Developing a Groundwater Flow Model for the East Flathead Valley

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Ground Water Investigation Program

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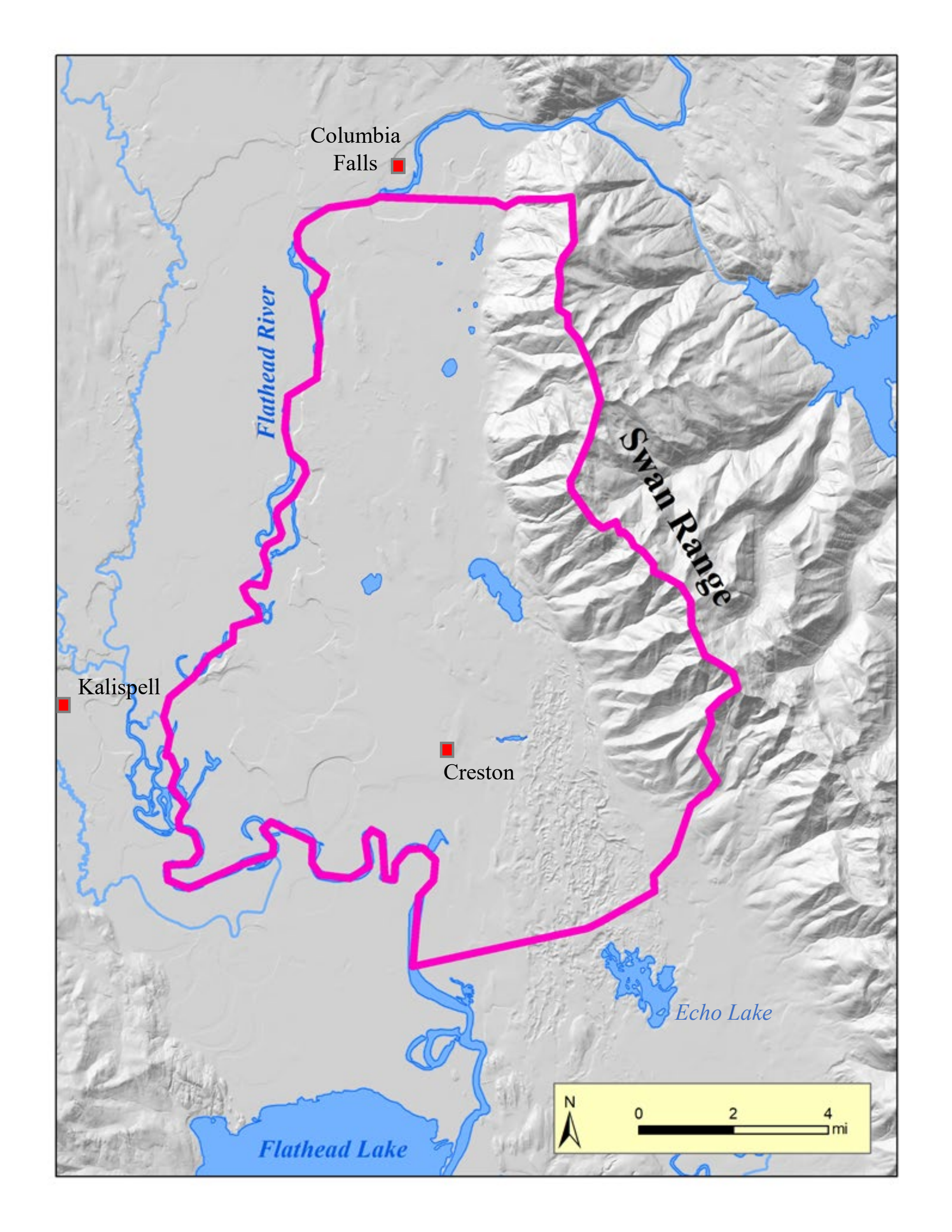
AWRA
October 11, 2024

Model Purpose

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



Study Area

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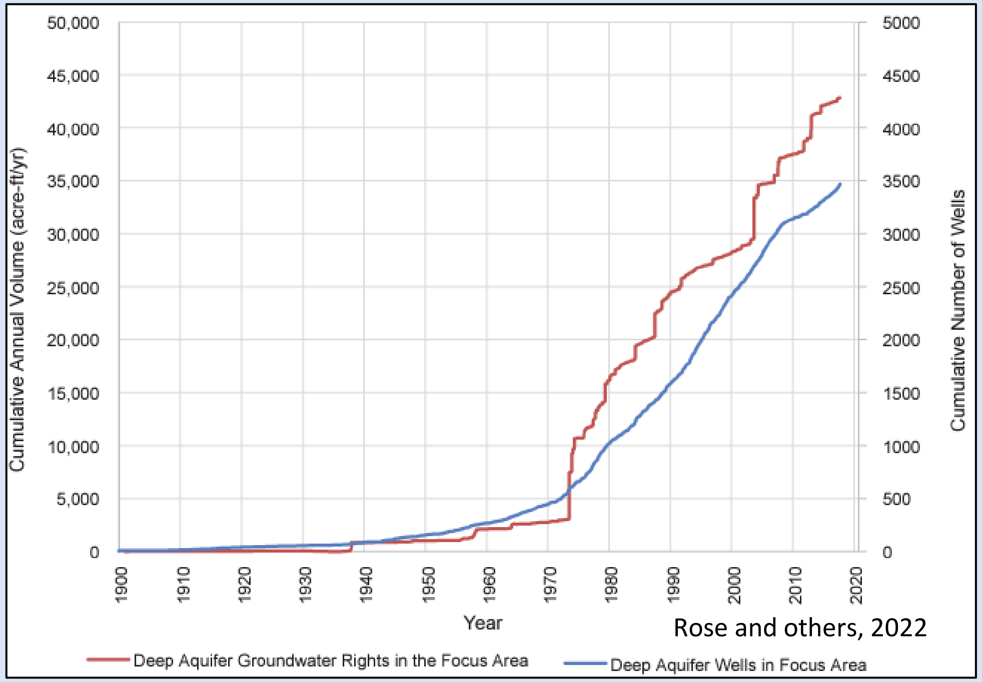
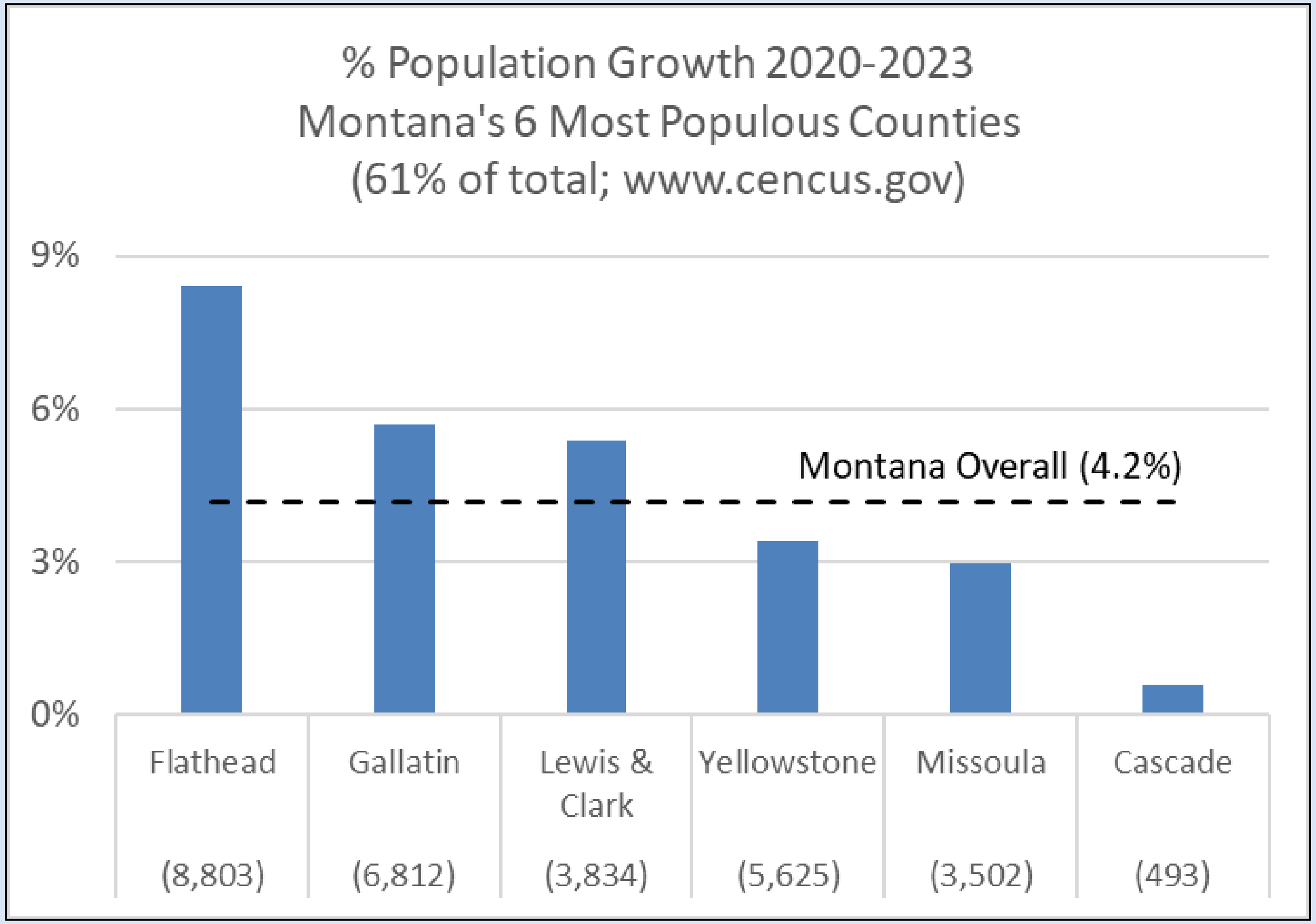
Model Purpose



