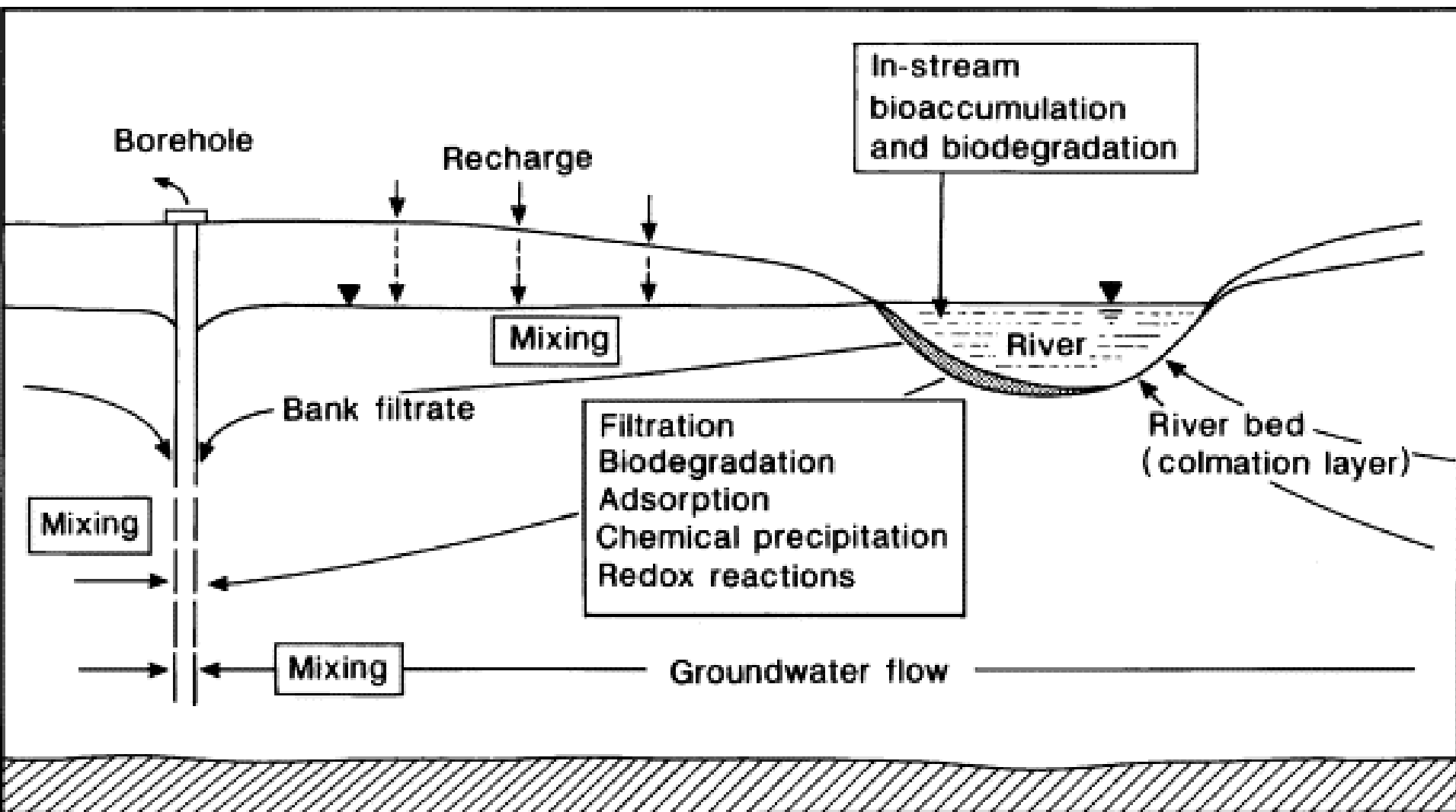
Alluvial Recharge Process



Alluvial Recharge Process



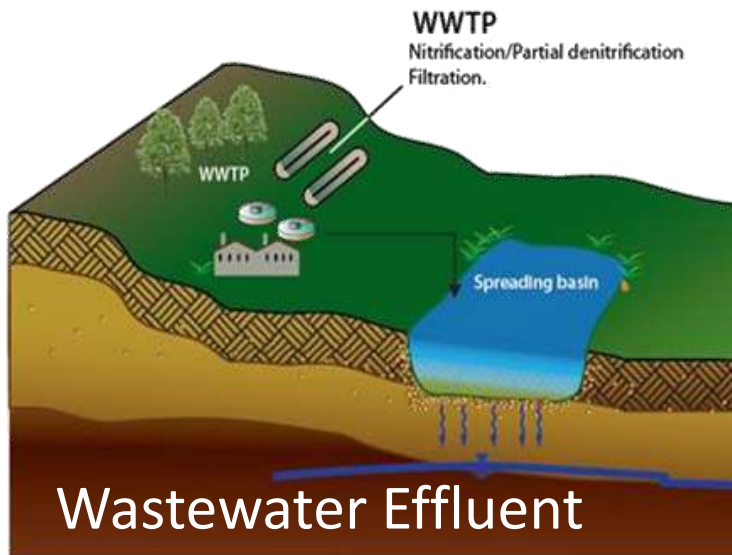
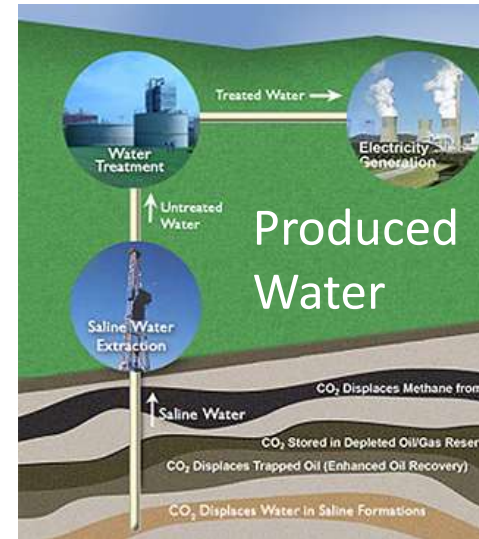
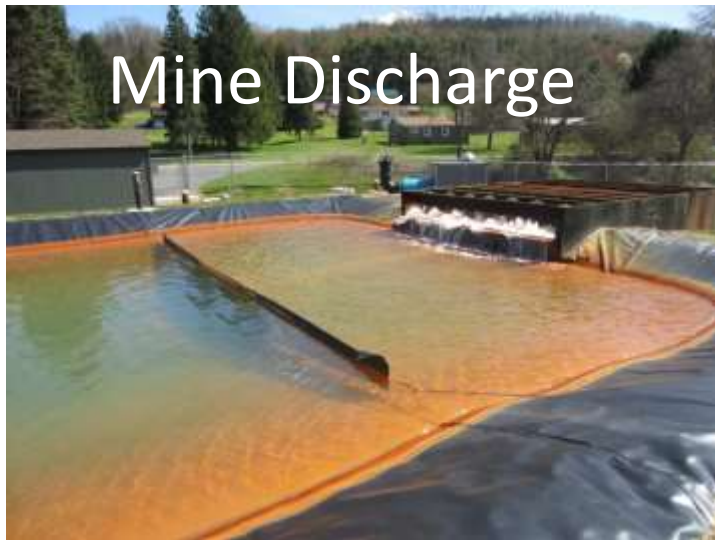
Aquifer Treatment Contaminant Removal



