Characterization of the Groundwater System in Ogden Valley, Weber County, Utah, with Emphasis on Groundwater–Surface-Water Interaction and the Groundwater Budget

By
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Utah Division of Water Rights Virtual Public Meeting, Dec 17, 2020

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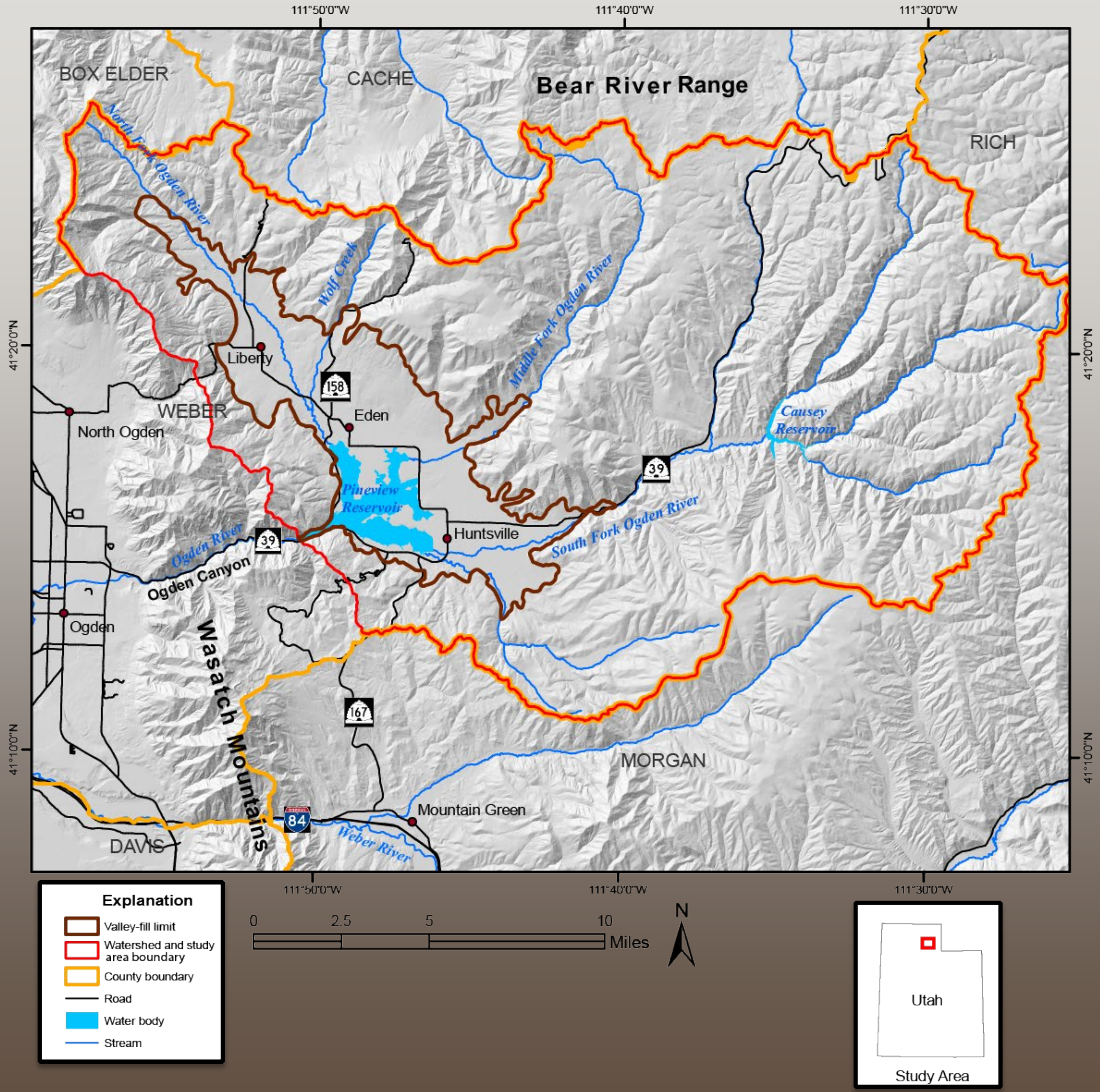
Utah Division of Water Rights
Utah Geological Survey
Weber County
Weber Basin Water Conservancy District
Ogden City
Utah Division of Drinking Water

Study Area

- 44 square miles
- 4800–9500 ft elev.
- Population 7000
- High seasonal use
- Ag and recreation
- Last study 1985
- Ogden R. drainage



UTAH DNR GEOLOGICAL SURVEY

Outline

- **Groundwater system**
  - Physical extent and position of the aquifers
  - Groundwater flow
  - Groundwater–surface-water connectedness
  - Differences in contributions to groundwater from surface water vs. bedrock
- **Water Budget**
  - Components of recharge and discharge
  - 2016 valley-fill aquifer water budget ~67,000 acre-ft/yr
- **Chemistry**
  - Nitrate distribution and potential effect of adding more septic tank wastewater disposal systems

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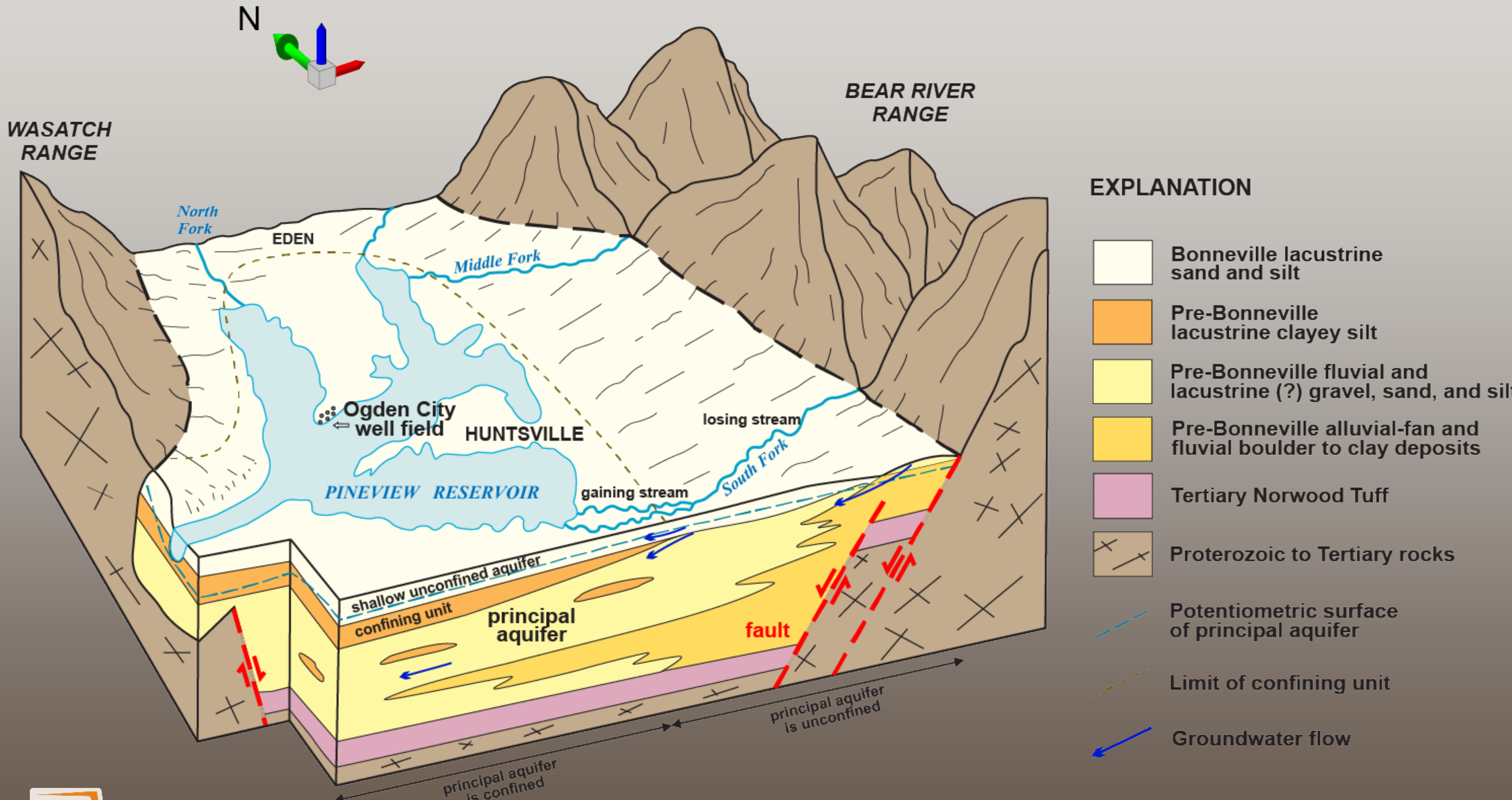
Hydrostratigraphy

Hydrogeologic System Schematic Diagram



Not to scale

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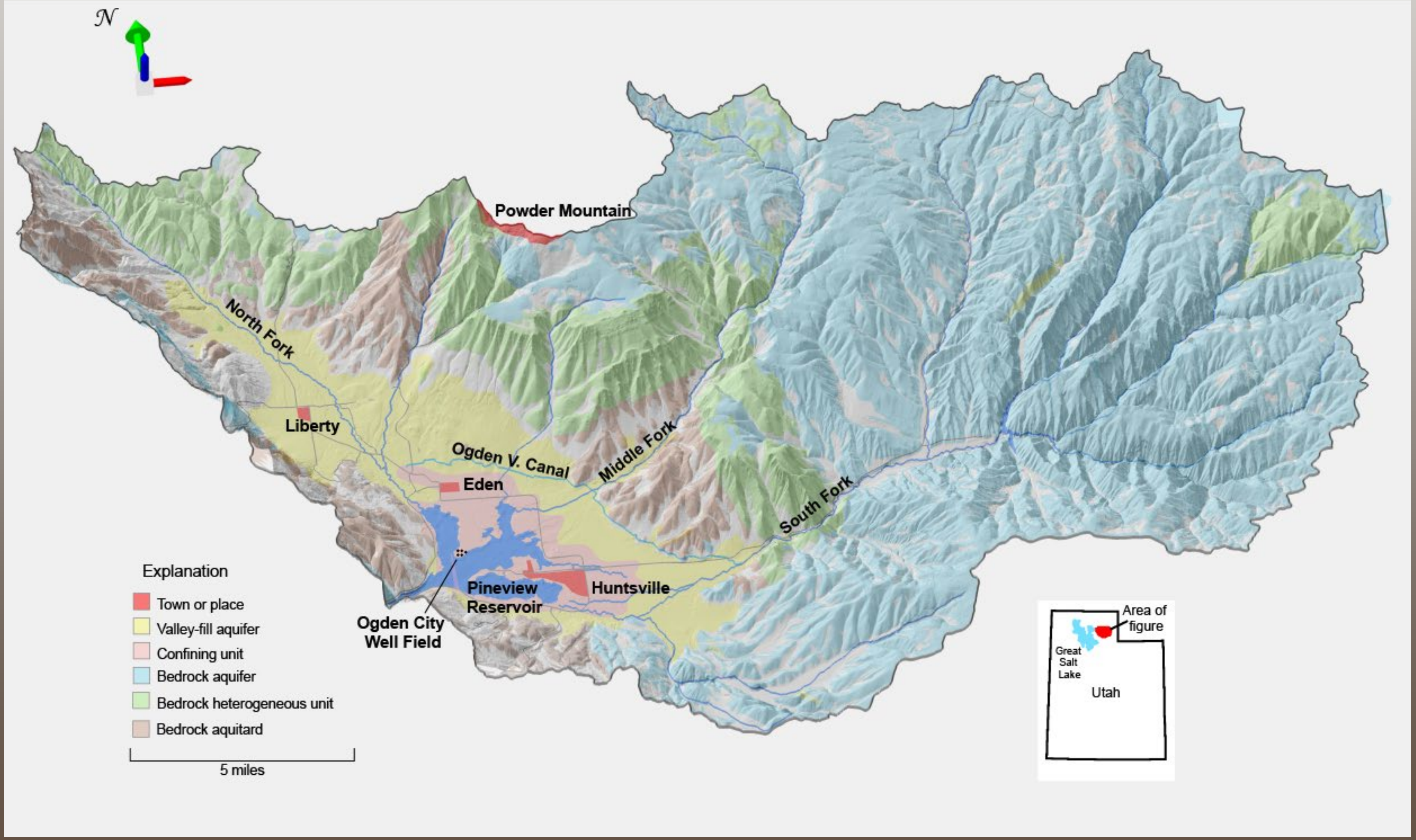
Hydrostratigraphy

- Units grouped based on hydrogeologic properties:
  - aquifer units (blues)
  - confining (pink/maroon)
  - heterogeneous (greens)



