Preliminary work on the Shasta basin: how can this support and contribute to the SGMA effort?

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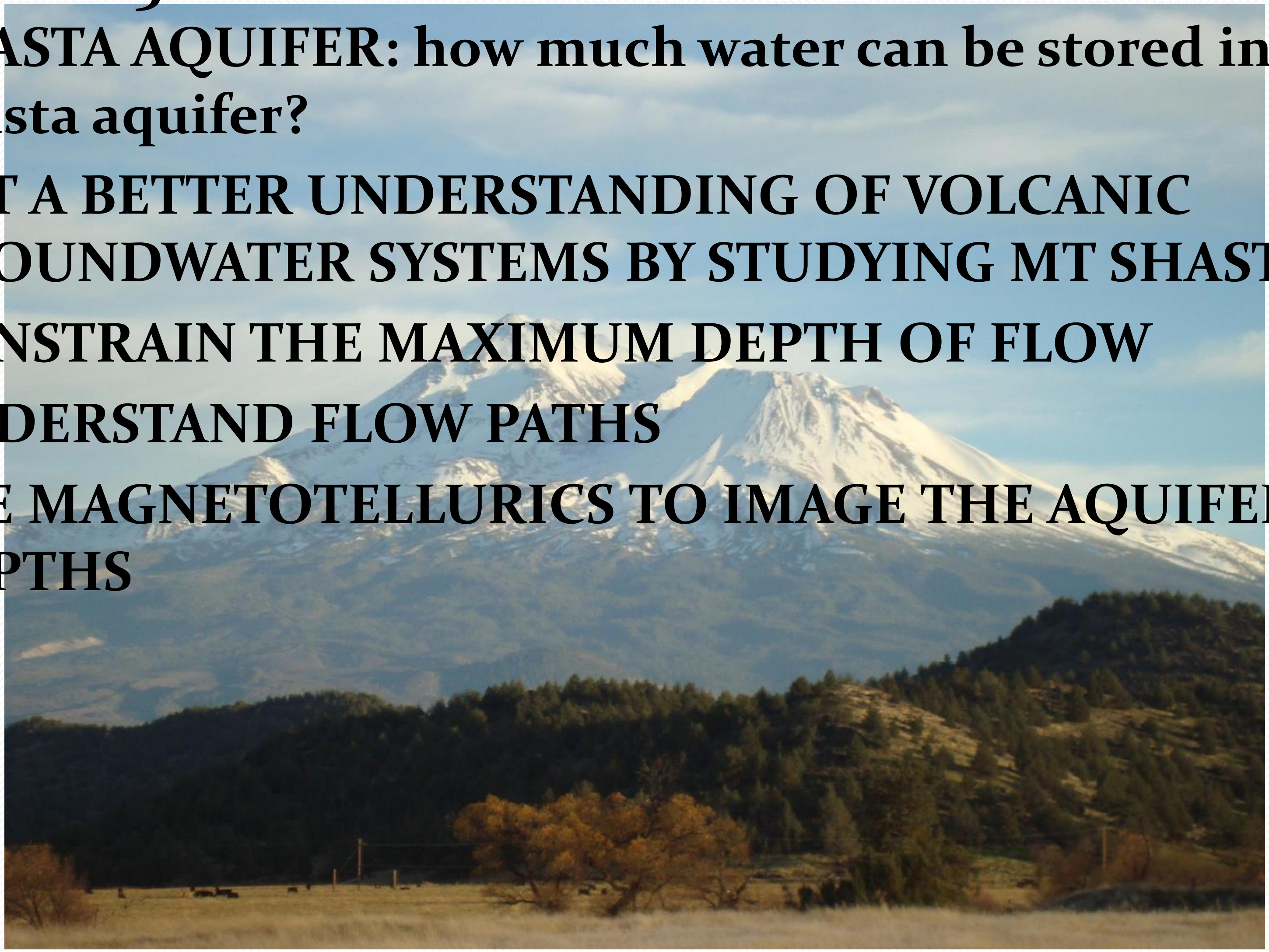
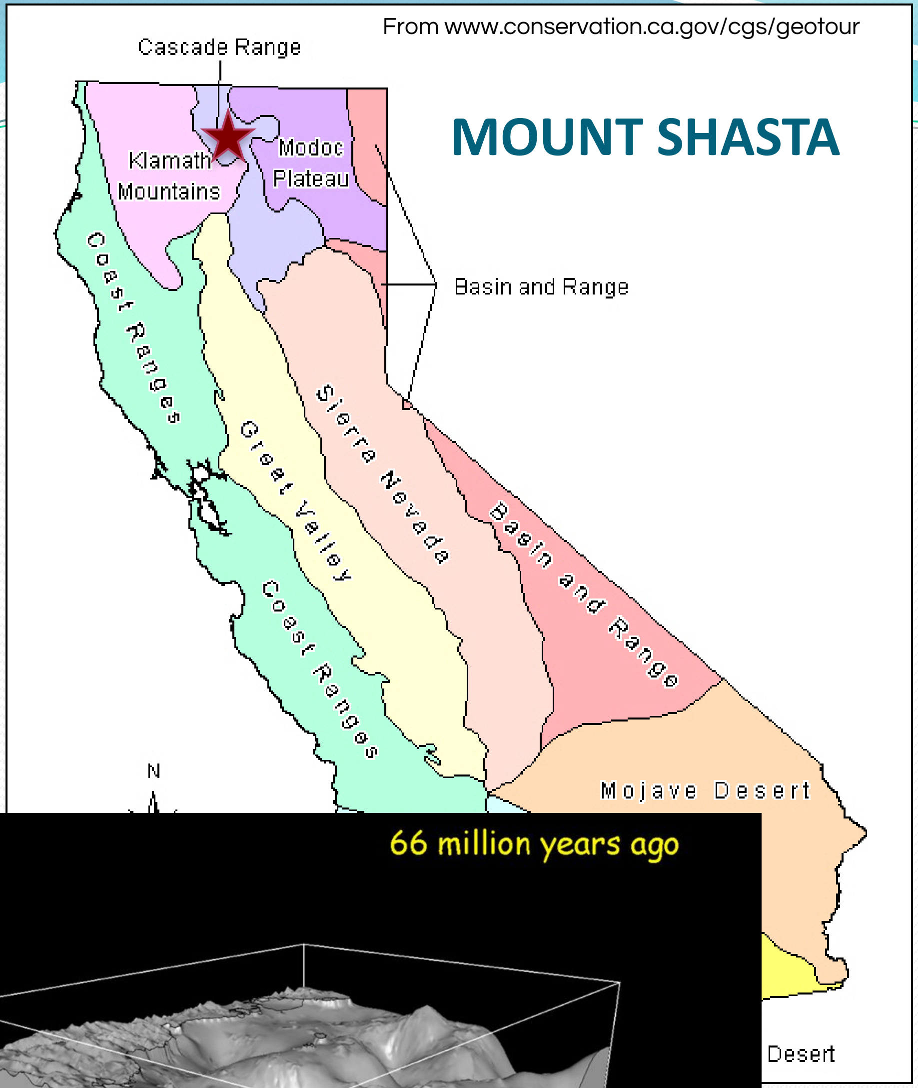
Outline

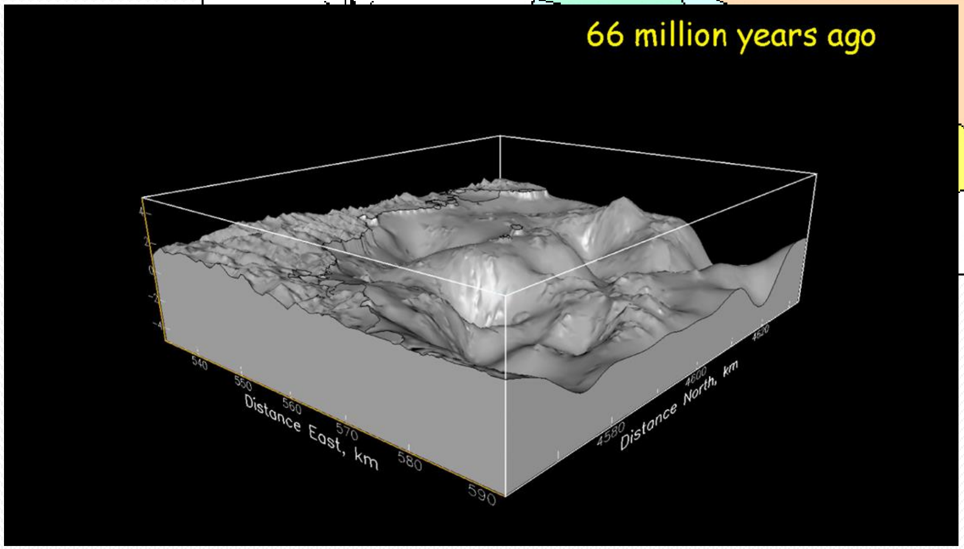
- Geologic assessment of the entire Shasta region
- Data collection
- Preliminary modelling efforts: 2D and 3D models
- CSU Chico effort in the little Shasta: water budget analysis
- Future research
- How can this help for SGMA compliance?

