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Groundwater Baseflow Study: Analysis Findings

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Outline

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- Introduction
- Background
- Data Availability
- Groundwater Level Relationship to Antecedent Snowpack
- Streamflow Level Relationship to Antecedent Snowpack
- Watershed Implications
- Recommendations
- Q&A

Introduction

Motivation

- The goal of this study is to identify relationship(s) between snowpack, groundwater, and/or streamflow
- This could inform drinking water management, especially in the context of meeting fish flow requirements.

The 71 Percent

Goals for Today

- Provide an overview of the study's methods
- Explore the findings of the study and educate about the implications of these findings
- Present recommendations for the next phase of the study
- Provide space for discussion

Analysis and Primary Criteria

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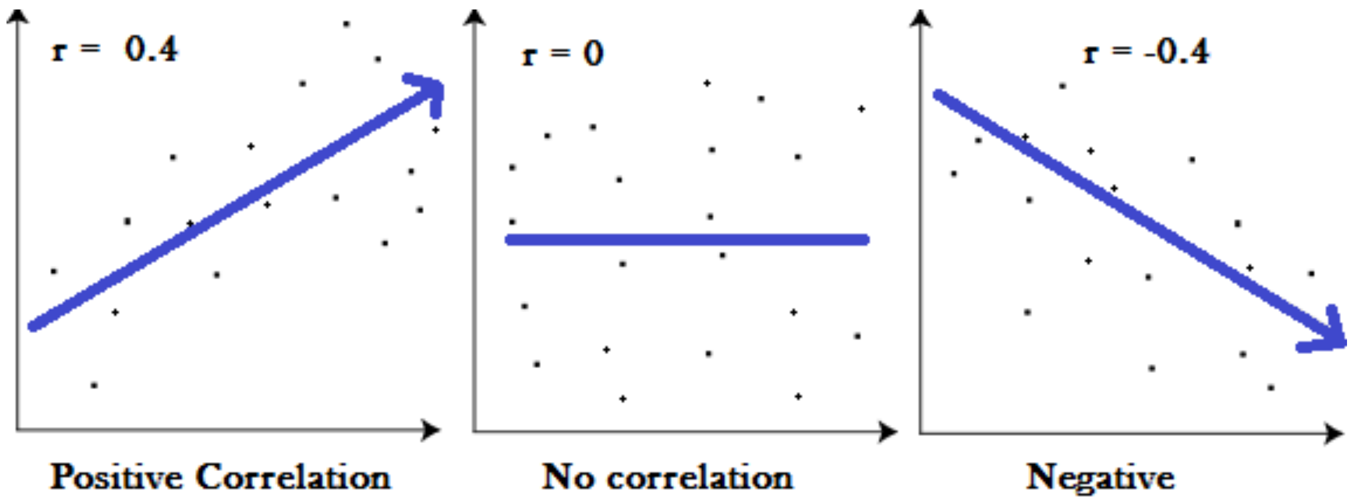
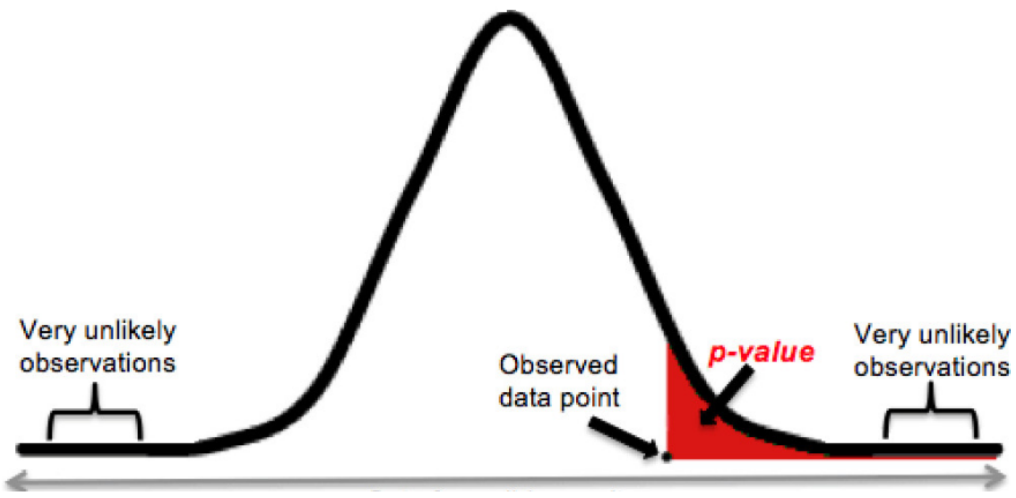
- Analysis hinged on visual and statistical analysis as data allowed.
- Criteria for statistical analysis included:
  - Correlation coefficient: value between 0.5 and 1 is statistically significant
  - P-value: value between 0 and 0.1 is statistically significant

Correlation Coefficient



P-Value



Key Findings

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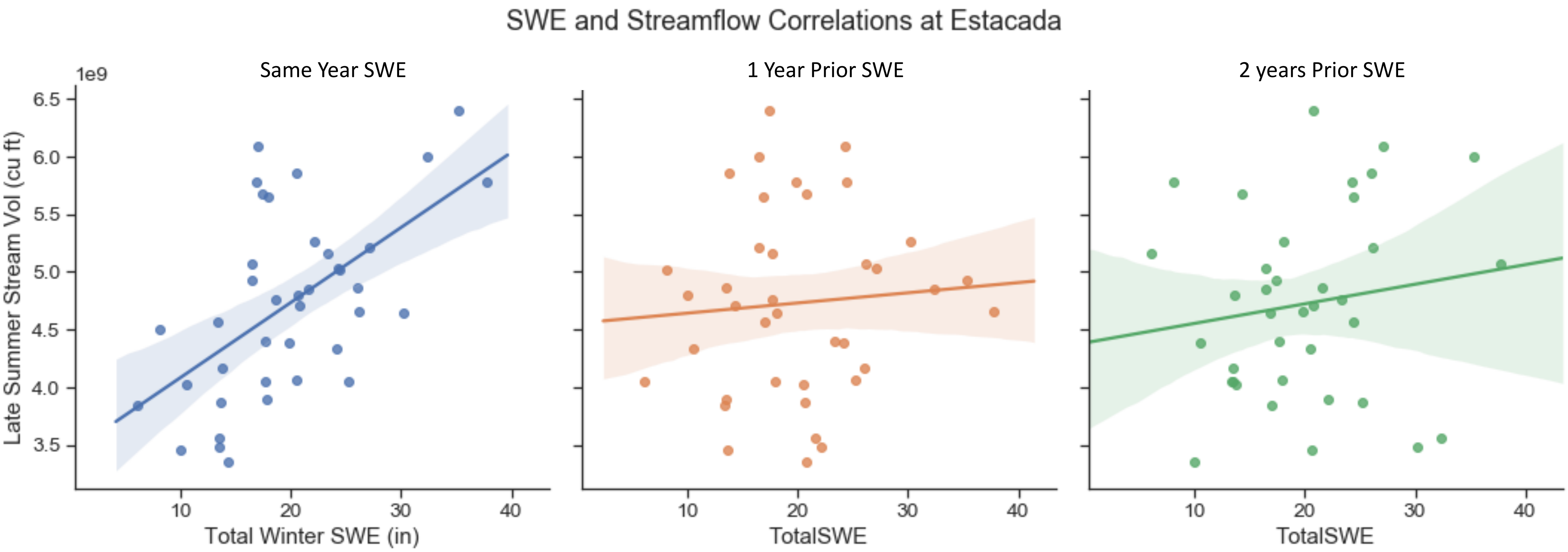
- Almost 60% of variability in late summer stream flow in the Clackamas River at Estacada can be accounted for by total winter snowpack.



