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# Effects of forest stand density reduction on nutrient transport at the Caspar Creek Watershed

## Progress report on Grant #124

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# 1 Introduction

## 1.1 Caspar Creek Experimental Watershed

The Caspar Creek Experimental Watershed, located in the Jackson Demonstration State Forest, has been continuously studied since its establishment in 1962 as a collaboration between the California Department of Forestry and Fire Protection (CDF) and the Pacific Southwest Research Station (PSW). The Caspar Creek experimental watershed has conducted thus far, two long-term research experiments. The primary goal of the first two experiments (1962-85, 1985-present) was to understand the effect of timber harvest on streamflow and suspended sediment concentrations in coastal forested watersheds. The first experiment was set up as classic paired watershed study. Cumulative effects (e.g. sediment, discharge) of removing 60-70% of the timber stand volume were studied in South Fork Caspar Creek and compared to the North Fork Caspar Creek sub-watershed, which served as control. In the second experiment (1985-present) modern California Forest Practice Rules (FPRs) were tested in different sub-watersheds of the North Fork Caspar Creek and effects were compared among the different sub-watersheds.

In 2016, the watershed hydrologist of Caspar Creek designed a third experiment with the goal to expand upon the findings of the first two experiments to investigate the effect that different reductions in stand density (e.g. reduction in the quantity of trees) might have on the interconnected hydrological, geomorphic, and ecological processes in coastal redwood forests. To improve this understanding several research projects were set up that study these processes at the tree, plot, hillslope, sub-catchment and catchment scale. Table 1 shows the proposed stand reductions in the sub-watersheds of South Fork Caspar Creek. Most of the research is focused on four sub-watersheds, which will be harvested beginning in June 2018. The WIL watershed will serve as a control (0% vegetation removal), the TRE watershed will demonstrate a light harvest (35% reduction in stand density), the UQL watershed is a moderate harvest (55% reduction) and the ZIE watershed represents a high harvest (75% reduction).

**Table 1.** South Fork Caspar Creek sub-watershed names and planned treatments.

| Sub-watershed name | Sub-watershed ID | Treatment (% Leaf area reduction) |
|---|---|---:|
| South Fork Caspar Creek | **SFC*** | TBD |
| Quetelet | QUE | TBD |
| Richards | RIC | 0 |
| Yocom | YOC | 0 |
| Williams | **WIL*** | 0 |
| Ogilvie | OGI | 25 |
| Treat | **TRE*** | 35 |
| Porter | POR | 45 |
| Uqlidisi | **UQL*** | 55 |
| Sequoyah | SEQ | 65 |
| Ziemer | **ZIE*** | 75 |

* Sub-watershed outlets intensively monitored for streamwater chemistry analysis.

Since summer 2016, monthly baseflow samples and more frequent winter stormwater samples have been collected at the outlet of the four sub-watersheds and the outlet of South Fork Caspar Creek to understand baseline conditions in flow and nutrient export from these watersheds. The baseline samples will be used to characterize the flow regime and biogeochemistry of Caspar Creek at near-pristine conditions and to evaluate whether all sub-watersheds behave hydrologically and biogeochemically in a similar manner. This catchment comparison ensures that observed differences in the flow regime and nutrient export from the sub-watersheds subject to stand reductions are due to the treatment and not the watershed characteristics themselves.

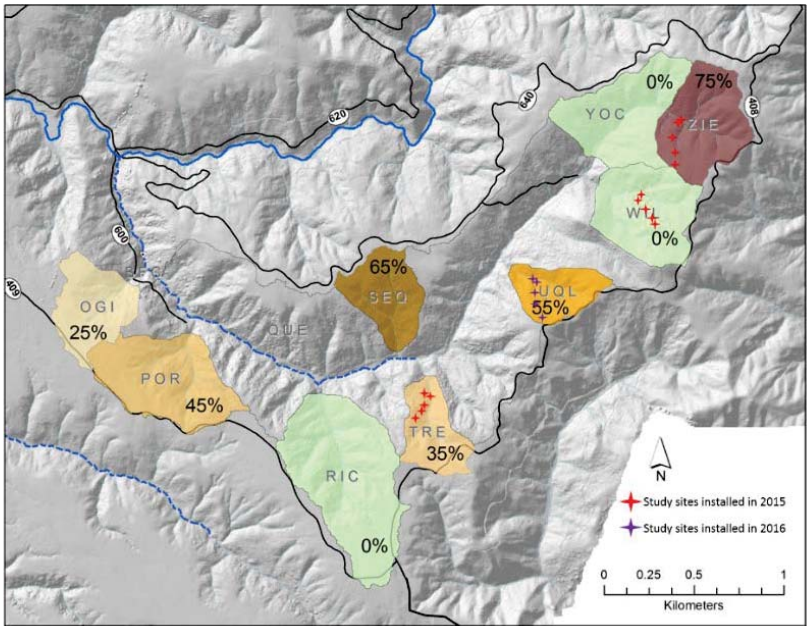


**Figure 1.** Study sites are located in a subset of gauged sub-watersheds in the South Fork Caspar Creek.

## 2 Research objectives

The goal of this research proposal is to examine changes in the mass balance of major nutrients (C, N, P) and base cations/anions across the main functional watershed units (e.g. whole watershed vs. sub-watersheds) of South Fork Caspar Creek watershed in response to different stand density reductions. The hypothesis of the project is that stand density reduction will increase export of total N, total P, $NO_3^-$, and particulate/dissolved organic C from the treated watersheds immediately following the forest harvest, with greater impacts observed with greater stand density reduction. The hypothesis is that the increased hydrologic connectivity associated with macropore flow and fast subsurface stormflow above the clay-rich, argillic soil horizon promote rapid flow pathways for storm flow and nutrient transport from hillslopes to streams. The proposed research attempted to address this hypothesis through the following specific objectives:

1) Determine the changes in stream water and soil water solute concentrations and nutrient fluxes during storm flow and baseflow conditions prior- and post-harvest in the South Fork Caspar Creek watershed.

2) Compare nutrient export between harvested and reference watersheds.

## 3 Methods and Materials

### 3.1 Study Site and Experimental Design

### *3.1.1 Study Site*

The Caspar Creek experimental watershed is located in coastal northern California in the Jackson Demonstration State Forest, at approximately 39° 21’ N, 123° 44’ W. The watershed is located approximately 7 miles from the Pacific coast and approximately 14 miles southeast of Fort Bragg, CA (Henry 1998). The Caspar Creek watershed has a total drainage area of 2,167 ha, of which 897 ha are included in the experimental watershed study area (Henry 1998). The study area contains two main drainage basins, the North Fork and the South Fork of Caspar Creek, with basin areas of 473 ha and 424 ha respectively (Dymond, 2016). The North Fork drainage basin is divided into thirteen sub watersheds ranging in individual drainage areas from 10 ha to 384 ha. Within the South Fork of Caspar Creek, there are 10 sub-watersheds, which range in drainage areas from 13 ha to 394 ha. (Table 2) The South and North Forks drain into the main branch of Caspar Creek, which, from their confluence point, flows northeast and empties into the Pacific Ocean (Figure 1).

**Table 2.** Physical characteristics of South Fork sub-watersheds.

| Sub-watershed ID | % Reduction | Area (ha) | Average slope (%) | Elevation range (m) | Dominant soil subgroups |
|---|---|---|---|---|---|
| **SFC*** | TBD | 424 | 60 | 46-329 | Ultic hapludalf |
| QUE | TBD | 394.3 | 50 | 48-329 | Mollic/Ultic hapludalf |
| RIC | 0 | 48.8 | 42 | 73-198 | Mollic/Ultic hapludalf |
| YOC | 0 | 52.9 | 48 | 146-329 | Typic haplohumult |
| **WIL*** | 0 | 26.5 | 51 | 146-323 | Typic haplohumult |
| OGI | 25 | 18.3 | 26 | 58-174 | Mollic/Ultic hapludalf |

| | | | | | |
|---|---|---|---|---|---|
| **TRE*** | 35 | 14.1 | 47 | 98-244 | Mollic/Ultic hapludalf |
| POR | 45 | 31.7 | 34 | 61-186 | Ultic hapludalf |
| **UQL*** | 55 | 12.5 | 49 | 122-323 | Typic haplohumult |
| SEQ | 65 | 16.8 | 38 | 79-207 | Ultic hapludalf |
| **ZIE*** | 75 | 25.3 | 43 | 213-329 | Typic haplohumult |

* Sub-watershed outlets intensively monitored for streamwater chemistry analysis.

The Caspar Creek watershed lies within the Jackson Demonstration State forest (JSDF) in Mendocino County. JSDF is the largest (19,689 ha) of eight demonstration forests in the state, and is managed and operated by the California Department of Forestry and Fire Protection. The main land use in JSDF is the growth and harvest of timber, revenue from which goes to fund research and demonstration opportunities in natural resource management, which include wildlife habitat and watershed protection and restoration. The forest stands in the South Fork of Caspar Creek were approximately 95 years old when they were last harvested during the First Experiment at Caspar Creek. Harvest began with the eastern portion of the South fork in 1971, and the final northwestern portion was completed in 1973. During this experiment, all ten sub-watersheds in the south fork were harvested, with stand volume reduction ranging from 60-70%. Results from the First Experiment have been reported by Rice (1979) and Ziemer (1998).

