# Geomorphology, hydrology, and geochemistry of a burned and logged stream catchment: Lemah Creek, McCall, Idaho

**Rachael C. Howse**
Department of Geology, Beloit College, 700 College St., Beloit, WI 53511-5595
*Faculty sponsor: Carl V. Mendelson, Beloit College*

**Kirsten L. Murch**
Department of Geology, Smith College, Northampton, MA 01063
*Faculty sponsor: Robert M. Newton, Smith College*

## INTRODUCTION

Payette Lake, a glacial remnant dammed by an end moraine and partially controlled by a modern dam, is the only reliable water source for the community of McCall, Idaho. It is located in west-central Idaho at the northern end of Long Valley in a heavily glaciated area near the contact of the Idaho batholith and metamorphosed sedimentary rocks. The lake is in transition from oligotrophy to mesotrophy, and has had its first algal bloom in two decades. Recognizing the importance of high-quality lake water, residents of McCall have instituted a comprehensive water-quality study. In the summer of 1996, the Keck Consortium funded a project to supplement the Payette Lake water-quality study. Twelve students analyzed six stream catchments discharging into Payette Lake in order to determine whether water coming from the catchments is contributing to the nutrient load of the lake, and to ascertain the effects of logging and extensive forest fires on catchment-water quality. In particular, we studied the south Lemah Creek catchment, 86% of which was burned in the 1994 Blackwell Fire, and 5% of which was later salvage logged.

## METHODS

We mapped surficial sediments, exposed bedrock, and logged and burned areas by reconnaissance. A Brunton compass and topographical maps were used to position and define contacts. Areas of map units were determined by using a planimeter.

We established a gaging station for taking stream stage readings using a staff, and discharge measurements using a Swoffer flow meter. A datalogger was installed and linked to a pressure transducer calibrated to the staff gauge to determine stream stage. The logger also recorded stream temperature and air temperature via thermocouples. Data were collected every five seconds and averaged over ten-minute intervals. Snow melt, response to hydrologic events, and high and low flow could be monitored. The thousands of measurements recorded by the datalogger were used to develop graphs of the relationship between stream stage and discharge. These data were further developed into a unit hydrograph, which took into account catchment size, and therefore allowed comparison with the discharges of the six catchments in the study.

A well was installed in order to monitor the level of the water table, groundwater depletion, and groundwater chemistry. Data obtained from the well allowed for the assessment of groundwater hydrology and the relationship of groundwater to surface-water properties. The well site was 50 yards below the gaging station, 8 feet from the stream at high water. The well is a 2-inch by 11-foot pipe, sunk into 9 feet of till bottomed by sand. We used a Trimble Global Positioning System to determine the height of the well water table in relation to the stream.

Surface-water samples from throughout the catchment were analyzed for pH, specific conductance, and acid-neutralization capacity. Chloride, nitrate, and sulfate concentrations were measured through ion chromatography. The results helped to determine how contaminants are entering the system and how long they are retained.

## GEOMORPHOLOGY

The geomorphology of the Lemah Creek catchment has been shaped by the flow of both a major glacier in Payette Valley and a smaller tributary glacier that originated in the cirque at the top of the Lemah Creek watershed (fig. 1). The Payette Valley Glacier moved from the north to the south, carving out the lower bedrock of the Lemah tributary valley, and leaving till [thick (>10 ft.) and thin till (<10 ft.)] below the curved end moraines of the Lemah Creek glacier. Lateral moraines from this ice sheet were identified in the north Lemah Creek catchment, and can be seen throughout the Payette Lake valley. Ice moved into Lemah and its neighboring valleys from the Box Glacier cirque on the eastern side of the divide (R. Newton, 1996, personal communication). An ice tongue crested the eastern ridge and spilled into the Lemah valley, depositing the lateral moraines that constitute the catchment boundaries. The Lemah Glacier continued west, carved out a hanging valley, and contacted the Payette Valley Glacier. An end moraine defines the edge of the hanging valley, and has subsequently been eroded by runoff and