Same Year SWE: pearsonr = 0.58; p = 0.0001

Recommendations

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- There are a couple of options:

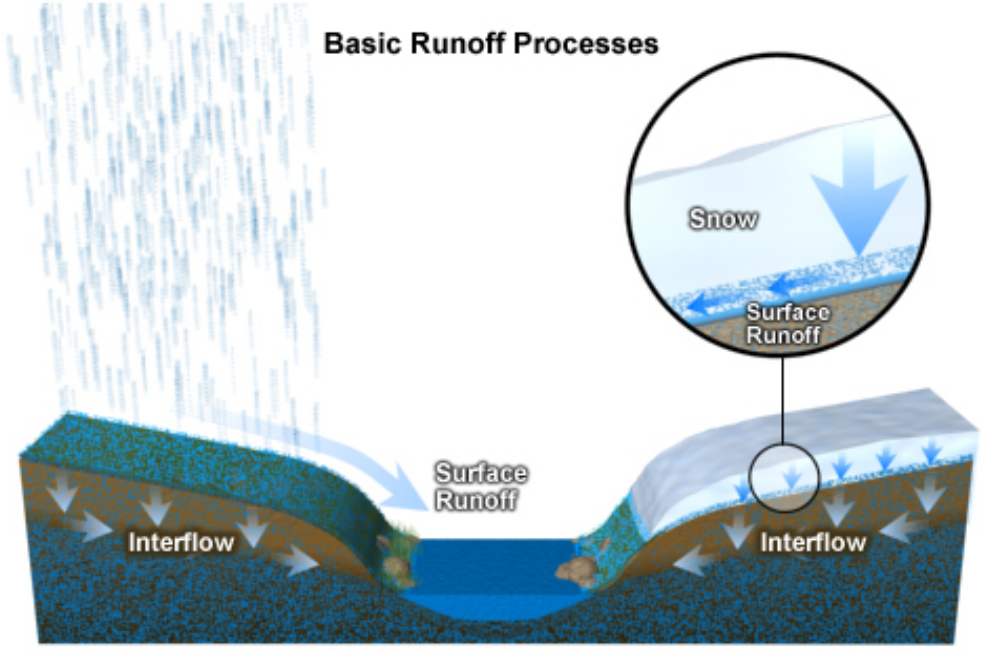
1. Data collection followed by additional analysis
   - Could take years to collect sufficient groundwater data
   - No guarantee that results will be useful due to confounding factors

2. Modeling approach in the Upper Basin
   - Could start getting results within a year
   - Modeling process and results could inform groundwater monitoring efforts and additional statistical analysis, which in turn could be used to improve the model to provide better results

Background

Background

- Low summer base flows in the Upper Clackamas River Basin are a function of the upper basin hydrology.
  - In the upper basin, snowpack melts into the unsaturated ground to become interflow.
  - Lateral groundwater flows downslope and enters the tributaries of the Clackamas River, Clackamas River, and the Willamette River.
  - Note PGE dams along the Clackamas



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Data Availability

SNOTEL Gauges

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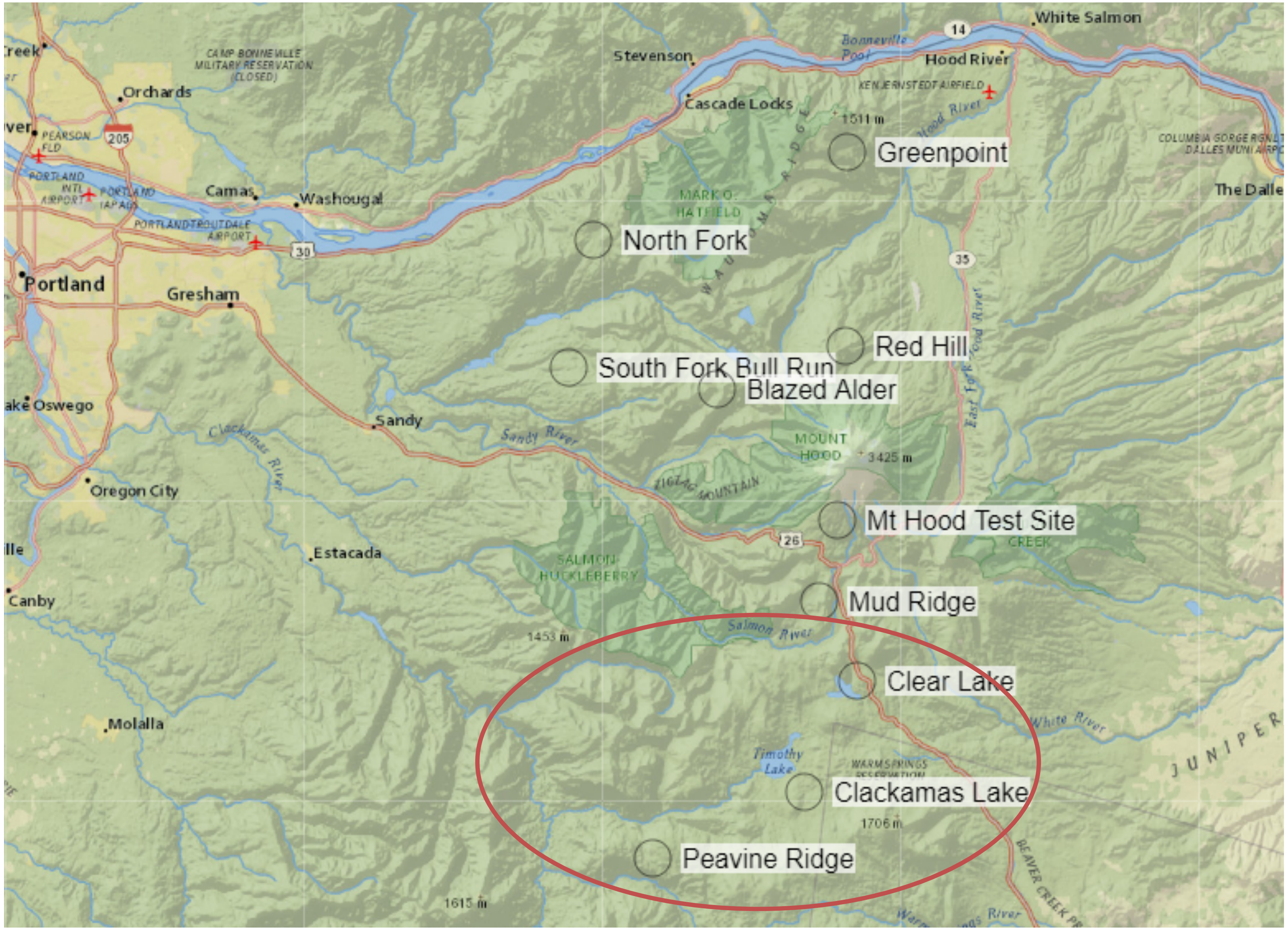