Forest vegetation in Caspar Creek is dominated by coast redwood (*Sequoia sempervirens* (D. Don) Endl.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), with some associated grand fir (*Abies grandis* (Doug. ex D. Don) Lindl.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and minor amounts of hardwoods, including tanoak (*Lithocarpus densiflorus* (Fook. and Arn. Rohn) and red alder (*Alnus rubus* Bong.). The understory vegetation is comprised of evergreen huckleberry (*Vaccinum ovatum* Pursh), Pacific rhododendron (*Rhododendron macrophyllum* D. Don), and sword fern (*Polystichum munitum* (Kaulf.) Presl.) (Henry 1998).

The northwest pacific coast of California has a Mediterranean climate regime, characterized by mild, moist winters of low-intensity rainfall. Summers are typically cool and dry, however coastal fog is frequently observed, and is thought to have a significant contribution to the total annual precipitation in coastal redwood forest ecosystems in the form of fog drip (Burgess and Dawson 2004).. Normal daily temperatures typically range from 5 to 14°C in the winter and 10 to 25°C during the summer (Dahlgren 1998). Between 1990-1995, minimum average temperature was 6.7°C in December and maximum average temperature was 15.6°C during July (Henry 1998). From 2001-2016, mean annual precipitation was approximately 1188.8 mm, approximately 90% of which occurs between the months of October through April.

Elevation in the South Fork of Caspar Creek ranges from 46 to 329 m, with sub-watershed slopes ranging from about 26 to 50%. In certain areas within the watershed, slopes can reach an excess of 50% (Diamond 2015). The geomorphology of this coastal system consists of uplifted marine terraces, which have been significantly incised by stream processes (Henry 1998). The soils in the Caspar Creek watershed are predominantly Alfisols and Ultisols, which have been derived from residuum of Franciscan sandstone and Cretaceous Age shale (Henry 1998). Soils in the watershed have been found to consistently exhibit thick argillic horizons, which are suspected to influence hydrologic processes occurring in response to storm events, specifically subsurface lateral flow (Dahlgren 1998). Dominant soil subgroups are identified in Table 2.

### *3.1.2 Experimental Watersheds – Third Experiment*

The main experimental study area for the Third Experiment is located in the South Fork of Caspar Creek. The entire South Fork watershed is divided into ten sub-watersheds, each of which has a direct outlet to the main stem of the South Fork (Figure 1). In 2000, each of the sub-watershed outlets was instrumented with a gaging station to monitor streamflow in preparation for the Third Experiment. Since the spring of 2016, all of the ten sub-watersheds have been sampled for water chemistry baseline analysis. Since initial streamwater sampling began, four of these ten sub-watersheds (TRE, UQL, WIL, and ZIE) have been more intensively sampled, and will be the primary focus of the streamwater chemistry study over the course of the Third Experiment.

### *3.1.3 Treatments*

Three of the ten South Fork sub-watersheds have been designated as long-term reference watersheds (WIL, RIC, YOC) and will not receive a harvest treatment. The seven other sub-watersheds have been assigned harvest treatments ranging from 25% to 75% reduction in leaf area. Forest managers typically prescribe stand harvest intensity based on basal area (the surface area of stems at a height of 4.5 feet above ground per unit ground area), as opposed to overstory density (leaf area), partially due to the difficulty of obtaining leaf area measurements. However, leaf-area-index (LAI) plays a large role when examining regrowth processes in coast redwood ecosystems due to stump resprouting (O'Hara and Berril 2010). Therefore, for the purpose of examining forest response to stand reduction, harvest reductions percentages will be calculated by leaf area index (the ratio of leaf area per unit of ground area) in the Third Experiment. Harvesting of the matrix area (i.e. remaining area surrounding the sub-watersheds in South Fork Caspar Creek) began in the summer of 2017, and harvest treatments of the seven sub-watersheds are expected to begin in June of 2018. Harvest treatments and corresponding sub-watersheds are summarized in Table 1.

### *3.1.4 Paired Watershed Study Design*

Paired watersheds have been widely used in hydrological and biogeochemical research to study long-term trends in forested systems (Hornbeck 1973, King 2008, Dahlgren 1994). This is partly due to the time it takes for forest stands to return to pre-treatment conditions, as well as difficulties in attributing effects to treatments as opposed to other time-dependent variables. The paired watershed design has been employed in both long-term experiments previously conducted at Caspar Creek (First and Second Experiments). The Third Experiment will also employ a paired watershed design, aiming to compare treatment effects between sub-watersheds in the South Fork. In order to employ the effective use of the paired watershed design, the ten south fork sub-watersheds have been assessed in terms of their physical, hydrologic, and streamwater chemical characteristics. The four sub-watersheds that will provide the majority of the water chemistry data (TRE, UQL, WIL and ZIE) are being closely monitored in order to validate this study design. Qualitative assessments of drainage area, watershed slope, topography, soil characteristics, and riparian zone characteristics will form the basis for sub-watershed compatibility. Forest density, vegetative cover, climate and precipitation parameters have been assumed to be identical among South Fork sub-watersheds.

## *3.2* Data Collection and Analysis

### *3.2.1 Soils*

Soil data for the initial soil assessment of South Fork watershed was obtained from the USDA-NRCS Web Soil Survey using the South Fork watershed boundary file provided by the Caspar Creek Experimental Watersheds project staff. Field soil sampling is planned to be conducted by the Sediment Fingerprinting Study lead by Jeff Hatten (Oregon State University).

### *3.2.2 Hydrology and Water Chemistry*

The outlet of the South Fork main stem is equipped with a compound weir with a 120° v-notch for weir stages up to 2 feet, and a 20 foot rectangular weir for stages above 2 feet. Turbidity is recorded at the South Fork weir using an FTS DTS-12 temperature/turbidity sensor. All subcatchment outlets are equipped with Montana flumes, and turbidity is recorded using Campbell Scientific OBS-3 turbidity sensors. Stage is measured at all flume and weir locations with Campbell Scientific pressure transducers. Stage and turbidity are recorded on a 10-minute interval. Stage is converted to discharge from a developed, site-specific stage-discharge relationship. Streamwater samples are collected by ISCO 6712 automated samplers, as well as by Caspar Creek staff, who manually collect grab samples during storm events. All samples are collected mid-stream where sufficient mixing is assumed to occur. Following streamwater sample collection, samples are shipped from Caspar Creek to UC Davis for laboratory analysis. The samples are shipped in insulated packaging and upon arrival, are stored below 4°C until analysis. Sub-samples are vacuum filtered through a 0.2-micron pore diameter membrane filter prior to analysis of pH, electric conductivity (EC) and dissolved nutrients. pH and EC are each measured potentiometrically using a combination electrode. Anion concentrations ($Cl^-$ and $SO_4^-$) and cation concentrations ($K^+$ and $Na^+$) were determined by ion chromatography using a Dionex ICS-2000 Ion Chromatograph. Orthophosphate, or "dissolved reactive phosphorous" (DRP), which includes $PO_4$-P plus any other compounds that might give $PO_4$-P during reaction conditions or react as $PO_4$-P, was determined using the 1 Phosphomolybdate blue/ascorbic acid method. Mg and Ca cation concentrations were determined using atomic absorption spectroscopy, with a Perkin Elmer AAnalyst 800 Spectrometer. Total dissolved nitrogen (TDN), dissolved organic nitrogen (DON), nitrate plus nitrite nitrogen ($NO_3$+$NO_2$-N) and ammonium ($NH_4$-N) were measured using spectrophotometric determination. Dissolved organic carbon was measured using (look up name/model of machine in PES).

All nutrient loads (e.g., $NO_3^-$) were calculated by first multiplying the analyte concentration with the measured water volume for each individual sample. The water volume associated with each sample was determined using the midpoint approach (the temporal midpoint between each sample was determined, and the water volume for that time period was determined by multiplying discharge by time-step, and summing over the time duration for each sample). The nutrient load for each sample is assumed to be representative over this time duration.

### *3.2.3 Statistical Analyses*

In order to validate the paired watershed design, King et al. 2008 has identified four criteria for paired watershed validation, each of which will be considered in this study. These criteria include (1) similar physical characteristics between paired watersheds including drainage area, slope and soil characteristics (Downes et al 2002), (2) moderate correlations between response variables (i.e., 0.6 or greater) between paired watersheds (Loftis et al. 2001), (3) lack of temporal trend differences between treatment and reference watersheds prior to treatments (Stewart-Oaten and Murdoch 1986), and (4) demonstration of minimal effect sizes needed to observe a significant change between reference and treatment watersheds (Clausen and Spooner 1993).

