Summer 2016

Comparison of the Chemical and Isotopic Composition of Groundwater and Surface Water in the South Sound Region

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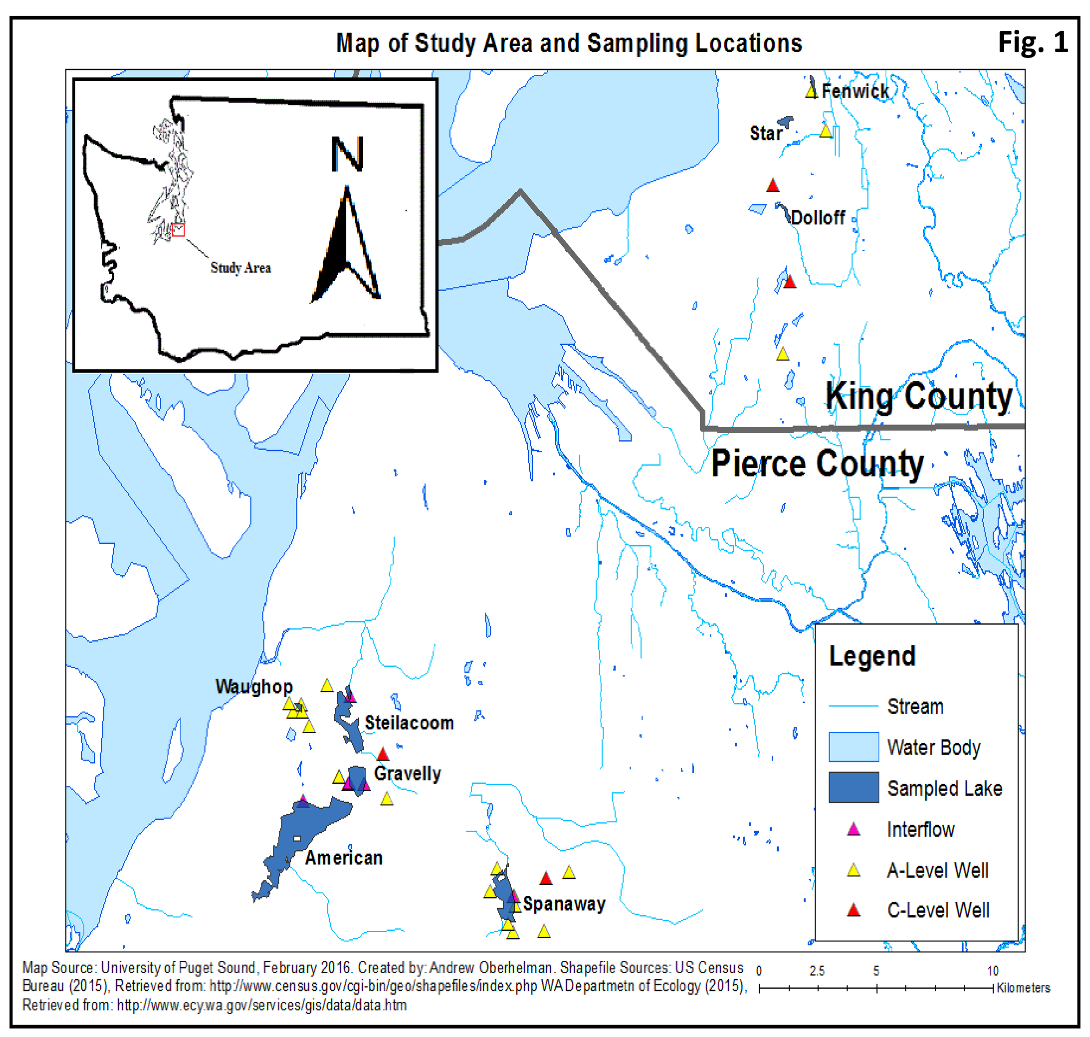
Introduction

The South Puget Sound region contains over 460 lakes, many of which originated as kettles. Although these lakes vary in size and depth, all are hosted in similar glacial outwash deposits and are fed by some combination of precipitation, surface runoff, and groundwater inflows, so one would expect their water compositions to be broadly similar. However, data collected by Puget Sound students over the past ~10 years reveal this is not the case: each of the dozen lakes studied is chemically distinct. Furthermore, plots of lake water chemistry define linear arrays suggestive of mixing between chemically distinct water sources (Fig. 2). The goal of this study is to analyze potential water sources, including surface runoff and groundwater, and assess whether mixing of these waters in varying proportions can explain variations in lake chemistry.

