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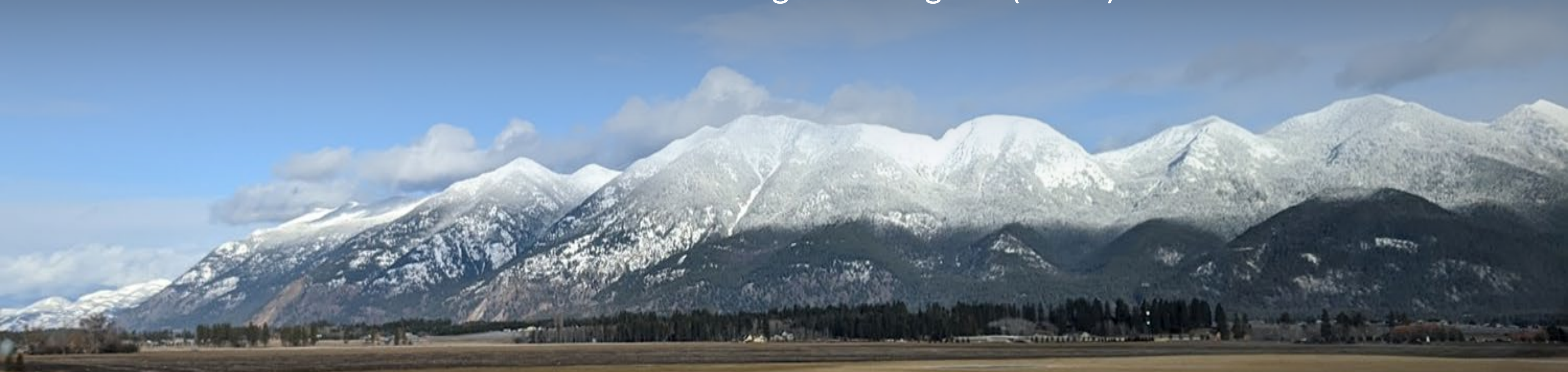
An Overview of the East Flathead Groundwater Investigation

Public Meeting 10/8/24
Kalispell, MT

Andrew Bobst

Assisted by: James L. Berglund, Larry N. Smith, Ali Gebril, Ginette Abdo, Dean Snyder, Carly Peach, Mary Sutherland, James Rose, Todd Myse, Tyler Kamp, John Allard, and others

Ground Water Investigation Program (GWIP)



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Our mission is to provide information for the sound use of Montana's geological and water resources.

- **Established in 1919 to provide reliable and unbiased earth science information**
- **Non regulatory, applied research**

Geology

- ✓ Geologic Mapping
- ✓ Geohazards/Earthquake Studies
- ✓ Economic Geology
- ✓ Energy Resources

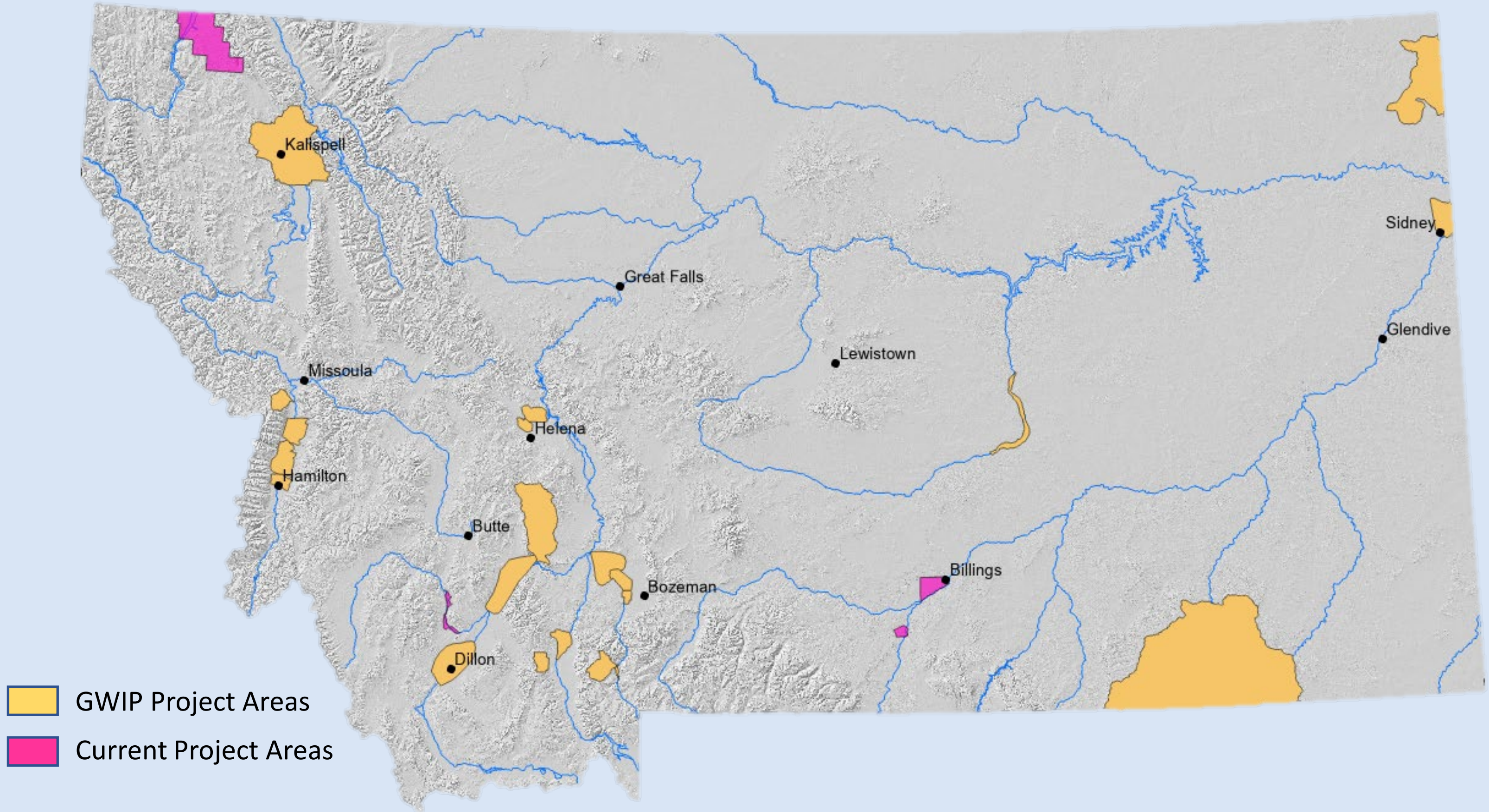
Water Resources

- ✓ State-wide groundwater monitoring network
- ✓ Ground Water Investigation Program
- ✓ Ground Water Assessment Program
- ✓ Environmental Studies

https://www.mbmg.mtech.edu/




Ground Water Investigation Program



- ✓ GWIP supports science-based water management in Montana by answering site-specific questions
- ✓ Projects can be nominated by anyone
- ✓ Project are ranked by the Groundwater Steering Committee

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Ground Water Investigation Program

- Some Types of GWIP Studies
  - Effects to groundwater availability due to land use change from irrigated agricultural to residential
  - Changes in water quality due to increased subdivisions
  - Effects on stream flow due to increased groundwater withdrawals
  - Impacts to groundwater and surface water from changing irrigation methods
  - Effects of drought on water resources

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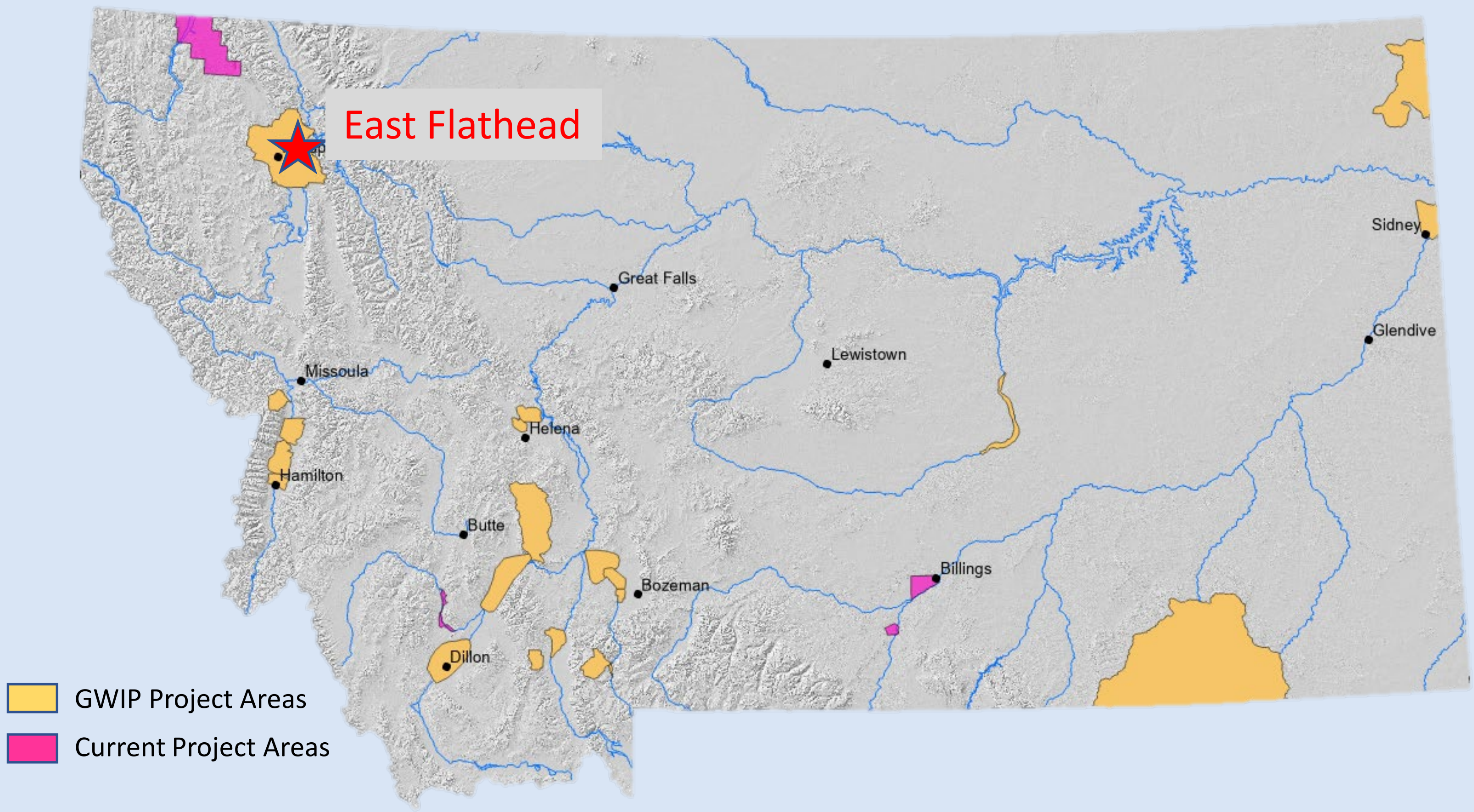
Ground Water Investigation Program



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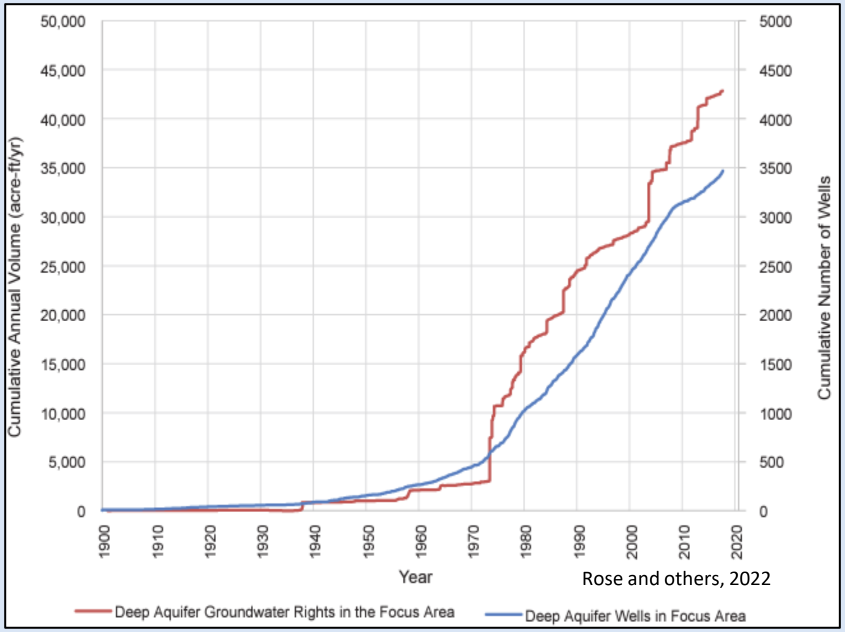
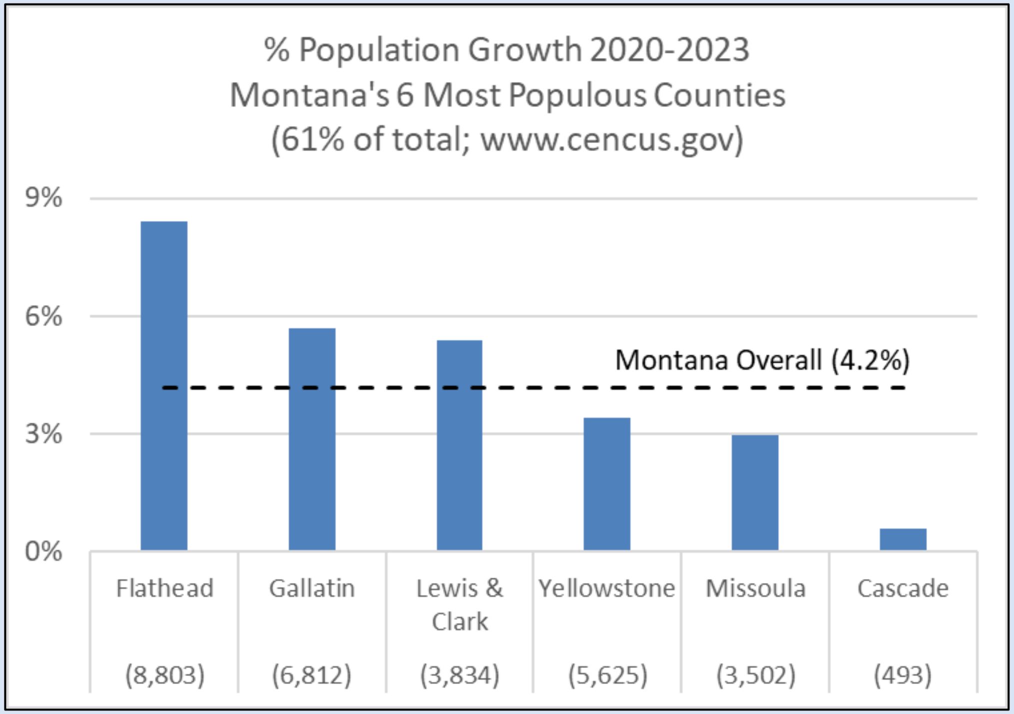
East Flathead Study Purpose

