# On declining groundwater levels in the Bitterroot Valley

## Groundwater withdrawals? Or …

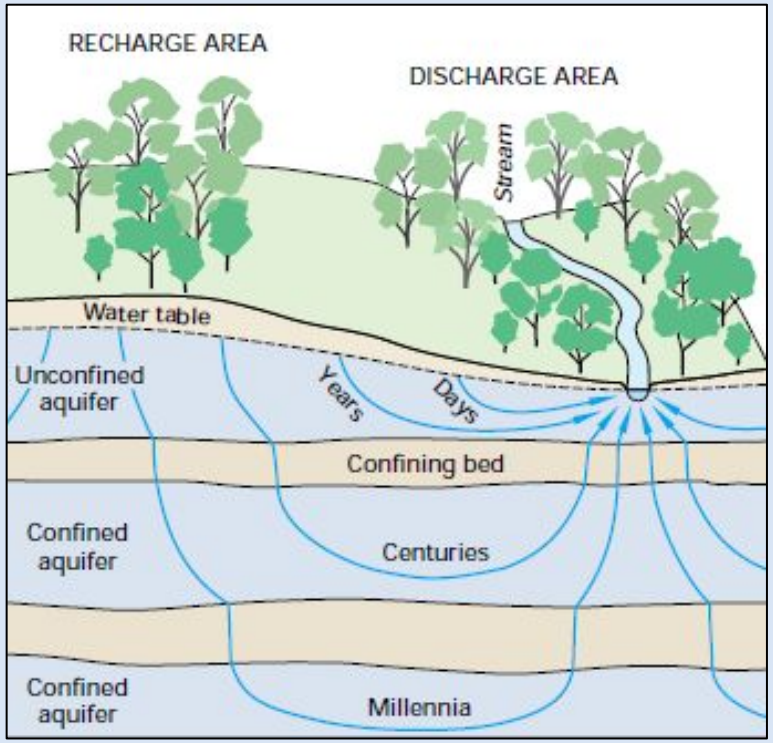
Buckley & John LaFave
AWRA
October 11, 2024

MBMG
Ground Water Assessment Program

# Hydrogeology - First Principles

Aquifer: A permeable geologic unit that can **Store** and **Transmit** groundwater.

Groundwater is moving… but slowly from areas of **Recharge** to areas of **Discharge**.

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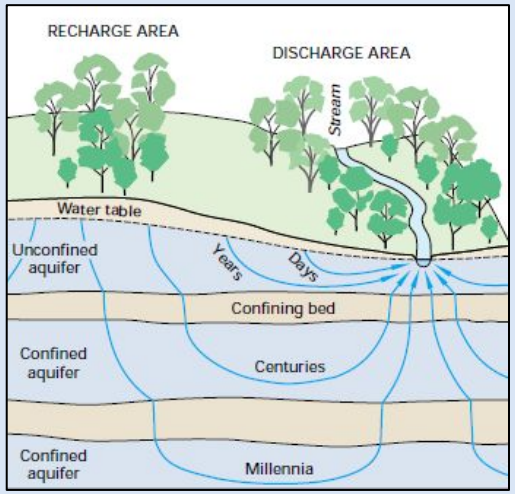


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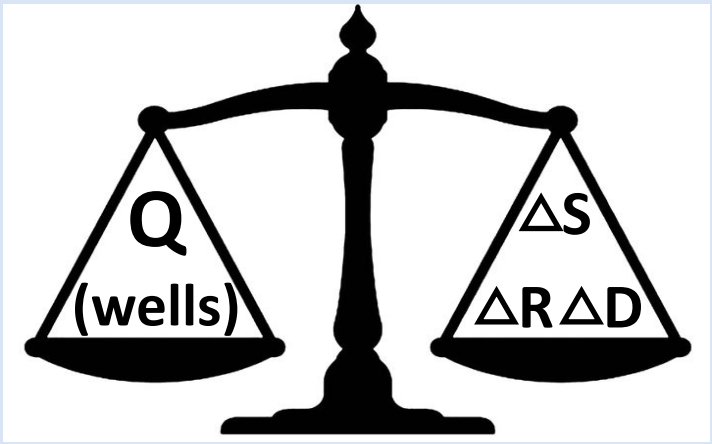


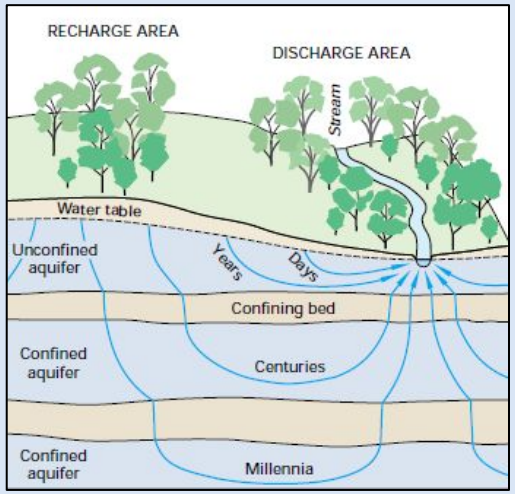


THE SOURCE OF WATER DERIVED FROM WELLS
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1940, Civil Engineering v.10, no. 5
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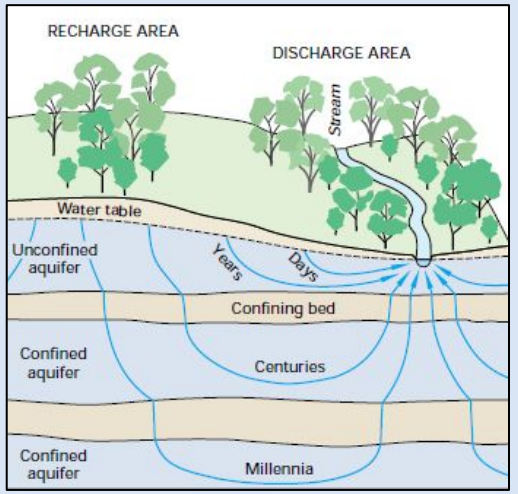


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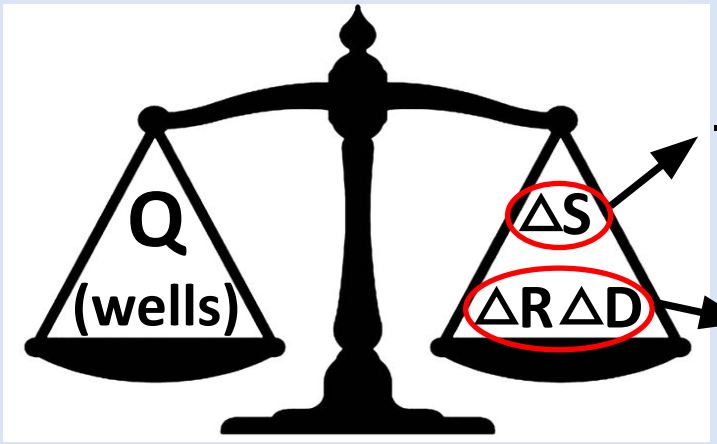
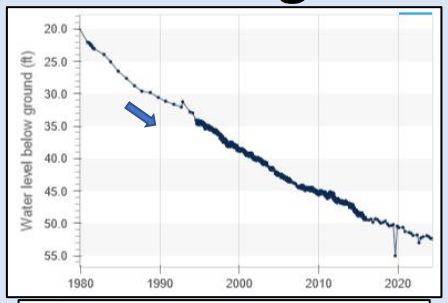



**Depletion**

Removing water from storage

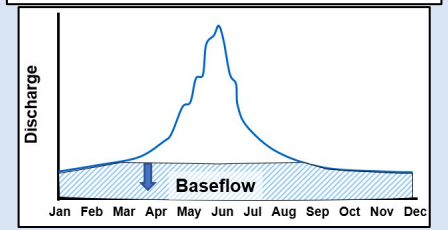
**GW Levels**

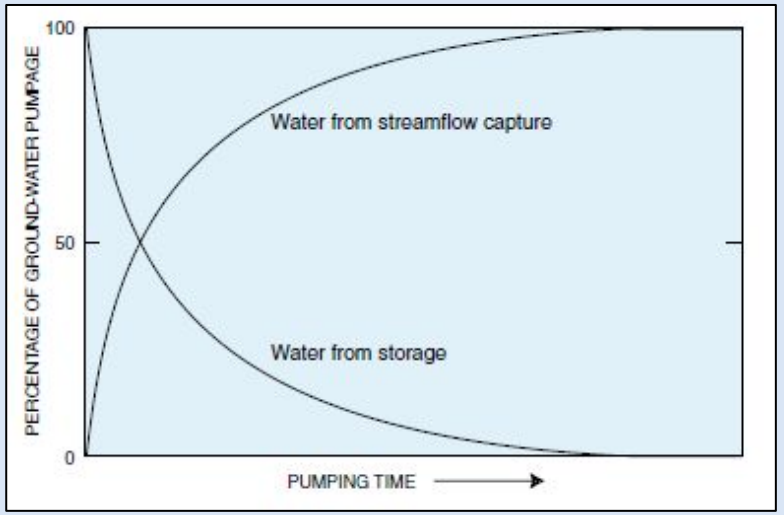



**Capture**

Intercepting streamflow

**Baseflow**

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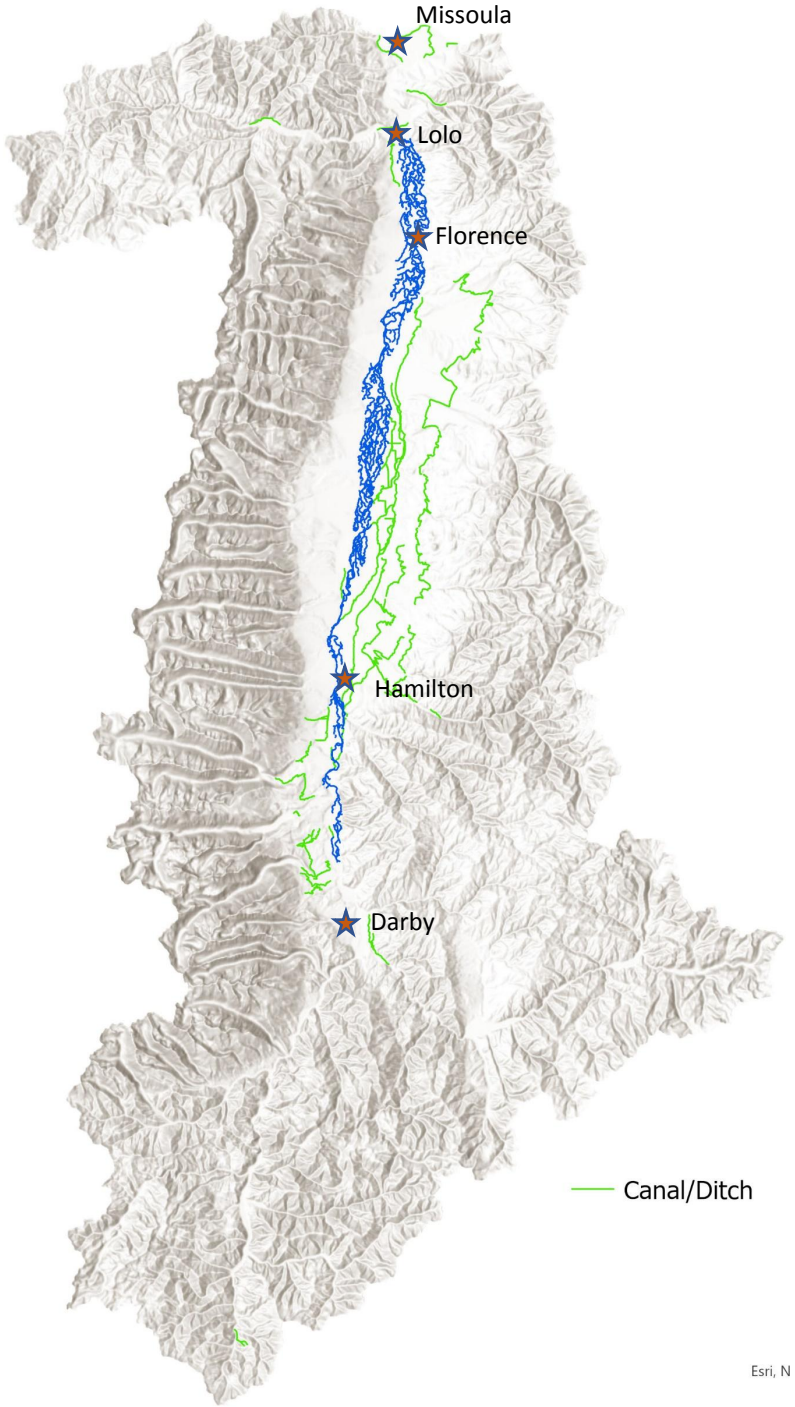
# Bitterroot Valley




termontane Basin – 1.8 million acres

amed by the Bitterroot and Sapphire Mtns

rained by north-flowing Bitterroot River

lley floor up to 6 miles wide

K irrigated acres, 382 MGD (USGS, 2015)

o to 75 inches precip. on Bitterroot Mtns.

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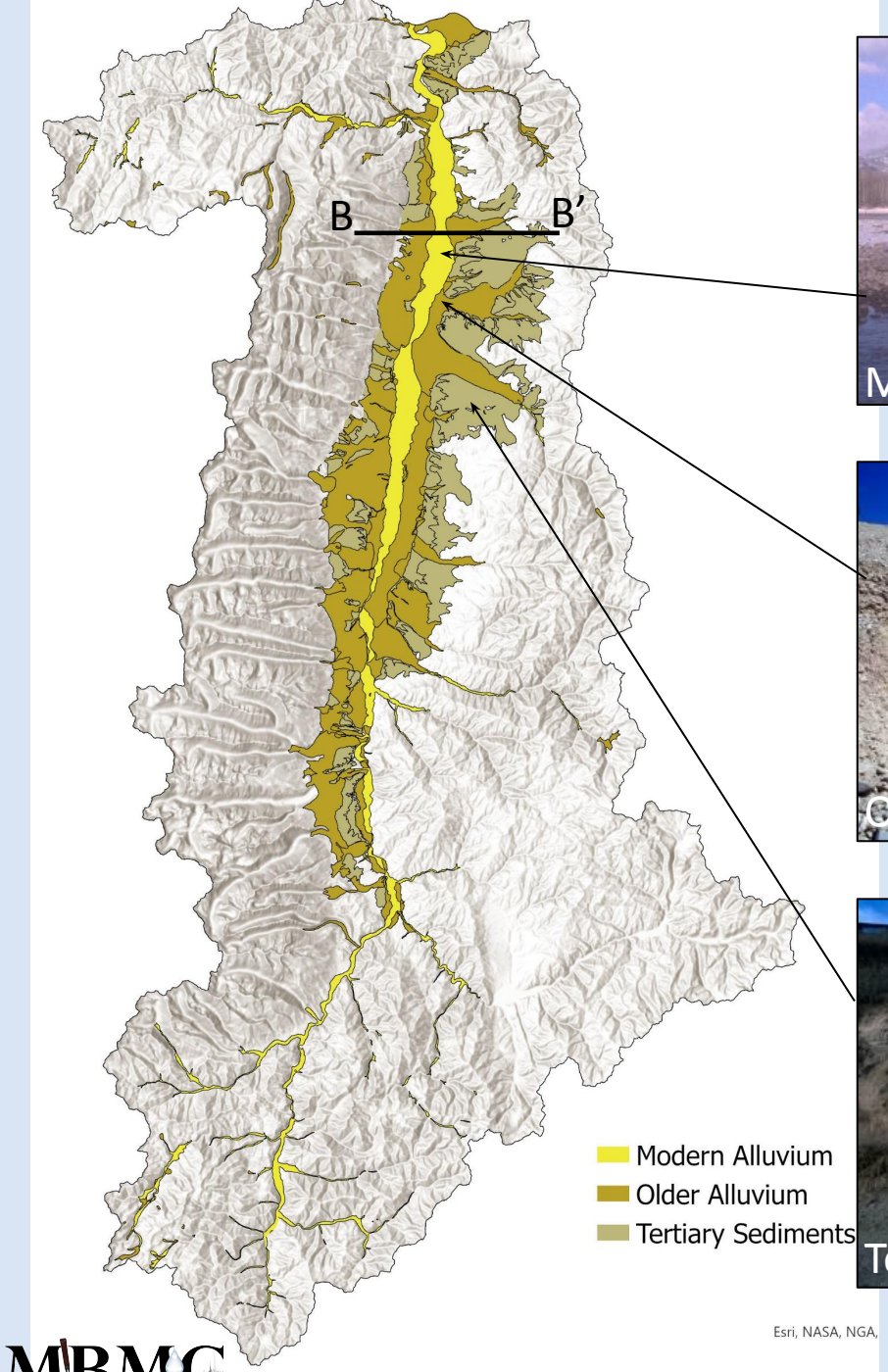
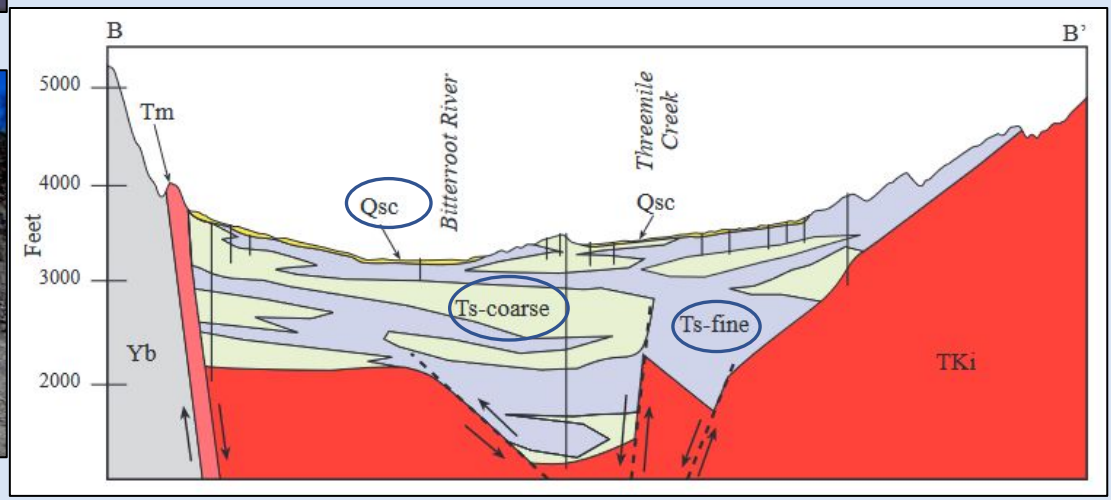
# Bitterroot Valley