Water Levels

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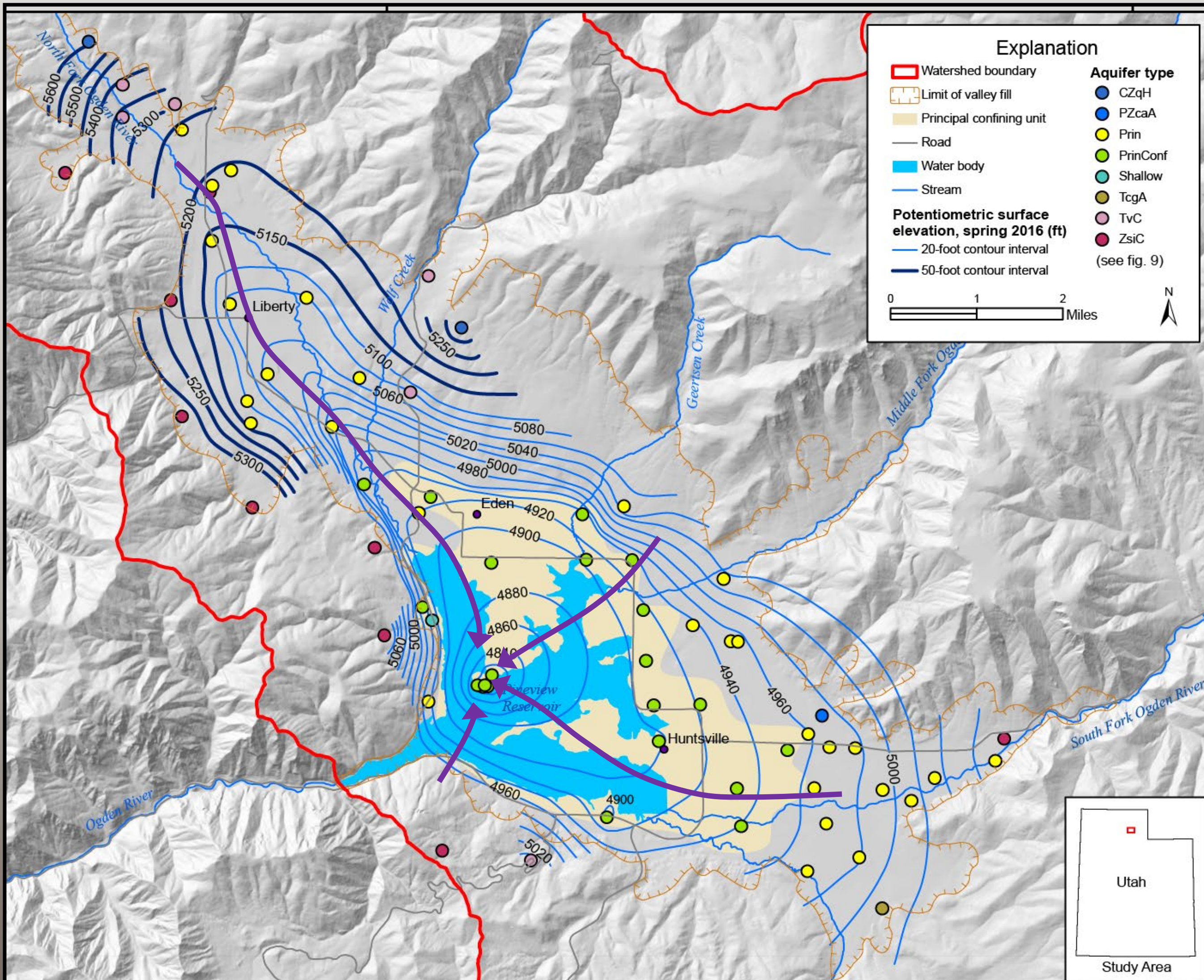

Spring 2016 Principal Aquifer Potentiometric Surface

- 60 wells measured April–May 2016
- 20- and 50-foot contour intervals
- Updated with Ogden City Well Field pumping water levels
- Groundwater flow to OCWF
- Well field pumping level still above bottom of confining unit

Groundwater flow direction

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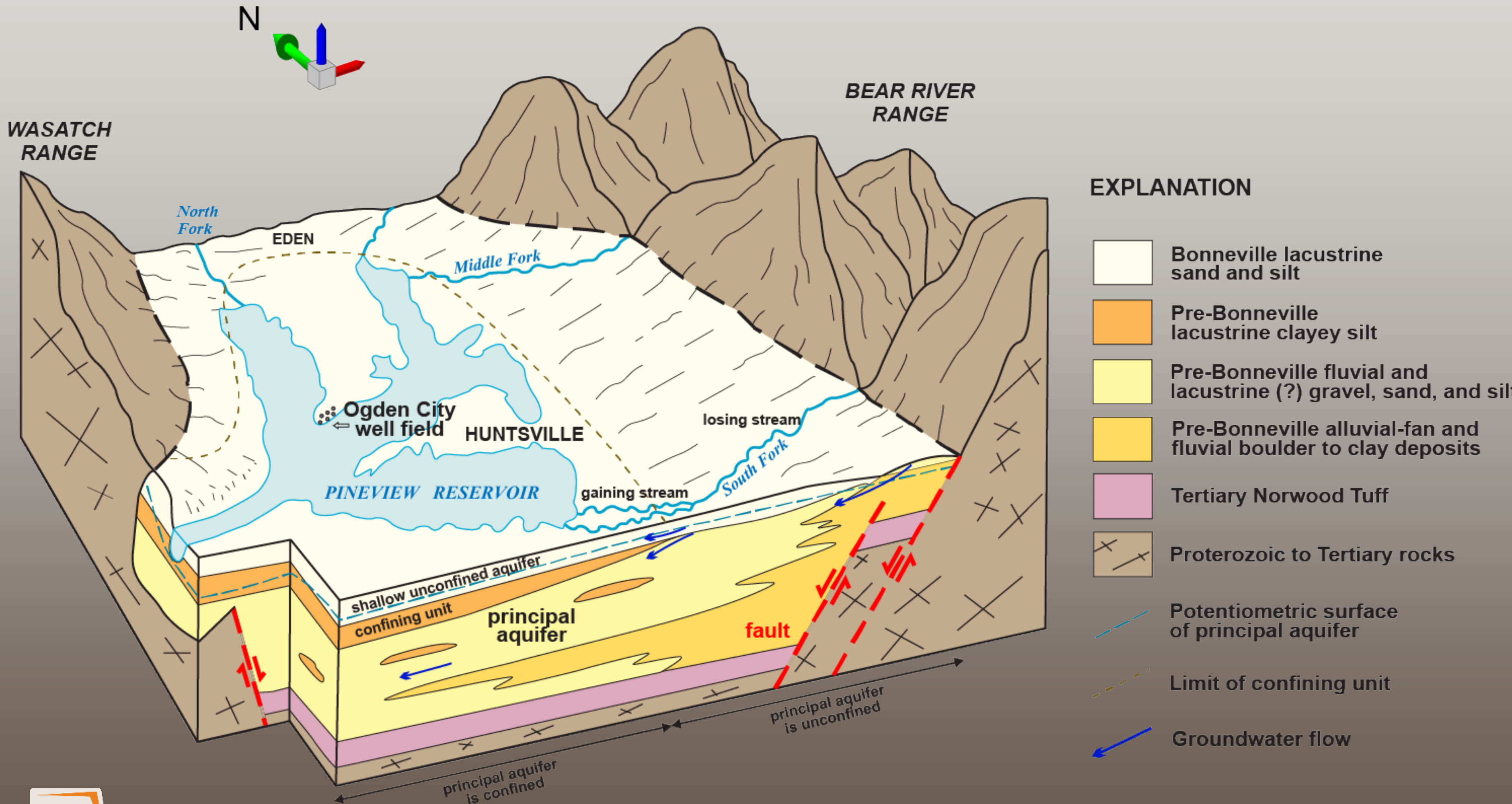
Hydrogeologic System Schematic Diagram



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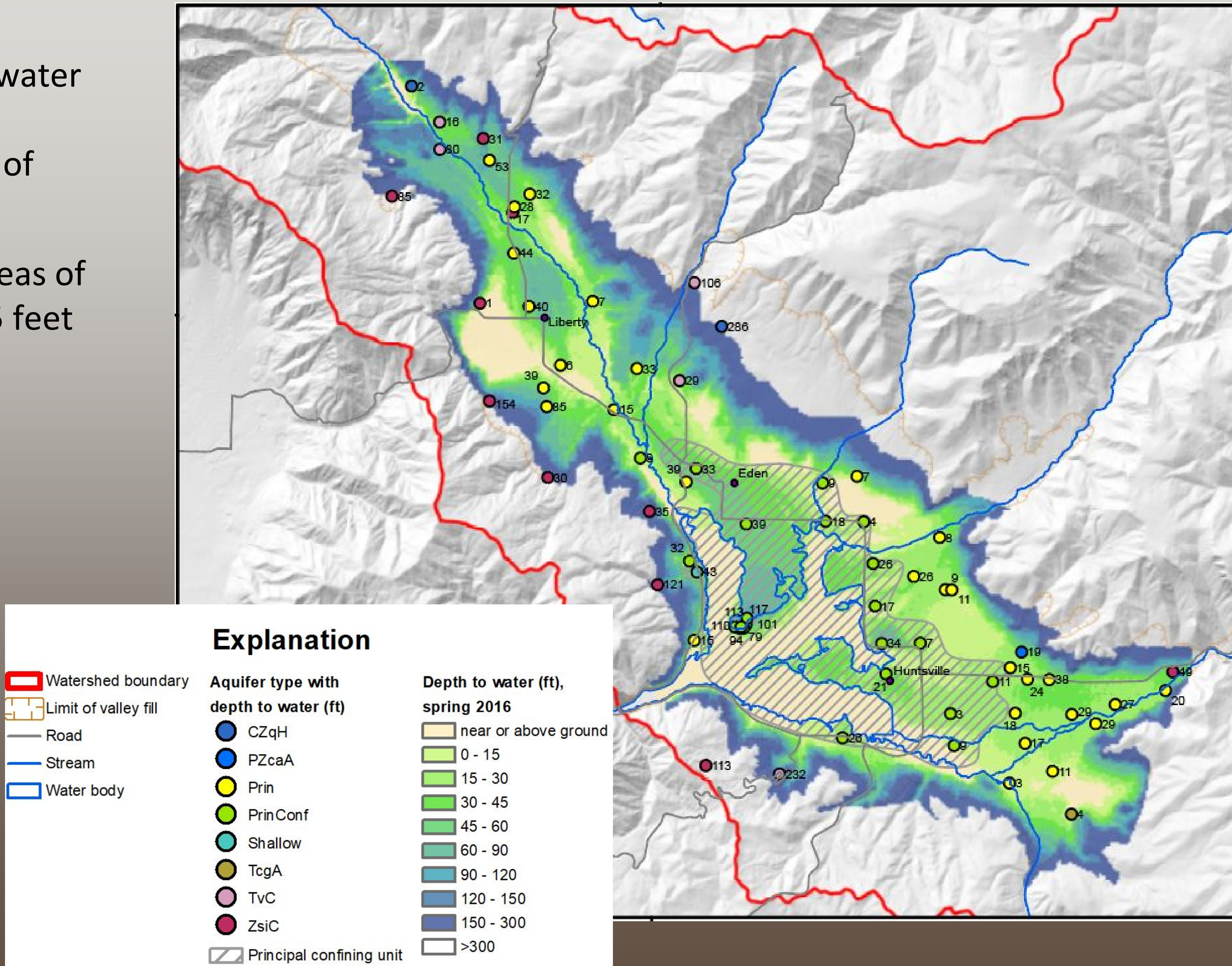
Depth to Water

- Deeper water table at margins of valley
- Large areas of DTW<15 feet



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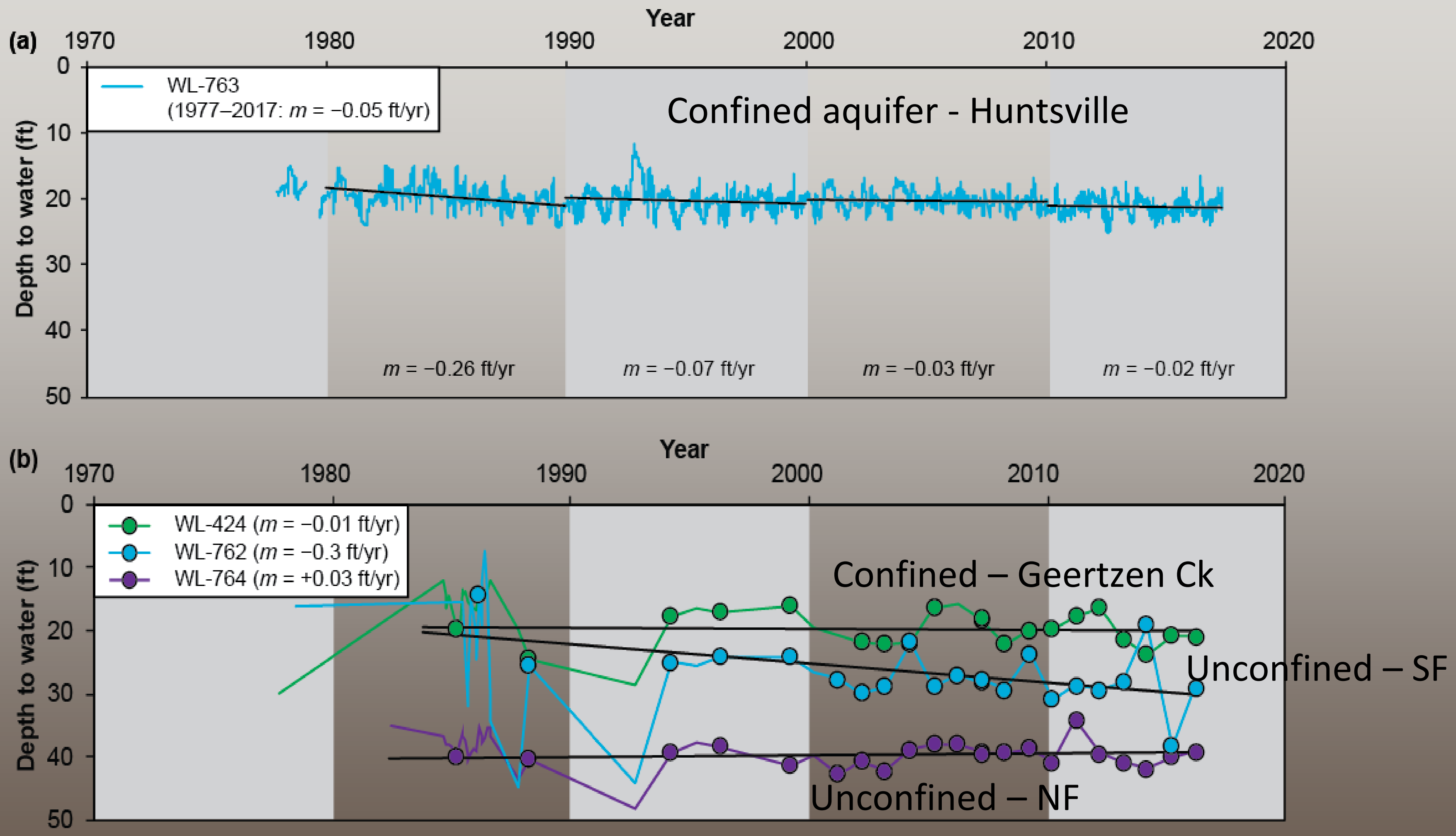
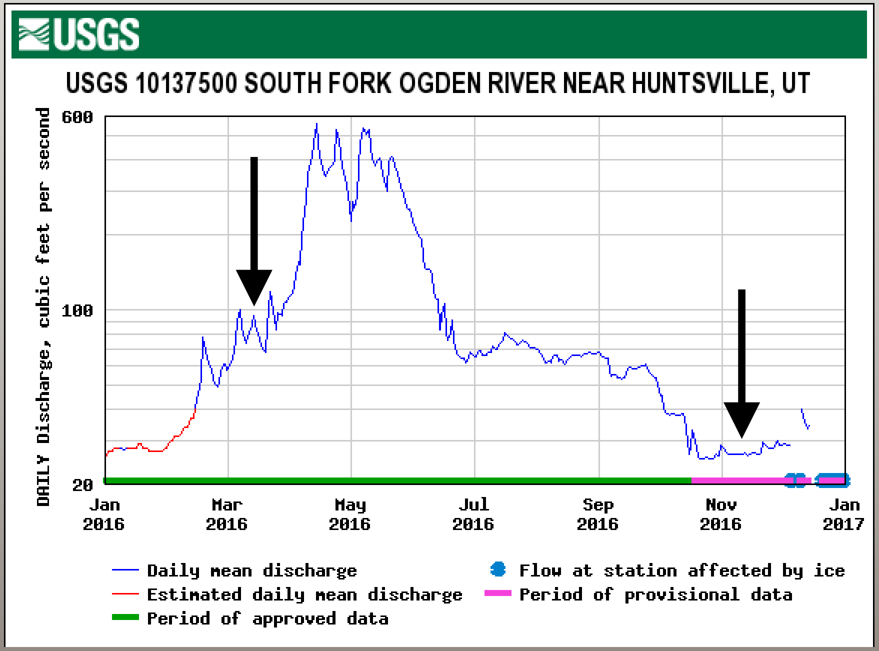
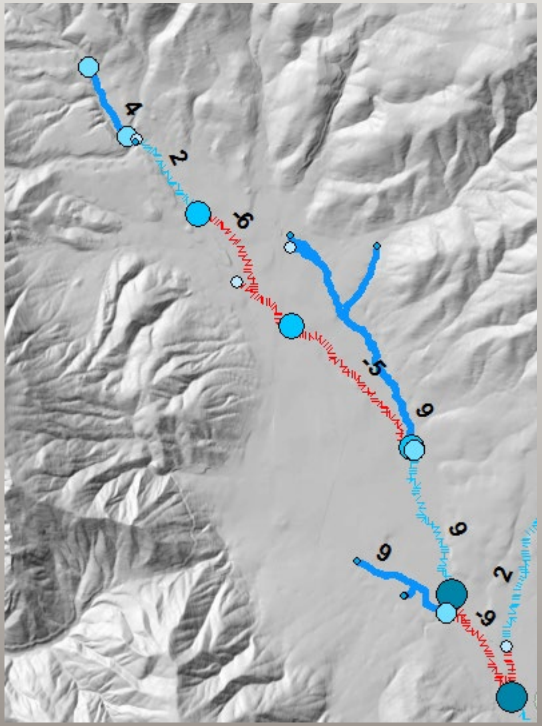
Long-Term Water-Level Trends