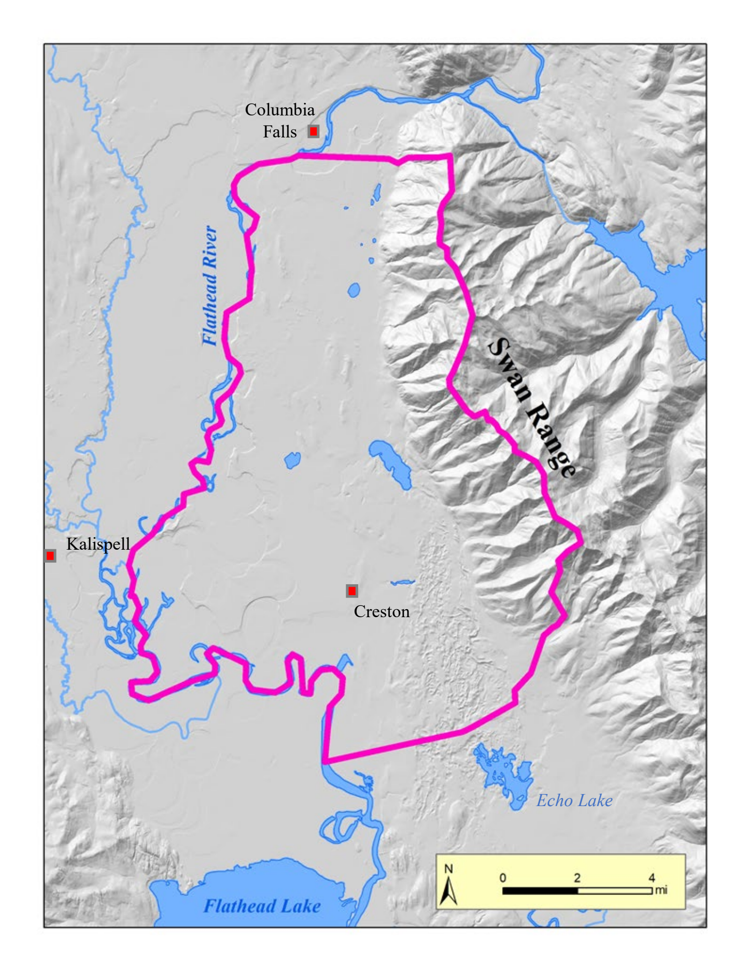


Water Rights and Wells in the Deep Aquifer of the Flathead Valley



East Flathead Study Purpose

- Provide a detailed understanding of the interconnection between aquifers and between surface-waters and groundwater



Study Area

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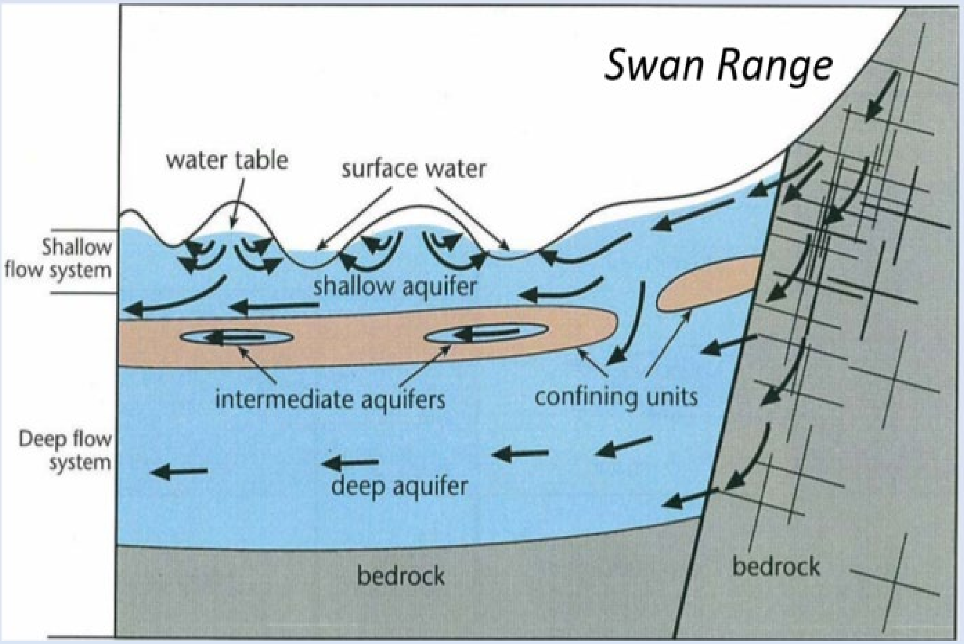
General Hydrostratigraphy

- Shallow Aquifer
  - Generally, Deposited by Streams (fluvial)
  - Young
  - Connected to Surface Waters
- Deep Aquifer
  - Glacial Outwash
  - Sand, Gravel, and Silt
  - May be highly productive (>1,000 gpm), but variable
- Confining Layer
  - Deposited at the Glacier's Base (Basal Till)
  - Deposited in Lakes (Lacustrine)
    - Near Shore
    - Deep Water
  - Present in much of the area
  - May be thin or have "windows"
  - May include Intermediate Aquifers
    - Subglacial melt channels



Conceptual diagram of flow systems in the Flathead Valley (reproduced from LaFave and others, 2004)

Overview of the Study

- Build a numerical groundwater flow model (MODFLOW)
  - Hydrogeologic Properties and Boundary Conditions
  - Calibrate to Monitoring Data
  - Use Calibrated model to evaluate select scenarios
  - Make the model available to allow for other scenarios to be tested, or to provide a starting point for more refined modeling.
- Understand the distribution of Hydrogeologic Units
  - Permeability and Storativity
- Develop a Groundwater Budget
  - Where is water coming from and going to, how much, and what are the relative magnitudes of these sources and sinks.
- Monitoring Data
  - Groundwater Elevations, Stream Gains and Losses, Stream and Lake Elevations, Water Quality and Tracers

Refining the Geologic Model

- Previous Hydrogeologic Work
  - Cross-Section - Uthman et al., 2000
  - Entire Flathead Valley
    - LaFave et al., 2004
    - Rose, 2018
    - Weight, 2019, 8 layer numerical flow model
    - DNRC, unpublished – 4 layer model based on Weight model

Refining the Geologic Model

- 446 Well Logs
- 9 Hydrogeologic Units (HGUs)
  - Bedrock
  - Deep Aquifer
  - Mountain Front Deposits
  - Basal Till Aquitard
  - Ablation Till
  - Intermediate Aquifer
  - Lacustrine Aquitard
  - Sandy Lacustrine Sediments
  - Shallow Aquifer

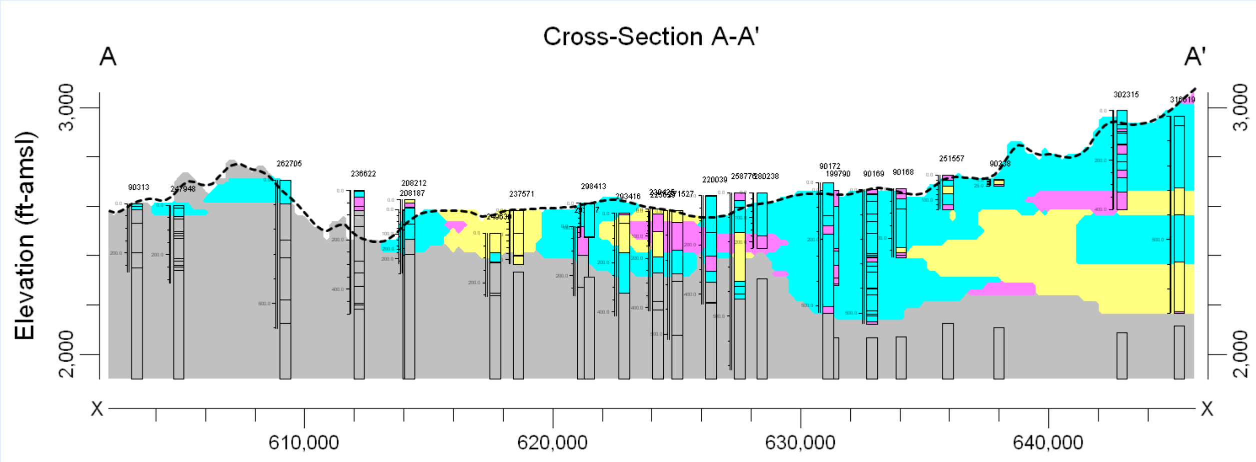
112ALVM - ALLUVIUM (PLEISTOCENE)

From	To	Description
0	1	TOP SOIL
1	10	REDDISH BROWN SILTY FINE SAND
10	35	REDDISH BROWN SILTY SAND
35	45	SANDY CLAY
45	80	SILTY CLAY
80	90	SAND AND CLAY
90	110	SILTY CLAY
110	115	CLAY AND GRAVEL
115	125	GRAVEL
125	138	CLAY
138	280	GRAVEL
138	145	COARSE GRAVEL AND SAND
145	180	COARSE GRAVEL AND SAND WITH FEW COBBLES
180	190	SAND AND GRAVEL
190	240	GRAVEL AND SAND WITH FEW COBBLES