## Hydrogeologic Setting







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# Bitterroot Valley

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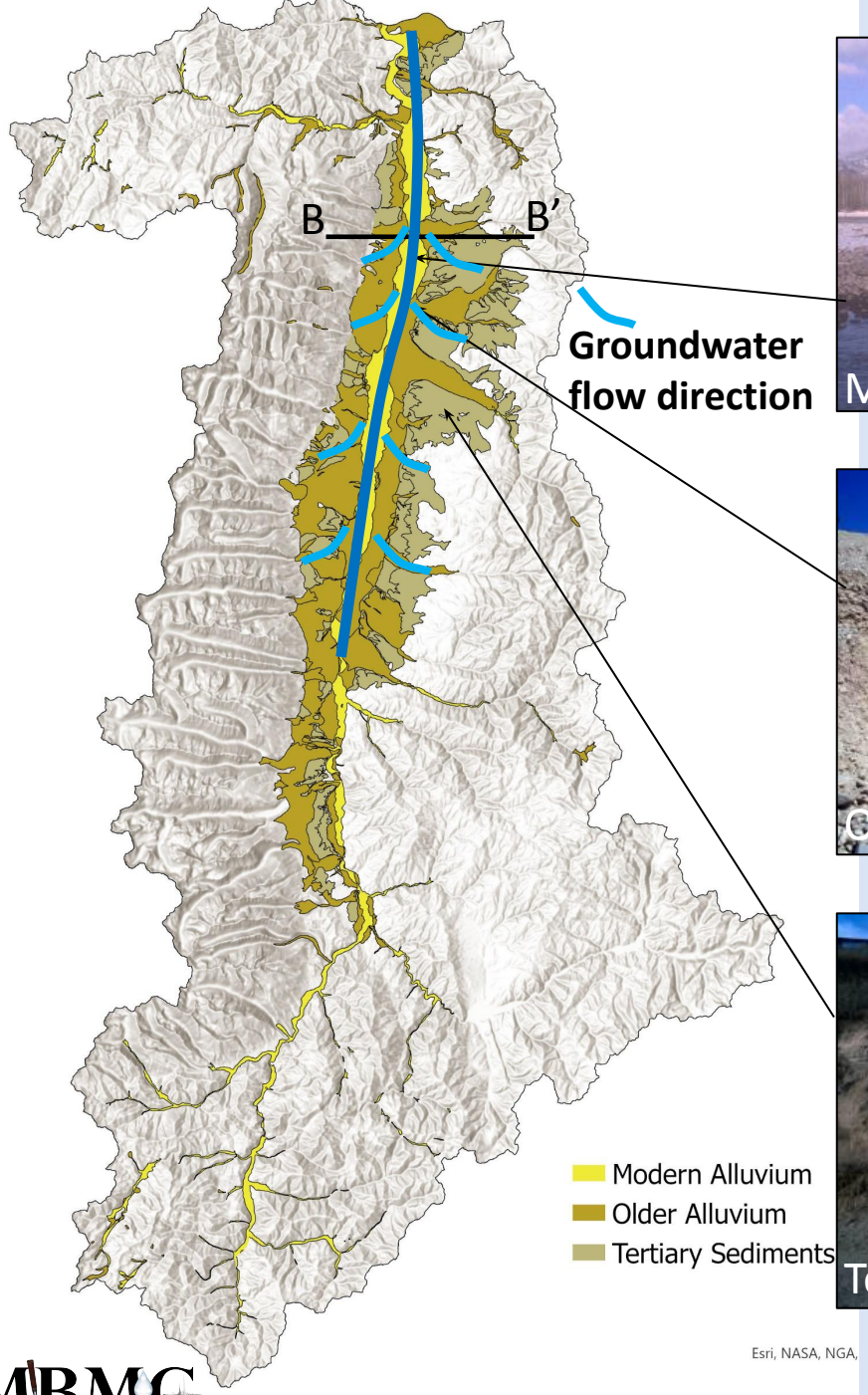
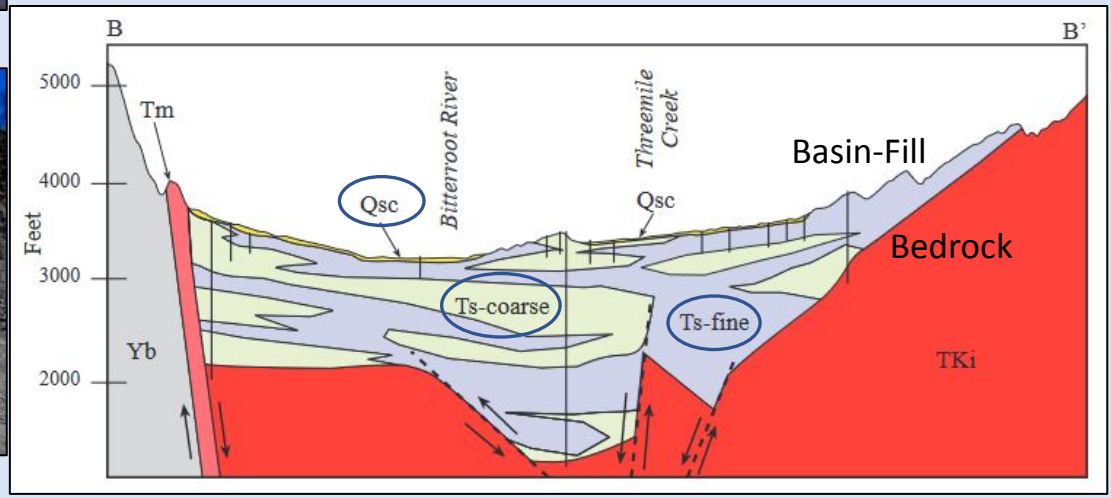






Cross Section: B – B'

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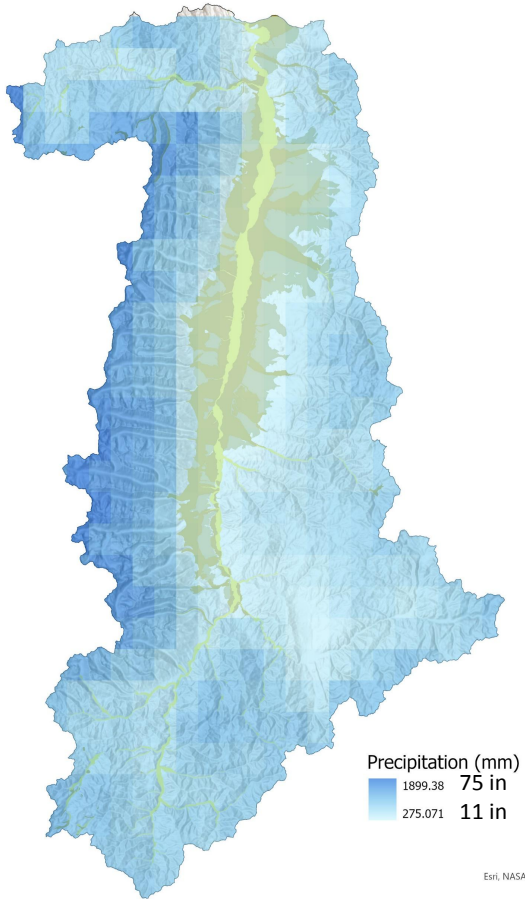
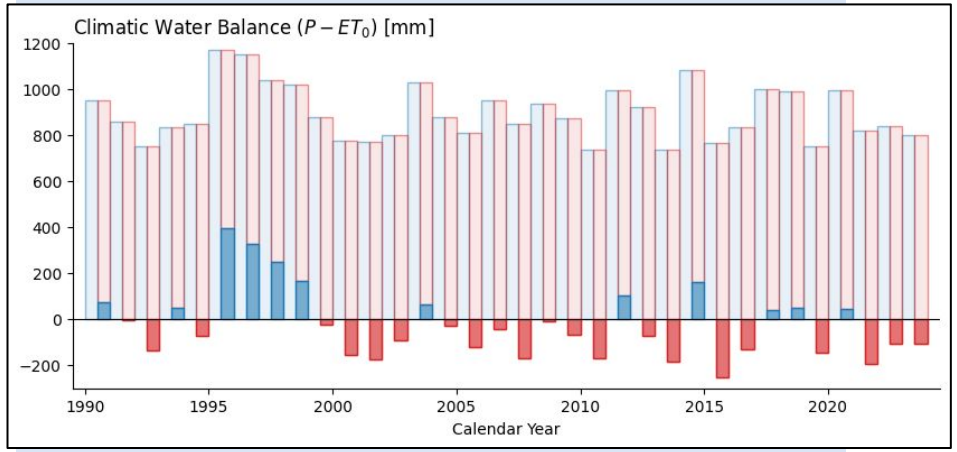
# Bitterroot Valley

