

Compilation and Assessment of Stormwater and Bear Creek Water Quality Data Collected After the Almeda Drive Fire



Prepared by:

Kate Perkins, Environmental Research

Jacob Kann, Aquatic Ecosystem Sciences

Under Contract to:

Aquatic Ecosystem Sciences LLC

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Prepared for:

Rogue Valley Council of Governments

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Abstract

Fire events are increasing in frequency and intensity across the western United States. Higher population densities can increase the likelihood of a human-ignited fire, and fire risk is greatest in areas that have both forested spaces and extensive urban and suburban development. While much is known about the effect of wildland fires on water quality, for example increased sedimentation and water temperatures, less is known about the effects of fires in more densely populated areas. Urban and suburban fires may input contaminants such as persistent organic pollutants that are not a concern in wildland ecosystems. Additionally, pollutants like metals may be found at higher concentrations in burned urban ecosystems due to inputs from impervious surfaces like roadways and rooftops.

The Almeda Drive Fire occurred along the Bear Creek riparian corridor and in adjacent urban and suburban areas, destroying homes and businesses in Ashland, Talent, Phoenix, and Medford, Oregon on September 8th, 2020. In an effort to better understand the effect of this fire on the water quality of Bear Creek, local organizations collected samples in stormwater and surface water following the fire. The goals of this project were to 1) compile Post-Almeda Drive Fire Monitoring data collected by Rogue Valley Council of Governance, Rogue Valley Sewer Services, and Department of Environmental Quality into a database for submission to a publicly available repository, 2) to characterize the water quality data collected during the effort, and 3) determine if a signal from the fire could be detected in the dataset. We compiled a database containing 437 parameters and over 7,000 data points extracted from 41 files. Data collected by deployed sondes were compiled separately into a database containing 10 parameters and over 500,000 data points extracted from 2 files.

We investigated metal and nutrient pollutants, water quality indicators such as dissolved oxygen and turbidity, and emerging contaminant 6PPD-q. Parameters included: metals aluminum, arsenic, cadmium, chromium, copper, iron, lead, zinc, emerging contaminant 6PPD-quinone, water quality parameters hardness, phosphorus, total organic carbon, total suspended solids, nitrate-nitrogen, nitrite-nitrogen, total Kjeldahl nitrogen, total nitrogen, pH, conductivity, E. coli, phosphorus, turbidity, dissolved oxygen, pH, specific conductivity, and water temperature. Other pollutants and toxics landing outside the scope of this report were characterized in other documents as part of the larger Bear Creek post-fire project involving multiple agencies and authors.

While we were able to characterize some general trends in these data, the ability to make inferences regarding the fire was limited due to lack of pre-fire data for many parameters, low sampling frequency, and limited overlap in time for longitudinal data collected above and below the fire area on Bear Creek. Key findings include:

- Stormwater sampling indicated that for most metals the West Valley View (WVV) site had greater concentrations than the other two stormwater sites (Culver Rd - CR and Northridge Terrace - NRT). Site WVV had the greatest burn intensity, however it also had the greatest traffic intensity. Given that metal pollutants can result from both fire and high-traffic roadways, as well as impervious surfaces like building roofs, it is difficult to disentangle the source of pollutants since before-fire data were not available.

- For several metals, concentrations were either similar at stormwater sites NRT and CR or greater at CR; this may be attributed to the larger CR watershed drainage area allowing increased metals from roadways. So even though CR is considered an unburned reference site, overall interpretation is again confounded by varying drainage areas and traffic patterns among the three stormwater sites.
- The in-stream station Bear Creek at US Cellular (BCUC) was sampled nearest in time to the fire and showed that metal concentrations tended to be greater on the November 15th, 2020 sampling date than the November 4th, 2020 sampling date. This trend likely reflects increased precipitation prior to and during the November 15th sampling date relative to the 4th sampling date, generating more surface runoff to suspend and transport pollutants to Bear Creek.
- While most data were collected after the fire, the Total Maximum Daily Load (TMDL) data set spanned the date of the Almeda Drive Fire. However, the only notable trend in the TMDL data was for conductivity where after the fire all three categories of sites, upstream, in, and downstream of the burn, displayed an increase relative to the prior four years. However, the values were similar to those in 2014 and 2015, well before the fire. In addition, while conductivity was greater at sites downstream of the burn than in the burn perimeter for all sampling dates prior to the burn, after the burn it tended to be equal or greater at sites within the burn perimeter.
- Concentrations of iron tended to be correlated with the other metals considered, zinc, arsenic, copper, and lead, with the exception being cadmium. This trend was also true for aluminum, although the correlation strength between aluminum and other metals was weaker than between iron and other metals. Aluminum and iron are both commonly found as oxides in rivers and streams, with redox reactive surfaces that attract other metals like lead. Other metals, like copper and zinc, had correlations with each other that were still present but weaker, possibly indicating a mutual source like a burned area or roadway contributing metal pollutants to stormwater.
- When considering all sites, both stormwater and in-stream, there were correlations between both iron and aluminum and total suspended solids. Since both iron and aluminum are found at high concentrations in soils, these correlations likely indicate the movement of material, such as soils and sediment, that are known to increase concentrations of total suspended solids.
- Four parameters, phosphorus, total Kjeldahl nitrogen, total organic carbon, and total suspended solids, were selected for analysis across six dates due to data availability (these were the only dates when all three sites were consistently sampled). Total phosphorus and TOC (lower quartile only) tended to be lower at NRT, and CR tended to be higher for total phosphorus and lower for TSS. Which site had the highest median concentration for each of the four parameters varied by analyte with no consistent pattern among the sites.
- The Oregon Department of Environmental Quality data beginning in 2014 for a suite of water quality parameters did not show substantially different year-to-year patterns relative to the long-term median. The infrequent point-in-time sampling data (approximately every other month) made it challenging to interpret before and after trends relative to the Almeda Drive Fire.

Given the sudden onset and intensity of the fire and ongoing logistical issues due to COVID, the Rogue Valley Council of Governments, Rogue Valley Sewer Services, and Oregon Department of Environmental Quality put forward a laudable effort to document Almeda Drive Fire water quality effects. Despite the difficulty in identifying water quality effects that can be directly tied to the Almeda Drive Fire, this monitoring effort and compilation of multiple sampling data by a variety of agencies provides a valuable dataset for characterizing important water quality constituents in Bear Creek and can be built upon for future monitoring efforts.

Contents

Abstract.....	3
1. Introduction	8
1.1 Fire & Water Quality	8
1.2 Land Use & Water Quality	9
2. Background	11
2.1 Bear Creek.....	11
2.2 Alameda Drive Fire.....	11
3. Methods.....	11
3.1 Data Sources	11
3.2 Data Collection Sites	12
3.3 Data Availability & Limitations to Analysis	15
3.4 Data Compilation & QA Methods	16
3.5 Data Trend Analysis.....	17
3.5.1 Time Series Plots	17
3.5.2 Boxplots.....	17
3.5.3 Scatterplots & Pearson Correlation	17
4. Flow & Precipitation.....	18
5. Site Characterization.....	19
5.1 Post-Fire Water Quality Stormwater Sites.....	19
5.1.1 West Valley View	19
5.1.2 North Ridge Terrace.....	20
5.1.3 Colver Rd	20
5.2 Post-Fire Water Quality In-Stream Sites	21
5.3 Total Maximum Daily Load Sites.....	22
5.4 Oregon Department of Environmental Quality Sites.....	22
6. Results & Discussion: Post-Fire Stormwater & In-Stream Data	22
6.1 6PPD-quinone	22
6.2 Metal Pollutants.....	23

6.2.1 Stormwater Site Analysis	23
6.2.2 Correlations Between Metals at In-Stream & Stormwater Sites	29
6.2.3 In-Stream Site Analysis.....	30
6.3 Additional Water Quality Parameters.....	33
6.3.1 Stormwater Site Analysis	33
6.3.2 Correlations Between Analytes.....	38
6.3.3 In-Stream Site Analysis.....	38
7. Results & Discussion: RVCOG TMDL Data	39
7.1 Water Temperature & pH	40
7.2 Trends in Conductivity	42
8. Results & Discussion: DEQ Water Quality Data	45
9. Results & Discussion: Sonde Data	48
Literature Cited	50
Appendix	55
Appendix A. Description of precipitation and flow trends	55
Appendix B. Analyte Concentration Tables	56
Appendix B.1 RVCOG Metals Data	56
Appendix B.2 RVCOG Water Quality Parameters	64
Appendix B.3 RVCOG TMDL Data.....	67
Appendix C. Scatterplots.....	78
Appendix C.1 Scatterplots of Metals at All Sites.....	78
Appendix C.2 Scatterplots of Water Quality Parameters at All Sites.....	79
Appendix C.3 Scatterplots of Water Quality Parameters Compared to Aluminum and Iron at All Sites	80
Appendix C.4 Scatterplots of TMDL Data at All Sites, Grouped by Location Relative to Burn Perimeter	81
Appendix D. Additional Figures.....	82
Appendix D.1 Time Series of metals at all in-stream sites.....	82
Appendix D.2 Time Series of water quality parameters at all in-stream sites.....	83
Appendix E. Period of Record Figures.....	86

1. Introduction

1.1 Fire & Water Quality

In the Pacific Northwest, like many places in the world, fire events are increasing in frequency and intensity due to changing climatic conditions (Halofsky et al., 2020; Williams et al., 2022). Fires that occur at the wildland-urban interface (WUI) are becoming increasingly common due to the expansion of populated areas into adjacent wildland spaces. Not only are fires at the WUI a greater risk in terms of loss of life and homes, they are more often ignited by humans living in these areas (Radeloff et al., 2018). The same is true for urban areas, where although urbanization reduces the amount of vegetation available to burn, denser populations increase the likelihood of human-ignited fires (Price & Bradstock, 2014). Fire risk is especially high in areas that are still vegetated or forested and also have considerable urban or suburban development (Price & Bradstock, 2014). The Alameda Drive Fire falls into this latter category, where extensive forested riparian areas present along Bear Creek border urban, commercial, and suburban developments in the cities of Ashland, Talent, Phoenix, and Medford, Oregon.

Research on the effects of wildland fire on surface water quality indicates changes to streamflow, sediment loading, temperature, and the concentration of algae following fires. Fire in wildland ecosystems can result in changes in water quantity; stream flow has been shown to increase after an area has burned, in some cases for five or more years after the fire (Hallema et al., 2018). This increase in flow is related to the decrease in water use by trees and other vegetation and reduced infiltration rates due to increased hydrophobicity in soils in the burned area (Williams et al., 2022). Elevated surface runoff in burned areas can result in increased inputs of pollutants to rivers and streams. A very common effect of fire on the landscape is greater sediment loads that can occur for eight years after a fire event, with the largest increase occurring in the year just after the fire (U.S. Forest Service, 2014). A review of the effects of wildfire across thirty-four studies found that 91% reported an increase in suspended sediment concentrations as a result of fire on the landscape (Paul et al., 2022). A comparison of burned and unburned zones in California described burned zones having less canopy cover and therefore higher stream temperatures when compared to unburned zones, in addition to higher concentrations of algae present (Cooper et al., 2015).

Wildland fires can also result in increased chemical loading (e.g., nitrogen, phosphorus, and metals) to surface waters, and cause changes to water properties such as pH and dissolved oxygen. An analysis of thirty-four fire studies found that most sites increased in nitrogen and phosphorus, particularly in the forms of nitrate, total phosphorus, and ammonium, after an area had been burned (Hampton et al., 2022). Another review concluded that downstream loads of nitrogen and phosphorus were regulated by remaining post-fire vegetation cover and correlated to fire severity (Rust et al., 2019). Some metals and trace elements can be transported to surface waters in sediment after a fire; for example, a study of the Station Fire near Los Angeles found that elevated concentrations of iron, manganese, and mercury, as well as trace elements like copper, selenium, zinc, and lead could be attributed to the fire (Burton et al., 2016). A review of metal release from fire found that a large range of metals were transported, both by

overland flow and due to airborne ash from the fire (Abraham et al., 2017). Other chemical responses have been noted in burned areas, including changes to pH, conductivity, dissolved oxygen, and organic carbon (Paul et al., 2022).

Fire suppression chemicals are regularly applied to wildland fires and were used on the Alameda Drive Fire, and these chemicals have been linked to fish kills and degradation of water quality. The U.S. Forest Service is required to have a 300 foot riparian buffer no drop zone around surface waters when applying fire suppressant chemicals to the landscape; however, accidental drops have resulted in fish kills and other adverse effects (Mohr, 2023). Multiple laboratory studies found that fire suppressant chemical quantities that are possible during an accidental drop could create surface water concentrations causing mortality and gill damage in fish (Dietrich et al., 2012; Gaikowski et al., 1996). One study of burned watersheds found no difference in stream concentrations of ammonia, phosphorus, and cyanide when comparing streams draining areas where fire suppressant was used and where it was not (Crouch et al., 2006). This aligns with a study from the U.S. Forest Service where the chemicals in fire suppressant were not toxic when entering streams as runoff from soils, however all four chemicals studied were toxic to aquatic species when applied directly (LABAT Environmental, 2013). Fish kills can occur due to the accidental application of fire suppressants to surface waters like rivers and lakes, and a lawsuit against the U.S. Forest Service is currently active citing that this activity is in violation of the Clean Water Act (Mohr, 2023). It is important to note that accidental application of fire suppressants to rivers and riparian areas is sometimes unavoidable in order to save properties and for public safety, especially in more urban fires.

While the effects of fire on water quality in wildland ecosystems are well established, the implications of urban fires for rivers and streams are less understood. In addition to the effects described above, urban fire can release organic and persistent organic pollutants. For example, a review found that polyaromatic hydrocarbons increased in concentration downstream of burned areas, and this includes varieties like fluorene and naphthalene (Paul et al., 2022). A study of two fires in the WUI in California described benzene detected in drinking water systems, likely released from burnt plastic pipes used to transport water (Proctor et al., 2020). A study of urban fringe fires found that copper, lead, and zinc flux were 112-to-736-times greater from burned urban areas than unburned urban areas and more than 900-times higher in burned urban areas than unburned natural areas (Stein et al., 2012). Polycyclic aromatic hydrocarbons were greater in burned than unburned urban areas, and ash deposited from the burned areas were found to increase metal and polycyclic aromatic hydrocarbons in unburned areas. The impact of urban and urban fringe fire on surface water quality is an area that would benefit from further research, especially given that the incidence of urban fires and fires in the WUI will likely increase with climate change and population growth (Committee on the Chemistry of Urban Wildfires et al., 2022; Paul et al., 2022).

1.2 Land Use & Water Quality

Urbanization alters the hydrologic cycle and surface waters' response to precipitation, in addition to inputting pollutants to surface waters through the stormwater system. In urban areas, impervious surfaces like concrete and buildings prevent water from infiltrating into the ground, creating runoff that

is carried away by stormwater systems before entering rivers and streams. The impervious nature of urban ecosystems alters the hydrologic cycle by increasing the frequency of high flows and reducing the volume of low flows, in addition to producing greater daily variability in water volume (Konrad & Booth, 2005).

Urban stream systems tend to have poorer water quality than streams in areas of forested, undisturbed land, and the water quality impairments in urban streams can be similar to those found in burned wildland ecosystems. When comparing the water quality impairments in unburned urban ecosystems and burned wildland ecosystems, the two scenarios face similar challenges due to comparable changes in hydrology when compared to an undisturbed, forested ecosystem (Beesley et al., 2016). Urban ecosystem streamflow has a strong response to precipitation because of the high impervious land cover, creating surface runoff that can carry pollutants from urban areas to surface waters (Chen & Chang, 2014). For example, nitrogen concentrations in stormwater runoff were positively correlated with rainfall in an urban residential drainage area, and the source was identified as tree material and grass clippings (Jani et al., 2020). A study on nitrogen and phosphorus runoff from lawns found higher concentrations in lawns irrigated with water reclaimed from the wastewater treatment plan (Toor et al., 2017), also highlighting the contribution of wastewater effluent to nutrient concentrations in surface waters (Carey & Migliaccio, 2009). Pet waste (Hobbie et al., 2017) and organic material from trees growing alongside roadways (Janke et al., 2017) have also been identified as sources of nutrient pollution that enter stormwater systems.

Metals are another common pollutant in urban surface waters, sourcing from roadways and structures in impervious areas before entering the stormwater system. The most urbanized areas, as measured by the relative amount of impervious surface present, tend to have the highest concentrations of metals measured in stormwater monitoring (Taka et al., 2022). Metal pollutants have been identified entering stormwater systems from metal roofing products, like zinc or copper-based roofs or gutters, that receive rainfall washing dissolved metals into stormwater (Charters et al., 2021; Sakson et al., 2018). Roadways and vehicle traffic are important contributors of metal pollutants to surface waters. Not only does the presence of a road correlate with the presence of metals, but more vehicle traffic is correlated with increased metal concentrations (Du et al., 2019; Tu, 2023). Zinc in particular tends to be associated with automobile-sourced pollutants (Ramirez et al., 2022). Urban streams also tend to measure higher in total suspended sediment (Chen & Chang, 2014) and temperature, while measuring lower in dissolved oxygen (Kolath & Egemose, 2023).

Emerging contaminant 6PPD-quinone is another water quality concern in urban ecosystems, as it has been linked to salmon mortality in rivers and streams. Because 6PPD-quinone is sourced from car tires, it travels from roads to stormwater, then from stormwater to surface waters (California Department of Toxic Substances Control, 2021). It has been identified as a highly toxic contaminant for some aquatic species, particularly salmonids, and the researchers that identified this contaminant described a toxicity threshold of 95 ng/L (Tian et al., 2022).

Precipitation in urban areas can have a large effect on water quality because surface runoff carries contaminants from impervious surfaces like roadways and roofs to stormwater then stream systems. For example, a study comparing urban, suburban, and rural streams found that pollutants including turbidity, phosphorus, and fecal coliform were higher during rain events. The authors also noted that the amount of rainfall occurring prior to the sampling date was positively correlated with pollutant concentrations (Mallin et al., 2009).

2. Background

2.1 Bear Creek

Bear Creek is a tributary of the Rogue River and flows through the length of the Alameda Drive Fire burn area. The Bear Creek Watershed encompasses an urban and suburban area passing south to north through the Oregon towns of Ashland, Talent, Phoenix, Medford, and Central Point before entering the Rogue River. More than eleven miles of the Bear Creek corridor were directly in or near the path of the Alameda Drive Fire, where many patches of the riparian zone were burned. Stormwater systems in burned areas, including burned structures, carried runoff directly to Bear Creek often with little or no treatment. This highlights the potential for pollutants from impervious surfaces in the burned area to contribute to water quality concerns.

2.2 Alameda Drive Fire

The Alameda Drive Fire in southern Oregon occurred on September 8th, 2020 and started in a dry field near the Ashland Wastewater Treatment plant. The fire was swiftly carried by high winds north along the Bear Creek Greenway, traveling through Ashland and Talent, spreading west into Talent and continuing up the Bear Creek Greenway into Phoenix and Medford. Approximately 3,000 acres burned in the fire, and more than 2,500 homes and 500 businesses in the towns of Ashland, Talent, Phoenix, Medford, and Central Point were damaged or destroyed.

Immediately following the fire, Rogue Valley Sewer Services applied biobags specially formulated to capture organic compounds in burned areas of Talent and Phoenix. Additionally, street sweeping and debris removal was undertaken to prevent ash and firefighting chemicals from entering the storm drain system and getting into Bear Creek.

3. Methods

3.1 Data Sources

After the Alameda Drive Fire, a collaborative working group was established to collect water quality data and investigate the effects of the fire on stormwater and surface water. The working group included the Rogue Valley Council of Governments (RVCOG), Rogue Valley Sewer Services (RVSS), Rogue River Watershed Council (RRWC), Medford Water Commission, and City of Grants Pass. For the structure and goals of the working group and the entities responsible for sample collection, see the Sampling and Analysis Plan for Alameda Post-Fire Monitoring (Rogue Valley Council of Governments, 2022). The Post-

Fire Monitoring data collection occurred one to three times per year depending on the site. Metrics collected have included metals, toxics like PFAS, dioxins, and furans, 6PPD-quinone, nutrients, and turbidity. For the purpose of this report, metals, nutrients, 6PPD-quinone, and other more standard water quality parameters like temperature and dissolved oxygen were analyzed. Analysis of toxins data such as PCBs and PFAS are beyond the scope of this report.

The RVCOG have been collecting water quality data to evaluate the water quality in Bear Creek relative to the TMDL requirements. This includes temperature, pH, turbidity, E. coli, phosphorus, and conductivity collected monthly. Data collection for the TMDL project occurred on Bear Creek both before and after the fire at locations located longitudinally along the fire corridor, and therefore is one of the only data sets with multiple stations spanning the date of the fire.

The OR DEQ has collected data monitoring Bear Creek dating back to 1971. Data were collected both before and after the Alameda Drive Fire and includes water quality parameters as well as toxics like VOCs. However, data were only collected at one site, Bear Creek at Kirtland Road, which is located more than ten river miles downstream from the burn. Additionally, data were collected every other month, a frequency making it difficult to detect temporal trends.

3.2 Data Collection Sites

The RVCOG, RVSS, and City of Grants Pass sampled three stormwater and four in-stream sites after the Alameda Drive Fire (Figure 1, Table 1). For a full description of sampling responsibilities see the Sampling and Analysis Plan for Alameda Post-Fire Monitoring. Two of the stormwater sites are located within the burn perimeter (WVV and NRT) while one is located in an unburned area and treated as a reference site (CR). In-stream sites are located with one upstream (BCOS) and three downstream from the burn (BCUC, BCJS, and BCKR), with one site, BCKR, just upstream of the confluence with the Rogue River. The Oregon Department of Environmental Quality (OR DEQ) also sampled at BCKR, with sampling beginning prior to the Alameda Drive Fire and occurring six plus times per year. RVCOG TMDL sites were sampled approximately once per month throughout the year (Figure 2, Table 2). The precipitation station¹ was located just upstream of the burn perimeter and the flow station² was located just inside the burn perimeter.

¹National Oceanic and Atmospheric Administration (NOAA) weather station: ASHLAND, OR US; Network ID: GHCND:USC00350304; Latitude: 42.21306°, Longitude: -122.71478°; elevation: 1730 ft).

² USGS Discharge for Bear Creek Below Ashland Creek at Ashland, OR – 14354200 <https://waterdata.usgs.gov/monitoring-location/14354200/#parameterCode=00065&period=P7D&showMedian=false>

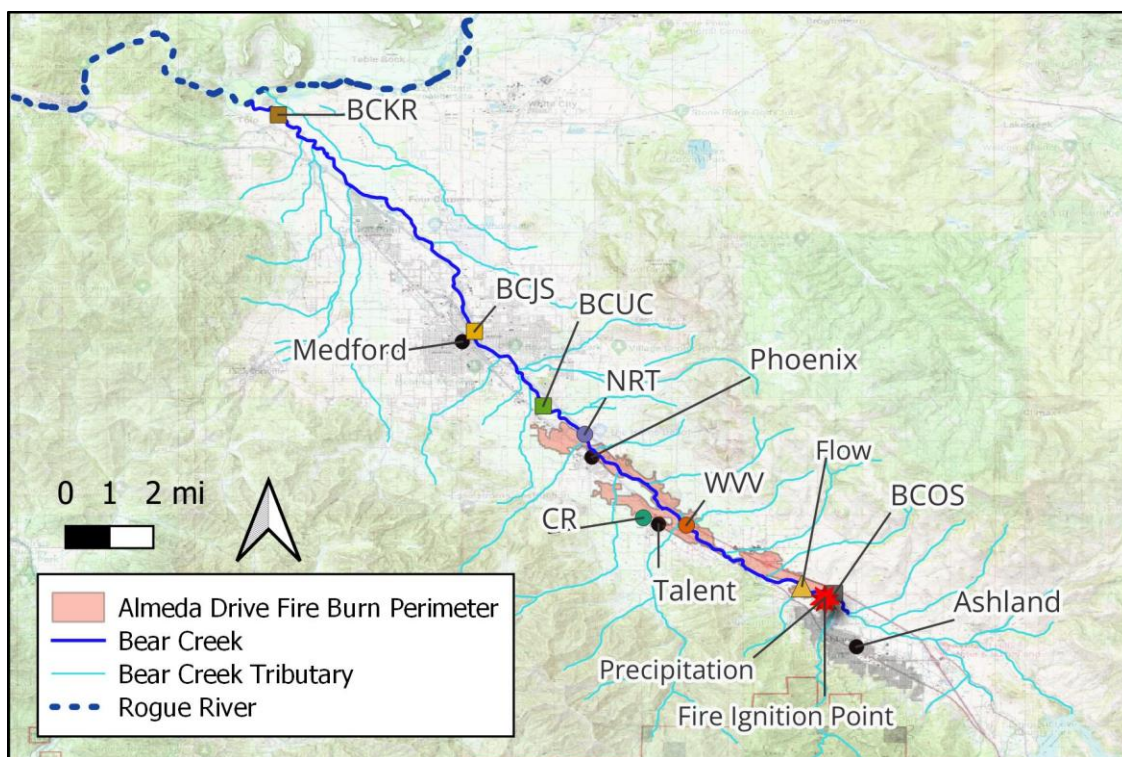


Figure 1. Map of Post-Fire Water Quality sites, including stormwater sites WVV, NRT, CR and in-stream sites BCOS, BCUC, BCJS, and BCKR. Site BCKR is also a collection location for the Oregon DEQ's sampling events, where they call the site DEQ-11051. This map includes the Almeda Drive Fire burn perimeter as determined by Jackson County, the fire ignition point near the wastewater treatment facility, and the locations of the cities of Ashland, Talent, Phoenix, and Medford. Square sampling points are in-stream sites, while circular sampling points are stormwater sites.

Table 1. Locations for Post-Fire Water Quality sites and the Oregon DEQ sampling site analyzed in the project, including both in-stream and stormwater.

Site Code	Type of Site	Site Name	Distance Downstream from BCOS	Latitude	Longitude
BCOS	In-Stream	Bear Creek Oak St.	0 mi	42.25047032	-122.6859795
BCUC	In-Stream	Bear Creek US Cellular	10.1 mi	42.33510313	-122.8243785
BCJS	In-Stream	Bear Creek at Jackson St.	13.1 mi	42.34195081	-122.8610647
BCKR	In-Stream	Bear Creek at Kirtland Rd.	22.4 mi	42.42120839	-122.9272482
11051-ORDEQ	In-Stream	Bear Creek at Kirtland Road (Central Point)	22.4 mi	42.42120839	-122.9272482
WVV	Stormwater	West Valley View Outfall	4.6 mi	42.25593087	-122.7684563
NRT	Stormwater	Northridge Terrace Outfall	8.6 mi	42.30120939	-122.8121847
CR	Stormwater	Colver Rd. Outfall	NA	42.24006095	-122.8405692

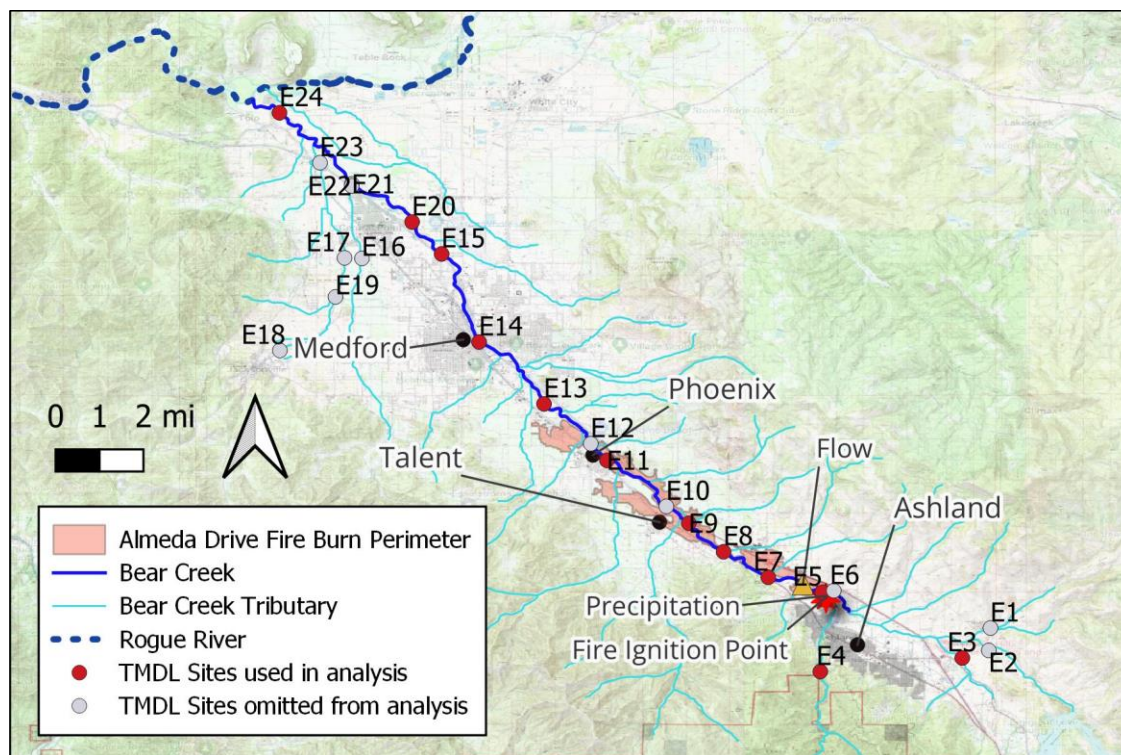


Figure 2. Map of the sites for the TMDL sampling by RVCOG. This map also includes the Alameda Drive Fire burn perimeter as determined by Jackson County, the fire ignition point near the wastewater treatment facility, and the locations of the cities of Ashland, Talent, Phoenix, and Medford. All TMDL sampling sites are in-stream.

Table 2. Site coordinates for the RVCOG TMDL sites that were used for analysis.

Site Code	Site Description	Latitude	Longitude	Site Code	Site Description	Latitude	Longitude
E03	Neil Creek off Dead Indian (Ashland)	42.18557	-122.65437	E11	Bear Creek @ B.H. Park (Phoenix)	42.27305	-122.8119
E04	Ashland Creek @ Granite St (Ashland)	42.17953	-122.71733	E13	Bear Creek @ JNC (S. Medford)	42.29806	-122.83983
E05	Ashland Creek below STP (Ashland)	42.21467	-122.71647	E14	Bear Creek @ 9th St (S. Medford)	42.32548	-122.8686
E7	Bear Creek @ S. Valley View (Ashland)	42.22127	-122.74038	E15	Bear Creek @ Table Rock Rd (N. Medford)	42.36447	-122.88523
E8	Bear Creek @ Greenway (S. Talent)	42.23258	-122.76021	E20	Bear Creek @ Pine St (CP)	42.37862	-122.8983
E9	Bear Creek @ Lynn Newbry Park (Talent)	42.2452	-122.77563	E24	Bear Creek @ Kirtland Rd (CP)	42.42698	-122.95711

3.3 Data Availability & Limitations to Analysis

Data availability can determine the type of analyses that are possible when working to parse out patterns in data. For example, surface waters cycle through daily and seasonal change in temperature and pH that can alter the concentration, bioavailability, and transport of metal and nutrient pollutants (Nimick et al., 2011). Even larger changes can occur when comparing samples across multiple years since inter-annual climate variability and land use change are important determinants of water quality constituents even in the absence of such disturbances as the Alameda Drive Fire. These daily, seasonal, and annual differences result in confounding factors that must be considered when analyzing trends in water quality data, and are especially important to consider when evaluating data collected at low frequency within and among years, such as in this study. Factors like precipitation, antecedent dry period, flow, air temperature, and land use change (e.g., housing developments) highlight the need to interpret differences between sample sites and dates with care. Additional confounding factors arise when considering the distance between sampling sites, site and drainage characteristics such as differences in road use intensity, area of impervious surface, and urban and suburban development that can alter the input of pollutants to surface waters through the stormwater system and riparian zone.

Similar to the need to consider spatial, seasonal, and inter-annual variability in water quality data analysis, the timing and frequency of sample collection can also confound the ability to determine water quality trends. For example, Post-Fire Water Quality data collection began more than 8 weeks after the fire, and only at one site just downstream of the burned area (BCUC) after two smaller precipitation events had already occurred (Figure 3; Figure 4). Similarly, while stormwater sampling began on the larger precipitation event that occurred on November 15th, the smaller first flush events after the Alameda Drive Fire were missed. Sampling continued one to three times per year through 2023. Other in-stream sites were captured more sporadically, including Bear Creek at Oak Street (BCOS) upstream of the burn perimeter and Bear Creek at Kirtland Rd (BCKR) and Bear Creek at Jackson Street (BCJS) both downstream. The data available also varied by sampling date for some dates and sites in terms of types

of analytes sampled. As an example of data availability that is similar to many other parameters (See Appendix E), Figure 3 displays the dates that data were available for copper at all sites. In general, sampling was intended to target precipitation events and not seasonality or time-series trends in the data.

While the monitoring effort and compiled dataset are valuable for characterizing important water quality constituents in Bear Creek and can be built upon for future monitoring efforts, more thorough statistical analysis based on location and sampling date are limited. Realistically, given the confounding factors discussed above, along with little pre-fire data and the type of more sporadic/low-frequency data available, it is difficult to identify water quality effects that can be directly tied to the Alameda Drive Fire.