Lithologic Log

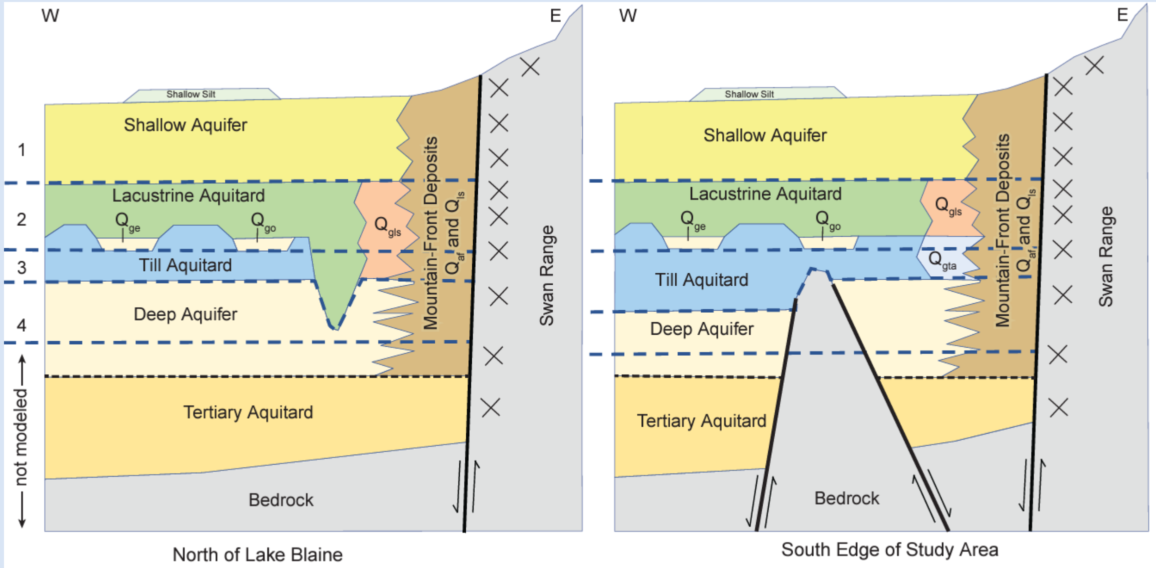
Refining the Geologic Model

- RockWorks



Example of Rockworks Cross Section

- Import to Groundwater Vistas
  - 4 Layer MODFLOW Model



Schematic Cross Sections and Model Layers

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Refining Geologic Model

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Drilling/RotoSonic

finely laminated silt and clay

Refining Geologic Model - RotoSonic Drilling

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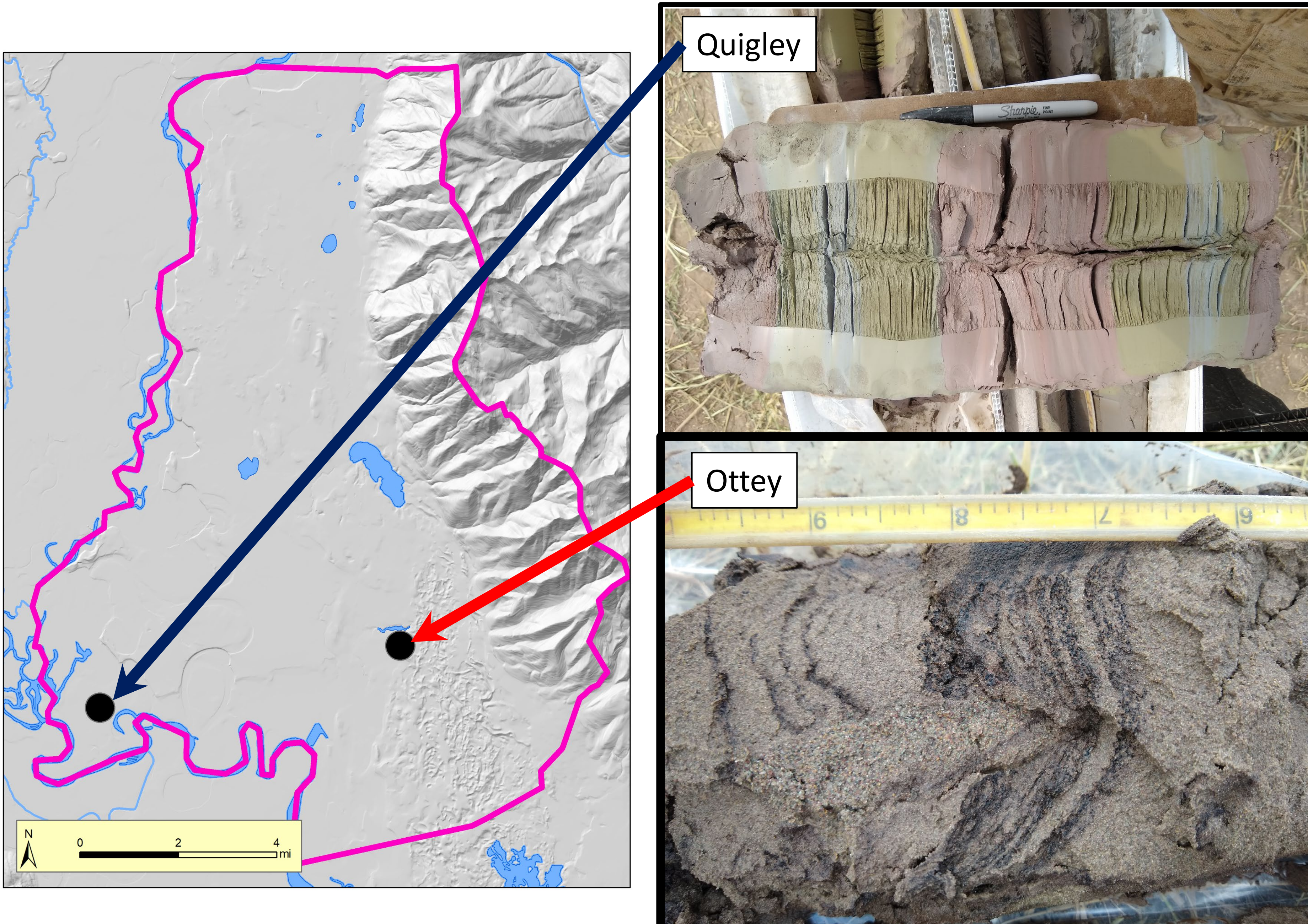
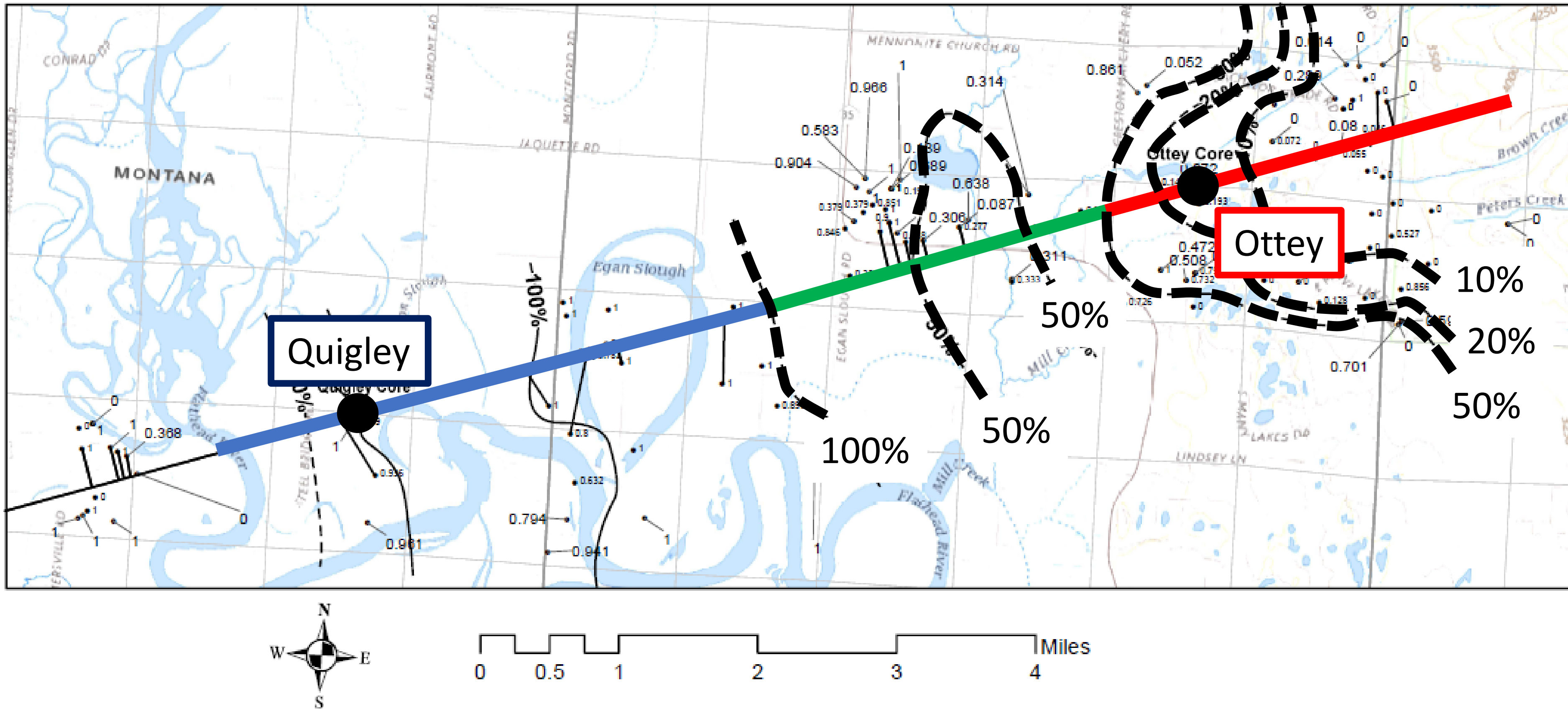


Refining Geologic Model - Lithologic Logs

Percent Fine-Grained Sediments



Preliminary Results Bobst and others, in prep

Refining Geologic Model - Lithologic Logs

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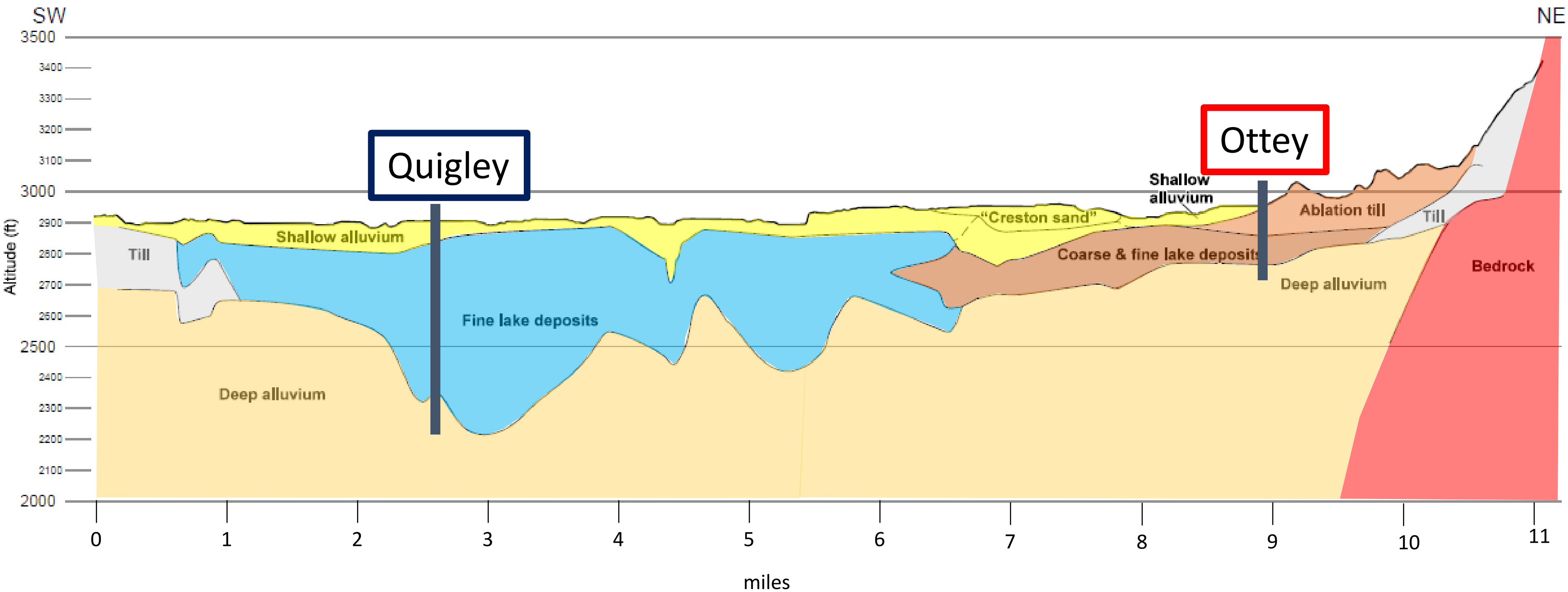
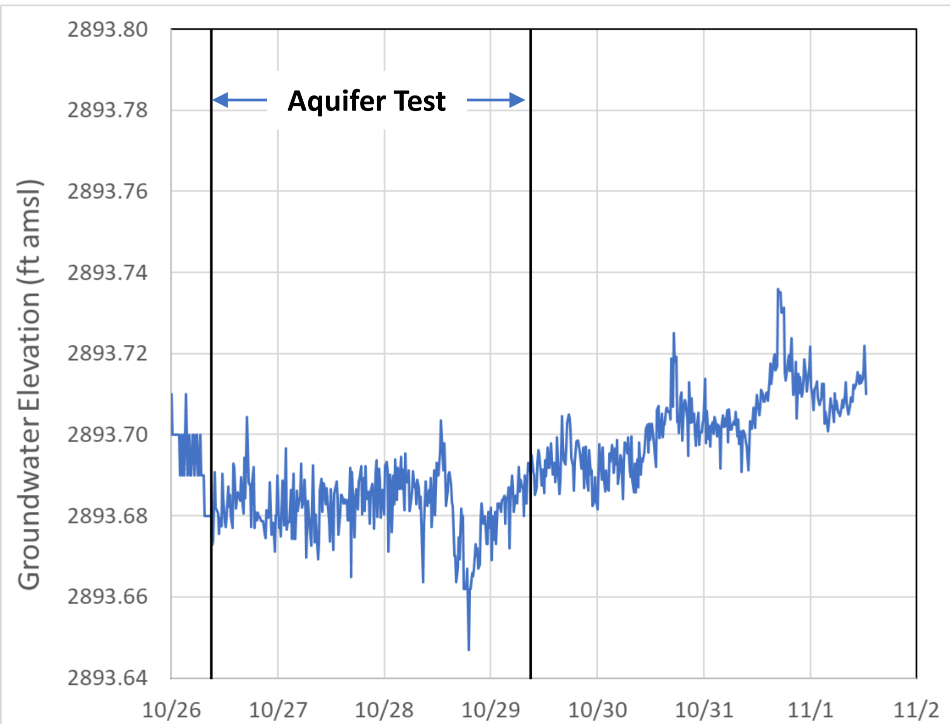


