Analysis of Surface Water Quality and Surface Geology Relationship in the Chambers-Clover Creek Watershed

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Research Question

How does the surface geology affect the water quality of the north fork and the south fork tributaries in Clover Creek?

Hypothesis

The surface geology at each site in Clover Creek will not accurately demonstrate why we see small variations in surface water quality data and we may have to look under the surface to determine a reasonable conclusion.

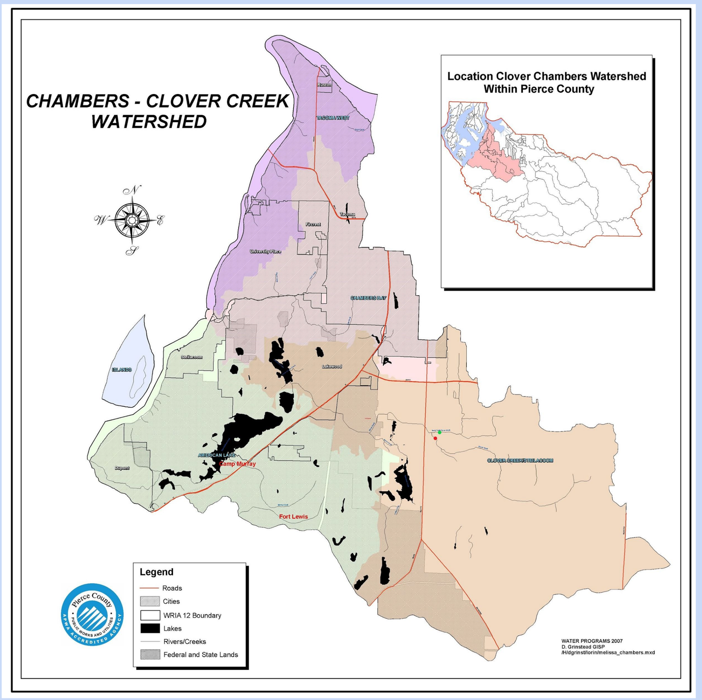

Figure 1. Location of sites (Clover Creek Reserve and Mayfair) and waterways in the CCCW (n.d.). Retrieved from https://www.co.pierce.wa.us/1860/Chambers---Clover-Watershed-Council?nid=1860

Abstract

This research regarding recent water quality analysis collection in collaboration with present surface geologic data was inspired by observations made while doing field work for the Environmental Methods 350 course at Pacific Lutheran. This project is derived from an interest in connecting those surface water qualities to surface geologic units, properties, and aquifers present within our Chambers-Clover Creek Watershed with the intention of connecting the interpretations of those data sets. Water quality parameters collected by environmental students were assessed and the water quality indices (WQI) at each site during each spring were calculated (Mitchell & Stapp, 1992). Surface geology, aquifer characteristics/locations and groundwater conductivity were assessed at Mayfair and Clover Creek Reserve sites (Savoca et al., 2010; Johnson et al., 2011). While the geologic and water quality properties are comparable at each study site, the presence of various aquifers potentially impacts those surface WQI based on infiltration rates, geologic characteristics, and groundwater flow patterns. My analysis of the current published data and connections to surface water quality did not provide significant improvements to the understanding of those connections in the CCCW, but does provide information that can be used in conjunction with further research on the topic.

Introduction

The water quality in the Chambers-Clover Creek Watershed (CCCW), extending north from Commencement Bay to Dupont in the south and east to Fredrickson, has been monitored for over 15 years (Figure 2). The CCCW has been an interest in past studies that either analyze the local water qualities of the streams and lakes, or that analyze the surface geology of the watershed as a whole. Historically, the water quality in the CCCW is generally poor and includes water bodies that do not meet Washington State's water quality criteria (Department of Ecology State of Washington, 2013; Kyer & Smolko, 2018). Water quality is highly impacted by land use, climate, and geology. Surface lithology impacts water flow through aquifers and have a strong influence on groundwater and surface water qualities (Warner & Ayotte, 2015). Calculating water quality indices (WQI) helps give a holistic view of the chemical composition of the studied waterway (Mitchell & Stapp, 1992). In the watershed and surrounding area, the underlying surface geology all comes from glacially deposited sediment during the last glaciation (Figure 3; Johnson et al., 2011). It is my goal to take what we learned about the impacts of water quality and use them to include existing data about the surface geology in the watershed to conclude how the water qualities at existing data sites may be influenced by the underlying geologic units.