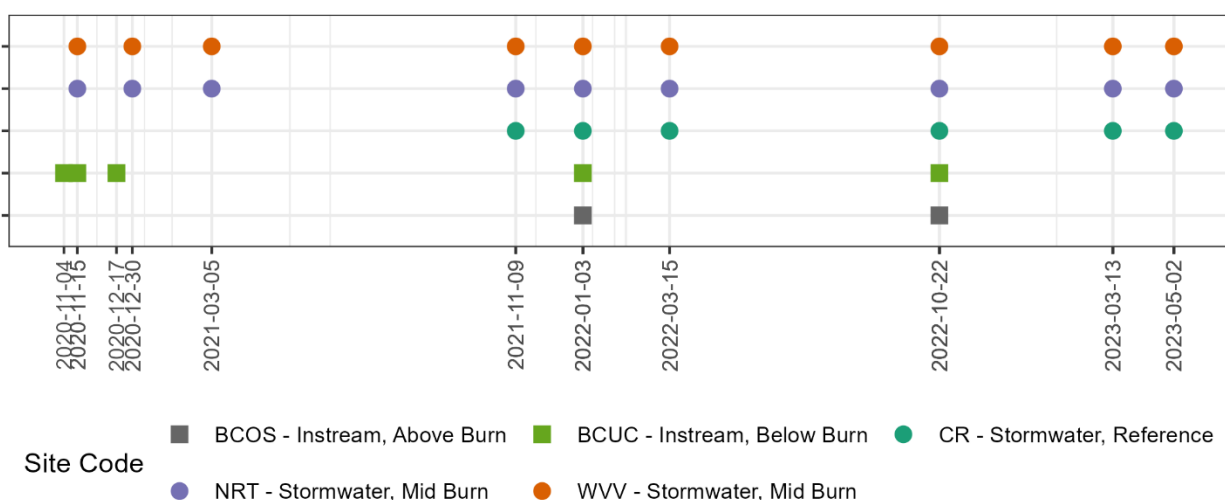


Figure 3. Sampling dates with data available for metal pollutant copper when considering in-stream and stormwater sites sampled for the Post-Fire Water Quality project. The circular data points are stormwater sites, and the square data points are in-stream sites. This figure presents all data points available for analysis.

3.4 Data Compilation & QA Methods

We compiled the various data sources using R Statistical Software (R Core Team, 2023). Data were compiled based on the OR DEQ requirements for archiving data in the state database. Most data considered for this study have been run through a QA process by the analysis laboratory. However, time series figures of these data were reviewed during the compilation process as well to check for outliers or other data abnormalities. Data arrived from different sources and laboratories in a variety of formats and with a variety of headings. After format and column names were changed to adhere to the DEQ template, data were checked against the original data set during the import to verify that the reformatting was completed accurately.

All newly collected data for the Post-Fire Water Quality Monitoring project were compiled into a database but previously published data provided by the OR DEQ were excluded. The sonde data

collected by RRWC were compiled separately given the volume of the hourly data collected. While other data, including toxics such as PFAS and flame retardants, were compiled into the database, analysis of toxics data was outside the scope of this report.

3.5 Data Trend Analysis

3.5.1 Time Series Plots

All data analyzed in this project were plotted in time series format for ready comparison to trends in flow and precipitation occurring concomitantly. Specific parameters were selected for analysis in the body of the report because they were sampled more regularly, sampled at more sites, or more relevant in terms of aquatic toxicity and ecological change in Bear Creek. Data not presented in the time series figures are presented in the tables in Appendix B. Analyte Concentration Tables. Most analytes were presented with a log base ten y-axis transformation, as opposed to transforming the data itself, to better visualize the small values measured.

3.5.2 Boxplots

Some data used in the project were analyzed for trends in analyte concentration by comparing across sites or dates using boxplots, thereby calculating median and interquartile range values. We included appropriately grouped data in each boxplot comparison. For example, all three stormwater sites were sampled on the same day for only five dates, therefore only those five dates were included in the boxplots comparing analyte concentrations at WVV, NRT, and CR. Boxplots require five data points to be built, and the median and interquartile range values provide different levels of inference. For example, comparing median values provides a general idea that one site or date has relatively higher or lower analyte concentration than another; however, the differences do not carry statistical weight. When the interquartile ranges of two groups do not overlap the difference is even greater, however still not statistically significant. Median and interquartile range values for boxplots presented are available in Appendix B. Analyte Concentration Tables.

3.5.3 Scatterplots & Pearson Correlation

Scatterplots provide a simple method to identify and understand the relationship between two variables. In this project, scatterplots were used to identify relationships between analytes such as between two different metals or between turbidity and nutrient concentrations. Additionally, they were employed to identify any relationships between flow, precipitation, or air temperature and analytes measured in these data. Scatterplot matrices were produced in R Statistical Software (R Core Team, 2023) using the GGally package (Schloerke et al., 2024). Using the GGally package provides output of the Pearson correlation coefficient for each comparison. The Pearson correlation measures the strength of relationship between two variables using linear modeling. The closer a Pearson correlation coefficient is to 1 or -1, the stronger the correlation between two parameters (Kenton et al., 2022). Scatterplots of variables with the Pearson correlation coefficients are presented in Appendix C. Scatterplots. Scatterplots, with some particularly interesting patterns reproduced and discussed within the report.

4. Flow & Precipitation

Precipitation, flow, and air temperature can provide a greater understanding of pollutant concentration dynamics in Bear Creek (Figure 4). Precipitation washes pollutants off impervious and semi-pervious surfaces into stormwater drains and direct overland flow that eventually lead into the surface waters of Bear Creek. Flow in Bear Creek is related to turbidity dynamics and also to the relative dilution or concentration of given in-stream water quality parameters. Air temperature is correlated with water temperature in Bear Creek, and in turn water temperature can alter the pH and dynamics of other chemical parameters.

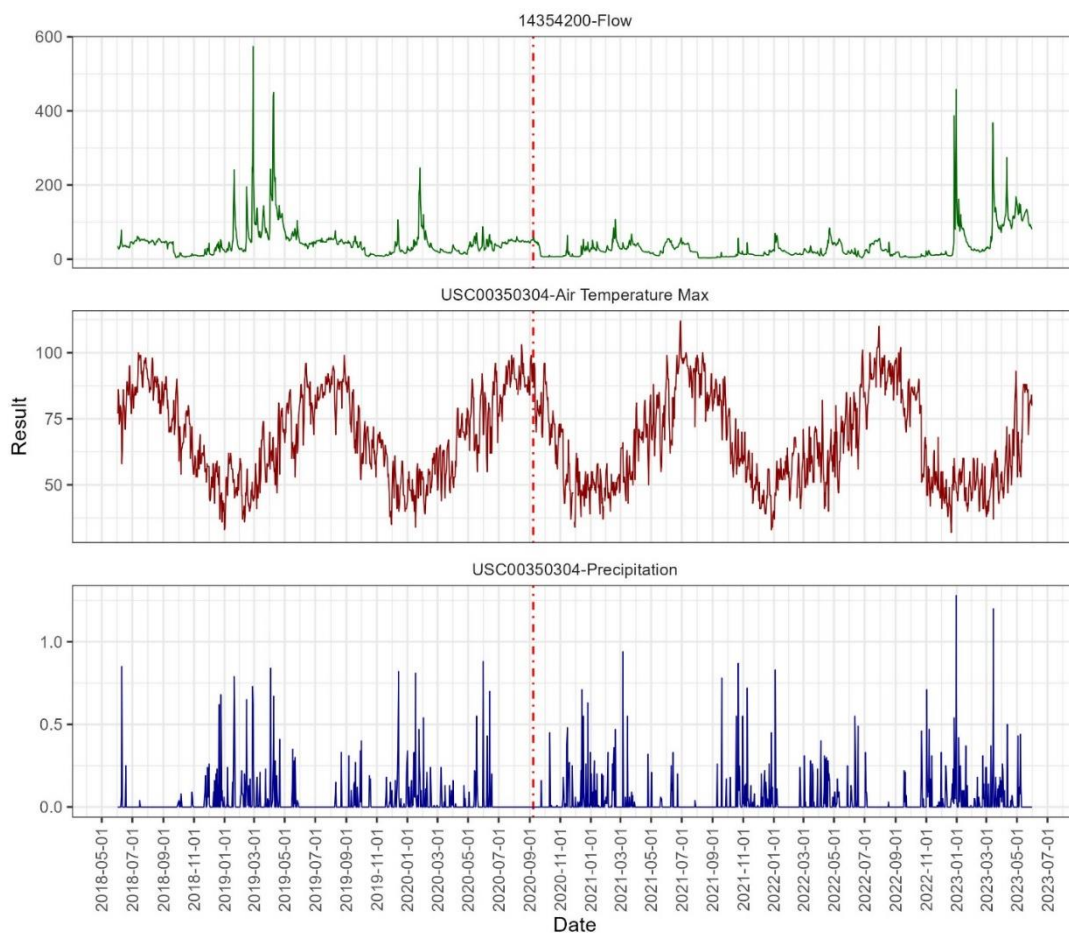


Figure 4. Figures of flow in cubic feet per second (CFS) at Ashland, OR (top, green), the daily maximum air temperature in Fahrenheit (F) at Ashland, OR (middle, red), and precipitation in inches (in.) at a USGS gaging station between Ashland and Talent (blue, bottom). The red dashed line indicates the date of the Almeda Drive Fire.

5. Site Characterization

5.1 Post-Fire Water Quality Stormwater Sites

Three stormwater outfall sites were sampled in this study, West Valley View (WVV), North Ridge Terrace (NRT), and Colver Road (CR). Each site differs in length of stormwater drainage and area drained, land use in the area drained, burn intensity, and traffic intensity.

5.1.1 West Valley View

Stormwater outfall site West Valley View (WVV), highlighted by the orange pentagon in Figure 5, captures runoff in 1,997 meters of stormwater drainage and from an area of 46 acres. This stormwater system drains residential and commercial areas as well as a busy, main thoroughfare for vehicle traffic. The residential areas were substantially burned in the Alameda Drive Fire; this included nearly complete burns of a neighborhood of single-family homes that were aerially treated with fire retardant and a mobile home park. While the mobile home park has only one point of connection with the stormwater system, overland flow tends to accumulate at that point from most other areas of the park due to the design of the roads and a lower elevation at the drainage point (verbal communications with Alex Galuzzo at RVSS). The commercial structure connected to this drainage system was not burned in the fire. In addition to a high burn intensity, this site drains a high-traffic roadway, Highway 99, for approximately 353 meters. This site is considered the highest burn intensity and traffic intensity of the three stormwater sample sites.

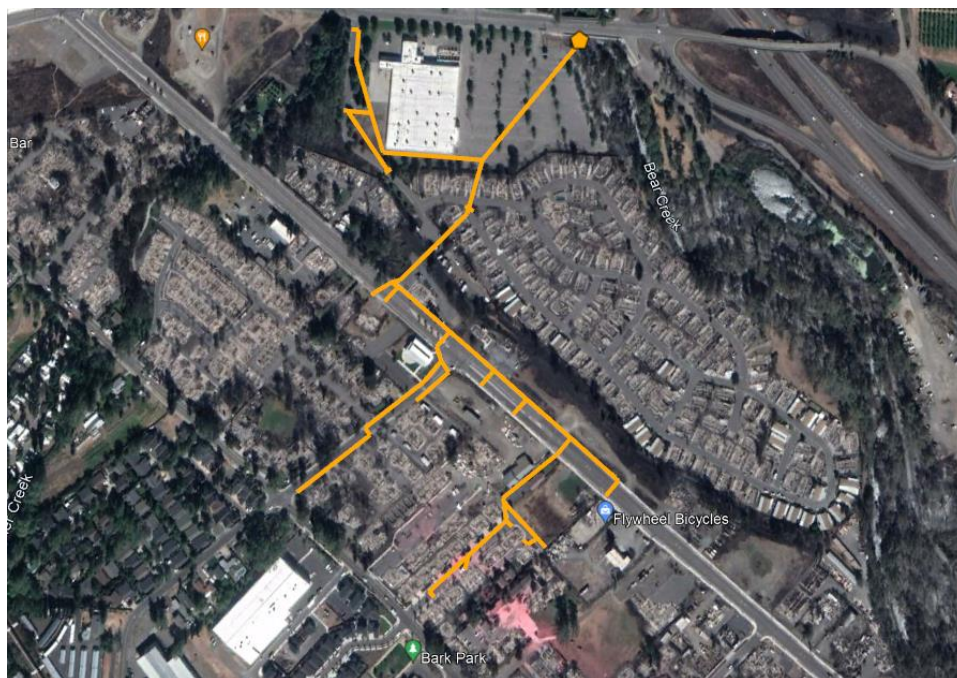


Figure 5. Stormwater path and outfall location for WVV. The map imagery is from September 2020, taken from satellite just after the Alameda Drive Fire.

5.1.2 North Ridge Terrace

The stormwater outfall site North Ridge Terrace (NRT) highlighted by the orange pentagon in Figure 6, captures runoff in 436 meters of stormwater drainage and from an area of 14.5 acres. This site drains residential and commercial areas, including nearly fully burned mobile home parks. The commercial structure, a storage unit facility, was not burned in the fire. The stormwater system captures drainage from surrounding areas before traveling down the road Northridge Terrace as overland flow. After flowing down Northridge Terrace, the overland flow water enters another stormwater system and drains to Bear Creek. The overland flow path on Northridge Terrace also captures runoff from the surrounding neighborhood to some extent. The burn intensity, area drained, and traffic intensity at NRT are less than WVV and greater than CR.

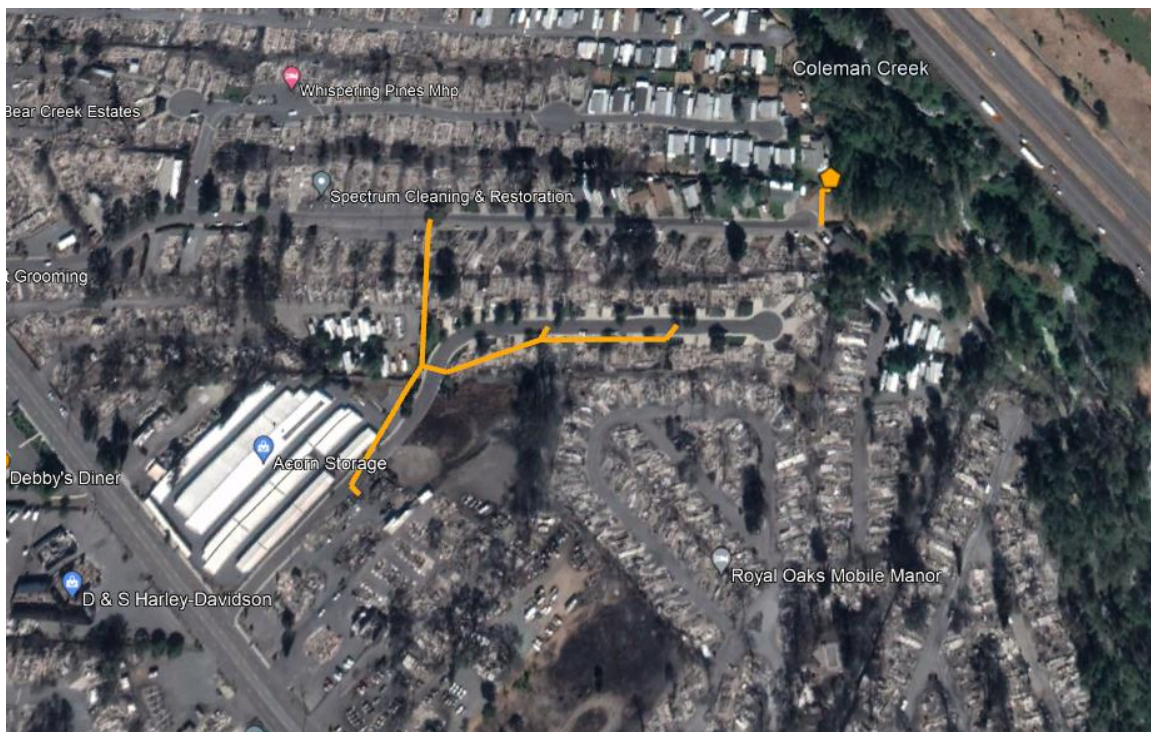


Figure 6. Stormwater path and outfall location for NRT. The map imagery is from September 2020, taken from satellite just after the Alameda Drive Fire.

5.1.3 Colver Rd

Colver Rd (CR) is considered the reference site for the project and is shown in Figure 7. This site is outside the fire perimeter, was unburned, and additionally does not drain directly into Bear Creek like the other two stormwater sites. The CR drainage basin is the largest at 55 acres with 2,260 meters of stormwater drainage, however it has the lowest burn intensity, lowest traffic intensity, and least dense population.

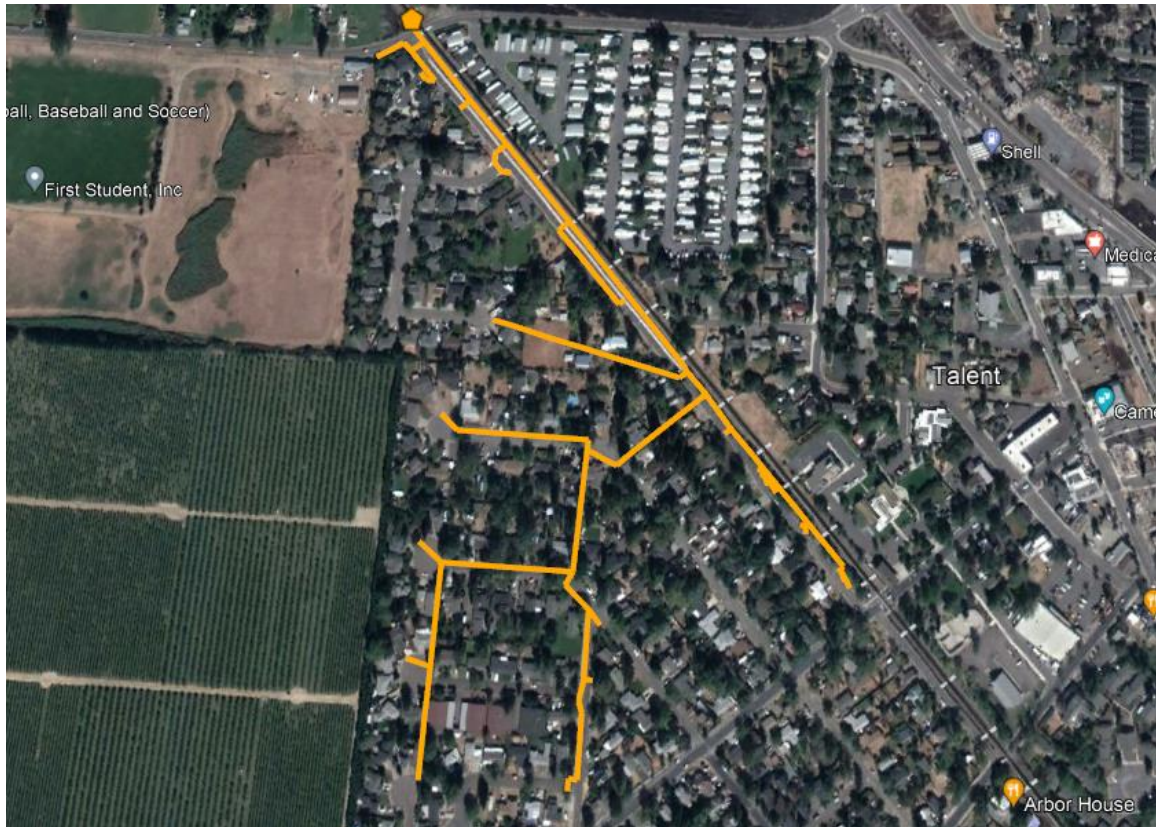


Figure 7. Stormwater path and outfall location for CR. The map imagery is from September 2020, taken from satellite just after the Almeda Drive Fire.

5.2 Post-Fire Water Quality In-Stream Sites

In-stream sites Bear Creek at Oak Street (BCOS), Bear Creek US Cellular (BCUC), Bear Creek at Jackson Street Bridge (BCJS), and Bear Creek at Kirtland Road (BCKR) were monitored sporadically after the fire occurred. Site BCOS is located $\frac{1}{4}$ mile upstream from the burn perimeter and also upstream from the city of Ashland, and therefore would likely receive inputs from agricultural land and suburban areas upstream of the burn area. Water quality at BCOS is also highly influenced by water released from Emigrant Lake³. Site BCUC is located 1.5 river miles downstream from the burned area and closest to it, and therefore is likely receiving stream waters with runoff from the Almeda Drive Fire. This site is also downstream of commercial, suburban, and urban land uses in Phoenix, Talent, and Ashland, Oregon, and is therefore likely to receive greater impervious surface runoff than BCOS. Site BCJS is 3 miles downstream from BCUC, after Bear Creek passes through suburban and commercial areas in Medford, Oregon. Finally, BCKR is furthest downstream from the burned area and is 22.4 river miles downstream from BCOS. This site is just upstream from the confluence of Bear Creek with the Rogue River.

³ Emigrant Lake serves as a release of irrigation water in the summer months and is subject to water quality concerns within the lake.

5.3 Total Maximum Daily Load Sites

The TMDL sites sampled monthly by the RVCOG are located along Bear Creek and its tributaries from upstream of where Bear Creek forms to just upstream of the confluence with the Rogue River. Sites E3 and E4 were grouped as sites upstream from the burn perimeter and are tributaries that meet and become Bear Creek. Sites E5, E7, E8, E9, E11, and E13 were grouped as sites within the burn perimeter and are located on Bear Creek. While site E13 is located just downstream of the burn perimeter, its proximity to the burn indicates it has the potential to be impacted by burn inputs. Sites E14, E15, E20, and E24 are located on Bear Creek downstream of the burned area. Other TMDL sites are located in tributaries of Bear Creek and therefore were not considered in this analysis. When reviewing data for completeness, some sites were removed from analysis due to large gaps in data availability, including: E01, E02, E06, E10, E12, and E21.

5.4 Oregon Department of Environmental Quality Sites

The OR DEQ has one data collection site located at the same location as BCKR. This site is 22.4 river miles downstream from BCOS, and over 13 river miles downstream from the burn perimeter, just above the confluence with the Rogue River.

6. Results & Discussion: Post-Fire Stormwater & In-Stream Data

6.1 6PPD-quinone

Emerging contaminant 6PPD-quinone is a chemical sourced from tire-wear particles that enters aquatic ecosystems through surface runoff and overland flow. Given that 6PPD-quinone was only more recently identified as an aquatic contaminant of concern, TMDLs haven't yet been established water quality criteria. Tian et al. (2022), the first research group to identify the toxicity of 6PPD-quinone, found that concentrations greater than 0.095 µg/L were potentially lethal for salmonids in surface waters. While research has focused on salmonids and other fish species, it is unclear what effect this toxic chemical could have on other aquatic organisms.

In Figure 8, concentrations of 6PPD-quinone are presented across dates and across sites (Figure 8). A time series of concentrations (Figure 8, Panel A) shows that the highest value was found on March 13, 2023 at site WVV (0.11 µg/L), and this value was greater than the laboratory-derived median lethal concentration (LC 50) from Tian et al. (2022) of 0.095 µg/L. Neither of the two in-stream sites tested greater than 0.095 µg/L, and the greatest in-stream concentration was found at BCOS (upstream from the burn perimeter) on January 3rd, 2022 (0.0091 µg/L). The highest mean concentration of stormwater sites occurred on October 22, 2022 (0.58 µg/L); this date also had the lowest precipitation in the weeks preceding the sampling event relative to other sample dates followed by a large precipitation event. Given that 6PPD-quinone is sourced from tire wear particles, the antecedent dry period may have allowed a build-up of tire wear particles containing 6PPD-quinone on roadways. The rainstorm that triggered the sampling event may have resulted in overland flow and runoff of tire wear particles into the stormwater system.

When comparing across stormwater sites (Figure 8, Panel B) based on non-overlapping inter-quartile ranges, WVV (Median: 0.0625 µg/L) had greater concentrations than NRT (Median: 0.0282 µg/L) and CR (Median: 0.011 µg/L), and NRT had a greater median concentration than CR. These findings align with the relative traffic intensities of the stormwater sites, with WVV draining high traffic intensity areas like Highway 99, NRT draining residential areas, and CR with the least traffic intensity. The concentration of 6PPD-quinone at in-stream sites BCOS and BCUC was less than stormwater for all sampling dates where both occurred. This is a result of the increased dilution that occurs in rivers and streams, decreasing the overall concentration of 6PPD-quinone.

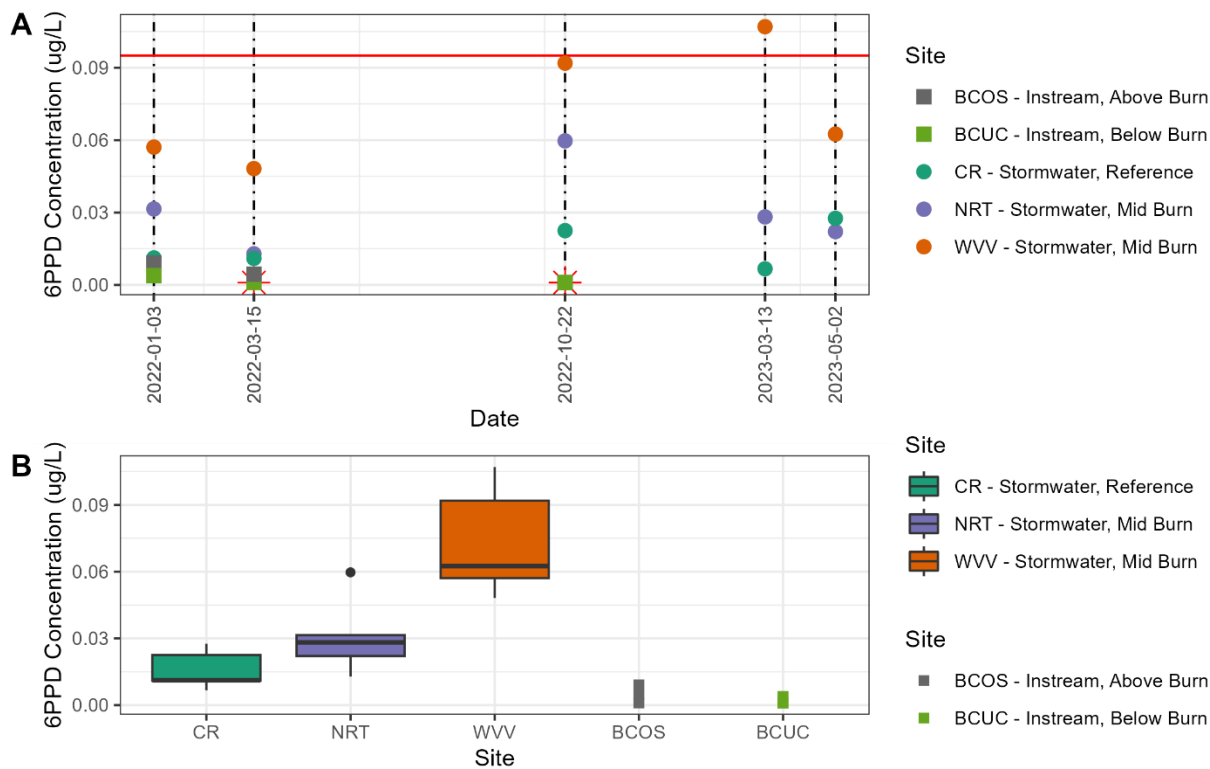


Figure 8. 6PPD-quinone concentrations for stormwater (WVV, NRT, and CR) sites and in-stream (BCOS and BCUC) sites across all sampling dates.

6.2 Metal Pollutants

6.2.1 Stormwater Site Analysis

6.2.1.1 Changes Over Time

Metal concentrations tended to be greater in the November 2020 to March 2021 date range when compared to the November 2021 to March 2022. While CR was not sampled in the earlier date range, WVV and NRT were 1.5 to 6 times greater in the 2020/2021 date range than 2021/2022. For example, the concentration of copper at WVV was greater on November 15th, 2020 (7.95 µg/L) than November 9th, 2021 (5.02 µg/L), greater on December 30th, 2020 (62.4 µg/L) than January 3rd, 2022 (10.3 µg/L), and greater on March 5th, 2021 (21.5 µg/L) than it was on March 15th, 2022 (7.31 µg/L) (Figure 10, Appendix

B.1.1 Values for all stormwater sites, Figure 9 and Figure 10). Two factors that were different between the two sampling periods that could be affecting stormwater metal concentrations include the amount of time that elapsed since the Alameda Drive Fire and the amount of precipitation prior to and over the sampling period. The first sampling period in 2020/2021 occurred soon after the fire on September 8th, 2020, indicating there could be more metal-containing surface runoff being contributed from the burn zone to stormwater. The first date range from 2020 to 2021 also had greater total precipitation in the five months considered than the later sampling events. The precipitation from November 2020 to March 2021 (10.66 in.) was approximately 74% greater than the total precipitation from November 2021 to March 2022 (6.13 in.). Increased precipitation may have carried more contaminants into the stormwater system through overland flow from burned and urban areas. Thus, the ability to attribute higher metals in the samples closer in time to the fire is confounded by differing antecedent precipitation between the two periods.

Metal concentrations tended to be greater on December 30th than November 15th of 2020 and this trend was more apparent at WVV than NRT. For example, the concentration of aluminum at WVV was more than seven times greater on December 30th (8220 µg/L) than November 15th (1150 µg/L), and aluminum concentrations at NRT were 28% greater on December 30th (884 µg/L) than November 15th (693 µg/L) (Figure 9, Appendix B.1.1 Values for all stormwater sites, Figure 9 and Figure 10). While precipitation was greater on November 15th (0.24 in) than December 30th (0.165 in), the weeks preceding the sampling dates showed greater rainfall prior to December 30th. For example, the two weeks prior to December 30th (1.01 in) had greater rainfall than two weeks before November 15th (0.73). Additionally, one month prior to December 30th (2.65 in.) there was substantially more rainfall than one month prior to November 15th (0.74 in.). The increased rainfall prior to the December 30th sampling date could indicate an increase in surface runoff and metals mobilized from burned areas, roadways, and urban areas more generally into the stormwater system.

Metal concentrations tended to be greater on May 2nd, 2023 than October 22nd, 2022 at site WVV and CR, while the opposite tended to occur for NRT. For example, lead concentrations were greater at WVV and CR on May 2nd, 2023 (WVV: 11.1 µg/L, CR: 3.11 µg/L) when compared to October 22nd, 2022 (WVV: 3.57 µg/L, CR: 1.39 µg/L), while they decreased for the same dates for NRT (10/22: 7.3 µg/L, 05/02: 3.56 µg/L) (Figure 10, Appendix B.1.1 Values for all stormwater sites, Figure 9 and Figure 10). While there was more precipitation at the time of the sampling event on October 22nd, 2022 (0.38 in.) relative to May 2nd, 2023 (0.215 in.), there was greater precipitation the month prior to the sampling date on May 2nd (1.23 in.) relative to October 22nd (0.76 in.). However, there was more precipitation in the two weeks prior to October 22nd (0.76 in.) than the two weeks prior to May 2nd (0.19 in.). The variability in precipitation for the two dates when considering the day of sampling, two weeks prior, and one month prior, as well as the variability in metal concentration differences relative to the site sampled makes it difficult to tease out potential controlling factors.

For a table of all metal and metalloid concentrations, including those not found in Figures 9 and 10, see Appendix B.1.1 Values for all stormwater sites, Figure 9 and Figure 10.