RESEARCH GOALS:

- **MAKE A 3D MODEL OF GROUNDWATER FLOW IN THE MT SHASTA AQUIFER: how much water can be stored in the Shasta aquifer?**
- **GET A BETTER UNDERSTANDING OF VOLCANIC GROUNDWATER SYSTEMS BY STUDYING MT SHASTA**
- **CONSTRAIN THE MAXIMUM DEPTH OF FLOW**
- **UNDERSTAND FLOW PATHS**
- **USE MAGNETOTELLURICS TO IMAGE THE AQUIFER DEPTHS**







Gravity model by Richard Blakely, USGS

Mount Shasta and Shasta Valley likely have greater permeability and connectivity than typical aquifers

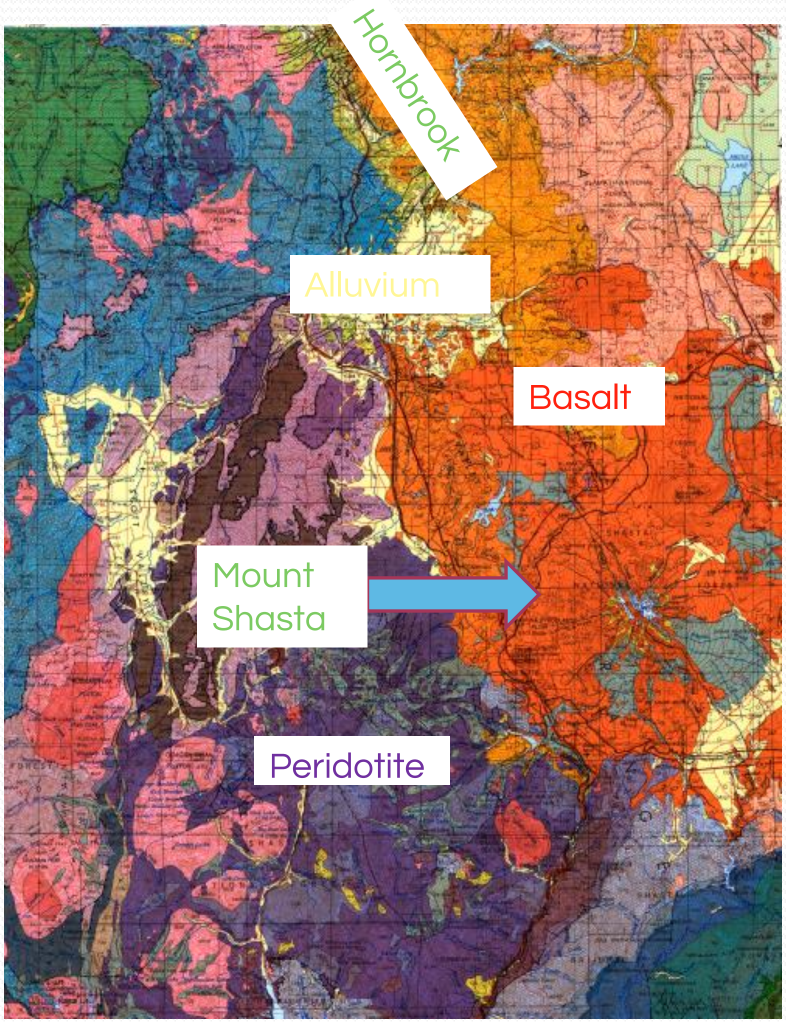
- *N-S striking faults and fractures*
- *Basin and Range influence*
- *Highly permeable volcanic rocks with a volcanic cone that could extend multiple km below the land surface*
- *Evidence of laterally extensive flow in springs*

THE SHASTA RIVER WATERSHED

- Shasta River is mostly spring-fed
- Spring isotopes show source water to be from precipitation on Mt. Shasta
- Water travels through the volcanic aquifer to reach the springs in Shasta Valley
- Nutrients in the river may be affected by the rocks the spring water travels through

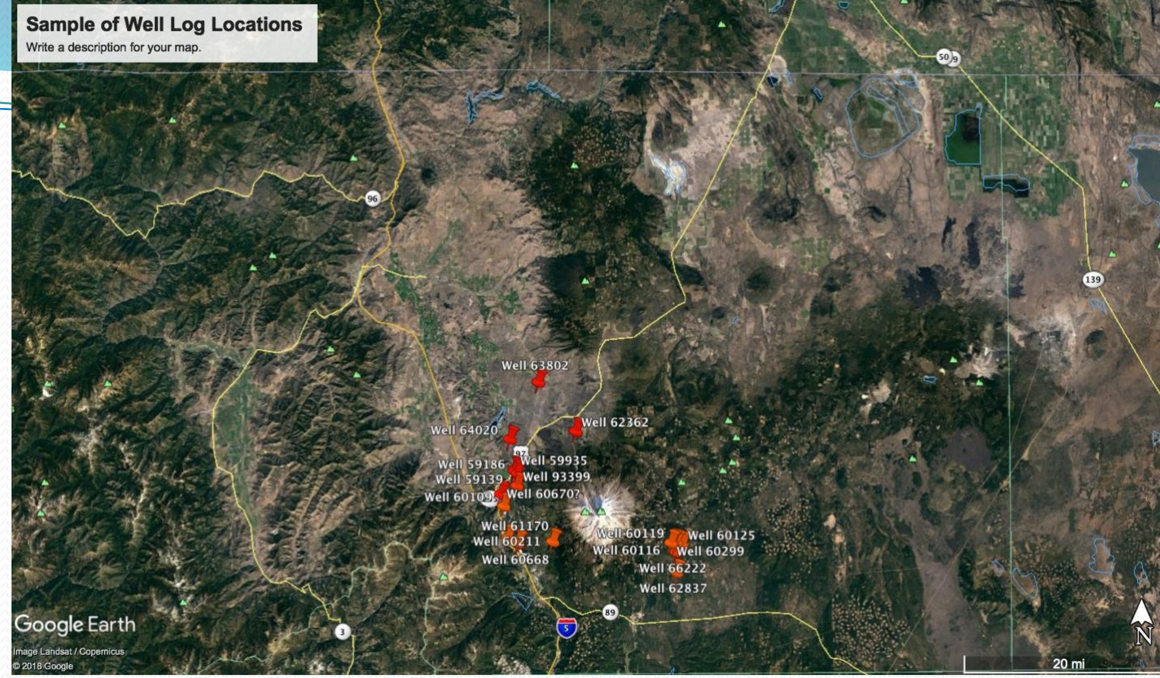
Geology:

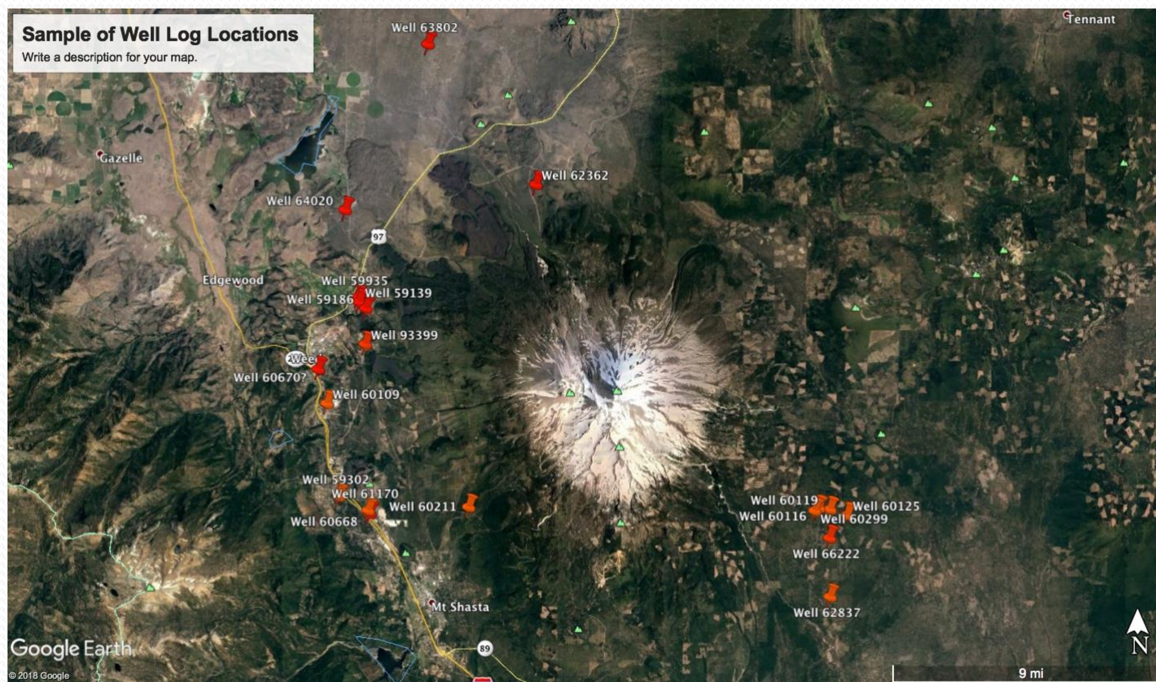
- BASALT: VERY PERMEABLE DUE TO POROUS VESICLES AND LAVA TUBES FORMED DURING PAST VOLCANIC ERUPTIONS
- PERIDOTITE AND OTHER METAMORPHIC ROCKS: LOW PERMEABILITY DO TO THE COMPRESSED NATURE OF METAMORPHIC ROCKS
- HORNBROOK SEDIMENTARY ROCKS: VARIABLE PERMEABILITY, MAY CONTRIBUTE NITROGEN TO SHASTA RIVER
- ALLUVIUM: VERY PERMEABLE RECENTLY DEPOSITED SEDIMENTS.