Preliminary Results Bobst and others, in prep
~12x vertical exaggeration

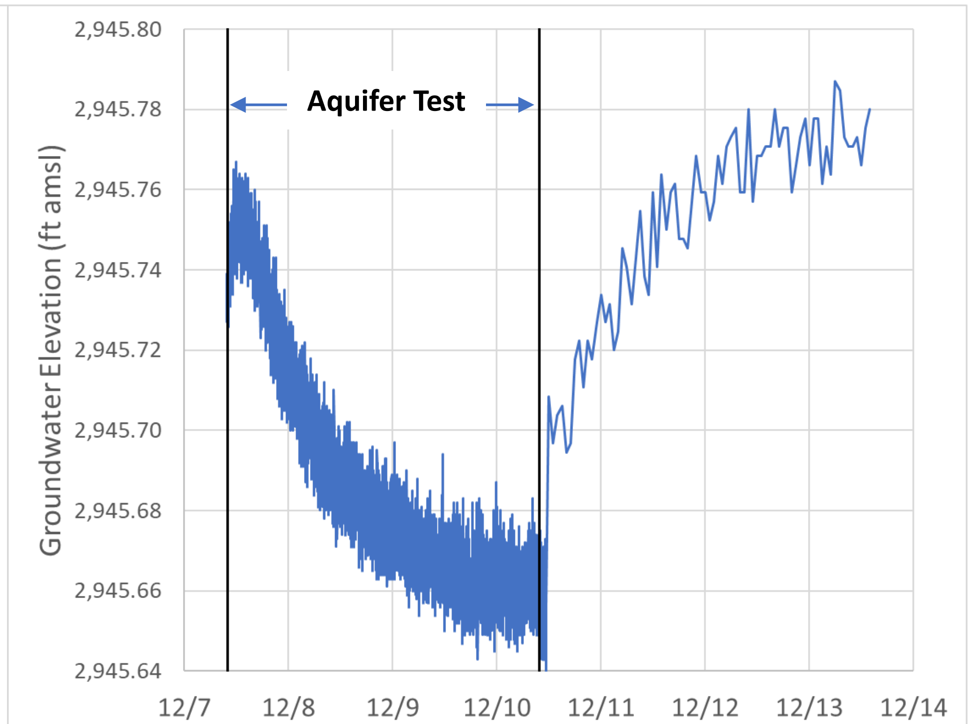
Refining Geologic Model - Aquifer Tests

Shallow Aquifer Response to Deep Pumping

Quigley



Ottey



Myse and others, 2023

Refining Geologic Model - Tracers

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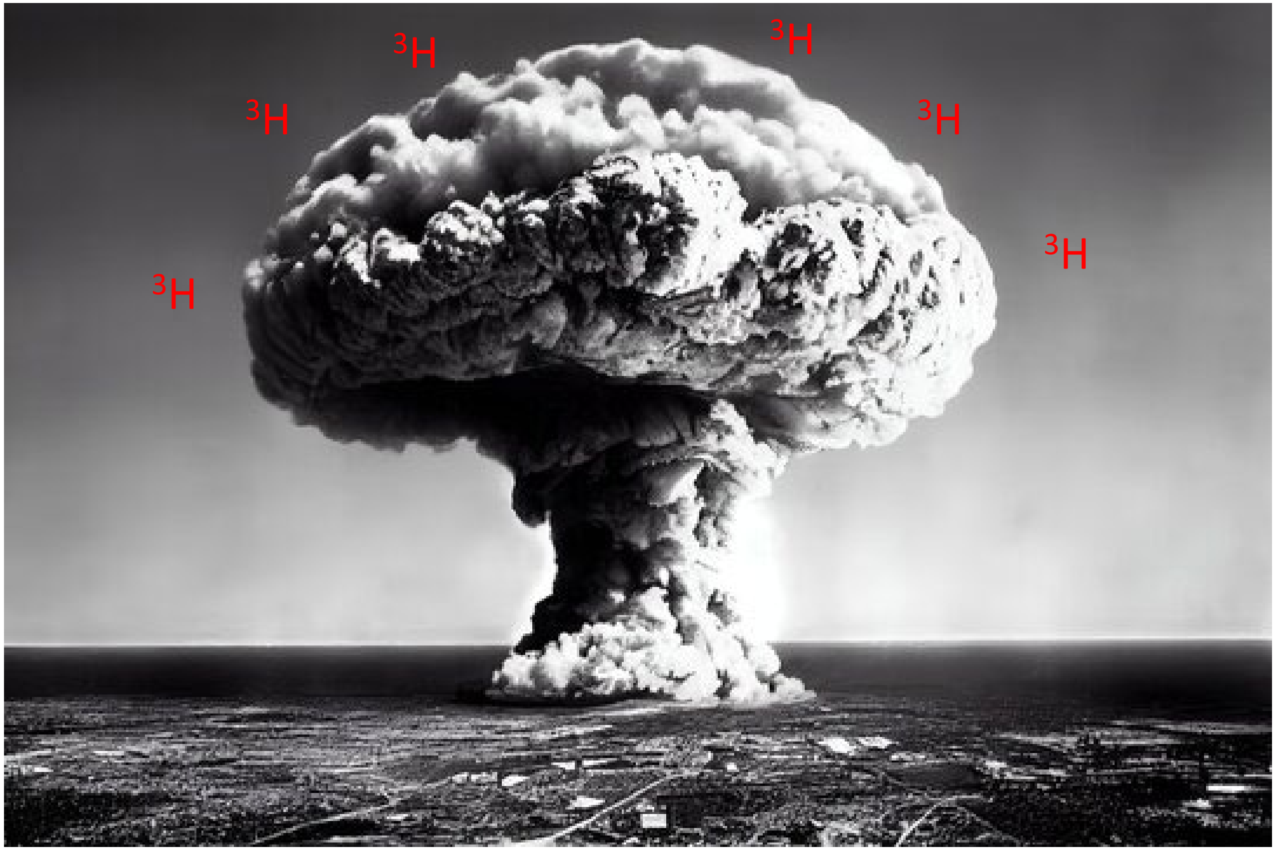
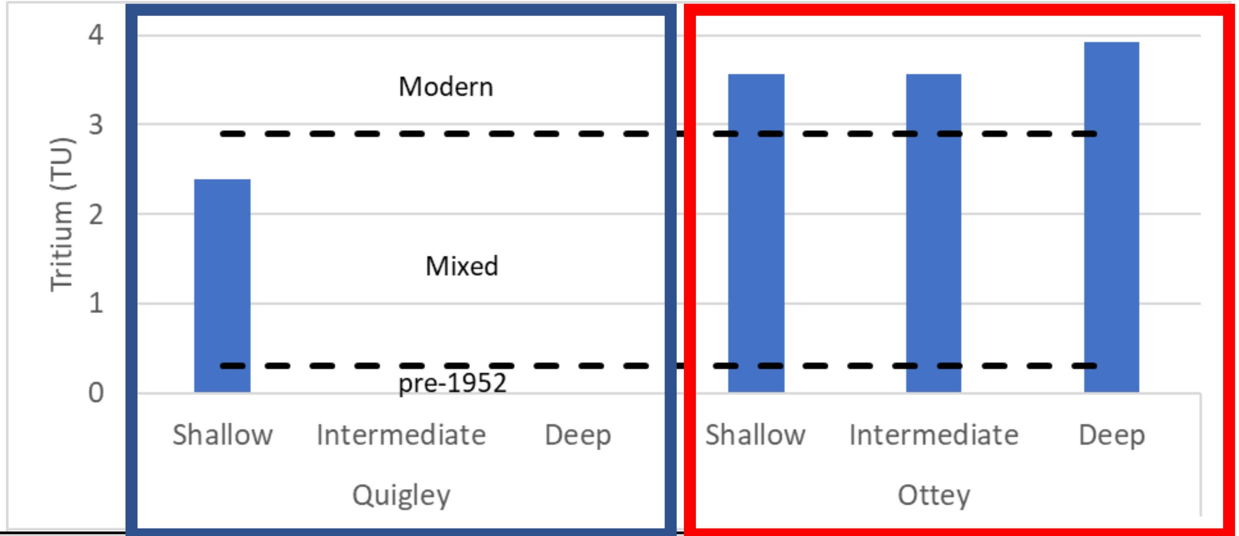


^3H half life
12.3 years

1963 Peak

Preliminary Results Bobst and others, in prep
Tritium ranges from Lindsay and others, 2019

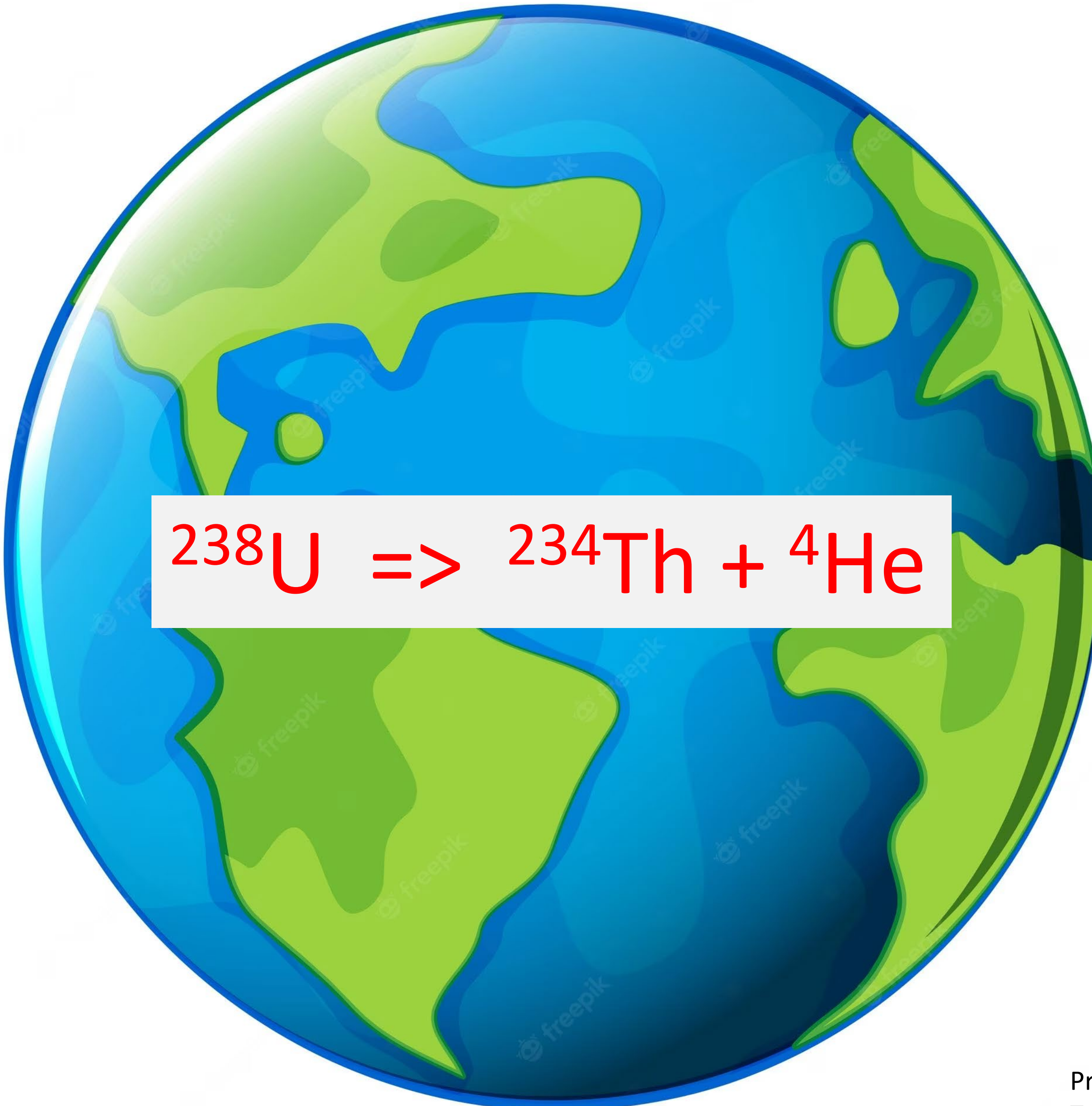
Refining Geologic Model - Tracers



Preliminary Results Bobst and others, in prep
Tritium ranges from Lindsay and others, 2019

Refining Geologic Model - Tracers

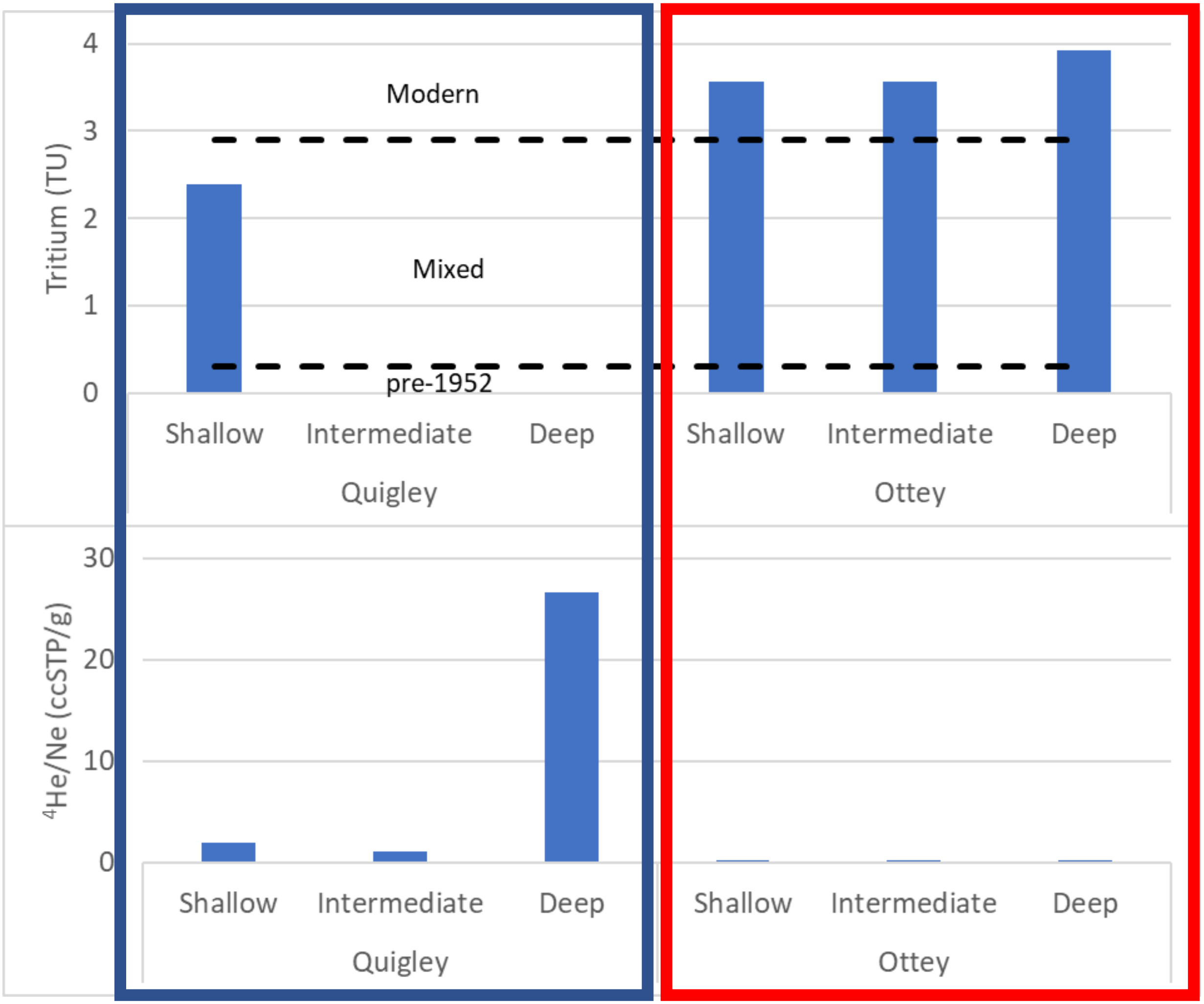
One of many decays that produce ^{4}He (α particles)



$$^{238}U \Rightarrow {}^{234}Th + {}^{4}He$$

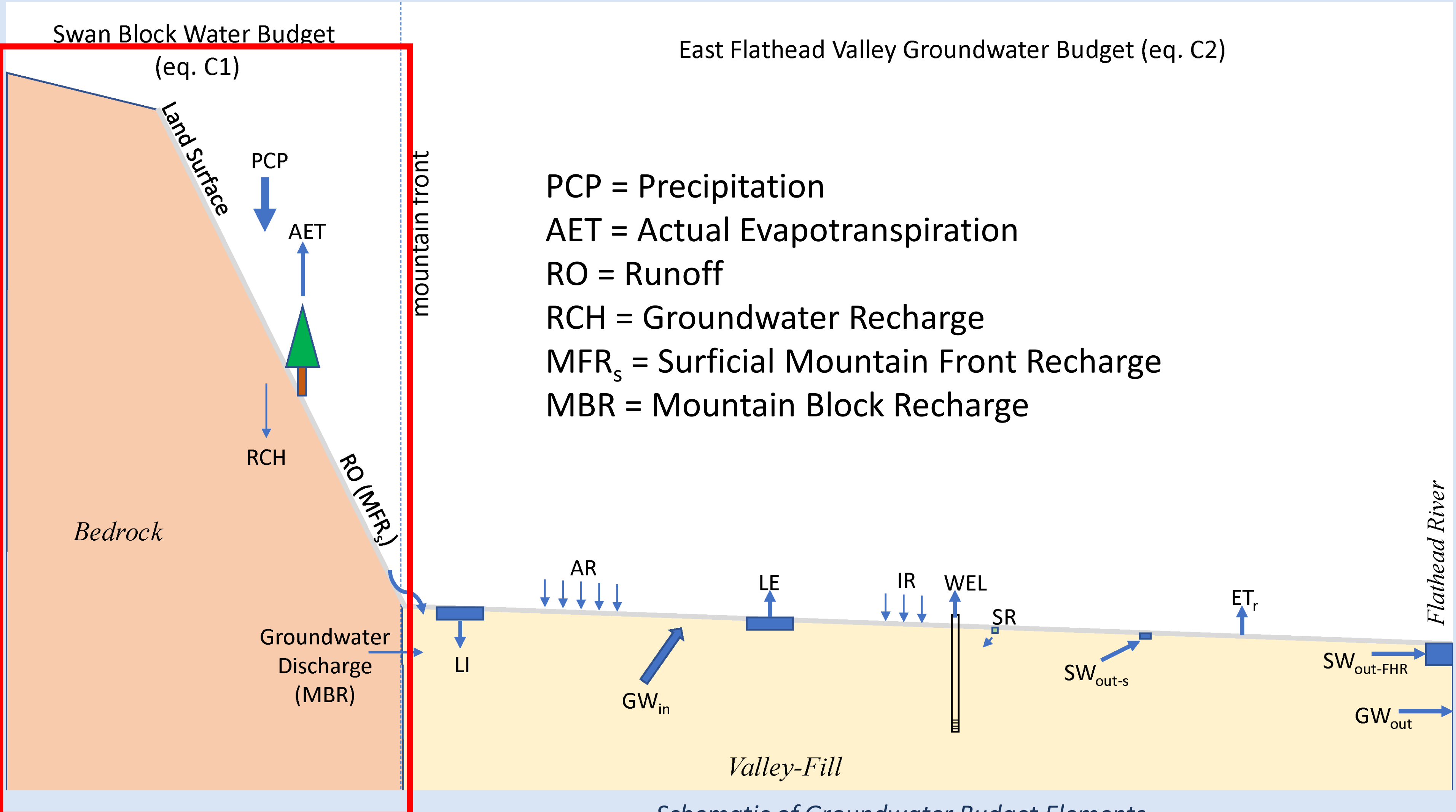
Preliminary Results Bobst and others, in prep
Tritium ranges from Lindsay and others, 2019