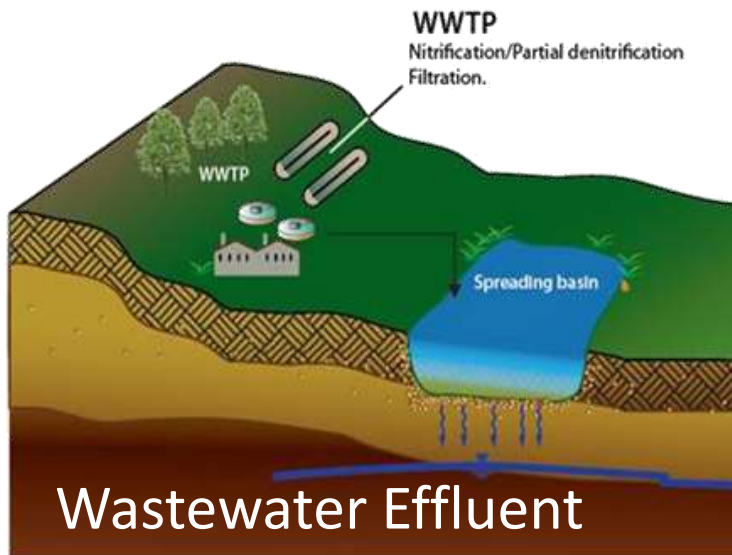
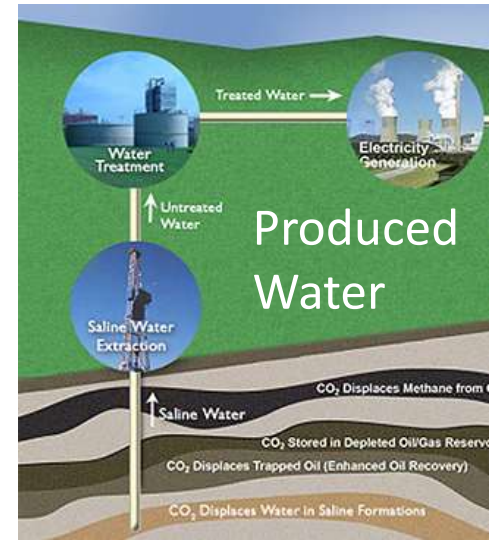
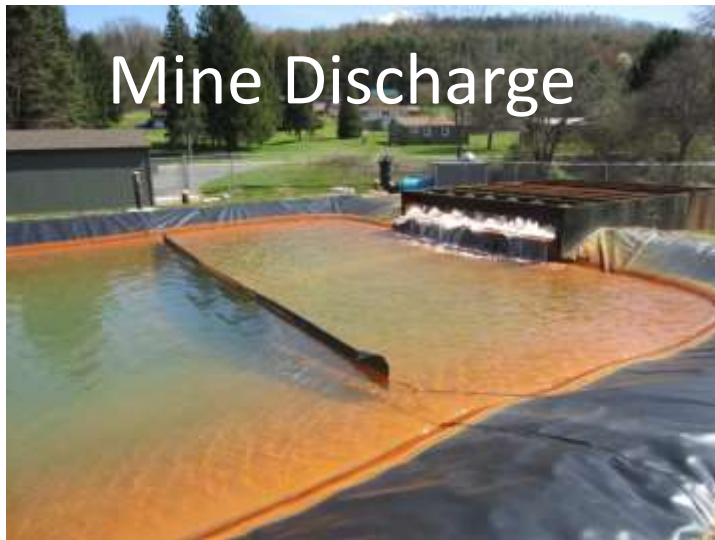
Source:

K.M. Hiscock, T. Grischek, 2002. Attenuation of groundwater pollution by bank filtration. Journal of Hydrology, Volume 266, Issues 3-4, 15 September 2002, Pages 139-144 [http://dx.doi.org/10.1016/S0022-1694\(02\)00158-0](http://dx.doi.org/10.1016/S0022-1694(02)00158-0)

Water Sources for Alluvial Recharge



Water Sources for Alluvial Recharge



Water / Energy Nexus



4th Annual

PRODUCED WATER REUSE INITIATIVE 2014

ROCKY MOUNTAINS TIGHT OIL & SHALE GAS PLAYS

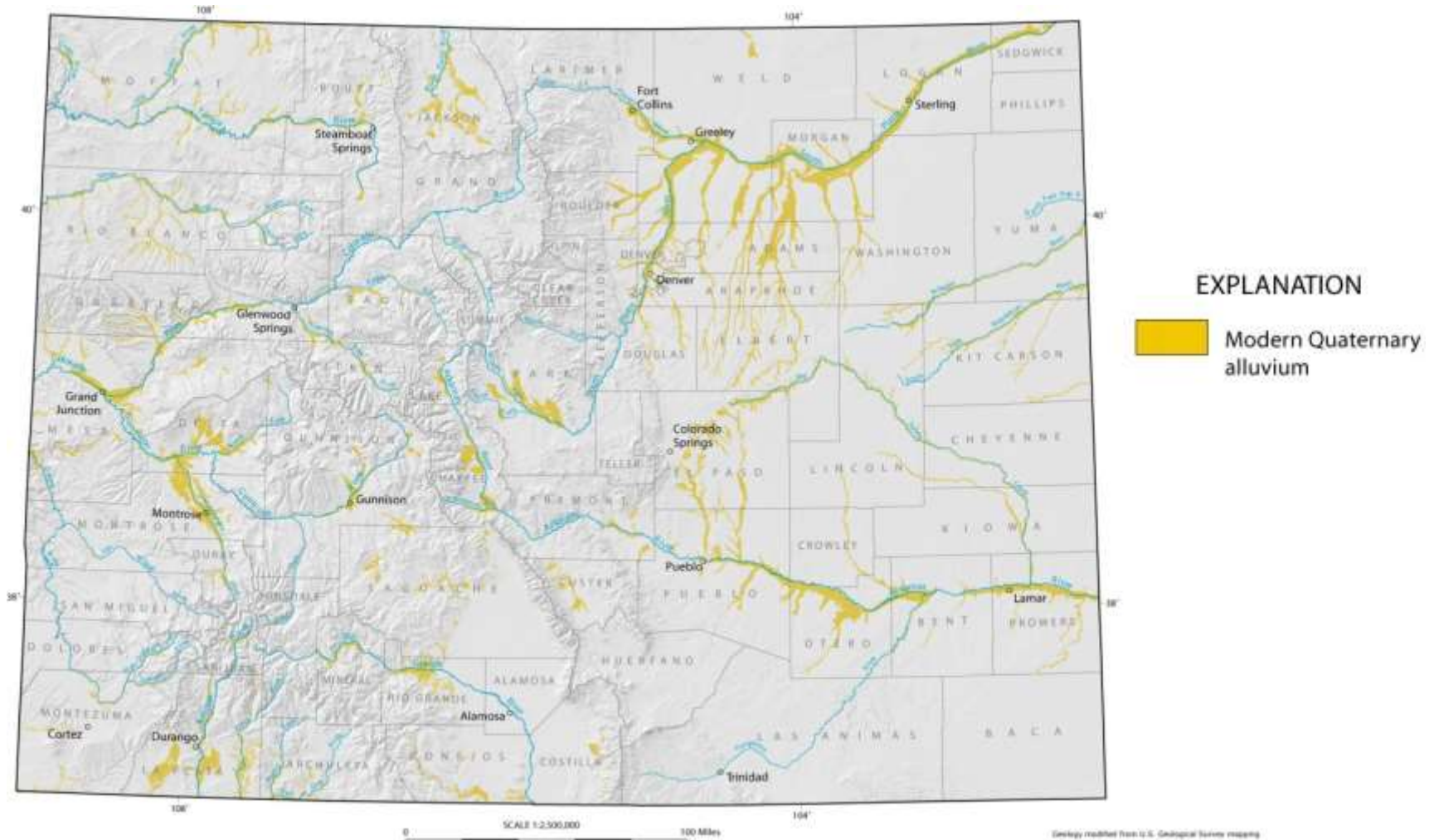


**Reusing Produced
Water In The
Rockies Could
Save Between...**

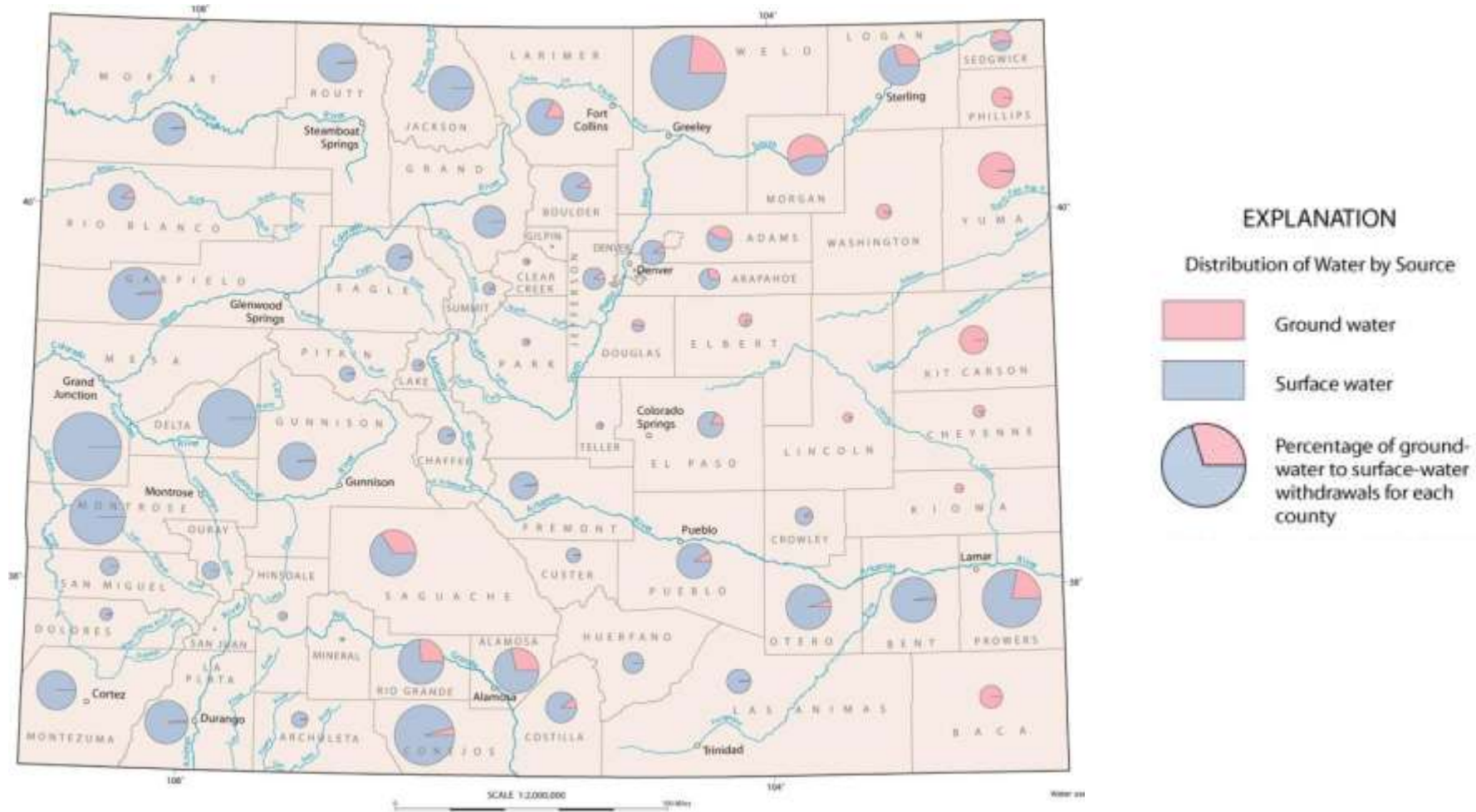
24% & 46%
Per Barrel

Water resources focused summary available at
<http://www.awracolorado.org/newsletter/>