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



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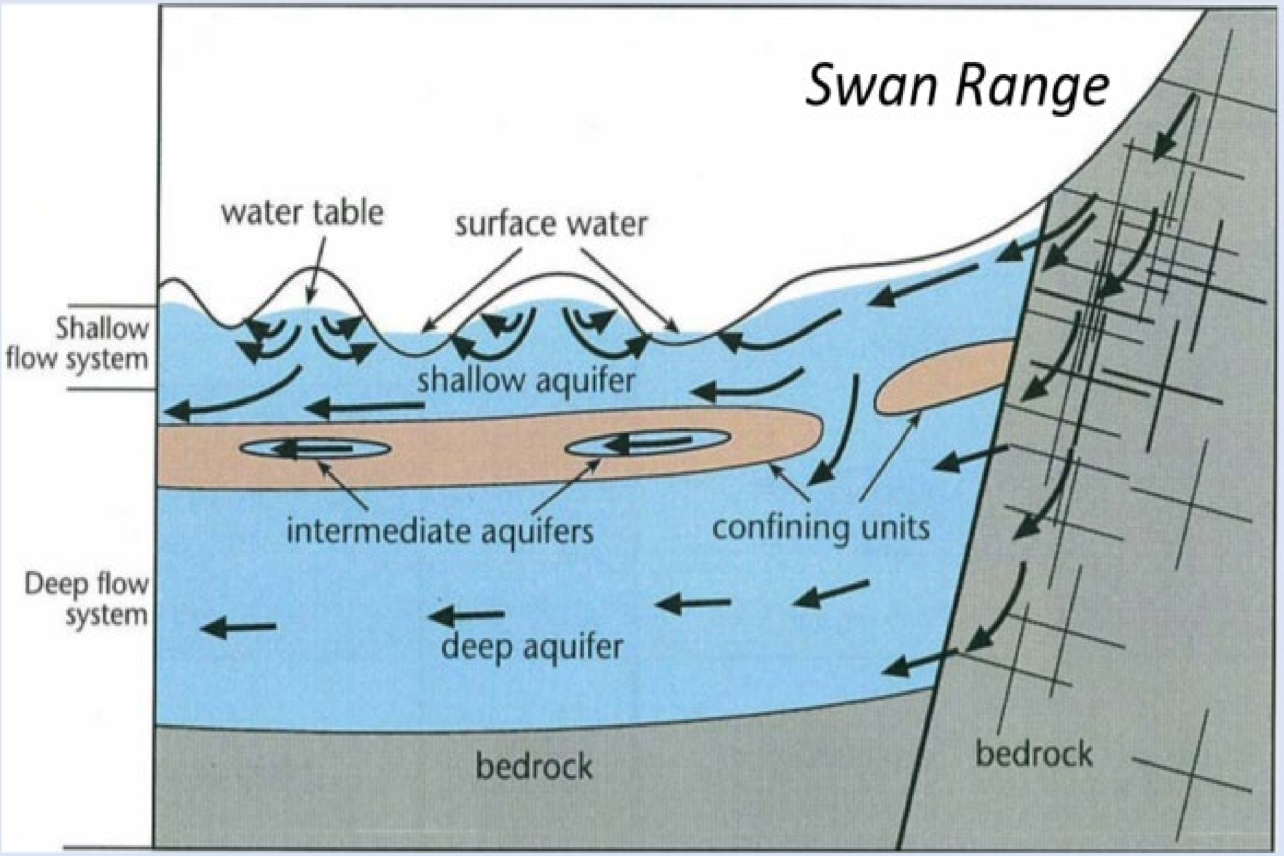
Outline

- Groundwater Model
  - 3D geologic model of hydrogeologic units
    - Aquifer Properties
  - Dynamic Groundwater Budget
  - Monitoring - Dynamic Observations
    - Groundwater Elevations
    - Stream Gains/Losses
    - Etc.

A calibrated groundwater model is supported by 3 elements

General Hydrostratigraphy

- Shallow Aquifer
  - Young
  - Connected to Surface Waters
  - Fluvial and Eolian
- Deep Aquifer
  - Glacial Outwash
  - Sand, Gravel, and Silt
  - May be highly productive (>1,000 gpm), but heterogeneous
- Confining Layer
  - Present in much of the area
  - May be thin or have “windows”
  - May include Intermediate Aquifers
  - Glacial and Lacustrine Deposits