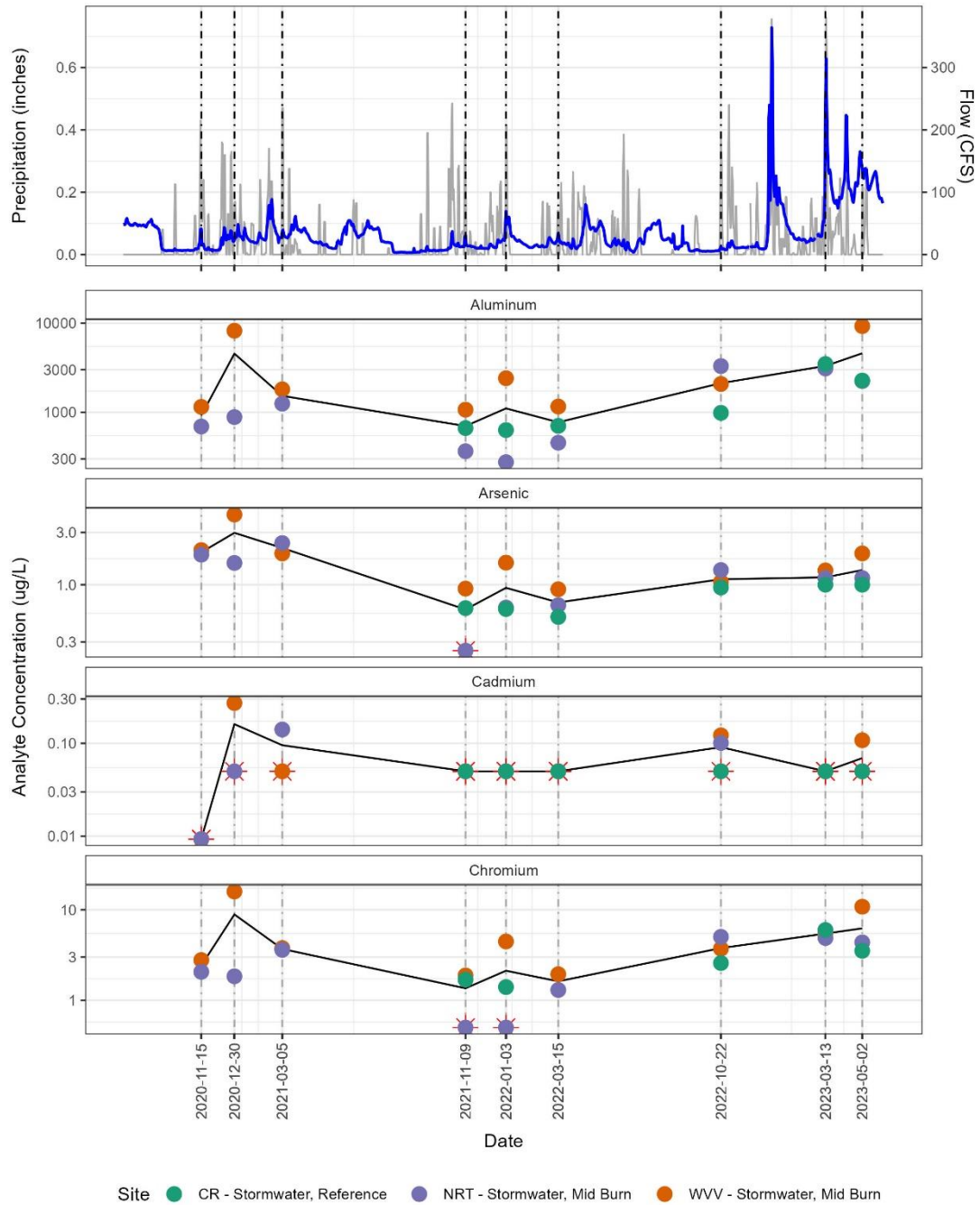


Figure 9. Precipitation (gray) and flow (blue) two day rolling means (top) compared to analyte concentrations for aluminum, arsenic, chromium, and copper for stormwater sites CR, NRT, and WVV. While WVV and NRT were sampled on all dates presented, CR was not sampled on the first three dates. Points in the time series figures with red stars behind them are non-detect values, indicating the instrument could not detect concentrations of that metal. The non-detect values are presented as values equal to 1/2 times the minimum detection limit ($0.5 \times \text{MDL}$) for ease of analysis and better representation of the presence of a data point. Mean values of all sites sampled on a date are presented with the black line. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis.

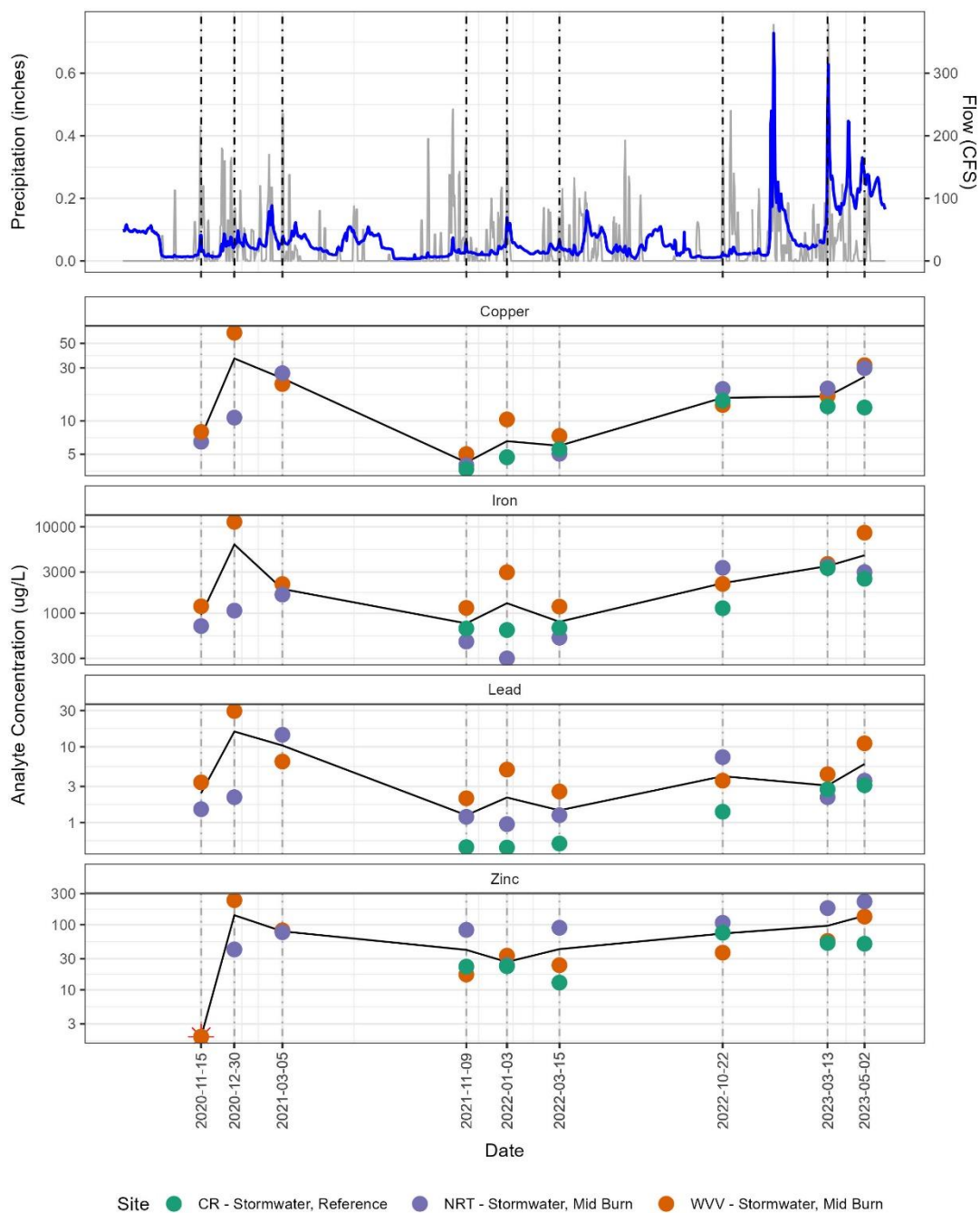


Figure 10. Precipitation (gray) and flow (blue) two day rolling means (top) compared to analyte concentrations for copper, iron, lead, and zinc for stormwater sites CR, NRT, and WVV. While WVV and NRT were sampled on all dates presented, CR was not sampled on the first three dates. Points in the time series figures with red stars behind them are non-detect values, indicating the instrument could not detect concentrations of that metal. The non-detect values are presented as values equal to 1/2 times the minimum detection limit ($0.5 \times \text{MDL}$) for ease of analysis and better representation of the presence of a data point. Mean values of all sites sampled on a date are presented with the black line. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis.

6.2.1.2 Site Comparison

Three stormwater sites were sampled for this project, West Valley View (WVV), North Ridge Terrace (NRT), and Colver Road (CR). Site CR is considered the reference site, as it captures stormwater from an unburned neighborhood with low traffic intensity. Sites WVV and NRT both capture runoff from burned areas, with the burn intensity and traffic intensity at WVV greater than NRT. All three stormwater sites, WVV, NRT, and CR, were sampled on a total of six dates: November 9th, 2021, January 3rd, 2022, March 15th, 2022, October 22nd, 2022, March 13th, 2023, and May 2nd, 2023. Sites WVV and NRT were also sampled on November 15th, 2020, December 20th, 2020, and March 5th, 2021 for a total of nine dates (see Figure 3 for an example of data availability).

WVV, NRT, and CR

Metal and metalloid concentrations tended to be greater at WVV than NRT and CR for the six sampling dates where all three sites were sampled, however variation among metal constituents existed in the relationship between NRT and CR (Figure 11). For example, aluminum had greatest median concentrations at WVV (2080 µg/L), with CR (705 µg/L) showing greater concentrations than NRT (456 µg/L). In contrast, lead had greatest median concentrations at WVV (3.57 µg/L), next highest concentrations at NRT (1.25 µg/L), and lowest concentrations at CR (0.53 µg/L). Zinc was the only metal with greatest median concentrations at NRT (89.7 µg/L), where concentrations were higher than at WVV (33.4 µg/L) and CR (23 µg/L). The tendency for metals to be greater in concentration at site WVV than NRT and CR may be a result of the greater burn and traffic intensity at WVV, as well as the larger stormwater drainage area when compared to NRT. For several metals, concentrations were either similar at NRT and CR or greater at CR; this may be attributed to the larger CR watershed drainage area allowing increased metals from roadways. So even though CR is considered an unburned reference site, overall interpretation is again confounded by varying drainage areas and traffic patterns among the three stormwater sites. For a table of all metal and metalloid concentration median and interquartile range values at WVV, NRT, and CR for these dates, including analytes not pictured here, see Appendix B.1.2 Values for comparison of WVV, NRT, and CR, Figure 11.

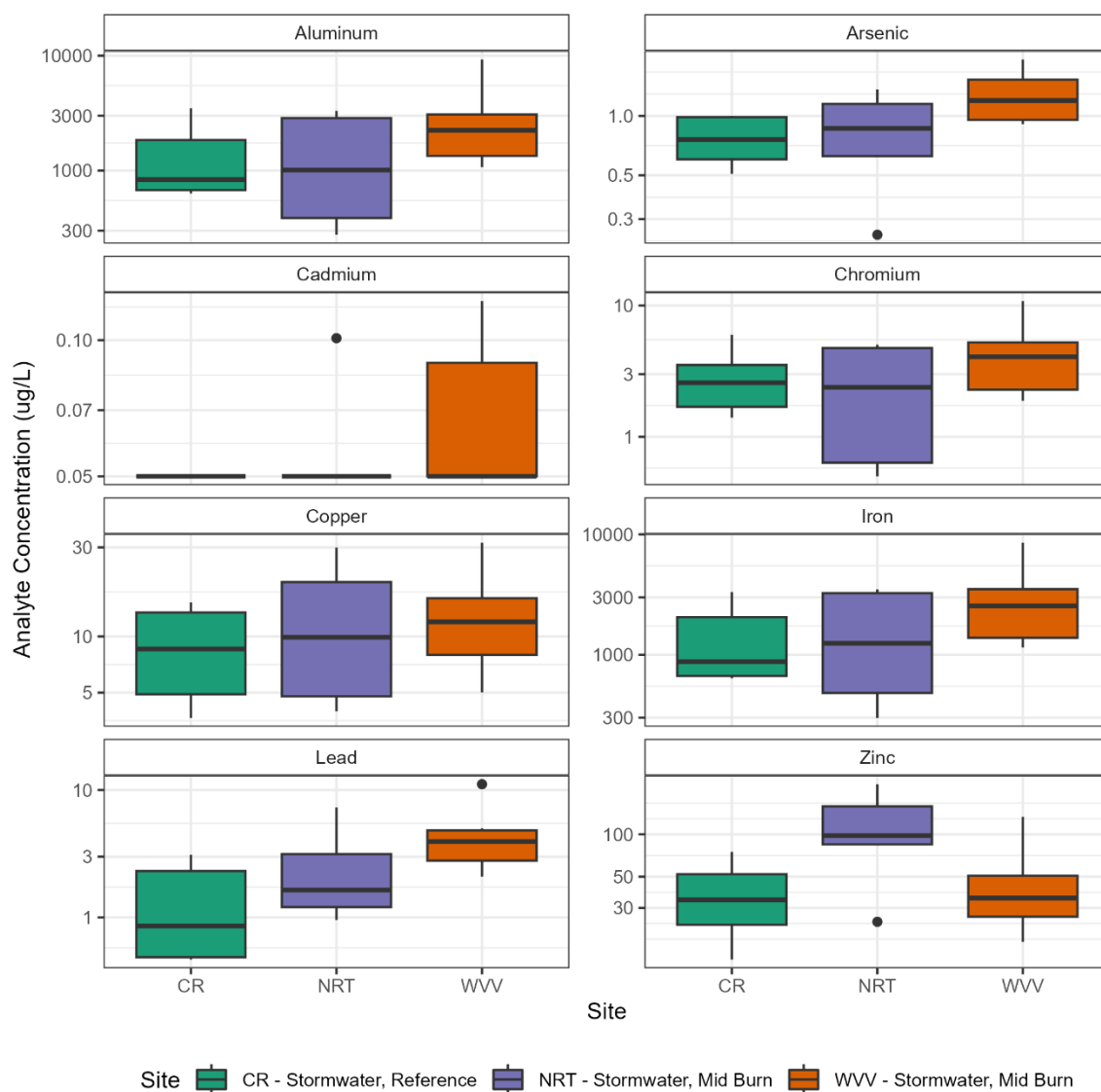


Figure 11. Comparison of metal concentrations at WVV, NRT, and CR for five dates: November 2021, January, March, and October 2022, March 2023, and May 2023.

WVV and NRT

Metal concentrations tended to be greater at WVV than NRT when considering all nine sampling dates presented in Figure 9 and Figure 10, which included sampling dates just after the fire in November and December of 2020. For example, the median concentration of aluminum at WVV ($1945 \mu\text{g/L}$) was more than double that of NRT ($788.5 \mu\text{g/L}$), and the pattern was similar for lead (WVV: $4.29 \mu\text{g/L}$, NRT: $1.83 \mu\text{g/L}$). In contrast, median arsenic concentrations were only slightly greater at WVV ($1.93 \mu\text{g/L}$) than NRT ($1.47 \mu\text{g/L}$). Zinc was the only metal with median concentrations at NRT ($59.1 \mu\text{g/L}$) greater than those at WVV ($35.3 \mu\text{g/L}$). Higher metal concentrations at WVV than NRT may be attributed to the increased burn and traffic intensity at this site, as well as the larger stormwater drainage area. For a table of all metal and metalloid concentration median and interquartile range values at WVV and NRT for these

dates, including analytes not pictured here, see Appendix B.1.3 Values for comparison of WVV and NRT, Figure 12.

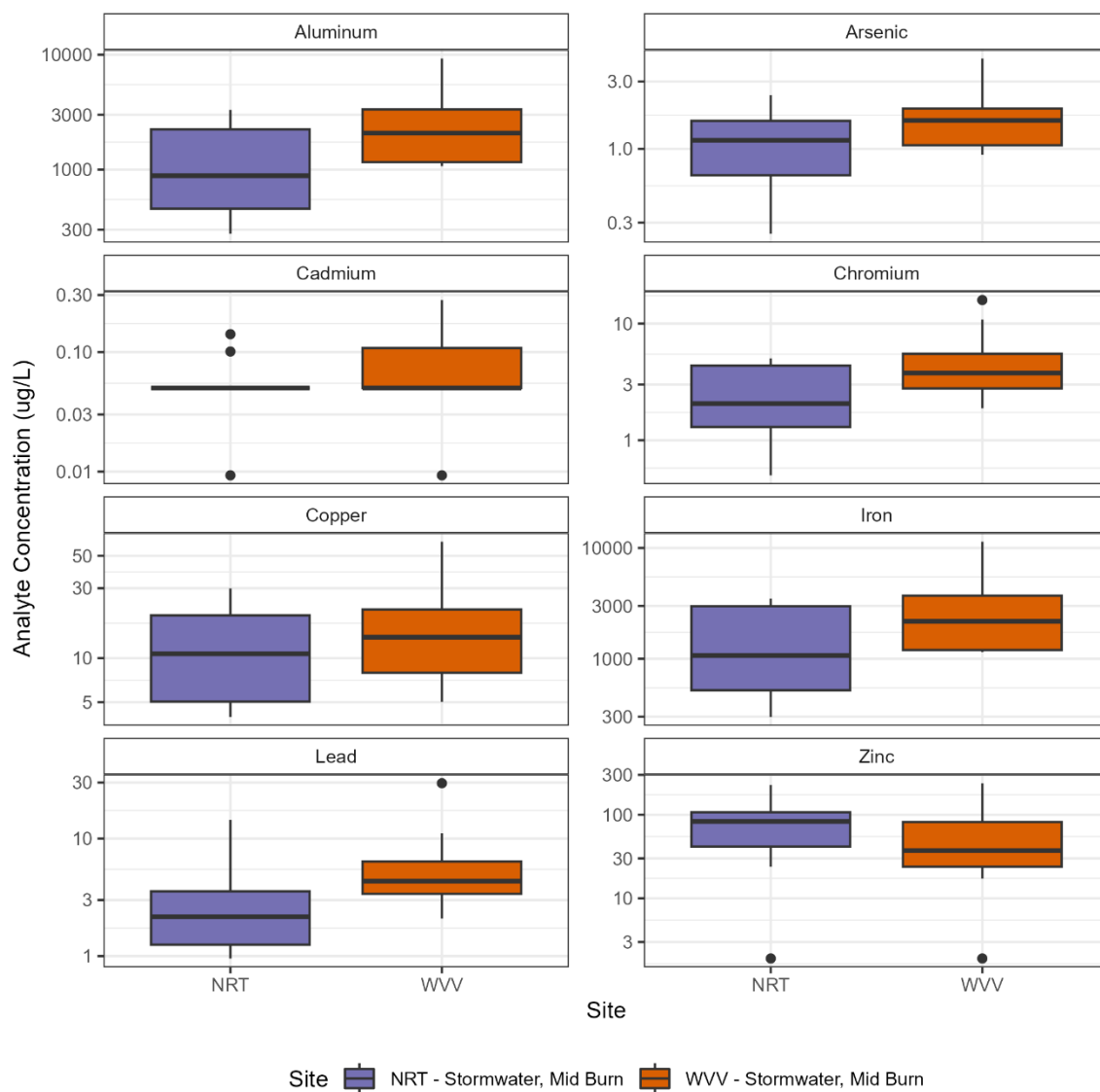


Figure 12. A comparison of WVV and NRT for eight sampling dates: November 15th, 2020, December 30th, 2020, March 5th, 2021, November 9th, 2021, January 3rd, 2022, March 15th, 2022, October 22nd, 2022, March 13th, 2023, and May 2nd, 2023.

6.2.2 Correlations Between Metals at In-Stream & Stormwater Sites

Metals and metalloids can be found in different forms in aquatic systems, ranging from ions to nanoparticles to colloidal particles. Particle size can speak to surface reactivity and the ability of a particle to stick to and transport with other metals. Nanoparticles and colloidal particles have increased surface reactivity relative to free metals like ions, especially reactive oxides like iron and aluminum. This can result in co-transport between iron and aluminum with other metals, as they often form oxide

particles (iron oxide and aluminum oxide) that bind other metals in transport through aquatic environments (Hochella et al., 2008). In stormwater, this may result in correlations between different elements of metal and metalloid concentrations. Correlations in metal concentrations may also result from a similar source transporting several different kinds of metals in stormwater simultaneously. For example, both iron and aluminum are often sourced from soils and sediments because they are found in these mediums at high concentrations.

In Appendix C.1 Scatterplots of Metals at All Sites, scatterplots show correlations between several metals. The strongest correlations are between iron and aluminum (PCC 0.971) with the next strongest correlations between concentrations of aluminum and chromium and iron and chromium. Concentrations of iron and aluminum tend to be correlated with the other metals considered, zinc, arsenic, copper, and lead, with the exception being cadmium. This trend is also true for aluminum, with less strong correlations. Iron and aluminum were also correlated with concentrations of total suspended solids, highlighting the high concentrations of iron and aluminum often found in soils and sediments. Many other metals had weaker correlations with each other, indicating the possibility of a mutual source like a burned area or roadway contributing metal pollutants to stormwater.

6.2.3 In-Stream Site Analysis

6.2.3.1 All In-Stream Sites

Four in-stream sites were sampled for metal pollutants across a range of dates, starting just after the fire and completing December 2022. One site, BCOS, was sampled above the burn area and one site, BCUC was sampled just downstream of the burn area. The other two sites, BCJS and BCKR, were sampled further downstream than BCUC. Given that these sites were sampled more sporadically and therefore contain less consistent data, they are presented in Appendix D.1, Figure 30 and Figure 31. For concentration values of all metals and metalloids at in-stream sites see Appendix D.1 Time Series of metals at all in-stream sites.

6.2.3.2 Analysis of BCUC

In-stream monitoring site BCUC occurred on five days, with three occurring soon after the Alameda Drive Fire and two in 2022. This site is located downstream and north of the burn perimeter, therefore capturing in-stream flow and stormwater drainage entering Bear Creek from a variety of sources including neighborhoods burned by the Alameda Drive Fire. This in-stream sampling site is the closest site to the burned area without being inside the fire perimeter.

Metals and metalloids aluminum, arsenic, chromium, copper, iron, and lead were greater in concentration on November 15th, 2020 relative to November 4th, 2020 (Figure 13). For example, the concentration of aluminum was more than nineteen times greater on November 15th (4290 µg/L) than November 4th (218 µg/L). Similarly, the concentration of lead was more than twelve times greater on November 15th (2.94 µg/L) than November 4th (0.233 µg/L). For a table containing concentrations of all metals and sampling dates for BCUC, see Appendix B.1.4 Values for in-stream site BCUC, Figure 13. On November 4th, there was low flow and low- to no- precipitation within a two-week antecedent dry

period. Before this two-week dry period, there were only small magnitude precipitation events occurring between the fire on September 20th and the sampling on November 4th. The precipitation between the fire on September 20th and the sampling event on November 4th (0.63 in.), a period of about a month and a half, was approximately half the precipitation as the eleven-day period between the November 4th and November 15th sampling (1.21 in.). On November 15th there was high flow conditions and a larger precipitation event than in previous weeks; the flow was over nine times greater, and the precipitation was 0.48 inches greater on November 15th than November 4th (Figure 4). This may indicate that precipitation events on and around November 15th after weeks of relatively dry weather captured metals and metalloids in surface runoff and overland flow from roadways and impervious surfaces in burned areas in the vicinity of the Alameda Drive Fire and upstream into Bear Creek, as well as from urban areas more generally, appearing as elevated concentrations at the BCUC in-stream site just downstream of the burned area.

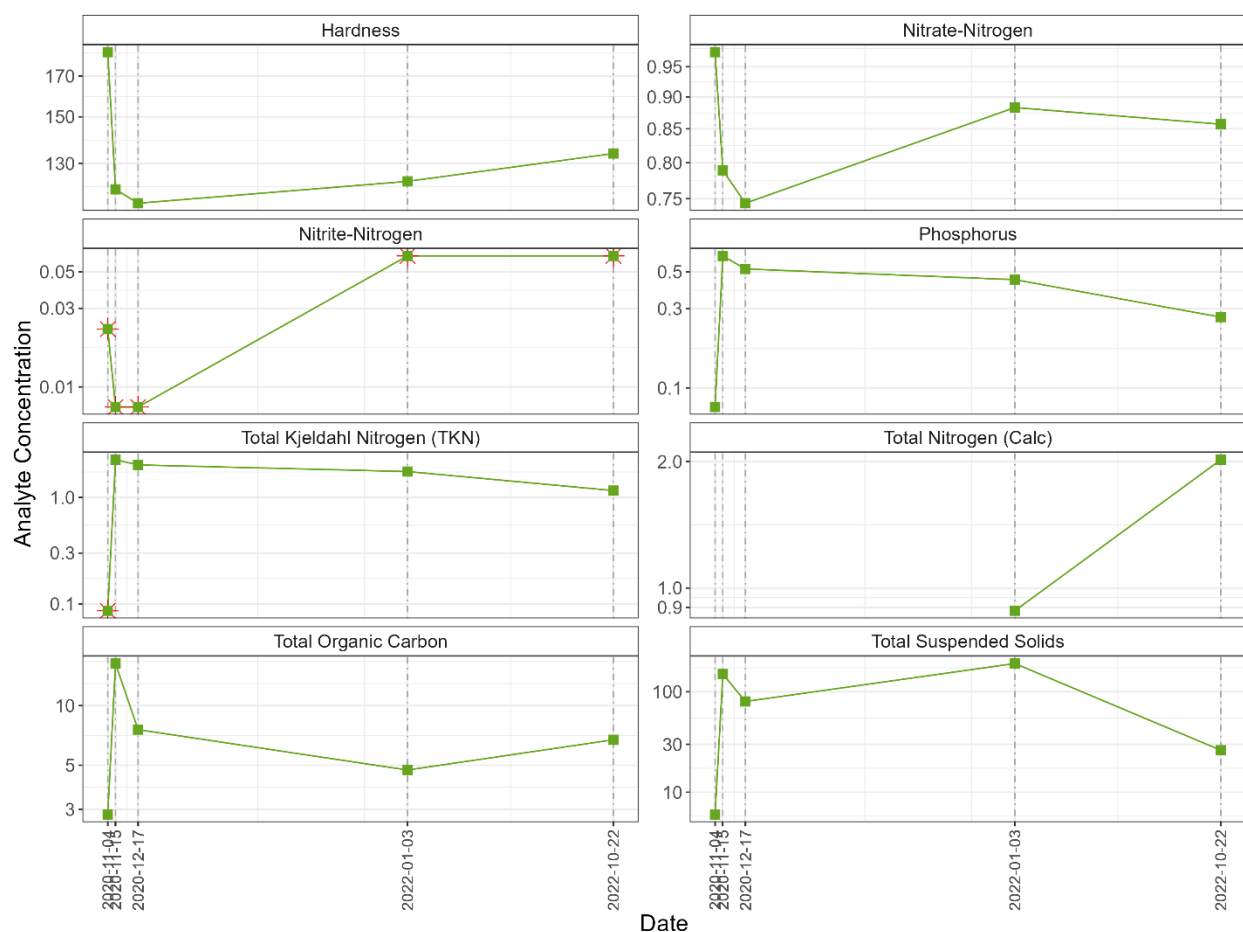


Figure 13. Concentrations of analytes at BCUC starting on November 4th, 2020 with a final sampling date on October 22, 2022. Because of the close proximity of the November 4th and 15th sampling dates in time, they are also somewhat muddled on the x-axis.

6.2.3.3 Aluminum and Iron at BCOS, BCJS, BCKR

In a comparison of iron and aluminum concentrations at in-stream sites BCOS, BCJS, and BCKR (Figure 14), concentrations were greater at BCKR than BCOS. Additionally, the median concentration values of both aluminum and iron were greater at BCJS (Al: 851 µg/L, Fe: 1070 µg/L) than BCOS (Al: 593 µg/L, Fe: 1040 µg/L). There is a large distance between two of the sites assessed in this section, as in-stream site BCOS is located upstream of the burn perimeter and BCKR is just upstream of the confluence with the Rogue River. Bear Creek passes through several cities/municipalities before reaching in-stream site BCKR. This leaves ample opportunity for the input of metals and metalloids, among other pollutants, from surface runoff generated by the high amount of impervious surfaces in more urban and suburban areas. Additionally, irrigation return flows enter Bear Creek along this stretch of river leaving the possibility of pollutants sourced from agriculture. Similar to the confounding caused by stormwater site characteristics, these factors (land use, irrigation, etc.) also confound the interpretation of higher aluminum and iron concentrations occurring upstream of the fire relative to downstream. For iron and aluminum concentration median and interquartile range values for all three sites, see Appendix B.1.5 Values for in-stream comparison of Al and Fe, Figure 14.

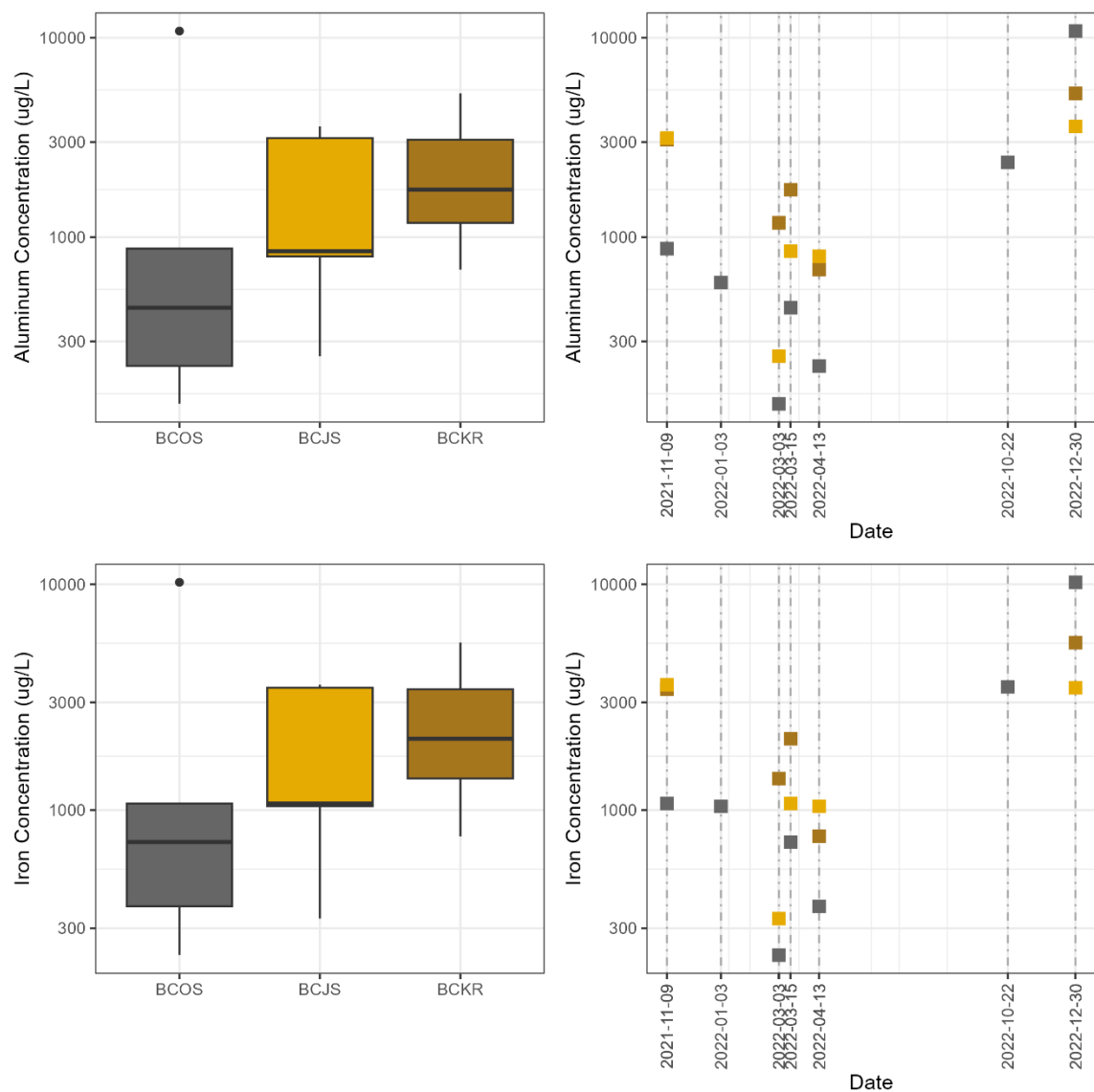


Figure 14. Aluminum and iron concentrations at in-stream sites BCOS, BCJS, and BCKR. On the left, boxplots describe site differences when considering the dates presented on the right with the exception of January 3rd, 2022 and October 10, 2022. These dates were excluded from the boxplot because only BCOS was sampled.

6.3 Additional Water Quality Parameters

6.3.1 Stormwater Site Analysis

6.3.1.1 Changes Over Time

Only two analytes were sampled on both November 15th and December 30th of 2020, the sample dates closest to the fire, and showed opposing trends (Figure 15 and Figure 16). Stormwater hardness was greater at the December sampling than November at both WVV and NRT. The difference between November and December was greater at WVV than NRT, and the hardness at WVV on December 30th (155 mg/L) was more than two times greater than on November 15th (58.3 mg/L). In contrast, the total

organic carbon at WVV was lower on December 30th (5.96 mg/L) than November 15th (10.6 mg/L). As noted in the analysis of metal pollutants at stormwater sites (Changes Over Time in Section 4.3.2.1), while the precipitation was greater on November 15th (0.24 inches) than December 30th (0.165 inches), the precipitation in the month preceding December 30th (2.65 inches) was greater than the month preceding November 15th (0.74 inches). Other parameters such as nutrients and TSS showed high variability among sites and dates with not clear patterns evident (Figure 15 and Figure 16). Due to limited data availability and time elapsed between sampling dates, there are many confounding factors that could be contributing to varying concentrations of water quality analytes.