Four statistical data analysis approaches will be used to validate these four criteria in this study. First, similarity in physical characteristics between watersheds will be compared by calculating the total or mean of each response variable (drainage area, slope and soil characteristics). Secondly, simple linear regression analysis will be employed for a subset of water chemistry and hydrologic (stream discharge) variables to determine the degree of correlation present between watersheds. Third, temporal trends between watersheds will be analyzed using the Daniels Test for Trend (Conover 1999). Lastly, minimum percent change required to detect significant differences in hydrology and water chemistry will be determined using Analysis of Covariance (ANCOVA) for data acquired before and after treatments are applied.

# 4 Results and Discussion

## 4.1 Sub-watershed comparison

Thus far, qualitative assessment between the South Fork sub-watersheds suggests that the sub-watersheds are moderately well correlated in terms of slope and soil characteristics. Table 3 shows the percent difference in watershed slopes between each treatment sub-watershed and each control (0% harvest) sub-watershed. Two sub-watersheds (OGI and POR) exceed a 25% difference in mean slope as compared to the WIL sub-watershed. One sub-watershed (OGI) exceeds a 25% difference in mean slope as compared with the two other control watersheds (RIC and YOC). All other comparisons of mean sub-watershed slope indicate a high degree of similarity, with percent differences less than 25%.

**Table 3.** Percent differences in slope between treatment sub-watersheds compared with reference watersheds.

| Sub-watershed ID | Reduction % | Average slope (%) | % difference to WIL | % difference to RIC | % difference to YOC |
|---|---|---|---|---|---|
| **SFC*** | TBD | 60 | 18.0 | 43.3 | 25.5 |
| QUE | TBD | 50 | 1.4 | 19.7 | 4.8 |
| RIC | 0 | 42 | 17.6 | 0.0 | 12.4 |
| YOC | 0 | 48 | 5.9 | 14.2 | 0.0 |
| **WIL*** | 0 | 51 | 0.0 | 21.4 | 6.3 |
| OGI | 25 | 26 | 47.9 | 36.8 | 44.6 |
| **TRE*** | 35 | 47 | 7.9 | 11.8 | 2.1 |
| POR | 45 | 34 | 32.3 | 17.8 | 28.0 |
| **UQL*** | 55 | 49 | 4.0 | 16.6 | 2.1 |
| SEQ | 65 | 38 | 25.0 | 8.9 | 20.2 |
| **ZIE*** | 75 | 43 | 14.9 | 3.4 | 9.5 |

* Sub-watershed outlets intensively monitored for streamwater chemistry analysis.

Soil characteristics are similar between all sub-watersheds, at the subgroup level, and are listed in Table 2. Soil data from the Soil Web Survey indicate that there are nine major soil units mapped in the South Fork watershed area. Of these nine soil units, the Dehaven-Hotel complex, the Irmulco-Tramway complex, and the Vandamme loam cover about 35.6%, 31.3% and 19.1% respectively. Figure 2 shows the soil map units and their distribution within the South Fork watershed, which is largely uniform and slope dependent.

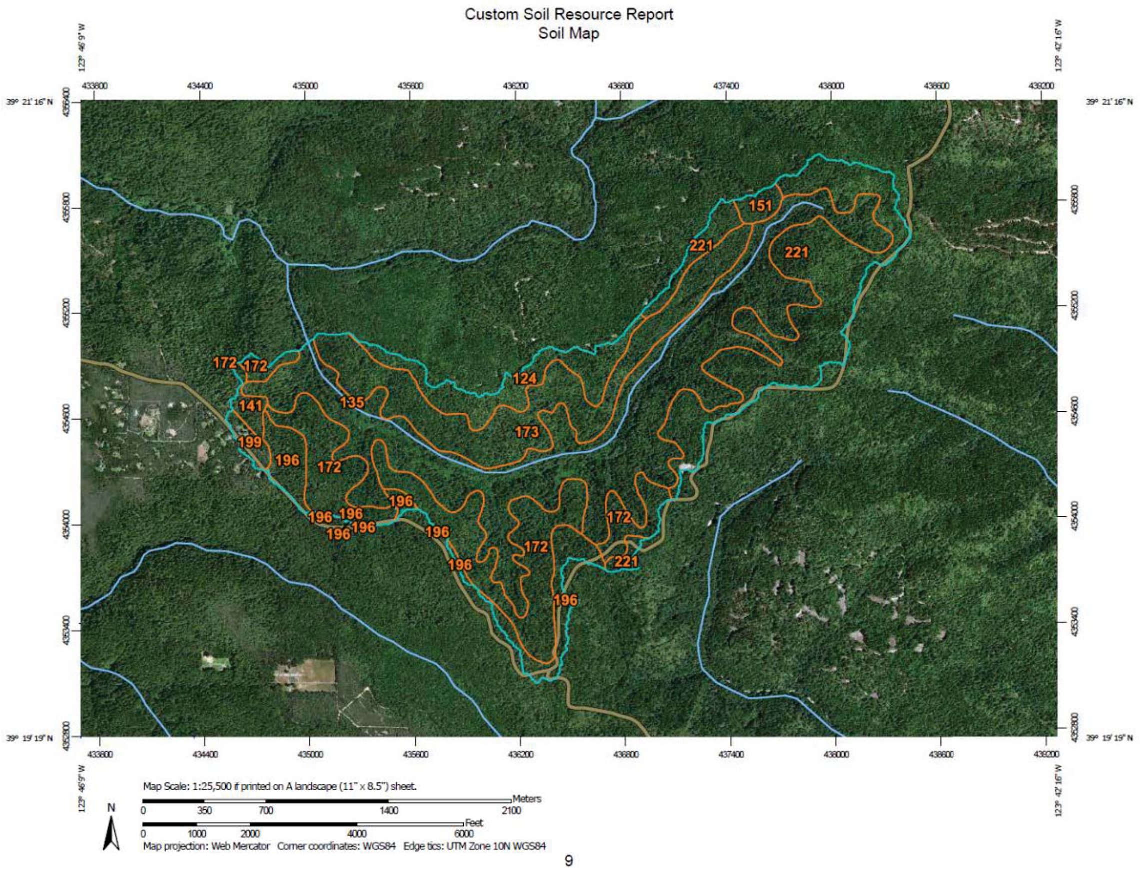


**Figure 2.** Soil map units within South Fork Caspar Creek watershed. Dominant map units include 135: Dehaven-Hotel complex, 172/173: Irmulco-Tramway complex, and 221: Vandamme loam.

Vegetation and aerial extent of the riparian zones in each sub-watershed have yet to be evaluated quantitatively, but a combination of GIS based analysis, and/or collaboration with another Third Experiment research team is anticipated. The Bioassessment Study Group plans to set up sampling sites within the South Fork and implement the State Water Board's Surface Water Ambient Monitoring Program (SWAMP). The SWAMP bioassessment protocol includes evaluation of riparian vegetation and habitat.

## 4.2 Hydrology

Stream discharge, precipitation and antecedent moisture conditions conditions have been analyzed for the entire monitoring period (May 2016-December 2017) and selected periods of interest including the summer baseflow period (May-September), the fall wetting-up period, and the winter rainy season based on discharge measurements taken at the WIL, TRE, UQL, and ZIE sub-watershed outlets. Discharge between August 2016 and August 2017 and associated chemical streamwater sampling events are displayed in Figures 3 to 6. The 2016 fall wetting-up period (early October through mid-October) was identified based on sub-watershed hydrographs and and cumulative precipitation totals were calculated for these periods.