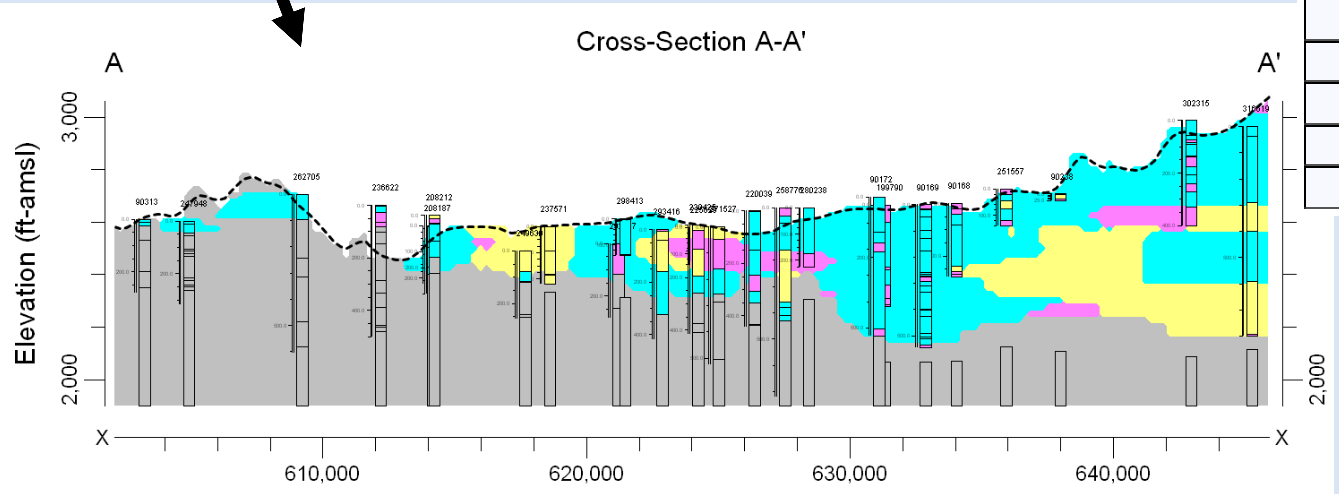
Conceptual diagram of flow systems in the Flathead Valley (reproduced from LaFave and others, 2004)

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
- RockWorks



Example of Rockworks Cross Section

112ALVM - ALLUVIUM (PLEISTOCENE)

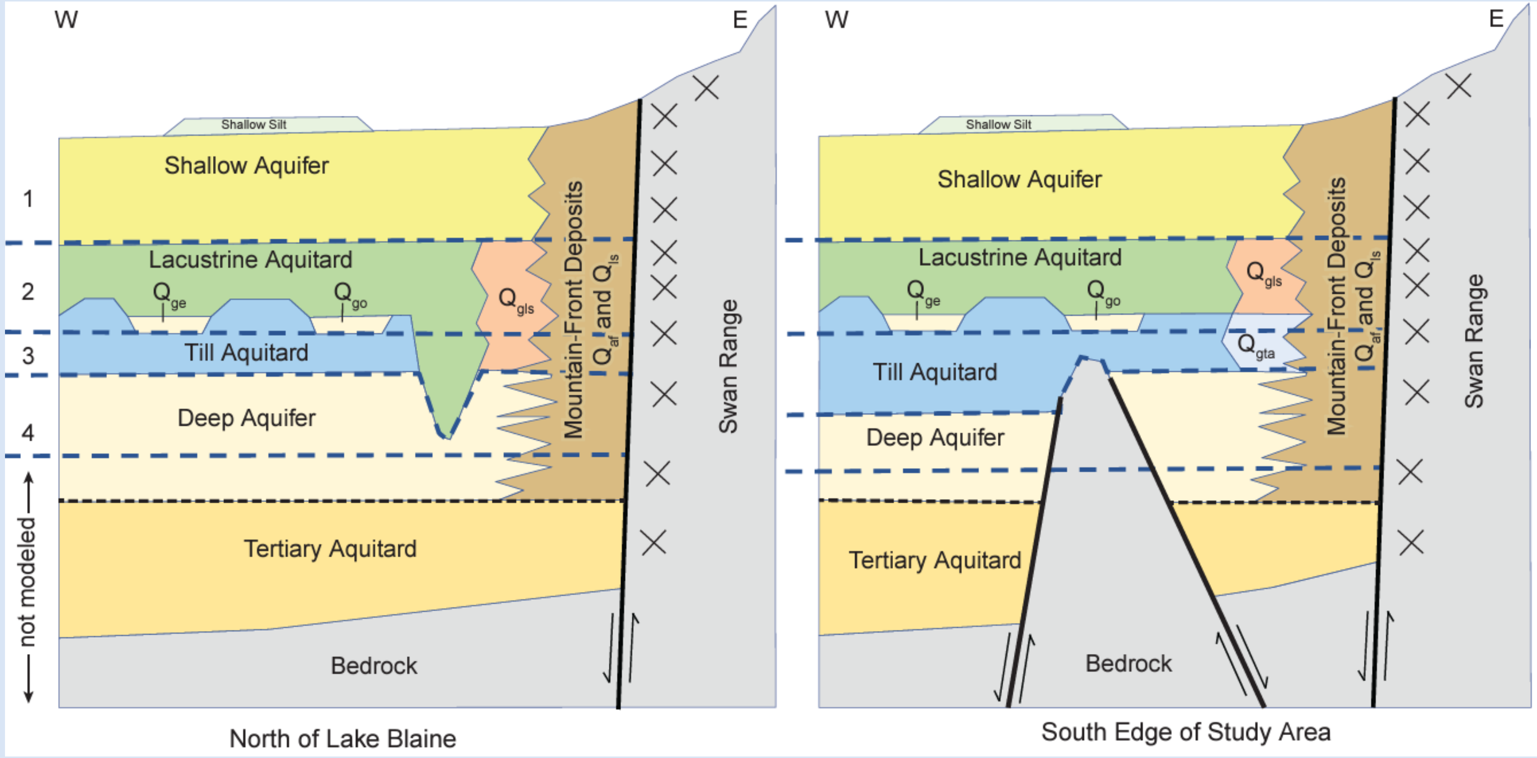
From	To	Description
0	1	TOP SOIL
1	10	REDDISH BROWN SILTY FINE SAND
10	35	REDDISH BROWN SILTY SAND
35	45	SANDY CLAY
45	80	SILTY CLAY
80	90	SAND AND CLAY
90	110	SILTY CLAY
110	115	CLAY AND GRAVEL
115	125	GRAVEL
125	138	CLAY
138	280	GRAVEL
138	145	COARSE GRAVEL AND SAND
145	180	COARSE GRAVEL AND SAND WITH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