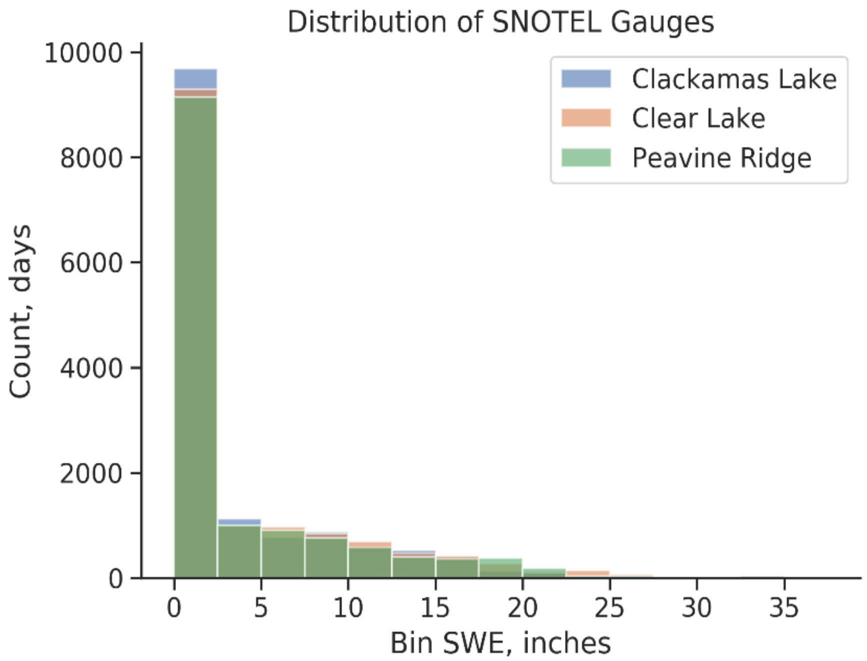

Streamflow Gauges

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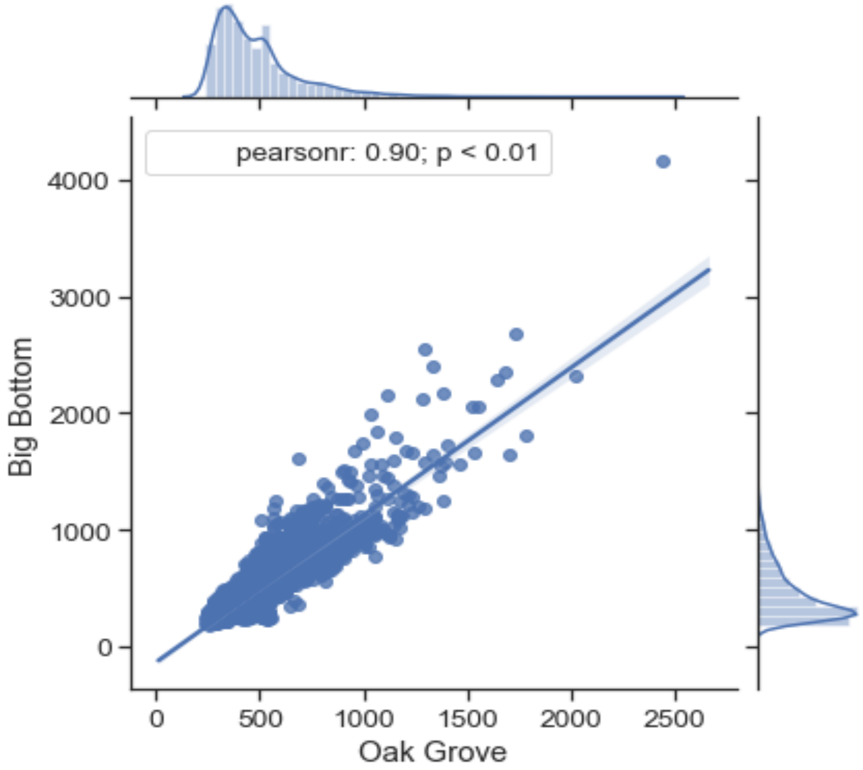
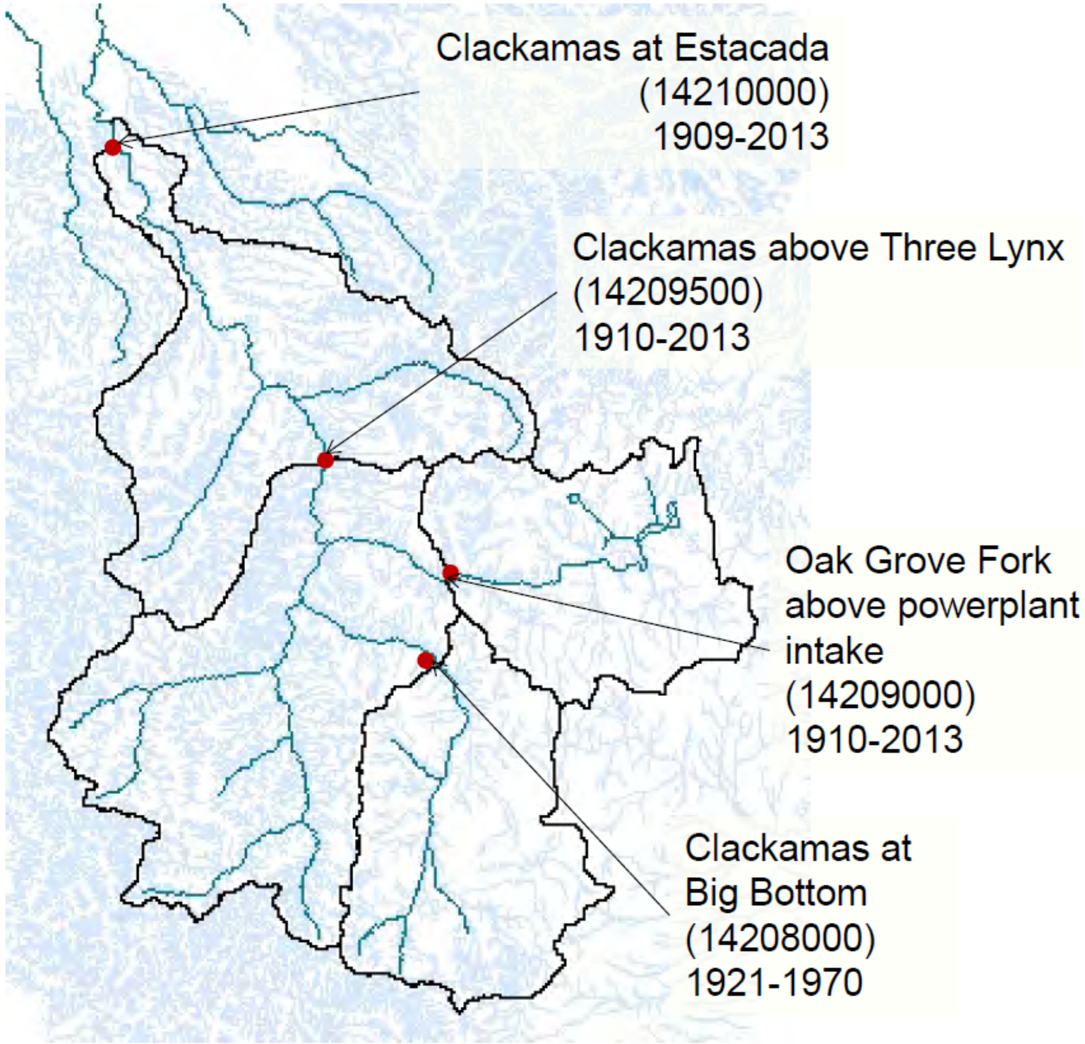