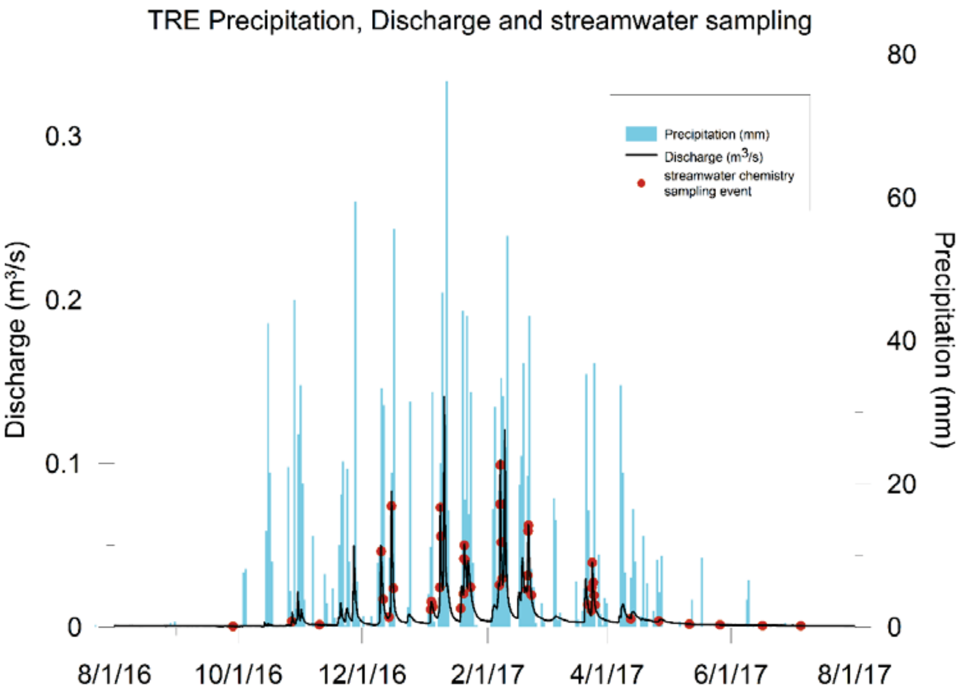


**Figure 3.** TRE precipitation, discharge and sampling events.

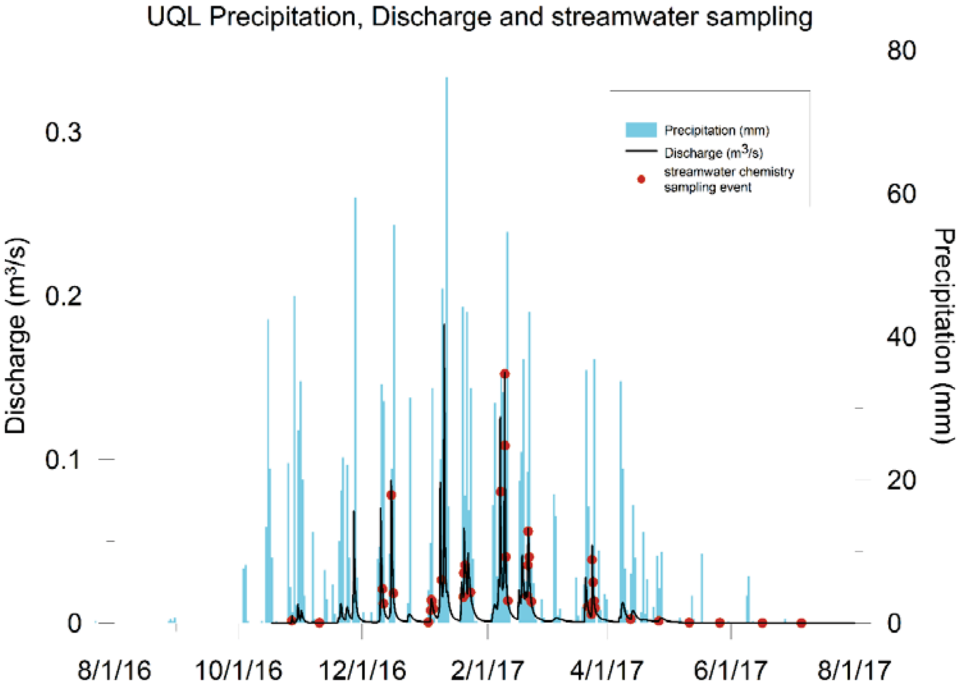


**Figure 4.** UQL precipitation, discharge and sampling events.

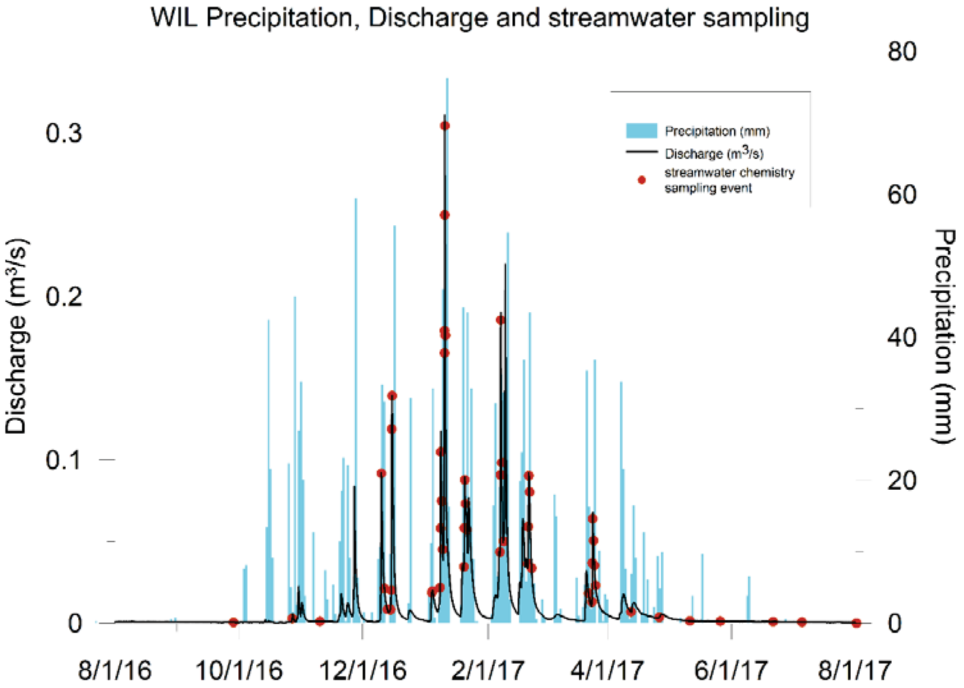


**Figure 5.** WIL precipitation, discharge and sampling events.

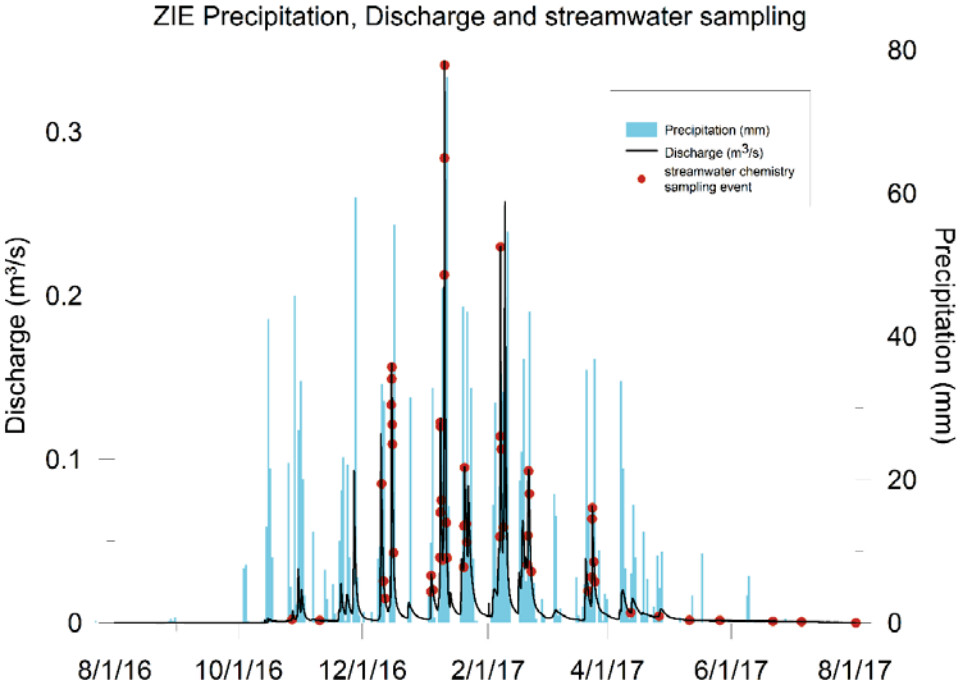


**Figure 6.** ZIE precipitation, discharge and sampling events.

Additionally, rainfall-runoff ratios were calculated for each sub-watershed for eleven storm events that occurred between November 2016 and March 2017 (Table 4). Runoff ratios represent the total amount of runoff volume generated for each individual storm event, normalized by sub-watershed area. The amount of runoff (in mm) is divided by the precipitation accumulated over the same time period, which gives a ratio of cumulative event runoff: cumulative event precipitation. During the fall wetting-up period runoff ratios in all watersheds were lower than at the height of the winter rainy season, indicating that a greater fraction of the observed event precipitation was used to wet-up the watershed. Antecedent precipitation in early October 2016 was 103.1 mm, reaching 295.4 mm by mid-November.

**Table 4.** Rainfall runoff ratios and antecedent moisture conditions for sub-watersheds TRE, UQL, WIL, and ZIE.

| **Event** | **WIL** | **TRE** | **UQL** | **ZIE** |
|---|---|---|---|---|
| 11/17/16 - 12/05/16 | 0.34 | 0.49 | 0.47 | 0.43 |
| 12/05/16 - 12/20/16 | 0.59 | 0.68 | 0.67 | 0.69 |
| 12/20/16 - 12/31/16 | 0.41 | 0.78 | 0.45 | 0.57 |
| 12/31/16 - 01/16/17 | 0.65 | 0.72 | 0.70 | 0.70 |
| 01/16/17 - 01/31/17 | 0.70 | 0.81 | 0.71 | 0.76 |
| 01/31/17 - 02/14/17 | 0.73 | 0.82 | NA | 0.80 |
| 02/14/17 - 03/03/17 | 0.71 | 0.94 | 0.76 | 0.74 |
| 03/03/17 - 03/14/17 | 0.35 | 0.89 | 0.38 | 0.48 |
| 03/17/17 - 04/05/17 | 0.56 | 0.77 | 0.57 | 0.58 |
| 04/05/17 - 04/23/17 | 0.38 | 0.56 | 0.38 | 0.41 |
| 04/23/17 - 05/10/17 | 0.68 | 1.25 | 0.53 | 0.86 |
| **Watershed Area (ha)** | 26.5 | 14.1 | 12.5 | 25.3 |
| **Treatment (% Reduction)** | 0 | 35 | 55 | 75 |

To evaluate the hydrologic compatibility of the sub-watersheds receiving timber reduction (TRE, UQL and ZIE) to the control watershed (WIL), a simple linear regression of the watersheds' discharges was conducted (Figures 7, 8 and 9). All treatment watersheds show a high degree of correlation with the control watershed WIL over the course of the 12 month data set that has been analyzed thus far. Similarity in discharge magnitude and relative change amongst runoff ratios of each sub-watershed indicate similarity in watershed behavior.