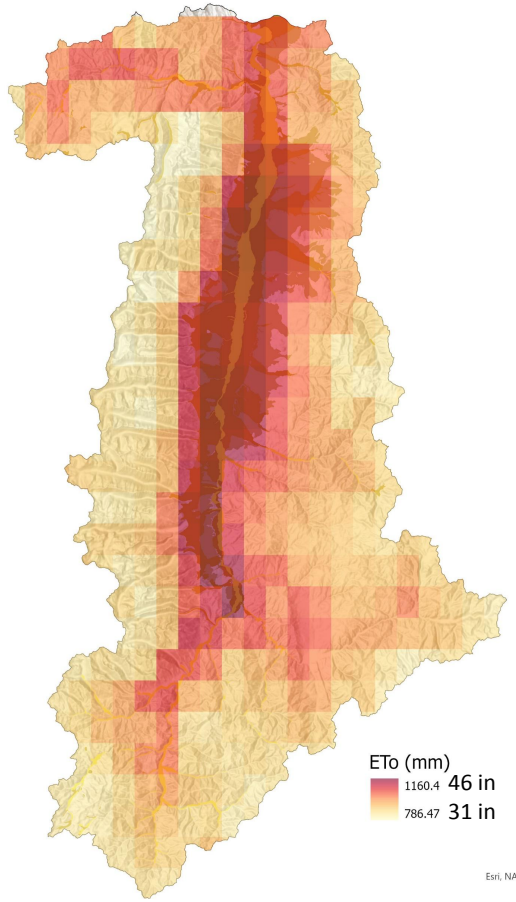
## Climatic Water Balance

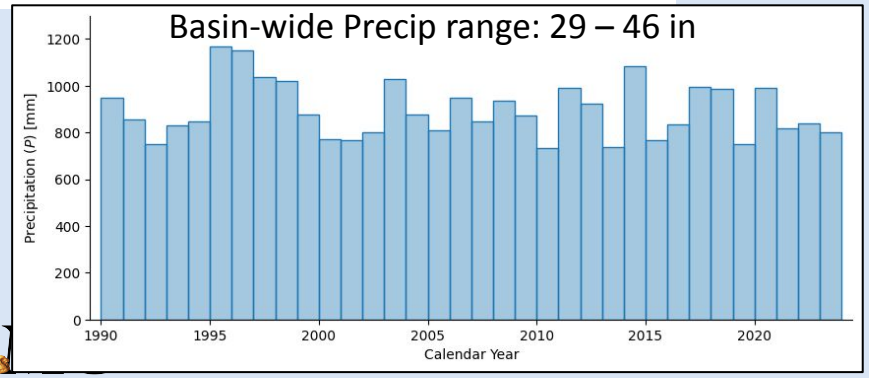
### Precip - IN

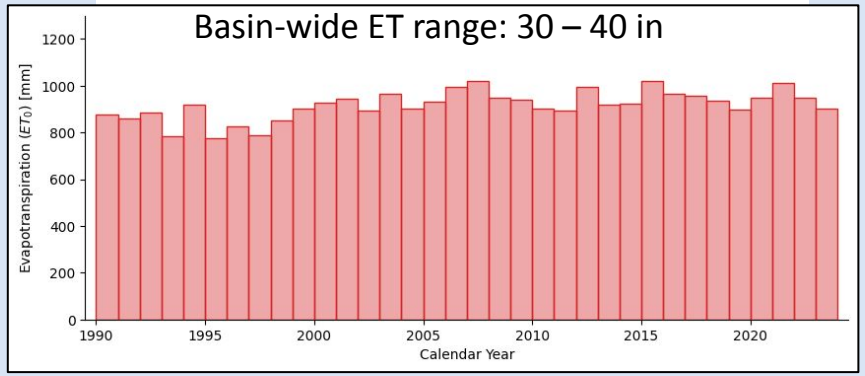



### ET - OUT

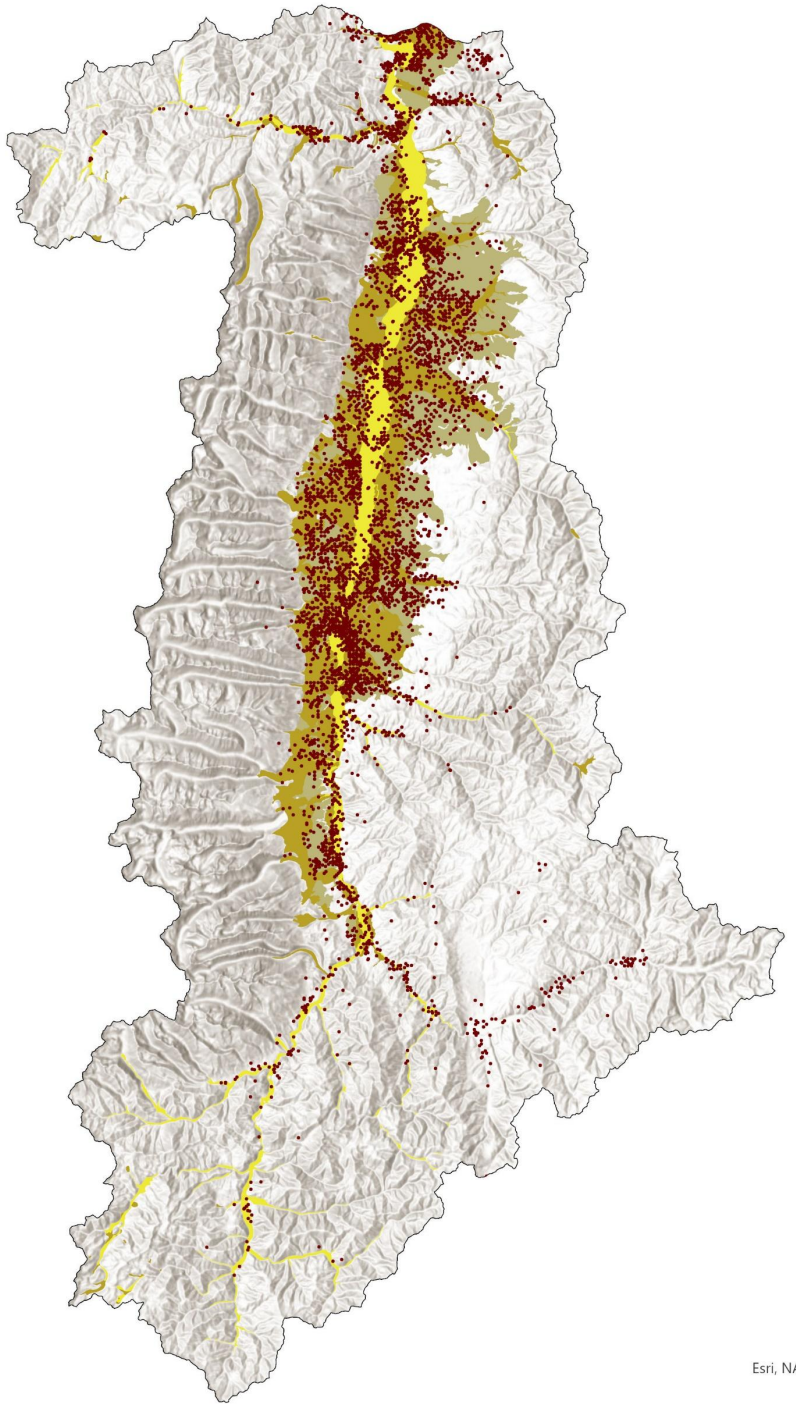


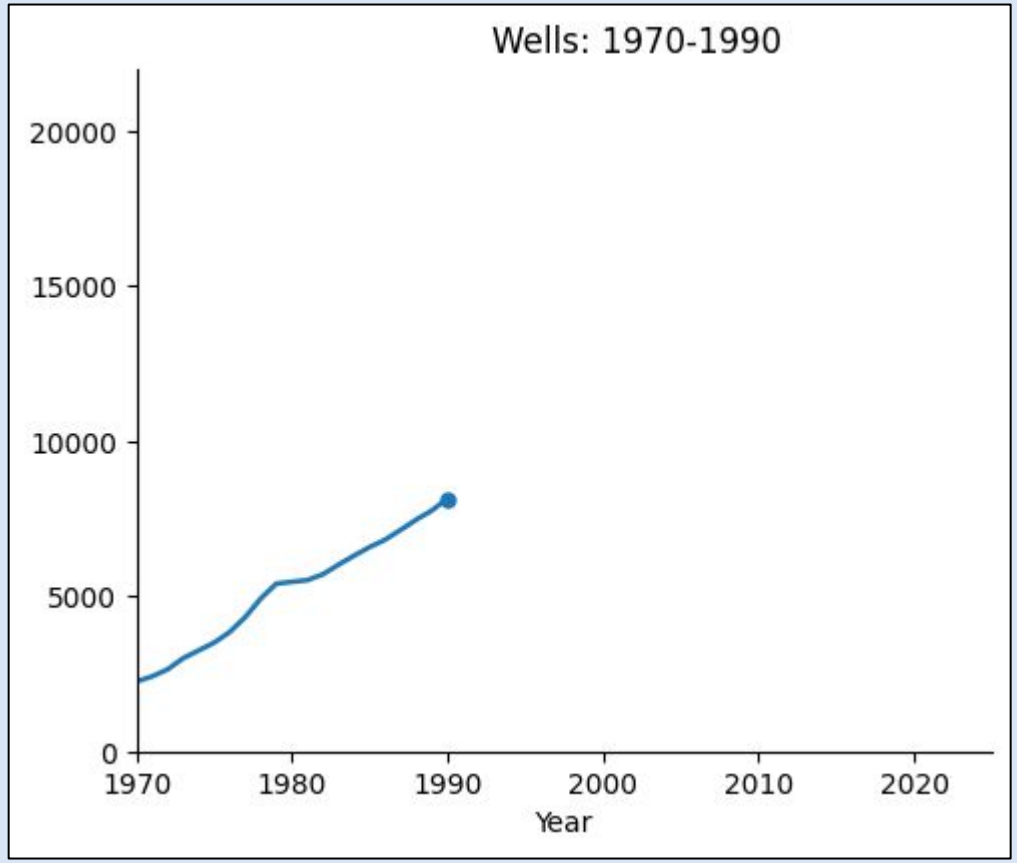



# Bitterroot Valley

## Groundwater Development

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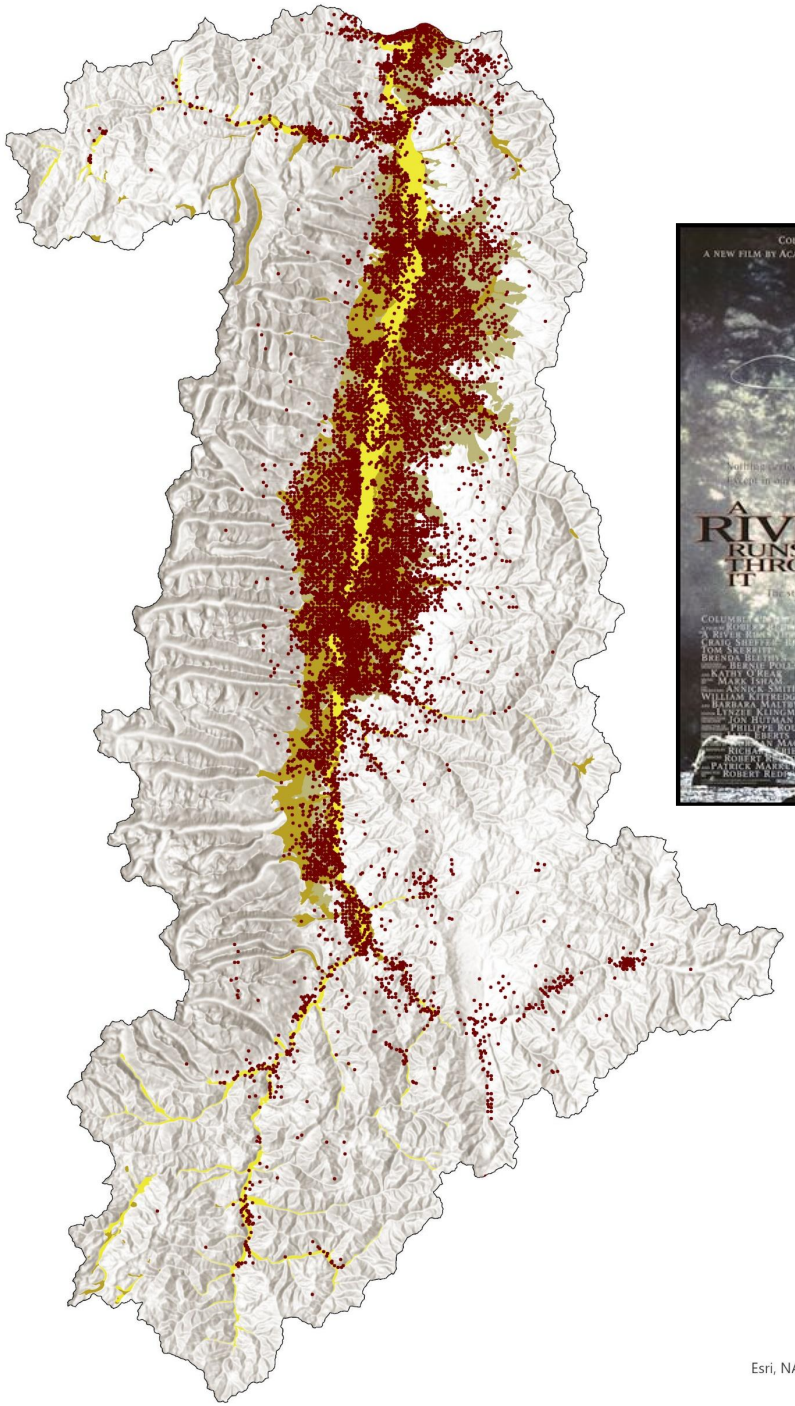
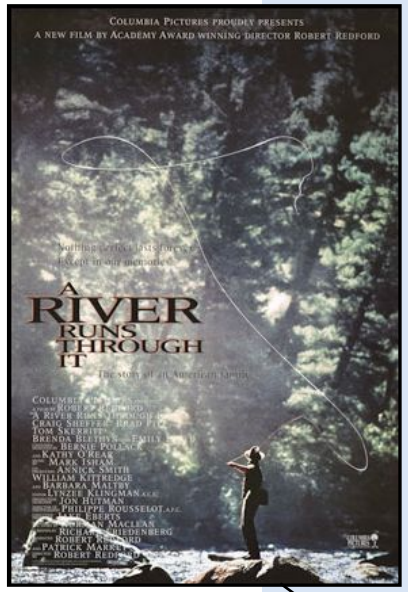
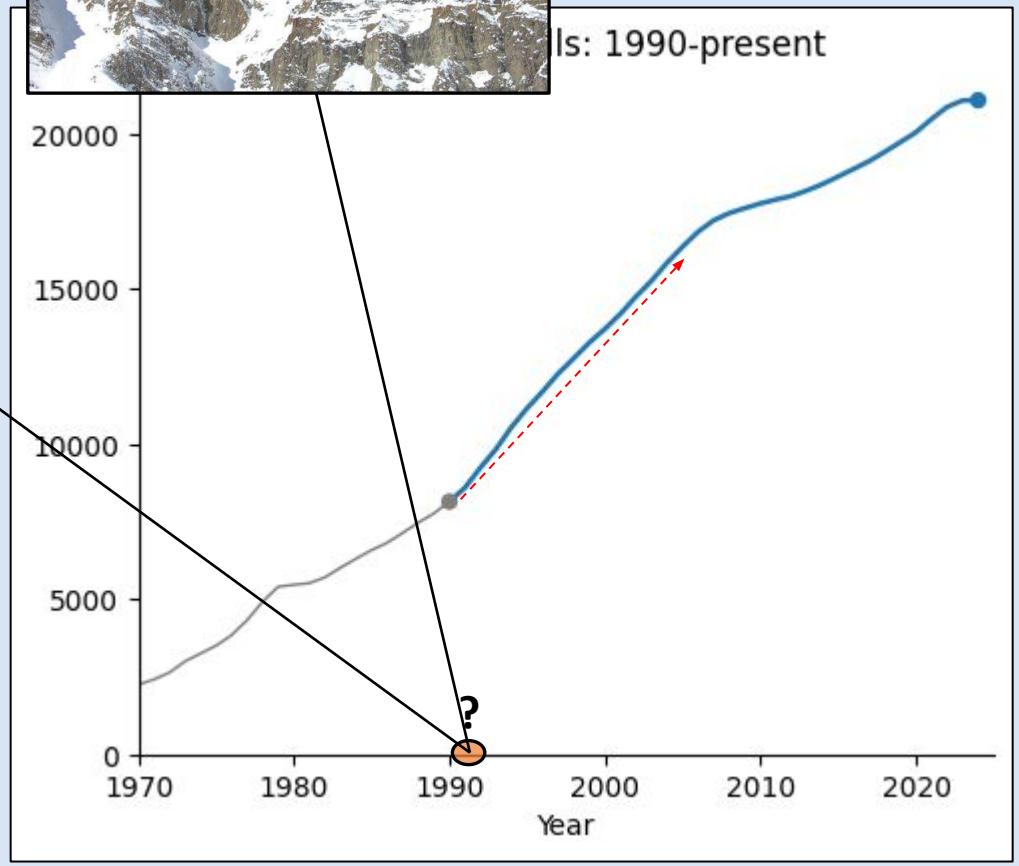
# Bitterroot Valley

## Groundwater

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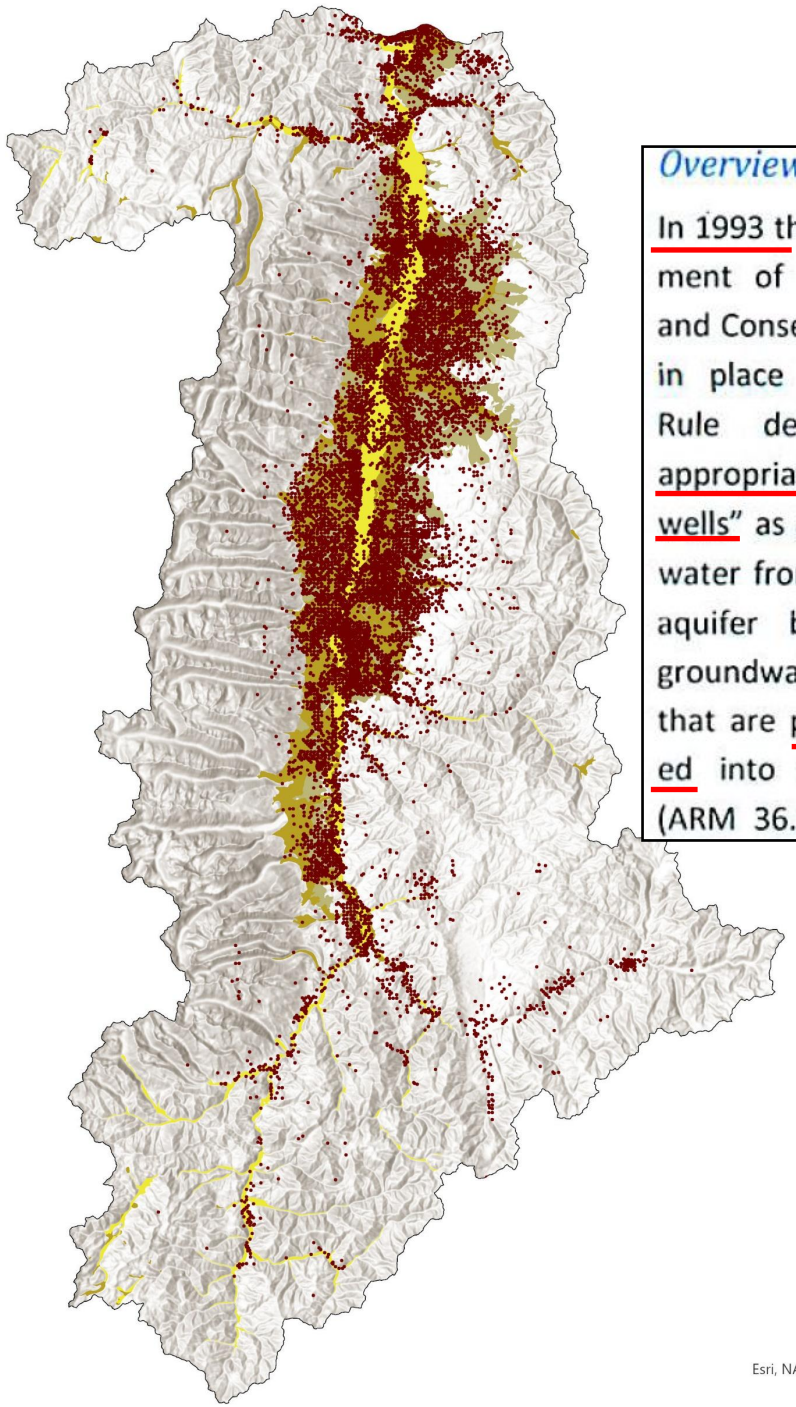
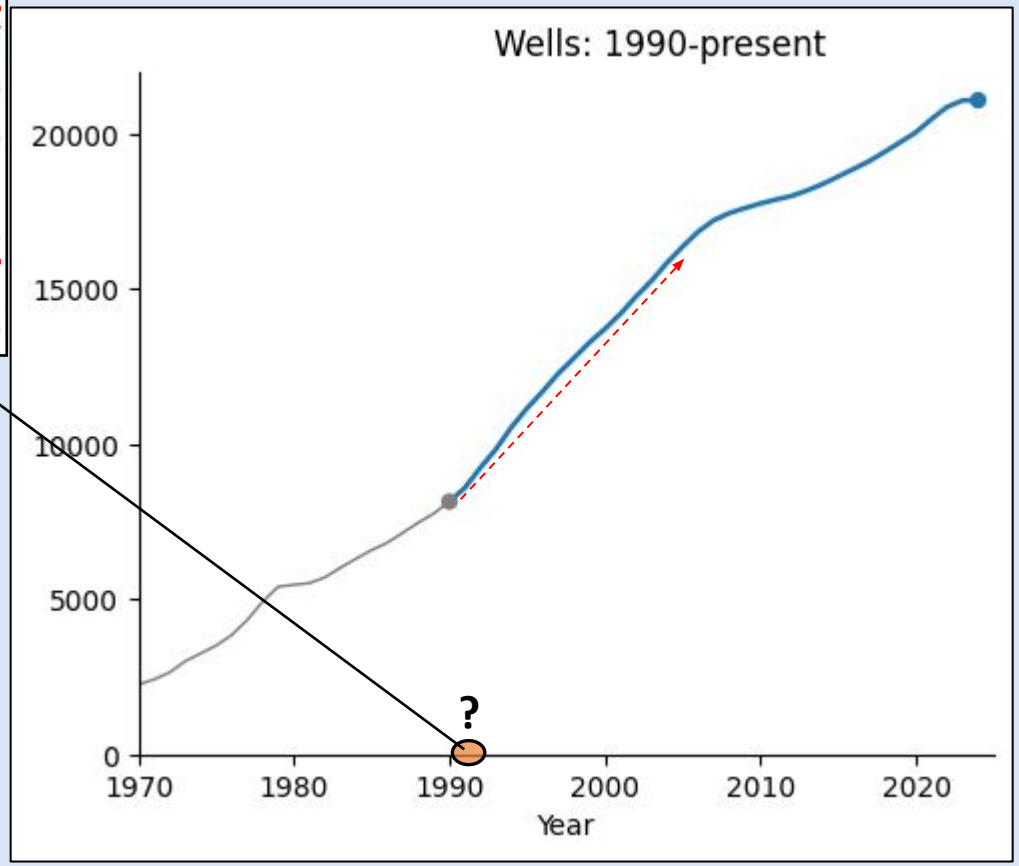



*Overview*

In 1993 the Montana Department of Natural Resources and Conservation (DNRC) put in place an Administrative Rule defining "combined appropriation of exempt wells" as an appropriation of water from the same source aquifer by two or more groundwater developments, that are physically manifolded into the same system (ARM 36.12.101(13)). Under

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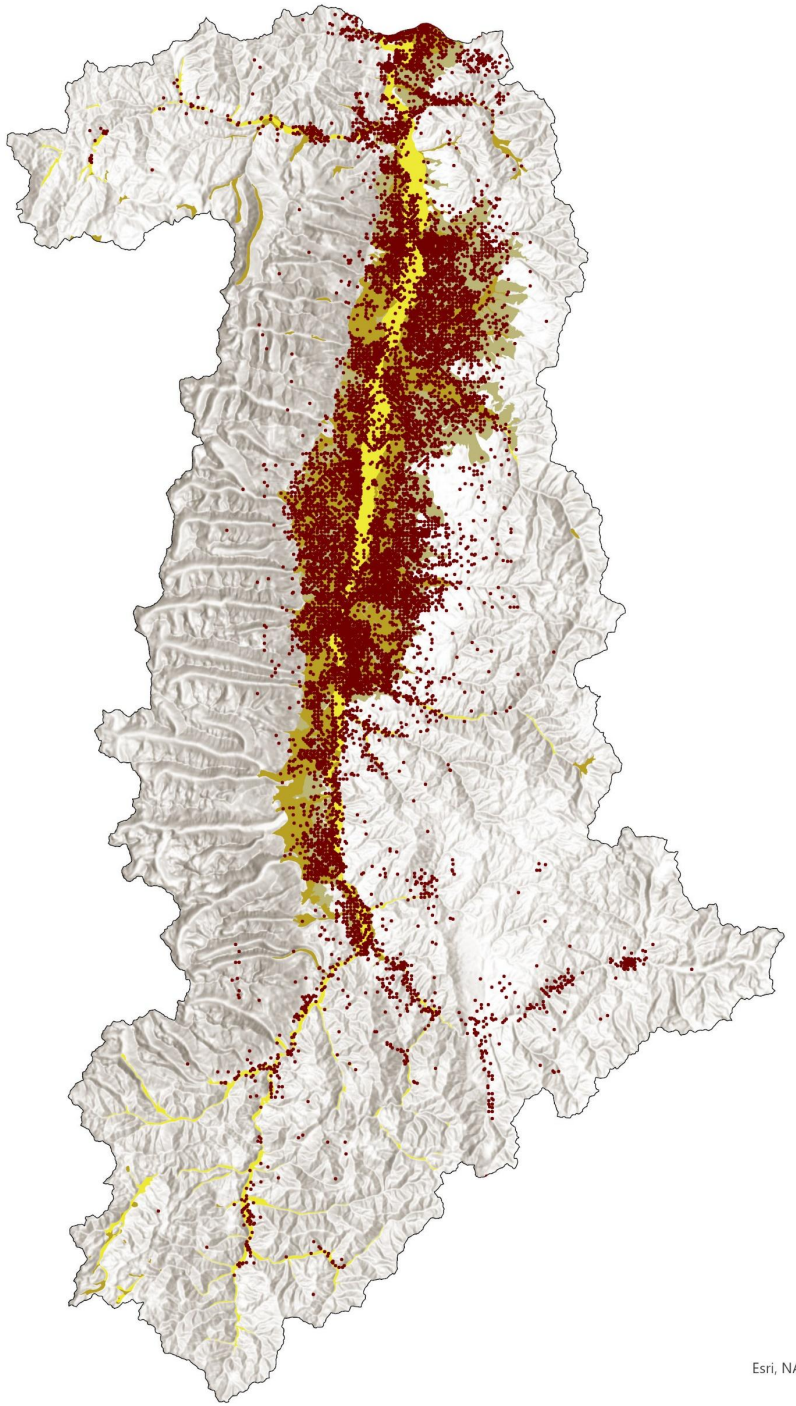