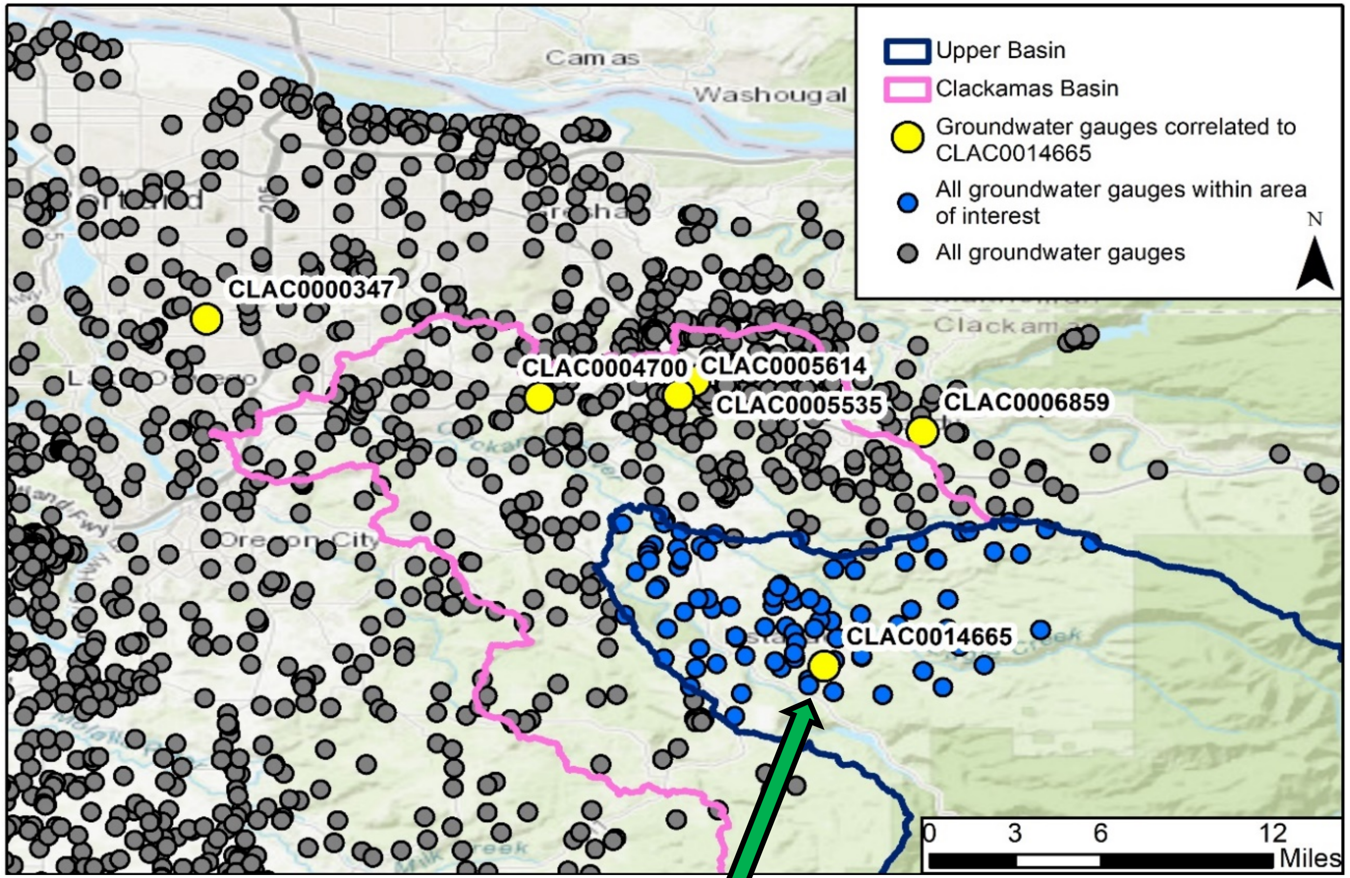
- Primary gauges at Estacada and Oak Grove Fork
  - No data at Big Bottom after 1970, but Oak Grove Fork is representative of both upper subbasins