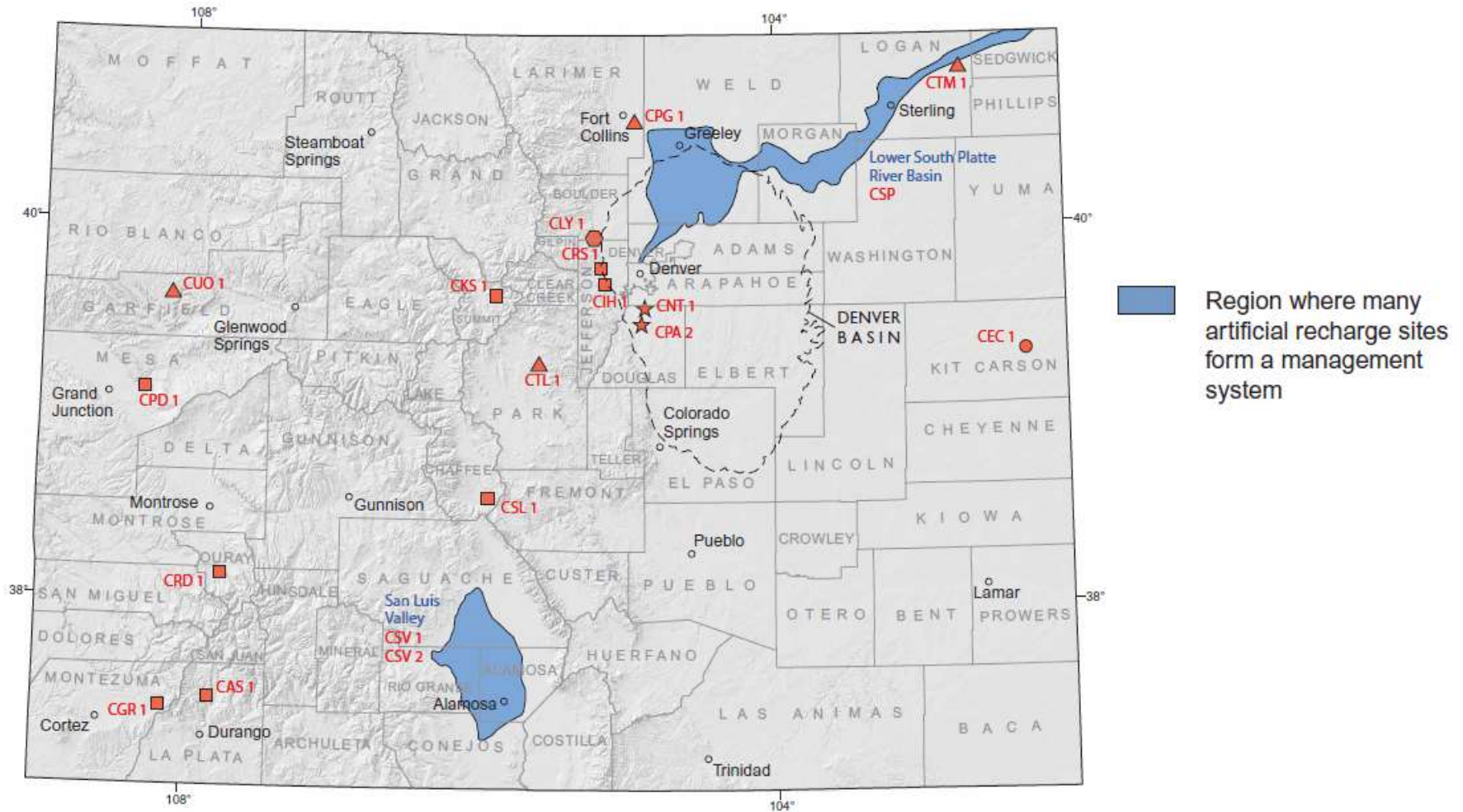
Colorado's Alluvial Aquifers



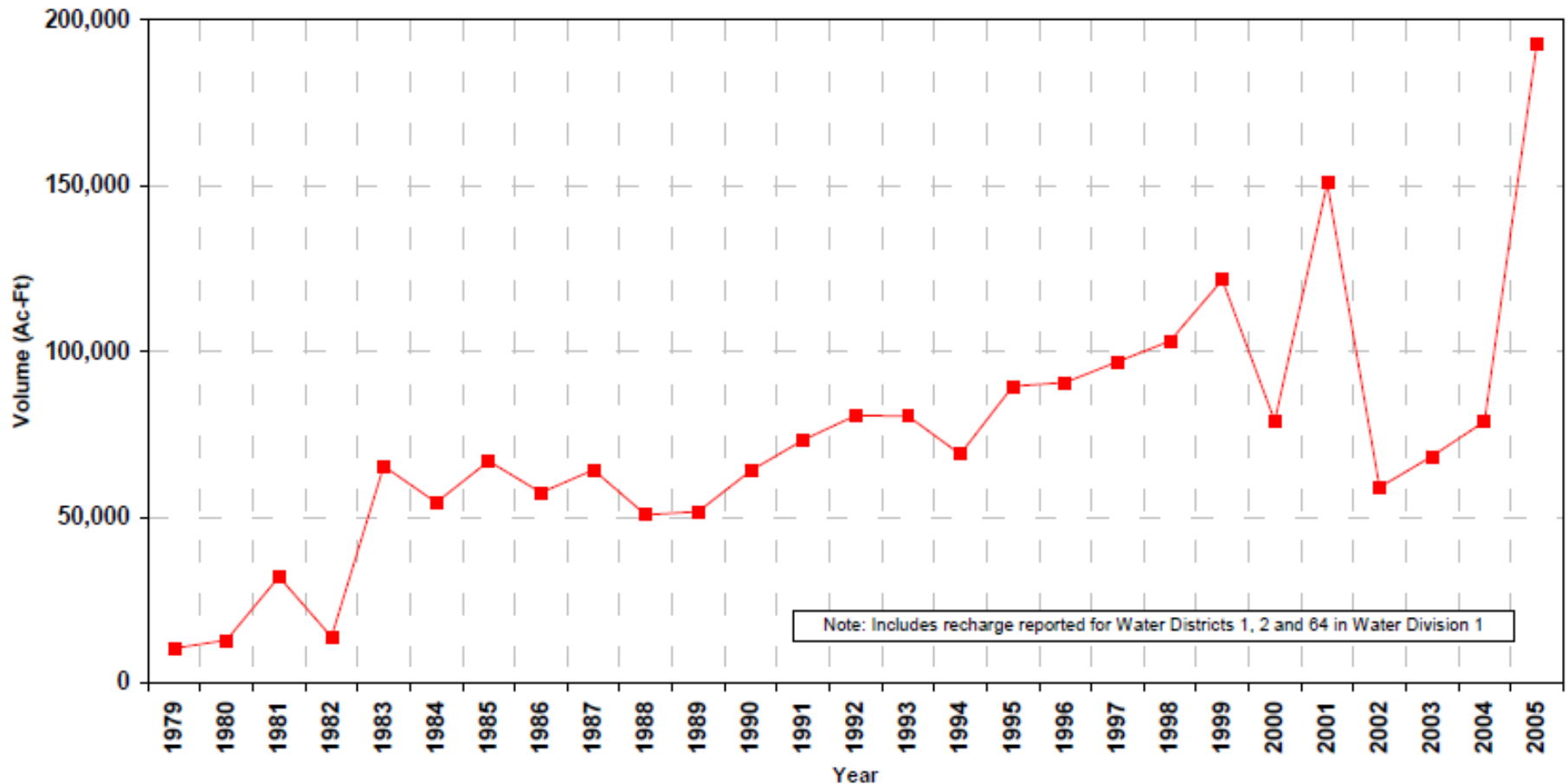
Groundwater Use in Colorado



Groundwater Recharge in Colorado



South Platte Alluvial Recharge



Source:

Senate Bill 06-193: Underground Water Storage Study; CWCB, 2006.