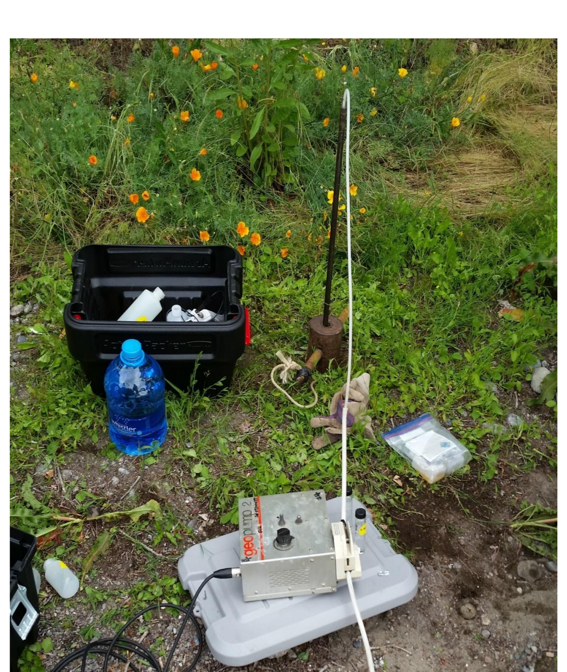
Research Questions

- Can observed chemical variations in the lakes be explained by mixing? If so, are the variations due to different proportions of groundwater inflow or to inputs of chemically different groundwater, or to both?
- What is the cause of high Mg^{2+} and SO_4 concentrations in groundwater?
- Can regional groundwater patterns be identified using existing and generated data?



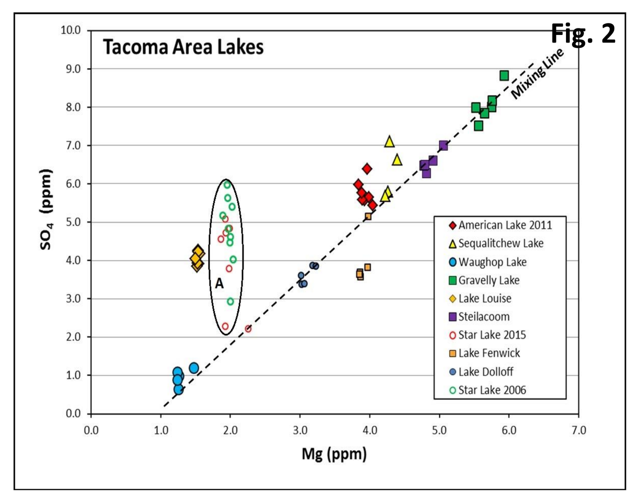
Methods

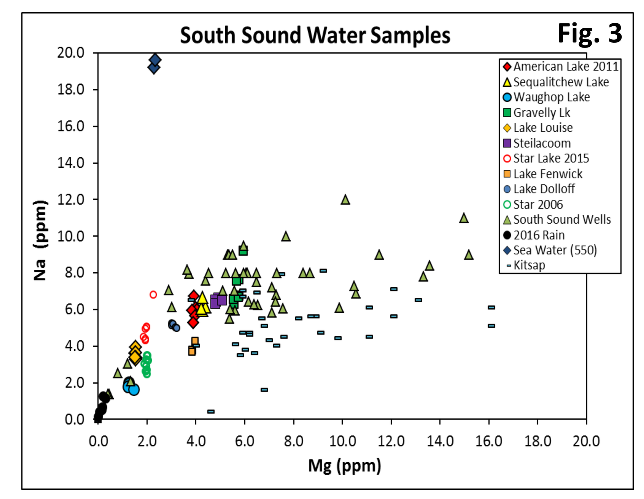
- 600ml of each sample were collected in polyethylene bottles washed with 20% HNO_3
- Wells were sampled after purging using a Geotech peristaltic pump, Proactive Tornado submersible Pump, or an onsite pump (See Below Images)
- Interflow was sampled using a drive point piezometer and a Geotech peristaltic pump (See Below Images).
- 200ml of each sample were filtered with 100ml being acidified to 2% HNO_3 for ICP-ES (major cations) and ICP-MS (trace metals) while the other 100ml were stored in the lab fridge for IC (major anions).
- The alkalinity of each sample was measured by titration
- The isotopic composition of each sample was measured using Picarro Cavity Ring Down Spectrometry.
- Mixing was modeled using a mass balance spreadsheet
- Charge balance error was calculated for each sample to assess the accuracy of analyses