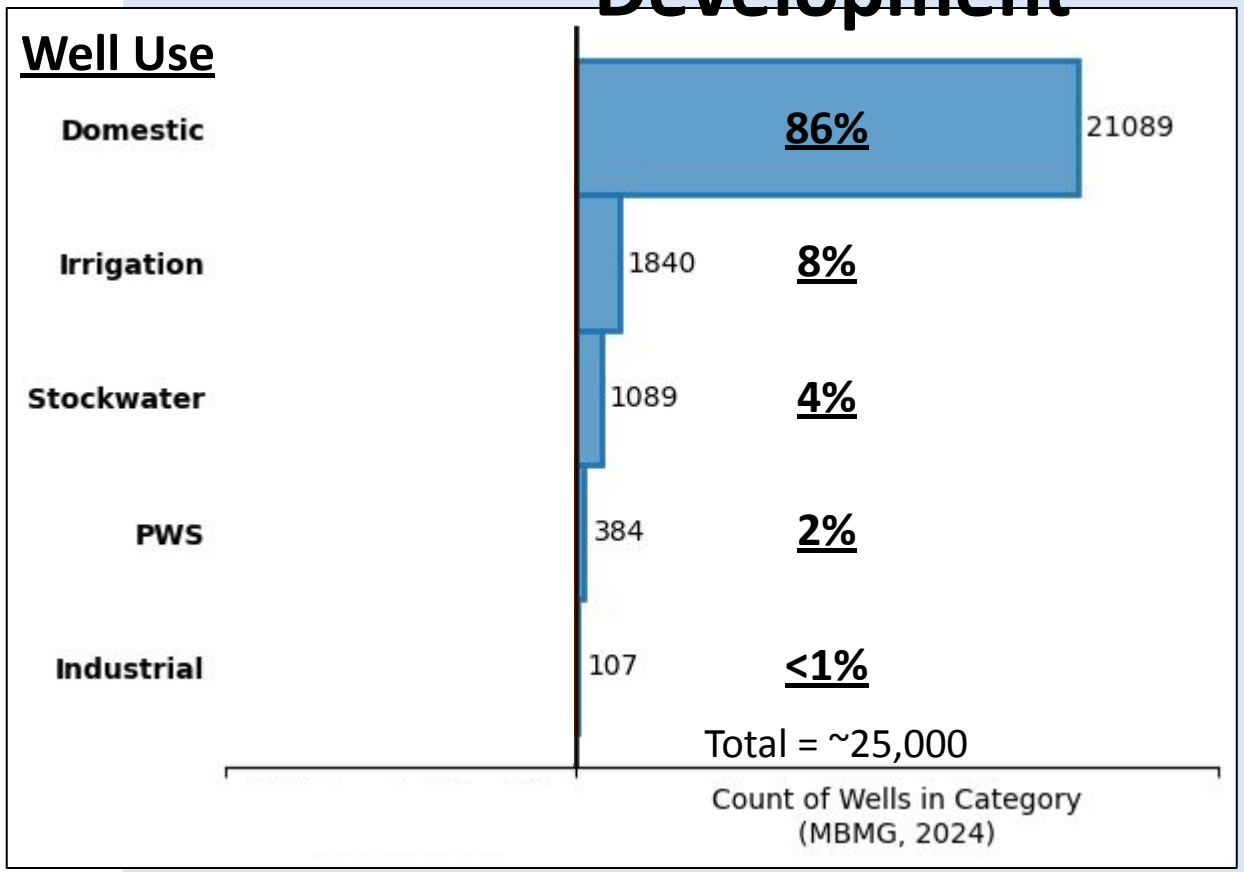


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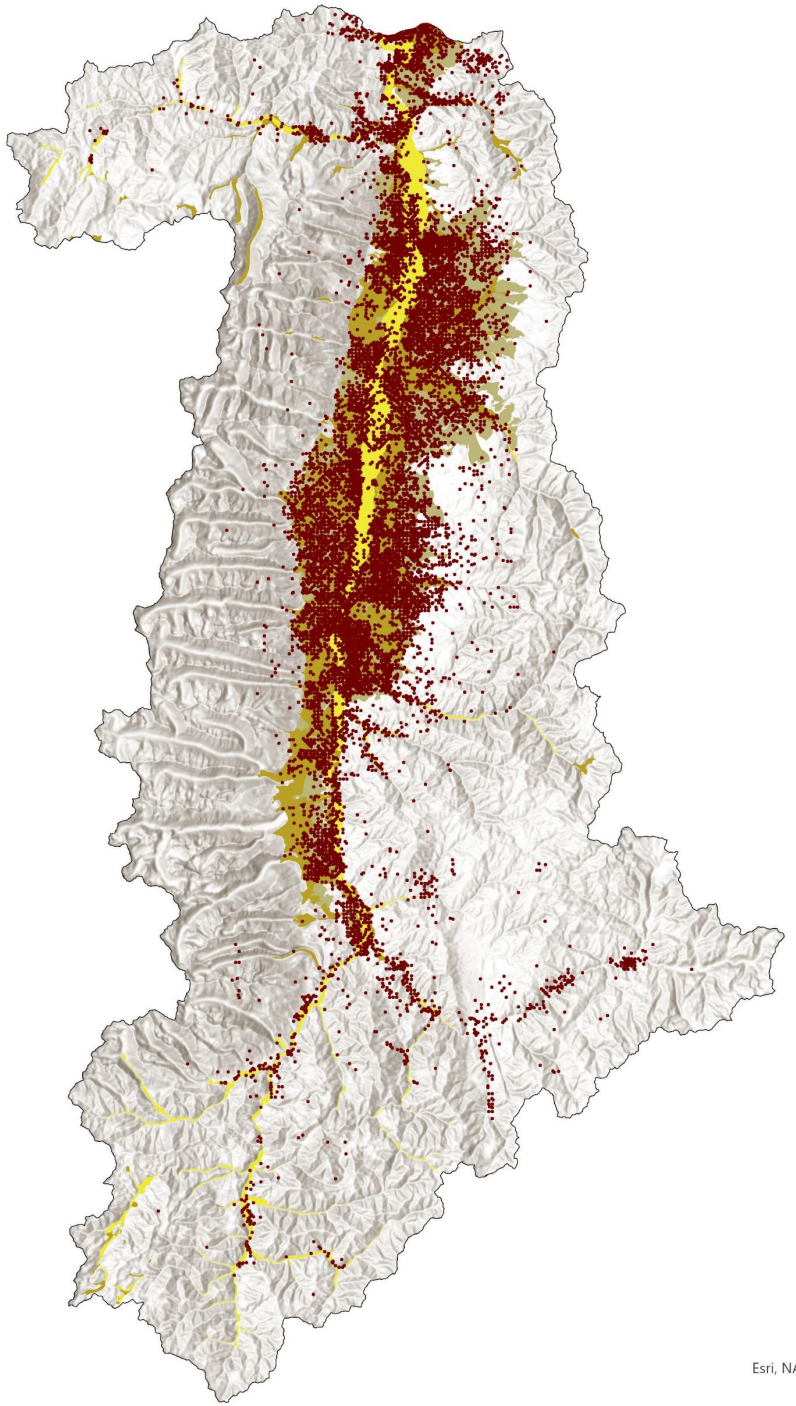


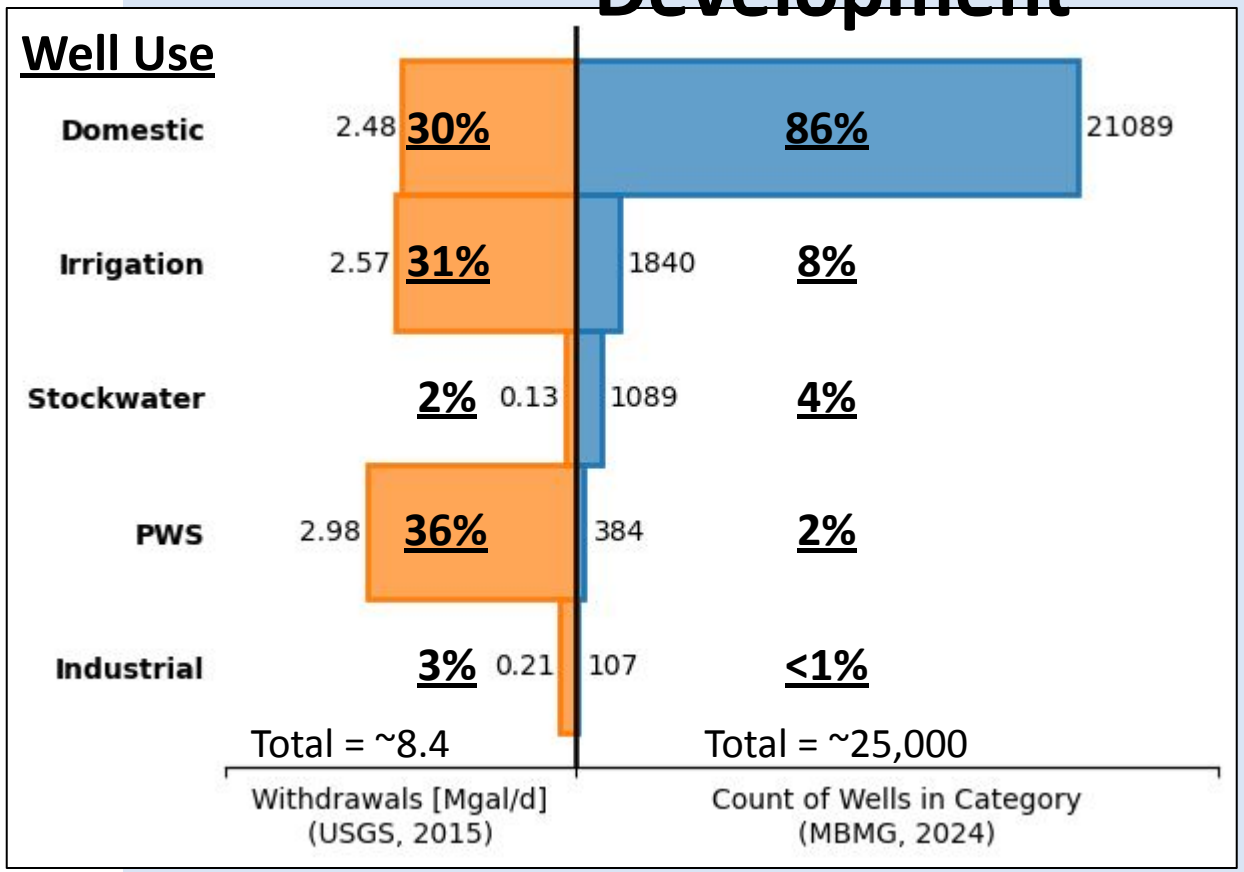


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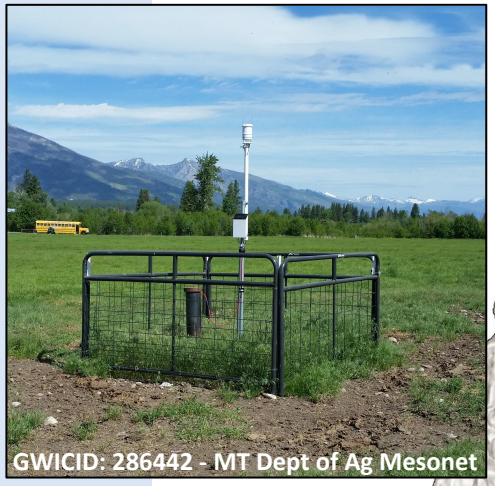


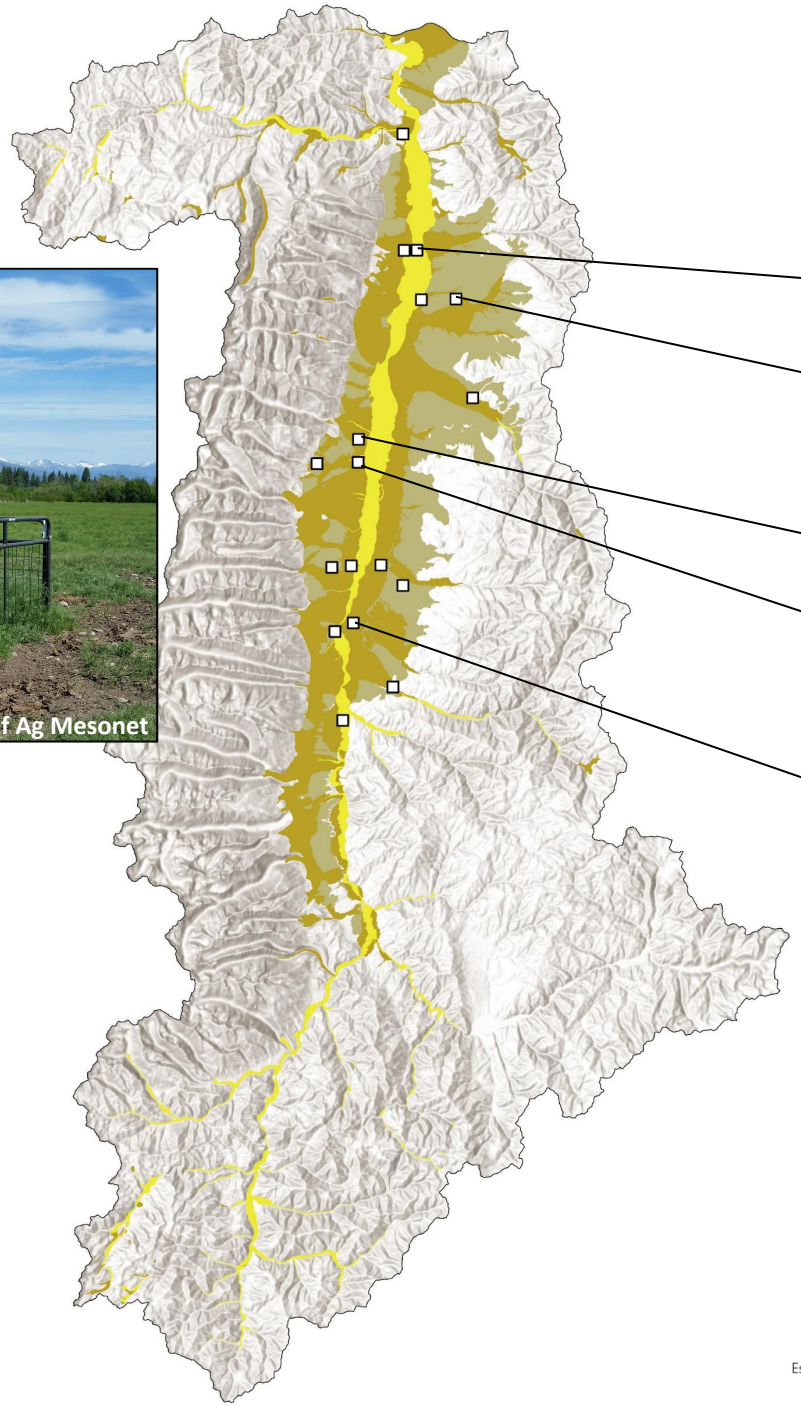


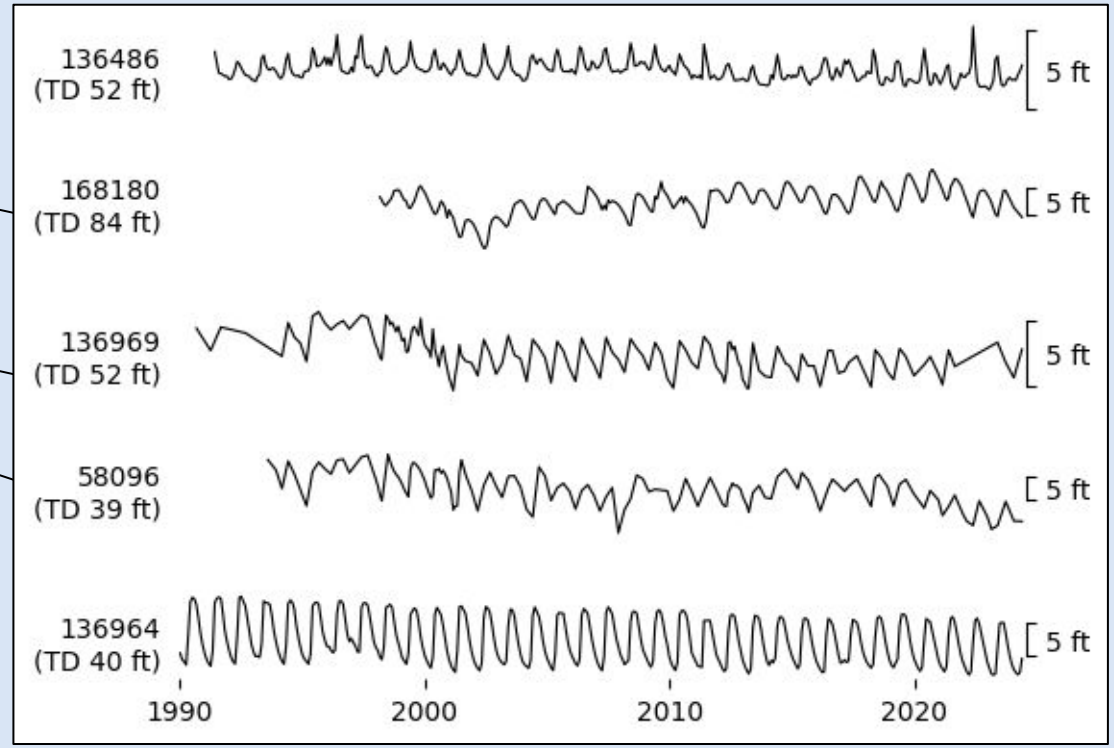


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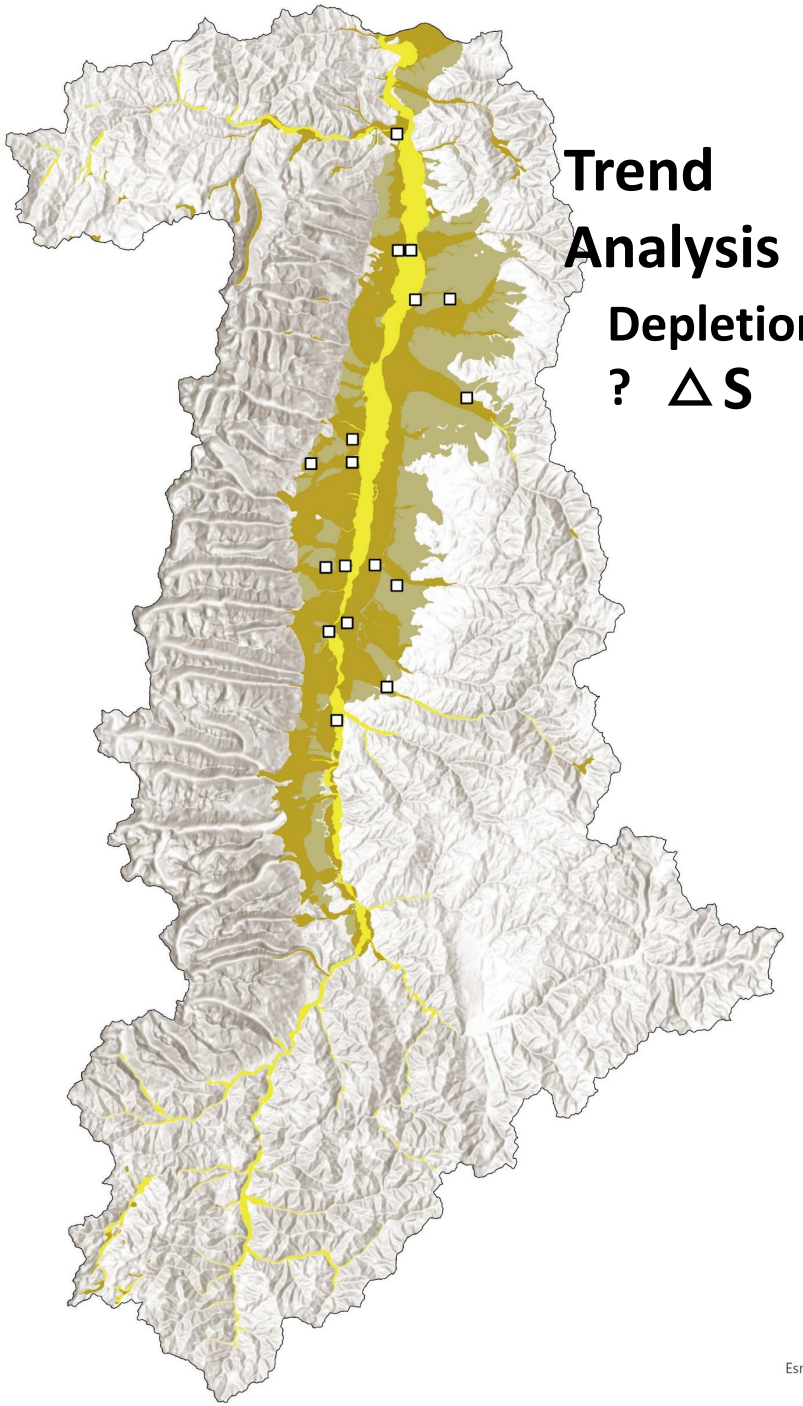
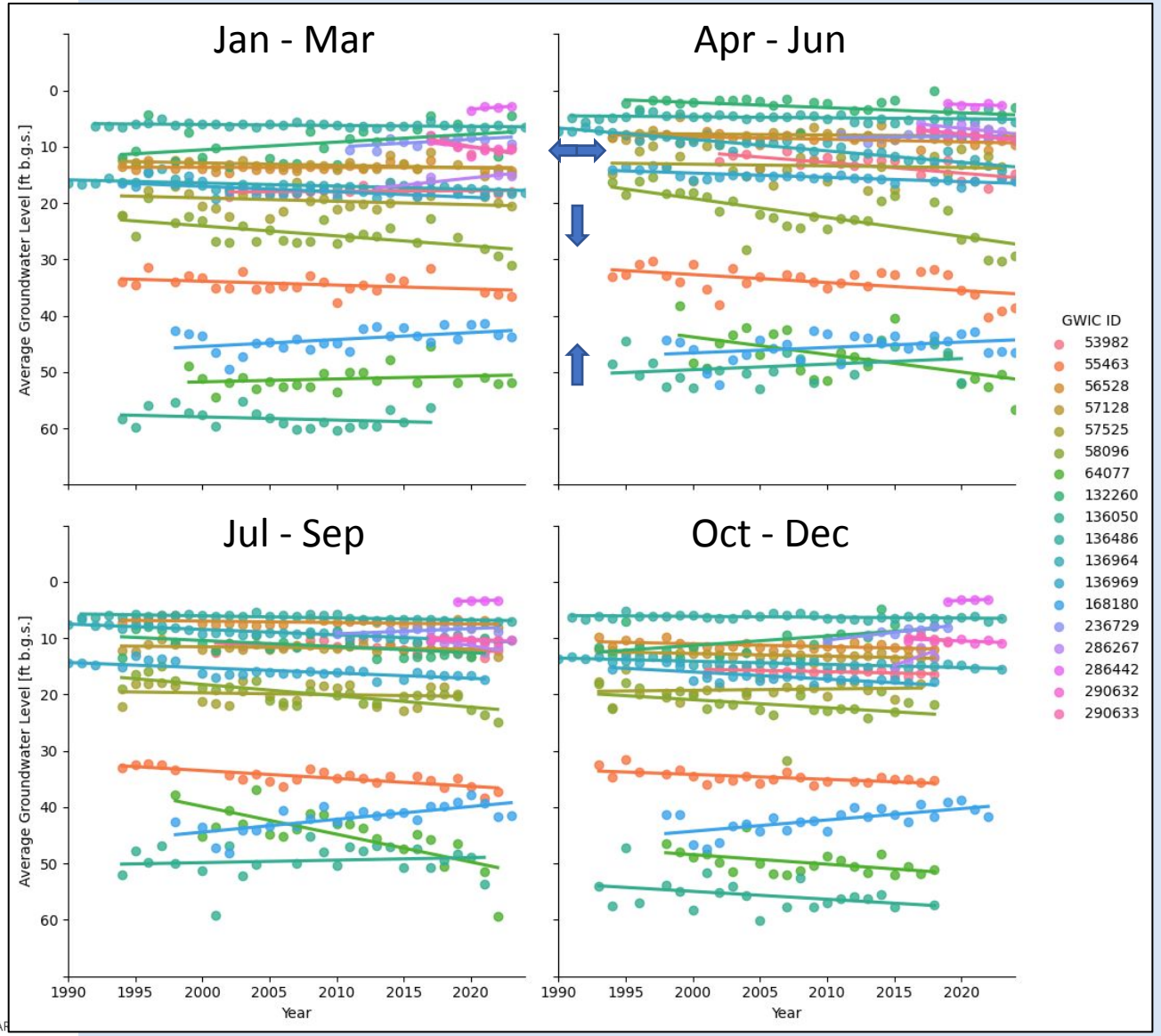


