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Carmel River Model

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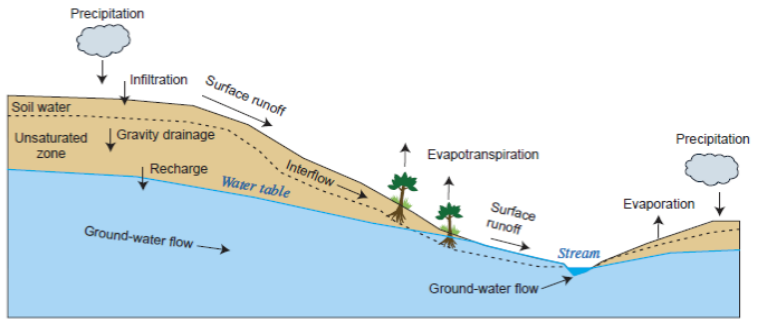
GSFLOW—Coupled Ground-Water and Surface-Water Flow Model Based on the Integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005)

Chapter 1 of
Section D, Ground-Water/Surface-Water
Book 6, Modeling Techniques

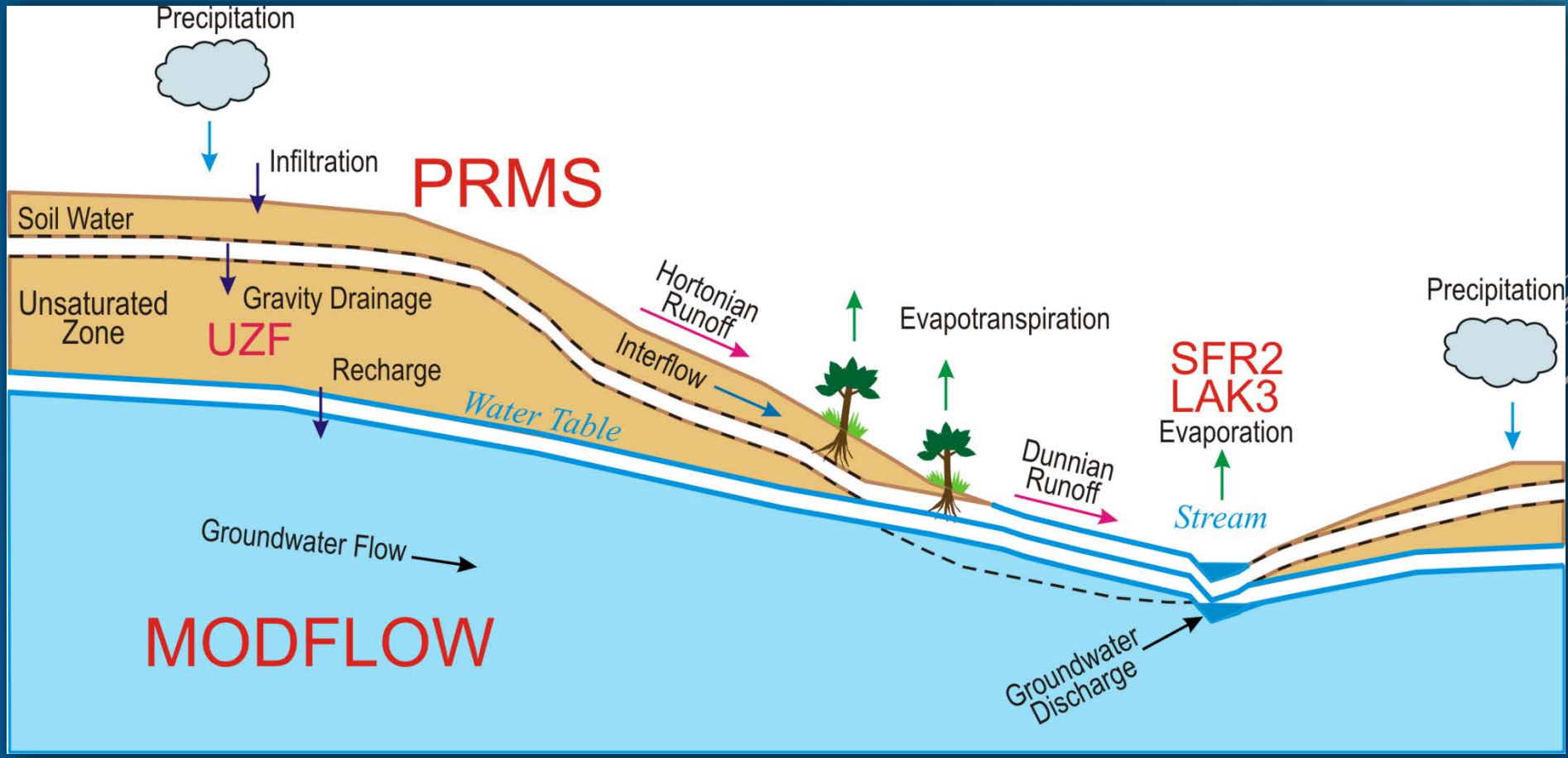


By Steven L. Markstrom, Richard G. Niswonger, R. Steven Regan, David E. Prudic, and Paul M. Barlow

U.S. Department of the Interior
U.S. Geological Survey

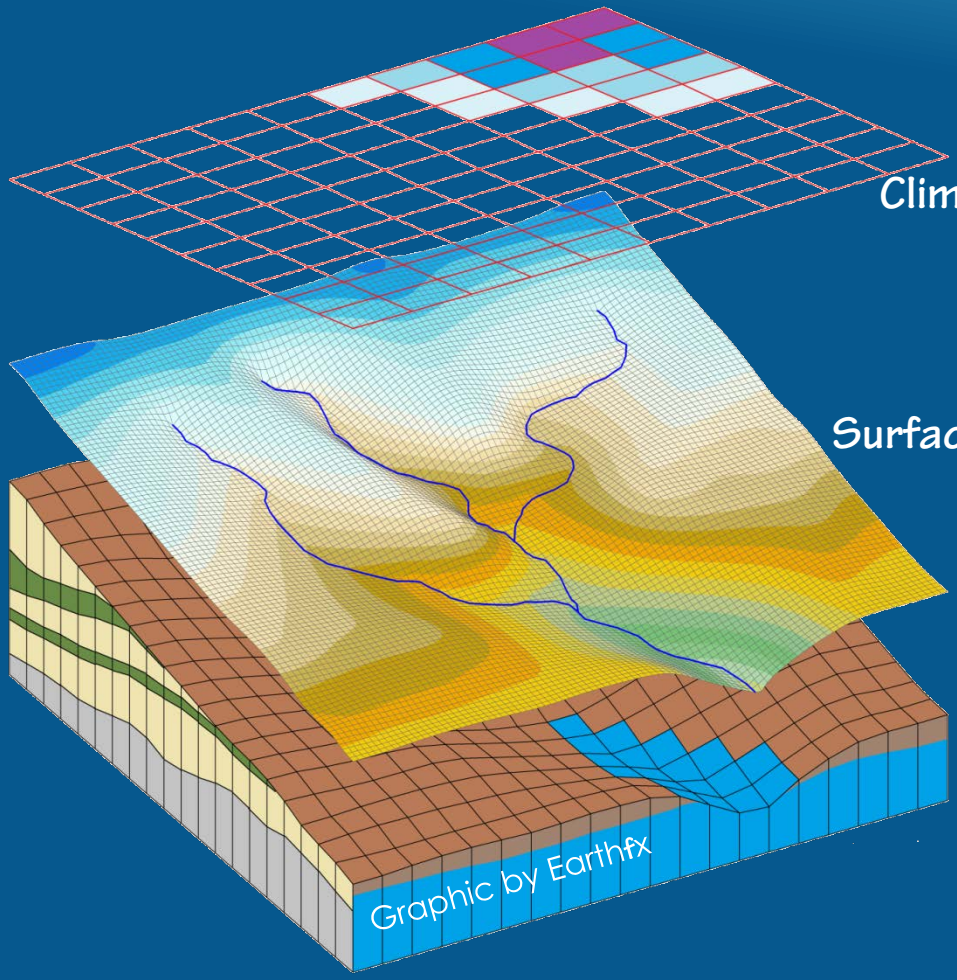
GSFLOW integrates MODFLOW and PRMS

GSFLOW—Simulation Of All Major Hydrologic Processes



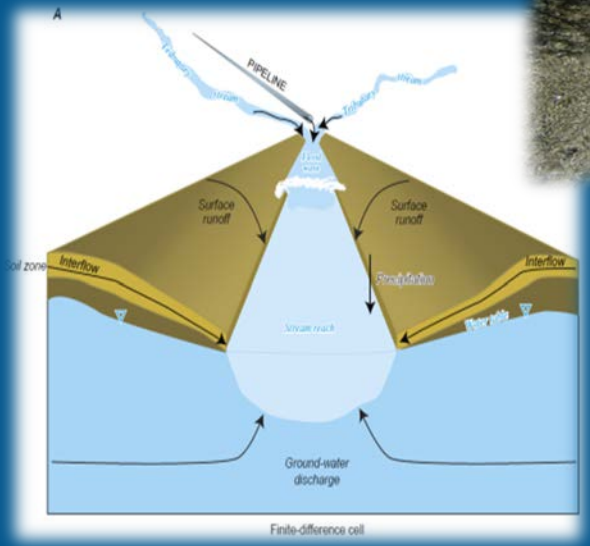
Design Concepts

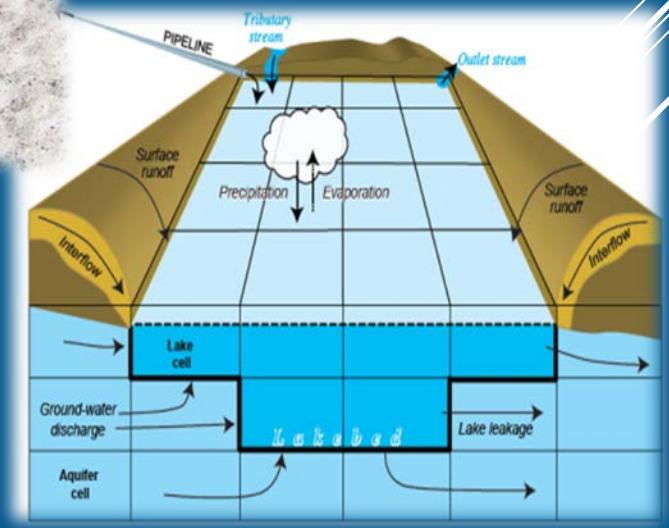
Surface and subsurface layers (PRMS to MODFLOW-NWT)



Design Concepts

Streams and lakes represented explicitly, flows routed

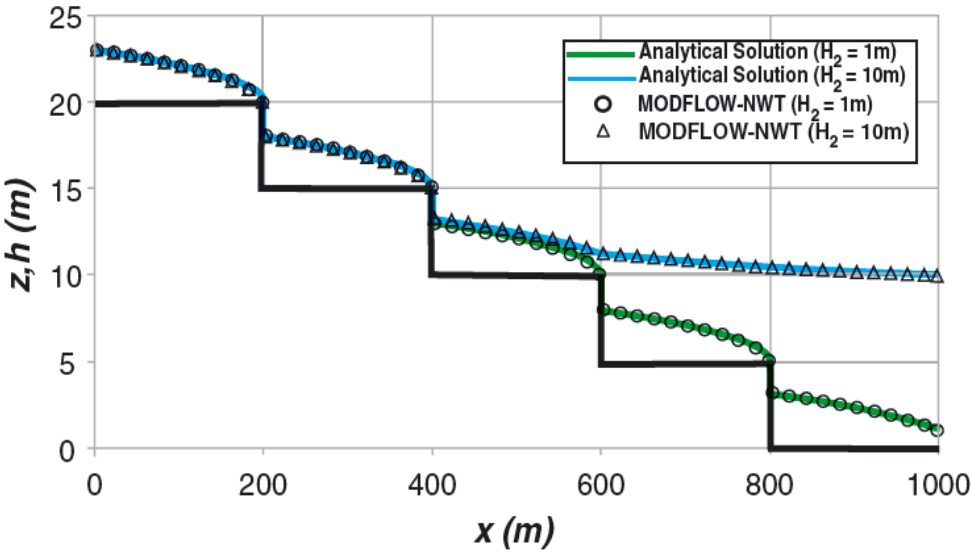


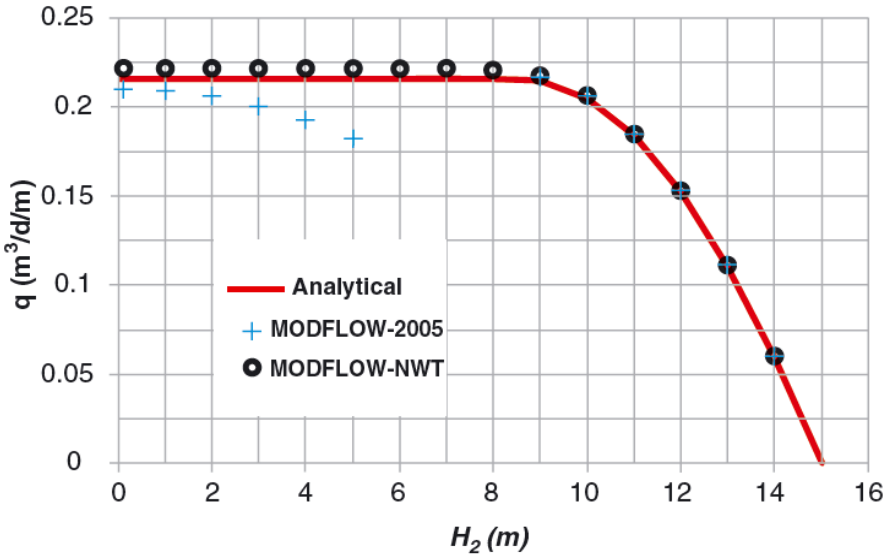


MODFLOW-NWT—Suited for Modeling Mountains

Niswonger, Panday, and Ibaraki, 2011, *U.S.G.S. T&M 6-A37*

Comparison to new analytical solutions for discontinuous aquifers

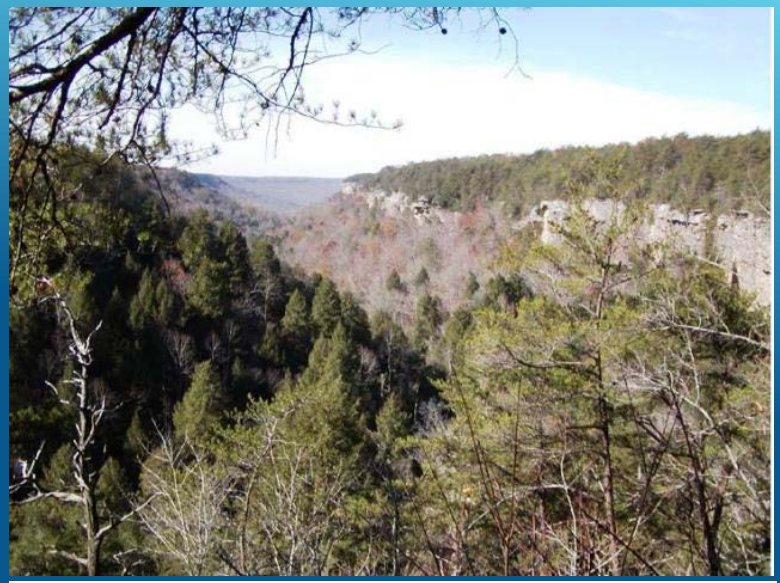


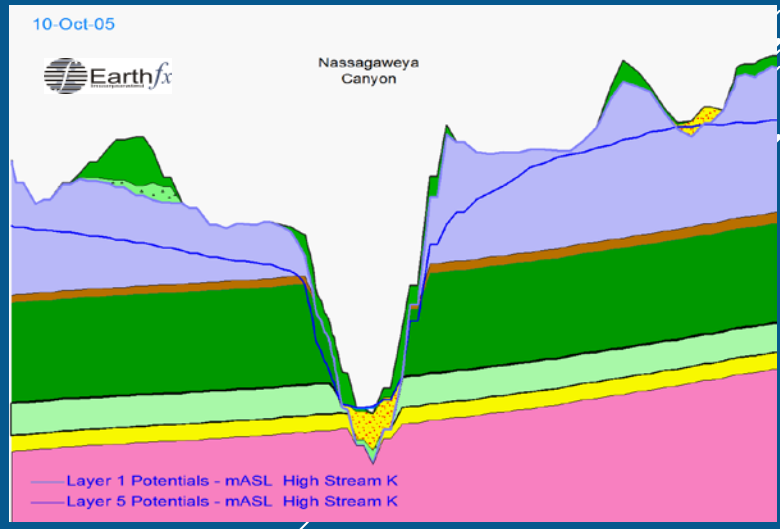


Jaidel, J, Ground Water, 2013

Design Concepts

- *Large contrasts in hydraulic conductivity, recharge, and runoff*
- *Steep topography, large hydraulic gradients*
- *Springs, seepage faces, (water falls!)*
- *Discontinuous aquifers (wet-dry issues)*





MODFLOW-NWT simulation

Why GSFLOW for the Carmel River Basin

- *Climate forcing (PPT and T) input directly and recharge process is simulated*
- *River flow and groundwater recharge is generated throughout the basin; need a way to simulate watershed processes and dynamic (daily) hydrograph*
- *SW-GW interactions very important for lows flows (e.g., river recharge and bank storage)*
- *Recharge occurs within dense network of intermittent streams (explicit representation)*
- *Representation of reservoirs and operation strategies*