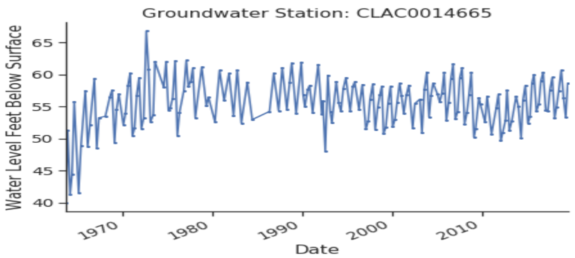


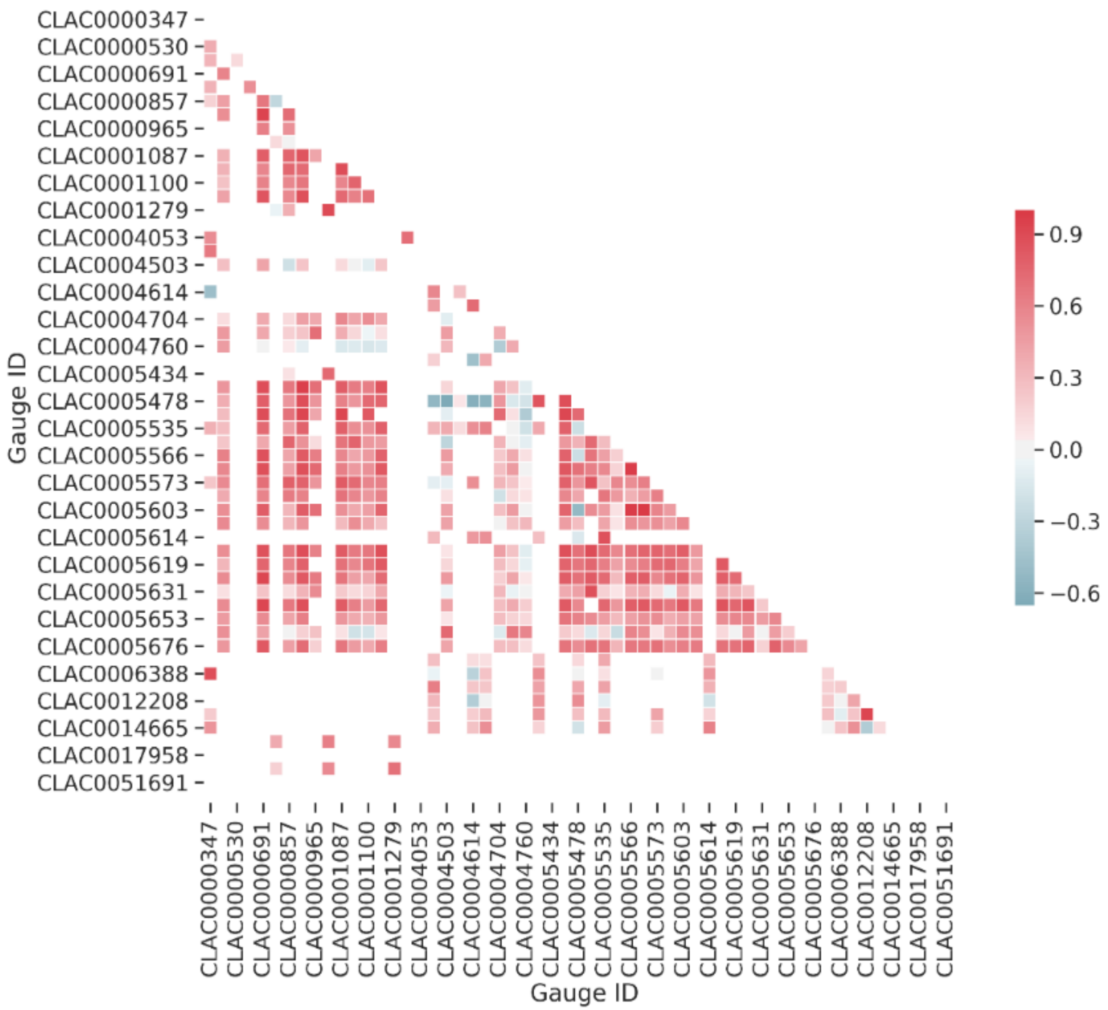


Groundwater Gauges



Primary groundwater gauge

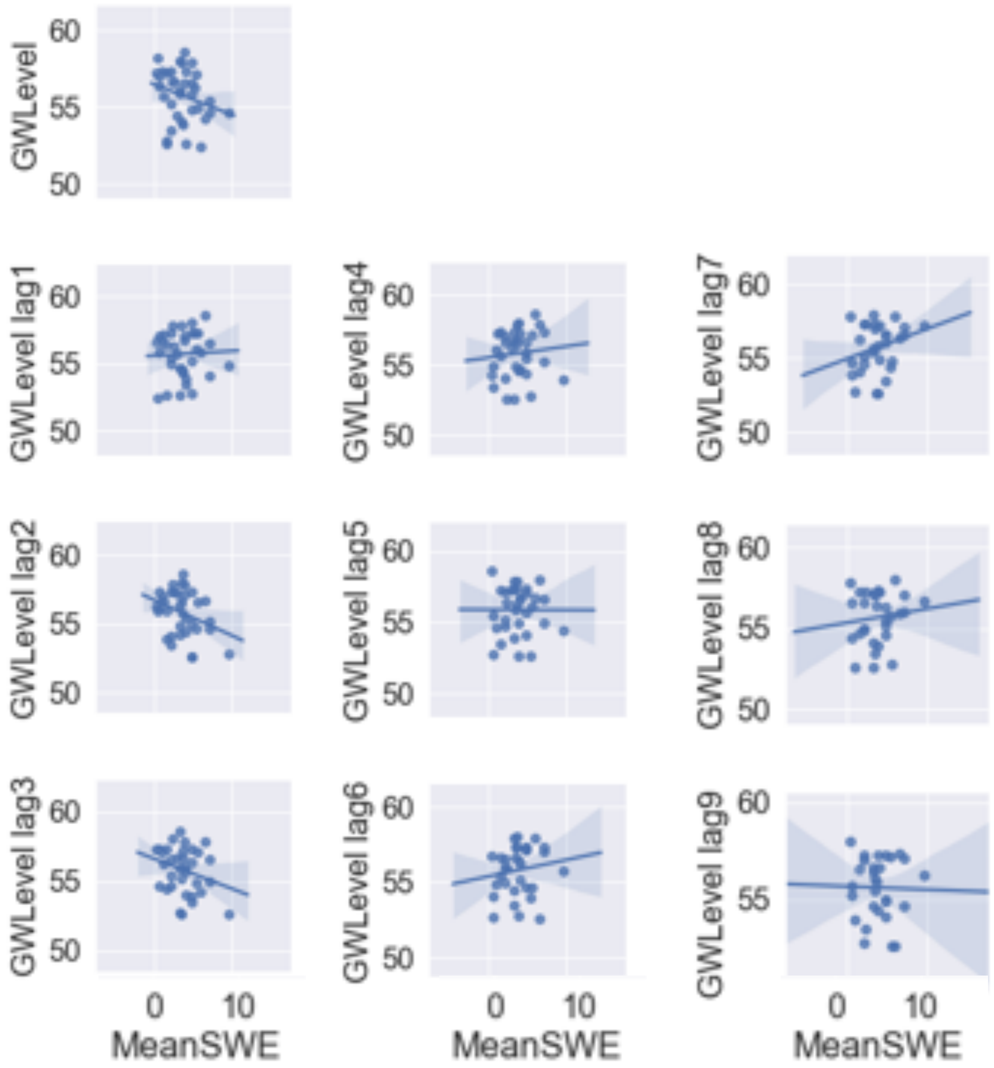




Groundwater Level Relationship to Antecedent Snowpack

Correlation Analysis

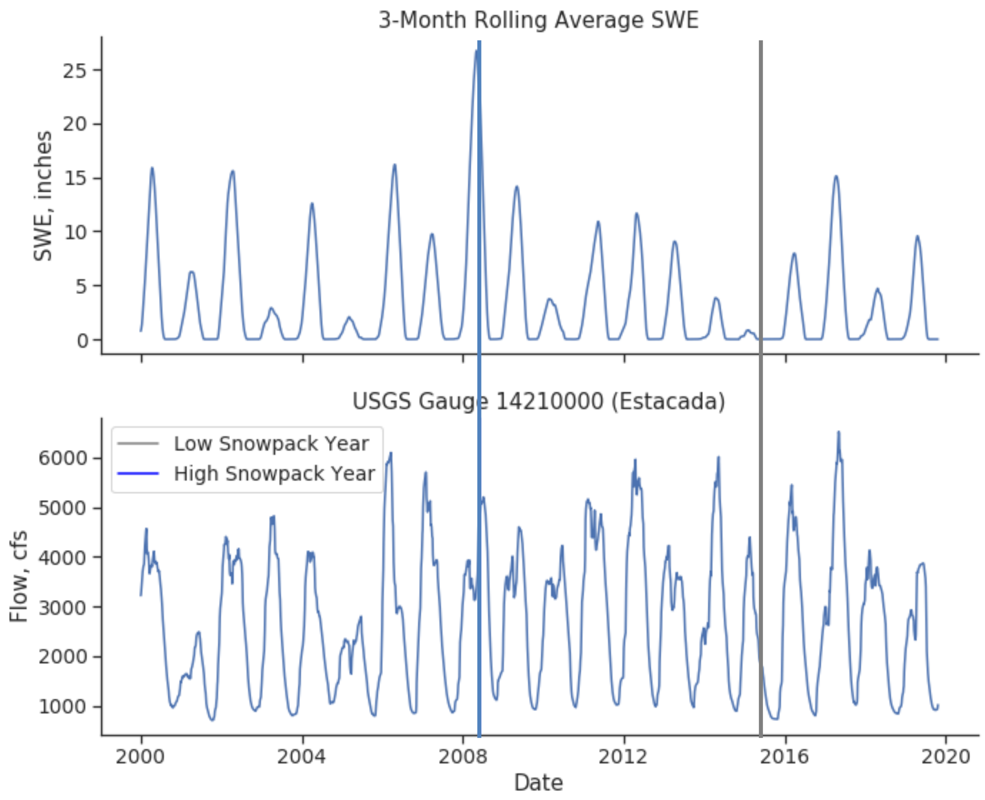
- Goal: find if groundwater level is directly related to snow water equivalent
- Correlations between water-year average snowpack and groundwater level lagged by several years
- No significant correlations found