Long-Term Water-Level Trends



Seepage Runs





- Flow measurements at 50 locations before peak runoff (March 7-10, 2016).
- Flow measurements at 39 locations (+11 dry) during baseflow (Nov 7-9, 2016).
- Losing stretches shown in red, gaining stretches shown in blue, stippled where within margin of error for measurement.
- Size of dots correlated to discharge.

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GEOLOGICAL SURVEY

March Seepage Run

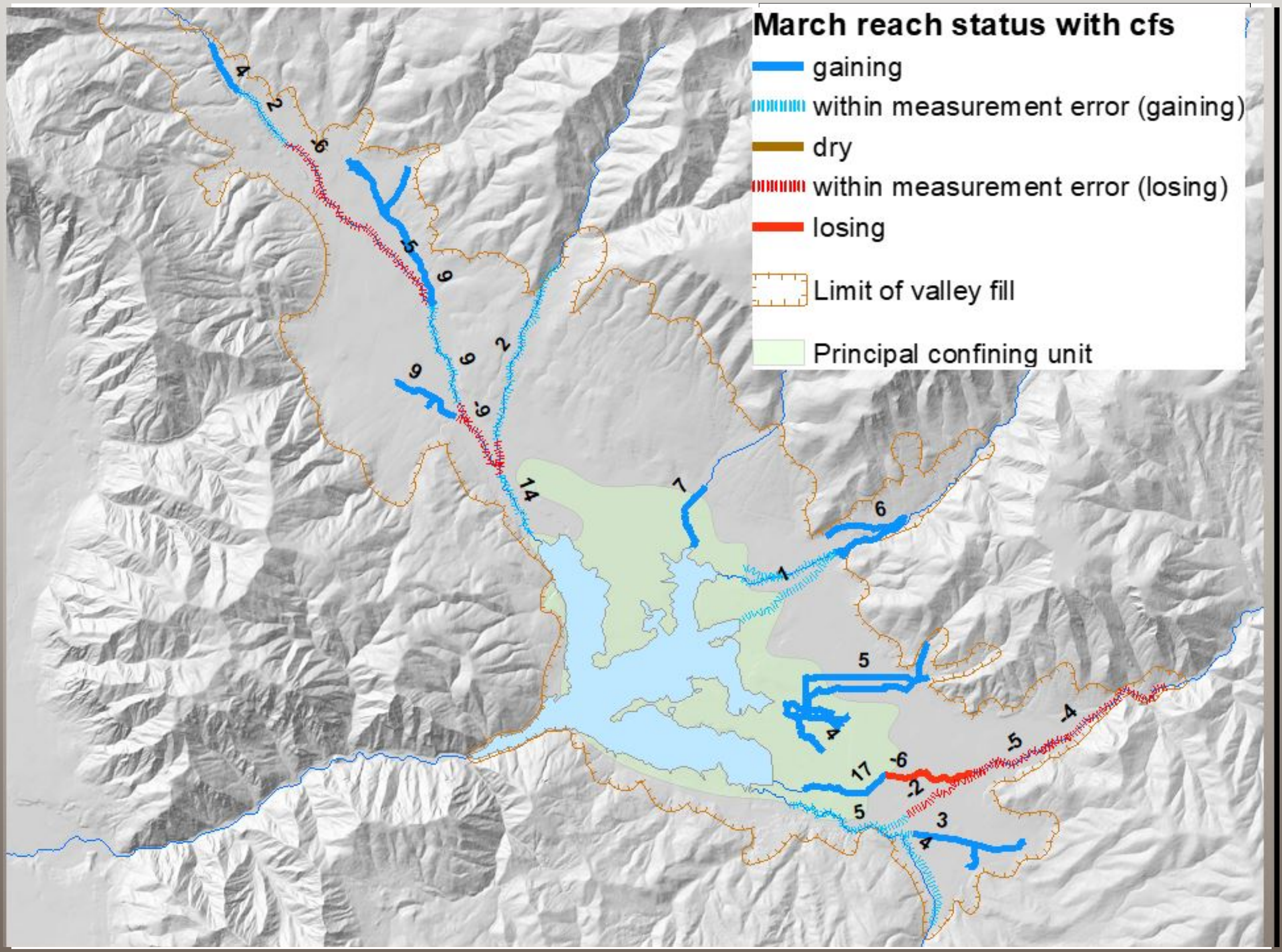
- Discharge: 0.2 to 96 cfs.

- Gain-loss per segment:
- +14 to -5 cfs/mile.

- South Fork losing 18 cfs to principal aquifer and gaining 29 cfs after crossing confining unit. Net 11% gain*.

- North Fork net: +29 cfs (~30%).

- Basin-wide net: +63 cfs (~22%) = 125 acft/d.



*Net gain or loss calculated as net cfs gained or lost divided by sum of discharge to reservoir.

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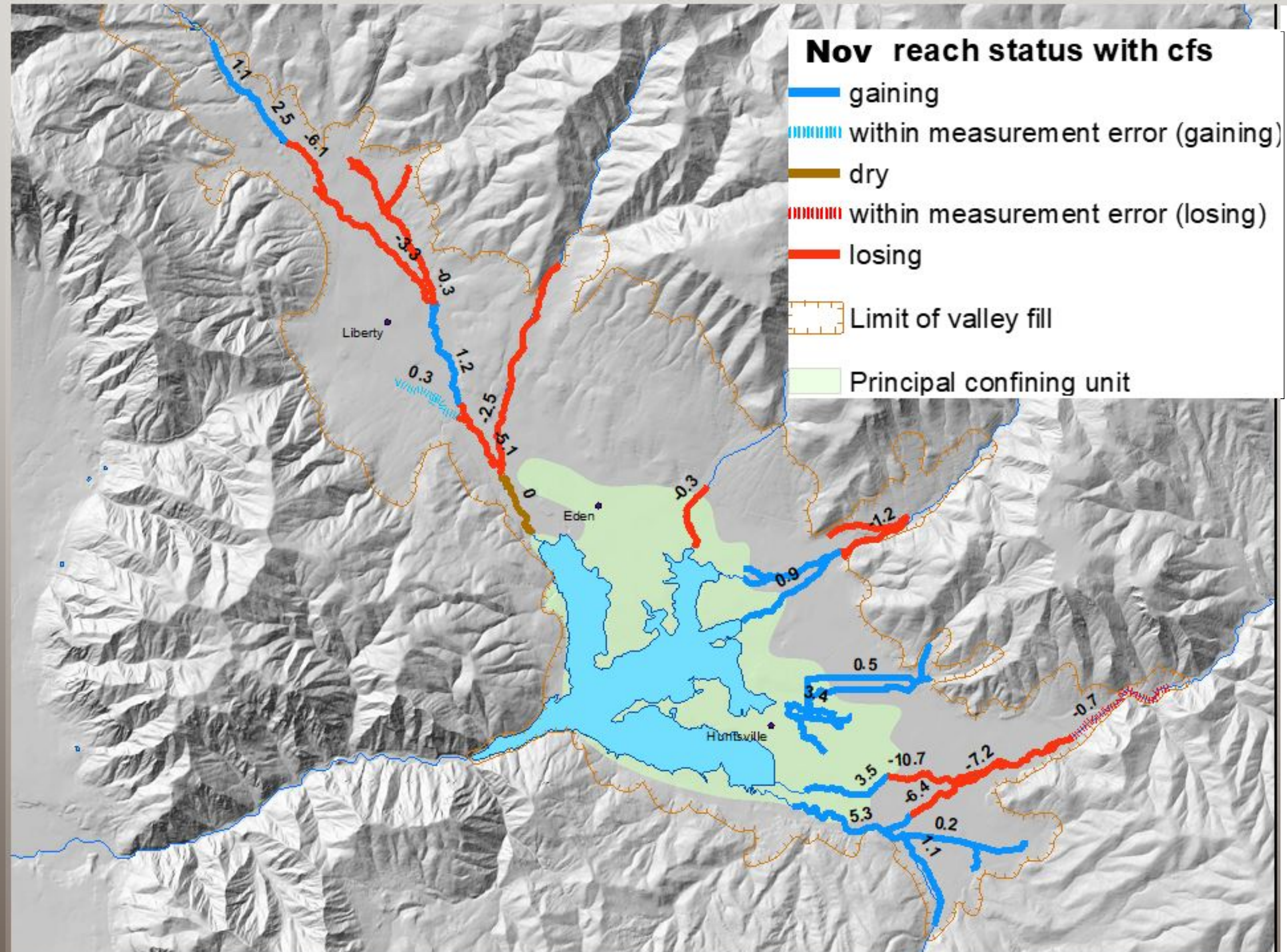
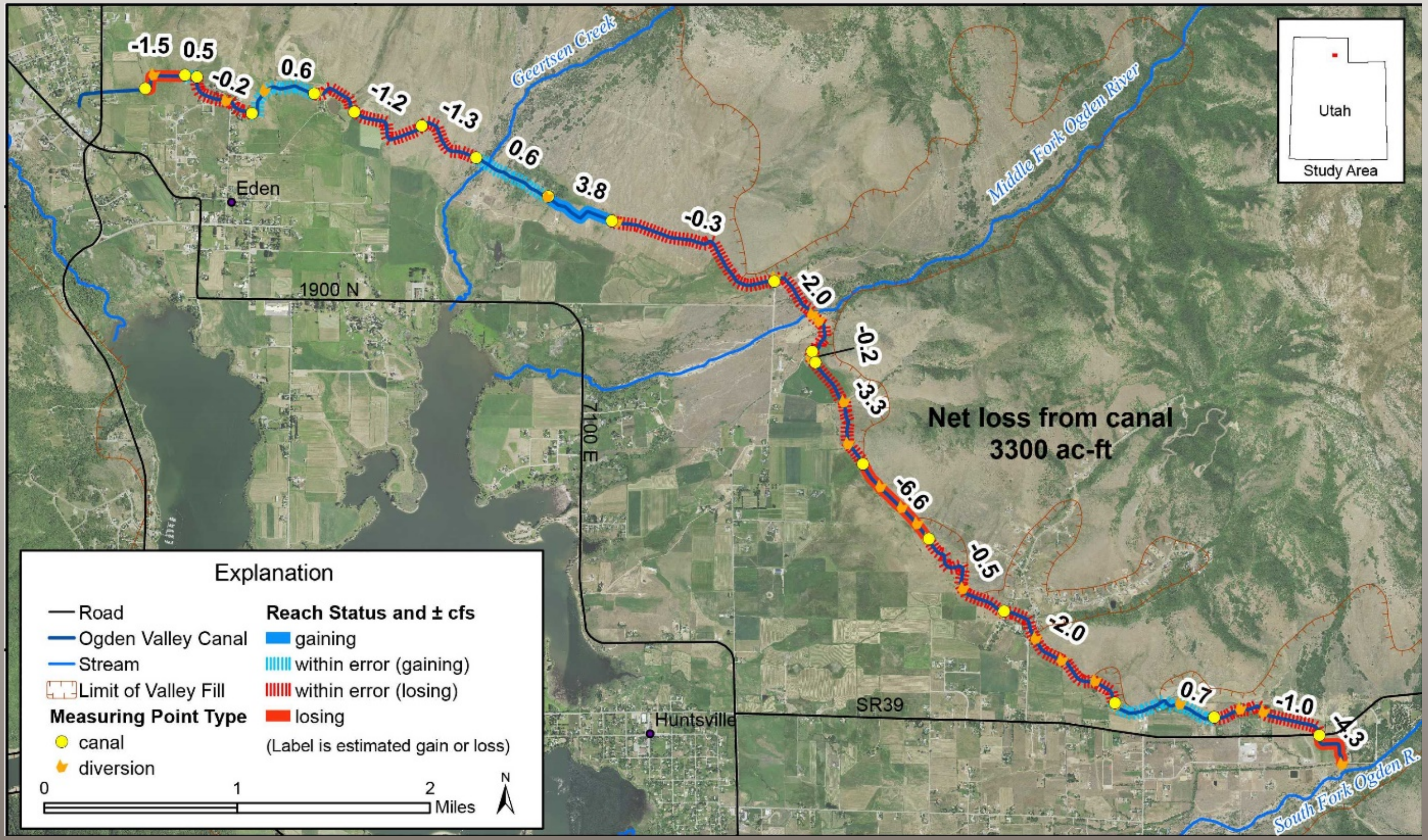
November Seepage Run

- Discharge: 0 to 25 cfs.
- Gain-loss per segment:
  +3 to -9 cfs/mile.
- South Fork losing 25 cfs to principal unconfined aquifer and gaining 10 cfs from shallow unconfined. Net -15 cfs. 100% loss, then 40% gain back.
- MF net gaining: 3 cfs
- North Fork net: -12 cfs (100%).
- Basin-wide net: -24 cfs (~-150%) = -48 acft/d
- More stream segments are losing during baseflow than during spring runoff.