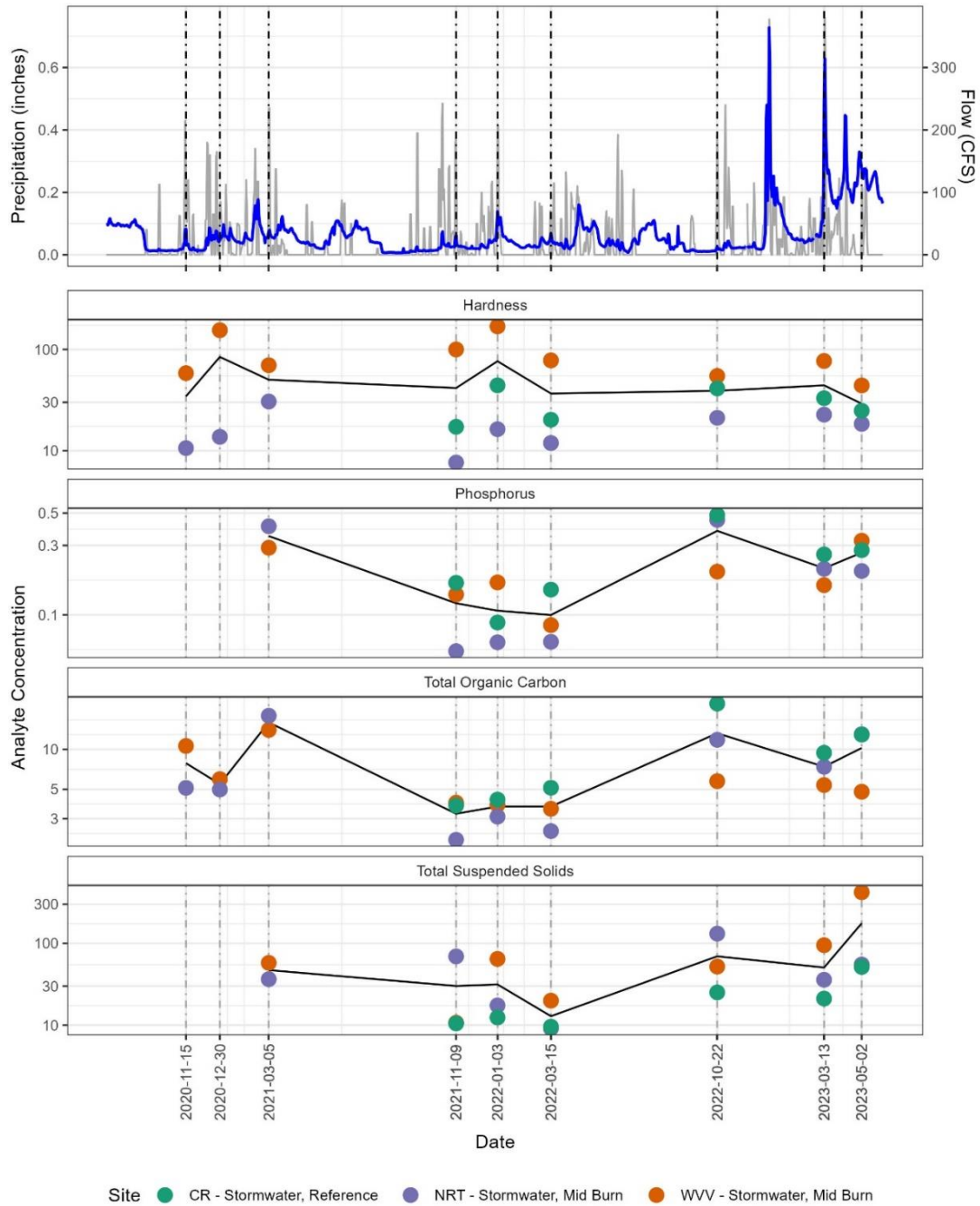


Figure 15. Precipitation (gray) and flow (blue) two day rolling means (top) compared to concentrations of hardness (mg CaCO₃/L), phosphorus (mg/L), total organic carbon (mg/L), and total suspended solids (mg/L) for stormwater sites CR, NRT, and WVV. Points in the time series figures with red stars behind them are non-detect values, indicating the instrument could not detect concentrations of that analyte. The non-detect values are presented as values equal to 1/2 times the minimum detection limit (0.5*MDL) for ease of analysis and better representation of the presence of a data point. Mean values of all sites sampled on a date are presented with the black line. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis.

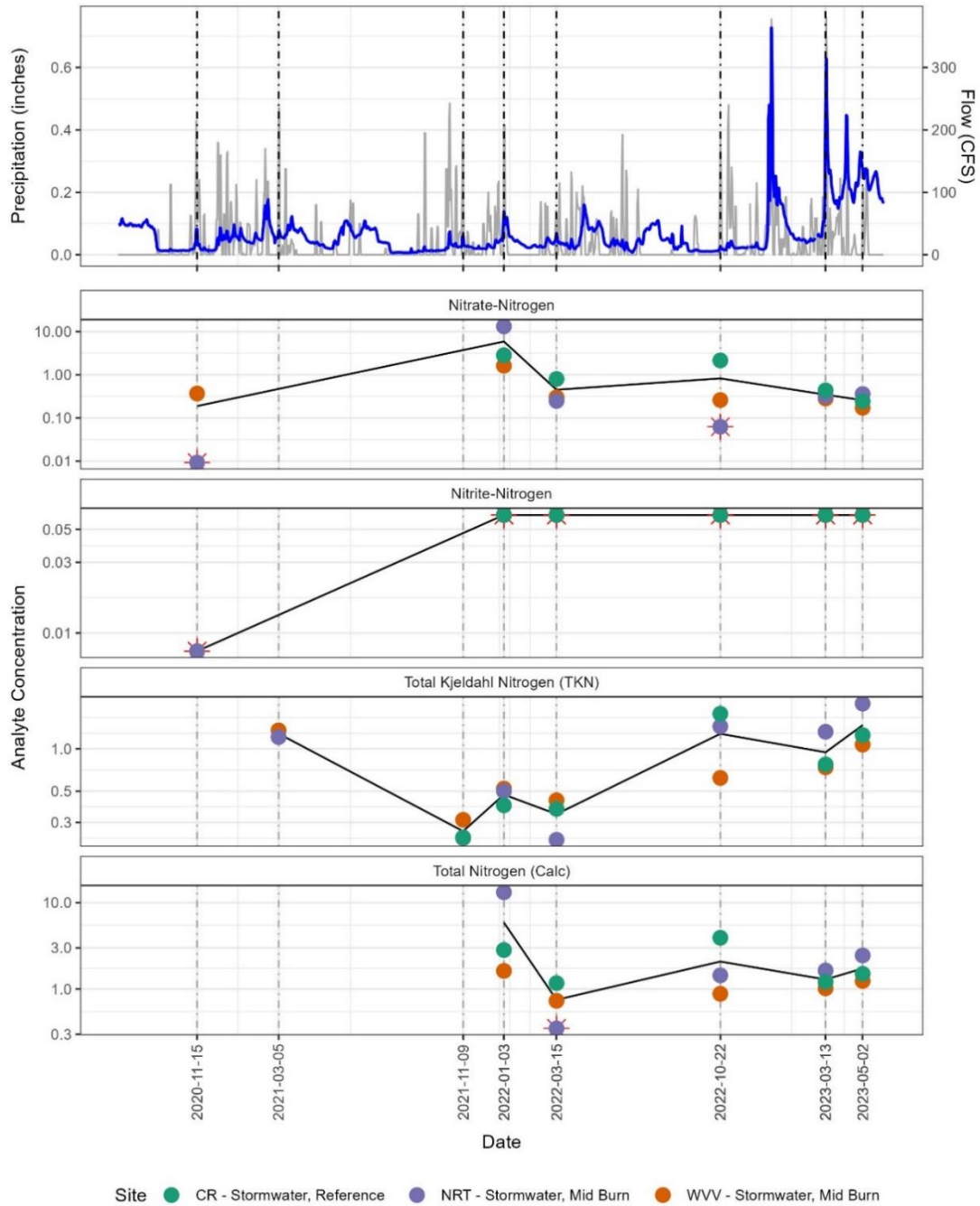


Figure 16. Precipitation (gray) and flow (blue) two day rolling means (top) compared to concentrations of nitrate-nitrogen (mg/L), nitrite-nitrogen (mg/L), total Kjeldahl nitrogen (mg/L), and total nitrogen (mg/L) for stormwater sites CR, NRT, and WVV. Points in the time series figures with red stars behind them are non-detect values, indicating the instrument could not detect concentrations of that analyte. The non-detect values are presented as values equal to 1/2 times the minimum detection limit ($0.5 \times \text{MDL}$) for ease of analysis and better representation of the presence of a data point. Mean values of all sites sampled on a date are presented with the black line. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis.

6.3.1.2 Site Comparison

WVV, NRT, and CR

Four parameters, phosphorus, total Kjeldahl nitrogen, total organic carbon, and total suspended solids, were selected for analysis across six dates due to data availability (these were the only dates when all three sites were consistently sampled). Total phosphorus and TOC (lower quartile only) tended to be lower at NRT, and CR tended to be higher for total phosphorus and lower for TSS. However, which site had the greatest median concentration varied by analyte. For example, the median phosphorus value was similar at WVV (0.167 µg/L) and CR (0.166 µg/L), and both were greater than NRT (0.0653 µg/L) and total organic carbon had a similar pattern. In contrast, total Kjeldahl nitrogen was similar in median concentration at WVV (0.522 µg/L) and NRT (0.5 µg/L), however it was slightly lower at CR (0.397 µg/L), with total suspended solids following a similar pattern. Site WVV tended to have a smaller range of values for phosphorus, nitrogen, and carbon than NRT and CR. For a table of median and interquartile range values for this figure, see Appendix B.2.2 Values for comparison of WVV, NRT, and CR, Figure 17.

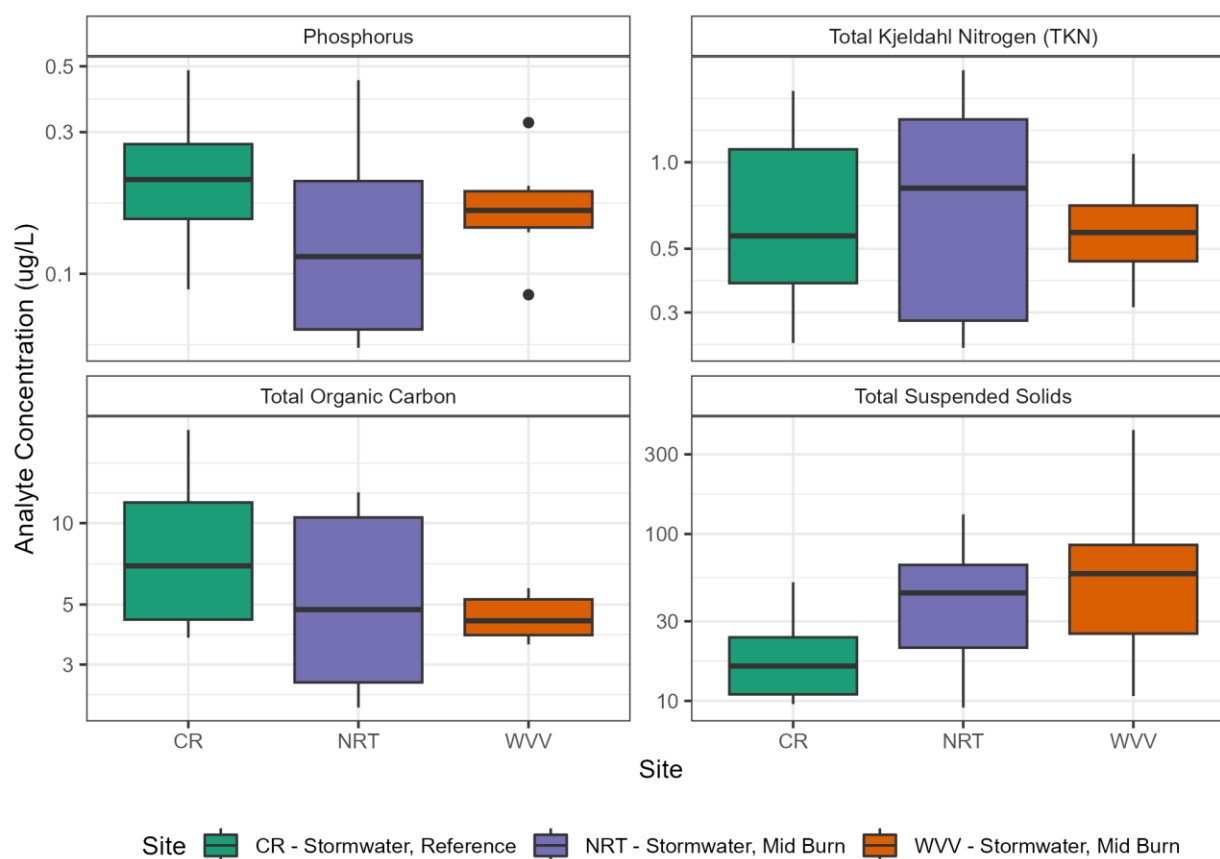


Figure 17. Comparison of phosphorus, total Kjeldahl nitrogen, total organic carbon, and total suspended solids concentrations at WVV, NRT, and CR for five dates: November 2021, January, March, and October 2022, March 2023, and May 2023.

6.3.2 Correlations Between Analytes

Some analytes may have correlations in concentrations due to factors like being sourced from a similar event or location or binding together in surface waters and therefore being co-transported. When considering all sites, both stormwater and in-stream, across thirteen sampling dates, there were correlations between nitrogen, phosphorus, and carbon. For example, the strongest correlation existed between total Kjeldahl nitrogen and phosphorus (PC: 0.869). Both nutrients can be sourced from similar locations, such as fertilizer runoff. Urban and suburban lawn ecosystems, like those contributing stormwater to Bear Creek, can be a contributor of nitrogen and phosphorus to aquatic ecosystems (Toor et al., 2017). The other correlations were between both total organic carbon and total Kjeldahl nitrogen (PC: 0.728) and phosphorus (PC: 0.701). Carbon and nitrogen can be coupled in a variety of ecosystems due to microbial processing and the reactivity of both molecules. This relationship maintains a resource stoichiometry between the two analytes (Taylor & Townsend, 2010).

Correlations may also exist between some analytes and aluminum or iron, because aluminum and iron often exist as oxide particles that have chemically reactive surfaces (Hochella et al., 2005). Due to these surface characteristics that can make aluminum and iron sticky to other analytes, co-transport may occur between these metals and other analytes in overland flow and surface waters. Additionally, a correlation may indicate pollutants from the same source being concurrently released into stormwater or surface waters. When considering all sites, both stormwater and in-stream, there were correlations between both iron and aluminum and total suspended solids. This may indicate that the release of material, such as soils, that increase concentrations of total suspended solids contain iron and aluminum; both iron and aluminum are found at high concentrations in soils (Hochella et al., 2008).

6.3.3 In-Stream Site Analysis

6.3.3.1 All In-Stream Sites

Four in-stream sites were sampled for water quality pollutants across a range of dates, starting just after the fire and completing December 2022. One site, BCOS, was sampled above the burn area and one site, BCUC was sampled just downstream of the burn area. The other two sites, BCJS and BCKR, were sampled further downstream than BCUC. Given that these sites were sampled more sporadically and therefore contain less consistent data, they are presented in Appendix D.2 Time Series of water quality parameters at all in-stream sites.

6.3.3.2 Analysis of BCUC

Like with metal concentrations, some water quality parameters were greater at in-stream site BCUC on November 15th when compared with November 4th (Figure 18). For example, total Kjeldahl nitrogen was not detected on November 4th (MDL: 0.172 µg/L), whereas concentrations were more than thirteen times the detection limit on November 15th (2.26 µg/L). Similar trends were observed for phosphorus, total organic carbon, and total suspended solids. In contrast, water hardness decreased on November 15th (120 µg/L) relative to November 4th (183 µg/L) and nitrate followed this same pattern. As noted in the metals section, the precipitation and flow on November 4th were low with a two-week antecedent dry period prior to the sampling event. There was less precipitation between the fire and the November

4th sampling date than there was between the November 4th and November 15th sampling dates (for more details, see the 'Analysis of BCUC' section in the Metals analysis). On November 15th there was high flow conditions and a larger precipitation event than in previous weeks; the flow was over nine times greater, and the precipitation was 0.48 inches greater on November 15th than November 4th (Figure 4). This may indicate that precipitation events on and around November 15th after weeks of relatively dry weather captured metals and metalloids in surface runoff from roadways and impervious surfaces in burned and urban areas in the vicinity of the Almeda Fire and upstream into Bear Creek, appearing as elevated concentrations of phosphorus, total Kjeldahl nitrogen, carbon, and suspended solids at the BCUC in-stream site just downstream of the burned area. For a table of concentration values at BCUC, see Appendix B.2.3 Values for in-stream site BCUC, .

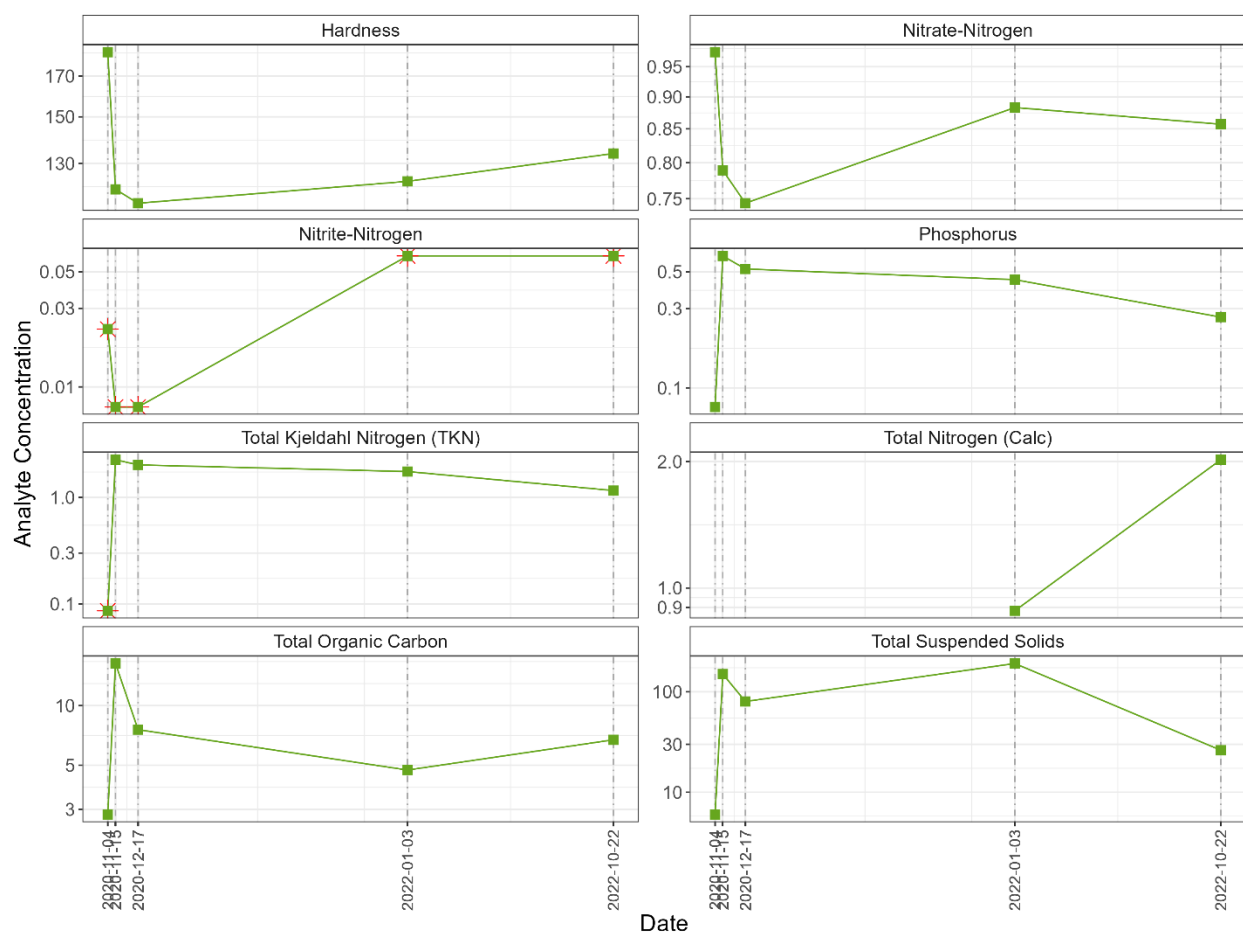


Figure 18. Concentrations of analytes at BCUC starting on November 4th, 2020 with a final sampling date on October 22, 2022. Because of the close proximity of the November 4th and 15th sampling dates in time, they are also somewhat muddled on the x-axis.

7. Results & Discussion: RVCOG TMDL Data

There are multiple water quality parameters with total maximum daily loads (TMDLs) in place for Bear Creek. To evaluate water quality in Bear Creek relative to the TMDL requirements, the RVCOG samples

Bear Creek once per month at up to twenty-four stations in-stream (Gruen, 2020). These sampling events are focused on *E. coli*, phosphorus, and water temperature, however other useful parameters including conductivity, turbidity, and pH are also measured. This data set is potentially useful to understand the effects of the Alameda Drive Fire because it was continuously collected both before and after the fire occurred, whereas most other sampling events presented in this report only occurred after. Data are available June 2011 through the present day. Some stations were located upstream of the Alameda Drive Fire burn perimeter, some within, and some downstream of the burn. These stations can be found in the captions of Figure 19 and Figure 21 and site map in Figure 2.

7.1 Water Temperature & pH

Trends in water temperature and pH were apparent in the period spanning six months before and one year after the Alameda Drive Fire relative to previous years (Figure 19). Prior to spring of 2020, before the fire occurred in September 2020, the mean pH had been higher at sites downstream of the burn perimeter than sites within the perimeter. However, starting in March 2020 the pH at sites within the burn perimeter often had pH values greater than those downstream. For example, in March 2019 the mean pH of sites downstream of the burn (8.7) was greater than in the burn (8.0), whereas in March 2020 the mean pH of sites downstream of the burn (8.2) was less than those in the burn (8.6). The pH values were greater at sites within the burn perimeter relative to downstream in March, April, May, and August of 2020, and again in early 2021 and summer 2021. Similarly, prior to 2020 the temperature of Bear Creek downstream of the Alameda burn perimeter tended to be greater than within the burn perimeter, but the pattern changed during the same time period as pH. Starting in spring 2020 water temperatures were greater within the burn perimeter on average than downstream. For example, in August 2020, the mean temperature of sites in the burn perimeter (21.2°C) was greater than the mean of sites downstream (18.9°C). Although this trend spans the fire, it began well before the fire during the spring of 2020, providing good indication that the observed pH and temperature trends were related to factors other than the Alameda fire. Climate is one such factor, and 2020 was among the more severe drought and low flow years for Bear Creek within the past decade. Moreover, although there are apparent temporal and spatial trends, the interpretation is somewhat confounded by diel changes in water chemistry since these values represent one discrete time of day, and both pH and temperature can vary greatly on a diel basis.

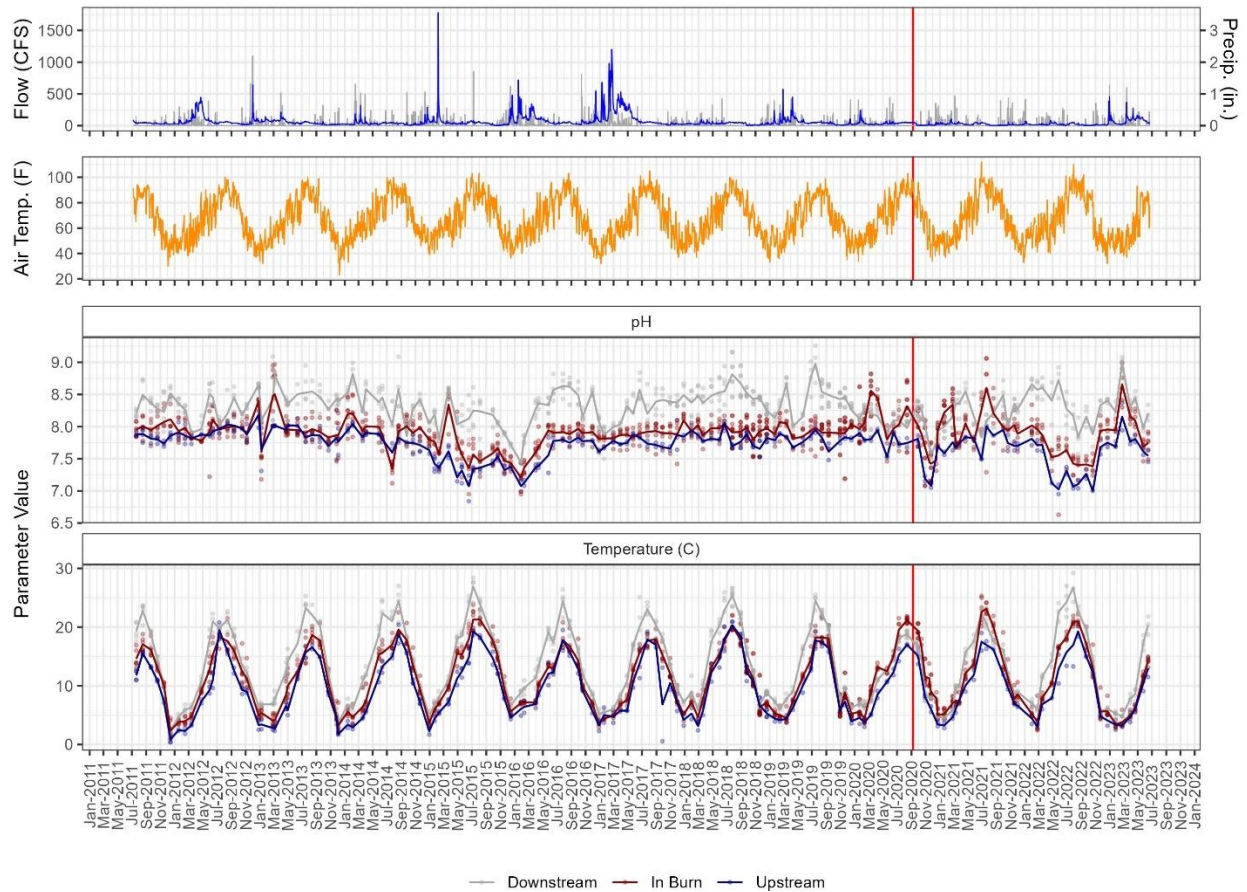


Figure 19. Time series figures of RVCOG TMDL monitoring sites for two parameters, pH and temperature (°C), that were collected starting in 2011. The colors differentiate between sampling sites in locations in either tributaries upstream of the burn that confluence to become Bear Creek (E3, E4), Bear Creek within the burn (E5, E7, E8, E9, E13), or Bear Creek downstream of the burn (E14, E15, E20, E24). The lines are means of stations sampled by sample site location. The vertical dashed red line indicates the date of the Almeda Drive Fire. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis. Parameters presented include pH and temperature (Celsius).

There was a correlation between water temperature in Bear Creek and the surrounding air temperature measured in Ashland. At downstream sites, the correlation was only slightly stronger before the burn ($R^2=0.81$) than after the burn ($R^2=0.79$) (Figure 20). The pattern was different at sites within the burn, where the correlation was slightly stronger after the burn ($R^2=0.82$) than before the burn ($R^2=0.78$). This change in correlation strength was likely not linked to the fire, however, as sites above the fire showed a similar change as sites within the burned area ($R^2_{\text{before}}=0.76$, $R^2_{\text{after}}=0.82$). In the Pacific Northwest, climate change has resulted in increased air temperatures and decreased in-stream flows, and this can lead to an increase in surface water temperature (Halofsky et al., 2022). As noted above, Oregon has been in a drought period with more intense conditions in recent years, stressing water supplies and surface waters (State of Oregon, 2022). Given the link between air temperature and water temperature, the increasing air temperatures in Oregon, and the declines in water supply, this

indicates that the change in water temperature relationships just before and after the Almeda Drive Fire could be linked to changing climatic conditions as opposed to a result of the fire.

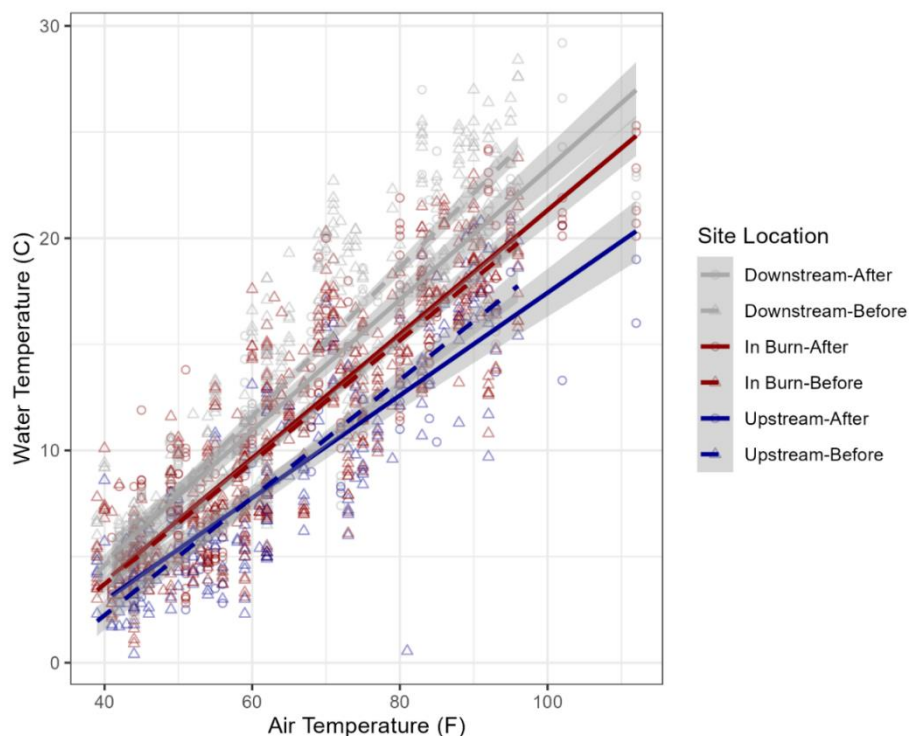


Figure 20. Correlation between air temperature (F) on the x-axis and water temperature (C) on the y-axis. The colors represent which grouped location the data points belong to – either downstream of the burned area (gray), in the burned area (red), or upstream of the burned area (blue). The dashed lines are the mean, by group, of data collected before the burn and the solid lines are means, by group, of data collected after the burn.

7.2 Trends in Conductivity

Although Most of the parameters did not have discernible patterns before and after the Almeda Drive Fire, conductivity showed an increase just after the fire that continued for the next two years.

Conductivity is a more general measure describing the ability of water to pass electrical current and may indicate an increase in concentration of a range of possible inorganic pollutants. Nine years of data are available for prior to the fire, and it appears that long-term there was a drop in conductivity in spring 2016 at sites within and downstream of the 2020 burn perimeter relative to the prior four years. Just after the fire, conductivity values increased relative to the 2016-2020 period, but were similar to those occurring in 2014 and 2015. All three categories of sites, upstream, in, and downstream of the burn, displayed an increase in conductivity just after the fire relative to the prior four years (Figure 21). For example, the mean conductivity at sites in the burn perimeter on August 19th, 2021 (376.4 $\mu\text{S}/\text{cm}$) was about twice as high than on August 13th, 2020 (187.8 $\mu\text{S}/\text{cm}$). While conductivity was greater at sites downstream of the burn than in the burn perimeter for all sampling dates prior to the burn, after the burn it tended to be equal or greater at sites within the burn perimeter. For example, the mean conductivity value of sites downstream of the burn on September 11, 2019 (224.7 $\mu\text{S}/\text{cm}$) was greater

than sites within the burn perimeter (205.9 $\mu\text{S}/\text{cm}$). In contrast, just after the fire on September 19, 2020, sites within the burn perimeter (370.7 $\mu\text{S}/\text{cm}$) were similar to conductivity values for sites downstream (371.6 $\mu\text{S}/\text{cm}$).

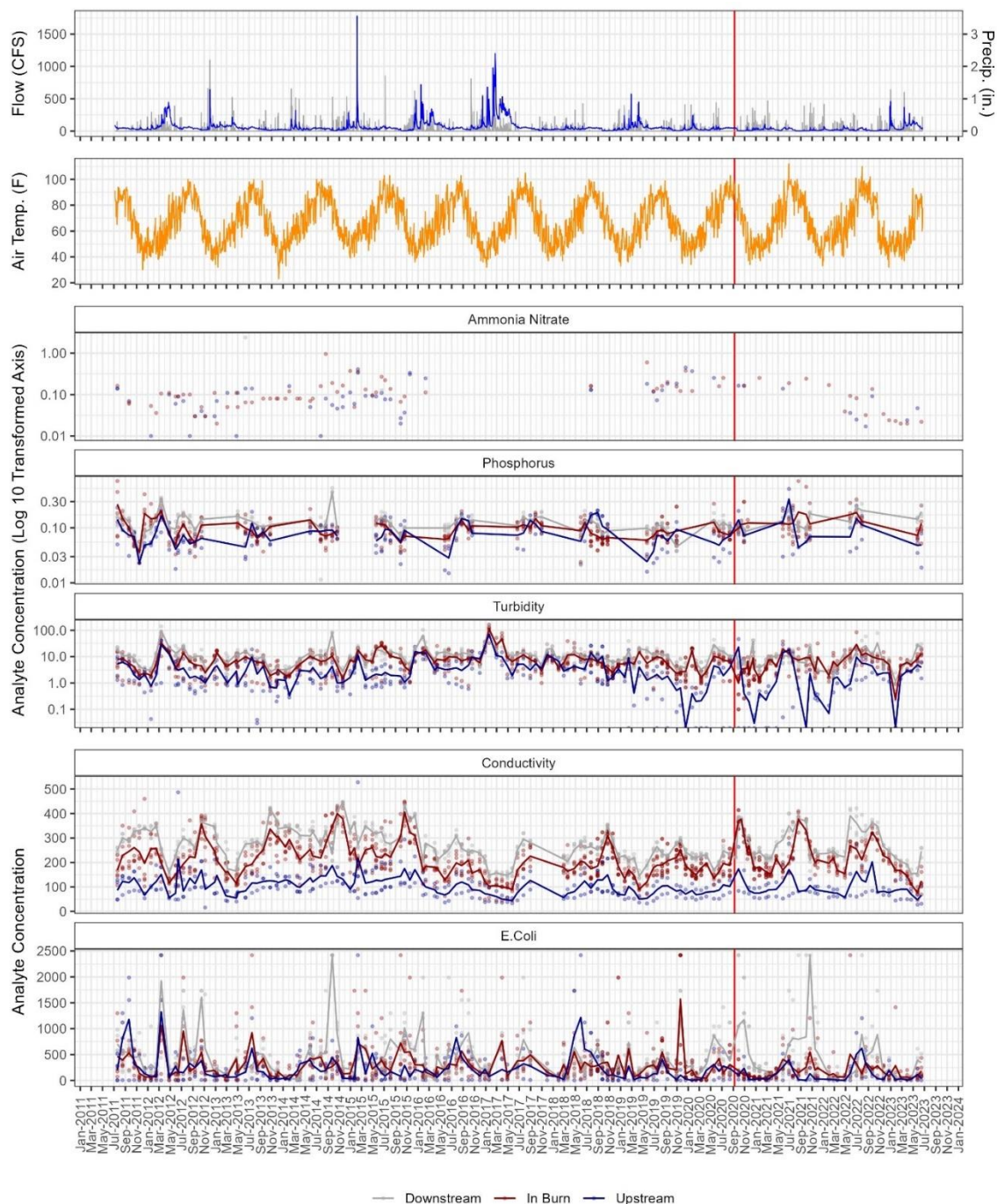


Figure 21. Time series figures of RVCOG TMDL monitoring sites for five parameters: conductivity ($\mu\text{S}/\text{cm}$), *E. coli* (MPN), phosphorus (mg/L), and turbidity (NTU). The colors differentiate between sampling sites in locations in either tributaries upstream of the burn that confluence to become Bear Creek (E3, E4), Bear Creek within the burn

(E5, E7, E8, E9, E13), or Bear Creek downstream of the burn (E14, E15, E20, E24). The lines are means of stations sampled by sample site location, with the exception of ammonia nitrate which did not have enough data points to calculate a mean. The vertical dashed red line indicates the date of the Alameda Drive Fire. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis. Ammonia Nitrate, Phosphorus, and Turbidity were plotted with a log-10 transformed axis to better visualize small values.