<http://cwcbeblink.state.co.us/weblink/0/doc/144062/Electronic.aspx?searchid=31104c98-5ffa-4943-84d1-03eb4b0af323>

State Groundwater Recharge Studies



Sources:

Artificial Recharge of Ground Water in Colorado; CGS 2004. <http://coloradogeologicalsurvey.org/water/artificial-recharge/>

Senate Bill 06-193: Underground Water Storage Study; CWCB, 2006.

<http://cwcbweblink.state.co.us/weblink/0/doc/144062/Electronic.aspx?searchid=31104c98-5ffa-4943-84d1-03eb4b0af323>

Upper Black Squirrel Creek Basin Aquifer Recharge and Storage Evaluation, CGS 2008.

http://upperblacksquirrelcreekwater.com/media/documents/studies/AquiferStorageEvaluation_2008/UBS_finalReport_0203.pdf

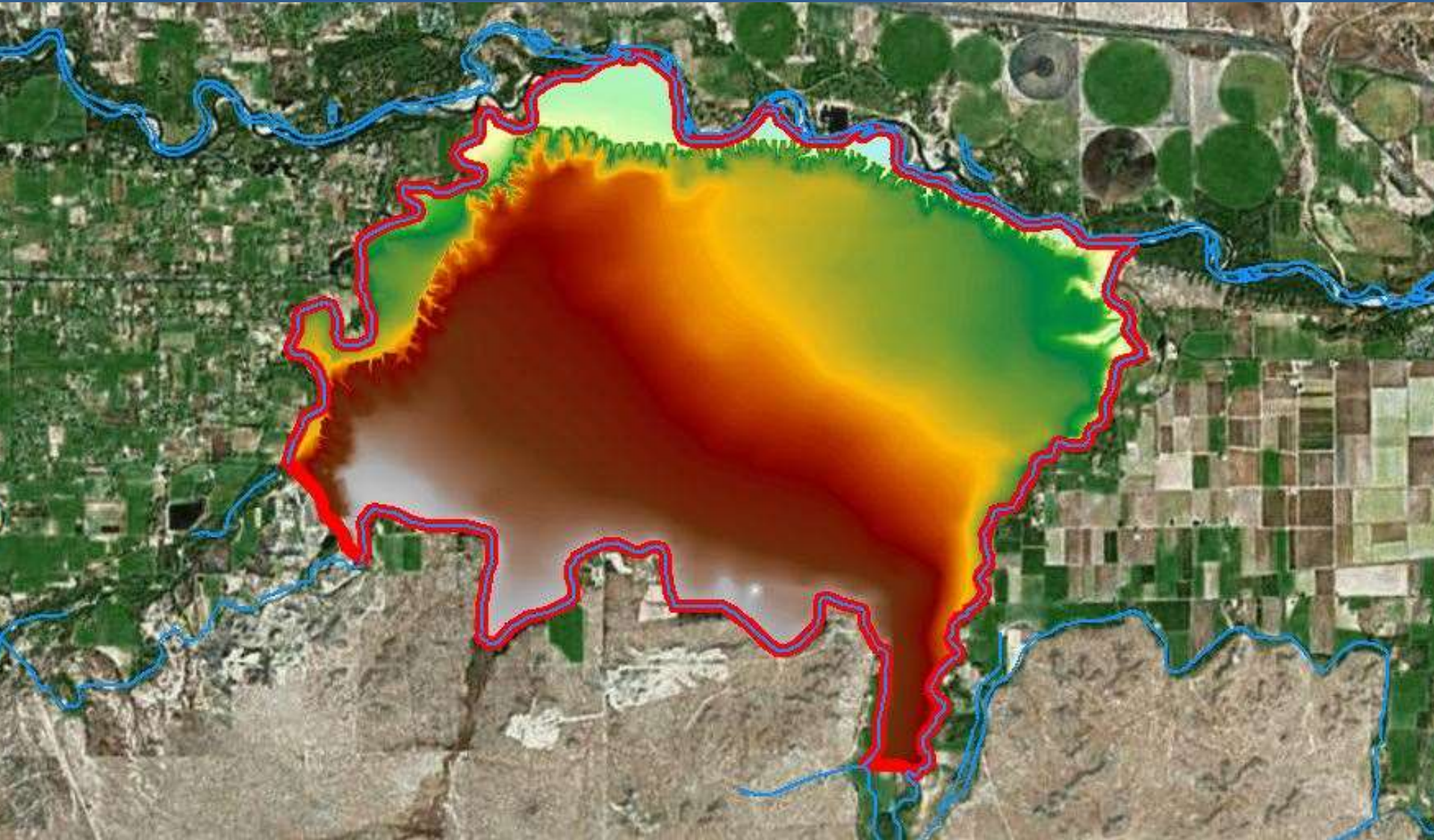
Groundwater and Surface-Water Interaction and Potential for Underground Water Storage in the Buena Vista-Salida Basin, Chaffee County, Colorado, 2011