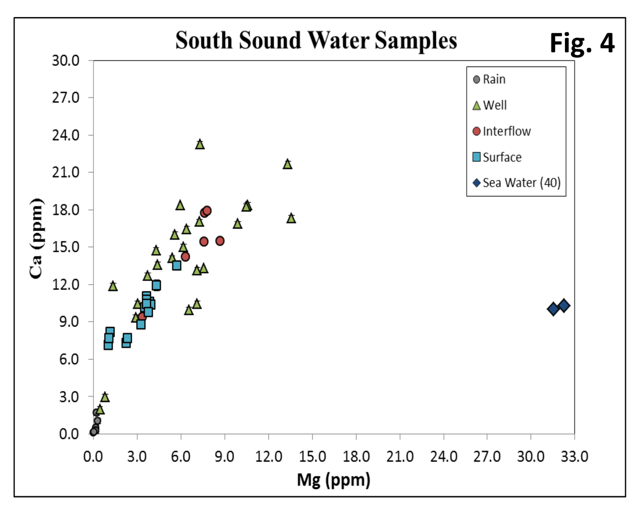


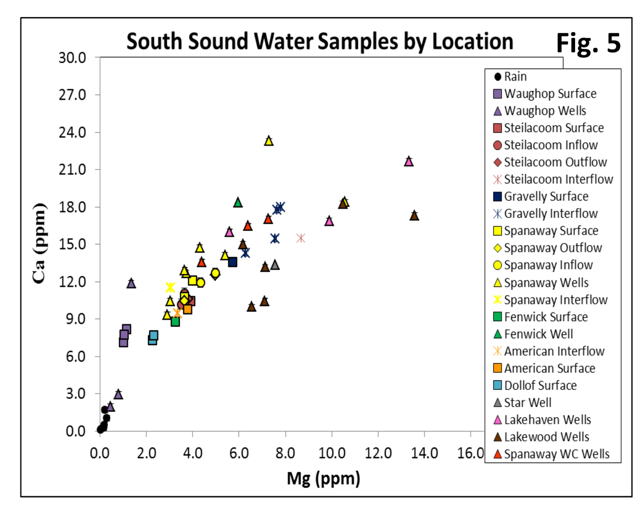
Surface Water Chemistry

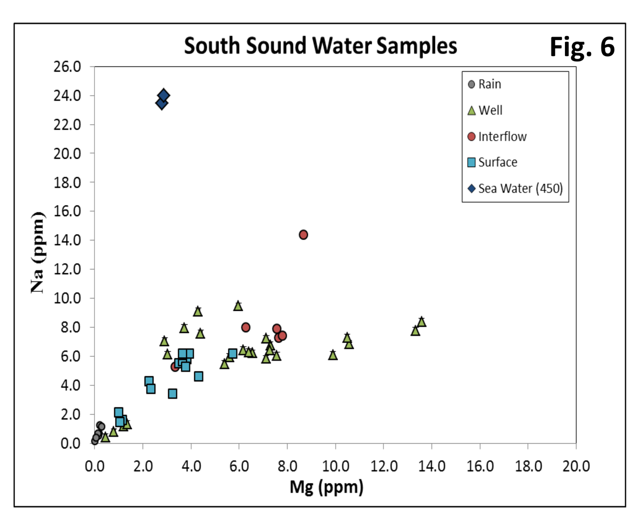
- Linear trends in the below graphs represent mixing between two sources, rain and groundwater. (Figs. 2-8)
- Groundwater is the high concentration component, exhibiting significant intra-aquifer variation, while rain or runoff is the dilute component (Figs. 2-8)
- Figures 2, 3, and 5 suggest Waughop Lake is rain dominated while Gravelly Lake is groundwater dominated
- Seawater does not appear to be a component in the mixing trend for these lakes
- Mg concentrations in groundwater appear to reach a maximum value while other conservative elements do not (Figs. 3 and 6)
- Figures 6-8 along with historical data tentatively suggest that there may be two diverging chemical trends within South Sound groundwater