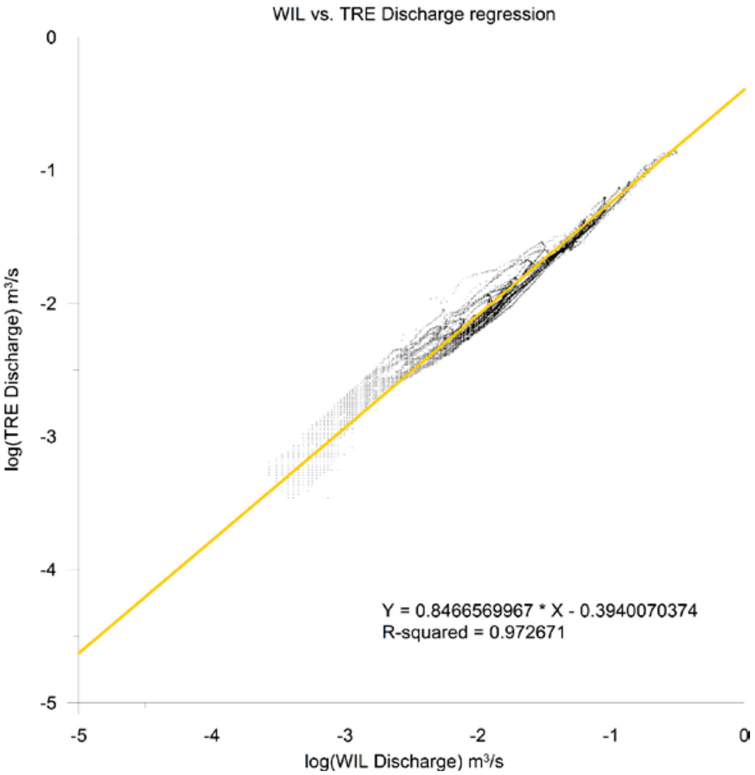


**Figure 7.** WIL vs. TRE discharge regression**.**

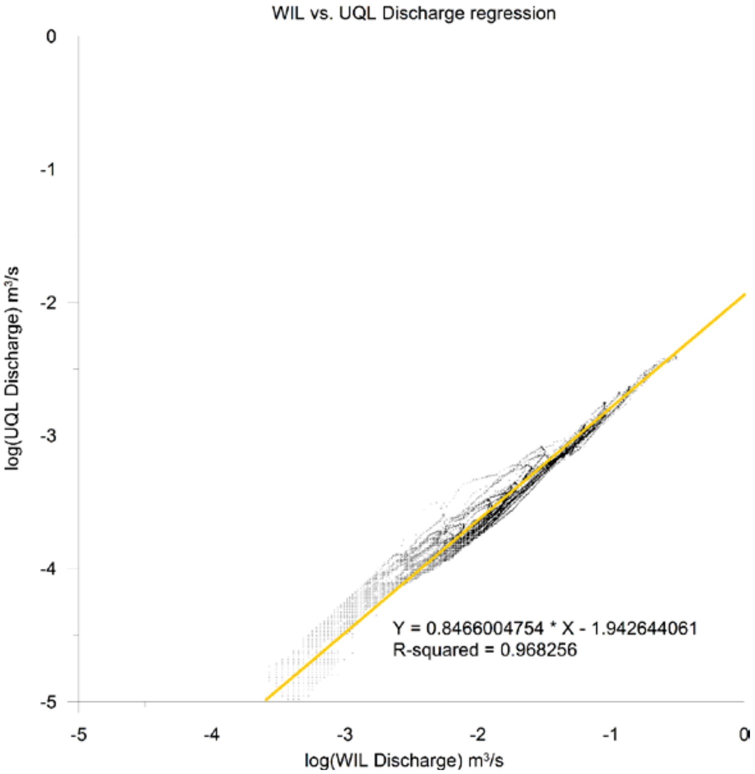


**Figure 8.** WIL vs. UQL discharge regression.

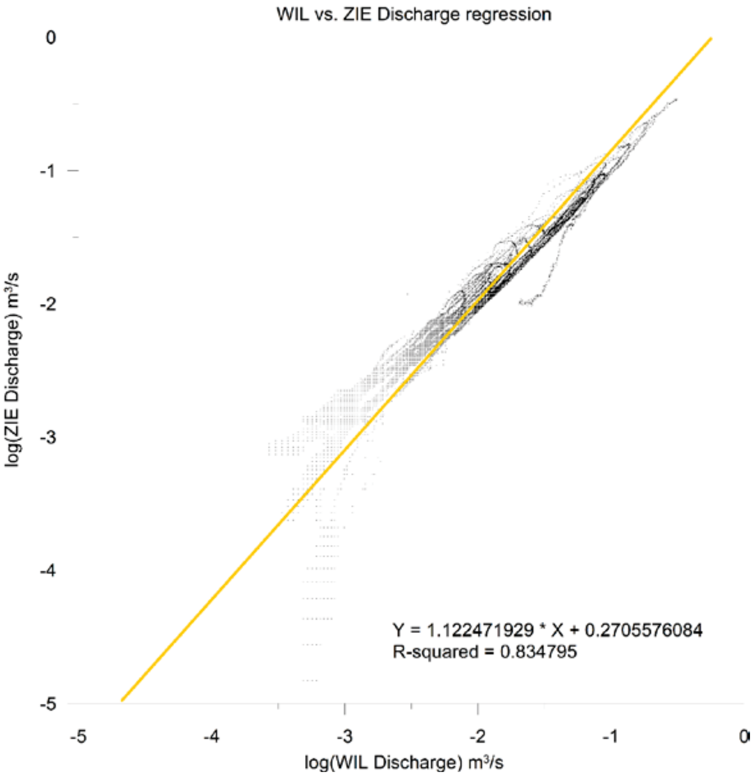
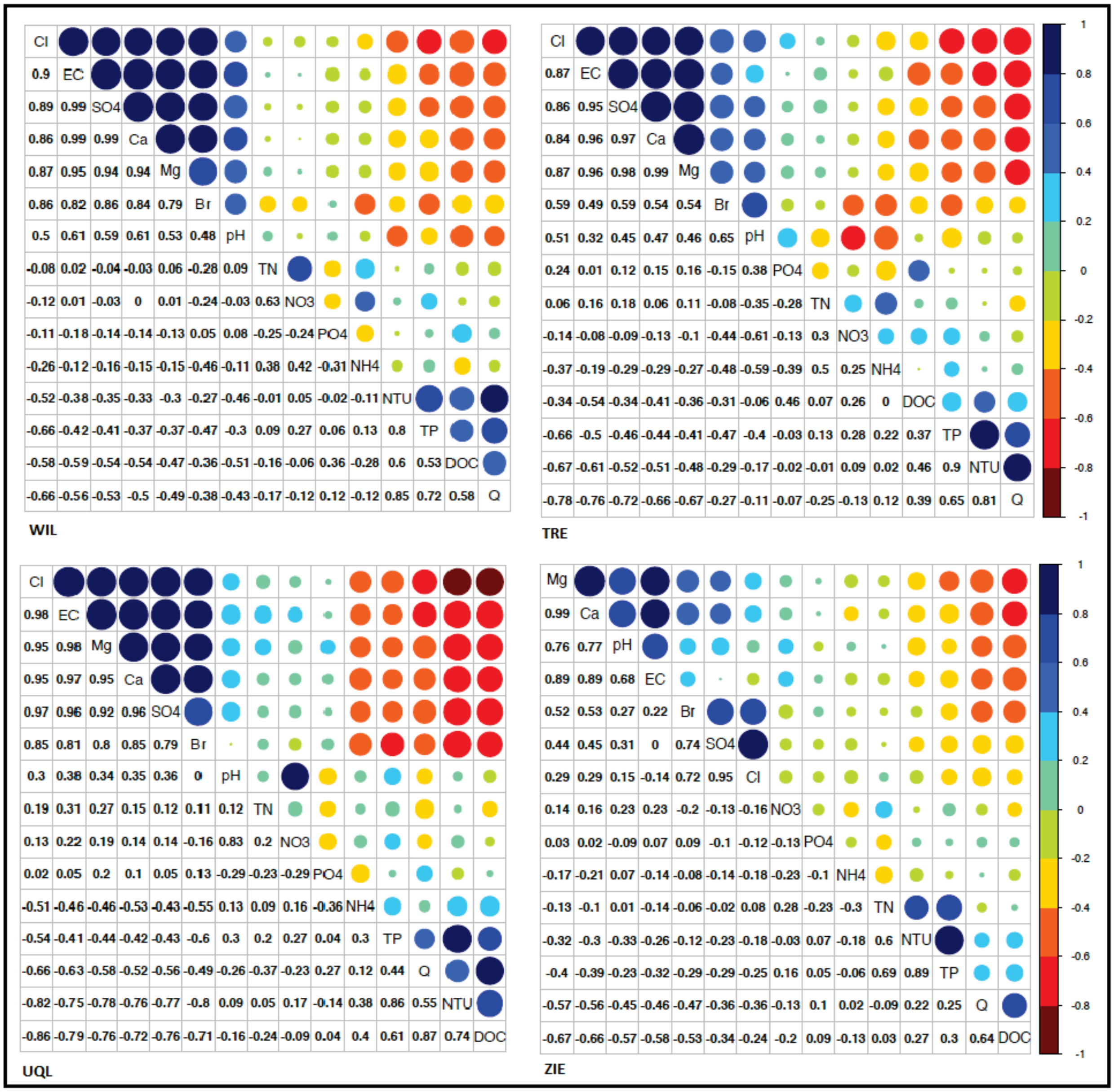