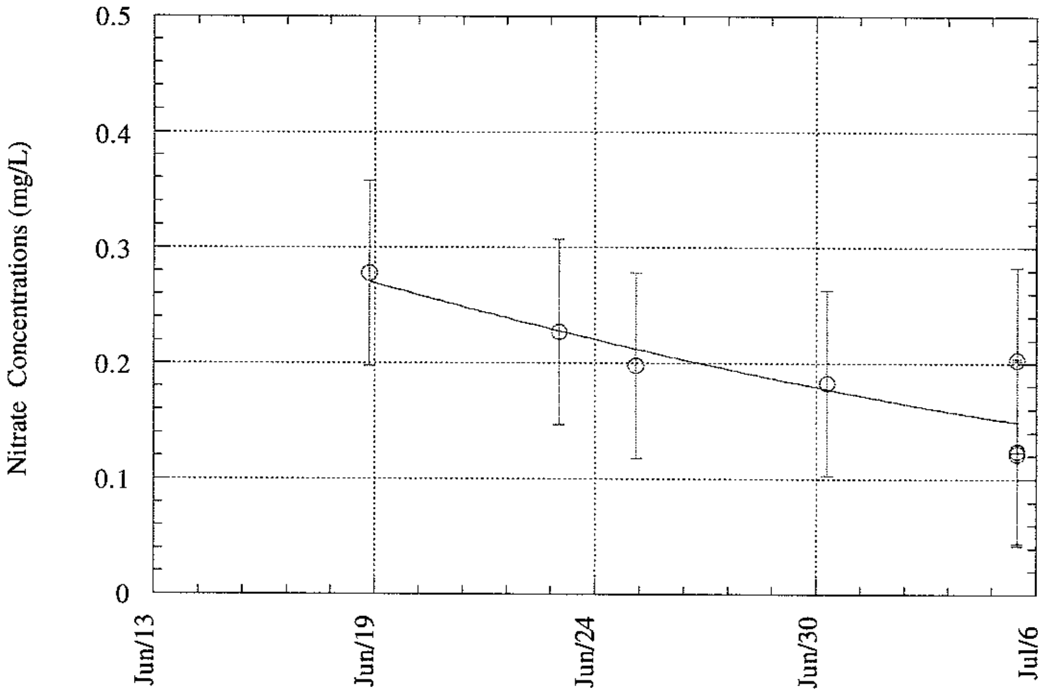


Figure 3: Nitrate Concentration at Gauge vs. Sample. Error is +/-0.04 mg/L, as calculated from the field replicate and lab split on July 6.

Dead Horse Creek's nitrate load over the study period was 340 kg; the significance of this relative to concentrations in Big Payette Lake is unknown. The nitrate concentration in the lake is approximately 0.2 mg/L (Newton 1996, pers. comm.), insignificantly different from observed concentrations in Dead Horse Creek.

**Comparison with Other Catchments.** Low nitrate levels released from the Dead Horse Creek catchment in comparison to burned catchments suggest that logging has a minimal impact on nitrate levels relative to forest fires. However, as no active logging occurred in the Dead Horse Creek catchment during the period of study, short term effects of logging are unknown. Data from the other catchments, all of which are at least 15% burned, suggest that burning and heating of organic materials releases a large supply of nitrates.

Nitrates released during logging are mostly the result of agitating the upper, organic rich layer of soil. With the cessation of logging the agitation ends and the soil surface soon restabilizes. Burning reduces vegetation cover and creates hydrophobic soils, increasing runoff that carries the easily erodible, nitrate rich ash. As the ash compacts and mixes with the soil, nitrates in surface runoff decrease. At the same time, water percolating through the nitrate rich ash dissolves nitrates and the nitrate levels in the groundwater increase. The nitrate rich groundwater of burned catchments explains the continuing high levels of nitrate discharged into the lake.

## CONCLUSIONS

Data collected in this study suggest that medium and long term effects of logging in the Dead Horse Creek catchment have a negligible effect on the nitrate levels and overall water chemistry of Big Payette Lake. More data are needed to determine the short term effects of logging on the water quality. In comparison to nitrate loads generated in the catchments burned during the 1994 Payette Region forest fires, logging is not a significant contributor to nitrate levels in Big Payette Lake.

## REFERENCES CITED


Burger, H.R., 1992, Exploration geophysics of the shallow subsurface and computer software, Prentice Hall, Englewood Cliffs, NJ, p. 18.