Weak correlations were present between temperature and conductivity for data points collected after the Alameda Drive Fire, whereas no correlation was present before the burn. For example, data collected after the fire were weakly correlated at sites within the burn ($R^2=0.22$), upstream ($R^2=0.27$), and downstream ($R^2=0.38$), with the three groupings having a correlation coefficient of 0.14 or less before the burn (Figure 22). However, given that this trend occurs at the sites upstream of the burn as well, this indicates that other dynamics are likely affecting this relationship. Bear Creek is sourced from Emigrant Lake, where flows are regulated. Additionally, Bear Creek has several irrigation projects and inputs of irrigation return flows (Oregon DEQ, 2007). These factors, combined with the ongoing drought described in the previous section, can result in increased conductivity with increasing water temperatures. For example, as water levels in Emigrant Lake decline, the conductivity may increase as water constituents become more concentrated. Similarly, as crops require increased irrigation, water levels in Bear Creek may decline and irrigation return flows carry pollutants to Bear Creek that increase conductivity levels. Due to these many confounding factors, it is difficult to isolate a single event affecting the conductivity and temperature relationship in Bear Creek.

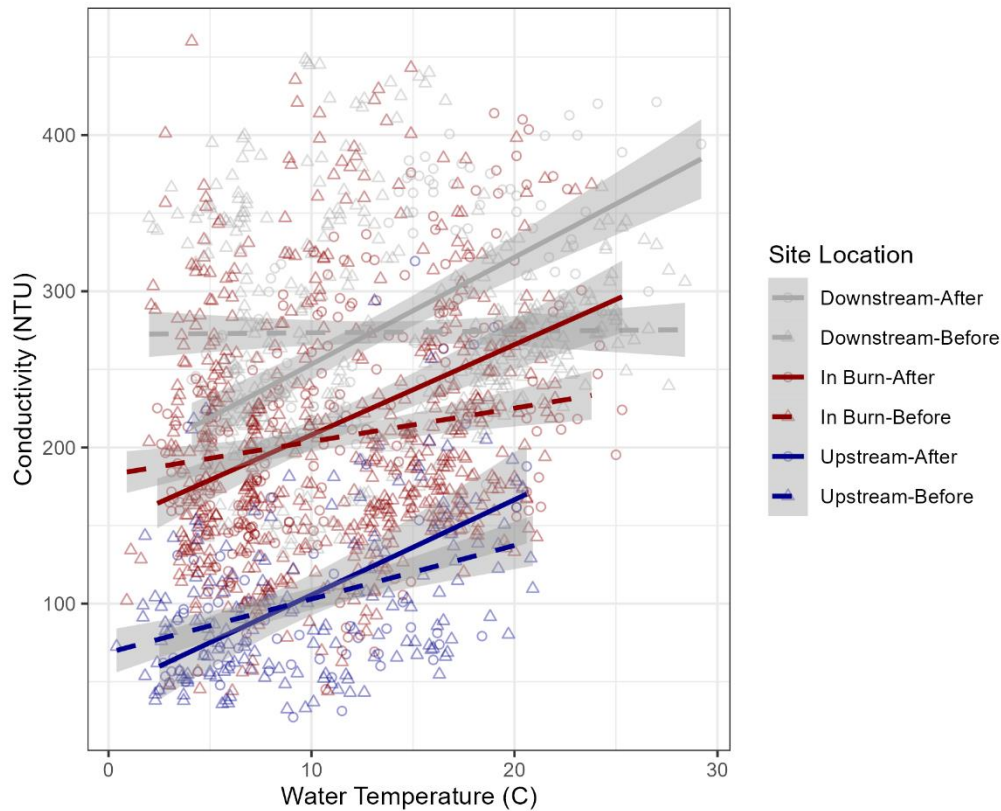


Figure 22. Weak correlations between water temperature (C) on the x-axis and conductivity ($\mu\text{S}/\text{cm}$) on the y-axis. The colors represent which grouped location the data points belong to – either downstream of the burned area (gray), in the burned area (red), or upstream of the burned area (blue). The plots have linear regression best fit lines, where the solid are data from before the burn and dashed are from after the burn. The regressions are grouped spatially.

8. Results & Discussion: DEQ Water Quality Data

Data collection by the Oregon Department of Environmental Quality (DEQ) occurred 6 – 7 times per year (approximately every other month) at a site over thirteen river miles downstream from the burned area, just upstream from the confluence with the Rogue River (Figure 23, Figure 24). Given the location of the sample site, many confounding factors exist due to the distance between the burned area and the sample collection site. For example, the river reach between the burn and the sample location receives input of surface runoff from urban and suburban areas as well as irrigation return flows. Data are missing from several months in 2020, just before the fire, due to sampling restrictions as a result of COVID-19. When considering water quality constituents before and after the fire, there does not appear to be a difference. For example, while total solids were sampled more frequently after the fire to capture signal from additional pollutants entering the water, the high values in October 2020 are similar in concentration to high values measured in November 2018. Additionally, data do not appear to be substantially different from year-to-year relative to the long-term median. The infrequent point-in-time sampling data makes shorter term assessments, like interpreting data measured since the Almeda Drive Fire, more challenging.

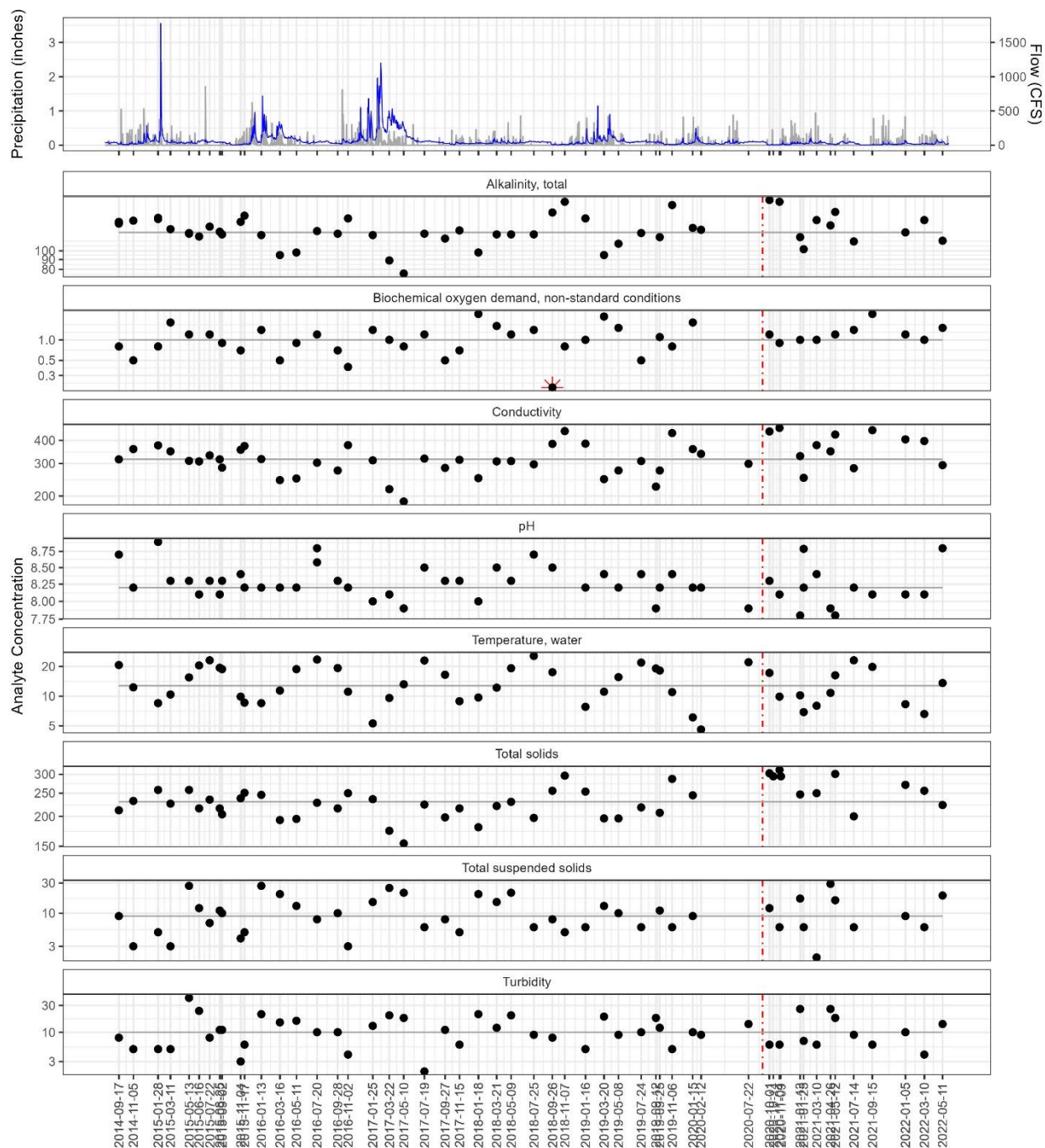


Figure 23. DEQ surface water monitoring data for station DEQ-11051, located at the same site as BCKR sampled in the Post-Fire Monitoring data. The horizontal gray line is the long-term median value of each parameter, and the vertical red dashed line is the date of the Almeda Drive Fire. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis. Parameters presented include, from top to bottom, total alkalinity (mg/L), biochemical oxygen demand (mg/L), conductivity (umho/cm), pH, water temperature (°C), total solids (mg/L), total suspended solids (mg/L), turbidity (NTU).

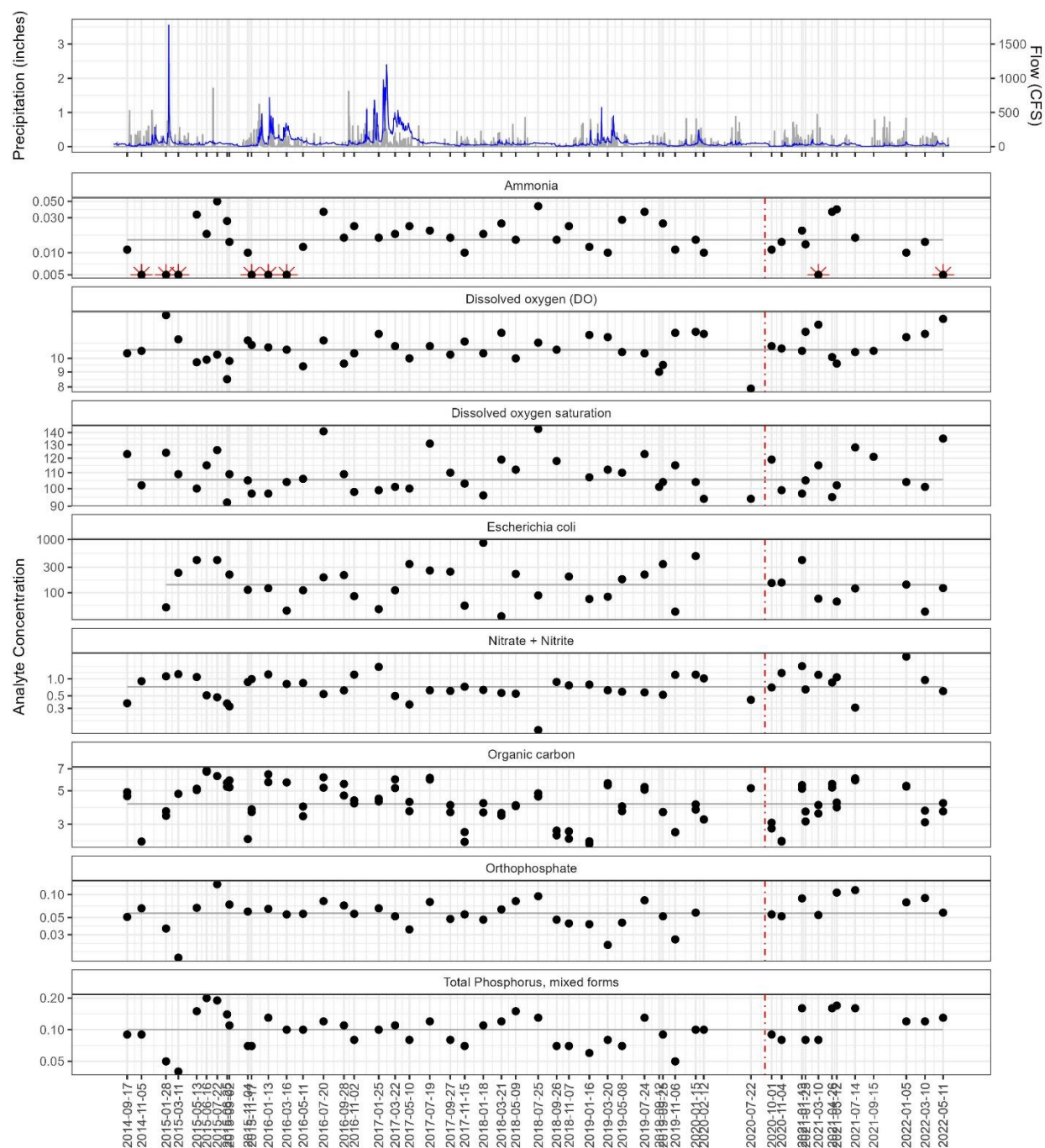


Figure 24. DEQ surface water monitoring data for station DEQ-11051, located at the same site as BCKR sampled in the Post-Fire Monitoring data. The horizontal gray line is the long-term median value of each parameter, and the vertical red dashed line is the date of the Almeda Drive Fire. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis. Parameters presented include, from top to bottom, ammonia (mg/L), dissolved oxygen (mg/L), dissolved oxygen saturation (%), *E. coli* (MPN/100m), nitrate + nitrite (mg/L), organic carbon (mg/L), orthophosphate (mg/L), and total phosphorus (mg/L).

9. Results & Discussion: Sonde Data

Data were collected through the deployment of two data sondes by the Rogue River Watershed Council from February 2021 to October 2022 (Figure 25). The sondes were deployed at sites that align with the Post-Fire Water Quality data collection; one sonde was deployed at BCOS above the burn and the other more than four river miles downstream from the burn perimeter at BCJS. The sondes were deployed more than four months after the fire occurred with precipitation events occurring between the fire and sonde deployment, therefore the sondes did not capture the first several flushes of surface runoff that occurred after the fire. Additionally, due to changing land use occurring over the substantial distance between the burned area and the downstream sonde deployment, BCJS also reflects all runoff from impervious surfaces both within and outside of the burned area. Similar to other analyses described in this report, there are many factors that confound the interpretation of Sonde water quality differences among sites.

Relative to BCOS, downstream site BCJS tended to have lower water temperature, lower dissolved oxygen concentrations, and greater daily variability in dissolved oxygen, particularly in the summer months. The pH at BCJS tended to be higher than at BCOS, while the daily pH variability at BCOS tended to be greater. The biggest difference between the two sites was in turbidity; upstream site BCOS had much lower turbidity than BCJS. Higher turbidity at BCJS may be caused by irrigation return flows and other runoff sources, including tributaries, occurring within the 13-mile reach between BCOS and BCJS.

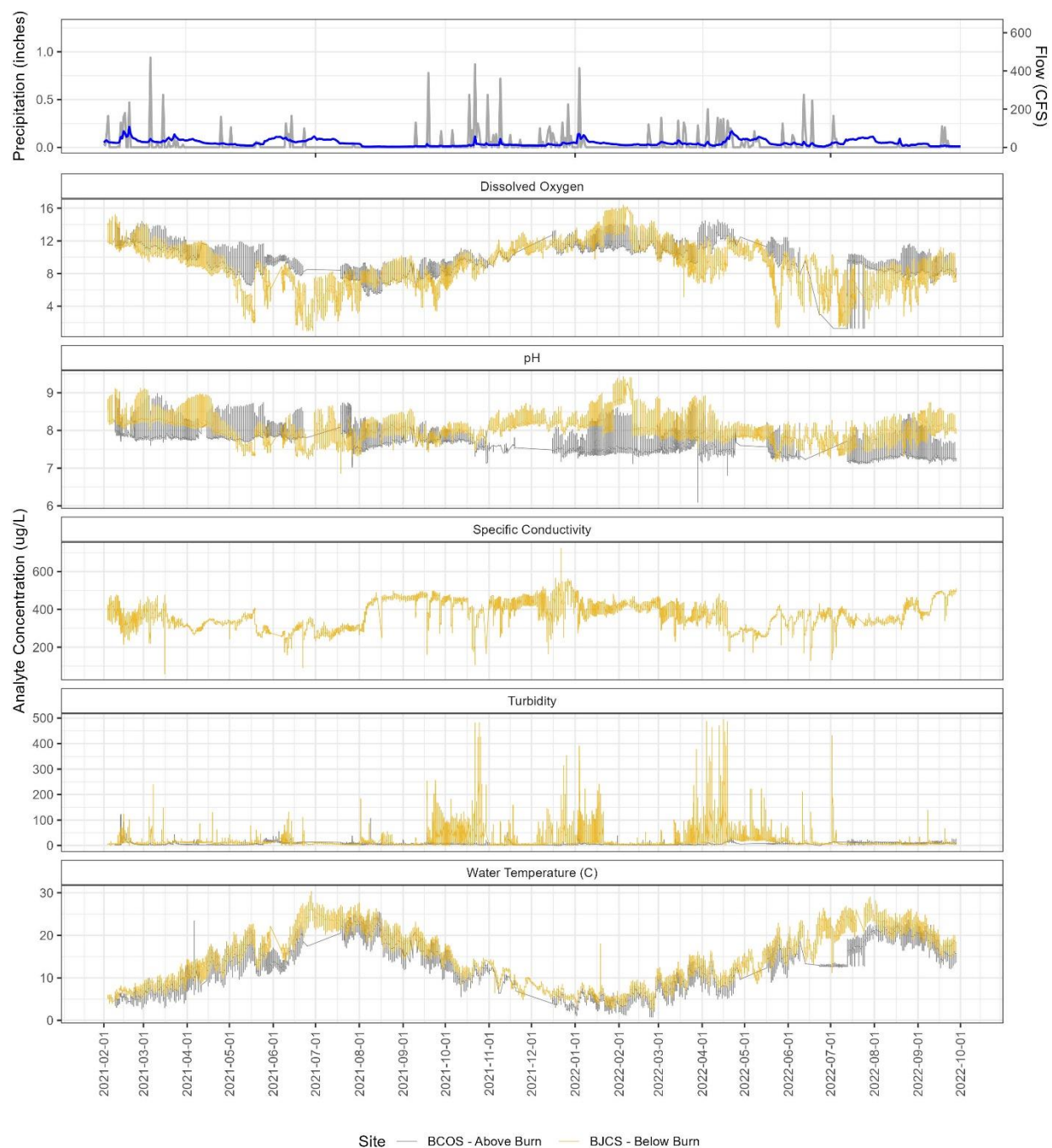


Figure 25. Bear Creek sonde data collected at BCOS (gray) and BJCS (orange) from February 2021 to October 2022. In the top figure, precipitation (inches) is the gray line represented by the left-hand axis and flow (cubic feet per second) is the blue line and right-hand axis. Parameters include dissolved oxygen (mg/L), pH, specific conductivity (umho/cm), turbidity (NTU), and water temperature (°C).

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Appendix

Appendix A. Description of precipitation and flow trends

Table 3. Precipitation and flow values, rolling means, and description of antecedent activity for the RVCOG sampling dates.

Date	Flow Original	Flow: Two Day Rolling Mean	Flow: Seven Day Rolling Mean	Flow Comment	PRCP Original	PRCP: Two Day Rolling Mean	PRCP: Seven Day Rolling Mean	Precipitation Comment
11/4/2020	6.69	6.84	7.15	Low flow in antecedent 2 weeks	0	2.60E-17	0.036	antecedent dry period of approximately 2 weeks
11/15/2020	63.70	41.5	23.85	Flow increase at time of sampling	0.48	0.24	0.184	multiple precipitation events in preceding weeks
12/17/2020	19.30	42.4	27.96	Larger flow increase days prior to sampling, low before that	0.55	0.32	0.203	multiple precipitation events in preceding weeks
12/30/2020	22.30	23.25	25.43	Higher flow in weeks prior to sampling	0	0.165	0.081	multiple precipitation events in preceding weeks
3/5/2021	31.30	37.75	31.89	Multiple flow events, including largest of the year, in weeks prior	0	0.47	0.134	period of low precipitation with some events in preceding week
11/9/2021	44.20	30.9	18.39	Some mid-range flow events in weeks prior	0.72	0.38	0.136	multiple precipitation events in preceding weeks
1/3/2022	69.00	69.35	43.87	Sample date occurs at large increase in flow relative to previous weeks, some small flow events present	0	0.415	0.134	multiple precipitation events in preceding weeks
3/3/2022	28.00	27.6	27.3	Some small flow events in weeks prior, this sample date in larger jump in flow	0.31	0.155	0.049	antecedent dry period of approximately 2 weeks
3/15/2022	35.70	34.35	24.27	previous sample date (3/3) was previous larger flow event	0.28	0.14	0.04	multiple precipitation events in preceding weeks
4/13/2022	14.90	14.85	15.73	some mid-range flow events in previous weeks	0.02	0.155	0.144	multiple precipitation events in preceding weeks
10/22/2022	13.80	12.85	8.85	low flow in antecedent 3 to 4 weeks	0.3	0.38	0.126	multiple precipitation events in preceding weeks

12/30/2022	270.00	364	223.1	mid-range flow in previous month, this sampling captures large increase in flow, the flow at this sampling event was larger than any other flow since the beginning of 2020	0.23	0.755	0.324	period of low precipitation with some events in preceding week
3/13/2023	116.00	242	155.6	similar to December 2022, this flow event was of magnitude greater than most flow events (besides Dec 2022) in the previous two years. The December 2022 flow event was the most recent large event prior to this.	0.02	0.17	0.273	multiple precipitation events in preceding weeks
5/2/2023	146.00	137.5	142.14	Several high flow events in the two months prior.	0	0.215	0.061	multiple precipitation events in preceding weeks

Appendix B. Analyte Concentration Tables

Appendix B.1 RVCOG Metals Data

Appendix B.1.1 Values for all stormwater sites, Figure 9 and Figure 10

Date	Parameter	WVV	NRT	CR
11/15/2020	Aluminum	1.15	0.693	NA
11/15/2020	Antimony	0.00113	0.000665	NA
11/15/2020	Arsenic	0.00207	0.00188	NA
11/15/2020	Beryllium	6.00E-04	ND	NA
11/15/2020	Cadmium	ND	ND	NA
11/15/2020	Chromium	0.00278	0.00206	NA
11/15/2020	Copper	0.00795	0.00648	NA
11/15/2020	Iron	1.2	0.709	NA
11/15/2020	Lead	0.00339	0.0015	NA
11/15/2020	Nickel	0.00196	0.00143	NA
11/15/2020	Selenium	ND	ND	NA
11/15/2020	Silver	ND	ND	NA
11/15/2020	Thallium	ND	ND	NA
11/15/2020	Zinc	ND	ND	NA
12/30/2020	Aluminum	8.22	0.884	NA
12/30/2020	Antimony	0.00253	ND	NA
12/30/2020	Arsenic	0.00437	0.00158	NA

12/30/2020	Beryllium	0.000218	ND	NA
12/30/2020	Cadmium	0.000272	ND	NA
12/30/2020	Chromium	0.0159	0.00184	NA
12/30/2020	Copper	0.0624	0.0107	NA
12/30/2020	Iron	11.4	1.07	NA
12/30/2020	Lead	0.0296	0.00216	NA
12/30/2020	Mercury	ND	ND	NA
12/30/2020	Nickel	0.0147	0.00201	NA
12/30/2020	Selenium	ND	ND	NA
12/30/2020	Silver	0.000103	ND	NA
12/30/2020	Thallium	ND	ND	NA
12/30/2020	Zinc	0.238	0.0416	NA
3/5/2021	Aluminum	1.81	1.25	NA
3/5/2021	Antimony	0.00153	0.00193	NA
3/5/2021	Arsenic	0.00193	0.0024	NA
3/5/2021	Beryllium	ND	ND	NA
3/5/2021	Cadmium	ND	0.000141	NA
3/5/2021	Chromium	0.00377	0.00361	NA
3/5/2021	Copper	0.0215	0.0269	NA
3/5/2021	Iron	2.17	1.64	NA
3/5/2021	Lead	0.00638	0.0144	NA
3/5/2021	Mercury	ND	ND	NA
3/5/2021	Nickel	0.00432	0.00306	NA
3/5/2021	Selenium	ND	ND	NA
3/5/2021	Silver	ND	ND	NA
3/5/2021	Thallium	ND	ND	NA
3/5/2021	Zinc	0.0818	0.0765	NA
11/9/2021	Aluminum	1070	366	666
11/9/2021	Antimony	ND	ND	ND
11/9/2021	Arsenic	0.921	ND	0.611
11/9/2021	Beryllium	ND	ND	ND
11/9/2021	Cadmium	ND	ND	ND
11/9/2021	Chromium	1.88	ND	1.69
11/9/2021	Copper	5.02	3.97	3.66
11/9/2021	Iron	1150	469	664
11/9/2021	Lead	2.09	1.19	0.474
11/9/2021	Mercury	ND	ND	ND
11/9/2021	Nickel	1.86	ND	1.27
11/9/2021	Selenium	ND	ND	ND
11/9/2021	Silver	ND	ND	ND
11/9/2021	Thallium	ND	ND	ND

11/9/2021	Zinc	17.2	83.2	22.7
1/3/2022	Aluminum	2410	276	632
1/3/2022	Antimony	ND	ND	ND
1/3/2022	Arsenic	1.59	0.618	0.6
1/3/2022	Beryllium	0.134	ND	ND
1/3/2022	Cadmium	ND	ND	ND
1/3/2022	Chromium	4.46	ND	1.4
1/3/2022	Copper	10.3	4.69	4.7
1/3/2022	Iron	2970	299	638
1/3/2022	Lead	5	0.954	0.468
1/3/2022	Mercury	ND	ND	ND
1/3/2022	Nickel	4.7	1.25	1.43
1/3/2022	Selenium	ND	ND	ND
1/3/2022	Silver	ND	ND	ND
1/3/2022	Thallium	ND	ND	ND
1/3/2022	Zinc	33.4	23.9	23
3/15/2022	Aluminum	1160	456	705
3/15/2022	Antimony	ND	ND	ND
3/15/2022	Arsenic	0.908	0.65	0.508
3/15/2022	Beryllium	ND	ND	ND
3/15/2022	Cadmium	ND	ND	ND
3/15/2022	Chromium	1.94	1.3	NA
3/15/2022	Copper	7.31	5.05	5.55
3/15/2022	Iron	1190	520	675
3/15/2022	Lead	2.57	1.25	0.529
3/15/2022	Mercury	ND	ND	ND
3/15/2022	Nickel	1.53	ND	ND
3/15/2022	Selenium	ND	ND	ND
3/15/2022	Silver	ND	0.176	ND
3/15/2022	Thallium	ND	ND	ND
3/15/2022	Zinc	23.9	89.7	12.9
10/22/2022	Aluminum	2080	3300	986
10/22/2022	Antimony	0.559	0.757	ND
10/22/2022	Arsenic	1.06	1.36	0.943
10/22/2022	Beryllium	ND	ND	ND
10/22/2022	Cadmium	0.122	0.101	ND
10/22/2022	Chromium	3.71	5.02	2.58
10/22/2022	Copper	13.9	19.4	15.2
10/22/2022	Iron	2180	3350	1140
10/22/2022	Lead	3.57	7.3	1.39
10/22/2022	Mercury	ND	ND	ND

10/22/2022	Nickel	3.41	5.6	3.21
10/22/2022	Selenium	ND	ND	ND
10/22/2022	Silver	ND	ND	ND
10/22/2022	Thallium	ND	ND	ND
10/22/2022	Zinc	37.2	107	75.1
5/2/2023	Aluminum	9260	2240	2270
5/2/2023	Antimony	1.03	0.569	ND
5/2/2023	Arsenic	1.93	1.15	1
5/2/2023	Beryllium	0.165	ND	ND
5/2/2023	Cadmium	0.108	ND	ND
5/2/2023	Chromium	10.8	4.36	3.52
5/2/2023	Copper	31.8	29.9	13.2
5/2/2023	Iron	8540	2980	2500
5/2/2023	Lead	11.1	3.56	3.11
5/2/2023	Mercury	ND	ND	ND
5/2/2023	Nickel	11.3	3.96	4.45
5/2/2023	Selenium	ND	ND	ND
5/2/2023	Silver	ND	ND	ND
5/2/2023	Thallium	ND	ND	ND
5/2/2023	Zinc	133	227	51

Appendix B.1.2 Values for comparison of WVV, NRT, and CR, Figure 11

Table 4. Metal concentration median and interquartile range values (excluding 3/13/2023).

Parameter	Site Code	Median	Lower Quartile	Upper Quartile
Aluminum	CR	705	666	986
Aluminum	NRT	456	366	2240
Aluminum	WVV	2080	1160	2410
Arsenic	CR	0.611	0.6	0.943
Arsenic	NRT	0.65	0.618	1.15
Arsenic	WVV	1.06	0.921	1.59
Cadmium	CR	0.05	0.05	0.05
Cadmium	NRT	0.05	0.05	0.05
Cadmium	WVV	0.05	0.05	0.108
Chromium	CR	2.135	1.4	2.58
Chromium	NRT	1.3	0.5	4.36
Chromium	WVV	3.71	1.94	4.46
Copper	CR	5.55	4.7	13.2
Copper	NRT	5.05	4.69	19.4
Copper	WVV	10.3	7.31	13.9
Iron	CR	675	664	1140
Iron	NRT	520	469	2980

Iron	WV	2180	1190	2970
Lead	CR	0.529	0.474	1.39
Lead	NRT	1.25	1.19	3.56
Lead	WV	3.57	2.57	5
Zinc	CR	23	22.7	51
Zinc	NRT	89.7	83.2	107
Zinc	WV	33.4	23.9	37.2

Appendix B.1.3 Values for comparison of WV and NRT, Figure 12

Table 5. Metal concentration median and interquartile range values comparing stormwater sites WV and NRT for eight dates: 11/15 2020, 12/30/2020, 3/5/2021, 11/9/2021, 1/3/2022, 3/15/2022, 10/22/2022, and 5/2/2023.

Parameter	Site Code	Median	Lower Quartile	Upper Quartile
Aluminum	NRT	788.5	456	1250
Aluminum	WV	1945	1150	8220
Antimony	NRT	0.617	0.25	0.757
Antimony	WV	1.08	0.25	1.53
Arsenic	NRT	1.47	0.65	1.88
Arsenic	WV	1.93	1.06	2.07
Beryllium	NRT	0.05	0.05	0.1945
Beryllium	WV	0.1495	0.05	0.218
Cadmium	NRT	0.05	0.05	0.101
Cadmium	WV	0.05	0.05	0.122
Chromium	NRT	1.95	1.3	3.61
Chromium	WV	3.74	2.78	10.8
Copper	NRT	8.59	5.05	19.4
Copper	WV	12.1	7.95	31.8
Iron	NRT	709	520	1640
Iron	WV	2170	1200	2970
Lead	NRT	1.83	1.25	3.56
Lead	WV	4.285	3.39	11.1
Mercury	NRT	0.02	0.02	0.02
Mercury	WV	0.02	0.02	0.02
Nickel	NRT	1.72	1.25	3.06
Nickel	WV	3.865	1.96	11.3
Selenium	NRT	0.25	0.25	0.25
Selenium	WV	0.25	0.25	0.25
Silver	NRT	0.05	0.05	0.05
Silver	WV	0.05	0.05	0.05
Thallium	NRT	0.05	0.05	0.05
Thallium	WV	0.05	0.05	0.05

Zinc	NRT	59.05	23.9	89.7
Zinc	WVV	35.3	17.2	133

Appendix B.1.4 Values for in-stream site BCUC, Figure 13

Table 6. Table of metal concentration values for in-stream site BCUC. This includes metals and metalloids not presented in the figure in addition to those presented.