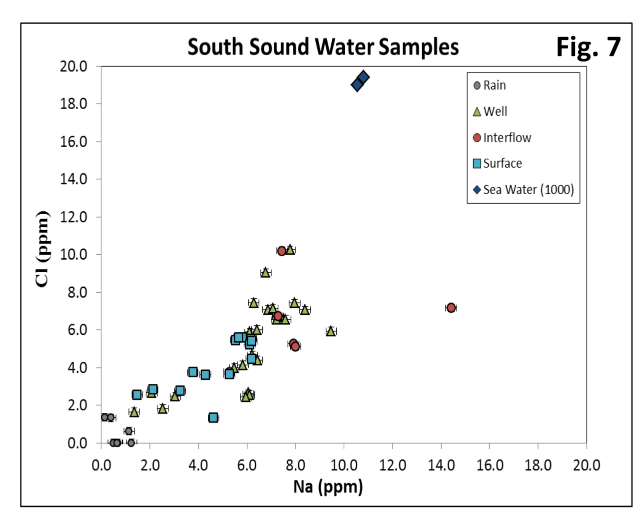


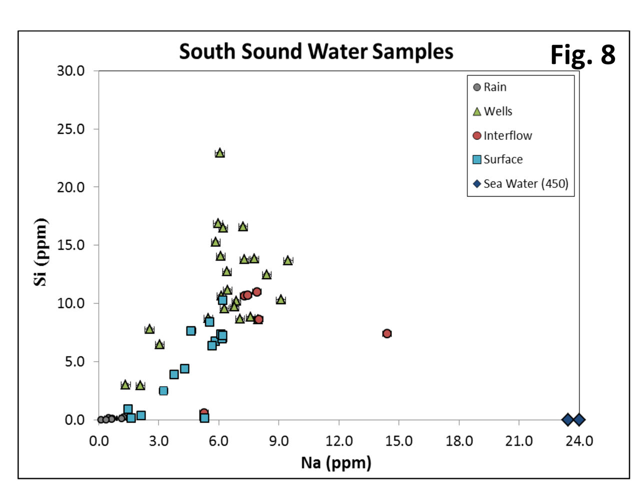


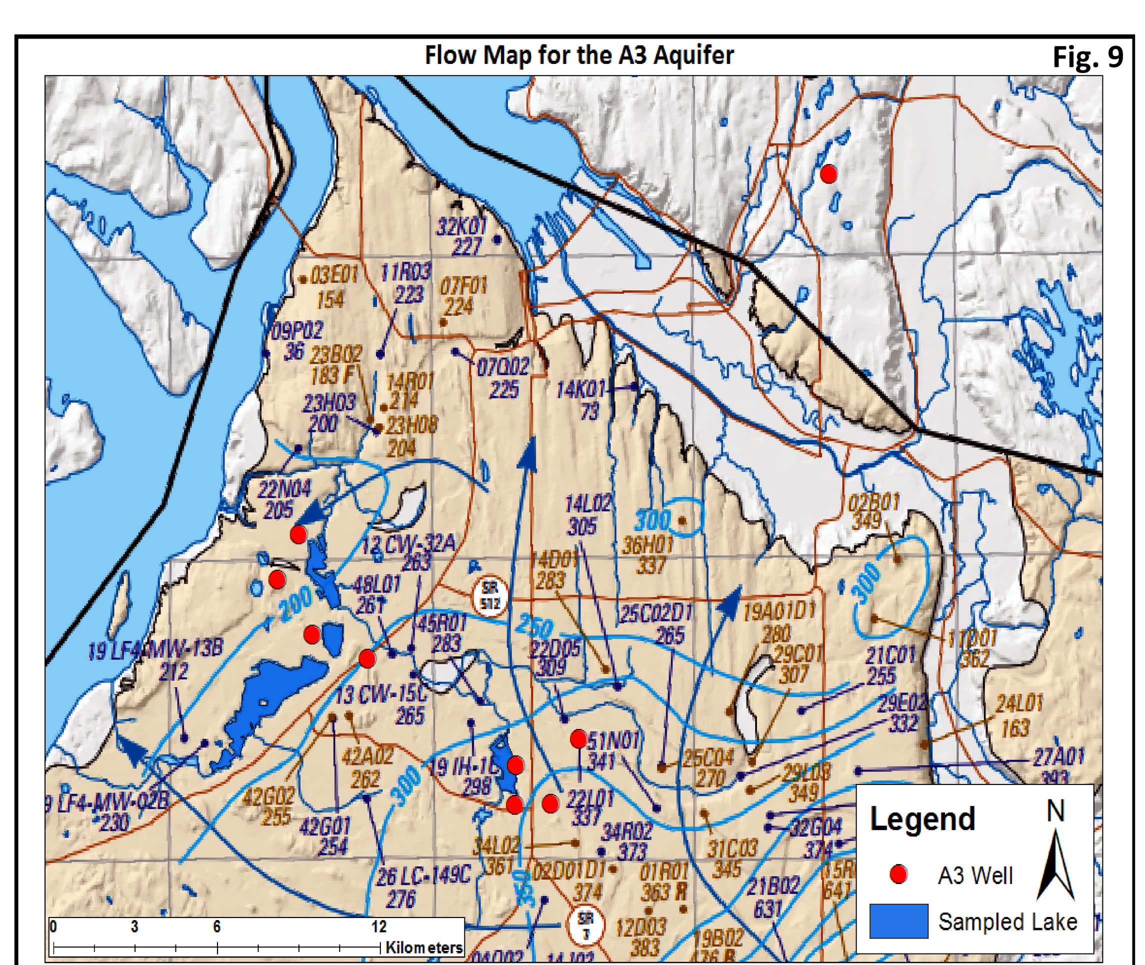












Modeling Water Sources

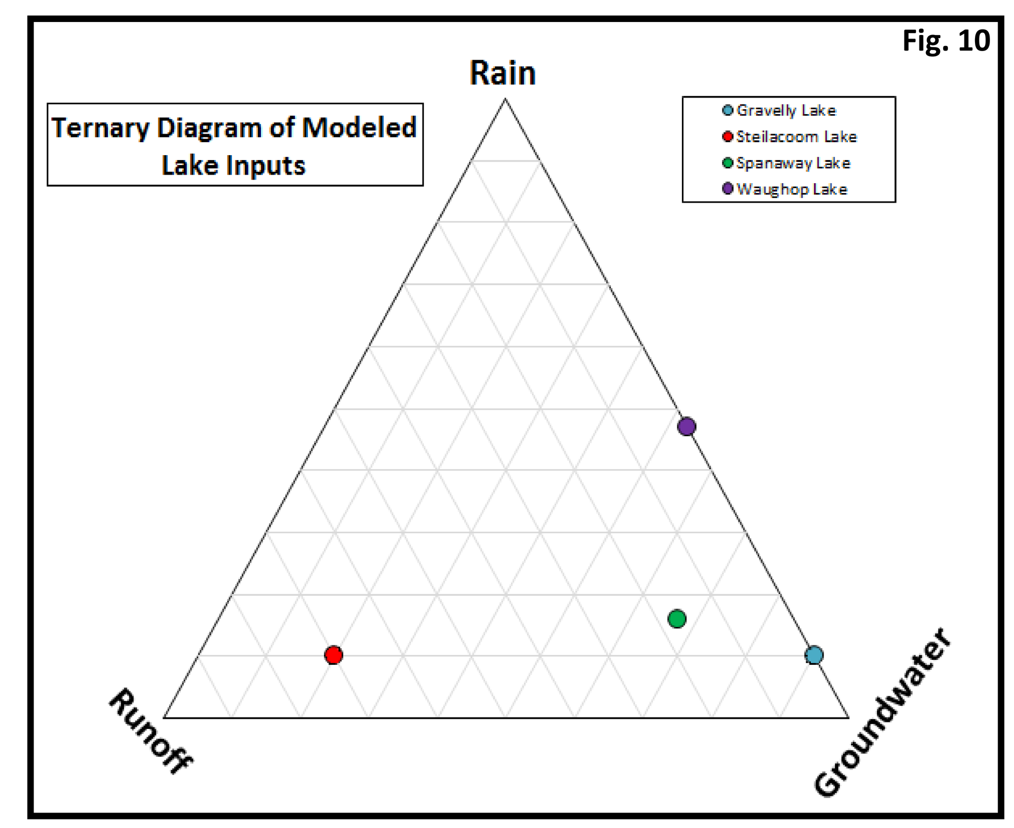
- Conservative elements (Cl, Mg, Na, Cl, and SO4) provide a means to obtain semi-quantitative estimates of the proportions of water sources in each of the modeled lakes (Table 1 and Fig. 10)
- The results of mass balance modeling are consistent with the proportions of lake inputs inferred from Figures 2, 3, 5, and 9.
- Proportions of lake inputs calculated from isotopic data are similar to those obtained from the chemical data for Gravelly Lake and Steilacoom Lake (Table 2)
- Isotopic values of rain vary seasonally, being lighter in the winter (Fig. 12). Groundwater samples overlap in isotopic composition with winter precipitation, indicating recharge of the aquifers supplying these lakes occurs mainly during this season (Fig. 11)