Trend Analysis

Depletion

? $\Delta S$




Esri, CGIAR

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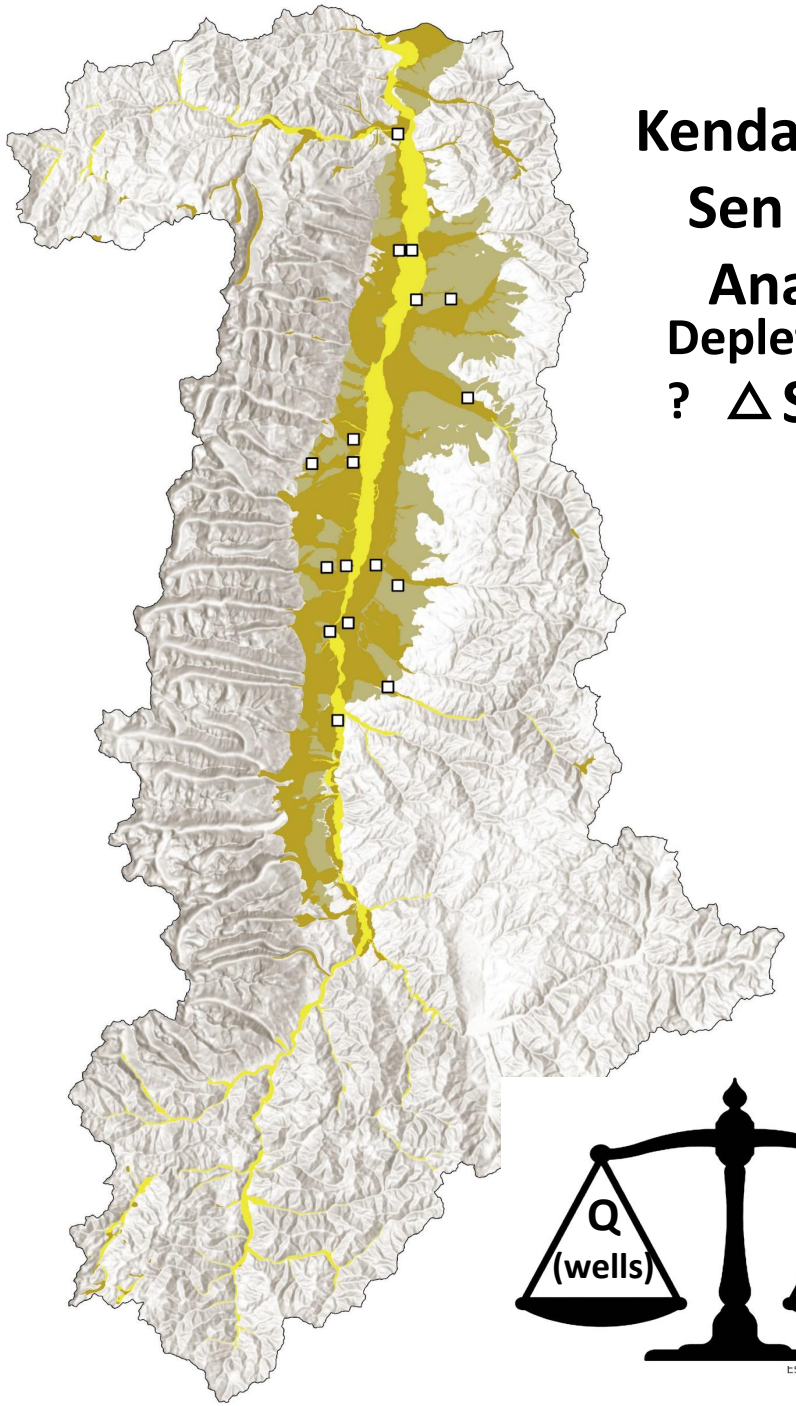


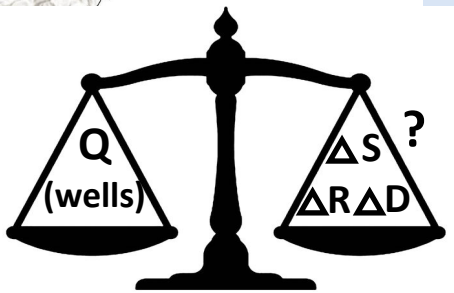
**Kendall Trend**

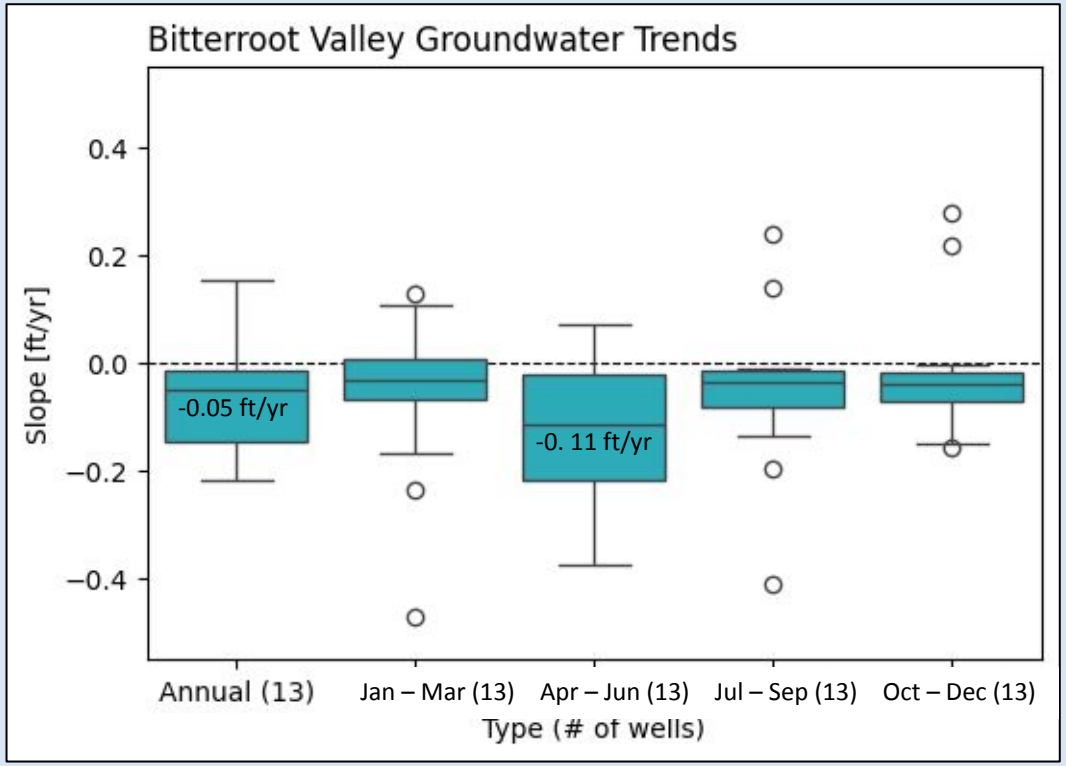
**Sen Slope**

**Analysis**

**Depletion**

**? ΔS**




- **Aligns with visual analysis**
- **Pronounced decline in snowmelt/runoff season**

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# Bitterroot Valley

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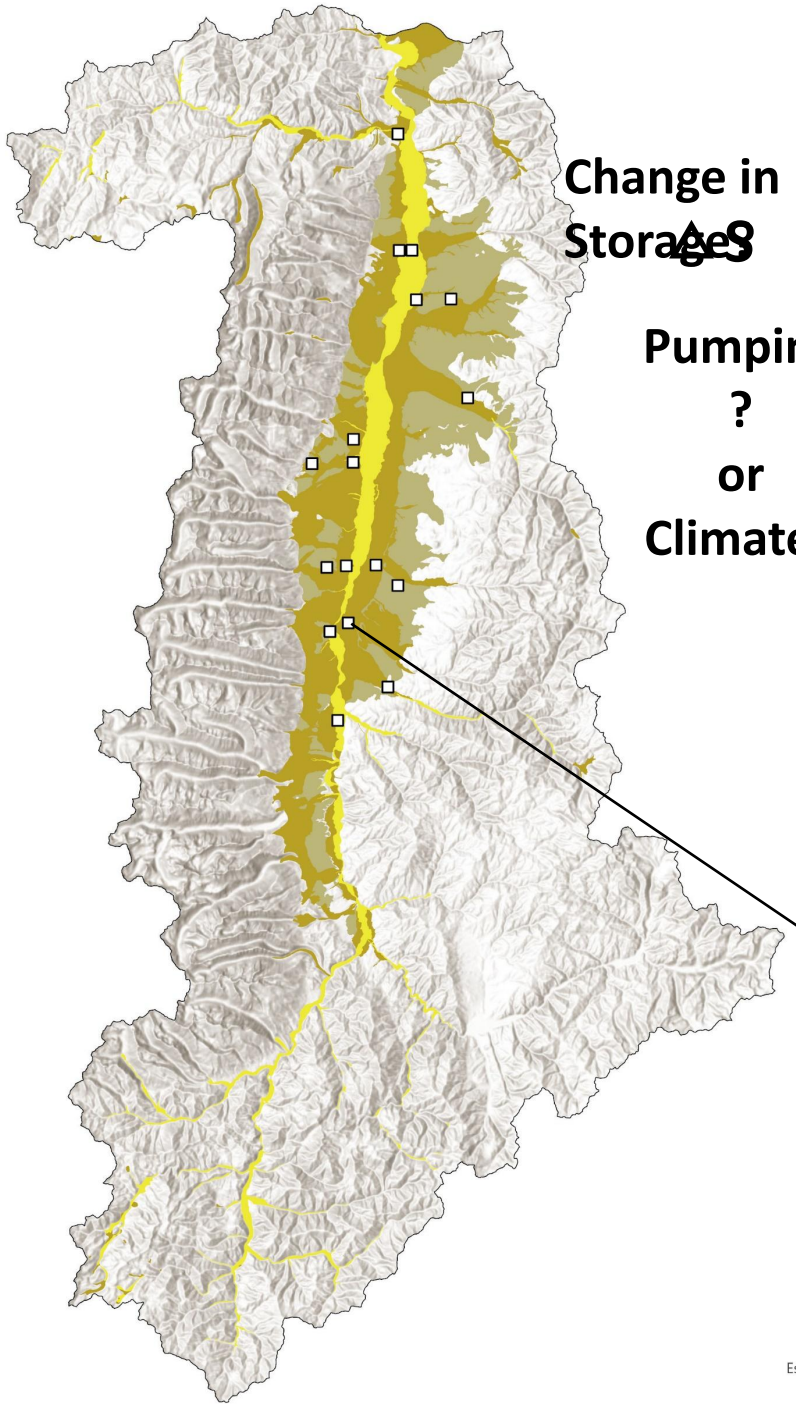