Date	Parameter	Units	BCUC
11/4/2020	Aluminum	ug/L	218
11/4/2020	Antimony	ug/L	ND
11/4/2020	Arsenic	ug/L	1.26
11/4/2020	Barium	ug/L	57.7
11/4/2020	Beryllium	ug/L	ND
11/4/2020	Boron	ug/L	672
11/4/2020	Cadmium	ug/L	ND
11/4/2020	Calcium	ug/L	47900
11/4/2020	Chromium	ug/L	ND
11/4/2020	Copper	ug/L	ND
11/4/2020	Iron	ug/L	335
11/4/2020	Lead	ug/L	0.233
11/4/2020	Lithium	ug/L	ND
11/4/2020	Magnesium	ug/L	15300
11/4/2020	Manganese	ug/L	58.5
11/4/2020	Mercury	ug/L	ND
11/4/2020	Molybdenum	ug/L	ND
11/4/2020	Nickel	ug/L	1.54
11/4/2020	Potassium	ug/L	4070
11/4/2020	Selenium	ug/L	ND
11/4/2020	Silica	ug/L	25700
11/4/2020	Silver	ug/L	ND
11/4/2020	Sodium	ug/L	31100
11/4/2020	Thallium	ug/L	ND
11/4/2020	Uranium	ug/L	0.866
11/4/2020	Vanadium	ug/L	ND
11/4/2020	Zinc	ug/L	ND
11/15/2020	Aluminum	ug/L	4290
11/15/2020	Antimony	ug/L	0.604
11/15/2020	Arsenic	ug/L	2.79
11/15/2020	Barium	ug/L	93.5
11/15/2020	Beryllium	ug/L	ND
11/15/2020	Boron	ug/L	322

Date	Parameter	Units	BCUC
12/17/2020	Barium	ug/L	62.2
12/17/2020	Beryllium	ug/L	ND
12/17/2020	Boron	ug/L	506
12/17/2020	Cadmium	ug/L	ND
12/17/2020	Calcium	ug/L	29600
12/17/2020	Chromium	ug/L	2.76
12/17/2020	Copper	ug/L	ND
12/17/2020	Iron	ug/L	3460
12/17/2020	Lead	ug/L	1.93
12/17/2020	Lithium	ug/L	ND
12/17/2020	Magnesium	ug/L	9880
12/17/2020	Manganese	ug/L	333
12/17/2020	Mercury	ug/L	ND
12/17/2020	Molybdenum	ug/L	ND
12/17/2020	Nickel	ug/L	3.24
12/17/2020	Potassium	ug/L	3870
12/17/2020	Selenium	ug/L	ND
12/17/2020	Silica	ug/L	28600
12/17/2020	Silver	ug/L	ND
12/17/2020	Sodium	ug/L	20600
12/17/2020	Thallium	ug/L	ND
12/17/2020	Uranium	ug/L	0.607
12/17/2020	Vanadium	ug/L	9.33
12/17/2020	Zinc	ug/L	ND
1/3/2022	Aluminum	ug/L	2520
1/3/2022	Antimony	ug/L	ND
1/3/2022	Arsenic	ug/L	1.92
1/3/2022	Beryllium	ug/L	0.132
1/3/2022	Cadmium	ug/L	ND
1/3/2022	Calcium	ug/L	32000
1/3/2022	Chromium	ug/L	4.33
1/3/2022	Copper	ug/L	11.6
1/3/2022	Iron	ug/L	4460

11/15/2020	Cadmium	ug/L	ND
11/15/2020	Calcium	ug/L	31200
11/15/2020	Chromium	ug/L	4.35
11/15/2020	Copper	ug/L	11.2
11/15/2020	Iron	ug/L	5370
11/15/2020	Lead	ug/L	2.94
11/15/2020	Lithium	ug/L	ND
11/15/2020	Magnesium	ug/L	10200
11/15/2020	Manganese	ug/L	860
11/15/2020	Mercury	ug/L	ND
11/15/2020	Molybdenum	ug/L	ND
11/15/2020	Nickel	ug/L	4.85
11/15/2020	Potassium	ug/L	6900
11/15/2020	Selenium	ug/L	ND
11/15/2020	Silica	ug/L	35400
11/15/2020	Silver	ug/L	ND
11/15/2020	Sodium	ug/L	18400
11/15/2020	Thallium	ug/L	ND
11/15/2020	Uranium	ug/L	0.726
11/15/2020	Vanadium	ug/L	14
11/15/2020	Zinc	ug/L	ND
12/17/2020	Aluminum	ug/L	3120
12/17/2020	Antimony	ug/L	ND
12/17/2020	Arsenic	ug/L	1.5

1/3/2022	Lead	ug/L	11.5
1/3/2022	Magnesium	ug/L	10600
1/3/2022	Mercury	ug/L	ND
1/3/2022	Nickel	ug/L	4.64
1/3/2022	Selenium	ug/L	ND
1/3/2022	Silver	ug/L	ND
1/3/2022	Thallium	ug/L	ND
1/3/2022	Zinc	ug/L	39.7
10/22/2022	Aluminum	ug/L	1340
10/22/2022	Antimony	ug/L	ND
10/22/2022	Arsenic	ug/L	1.45
10/22/2022	Beryllium	ug/L	ND
10/22/2022	Cadmium	ug/L	ND
10/22/2022	Calcium	ug/L	34900
10/22/2022	Chromium	ug/L	2.27
10/22/2022	Copper	ug/L	7.41
10/22/2022	Iron	ug/L	1810
10/22/2022	Lead	ug/L	8.84
10/22/2022	Magnesium	ug/L	11300
10/22/2022	Mercury	ug/L	ND
10/22/2022	Nickel	ug/L	2.51
10/22/2022	Selenium	ug/L	ND
10/22/2022	Silver	ug/L	ND
10/22/2022	Thallium	ug/L	ND
10/22/2022	Zinc	ug/L	21.9

Appendix B.1.5 Values for in-stream comparison of Al and Fe, Figure 14

Table 7. Aluminum and iron concentration median and interquartile range values for in-stream sites BCOS, BCJS, and BCKR.

Parameter	Site Code	Median	Lower Quantile	Upper Quantile
Aluminum	BCOS	593	226	2370
Aluminum	BCJS	851	802	3140
Aluminum	BCKR	1730	1180	3080
Iron	BCOS	1040	375	3510
Iron	BCJS	1070	1040	3480
Iron	BCKR	2070	1380	3430

Appendix B.1.6 Values for comparison of stormwater and in-stream sites

Table 8. Metal concentration values to compare in-stream sites BCOS and BCUC to stormwater sites WVV, NRT, and CR for two dates, 1/3/2022 and 10/22/2022.

Site Code	Parameter	1/3/2022	10/22/2022	Site Code	Parameter	1/3/2022	10/22/2022
WVV	Aluminum	2410	2080	WVV	Copper	10.3	13.9
NRT	Aluminum	276	3300	NRT	Copper	4.69	19.4
CR	Aluminum	632	986	CR	Copper	4.7	15.2
BCUC	Aluminum	2520	1340	BCUC	Copper	11.6	7.41
BCOS	Aluminum	593	2370	BCOS	Copper	3.52	8.39
WVV	Arsenic	1.59	1.06	WVV	Iron	2970	2180
NRT	Arsenic	0.618	1.36	NRT	Iron	299	3350
CR	Arsenic	0.6	0.943	CR	Iron	638	1140
BCUC	Arsenic	1.92	1.45	BCUC	Iron	4460	1810
BCOS	Arsenic	0.82	2.32	BCOS	Iron	1040	3510
WVV	Cadmium	0.05	0.122	WVV	Lead	5	3.57
NRT	Cadmium	0.05	0.101	NRT	Lead	0.954	7.3
CR	Cadmium	0.05	0.05	CR	Lead	0.468	1.39
BCUC	Cadmium	0.05	0.05	BCUC	Lead	11.5	8.84
BCOS	Cadmium	0.05	0.05	BCOS	Lead	3.14	18.3
WVV	Chromium	4.46	3.71	WVV	Zinc	33.4	37.2
NRT	Chromium	0.5	5.02	NRT	Zinc	23.9	107
CR	Chromium	1.4	2.58	CR	Zinc	23	75.1
BCUC	Chromium	4.33	2.27	BCUC	Zinc	39.7	21.9
BCOS	Chromium	1.14	3.02	BCOS	Zinc	16.7	23.8

Table 9. Metal concentration mean values to compare in-stream sites BCOS and BCUC to stormwater sites WVV, NRT, and CR for two dates, 1/3/2022 and 10/22/2022.

Date	Parameter	Stormwater	In-Stream
1/3/2022	Aluminum	1106	1556.5
10/22/2022	Aluminum	2122	1855
1/3/2022	Antimony	0.25	0.25
10/22/2022	Antimony	0.522	0.5135
1/3/2022	Arsenic	0.936	1.37
10/22/2022	Arsenic	1.121	1.885
1/3/2022	Beryllium	0.078	0.091
10/22/2022	Beryllium	0.05	0.05
1/3/2022	Cadmium	0.05	0.05
10/22/2022	Cadmium	0.091	0.05
1/3/2022	Calcium	21223.33	26950

10/22/2022	Calcium	11646.67	30300
1/3/2022	Chromium	2.12	2.735
10/22/2022	Chromium	3.77	2.645
1/3/2022	Copper	6.563333	7.56
10/22/2022	Copper	16.16667	7.9
1/3/2022	Iron	1302.333	2750
10/22/2022	Iron	2223.333	2660
1/3/2022	Lead	2.140667	7.32
10/22/2022	Lead	4.086667	13.57
1/3/2022	Magnesium	5720.667	9620
10/22/2022	Magnesium	2426.667	10420
1/3/2022	Mercury	0.02	0.02
10/22/2022	Mercury	0.02	0.02
1/3/2022	Nickel	2.46	3.29
10/22/2022	Nickel	4.073333	3.075
1/3/2022	Selenium	0.5	0.5
10/22/2022	Selenium	0.25	0.25
1/3/2022	Silver	0.05	0.05
10/22/2022	Silver	0.05	0.05
1/3/2022	Thallium	0.05	0.05
10/22/2022	Thallium	0.05	0.05
1/3/2022	Zinc	26.76667	28.2
10/22/2022	Zinc	73.1	22.85

Appendix B.2 RVCOG Water Quality Parameters

Appendix B.2.1 Values for all stormwater sites, Figure 15 & Figure 16

Table 10. Stormwater concentrations of water quality parameters for all dates. Analytes are in mg/L.

Date	Parameter	WV	NRT	CR
11/15/2020	Hardness	58.3	10.6	NA
11/15/2020	Nitrate-Nitrogen	0.367	ND	NA
11/15/2020	Nitrite-Nitrogen	ND	ND	NA
11/15/2020	Total Organic Carbon	10.6	5.12	NA
12/30/2020	Hardness	155	13.7	NA
12/30/2020	Total Organic Carbon	5.96	4.98	NA
3/5/2021	Hardness	69.8	30.6	NA
3/5/2021	Phosphorus	0.289	0.406	NA
3/5/2021	Total Kjeldahl Nitrogen (TKN)	1.35	1.21	NA
3/5/2021	Total Organic Carbon	14	17.9	NA
3/5/2021	Total Suspended Solids	57.6	36.4	NA

11/9/2021	Hardness	100	7.63	17.2
11/9/2021	Phosphorus	0.138	0.0563	0.166
11/9/2021	Total Kjeldahl Nitrogen (TKN)	0.313	0.232	0.235
11/9/2021	Total Organic Carbon	3.96	2.08	3.77
11/9/2021	Total Suspended Solids	10.7	69.1	10.5
1/3/2022	Hardness	169	16.3	44.2
1/3/2022	Nitrate-Nitrogen	1.62	13.2	2.83
1/3/2022	Nitrite-Nitrogen	ND	ND	ND
1/3/2022	Phosphorus	0.167	0.0648	0.0886
1/3/2022	Total Kjeldahl Nitrogen (TKN)	0.522	0.5	0.397
1/3/2022	Total Nitrogen (Calc)	1.62	13.2	2.83
1/3/2022	Total Organic Carbon	3.82	3.11	4.18
1/3/2022	Total Suspended Solids	64.4	17.4	12.4
3/15/2022	Hardness	78	11.9	20.2
3/15/2022	Nitrate-Nitrogen	0.3	0.248	0.798
3/15/2022	Nitrite-Nitrogen	ND	ND	ND
3/15/2022	Phosphorus	0.085	0.0653	0.149
3/15/2022	Total Kjeldahl Nitrogen (TKN)	0.431	0.226	0.374
3/15/2022	Total Nitrogen (Calc)	0.731	ND	1.17
3/15/2022	Total Organic Carbon	3.56	2.42	5.13
3/15/2022	Total Suspended Solids	19.9	9.12	9.57
10/22/2022	Hardness	54.7	21.1	41.2
10/22/2022	Nitrate-Nitrogen	0.26	ND	2.15
10/22/2022	Nitrite-Nitrogen	ND	ND	ND
10/22/2022	Phosphorus	0.198	0.449	0.485
10/22/2022	Total Kjeldahl Nitrogen (TKN)	0.621	1.44	1.77
10/22/2022	Total Nitrogen (Calc)	0.881	1.44	3.92
10/22/2022	Total Organic Carbon	5.75	11.8	22.1
10/22/2022	Total Suspended Solids	51.9	131	25.1
5/2/2023	Hardness	44.1	18.4	24.8
5/2/2023	Nitrate-Nitrogen	0.172	0.358	0.243
5/2/2023	Nitrite-Nitrogen	ND	ND	ND
5/2/2023	Phosphorus	0.323	0.2	0.278
5/2/2023	Total Kjeldahl Nitrogen (TKN)	1.07	2.09	1.25
5/2/2023	Total Nitrogen (Calc)	1.24	2.45	1.5
5/2/2023	Total Organic Carbon	4.79	13	12.9
5/2/2023	Total Suspended Solids	420	55	51.4

Appendix B.2.2 Values for comparison of WVV, NRT, and CR, Figure 17

Table 11. Median and interquartile range values for four parameters comparing the three stormwater sites for five dates. Analytes are in mg/L.

Parameter	Site Code	Median	Lower Quantile	Upper Quantile
Phosphorus	CR	0.166	0.149	0.278
Phosphorus	NRT	0.0653	0.0648	0.2
Phosphorus	WVV	0.167	0.138	0.198
Total Kjeldahl Nitrogen (TKN)	CR	0.397	0.374	1.25
Total Kjeldahl Nitrogen (TKN)	NRT	0.5	0.232	1.44
Total Kjeldahl Nitrogen (TKN)	WVV	0.522	0.431	0.621
Total Organic Carbon	CR	5.13	4.18	12.9
Total Organic Carbon	NRT	3.11	2.42	11.8
Total Organic Carbon	WVV	3.96	3.82	4.79
Total Suspended Solids	CR	12.4	10.5	25.1
Total Suspended Solids	NRT	55	17.4	69.1
Total Suspended Solids	WVV	51.9	19.9	64.4

Appendix B.2.3 Values for in-stream site BCUC, Figure 18

Date	Site Code	Nitrate-Nitrogen	Nitrite-Nitrogen	Hardness	Total Suspended Solids	Phosphorus	Total Kjeldahl Nitrogen (TKN)	Total Organic Carbon	Total Nitrogen (Calc)
11/4/2020	BCUC	0.975	ND	183	6	0.0767	ND	2.82	NA
11/15/2020	BCUC	0.789	ND	120	150	0.624	2.26	16.3	NA
12/17/2020	BCUC	0.744	ND	115	80	0.521	2.02	7.56	NA
1/3/2022	BCUC	0.883	ND	123	191	0.449	1.75	4.73	0.883
10/22/2022	BCUC	0.857	ND	134	26.2	0.267	1.16	6.72	2.02

Appendix B.2.4 Values for comparison of stormwater and in-stream sites

Table 12. Mean water quality analyte values by site type, stormwater or in-stream. Analytes are in mg/L.

Date	Parameter	Stormwater Mean	In-Stream Mean
1/3/2022	Hardness	76.5	106.7
1/3/2022	Nitrate-Nitrogen	5.883333	0.7655
1/3/2022	Nitrite-Nitrogen	0.0625	0.0625
1/3/2022	Total Kjeldahl Nitrogen (TKN)	0.473	1.1335
1/3/2022	Total Nitrogen (Calc)	5.883333	0.7655
1/3/2022	Total Organic Carbon	3.703333	5.495
1/3/2022	Phosphorus	0.1068	0.2885
1/3/2022	Total Suspended Solids	31.4	105.45
10/22/2022	Hardness	39	119

10/22/2022	Nitrate-Nitrogen	0.824167	0.4945
10/22/2022	Nitrite-Nitrogen	0.0625	0.0625
10/22/2022	Total Nitrogen (Calc)	2.080333	1.92
10/22/2022	Total Organic Carbon	13.21667	8.265
10/22/2022	Phosphorus	0.377333	0.295
10/22/2022	Total Suspended Solids	69.33333	75.1
10/22/2022	Total Kjeldahl Nitrogen (TKN)	1.277	1.425

Appendix B.3 RVCOG TMDL Data

Appendix B.3.1 Values for means of TMDL data by site location, Figure 19 and Figure 21

Table 13. Mean values for TMDL data grouped by location of the site, whether upstream, in, or downstream of the burn area.

Date	Site Location	pH	Temperature (°C)	Conductivity (μS/cm)	Turbidity (NTU)	Phosphorus (mg/L)	E. coli (MPN)
7/20/2011	Downstream	8.204	19.26	NA	NA	NA	NA
7/20/2011	In Burn	7.955	14.6	NA	NA	NA	NA
7/20/2011	Upstream	7.88	11.75	NA	NA	NA	NA
8/17/2011	Downstream	8.494	22.8	NA	NA	NA	NA
8/17/2011	In Burn	8.006666667	17.05	NA	NA	NA	NA
8/17/2011	Upstream	7.885	15.5	NA	NA	NA	NA
9/21/2011	Downstream	8.368	18.78	NA	NA	NA	NA
9/21/2011	In Burn	7.946666667	16.15	NA	NA	NA	NA
9/21/2011	Upstream	7.813333333	13.16666667	NA	NA	NA	NA
10/19/2011	Downstream	8.278	14.4	NA	NA	NA	NA
10/19/2011	In Burn	8.011666667	13.1	NA	NA	NA	NA
10/19/2011	Upstream	7.8	10.9	NA	NA	NA	NA
11/16/2011	Downstream	8.228	10.08	NA	NA	NA	NA
11/16/2011	In Burn	8.071666667	10.13333333	NA	NA	NA	NA
11/16/2011	Upstream	7.735	7.4	NA	NA	NA	NA
12/14/2011	Downstream	8.514	2.4	NA	NA	NA	NA
12/14/2011	In Burn	8.113333333	2.366666667	NA	NA	NA	NA
12/14/2011	Upstream	7.86	0.866666667	NA	NA	NA	NA
1/18/2012	Downstream	8.36	4.675	NA	NA	NA	NA
1/18/2012	In Burn	7.93	3.816666667	NA	NA	NA	NA
1/18/2012	Upstream	7.91	2.45	NA	NA	NA	NA
2/15/2012	Downstream	8.262	5.95	NA	NA	NA	NA
2/15/2012	In Burn	7.978333333	3.966666667	NA	NA	NA	NA
2/15/2012	Upstream	7.86	2.3	NA	NA	NA	NA
3/13/2012	Downstream	7.9025	6.275	NA	NA	NA	NA
3/13/2012	In Burn	7.831666667	4.7	NA	NA	NA	NA

3/13/2012	Upstream	7.816666667	3.3	NA	NA	NA	NA
4/25/2012	Downstream	7.96	10.75	NA	NA	NA	NA
4/25/2012	In Burn	7.776666667	9.133333333	NA	NA	NA	NA
4/25/2012	Upstream	7.875	7.35	NA	NA	NA	NA
5/30/2012	Downstream	8.512	17.78	NA	NA	NA	NA
5/30/2012	In Burn	7.921666667	12.75	NA	NA	NA	NA
5/30/2012	Upstream	7.865	9.25	NA	NA	NA	NA
6/13/2012	Downstream	8.453333333	20.93333333	NA	NA	NA	NA
6/13/2012	In Burn	8.11	15.23333333	NA	NA	NA	NA
6/13/2012	Upstream	7.926666667	10.95	NA	NA	NA	NA
7/11/2012	Downstream	8.018	19.825	NA	NA	NA	NA
7/11/2012	In Burn	7.958	18.34	NA	NA	NA	NA
7/11/2012	Upstream	7.963333333	19.45	NA	NA	NA	NA
8/15/2012	Downstream	8.2025	21.25	NA	NA	NA	NA
8/15/2012	In Burn	7.986666667	17.6	NA	NA	NA	NA
8/15/2012	Upstream	8.03	15.9	NA	NA	NA	NA
9/12/2012	Downstream	8.445	18.45	NA	NA	NA	NA
9/12/2012	In Burn	8.006666667	16	NA	NA	NA	NA
9/12/2012	Upstream	8.016666667	12.6	NA	NA	NA	NA
10/17/2012	Downstream	8.1825	13.5	NA	NA	NA	NA
10/17/2012	In Burn	7.978333333	12.4	NA	NA	NA	NA
10/17/2012	Upstream	7.97	9.3	NA	NA	NA	NA
11/6/2012	Downstream	8.315	12.225	NA	NA	NA	NA
11/6/2012	In Burn	7.895	11.25	NA	NA	NA	NA
11/6/2012	Upstream	7.876666667	9	NA	NA	NA	NA
12/27/2012	Downstream	8.65	6.55	NA	NA	NA	NA
12/27/2012	In Burn	8.396666667	4.966666667	NA	NA	NA	NA
12/27/2012	Upstream	8.186666667	3.3	NA	NA	NA	NA
1/8/2013	Downstream	8.0975	6.8	NA	NA	NA	NA
1/8/2013	In Burn	7.605714286	5.383333333	NA	NA	NA	NA
1/8/2013	Upstream	7.645	3.4	NA	NA	NA	NA
2/26/2013	Downstream	8.43	6.9	NA	NA	NA	NA
2/26/2013	In Burn	8.476666667	4.066666667	NA	NA	NA	NA
2/26/2013	Upstream	8.01	2.8	NA	NA	NA	NA
3/6/2013	Downstream	8.803333333	7.74	NA	NA	NA	NA
3/6/2013	In Burn	8.503333333	4.1	NA	NA	NA	NA
3/6/2013	Upstream	8.015	2.65	NA	NA	NA	NA
4/24/2013	Downstream	8.4025	12.425	NA	NA	NA	NA
4/24/2013	In Burn	7.948333333	8.5	NA	NA	NA	NA
4/24/2013	Upstream	7.95	6.6	NA	NA	NA	NA
5/1/2013	Downstream	8.354	14.2	NA	NA	NA	NA

5/1/2013	In Burn	7.953333333	9.983333333	NA	NA	NA	NA
5/1/2013	Upstream	8.02	5.85	NA	NA	NA	NA
6/12/2013	Downstream	8.505	17.2	NA	NA	NA	NA
6/12/2013	In Burn	7.947142857	12.46666667	NA	NA	NA	NA
6/12/2013	Upstream	8.016666667	11.65	NA	NA	NA	NA
7/17/2013	Downstream	8.528	23.24	NA	NA	NA	NA
7/17/2013	In Burn	7.903333333	16.13333333	NA	NA	NA	NA
7/17/2013	Upstream	7.835	15.7	NA	NA	NA	NA
8/14/2013	Downstream	8.545	22.05	NA	NA	NA	NA
8/14/2013	In Burn	7.961666667	18.65	NA	NA	NA	NA
8/14/2013	Upstream	7.87	16.55	NA	NA	NA	NA
9/16/2013	Downstream	8.4625	20.25	NA	NA	NA	NA
9/16/2013	In Burn	7.918333333	17.7	NA	NA	NA	NA
9/16/2013	Upstream	7.863333333	14.9	NA	NA	NA	NA
10/23/2013	Downstream	8.2675	12.05	NA	NA	NA	NA
10/23/2013	In Burn	7.83	10.36666667	NA	NA	NA	NA
10/23/2013	Upstream	7.7	8.65	NA	NA	NA	NA
11/27/2013	Downstream	8.4275	5.375	NA	NA	NA	NA
11/27/2013	In Burn	7.868333333	4.816666667	NA	NA	NA	NA
11/27/2013	Upstream	7.826666667	4.4	NA	NA	NA	NA
12/4/2013	Downstream	8.394	3.625	NA	NA	NA	NA
12/4/2013	In Burn	7.868333333	3.216666667	NA	NA	NA	NA
12/4/2013	Upstream	7.765	1.75	NA	NA	NA	NA
1/14/2014	Downstream	8.525	6.85	NA	NA	NA	NA
1/14/2014	In Burn	8.198571429	5.6	NA	NA	NA	NA
1/14/2014	Upstream	7.946666667	3.4	NA	NA	NA	NA
2/4/2014	Downstream	8.82	6.05	NA	NA	NA	NA
2/4/2014	In Burn	8.202857143	4.65	NA	NA	NA	NA
2/4/2014	Upstream	8.036666667	2.9	NA	NA	NA	NA
3/19/2014	Downstream	8.222	10.76	NA	NA	NA	NA
3/19/2014	In Burn	7.933333333	6.416666667	NA	NA	NA	NA
3/19/2014	Upstream	7.836666667	4.5	NA	NA	NA	NA
4/2/2014	Downstream	8.5825	11.9	NA	NA	NA	NA
4/2/2014	In Burn	8.003333333	7.466666667	NA	NA	NA	NA
4/2/2014	Upstream	7.903333333	5.65	NA	NA	NA	NA
5/28/2014	Downstream	8.38	18.7	NA	NA	NA	NA
5/28/2014	In Burn	7.994	15.36	NA	NA	NA	NA
5/28/2014	Upstream	7.883333333	11.5	NA	NA	NA	NA
6/11/2014	Downstream	8.4525	22.35	NA	NA	NA	NA
6/11/2014	In Burn	7.874	15.58	NA	NA	NA	NA
6/11/2014	Upstream	7.806666667	13.25	NA	NA	NA	NA

7/24/2014	Downstream	8.026	21.025	NA	NA	NA	NA
7/24/2014	In Burn	7.338571429	17	NA	NA	NA	NA
7/24/2014	Upstream	7.595	15	NA	NA	NA	NA
8/20/2014	Downstream	8.585	24.45	NA	NA	NA	NA
8/20/2014	In Burn	7.9225	19.56666667	NA	NA	NA	NA
8/20/2014	Upstream	7.83	18.8	NA	NA	NA	NA
9/24/2014	Downstream	7.8525	18.225	NA	NA	NA	NA
9/24/2014	In Burn	8.00375	17.8	NA	NA	NA	NA
9/24/2014	Upstream	7.75	15.7	NA	NA	NA	NA
10/21/2014	Downstream	8.2725	14.3	NA	NA	NA	NA
10/21/2014	In Burn	7.901428571	13.45714286	NA	NA	NA	NA
10/21/2014	Upstream	7.746666667	10.66666667	NA	NA	NA	NA
11/20/2014	Downstream	8.42	9.95	NA	NA	NA	NA
11/20/2014	In Burn	7.985	9.416666667	NA	NA	NA	NA
11/20/2014	Upstream	7.7125	7.3	NA	NA	NA	NA
12/30/2014	Downstream	8.0425	4.9	NA	NA	NA	NA
12/30/2014	In Burn	7.797142857	3.666666667	NA	NA	NA	NA
12/30/2014	Upstream	7.635	2.25	NA	NA	NA	NA
1/22/2015	Downstream	8.19	6.775	NA	NA	NA	NA
1/22/2015	In Burn	7.765	6.016666667	NA	NA	NA	NA
1/22/2015	Upstream	7.42	4.4	NA	NA	NA	NA
2/10/2015	Downstream	7.8075	8.05	NA	NA	NA	NA
2/10/2015	In Burn	7.561666667	7.033333333	NA	NA	NA	NA
2/10/2015	Upstream	7.36	5.433333333	NA	NA	NA	NA
3/23/2015	Downstream	8.5925	11.025	NA	NA	NA	NA
3/23/2015	In Burn	8.341666667	9.75	NA	NA	NA	NA
3/23/2015	Upstream	7.615	7.275	NA	NA	NA	NA
4/29/2015	Downstream	8.0325	18.05	NA	NA	NA	NA
4/29/2015	In Burn	7.763333333	15.5	NA	NA	NA	NA
4/29/2015	Upstream	7.21	11.25	NA	NA	NA	NA
5/19/2015	Downstream	8.07	18.45	NA	NA	NA	NA
5/19/2015	In Burn	7.565	15.31666667	NA	NA	NA	NA
5/19/2015	Upstream	7.3175	12.43333333	NA	NA	NA	NA
6/18/2015	Downstream	8.1225	23.75	NA	NA	NA	NA
6/18/2015	In Burn	7.355714286	17.9	NA	NA	NA	NA
6/18/2015	Upstream	7.073333333	14.8	NA	NA	NA	NA
7/7/2015	Downstream	8.25	26.925	NA	NA	NA	NA
7/7/2015	In Burn	7.565	21.28571429	NA	NA	NA	NA
7/7/2015	Upstream	7.34	19.25	NA	NA	NA	NA
8/5/2015	Downstream	8.2375	23.925	NA	NA	NA	NA
8/5/2015	In Burn	7.46	21.28333333	NA	NA	NA	NA

8/5/2015	Upstream	7.36	18.3	NA	NA	NA	NA
9/29/2015	Downstream	8.1825	18.175	NA	NA	NA	NA
9/29/2015	In Burn	7.585	17.76666667	NA	NA	NA	NA
9/29/2015	Upstream	7.43	14.7	NA	NA	NA	NA
10/20/2015	Downstream	8.0575	15.825	NA	NA	NA	NA
10/20/2015	In Burn	7.662857143	15.08571429	NA	NA	NA	NA
10/20/2015	Upstream	7.536666667	12.4	NA	NA	NA	NA
11/18/2015	Downstream	7.895	10.325	NA	NA	NA	NA
11/18/2015	In Burn	7.46875	9.314285714	NA	NA	NA	NA
11/18/2015	Upstream	7.325	7.85	NA	NA	NA	NA
12/15/2015	Downstream	7.7175	6.7	NA	NA	NA	NA
12/15/2015	In Burn	7.435	5.633333333	NA	NA	NA	NA
12/15/2015	Upstream	7.375	4.55	NA	NA	NA	NA
1/28/2016	Downstream	7.445	8.875	NA	NA	NA	NA
1/28/2016	In Burn	7.20875	7.033333333	NA	NA	NA	NA
1/28/2016	Upstream	7.075	6.05	NA	NA	NA	NA
2/11/2016	Downstream	7.805	9.6	NA	NA	NA	NA
2/11/2016	In Burn	7.361666667	7.183333333	NA	NA	NA	NA
2/11/2016	Upstream	7.125	6.4	NA	NA	NA	NA
3/31/2016	Downstream	8.275	11.325	NA	NA	NA	NA
3/31/2016	In Burn	7.598571429	7.15	NA	NA	NA	NA
3/31/2016	Upstream	7.365	6.9	NA	NA	NA	NA
4/13/2016	Downstream	8.3625	13.4	NA	NA	NA	NA
4/13/2016	In Burn	7.678571429	10.26666667	NA	NA	NA	NA
4/13/2016	Upstream	7.39	8.7	NA	NA	NA	NA
5/25/2016	Downstream	8.334	19.175	NA	NA	NA	NA
5/25/2016	In Burn	7.941666667	13.23333333	NA	NA	NA	NA
5/25/2016	Upstream	7.555	12.05	NA	NA	NA	NA
6/15/2016	Downstream	8.57	17.3	NA	NA	NA	NA
6/15/2016	In Burn	7.905	12.96666667	NA	NA	NA	NA
6/15/2016	Upstream	7.775	12.3	NA	NA	NA	NA
7/26/2016	Downstream	8.634	24.45	NA	NA	NA	NA
7/26/2016	In Burn	7.913333333	17.76666667	NA	NA	NA	NA
7/26/2016	Upstream	7.795	17.75	NA	NA	NA	NA
8/24/2016	Downstream	8.622	20.225	NA	NA	NA	NA
8/24/2016	In Burn	7.883333333	16.71666667	NA	NA	NA	NA
8/24/2016	Upstream	7.75	15.8	NA	NA	NA	NA
9/30/2016	Downstream	8.4925	16.025	NA	NA	NA	NA
9/30/2016	In Burn	7.965	14.3	NA	NA	NA	NA
9/30/2016	Upstream	7.83	12.85	NA	NA	NA	NA
10/19/2016	Downstream	8.156	11.84	NA	NA	NA	NA