Colman, S.M., and Pierce, K.L, 1986, Glacial sequence near McCall, Idaho: weathering rinds, soil development, morphology, and other relative-age criteria, *in* Quaternary Research, v. 25, p. 25-42.

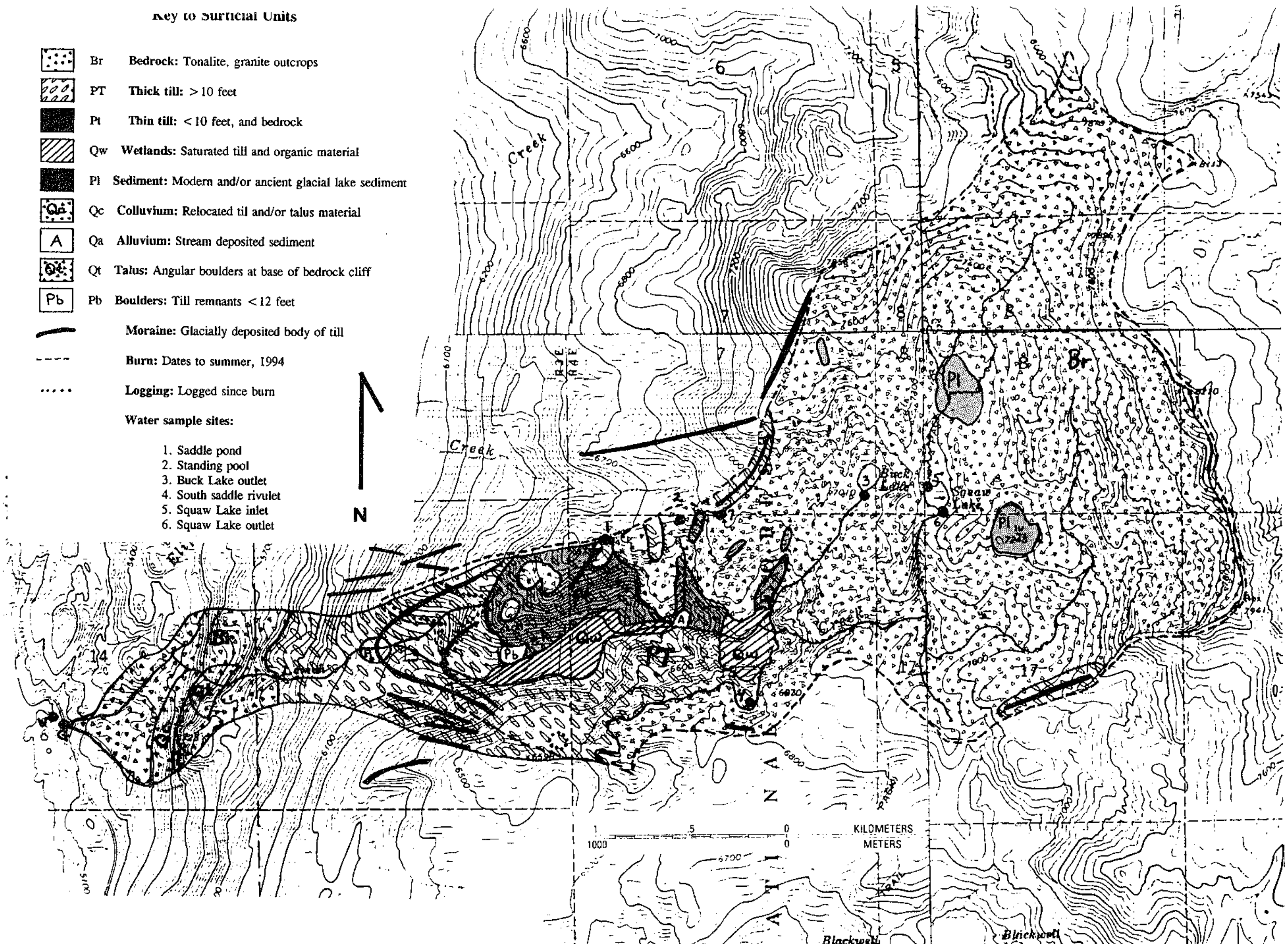


Fig. 1. Surficial units and geomorphic features of the Lemah Creek watershed.

stream action. Now the end-moraine relic has the form of two large eroded moraines pointing toward the center of the valley and angled downstream, with a boulder pile between; the fines have since been washed downstream. Till below the end moraine was deposited from two sources: the Payette Glacier lateral moraine and washout from the Lemah end moraine. The moraine on the north-central upper watershed boundary has been severely excavated by runoff erosion, leaving large areas of bedrock exposure.