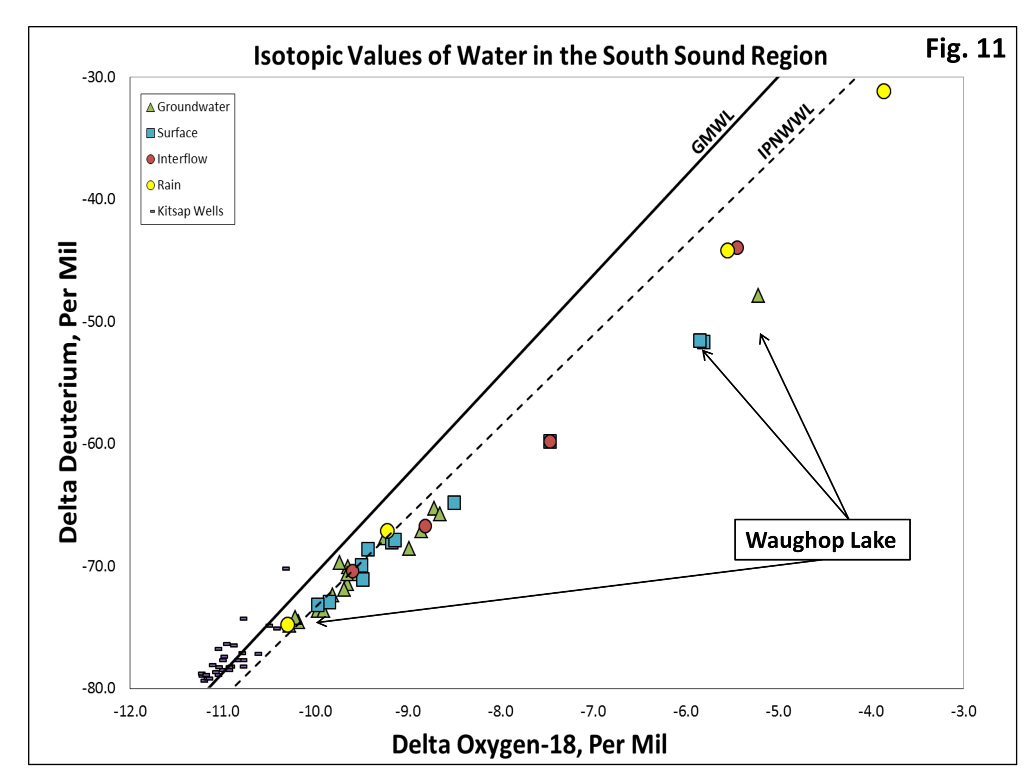
Table 1. Summary of Modeled Mixing Showing the Fraction of each Lake Input

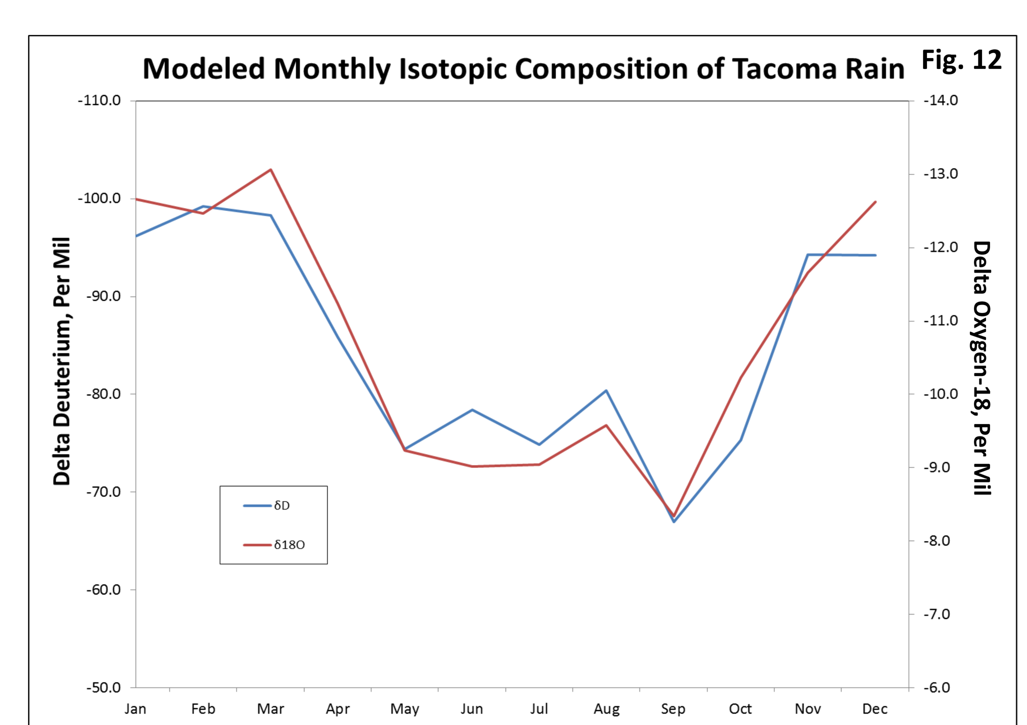
Component:	Rain	Interflow	A-Level	C-Level	Inflow 1	Inflow 2	Pore Water	Shallow Lake Wells	Sample ID's
Gravelly Lk	0.10 (0.08-0.11)	0.15 (0.05-0.24)	0.70 (0.58-0.81)	0.05 (0.05-0.07)	-	-	-	N/A	G003/H-1/D-2
Steilacoom Lk	0.10 (0.10-0.12)	0.10 (0.09-0.11)	0.10 (0.10-0.14)	-	0.34 (0.30-0.40)	0.36 (0.3-0.4)	-	N/A	H-1/Ponce/Clover
Spanaway Lk	0.16 (0.12-0.20)	0.27 (0.20-0.30)	0.15 (0.15-0.26)	-	0.17 (0.15-0.21)	-	-	0.25 (0.10-.30)	Well 1/Sp002
Waughop Lk	0.47 (0.43-0.47)	-	0.11 (0.07-0.11)	-	-	-	0.06 (0.05-0.10)	-	L-2/WGW-AVG