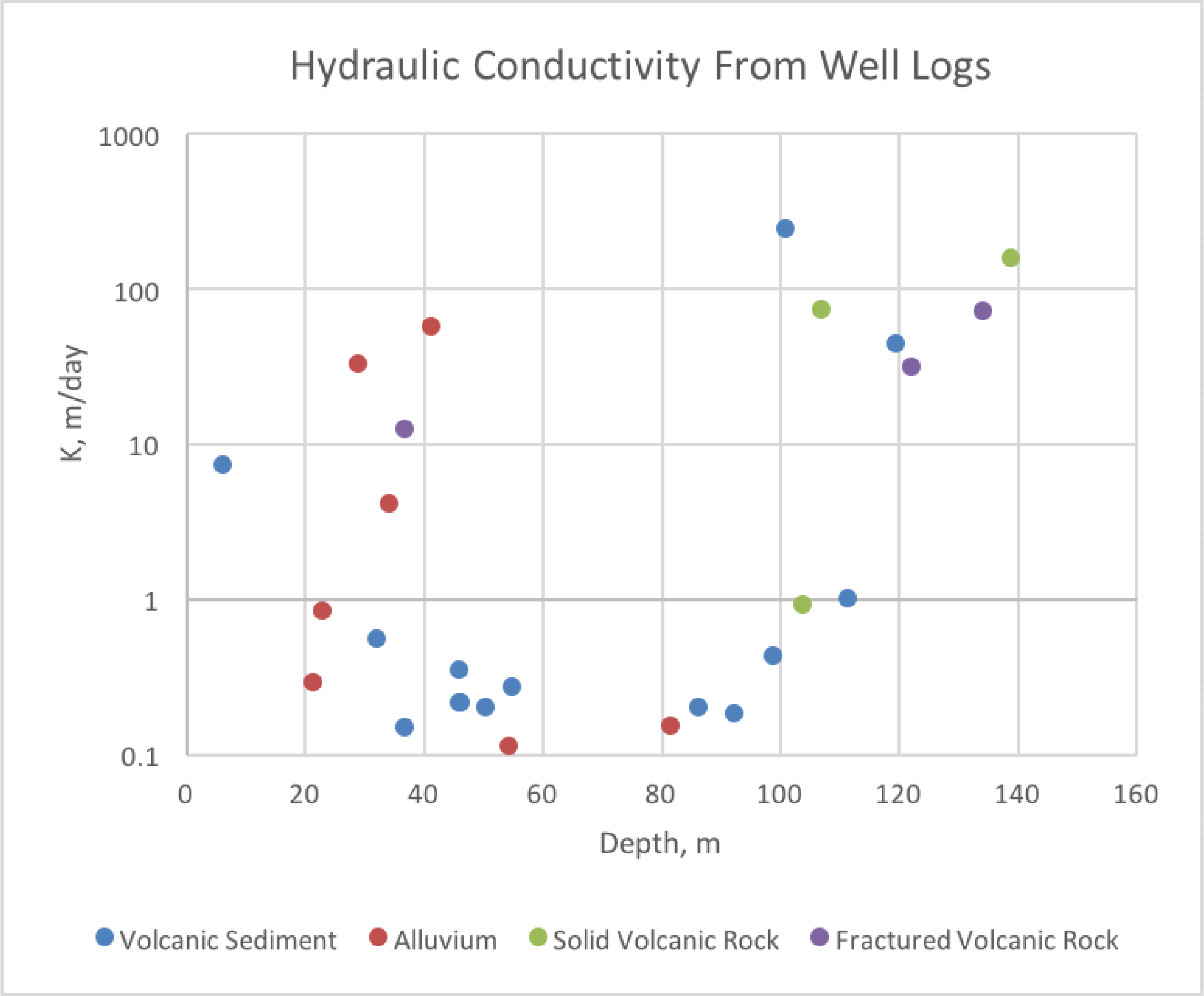
Analyzing wells:

- Sections : 40N2W, 40N3W, 40N4W, 41N2W, 41N4W, 42N3W, and 42N4W.
- All the wells within about a 10 mile radius of the summit in map view, but not all the well logs end up being in the township or section they were originally reported as

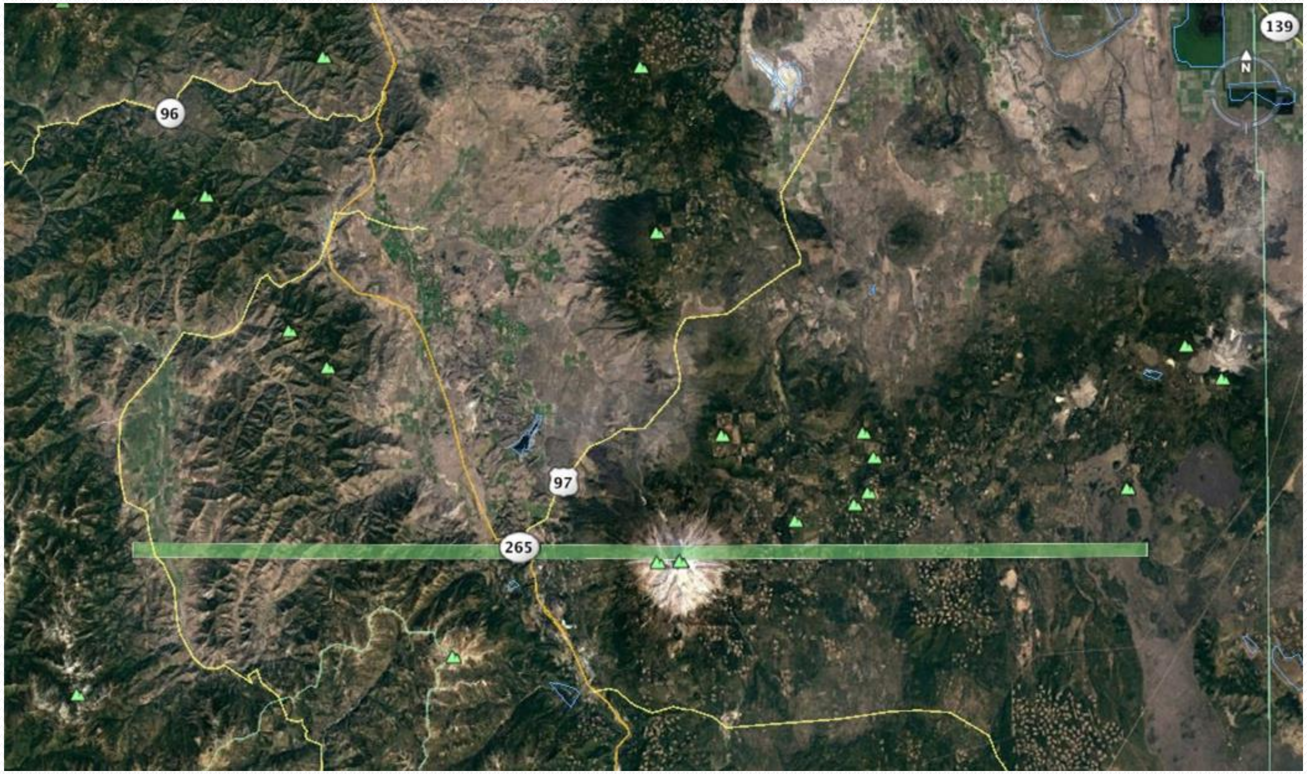




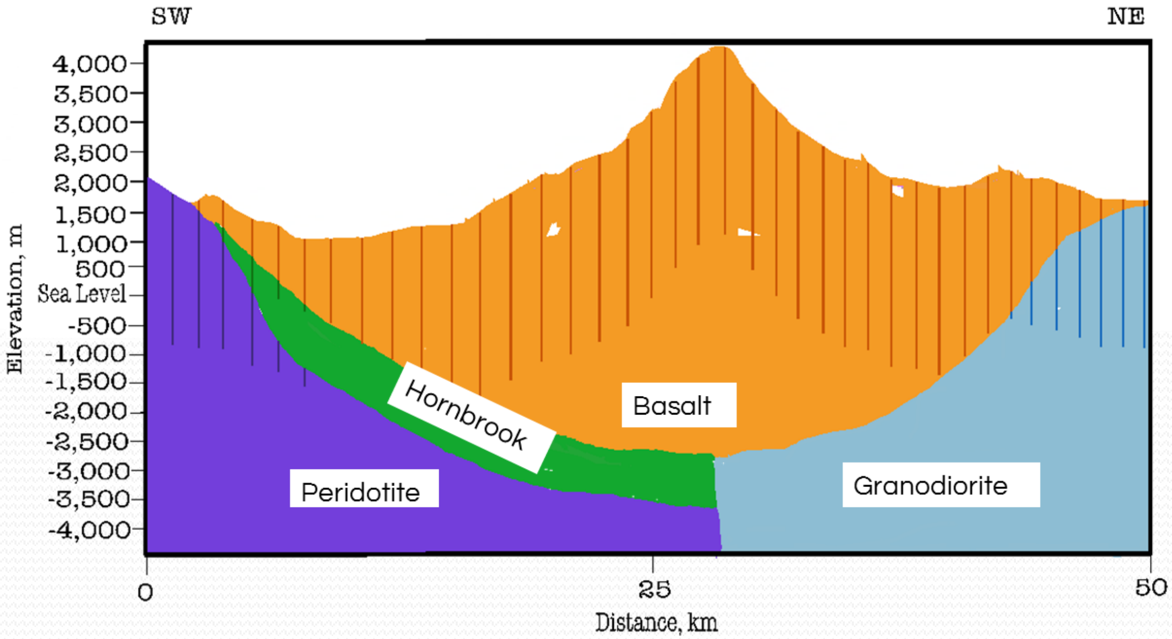
Preliminary estimate of hydraulic conductivity from well logs