Lithologic Log

Refining the Geologic Model

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

- Import to Groundwater Vistas
  - 4 Layer MODFLOW Model



Schematic Cross Sections and Model Layers

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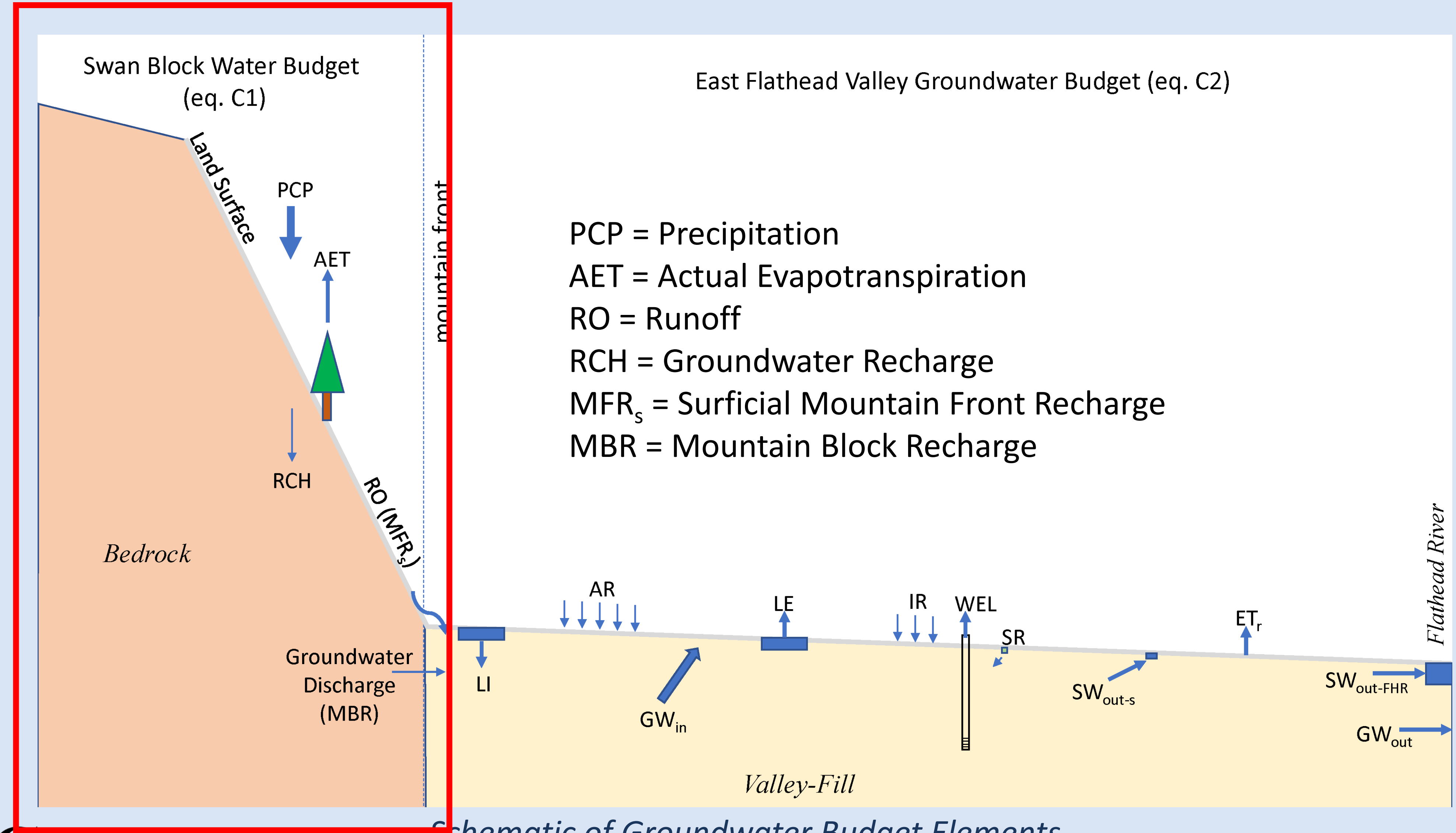
Groundwater Budget



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)

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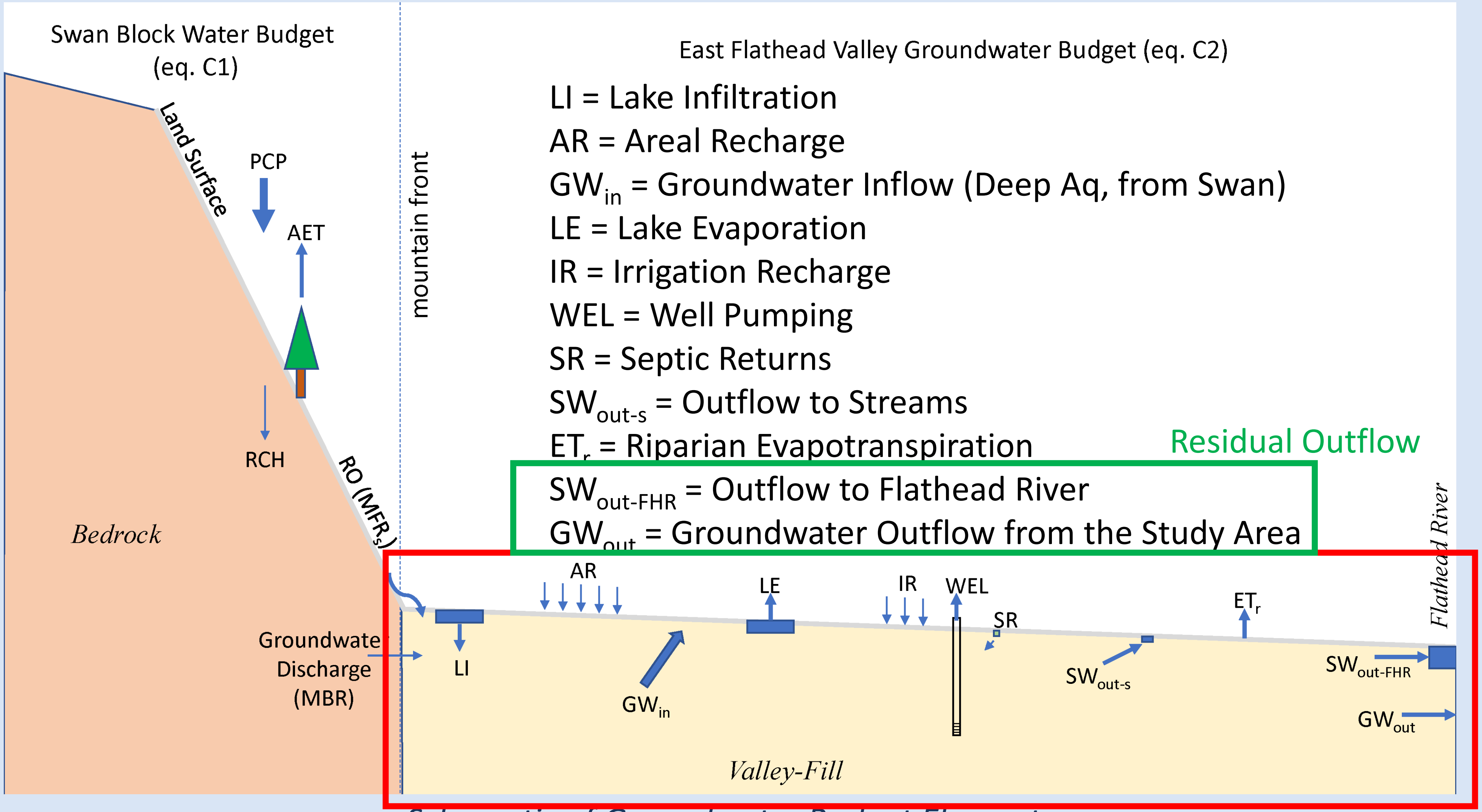
Groundwater Budget