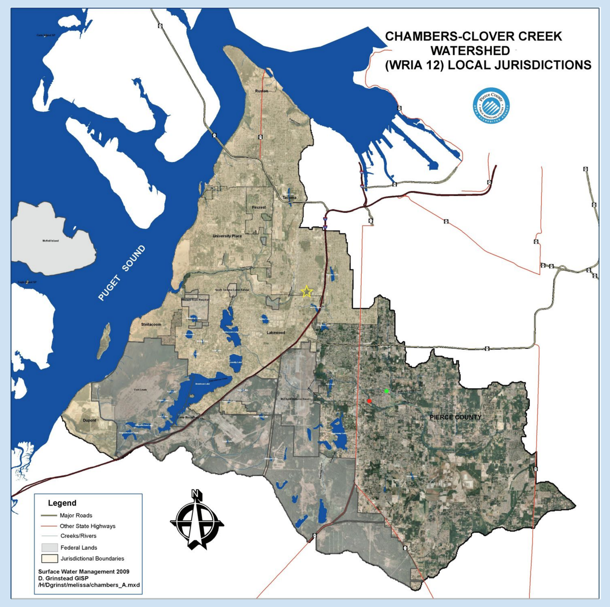

Figure 2. Chambers-Clover Creek Watershed boundaries with Mayfair (green) and Clover Creek Reserve (red) sites indicated (Kyer & Smolko, 2018).

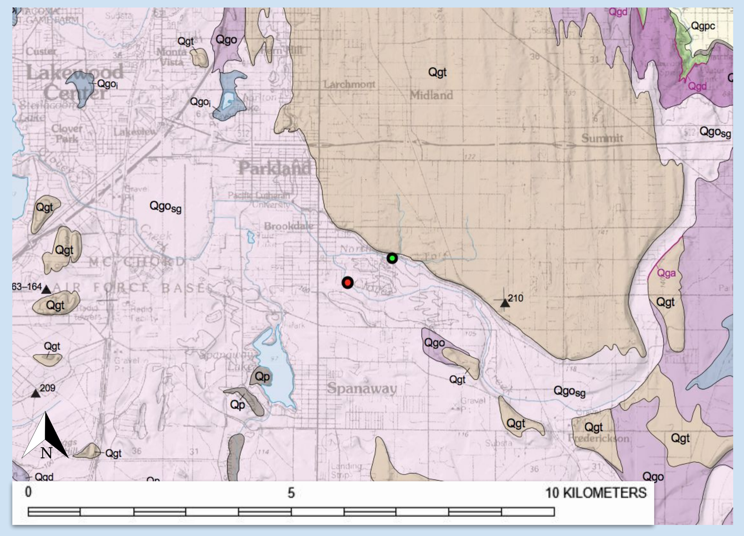

Figure 3. Image of map provided by WA State Department of Natural Resources, indicating Mayfair and Clover Creek Reserve locations. Unit Qgosg represents recessional outwash, Steilacoom Gravel consisting of pebbles with boulders, local cross-bedding and ice-contact depressions (Shuster et. al, 2015). Qgt represents Vashon Till, consisting of clay, silt, sand and gravel with low permeability and porosity and includes features like moraines, drumlins and flutes (Shuster et. al, 2015).