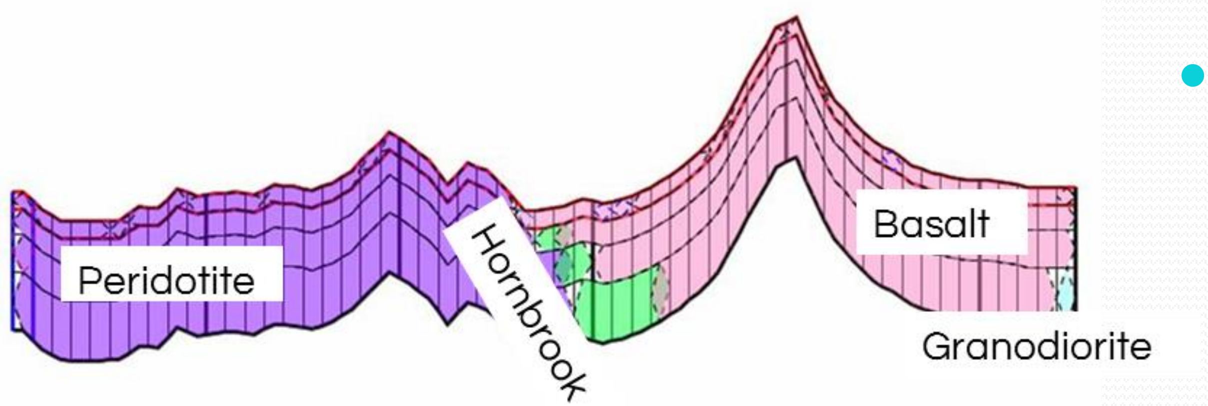


Preliminary 2D GROUNDWATER MODEL: E-W CROSS SECTION THROUGH THE SUMMIT



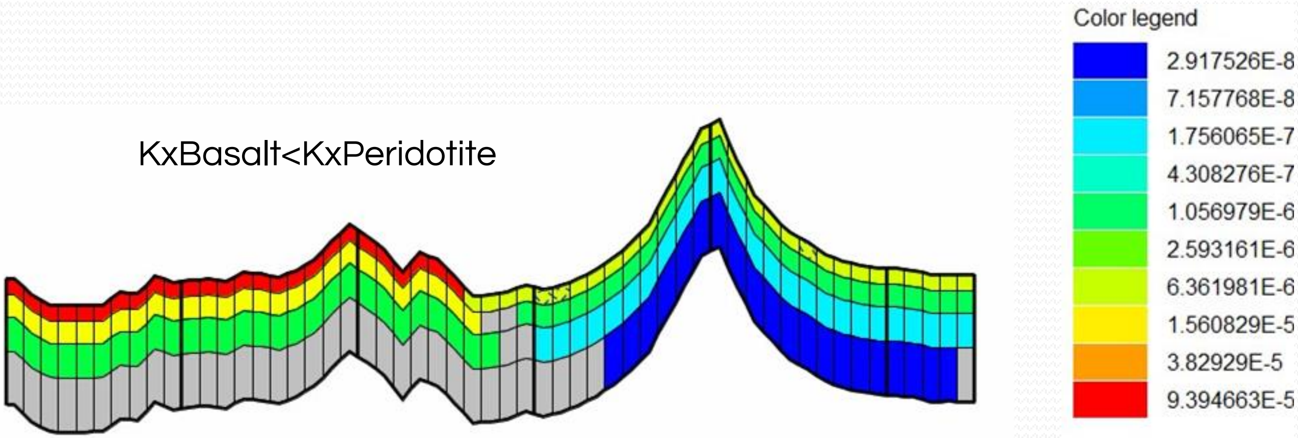
2D CONCEPTUAL MODEL

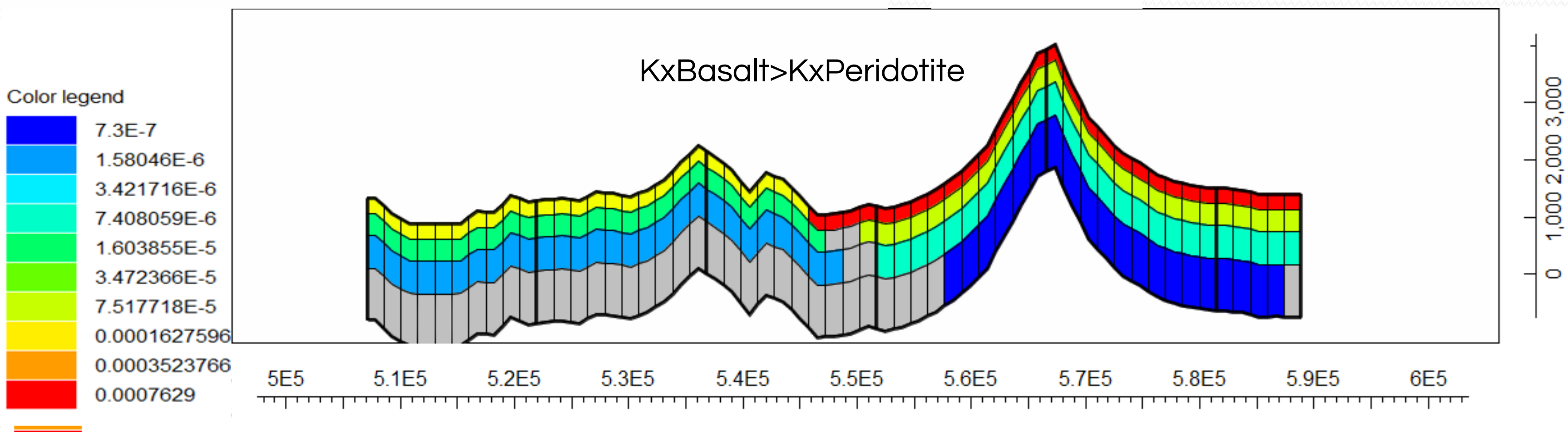




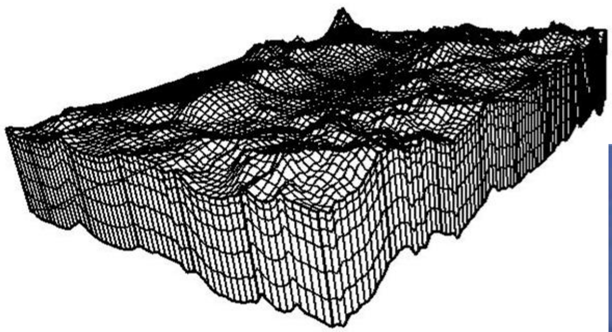
- 4 LAYERS, EACH LAYER HAS 1/10TH THE PERMEABILITY OF LAYER ABOVE
- 4 ROCK TYPES- BASALT, PERIDOTITE, HORNBROOK SEDIMENTARY FORMATION, AND GRANODIORITE
- CROSS SECTION WIDTH: 119KM
- DEPTH EXTENT: 2.1KM