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

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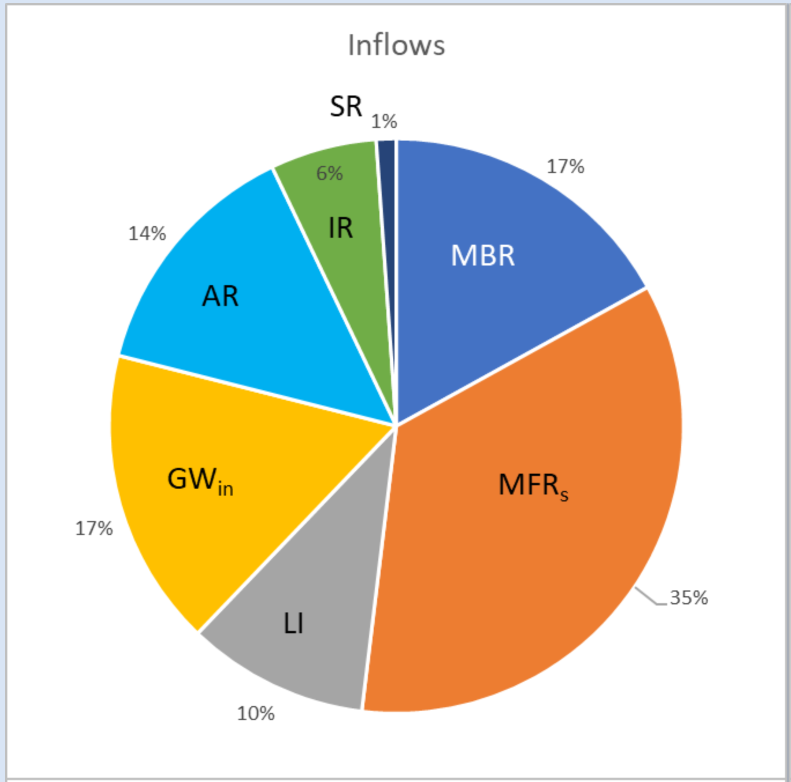
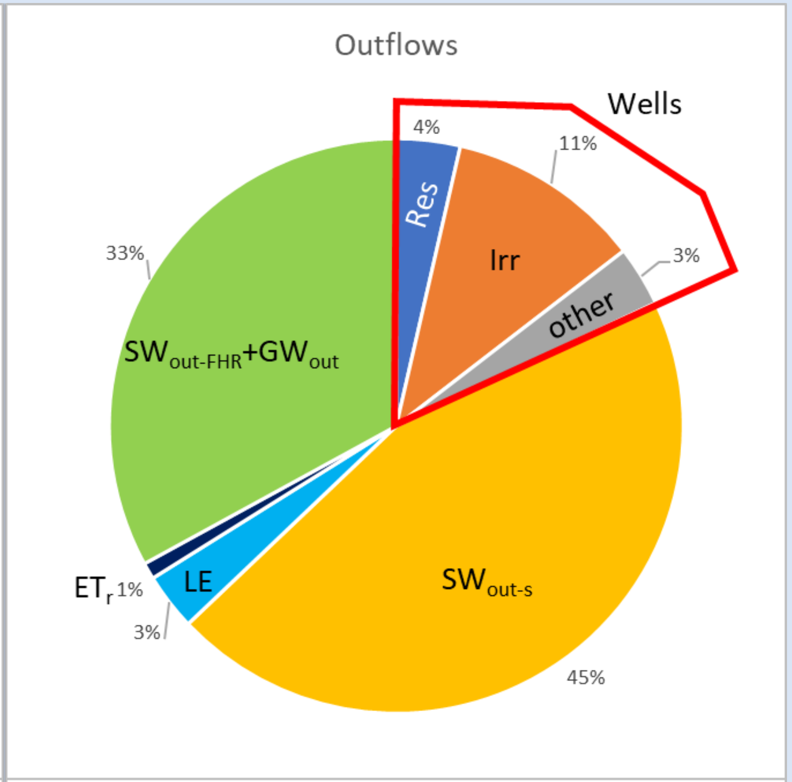
Groundwater Budget



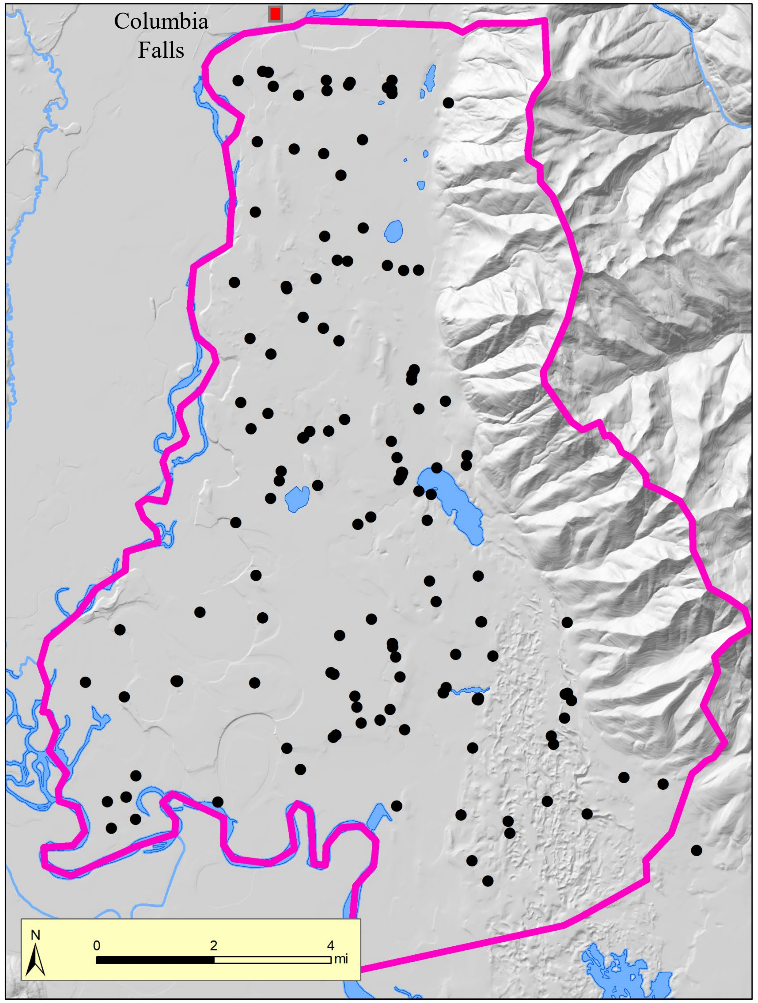


MBR = Mountain Block Recharge
MFR$_s$ = Surficial Mountain-Front Recharge
LI = Lake Infiltration
GW$_{in}$ = Groundwater Inflow
AR = Areal Recharge
IR = Irrigation Recharge
SR = Septic Returns

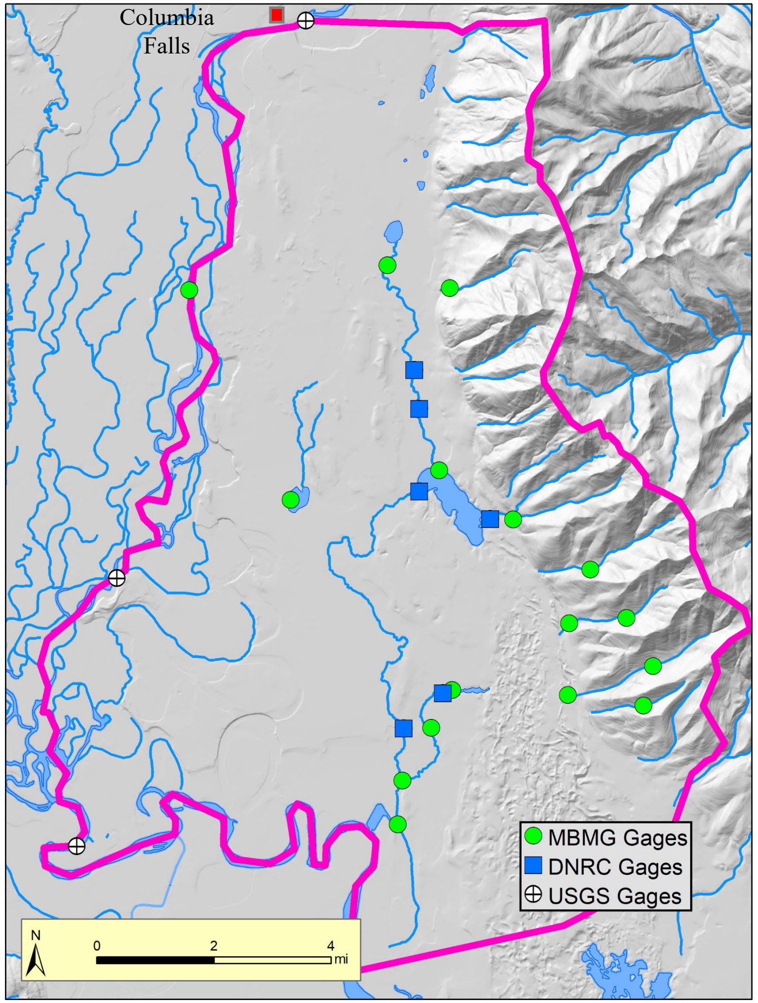
Res = Residential Wells
Irr = Irrigation Wells
other = Other Wells
SW$_{out\text{-}s}$ = Discharge to Streams
LE = Lake Evaporation
ET$_r$ = Riparian Evapotranspiration
SW$_{out\text{-}FHR}$ + GW$_{out}$ = Residual Outflow