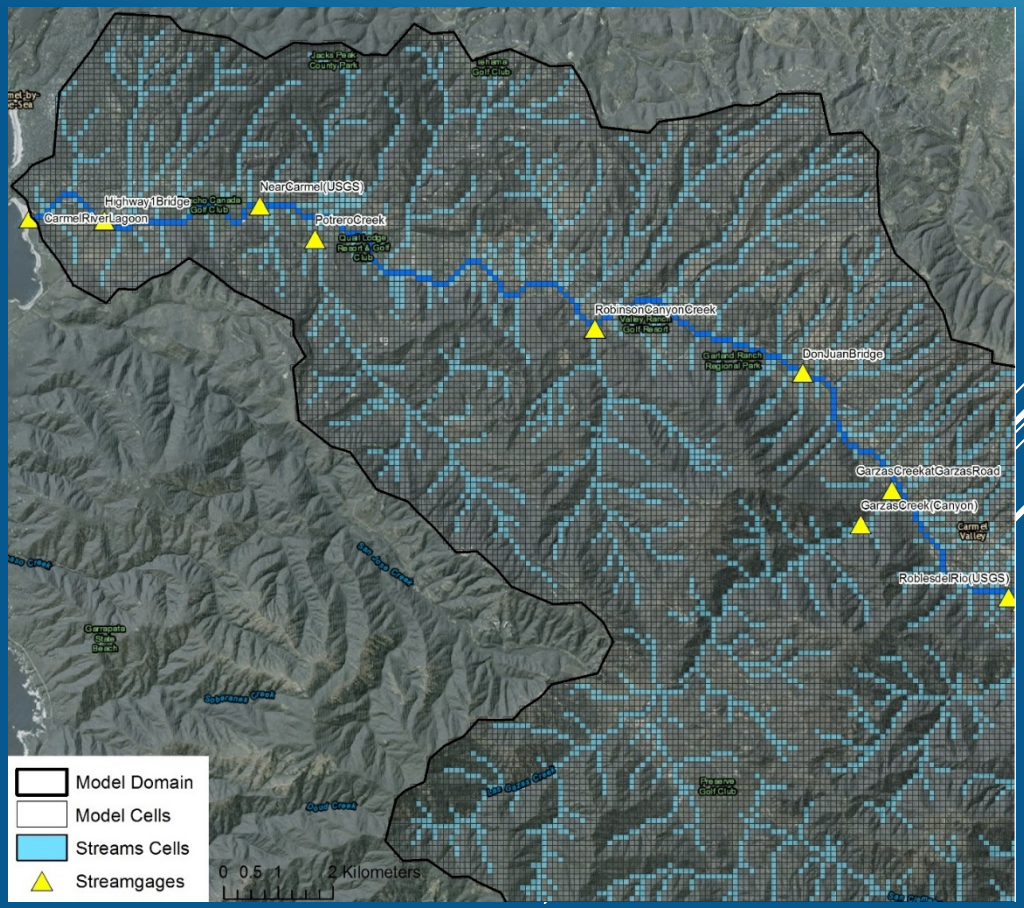
Objectives/Purpose of Model

Simulate/evaluate:

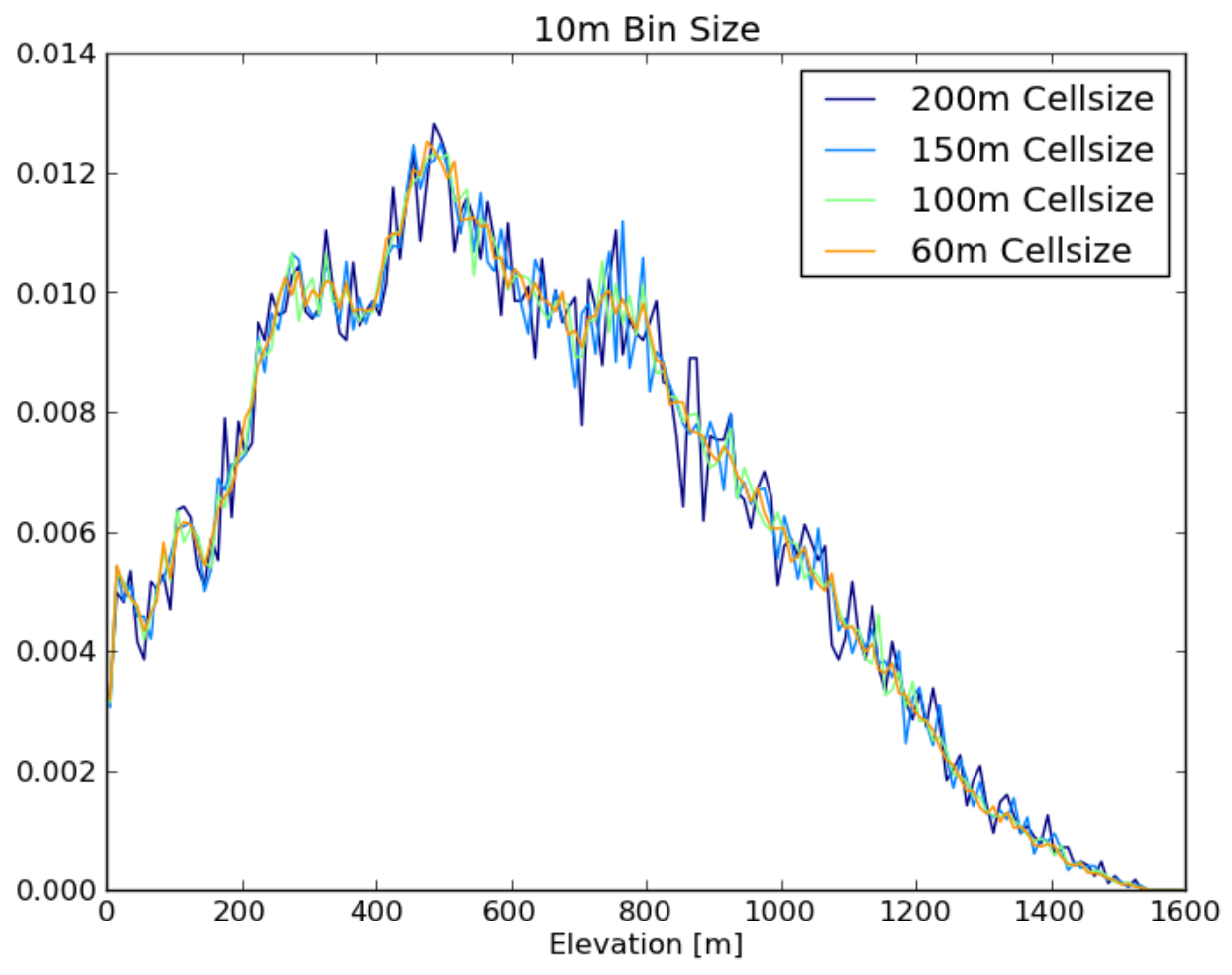
- Future changes in Cal-Am operations (i.e., Order 95-10 compliance)
- Los Padres dam alternatives; dam removal, sediment management, raising of dam
- Diversion impacts on fish passage
- Effects of climate change (Carmel River Basin Study with BOR); flow in river, groundwater sustainability

MODEL CONSTRUCTION

- *100m x 100m Grid cells, 3 Layers, 328 rows, and 426 columns; daily time steps/stress periods*
- *Layer 1, river and trib cells; layer 2 principal aquifer; layer 3 weathered basement*
- *Streamflow routing Package (SFR2) for routing streamflow; Lake Package for Los Padres Reservoir;*

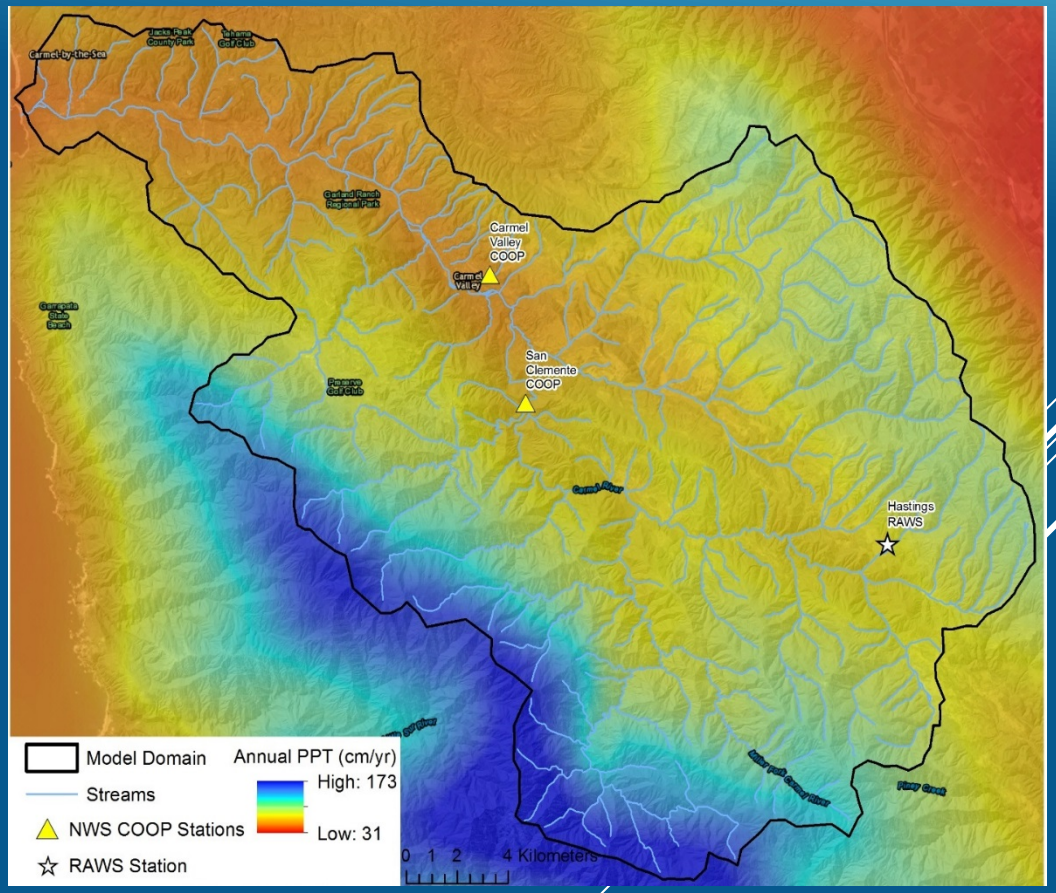


CHOICE OF MODEL CELL SIZE



DISTRIBUTING CLIMATE

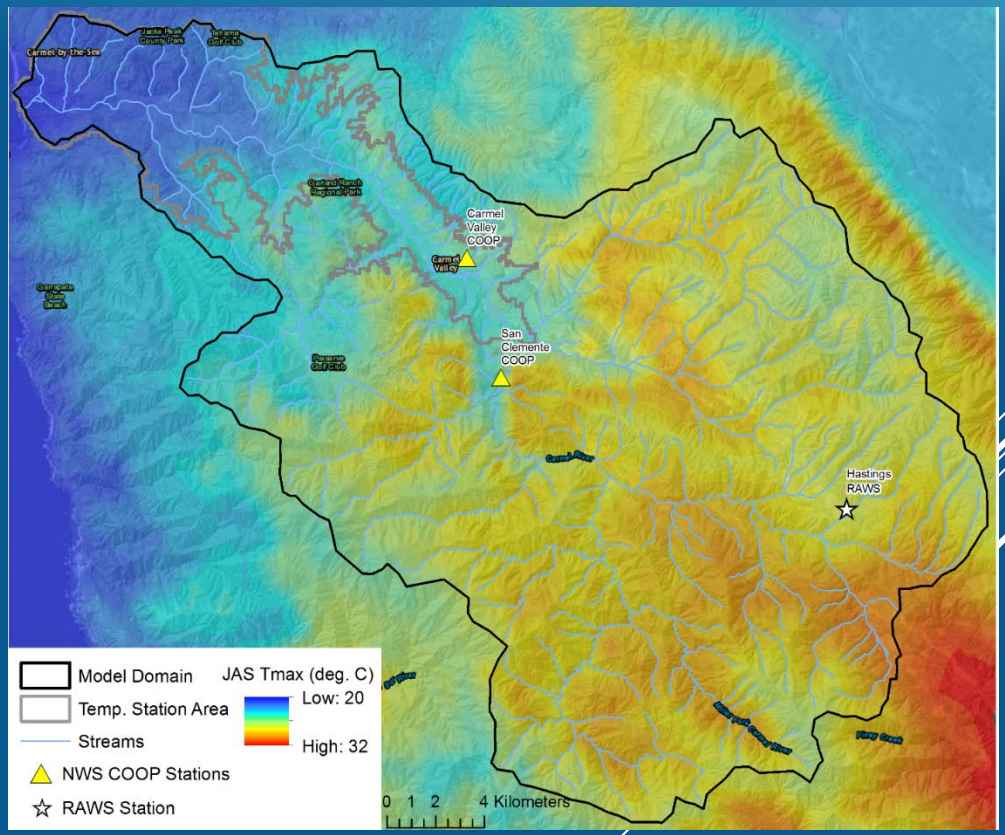
- PRISM mean annual (1981-2010) precipitation
- climate stations used to distribute precipitation and temperature
- calibrate precipitation, solar radiation, and potential ET module parameters
- Majority of precipitation falls at high altitudes near the southern watershed boundary



DISTRIBUTING CLIMATE

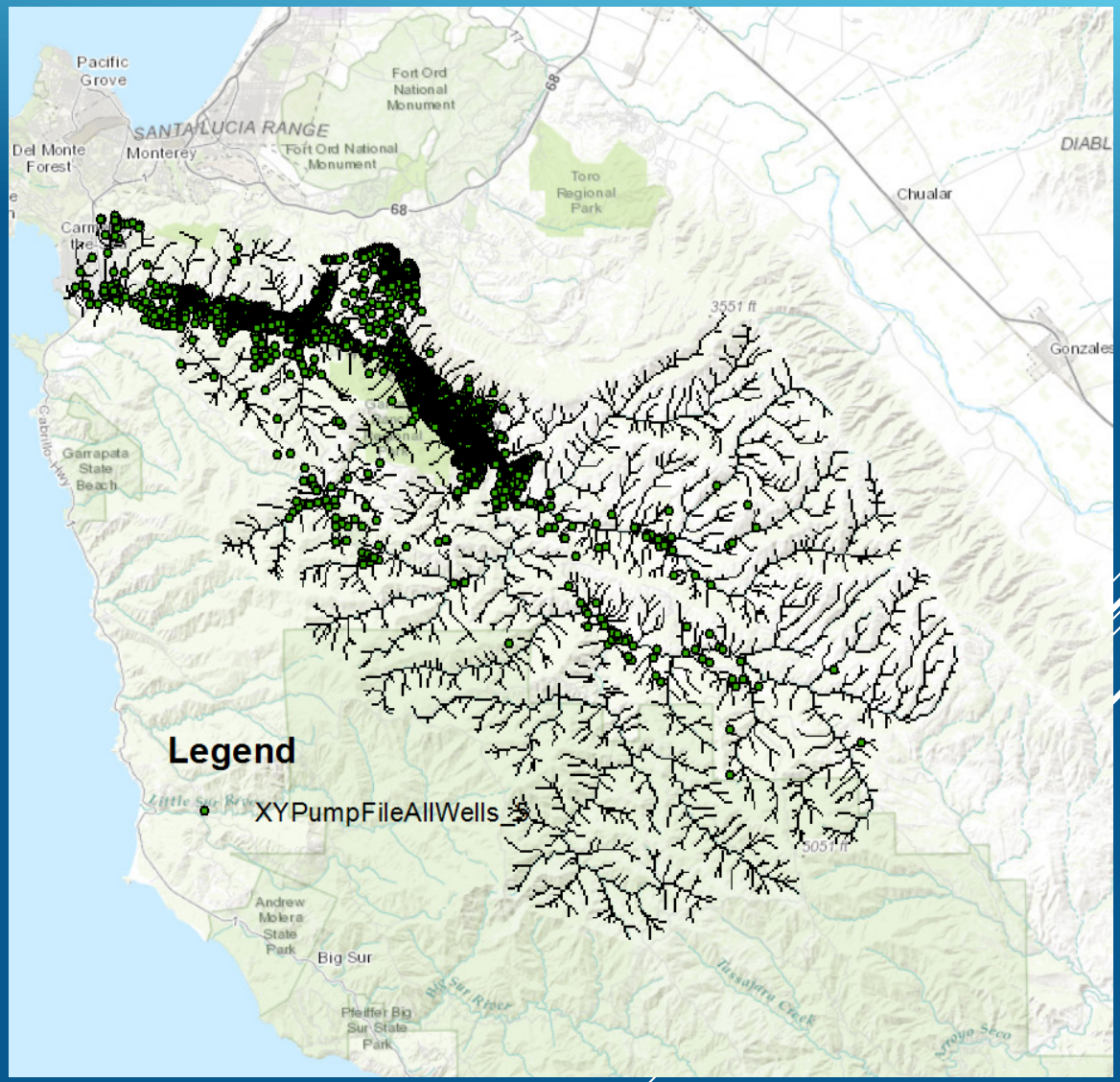
- PRISM July, August, September (JAS) monthly average maximum temperature

- Grey area uses Carmel Valley COOP station for T
- Uplands area uses Hastings RAWS station
- Represent T inversions