**Figure 9.** WIL vs. ZIE discharge regression.

## 4.3 Water Chemistry

Water chemistry components of each sub-watershed have been evaluated by correlation matrices between all biogeochemical variables analyzed in this study. These variables include stream discharge (Q), Turbidity (NTU), Electrical Conductivity (EC), pH, Total Phosphorous (TP), Total Nitrogen (TN), dissolved organic carbon (DOC), major cations (Ca, Mg, and NH4-N), and major anions (Cl, SO4, Br, PO4, and NO3-N). Potassium and sodium are also among the major cations included in our chemical analysis, but have been excluded from the correlation analysis at this time due to an ongoing quality assurance and quality control analysis. Correlation matrices of all variables are summarized for the sub-watersheds TRE, UQL, ZIE, and WIL in Figure 10.

High degrees of positive correlation (coefficients >0.6) are observed in all watersheds between Mg, Ca, Cl, Br, and EC. Turbidity and discharge are also generally strongly correlated with dissolved organic carbon and total phosphorous in most of the examined sub-watersheds. Negative correlation trends between Mg/Ca and DOC/TP/NTU/Q are also observable. The high degree of negative or positive correlation between biogeochemical variables is a good indication that the selected sub-watersheds behave hydrologically and biogeochemically in a similar manner. This ensures that these watersheds can be used to assess changes in the water balance and nutrient export as a result of the different timber harvest treatments. Streamwater chemistry will continue to be monitored throughout the winter of 2018, and will be statistically evaluated as chemical sample analysis continues.



| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cl | | | | | | | | | | | | | | |
| 0.9 | EC | | | | | | | | | | | | | |
| 0.89 | 0.99 | SO4 | | | | | | | | | | | | |
| 0.86 | 0.99 | 0.99 | Ca | | | | | | | | | | | |
| 0.87 | 0.95 | 0.94 | 0.94 | Mg | | | | | | | | | | |
| 0.86 | 0.82 | 0.86 | 0.84 | 0.79 | Br | | | | | | | | | |
| 0.5 | 0.61 | 0.59 | 0.61 | 0.53 | 0.48 | pH | | | | | | | | |
| -0.08 | 0.02 | -0.04 | -0.03 | 0.06 | -0.28 | 0.09 | TN | | | | | | | |
| -0.12 | 0.01 | -0.03 | 0 | 0.01 | -0.24 | -0.03 | 0.63 | NO3 | | | | | | |
| -0.11 | -0.18 | -0.14 | -0.14 | -0.13 | 0.05 | 0.08 | -0.25 | -0.24 | PO4 | | | | | |
| -0.26 | -0.12 | -0.16 | -0.15 | -0.15 | -0.46 | -0.11 | 0.38 | 0.42 | -0.31 | NH4 | | | | |
| -0.52 | -0.38 | -0.35 | -0.33 | -0.3 | -0.27 | -0.46 | -0.01 | 0.05 | -0.02 | -0.11 | NTU | | | |
| -0.66 | -0.42 | -0.41 | -0.37 | -0.37 | -0.47 | -0.3 | 0.09 | 0.27 | 0.06 | 0.13 | 0.8 | TP | | |
| -0.58 | -0.59 | -0.54 | -0.54 | -0.47 | -0.36 | -0.51 | -0.16 | -0.06 | 0.36 | -0.28 | 0.6 | 0.53 | DOC | |
| -0.66 | -0.56 | -0.53 | -0.5 | -0.49 | -0.38 | -0.43 | -0.17 | -0.12 | 0.12 | -0.12 | 0.85 | 0.72 | 0.58 | Q |

**WIL**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cl | | | | | | | | | | | | | | |
| 0.87 | EC | | | | | | | | | | | | | |
| 0.86 | 0.95 | SO4 | | | | | | | | | | | | |
| 0.84 | 0.96 | 0.97 | Ca | | | | | | | | | | | |
| 0.87 | 0.96 | 0.98 | 0.99 | Mg | | | | | | | | | | |
| 0.59 | 0.49 | 0.59 | 0.54 | 0.54 | Br | | | | | | | | | |
| 0.51 | 0.32 | 0.45 | 0.47 | 0.46 | 0.65 | pH | | | | | | | | |
| 0.24 | 0.01 | 0.12 | 0.15 | 0.16 | -0.15 | 0.38 | PO4 | | | | | | | |
| 0.06 | 0.16 | 0.18 | 0.06 | 0.11 | -0.08 | -0.35 | -0.28 | TN | | | | | | |
| -0.14 | -0.08 | -0.09 | -0.13 | -0.1 | -0.44 | -0.61 | -0.13 | 0.3 | NO3 | | | | | |
| -0.37 | -0.19 | -0.29 | -0.29 | -0.27 | -0.48 | -0.59 | -0.39 | 0.5 | 0.25 | NH4 | | | | |
| -0.34 | -0.54 | -0.34 | -0.41 | -0.36 | -0.31 | -0.06 | 0.46 | 0.07 | 0.26 | 0 | DOC | | | |
| -0.66 | -0.5 | -0.46 | -0.44 | -0.41 | -0.47 | -0.4 | -0.03 | 0.13 | 0.28 | 0.22 | 0.37 | TP | | |
| -0.67 | -0.61 | -0.52 | -0.51 | -0.48 | -0.29 | -0.17 | -0.02 | -0.01 | 0.09 | 0.02 | 0.46 | 0.9 | NTU | |
| -0.78 | -0.76 | -0.72 | -0.66 | -0.67 | -0.27 | -0.11 | -0.07 | -0.25 | -0.13 | 0.12 | 0.39 | 0.65 | 0.81 | Q |

**TRE**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cl | | | | | | | | | | | | | | |
| 0.98 | EC | | | | | | | | | | | | | |
| 0.95 | 0.98 | Mg | | | | | | | | | | | | |
| 0.95 | 0.97 | 0.95 | Ca | | | | | | | | | | | |
| 0.97 | 0.96 | 0.92 | 0.96 | SO4 | | | | | | | | | | |
| 0.85 | 0.81 | 0.8 | 0.85 | 0.79 | Br | | | | | | | | | |
| 0.3 | 0.38 | 0.34 | 0.35 | 0.36 | 0 | pH | | | | | | | | |
| 0.19 | 0.31 | 0.27 | 0.15 | 0.12 | 0.11 | 0.12 | TN | | | | | | | |
| 0.13 | 0.22 | 0.19 | 0.14 | 0.14 | -0.16 | 0.83 | 0.2 | NO3 | | | | | | |
| 0.02 | 0.05 | 0.2 | 0.1 | 0.05 | 0.13 | -0.29 | -0.23 | -0.29 | PO4 | | | | | |
| -0.51 | -0.46 | -0.46 | -0.53 | -0.43 | -0.55 | 0.13 | 0.09 | 0.16 | -0.36 | NH4 | | | | |
| -0.54 | -0.41 | -0.44 | -0.42 | -0.43 | -0.6 | 0.3 | 0.2 | 0.27 | 0.04 | 0.3 | TP | | | |
| -0.66 | -0.63 | -0.58 | -0.52 | -0.56 | -0.49 | -0.26 | -0.37 | -0.23 | 0.27 | 0.12 | 0.44 | Q | | |
| -0.82 | -0.75 | -0.78 | -0.76 | -0.77 | -0.8 | 0.09 | 0.05 | 0.17 | -0.14 | 0.38 | 0.86 | 0.55 | NTU | |
| -0.86 | -0.79 | -0.76 | -0.72 | -0.76 | -0.71 | -0.16 | -0.24 | -0.09 | 0.04 | 0.4 | 0.61 | 0.87 | 0.74 | DOC |