10/19/2016	In Burn	7.896666667	9.866666667	NA	NA	NA	NA
10/19/2016	Upstream	7.775	9.2	NA	NA	NA	NA
11/30/2016	Downstream	8.542	8.55	NA	NA	NA	NA
11/30/2016	In Burn	7.915	6.983333333	NA	NA	NA	NA
11/30/2016	Upstream	7.78	5.7	NA	NA	NA	NA
12/28/2016	Downstream	8.078	5.25	NA	NA	NA	NA
12/28/2016	In Burn	7.811666667	3.566666667	NA	NA	NA	NA
12/28/2016	Upstream	7.61	3.25	NA	NA	NA	NA
1/19/2017	Downstream	7.872	5.425	NA	NA	NA	NA
1/19/2017	In Burn	7.815	4.383333333	NA	NA	NA	NA
1/19/2017	Upstream	7.675	5	NA	NA	NA	NA
2/28/2017	Downstream	7.993333333	6.066666667	NA	NA	NA	NA
2/28/2017	In Burn	7.818333333	4.966666667	NA	NA	NA	NA
2/28/2017	Upstream	7.78	4.75	NA	NA	NA	NA
3/30/2017	Downstream	8.033333333	8.333333333	NA	NA	NA	NA
3/30/2017	In Burn	7.871666667	6.85	NA	NA	NA	NA
3/30/2017	Upstream	7.725	5.75	NA	NA	NA	NA
4/28/2017	Downstream	8.32	10.76	NA	NA	NA	NA
4/28/2017	In Burn	7.871666667	7.583333333	NA	NA	NA	NA
4/28/2017	Upstream	7.75	5.75	NA	NA	NA	NA
5/24/2017	Downstream	8.202	16.82	NA	NA	NA	NA
5/24/2017	In Burn	7.841666667	12.56666667	NA	NA	NA	NA
5/24/2017	Upstream	7.875	10.7	NA	NA	NA	NA
6/21/2017	Downstream	8.574	20.1	NA	NA	NA	NA
6/21/2017	In Burn	7.893333333	15.71666667	NA	NA	NA	NA
6/21/2017	Upstream	7.83	13.8	NA	NA	NA	NA
7/24/2017	Downstream	8.2	23.05	NA	NA	NA	NA
7/24/2017	In Burn	7.918333333	17.65	NA	NA	NA	NA
7/24/2017	Upstream	7.735	17.9	NA	NA	NA	NA
8/30/2017	Downstream	8.3875	20.325	NA	NA	NA	NA
8/30/2017	In Burn	7.93	17.95	NA	NA	NA	NA
8/30/2017	Upstream	7.715	16.95	NA	NA	NA	NA
9/27/2017	Downstream	8.416666667	18.06666667	NA	NA	NA	NA
9/27/2017	In Burn	7.898333333	15.25	NA	NA	NA	NA
9/27/2017	Upstream	7.68	6.822569444	NA	NA	NA	NA
10/30/2017	Downstream	8.388	13.48	NA	NA	NA	NA
10/30/2017	In Burn	7.896666667	12.06666667	NA	NA	NA	NA
10/30/2017	Upstream	7.66	10.45	NA	NA	NA	NA
11/29/2017	Downstream	8.372	9.5	NA	NA	NA	NA
11/29/2017	In Burn	7.876666667	7.666666667	NA	NA	NA	NA
11/29/2017	Upstream	7.87	7.15	NA	NA	NA	NA

12/27/2017	Downstream	8.4925	7.166666667	NA	NA	NA	NA
12/27/2017	In Burn	8.095	5.083333333	NA	NA	NA	NA
12/27/2017	Upstream	7.845	4.2	NA	NA	NA	NA
1/30/2018	Downstream	8.372	8.88	NA	NA	NA	NA
1/30/2018	In Burn	7.927142857	7.214285714	NA	NA	NA	NA
1/30/2018	Upstream	7.94	5.25	NA	NA	NA	NA
2/27/2018	Downstream	8.48	5.88	NA	NA	NA	NA
2/27/2018	In Burn	8.024285714	4.642857143	NA	NA	NA	NA
2/27/2018	Upstream	7.87	3.15	NA	NA	NA	NA
3/20/2018	Downstream	8.37	9.64	NA	NA	NA	NA
3/20/2018	In Burn	7.861428571	7.7	NA	NA	NA	NA
3/20/2018	Upstream	7.775	5.75	NA	NA	NA	NA
4/25/2018	Downstream	8.48	17.56	NA	NA	NA	NA
4/25/2018	In Burn	7.975714286	13.14285714	NA	NA	NA	NA
4/25/2018	Upstream	7.81	12.25	NA	NA	NA	NA
5/30/2018	Downstream	8.534	20.3	NA	NA	NA	NA
5/30/2018	In Burn	7.974285714	15.38333333	NA	NA	NA	NA
5/30/2018	Upstream	7.795	14.55	NA	NA	NA	NA
6/20/2018	Downstream	8.544	22.86	NA	NA	NA	NA
6/20/2018	In Burn	8.041428571	17.62857143	NA	NA	NA	NA
6/20/2018	Upstream	8.055	18	NA	NA	NA	NA
7/24/2018	Downstream	8.8125	25.375	NA	NA	NA	NA
7/24/2018	In Burn	7.92	20.16666667	NA	NA	NA	NA
7/24/2018	Upstream	7.695	20.3	NA	NA	NA	NA
8/29/2018	Downstream	8.6725	21.6	NA	NA	NA	NA
8/29/2018	In Burn	7.916666667	17.83333333	NA	NA	NA	NA
8/29/2018	Upstream	7.765	18.45	NA	NA	NA	NA
9/24/2018	Downstream	8.5125	15.65	NA	NA	NA	NA
9/24/2018	In Burn	7.99	13.41666667	NA	NA	NA	NA
9/24/2018	Upstream	7.89	12.1	NA	NA	NA	NA
10/22/2018	Downstream	8.43	12.46666667	NA	NA	NA	NA
10/22/2018	In Burn	7.79875	11.21428571	NA	NA	NA	NA
10/22/2018	Upstream	7.7	10.75	NA	NA	NA	NA
11/19/2018	Downstream	8.4475	6.85	NA	NA	NA	NA
11/19/2018	In Burn	7.94125	6.314285714	NA	NA	NA	NA
11/19/2018	Upstream	7.655	6.7	NA	NA	NA	NA
12/19/2018	Downstream	8.25	8.82	NA	NA	NA	NA
12/19/2018	In Burn	7.973333333	7.166666667	NA	NA	NA	NA
12/19/2018	Upstream	7.82	5.3	NA	NA	NA	NA
7/16/2019	Downstream	8.98	24.55	265.225	12.785	0.11025	429.575
7/16/2019	In Burn	7.983333333	18.2	188.2166667	9.92	0.086	211.5666667

7/16/2019	Upstream	7.95	17.75	88.55	2.105	0.0725	126.1
8/13/2019	Downstream	8.54	22.175	237.125	12.43	0.11075	370.775
8/13/2019	In Burn	7.906666667	18.25	190.4833333	8.688333333	0.092166667	550.0333333
8/13/2019	Upstream	7.83	17.45	103.65	1.37	0.072	413.25
9/11/2019	Downstream	8.49	20	224.65	10.6375	0.08225	397.8
9/11/2019	In Burn	7.908333333	18.03333333	205.8833333	5.058333333	0.077833333	242.7833333
9/11/2019	Upstream	7.61	16.4	105.05	1.835	0.0575	162.45
10/30/2019	Downstream	8.4275	7.45	277.525	3.1475	0.04525	190.575
10/30/2019	In Burn	7.895	5.7	220.9333333	2.268333333	0.087666667	201.9333333
10/30/2019	Upstream	7.78	5.8	82.7	0.525	0.094	18.25
11/20/2019	Downstream	8.45	9.55	291.825	4.425	NA	1275.575
11/20/2019	In Burn	7.9	8.866666667	251.8333333	2.638333333	NA	1569.533333
11/20/2019	Upstream	7.835	7.3	87.2	0.65	NA	102.8
12/18/2019	Downstream	8.26	6.325	243.25	3.6325	NA	255.175
12/18/2019	In Burn	8.033333333	5.2	187.5666667	2.743333333	NA	127.75
12/18/2019	Upstream	7.81	3.95	70.9	0	NA	27.85
1/22/2020	Downstream	8.12	6.925	223.45	14.8875	NA	281.55
1/22/2020	In Burn	7.963333333	5.616666667	160.8333333	17.315	NA	199.0166667
1/22/2020	Upstream	7.9	4.55	85.1	0.395	NA	1
2/12/2020	Downstream	8.28	6.675	220.15	5.665	NA	60
2/12/2020	In Burn	8.058333333	4.4	149.5666667	3.868333333	NA	62.85
2/12/2020	Upstream	7.79	3.75	68.55	0.2	NA	18.25
3/11/2020	Downstream	8.1975	7.55	227.225	3.325	NA	173.6
3/11/2020	In Burn	8.556666667	8.916666667	177.3666667	1.601666667	NA	47.51666667
3/11/2020	Upstream	7.805	5.1	70.55	0.215	NA	12.1
4/8/2020	Downstream	8.165	11.025	231.025	4.4	NA	314.5
4/8/2020	In Burn	8.448	13.16	196.94	2.69	NA	46.02
4/8/2020	Upstream	7.945	8.5	78.6	0.44	NA	194.65
5/19/2020	Downstream	7.9025	12.775	167.8	28.3225	0.1415	866.425
5/19/2020	In Burn	7.8	12.48	135.24	10.22	0.1264	281.08
5/19/2020	Upstream	7.53	10.7	81.25	4.455	0.0535	310.75
6/16/2020	Downstream	8.0975	14.575	198.85	17.2475	0.10875	698.65
6/16/2020	In Burn	7.97	15.08	162.34	9.18	0.0852	416.62
6/16/2020	Upstream	7.915	12.35	86.9	3.82	0.0485	179.4
7/9/2020	Downstream	8.1	18.1	247.3	15.63	0.12875	615.475
7/9/2020	In Burn	8.03	19.55	195.9833333	7.326666667	0.0805	147.7333333
7/9/2020	Upstream	7.72	15.25	108.1	1.905	0.0615	276.35
8/13/2020	Downstream	7.9775	18.85	233.85	9.8175	0.10225	379.175
8/13/2020	In Burn	8.316666667	21.16666667	187.8333333	6.611666667	0.073	307.1
8/13/2020	Upstream	7.745	17	102.2	3.765	0.071	229.25
9/15/2020	Downstream	8.255	17.15	219	12.23	NA	NA

9/24/2020	Downstream	8.305	17.4	339.65	7.69	0.098	NA
9/29/2020	Downstream	8.235	15.6	371.6	4.745	0.1015	1059.575
9/29/2020	In Burn	8.01	19.35555556	370.6777778	0.983333333	0.099444444	186.7
9/29/2020	Upstream	7.81	15.1	173.6	23.05	0.1395	106.6
10/14/2020	Downstream	8.27	14.85	373.4	7.6725	0.1275	NA
10/14/2020	In Burn	7.886666667	16.63333333	376	3.34	0.115666667	NA
10/29/2020	Downstream	8.0175	8.225	310.025	6.6825	0.08525	1174.2
10/29/2020	In Burn	7.682	11.58	312.94	3.42	0.118	104.8
10/29/2020	Upstream	7.19	8.15	122.7	0.39	0.0725	236
11/16/2020	In Burn	NA	11.26666667	240.5333333	3.666666667	NA	NA
11/18/2020	In Burn	7.44	10.25	254.3	6.765	0.1225	NA
11/24/2020	Downstream	7.576666667	8	293.9333333	5.546666667	NA	514.1333333
11/24/2020	In Burn	7.425	8.933333333	268.5166667	2.096666667	NA	94.26666667
11/24/2020	Upstream	7.08	6	84.7	0.2	NA	20.05
12/17/2020	Downstream	7.73	7.633333333	198.8	38.13333333	NA	NA
12/17/2020	In Burn	7.48	7.866666667	NA	8.8	NA	NA
12/23/2020	Downstream	7.9325	4.775	230.775	4.76	NA	265.2
12/23/2020	In Burn	7.944	5	174.88	3.364	NA	60.56
12/23/2020	Upstream	7.695	3.4	75.25	0.03	NA	16.5
1/20/2021	Downstream	8.0025	4.5	242.5	3.6375	NA	213.6
1/20/2021	In Burn	8.221666667	5.166666667	181.7833333	1.433333333	NA	39.08333333
1/20/2021	Upstream	7.585	3.25	74.95	0.405	NA	37.3
2/25/2021	Downstream	8.155	5.85	216.175	5.8625	NA	179.425
2/25/2021	In Burn	8.34	7.066666667	162.3333333	3.751666667	NA	46.88333333
2/25/2021	Upstream	7.755	4.65	82.05	0.225	NA	25.7
3/10/2021	Downstream	8.3575	9.875	217.55	9.045	NA	89.15
3/10/2021	In Burn	7.748333333	7.416666667	155.3333333	7.531666667	NA	95.58333333
3/10/2021	Upstream	7.685	6.05	88	0.38	NA	32.2
3/25/2021	Downstream	8.3575	9.875	217.55	9.045	NA	89.15
3/25/2021	In Burn	7.748333333	7.416666667	155.3333333	7.531666667	NA	95.58333333
4/21/2021	Downstream	8.55	15.66666667	272.6	11.18666667	NA	145.2666667
4/21/2021	In Burn	8.05	12.13333333	215.7333333	4.233333333	NA	137.25
4/21/2021	Upstream	7.835	10.05	90.05	1.12	NA	124.65
5/27/2021	Downstream	8.155	17.55	293.35	11.1825	0.13525	310.175
5/27/2021	In Burn	7.758333333	13.71666667	169.3333333	18.92333333	0.12	407.9166667
5/27/2021	Upstream	7.82	11.85	121	14.275	0.1285	260.65
6/29/2021	Downstream	7.835	22.375	350.125	10.4075	0.2225	706.4333333
6/29/2021	In Burn	8.266666667	22.61666667	199.5666667	13.045	0.116333333	336.2666667
6/29/2021	Upstream	7.495	17.5	170.5	17.695	0.333	404.5
7/20/2021	Downstream	8.09	20.5	324.75	12.14	0.11825	814.125
7/20/2021	In Burn	8.601666667	23.08333333	254.4	9.043333333	0.121166667	236.0166667

7/20/2021	Upstream	8	16.95	144.5	6.81	0.133	198
8/19/2021	Downstream	8.2125	17.575	379.225	6.2025	0.11075	796.75
8/19/2021	In Burn	8.21	20.01666667	376.4333333	7.343333333	0.1935	147.7833333
8/19/2021	Upstream	7.86	16.2	81.2	0.6	0.044	14.4
9/30/2021	Downstream	8.4925	16.075	368.625	5.8075	0.09275	843.375
9/30/2021	In Burn	7.992	14.16	329.94	9.186	0.1758	258.16
9/30/2021	Upstream	7.95	11.9	85.6	0	0.056	4.1
10/20/2021	Downstream	7.995	12.025	208.775	23.5325	0.1795	2419.2
10/20/2021	In Burn	7.941666667	11.4	261.4833333	8.861666667	0.118333333	550.65
10/20/2021	Upstream	7.745	9.75	105.95	2.295	0.0695	133
11/17/2021	Downstream	8.355	8.625	246.6	3.6425	NA	604.525
11/17/2021	In Burn	8.022	7.72	198	2.88	NA	200.7
11/17/2021	Upstream	7.7	6.9	88.4	0.335	NA	24.85
12/1/2021	Downstream	8.27	8.933333333	234.5	2.973333333	NA	533.3333333
12/1/2021	In Burn	7.888	8.54	210.28	9.67	NA	242.8
12/1/2021	Upstream	7.7	6.6	86.45	0.295	NA	28.25
1/31/2022	Downstream	8.66	7	237.85	2.6225	NA	101.7
1/31/2022	In Burn	8.016666667	5.216666667	196.8333333	1.91	NA	102.65
1/31/2022	Upstream	7.81	4.45	79	0.07	NA	21.9
2/24/2022	Downstream	8.5725	6.05	247.325	2.025	NA	14.8
2/24/2022	In Burn	7.96	3.9	219.3666667	6.546666667	NA	130.9833333
2/24/2022	Upstream	7.71	3.05	75.8	1.45	NA	18.95
3/17/2022	Downstream	8.6075	11.575	230.15	4.585	NA	99.675
3/17/2022	In Burn	7.868333333	7.95	167.7166667	4.371666667	NA	67.8
3/17/2022	Upstream	7.715	6.85	74.7	1.675	NA	8.2
4/27/2022	Downstream	8.403333333	14.3	222.5	14.62333333	NA	56.33333333
4/27/2022	In Burn	7.524	10.38	154.14	8.808	NA	69.46
4/27/2022	Upstream	7.12	7.9	56.9	0.68	NA	4.1
5/26/2022	Downstream	8.726666667	22.56666667	391.0666667	5.643333333	0.129	99.6
5/26/2022	In Burn	7.551666667	16.53333333	268.25	12.54666667	0.173833333	505.4666667
5/26/2022	Upstream	7.025	12.85	109	0.925	0.0685	138.75
6/29/2022	Downstream	8.275	24.25	360.775	15.505	0.23775	201.4
6/29/2022	In Burn	7.632	18.26	254.68	28.768	0.1896	322.18
6/29/2022	Upstream	7.315	15.7	162.95	9.585	0.148	508.4
7/28/2022	Downstream	8.166666667	26.7	326.8333333	21.04	0.207666667	886.1666667
7/28/2022	In Burn	7.425	20.88333333	210.3333333	11.335	0.132	128.1666667
7/28/2022	Upstream	7.065	16.95	127.85	5.55	0.1135	620.3
8/18/2022	Downstream	7.84	22.675	323.65	25.7925	NA	458.65
8/18/2022	In Burn	7.4	20.98	254.3	13.592	NA	349.08
8/18/2022	Upstream	7.105	19.25	120.5	5.41	NA	322.55
9/22/2022	Downstream	8.155	19.6	363.1	10.3525	NA	567.6

9/22/2022	In Burn	7.412	17.18	323.9	9.81	NA	214.18
9/22/2022	Upstream	7.265	15	202.05	4.405	NA	122.65
10/20/2022	Downstream	7.88	14.36666667	348.2666667	33.43333333	NA	885.5
10/20/2022	In Burn	7.382	13.04	289.66	8.432	NA	281.74
10/20/2022	Upstream	7	12.3	78.1	2.06	NA	37.9
11/22/2022	Downstream	8.3325	5.625	264.475	5.355	NA	123.675
11/22/2022	In Burn	7.935	5.6	227.45	7.65	NA	160.35
11/22/2022	Upstream	7.68	4.8	82.25	2.4	NA	18.7
12/22/2022	Downstream	8.4075	6.1	245.875	6.01	NA	223.75
12/22/2022	In Burn	7.955	5.66666667	215.9333333	4.991666667	NA	78.58333333
12/22/2022	Upstream	7.75	4.1	76.45	2.395	NA	194.15
1/26/2023	Downstream	8.2275	5.25	219.075	1.12	NA	72.225
1/26/2023	In Burn	7.945	3.46666667	167.6166667	0.233333333	NA	286.7666667
1/26/2023	Upstream	7.69	3.35	86.25	0	NA	15.5
2/23/2023	Downstream	8.99	4.8	204.1	3.325	NA	26.4
2/23/2023	In Burn	8.658333333	3.783333333	167.5	4.581666667	NA	59.25
2/23/2023	Upstream	8.155	3.2	90.3	1.765	NA	31.6
3/30/2023	Downstream	8.305	7.8	193	6.3575	NA	66.8
3/30/2023	In Burn	8.158333333	4.95	144.6	6.038333333	NA	65.65
3/30/2023	Upstream	7.765	4.65	90.15	2.875	NA	12.2
4/20/2023	Downstream	8.4475	8.6	153.775	5.7875	NA	30.725
4/20/2023	In Burn	8.095	6.183333333	111.6833333	4.865	NA	41.75
4/20/2023	Upstream	7.81	6	70.1	2.79	NA	21
5/25/2023	Downstream	7.9825	17.3	155.75	26.6	0.14375	392.25
5/25/2023	In Burn	7.685	11.58333333	76.36666667	8.351666667	0.073166667	94.96666667
5/25/2023	Upstream	7.615	10.4	47.45	4.88	0.048	117.15
6/15/2023	Downstream	8.206666667	20.33333333	246.1666667	23.76666667	0.197666667	344.75
6/15/2023	In Burn	7.746666667	14.28333333	124.7666667	13.33833333	0.1215	181.4833333
6/15/2023	Upstream	7.545	13	66.15	3.89	0.049	36

Appendix C. Scatterplots

Appendix C.1 Scatterplots of Metals at All Sites

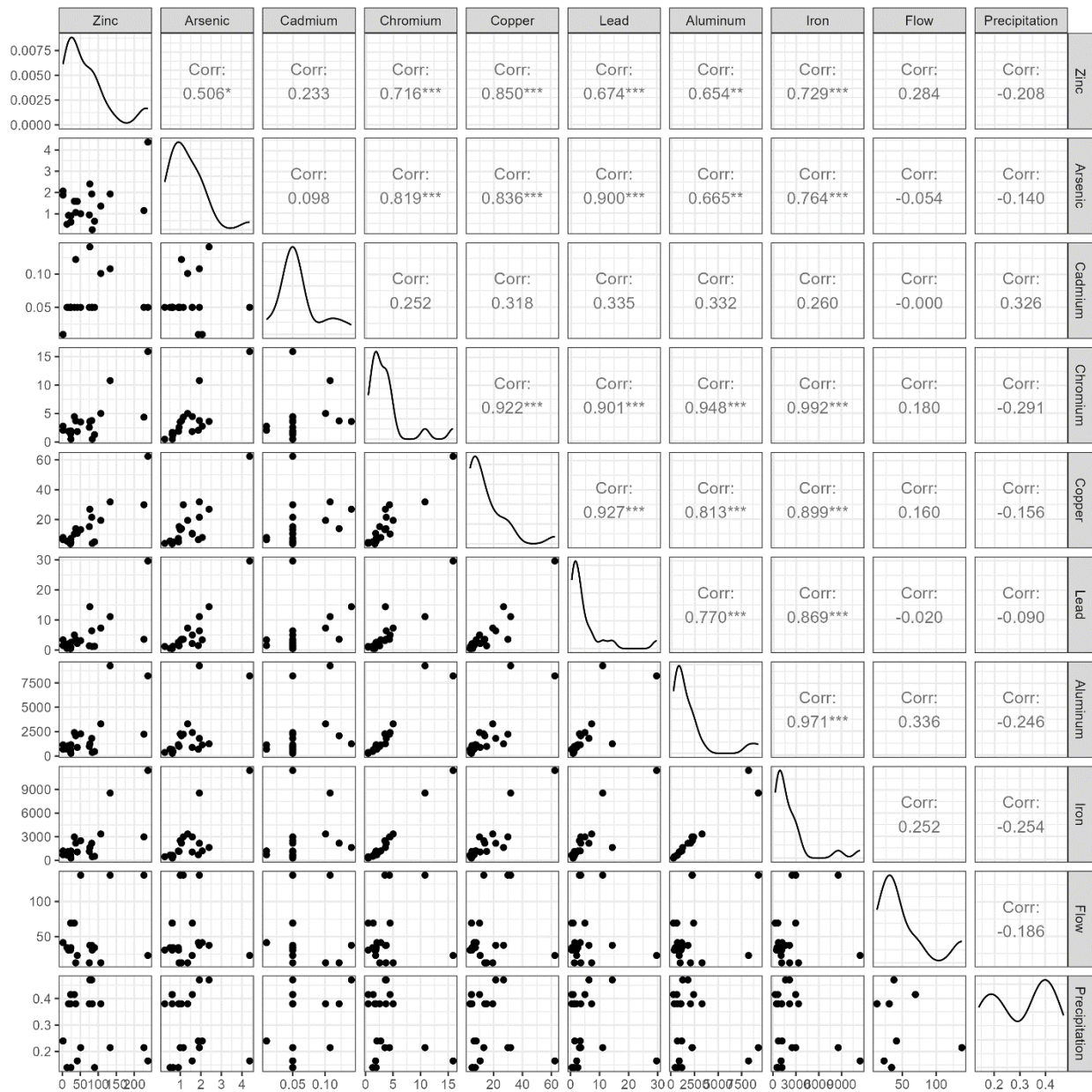


Figure 26. Scatterplot of stormwater and in-stream metals, including a comparison to flow and precipitation two day rolling mean. The correlation values on the righthand side of the figure are Pearson Correlation values, which describes the relationship between two variables in a linear model. This value assumes the relationship between two variables is linear. A Pearson Correlation value greater than 0.7 is generally considered strong and marked in this figure with three asterisks. Both stormwater and in-stream sites were included in this comparison.

Appendix C.2 Scatterplots of Water Quality Parameters at All Sites

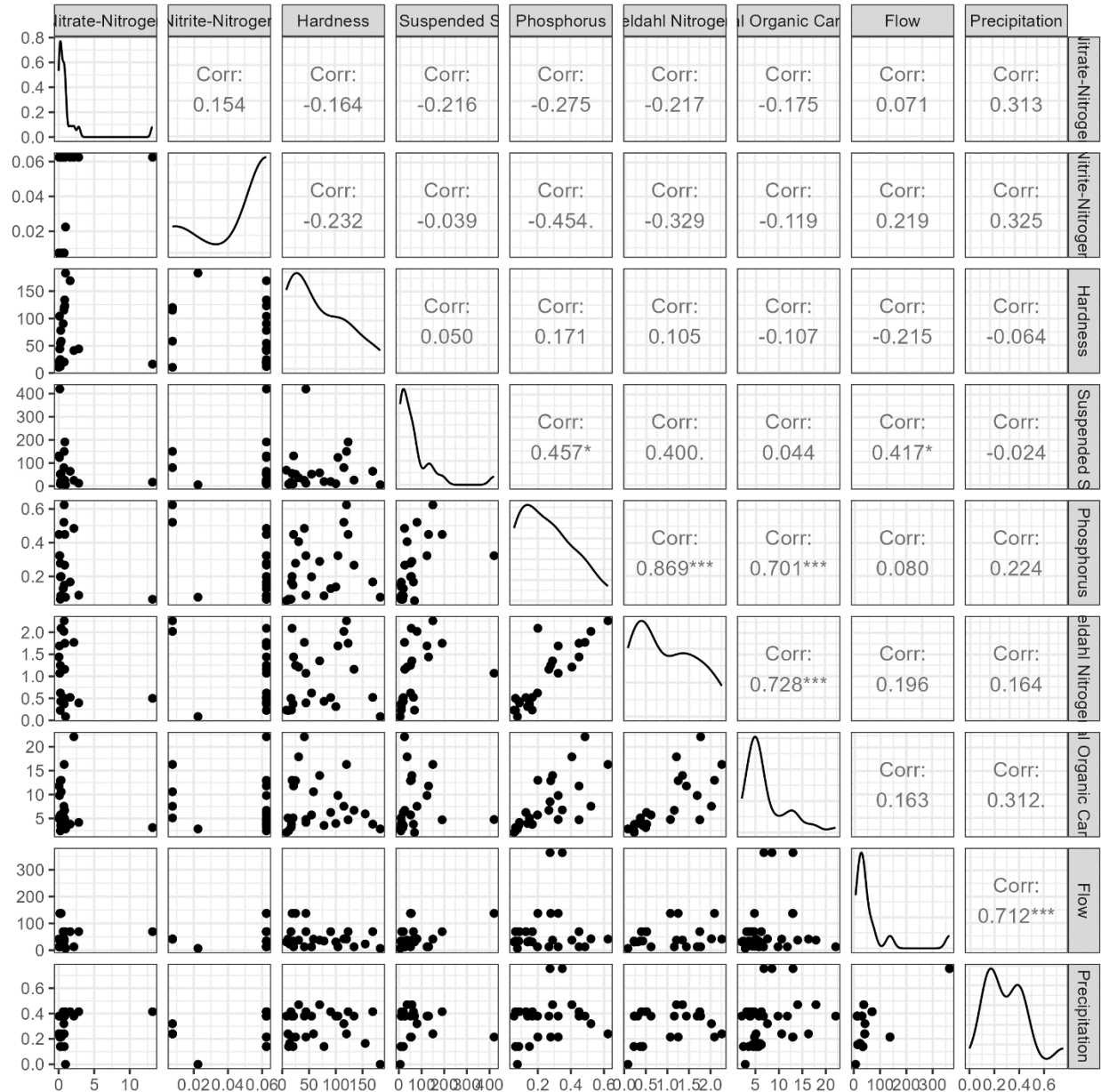


Figure 27. Scatterplot of stormwater and in-stream water quality parameters, including a comparison to flow and precipitation two day rolling mean. The correlation values on the righthand side of the figure are Pearson Correlation values, which describes the relationship between two variables in a linear model. This value assumes the relationship between two variables is linear. A Pearson Correlation value greater than 0.7 is generally considered strong and marked in this figure with three asterisks. Both stormwater and in-stream sites were included in this comparison.

Appendix C.3 Scatterplots of Water Quality Parameters Compared to Aluminum and Iron at All Sites

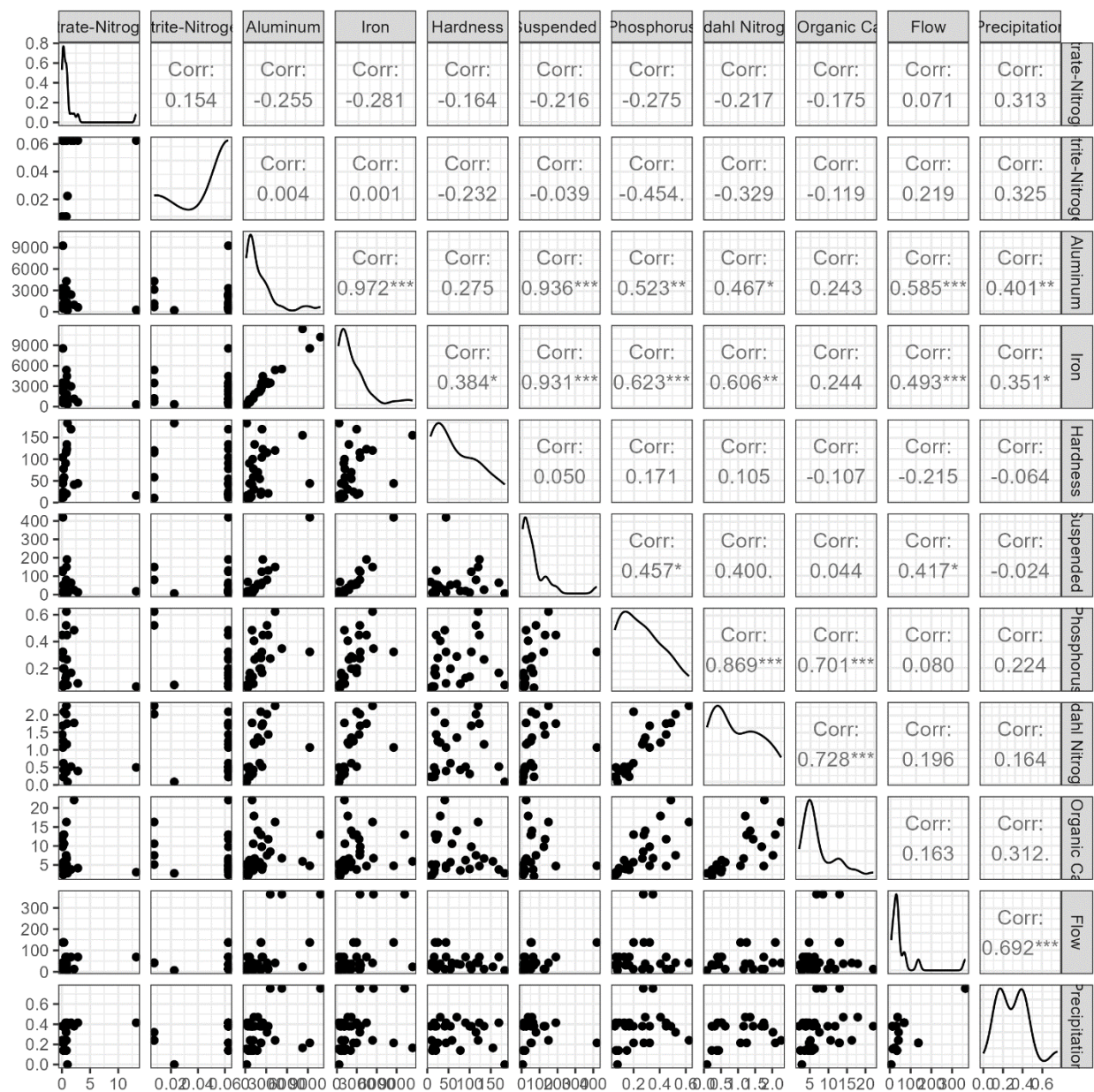


Figure 28. Scatterplot of stormwater and in-stream water quality parameters plus metals iron and aluminum, including a comparison to flow and precipitation two day rolling mean. The correlation values on the righthand side of the figure are Pearson Correlation values, which describes the relationship between two variables in a linear model. This value assumes the relationship between two variables is linear. A Pearson Correlation value greater than 0.7 is generally considered strong and marked in this figure with three asterisks. Both stormwater and in-stream sites were included in this comparison.