Background

The most recent advance and retreat of glaciers in the Pleistocene epoch, the Puget Lobe of the Cordilleran ice sheet, has left behind complex intervals of glacial and interglacial deposited sediments (Johnson et al., 2011). During those glacial and interglacial periods, advance outwash sands and gravels, glacial till, and interglacial clays/silts were deposited in area (Johnson et al., 2011). Mayfair Playfield, a site on the North Fork tributary to Clover Creek, and the Clover Creek Reserve are two locations that have been studied in the CCCW by students during past P.L.U. Environmental Methods courses. Monitoring the water quality in CCCW has prompted the WA State Department of Ecology to label both the North Fork and Clover Creek Reserve site on Washington's 303(d) list of impaired water bodies (Reiman, n.d.). Labeled as Category 5 for bacteria, both sites require a water improvement plan. The Reserve also measures as Category 2 for temperature, indicating concern without violating standards. Both sites are located in similar geologic units and are impacted by varying aquifers that spread throughout the CCCW (Savoca et al., 2010). These sites give insight to possible impacts that surface geology and the presence of aquifers have on surface water quality at a small-scale within our watershed.

	Dissolved Oxygen (%)	Fecal Coliform (colonies/ 100ml)	pH	BOD (mg/l)	Temp. ℃	Phos-phate (mg/l)	Nitrate (mg/l)	Turbidity (NTU)	Total Solids (mg/l)	Overall WQI
Mayfair **2017**	113	603	7	4.5	8.4	0.24	0.63	6.9	115.97	72
Clover Creek Reserve **2017**	84	451	7	0	10	0.26	1.55	6.2	109.37	76
Mayfair **2018**	103.2	287	7.2	4.5	12.1	0.26	0.43	5.89	121	73
Clover Creek Reserve **2018**	103.5	517	7.1	2.5	10.3	0.1	1.7	2.2	131	75

Table 1. Water Quality indices for spring of 2017 and 2018 (Oram, n.d.).

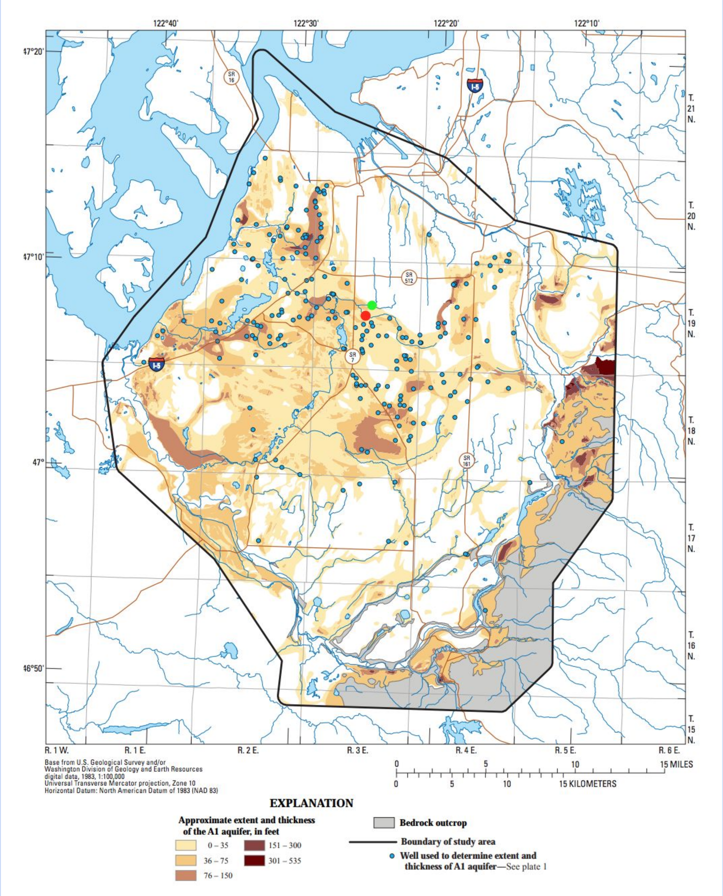

Figure 4 . Mayfair indicated by green dot; Clover Creek reserve indicated by red dot. A1 aquifer - land surface, Vashon recessional outwash deposits (Qvr); consistent and coarse (Savoca et. al, 2015).