*Net gain or loss calculated as net cfs gained or lost divided by sum of discharge to reservoir.

Ogden Valley Canal July 19, 2016 Seepage Run



- Measured flow in canal or at diversions at 23 places. Supplemented with 4 measurements from canal operator (WBWCD)
- WBWCD measurements within 10% of our measurements
- 18 cfs loss on the day of the seepage run, which is 47% of the flow at the start of the canal that day. Extrapolate that rate of loss to the 2016 total flow at start of canal as reported in 2016 Commissioner's Report [7020 acre-ft x 47%]= 3300 acre-ft per year lost.

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Environmental Tracers

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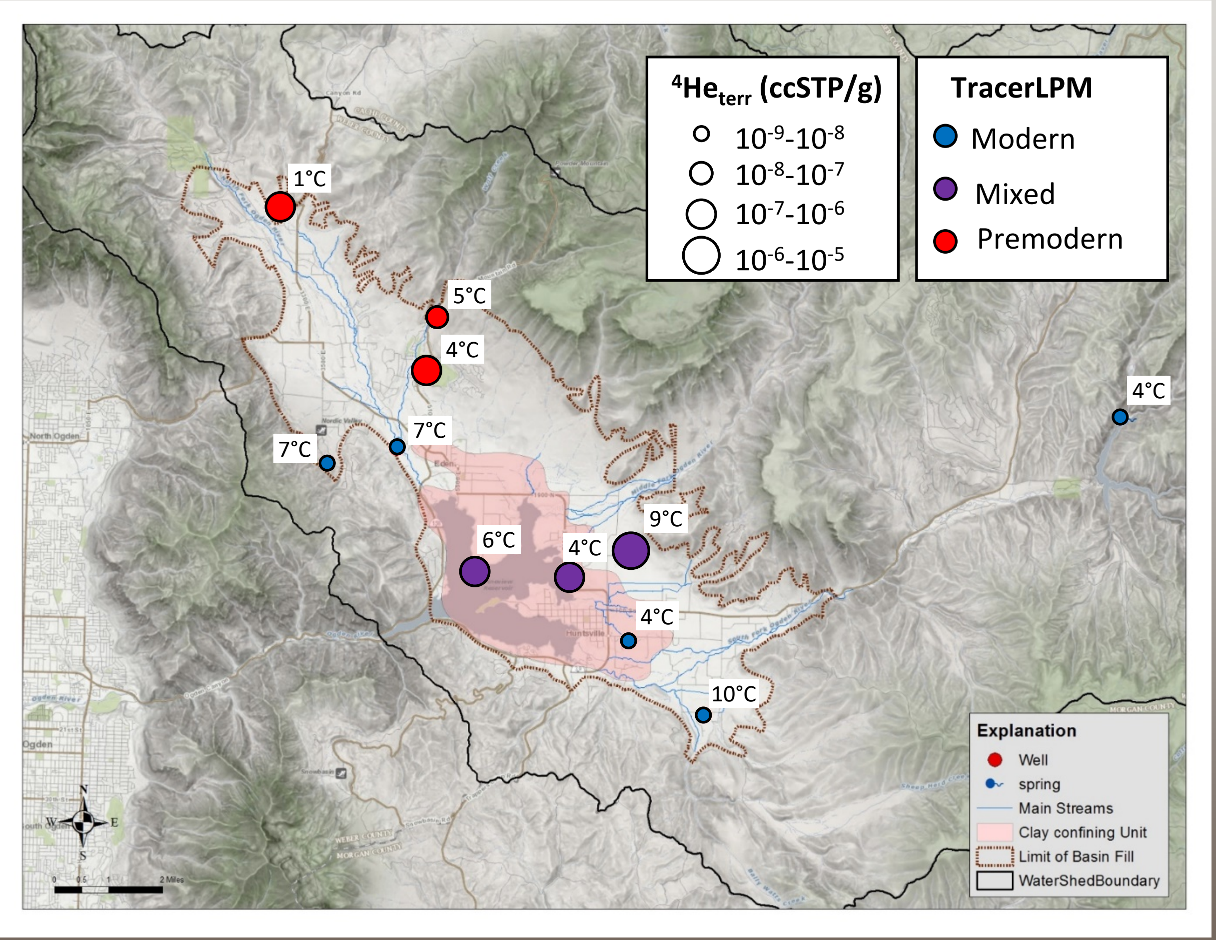
RECHARGE TEMPERATURE AND GROUNDWATER AGE

- Derived from dissolved noble gas concentrations
- Mean recharge temperatures ~2–4°C cooler than basin ground temperature
- 3 samples contain a mixture of old and young water
- Older water has lower recharge temperatures



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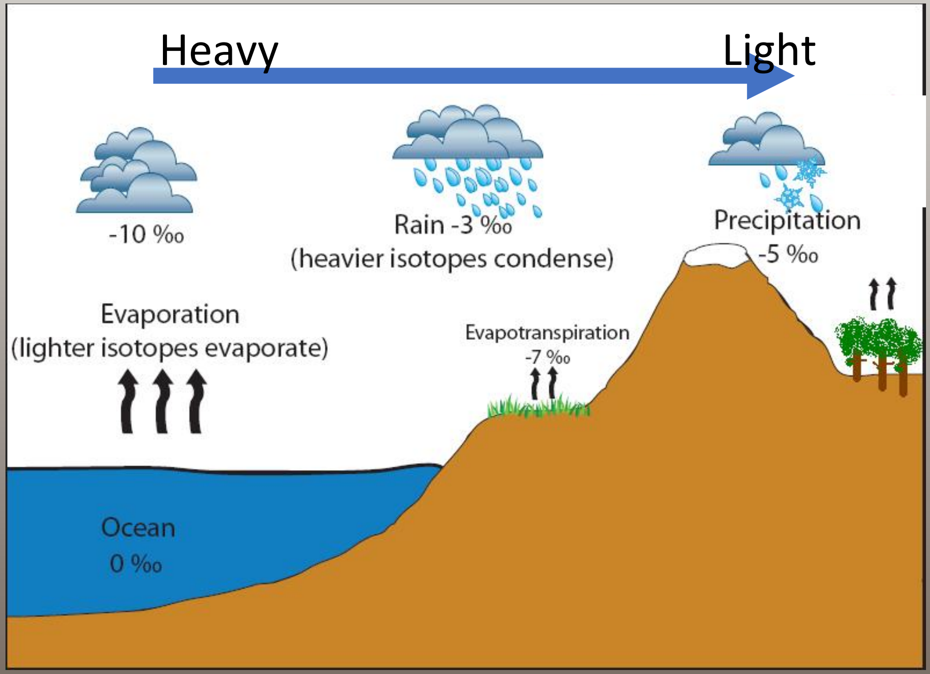
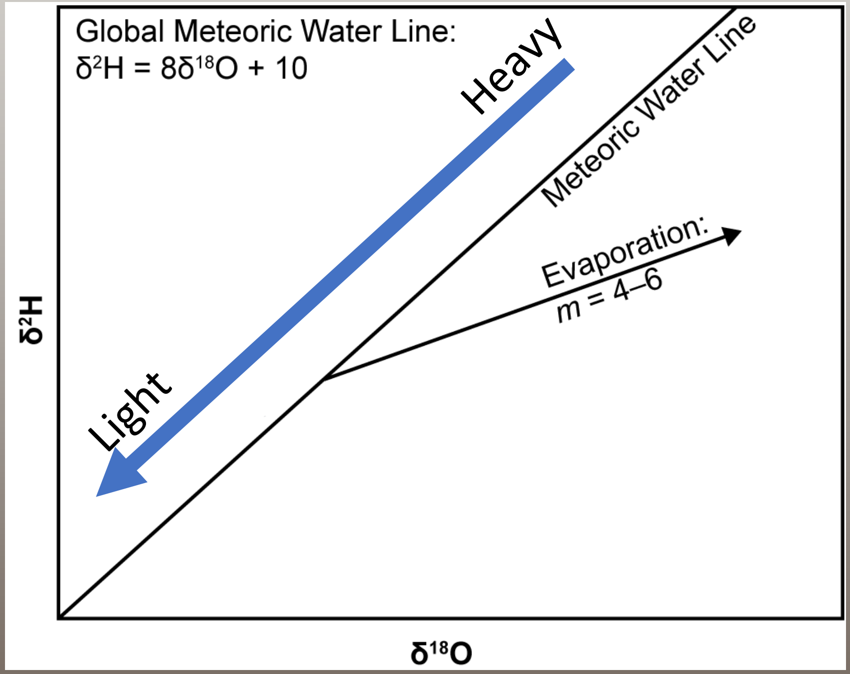
STABLE ISOTOPES OF WATER

- Isotopes are forms of an element that contain equal numbers of protons but different numbers of neutrons, so they have different mass.
- Phase changes in the hydro cycle concentrate heavier isotopes in the water phase.
- Affected by temperature (=elevation) and distance from the ocean.





SERC-Carleton

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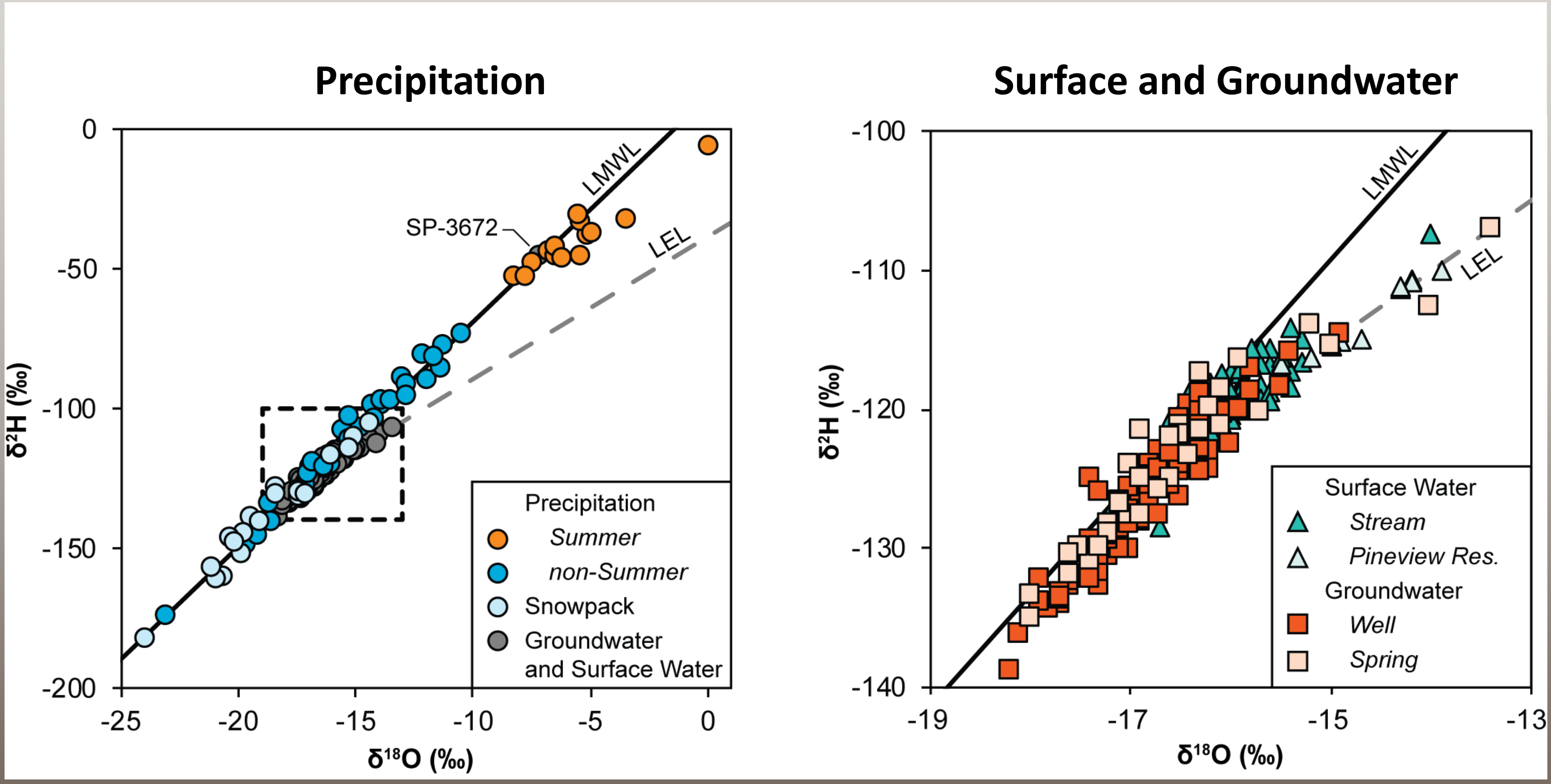
STABLE ISOTOPES OF WATER



- Summer precipitation does not show up in groundwater
- Groundwater is an integration of the non-summer precipitation
- Evaporation signature in reservoir, springs, and stream