The Lemah cirque lacks a strong headwall, and is therefore considered to be poorly developed. Its weakly developed morphology was caused by the Box Glacier ice spilling over the divide, and filling the Lemah catchment cirque. This process prevented Lemah catchment ice from creating a stronger headwall. Buck and Squaw lakes below the cirque are tarns: they occupy bedrock bowls plucked by glacial ice. The two large sediment pockets near Squaw Lake are the only areas of sediment contained in the bedrock expanse in the eastern catchment. This suggests that both pockets were deposited by glacial lakes.

Bedrock jointing throughout the catchment has been excavated by glacial erosion, stream action, and erosion due to runoff. Sediment fills many of the excavated joints, and many joint surfaces in the upper catchment, such as the Buck Lake outlet (fig. 1), serve as drainage paths for surrounding bedrock exposures.

## HYDROLOGY

Hydrologic flow through the watershed consists mainly of surface runoff of snowmelt and rain over bedrock in both the upper and lower sections of the catchment. The expansive bedrock in these sections cause the quick response to and recovery from hydrologic events, as we observed during the 24 June 97 hydrologic event. The till deposits are the only major reservoir for groundwater in the watershed, and the small ratio of till surface area to that of the total watershed suggests that the Lemah catchment holds little groundwater. Joints throughout the catchment constitute another possible small reservoir for groundwater.

The datalogger recorded a daily fluctuation in discharge (fig 2). We attribute the daily peaks from 28 June to 7 July to large amounts of snow melt as well as two rain events. Over time, the peaks decreased in amplitude, and the peaks and troughs lowered daily as the amount of snow melt decreased. The end of snow melt was recorded as a sharp drop in discharge as the stream entered its base flow, as shown by a daily variation of less than 1 cfs. The very small fluctuation of discharge at base flow was due to both direct evaporation from the stream, and water absorbed from the groundwater by trees.

Well-water level dropped continuously during the study. A datalogger monitored well level for two days during base flow, and showed that the well level had a daily variation on the order of hundredths of a foot (fig. 4). Data from the well datalogger and total station categorized the Lemah Creek as a losing stream after the stream reached base flow Well level fluctuation was attributed to stream pressure alternately pulling water out of the groundwater and recharging it.

## GEOCHEMISTRY

Ion chromatography results from the gaging station (fig. 3) show that high nitrate concentrations occur early in the snow melt season and during times of high runoff. During times of high runoff, the stream utilizes many overflow channels and passes through a larger area of the burn, where the water picks up nitrate. Early in the season, the water table is high; snow melt and high runoff are not able to infiltrate the groundwater, and thus surface runoff washes ions into the stream.

Acid-neutralizing capacity (ANC) in the stream is relatively low, due to the speed at which water passes through the system; the ANC that the stream does exhibit has been picked up from groundwater feeding the system, as shown by high ANC values in all well samples (fig 3). Consequently, ANC is slightly higher during low flow, when the ratio of groundwater to runoff is higher. Our interpretation of the low level of specific conductance, a measure of total dissolved solids, in the Lemah Creek water samples is that the short residence time and limited weathering of the bedrock does not allow groundwater to pick up a significant amount of ions as it passes through the system.

## CONCLUSIONS

The Payette Lake watershed was strongly impacted by the fires of 1994. The rate at which nitrate, chloride, and sulfate leave the watershed is a function of water storage capacity and residence time of groundwater, and amount of surface runoff in a given catchment.

Nitrate is a highly soluble ion, and therefore most of the nitrate released by the forest fires was probably washed out of the catchments into the lake during the first spring after the fires, decreasing each successive season. Highest stream nitrate concentrations are in spring because the ground is saturated and photosynthesis is at low levels, which allows nitrate released by the fires to wash directly into the stream.