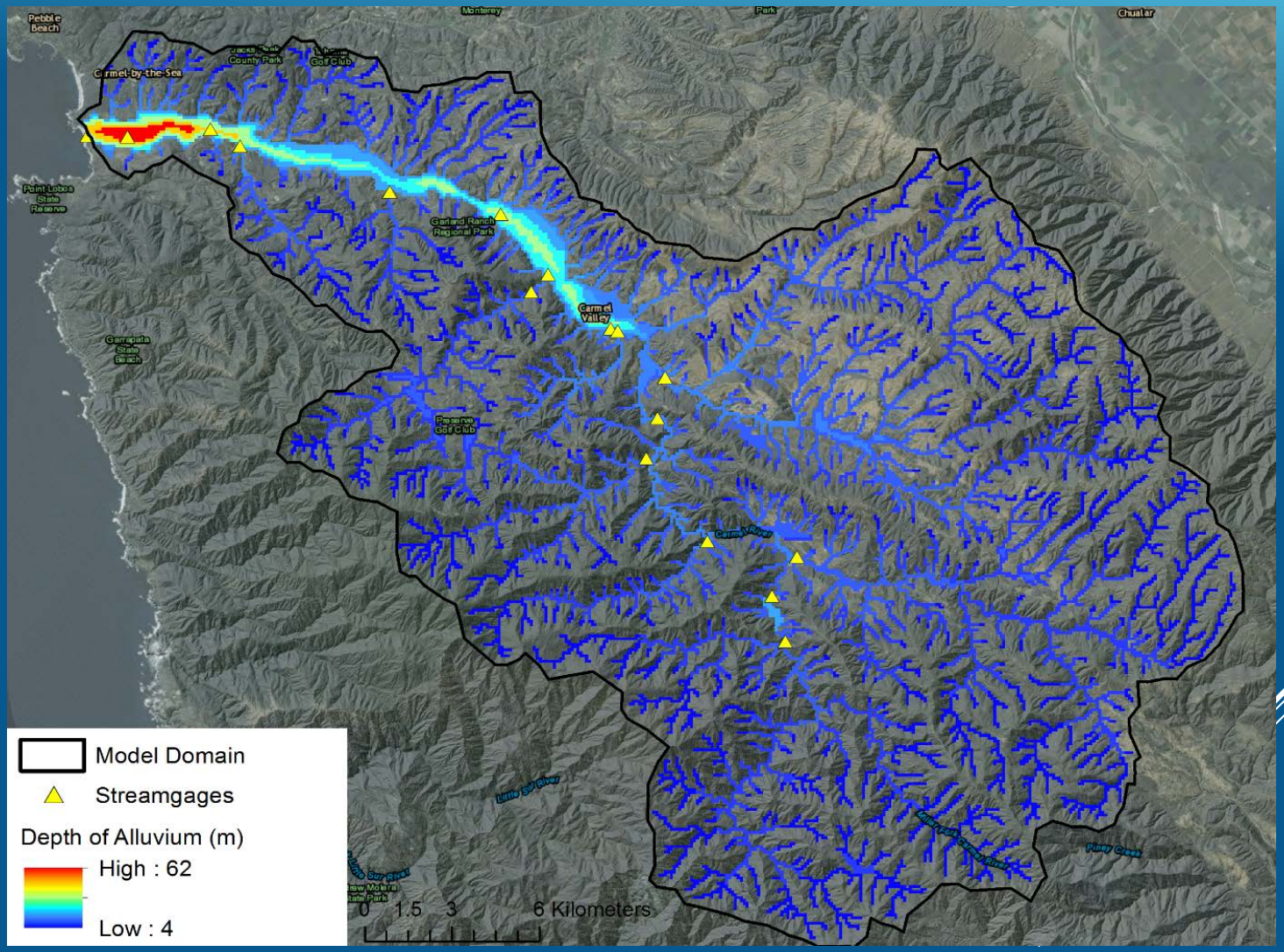


GROUNDWATER PUMPING

- Pumping data from CalAm monthly meter reads for all wells
- Private wells reported annually. District reads meters of larger producing wells; monthly water usage by sector (agriculture, domestic, industrial, rural); information used to estimate monthly pumping.
- Wells outside of the District, the District has a land use estimation method for non-metered wells (90% of the wells in the model domain are metered.)



DEPTH OF ALLUVIUM



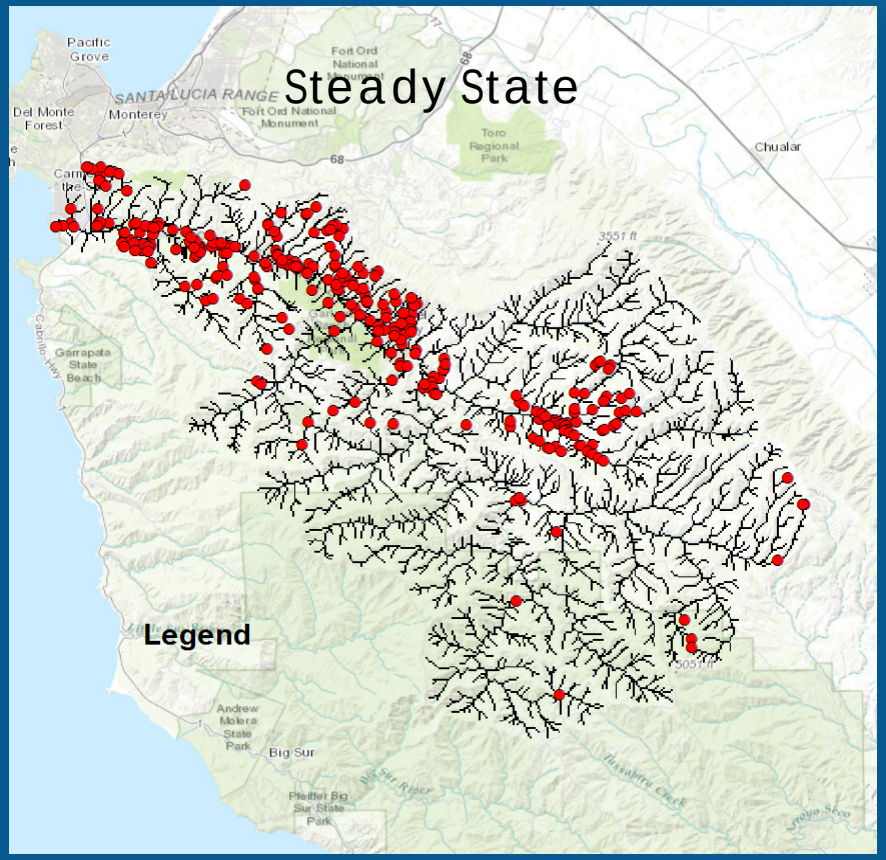
CALIBRATION PROCESS

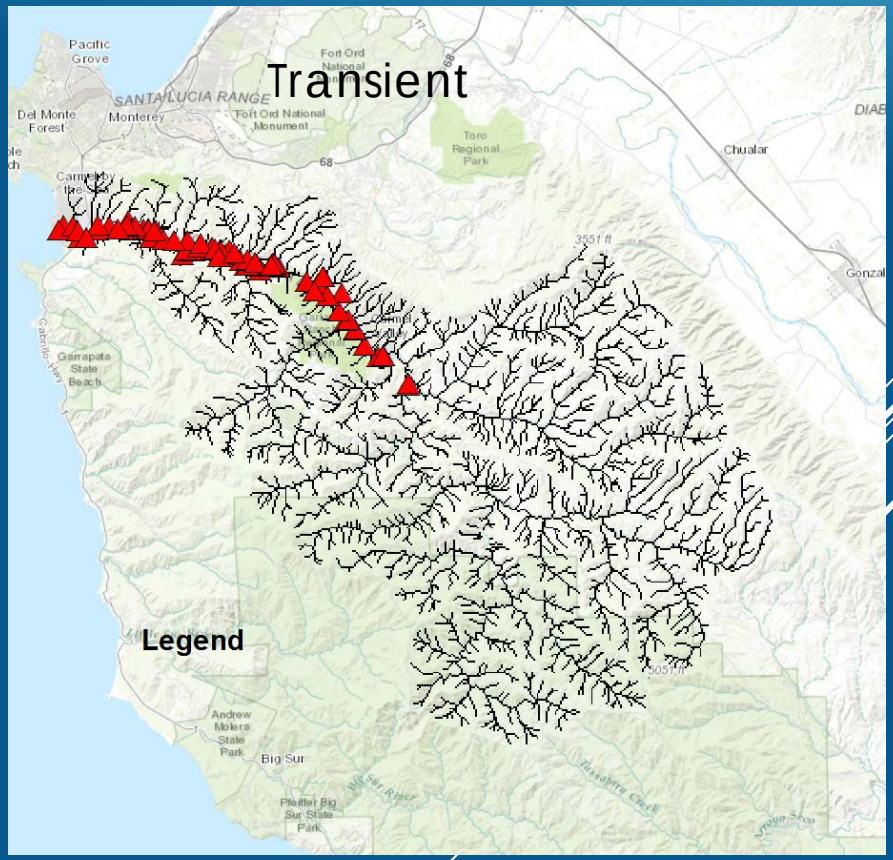
- *Steady state calibration using average climate and stresses for 1980-1990 period (GW heads, average River flow, baseflow)*

- *Transient calibration for 1990-1995*
- *Post assessment for 1995-2014*

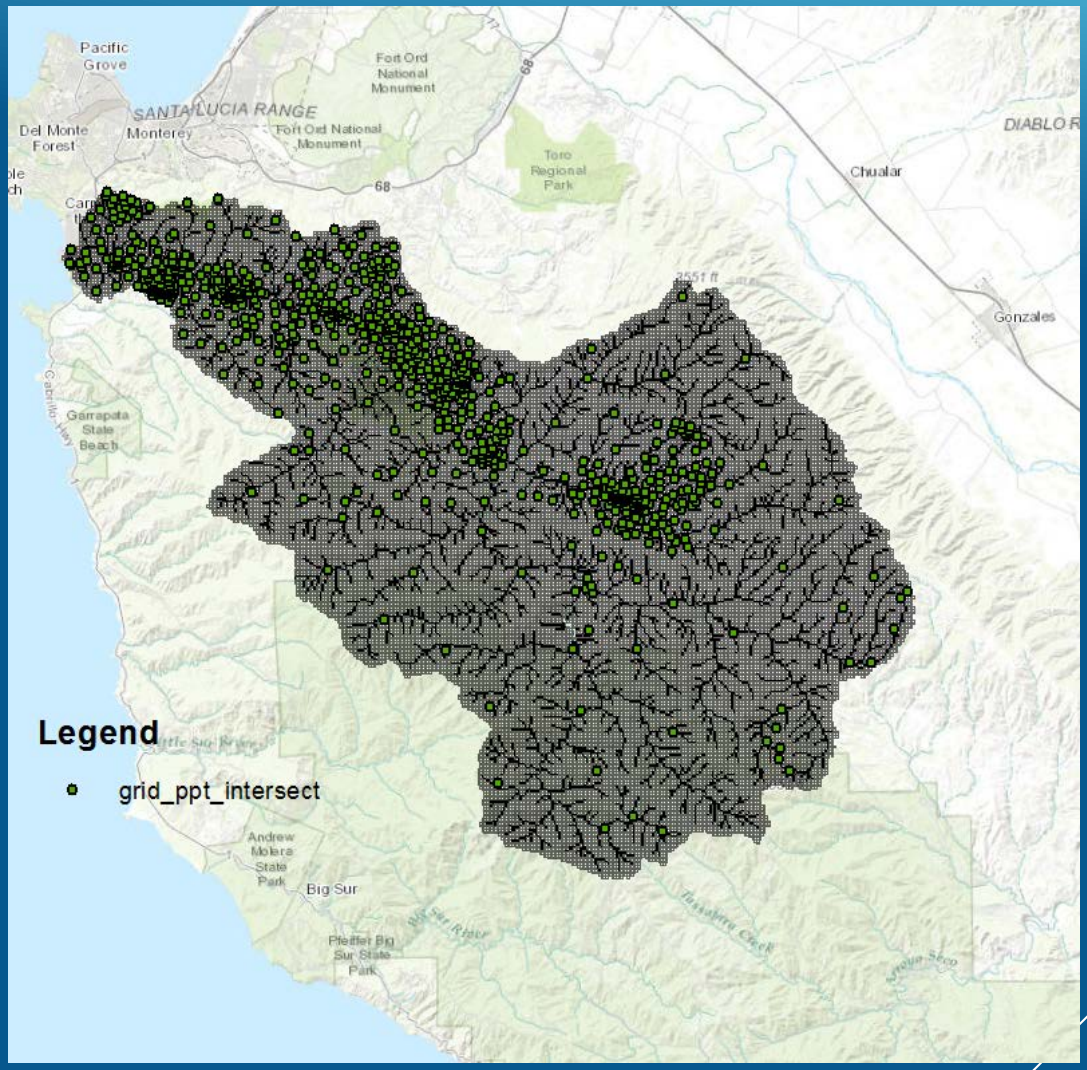
- *Calibration using Pest with pilot points; observations include GW heads, river flows, and total GW pumping*