Streamflow Level Relationship to Antecedent Snowpack

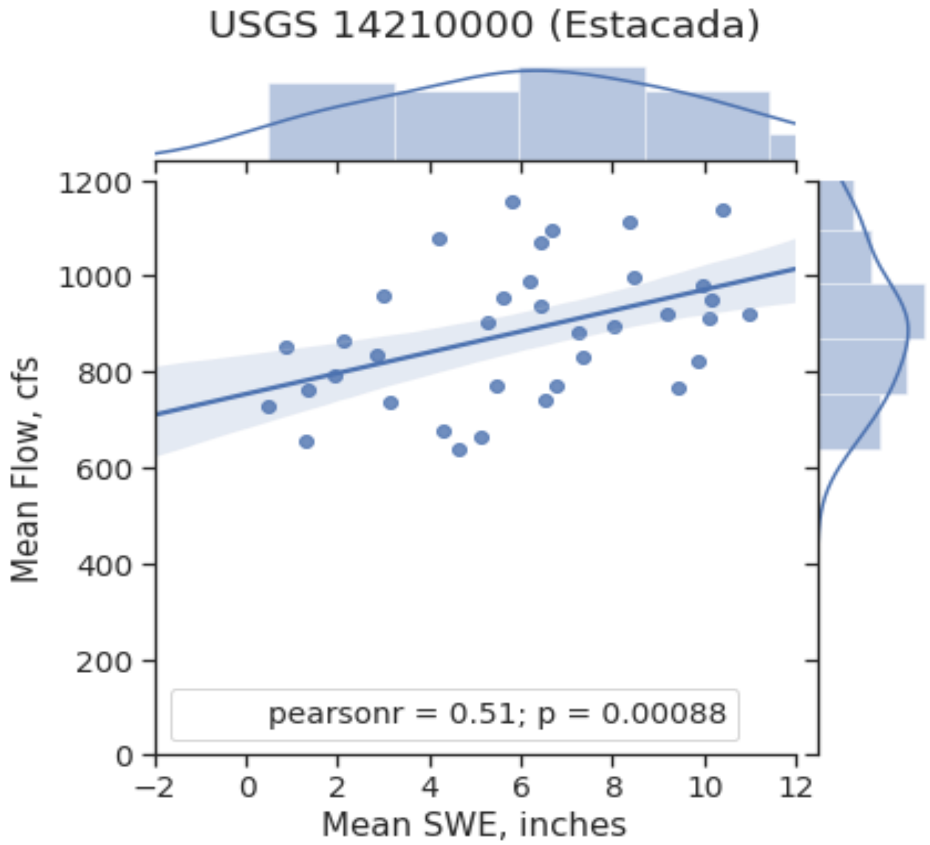
Timeseries Analysis

- 3-month rolling-average plots suggest a potential relationship between maximum SWE and minimum flow for the same water year.



Correlation Analysis

- Goal: find if streamflow is directly related to snow water equivalent
- The relationship between the Estacada gauge average summer low flow and average winter snowpack is promising.



Correlation Analysis

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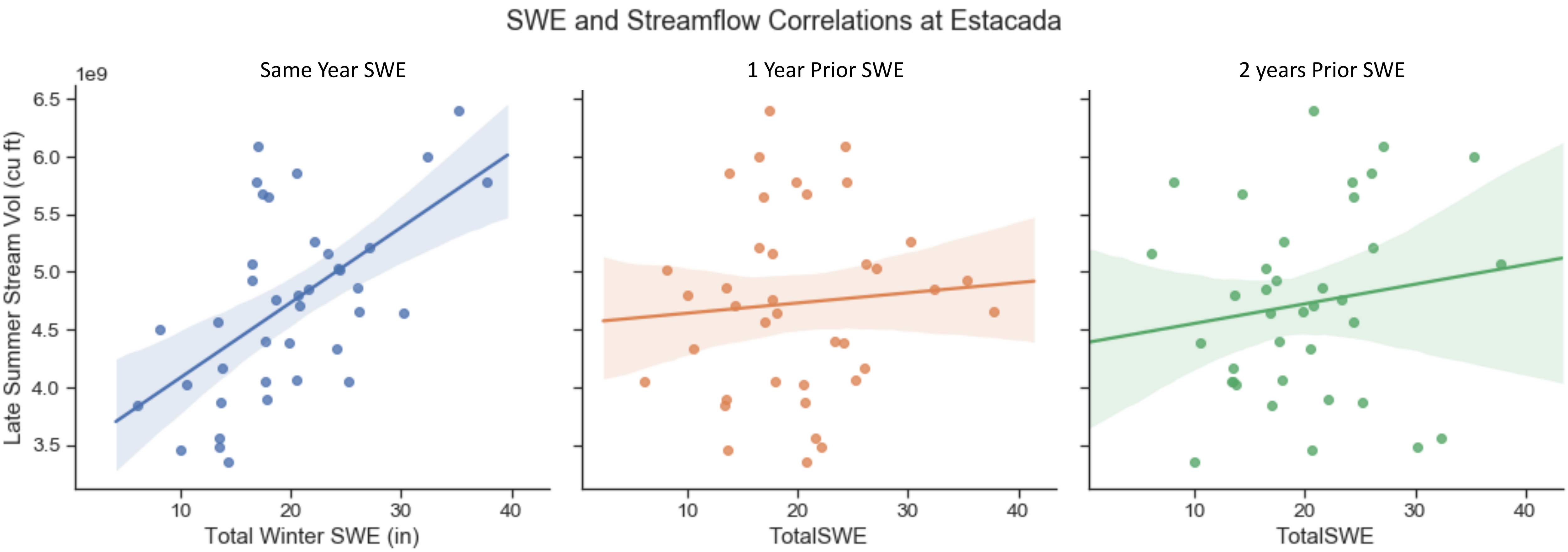
- Conclusion: some limited predictive power over late summer stream flow (50-60% of the variability) with further investigation