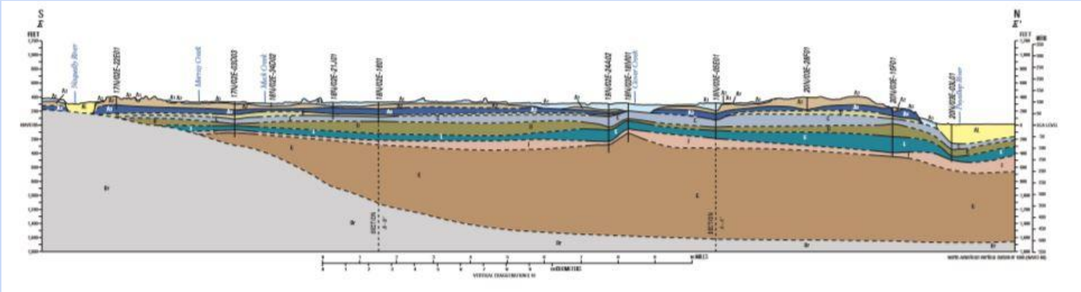

Figure 5. Image from Savoca et al., indicating the location and extent of various aquifers and subsurface geologic units at Clover Creek (2010). Clover Creek is immediately impacted by the A1 aquifer (light blue) as it is the closest, unconfined aquifer to the surface.

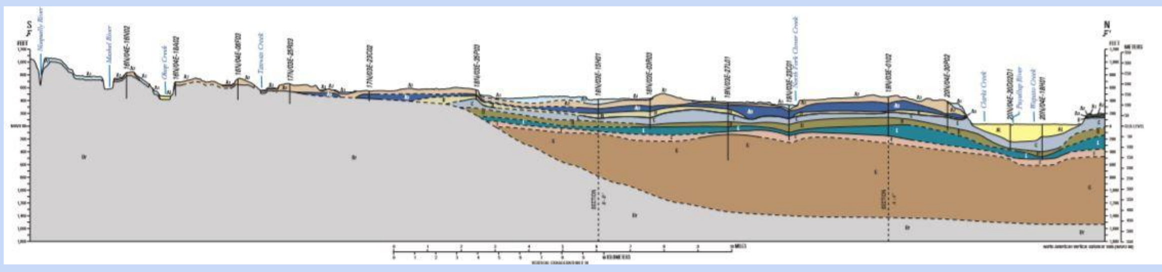

Figure 6. From Savoca et al., indicating location and extent of aquifer units where the North Fork of Clover Creek is located (2010).

Results

- The surface geology at each site shows little variation due to the Vashon Stade of the Fraser Glaciation (Figure 3)
  - Qgo recessional outwash at both sites - coarse and moderately sorted materials with more groundwater storage
  - Qgt along North Fork tributary - increased amounts of fine, well sorted materials present at surface
- Water quality indices are comparable at both sites (Table 1)
  - Clover Creek Reserve impacted by fecal coliform both years
  - Dissolved oxygen carries 0.17 of weight determining WQI, excellent at both sites (Oram, n.d)
  - Turbidity measurements are higher at Mayfair where there is an increase in the presence of till.
- Both the North Fork and Clover Creek streams are impacted by the A1 unconfined aquifer (Figure 4)
- The A1 aquifer at each site is relatively thin - ranging from 0-75 ft in extent (Figure 4)
- The thickness of the A1 aquifer is greater at Clover Creek then along the north fork tributary (Figure 5)
  - The underlying aquifers do not contribute to surface water quality conditions (Figure 5)