<http://pubs.usgs.gov/sir/2014/5095/>

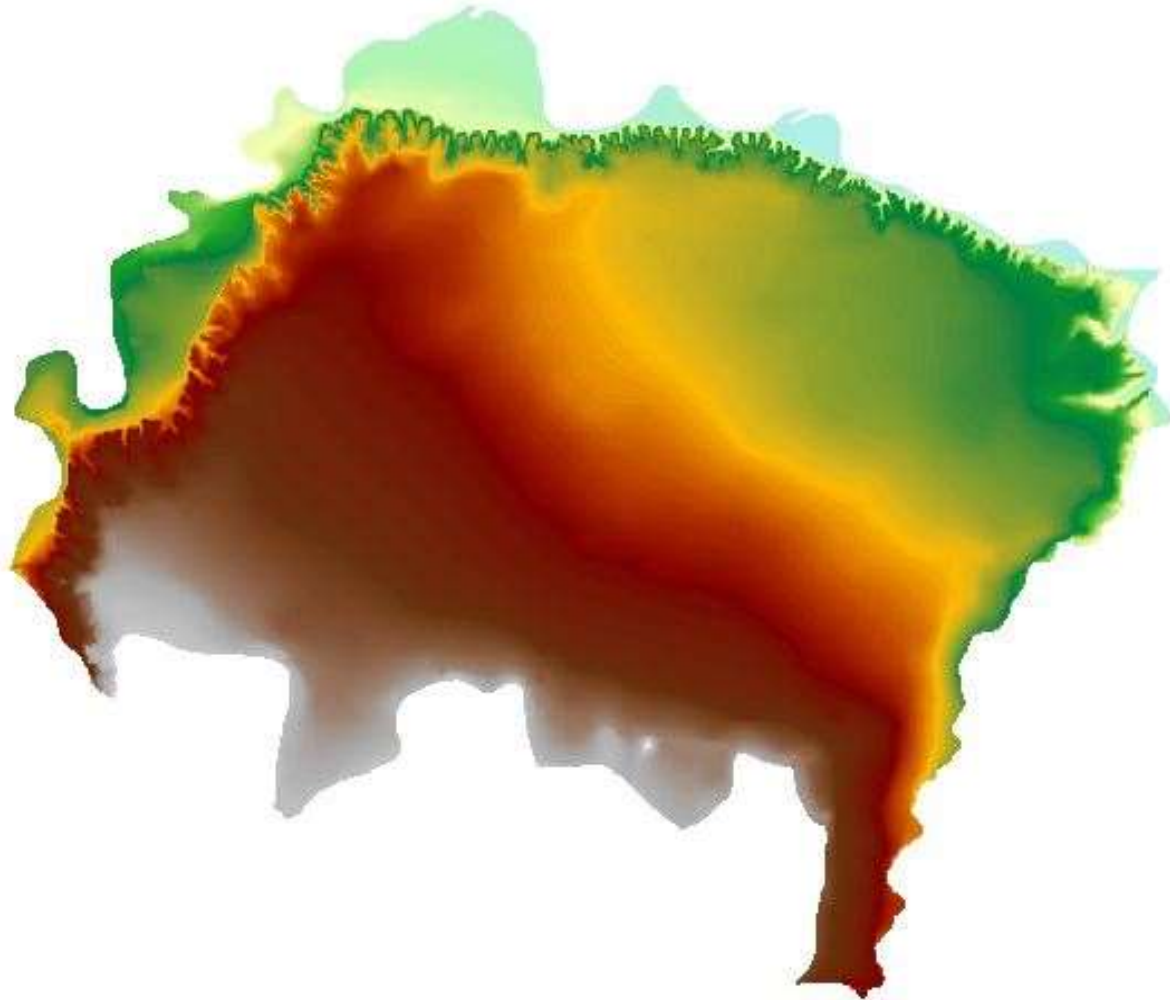
Alluvial Recharge Feasibility Studies



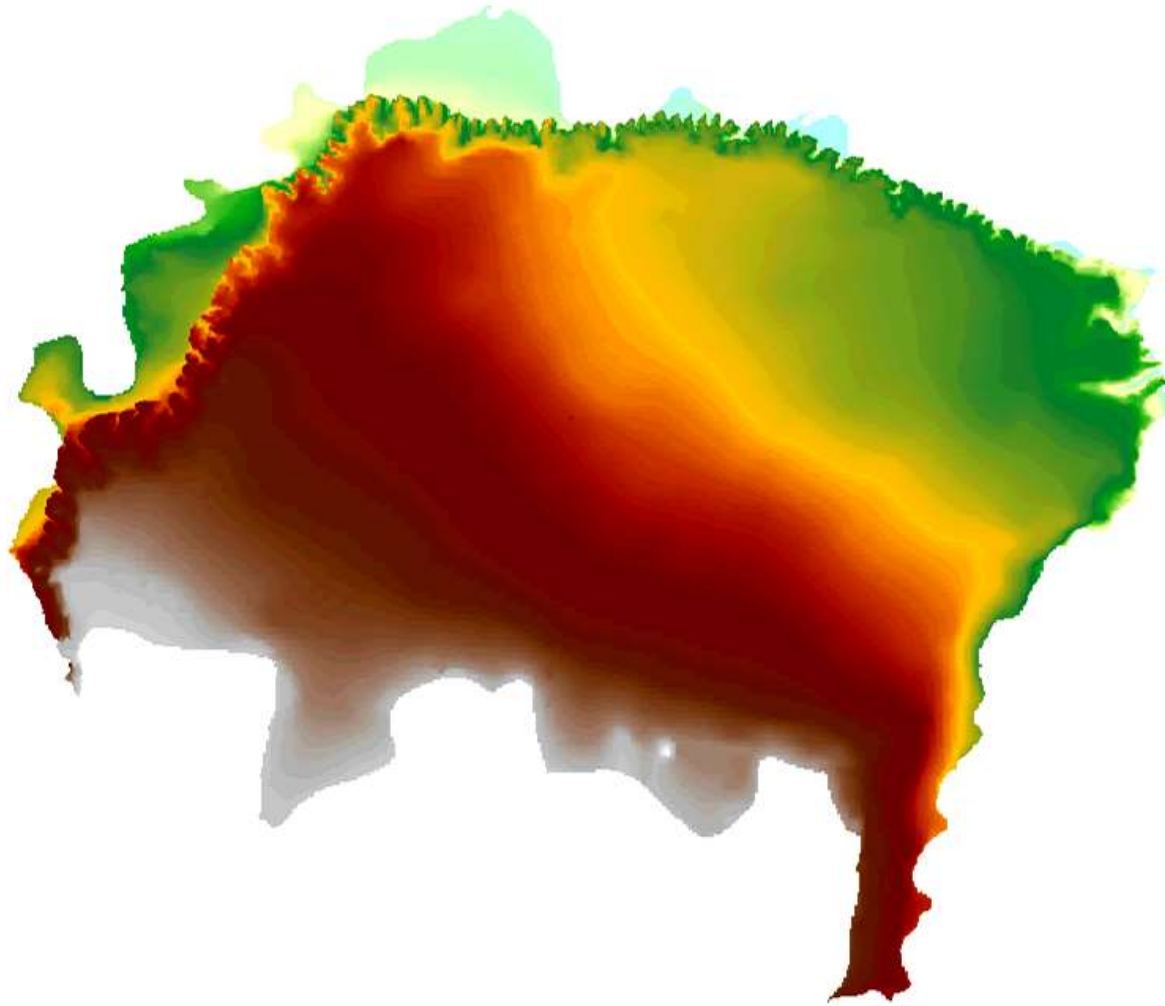
Alluvial Recharge Feasibility Studies



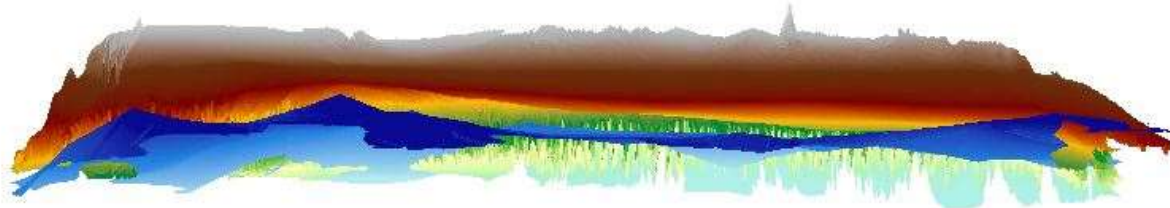
Alluvial Recharge Feasibility Studies



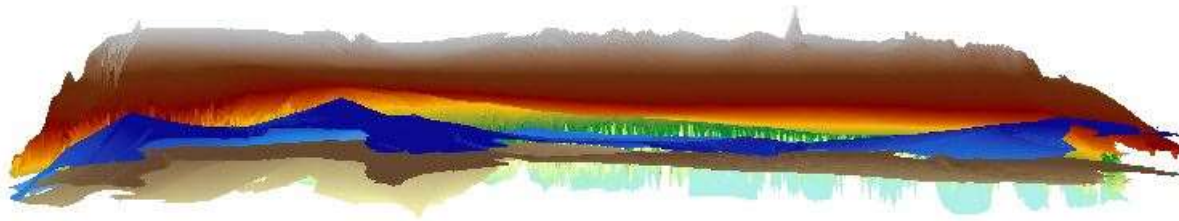
Alluvial Recharge Feasibility Studies



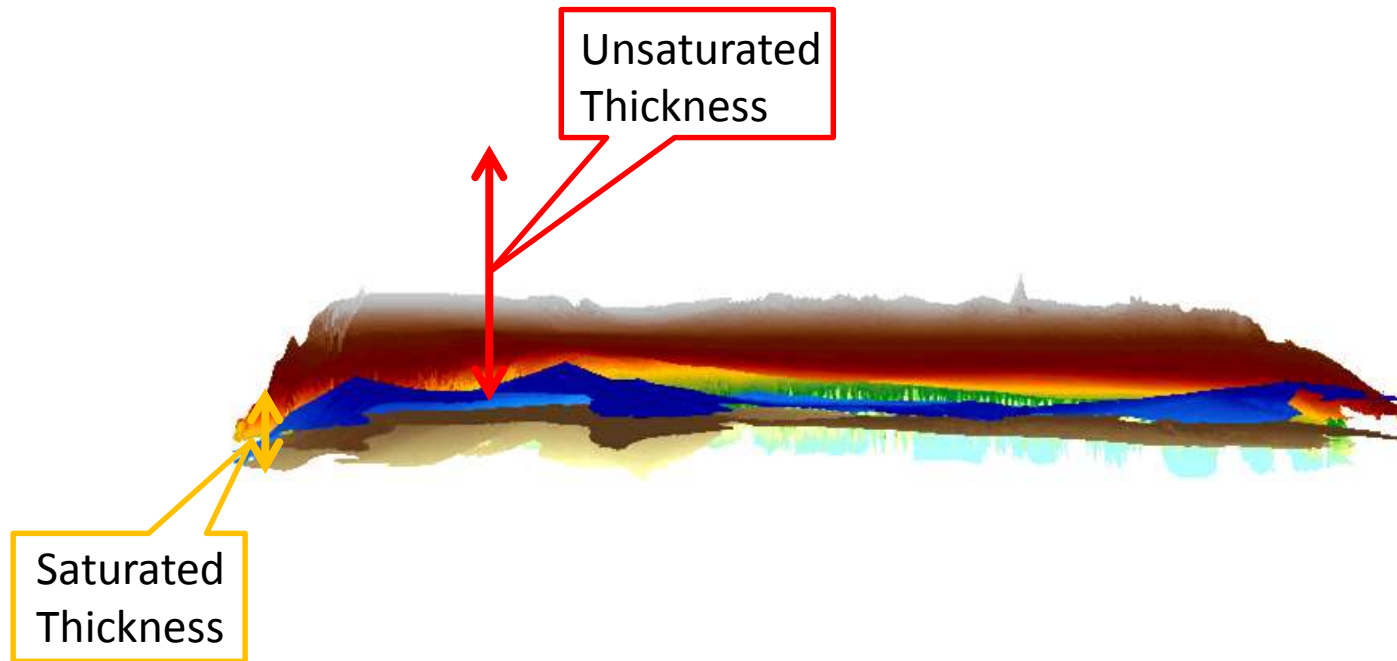
Alluvial Recharge Feasibility Studies



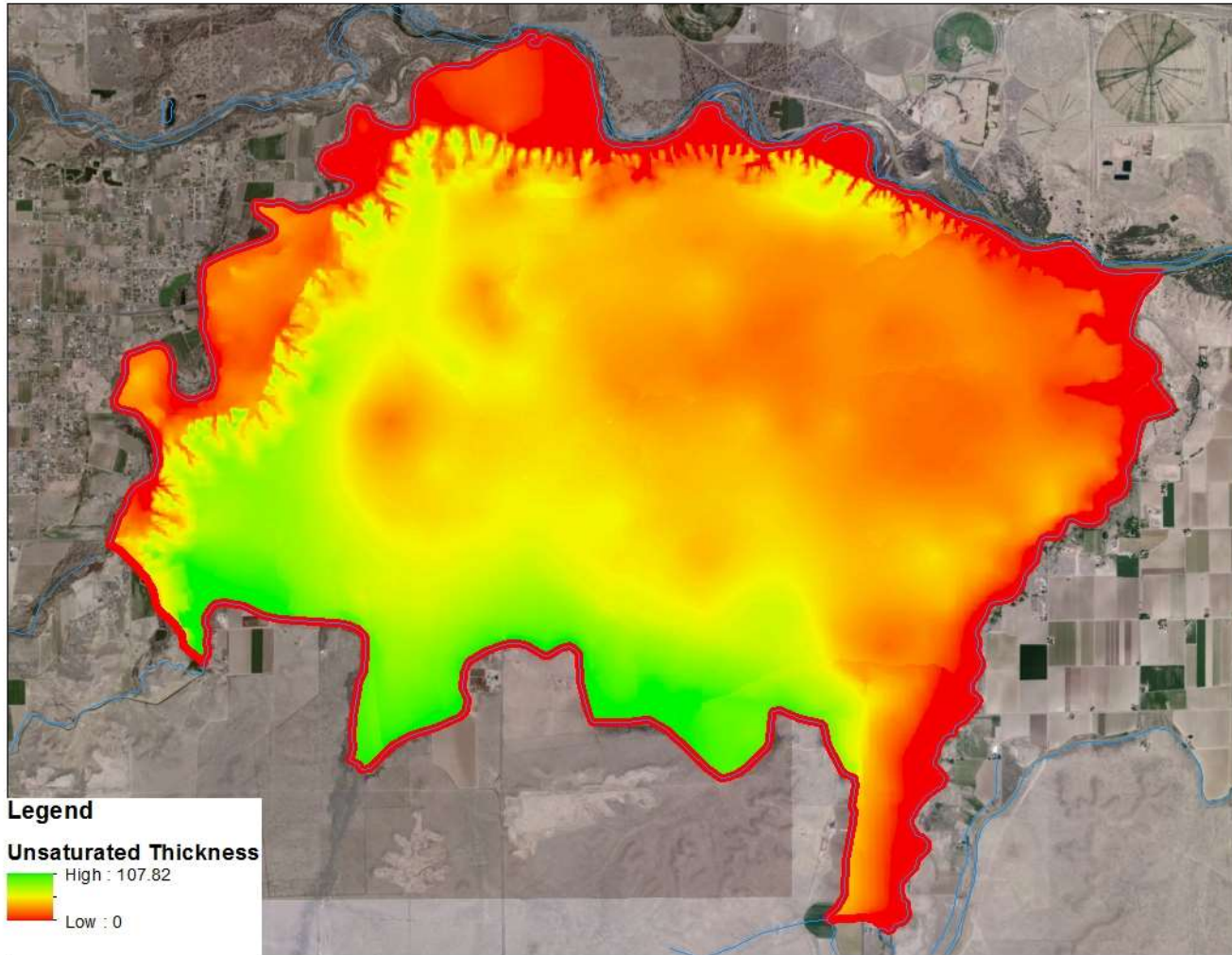