Same Year SWE: pearsonr = 0.58; p = 0.0001

Seasonal Decomposition Analysis

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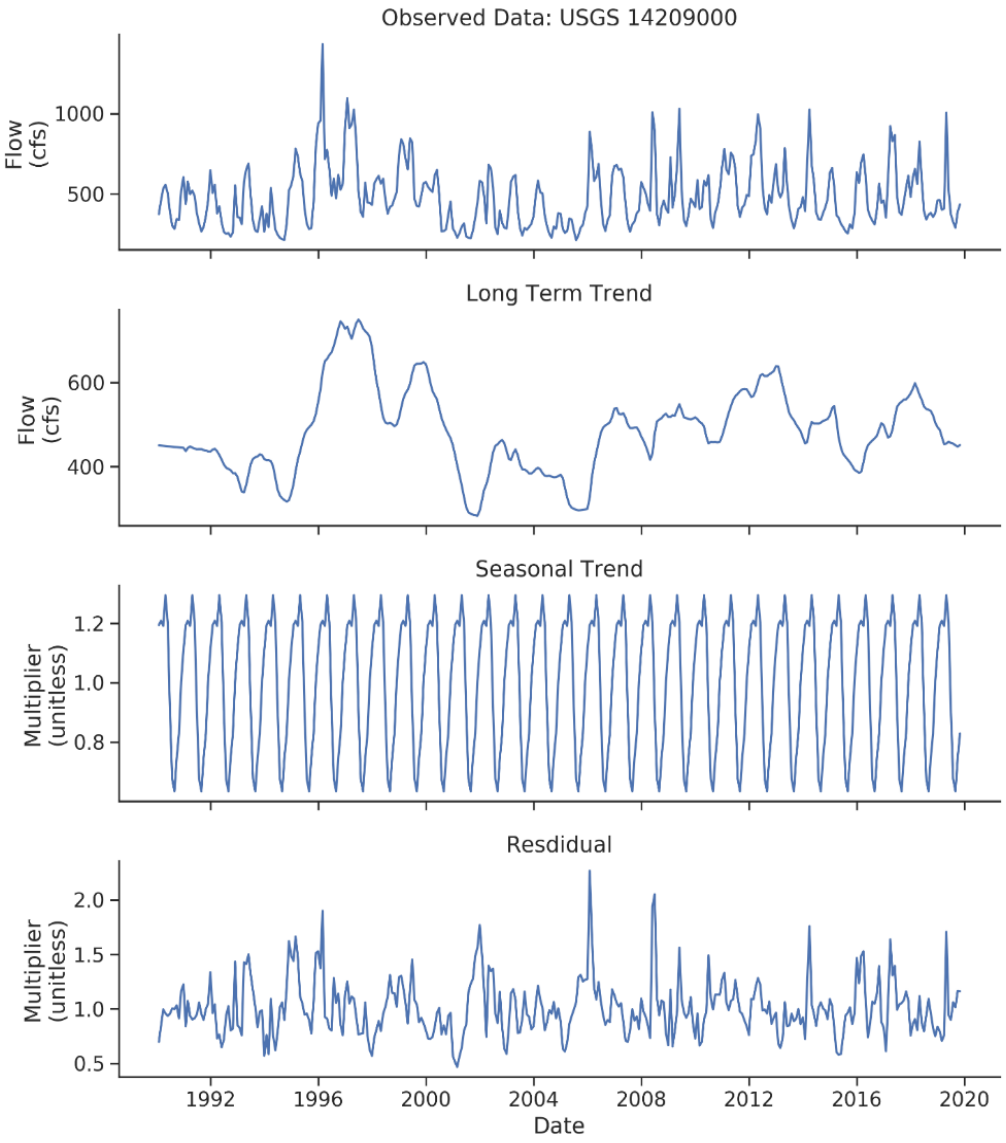
- The monthly mean timeseries seasonal decomposition reveals:
  - Long-term trend (baseflow)
  - Seasonal component (seasonal baseflow and seasonal runoff)
  - Residuals (single occurrence flow events)



Seasonal Decomposition Analysis

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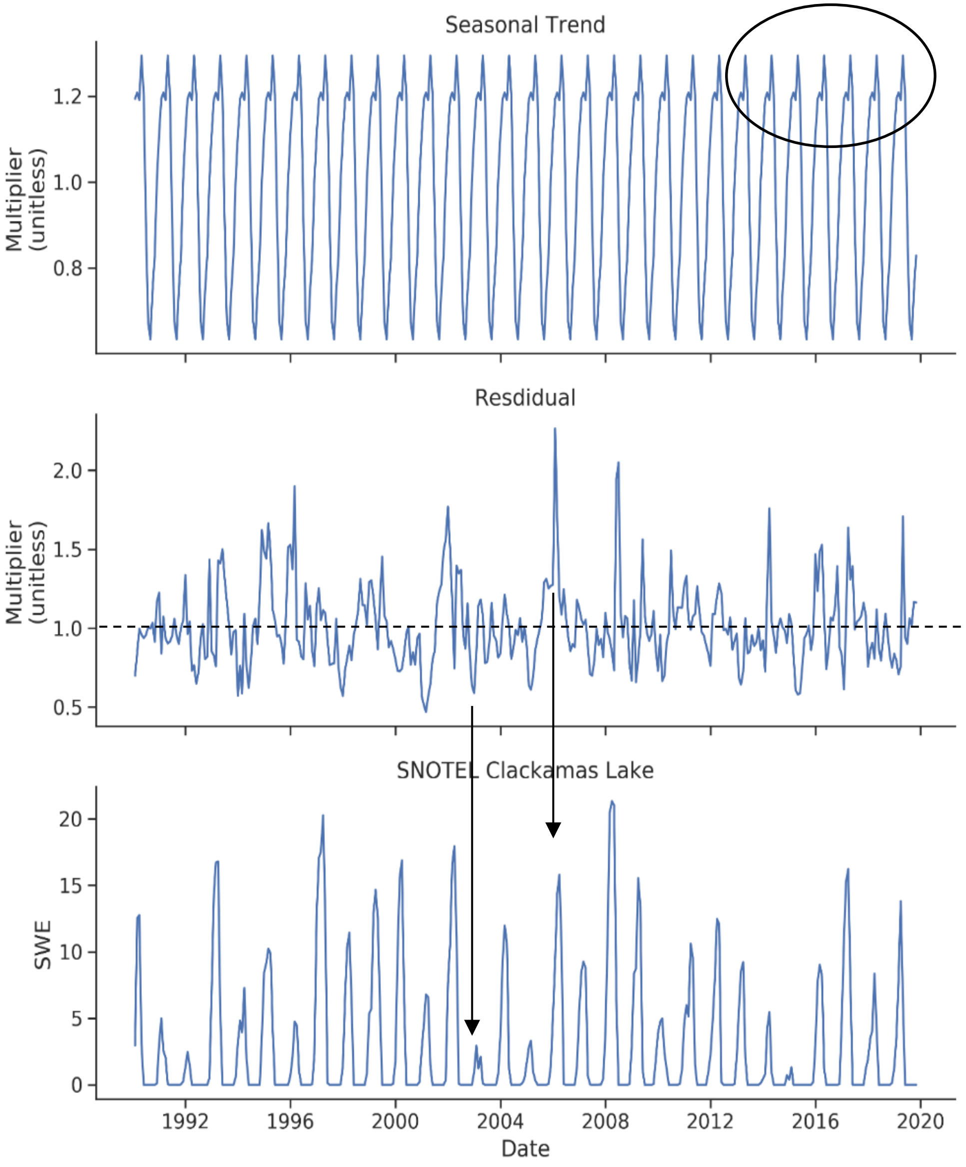