**UQL**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mg | | | | | | | | | | | | | | |
| 0.99 | Ca | | | | | | | | | | | | | |
| 0.76 | 0.77 | pH | | | | | | | | | | | | |
| 0.89 | 0.89 | 0.68 | EC | | | | | | | | | | | |
| 0.52 | 0.53 | 0.27 | 0.22 | Br | | | | | | | | | | |
| 0.44 | 0.45 | 0.31 | 0 | 0.74 | SO4 | | | | | | | | | |
| 0.29 | 0.29 | 0.15 | -0.14 | 0.72 | 0.95 | Cl | | | | | | | | |
| 0.14 | 0.16 | 0.23 | 0.23 | -0.2 | -0.13 | -0.16 | NO3 | | | | | | | |
| 0.03 | 0.02 | -0.09 | 0.07 | 0.09 | -0.1 | -0.12 | -0.13 | PO4 | | | | | | |
| -0.17 | -0.21 | 0.07 | -0.14 | -0.08 | -0.14 | -0.18 | -0.23 | -0.1 | NH4 | | | | | |
| -0.13 | -0.1 | 0.01 | -0.14 | -0.06 | -0.02 | 0.08 | 0.28 | -0.23 | -0.3 | TN | | | | |
| -0.32 | -0.3 | -0.33 | -0.26 | -0.12 | -0.23 | -0.18 | -0.03 | 0.07 | -0.18 | 0.6 | NTU | | | |
| -0.4 | -0.39 | -0.23 | -0.32 | -0.29 | -0.29 | -0.25 | 0.16 | 0.05 | -0.06 | 0.69 | 0.89 | TP | | |
| -0.57 | -0.56 | -0.45 | -0.46 | -0.47 | -0.36 | -0.36 | -0.13 | 0.1 | 0.02 | -0.09 | 0.22 | 0.25 | Q | |
| -0.67 | -0.66 | -0.57 | -0.58 | -0.53 | -0.34 | -0.24 | -0.2 | 0.09 | -0.13 | 0.03 | 0.27 | 0.3 | 0.64 | DOC |

**ZIE**

**Figure 10.** Pearson correlation coefficient matrices for sub-watersheds WIL, TRE, UQL, and ZIE of selected watershed and water chemistry parameters. The diagonal indicates what parameters are correlated and numbers in the lower half indicate the Pearson correlation coefficient, r.

Nutrient loads for 10 storm events between November 2016 and April 2017 have been calculated for each of the four sub-watersheds sampled for streamwater chemistry. Additionally, nutrient loads for the 2016 fall wetting period (mid-Oct. to Nov. 2016), and the total nutrient flux over the antecedent moisture period (mid-October through end of November 2016) have been calculated. Nutrient loads for each sampled sub-watershed are summarized in Table 5. Nutrient load calculations are indicative of general trends in watershed nutrient fluxes in response to storm events and during baseline conditions. These trends are particularly informative about the initial conditions in each watershed during the calibration (pre-treatment) period, and allow for more informed evaluation of observed nutrient fluxes in the post-treatment phase.

**Table 5.** Event based flux of selected nutrients (in kg/ha/event).

| TRE | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Event** | **Start** | **End** | **TN** | **NH4-N** | **NO3-N** | **TP** | **PO4** | **DOC** | **Cl** | **SO4** | **Br** | **Ca** | **Mg** |
| **W** | **10/12/16 22:17** | **11/3/16 5:05** | 0.03 | 0.00 | 0.01 | 0.01 | 0.01 | 0.34 | 6.59 | 2.12 | 0.12 | 0.00 | 0.00 |
| **A** | **10/12/16 22:17** | **11/25/16 5:45** | 0.20 | 0.00 | 0.02 | 0.04 | 0.02 | 2.62 | 14.59 | 4.97 | 0.27 | 0.00 | 0.00 |
| **1** | **11/25/16 5:45** | **12/16/16 0:10** | 0.28 | 0.03 | 0.02 | 0.04 | 0.01 | 4.04 | 24.07 | 9.43 | 0.37 | 0.00 | 0.00 |
| **2** | **12/16/16 0:10** | **12/25/16 16:25** | 0.13 | 0.00 | 0.01 | 0.05 | 0.00 | 1.48 | 5.60 | 1.48 | 0.10 | 0.00 | 0.00 |
| **3** | **12/25/16 16:25** | **1/13/17 19:05** | 0.37 | 0.03 | 0.03 | 0.08 | 0.01 | 6.63 | 22.66 | 6.63 | 0.34 | 2.82 | 2.91 |
| **4** | **1/13/17 19:05** | **1/30/17 16:05** | 0.16 | 0.03 | 0.02 | 0.04 | 0.01 | 5.24 | 19.77 | 5.23 | 0.27 | 2.62 | 2.70 |
| **5** | **1/30/17 16:05** | **2/7/17 23:00** | 0.15 | 0.03 | 0.01 | 0.05 | 0.00 | 2.89 | 10.72 | 2.94 | 0.17 | 1.48 | 1.50 |
| **6** | **2/14/17 8:00** | **3/8/17 11:46** | 0.46 | 0.23 | 0.01 | 0.08 | 0.01 | 4.16 | 21.65 | 6.01 | 0.33 | 3.09 | 3.14 |
| **7** | **3/8/17 11:46** | **3/25/17 6:00** | 0.15 | 0.04 | 0.01 | 0.03 | 0.00 | 1.61 | 10.39 | 2.89 | 0.09 | 1.40 | 1.44 |
| **8** | **3/25/17 6:00** | **4/3/17 18:02** | 0.12 | 0.06 | 0.01 | 0.02 | 0.00 | 0.60 | 4.80 | 1.43 | 0.02 | 0.70 | 0.72 |
| **9** | **4/3/17 18:02** | **4/19/17 11:32** | 0.12 | 0.04 | 0.03 | 0.03 | 0.00 | 0.91 | 8.56 | 2.55 | 0.05 | 1.20 | 1.23 |
| **10** | **4/19/17 11:32** | **5/3/17 22:25** | 0.09 | 0.00 | 0.00 | 0.01 | 0.00 | 0.44 | 5.06 | 1.69 | 0.10 | 0.70 | 0.81 |
| **Total flux** | **10/12/16 22:17** | **5/3/17 22:25** | 2.24 | 0.48 | 0.15 | 0.47 | 0.07 | 30.62 | 147.8 | 45.25 | 2.11 | 14.02 | 14.44 |

| UQL FLUX | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Event** | **Start** | **End** | **TN** | **NH4-N** | **NO3-N** | **TP** | **PO4** | **DOC** | **Cl** | **SO4** | **Br** | **Ca** | **Mg** |
| **W** | **10/12/16 22:17** | **11/3/16 5:05** | 0.04 | 0.00 | 0.00 | 0.00 | 0.00 | 1.35 | 4.80 | 1.74 | 0.06 | 0.00 | 0.00 |
| **A** | **10/12/16 22:17** | **11/25/16 5:45** | 0.56 | 0.05 | 0.02 | 0.10 | 0.01 | 9.38 | 32.99 | 8.71 | 0.26 | 0.00 | 0.00 |
| **1** | **11/25/16 5:45** | **12/16/16 0:10** | 0.03 | 0.00 | 0.00 | 0.01 | 0.00 | 0.73 | 2.57 | 0.72 | 0.03 | 0.00 | 0.00 |
| **2** | **12/16/16 0:10** | **12/25/16 16:25** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.08 | 0.33 | 0.10 | 0.01 | 0.00 | 0.00 |
| **3** | **12/25/16 16:25** | **1/13/17 19:05** | 0.34 | 0.07 | 0.01 | 0.12 | 0.01 | 15.93 | 47.36 | 13.46 | 0.57 | 0.00 | 0.00 |
| **4** | **1/13/17 19:05** | **1/30/17 16:05** | 0.28 | 0.16 | 0.00 | 0.06 | 0.00 | 4.24 | 13.58 | 4.03 | 0.13 | 1.97 | 1.86 |
| **5** | **1/30/17 16:05** | **2/7/17 23:00** | 0.24 | 0.11 | 0.00 | 0.02 | 0.00 | 2.17 | 8.23 | 2.45 | 0.11 | 1.31 | 1.20 |
| **6** | **2/14/17 8:00** | **3/8/17 11:46** | 0.11 | 0.04 | 0.00 | 0.02 | 0.00 | 0.89 | 3.44 | 1.09 | 0.02 | 0.58 | 0.57 |
| **7** | **3/8/17 11:46** | **3/25/17 6:00** | 0.33 | 0.07 | 0.00 | 0.03 | 0.00 | 1.63 | 11.97 | 3.79 | 0.12 | 1.87 | 1.95 |
| **8** | **3/25/17 6:00** | **4/3/17 18:02** | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.25 | 0.10 | 0.01 | 0.05 | 0.06 |
| **9** | **4/3/17 18:02** | **4/19/17 11:32** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **10** | **4/19/17 11:32** | **5/3/17 22:25** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Total flux** | **10/12/16 22:17** | **5/3/17 22:25** | 1.89 | 0.49 | 0.04 | 0.34 | 0.02 | 35.07 | 120.7 | 34.44 | 1.24 | 5.79 | 5.63 |

*W=Wetting period, A=Antecedent moisture period. **Sample dates based on midpoint approach.