Appendix C.4 Scatterplots of TMDL Data at All Sites, Grouped by Location Relative to Burn Perimeter

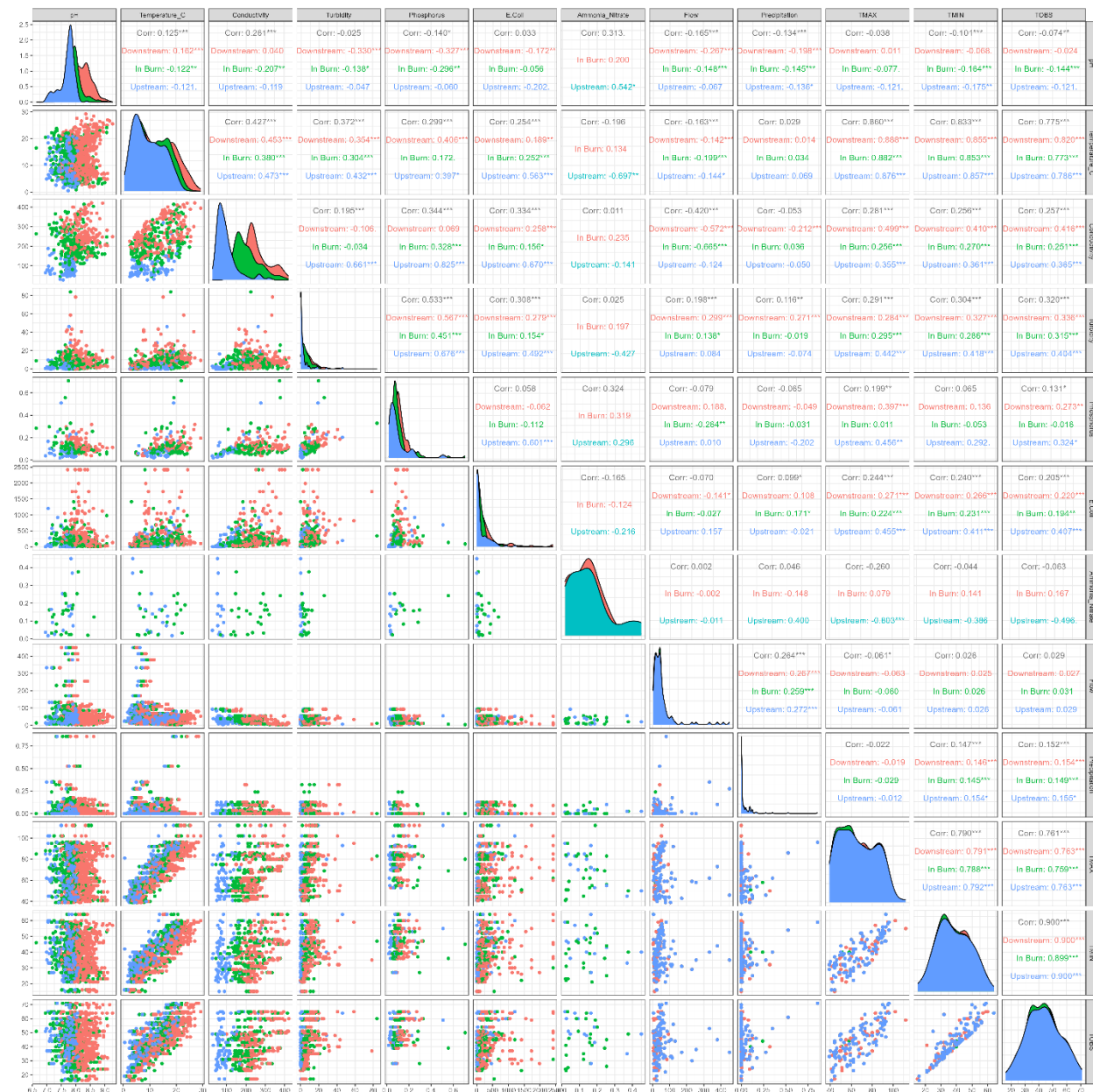


Figure 29. Scatterplot of TMDL water quality parameters, including a comparison to flow and precipitation two day rolling mean. The correlation values on the righthand side of the figure are Pearson Correlation values, which describes the relationship between two variables in a linear model. This value assumes the relationship between two variables is linear. A Pearson Correlation value greater than 0.7 is generally considered strong and marked in this figure with three asterisks. Both stormwater and in-stream sites were included in this comparison.

Appendix D. Additional Figures

Appendix D.1 Time Series of metals at all in-stream sites

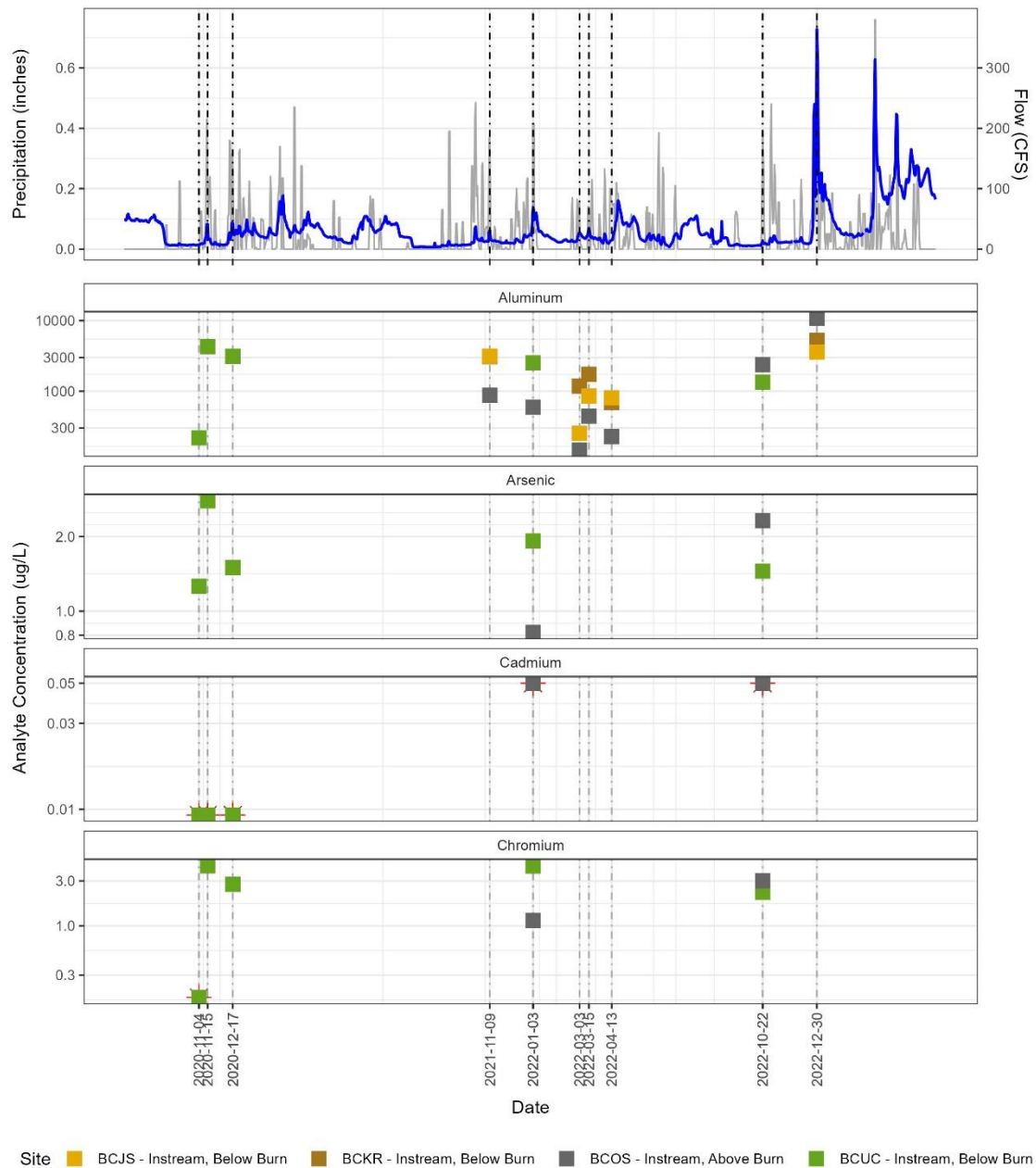


Figure 30. Time series of all in-stream sampling sites, BCOS, BCUC, BCJS, and BCKR. Not all sites were sampled on every date, and only BCUC was sampled immediately after the Almeda Drive Fire. The top panel has precipitation (gray) and flow (blue) for the sampling dates presented in the figures. Points in the time series figures with red stars behind them are non-detect values, indicating the instrument could not detect concentrations of that metal. The non-detect values are presented as values equal to 1/2 times the minimum detection limit ($0.5 \times \text{MDL}$) for ease of analysis and better representation of the presence of a data point.

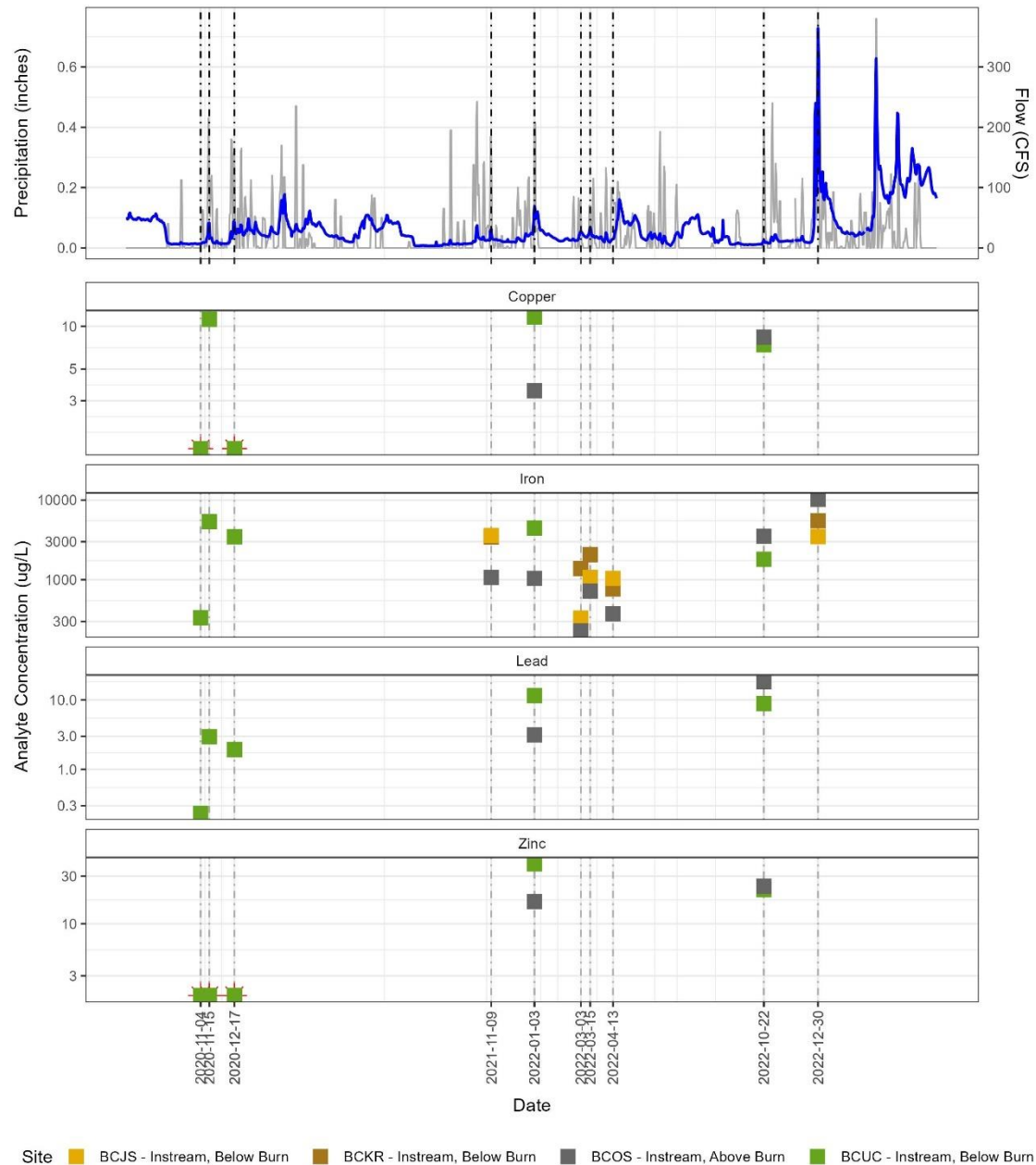


Figure 31. Time series of all in-stream sampling sites, BCOS, BCUC, BCJS, and BCKR. Not all sites were sampled on every date, and only BCUC was sampled immediately after the Alameda Drive Fire. The top panel has precipitation (gray) and flow (blue) for the sampling dates presented in the figures. Points in the time series figures with red stars behind them are non-detect values, indicating the instrument could not detect concentrations of that metal. The non-detect values are presented as values equal to 1/2 times the minimum detection limit ($0.5 \times \text{MDL}$) for ease of analysis and better representation of the presence of a data point.

Appendix D.2 Time Series of water quality parameters at all in-stream sites

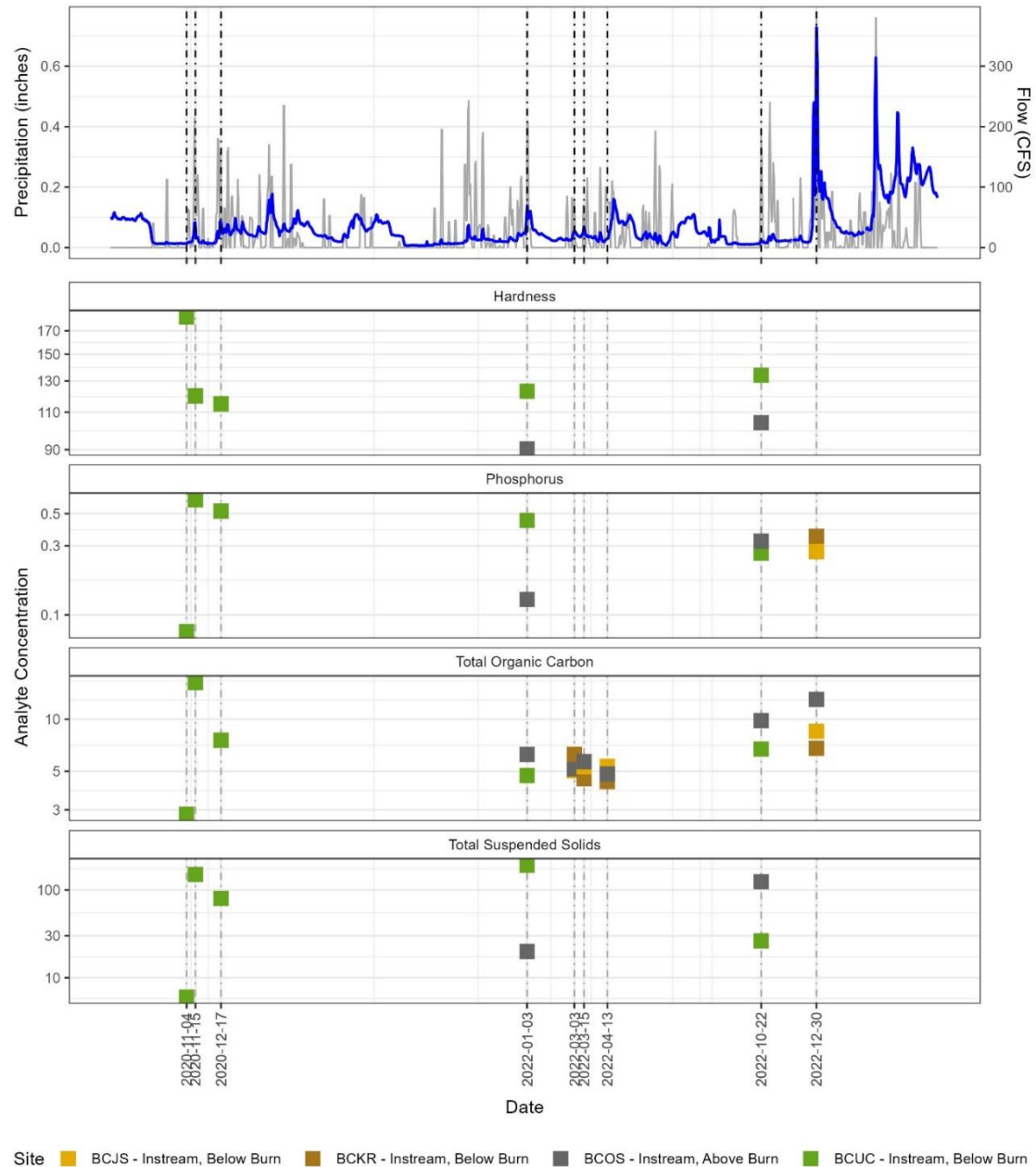


Figure 32. Time series of all in-stream sampling sites, BCOS, BCUC, BCJS, and BCKR. Not all sites were sampled on every date, and only BCUC was sampled immediately after the Almeda Drive Fire. The top panel has precipitation (gray) and flow (blue) for the sampling dates presented in the figures. Points in the time series figures with red stars behind them are non-detect values, indicating the instrument could not detect concentrations of that metal. The non-detect values are presented as values equal to 1/2 times the minimum detection limit ($0.5 \times \text{MDL}$) for ease of analysis and better representation of the presence of a data point.

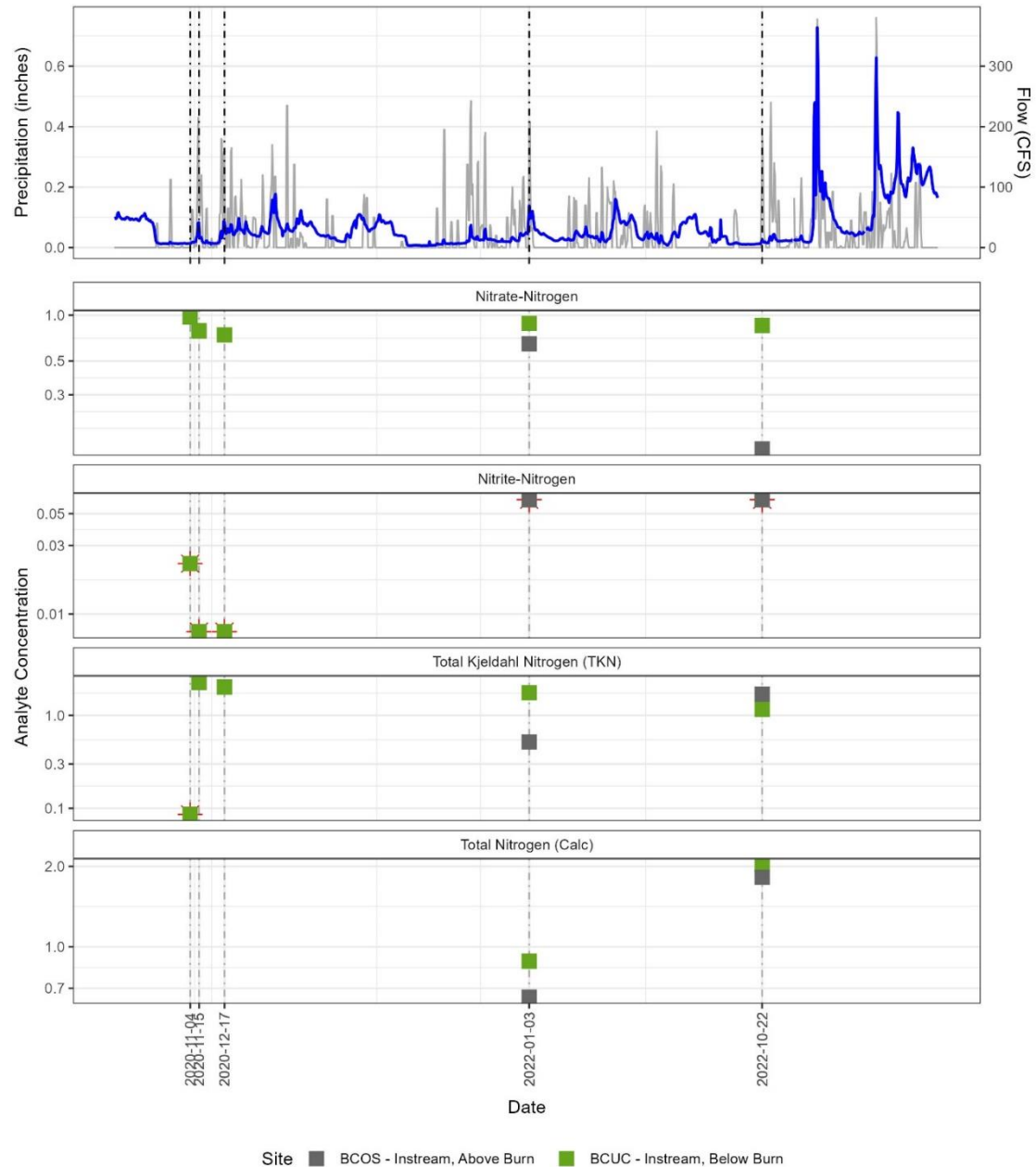


Figure 33. Time series of all in-stream sampling sites, BCOS and BCUC. Not all sites were sampled on every date, and only BCUC was sampled immediately after the Almeda Drive Fire. The top panel has precipitation (gray) and flow (blue) for the sampling dates presented in the figures. Points in the time series figures with red stars behind them are non-detect values, indicating the instrument could not detect concentrations of that metal. The non-detect values are presented as values equal to 1/2 times the minimum detection limit ($0.5 \times \text{MDL}$) for ease of analysis and better representation of the presence of a data point.

Appendix E. Period of Record Figures

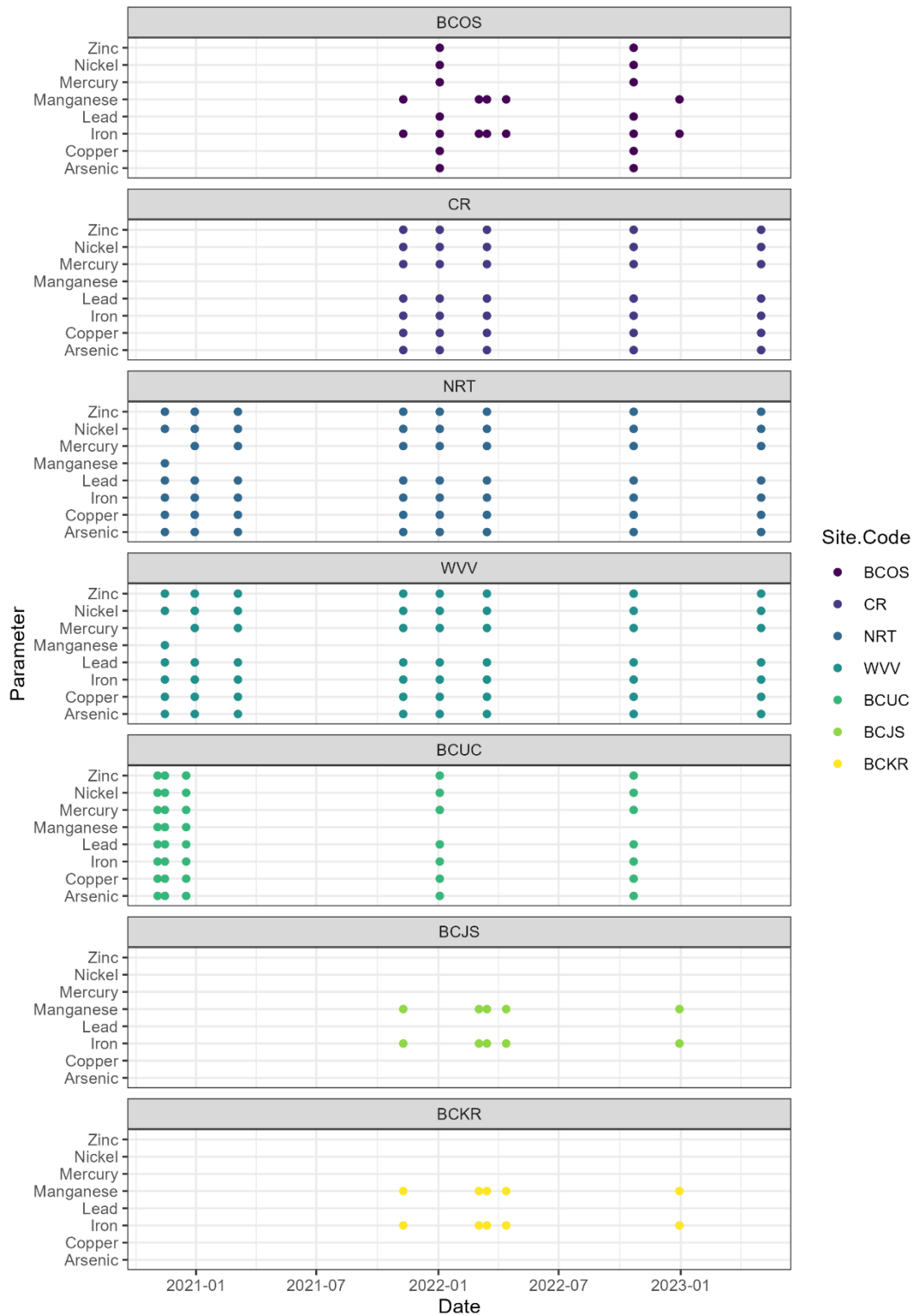


Figure 34. Period of record figure for select metals collected as part of the Post-Fire Water Quality Monitoring for all available sites.

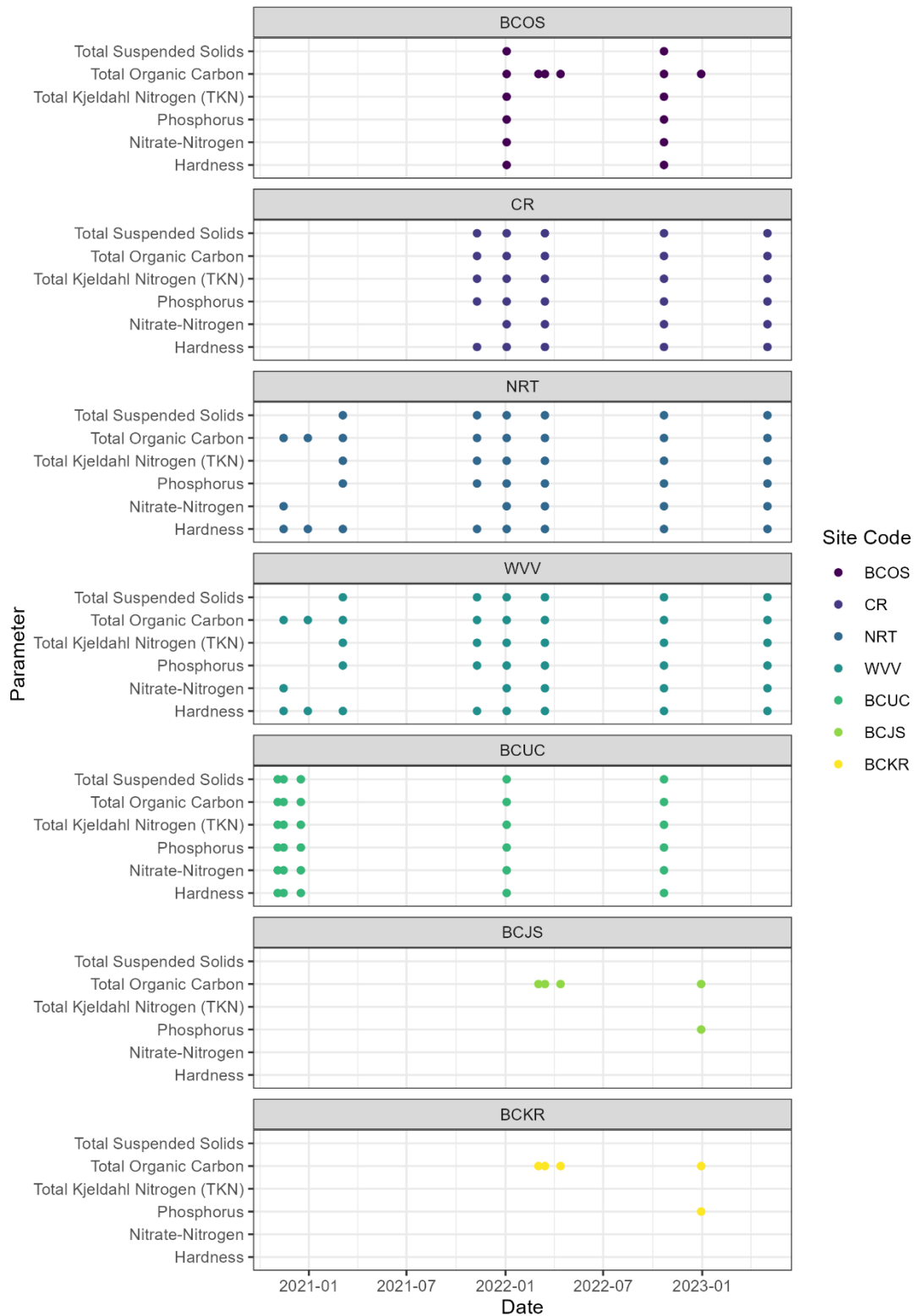


Figure 35. Period of record figure for select water quality parameters collected as part of the Post-Fire Water Quality Monitoring for all available sites.

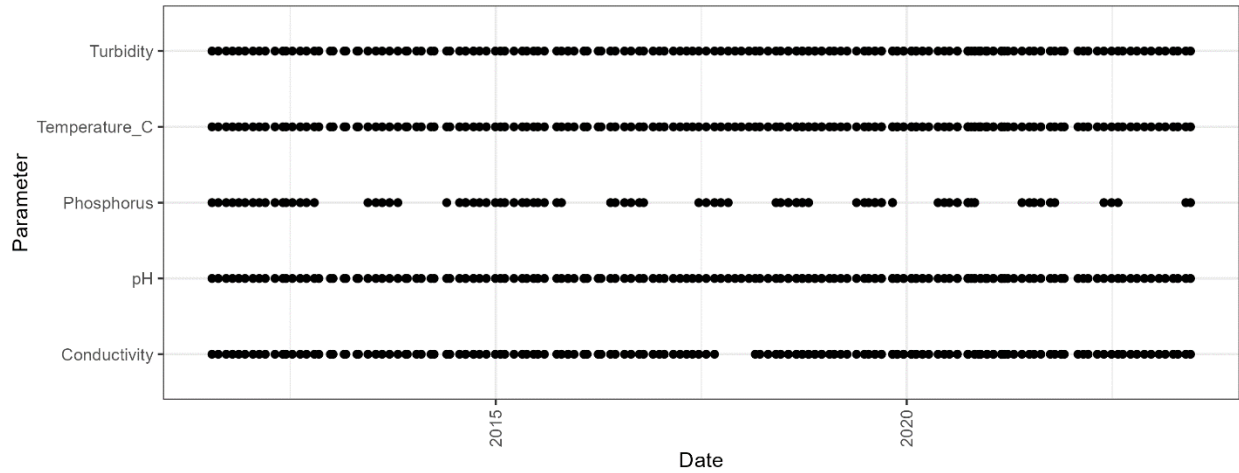


Figure 36. Period of record figure for select parameters collected as part of the Total Maximum Daily Load sampling for one representative site.

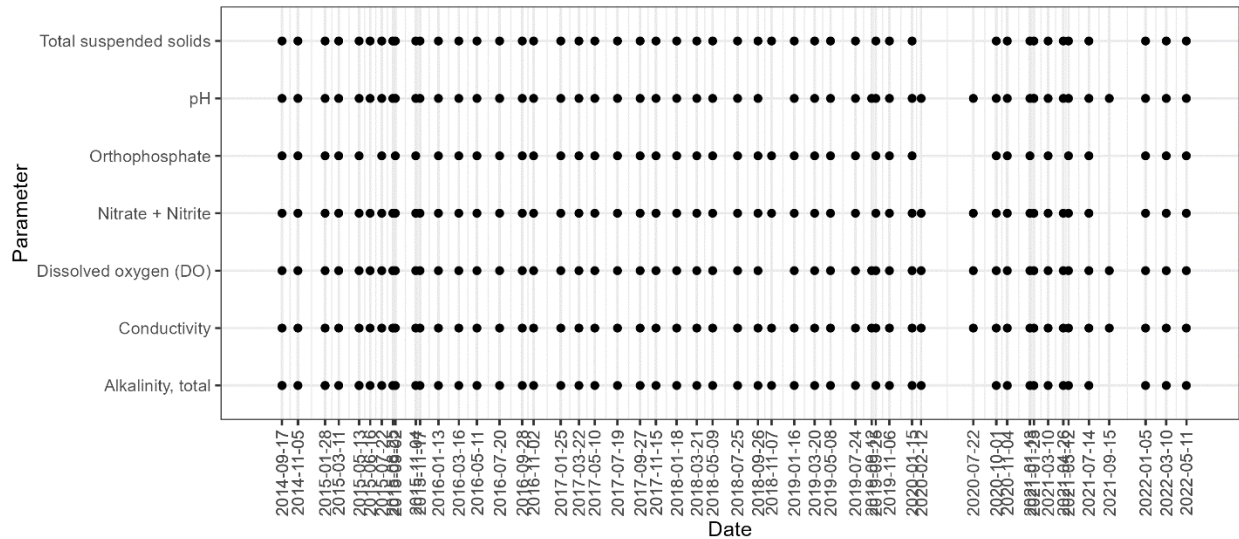


Figure 37. Period of record figure for select parameters collected by the Oregon DEQ for site BCKR.