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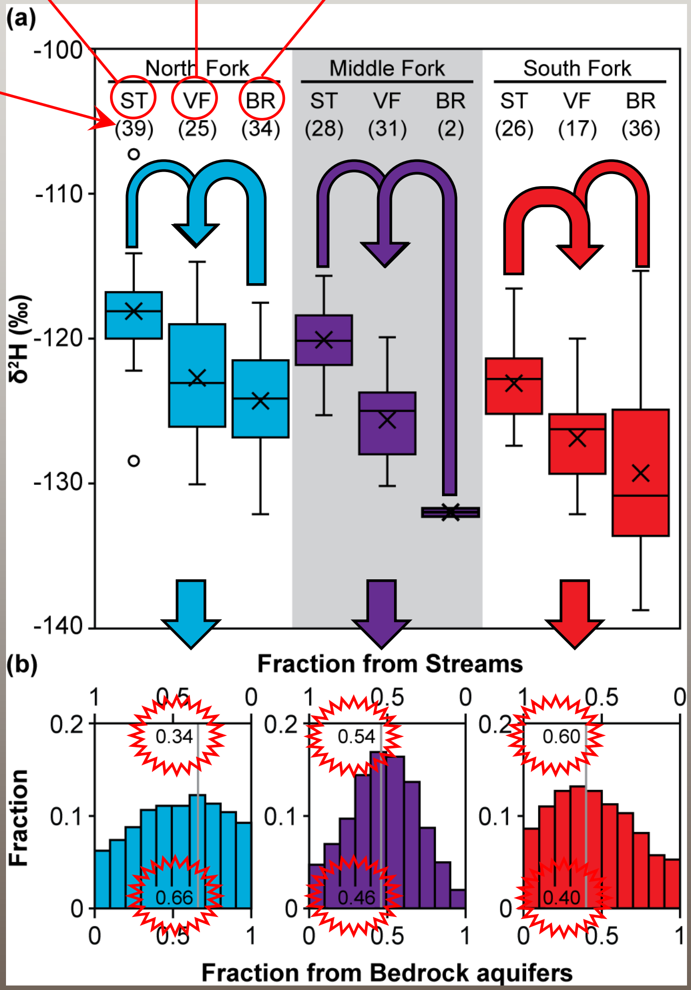
How much recharge is from streams vs. bedrock in each sub-basin?

streams

valley fill

bedrock

# of samples



Conclusions from the Monte Carlo analysis

- About half the water in the valley-fill aquifer comes from streams and surface and half comes from bedrock
- North Fork is more bedrock dominated
- South Fork is more surface-water dominated

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Water Budget

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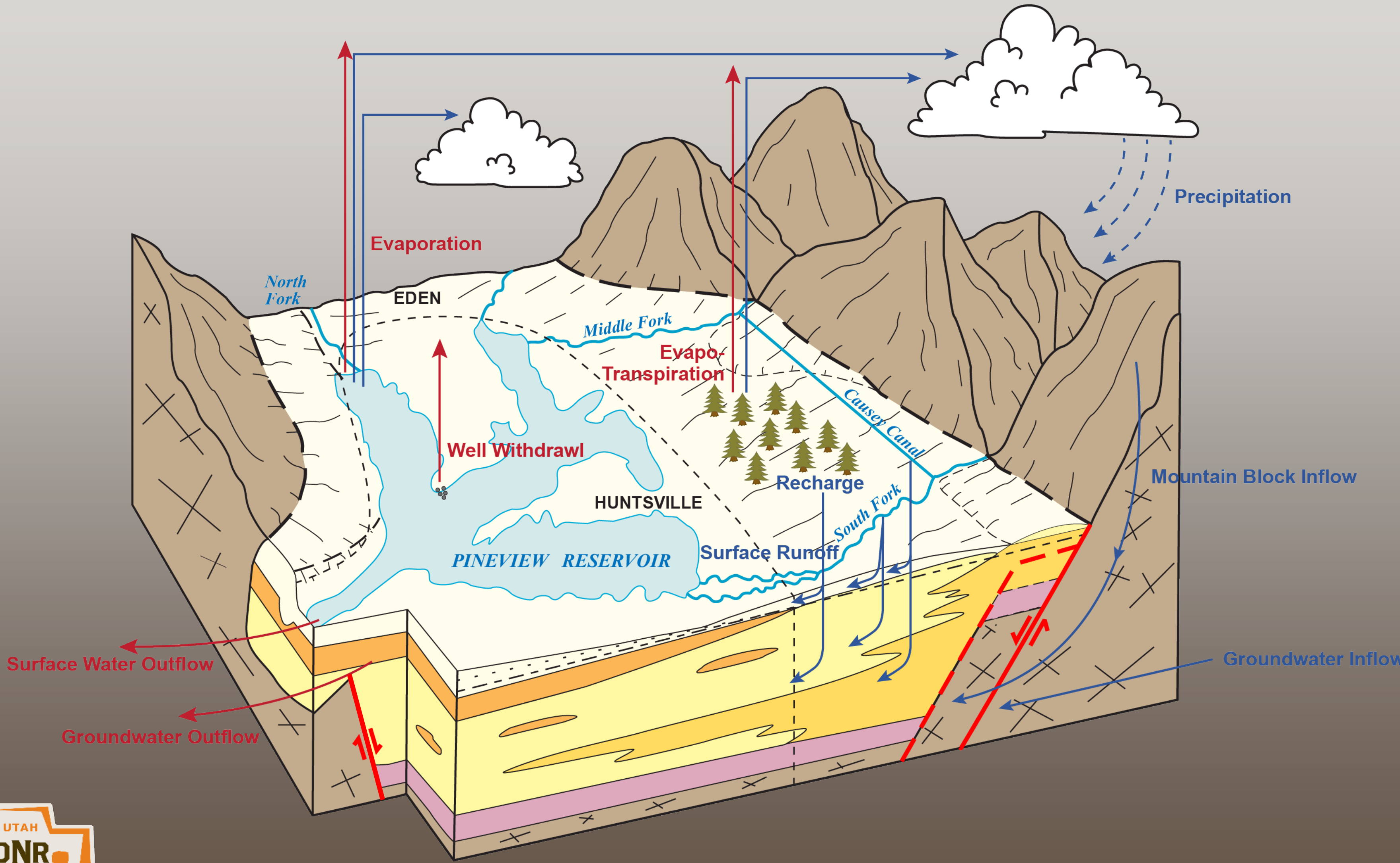
Water Budget Inputs and Outputs



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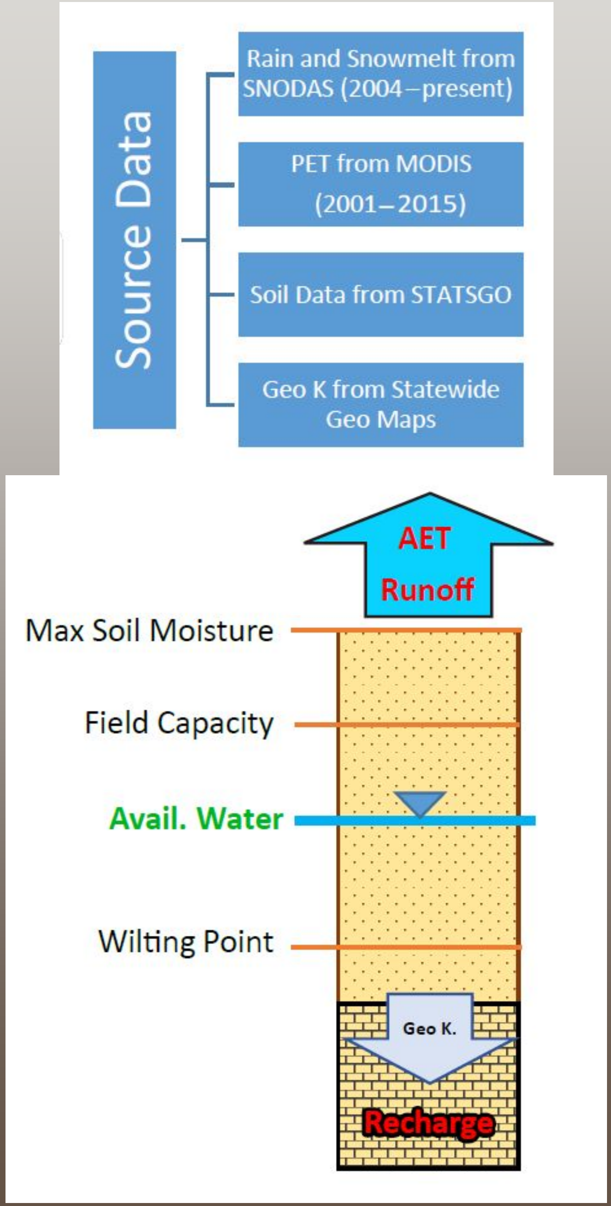
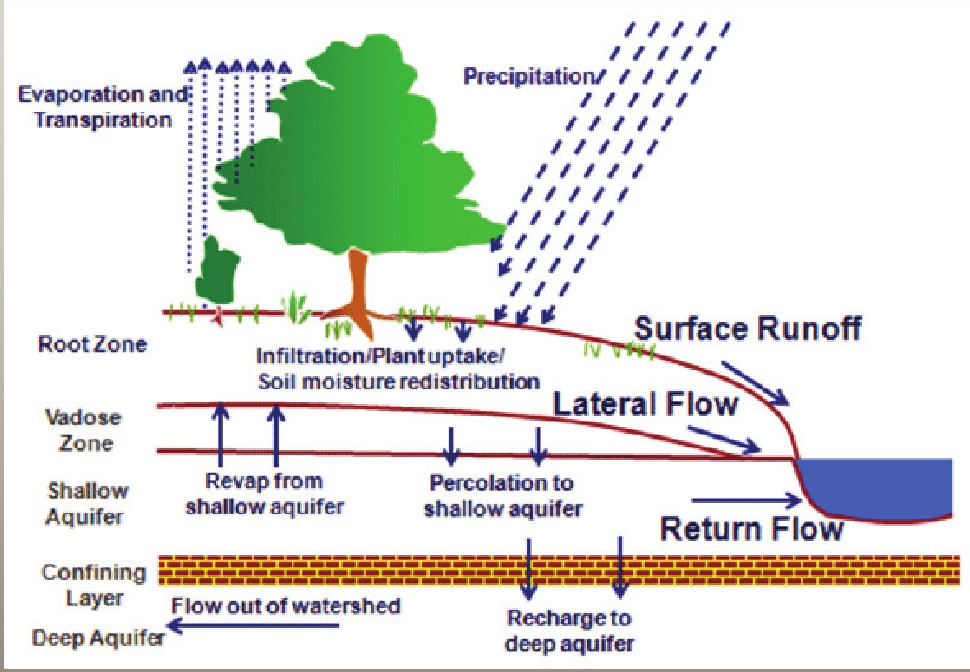
UBM model (Utah Basin Model)

SWAT (Soil and Water Assessment Tool)





Quasi 3D

HRUs instead of 3D cells like Modflow

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Basin-wide water budget for the Ogden Valley drainage basin, water years 2004 to 2016

Budget component	**Average**	**Range**
INPUT	**acre-ft/yr**	**acre-ft/yr**
Precipitation	**537,000**	394,000 – 800,000
OUTPUT		
Evapotranspiration	372,000	341,000 – 410,000
Pineview Reservoir discharge	150,000	71,080 – 57,250
Ogden City well field	11,300	9140 – 12,240
Groundwater discharge out	400	400
Total discharge	**534,000**	443,720 – 779,890
CHANGE IN STORAGE		
Pineview Reservoir	3000	-44700 – +36,330
Soil and groundwater	0	-60,400 – +63,500
Total change in storage	3000	-105,100 – 85,660

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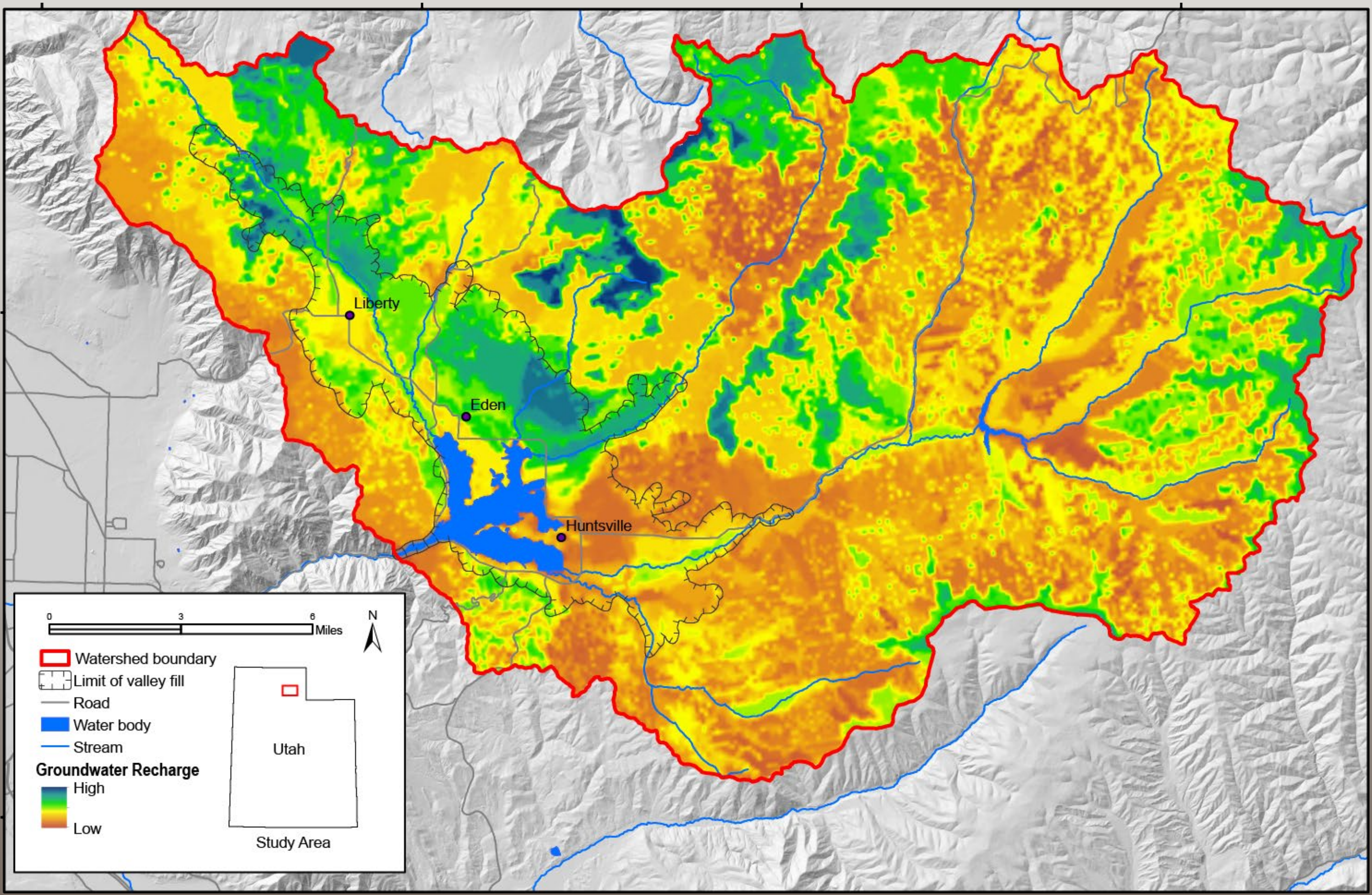
Relative recharge distribution