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

Monitoring

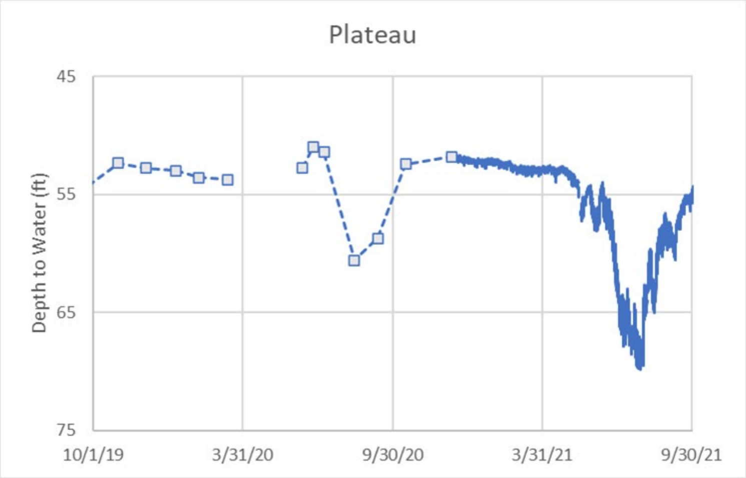


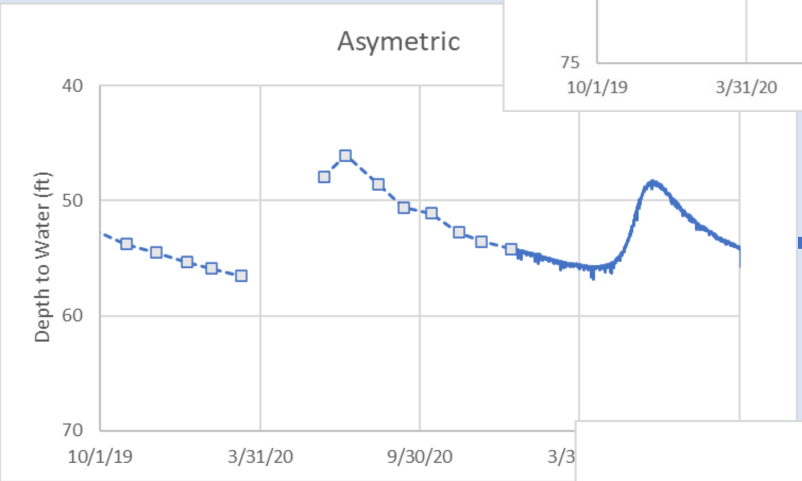
Groundwater Monitoring (144 wells)

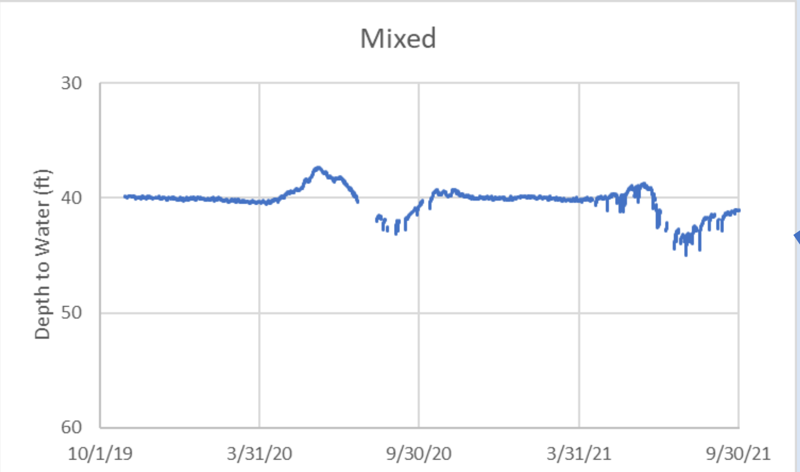


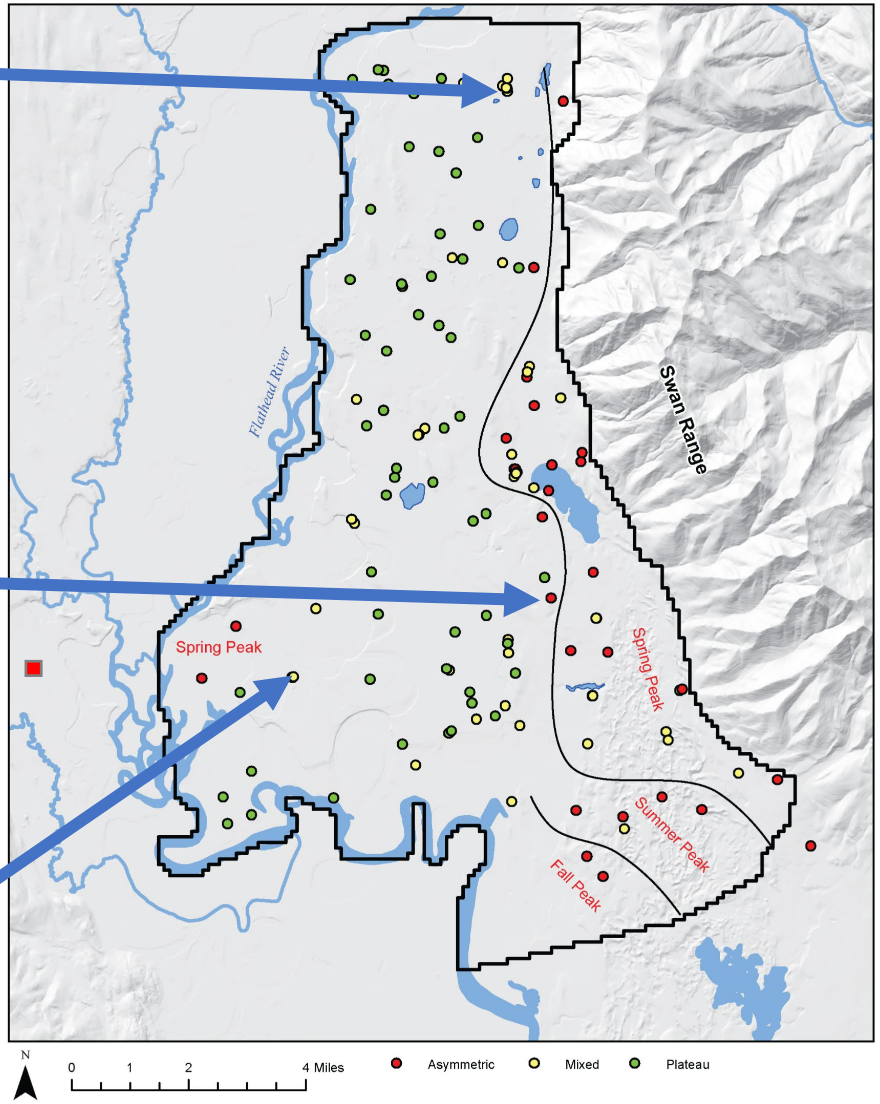
Surface-Water Monitoring (24 sites)