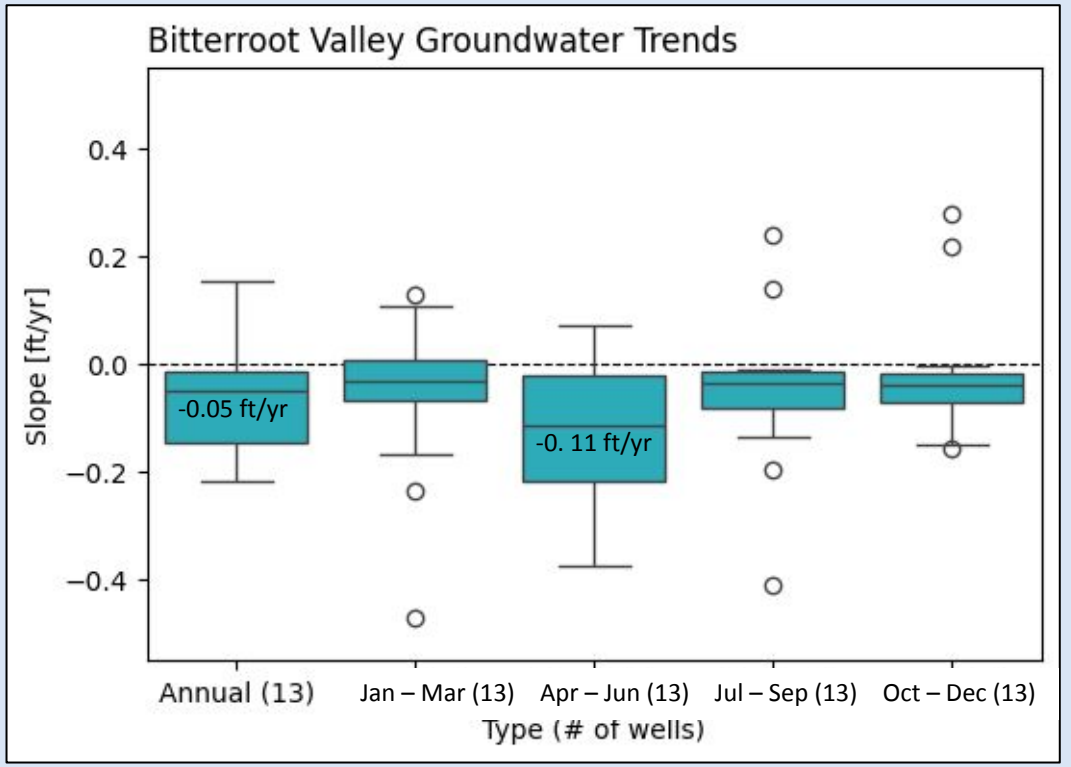


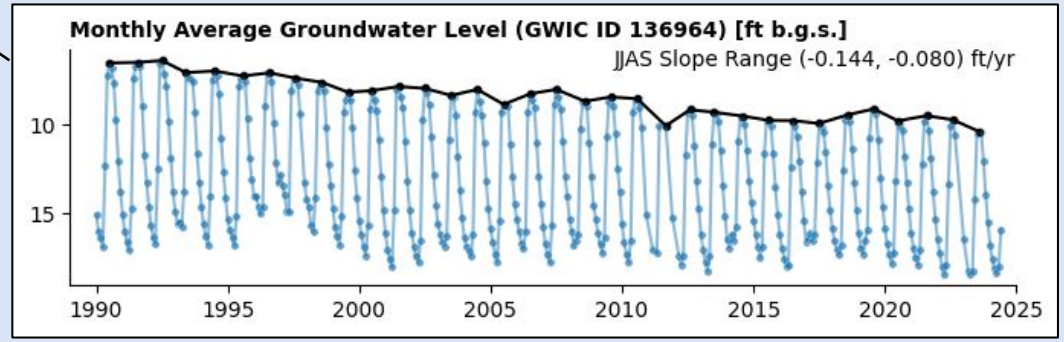


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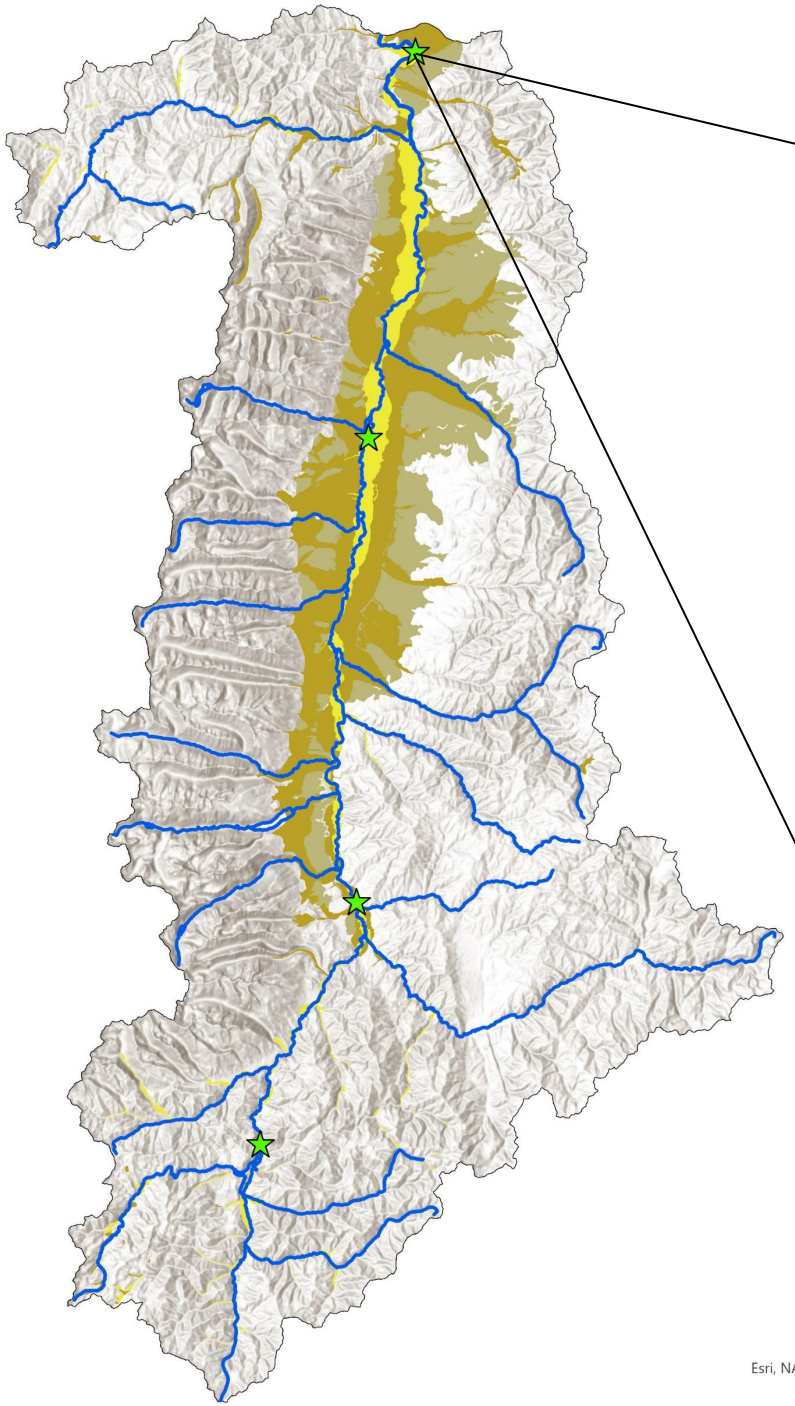
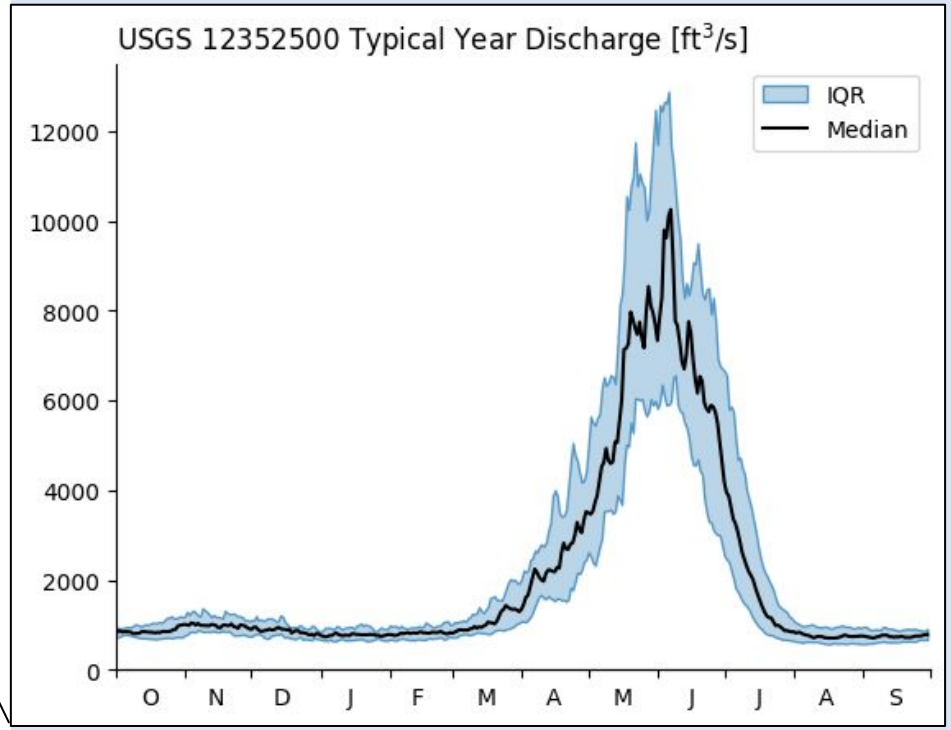
# Bitterroot Valley

## Baseflow

### Capture

? △D

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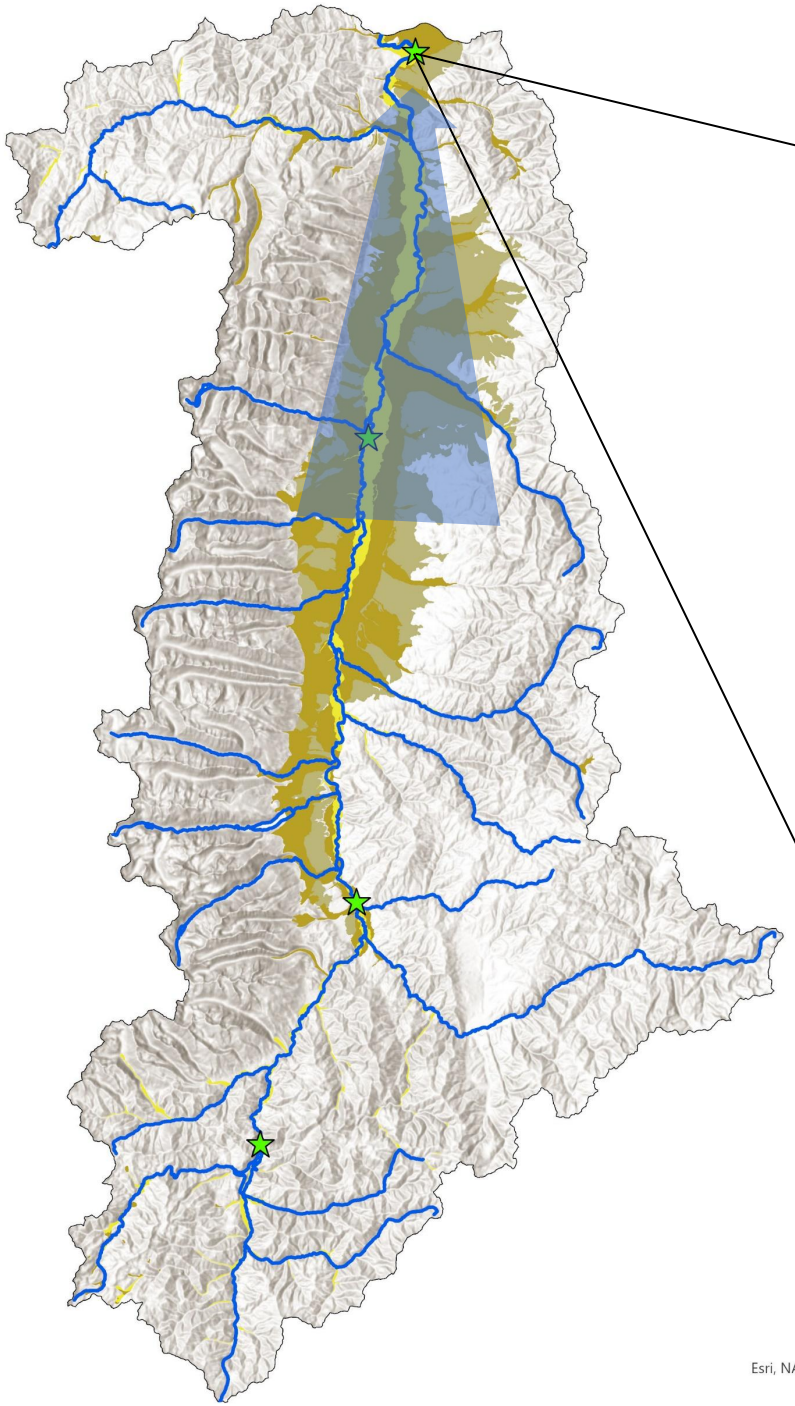


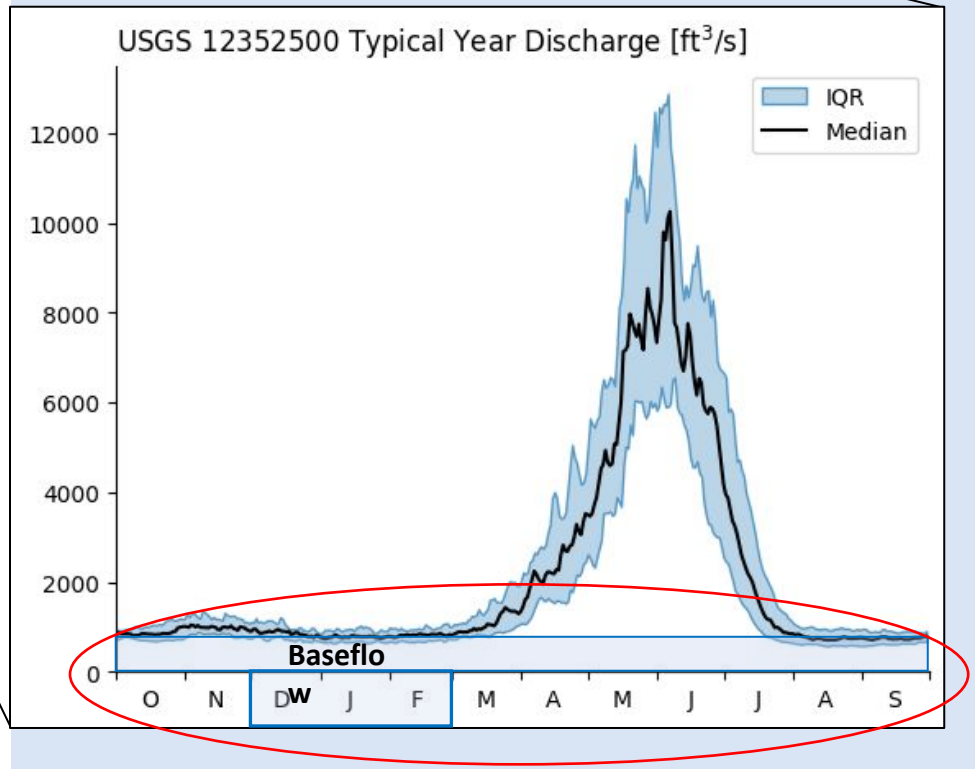


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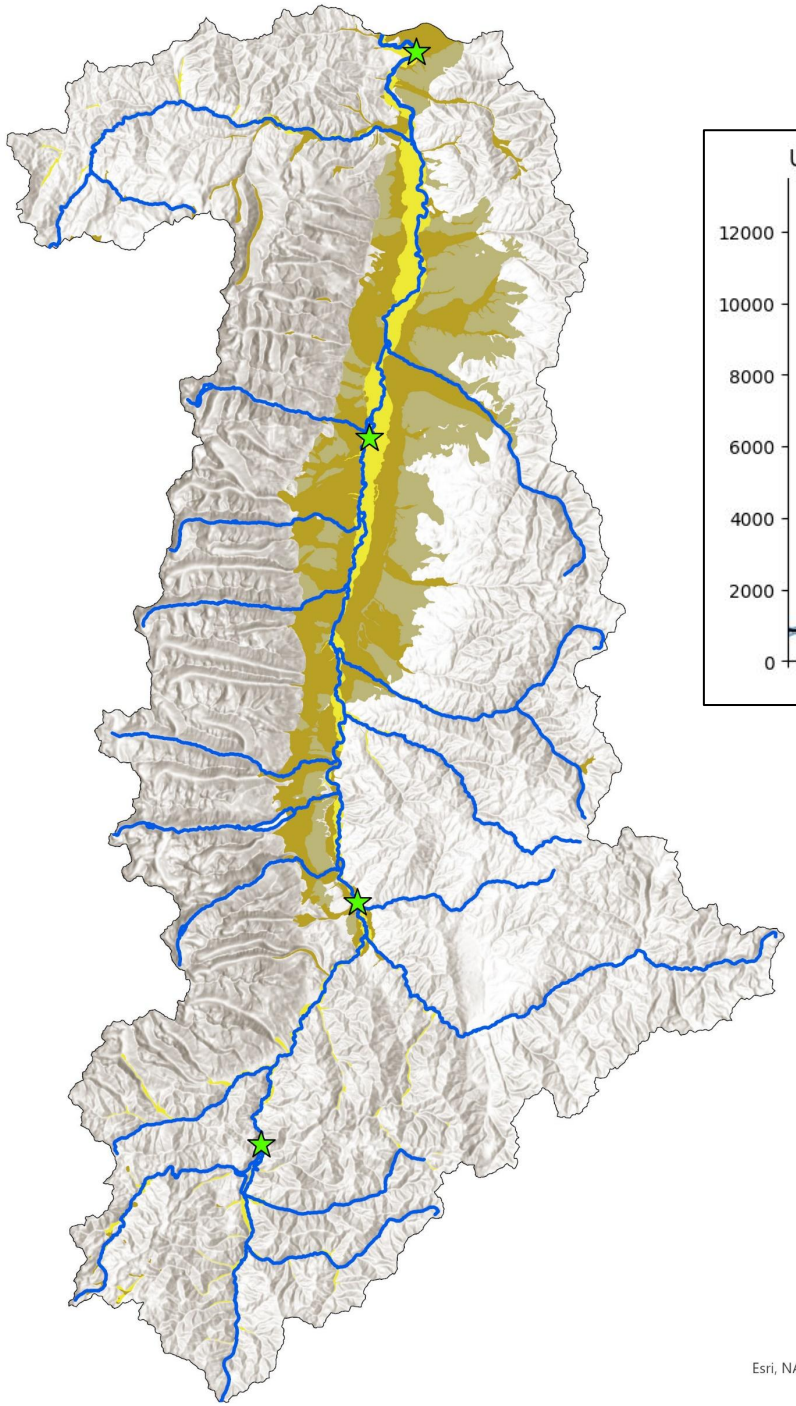


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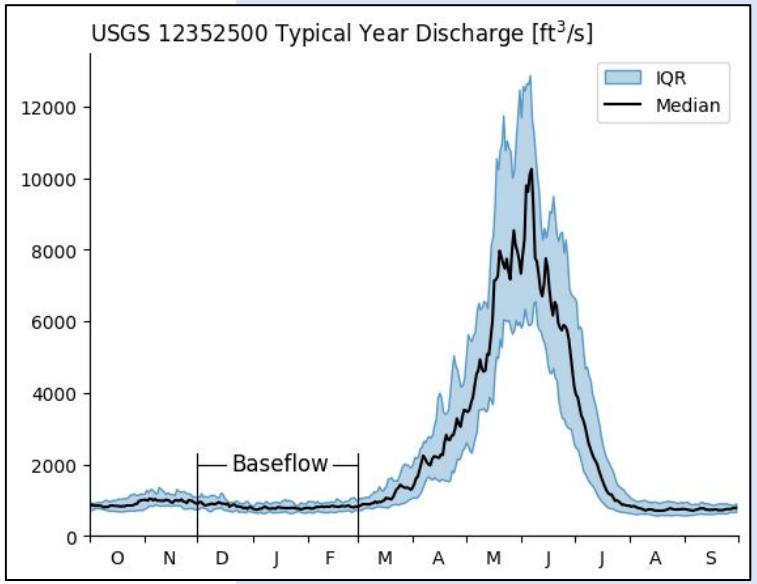


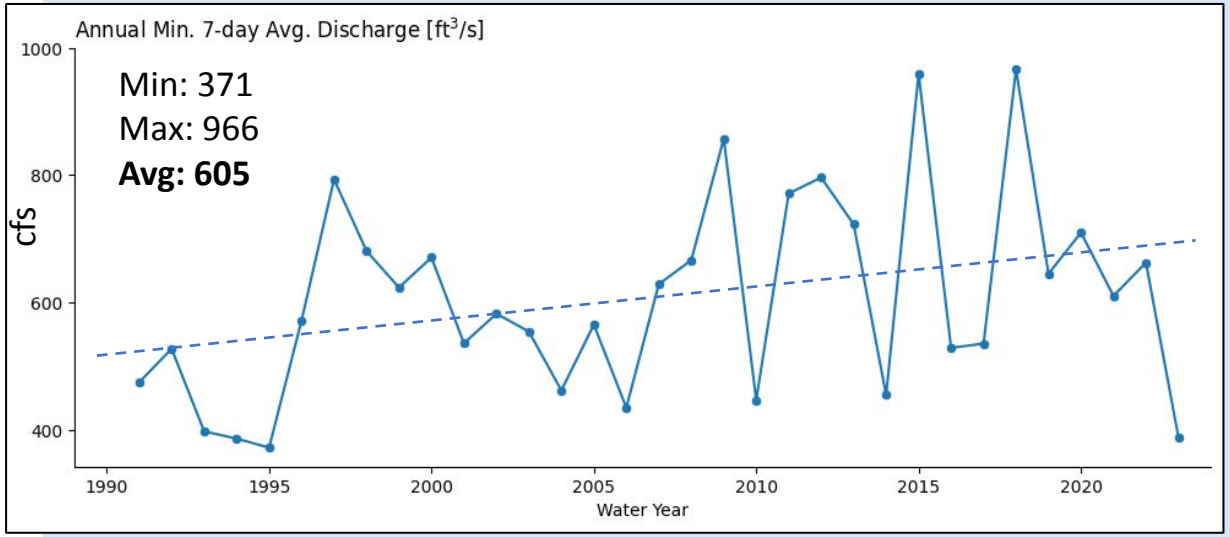


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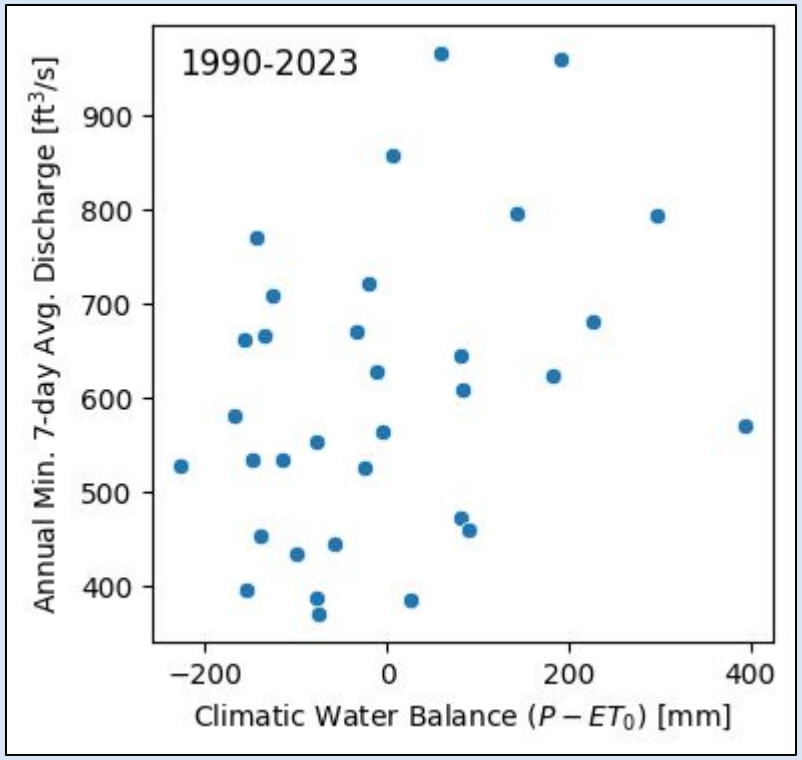
# 7-day low flow vs. climatic water balance