OBSERVATIONS WELLS

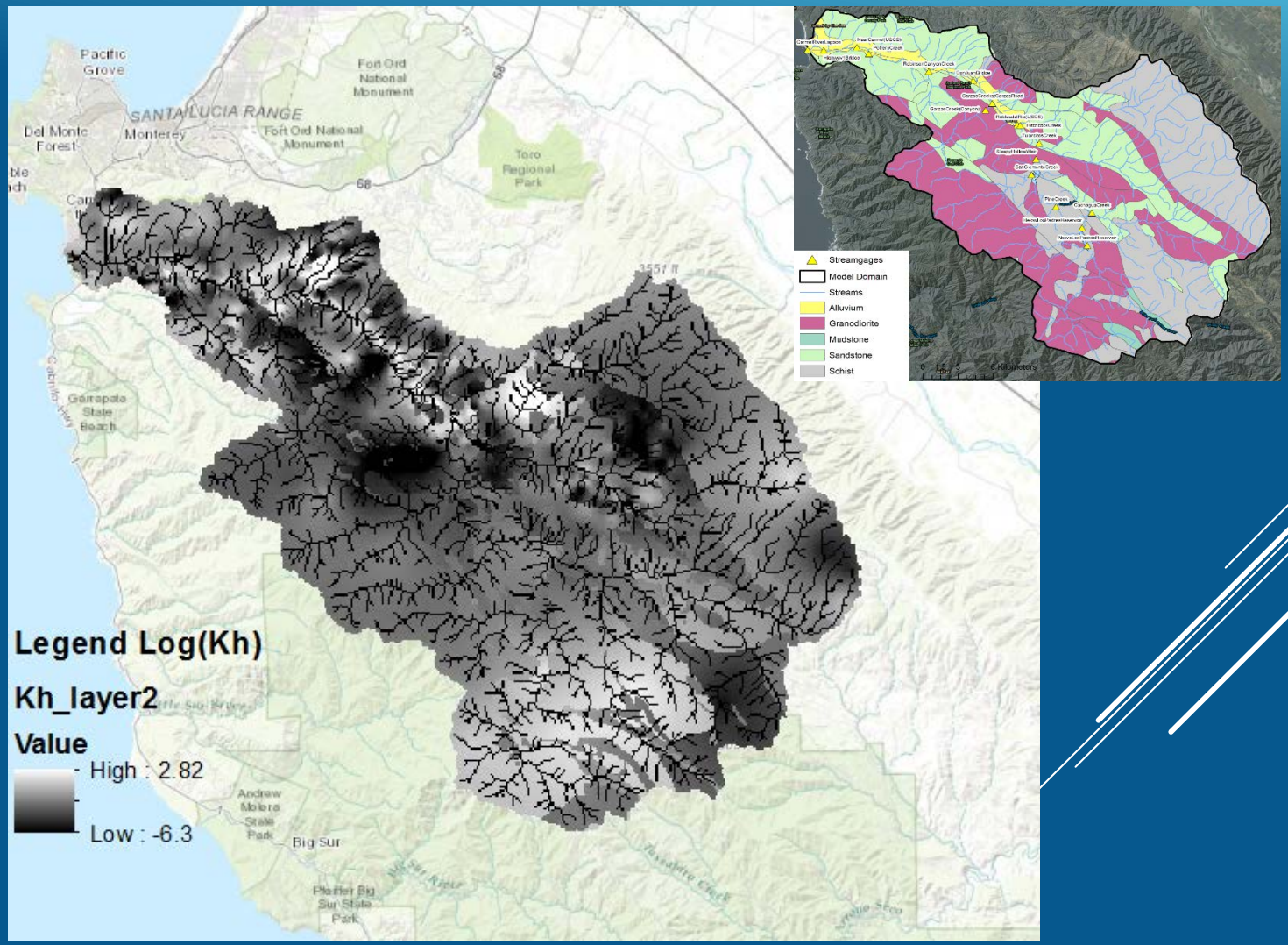




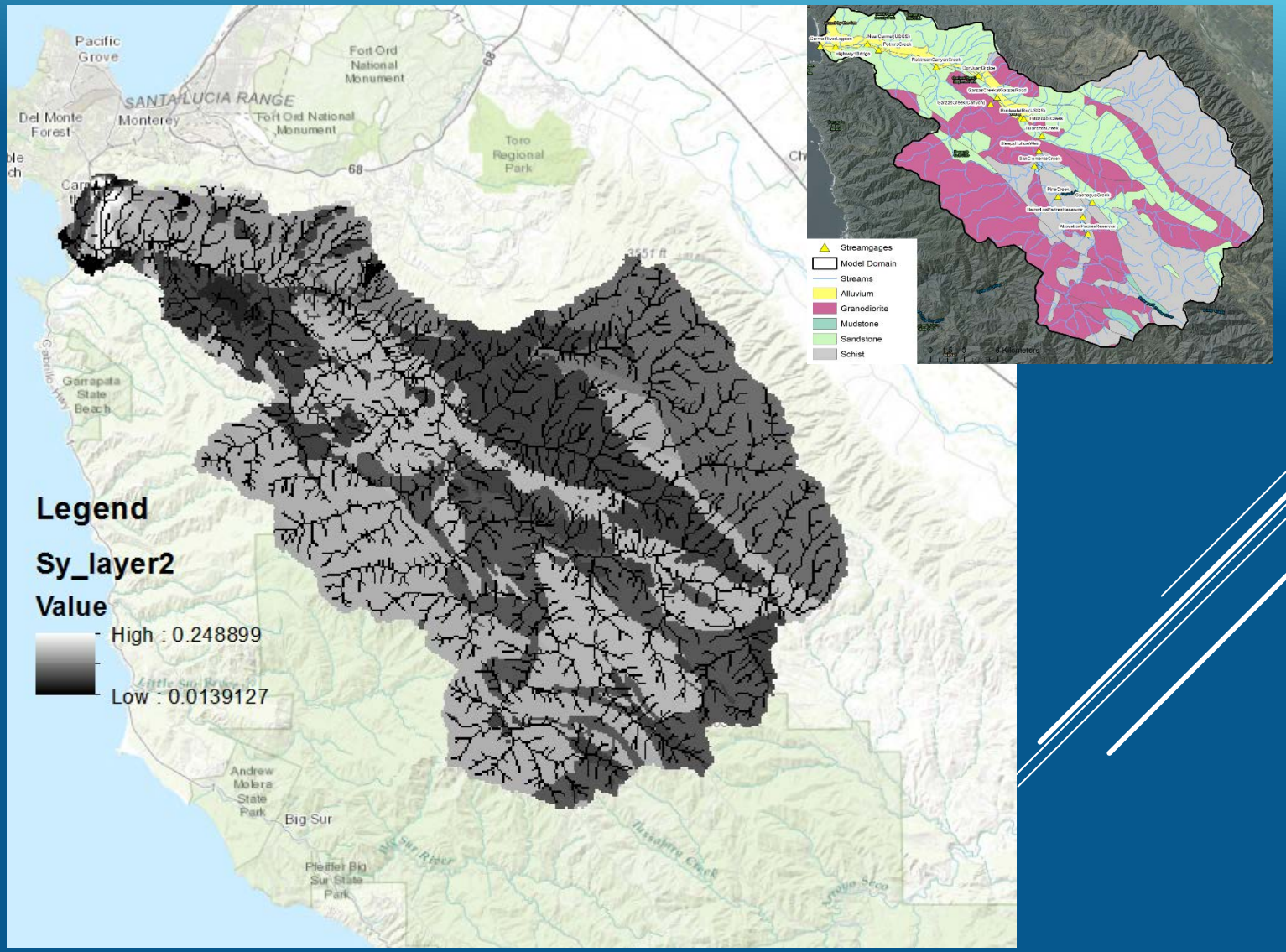
PILOT POINTS



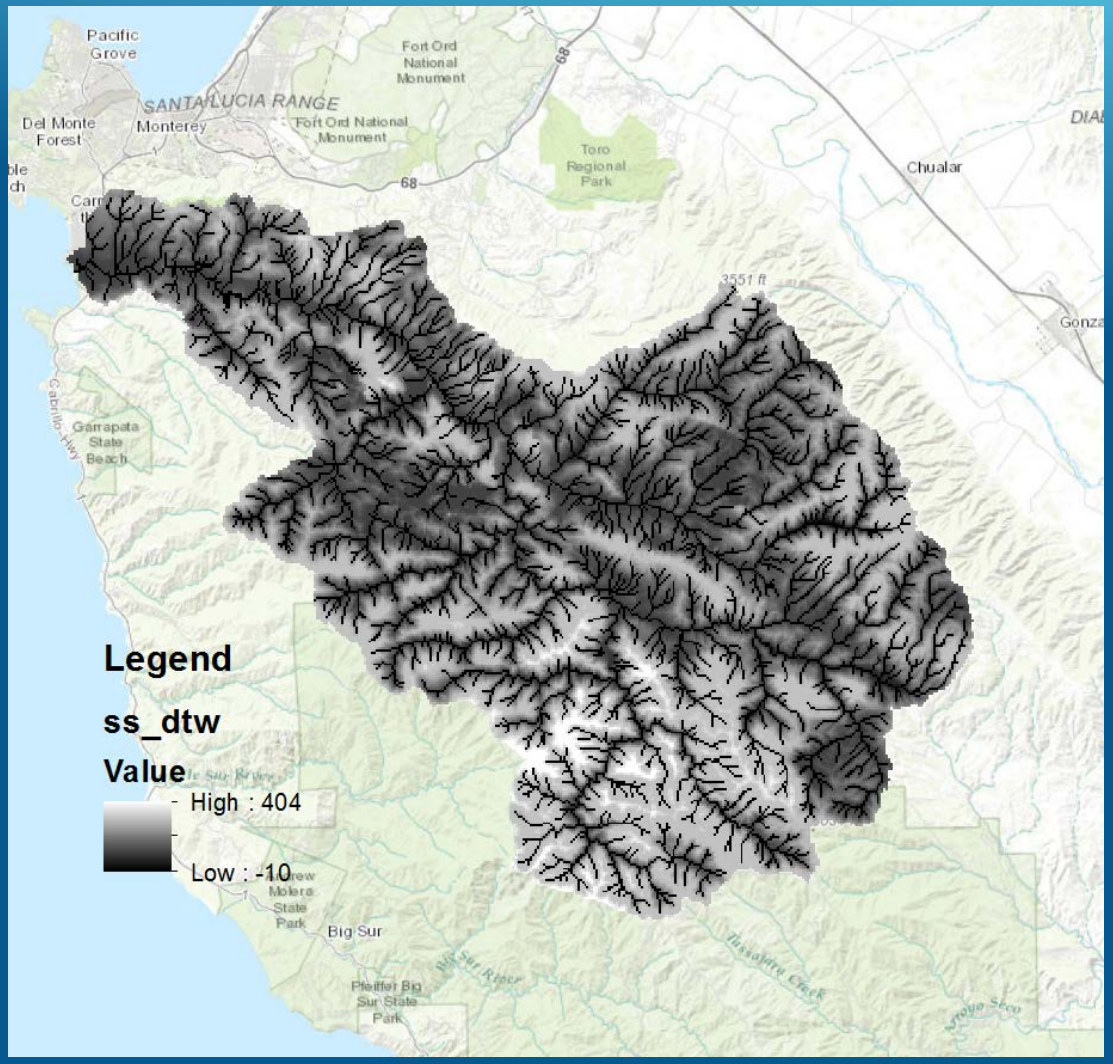
LAYER 2 (PRINCIPAL AQUIFER) LOG(KH)



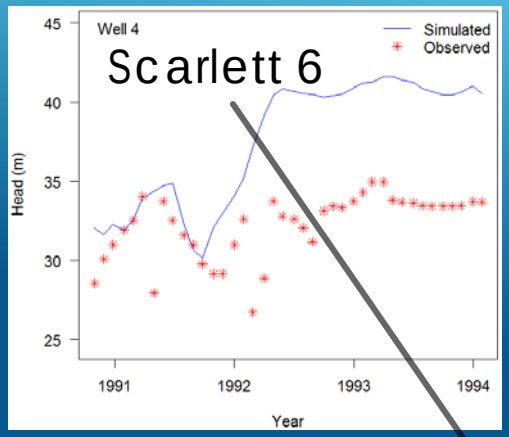
LAYER 2 AQUIFER SPECIFIC YIELD

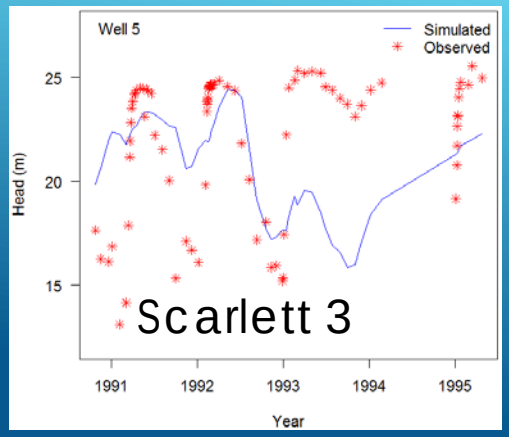


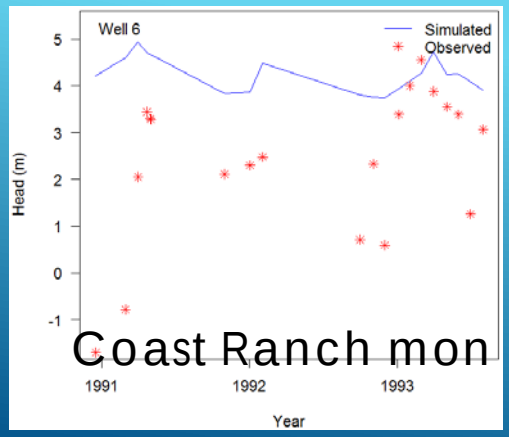
SIMULATED DEPTH TO WATER TABLE

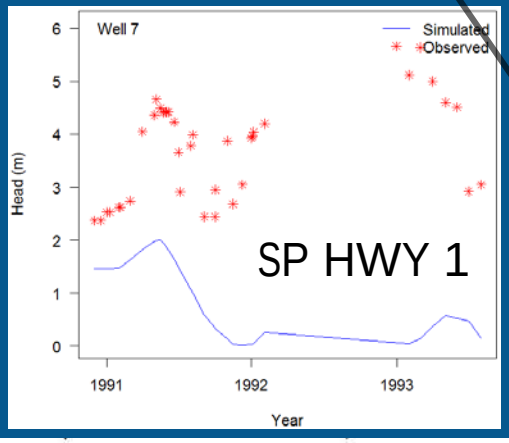


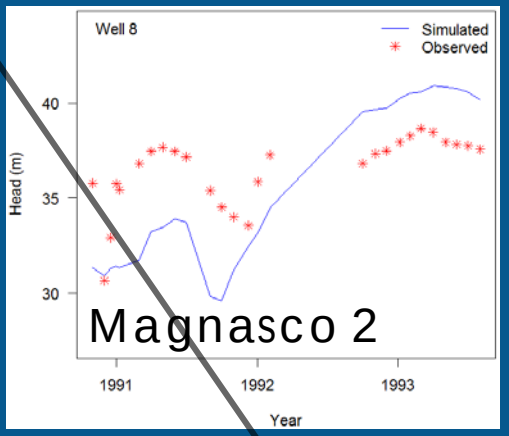
SIMULATED VERSES MEASURED GW HEAD

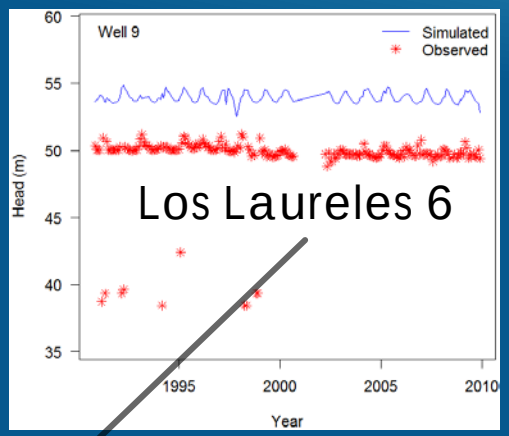


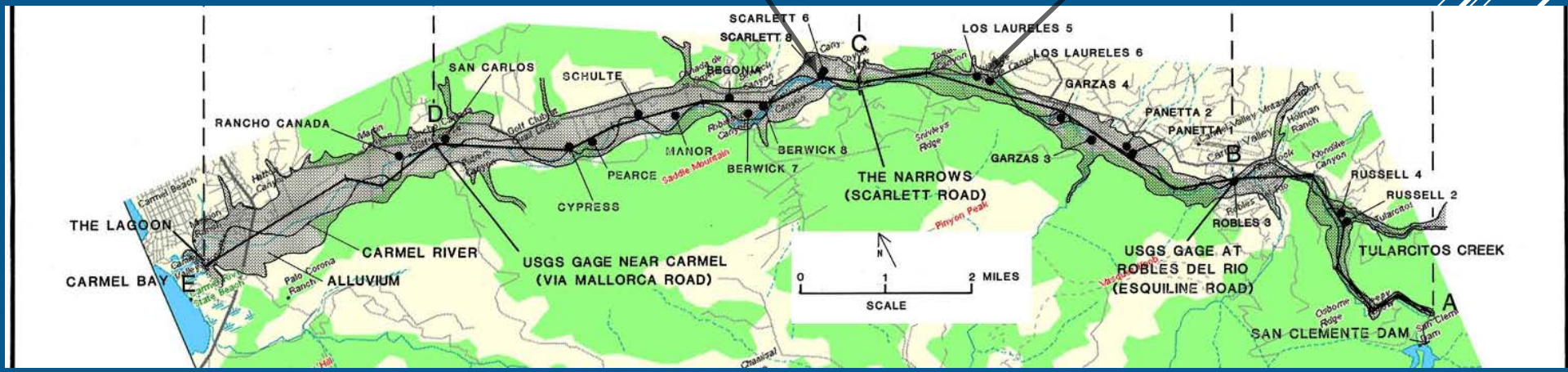












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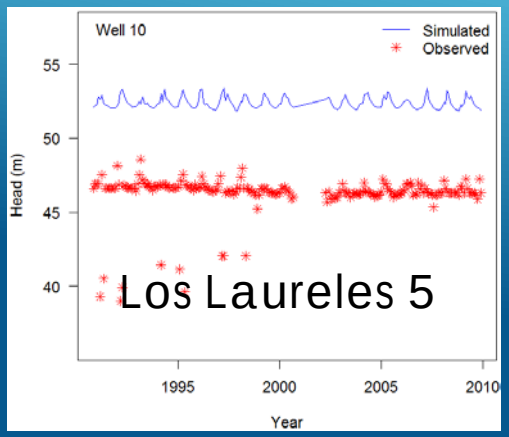

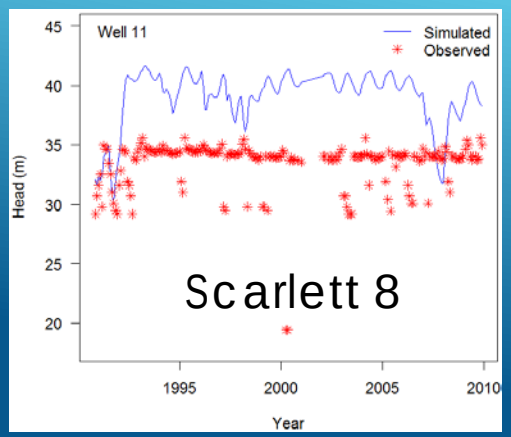

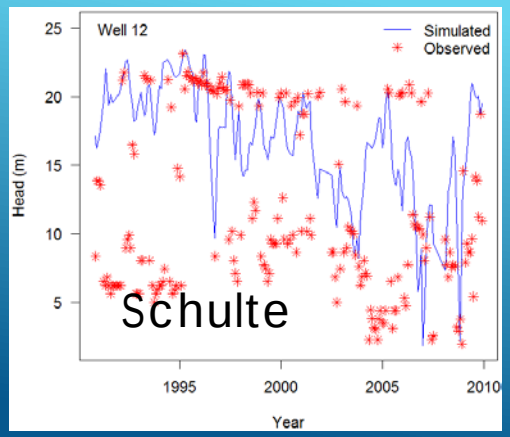

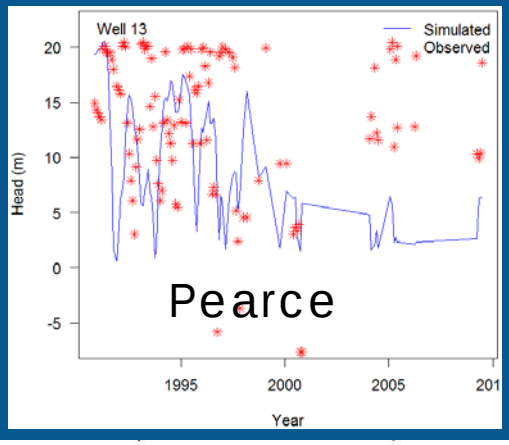

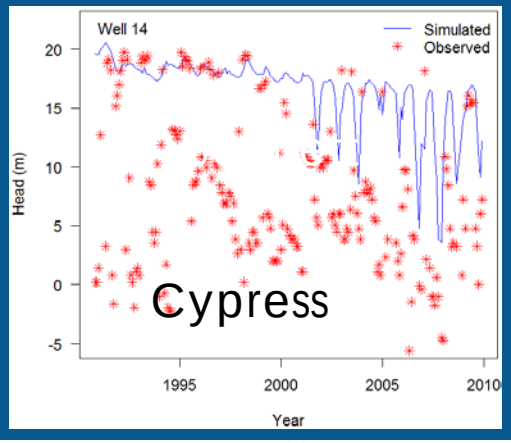

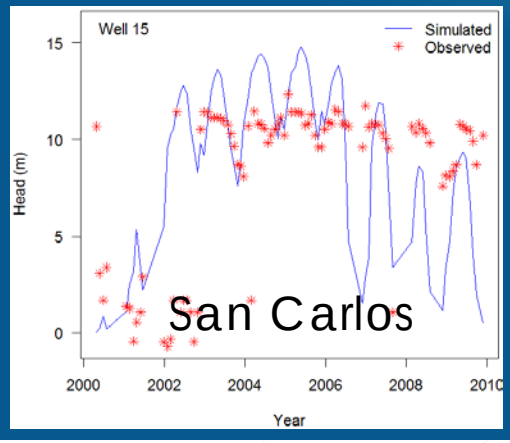

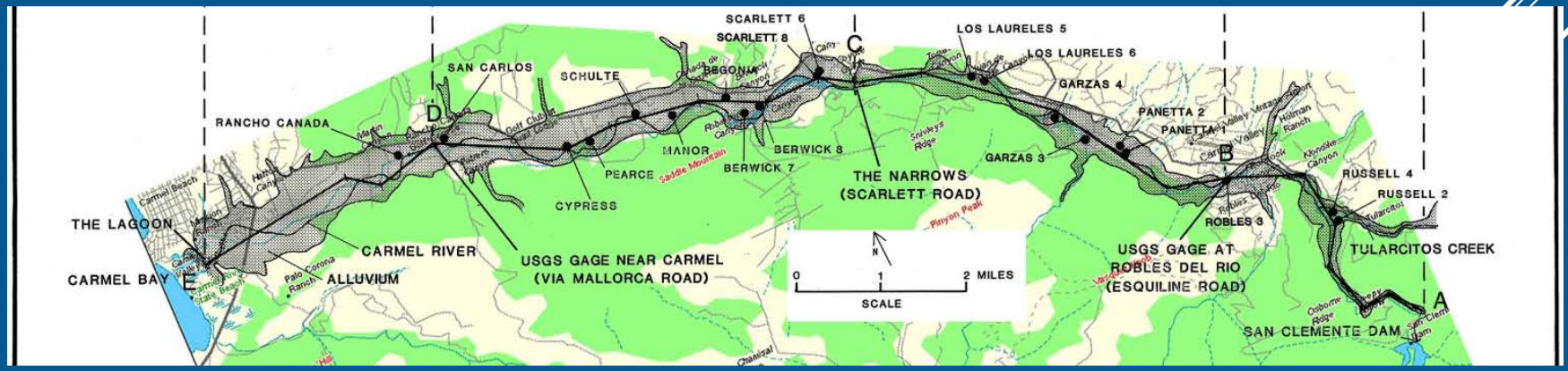

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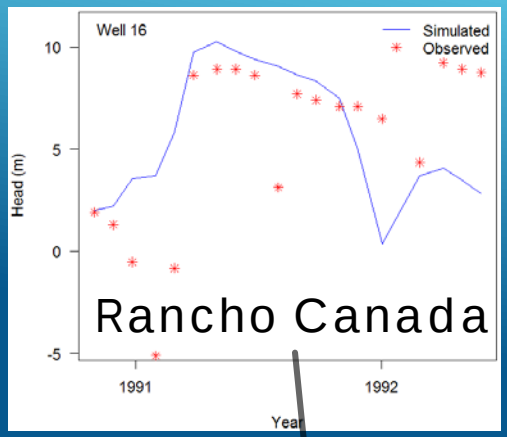