Chloride and sulfate concentrations are controlled by the amount of precipitation, evaporation, and evapotranspiration that takes place within the watersheds. Increased chloride and sulfate concentrations occur where water has a high residence time, such as Buck Lake (fig. 3). Decreased values occur when water is diluted by runoff and snow melt. There is no significant source of either chloride or sulfate in the Lemah Creek watershed; therefore, we conclude that chloride and sulfate enter the system through precipitation.

ANC values in the catchment correlate with groundwater residence time, size of groundwater reservoir, and rock type. For example, more severe weathering produces higher ANC values. Later in summer when the groundwater level is not recharged by runoff, ANC levels drop, possibly due to organic acids infiltrating the soil instead of being washed off or diluted by runoff. Bedrock runoff does not significantly increase ANC because the water is in contact with only a small surface area for a short time.

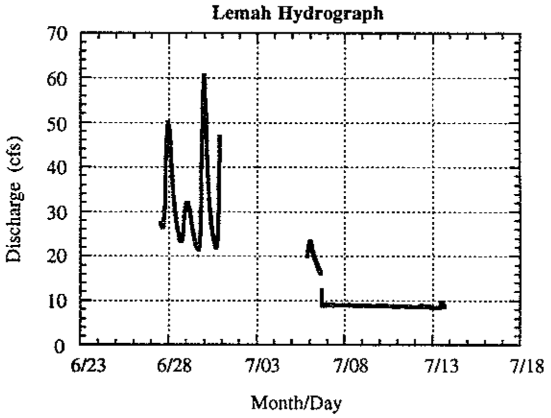


Fig. 2. Hydrograph of snowmelt and base-flow conditions.

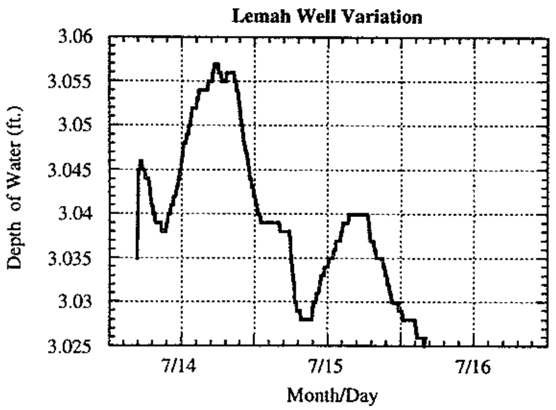


Fig. 4. Well cycle during base flow of Lemah Creek.

| Sample Description | Sample Code | lab pH | Spec. Cond. (μ mhos) | ANC (μ eq) | Cl- (mg/L) | NO3- (mg/L) | SO4-- (mg/L) | IC Run Code |
|---|---|---|---|---|---|---|---|---|
| snowmelt dilution | LC6191400-g | 5.43 | 10.20 | 77.14 | 0.556 | 1.250 | 0.820 | 1 |
| sample after rain (6/24) | LC6241445-g | 6.50 | 8.50 | 63.63 | 0.368 | 0.857 | 0.700 | 2 |
| midnight - high flow | LC7012400-g | 6.56 | 8.00 | 60.08 | 0.500 | 0.451 | 0.560 | A |
| low flow | LC7051600-g | 6.72 | 8.10 | 84.08 | 0.623 | 0.539 | 0.651 | A |
| saddle pond | LC6251310-1 | 6.42 | 9.70 | 89.11 | 0.885 | 0.000 | 0.768 | B |
| south saddle rivulet | LC6281300-2 | 6.44 | 13.20 | 110.95 | 0.835 | 0.404 | 0.979 | B |
| Buck Lake outlet | LC6261330-3 | 6.64 | 7.70 | 59.54 | 0.863 | 1.201 | 0.741 | 2 |
| pool at site 12 | LC6251335-4 | 6.66 | 16.20 | 187.44 | 1.019 | 0.000 | 0.521 | 2 |
| Squaw Lake inlet | LC7011435-5 | 6.33 | 6.20 | 36.33 | 0.510 | 0.226 | 0.438 | A |
| Squaw Lake outlet | LC7011450-6 | 6.31 | 7.60 | 48.19 | 0.596 | 0.266 | 0.475 | B |
| ash sample | LC6251400-7 | ND | ND | ND | 1.82 | 0.000 | 2.866 | NC |
| Well-S1 | LC6221130-w1 | 5.83 | 23.60 | 287.96 | 1.261 | 0.046 | 1.844 | 1 |
| Well-S2 | LC7051610-w2 | 6.06 | 21.30 | 233.67 | 1.252 | 0.000 | 1.166 | NC |
| Well-S3 | LC7101215-w3 | 5.93 | 19.50 | 218.19 | 2.157 | 0.000 | 0.947 | NC |
| Well-S3 replicate | LC7101215-w3 | 6.14 | 27.2 | 236.13 | ND | ND | ND | NC |