Alluvial Recharge Feasibility Studies



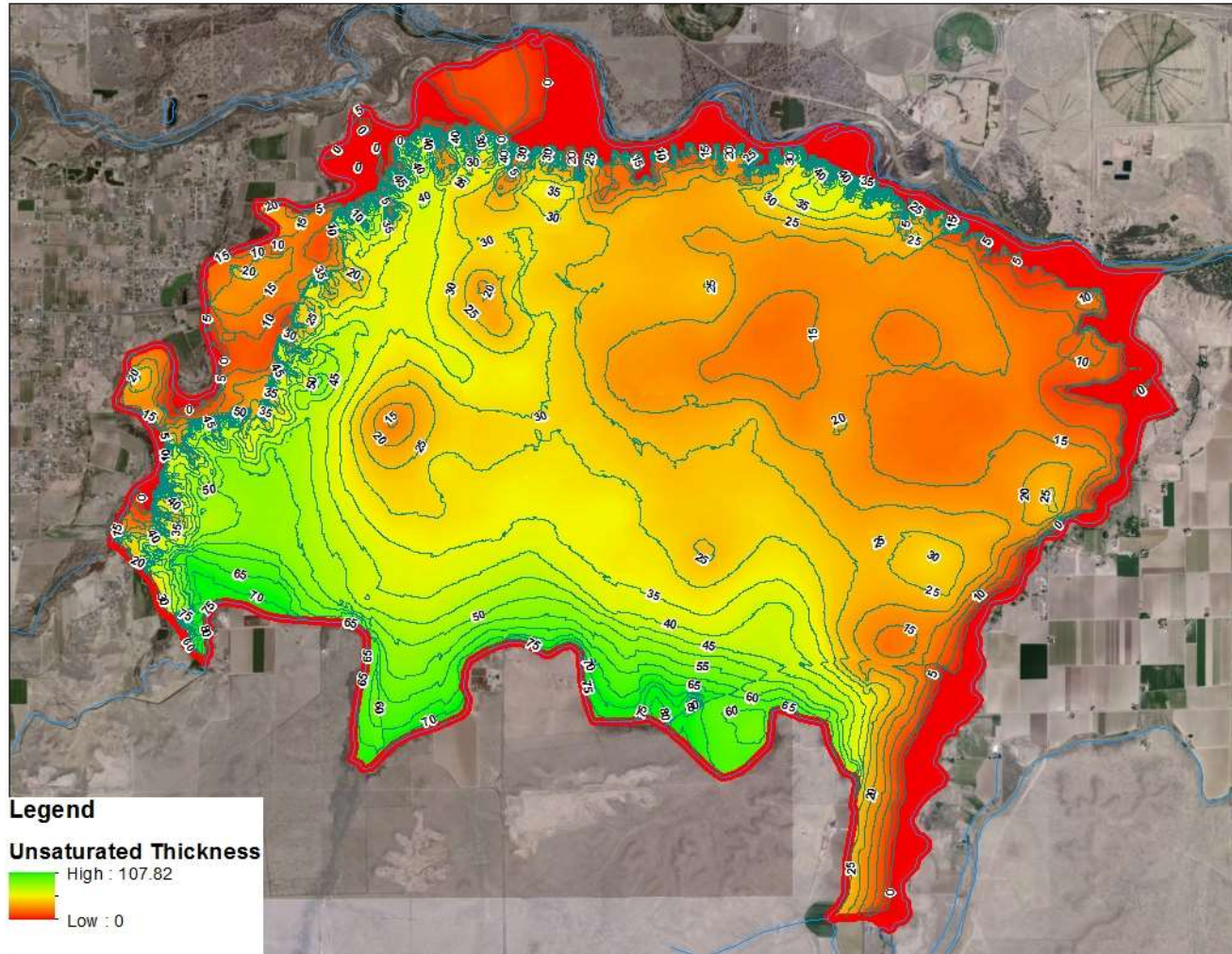
Alluvial Recharge Feasibility Studies



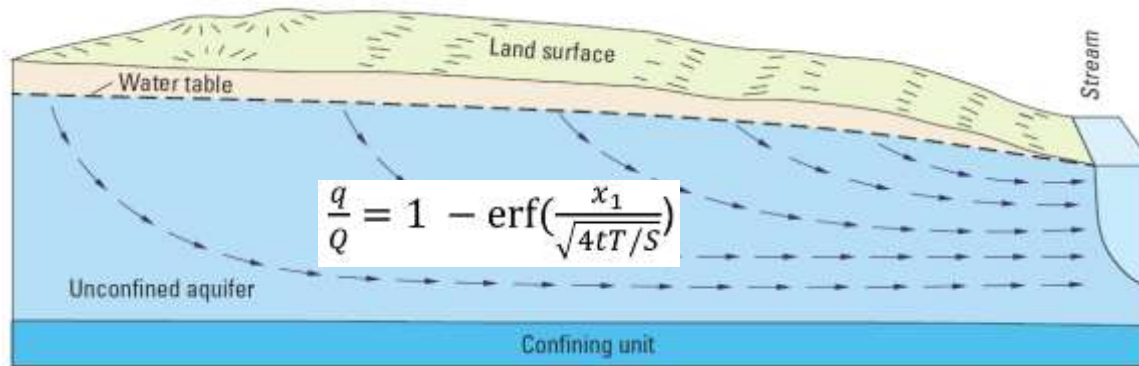
Alluvial Recharge Feasibility Studies



Alluvial Recharge Feasibility Studies



Modeling Alluvial Recharge

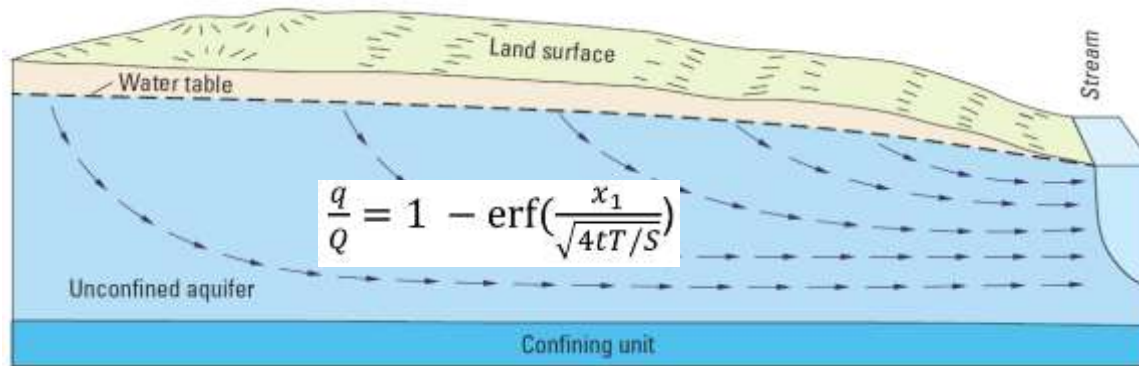


Analytical
Models

Modeling Alluvial Recharge

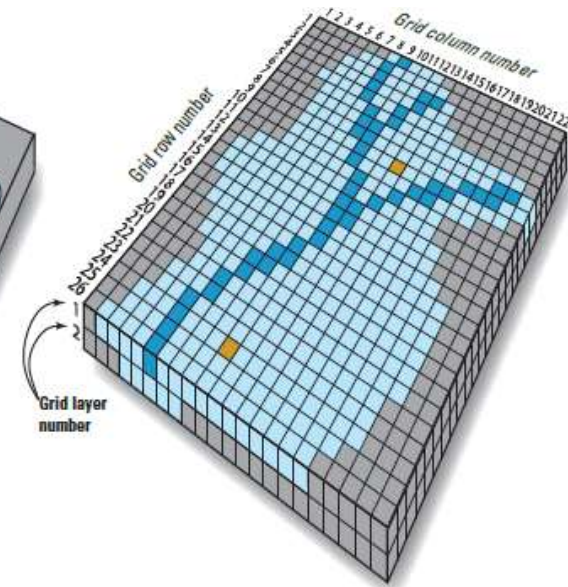
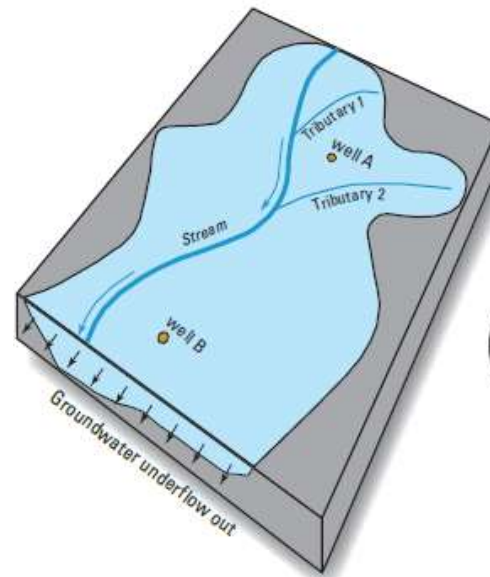
$$\frac{q}{Q} = 1 - \operatorname{erf}\left(\frac{x_1}{\sqrt{4tT/S}}\right)$$