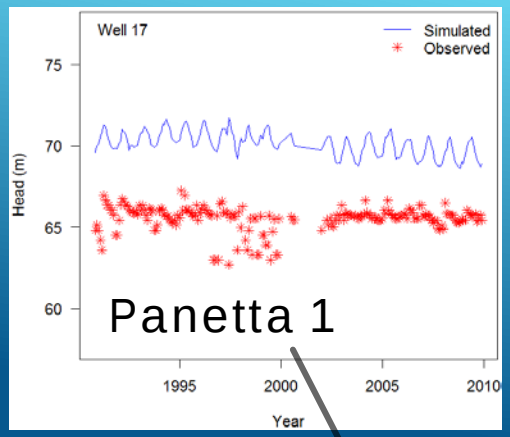

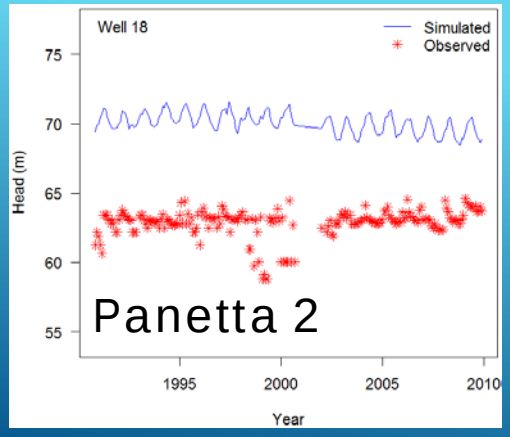

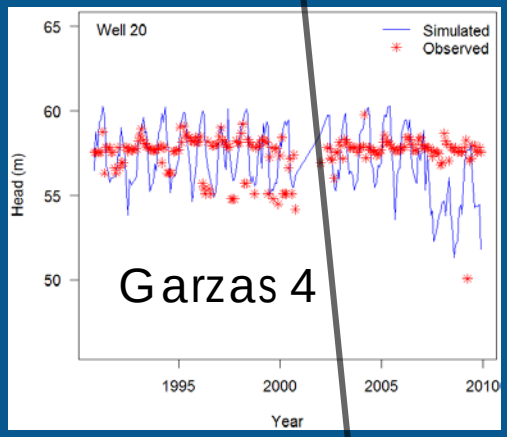

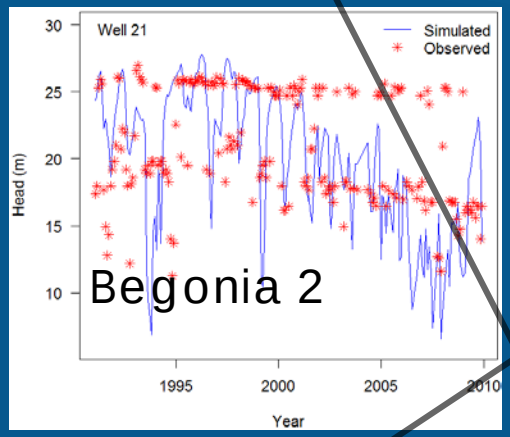

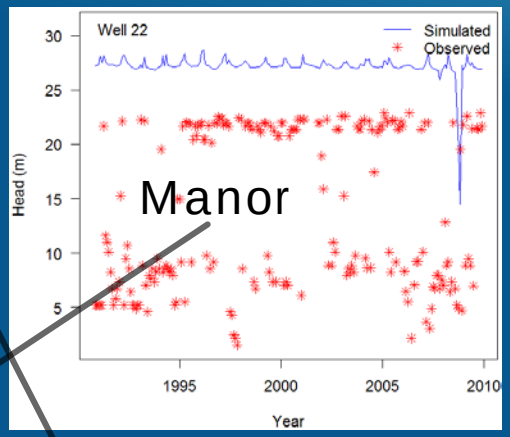

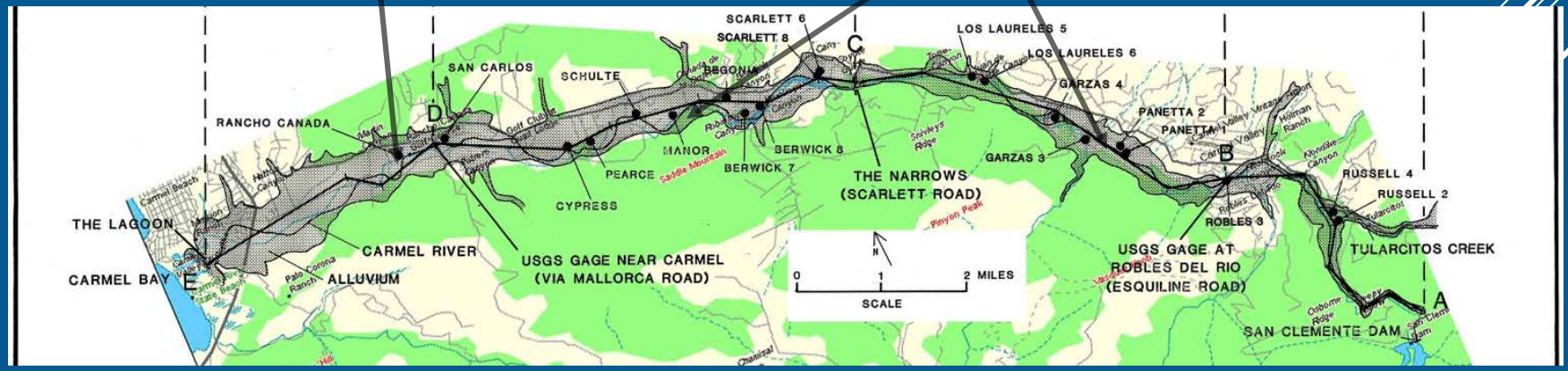

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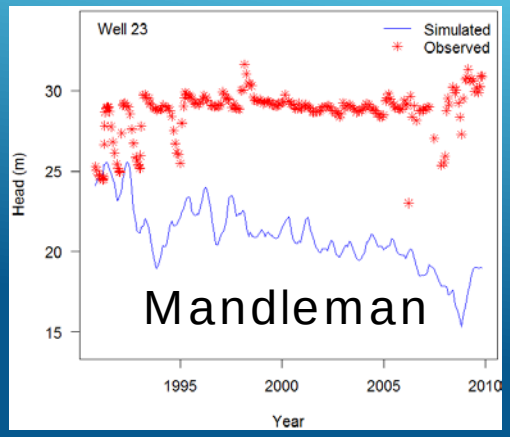
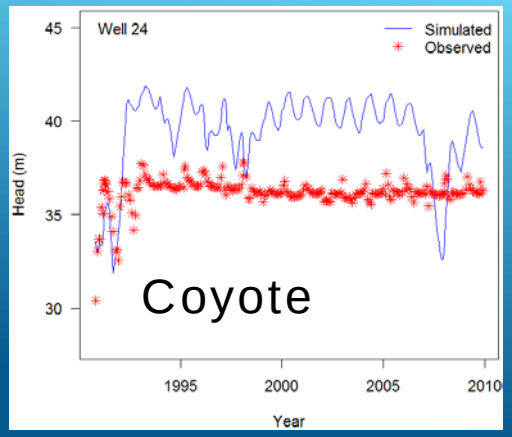
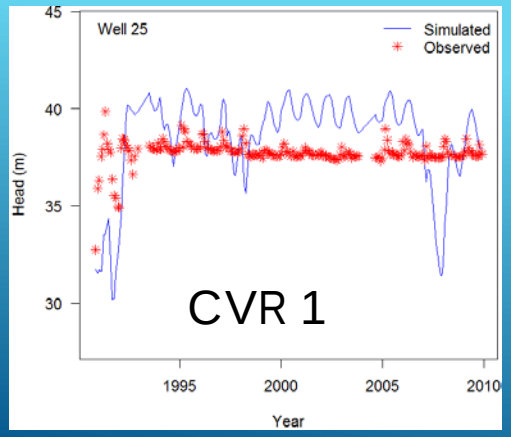
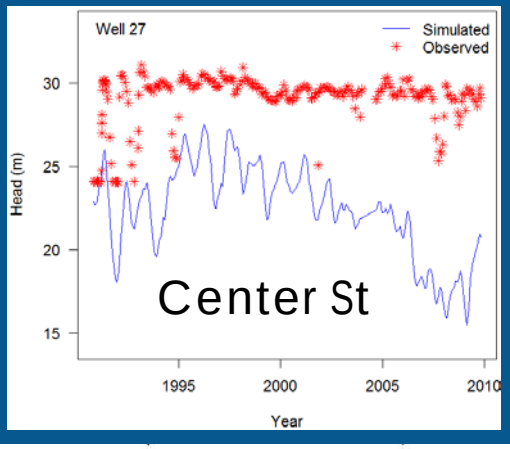
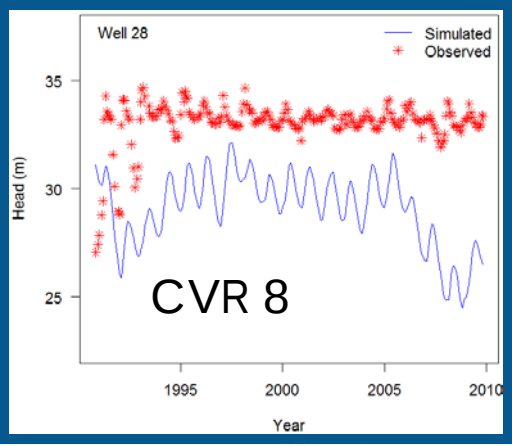
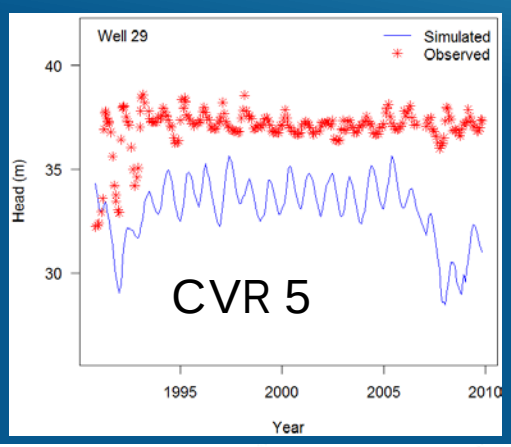


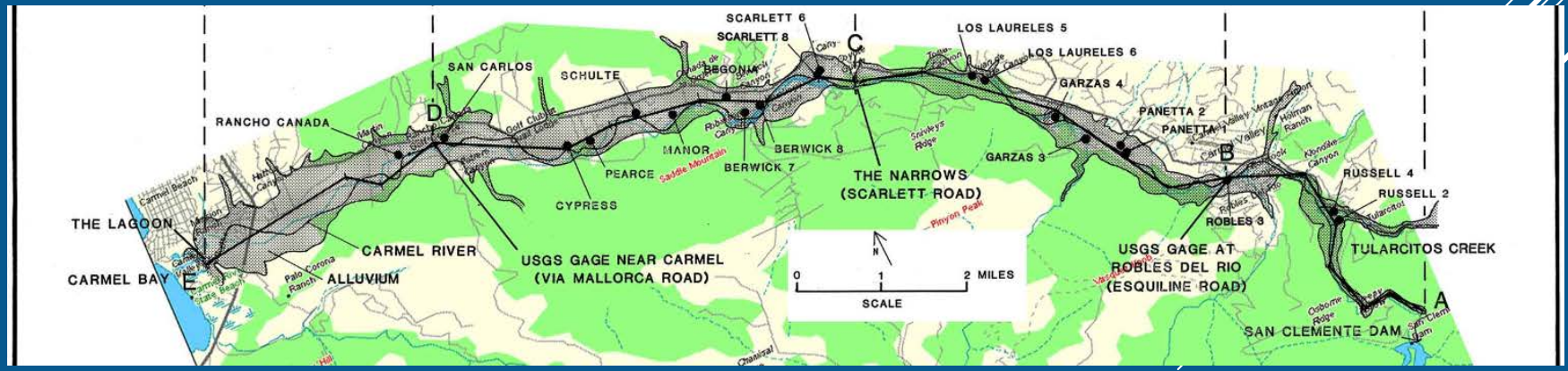




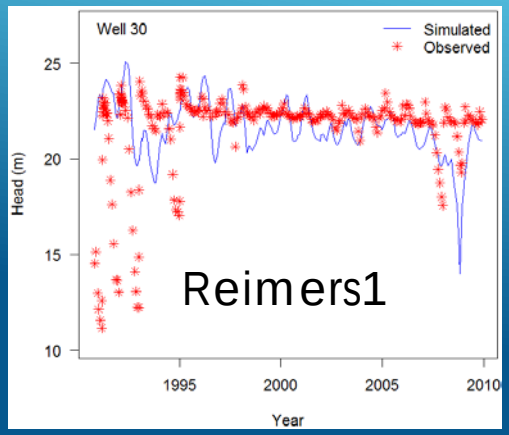


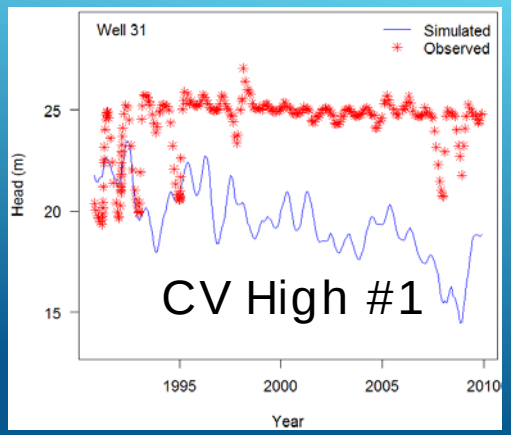


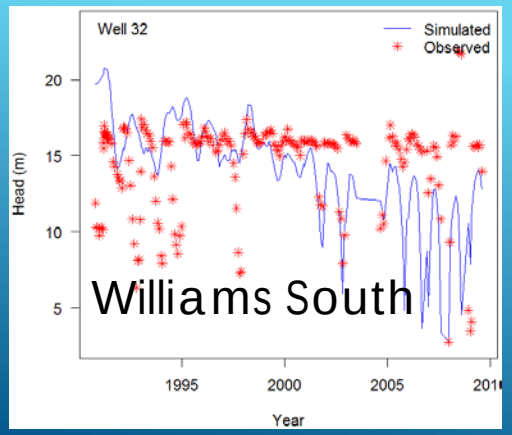


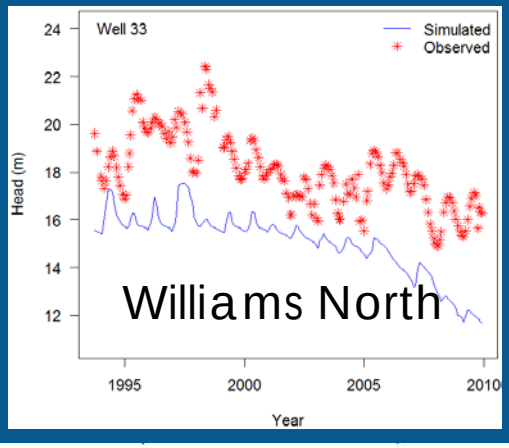


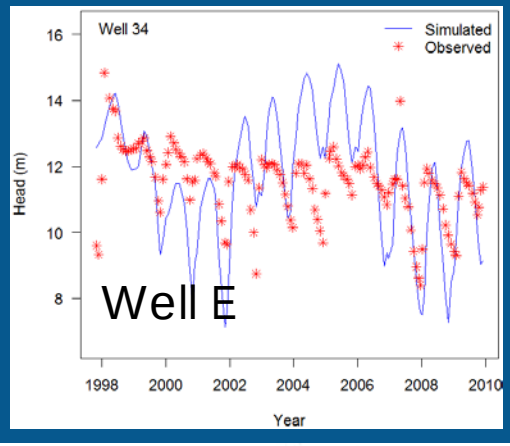
SIMULATED VERSES MEASURED GW HEAD

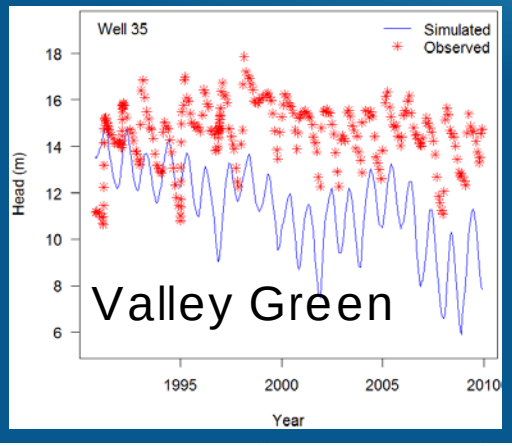


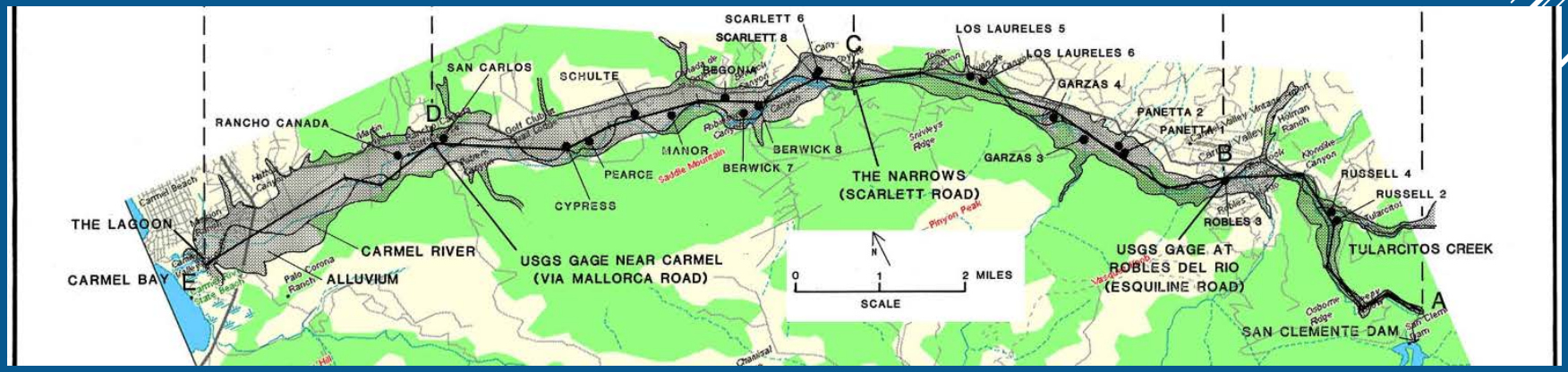












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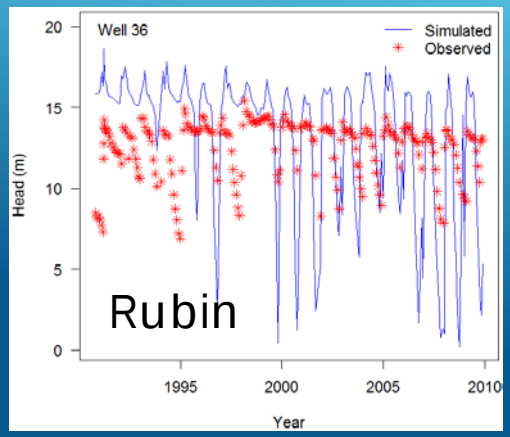