Table 2. Comparsion of Isotpe and Ion Mixing Ratios

Input:	Rain	C-Level	A-Level	Interflow	Inflow	Inflow 2	% Diff. between Measured and Mixed
Gravelly Lake							
Best Iso ratio:	0.13	0.04	0.65	0.18	-	-	0.31
Best Ion Ratio:	0.10	0.05	0.70	0.15	-	-	2.62
Abs Val Difference:	0.03	0.01	0.05	0.03	-	-	-
Steilacoom Lake							
Best Iso ratio:	0.09	-	0.17	0.09	0.33	0.32	0.16
Best Ion Ratio:	0.10	-	0.10	0.10	0.34	0.36	5.10
Abs Val Difference:	0.01	-	0.07	0.01	0.01	0.04	-

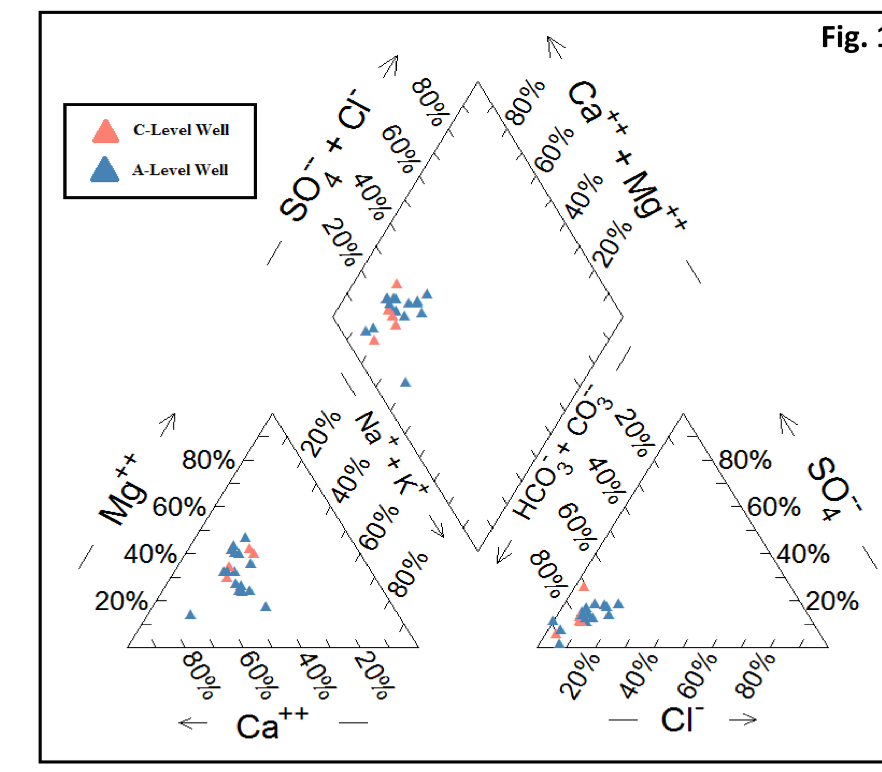


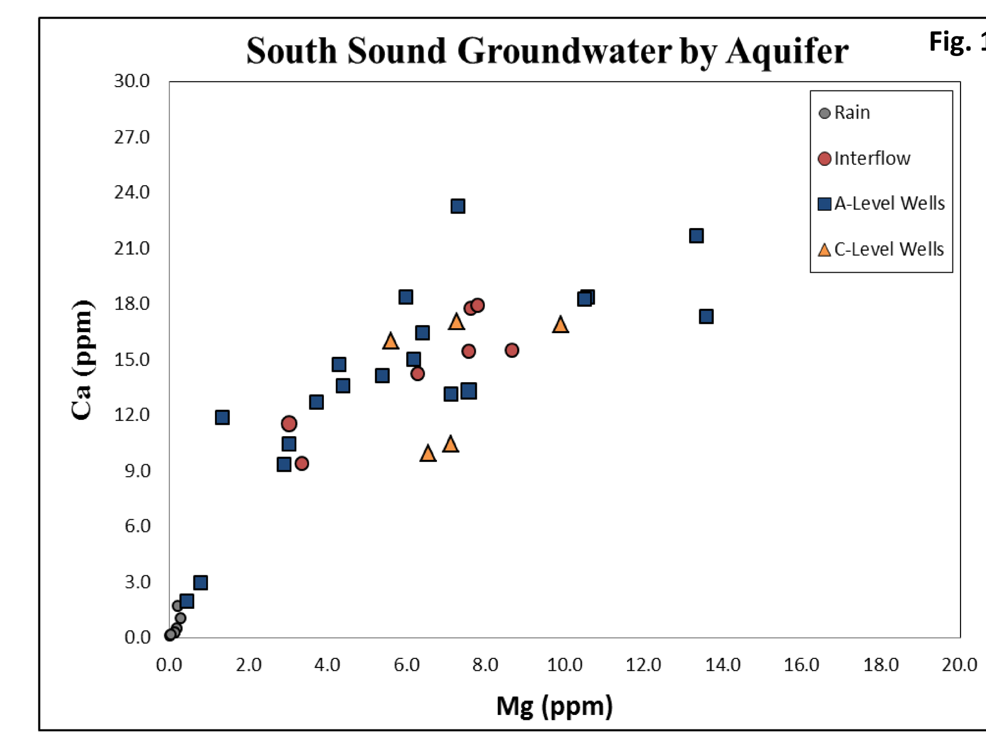


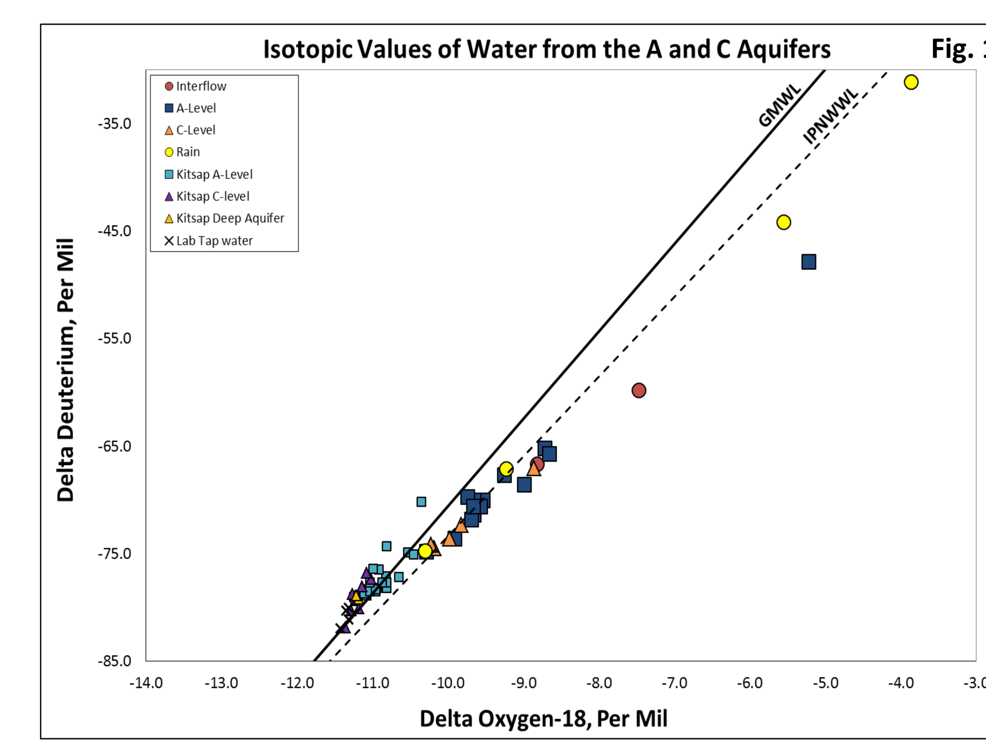


Aquifer Chemistry

- Waters from the "A" and "C" aquifers overlap significantly in chemical and O/H isotopic compositions (Figs. 13, 14, and 15)
- There are no systematic geographic trends in conservative element concentrations in groundwater in the study area (Figs 13, 14, and 15)







Implications

- Mass balance ("mixing") calculations with conservative elements and with O and H isotopes provides a quick and fairly accurate method of estimating the contributions of different water sources to a lake
- Groundwater inflow is a significant component of the modeled South Sound Lakes, and probably others in the region as well.
- Knowledge of water sources is important for managing lake health and for understanding movement of pollutants.

Future Work

- Monitor, chemically and isotopically, a series of lakes and their inputs on a monthly basis to adjust the mixing model for seasonal variations.
- Thoroughly characterize the "C" aquifer for a better comparison with the "A" aquifer
- Explore the influence of aquifer mineralogy on groundwater chemistry

Acknowledgements

The author thanks Burt Clothier (Robinson Noble) for providing guidance and essential contacts for groundwater collection, Steve Cox (USGS) for help with sampling shallow interflow and for providing advice on well sampling, the Lakehaven, Lakewood, and Spanaway Water Districts for providing access to their municipal wells, and numerous private land owners who allowed sampling of their wells. Lastly, the author thanks the McCormick Grant for funding this research.