Modeling Alluvial Recharge



Analytical Models

Numerical Models

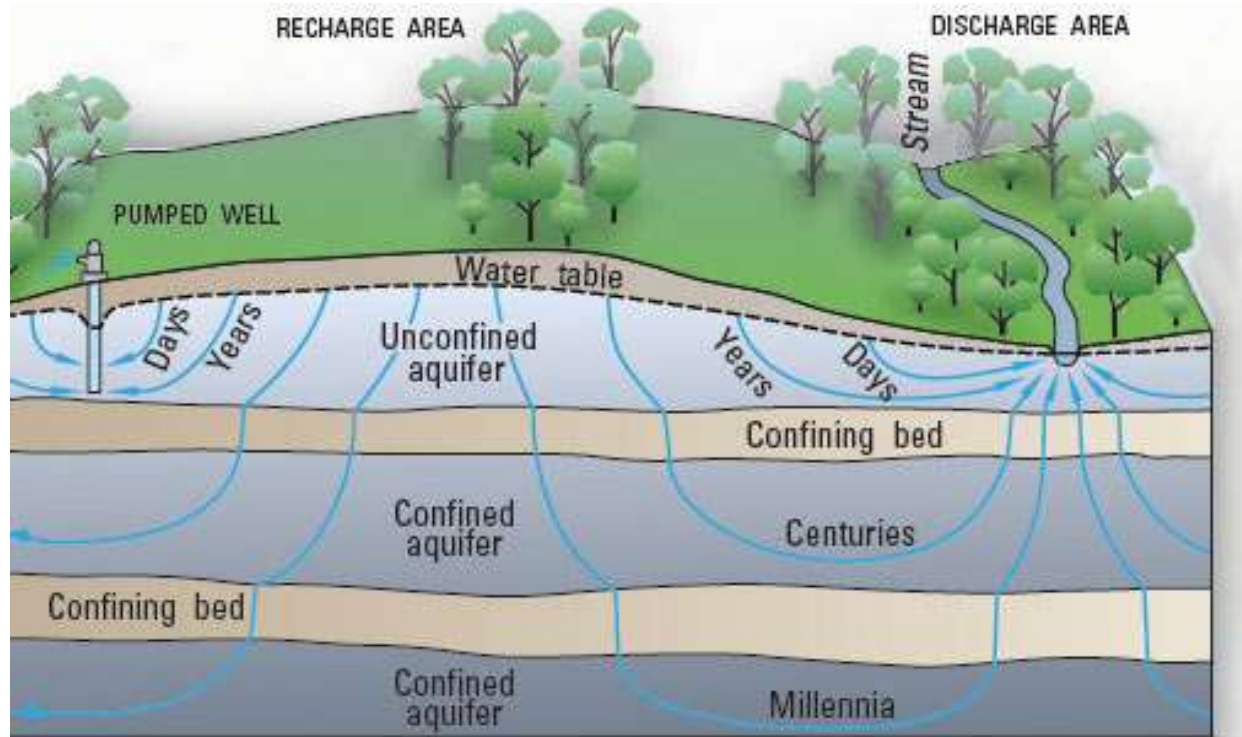


Source:
Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, 84 p. (Also available at <http://pubs.usgs.gov/circ/1376/>)

Limitations/Considerations of Alluvial Recharge

Limitations/Considerations of Alluvial Recharge

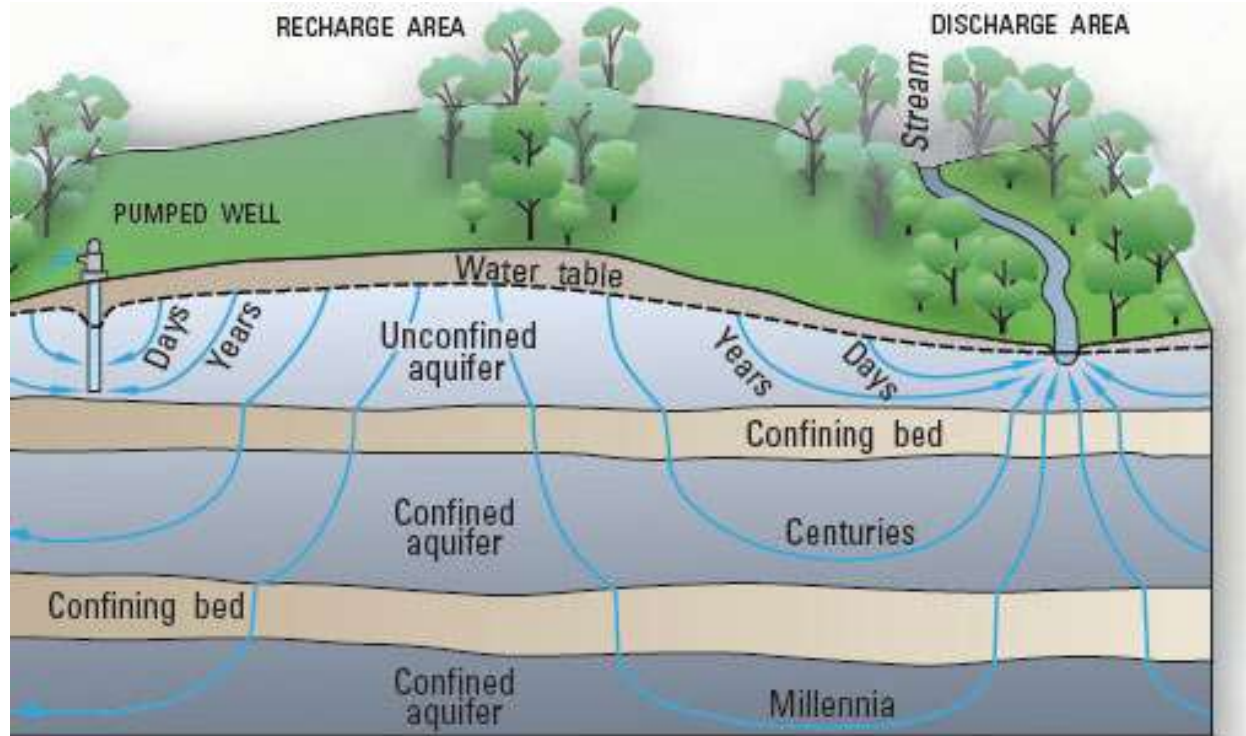
- Uncertainty



Source:
Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, 84 p.
(Also available at <http://pubs.usgs.gov/circ/1376/>)