Groundwater Monitoring









Distribution of Hydrograph Types

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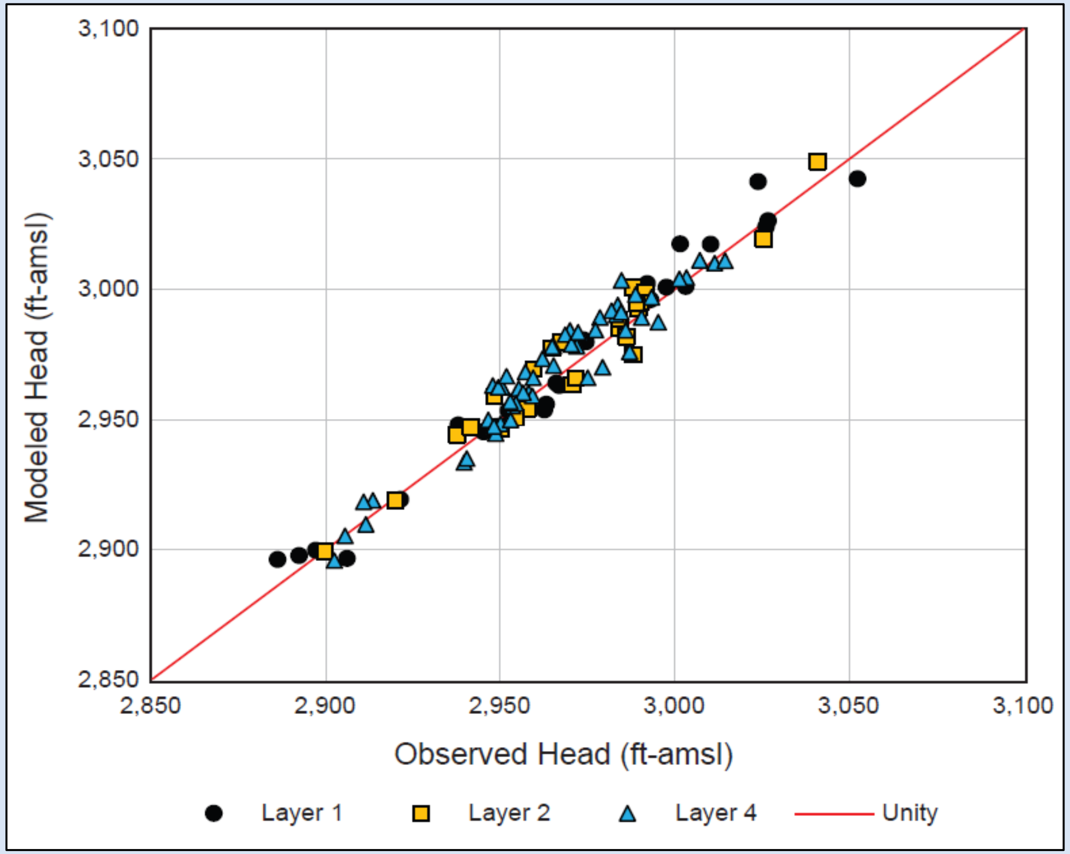
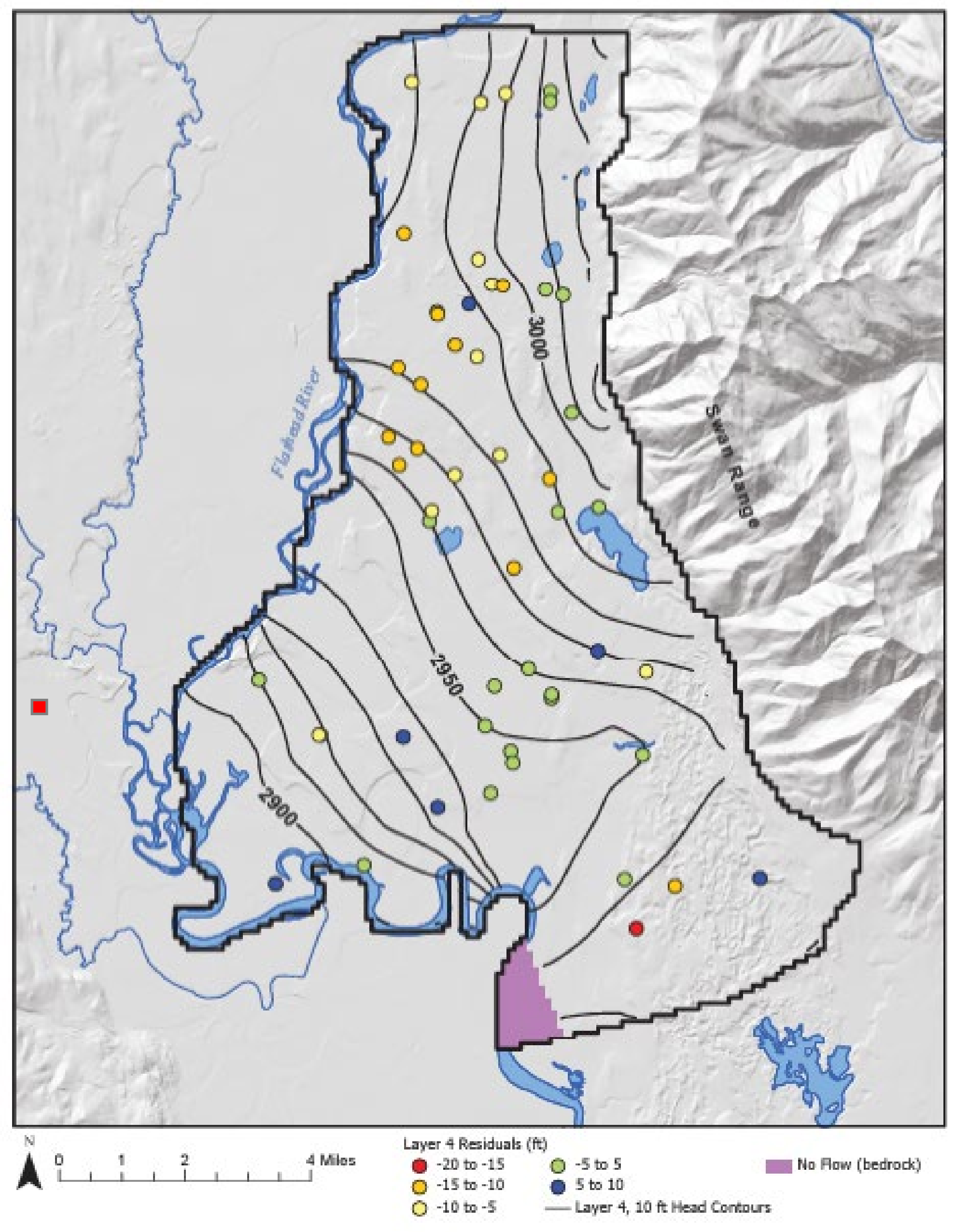
Steady-State Calibration (January, 2020)



105 wells
RMSE = 8.16 ft (4.7% of range)



Potentiometric Surface of Layer 4, with head residuals (deep aquifer; Berglund and others, 2024)