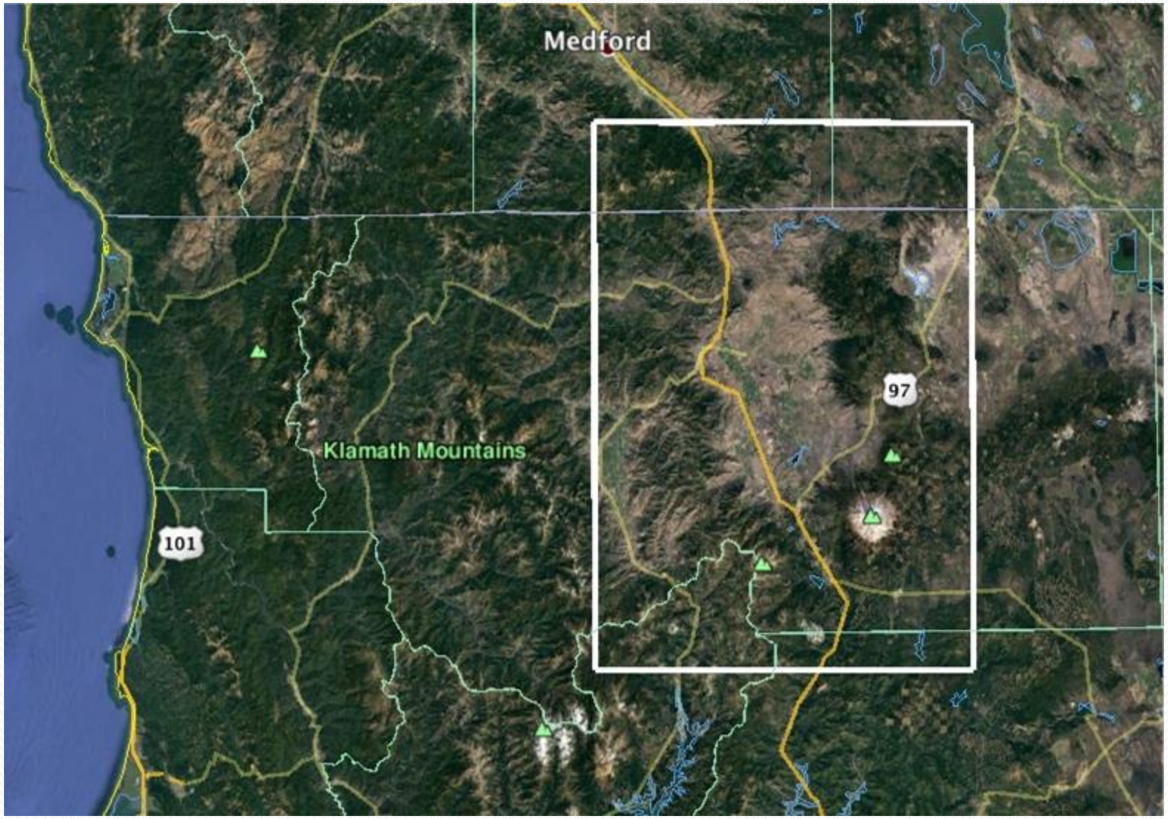
LAYER AND ROCK KX, M/S: 2 MODELS



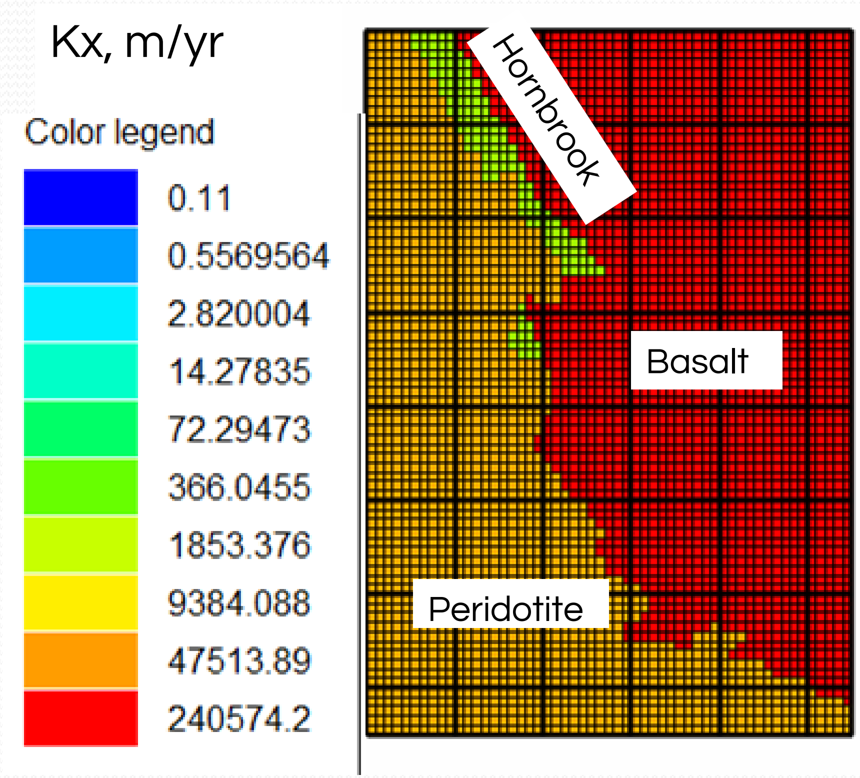


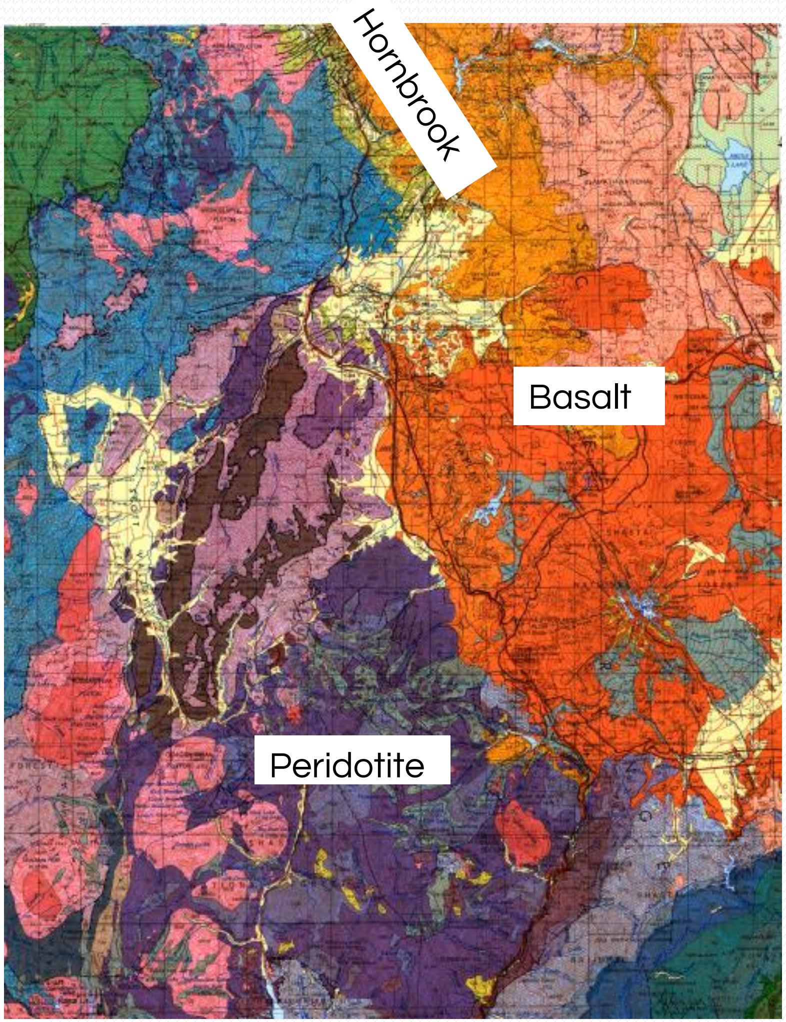
3D MODEL





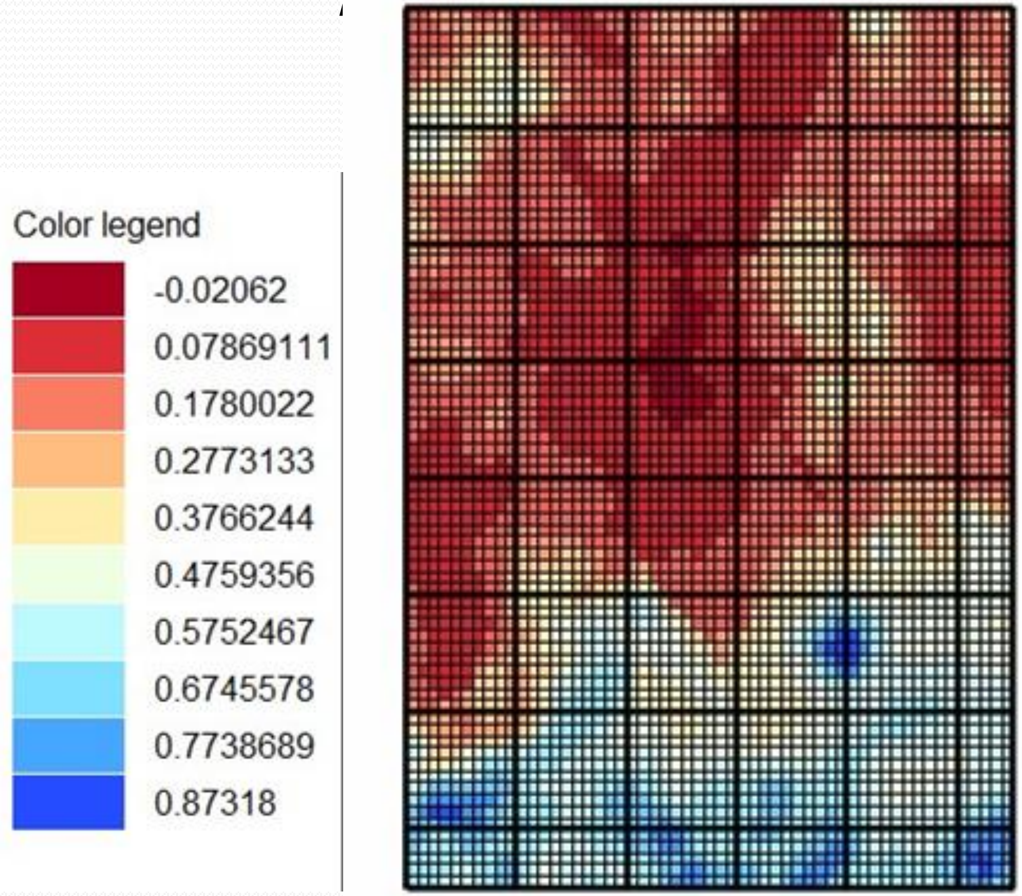
GEOLOGY MODELED





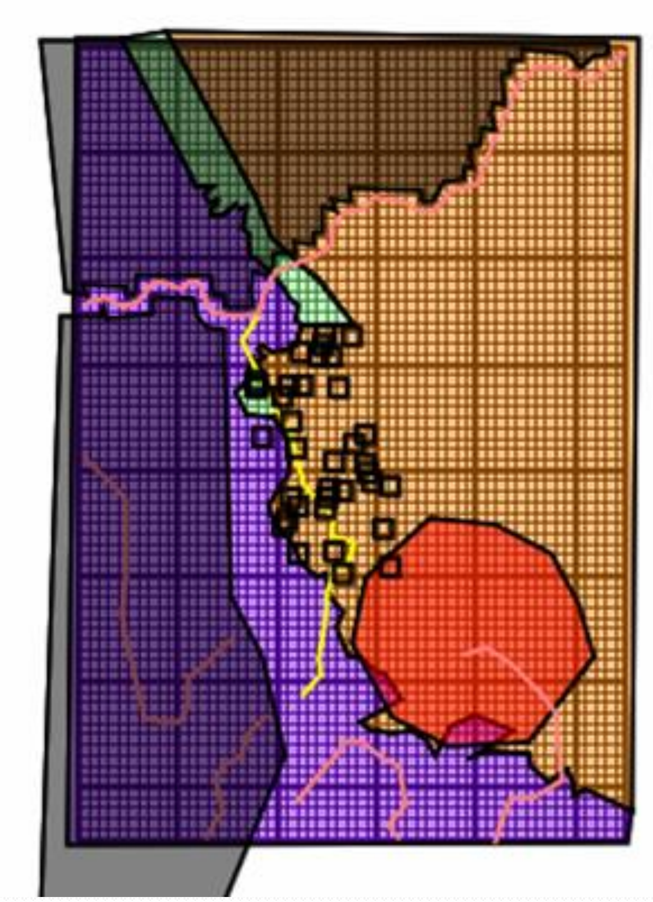
PRECIPITATION M/YR

- PRISM 30 YR NORMALS FROM 1981-2010
- ET OF 40% ASSUMED
- EXTRA .1M/YR OF ET IN VALLEY

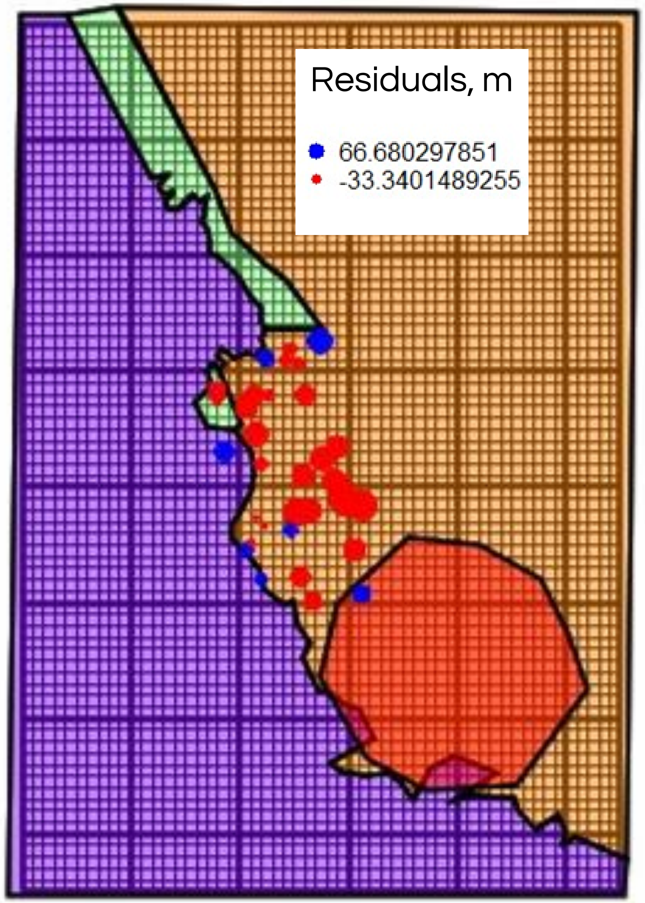


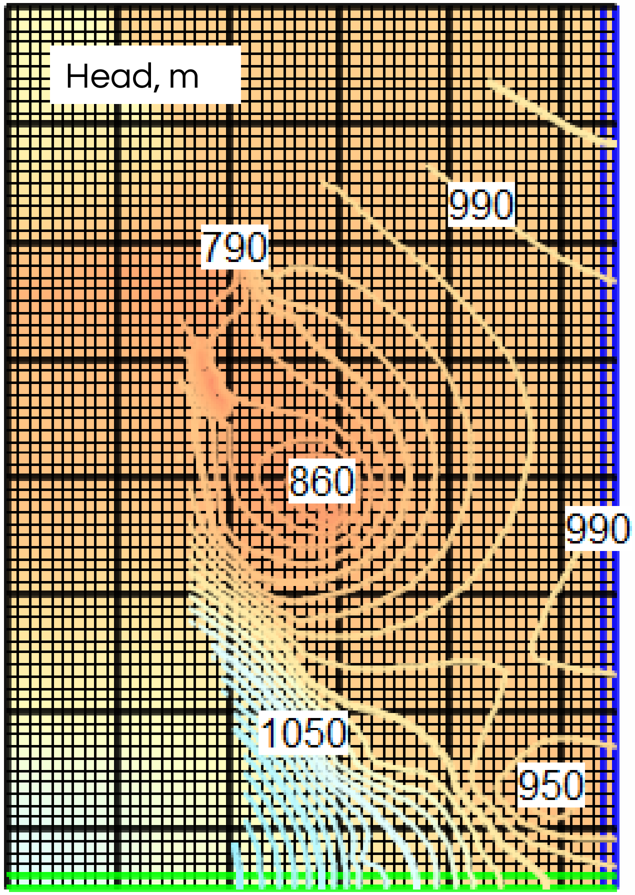
BOUNDARIES

- WEST AND NORTH SIDES NO-FLOW
- EAST AND SOUTH SIDES USED HEAD-ELEVATION TREND TO ESTIMATE GHB
- KLAMATH RIVER IS A CONSTANT HEAD BOUNDARY(RIV)
- BLACK BOXES SHOW WELL LOG LOCATIONS (HOB)



RESULTS


Residuals, m
66.680297851
-33.3401489255


Head, m
990
790
860
990
1050
950

Preliminary CONCLUSIONS

- BASALT MAY HAVE LOWER K THAN EXPECTED
- MODEL NOT SENSITIVE ENOUGH TO DETERMINE DEEP LAYERS WITH WELL LOGS ALONE
- POSSIBLY TEMPERATURE ESTIMATES AND HEAT FLOW MODEL WILL BE MORE SENSITIVE TO DEPTH
- FLOW MODELING ALONE CANNOT SHOW THE DEPTH EXTENT- MORE OBSERVATIONS ARE NEEDED (ISOTOPES, TEMPERATURE, FLOWS)
- ADDING IN MEASUREMENTS THAT GO DEEP CAN CHANGE THE SENSITIVITY.