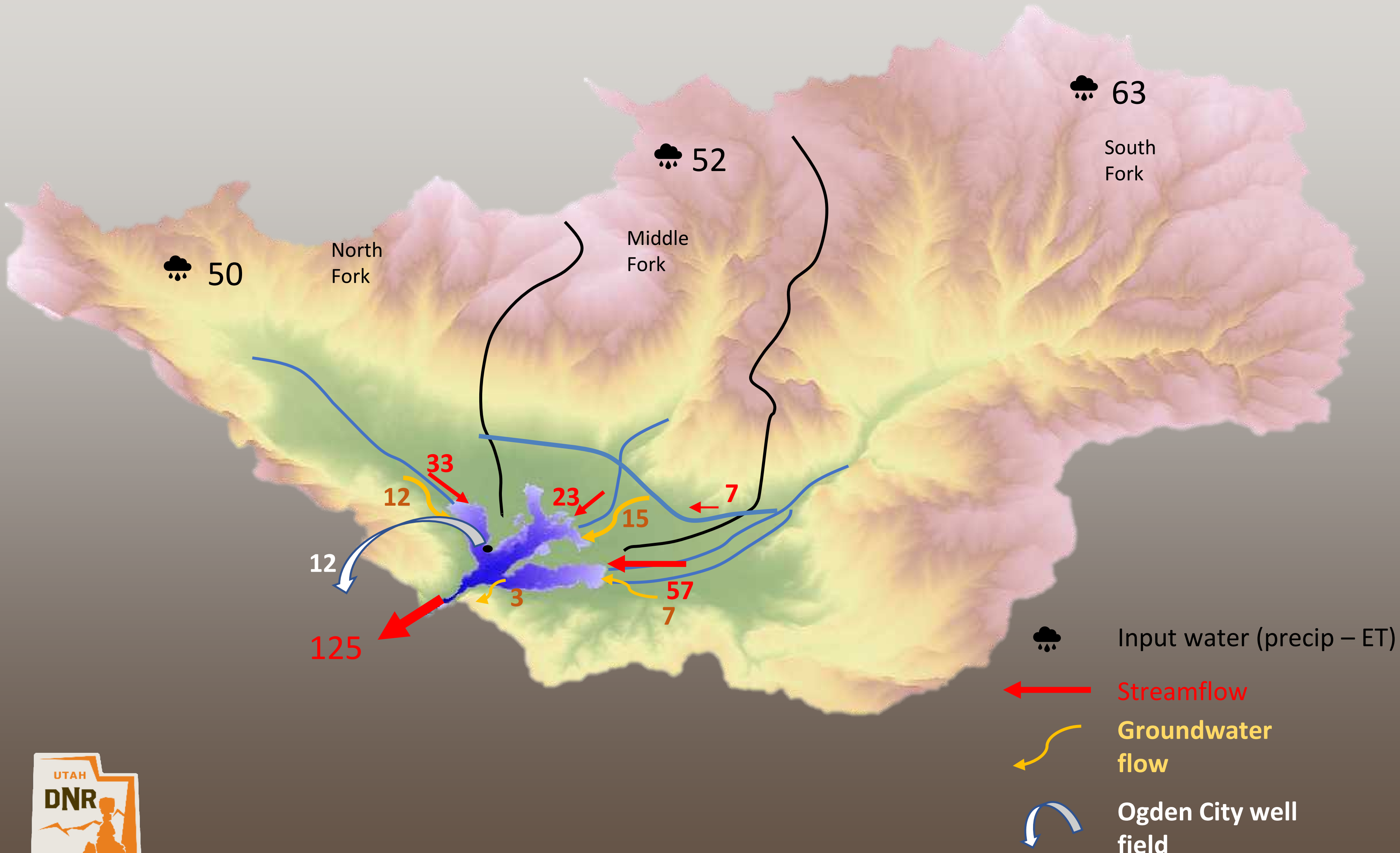
Zones of high recharge:

- moderate slopes
- high precipitation
- permeable rock

South Fork area: overall lower rate but large area

Sub-watershed water budget components, 2016

Quantities in thousands of acre-feet per year



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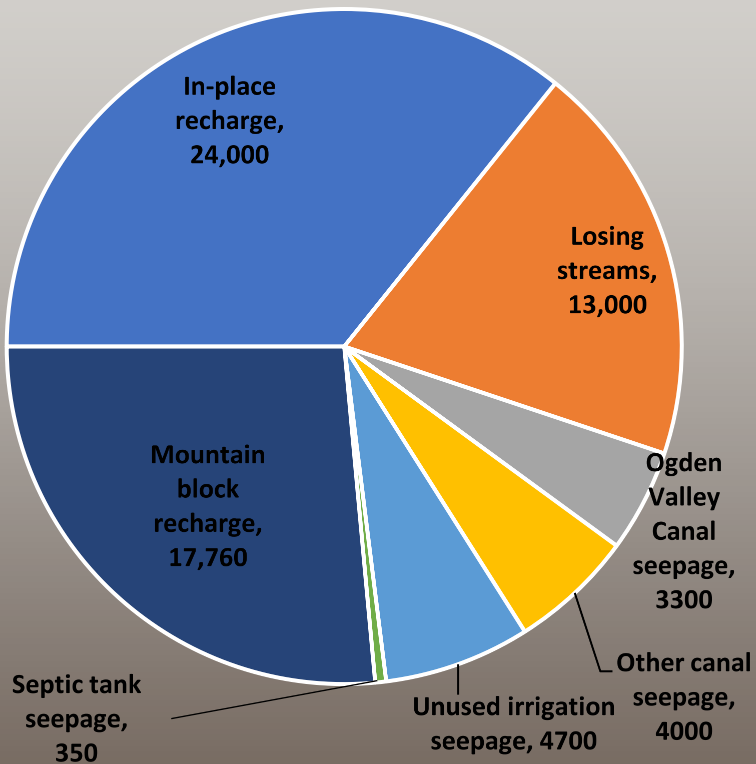
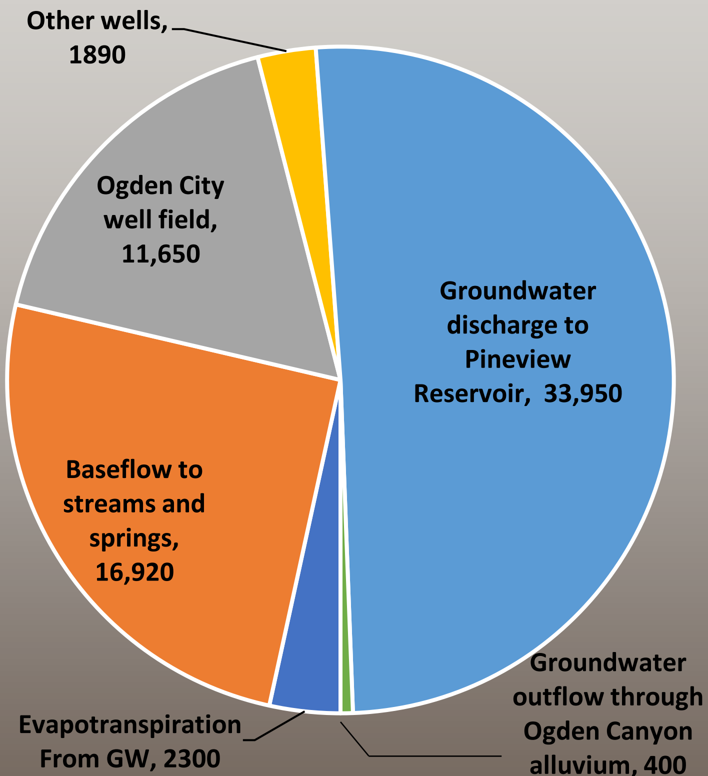
2016 valley-fill aquifer groundwater budget, in acre-feet

Recharge (67,100 acre-ft)



Discharge (67,100 acre-ft)



- 2016 was an average year
- In-place recharge on valley floor is only 7% of total in-place recharge for basin.
- Streams & canals = mountain block = in-place recharge
- Baseflow from VF aquifer shown here
- Total water budget is roughly half the volume compared to 1985 water budget

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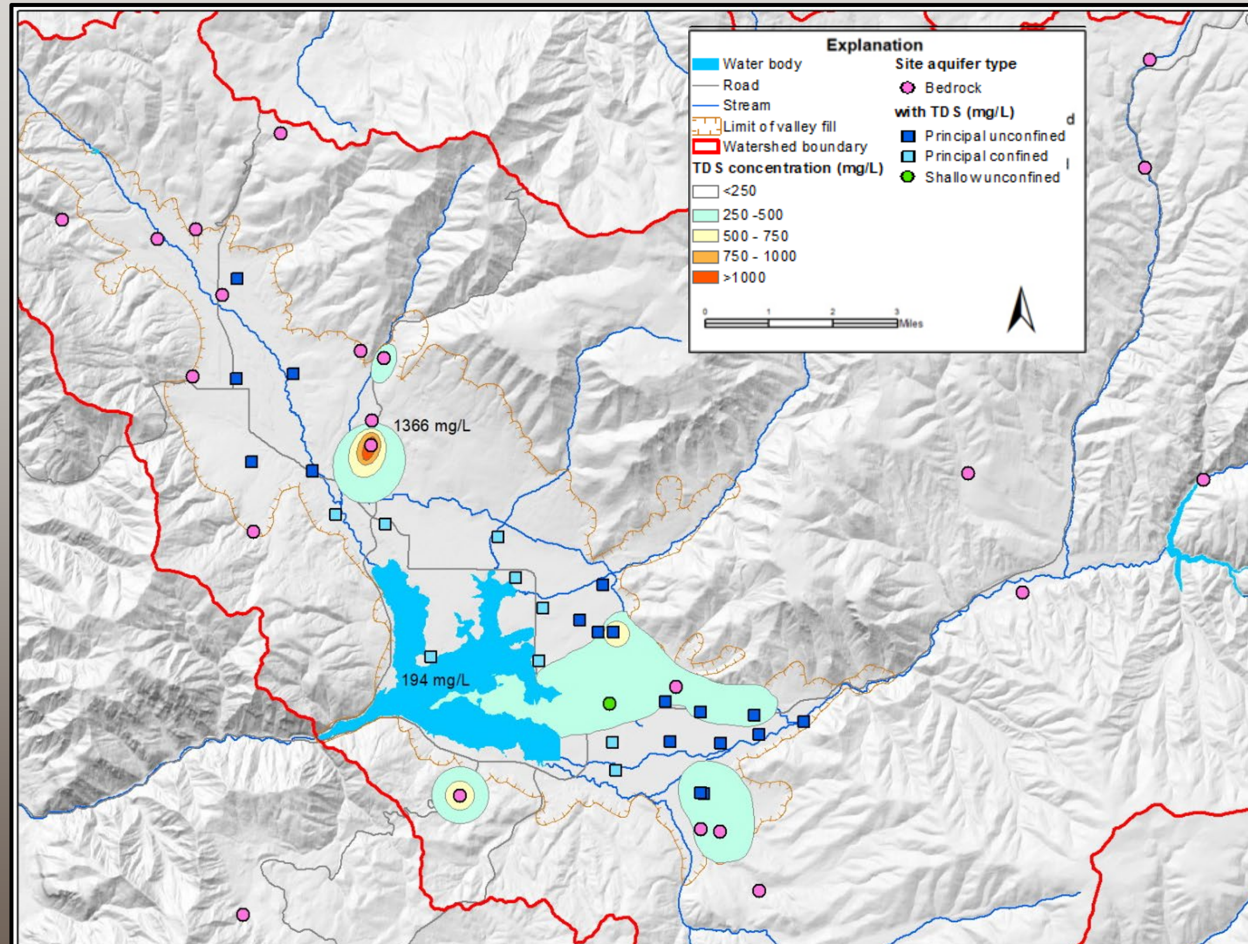
Water Quality and Septic-Tank Density

Chemistry Sampling and Water Quality

Total samples:
- general chemistry (57)
- filtered metals (13)
- nutrients (43)
- radiometric and diss. gases (11)
- water isotopes (307)

- Good groundwater quality
- TDS: Max 1366; Min <10; Average 243 mg/L
- One well had arsenic near drinking water standard



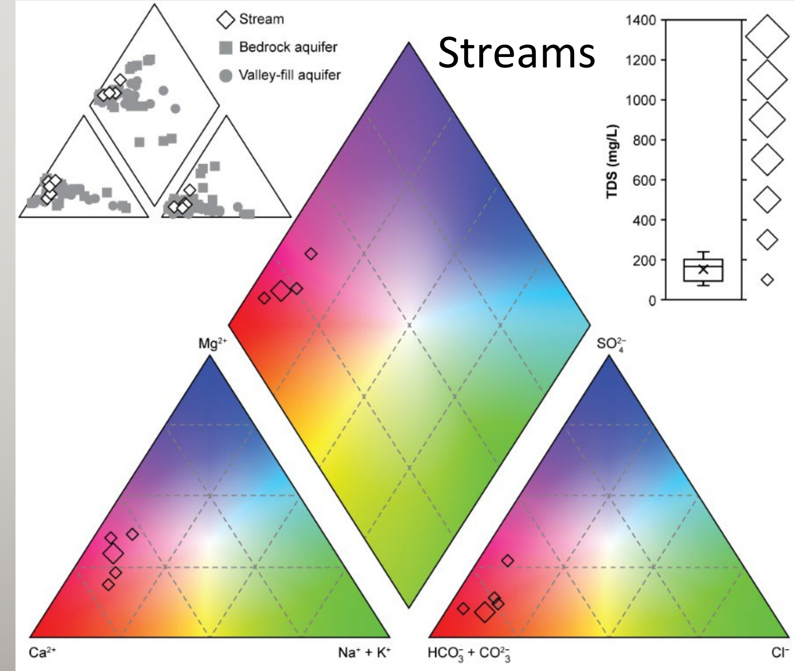
Map of Total Dissolved Solids – a measure of general water quality