Refining Geologic Model - Tracers



Preliminary Results Bobst and others, in prep
Tritium ranges from Lindsay and others, 2019

Groundwater Budget



PCP = Precipitation

AET = Actual Evapotranspiration

RO = Runoff

RCH = Groundwater Recharge

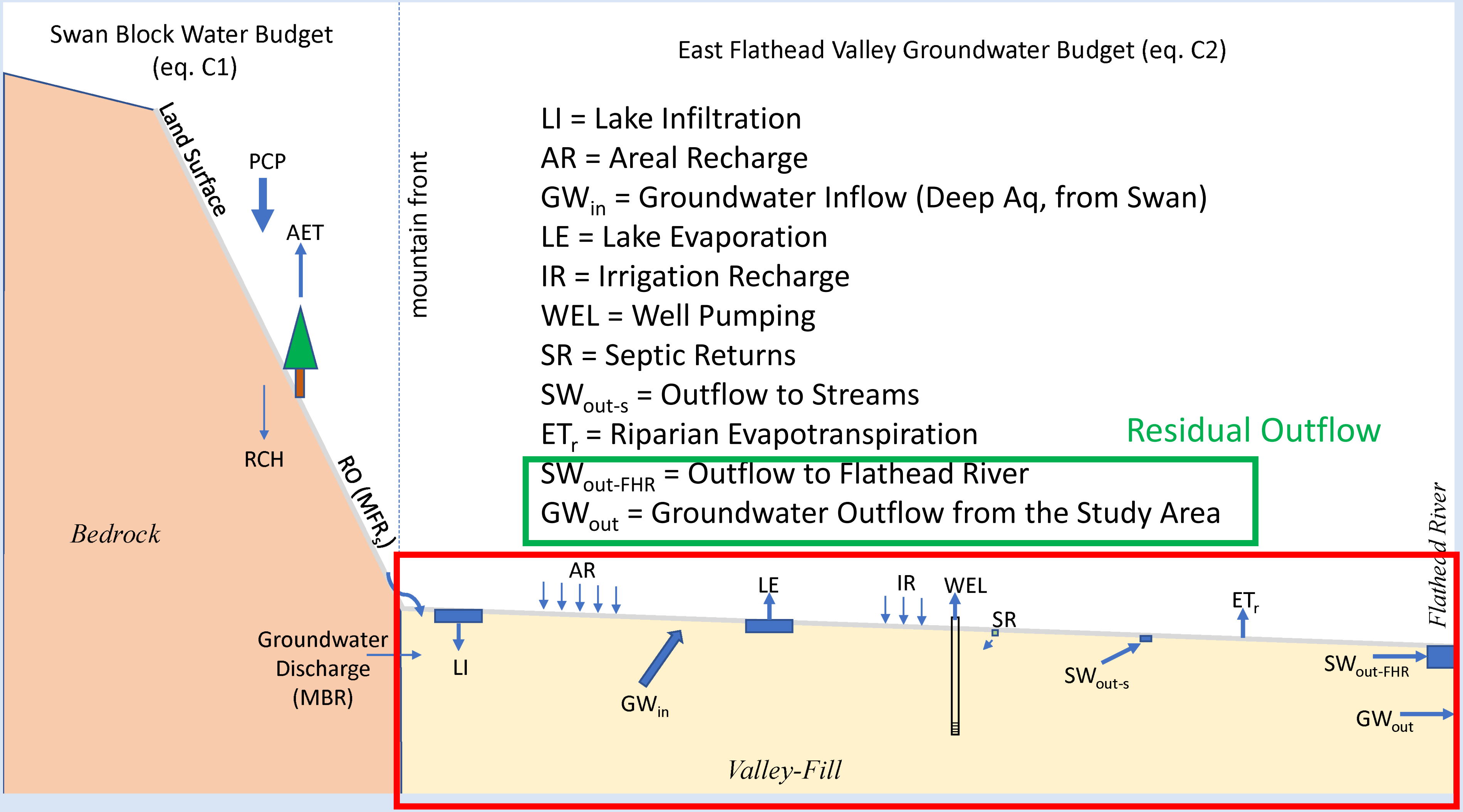
MFR$_s$ = Surficial Mountain Front Recharge

MBR = Mountain Block Recharge

Schematic of Groundwater Budget Elements (Berglund and others, 2024)

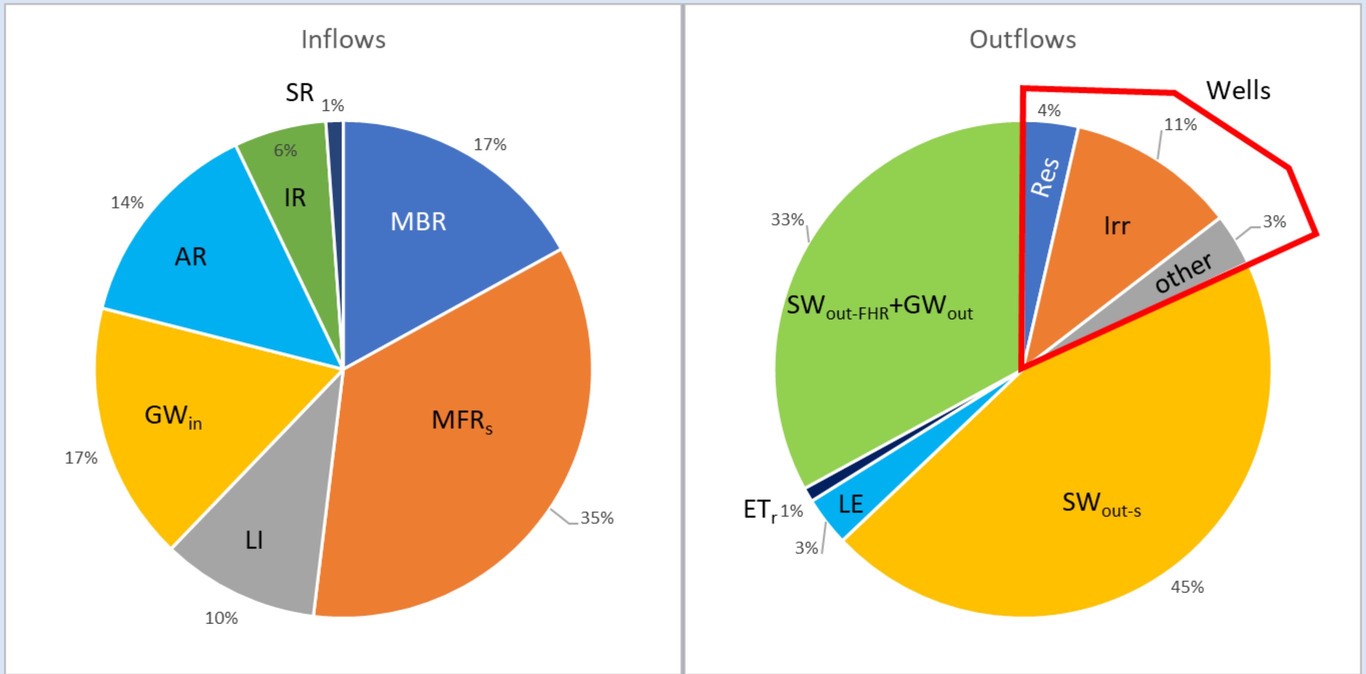
Ground Water Investigation Program

Groundwater Budget



Schematic of Groundwater Budget Elements
(Berglund and others, 2024)

Groundwater Budget



MBR = Mountain Block Recharge	Res = Residential Wells
MFR$_s$ = Surficial Mountain-Front Recharge	Irr = Irrigation Wells
LI = Lake Infiltration	other = Other Wells
GW$_{in}$ = Groundwater Inflow	SW$_{out\text{-}s}$ = Discharge to Streams
AR = Areal Recharge	LE = Lake Evaporation
IR = Irrigation Recharge	ET$_r$ = Riparian Evapotranspiration
SR = Septic Returns	SW$_{out\text{-}FHR}$ + GW$_{out}$ = Residual Outflow

Relative Groundwater Budget (Berglund and others, 2024)
Total Annual In/Out ~60,000 ac-ft/yr

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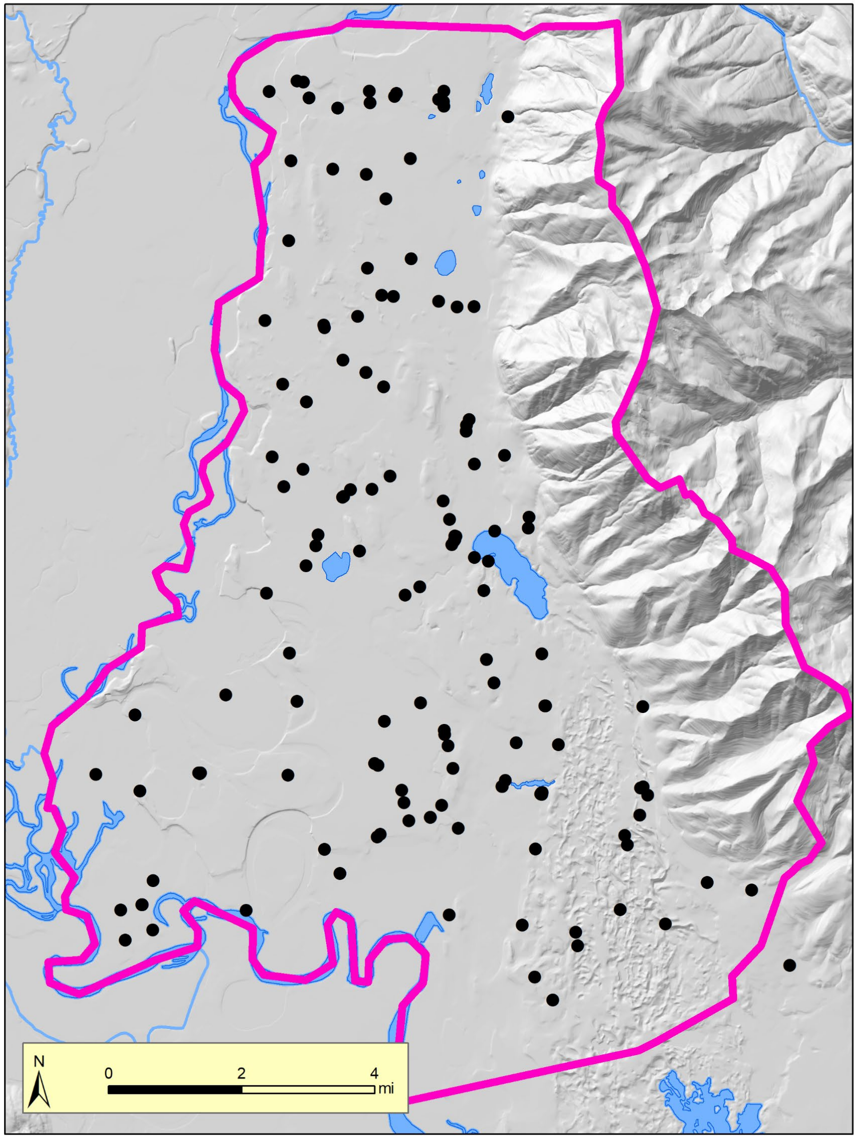
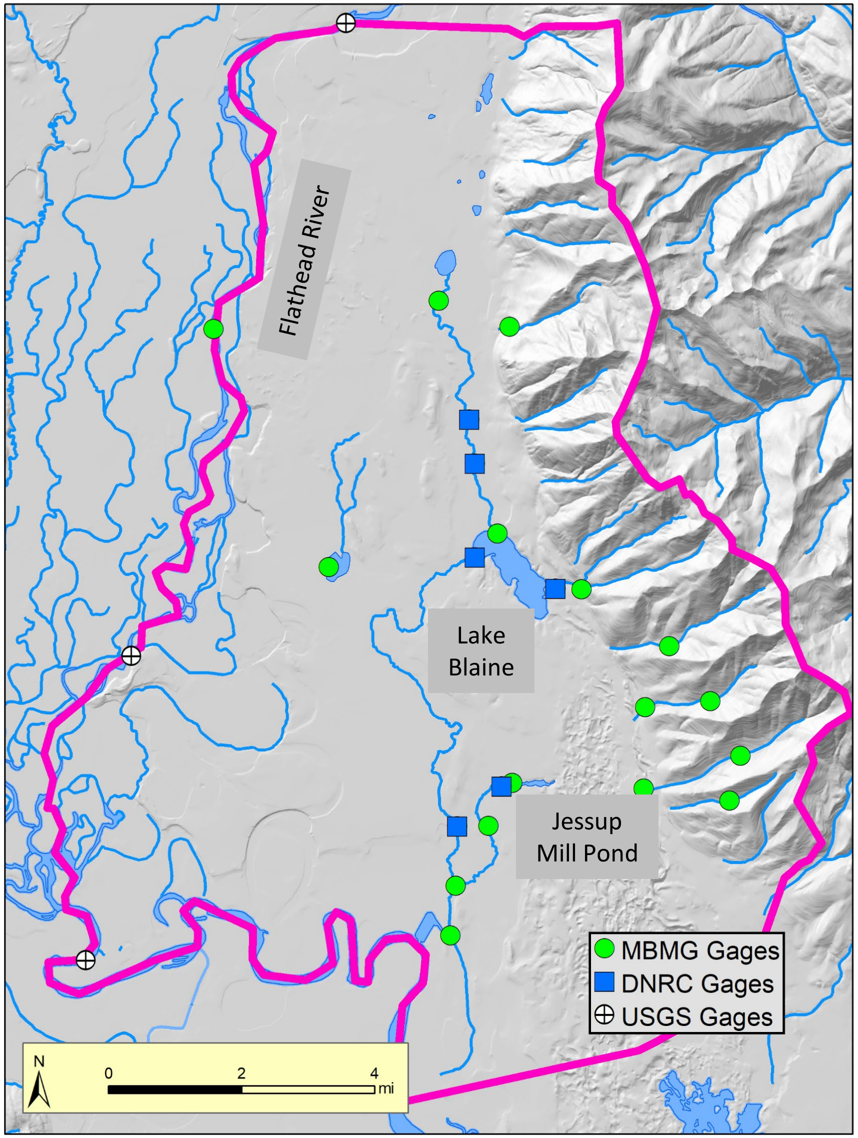
Monitoring (2019-2021)