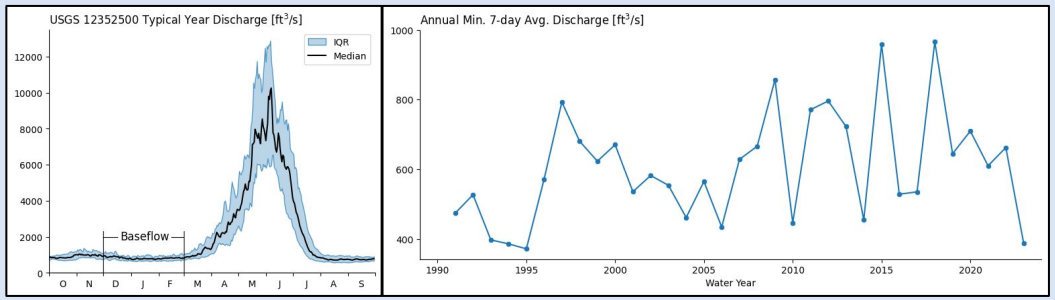
$$Y = B_1x_2 + B_2x_2 + \text{intercept}$$



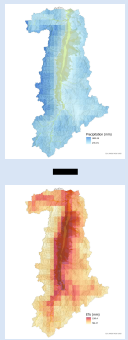

Baseflow = $\underbrace{\text{Slope Climate Variable} \times (\text{Climate Balance})}$ + $\text{Slope wells Variable} \times (\text{wells}) + \text{intercept}$

| | Value | t p-value |
|---|---|---|
| Intercept | 263.6053 | 0.023 |
| Climatic Water Balance | 0.5203 | 0.004 |
| Number of Domestic Wells | 0.0215 | 0.003 |

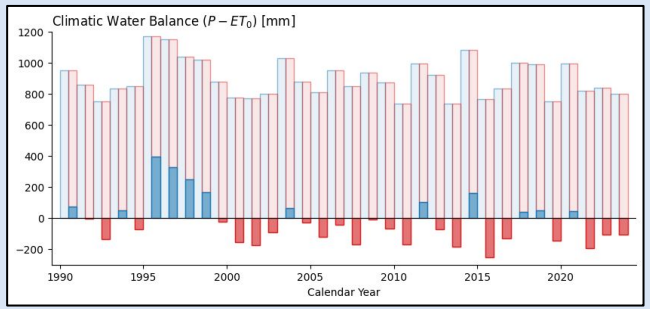
Baseflow – Response Variable




vs.



Climate – Explanatory Variable

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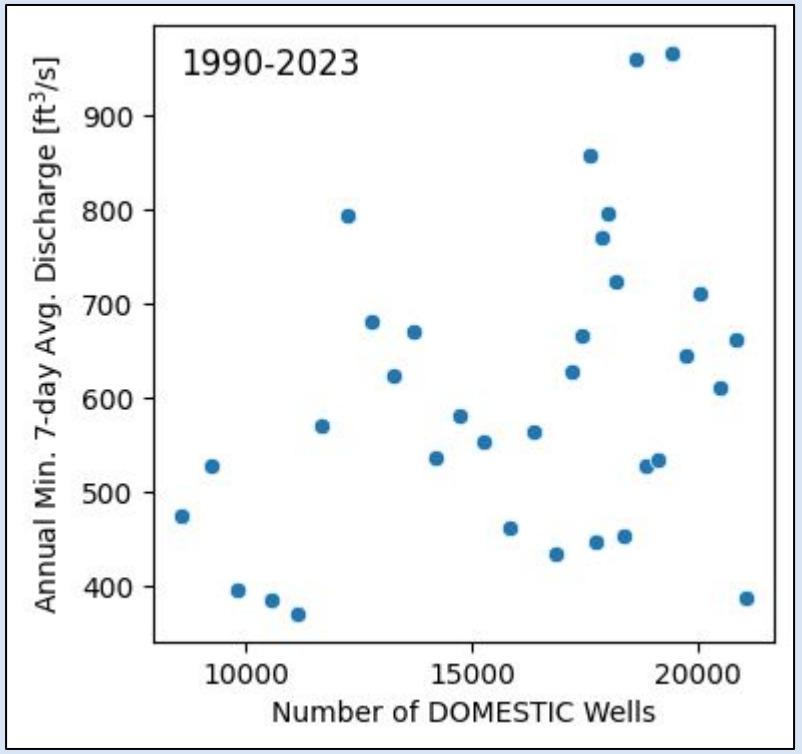
# 7-day low flow vs. number of domestic wells

$$Y = B_1x_2 + B_2x_2 + \text{intercept}$$




Baseflow = Slope Climate Variable x (Climate Balance) + Slope wells Variable x (wells) + intercept

| | Value | t p-value |
|---|---|---|
| Intercept | 263.6053 | 0.023 |
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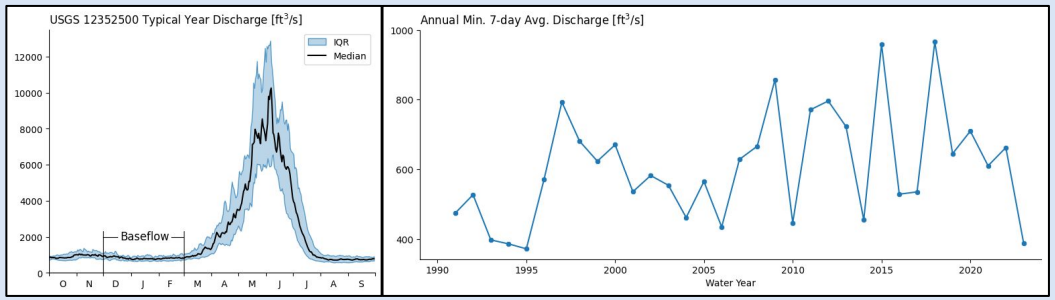
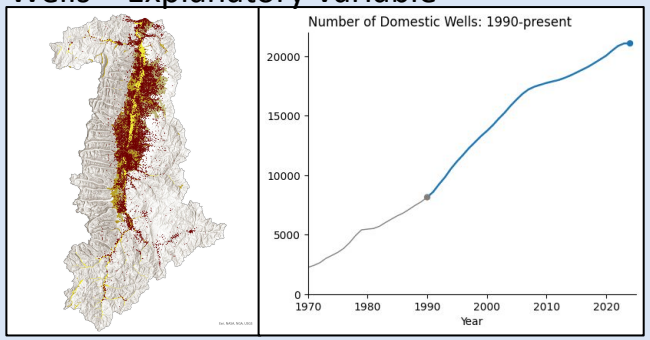
| Number of Domestic Wells | 0.0215 | 0.003 |

Baseflow – Response Variable




vs.

Wells – Explanatory Variable

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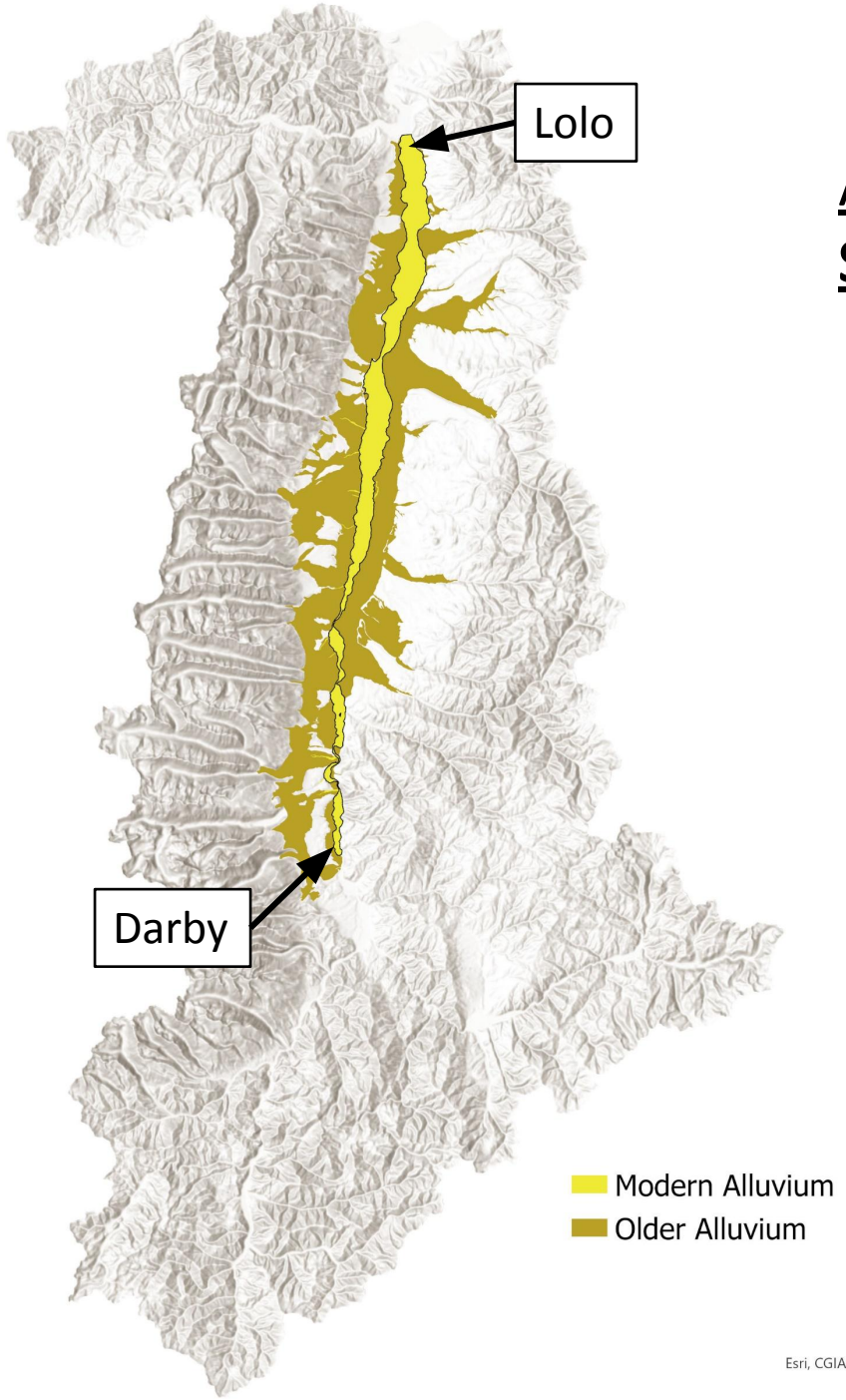
# Bitterroot Valley




Aquifer: A permeable geologic unit that can **Store** and **Transmit** groundwater.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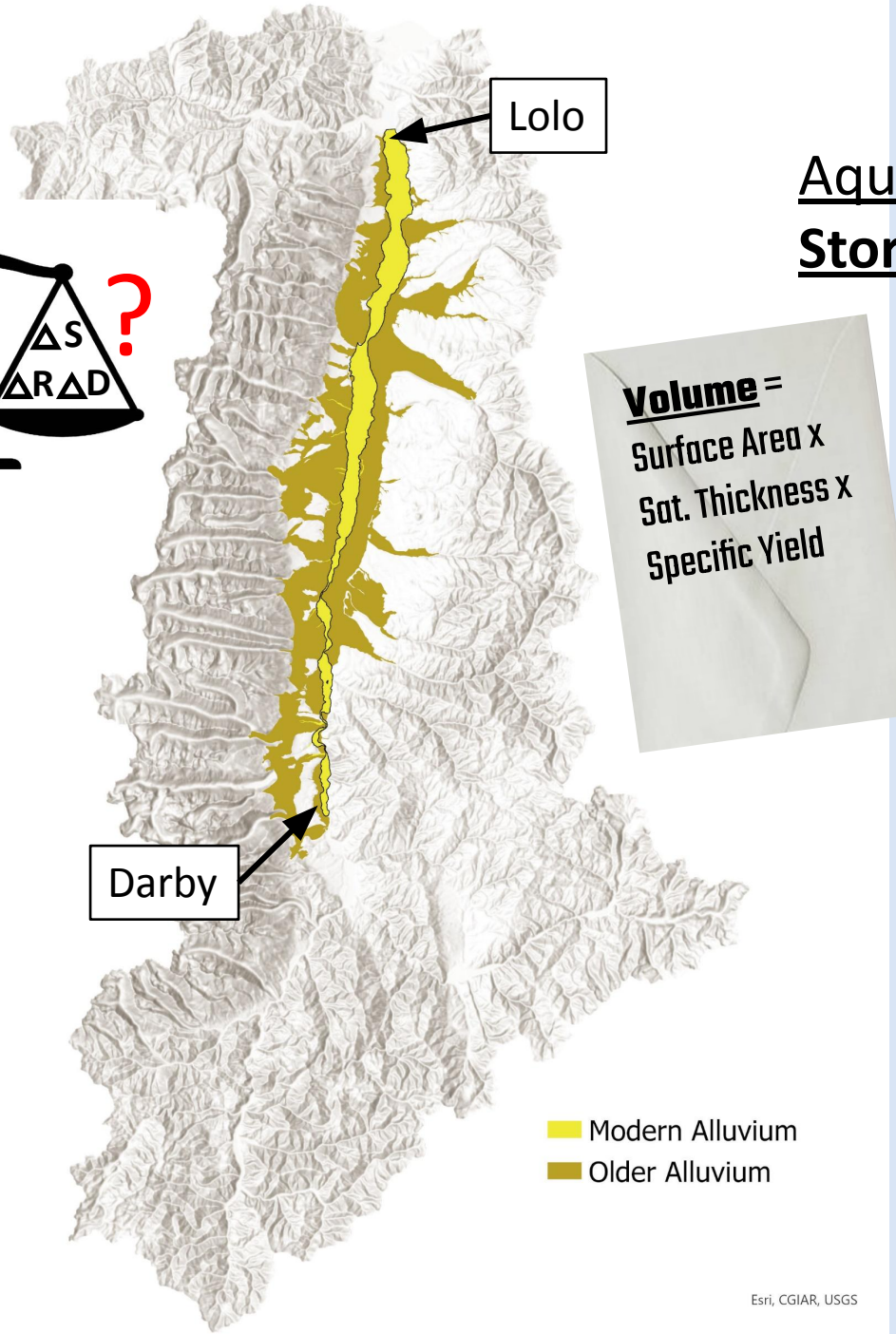
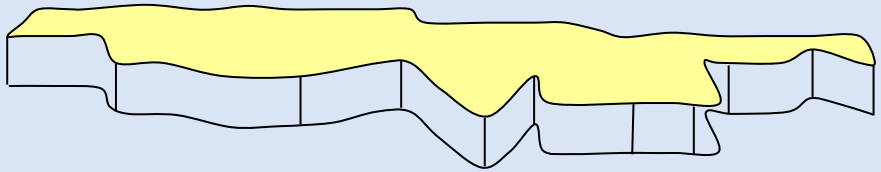
# Bitterroot Valley


**Volume** =
Surface Area x
Sat. Thickness x
Specific Yield

Aquifer: A permeable geologic unit that can **Store** and Transmit groundwater.



Volume = 153,660 acre [aquifer area]
* 40 ft [sat. thickness]
* 0.20 [specific yield]

= 1.2 million acre-ft

= 401 billion gallons

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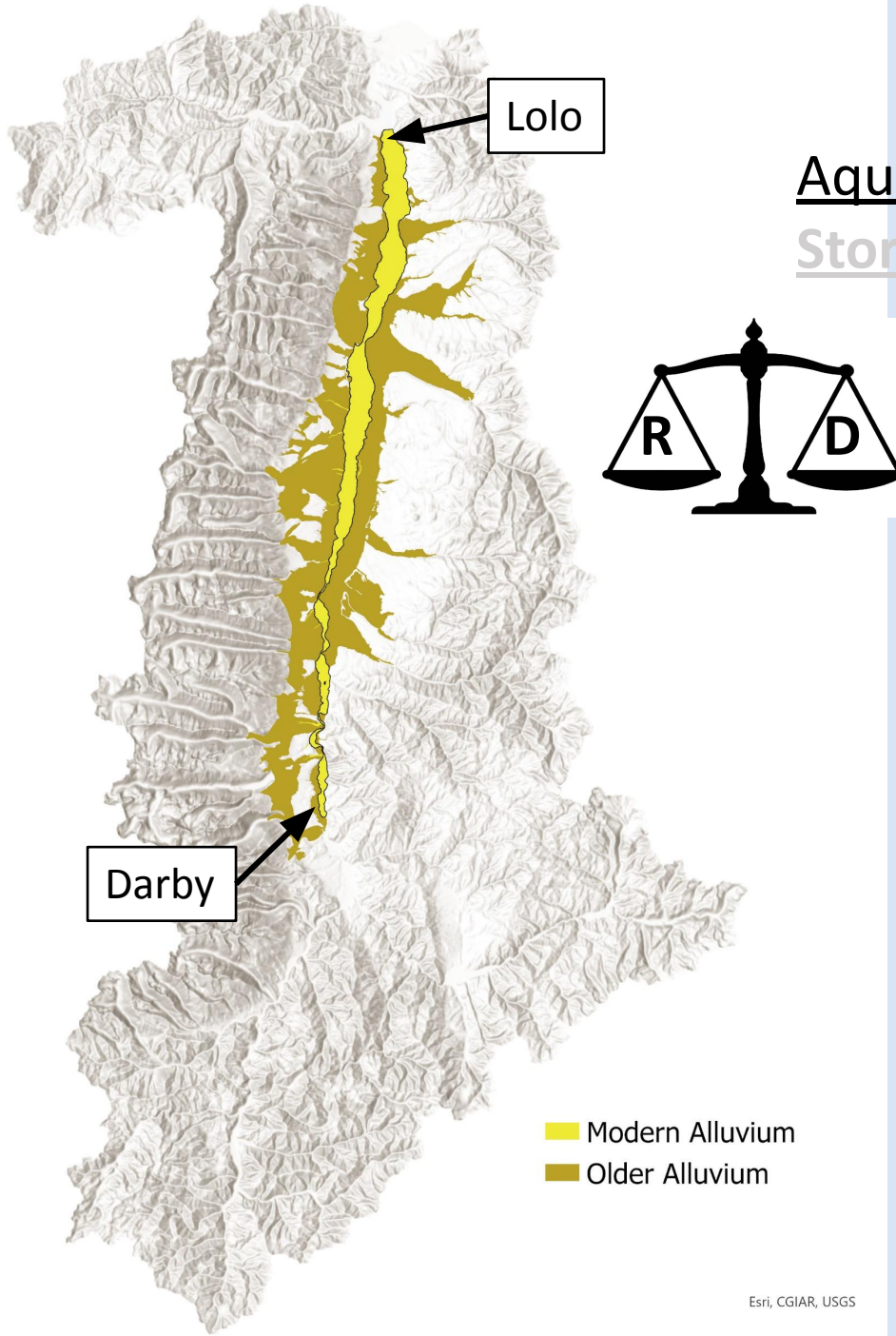
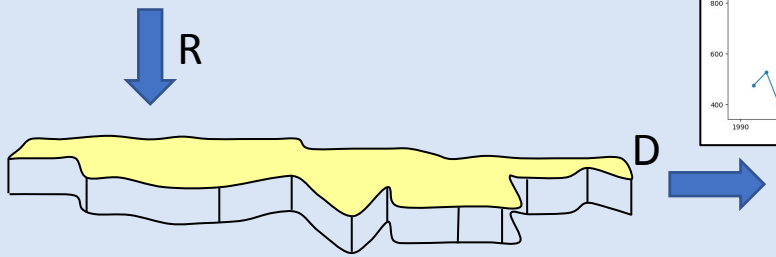
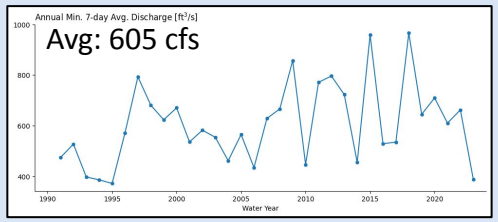
# Bitterroot Valley