## Table 5 ( continued)

**WIL FLUX**

| Event | Start | End | TN | NH4-N | NO3-N | TP | PO4 | DOC | Cl | SO4 | Br | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 10/12/16 22:17 | 11/3/16 5:05 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.43 | 0.42 | 0.02 | 0.00 | 0.00 |
| A | 10/12/16 22:17 | 11/25/16 5:45 | 0.24 | 0.01 | 0.01 | 0.05 | 0.01 | 4.70 | 20.57 | 1.26 | 0.07 | 0.00 | 0.00 |
| 1 | 11/25/16 5:45 | 12/16/16 0:10 | 0.03 | 0.00 | 0.00 | 0.01 | 0.00 | 0.43 | 2.18 | 1.15 | 0.04 | 0.00 | 0.00 |
| 2 | 12/16/16 0:10 | 12/25/16 16:25 | 0.19 | 0.01 | 0.02 | 0.07 | 0.01 | 2.63 | 7.01 | 0.14 | 0.01 | 0.00 | 0.00 |
| 3 | 12/25/16 16:25 | 1/13/17 19:05 | 0.22 | 0.01 | 0.01 | 0.03 | 0.01 | 2.59 | 8.26 | 1.16 | 0.08 | 1.64 | 1.38 |
| 4 | 1/13/17 19:05 | 1/30/17 16:05 | 0.44 | 0.03 | 0.01 | 0.14 | 0.01 | 5.63 | 13.26 | 0.70 | 0.05 | 2.63 | 2.15 |
| 5 | 1/30/17 16:05 | 2/7/17 23:00 | 0.42 | 0.02 | 0.00 | 0.06 | 0.04 | 3.24 | 13.08 | 0.58 | 0.04 | 2.56 | 2.18 |
| 6 | 2/14/17 8:00 | 3/8/17 11:46 | 0.31 | 0.13 | 0.00 | 0.12 | 0.02 | 4.98 | 23.06 | 0.66 | 0.04 | 2.80 | 4.18 |
| 7 | 3/8/17 11:46 | 3/25/17 6:00 | 0.30 | 0.18 | 0.00 | 0.04 | 0.01 | 2.19 | 11.86 | 0.70 | 0.03 | 2.26 | 1.87 |
| 8 | 3/25/17 6:00 | 4/3/17 18:02 | 0.03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.78 | 0.39 | 0.02 | 0.21 | 0.19 |
| 9 | 4/3/17 18:02 | 4/19/17 11:32 | 0.03 | 0.01 | 0.00 | 0.01 | 0.00 | 0.22 | 0.79 | 0.16 | 0.00 | 0.22 | 0.19 |
| 10 | 4/19/17 11:32 | 5/3/17 22:25 | 0.07 | 0.02 | 0.01 | 0.01 | 0.00 | 0.23 | 0.86 | 0.15 | 0.01 | 0.22 | 0.19 |
| Total flux | 10/12/16 22:17 | 5/3/17 22:25 | 2.28 | 0.42 | 0.06 | 0.54 | 0.11 | 26.94 | 101.71 | 7.04 | 0.38 | 12.54 | 12.32 |

**ZIE FLUX**

| Event | Start | End | TN | NH4-N | NO3-N | TP | PO4 | DOC | Cl | SO4 | Br | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W | 10/12/16 22:17 | 11/3/16 5:05 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.93 | 0.44 | 0.02 | 0.00 | 0.00 |
| A | 10/12/16 22:17 | 11/25/16 5:45 | 0.27 | 0.00 | 0.00 | 0.05 | 0.01 | 5.72 | 19.94 | 1.32 | 0.07 | 0.00 | 0.00 |
| 1 | 11/25/16 5:45 | 12/16/16 0:10 | 0.09 | 0.01 | 0.01 | 0.02 | 0.00 | 1.25 | 5.18 | 1.20 | 0.04 | 0.00 | 0.00 |
| 2 | 12/16/16 0:10 | 12/25/16 16:25 | 0.03 | 0.00 | 0.00 | 0.01 | 0.00 | 0.35 | 0.94 | 0.14 | 0.01 | 0.00 | 0.00 |
| 3 | 12/25/16 16:25 | 1/13/17 19:05 | 0.18 | 0.02 | 0.02 | 0.04 | 0.00 | 3.28 | 10.41 | 1.22 | 0.08 | 0.43 | 0.46 |
| 4 | 1/13/17 19:05 | 1/30/17 16:05 | 0.05 | 0.00 | 0.00 | 0.02 | 0.00 | 2.54 | 5.52 | 0.73 | 0.05 | 0.70 | 0.70 |
| 5 | 1/30/17 16:05 | 2/7/17 23:00 | 0.31 | 0.02 | 0.01 | 0.05 | 0.00 | 4.33 | 7.82 | 0.60 | 0.04 | 1.33 | 1.31 |
| 6 | 2/14/17 8:00 | 3/8/17 11:46 | 0.34 | 0.04 | 0.01 | 0.03 | 0.00 | 5.02 | 14.74 | 0.69 | 0.04 | 2.47 | 2.60 |
| 7 | 3/8/17 11:46 | 3/25/17 6:00 | 0.40 | 0.19 | 0.01 | 0.11 | 0.00 | 6.09 | 18.24 | 0.73 | 0.04 | 3.55 | 3.39 |
| 8 | 3/25/17 6:00 | 4/3/17 18:02 | 0.04 | 0.02 | 0.00 | 0.01 | 0.00 | 0.46 | 1.56 | 0.41 | 0.02 | 0.29 | 0.29 |
| 9 | 4/3/17 18:02 | 4/19/17 11:32 | 0.04 | 0.02 | 0.00 | 0.01 | 0.00 | 0.48 | 1.42 | 0.17 | 0.00 | 0.26 | 0.24 |
| 10 | 4/19/17 11:32 | 5/3/17 22:25 | 0.08 | 0.03 | 0.00 | 0.02 | 0.00 | 0.99 | 3.72 | 0.16 | 0.01 | 0.70 | 0.68 |
| Total flux | 10/12/16 22:17 | 5/3/17 22:25 | 1.82 | 0.35 | 0.07 | 0.35 | 0.03 | 30.51 | 89.49 | 7.37 | 0.40 | 9.72 | 9.68 |

*W=Wetting period, A=Antecedent moisture period. **Sample dates based on midpoint approach.

Total nutrient loads from the four watersheds were overall pretty similar. Export of TN, NH4, NO3-, PO4, and TP were negligible and ranged between 0.02 and 2.28 kg for the ten storm events between October 2016 and May 2017. In comparison, export of DOC, chloride and sulfate (SO4-) were much higher. DOC export from the control sub-watershed WIL (27 kg/ha) was lowest among the four sub-watersheds and slightly higher (30-35 kg/ha) in the three sub-watersheds receiving the timber reduction treatments. Chloride export was highest in the TRE sub-watershed (147 kg/ha, 14.1 ha) and lowest in the ZIL sub-watershed (89 kg/ha, 25.3 ha). Further, sulfate showed a clear difference between the four sub-watersheds. Both WIL and ZIL showed low Sulfate loads (7kg/ha each) for the ten winter storms, while TRE and WIL showed SO4 loads that were at least 5-8 times higher (45 and 34 kg/ha respectively). In order to understand these differences in nutrient export more detailed statistical analyses will be conducted in the coming months.

# 5 Summary and Conclusions

## 5.1 Continued hydrologic monitoring and chemical/statistical analysis

Hydrologic monitoring will continue throughout 2018 winter and spring until the scheduled harvest treatments are applied starting in June of 2018. The addition of at least one (or more) chemical sampling locations along the main stem of the South Fork are underway, and will provide additional data to assess nutrient fluxes and downstream effects in response to harvest treatments. Chemical analysis of samples obtained between August 2017 and January 2018 is ongoing, and will continue for incoming samples throughout the year. Further statistical analysis including the Daniel's Test for Trend to examine temporal trends among sub-watersheds will be implemented as discharge data for the winter 2018 continues to be obtained from Caspar Creek Experimental Watersheds staff.

## 5.2 Future collaborations

Collaboration and data circulation among research groups involved in the Third Experiment is expected to increase during the coming months as project goals align in anticipation of the beginning of harvest treatments in June. Data collection, field sampling, and group collaboration efforts will likely intensify at the Caspar Creek watershed after the rainy season comes to an end and as overall site and sub-watershed accessibility increases to field researchers. Collaborations specifically of interest to our group will be with the Sediment Fingerprinting Study Group and the Bioassessment Study Group. These collaborations will be useful in order to synthesize the initial findings of soil and biogeochemical, hydrologic and ecology-based investigations in the Third Experiment.

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