Groundwater Network (144 wells)



Surface-Water Network (27 sites)



Monitoring – Potentiometric Surfaces

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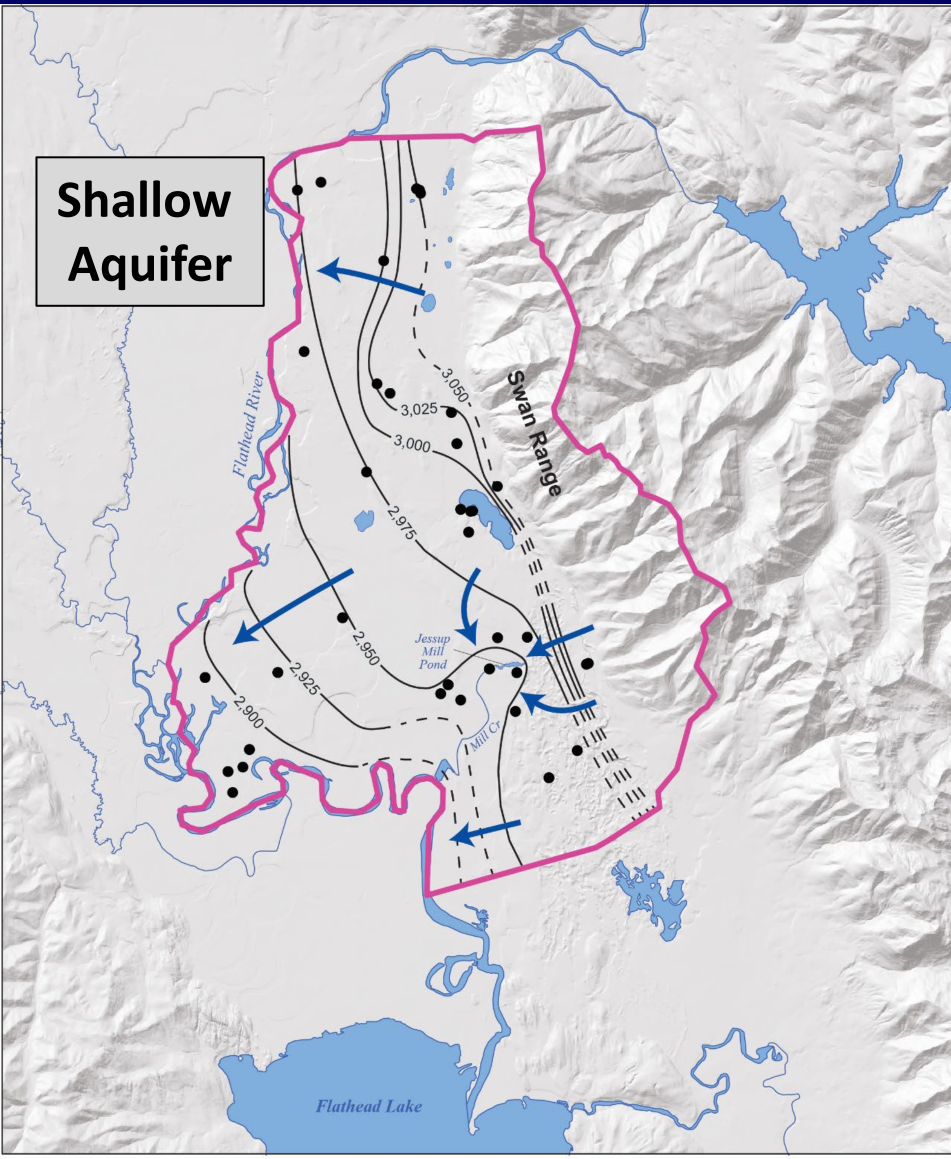
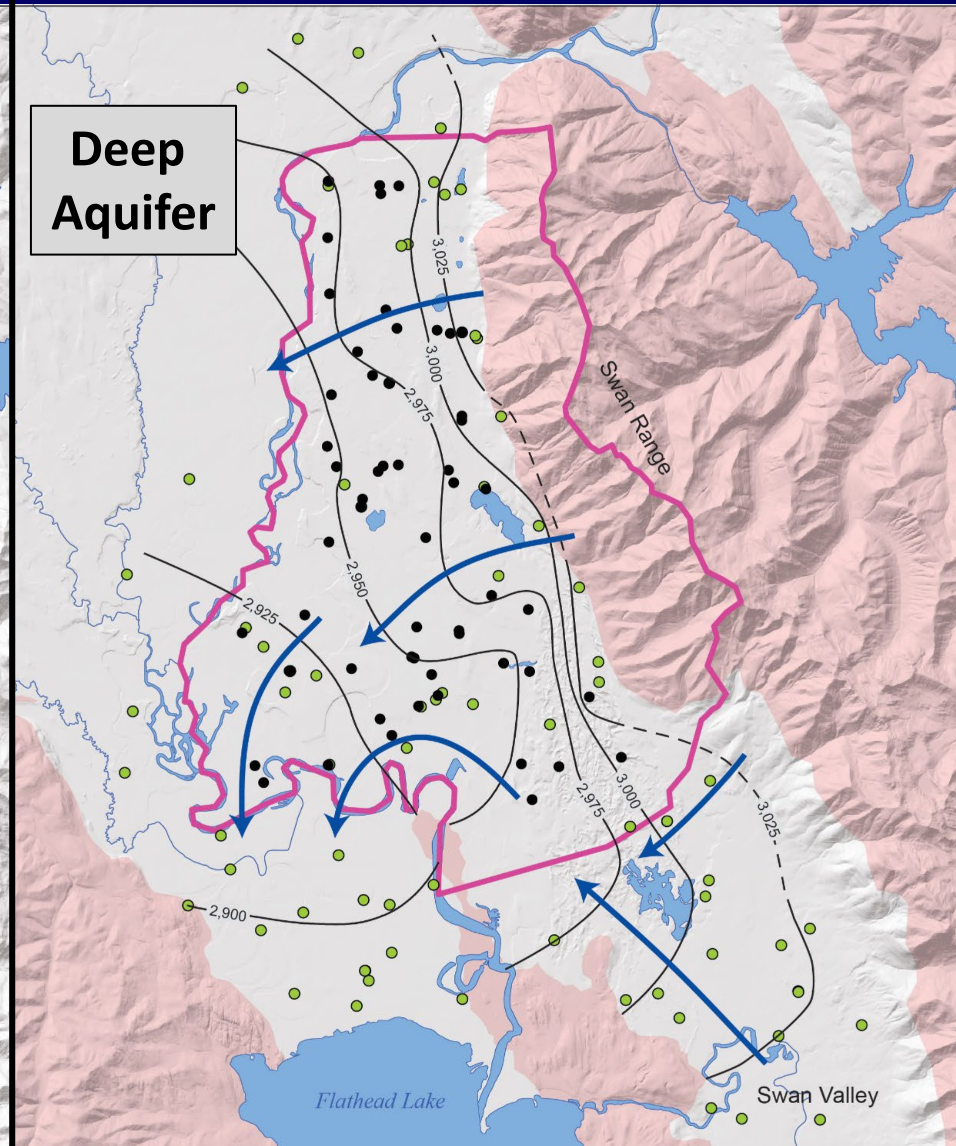
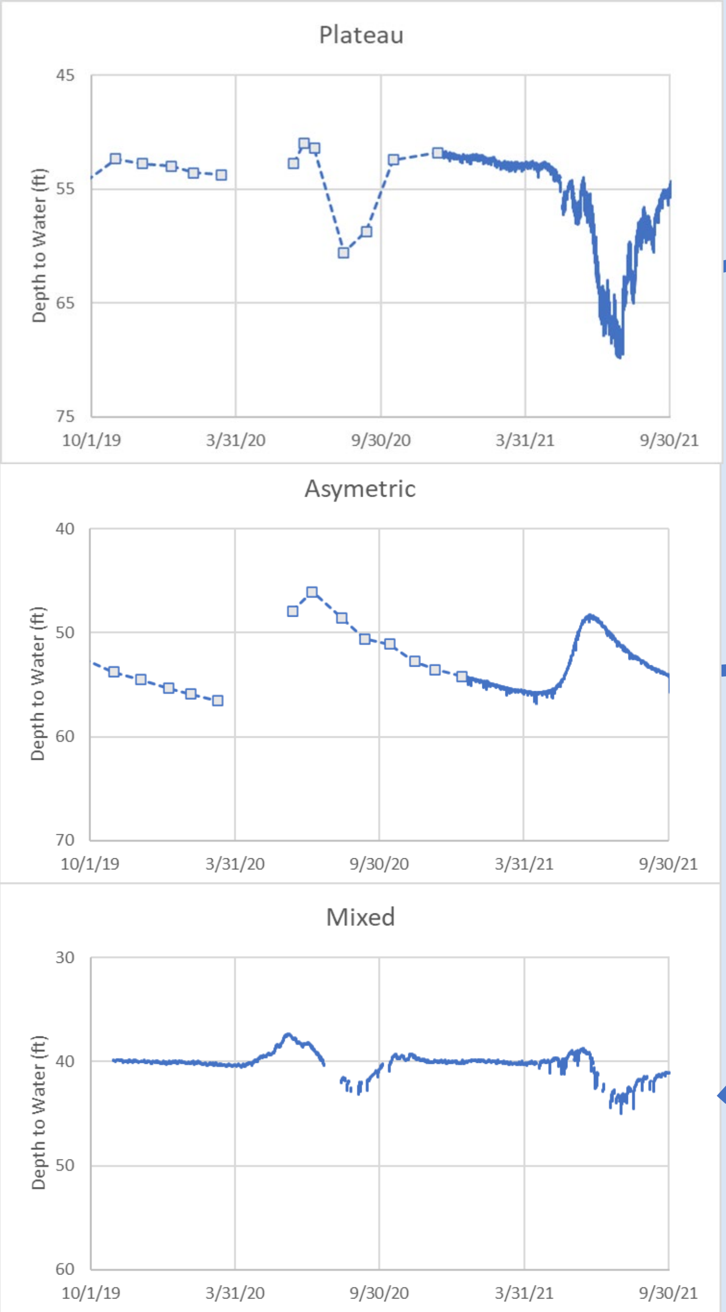


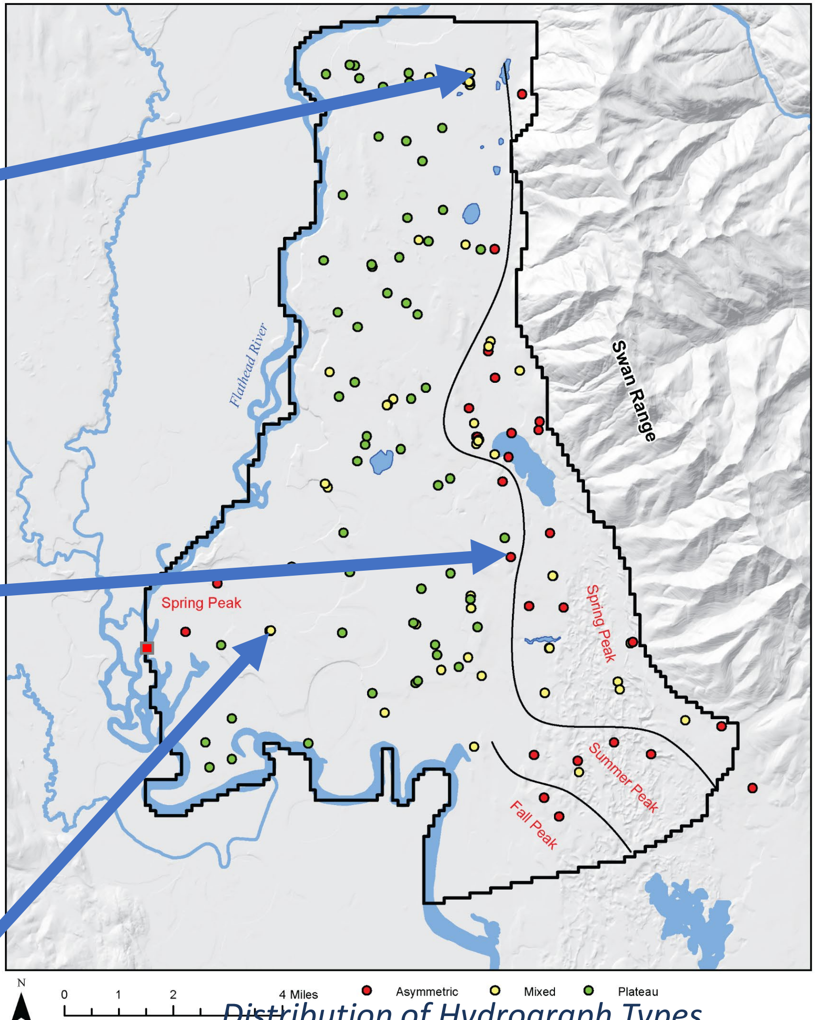
Monitored Wells
Potentiometric Contours (ft)
Interpolated Potentiometric Contours (ft)
Groundwater Flow Lines
N
0 2.25 4.5 9 Miles



This Study
Previous Studies
Potentiometric Contours (ft)
Interpolated Potentiometric Contours (ft)
Bedrock (modified from Vuke and others, 2007 and Rose, 2018)
Groundwater Flow Lines
N
0 2.25 4.5 9 Miles