Limitations/Considerations of Alluvial Recharge

- Uncertainty
- Dominion and Control



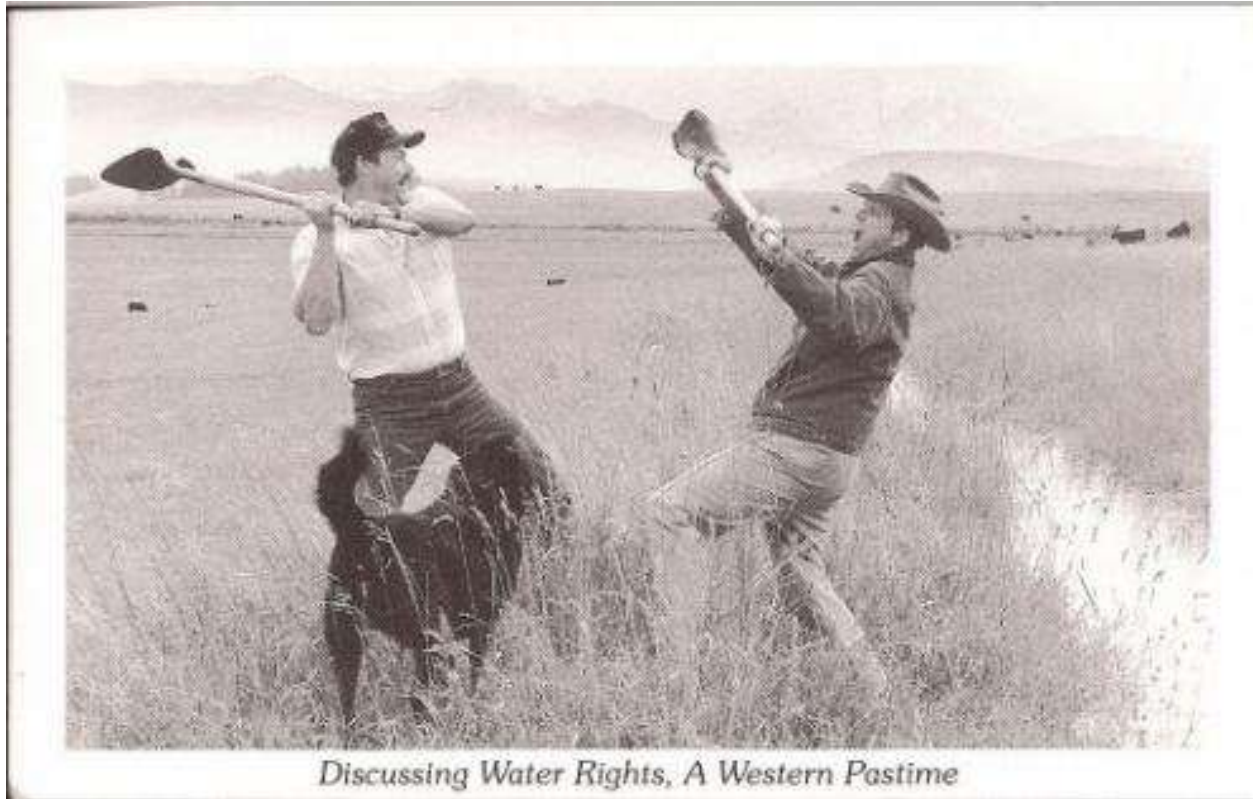
Source:
Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, 84 p.
(Also available at <http://pubs.usgs.gov/circ/1376/>)

Limitations/Considerations of Alluvial Recharge



- Uncertainty
- Dominion and Control
- **Regulatory concerns**

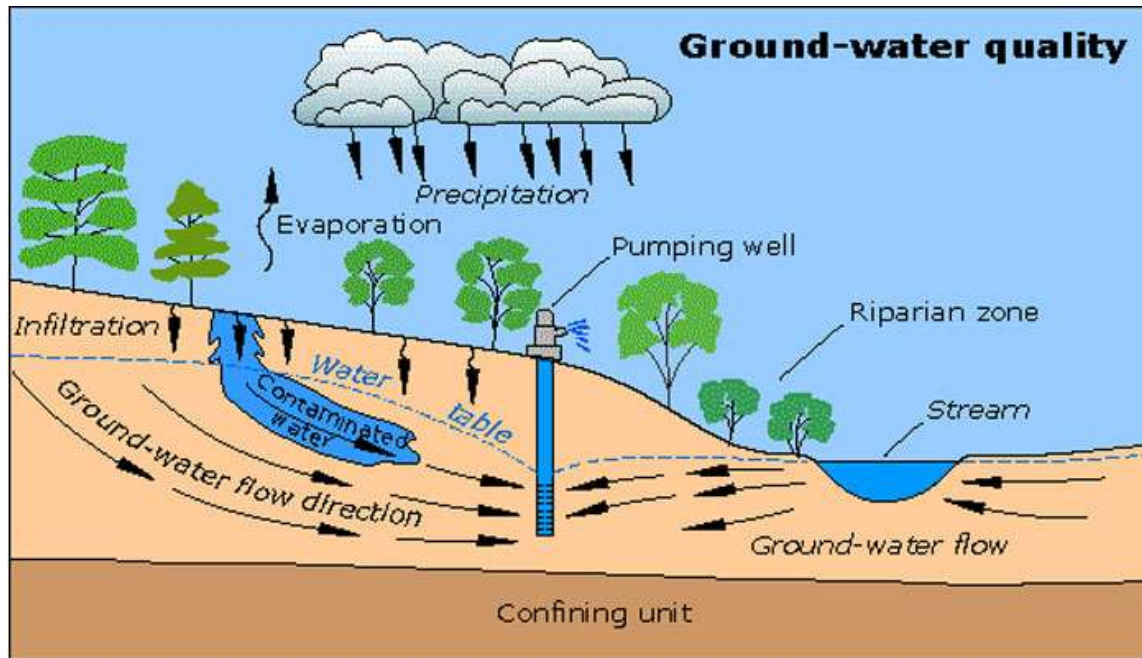
Limitations/Considerations of Alluvial Recharge



Source: http://www.onearth.org/files/onearth/water_rights.jpg

- Uncertainty
- Dominion and Control
- Regulatory concerns
- **Water Rights/
Beneficial Use**

Limitations/Considerations of Alluvial Recharge



- Uncertainty
- Dominion and Control
- Regulatory concerns
- Water Rights/Beneficial Use
- **Water Quality Impacts**

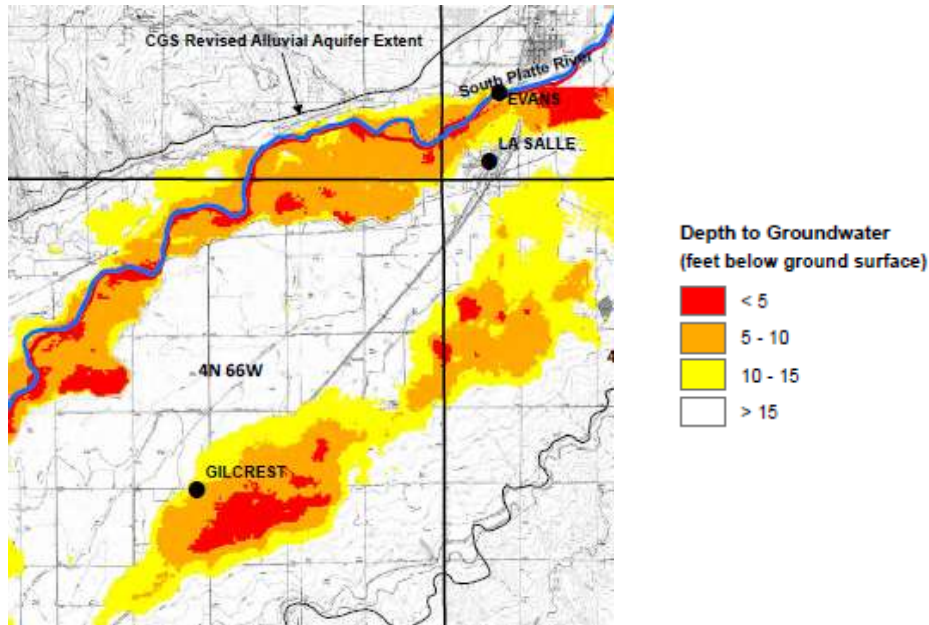
Source: <http://www.learner.org/courses/envsci/unit/text.php?unit=8&secNum=8>

Limitations/Considerations of Alluvial Recharge

Gilcrest/LaSalle Pilot Project Hydrogeologic Characterization R



COLORADO GEOLOGICAL SURVEY



- Uncertainty
- Dominion and Control
- Regulatory concerns
- Water Rights/Beneficial Use
- Water Quality Impacts
- Increased non-beneficial plant use
- Unintended high groundwater

<http://water.state.co.us/DivisionsOffices/Div1SPlatteRiverBasin/Pages/GilcrestLaSalleGroundwaterPilotProject.aspx>

Thank You!