- Notice the double-humped seasonal trend
  - This is consistent with previous studies which found that seasonal flow experiences two periods of high flow:
    - the first is during the wet winter
    - the second, larger one is during spring melt
- The spikes of the residuals mirror the horizontal line at the multiplier of 1
  - This means they are normally distributed, and the decomposition fits well
- Finally, the residual spikes generally coincide with a SWE peak or valley

Watershed Implications

Watershed Implications

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- More than 50% of the variability of the late-summer flow at the Estacada stream gauge is accounted for by the winter snow water equivalent for that same water year.
- However, this relationship does not provide the desired level of predictive power that would be useful for managing fish flow requirements.
- Data limitations and confounding factors in the watershed present obstacles to further statistical analysis

Recommendations

Recommendations

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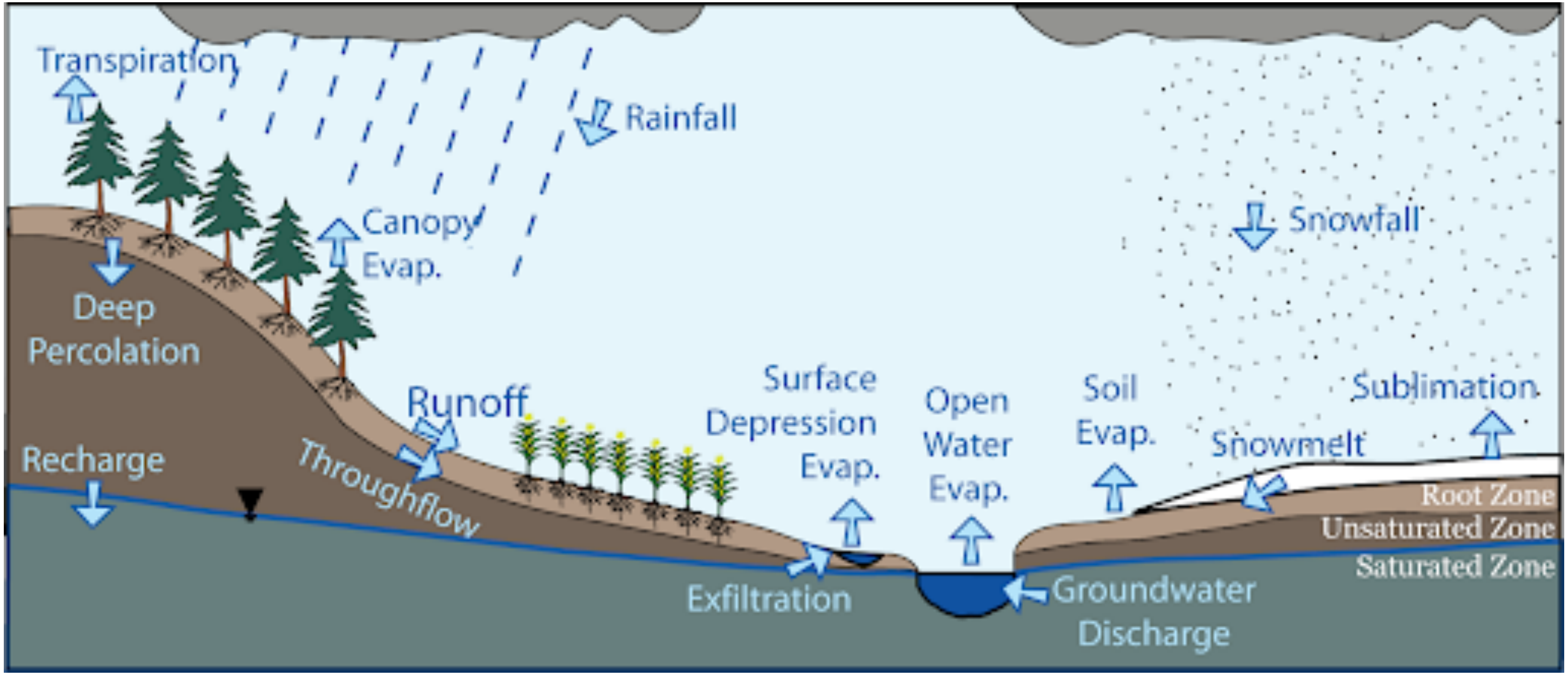
- Further statistical analysis could reveal some of what is left to uncover, however:
  - Acquisition of additional groundwater level data could take years or decades
  - There is no guarantee that further analysis will untangle the influence of confounding factors
- Resources may be spent more effectively on development of a linked hydrologic-groundwater model
  - Such a model could leverage existing work done.

Recommendations

- There are many types of hydrologic and groundwater models
  - Each account for the same water processes in different ways



MSU, 2007

Recommendations

Model(s)	Pros	Cons
PRMS hydrology component + MODFLOW-2000 groundwater model	• A 2014 USGS linked PRMS-MODFLOW model could be leveraged • MODFLOW can be set up simply at first, then refined over time • Both PRMS and MODFLOW are commonly used, well-documented models	• The USGS model domain does not fully cover our area of interest, so the amount that can be carried over is uncertain
MIKE-SHE	• Snowpack and groundwater modeling all in one package • Flexible groundwater component can be set up simply at first, then made more complex over time	• Fully integrated hydrology and groundwater modeling may be overkill and introduce unnecessary complexity
HSPF/LSPC	• Modeling framework includes snowpack, surface water, and baseflow (proxy for groundwater) modules • Could provide preliminary, diagnostic information	• Used most as a surface water model so groundwater modeling module is not well defined • Difficult to leverage into more detailed groundwater modeling

Questions?

Data Limitations

- Lack of groundwater gauges with more than 20 observations
- Lack of wells maintaining long-term observations in the upper Clackamas Basin
- Wells with periods of record that did not overlap, preventing effective correlations to expand/patch data gaps in the records
- Lack of hydrogeologic and stratigraphic information to allow expansion of the area of interest to include connected groundwater aquifers.

Analysis Limitations

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- The analysis presented here provides an overview of key potential relationships in the watershed. Several descriptive statistics originally included in the Scope of Work (SOW), such as boxplots and histograms of individual datasets, were excluded from this report and can be provided as-is or in a future report upon request.
- Quantile-quantile (QQ) plots are typically used to verify strong correlations. In the absence of strong statistically significant correlations QQ plots were dismissed from the analysis.
- We did not analyze results from the Mann-Whitney rank sum test after observing poor statistically significant relationships between SWE and streamflow in preceding analyses.
- We did not analyze results from the Seasonal Kendall’s tau to statistically identify long term temporal trends in flow rate because no long-term trend was visually observed after time series decomposition.

Streamflow Gauge Summary

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