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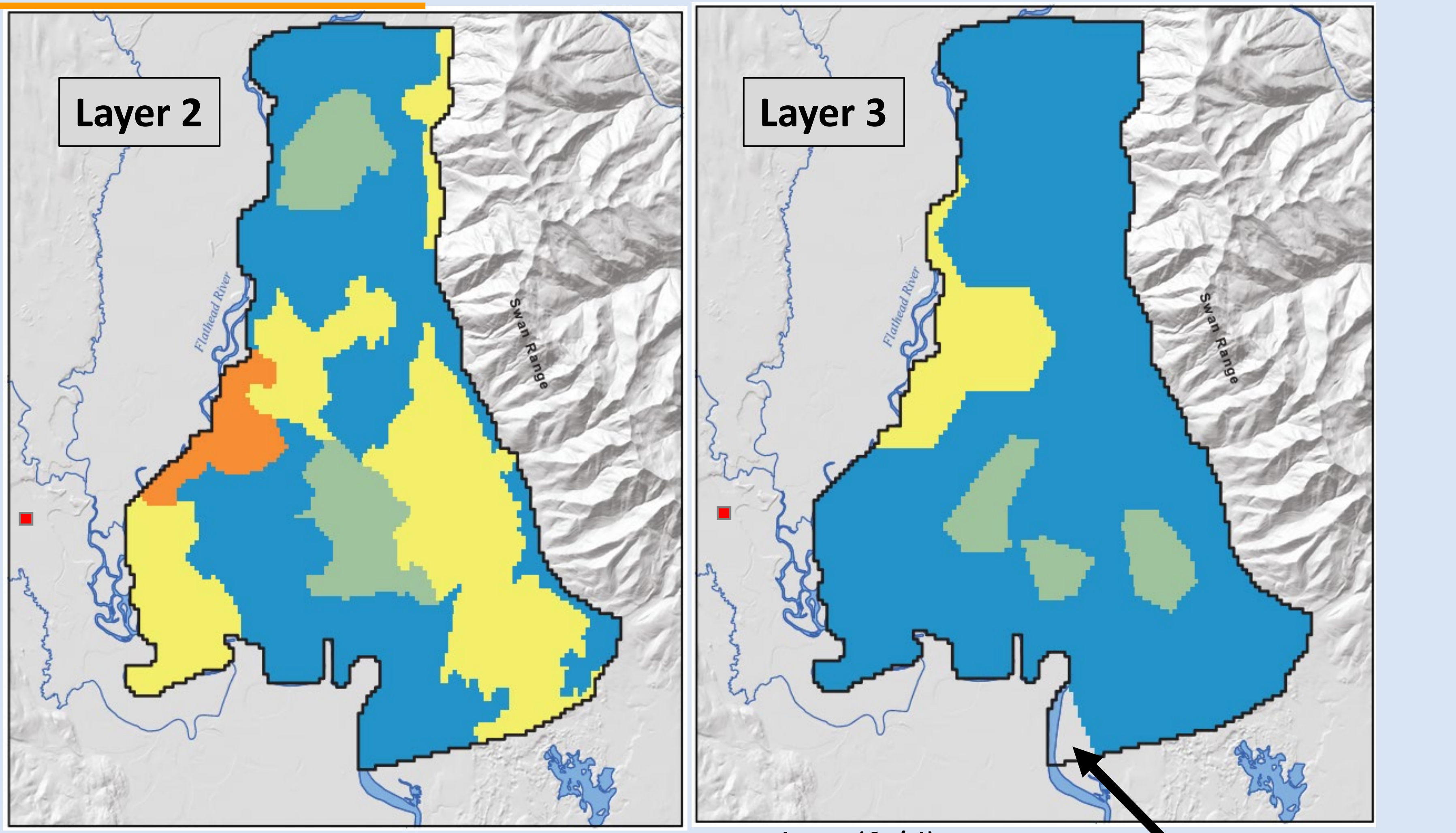
Steady-State Calibration
Confining-Layer Continuity



K Values (ft/d)

<5	5-10	10-50	50-100

Scenarios

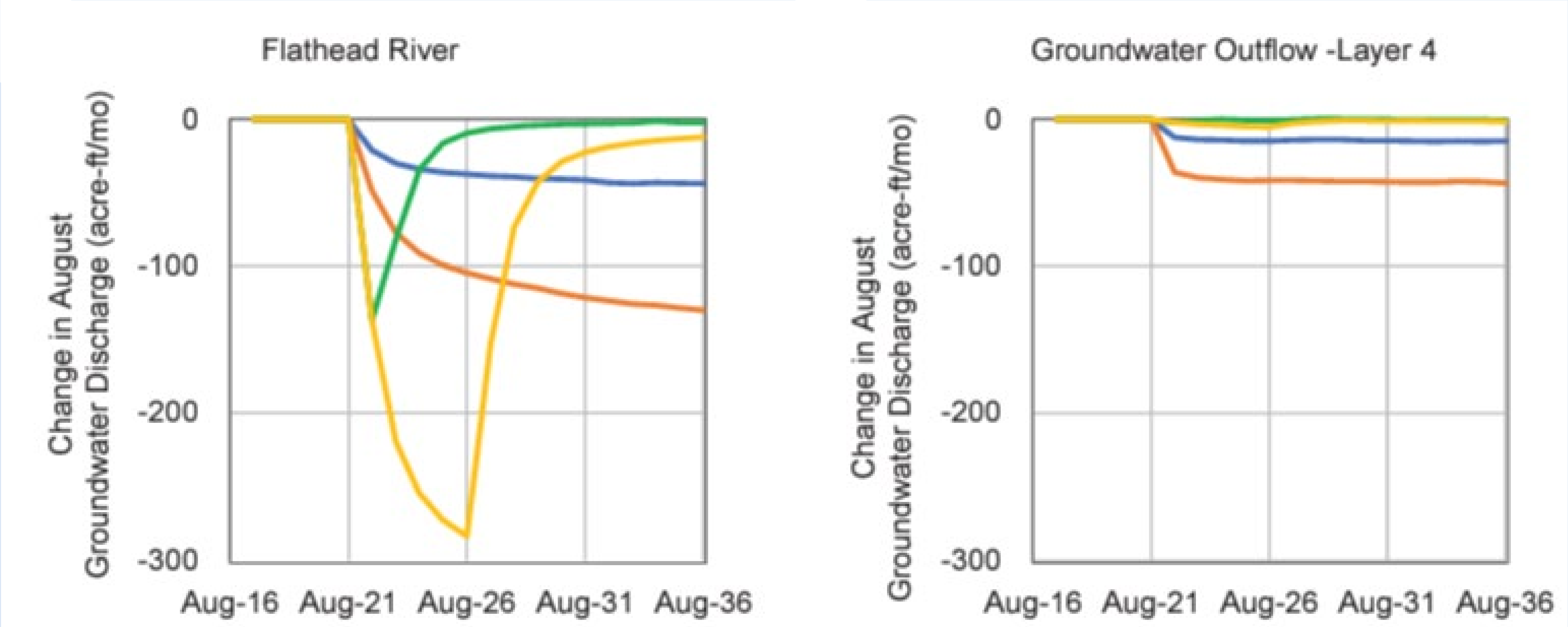
Transient calibration (2017-2021)

Extend calibrated transient model to run for 20 yr (2017-2036)

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

1. Double Residential Pumping
   - Double rates for domestic and PWS wells, and double septic returns
   - Same locations and layers as existing
2. Double Irrigation Pumping
   - Double rates for irrigation wells
   - Same locations and layers as existing
3. 1-year Drought
   - Reduce MFR and AR by 25% for 1 yr
4. 5-year Drought
   - Reduce MFR and AR by 25% for 5 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

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Conclusions

- 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... (my talk last year)
  - 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.

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