ND = no data collected
NC = no run code

Fig. 3. Geochemistry data for the Lemah Creek watershed. Sample codes refer to date, time, and place of collection. The characters after the dash refer to the gaging station (-g), upper catchment (-#), and the well (-w). Sites referred to under "Sample Description" are located on figure 1.

# Surficial geology and hydrology of Pearl Creek: effects on anion concentration

**Rose Lauck**
Whitman College, 200 Broyer St., Walla Walla, WA 99362
*Faculty sponsor*: Berry Goldstein, University of Puget Sound

**Vionette De Choudens**
University of Puerto Rico, Mayagüez, P.O. Box 5000, Mayagüez, PR 00681

## INTRODUCTION

This study's goal is to determine how the extensive logging of the headwater catchments and the fire increase the release rate of $NO_3$ into the water. It has been determined that burning of organic material significantly increases concentrations of nitrates into the system (Robert Newton, 1996). To do this effectively, six water catchments were studied and compared. Cougar Creek, Trail Creek, Lemah Creek and Pearl Creek are used to determine the effects of burn, specifically the concentration of nitrates added. The Dead Horse Creek watershed has been only logged and was used to determine the effects of logging in relation to nitrate concentration. Deep Creek has not been significantly effected by either fire nor logging and serves as the control for the study. By comparing geological, chemical, and hydrological characteristics of each of the watersheds concentrations of nitrates in the water can be determined.

This paper will concentrate on the Pearl Creek watershed study. The Pearl Creek watershed is the only catchment to be logged, burned, and logged again. The geology of the area was consistent through out each of the watersheds; each had been glaciated and were underlayed with bedrock which was a portion of the Atlantic Batholith. It is expected that the nitrate levels of this catchment would be the highest because of the compounded effects of logging and burning. To determine this, measurements of nitrate, sulfate, chloride, acid neutralizing capacity, pH, and specific conductance will be taken. In addition, the surficial geology will be mapped to determine the effect of water storage capacity. Discharge and stage readings will also be used to obtain an idea of the hydrology of the areas. The chemical and hydrological data combined, will enable a means to determine concentration of chemicals and the rate at which they empty into the Payette system.

## METHODS

The discharge of the creek was determined by creating a rating curve based on the relationship between the stage of the creek and the corresponding velocities. This was significant in determining the rate at which the water was leaving the catchment. Daily fluctuations in discharge were recorded with a data logger with a pressure transducer.

A well was established to monitor the ground water. First a deep hole was dug, followed by auguring down further. This produced a well of 3.8 feet in depth. A screened PVC pipe, with a conic end piece was pounded in to the hole serving as the encasement for the well. From this, the permeability and porosity of the till could be observed by bailing out the well and measuring the recovery time. Measurements of the depth of the well were taken over the four week period and then related to the stage of the creek..

The surficial geology was mapped. The mapping was conducted over a three week period by visual observation. The percentage of burned areas were also mapped because of its impact upon run-off. The thickness of surficial sediment was estimated in the field and then confirmed using seismic refraction methods.

ANC, the measure of the acid neutralizing capability of the water, was determined by using the Gran Titration method. Along with this, the Specific Conductance was measured. This information further supports the findings of the levels of ANC.

The concentrations of anions: nitrate, sulfate, and chloride were measured with an ion chromatography. This process determined the concentrations of nitrate, chloride, and sulfate.

Quality assurance/quality control was conducted by doing split measurements of the same water samples. These margins of error determined the validity of the data that was collected.