Methods

- Review of published literature and past studies to determine the water quality and surface geology of the watershed.
- Data taken in North Fork and Clover Creek in the CCCW by Environmental Methods students (Table 1).
  - Available data collected during spring semesters of 2017-2018
  - Each fork categorized using Washington Department of Ecology's water quality atlas data showing concerns about surface water qualities (Reiman, n.d.)
- Water quality indices calculated using the Washington water quality parameters and online WQI calculator (Table 1; Oram, n.d.)
  - 9 parameters - combination of values using weighted mean (Mitchell & Stapp, 1992)
    - Weighted factors measure relative importance of each test in determining WQ (Mitchell & Stapp, 1992)
    - 90-100: Excellent; 70-90: Good; 50-70: Medium; 25-50 Poor; 0-25: Very Poor (Mitchell & Stapp, 1992)
  - Phosphates, D.O., nitrates, temperature change, pH, B.O.D., turbidity, total solids, and fecal coliform measurements
    - Biological oxygen demand (B.O.D.) is index of the degree of organic pollution present; D.O. refers to oxygen available for use by organisms (Mitchell & Stapp, 1992)
- The water quality index data averaged at each site is compared to the underlying geologic unit in which the site is located
  - Geologic surface map from WA Division of Geology and Earth Resources (2010).
  - Existing aquifers from Savoca et al. (2010)

Interpretations

- Variations in lithology may be used in conjunction with local aquifers to determine geologic impacts on surface water quality (Savoca et al., 2010)
- Though both sites are found in recessional outwash materials, the Mayfair tributaries extend through glacial till; assumption that there is less groundwater infiltration and more surface runoff contributing to this sites overall water quality.
  - Low permeability results in less groundwater recharge, increasing the amount of water in the stream and decreasing groundwater levels (Johnson et al., 2011)
  - Groundwater flowing towards northwest contributes to baseflow in Clover Creek (Johnson et al., 2011)
- Outwash sediments assist groundwater flow and can hold large volumes of water for supply, while till is inhibits flow and producing less water for stream supply through groundwater recharge (Johnson et al., 2011)
  - Thus we might expect Mayfair specifically to have limited water supply during drier seasons, impacting the streams overall WQI attributes such as dissolved oxygen and temperature.
  - Dissolved oxygen is impacted by temperature, and the temperature at my sites is lower at the north fork where the stream was highly impacted by till.
- The presence of A1 aquifer at surface allows for ground water infiltration to occur at each site, though is not present at Mayfair's tributaries.
  - A1 has large initial specific storage - groundwater storage (Johnson et al., 2011)
- Although deeper aquifers are present, the WQ at these sites may only be affected by surface aquifer conditions - A1 aquifer in CCCW (Savoca et al., 2010)
  - The underlying aquifers do not contribute to surface water quality conditions because anything below the A1 aquifer has a greater effect on groundwater than surface water qualities (Figure 5; Savoca et al., 2010)
- Sediment weathering and suspension can contribute to the amount of total solids present in a stream and the turbidity of a stream, overall decreasing water quality and ecosystem health (Mitchell & Stapp, 1992).
  - The greater amounts of till/fine material at the Mayfair tributary can be attributed to the respective turbidity measurements, influenced by D.O. and B.O.D. (Tables 1 & 2)

Conclusions

Surface water is impacted and can be altered both physically and chemically by the geologic units it runs over and through. Aspects of the WQI parameters at Mayfair and the Clover Creek Reserve can be attributed to the surface geologic units they are located in, such as turbidity, temperature, total/suspended solids, and dissolved oxygen. Both sites were impacted by the A1 aquifer, ranging from 0-75 feet in thickness and depth (Savoca et al., 2010). When observing the relationship between geology and surface WQ, geologic units and aquifer presences must be consulted. Future studies may be conducted to observe the chemical properties of the surface geologic units and aquifers in the watershed to conclude the effects surface geology has on water quality parameters.

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