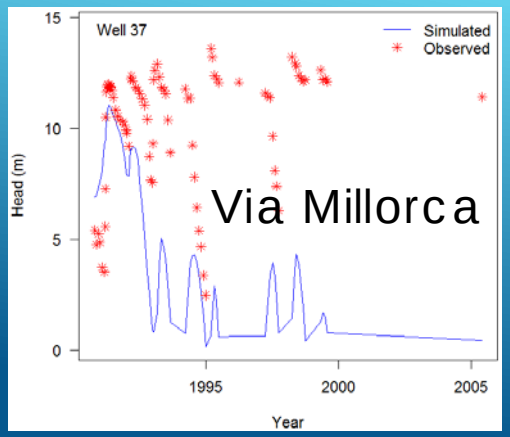

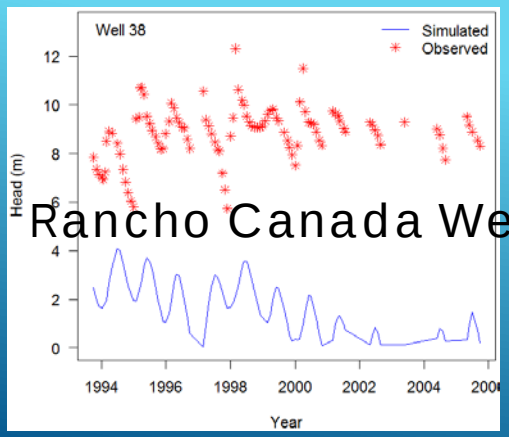

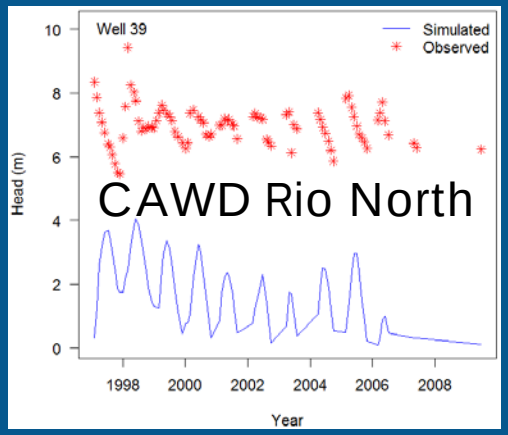

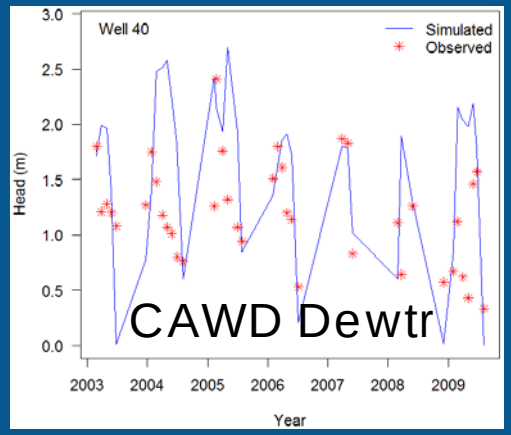

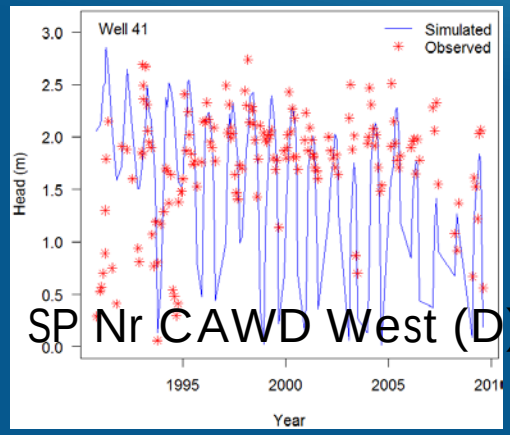

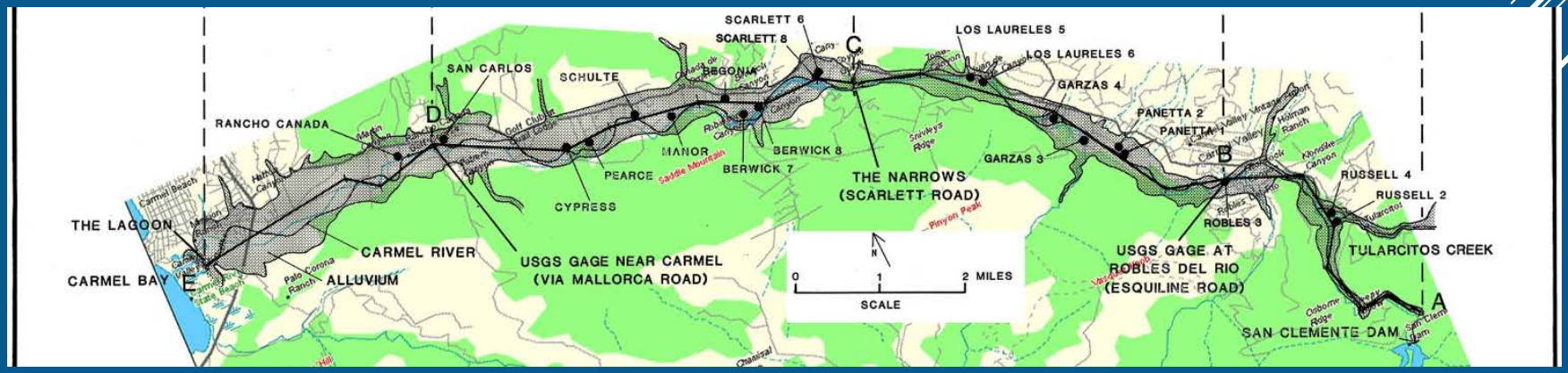

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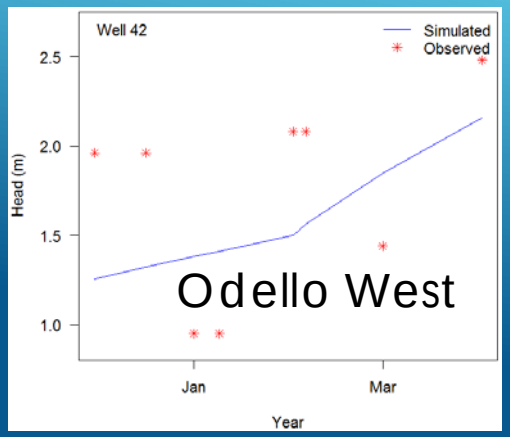

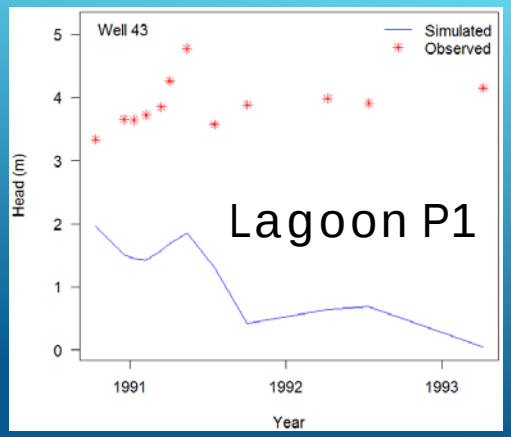

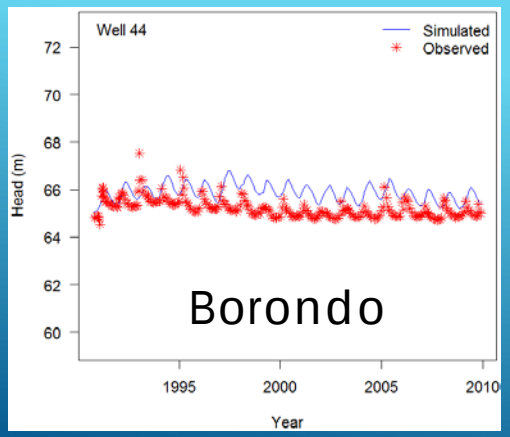

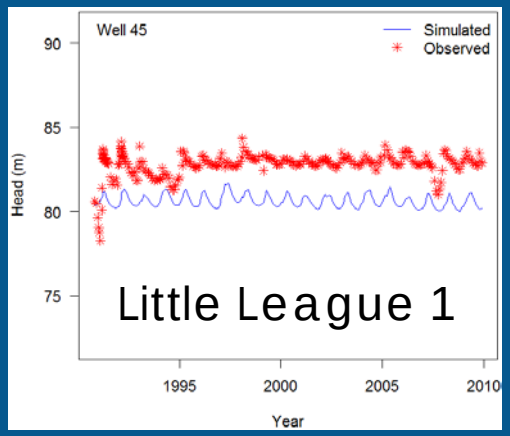

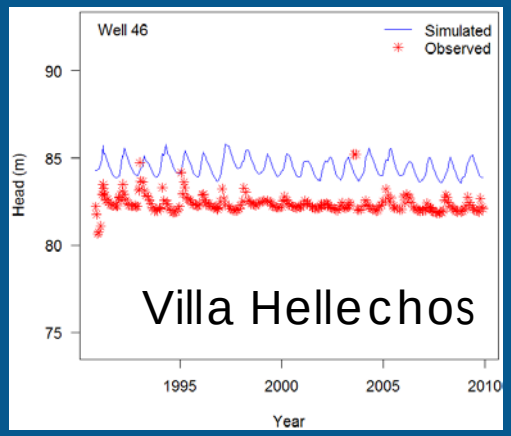

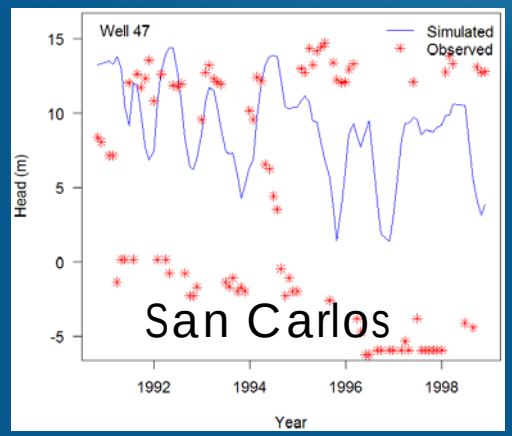

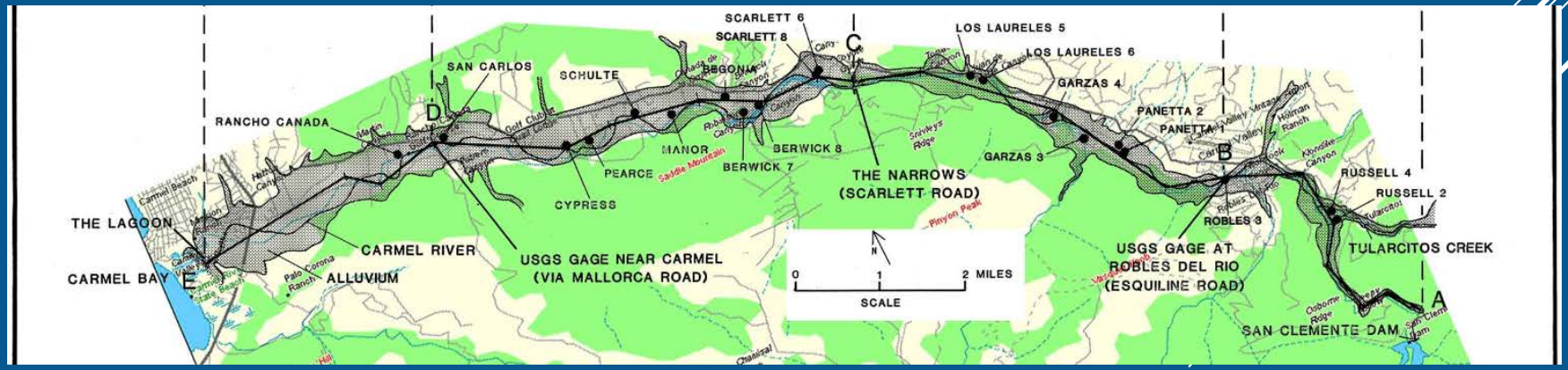

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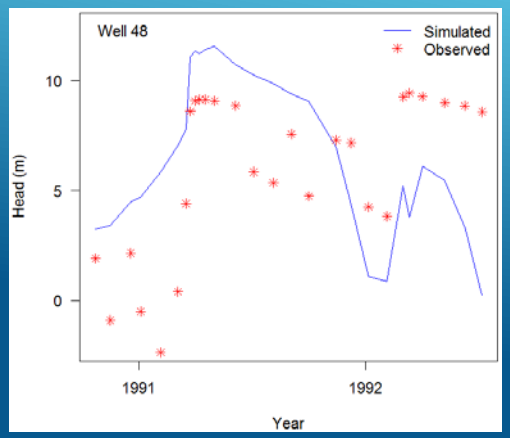