Groundwater Monitoring – Hydrograph Types





Distribution of Hydrograph Types

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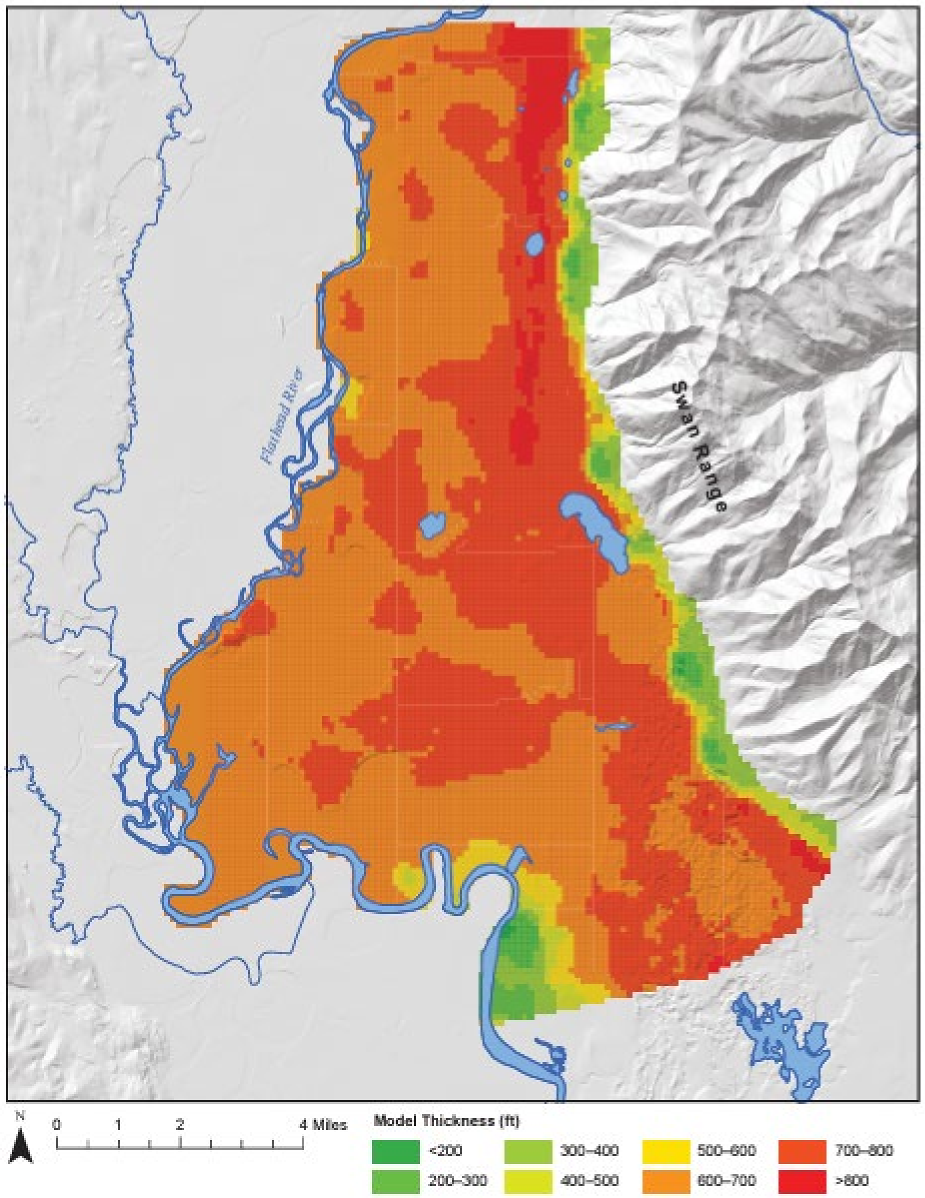
Modeling - Spatial and Temporal Discretization

- Cells are uniformly 500 ft x 500 ft horizontally
- 4 Layers - Thickness varies based on Hydrogeologic Model
- 41,460 active cells

- Monthly Stress Periods



Berglund and others, 2024

Modeling - Steady-State Calibration (January 2020)

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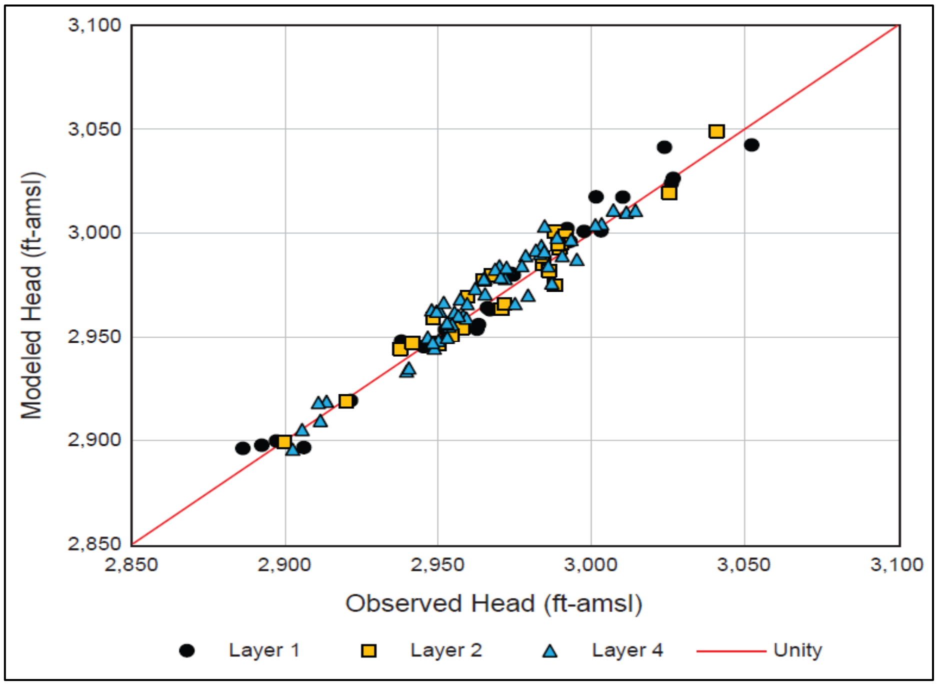
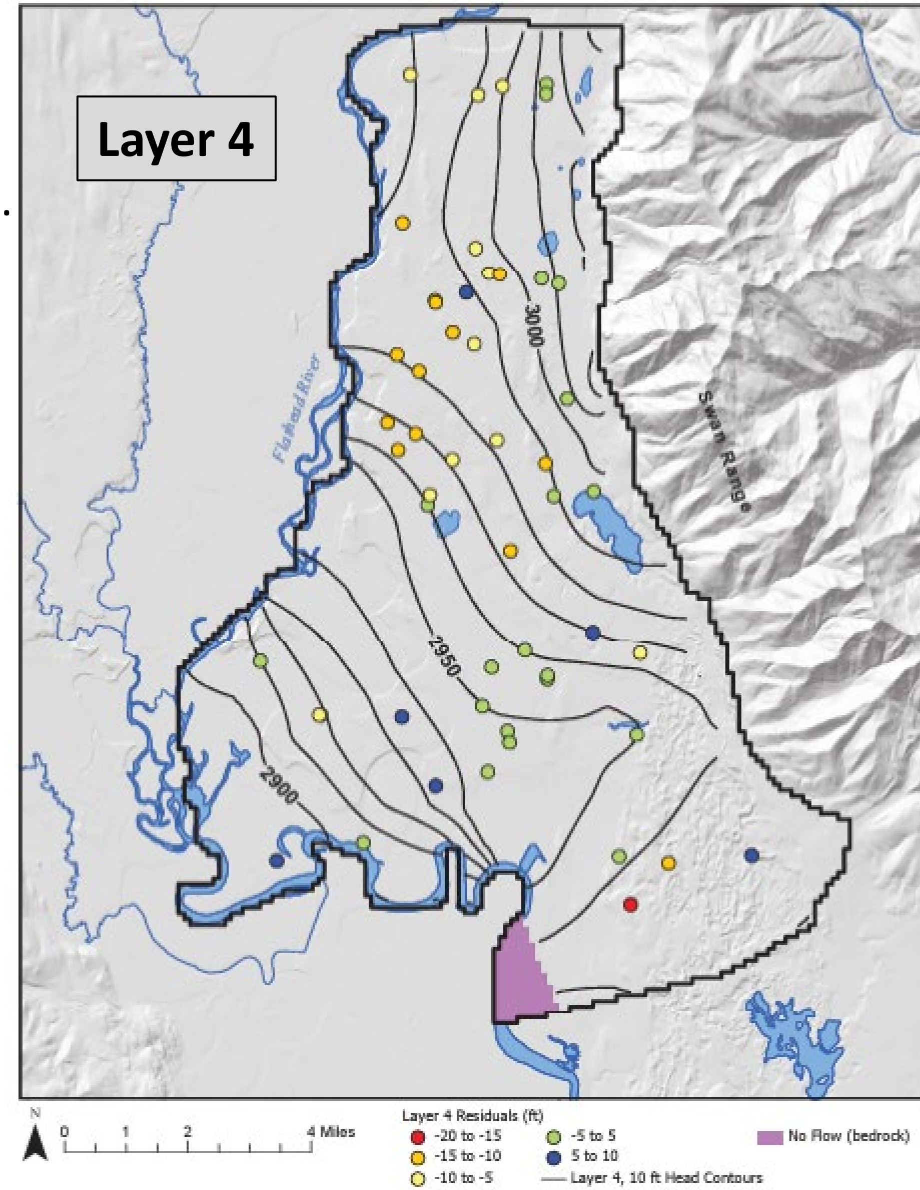
Calibration: Use a mechanistic model to simulate observations while respecting knowledge of geology and groundwater budget.



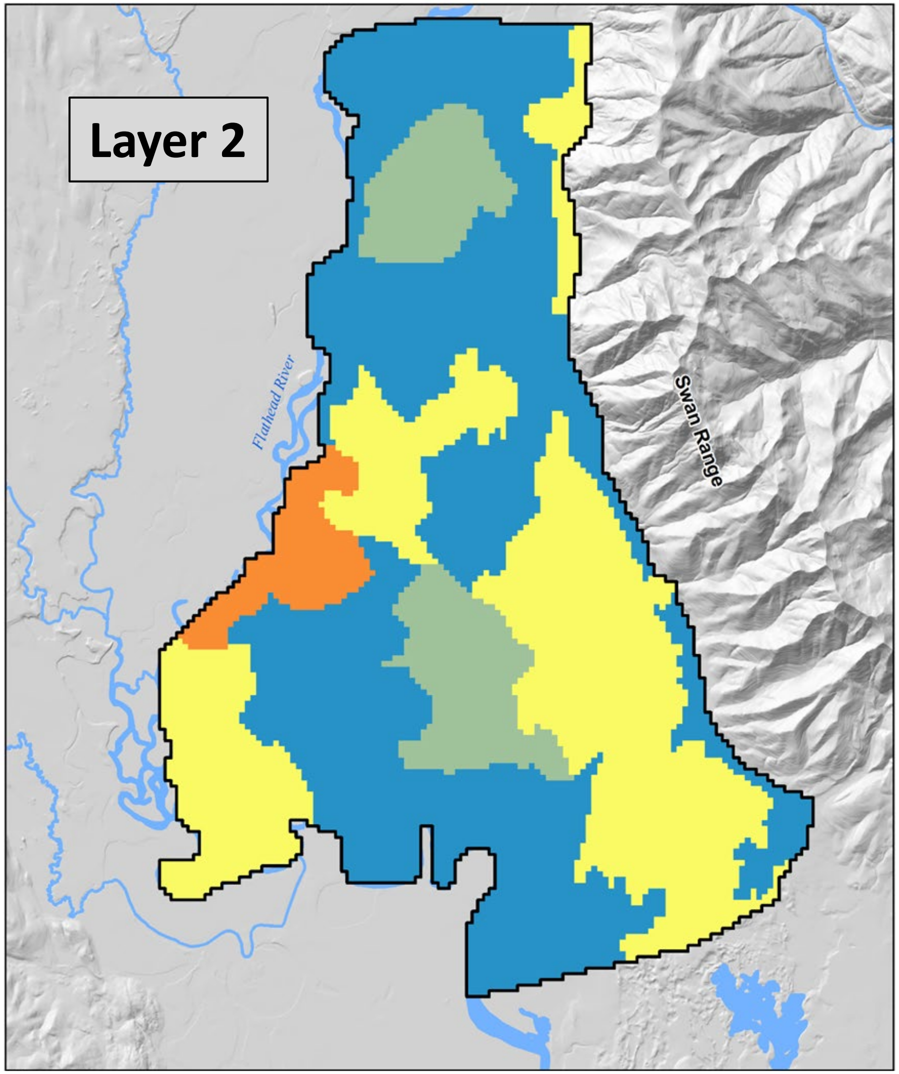
105 wells

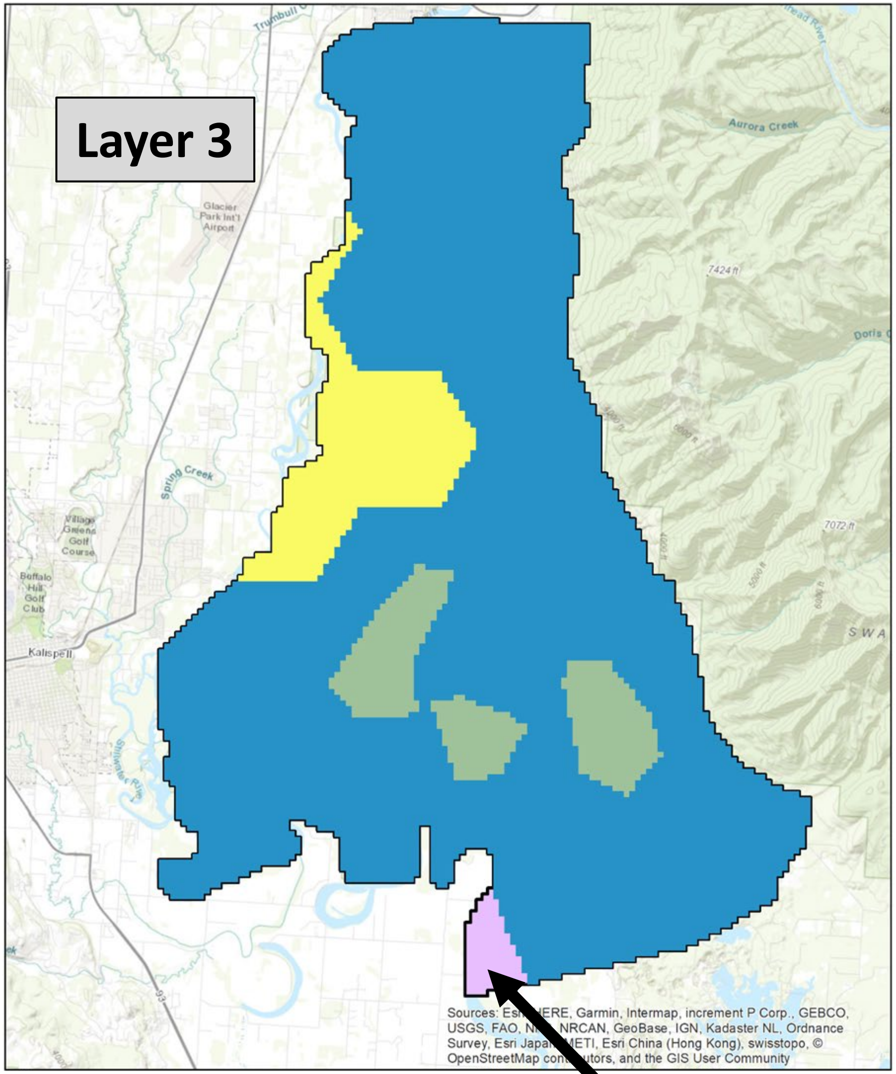
RMSE = 8.16 ft (4.7% of range)