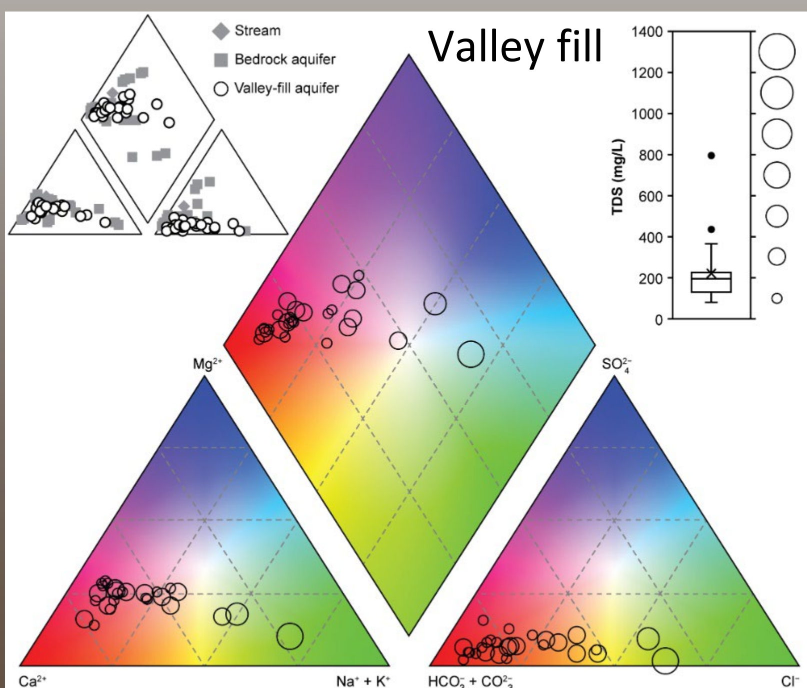
General Chemistry

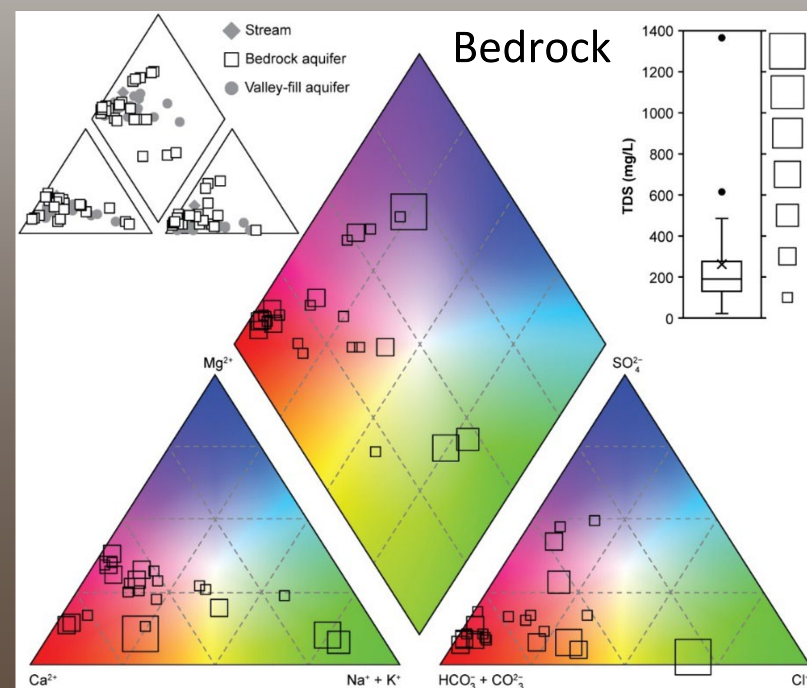
More dilute → More concentrated

Homogeneous → Variable

Streams → Valley fill → Bedrock

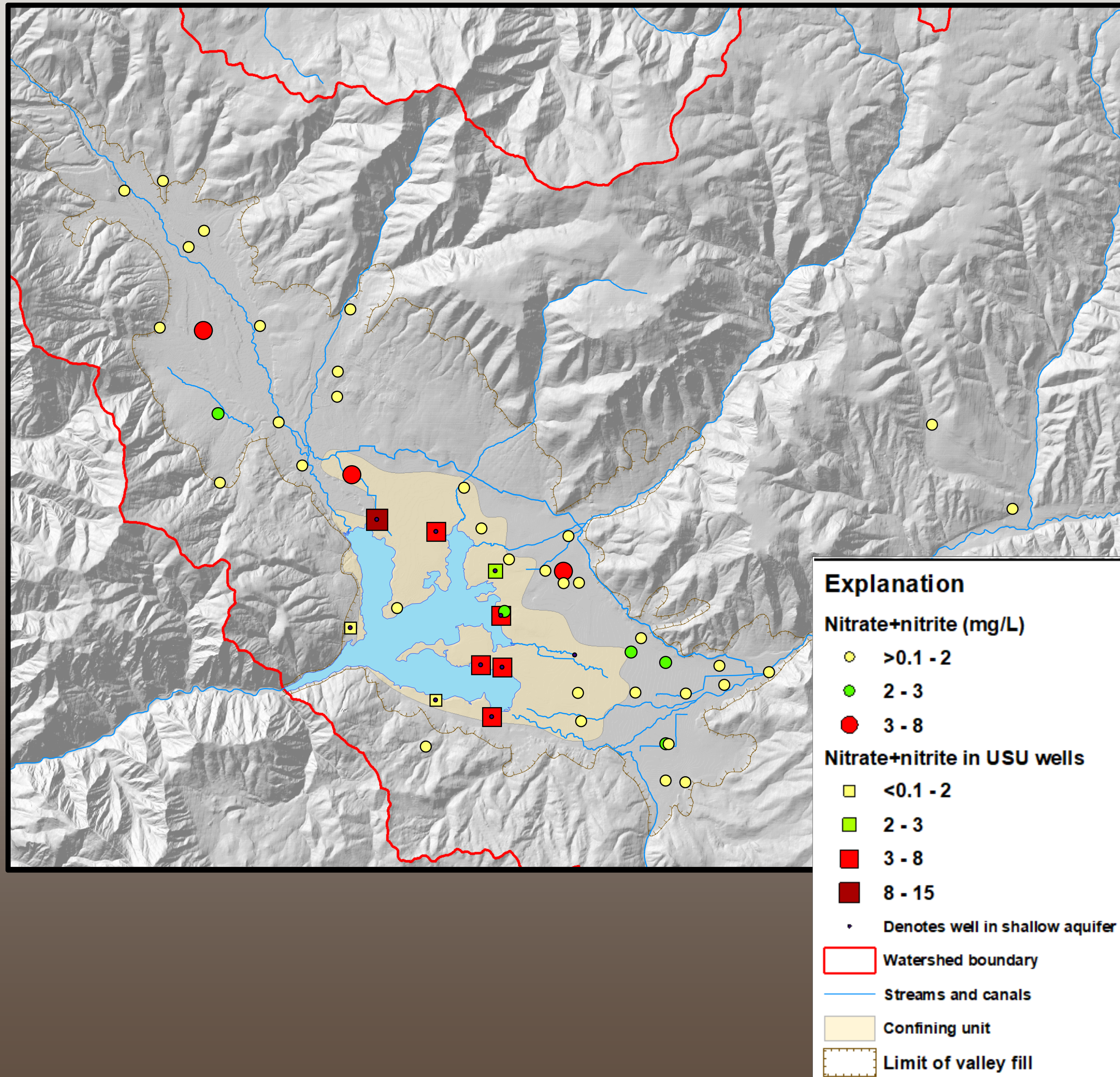






Nitrate

- Nitrate concentration in UGS samples: Max 7.7; Min <0.1
- USU samples in shallow aquifer: Max 47 mg/L
- 8 of 42 wells > 2 mg/L plus 7 of 9 shallow wells
- Geometric mean 0.45 mg/L
- Geometric mean principal aquifer 0.81 mg/L
- Geometric mean shallow unconfined aquifer 3.0 mg/L
- Geometric mean all valley-fill wells 1.1 mg/L.
- **Geometric mean unconfined aquifers 1.43 mg/L**
- **Nitrate in principal aquifer statistically higher in 2016 (0.81 mg/L) than 1998+1985 (0.42mg/L).**

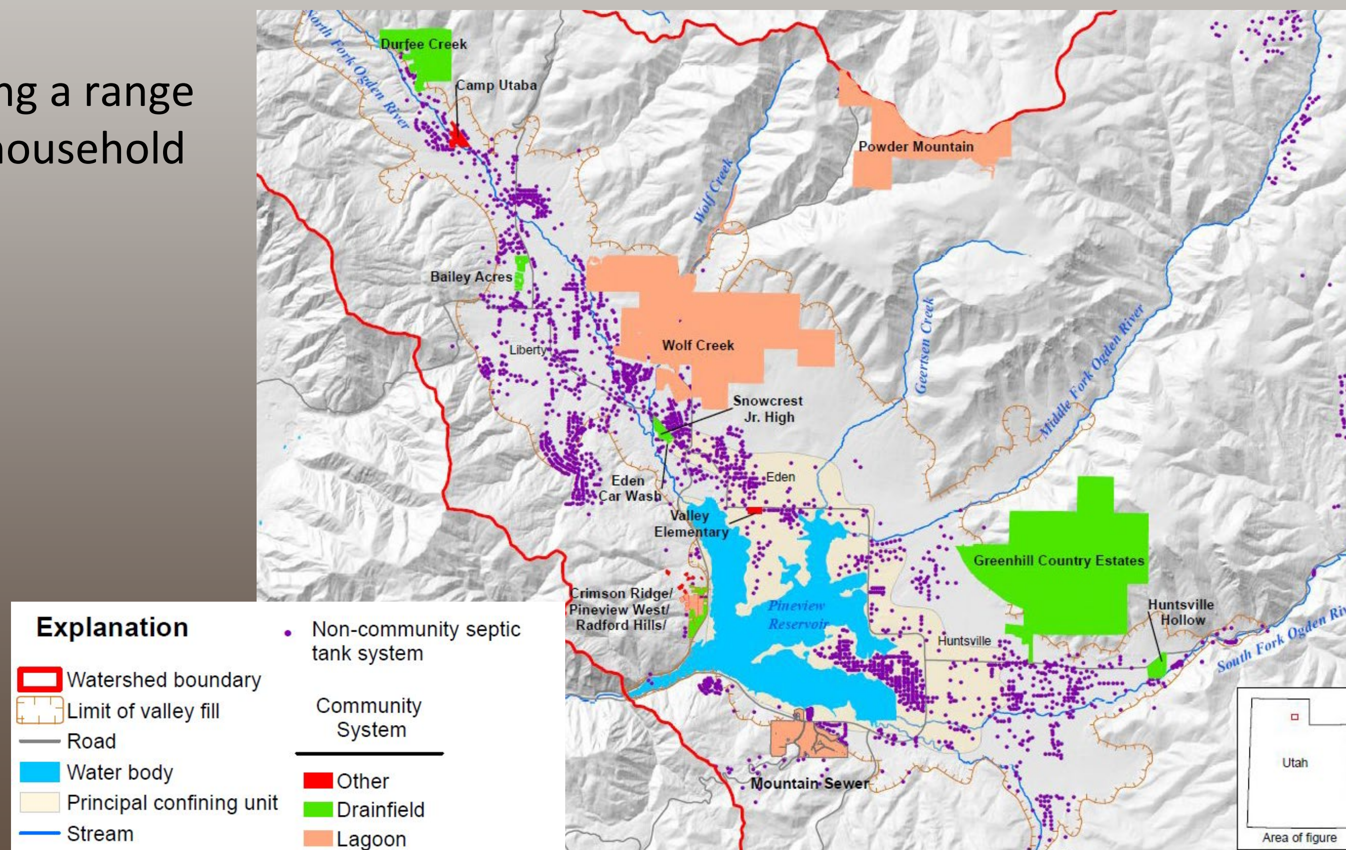


How is Water Quality Affected If More Septic Tank Wastewater Systems are Installed?

- Mass balance approach:

$$\frac{\textbf{N mass from new septic tanks + ambient N mass}}{\textbf{wastewater volume + groundwater flux}}$$

- Spreadsheet model
- Ran 3 scenarios using a range of # of people per household (1.7, 2.4, & 3.0)



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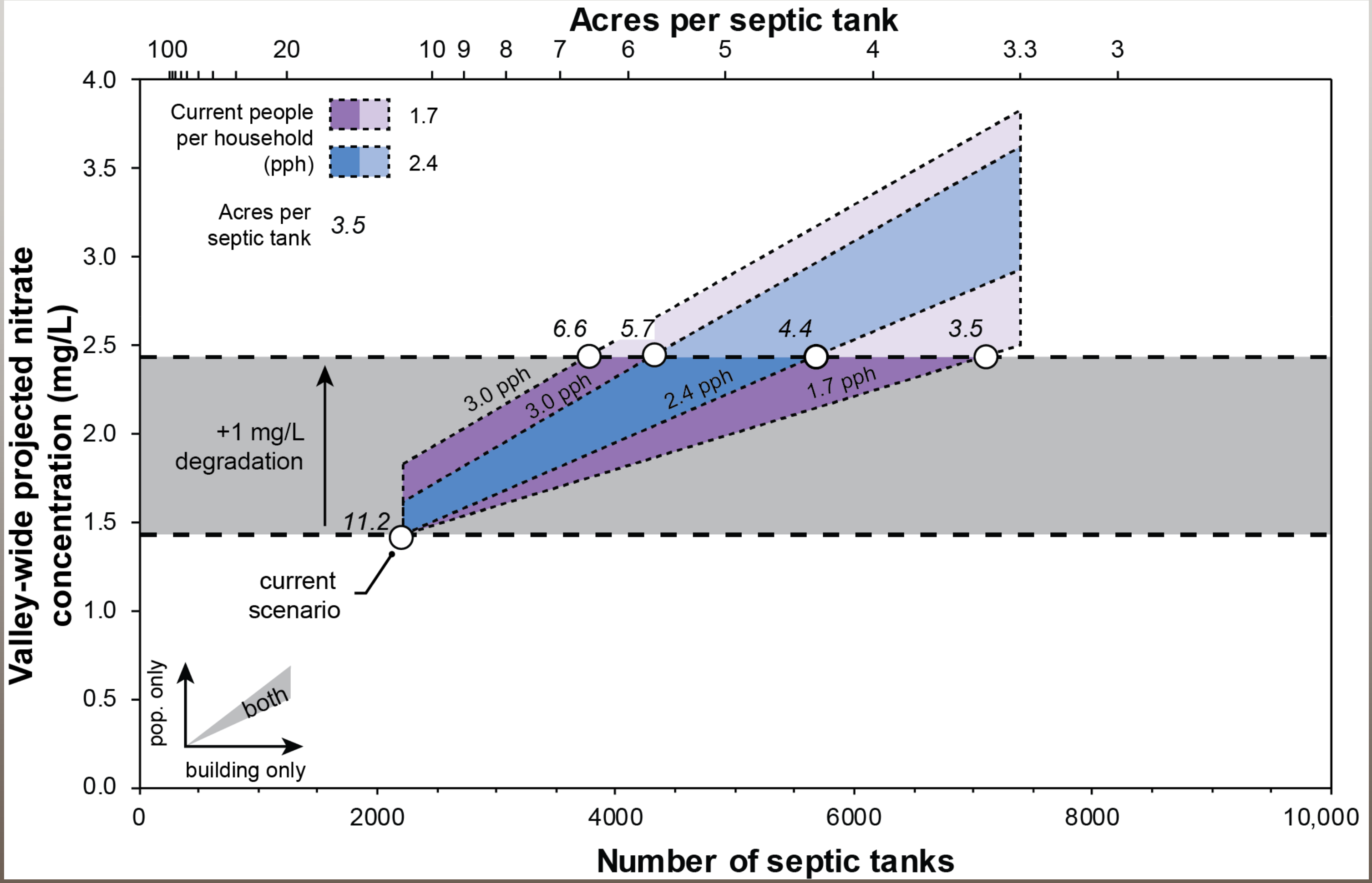
Predicted Septic Tank Impact in Future Growth Scenarios