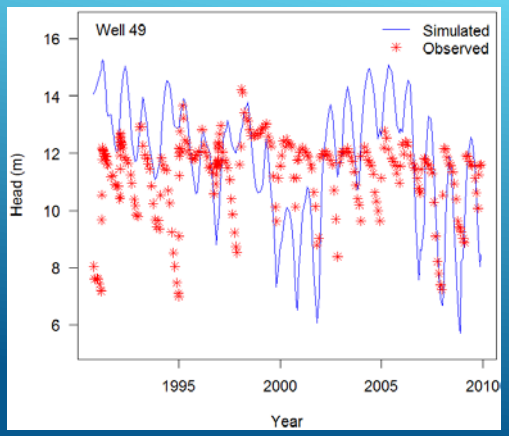

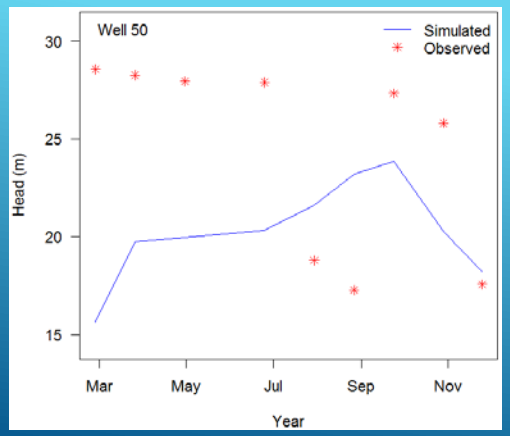

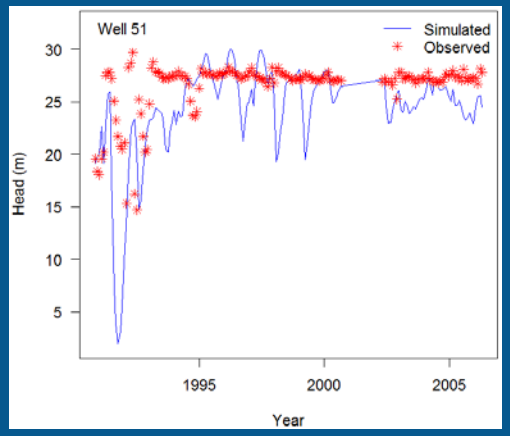

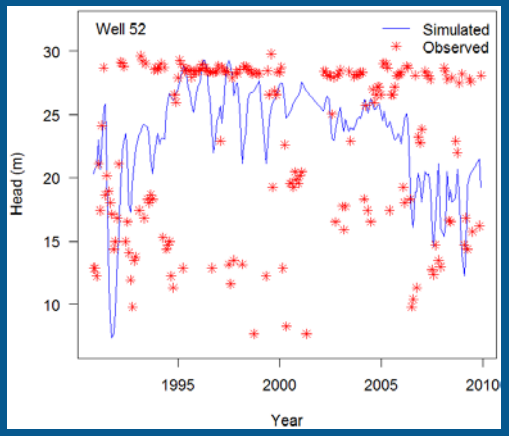

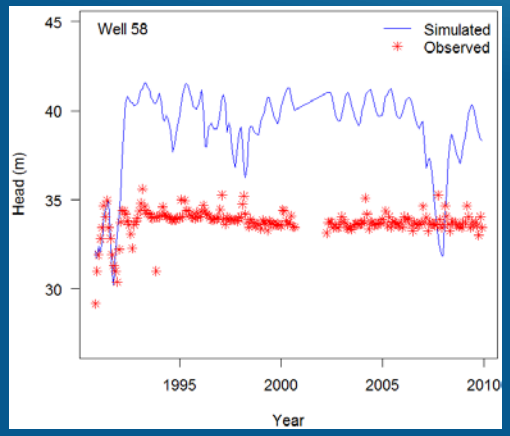

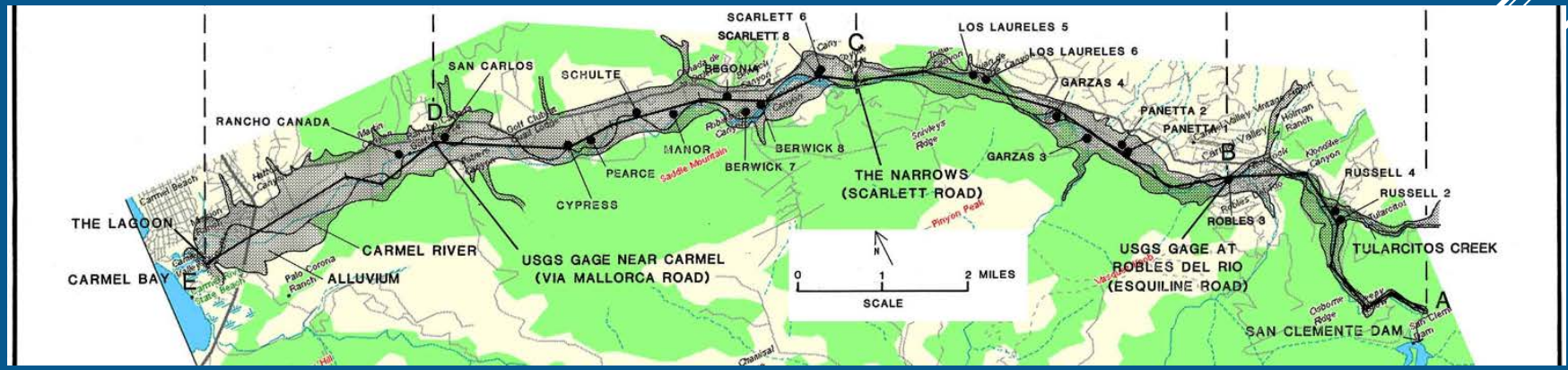

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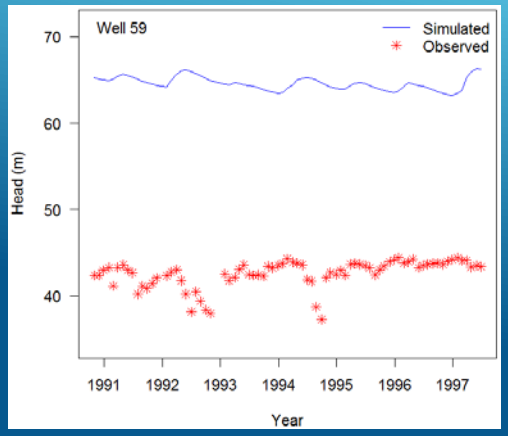
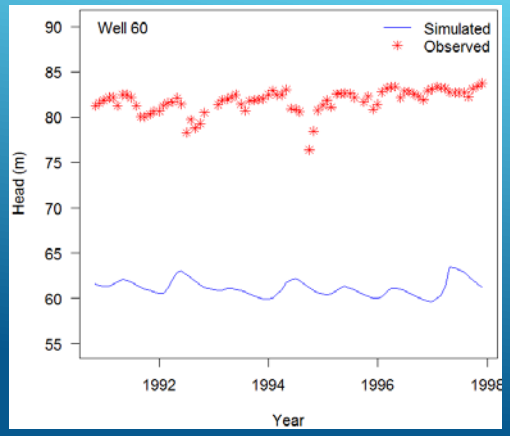
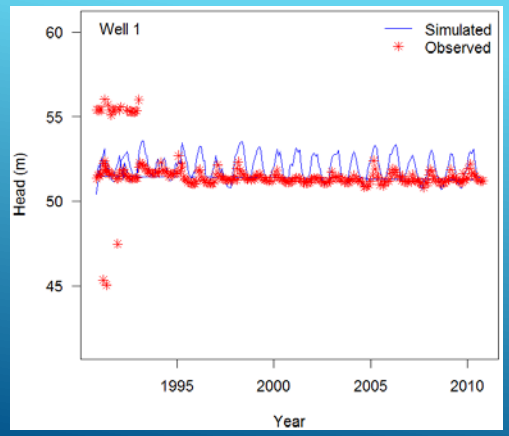
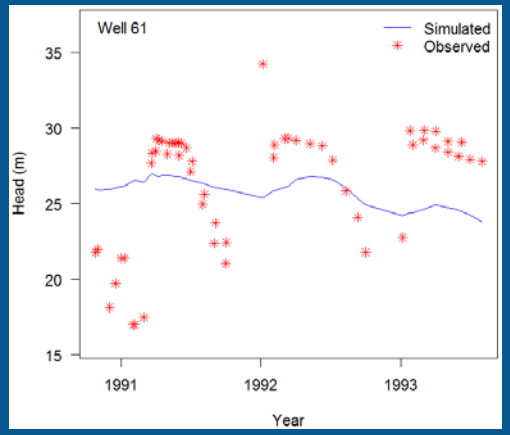
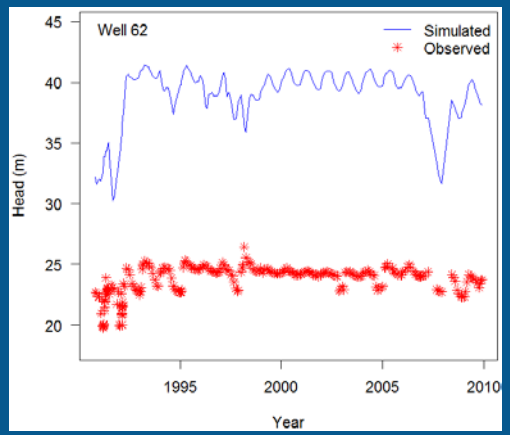
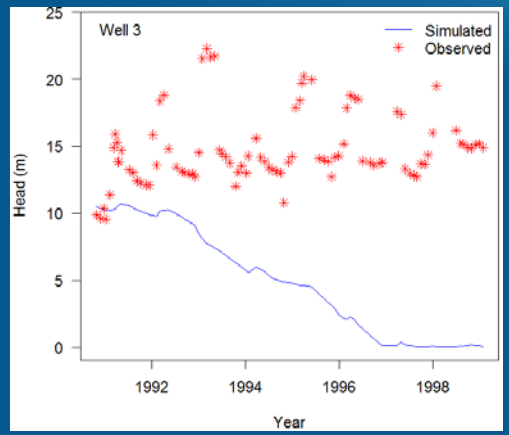


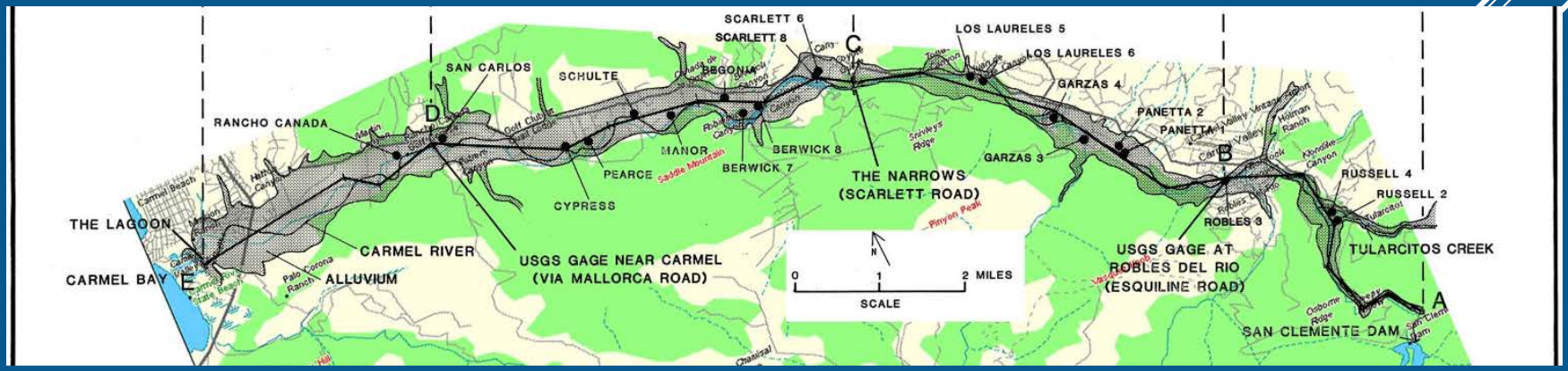




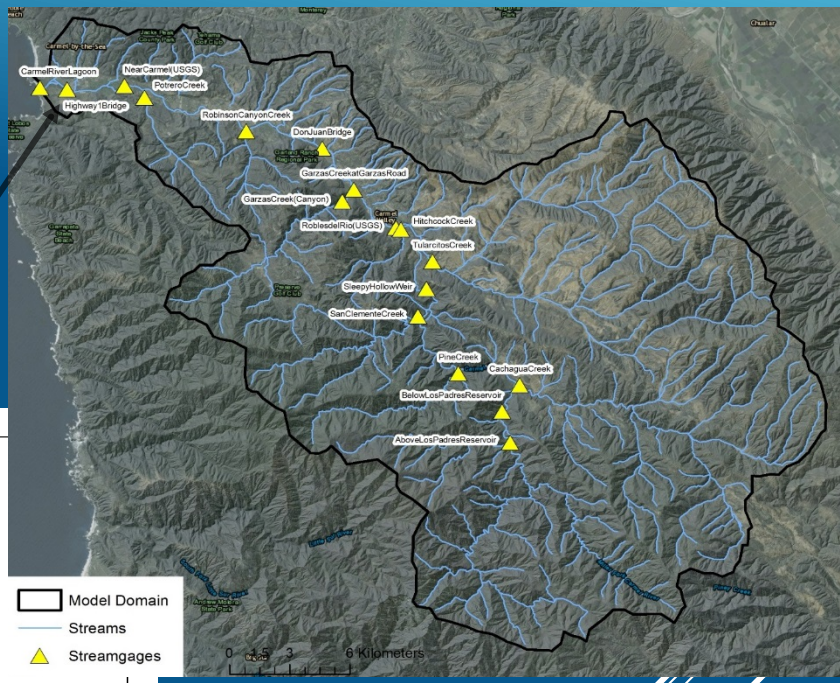


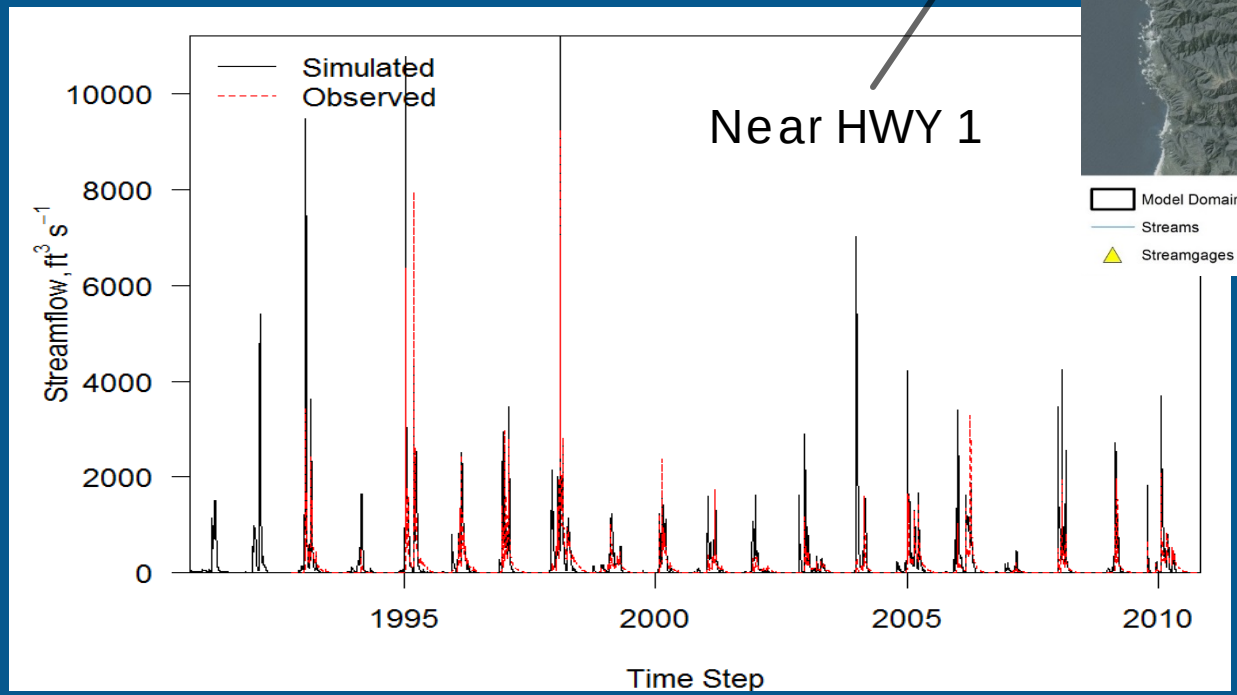






SIMULATED VERSES MEASURED STREAMFLOW





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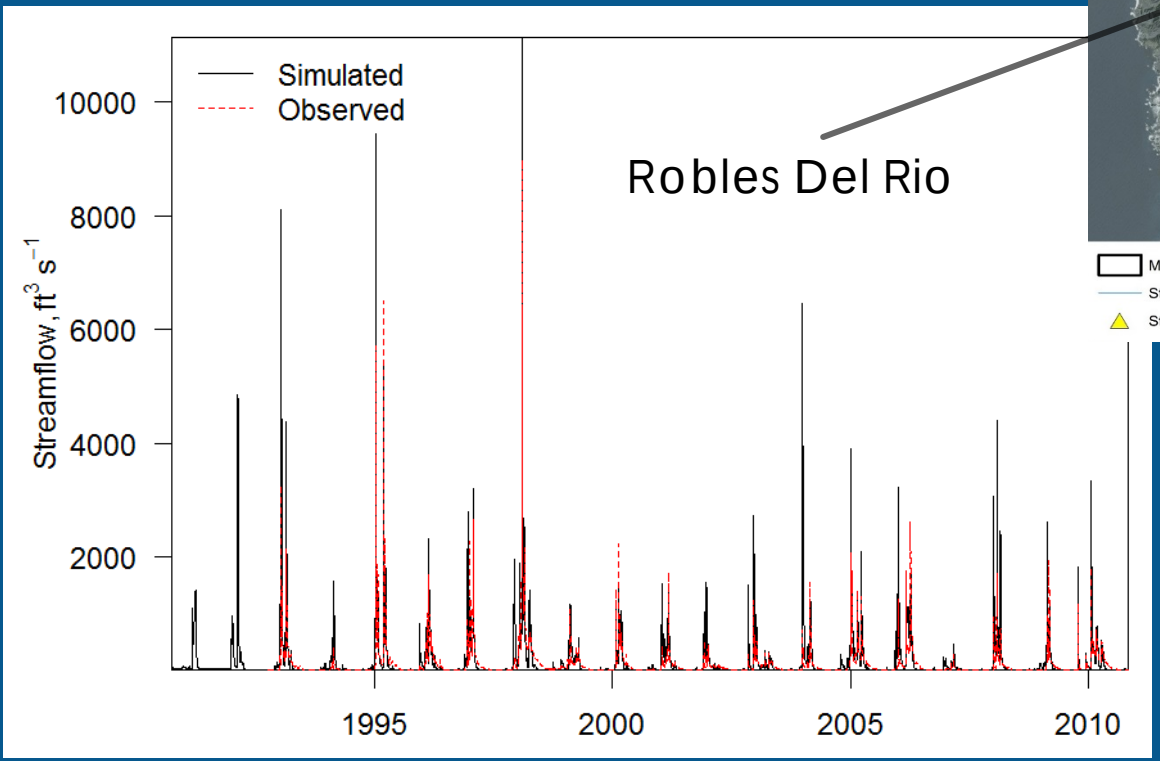