Berglund and others, 2024

Modeling - Confining Layer Continuity





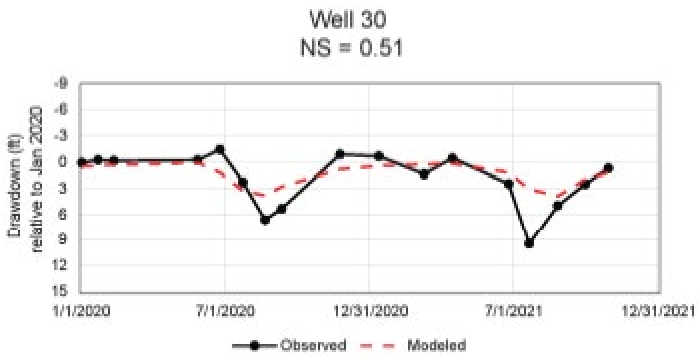
K Values (ft/d)

<5	5-10	10-50	50-100

Berglund and others, 2024

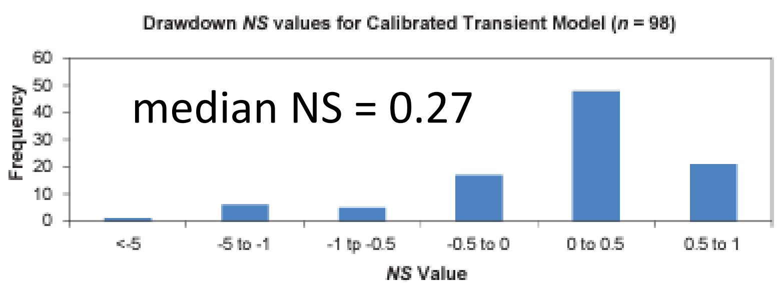
Modeling - Transient Calibration (2017-2021)

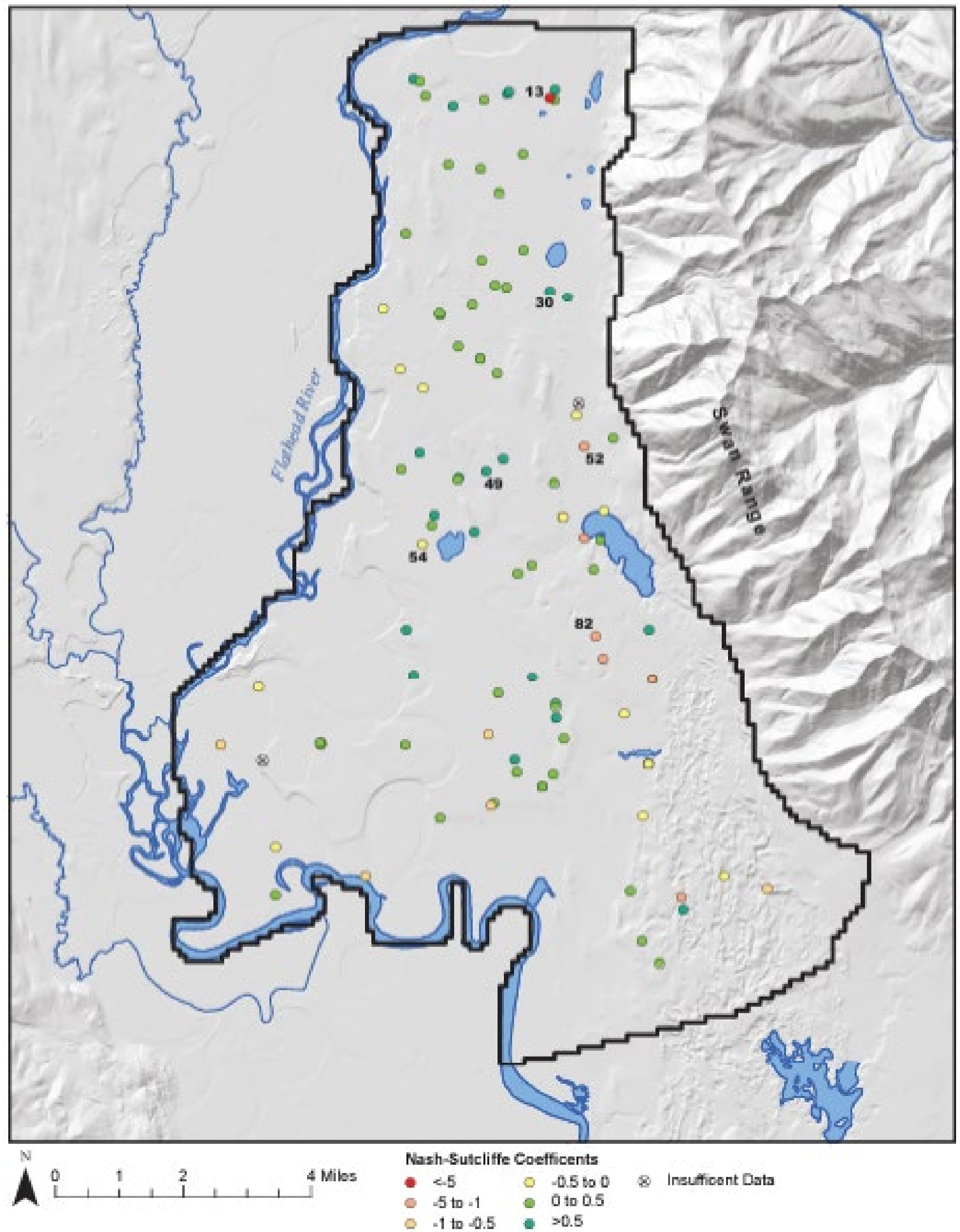
a. Calibration to changes in head over time.



b. Maximize the median Nash-Sutcliffe coefficient

$$NS = 1 - \frac{\sum_{i=1}^{n} \left| dh_m - dh_s \right|_i^2}{\sum_{i=1}^{n} \left| dh_m - \overline{dh}_m \right|_i^2}$$





Berglund and others, 2024

Modeling - Scenarios

Extend calibrated transient model to run from 2017-2036

Run 2017-2021 at baseline values, then add new stress

1 - Double Residential Pumping (from 2,153 to 4,306 ac-ft/yr)

- Double rates for domestic and PWS wells, and double septic returns
- Same locations and layers as existing

2 - Double Irrigation Pumping (from 6,679 to 13,358 ac-ft/yr)

- Double rates for irrigation wells
- Same locations and layers as existing

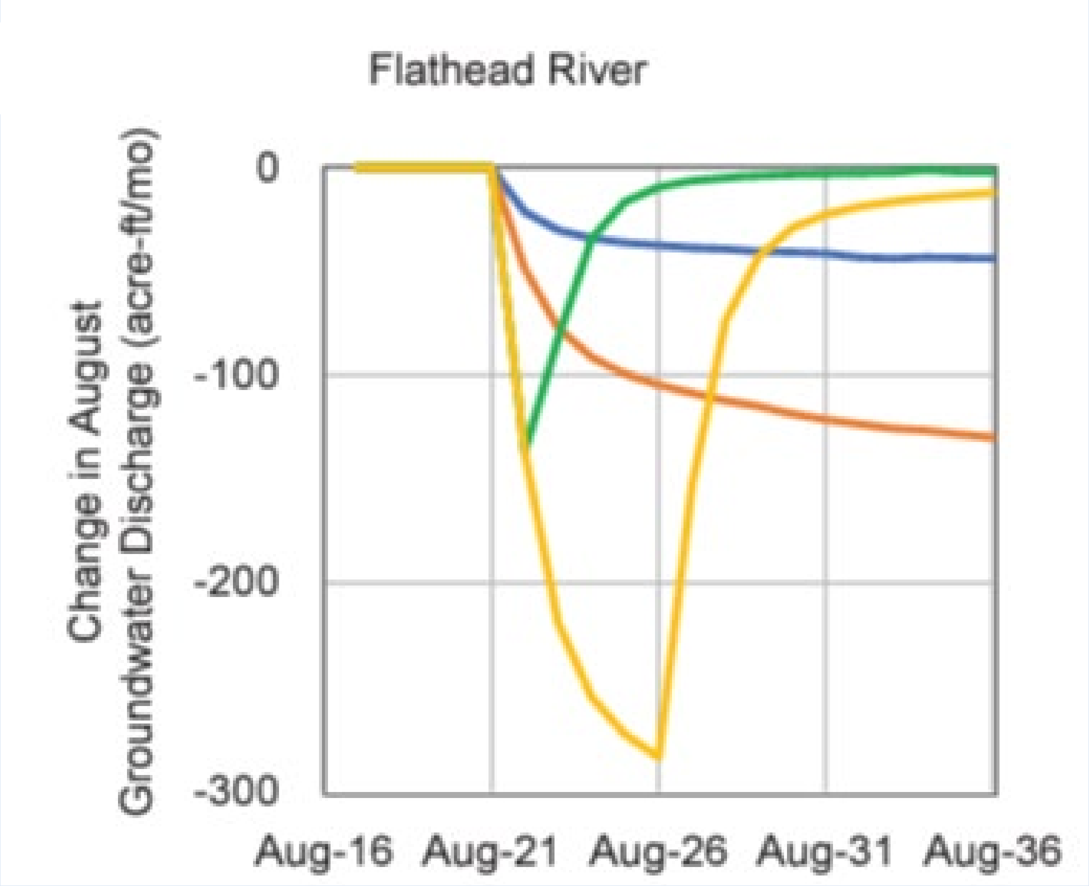
3 – 1 yr Drought

- MFR and AR reduced by 25% for 1 yr (from 40,480 to 30,361 ac-ft/yr)
- Approximates a 20-yr drought

4 – 5 yr Drought

- MFR and AR reduced by 25% for 5 yr (from 40,480 to 30,361 ac-ft/yr)

Scenario Results



#1: Double Residential Pumping
#2: Double Irrigation Pumping
#3: 1 year Drought
#4: 5 year Drought

Simulated changes in flow to the Flathead River and Groundwater Discharge in August due to the scenarios

Conclusions

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- Shallow Aquifers and Surface Waters are Interconnected
  - Well documented (Konizeski and others, 1968; Noble and Stanford, 1986; Smith, 2004; LaFave and others, 2004; Rose, 2018; Rose and others, 2022)
- The Shallow Aquifers and the Deep Aquifer are Interconnected in some areas
  - Well Log Analysis, Drilling, Rotosonic, tracers
  - We needed to add “windows” in the confining layer to reach reasonable calibration
- Pumping from either the shallow or deep aquifers is likely to eventually result in surface-water depletion
  - The timing and location of that depletion will depend on the specific locations and operations
- Drought has potential to create greater short-term effects, development creates long-term effects.
- The calibrated transient model can be used directly or as a starting point to evaluate many other scenarios.

Questions?

Recent and Upcoming MBMG Publications/Presentations:

Bobst, A., Berglund, J., Smith, L., and Gebril, A., in review, Hydrogeologic Investigation of the East Flathead Valley, Montana Bureau of Mines and Geology Report of Investigation.

Smith, L., and Bobst, A., in review, Evaluation of Roto-Sonic Cores and a Lithologic Cross Section in the East Flathead Valley, Montana Bureau of Mines and Geology Open-File Report.

Berglund, J., Bobst, A., and Gebril, A., 2024, A groundwater flow model for the East Flathead Valley, Montana Bureau of Mines and Geology Report of Investigation 36, 110 p.

Smith, L., Montejo, C., and Bobst, A., 2024, Flathead Lobe recession in the Flathead Valley: Implications for ice-marginal lake draining; Geological Society of America Joint Cordilleran and Rocky Mountain Section Meeting – Spokane, WA, Abstract with Program.

Myse, T., Bobst, A., and Rose, J., 2023, Analyses of three constant-rate aquifer tests, East Flathead Valley, northwest Montana: Montana Bureau of Mines and Geology Open-File Report 757, 44 p.

Bobst, A., Berglund, J., and Smith, L., 2023, Investigating Hydraulic Connections between Aquifers and Surface Waters in the East Flathead Valley: American Water Resources Association (Montana Section) – Missoula, MT, Abstract with Program.

Bobst, A., Rose, J., and Berglund, J., 2022, An evaluation of the unconsolidated hydrogeologic units in the south-central Flathead Valley, Montana: Montana Bureau of Mines and Geology Open-File Report 752, 16 p.

Rose, J., Bobst, A., and Gebril, A., 2022, Hydrogeologic investigation of the deep alluvial aquifer, Flathead Valley, Montana: Montana Bureau of Mines and Geology Report of Investigation 32, 44 p.

Bobst, A., and Rose, J., 2022, Thickness of the Deep Aquifer and Character of the Underlying Sediments in the Flathead Valley: American Water Resources Association (Montana Section) – Butte, MT, Abstract with Program.

Burglund, J., and Bobst, A., 2022, Improving a hydrogeologically complex aquifer model using transient groundwater levels, East Flathead Valley, Montana: Geological Society of America Abstracts with Programs, v. 54, no. 5.

Berglund, J.L., Snyder, D., and Bobst, A., 2020, Spatiotemporal patterns of groundwater levels in the East Flathead Valley aquifer system: insights into recharge and groundwater use: American Water Resources Association (Montana Section) – Butte, MT, Abstract with Program.

Rose, J., 2018, Three-dimensional hydrostratigraphic model of the subsurface geology, Flathead Valley, Kalispell, Montana: Montana Bureau of Mines and Geology Open-File Report 703, 44 p., 1 sheet.