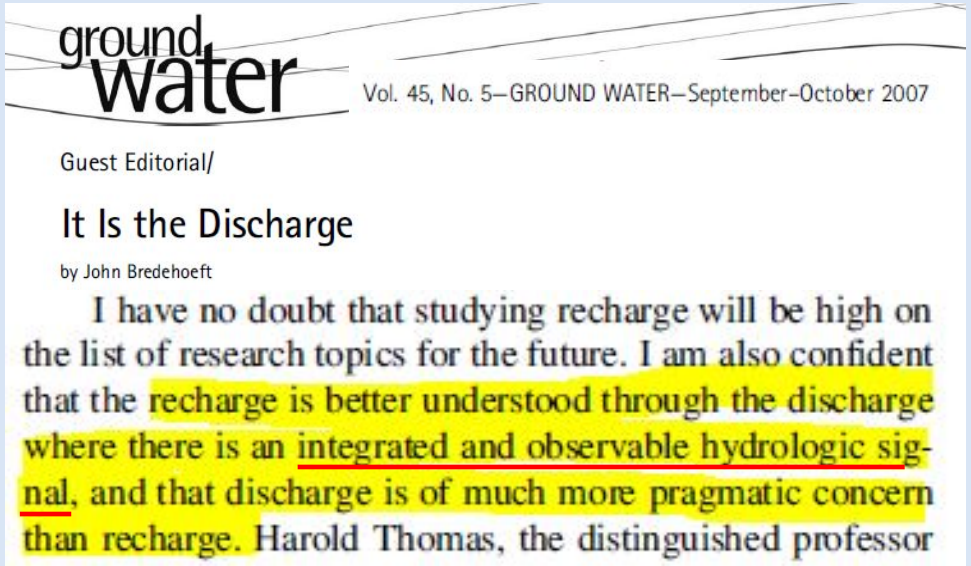



<u>Aquifer:</u> A permeable geologic unit that can Store and **<u>Transmit</u>** groundwater.



ground water Vol. 45, No. 5—GROUND WATER—September–October 2007

Guest Editorial/

## It Is the Discharge

by John Bredehoeft

I have no doubt that studying recharge will be high on the list of research topics for the future. I am also confident that the recharge is better understood through the discharge where there is an integrated and observable hydrologic signal, and that discharge is of much more pragmatic concern than recharge. Harold Thomas, the distinguished professor

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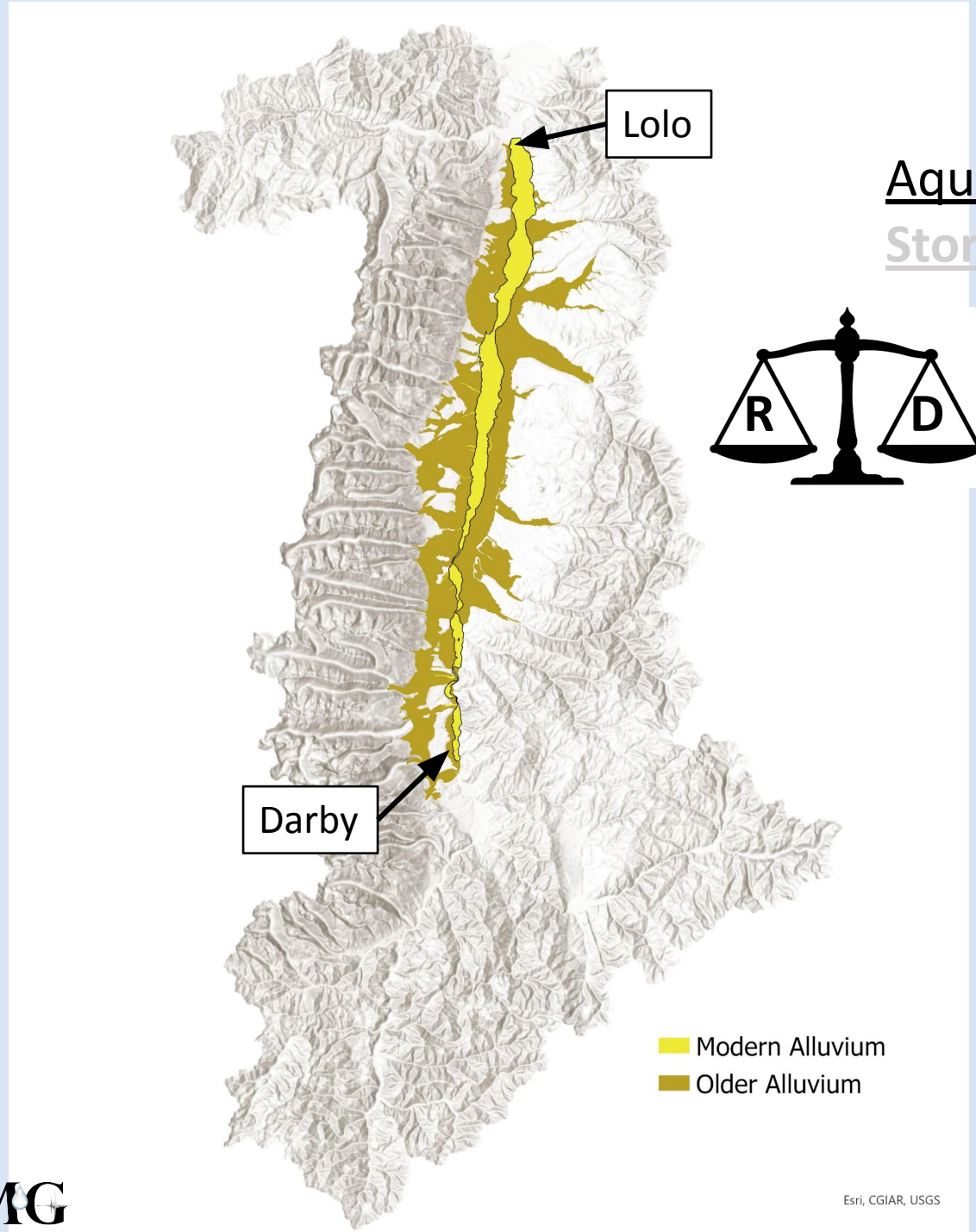
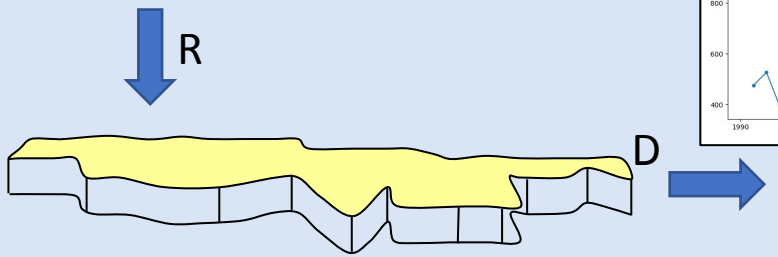
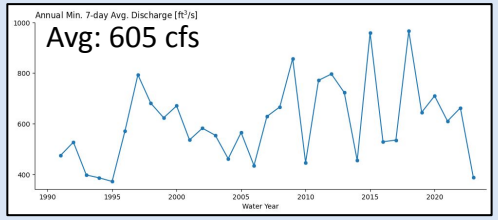
# Bitterroot Valley

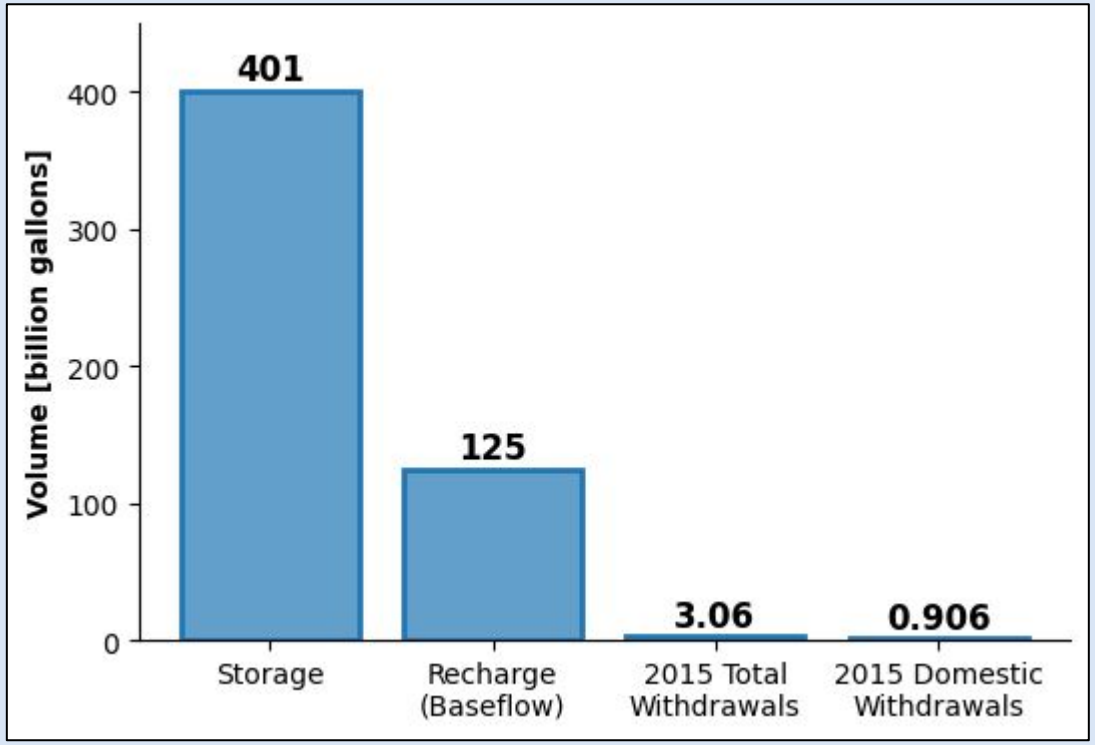



<u>Aquifer:</u> A permeable geologic unit that can <u>Store</u> and **<u>Transmit</u>** groundwater.

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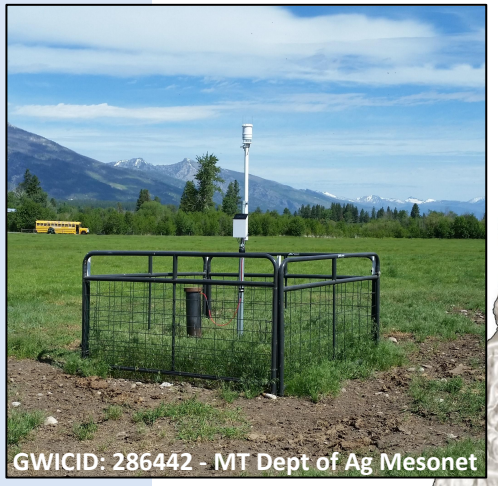
***"The imperative need in groundwater development is to know what we are doing"***

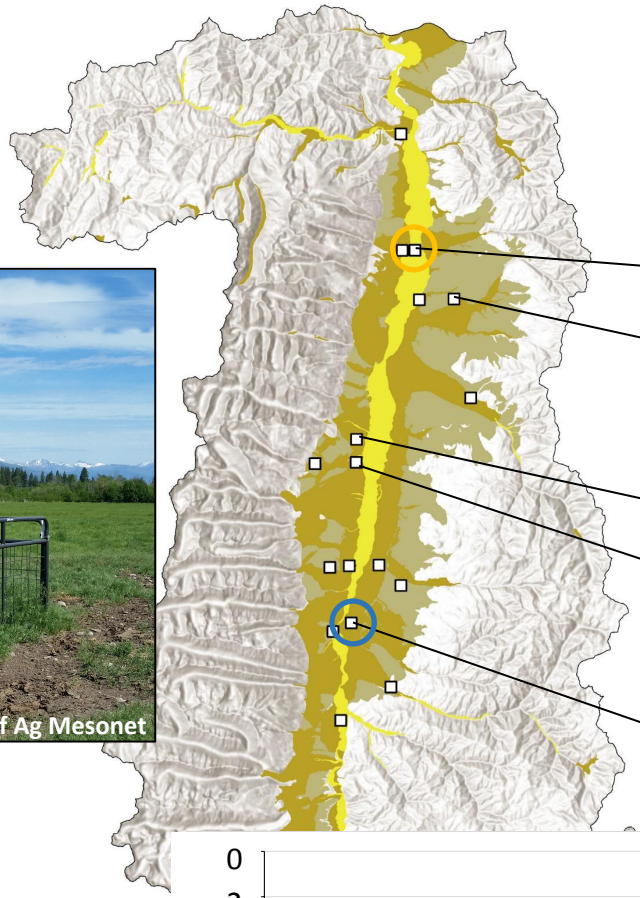
**Harold Thomas, 1951**

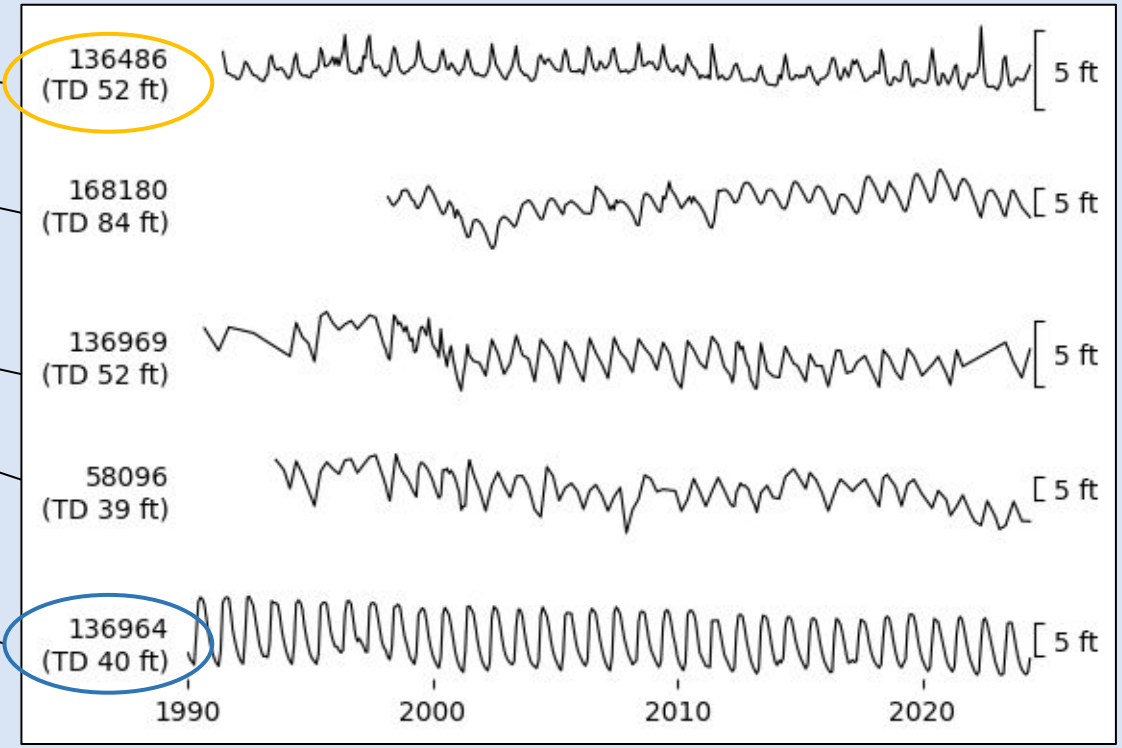
- Large scale, basin-wide analysis – can mask over local effects
  - Considerable uncertainty – temporal and spatial scales
- Climate is driving the Bitterroot Hydrologic system
  - Hydrogeologic and climatic conditions favorable for GW recharge
- Long-term monitoring is important
  - Years to decades to address fundamental questions
  - Small decreases in GW storage can have disproportionate baseflow impact

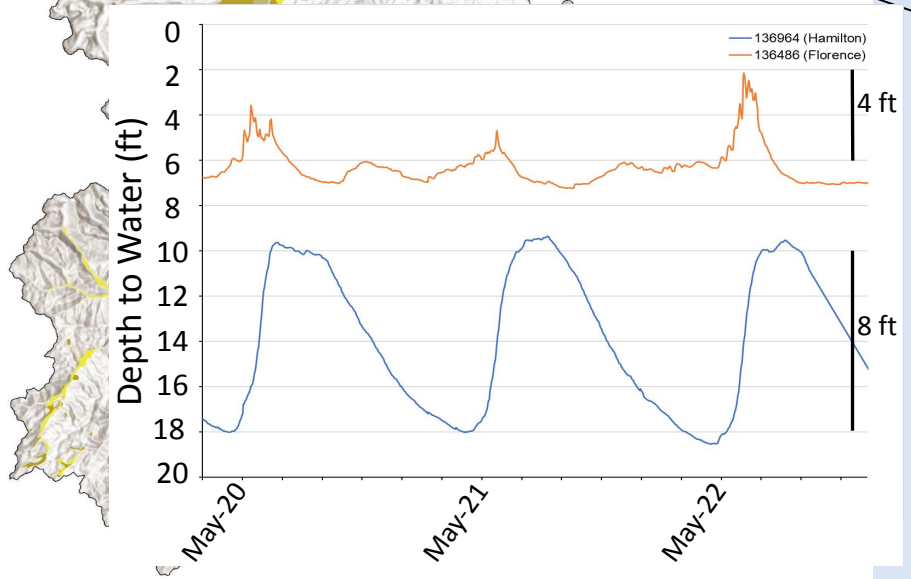
# Bitterroot Valley

## Groundwater Monitoring



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