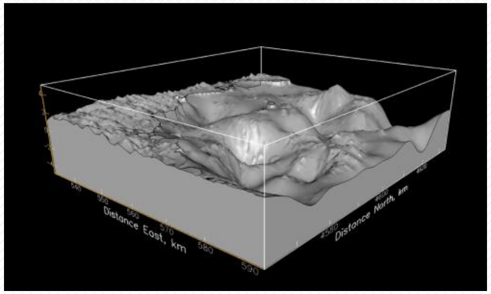
FUTURE MODELS AND DATA COLLECTION

- KECK CAVES TO GET BETTER 3D GEOMETRY
- FEFLOW FINITE ELEMENT TO BETTER HANDLE THE GRADIENT AND GEOMETRY
- FEFLOW CAN INCLUDE HEAT INFORMATION, AND WILL BE USED TO INFORM FUTURE VERSIONS OF THE MODFLOW MODEL FOR SGMA
- MAGNETO-TELLURIC SURVEY CAN PROVIDE OBSERVATIONS AT DEPTH

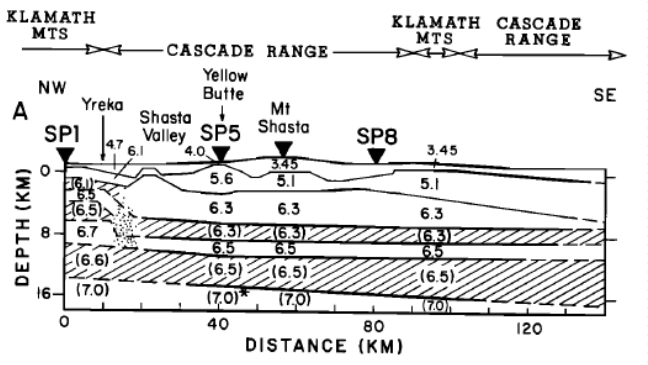
KECK CAVES

MAKE A COHESIVE 3D MODEL OF GEOLOGY BY COMBINING

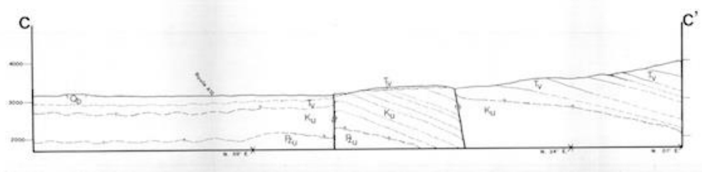
PAST STUDIES



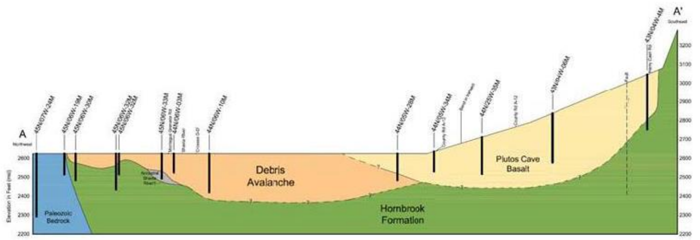
Gravity Model (Blakely)



Seismic Profile (Zucca et al 1986)

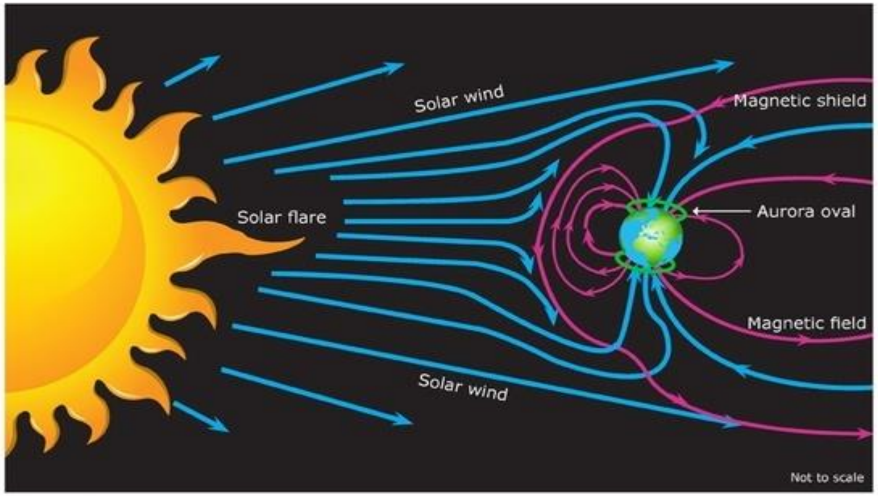


Cross Sections (eg, Holliday 1983)



DWR wells (Figure from Buck, 2012)

MAGNETOTELLURICS

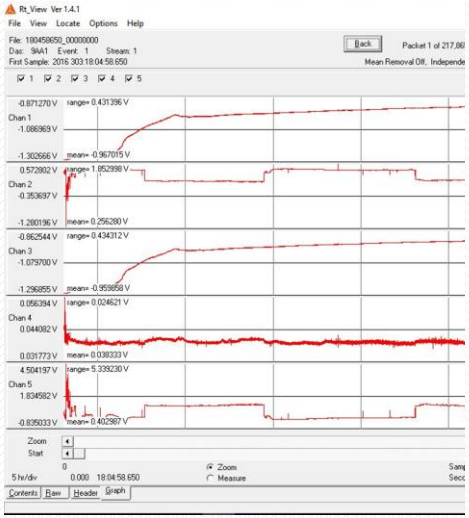


- ROCKS ACT AS RESISTORS AND ALTER THE ELECTRIC SIGNAL
- COMPARING THE ELECTRIC AND MAGNETIC SIGNALS GIVES YOU THE RESISTIVITY
- WATER DECREASES RESISTIVITY
- DIFFERENT FREQUENCY WAVES MEASURE DIFFERENT DEPTHS
- INCOMING EM WAVES GO INTO ROCKS, AND COME OUT WITH A SLIGHTLY DIFFERENT SIGNAL THAT CAN BE MEASURED