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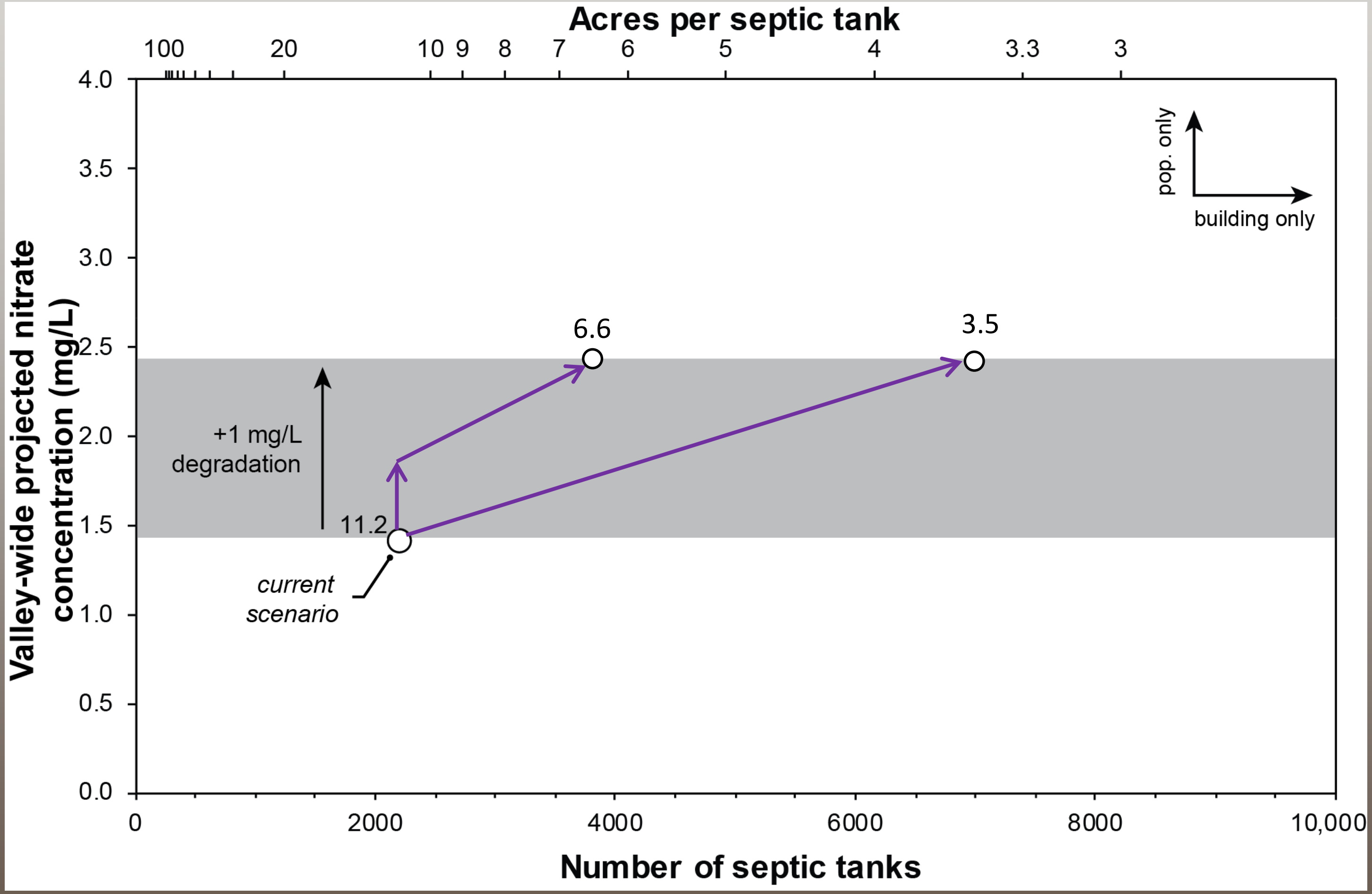
Scenario 1: Development continues at 1.7 pph, ignores seasonal use impact

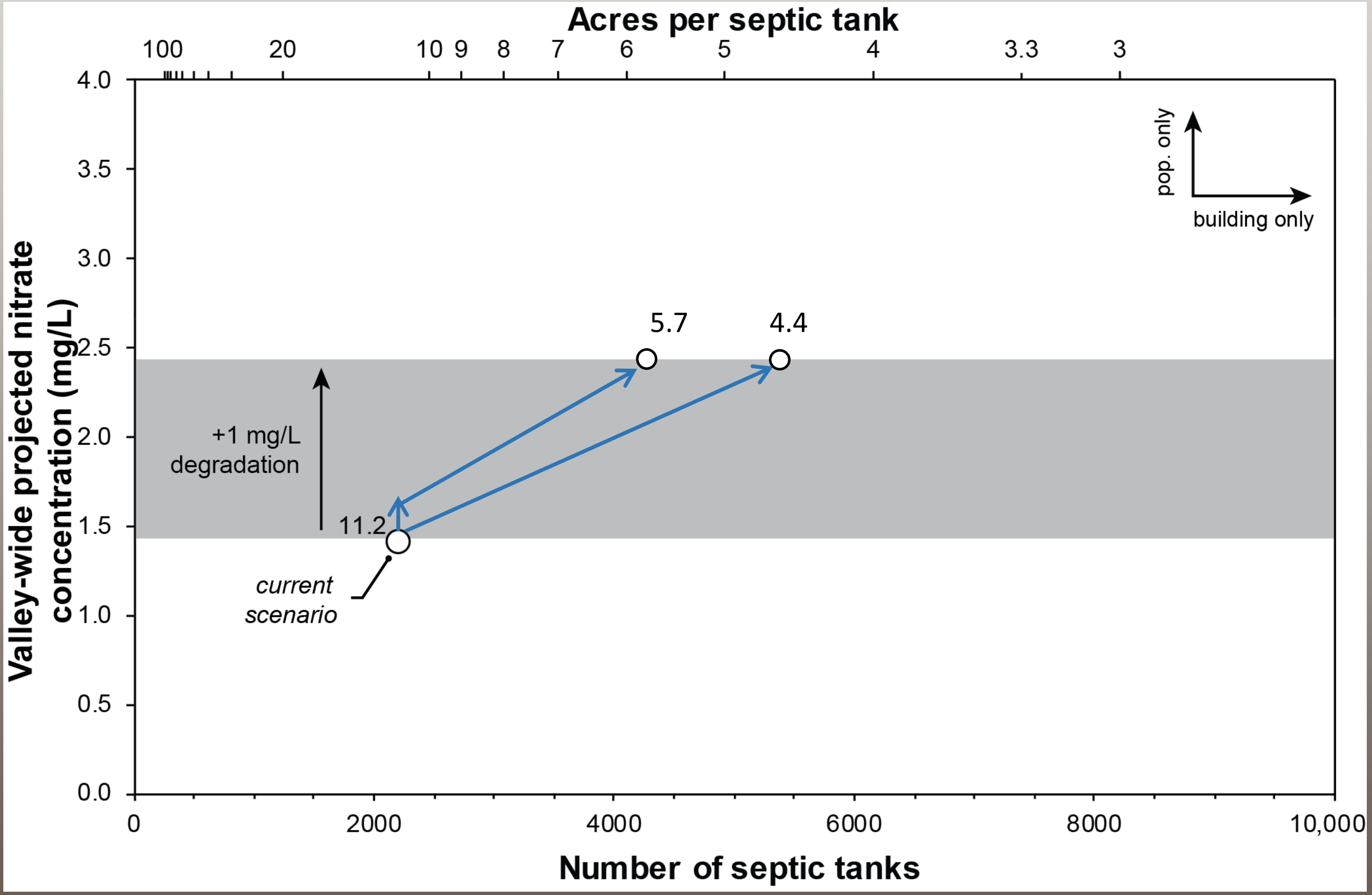
Scenario 1 alt: Fill up houses to 3.0 pph, then grow



Past population growth is not a predictor of future population growth.

Scenario 2: Development continues at 2.4 pph

Scenario 2 alt: Fill up houses to 3.0 pph, then grow



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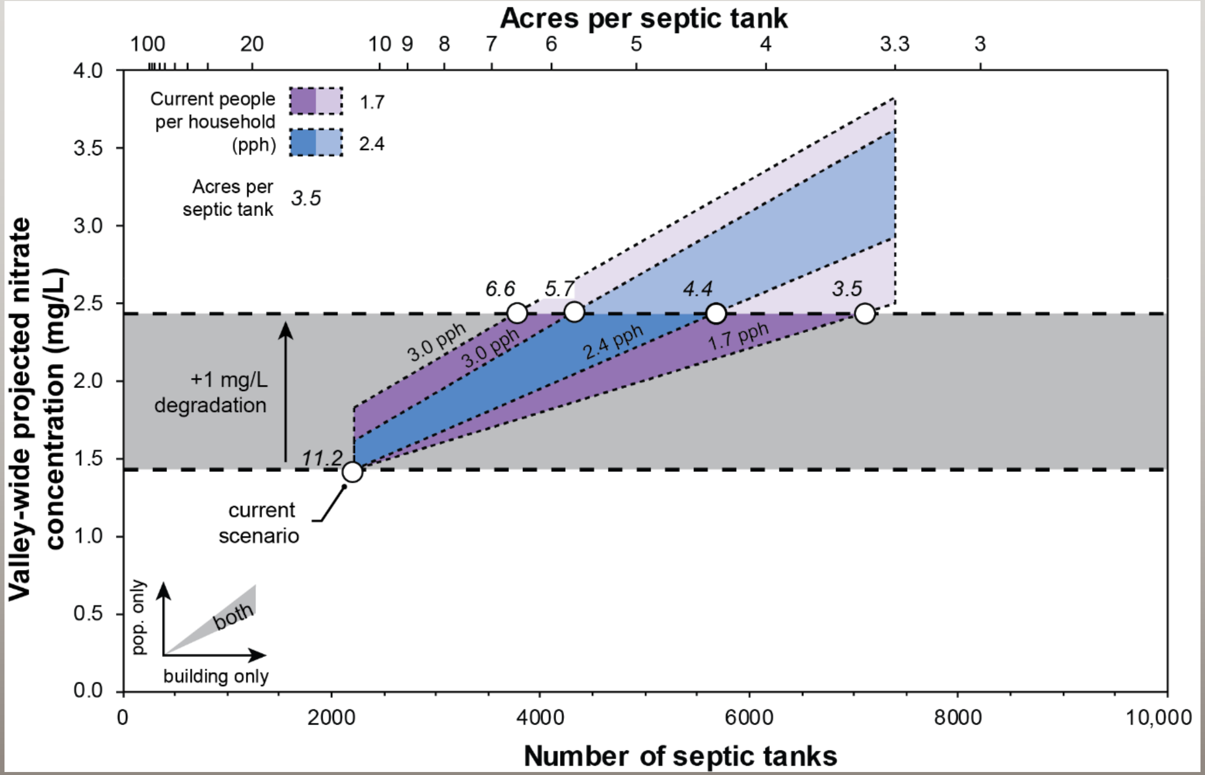

Using realistic current and future population density values, we recommend lot sizes ≥6 acres if using conventional septic tanks. Advanced septic systems or sewer are options to accommodate higher density housing.

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Major Conclusions

- **Groundwater system**
  - Position and thickness of the principal confining unit is important to groundwater flow and water quality.
  - Surface water and groundwater are highly connected. Streams can change from gaining to losing throughout the year. Canals are leaky and recharge the aquifer.
  - Long-term water levels indicate most of the system is NOT in an overdraft state.
  - Half of the water in the valley-fill aquifer is from surface water. South Fork arm is surface water dominated; North Fork arm is bedrock water dominated.
- **Water Budget**
  - 2016 valley-fill aquifer ~67,000 acre-ft/yr water budget.
  - Roughly equal recharge from streams + canals = mountain block = in-place (precip) recharge.
  - Largest discharge component is Ogden River
- **Chemistry**
  - Generally good water quality. Nitrate is high in the shallow unconfined aquifer.
  - Continued development using conventional septic tanks will likely degrade water quality Recommend lot size ≥6 acres, use advanced system, or sewer.

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How might changes manifest?

Because groundwater & surface water are so interconnected, climate change or changes in water usage could have impacts.

1. Drying climate or more water use in the mountains may decrease mountain spring flow, baseflow to streams, and bedrock potentiometric surface. Effects may not be seen immediately. May eventually result in lower valley-fill aquifer water table.
2. Reducing canal leakage may lower valley-fill aquifer water table.

If valley-fill aquifer water table declines:

1. Reduced baseflow to valley streams,
2. Reduced valley-fill aquifer discharge to Pineview Reservoir, potentially creating stronger downward gradient at Ogden City well field,
3. More shallow groundwater from the principal unconfined aquifer (susceptible to surface contamination) would recharge the confined aquifer.
4. Shallow domestic wells may be more likely to exceed nitrate standard.

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GEOLOGICAL SURVEY

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Thanks to our funding partners:

Utah Division of Water Rights
Weber County
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Ogden City
Utah Division of Drinking Water

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