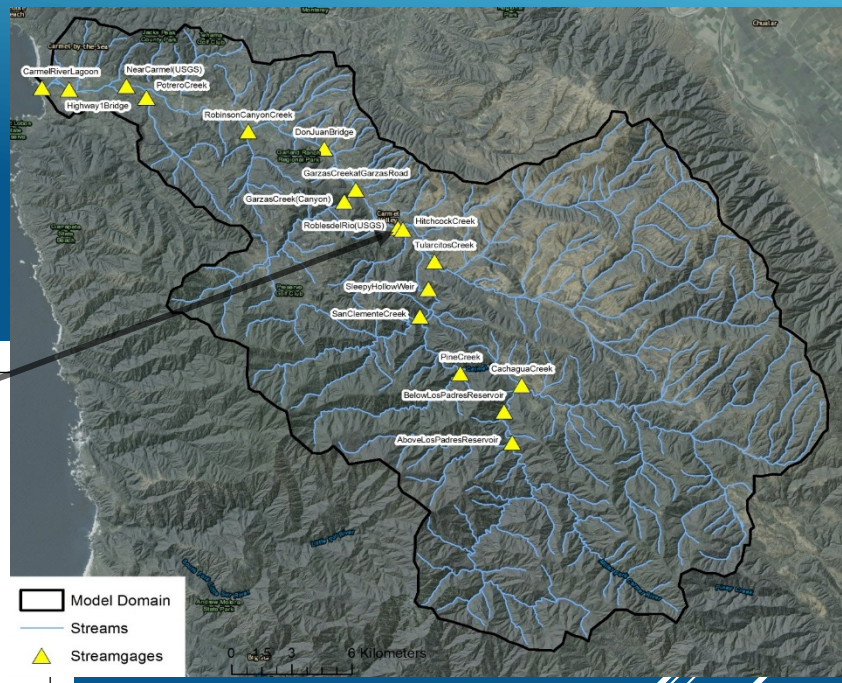

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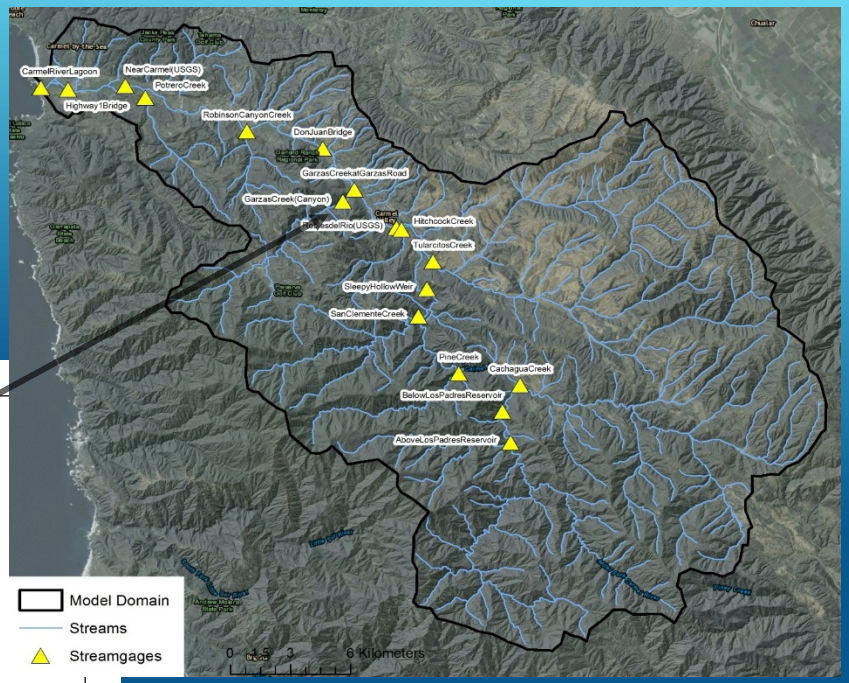

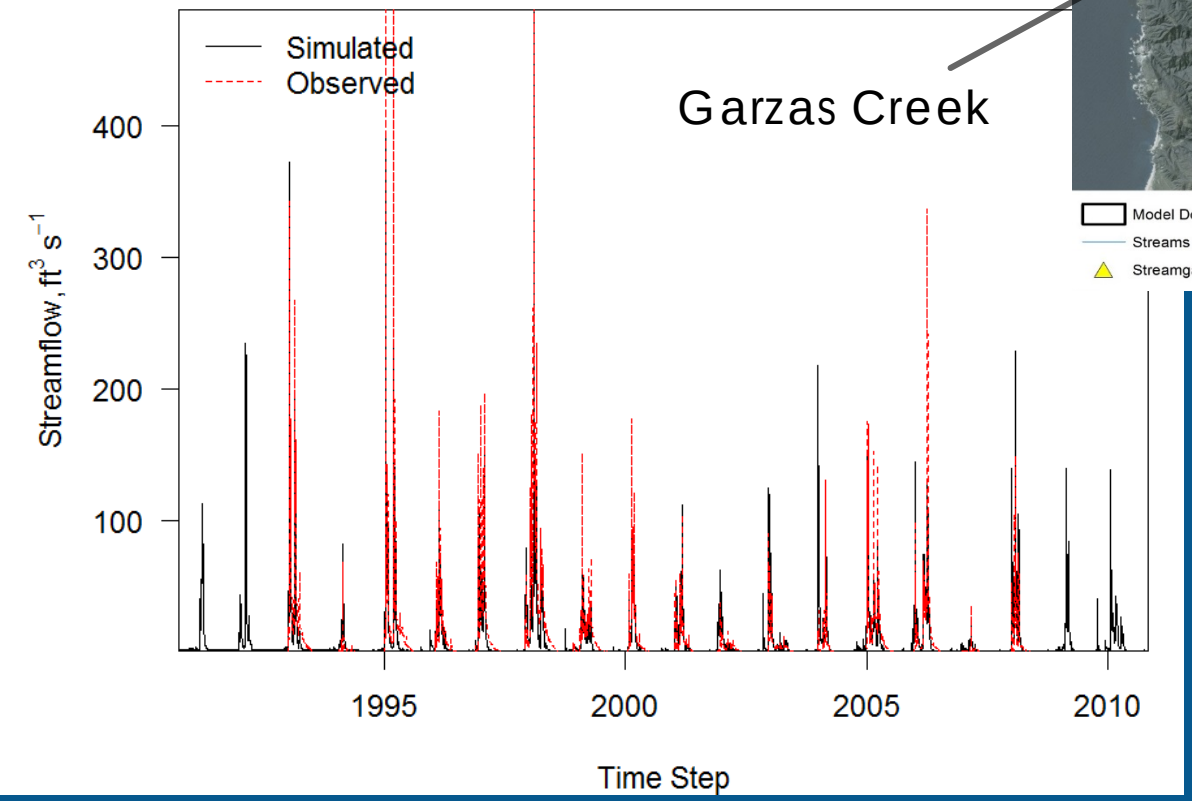

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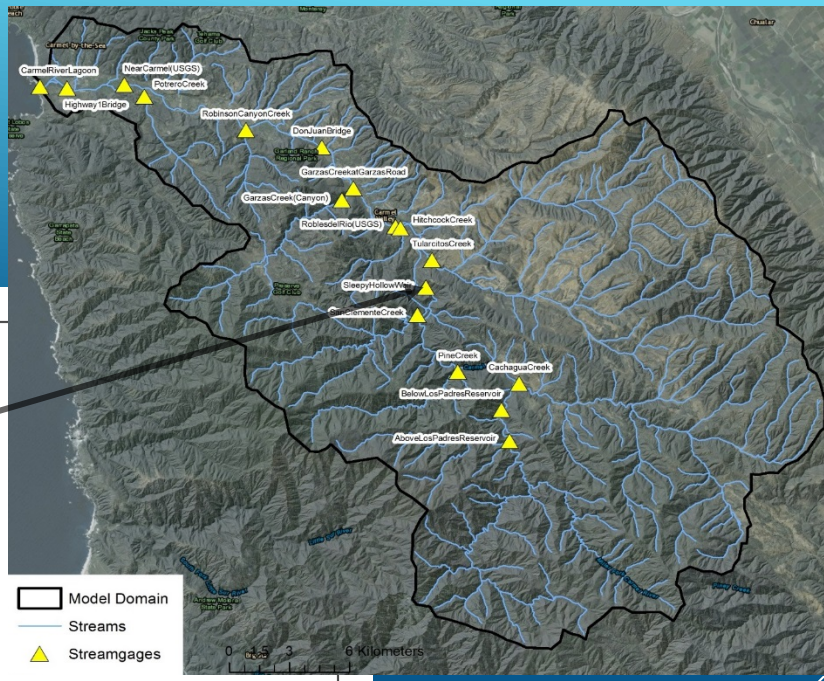

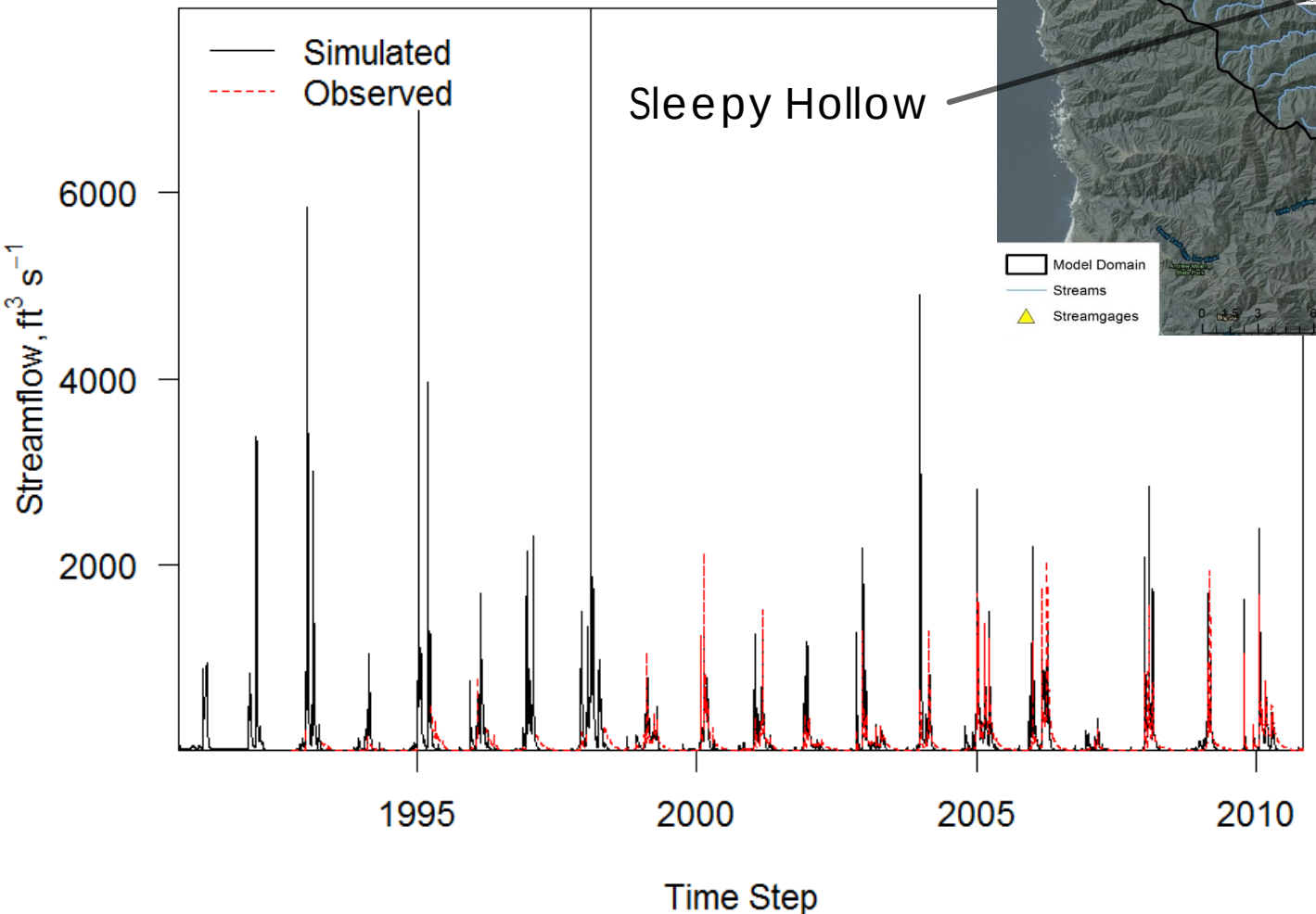

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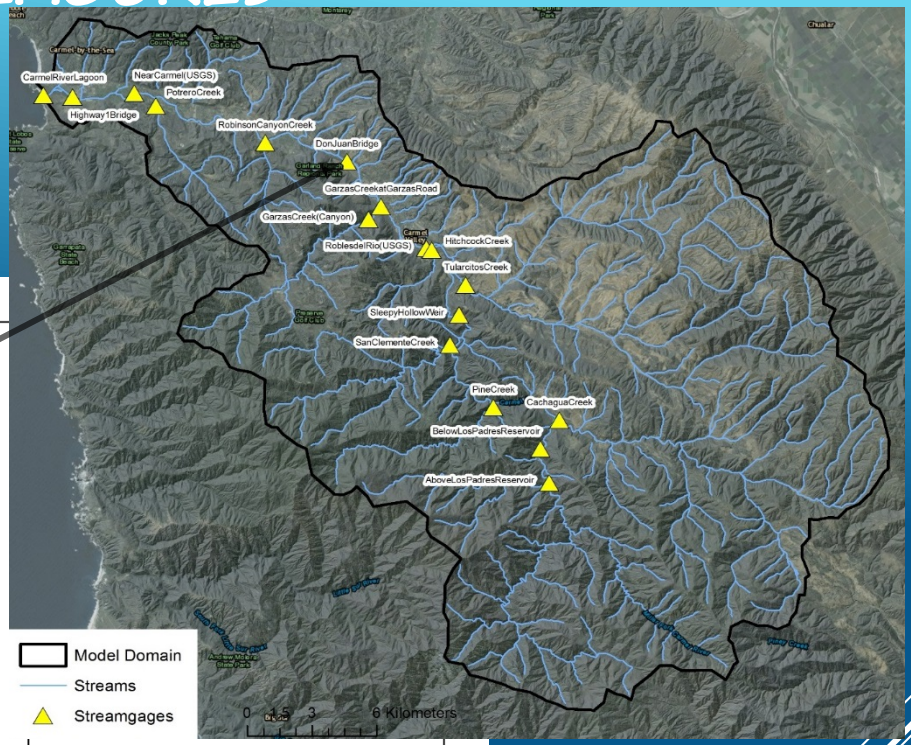

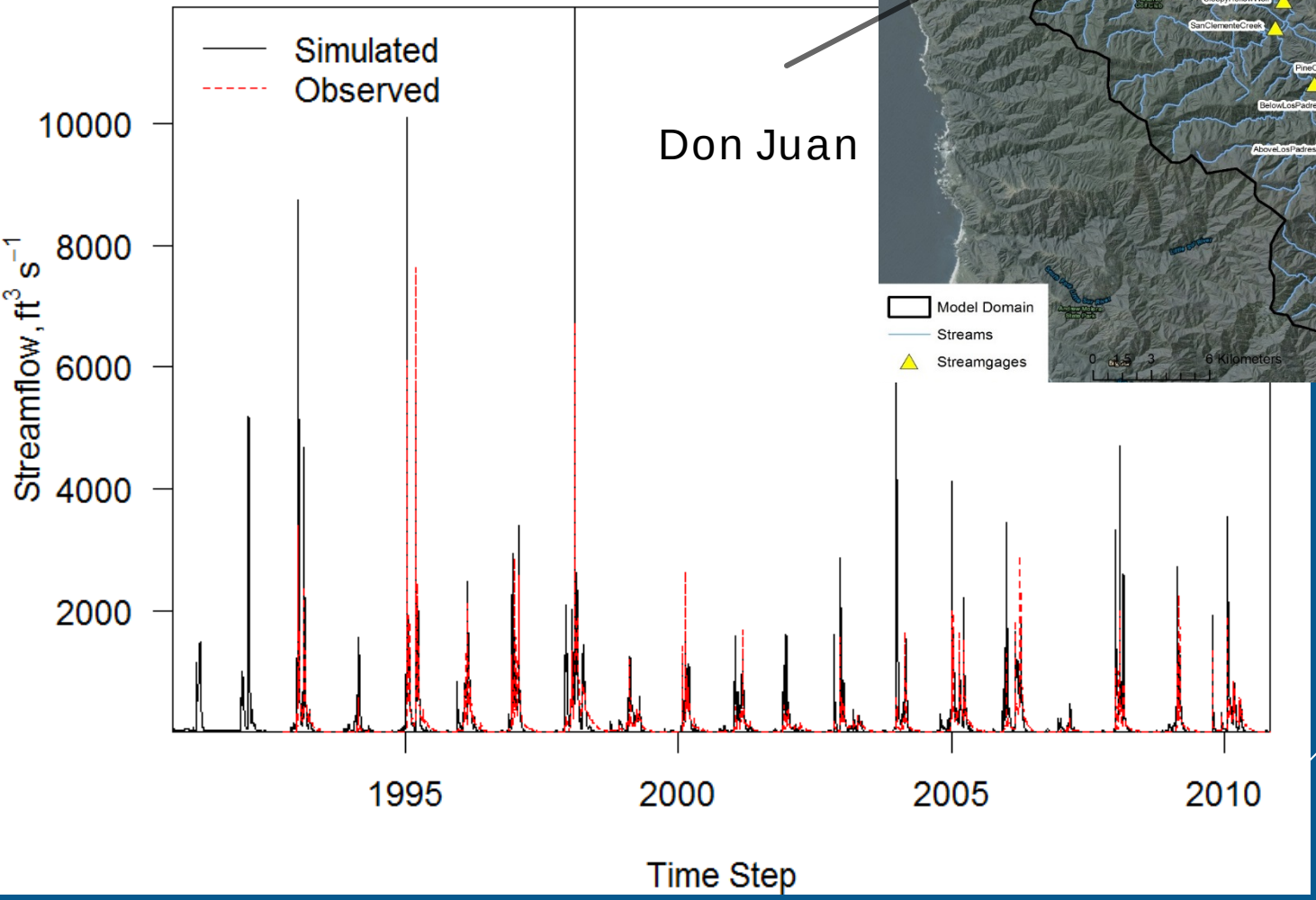

Management Scenarios

1) existing conditions: existing LP reservoir storage (estimate as of August 2016), existing Cal-Am diversions/operation in Carmel Valley; MPWMD will cooperate with CAW to develop assumptions for Carmel Valley operations for the short-term (i.e., 2016-2021); presume operations don't change starting in 2022 (this is so we can compare with and without completion of the Monterey Peninsula Water Supply Project (MPWSP); model the Pure Water Monterey Project coming on line in 2019(?); model ASR operations presuming the Monterey Pipeline is built (?).

2) existing LP reservoir storage, proposed Cal-Am diversions/operations in Carmel Valley with MPWSP completed (i.e., operations from Jan. 1, 2022 forward); MPWMD will cooperate with CAW to develop assumptions for proposed Cal-Am operations; annual depletion of reservoir storage of 10 to 20 AFY (need to re-evaluate long-term rate using 2016 bathymetric study results).

3) existing LP reservoir storage to start; change in 2022 to new operations; maintain reservoir storage at 2016 level.

4) dam removal aka no LP reservoir storage; start run in 2026? (presume it takes at least 10 years to complete project); proposed Cal-Am diversions/operation w/ MPWSP;

5) recover LP reservoir storage (3,030 AF); start run in 2026? (presume it takes at least 10 years to complete project); proposed Cal-Am diversions/operation w/ MPWSP; periodic reservoir maintenance to maintain capacity.

6) expand reservoir storage; amount TBD (presume it takes at least 10 years to complete project); proposed Cal-Am diversions/operation w/ MPWSP.

THANK YOU!