→ 4 more MT lines will be measured and analyzed in the summer 2018

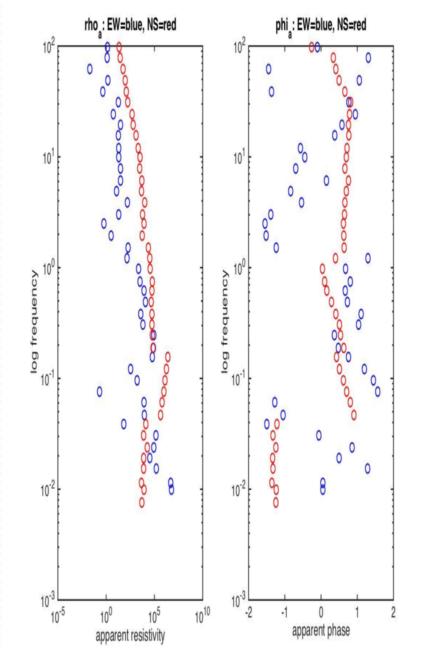
DATA PROCESSING

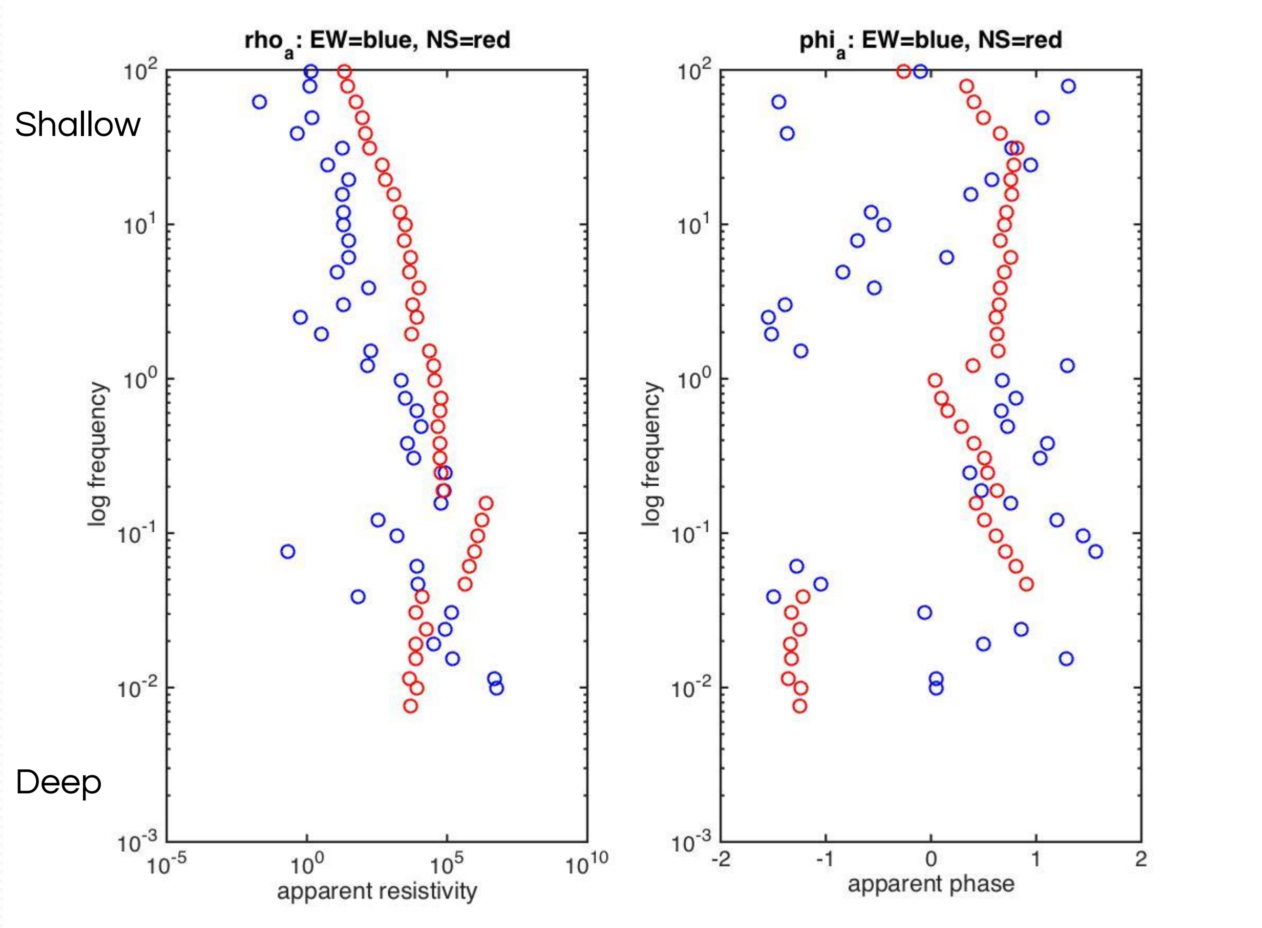
Data Channels



- Break up into time chunks for more data points
- FFT to separate frequencies
- Impedance Tensor and Phase

Resistivity and Phase plots!





High Resistivity → Less Water Content
Low Resistivity → More Water Content

High Phase → Water ↑ with depth
Low Phase → Water ↓ with depth

Spatial and Temporal Analysis of Stream Restoration Efforts in Depleted Aquifer Systems

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California State University, Chico

April 2011

The Shasta Valley A Unique Place

- Hydrology
  - Cool Groundwater Discharge from High Cascades
- Geology
  - Klamath Province and Cascade Province
- Water Chemistry
  - Nutrient signatures and Aquatic Macrophyte Production
- Fishery
  - Historically Productive Anadromous Fishery

Source: Jeff Davids

SGMA Questions

- Stream/aquifer interaction
  - Magnitudes, timescales and spatial extents
  - Groundwater Dependent Ecosystems

Approach

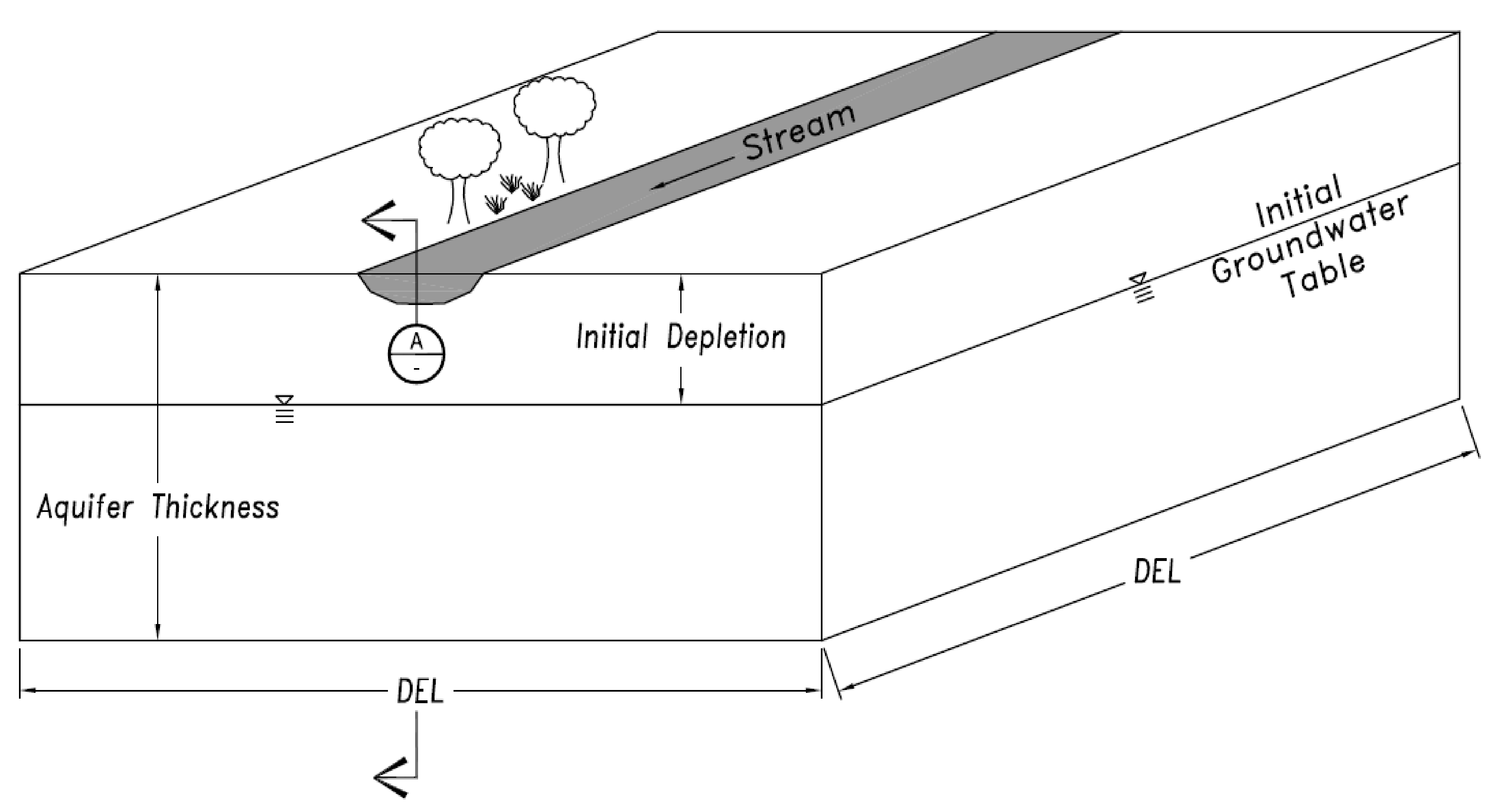
- An Integrated approach between:
  - Field Based Data Collection
    - Little Shasta Valley
  - Parametric Modeling Analysis
  - Application to Little Shasta Valley

Field Based Data Collection

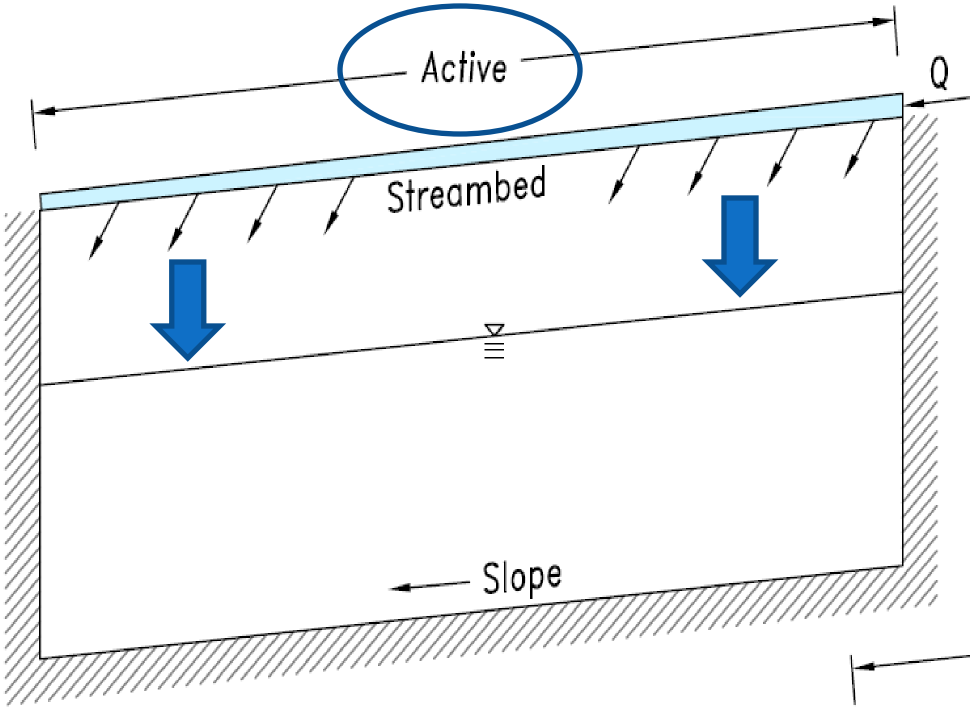
Approach – Modeling Tools

- MODFLOW 2005 Model
  - Stream-aquifer interaction represented by StreamFlow Routing Package (SFR2)
- UCODE
  - Parametric modeling runs
  - Results used for global sensitivity analysis

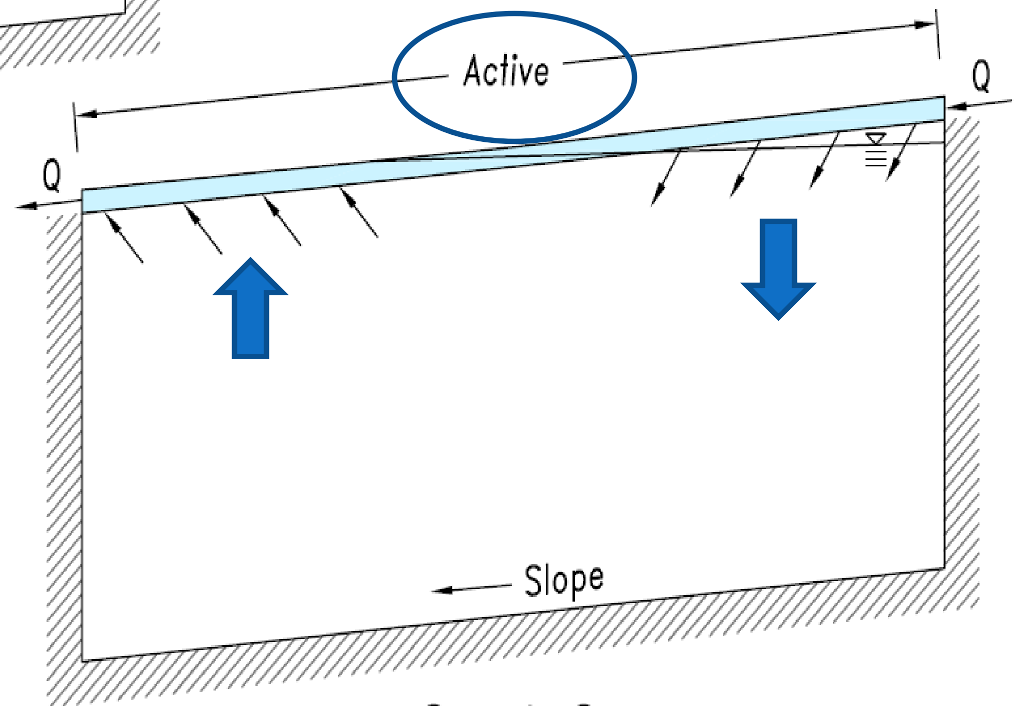
Approach – Model Construct



Regime 3



Initial State



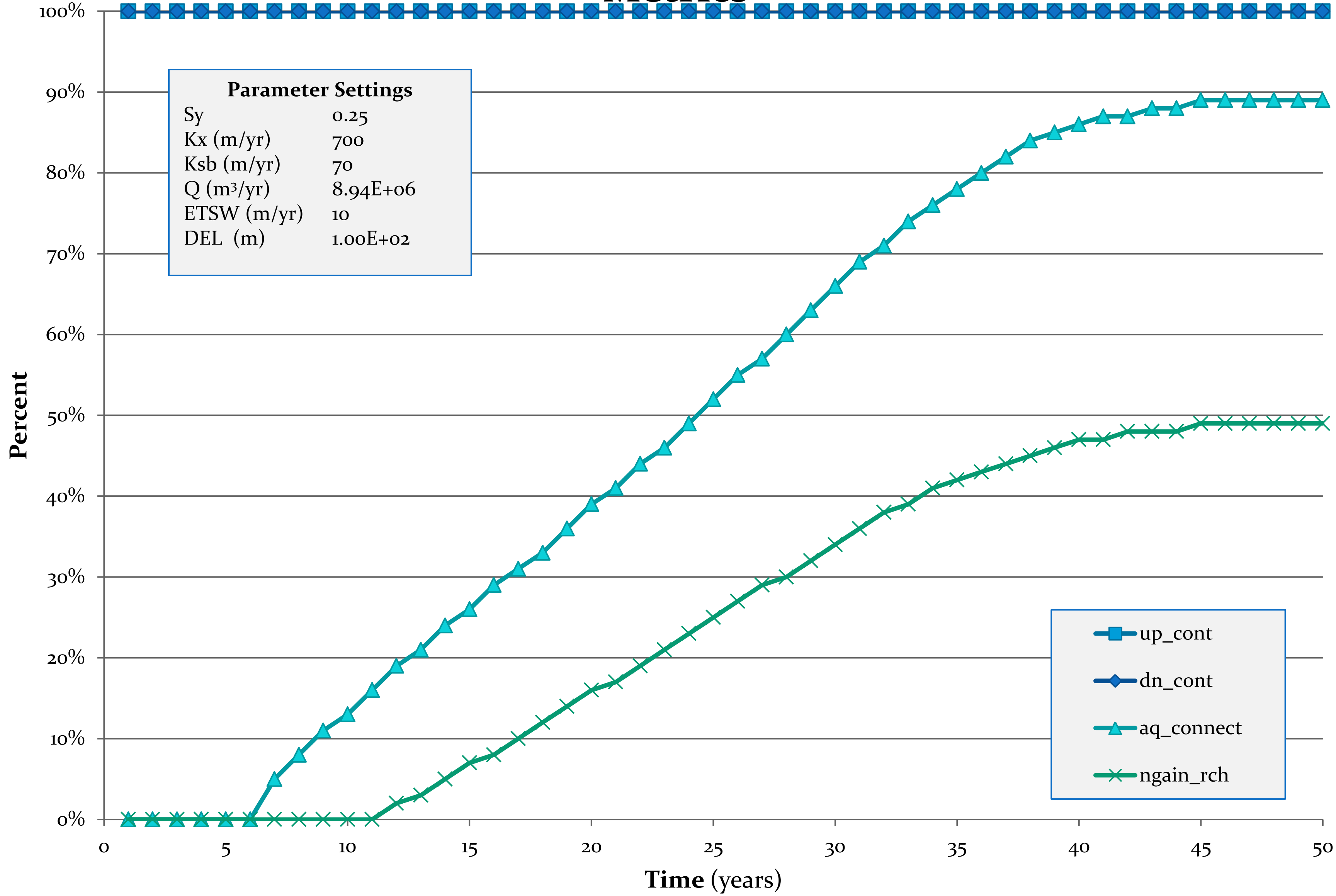
Steady State

Application and Results

- Little Shasta Valley Parameter Ranges
  - Specific Yield (Sy)
  - Aquifer Conductivity (Kx) – Aquifer Performance Tests
  - Streambed Conductivity (Ks) – Infiltration Tests
  - Streamflow (Q) – Flow Measurements,
  - Basin Scale (DEL) and Slope (SLOPE) – DEM
  - ET from Stream Area (ETSW)

Sy	Kx (m/yr)	Ksb (m/yr)	Q (m^3/yr)	ETSW (m/yr)	DEL (m)
0.25	700	70	8.94E+06	10	1.00E+02

Little Shasta Valley Snapshot Continuity and Connection Metrics



Conclusions

- Management of both the surface water and groundwater systems are required for addressing stream/aquifer interaction under SGMA
- Attaining a new steady state, whereby the groundwater system regains two way interactions with the stream is an important component of GDE health.